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National Water-Use Science Project

Guidelines for Preparation of State Water-Use Estimates for 2015

Open-File Report 2017–1029

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

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Compiled by Michael W. Bradley

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U.S. Department of the Interior
RYAN K. ZINKE, Secretary

U.S. Geological Survey
William H. Werkheiser, Acting Director

U.S. Geological Survey, Reston, Virginia: 2017

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Contents

Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	43,560	square feet (ft^2)
acre	4,047	square meter (m^2)
acre-foot (acre-ft)	1,233	square hectometer (hm^2)
acre-foot per day (acre-ft/d)	0.3259	hectare (ha)
acre-foot per acre (acre-ft/acre)	3,047	cubic meter per hectare (m^3/ha)
	Volume	
gallon (gal)	3.785	liter (L)
gallon (gal)	0.003785	cubic meter (m^3)
gallon (gal)	3.785	cubic decimeter (dm^3)
million gallons (Mgal)	3,785	cubic meter (m^3)
cubic mile (mi^3)	4.168	cubic kilometer (km^3)
acre-foot (acre-ft)	1,233	cubic meter (m^3)
acre-foot (acre-ft)	0.001233	cubic hectometer (hm^3)
	Flow rate	
acre-foot per day (acre-ft/d)	0.01427	cubic meter per second (m^3/s)
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year (m^3/yr)
acre-foot per year (acre-ft/yr)	0.001233	cubic hectometer per year (hm^3/yr)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
gallon per day (gal/d)	0.003785	cubic meter per day (m^3/d)
gallon per day per square mile [(gal/d)/mi^2]	0.001461	cubic meter per day per square kilometer [(m^3/d)/km^2]
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
million gallons per day per square mile [(Mgal/d)/mi^2]	1,461	cubic meter per day per square kilometer [(m^3/d)/km^2]
inch per hour (in/h)	0 .0254	meter per hour (m/h)
inch per year (in/yr)	25.4	millimeter per year (mm/yr)
mile per hour (mi/h)	1.609	kilometer per hour (km/h)
	Mass	
pound (lb)	453.6	gram (g)
	Density	
pound per cubic foot (lb/ft^3)	16.02	kilogram per cubic meter (kg/m^3)
pound per cubic foot (lb/ft^3)	0.01602	gram per cubic centimeter (g/cm^3)

Conversion Factors—Continued

U.S. customary units to International System of Units

Multiply	By	To obtain
	Energy	
gigawatthour (GWh)	1,000	megawatthour (MWh)
kilowatthour (kWh)	3,412	British thermal unit (Btu)
Megawatt	56,920	British thermal unit per minute (Btu/min)
Megawatt	1,000,000	watts

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

$$°C = (°F - 32) / 1.8.$$

Concentrations of chemical constituents in water are given in milligrams per liter (mg/L).

Abbreviations

ASDWA	Association of State Drinking Water Administrators
AWRA	American Water Resources Agency
AWWA	American Water Works Association
AWUDS	Aggregate Water-Use Data System
CHP	Combined Heat and Power
CWS	Community Water System
DMR	DMR Discharge Monitoring Reports
DOE-EIA	Department of Energy–Energy Information Administration
EPA	U.S. Environmental Protection Agency
FAO	Food and Agriculture Organization
FERC	Federal Energy Regulatory Commission
FIPS	Federal Information Processing Standards
GIS	Geographic Information System
HIFLD	Homeland Infrastructure Foundation-Level Data
HUC	Hydrologic Unit Code
NASS	National Agricultural Statistics Service
NAICS	North American Industrial Classification System
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service

Abbreviations—Continued

NWS	National Weather Service
NWUSP	National Water-Use Science Project
POTW	Publicly-Owned Treatment Works
SDWIS	Safe Drinking Water Information System
SIC	Standard Industrial Classification
SWUDS	Site-Specific Water-Use Data System
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey

Guidelines for Preparation of State Water-Use Estimates for 2015

Compiled by Michael W. Bradley

Abstract

The U.S. Geological Survey (USGS) has estimated the use of water in the United States at 5-year intervals since 1950. This report describes the water-use categories and data elements used for the national water-use compilation conducted as part of the USGS National Water-Use Science Project. The report identifies sources of water-use information, provides standard methods and techniques for estimating water use at the county level, and outlines steps for preparing documentation for the United States, the District of Columbia, Puerto Rico, and the U.S. Virgin Islands.

As part of this USGS program to document water use on a national scale, estimates of water withdrawals for the categories of public supply, self-supplied domestic, industrial, irrigation, and thermoelectric power are prepared for each county in each State, District, or territory by using the guidelines in this report. County estimates of water withdrawals for aquaculture, livestock, and mining are prepared for each State by using a county-based national model, although water-use programs in each State or Water Science Center have the option of producing independent county estimates of water withdrawals for these categories. Estimates of water withdrawals and consumptive use for thermoelectric power will be aggregated to the county level for each State by the national project; additionally, irrigation consumptive use at the county level will also be provided, although study chiefs in each State have the option of producing independent county estimates of water withdrawals and consumptive use for these categories.

Estimates of deliveries of water from public supplies for domestic use by county also will be prepared for each State. As a result, total domestic water use can be determined for each State by combining self-supplied domestic withdrawals and public-supplied domestic deliveries. Fresh groundwater and surface-water estimates will be prepared for all categories of use, and saline groundwater and surface-water estimates by county will be prepared for the categories of public supply, industrial, mining, and thermoelectric power. Power production for thermoelectric power and irrigated acres by irrigation system type will be compiled. If data are available, reclaimed-wastewater use will be compiled for the public-supply, industrial, mining, thermoelectric-power, and irrigation categories.

Optional water-use categories are commercial, hydroelectric power, and wastewater treatment. Optional data elements are public-supply deliveries to commercial, industrial, and thermoelectric-power users; consumptive use (for categories other than thermoelectric power and irrigation); irrigation conveyance loss; and number of facilities. Aggregation of water-use data by stream basin (eight-digit hydrologic unit code) and principal aquifers also is optional.

Water-use data compiled by the States will be stored in the USGS Aggregate Water-Use Data System (AWUDS). This database is a comprehensive aggregated database designed to store mandatory and optional data elements. AWUDS contains several routines that can be used for quality assurance and quality control of the data, and AWUDS produces tables of water-use data from the previous compilations.

Introduction

The U.S. Geological Survey (USGS) has compiled and published estimates of water use for the Nation at 5-year intervals since 1950. During 1977, Congress provided funding for the USGS to establish the National Water-Use Science Project (NWUSP), which is a cooperative effort with States to collect reliable and uniform water-use information. Most water-use information is collected by State or other Federal agencies with whom the USGS has close working relationships. The national water-use compilations are stored electronically, and the data and reports are available to all researchers through the NWUSP website Water Use in the United States (http://water.usgs.gov/watuse/). The published USGS circulars entitled Estimated Use of Water in the United States present data collected for each State in the United States, the District of Columbia, Puerto Rico, and the U.S. Virgin Islands (MacKichan, 1951, 1957; MacKichan and Kammerer, 1961; Murray, 1968; Murray and Reeves, 1972, 1977; Solley and others, 1983, 1988, 1993, 1998; Hutson and others, 2004; Kenny and others, 2009; Maupin and others, 2014).

Currently, estimates of water withdrawals are mandatory for the categories of public-supply, self-supplied domestic, industrial, irrigation, livestock, aquaculture, mining, and thermoelectric power, and optional for commercial, hydroelectric power, wastewater treatment, and reservoir evaporation. The NWUSP has developed nationally consistent methods to estimate water withdrawals for livestock, mining, aquaculture, and thermoelectric power. Methods have also been developed to estimate water consumption for irrigation and thermoelectric power. Estimates of saline groundwater and surface-water withdrawals by county are mandatory for the categories of public supply, industrial, mining, and thermoelectric power. Estimates of reclaimed-wastewater use by county are mandatory for the irrigation and industrial categories, but null values are allowed if there is an uncertainty about the use of reclaimed wastewater in the county. Estimates for the optional categories were last compiled nationally in 1995.

The Aggregate Water-Use Data System (AWUDS) is a USGS database that is specifically designed to store and analyze annual water-use data aggregated by county, aquifer, or hydrologic unit code (HUC) compiled for any year after 1985. Water-use data for years ending in '0' and '5' are used for the 5-year reports. AWUDS is capable of storing only annual aggregate State-level water-use data for the years prior to 1985.

Estimates of water withdrawals compiled by the USGS enable the depiction of trends in total water use for the Nation among different geographic areas, categories of use, and sources over time. The USGS is dedicated to providing reliable scientific information that accurately describes current and historical conditions and enables a better understanding of the Earth's precious water resources. Water-use information complements and supports surface-water and groundwater availability studies and the water budgets that are critical to these studies. This information is also essential to accurately understand how future water demands will be met while maintaining adequate water quality and quantities for human and ecosystem needs.

Purpose and Scope

The purpose of these guidelines is to present a nationally consistent set of methods for the collection and estimation of water-use data and for the compilation of these values for use in the 5-year publications entitled "Estimated Use of Water in the United States." Each chapter in this publication describes a single water-use category, the relevant data elements, sources of data, and estimation methods. The guidelines are intended to aid personnel in producing more useful, consistent, and reliable water-use estimates. The guidelines included in this report have been updated and compiled from Kenny (2004) and Hutson (2007) and from changes in the guidelines for the 2010 water-use compilation (USGS internal-only site https://water.usgs.gov/usgs/watuse/2010compilation/guidelines2010update.html).

The chapters in these guidelines can be updated as methods are improved or become more detailed. The date listed with the chapter title in the on-line version of this document reflects the current version of the guidelines for that water-use category.

The scope of this report includes methods for the following mandatory water-use categories: public supply, self-supply domestic, industrial, irrigation, thermoelectric power, livestock, aquaculture, and mining. Methods are also included for estimates of water withdrawals for (optional) categories of commercial, hydroelectric power, wastewater-treatment and reservoir evaporation. Optional data elements described herein include reclaimed-wastewater use for commercial, thermoelectric power and wastewater-treatment purposes; public-supply population served by source of supply; consumptive use for categories other than irrigation and thermoelectric power; irrigation conveyance loss; deliveries from public-water suppliers to commercial, industrial, and thermoelectric power users; and number of facilities. Estimates for all categories may be compiled and stored in the AWUDS database to meet State or USGS Water Science Center (WSC) needs. Over the history of the water-use program, the categories and terminology have changed. The changes in the water-use categories by 5-year compilation are described at http://water.usgs.gov/watuse/WU-Category-Changes.html (U.S. Geological Survey, 2016a).

Because of the variability in available data by State, the methods presented are general in nature and are not intended to replace more specific methodologies that may be used in some States, but do provide guidance as to the acceptable procedures required to complete the national compilation, and are designed to be used in conjunction with the 2015 water-use coding forms (Appendix A). Required documentation of the methodology used in the compilation of water-use data for each State is part of scientific protocol and is especially important for this study because data availability and reliability vary from State to State. Each USGS WSC maintains documentation as a reference for current data and as a starting point for continued data collection.

Water-Use Compilation Requirements

Minimum requirements for the national compilation are designed to produce a more cost-effective product that meets the scientific priorities of the USGS and NWUSP. The national data compilation currently (2015) focuses on the aggregation of water-use data to the county level. The data can, depending on local and regional needs, be aggregated based on the hydrologic unit code or by national aquifer code. The national aquifer codes are defined for the principal aquifer of the United States (https://water.usgs.gov/ogw/NatlAqCode-reflist.html). The national data model is not intended to limit any efforts to meet the needs of local programs and cooperators. Mandatory and optional water-use categories, and their associated data elements, are summarized on the coding forms in Appendix A.

Water-Use Categories and Data Elements

For the compilation, water-use data are mandatory by county and are optional for eight-digit HUCs, and principal aquifers. Fresh groundwater and surface-water estimates will be prepared for the mandatory categories of public supply (including domestic deliveries), self-supplied domestic, industrial, irrigation, livestock, mining, aquaculture, and thermoelectric power. Estimates may be prepared for the optional categories of commercial, hydroelectric power, reservoir evaporation, and wastewater treatment. Saline groundwater and surface-water estimates are mandatory for only the categories of public supply, industrial, mining, and thermoelectric power (for once-through and closed-loop cooling systems).

Irrigation withdrawals may be reported either as a total amount or as subcategories of crop and golf-course irrigation; acres irrigated are mandatory and will be reported either way. The choice of reporting irrigation as a total for the category or by subcategory must be consistent for all counties in the State. Consumptive use by irrigation and thermoelectric power will be reported by county. Reclaimed-wastewater use is a mandatory data element for the industrial and irrigation categories, and zeros should be reported for counties where the delivery of reclaimed wastewater does not occur; null values can be stored in AWUDS for counties where there is an uncertainty about the use of reclaimed wastewater. Compiling domestic deliveries from public supply and power generated by thermoelectric power plants by cooling type are mandatory.

Estimates of county water withdrawals and consumptive use for thermoelectric power and irrigation consumptive use will be provided to the study chiefs by NWUSP. However, a study chief may decide not to use the nationally generated numbers but, instead, use independently estimated values for water withdrawals for the three categories. Compiling total population served by public-water suppliers is mandatory for each county. Once county population estimates are available from the U.S. Census Bureau, NWUSP will provide the dataset to the study chief in a format that can be readily input into AWUDS. County self-supplied domestic population in AWUDS is calculated automatically as the county population minus the county population served by public supply.

Optional categories and data elements also are described in this report and summarized in the coding forms in Appendix A or are available at http://water.usgs.gov/usgs/watuse/2015compilation/coding-forms/forms2015.html. Data for the optional categories may be compiled and stored in the AWUDS database. Guidance for compiling data for the optional categories and data elements are based largely on guidelines for 1995 (E. James Crompton and Wayne B. Solley, U.S. Geological Survey, written commun., March 27, 1995) and 2000 (Kenny, 2004). Optional categories include self-supplied commercial, hydroelectric power (instream and offstream and associated power generations), and wastewater-treatment, and reservoir evaporation. Optional data elements in the public-supply category include deliveries to commercial and industrial users and for thermoelectric-power purposes. Consumptive use for all categories except thermoelectric and irrigation (such as commercial, self-supplied domestic, industrial, mining, livestock, and aquaculture) are optional data elements. Irrigation conveyance loss is an optional data element of the irrigation category. The following are optional data elements: power production data for hydroelectric power; the number of facilities for public-supply, industrial, thermoelectric power, hydroelectric power, and wastewater-treatment categories; and reclaimed-wastewater use for the commercial, public-supply, mining, thermoelectric power (once-through and closed-loop cooling systems), and wastewater-treatment categories.

Units of Measurement

Annual average daily water withdrawals are stored in AWUDS in units of million gallons per day (Mgal/d). Population is stored in units of thousands of persons. Acres irrigated are stored in units of thousand acres. Power production is stored in units of gigawatthours; a gigawatthour is equivalent to 1,000 megawatthours or 1 billion watthours. All values, except population, are stored with two places after the decimal point; population is stored with three places after the decimal point. A value of zero usage for a data element indicates either no usage or usage of less than 0.01 Mgal/d. A null value for reclaimed-wastewater use indicates uncertainty as to the presence of the water-use activity in the county. Care must be taken to ensure that zeros are not coded when the field is intended to be left blank.

Aggregation Levels

Water withdrawals for the public-supply (including domestic deliveries), irrigation, self-supplied domestic, industrial, thermoelectric power, mining, livestock, and aquaculture categories will be compiled by county for each State. Total population and population served from public supply are also reported by county for each State. For the national compilation, the District of Columbia, Puerto Rico, and the U.S. Virgin Islands are treated as States, and Alaska boroughs, Louisiana parishes, and Virginia independent cities are treated as counties. Water withdrawals aggregated by principal aquifer (U.S. Geological Survey, 2003) for each State and also for aquifer by county are optional and may be entered into AWUDS, but will not be part of the national water-use compilation as published in the water-use circular series. Entry of the withdrawals by aquifer of any scale (statewide

or by county-aquifer subsets) is encouraged, and the data will be available for other studies. Information on the principal aquifers of the United States and geographic information system (GIS) files are available at http://water.usgs.gov/ogw/aquifer/map.html (U.S. Geological Survey, 2015).

Aggregate Water-Use Data System Database

The AWUDS is the official USGS database to store areal water-use data, and must be used for the 5-year compilations as well as to store water-use data for local, regional, watershed, or aquifer studies. Water-use data compilers are required to enter aggregate data by county for mandatory water-use categories except for self-supplied domestic population, which is calculated internally. Data from AWUDS are available by State and county through the USGS Water Use Data for the Nation website at http://waterdata.usgs.gov/nwis/wu (U.S. Geological Survey, 2016b).

The AWUDS database was created to store data aggregated by county, HUC, or principal aquifer and is released as a personal computer-based system available to each USGS WSC. AWUDS data for each State are reviewed and revised for each compilation in order to accommodate updated compilation requirements. AWUDS also is able to store the optional data elements by county and eight-digit HUC, as well as selected groundwater categories by principal aquifer.

In addition to meeting the storage requirements for the 5-year compilation, AWUDS also can store water-use data for any other year after 1985; data for years prior to 1985 may be stored as State-level totals. Within AWUDS, data are entered and edited interactively or imported from machine-readable files. AWUDS can generate tables by category of use or by county, eight-digit HUC, or principal aquifer. Summary tables output from AWUDS show entered data elements or provide calculated values for categories. Quality-assurance and quality-control (QA/QC) programs within AWUDS include checks for erroneous values, comparison of totals by area, and comparison of data between years.

