Prepared in cooperation with the Ohio Water Development Authority and the Muskingum Watershed Conservancy District

Estimation of Upstream Water Use with Ohio's StreamStats Application

Scientific Investigations Report 2016–5077

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

Cover. Fountain in downtown Columbus, Ohio. (Rendering based on original photograph by G.F. Koltun, U.S. Geological Survey)

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Conversion Factors

[U.S. customary units to International System of Units]

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
	Area	
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
million gallons (Mgal)	3,785	cubic meters (m^3)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
gallons per day (gal/d)	4.381×10^{-8}	cubic meter per second (m^3/s)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)

Abbreviations

Esri	Environmental Systems Research Institute, Inc.
GIS	geographic information systems
HTTP	Hypertext Transfer Protocol
JSON	JavaScript Object Notation
NAICS	North American Industry Classification System
ODNR	Ohio Department of Natural Resources
PRISM	Parameter-Elevation Regressions on Independent Slopes Model
SIC	Standard Industrial Classification
SWUDS	Site-Specific Water-Use Data System
USGS	U.S. Geological Survey
WWFRP	Water Withdrawal Facilities Registration Program
VBA	Visual Basic for Applications
XML	Extensible Markup Language

Estimation of Upstream Water Use with Ohio’s StreamStats Application

By G.F. Koltun, Mark Nardi, and Kim Shaffer

Abstract

This report describes the analytical methods and results of a pilot study to enhance the Ohio StreamStats application by adding the ability to obtain water-use information for selected areas in the northeast quadrant of Ohio. Water-use estimates are determined in StreamStats through a simple multistep process.

Water-use data used to develop the Ohio StreamStats water-use application were obtained from the Ohio Department of Natural Resources (ODNR) and 2010 countywide estimates of self-supplied domestic water use (hereafter referred to as “domestic water use”) compiled by the U.S. Geological Survey (USGS). With the exception of domestic water uses, monthly time series of reported water uses for 2005–2012 are used to calculate average monthly and average annual withdrawals. Domestic water use is estimated from the USGS 2010 countywide estimates, assuming that water use is distributed uniformly in space and time. Consumptive-use coefficients are used to estimate net withdrawals and facilitate computation of return flows.

Temporary water-use registrations for hydraulic fracturing are tabulated separately from the other water uses. Water-use indices are computed by dividing average annual net withdrawals (with and without temporary registrations) by the mean October streamflow estimated with StreamStats. The water-use indices are intended to provide metrics of potential consumptive water use.

Introduction

In 2010, an average of more than 9.4 billion gallons of water was used daily in Ohio, with more than 90 percent of the water coming from surface-water sources (Maupin and others, 2014). Overall, water use decreased nationally from 2005 to 2010; however, certain categories of water use increased during that time period (Maupin and others, 2014). In particular, among the water-use categories tabulated, mining withdrawals (which include withdrawals used for injection of water for oil and gas recovery [including hydraulic fracturing]) accounted for the largest percentage increase (39 percent) in water use between 2005 and 2010.

Ohio is one of several states where shale-well drilling and hydraulic fracturing have increased appreciably in recent years. Between January 2011 and August 2015, the Ohio Department of Natural Resources (ODNR), Division of Oil and Gas Resources, issued about 1,900 permits for horizontal drilling in Ohio shales (Ohio Department of Natural Resources, 2015a). Most of the permits in Ohio have been issued for locations in the Utica-Point Pleasant shale play, predominately along the eastern edges of the Muskingum River Basin and basins along the eastern border of Ohio that are direct tributaries to the Ohio River (typically ranging from Columbiana County on the north