Documentation

Documentation of data sources and methodology is required as part of the 5-year compilation. Documentation corroborates the data that will be published in the USGS water-use circular and provides a guideline for subsequent compilations. The NWUSP documentation template provides a nationally consistent format for each water-use study chief to document the sources, methods, and quality assurance of the data. All documentation must include the following elements.

- Sources of data and sources of coefficients used.
- Source agency and contact information.
- Methods, techniques, and coefficients used to collect or estimate data.
- Location and types of data files.
- Explanation of substantial changes from previous water-use data compilations.
- Results of QA/QC review on acquired or estimated data—If the current water-use estimates of values for the data elements differ substantially from those reported for the previous compilation, possible explanations for these differences should be included in the documentation. For example, a major nuclear-fueled power plant may have started operation, several pulp and paper industries may have closed, or irrigation may have been encouraged or limited in an area of the State. Any information that can add to the understanding of water use in the State should be included in the documentation.

Water-use study chiefs will transmit completed documentation in electronic form to the respective USGS regional water-use specialist. A standardized naming convention for the documentation file includes the State postal code and the date. For example, for Alabama, the name of the documentation file will be "ALdoc*yymmdd*."

Compilation Methods

The compilation of water-use data for the current (2015) compilation should begin with the review of previous compilation documentation. Although the format of the documentation has changed with time, the documentation should provide the water-use study chief with a starting point for developing an approach and a time-task plan. The previous documentation should

contain the location and types of electronic and paper water-use files; agency and contact information; sources of data; and methods, techniques, and coefficients used to collect or estimate data. Several methods are described in each section of these guidelines. If needed, study chiefs are encouraged to investigate other methods outside of those suggested.

General Methodologies and Techniques

The availability of data, the year of the most recent data, and the completeness of the data can vary among States and among the counties within a State. Accessing the data for estimating water use can be as uncomplicated as asking agencies or organizations for the data reported to them or as involved as designing a survey to collect the data. When data are not readily available, for some categories, water-use data can be collected either by an inventory of all sites or a partial inventory of the water-use sites using several sampling techniques. Site-specific water-use data more commonly are available for public-supply, industrial, and thermoelectric-power facilities and less commonly available for self-supplied domestic, irrigation, aquaculture, livestock, and mining water-use sites. When site-specific data are not available, water-use estimates may be determined by using ancillary data and a water-use coefficient.

An inventory accounts for all of the individual sites and ancillary data in contrast to a partial inventory that queries selected water-use sites using several sampling criteria. Once an inventory has been developed, some or all of the users can be surveyed to determine water usage. Federal agencies cannot distribute surveys without meeting the requirements of the Paper Reduction Act of 1995 (U.S. Congress, 1995). Generally, the guidelines for developing a survey are as listed.

- Identify agencies with the authority or legal mandate to collect the data.
- Identify the type of facilities information needed.
- Identify the agency and organization sources of facility information for the category of use.
- Construct a master list of facilities.
- Decide on a sampling approach if not all users are to be surveyed.
- Create a survey form that is short and easy for the user to complete.
- Write a concise description of the requested data.
- Provide a contact name and phone number.
- Provide a desired completion date.
- Include a statement of confidentiality.
- Identify an agency or organization to cooperate in distributing the surveys; the entity may be different from the agency with the authority and legal mandate to collect the data.
- Send survey forms by mail, fax, or e-mail or conduct the survey by phone.
- Develop a tracking process for receiving and managing the returned survey forms.
- Implement a follow-up procedure for contacting facilities that do not respond by the requested time.

To produce the most complete and defensible data for each State, the greatest effort and time are spent collecting information about the largest users and the largest categories of use in individual States. Compilation of accurate data for the largest public suppliers, industries, agricultural regions, and power plants produces State totals that are fairly reliable. As time and resources permit, data on smaller-volume water users also should be collected within each category.

Without site-specific data, water use often is estimated by using a coefficient that represents a unit-use water requirement and number of units such as population served, number of employees, acres of cropland, or number of golf courses or golf holes. Some water-use coefficients already have been developed and are part of the technical literature or administrative and legislative documents for a State. If water-use coefficients are not available or perhaps no longer suitable, coefficients can be developed from a representative sample of typical users that are more pertinent to a specific facility, county, or State. The source of the coefficients, the source of the ancillary data, and the date they were accessed should be documented.

Quality Assurance and Quality Control

Errors can occur in both the compiled and entered data. QA/QC procedures are scientific protocols implemented to ensure the quality of the water-use estimate. By definition, quality assurance is the program for the systematic monitoring and evaluation of several aspects of a project to ensure that standards of quality are being met. Quality control is an aggregate of activities designed to ensure adequate data quality. AWUDS provides a system of QA/QC procedures to check for errors.

The following basic checks can be made during data compilation and after AWUDS data entry.

- Use AWUDS quality-assurance programs to check for erroneous data and to compare State totals with principal aquifer or hydrologic unit totals by category.
- Review spatial distribution of data using choropleth or other types of maps or GIS analysis.
- Compare data with those from the previous compilations. Examine changes based on percentage change, statistical analysis, or general geographic patterns of use within a State.
- Use sorting routines to check for possible errors in largest and smallest water withdrawals by ranking values for data elements by county, HUC, or aquifer.
- Examine calculated values such as per capita use and irrigation application rates.
- Check county and State data for population served to ensure that they do not exceed total census populations.

Much of the data that will be used in the compilation will be received from other entities. A preliminary QA/QC check should be performed, if possible, before the data are integrated into the USGS analysis and database. The QA/QC check should include an evaluation of the documentation of the level of completeness, degree of accuracy, and amount of review given to the data by the entities from whom the data were received. AWUDS can also be used to generate a QA/QC check for the entered data that includes many of the required QA/QC checks.

The QA/QC check should determine whether the data are based on a census enumeration or are statistically derived data, like the National Agricultural Statistics Service (NASS) data. Completeness of the data can be examined by determining, for example, if reported crop acreages include total acreages or just irrigated acreages; if irrigated acreages and water deliveries are reported for a management area of a particular agency, or for an entire county; or if some data are censored for privacy reasons. Additionally, any data obtained from surveys, questionnaires, or cooperator reports should be checked against former data to ensure reporting consistency and consistency in location over time. Site visits to select or problem sites should be conducted, if possible. Outliers in the data should be identified, evaluated, and confirmed or corrected, and units of measurement should be verified.

Standard Industrial Classification Coding System

The Standard Industrial Classification (SIC) coding system was developed to promote the comparability of establishment data describing several facets of the U.S. economy (Office of Management and Budget, 1987). The SIC coding system was intended to cover the entire field of economic activities—agriculture, forestry, fishing, hunting, and trapping; mining; construction; manufacturing; transportation, communications, electric, gas, and sanitary services; wholesale trade; retail trade; finance, insurance, and real estate; personal, business, professional, repair, recreation, and other services; and public administration. The SIC coding system is based on the primary activity in which the industry is engaged. The structure of the classification makes it possible to tabulate, analyze, and publish industry data based on a two-digit major group, a three-digit industry group, or a four-digit industry code. A newer system of classification, the North American Industry Classification System (NAICS), went into effect in 1997. The U.S. Census Bureau (U.S. Department of Commerce, 2000, 2002) published descriptions of the NAICS codes and the correlation with SIC codes.

The USGS has assigned each four-digit industry code in the 1987 SIC manual (Office of Management and Budget, 1987) to a water-use category. In some cases, a code may be listed under more than one water-use category. Each of these SIC codes was then correlated to one or more NAICS codes. The SIC and NAICS codes can be useful for assigning withdrawals to the public-supply, industrial, mining, thermoelectric-power, and commercial categories. A list of SIC codes by water-use category can be found in table 3 of Guidelines for Preparation of State Water-Use Estimates for 2000 (Kenny, 2004, accessed at http://pubs.usgs.gov/tm/2005/tm4A4/). Reference lists of the SIC and NAICS codes for each category can be generated by the template builder in the Site-Specific Water-Use Data System (SWUDS).

Public Supply

Public supply refers to water withdrawn from ground and surface sources by public and private water systems for use by cities, towns, rural water districts, mobile-home parks, Native American Indian reservations, and military bases. Public-supply facilities provide water to at least 25 persons or have a minimum of 15 service connections and are classified as SIC 4941. Water withdrawn by public suppliers may be delivered to users for domestic, commercial, industrial, and thermoelectric-power purposes, as well as to other public-water suppliers. Public-supply water is also used for public services (public uses)—such as pools, parks, and public buildings—and may have unaccounted uses (losses) because of system leaks or such non-metered services as firefighting, flushing of water lines, or backwashing at treatment plants. Some public-supply water may be used in the processes of water and wastewater treatment.

Some public suppliers treat saline water before distributing the water. Estimates of saline groundwater and surface-water withdrawals for public supply are mandatory for the national compilation. The definition of saline water for public supply refers to water that requires treatment to reduce the concentration of dissolved solids through the process of desalination or dilution.

Data Elements

The public-supply category includes not only the water withdrawals, but also includes delivery of water to various users. Deliveries for domestic use are reported and are mandatory data elements. Deliveries to commercial, industrial, or thermo-electric users are optional data elements. The mandatory and optional data elements are described below. Data for the optional elements may be compiled and entered into AWUDS, but will not be part of the national water-use analysis as published in the water-use circular series. The optional data, however, will be available for other types of water studies.

Mandatory

- Groundwater withdrawals, freshwater, by county.
- Surface-water withdrawals, freshwater, by county.
- Groundwater withdrawals, saline water, by county.
- Surface-water withdrawals, saline water, by county.
- Domestic deliveries from public supply, by county (also see Self-Supplied Domestic).
- Total population served, by county.

Optional

- Population served by groundwater, by county.
- Population served by surface water, by county.
- Deliveries, from public supply, to commercial, industrial, and thermoelectric-power (once-through and closed-loop systems) deliveries, by county.
- Number of facilities, by county.
- Reclaimed-wastewater use, by county.
- Any data aggregated by eight-digit HUC.
- Groundwater withdrawals, freshwater, by principal aquifer.
- Groundwater withdrawals, saline water, by principal aquifer.
- Population served, by principal aquifer.

Sources of Information

For each USGS WSC, the documentation for the previous compilations should be the starting point for planning the data collection for the current compilation. The previous documentation for the public-supply category may contain the location and types of electronic and paper files; agency and contact information; agency and internet resources; and methods, techniques, and coefficients used to collect or estimate data. With this information, the compiler should know where to begin to create or update a master list of public-supply systems and collect data on public-supply withdrawals, sources of water, and population served. Additional information concerning public-supply water use may be obtained from the sources described in the following sections. Other sources of information may also be available in each State.

Agencies or Other Entities

Water-use data from the following sources can range from reported water withdrawals to coefficients and ancillary data that can be used to estimate water withdrawals and domestic deliveries. Multiple datasets can be used to determine the best estimates and can be used during QA/QC review of the estimated withdrawals and ancillary information.

- Individual public-water suppliers.
- State agencies that administer water rights, allocate water to users, or collect water-use data.
- State agencies that enforce the Safe Drinking Water Act and issue permits for water discharge.
- State public health agencies.
- State agencies that regulate utility rates.
- State, regional, county, or community planning, development, or zoning agencies.
- State natural-resource agencies.
- Consulting firms.

Internet Resources

Many agencies and other entities maintain databases and information on the internet related to public-water withdrawals, population, per capita water use, or other supporting information. Some of the agencies and the websites are listed below.

- U.S. Census Bureau, accessed at http://www.census.gov/.
  - American FactFinder database, the U.S. Census Bureau's online data source, containing information on population and housing, accessed at http://factfinder.census.gov/.
- U.S. Environmental Protection Agency (EPA), accessed at http://www.epa.gov/.
  - EPA Water Science—links to water-related regulatory programs and includes information on drinking water and drinking water systems, accessed at http://www.epa.gov/science-and-technology/water-science.
  - Safe Drinking Water Information System (SDWIS)—Data that States must report to the EPA as required by the Safe Drinking Water Act, accessed at https://www.epa.gov/enviro/sdwis-search. The system can also be used to query the SDWIS Federal Data Warehouse and create reports of public-water systems by State, county, or other options.
  - National Pollutant Discharge Elimination System (NPDES)—Information and data regarding facilities holding NPDES permits. Specify the facilities by using any combination of facility name, geographic location, SIC code, and chemicals, accessed at http://www.epa.gov/npdes.
- American Water Works Association (AWWA), accessed at http://www.awwa.org/.
  - Links to local AWWA sections, sites and contacts, accessed at http://www.awwa.org/membership/sections-your-local-awwa.aspx.

- The Association of State Drinking Water Administrators (ASDWA) maintains links to a variety of Internet resources including a page with links for each State's drinking water program pages and the primary State agency responsible for drinking water, accessed at http://www.asdwa.org/.
- National Rural Water Association, accessed at http://www.nrwa.org/. Organizations whose membership rosters include public or private utilities, such as League of Municipalities or State rural water associations.
- Proceedings and reports on domestic water use are available through the American Water Resources Association (AWRA), accessed at http://www.awra.org/.

Compilation Techniques

Constructing a master list of public-supply systems is fundamental to all of the compilation techniques. A master list, at a minimum, consists of the names and locations of public-water suppliers, populations served, and sources of water. The information to build or update this list may be available from previous documentation, one or more State agencies, or USGS water-use databases. The EPA SDWIS database is a secondary source containing information on public supplies obtained from the State agencies that administer water-quality regulations for drinking water.

The SDWIS database includes information on the names and locations of systems, source of supply, location of water intakes, and population served for all community water systems (CWS), which are those serving at least 25 persons or 15 or more service connections on a year-round basis. SDWIS does not include any information on quantity of water withdrawn. In some cases, the State agencies providing the data to SDWIS may have more up-to-date and complete information than SDWIS.

Water Withdrawals

Public-supply information may be obtained from water suppliers by cooperator surveys and permit information. If water suppliers cannot be contacted by cooperator surveys, then information may be obtained from a State agency that administers water-withdrawal permits. Public-supply withdrawals are reported in the compilation for the county in which the withdrawals occur, although the water subsequently may be distributed and used elsewhere. State reporting programs and individual public-water suppliers are good sources of data. Individual State reporting agencies have varying criteria for obtaining public-supply water-use data; these criteria may be based on such permit requirements as size of system or magnitude of withdrawals. Return rates of the required surveys to the State reporting agency, as well as the amount of QA/QC review, also may vary from State to State. For these reasons, some needed public-supply system information may not have been collected by the State agency and must be obtained directly from the public-supply system or be determined from other ancillary information.

Study chiefs may survey public-water suppliers by telephone calls or visits to the systems. However, surveys mailed from the USGS offices must meet all requirements of the 1995 Paper Reduction Act (U.S. Congress, 1995). Usually, information can be obtained from a director of public works, city engineer, city clerk, bookkeeper, manager, or operator. The level of detail obtained depends on the availability of the information and the necessary resources available to collect the data. Useful information to request from these contacts includes the following list of items.

- **Source(s) of water.** Well information (local name or number, depth, location) and names of aquifers used for groundwater sources; names and locations of surface-water sources (streams, lakes, reservoirs); and sources of any purchased water. Some water suppliers use combinations of groundwater, surface water, or purchased water.
- **Total withdrawals.** Amounts of water pumped may have been measured by flowmeters or calculated using pump rates and number of hours pumped. The rate of withdrawal may be by day, month, or year and should be converted to million gallons per day.
- **Metering points.** Water may be metered before treatment, during transport to another location, or as it is delivered to users. Knowing the metering point allows for the accounting of treatment or transit losses and helps avoid double counting of water.
- **Type of treatment plant.** Surface water usually requires more water for treatment processes, such as backwashing filters, than groundwater does. If total reported water is finished water rather than raw water, an amount or percentage of water for treatment should be added for systems to account for water-treatment usage.

- **Names of other connected water suppliers and amounts of water purchased or sold.** Many water suppliers purchase and sell water to other systems, and the amount of water transferred in both directions is needed to accurately determine water use and subsequent water-use coefficients.
- **Number of service connections by type.** Numbers of active residential, commercial, industrial, or other meters may be used with a coefficient to estimate delivery amounts by customer types. Coefficients also may be derived from the number of meters, the amount of water delivered, and population or employment counts. Numbers of active residential meters, including single-family and multifamily housing, are useful for determining population served.
- **Amounts of water delivered for several purposes.** Total water use for a public supply is accounted for through deliveries to other public supplies, to local domestic, commercial, industrial, and thermoelectric-power customers, and in public use and losses. Delivery data can be used to develop water-use coefficients for estimating withdrawals for similar public suppliers. Total metered uses also can be subtracted from total withdrawals to determine amounts of public use and losses.
- **Location of retail service areas.** Many public-water suppliers serve customers outside city limits or in multiple counties or States. Water sold or distributed to other counties will affect county totals and should be defined.

Estimating public-water losses and transfer water amounts for public supply is not mandatory; however, the data are likely to be collected as part of the survey. In Solley and others (1998), the difference between total raw water withdrawals and metered water use is equivalent to public use and losses, and that difference averaged about 15 percent of public-supply withdrawals in the United States during 1995. Public use and losses vary substantially among water suppliers, depending on treatment needs, system efficiency, condition and age of the infrastructure, and the amount of public-supply water use. For example, older systems and those that are undergoing repairs to lines or towers have greater losses because of leaks, flushing, and tower draining than systems with few problems. Often public use and system losses cannot be separated.

Information on water transfers is necessary for estimating public-supply withdrawals. Estimates of total water use for suppliers using a combination of their own withdrawals and purchased water, or for those selling water wholesale, should be adjusted to identify withdrawals by the county in which they occur.

An effort should be made to estimate water withdrawals for each public-supply system in the county. At a minimum, water-withdrawal data should be obtained for the largest public suppliers in each county. For public suppliers of smaller amounts of water, water use may be estimated based on water-right allocations, average water production, previously reported usage, or changes in population or population served. Sometimes estimates of total withdrawal for a public-supply system are based on estimates of water delivered to residential, commercial, or industrial customers or perhaps only on estimates of public-supply deliveries to residential customers. Depending on the size of the public-supply system and on the available time and resources, estimates of commercial and industrial deliveries and public use and losses should be added to domestic-delivery estimates to approximate total public-supply water use. References that can be used to aid in estimating commercial deliveries included McCuen and others (1975), Wolff and others (1975), Kim and McCuen (1979), Kammerer (1982), Jones and others (1984), and Bucca and Marella (1992). Information and data on residential water use, indoor and outdoor use, are available from a detailed study for California (Gleick and others, 2003).

Public-supply water withdrawals for the smaller systems also may be estimated using population served and a total public-supply per capita use coefficient. Preferably, the coefficient is derived from public-supply systems of similar size, similar customer base, similar rate structures, similar demographic and socioeconomic characteristics, or similar climatic and geographic settings.

Per Capita Use Coefficients

A per capita use coefficient may be used to estimate total public-supply water use or domestic deliveries from public supply. In each case, the per capita use coefficient usually has a different value. Per capita coefficients for total public-supply withdrawals and domestic deliveries are commonly expressed in terms of gallons per person per day and require an estimate of population served. For the compilation, the different per capita use terms are defined, for clarity and convenience of discussion, as total public-supply per capita use coefficient and public-supply domestic per capita use coefficient. Total public-supply per capita use is derived by dividing average daily total public-supply water use by the population served only by the system. Total water use accounts for the water withdrawn and purchased by a system and subtracts from that amount the water sold to other systems. Total public-supply per capita use coefficients are generally larger for systems that serve industrial and commercial users or have large losses. Public-supply domestic per capita use is derived by dividing average daily domestic deliveries by the

population served only by the system. The coefficients can be compared to other sources of total public-supply per capita use, and public-supply domestic per capita use coefficients include the documentation from previous compilations, technical literature, or State administrative or legislative documents.

Population Served

Population served refers to the population within a county receiving water from a public-supply system on a year-round basis and excludes vacationers and second-home owners. Persons living on military bases, on Native American Indian reservations, and in prisons constitute a population served by the public-water system serving those communities. Population served by public-water suppliers is estimated for all public-water suppliers regardless of the source of the water (groundwater, surface water, purchased water, or a combination of sources of water). Population served is compiled in the county of residence, which is not necessarily the county where the withdrawals occur. Population served within a county cannot exceed the total county population.

Individual public-water systems, State agencies, and SDWIS are sources of population-served data. Additionally, county estimates of the source of water (public or private water system, individual drilled well, individual dug well, or other) to housing units were published in the 1990 Census of Housing: Detailed Housing Characteristics (U.S. Department of Commerce, U.S. Census Bureau, 1993). Although the data are dated and apply to the number of housing units rather than the number of occupied housing units, the data can aid in the overall analysis of population served in a county and perhaps serve as a baseline from which to compare the population-served data received from the other sources.

Population-served numbers may be unreliable for several reasons and should be checked. Some potential problems include service-area boundaries, which for many public suppliers do not correspond to political boundaries such as city limits or county lines; therefore, census population is adjusted to accommodate customers living outside city limits or county lines to account for total population served. For water suppliers with service areas that span more than one county, an estimate is made of the population residing in each county.

In estimating population served, other errors may be caused by counting the population served more than once, especially if a supplier providing wholesale water supplies to other systems reports a population-served number that may erroneously include both retail and wholesale population-served numbers. Errors in a reported population served sometimes can be detected when comparing aggregated county population served to total county census populations.

If population-served numbers are not available, population served can be estimated based on the number of residential connections and the number of persons per household. Individual water suppliers can provide the number of residential connections, which may include multifamily dwellings. Because the number of billed residential connections often approximates the number of households that are occupied in the service area, this statistic, although not always available, is preferred to the more general statistic, total number of residential connections. The use of total residential connections would likely overestimate the population served.

Census data on housing characteristics for counties and the incorporated places within the counties include ratios of average persons per household. As with the population served numbers from different sources, the reliability of the number of persons per household also should be checked. The population served that is reported by public-water suppliers may be over-reported, if it is estimated by using a ratio of persons per household that is too large.

Domestic Deliveries

Public-supply deliveries for domestic purposes will be estimated for the compilation. Domestic-delivery data may be collected from the appropriate State agency or from the public-supply system, estimated using population served and a public-supply domestic per capita use coefficient, or estimated from a sampling of the public-supply systems. Two additional sets of data may be available from the public-water systems and are helpful:

- The number of billed residential customers or the number of residential service connections.
- Amount of water delivered for domestic purposes during the compilation year.

Domestic deliveries from public supply can be estimated, if needed, by using a per capita water use coefficient, or estimated as a percentage of the total withdrawal for public supply, based on data from other public-water systems of similar size and in the same general region of a State. The method used to determine domestic deliveries must be fully described in the documentation for the compilation.

Estimating Domestic Deliveries Using Population Served and a Coefficient

Domestic deliveries from public supply can be estimated by using population served and a public-supply domestic per capita use coefficient. Residential use varies from household to household; however, households served by the same public-supply system often have a common pattern of use influenced by factors such as water rates, water-conservation programs, lot size, customer affluence, climate, and topography. Although public-supply systems with similar water-use characteristics are likely to have similar per capita use coefficients among systems, a common pattern of residential use, especially outdoor use, may not exist because of variation in this set of factors. Therefore, the coefficient for one system may or may not be valid for all systems within the State, and more than one public-supply domestic per capita use coefficient may have to be determined for a State.

Outdoor water use can be a major component of domestic deliveries, especially in arid climates; this outdoor usage is reflected in the per capita use coefficient. In some areas, residential communities may receive potable water from a public-water supplier for indoor use and nonpotable water through a separate distribution system for outdoor irrigation of lawns and gardens. An example of a "dual-use" area is where developers provide the nonpotable water to houses in urban areas built on former farmland, using water previously allocated for agricultural irrigation use. Homeowners may also use wells to supply nonpotable water for landscape and yard irrigations. Public-supply domestic per capita use coefficients in these dual-use areas generally are lower than in areas where customers use publicly supplied water for indoor and outdoor uses. The nonpotable water in the examples previously described would be counted as self-supplied domestic rather than as a delivery from public-supply to domestic use.

Estimating Domestic Deliveries as a Percentage of Total Public-Supply Water Use

If data are not available for other methods, domestic deliveries may be estimated as a percentage of the total water use for a system, a county, or a State. However, because the customer base of public suppliers and use patterns may vary a great deal, caution should be used in applying county- or State-wide percentages. The percentage of total water withdrawals used for domestic delivery should be based on percentages calculated for systems with reported domestic deliveries and applied to systems of similar size and similar geographic area. Care should also be taken when applying percentages from previous compilations because the water-use demographics and domestic, commercial, and industrial deliveries likely change through time. In determining the percentage of domestic deliveries compared to total deliveries, an exploratory sampling of a selected set of public-supply delivery data should be taken to determine a representative percentage and tested to see if applying a percentage to total deliveries would be a valid approach.

Self-Supplied Domestic

Domestic water use is water used for indoor and outdoor household purposes. Common indoor uses include water for drinking, food preparation, bathing, washing clothes and dishes, and flushing toilets. Major outdoor uses include watering lawns and gardens and washing cars. Water for domestic use may be delivered from a public supplier or may be self-supplied. Self-supplied users may withdraw water from a private source, such as a well or spring, or capture rainwater in a cistern.

Data Elements

The category of self-supplied domestic consists of the following mandatory and optional data elements. Data for the optional elements may be compiled and entered into AWUDS, but will not be part of the national water-use compilation as published in the water-use circular series. The optional data, however, will be available for other types of water studies.

Mandatory

- Groundwater withdrawals, freshwater, by county.
- Surface-water withdrawals, freshwater, by county.

Optional

- Consumptive water use.
- Withdrawals aggregated by HUC.
- Groundwater withdrawals aggregated by principal aquifer.

Sources of Information

For each USGS WSC, the documentation for the previous compilations should be the starting point for planning the data collection for the current compilation.

The previous documentation for the self-supplied domestic category may contain the location and types of electronic and paper files; agency and contact information; agency and internet resources; and methods, techniques, and coefficients used to collect or estimate data. Other sources of information may be available in each State. Additional information concerning self-supplied domestic water use may be obtained from the following sources.

Agencies or Other Entities

Possible contacts for self-supplied domestic water-use data are listed as follows. Water-use data from these sources can range from reported water withdrawals to coefficients and ancillary data that can be used to estimate water withdrawals and domestic self-supplied population. Multiple datasets can be used to determine the best estimates and can be used during the QA/QC review.

- Governmental agency responsible for well permits.
- Public-water supply records of residential use.
- Public-water supply records of population served.
- State agency responsible for permitting water withdrawals or private wells.
- Groundwater resource studies.
- Local chambers of commerce.
- State public health agencies.
- State and regional planning agencies.
- Technical literature.
- AWWA research.
- Consulting firms.

Internet Resources

Many agencies and other entities maintain self-supplied domestic water-use information and databases on the internet. Sources of information include the following.

- U.S. Census Bureau, accessed at http://www.census.gov/.
    - Selected population and housing characteristics by county and down to the block/ census tract level—the American FactFinder, accessed at http://factfinder.census.gov/.
- EPA, accessed at http://www.epa.gov/.
- AWWA, accessed at http://www.awwa.org/.
- Proceedings and reports on domestic water use are available through the AWRA, accessed at http://www.awra.org/.

Compilation Techniques

Self-supplied domestic water withdrawals typically are estimated by multiplying the self-supplied population by a self-supplied domestic per capita use coefficient. However, the approach to estimating self-supplied domestic water withdrawals may vary depending on the type of data available to the study chief. Self-supplied population is automatically calculated in AWUDS by subtracting total population served by a public supply in a county from the total census population in the county.

The reliability of the estimate of self-supplied population depends on the reliability of the population-served data reported for the public-water systems. The reliability and accuracy of the self-supplied domestic water-withdrawal estimates are also dependent on the domestic per capita use coefficient. The coefficient may be more accurate if it is determined for separate geographic areas of the State that have distinctive climatic or water-use characteristics. A public-supply domestic per capita use coefficient may be substituted for a self-supplied domestic per capita use coefficient if the publicly supplied and self-supplied populations are believed to be similar in terms of water use, especially if the public-water supply system is relatively small with minimal commercial deliveries and zero industrial deliveries. If the public-supply domestic per capita use rates developed from the sampling indicate regional differences within the State, an average public-supply domestic per capita use should be estimated for each county or region.

Self-supplied or publicly supplied domestic per capita use coefficients also may be obtained from estimates provided by other agencies or from technical, administrative, or legislative literature. Some States have published projections of future water demands and may have calculated per capita use rates. Regional and State planning agencies, State natural-resource agencies, or the State's public health agency are possible sources for this information. Per capita use coefficients also have been determined as part of research conducted by professional organizations, such as the AWWA, and by consulting firms.

In areas where sewer districts serve houses that are not on public-water supplies, wastewater-treatment facilities often maintain information about self-supplied residences for billing purposes. This information can be used to estimate withdrawals for areas and to develop per capita use coefficients along with population and housing data. State pollution-control agencies also estimate per capita uses when designing wastewater lagoons. These design values, usually from about 80 to 100 gallons per capita per day (gpcd), may provide a good estimate of domestic per capita use. Other coefficients, such as gallons per day per household or gallons per day per household market value can be used to determine domestic self-supplied withdrawals in areas for which ancillary data on housing are available.

Domestic self-supplied withdrawals typically are from wells. The source for about 98 percent of self-supplied domestic withdrawals during 2000 was groundwater (Hutson and others, 2004). Information on the use of surface water for domestic supply may be obtained from the State public health agency, the State agency responsible for permitting or water-use data collection, census housing data, or local knowledge of areas where surface water is used. Cisterns used to collect rainwater for domestic use generally are considered to be surface-water sources. Springs are considered surface water in some States and groundwater in others.

Consumptive Use

Consumptive use can be estimated for the total of self-supplied and publicly supplied domestic water uses. Domestic consumptive use is typically estimated as a percentage of the water that is withdrawn and delivered for domestic purposes. Percent consumptive use should be based on information obtained from water suppliers or from references for your State.

Commercial

The commercial water-use category was a mandatory category through 1995 and became an optional category starting with the 2000 national compilation (Kenny, 2004). The commercial water-use category includes water used by commercial facilities such as hotels, restaurants, office buildings, educational institutions, prisons, government and military facilities, and retail sales stores. The water used by commercial facilities can be self-supplied or delivered by public-water suppliers. For military bases and prisons, if domestic use cannot be determined, all withdrawals should go in the commercial category.

The irrigation water provided by public suppliers to golf courses, parks, and other landscaped areas can be reported as a delivery to commercial use. Public-supplied deliveries for clubhouses and other non-irrigation uses at golf courses can be reported as a commercial use. Also for the 1995 compilation, offstream fish hatchery withdrawals were reported in the commercial water-use category. For the current compilation, offstream fish hatchery withdrawals will be reported as aquaculture. A list of commercial facility types by SIC and NAICS codes can be generated with the SWUDS template builder.

Data Elements

Currently (2015), all commercial data elements are optional.

- Self-supplied groundwater withdrawals (fresh).
- Self-supplied surface-water withdrawals (fresh).

- Deliveries from public suppliers.
- Consumptive use (fresh).
- Reclaimed wastewater.

Sources of Information

Information concerning commercial water use may be obtained from the following sources. These sources are not all encompassing. They are examples only.

- Individual facilities (by personal visits and [or] cooperator surveys).
- Water suppliers (for deliveries).
- State agency that permits the use of water.
- State or local department of economic development.
- Local chamber of commerce.
- Sewage-treatment facilities.
- Tax appraiser and county assessors.
- State board of education (student enrollments).

Compilation Techniques

The compilation methods described in this section are not intended to be all encompassing. These techniques can be used if better methods are not available.

Water Withdrawals

The water withdrawals by self-supplied commercial facilities vary with the size and type of the commercial facility. The water withdrawn by commercial facilities may be available at the facility or reported to State or local agencies. If the information is not available, commercial water-use coefficients (gallons per day per person, thousand gallons per day per building, gallons per day per square foot, gallons per night per hotel room) may be used. Estimates of withdrawals by self-supplied commercial facilities may be determined from information available by similar SIC code commercial facilities in the State or in an adjacent State. Sewage-treatment plants may maintain some information, such as billing records, about self-supplied facilities that release wastewater to the plants. Withdrawals may be estimated by using this source if better information is not available. The larger commercial water-using facilities are institutions, water parks, resorts, and military installations. If the domestic population can be determined for military installations and institutions, then the withdrawals should be categorized as public supply with deliveries to domestic and commercial users.

Selected references that contain some commercial water-use coefficients include Wolff and others (1975), Baumann and others (1981), van der Leeden and others (1990), LaTour (1991), Metcalf and Eddy, Inc. (1991), Bucca and Marella (1992), and Adams (1993). Literature coefficients may be applied in areas that have similar climate and socioeconomic factors to the area in which data were collected in order to estimate water withdrawals. Information and data on commercial water use are also available from a study for California (Gleick and others, 2003).

Deliveries from Public Suppliers

The volume of water delivered to commercial facilities is an optional data element, and may be obtained from the public supplier when compiling information about public-supply withdrawals. Public suppliers may have in their billing systems the number of connections and volume of water delivered to commercial users. If delivery data are available by meter size rather than by connection or use type, water suppliers may be able to indicate the size of meters installed in commercial establishments for their water system. In this case, the information may be used to separate commercial deliveries from the public supply. If

specific information is not available for deliveries to commercial users, then an estimate of the percentage of total water delivered to the commercial users can be used based on previous information or requested from the public-water system.

If commercial-delivery data or estimates are not available from the water supplier, then the delivery data must be estimated by other methods. One estimation method is to apply a coefficient based on data obtained from the commercial facility or the public-water supplier. Another method is to subtract the distribution loss and domestic use (possibly calculated from population multiplied by per capita use) and other uses (industrial, power, public use) from the public-supply withdrawal.

Consumptive Use

Consumptive use by commercial uses is an optional data element, and may be estimated for all commercial users as a percentage of the combined self-supplied withdrawals and public-supply deliveries of water. The best consumptive-use estimates are usually obtained through contacts with commercial establishments that withdraw the largest volume of water and have the largest consumptive use.

The most common method to estimate consumptive use is using coefficients. In 1990, State estimates of coefficients of commercial consumptive use ranged from 5 to 30 percent of withdrawals and deliveries (Solley and others, 1993). Coefficients of consumptive use may be derived by subtracting releases from withdrawals using data from commercial facilities that maintain withdrawal and release records. Consumptive-use coefficients determined for a commercial facility can then be applied to similar facilities in the same area.

Reclaimed Wastewater

The total use of reclaimed wastewater by commercial facilities is an optional data element. The wastewater-treatment facility or the utility department may be able to provide information about the use of reclaimed wastewater by commercial facilities. In many States, separate records are maintained on further use of treated wastewater.

Industrial

Industrial water use includes water used for such purposes as fabricating, processing, washing, diluting, cooling, or transporting a product; incorporating water into a product; or for sanitation, maintenance, or landscaping needs of a facility. Industrial water users are businesses classified in the SIC codes under construction and manufacturing. Water supplies may be self-supplied industrial withdrawals derived from groundwater and (or) surface water, may be provided by a public-water supplier (public-supply industrial deliveries), or may include water from reclaimed wastewater.

Data Elements

The industrial water-use category consists of mandatory, mandatory with null values allowed, and optional data elements. Data for the optional elements may be compiled and entered into AWUDS, but will not be part of the national water-use analysis as published in the water-use circular series. The optional data, however, will be available for other types of water studies. Reclaimed-wastewater use is a mandatory data element for the industrial category. Zeros should be reported for counties where the delivery of reclaimed wastewater does not occur, but null values can be stored in AWUDS for counties where the use of reclaimed wastewater is uncertain or unknown.

Mandatory

- Groundwater withdrawals, freshwater, by county.
- Groundwater withdrawals, saline water, by county.
- Surface-water withdrawals, freshwater, by county.
- Surface-water withdrawals, saline water, by county.

Mandatory But Null Values Allowed

- Reclaimed wastewater, by county.

Optional

- Deliveries from public supply, by county.
- Consumptive use, freshwater, by county.
- Consumptive use, saline water, by county.
- Number of facilities, by county.
- Any data aggregated by eight-digit HUC.
- Groundwater withdrawals aggregated by principal aquifer.

Sources of Information

For each USGS WSC, the documentation for the previous compilations should be the starting point for planning the data collection for the current compilation. The previous documentation for the industrial water-use category may contain the location and types of electronic and paper files; agency and contact information; agency and internet resources; and methods, techniques, and coefficients used to collect or estimate industrial data. Additional information on industrial facilities and the associated water use may be obtained from the sources listed below. Other sources of information may be available in each State.

Agencies or Other Entities

Possible contacts for industrial water-use data are listed below. Water-use data from these sources can range from reported water withdrawals to coefficients and ancillary data that can be used to estimate water withdrawals. Multiple datasets can be used to determine the best estimates and can be used during the QA/QC review.

- State agencies that administer water rights, allocate water to users, or collect water-use data.
- State agencies that issue permits for the discharge of water.
- Health departments or public-water suppliers—many industries receive treated water for sanitary uses.
- Wastewater-treatment facilities.
- State department of labor.
- State directories of manufacturers.
- Local chambers of commerce.
- County assessors and zoning boards.
- Individual facilities (by personal visits and [or] cooperator surveys).
- Public-water suppliers (for deliveries).

Internet Resources

Many agencies and other entities maintain industrial water-use information and databases on the internet:

- U.S. Census Bureau, accessed at http://www.census.gov/.

- Economic Census and Surveys, including sector-specific reports by State, accessed at http://www.census.gov/econ/census/.
- County-level data; number of establishments and employees by manufacturing industry; accessed through the U.S. Census Bureau, American FactFinder, at http://factfinder.census.gov/.
- Industry series reports—Manufacturing, accessed at http://www.census.gov/econ/census/help/sector/industry_series.html.
- EPA, accessed at http://www3.epa.gov/.
- Water Discharge Permits (NPDES)—Information and data regarding facilities holding NPDES permits. Specify the facilities by using any combination of facility name, geographic location, SIC code, and chemicals, accessed at http://www.epa.gov/npdes.
- Hoovers (previously Harris InfoSource)—Source to purchase lists of manufacturing establishments. Profile reports include primary and secondary SIC codes, number of employees, and Internet address of company, if available, accessed at http://www.hoovers.com/. Data are owned and distributed by Dun and Bradstreet (http://www.dnb.com/) and may be downloaded for a cost.
- Homeland Infrastructure Foundation-Level Data (HIFLD) datasets—Homeland Security Infrastructure Program (HSIP) Gold and HSIP Freedom—HSIP Gold is a database assembled by the National Geospatial-Intelligence Agency in partnership with the HIFLD Working Group for use by various homeland defense, security, and preparedness agencies, and is available at no cost to other Federal agencies. HSIP Freedom is a license-free subset of HSIP Gold. The databases are compilations of geospatially enabled baseline infrastructure datasets. Users must apply for access and sign a use agreement (https://gii.dhs.gov/HIFLD/public/HSIP-Gold-Freedom-One-Pager-2015.pdf).

Compilation Techniques

Self-supplied industrial withdrawals tend to occur within particular industry groups that require large amounts of water for fabricating, processing, washing, diluting, cooling, or transporting a product or incorporating water into a product. However, there are exceptions in which the more water-use-intensive industries are publicly supplied and the less water-use-intensive industries are self-supplied. Major industrial groups that historically have been self-supplied include food and kindred products (SIC 2011–2099), paper and allied products (SIC 2611–2679), chemicals and allied products (SIC 2812–2899), petroleum-refining and petroleum-related industries (SIC 2911–2999), and primary metals industries (SIC 3312–3399). Although these types of industries historically have used the most water per facility, the most important industry in any given county may not fall into one of these five groups. Therefore, it is important to consider any industries outside these groups.

Constructing a master list of industrial facilities is fundamental to all of the compilation techniques. A master list, at a minimum, consists of the names and locations of industries, and sources of water. The information to build or update this list may be available from previous documentation, one or more State agencies, or from USGS water-use databases. State reporting programs and individual industries are good sources of data. Reporting agencies have varying criteria for obtaining industrial water-use data. These criteria determine if withdrawals are permitted, registered, or monitored; the trigger levels for reporting and the application of the trigger level to groundwater or surface-water sources; and whether the reporting is statewide or applies to selected counties or watersheds. If the State agencies use a relatively large minimum water withdrawal rate as a reporting criterion, data for a substantial number of small industries may not be collected or reported. Therefore, some needed facility information must be obtained directly from the industry or be determined from other ancillary information.

Water Withdrawals

The self-supplied withdrawals at industrial facilities vary depending on the size and type of industry. Water-withdrawal data may be available from the facility or from State or local agencies. Three general approaches can be used to compile industrial water-withdrawal data:

1. Acquire site information and withdrawal data for individual industries. If needed, focus on industries with larger withdrawals while striving for an adequate representation of the withdrawals in each county.
2. Acquire site information with ancillary data on employment or production, and estimate water withdrawals by using water-use coefficients. The coefficients are usually in the form of usage in gallons per day per employee or per unit of product.

3. Combine the two approaches by acquiring industrial facility information and water withdrawals for the larger industries and using these data to develop water-use coefficients to estimate withdrawals for smaller industries.

Industrial water information may be acquired through telephone contacts, site visits, or surveys sent out by cooperating agencies. The level of detail obtained depends on the availability of the information and the necessary resources available to collect the data. Confidentiality should be considered. Useful data to acquire include the following:

- Facility name, mailing address, physical plant facility address.
- County.
- Contact name, title, telephone and fax number, and e-mail.
- Industry description or principal products.
- SIC codes—primary and secondary.
- Estimated annual quantity of product produced.
- Total number of employees.
- Number of groundwater sources, aquifer names, and number and depth of well(s).
- Number of surface-water sources and names of streams or water bodies.
- Latitude and longitude of wells or intakes.
- Maps of facility and water intakes.
- Name of public water-supply sources.
- Amounts of water withdrawn and time period of withdrawal for each source.
- Amount or percentage of total withdrawal that is freshwater or saline water, groundwater or surface water.
- Method of determining or estimating water withdrawals.
- Percentage of total or amount of water used for cooling, processing, sanitary use, boiler feed, power generation, or other amount of water recycled or reused.
- Wastewater discharge—average amount of discharge or percentage relative to withdrawals.
- Number of days operating each year.
- Average number of hours of operation each day.
- Approximate age of the facility.
- Confidentiality statement, if needed.

Water-Use Coefficients

Industrial water withdrawals can be estimated by using water-use coefficients and ancillary data such as numbers of employees, units of production, or annual sales if reported data are not available. Reported water-use data from the largest industries can be used to develop locally adjusted water-use coefficients to estimate withdrawals for smaller industries of the same type.

The use of coefficients to estimate industrial water use is imprecise because of the variability in factors affecting water use by industries. The specific processes, age of the facility, cost of the water and wastewater treatment, and amount of recycling all contribute to the amounts of water needed by an industry. These factors should be considered when using national coefficients or when developing and adjusting local coefficients for industries not surveyed. The coefficients and the source of coefficients to estimate industrial water use should always be well documented.

Deliveries from Public Suppliers

Water deliveries to industrial facilities is an optional data element and may be obtained from public suppliers when compiling information about public-supply withdrawals. Public suppliers may have water sales information concerning the number of connections, use, and volume of water delivered to industrial users. If metered delivery data are available by meter size, public suppliers should be able to indicate, for their system, the size of meters installed in industrial establishments. If the information is not available, the water-utility operator may be able to provide some estimate of the percentage of total water delivered to industrial users.

If data or estimates on deliveries for industrial purposes are not available from water suppliers, the data must be estimated by other methods. One method is to subtract the estimated distribution loss and domestic use (possibly calculated from population multiplied by per capita use) and other uses (commercial, power, public use) from total deliveries. Please refer to other sections in these guidelines for more detailed information on individual category calculation techniques.

Consumptive Use

Consumptive use by industrial uses is an optional data element, and if computed must be estimated for the total of self-supplied and public-supply industrial water. Consumptive-use estimates could be determined from information obtained through contacts with industrial establishments that withdraw or consume the largest volumes of water. If no other data are available, estimates of consumptive use by SIC can be inferred from information available in the literature.

If delivery and release information are available for industrial facilities, then consumptive-use information could be estimated by the difference between the deliveries and releases. The consumptive-use coefficients determined may be applied to similar facilities (same SIC) in the same geographic area.

Allocation of Water Withdrawals by Source

The industrial water-use withdrawals by source are mandatory data elements, and should be allocated to the county in which the withdrawal occurs. If the source, location, or quality of the water are not known, the allocation of the industrial water withdrawals by source and quality can be estimated by discussion with local or State agencies or by combining local knowledge of water sources and applying spatial analysis. Determining whether water is freshwater or saline water also may require some knowledge of the type of industrial activity. Spatial analysis may indicate the possibility of tapping into a saline water source; however, the industrial process for which the water is needed may require freshwater. Seawater and estuary-bay water are the primary sources of saline surface water in the United States. Generally, because the use of saline groundwater for industrial use is both specific and unique, the use of saline groundwater is generally known within the State. Saline water is water that contains 1,000 milligrams per liter or more of dissolved solids.

Thermoelectric Power

Thermoelectric-power water use is the amount of water used in the process of generating electricity from heat by steam-driven turbines. Thermoelectric power plants use fossil fuels, nuclear fission, solar energy, and geothermal energy to heat water into steam which then turns turbines to generate electricity. After powering the turbines, the steam is then cooled and condensed back to water through the transfer of heat to cooling water flowing through a condenser (heat exchanger). The condensed water is then routed back to the heat source where the cycle begins again. Although some water, in the form of steam, is used to turn the turbines and generate electricity, the predominant use of thermoelectric-power water is in the cooling process. Most water for thermoelectric use is self-supplied from freshwater or saline surface-water sources. Smaller quantities are derived from groundwater sources or provided by public suppliers. The water used to create steam to drive the turbines must be freshwater; however, cooling water may be fresh or saline. All thermoelectric power plants are classified as SIC 4911 and as NAICS codes 221112 through 221118, excluding 221115 which is wind electric power generation.

The amount of water withdrawn and consumed at thermoelectric power plants primarily depends on the type of cooling system at the plant. The two general types of cooling are once-through (open-loop) cooling and recirculating (closed-loop) cooling. For the compilation, water withdrawal and consumptive use will be compiled for each type of cooling system and will be stored in AWUDS in units of million gallons per day.

Once-through cooling systems withdraw large amounts of water because the water is not recirculated within the facility. The water is withdrawn from a surface-water source, circulated through the condenser, and then returned to a surface-water body at a higher temperature. Withdrawal for a once-through cooling system is the amount of water that flows through the condenser,

and consumptive use is the amount of water lost through evaporation from the surface-water body due to the heated return flow. This technology is common in older facilities but generally is not used for new facilities because of increasingly restrictive thermal and other water-quality requirements for return water.

Recirculating cooling systems include cooling ponds and wet cooling towers. They recirculate water within the facility, thus reducing the overall water withdrawal requirement. Withdrawals for recirculating systems (also known as "makeup" water) replace cooling water lost to evaporation, blowdown, drift, and leakage, and are much less than the water flowing through the condenser. Cooling ponds are typically shallow reservoirs with large surface areas that receive heated water from the condenser. The water is cooled by evaporation, which is consumptive use, and reused in the cooling process. In cooling towers, heated water from the condenser flows through a volume of fill within a tower while air flows through the same volume. Water is cooled by evaporation, which is consumptive use, and is collected in basins beneath the fill where it is piped back to the condenser for reuse. Cooling towers are the most common cooling-system type of newer power plants, especially where water resources are limited, or where local regulations prohibit the release of heated return flow water.

Net electrical generation, the amount of electricity that is generated, transmitted, and distributed for consumer use, will also be compiled for each type of cooling system. The value will be stored in AWUDS in units of gigawatthours. A gigawatthour is equivalent to 1,000 megawatthours or 1 billion watthours.

Another type of thermoelectric plant is the combined heat and power (CHP or cogeneration) plant. A cogeneration plant produces electricity and heat simultaneously, and uses the heat for industrial or commercial purposes. Many, but not all, cogeneration plants are industrial or commercial facilities. An example is a university with a power plant on campus that generates electricity and heats the campus buildings. On the other hand, some are independent power producers that identify as utilities and sell power to the electrical grid. If the data from a cogeneration facility are sufficient to identify water used in power generation separately from the water used for industrial or commercial purposes, then the water used in power generation and the power generated are compiled with other county thermoelectric-power water-use data.

Water-use data for geothermal power plants are reported in much the same way as recirculating cooling systems at thermoelectric plants. The make-up water withdrawn from a geothermal source is reported but the recirculating water in the plant is not reported. The two primary types of geothermal power plants are the dual-flash plant and the binary plant. In the dual-flash system, superheated water (above 212 degrees Fahrenheit) is released from pressure near the surface, where it "flashes" into steam in a separator. The water that does not turn to steam is sent to a second separator where the pressure is further reduced and another portion of it flashes to steam. The steam from the separators is directed to the turbines. The steam turns the turbines, then is cooled and condensed into water and injected back into the geothermal reservoir. Water use is reported for uses such as maintenance of the geothermal systems (makeup or maintenance water).

In the binary system, or heat exchange system, the geothermal water is pumped through a heat exchanger and injected back into the geothermal reservoir. The heat exchanger contains a second fluid that has a low boiling point. The heat from the geothermal water is transferred to this second fluid making it boil and vaporize. The vapor that pushes against the turbine blades is condensed back to a fluid and recycled through the heat exchanger. The binary system method enables the use of lower temperature geothermal water to produce electric power. The water pumped from and reinjected into the geothermal reservoir is not reported as use. Water use at this type of system is reported for any maintenance water.

Data Elements

The category of thermoelectric power consists of the following mandatory and optional data elements. Data for the optional elements may be compiled and entered into AWUDS, but will not be part of the national water-use analysis as published in the water-use circular series. The optional data, however, will be available for other types of water studies.

Mandatory

- Groundwater withdrawals, once-through cooling, freshwater, by county.
- Groundwater withdrawals, once-through cooling, saline water, by county.
- Surface-water withdrawals, once-through cooling, freshwater, by county.
- Surface-water withdrawals, once-through cooling, saline water, by county.
- Groundwater withdrawals, recirculating cooling, freshwater, by county.
- Groundwater withdrawals, recirculating cooling, saline water, by county.

- Surface-water withdrawals, recirculating cooling, freshwater, by county.
- Surface-water withdrawals, recirculating cooling, saline water, by county.
- Consumptive use, once-through cooling, freshwater, by county.
- Consumptive use, closed-loop cooling, freshwater, by county.
- Power generated, once-through cooling, by county.
- Power generated, closed-loop cooling, by county.

Optional

- Deliveries from public supply, once-through cooling, by county.
- Deliveries from public supply, closed-loop cooling, by county.
- Number of facilities, once-through cooling, by county.
- Number of facilities, closed-loop cooling, by county.
- Reclaimed wastewater, once-through cooling, by county.
- Reclaimed wastewater, closed-loop cooling, by county.
- Any data aggregated by eight-digit HUC.
- Any data aggregated by aquifer.

Sources of Information

For each USGS WSC, the documentation from previous compilations and the available reports and methods for estimating withdrawals and consumption should be the starting point for planning the data collection for the current compilation. The previous documentation for the thermoelectric-power category may contain the location and types of electronic and paper files; agency and contact information; agency and internet resources; and methods, techniques, and coefficients used to collect or estimate data.

USGS National Water-Use Science Project (NWUSP)

The USGS NWUSP will provide a data file of *model-estimated* average daily water withdrawal and consumptive use, along with verified cooling-system types, for every thermoelectric plant in the United States, including cogeneration (or CHP) plants that are identified as utilities according to SIC/NAICS codes. The USGS method for estimating water use at thermoelectric power plants is based on linked heat and water budgets constrained by plant generation technologies, cooling system technologies, and environmental variables such as air temperature, water temperature, and wind speed. In addition to the "best" model-estimated average daily water withdrawals and consumptive use, plant-specific plausible ranges of withdrawals and consumptive use will also be provided. These ranges provide a QA/QC tool with which to compare reported and other estimated thermoelectric water-use data. The methods for estimating water withdrawal and consumptive use at thermoelectric plants are described in the following reports:

- Diehl and Harris, 2014: Withdrawal and Consumption of Water by Thermoelectric Power Plants in the United States, 2010 Scientific Investigations Report 2014–5184, available at http://dx.doi.org/10.3133/sir20145184.
- Diehl and others, 2013: Methods for Estimating Water Consumption for Thermoelectric Power Plants in the United States, Scientific Investigations Report 2013–5188, available at http://dx.doi.org/10.3133/sir20135188.

The NWUSP will also provide a data file of *reported* average daily water withdrawals, returns, consumptive use, and net electrical generation by thermoelectric plants, including cogeneration plants that are identified as utilities according to SIC and NAICS codes. The source of the reported data is the U.S. Department of Energy–Energy Information Administration

(DOE–EIA) electricity databases. The DOE–EIA maintains site-specific water-use data for thermoelectric power and cogeneration plants with nameplate capacities of 100 megawatts or more and net electrical generation data for plants with nameplate capacities of 1 megawatt or more.

Agencies and Other Entities

Other possible sources of thermoelectric water-use data are listed below. Water-use data from these sources can range from reported water withdrawals to coefficients and ancillary data that can be used to estimate water withdrawals, consumptive use, and power generation by cooling-system type. Multiple datasets can be used to determine the best estimates and can be used during the QA/QC review.

- State agencies that administer water rights, allocate water to users, or collect water-use data.
- State agency responsible for compliance with EPA's Clean Water Act Program through the NPDES and Permit Compliance System (PCS) and Integrated Compliance Information Systems (ICIS).
- State agency for power administration.
- Regional "power pools" (groups of electric utility companies).
- Individual thermoelectric plant operators.

Internet Resources

A few Federal agencies maintain thermoelectric water-use information and databases on the internet (some State agencies may also have this information). Below are links to Federal agency information on thermoelectric power plants.

- U.S. Department of Energy (DOE), accessed February 11, 2016, at http://energy.gov/.
  - Energy Information Administration (EIA, part of DOE), at https://www.eia.gov/.
  - List of EIA survey-level detailed data files, accessed February 11, 2016, at https://www.eia.gov/electricity/data/detail-data.html.This list includes contact information for each type of report:
    - EIA-860 (Electric generator capacity data—annual)—Electric utility and non-utility generator-specific plant data, including in-service date, prime movers, generating capacity, energy sources, existing and proposed generators, county and State location, ownership, plant configuration and environmental control system characteristics (including cooling-system data), and Federal Energy Regulatory Commission (FERC) qualifying facility status at https://www.eia.gov/electricity/data/eia860/.
    - EIA-923—(Power plant operating data—annual and monthly—with predecessor Forms EIA-920, 906, 423 and FERC-423)—Contains data on electricity generation, fuel consumption, environmental data (including water-use data), useful thermal output, fossil fuel stocks, fuel deliveries, quantity delivered, supplier, coal mine type, British thermal units (BTU), sulfur and ash content, and receipts at the power plant and prime mover level. Includes operating data for combined heat and power plants, at https://www.eia.gov/electricity/data/eia923/.
    - EIA-860M (Electric generator capacity data—monthly)—Supplements the annual survey form EIA-860 data. Includes *preliminary* generator-specific data, including in-service date, prime movers, generating capacity, energy sources, and reporting entity, at https://www.eia.gov/electricity/data/eia860m/.
    - EIA-767 (Discontinued in 2005: Steam-electric plant operation and design data—annual)—Plant operations and equipment design information, including boilers, generators, cooling systems, flue gas desulfurization, flue gas particulate collectors, and stacks. Data now collected on Forms 923 and 860. Historical data, available at https://www.eia.gov/electricity/data/eia767/.
    - Detailed State data (summaries, profiles, graphics), accessed February 11, 2016, at https://www.eia.gov/electricity/data/state/.

- EPA NPDES permits, PCS-ICIS database—Access to data regarding facilities holding NPDES permits. Specify the facilities by using any combination of facility name, geographic location, SIC code, and chemicals. Accessed at http://www3.epa.gov/enviro/facts/pcs-icis/search.html.

Compilation Techniques

The recommended approach for compiling data for thermoelectric power is to use site-specific water withdrawal, consumptive use, and power-generation data. Site-specific data can come from the NWUSP-provided USGS model-estimated data, or the federally reported EIA data. Data could also be collected from other sources such as State agencies, or obtained directly from plant operators. Water withdrawal and consumptive-use data can be obtained from the USGS model-estimated data, the EIA-reported data, State agencies, or plant operators. However, net electrical generation data will come from EIA and will be provided, but could also possibly be obtained through State agencies and plant operators. State agencies that administer water rights or monitor water use may have water withdrawal and consumptive-use information. The State agency that is responsible for compliance with EPA's Clean Water Act is an important source for this information.

EPA administers the PCS-ICIS database, which was designed to track permit, compliance, and enforcement status data for the NPDES program under the Clean Water Act. An NPDES permit is required for all point discharges into U.S. waterways. The PCS-ICIS database contains descriptive information on major power-generating facilities, their location, and monthly return flows. The NPDES permit application and the permit itself usually include detailed descriptions of the plant that provide basic information on all the sources of supply for the plant, the different ways in which water is used in the plant, and water included in the reported discharge values.

Water-use and power-generation data may also be collected by contacting the individual power plant facility. If the contact person for a power plant facility is not known, a good place to start is the person at the plant who prepares the Discharge Monitoring Reports (DMRs) for EPA. DMRs contain information on volume discharged from all pipes in the facility and can be compared to the permit or permit application as to the source of the water and how it was used. The following selected terminology may help in conversations with plant personnel—blowdown, capacity, drift, and makeup water. These terms are defined in the Glossary.

Power-generation data can be used to estimate thermoelectric-power water withdrawals. A coefficient to estimate the gallons of water used per unit-hour of electricity generated is calculated by using information on water withdrawals and power generation from plants of similar age, design, and cooling methods. This coefficient then can be multiplied by the amount of electricity generated during a specified time period by the plant for which withdrawals are being estimated. Coefficients ideally are derived by using the gross power produced, which is the net electrical generation plus the amount of electricity used within the power plant itself. Monthly gross and net power generation, in megawatthours, is available in the EIA-923 database. The in-plant electricity use will not be part of the NWUSP derivative data file provided to the study chiefs.

Quality Assurance/Quality Control

One of the most important aspects of compiling thermoelectric water-use data is thorough QA/QC review of the data. The NWUSP-provided USGS model-estimated data, with plant-specific plausible ranges of withdrawals and consumptive use, provide a QA/QC tool with which to compare reported and other estimated thermoelectric water-use data. If reported or estimated data for a plant are outside the plausible range of withdrawal or consumptive use, further investigation is needed. Similarly, if data are outliers in comparison to data from previous years, further investigation is needed. Contact the source of the data for possible explanations for data variability. Also, keep USGS definitions of thermoelectric withdrawal and consumptive use in mind. Other sources may define these terms differently; the compilation requires USGS definitions to be followed. Data from multiple sources may be used to achieve the most accurate estimates of thermoelectric water use. Document QA/QC methods as well as compilation methods and data sources.

Mining

Prior to 1985, mining withdrawals were categorized as an industrial use. In 1985, mining became a separate water-use category. Beginning in 2005 and continuing through the current compilation (2015), estimates for mining withdrawals will be provided by the NWUSP for all States. USGS WSCs still have the option of reporting their own estimates for mining water use.

The mining water-use category is water used for the extraction of minerals: solids, such as coal and ores; liquids, such as crude petroleum; and gases, such as natural gas. The category includes quarrying, milling (crushing, screening, washing, and

flotation), and other operations as part of a mining activity. It does not include the processing of raw materials, such as smelting ores, refining petroleum, and slurry pipeline operations; these are considered industrial uses of water. Water that is pumped and then reinjected for secondary-oil recovery is considered a water use and should be included in the mining category.

Water pumped from mines (dewatering) or produced as a byproduct of primary oil production is not included if the water is drained and discharged, i.e., transferred from one place to another (usually groundwater to surface water) without being put to use. If water is put to some beneficial use such as washing or dampening roads for dust control, then the water is categorized as a mining use.

Four major SIC groups account for most of the water used in this category:

- SIC 10, Metal mining.
- SIC 12, Coal mining.
- SIC 13, Oil and gas extraction.
- SIC 14, Mining and quarrying of nonmetallic minerals, except fuels.

Data Elements

The category of mining consists of the following mandatory and optional data elements. Data for the optional elements may be compiled and entered into AWUDS, but will not be part of the national water-use analysis as published in the water-use circular series. The optional data, however, will be available for other types of water studies.

Mandatory

- Self-supplied groundwater withdrawals (fresh), by county.
- Self-supplied groundwater withdrawals (saline), by county.
- Self-supplied surface-water withdrawals (fresh), by county.
- Self-supplied surface-water withdrawals (saline), by county.

Optional

- Consumptive use (fresh).
- Consumptive use (saline).
- Reclaimed wastewater.

Sources of Information

Information concerning mining water use may be obtained from any or all of the following sources. Other sources may be available within each State.

- Individual facilities (by personal visits and [or] cooperator surveys).
- State agency that permits the use of water.
- State agency that permits land-reclamation/erosion-control activities.
- State agency that permits mining activities.
- State agency for economic development.
- State geological survey.
- U.S. Bureau of Mines.
- Universities, departments of geology and mines.

Compilation Techniques

The estimation methods described in this section are not all encompassing. The methods described offer consistent techniques to estimate mining water use if better methods are not available. Other methods used to estimate water use for this sector should be fully documented for the compilation.

The NWUSP estimates are based on production amounts and water-use coefficients. The classification of sources as surface water or groundwater will be estimated based on the percentages reported in previous compilations unless better information is available. Methods used in the national estimates for mining water use are described in Lovelace (2009c).

Withdrawals

The withdrawals by mining facilities will vary depending on the size and type of mining operation. The amount of water withdrawn may be available from the facility or from State or local agencies. It may be possible to develop coefficients such as water used per ton produced or volume of sales from facilities with the same SIC code that have water-use information available. Major mines should be contacted to determine water withdrawals, water use at the plant, and the current source of water.

Consumptive Use

Consumptive-use estimates are optional but they should be based on information obtained through contacts with those mining establishments that withdraw or consume the largest volumes of water. In 1990, State estimates of mining consumptive use ranged from 10 to 100 percent of the withdrawals, depending on the type of mining activity (Solley and others, 1993). Consumptive-use coefficients may be estimated by calculating the difference between water intake and water discharges listed by SIC and region. The 1982 Census of Mineral Industries publication series provides dated information that may guide consumptive-use if more recent data are not available (U.S. Bureau of the Census, 1985). Quan (1988) used sales and volume production to calculate coefficients for water consumption in the domestic non-fuel minerals industry. Consumptive-use rates determined at a mining facility may be applied to similar facilities in a geographic area.

Reclaimed Wastewater

If information is available, the total use (fresh and saline) of reclaimed wastewater by mining facilities should be reported. If the wastewater-treatment facility or the utility department cannot provide information about the use of reclaimed wastewater by mining facilities, then the larger individual mines should be contacted.

Livestock

Prior to 1985, livestock and rural domestic withdrawals were combined under Rural Uses. Beginning in 2005, withdrawals for livestock and aquaculture were estimated by the NWUSP for all States. The estimates for livestock water withdrawals will continue to be provided by the NWUSP, though WSCs still have the option of reporting their own withdrawal estimates.

National estimates will be made based on animal populations or some other measure of production and coefficients. The classification of sources as surface water or groundwater and as saline water or freshwater will be made based on previous compilations unless better information is available.

Livestock water use is water associated with livestock watering, feedlots, dairy operations, and other on-farm needs. Livestock includes dairy cattle, beef cattle, sheep and lambs, goats, hogs and pigs, horses, and poultry. Other livestock water uses include cooling of facilities for the animals and products, dairy sanitation and wash down of facilities, animal waste-disposal systems, and incidental water losses. All withdrawals are considered self-supplied. The livestock category excludes on-farm domestic use, lawn and garden watering, and irrigation water use.

Estimates of livestock withdrawals are primarily derived by using animal population data and water-use coefficients, in gallons per head per day for each animal type, because few State agencies require livestock operations to report water withdrawals. Animal population data generally are available from State agricultural agencies and the U.S. Department of Agriculture (USDA) NASS (available at http://www.nass.usda.gov/). Coefficients vary by State and, for many States, are provided by agricultural extension agents or water-permitting agencies. Coefficients may reflect facility maintenance needs and effects of climate on animal watering. Many of the 2010 withdrawals for livestock were estimated according to methods described by Lovelace (2009a), using livestock population data compiled for the NASS Census of Agriculture and water-use coefficients.

Data Elements

Mandatory

- Groundwater withdrawals (freshwater), by county.
- Surface-water withdrawals (freshwater), by county.

Optional

- Consumptive use (fresh).

Compilation Techniques

Livestock water use is determined by stock numbers and production practices. To estimate withdrawals, it is first necessary to determine the number of animals in a county or hydrologic unit by animal class. Livestock water use is calculated by multiplying the number of animals per geographic area by a coefficient in gallons per day per head for each different animal class. Coefficient values for different animal classes can be obtained at State agricultural colleges and from many county extension service offices. The distribution of State totals of the number and class of animals and farms may be modified based on local knowledge. If coefficient values are used to estimate water use for livestock or poultry operations that raise more than one crop during the reporting period, care must be taken to ensure that the coefficient is applied to the correct head count for the full operation. The time-span of a livestock feeding operation or poultry operations for meat or egg production and the average head count can be used to estimate total populations to estimate water use.

The distribution of the estimated livestock withdrawals between groundwater and surface-water sources may be more difficult to estimate. The distribution of withdrawals by source can be especially difficult in States where surface-water sources are used during late spring, summer, and fall, and groundwater sources are used throughout the year. The distribution by source can be made in direct proportion to the amount of time each source is used if seasonal consumption data are not available. County extension agents and personnel at an agricultural college, experiment station, or research center may be able to provide information about seasonal water sources used by animals.

Aquaculture

Aquaculture water use is associated with raising organisms that live in water—such as finfish and shellfish—for food, restoration, conservation, or sport. Major aquaculture operations in the United States include alligator, crawfish, catfish, and trout farms. Aquaculture production occurs under controlled feeding, sanitation, and harvesting procedures primarily in ponds, flow-through raceways, and, to a lesser extent, cages, net pens, and tanks. Aquaculture ponds, raceways, and tanks usually require the withdrawal or diversion of water from a ground or surface source. Most water withdrawn or diverted for aquaculture production is used to maintain pond levels and (or) water quality. Water typically is added for maintenance of levels, oxygenation, temperature control, and flushing of wastes. Instream use of water for aquaculture generally is not considered a withdrawal unless water is being diverted or used for a confined instream operation, such as flow-through fish raceways.

Prior to 1985, aquaculture withdrawals were part of the self-supplied industrial use category. In 1985, total livestock use was made up of withdrawals for livestock and withdrawals for “animal specialties,” which, among other things, included aquaculture. Beginning in 2005 and continuing with the current compilation (2015), withdrawals for aquaculture will be estimated by the NWUSP for all States. Details on the methods used in estimating aquaculture water use are described in Lovelace (2009b). USGS WSCs will have the option of reporting their own withdrawal estimates. The percentages of surface water and groundwater and of saline water and freshwater will be calculated based on percentages reported for the previous compilations unless better information is available.

Data Elements

The aquaculture category consists of the following mandatory and optional data elements. Data for the optional elements may be compiled and entered into AWUDS, but will not be part of the national water-use analysis as published in the water-use circular series. The optional data, however, will be available for other types of water studies.

Mandatory

- Groundwater withdrawals, freshwater, by county.
- Surface-water withdrawals, freshwater, by county.

Optional

- Groundwater withdrawals, saline water, by county.
- Surface-water withdrawals, saline water, by county.
- Consumptive use, freshwater, by county.
- Consumptive use, saline water, by county.

Sources of Information

If the aquaculture estimates will be determined by the USGS WSC, the documentation for the previous compilations should be the starting point for planning the data collection and compilation. The documentation for the previous compilation may contain the location and types of electronic and paper files; agency and contact information; agency and internet resources; and methods, techniques, and coefficients used to collect or estimate data. Additional information concerning aquaculture water use may be obtained from the following sources. Other sources of information may be available in each State.

Possible contacts for aquaculture are listed as follows. Data from these sources can range from reported water withdrawals to coefficients and ancillary data that can be used to estimate water withdrawals. Multiple datasets can be used to determine the best estimates and can be used during the QA/QC review.

- State agencies that administer water rights, allocate water to users, or collect water-use data.
- State agencies that issue permits for the discharge of water.
- State agencies that regulate or license aquaculture.
- State department of agriculture.
- State and county planning departments.
- Local or county agriculture extension offices.

Compilation Techniques

Little information is available on total water use by fish farms, probably because the water is used only as a vehicle to raise or hold the fish and a large portion is still available for other uses. It is best to obtain local information from fish farm operations in each State. Coefficients to estimate water use by fish may be expressed in terms of water volume per facility, water volume per pond surface area, or water volume or pond surface area per pound of fish produced (Trotta, 1988). Water use by fish farms is generally equated to amount of “make-up” water necessary to maintain pond water levels. Loss of water is due to leakage and evaporation.

Evaporation and leakage from ponds and raceways are major consumptive uses of water by aquaculture. In these cases, any replacement withdrawals are considered makeup water, and would equal consumptive use.

Irrigation

Water for irrigation is applied by an irrigation system to sustain growth in agricultural and horticultural vegetation and also is applied for the purposes of pre-irrigation, frost protection, weed control, field preparation, crop cooling, harvesting, dust suppression, leaching of salts from the root zone, and the application of chemicals (SIC 0111–0191 and 4971). Irrigation withdrawals include conveyance losses. Irrigation of golf courses (SIC 7992 and 7997), parks, nurseries, turf farms, and cemeteries and other self-supplied landscape-watering uses also are included in the irrigation category. Water use in this category may be withdrawn by the irrigator or delivered from irrigation companies, irrigation districts, irrigation cooperatives, or governmental entities. The irrigation category does not include potable water purchased from a public supply for use by golf courses. Instead, public-supply deliveries of potable water for golf courses, parks, cemeteries, and others are either commercial deliveries or public-use water. Non-potable water provided for outdoor irrigation at publicly owned golf courses may be reported as golf course irrigation, but if so, should not be included in public-supply withdrawals to avoid double-counting the water as public supply.

The number of irrigated acres by type of irrigation system—sprinkler, surface (flood), and microirrigation are mandatory data elements in the irrigation category. Reclaimed-wastewater use is also a mandatory data element, however, zeros are reported for counties where the delivery of reclaimed wastewater does not occur, and null values can be stored for counties where the use of reclaimed wastewater is uncertain or unknown. Consumptive use of water by irrigation is a mandatory data element and includes the water incorporated into the crops or turf, evaporated from soils or transpired from plants, or otherwise not available for immediate use, but does not include conveyance loss.

For the compilation, States may divide total irrigation water use into crop irrigation and golf course irrigation. If the irrigation is divided, all other landscape irrigation is included with crop irrigation. If irrigation is divided in this manner, county-level totals for crop and golf course irrigation are mandatory where applicable, and total irrigation water withdrawals are automatically calculated as the sum of the two subcategories by AWUDS for report tables. If irrigation withdrawals are not divided into crop and golf course withdrawals, then all irrigation is reported as total withdrawals and may include both crop irrigation and irrigation for golf courses.

Data Elements

The category of irrigation consists of the following mandatory, mandatory but null values allowed, and optional data elements. Data for the optional elements may be compiled and entered into AWUDS, but will not be part of the national water-use analysis. The optional data, however, will be available for other types of water studies.

Mandatory

- Groundwater total withdrawals, freshwater, by county.
- Surface-water total withdrawals, freshwater, by county.
- Consumptive use – freshwater, by county (data provided from the NWUSP).
- Acres irrigated by sprinkler systems, by county.
- Acres irrigated by surface systems, by county.
- Acres irrigated by microirrigation systems, by county.

Mandatory but Null Values Allowed

- Reclaimed wastewater, by county.

Optional

- Divided crop and golf course groundwater withdrawals, freshwater, by county.
- Divided crop and golf course surface-water withdrawals, freshwater, by county.

- Conveyance loss, by county and divided for crop and golf course irrigation.
- Acres irrigated by sprinkler systems, divided for crop and golf course irrigation.
- Acres irrigated by surface systems, divided for crop and golf course irrigation.
- Acres irrigated by microirrigation systems, divided for crop and golf course irrigation.
- Any data aggregated by eight-digit HUC.
- Total groundwater withdrawals, by principal aquifer.

Sources of Information

For each USGS WSC, the documentation for the previous compilations should be the starting point for planning the data collection for the current compilation. The previous documentation for the irrigation category may contain the location and types of electronic and paper files; agency and contact information; agency and internet resources; and methods, techniques, and coefficients used to collect or estimate data. Additional information concerning irrigation water use may be obtained from the sources listed in the following section. Other sources of information may be available in each State.

Agencies or Other Entities

Possible contacts for irrigation water-use data are listed as follows. Water-use data from these sources can range from reported water withdrawals to coefficients and ancillary data that can be used to estimate water withdrawals and determine irrigated acreage by irrigation system type. Multiple datasets can be used to determine the best estimates and can be used during the QA/QC review.

- State agencies that administer water rights, allocate water to users, or collect water-use data.
- U.S. Department of Agriculture (USDA), Agricultural Statistics Service for a specific State.
- USDA, NASS.
- USDA, Natural Resources Conservation Service (NRCS), State or county offices.
- USGS research or studies.
- Equipment manufacturers.
- Water well drillers or state drilling associations.
- Federal or State crop and livestock reporting services.
- State and local turf-grower associations.
- County assessor.
- Land-grant universities—college of agriculture, departments of watershed science, soil science, plant science, crop science, or irrigation engineering.
- Water management districts, irrigation districts, and irrigation companies.
- Irrigation equipment dealers.
- Farm and crop improvement associations.
- Golf courses, parks, and other recreational areas.
- Professional, technical, and trade journals.
- State departments of commerce and tourism.
- Water-user associations.

Internet Resources

Many agencies and other entities maintain irrigation water-use information and databases on the internet.

- USDA, accessed at http://www.usda.gov/.
  - USDA National Resources Inventory—A statistical survey of land use and natural resource conditions and trends on U.S. non-Federal lands. Accessed at http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/nri/.
  - USDA, NASS, provides statistics and reports on agriculture, including irrigation, in the United States. Includes reports from the Census of Agriculture, Census of Horticulture, and the Farm and Ranch Irrigation Surveys. Accessed at http://www.nass.usda.gov/.
  - USDA, NRCS, includes information on irrigation rates, methods, and science and research. Accessed at http://www.nrcs.usda.gov/.
  - USDA Farm Service Agency, accessed at http://www.fsa.usda.gov/.
- U.S. Department of the Interior, Bureau of Reclamation, accessed at http://www.usbr.gov/.
- Food and Agriculture Organization (FAO) of the United Nations, accessed at http://www.fao.org.
  - FAO reports available through the FAO publications website accessed at http://www.fao.org/publications/en/ and the FAO document repository accessed at http://www.fao.org/documents/en/.
- A database for a listing of golf courses in each State—includes information on number of holes. Data are available through Golf, accessed at http://www.golf.com/.
- National Golf Foundation—provides information through a member-only searchable database and publications available to nonmembers. Accessed at http://www.ngf.org/.
- Golf Course Database—a website listing of golf courses in each State, for a fee—includes data on public and private courses, number of holes, location, and links to each course's profile and website (if they have one). Accessed at http://golf-course-database.com/.

Compilation Techniques

Irrigation water withdrawals and reclaimed-wastewater use are compiled according to the county in which the withdrawals or diversions occur. The number of acres irrigated is counted where the irrigation water is applied. In most cases, irrigation water is applied close to where it is withdrawn or diverted; in some cases, the irrigation water is transported long distances through canals. Problems in estimating irrigation water use include

- Unknown number of irrigated acres.
- Possibility of single or multiple cropping patterns.
- Possibility of multiple sources of water: surface water, groundwater, or reclaimed wastewater.
- The effect of age and design on application rates for irrigation systems.
- Unexpected seasonal irrigation needs such as frost protection or harvesting.
- Gap in permitted amounts compared to used amounts.
- Censoring of data for privacy reasons.
- Spatial scale (watershed, irrigation district, etc.) of primary-source data compared to the needed county-scale data for the compilation.

Direct methods for compiling information on irrigation withdrawals and irrigated acres include use of reported data, surveys, and personal contact. Indirect approaches for estimating withdrawals include calculation of crop water needs and statistical sampling. Data on irrigated acres by crop type and golf course, coupled with irrigation system type, are used in most estimation methods for determining withdrawals.

Reported Data

Some States require individual water users or water-right holders to measure and report their withdrawals and irrigated acreages for each well or surface-water diversion. Reported withdrawal data that can be assigned an accurate location can be aggregated to a county, aquifer, or HUC and are considered to be good quality. Other sources of reported data may yield partial coverage of irrigation use. USGS cooperative studies may include measurement of site-specific data in local areas within a State. Irrigation districts or other agencies may own water rights and distribute water to users; these entities usually measure withdrawals and deliveries. Watermasters may have been assigned to measure or compile measured withdrawals and deliveries in some areas, in which case they are excellent sources of data.

Reported measurements are the most defensible data; however, the completeness of reported data varies among States. Before using data that are reported to or by other Federal, State, and local agencies, it is important to understand the level of completeness, the degree of accuracy, and the amount of QA/QC review given to data. USGS water-use study chiefs need to verify whether the data are based on full and complete enumerations, like a census, or are statistically based, like the NASS data. Reported crop acreages may include all crop acreages or just irrigated acreages. Irrigated acreages and water deliveries may be reported for an area managed by a particular agency, or for an entire county. Some data may be censored for privacy reasons in areas with few irrigators. Reported withdrawals and acreage data need to be reviewed for errors, either by the reporting agency or by the USGS water-use study chief. Knowing the level of QA/QC review for data that are reported by other agencies may prevent calculations that are based on incorrect assumptions.

Surveys and Personal Contact

Another method of estimating irrigation water use is by a local survey conducted by a cooperating agency. Surveys that are conducted by the USGS are discouraged, but where used, must comply with the requirements of the 1995 Paper Reduction Act. Ideally, survey forms include a complete background about why the information is being requested, how it will be used, and by whom. Other important components of the survey are (1) a concise description of the requested data, (2) a contact name and phone number to direct questions to, and (3) a desired completion date. In any case, efficient collection and processing of survey data can be best achieved if the survey forms are short and easy for the user to complete. Typically, other State and local agencies distribute surveys, and the data are shared with the USGS.

It is important to obtain accurate data on water users who use great amounts of water; these users typically have more data available than water users who use lesser amounts of water. When developing survey lists, data sources such as the USDA's Census of Agriculture can be used to target counties with the water users who use great amount of water. Some of the most beneficial survey information includes the following:

- Total irrigated acreage.
- Crop and pasture acreage.
- Type and efficiency of irrigation system(s).
- Quantity or flow rate of water by source.
- Irrigation scheduling and frequency.
- Number of irrigation wells.
- Total depth of well(s).
- Capacity of well(s).
- Identification of the aquifer or aquifer system.
- Total annual energy usage.
- Power consumption coefficient(s), if known.

Other useful data include information on crop water shortages, acres harvested and yields by crop, energy sources, water and agricultural management practices, and any agricultural resources that generally are contacted when the irrigator needs additional guidance.

Estimates of Crop Water Needs

A commonly used method to estimate irrigation withdrawals involves calculating consumptive use for irrigated crops by using crop water-consumption coefficients for several crops and system types (see U.S. Department of Agriculture, 1970, 1976, 1997, 2002; Allen and others, 1998). The amount of water consumed by crops, plus additional water used in conveyance or needed for other irrigation uses, is the total withdrawal. The consumptive-use method requires that ancillary data exist for total irrigated acres for each type of crop, irrigation system efficiencies, conveyance losses, climatic variables, and other irrigation management practices, such as pre-irrigation, frost protection, weed control, and leaching salts from soils. The consumptive-use technique assumes that the irrigation water applied is adequate for optimal plant growth and that the plants are not being irrigated with more or less water than needed.

Application efficiency is a measure of the effectiveness of the irrigation system in applying the right amount of water to the soil and root zones over time. Application efficiency must be taken into account if irrigation withdrawals are estimated from crop water-consumption coefficients. Application efficiencies vary with the type of irrigation system and soil, crop, topographic, and climatic conditions. Pertinent climatic conditions that have large effects on irrigation efficiencies include wind speed, relative humidity, and air temperature.

In many cases, compilation of State withdrawals based on crop consumptive use, plus additional climatic and soil factors, is not feasible because of the amount of work and level of detailed data necessary. Use of previously determined crop consumption values may be the most cost-effective method of estimating irrigation withdrawals. These values may be obtained from sources such as the USDA irrigation guide (U.S. Department of Agriculture, 1970).

Statistical Sampling

For large irrigated areas where few measurements exist, statistical sampling represents a cost-effective way to estimate irrigation withdrawals. For this method, withdrawals are measured at sampling sites where data also are available for such variables as power consumption, lift, or crop type. Water-use coefficients are developed from these sample data and then are used to estimate withdrawals at unsampled sites where the predictor variable(s) is known.

Statistical approaches may have transfer value to other areas if there is good understanding of the predictor variables, the statistical significance of the predictor variables, and the level of expected accuracy. For example, by understanding the variability of the predictor variable, a specific number of sampling sites may be determined that will enable calculations of withdrawals for all sites with a probability that the calculated values are within a specific margin of error. Luckey (1972) and Helsel and Hirsch (1995) provide a complete description of how to determine a sufficient sample size.

Allocation of Withdrawals by Source

If site-specific measurements of withdrawals are unavailable, then the estimates of total withdrawals need to be allocated between groundwater and surface-water sources. Geographic location can be a major determinant of water availability from each source. Often, a given State or geographic area will have a predominant source of water supply for irrigation. For example, in the Mississippi River alluvial plain in southeastern Missouri, western Kentucky and Tennessee, Arkansas, Mississippi, and Louisiana groundwater from the Mississippi River Valley alluvial aquifer is the predominant source of water for irrigation (Maupin and Barber, 2005). Personnel with State agricultural agencies, county extension agents, and staff with irrigation districts and equipment dealers can be good sources of local information on irrigation rates, methods, and sources of water.

Consumptive Use by Irrigation

Estimates of water consumption by irrigation will be reported at the county level. The NWUSP will provide estimates of consumption that can be used in the national compilation. The estimates from NWUSP do not preclude the USGS WSC from developing other estimates. If the local compiler for the WSC uses a different method to estimate water consumption, the method, assumptions, sources of data, and results must be included in the documentation.

Acres Irrigated by System Type

Estimates of irrigated acres by system type are compiled for each State at the county level. Irrigated acreage is reported by three general methods of application—sprinkler, surface, and microirrigation. Many types of irrigation systems are included in each of these categories.

- Sprinkler methods include all boom, center-pivot, lateral-move, low-energy precision application (LEPA), permanent, portable, side-move, side-roll, solid-set, traveling-gun, towed, and other sprinkler irrigation systems.
- Surface methods include all borders, ditch, flood, furrow, gated-pipe, surge-flow, water-spreading, and other gravity systems.
- Microirrigation methods include all bubbler, drip, micro-jet, mist, porous trickle-tubing, spray, trickle, and other low-volume irrigation systems, and subsurface systems.

Reliable data on irrigated acreage also are essential for most methods of estimating irrigation water withdrawals. Site-specific irrigated acres by irrigation system type generally are difficult to obtain, unless State agencies require irrigators to report detailed information that includes irrigation methods.

The USDA Census of Agriculture, conducted in years ending in "2" and "7," provides the most recent national dataset of irrigated crop acreages by county (U.S. Department of Agriculture, 2002). The USDA Farm and Ranch Irrigation Survey provides a national dataset of irrigated acreage by irrigation method by State. County assessors also are possible sources for county-level information on irrigated acreage and irrigation system type. Remote sensing has been used as an indirect method of determining acres irrigated and crop types (Raymond and others, 1992), but is not a common tool used in this study.

In some parts of the United States, the growing season is long enough that double and triple cropping can occur on the same irrigated acreage. In these cases, irrigated acres are counted each time an acre is irrigated to reflect the total acreage irrigated during the year; therefore, when any acre of land is cropped twice, it is counted as 2 irrigated acres. Counting acreage in this manner produces an application rate that is comparable to a single-cropping season. The irrigation method used on subsequent crops may be different. If multiple irrigation methods are used on a crop in a single growing season, acreages are reported under the method that provides most of the water to the crop.

Golf Course Irrigation

Golf courses may use water from ground or surface sources, purchased water (from a public supplier or irrigation district), reclaimed water from a public wastewater-treatment facility, or a combination of these sources. If the data and resources are available, it is best to obtain metered withdrawals for specific golf courses. Water withdrawals by golf courses may also be reported to State water-resource agencies. The metered or reported withdrawal data can be used to estimate water use for similar golf courses for which data are not available. For golf courses, the best information on source of water is obtained directly from the golf course maintenance personnel who may know how much water is diverted, withdrawn, or delivered from each of the possible sources.

Factors affecting the amount of irrigation water used at golf courses include course design, climatic conditions, acreage, irrigation systems, soils, availability of water for irrigation, and local irrigation practices. Normally, more water per unit of area is applied to the greens and tees than to the fairways. If site-specific data are not available, irrigation withdrawals may be estimated by using coefficients developed based on information on other golf courses in a State. Information collected should include all necessary data to estimate withdrawals based on an application rate and the irrigated acres.

Hydroelectric Power

The hydroelectric power water-use category was a mandatory category through 1995 and became an optional category for the 2000 national compilation (Kenny, 2004) and is an optional category for the current compilation. Hydroelectric power water use is defined as the amount of water used at power plants where the turbine generators are driven by falling water. In most instances, the facility is located in the stream channel, and water used to drive the generators is considered to be an instream water use and is reported as such. In some instances, however, the water may be diverted away from the stream channel in order to generate power at a hydroelectric facility potentially in a different watershed. The amount of water diverted is reported as an offstream water withdrawal. References used in previous compilations for hydroelectric power include Warnick (1984), Fardo and Patrick (1985), Viessman (1985), and Jog (1989).

The annual production of electricity, in gigawatthours, may also be reported for the hydroelectric power plants. Power plants may report power production in kilowatt- or megawatthours that will have to be converted to gigawatthours (1 gigawatthour equals 1 million kilowatthours).

Pumped-storage power plants are hydroelectric facilities capable of pumping water to a storage reservoir at a higher elevation or upstream to store the water for use to generate electricity during peak electrical demands. Many of the pumped-storage sites are intended to supplement peak electrical needs and actually have an overall negative net power generation due to the fact

that more power is expended during off-peak periods to lift the water to the storage reservoir than is generated. Water use and net power generation for pump storage sites should not be reported in AWUDS for the current compilation, but may be compiled and recorded for State or regional needs.

Data Elements

Water use for hydroelectric power is an optional category. If reported, the following data elements should be included:

- Instream water use.
- Offstream surface-water withdrawals.
- Power generation by instream use (gigawatthours).
- Power generation by offstream use (gigawatthours).
- Number of instream facilities.
- Number of offstream facilities.

Sources of Information

Information concerning hydroelectric power water use may be obtained from the following sources. These sources are examples, and other sources may be available.

- Individual facilities or utility companies.
- State agencies that administer water rights, allocate water to users, or collect water-use data or issue permits for the use of water.
- EPA NPDES general permits (permit may give information on turbines and pump-storage status) and ICIS database.
- DOE-EIA form EIA-860, Electric Generator Capacity Data, (http://www.eia.gov/electricity/data/eia860/) and form EIA-923, Power Plant Operations Report (http://www.eia.gov/electricity/data/eia923/index.html).
- U.S. Army Corps of Engineers (USACE), Bureau of Reclamation, Bureau of Land Management, Tennessee Valley Authority, Bonneville Power Administration, or other Federal agencies that operate hydroelectric plants.
- State agency for power administration.
- FERC.

Compilation Techniques

Data compiled for the hydroelectric category includes water withdrawals for offstream use, instream water use, the amount of power generated, and the number of facilities. The estimation methods described in this section are not intended to be all-encompassing but do provide a consistent set of techniques if better methods are not available.

Instream Water Use

Information on the withdrawal of water (instream water use) to generate electric power at hydroelectric power plants can be obtained directly or estimated by utilizing other available data on the power generated and the relative difference in water elevation. The data on the instream use of water in generating electric power will normally be obtained from each individual utility or possibly a State regulatory agency. Because the water is diverted from the stream channel, hydroelectric power withdrawals may also be available from State water regulatory agencies that do not otherwise regulate hydroelectric power facilities. The amount of water to be reported is the flow through the turbines to generate power, and should not include spillway flow or other amounts that do not flow through the turbines. If the contact person for a utility is not known, a good place to start is the person at the utility who prepares the DMRs for the EPA.

For sites where instream use information is not available, the instream water use (Q_{wu}) can be estimated by using the standard energy equation (equation 1, modified from Hall and others, 2004). The equation estimates instream water use by using gross head (difference in height between the water intake level and the tailrace level) for the dam, generated electricity, and plant efficiency.

$$P = H \times Q \times r \times (1.356 \times 10^{-3}) \times e \quad (1)$$

where

P is the power generated, in kilowatts
H is the gross head, in feet;
Q is the flow rate through the penstock, in cubic feet per second;
r is the density of water (62.4 pounds per cubic foot);
1.356×10^{-3} is the conversion factor for foot-pounds per second to kilowatts where 0.746 kW = 1 horsepower (hp) and 550 ft-lb/sec = 1 hp; and
e is the efficiency of the turbines and generators.

Solving Equation 1 for flow:

$$Q = P / (H \times r \times (1.356 \times 10^{-3}) \times e) \quad (2)$$

The flow rate in equations 1 and 2 are in cubic feet per second, and the power generated is in kilowatts. The power term should be converted to kilowatthours by dividing P (power in kilowatts) by the hours (t) of operation of the facility and the resulting flow rate converted to million gallons per day, so that:

$$Q_{wu} = P_t / (H \times r \times (1.356 \times 10^{-3}) \times e \times 1.55) \quad (3)$$

where

Q_{wu} is instream water use, in million gallons per day;
P_t is the power generated in kilowatthours; and
1.55 is the conversion from cubic feet per second to million gallons per day.

Power Generation

The DOE-EIA maintains power generation statistics such as ownership, location, generation capacity, and power generated for a given calendar year. The monthly net power generation is available on EIA Form 923. More extensive yearly information on each facility is also available from the DOE-EIA.

Some of the electricity generated at a hydroelectric power plant is used to run the power plant itself. It is important to ask a plant operator if the power production estimate is for the gross or net amount of power produced. The net amount is to be reported.

Some industrial facilities also generate electric power. These combined heat and power facilities are called CHP or cogeneration facilities. The amount of water used by the industry to generate electricity should be reported as a power generation water use in the thermoelectric power generation category, *if* the data provided from the industrial facility are sufficient to differentiate water used in power generation and the amount of water used for the industrial processes of the plant. These water and power generation values should not be reported in the hydroelectric category.

Some hydroelectric power plants have been designed to pump water to a reservoir at a higher elevation during non-peak hours. The water is then run through the turbines to produce electricity during peak demand periods. Currently, the net power production is assumed to be zero as is the net water use.

For pumped-storage hydroelectric power plants, the actual net power production is generally negative—more power is used than generated, but with the benefit of shifting production to peak demand periods. If actual power production is not available, the net power production is assumed to be zero as is the net water use.

Number of Facilities

Use SWUDS or a State-maintained site-specific database to determine the number of hydroelectric facilities. If site-specific data are not available for your State, use the DOE-EIA data to determine the number of facilities.

Wastewater Treatment

The wastewater-treatment (WWT) category was a mandatory category in the 1980 through 1995 national water-use compilations, then it became an optional category in the 2000 compilation (Kenny, 2004), and will remain optional for the current compilation. The WWT category includes information on facilities engaged primarily in the collection, treatment, and disposal of wastewater conveyed through a sewer system. This category includes information on water returned to the hydrologic system by WWT facilities, water released for beneficial reuse, and the number of facilities that treat wastewater. Treatment facilities are separated into two categories: publicly owned treatment works (POTWs) and "other." POTWs receive and treat wastewater from various domestic, commercial, and industrial users. "Other" wastewater facilities are privately owned and include commercial, industrial, and other facilities that treat their own wastewater.

Water returns generally refer to flows leaving WWT facilities. However, for the purpose of the current compilation, flows entering a WWT facility are assumed equal to those leaving the facility, with no losses occurring from consumptive use by the facility. Overflows from wastewater holding lagoons are considered water returns, but seepage from lagoons is not.

Reclaimed wastewater (also known as reclaimed sewage) is that water which is released for reuse after being processed at a WWT facility. No attempt should be made to make the quantity of reclaimed wastewater released by WWT plants equal to the deliveries of reclaimed wastewater. If the purpose of the land spreading of reclaimed wastewater is to dispose of the water, this does not qualify as reclaimed wastewater.

Prior to 2000, the WWT category included only return flows from the POTWs. Also, prior to 2000, privately owned wastewater facilities including commercial, industrial, and other facilities that treated and released their own wastewater were coded as "Other." After 2000 and continuing to the current compilation, the wastewater-treatment category is total wastewater releases and includes wastewater releases from WWT plants and those systems that would have been considered as "Other" prior to 2000. Return-flow data from WWT facilities in the pre-2000 datasets will remain in the originally reported data elements.

Data Elements

The WWT category and all of its data elements are optional.

- Number of WWT facilities in a site-specific database.
- Total wastewater returns by public wastewater facilities.
- Reclaimed wastewater released to other facilities by the public wastewater facilities.

Sources of Information

Information concerning WWT may be obtained from any or all of the following sources. Other sources of data may be available for the compilation.

- Individual WWT facilities.
- City water departments.
- State pollution control or environmental protection agencies.
- PCS and ICIS database—EPA.
- Clean Watershed Needs Survey—EPA.
- EPA Pollutant Loading Tool.
- EPA Industrial Facilities Discharge (IFD) files.
- USGS surface-water modeling teams.

Compilation Techniques

Data compiled for the wastewater category include the number of facilities, wastewater returns, and the amount of reclaimed wastewater used. The estimation methods described in this section are not intended to be all encompassing but do provide a consistent set of techniques if better methods are not available.

Number of Facilities

If site-specific data are not available for the State, use the EPA IFD files or the EPA PCS to determine the number of facilities.

Wastewater Returns

Water-return information is typically available from the State agency responsible for the program that supports the Clean Water Act. Information may also be available from the EPA PCS-ICIS (https://www.epa.gov/enviro/pcs-icis-overview), which is a national database that contains water quantity and quality information about facilities that have an NPDES permit to return water. Information available from PCS/ICIS includes return flows, location, and facility type (such as public or industrial). Information on wastewater management facilities including wastewater facilities, stormwater and combined sewers, and decentralized wastewater management is available at the Clean Watershed Needs Survey (https://www.epa.gov/cwns). Wastewater pollutant discharge data including rates and loads are available through the Pollutant Loading Tool (https://cfpub.epa.gov/dmr/).

Water returns may be estimated from design-flow capacity data, which may be available from the previously listed sources. Design-flow capacity data represent the flow that a facility is designed to support, and is expressed as an average or maximum. Facility operators may be able to provide information about how actual returns compare to the average or maximum-design capacity of the plant. An effort should be made to contact large WWT facilities to verify data obtained by indirect sources of information. Information on wastewater generation rates, peak rates, and return coefficients are available in Chapter 6 Wastewater Planning Criteria by the Vallecitos Water District (2011).

Water returns for a community may be estimated by using deliveries by public supply and subtracting estimated distribution losses, adding distribution gains, subtracting consumptive uses and wastewater returns by water users (commercial, industrial, etc.), and adding any discharges to the community wastewater system by self-supplied users. Stated as an equation: wastewater-treatment returns = deliveries – distribution losses + distribution gains – consumptive uses – private returns to hydrologic system + self-supplied user discharge to sewer. It should be noted however, that many of these terms are difficult to quantify or have large margins of error. If this methods is used, the source and estimates for all of the terms should be included in the documentation.

Coefficients for estimating water returns are generally not available from the literature because distribution systems vary, although some information may be available. If public-supply deliveries and population served are not available for a community, however, then wastewater returns may be estimated by using coefficients determined for the State. Per capita uses and distribution losses or gains coefficients can be determined from communities with delivery and return-flow information, and then applied to facilities that support a similar population size and type of distribution system. Selected references with coefficients for WWT are Metcalf and Eddy, Inc. (1991) and Pennsylvania Department of Environmental Resources (1991). Distribution loss and gain estimates are sometimes available from consulting firms. It is helpful to use available return-flow information for WWT facilities with similar population sizes and similar type distribution systems to develop coefficients.

An arithmetic check between public-supply withdrawals and WWT return should be made and be part of the QA/QC review. If the WWT return is significantly larger than public-supply withdrawals minus consumptive uses and distribution losses, then determine if an interbasin transfer, stormwater runoff, or self-supplied users are affecting the amount of water entering the WWT.

Reclaimed Wastewater

Information about the amount of reclaimed wastewater can be obtained from WWT plant operators and local utility departments in the State. Summaries on city/town water and wastewater websites can also indicate whether wastewater is sold or reused for irrigation (rights-of-way, parks, cemeteries, golf courses), for industrial purposes, and for thermoelectric cooling. Contacting officials for the city/town may provide reclaimed wastewater sales amounts.

Reservoir Evaporation

Reservoir evaporation is water loss by evaporation from manmade impoundments with a normal capacity of 5,000 acre-feet or greater. The reservoir evaporation category was a mandatory category in 1995, and was aggregated to the eight-digit HUC areas only, but the data were not published in the water-use compilation for 1995 (Solley and others, 1998). Estimates for reservoir operation were not made for 2000 (Kenny, 2004) and were optional for the 2005 (Hutson, 2007) and 2010 compilations. Reservoir evaporation is an optional water-use category for 2015.

Evaporation is a major component of the hydrologic cycle, especially in western States. Evaporation from a lake or reservoir surface is controlled by several factors, in simple terms—the complexities in climatic conditions and the location, size, and depth of reservoirs. Recent advancements in the science of estimating reservoir evaporation employ the use of new climate models, other models (eddy covariance and Bowen Ratio Energy Balance), remote sensing technology, and on-site instrumentation. Large reservoirs, particularly in the West, are managed by Federal agencies such as the USACE and the Bureau of Reclamation. These agencies, along with the USGS, are cooperatively monitoring and improving their understanding of reservoir evaporation and the implications on their management operations. The Bureau of Reclamation, West-Wide Climate Risk Assessments (http://www.usbr.gov/watersmart/wcra/) describes the results of projects specifically targeted to evaluate irrigation demand and reservoir evaporation in 17 western States, plus parts of Iowa and Missouri.

The National Oceanic and Atmospheric Administration (NOAA) explained the relationship between pan evaporation, free water surface (FWS) evaporation, and lake evaporation in their publication by Farnsworth and others (1982). Pan evaporation is the observed evaporation rate at a standard National Weather Service (NWS) Class A pan installation. FWS evaporation is defined as evaporation from a thin film of water having no appreciable heat storage. Lake evaporation may differ substantially from FWS evaporation during a given month because of changes in heat storage in the water body. On an annual basis, FWS evaporation and lake evaporation are generally about the same. Use of a pan evaporation method to calculate reservoir evaporation is not recommended because the class A pan evaporation rate is consistently greater than the water evaporation from a lake.

More recent studies by the USACE and the Bureau of Reclamation (Bureau of Reclamation, 2015), in cooperation with the Desert Research Institute (http://www.dri.edu/), have improved the understanding of reservoir evaporation. The Desert Research Institute has an Open Water Evaporation Network (https://owen.dri.edu/) with a geographic extent in the Pacific Northwest and Southwest States. The network was developed and funded through collaboration between the Bureau of Reclamation, the California Department of Water Resources, and the Desert Research Institute, with the intent to improve estimates of reservoir evaporation through continuous and near real-time monitoring of water temperatures and weather variables at sites on or over the water surface. The network of sites has expanded and shrunk over time, but information may be available to help determine reservoir evaporation in other places. Estimates of reservoir evaporation for selected reservoirs in California and Nevada and the methods used are described in Huntington and McEvoy (2011).

The reservoirs behind some dams may extend into more than one State. In these instances, coordination between neighboring States is essential to ensure that the surface area of the reservoir is divided proportionately between the States and that the same method for calculating the reservoir evaporation is used.

Data Elements

Reservoir evaporation is an optional category. If the data are reported in AWUDS, the following data elements should be included for this category:

- Reservoir surface area.
- Reservoir evaporation.

Reservoir evaporation estimates are only reported for the eight-digit HUC.

Sources of Data

Information concerning reservoir area and location may be obtained from many of the following sources. The sources below are not all encompassing and are examples only.

- Owner of the dam or reservoir.
- State agency responsible for dam safety.
- State agency that administers permits for the storage of water.

- USGS Reservoir File.
- Federal agencies, including the USACE, NRCS, Bureau of Reclamation, Tennessee Valley Authority, and Federal Emergency Management Agency.

Sources for information concerning lake evaporation, in addition to the sources listed above, include the following:

- State climatologist.
- NOAA Technical Report NWS 33, Map 3, Annual FWS evaporation (shallow lake).
- Hydrology textbooks.
- Desert Research Institute.
- Bureau of Reclamation Technical Services Office (Denver).

Compilation Techniques

The estimation methods described in this section are not intended to be all encompassing. They offer techniques if better methods are not available.

Surface Area

The USGS Reservoir File contains surface area for reservoirs with a total capacity of at least 25,000 acre-feet or a normal capacity of at least 5,000 acre-feet (Ruddy and Hitt, 1990). Total capacity is defined as the total volume in the reservoir below the maximum attainable water-surface elevation and includes any surcharge storage (surcharge storage is the storage above the total retention level). It is recommended that each USGS WSC review the reservoirs in their State and consult with the Federal or legal entity that operates the dam and reservoir (Bureau of Reclamation, USACE, Tennessee Valley Authority, etc.). Be aware that the area data in a reservoir file may show the reservoir area values at normal capacity, and evaporation estimates should be based on the average reservoir surface area, which may be different from the area value listed. Surface area should be proportional between adjoining States when a reservoir is in more than one State.

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Glossary

Water-use terminology has changed in the series of water-use circulars prepared at 5-year intervals. The term *water use*, as initially used in the report for 1950, meant withdrawals of water; in the report for 1960, the term was redefined to include consumptive use of water as well as withdrawals. With the beginning of the U.S. Geological Survey National Water-Use Information Program in 1978, the term was again redefined to include withdrawals plus deliveries from public suppliers. In the water-use circular for 2000, water use was defined as it was initially used in 1950 as withdrawals of water. Beginning with the 2005 circular, water use was defined as water withdrawals plus deliveries. The following terms are referenced in the text and are part of the water-use circular series.

A

aquaculture water use Water used in the production of organisms that live in water within a confined space and under controlled feeding, sanitation, and harvesting procedures, and establishments primarily engaged in hatching fish and in operating fishing preserves. *See also* commercial water use, fish farms, and fish hatcheries.

aquifer A geologic formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

B

blowdown The continuous or intermittent discharge, or purging, of a small amount of circulating water, such as in a recirculating cooling tower. Blowdown normally is expressed as a percentage of the water being circulated. Its purpose is to prevent an increase in the concentration of solids in the water because of evaporation.

C

capacity The average amount of water circulating in the cooling system of a thermoelectric power plant, usually expressed in gallons per minute.

closed-loop cooling system A cooling system in which water is withdrawn, circulated through heat exchangers, then cooled and recycled. Subsequent withdrawals are used to replace water lost to evaporation, blowdown, drift, and leakage.

commercial water use Water used for motels, hotels, restaurants, office buildings, other commercial facilities, and institutions. The water may be obtained from a public supply or may be self-supplied. Also includes irrigation water provided by public suppliers to golf courses, parks, and other landscaped areas as well as deliveries for clubhouses and other non-irrigation uses at golf courses. In previous compilations, commercial water use included water use by fish hatcheries which is now included in aquaculture.

consumptive use The part of water withdrawn that is evaporated, transpired, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment. Also referred to as water consumed.

conveyance loss Water that is lost because of leakage or evaporation while in transit through a pipe, canal, conduit, or ditch. Leakage from an irrigation ditch may percolate to a groundwater source and be available for further use.

cooling system Equipment that is used for cooling purposes, such as condensers at power plants or factories. Includes water intakes and outlets, cooling towers, and cooling ponds.

cooling-system type *See* closed-loop cooling system and once-through cooling system.

D

deliveries Water distributed by public-water suppliers for domestic, commercial, industrial, or thermoelectric-power uses.

desalination Separation of water from salts and minerals using thermal and membrane processes. Sources of water are brackish groundwater, brackish surface water, and seawater. *See also* freshwater and saline water.

dewatering The removal of water through draining or pumping to lower the water table for mining or agriculture.

dissolved solids A measure of the dissolved minerals and organic matter in water, usually expressed in milligrams per liter (mg/L). Water containing 1,000 mg/L or more of dissolved solids is considered saline for all purposes except public supply in this report. *See also* desalination.

domestic deliveries Water provided to domestic users from a public supply.

domestic water use Water used for household purposes, such as drinking, food preparation, bathing, washing clothes and dishes, flushing toilets, and watering lawns and gardens. Also called residential water use. The water may be obtained from a public supply or may be self-supplied. *See also* public-supply water use and self-supplied water.

drift Fine water droplets blown out of a cooling tower along with exhaust air, usually expressed as a percentage of water circulated.

E

evaporation Process by which water is changed from a liquid into a vapor. *See also* evapotranspiration and transpiration.

evapotranspiration Water that is vaporized because of evaporation from the soil or plant transpiration. *See also* evaporation and transpiration.

F

finished water Water that is filtered or treated. *See also* raw water and water treatment.

fish farms Facilities that produce finfish or shellfish under controlled feeding, sanitation, and harvesting procedures for commercial purposes. Water use by fish farms is included in the aquaculture category. *See also* aquaculture water use.

freshwater Water that contains less than 1,000 mg/L of dissolved solids. Generally, water with more than 500 mg/L of dissolved solids is undesirable for drinking and many industrial uses. *See also* desalination and saline water.

G

gigawatthour (GWh) A unit of energy equivalent to 1,000 megawatthours or 1 billion watthours.

groundwater All subsurface water, distinct from surface water. Specifically, that part of the subsurface water in the saturated zone, which is a zone where all voids are filled with water.

H

hydroelectric power water use The use of water in the generation of electricity at plants where the turbine generators are driven by falling water. Hydroelectric water use is most commonly an instream use.

hydrologic cataloging unit An eight-digit cataloging unit that identifies a geographic area representing part or all of a surface drainage basin, a combination of basins, or a distinct hydrologic feature. Sometimes known as a watershed. Each hydrologic unit is identified by a unique hydrologic unit code (HUC).

hydrologic unit code A unique number consisting of two to eight or more digits based on the levels of classification in the hydrologic unit system.

I

industrial water use Water used for industrial purposes such as fabrication, processing, washing, and cooling, and includes such industries as steel, chemical and allied products, paper and allied products, smelting, and petroleum refining. The water may be obtained from a public supply or may be self-supplied. *See also* public-supply water use and self-supplied water.

instream use Water that is used within a stream channel for such purposes as hydroelectric power generation, navigation, water-quality improvement, fish propagation, and recreation. Sometimes called nonwithdrawal use or in-channel use.

irrigation district A cooperative, self-governing public corporation with definite geographic boundaries and taxing power. Its function is to obtain and distribute water for irrigation of lands within the district.

irrigation system Equipment used to distribute water to crops or other irrigated lands. Irrigation systems are grouped into the following three broad categories:

> **microirrigation** An irrigation system that wets only a discrete part of the soil surface near the plant by means of applicators operated under low pressure. The applicators can be placed on or below the surface of the ground or can be suspended from supports. Subsurface systems that control the height of the water table are included in this category.
>
> **sprinkler** An irrigation system in which water is applied by means of perforated pipes or nozzles operated under pressure to form a spray pattern.
>
> **surface** Irrigation by means of flood, furrow, or gravity. Flood irrigation is the application of irrigation water in which the entire soil surface is covered by ponded water. Furrow is a partial surface-flooding method of irrigation in which water is

applied in furrows or rows of sufficient capacity to contain the irrigation stream. Gravity is an irrigation method in which water is not pumped, but flows in ditches or pipes and is distributed by gravity.

irrigation water use Application of water on lands to assist in the growing of crops and pastures or to maintain vegetative growth on recreational lands such as parks and golf courses. Includes water applied for pre-irrigation, frost protection, chemical application, leaching salts from the root zone, and dust suppression, as well as water lost in conveyance. Also includes irrigation for cemeteries, turf farms, and other landscaped areas but does not include domestic lawns and gardens, which are included in the domestic water-use category.

K

kilowatthour (kWh) A unit of energy equivalent to 1,000 watthours.

L

livestock water use Water for livestock watering, feedlots, dairy operations, and other on-farm needs. Livestock includes cattle, sheep, goats, hogs, poultry, horses, and fur-bearing animals.

M

makeup water The water pumped into a closed-loop cooling system to replace the circulating water lost by evaporation, drift, blowdown, and leakage. Makeup water usually is expressed as a percentage of the total amount of water circulated.

mining water use Water used for the extraction of naturally occurring minerals including solids, such as coal and ores; liquids, such as crude petroleum; and gases, such as natural gas. Also includes uses associated with quarrying, well operations, milling, and other preparations customarily done at a mine site or as part of a mining activity. Mining water use does not include water used in processing, such as smelting, refining petroleum, or slurry pipeline operations, which are included in industrial water use.

N

North American Industry Classification System (NAICS) codes Three-digit codes established in 1997 by the Office of Management and Budget in cooperation with its counterparts in Canada and Mexico. NAICS are used in the classification of establishments by type of activity in which they are engaged, thus enabling comparison of industries from the three countries. NAICS replaces the Standard Industrial Classification (SIC) system. See also Standard Industrial Classification (SIC) codes.

O

offstream use Water withdrawn or diverted from a surface-water source for public-water supply, domestic, industry, irrigation, livestock, thermoelectric-power generation, and other uses. Sometimes called off-channel use or withdrawal.

once-through cooling system A cooling system in which water is withdrawn, circulated through heat exchangers, and then returned to a body of water at a higher temperature. Also referred to as an open-loop cooling system.

P

per capita water use The average amount of water used per person during a standard time period, generally per day. Per capita use may be calculated based on total water use, public-supply water use, self-supplied domestic water use, or domestic deliveries from public supply.

pre-irrigation The application of water to cropland before planting to assure adequate soil moisture for crop germination and early plant growth.

public-supply water use Water withdrawn by public and private water suppliers that furnish water to at least 25 persons or have a minimum of 15 connections. Public suppliers provide water for a variety of uses, such as domestic, commercial, industrial, thermoelectric power, and public use. See also domestic water use, industrial water use, thermoelectric-power water use, and public water use.

public water use Water provided by a public supply for such uses as firefighting, street washing, water treatment, municipal buildings, parks, and swimming pools. *See also* public-supply water use.

R

raw water Water that has not been filtered or treated before use. See also finished water and water treatment.

reclaimed wastewater Wastewater-treatment plant effluent that has been diverted for beneficial use before it reaches a natural waterway or aquifer.

recycled water Water that is used more than once after withdrawal and before it returns to the natural hydrologic system. *See also* reclaimed wastewater.

return flow Water that reaches a groundwater or surface-water source after it is released from the point of use, and thus becomes available for further use.

reuse Use of water that has undergone wastewater treatment and is delivered to a user as reclaimed wastewater. *See also* reclaimed wastewater, recycled water, and wastewater treatment.

S

saline water Water that contains 1,000 mg/L or more of dissolved solids. For public supply, water that requires desalination or dilution to make it potable is considered saline. *See also* desalination and freshwater.

self-supplied water Water that is withdrawn directly from a groundwater or a surface-water source by a user, as opposed to water that is delivered by a public supplier.

Standard Industrial Classification (SIC) codes Four-digit codes established by the Office of Management and Budget, last revised during 1987, and used in the classification of establishments by type of activity in which they are engaged. SIC codes are being replaced by NAICS codes. *See also* North American Industry Classification System codes.

surface water An open body of water, such as a stream, lake, or reservoir.

T

thermoelectric-power water use Water used in the process of generating electricity primarily by steam-driven turbine generators, but also includes water used to cool inlet air to gas combustion turbines (both stand-alone gas turbines and gas turbines that are part of a natural gas combined cycle unit). The water may be obtained from a public supply or may be self-supplied. *See also* public-supply water use and self-supplied water.

transpiration Process by which water that is absorbed by plants, usually through the roots, is evaporated into the atmosphere from the plant surface. *See also* evaporation and evapotranspiration.

W

wastewater treatment Removal or reduction of solids, pathogens, or other undesirable constituents from wastewater. *See also* reclaimed wastewater and recycled water.

water transfer Conveyance of water from one area to another by using natural or human-made channels.

water treatment Processes such as filtration and disinfection of water prior to delivery and use.

water-use coefficient A factor or ratio used to estimate a quantity of water used based on a related quantity. Examples of water-use coefficients include daily per capita water use, consumptive crop irrigation requirements, livestock water requirements, per employee water use, and per unit of product water use.

withdrawal The removal of groundwater or surface water from the natural hydrologic system for uses including public supply, commercial, domestic, industry, irrigation, mining, livestock, aquaculture, and thermoelectric-power generation. *See also* offstream use.

Appendix 1. Coding Forms for the Compilation of Water-Use Data

Coding forms are included for the 2015 national compilation and are also available at the USGS internal-only website at http://water.usgs.gov/usgs/watuse/2015compilation/coding-forms/forms2015.html. The coding forms show the water-use category names in columns and the associated data elements for each category in rows. The forms are not intended to be used as manual coding forms, but as references summarizing the scope of the data to be collected for the national water-use compilation. The first form shows the mandatory data elements for all States at the county aggregation level. The second, third, and fourth forms show all data elements that may be stored in the Aggregate Water-Use Data System (AWUDS) for areas such as county, aquifer, and hydrologic unit code (HUC), respectively.

The cells on the coding forms are color coded to indicate the data to be stored in AWUDS and whether the data are mandatory or optional. A black cell on the coding form indicates that data cannot be stored in AWUDS for the category and data element corresponding to that cell. Mandatory data elements are shaded in yellow on the data coding forms, and cells with black stripes and yellow shading indicate mandatory elements that allow null values to be reported for an unknown water use. Cells on the coding forms shaded light blue indicate optional categories and data elements that can be stored in AWUDS for State use.

The coding forms use the county Federal Information Processing Standard (FIPS) codes, HUCs and national aquifer codes for the principal aquifer of the United States (https://water.usgs.gov/ogw/NatlAqCode-reflist.html) to identify and aggregate the water-use data, and identify the mandatory and optional water-use data stored in the AWUDS database. The FIPS codes are available through several sources, including the U.S. Census Bureau at the web page https://www.census.gov/geo/reference/codes/cou.html. Hydrologic unit codes are available at http://water.usgs.gov/GIS/huc.html. National aquifer codes for the principal aquifers of the United States are available through the USGS Office of Groundwater at http://water.usgs.gov/ogw/NatlAqCode-reflist.html. Optionally, local aquifer or geologic codes may be added to the forms to meet State or project needs. The codes for the individual aquifers and geologic units are available through the National Water Information System (NWIS) Help web page at http://help.waterdata.usgs.gov/code/aqfr_cd_query?fmt=html.

ESTIMATED USE OF WATER IN THE UNITED STATES—MANDATORY ELEMENTS

2015 Data Collection Form

County Name: _____ County Code: _____ Total Population (000s): †

Data Element	Public Supply	Domestic	Industrial	Thermoelectric: Once-through	Thermoelectric: Closed-loop	Mining	Livestock	Aquaculture	Irrigation
Withdrawals - GW - fresh				●	●	●	●	●	
Withdrawals - GW - saline				●	●	●			
Withdrawals - SW - fresh				●	●	●	●	●	
Withdrawals - SW - saline				●	●	●			
Population served - Total (000s)									
Deliveries from public supply									
Consumptive use - fresh				●	●				●
Consumptive use - saline									
Acres irrigated - sprinkler (000s)									
Acres irrigated - micro (000s)									
Acres irrigated - surface (000s)									
Power generated (gigawatt-hours)				●	●				
Reclaimed wastewater									

† **Data will be provided by the National Water Use Science Project for all States.**

● **Data will be provided by the National Water Use Science Project for all States: States may make independent estimates if desired**

Mandatory but null values allowed

Figure 1–1. Water-use coding form listing mandatory elements to be aggregated by county.

ESTIMATED USE OF WATER IN THE UNITED STATES

2015 Data Collection Form

County Name: _____ County Code: _____ Total Population (000s): +

Data Element	Public Supply	Domestic	Commercial	Industrial	Thermoelectric: Once-through	Thermoelectric: Closed-loop	Mining	Livestock	Aquaculture	Irrigation (Crop/Golf is optional): Total	Irrigation: OR	Irrigation: Crop irrigation	Irrigation: Golf-course irrigation	Hydroelectric: Instream	Hydroelectric: Offstream	Wastewater treatment
Instream water use														▭		
Withdrawals - GW - fresh	■	■	▭	■	•	•	•	•	•	■		1	1			
Withdrawals - GW - saline	■			■	•	•	•		▭							
Withdrawals - SW - fresh	■	■	▭	■	•	•	•	•	•	■		1	1		▭	
Withdrawals - SW - saline	■			■	•	•	•		▭							
Population served - Total (000s)	■															
Population served - GW (000s)	▭															
Population served - SW (000s)	▭															
Deliveries from public supply		■	▭	▭	▭	▭										
Consumptive use - fresh		▭	▭	▭	•	•	▭	▭	▭	•		1	1			
Consumptive use - saline				▭	■	■	▭		▭							
Conveyance loss										▭	▭	▭	▭			
Power generated (gigawatt-hours)					•	•								▭	▭	
Acres irrigated - sprinkler (000s)										■		1	1			
Acres irrigated - micro (000s)										■		1	1			
Acres irrigated - surface (000s)										■		1	1			
Facilities (number)	▭			▭	▭	▭								▭	▭	▭
Wastewater returns																▭
Reclaimed wastewater	▭		▭	▨	▭	▭	▭			▨		1	1			▭

+ Data will be provided by the National Water Use Science Project for all States.

• Data will be provided by the National Water Use Science Project for all States: States may make independent estimates if desired

1 If the option to report Irrigation as crop and golf-course subtotals is chosen, these data elements become mandatory. Total irrigation will be calculated by AWUDS from the subtotals.

■ Mandatory
▨ Mandatory but null values allowed
▭ Non-mandatory

Figure 1–2. Water-use coding form listing mandatory and optional elements to be aggregated by county.

ESTIMATED USE OF WATER IN THE UNITED STATES

2015 Data Collection Form

Aquifer Name: _____ Aquifer Code: _____

Data Element	Public Supply	Domestic	Commercial	Industrial	Thermoelectric: Once-through	Thermoelectric: Closed-loop	Mining	Livestock	Aquaculture	Irrigation (Crop/Golf is optional): Total	OR Crop irrigation	Golf-course irrigation
Withdrawals - GW - fresh												
Withdrawals - GW - saline												
Population served - GW (000s)												
Self-supplied population - GW (000s)												

Figure 1–3*A*. Water-use coding form listing mandatory and optional elements to be aggregated by county.

ESTIMATED USE OF WATER IN THE UNITED STATES

2015 Data Collection Form

County Name: _____ County Aquifer Code: ___-___-_____

State FIPS - County FIPS - National Aquifer Code

Aquifer Name: _____

Data Element	Public Supply	Domestic	Commercial	Industrial	Thermoelectric: Once-through	Thermoelectric: Closed-loop	Mining	Livestock	Aquaculture	Irrigation (Crop/Golf is optional): Total	OR Crop irrigation	Golf-course irrigation
Withdrawals - GW - fresh												
Withdrawals - GW - saline												
Population served - GW (000s)												
Self-supplied population - GW (000s)												

Figure 1–3*B*. Water-use coding form listing optional elements to be aggregated by county and aquifer.

ESTIMATED USE OF WATER IN THE UNITED STATES

2015 Data Collection Form

HUC Name: _____ HUC: _____ Total Population (000s): [ ]

Data Element	Public Supply	Domestic	Commercial	Industrial	Thermoelectric: Once-through	Thermoelectric: Closed-loop	Mining	Livestock	Aquaculture	Irrigation (Crop/Golf is optional): Total	OR	Irrigation: Crop irrigation	Irrigation: Golf-course irrigation	Hydroelectric: Instream	Hydroelectric: Offstream	Wastewater treatment	Reservoir evaporation
Instream water use																	
Withdrawals - GW - fresh																	
Withdrawals - GW - saline																	
Withdrawals - SW - fresh																	
Withdrawals - SW - saline																	
Population served - Total (000s)																	
Population served - GW (000s)																	
Population served - SW (000s)																	
Deliveries from public supply																	
Consumptive use - fresh																	
Consumptive use - saline																	
Conveyance loss																	
Power generated (gigawatt-hours)																	
Acres irrigated - sprinkler (000s)																	
Acres irrigated - micro (000s)																	
Acres irrigated - surface (000s)																	
Facilities (number)																	
Wastewater returns																	
Reclaimed wastewater																	
Reservoir surface area (thous. ac)																	
Reservoir evaporation (thous. ac-ft)																	

Figure 1–4. Water-use coding form listing optional elements to be aggregated by hydrologic unit.

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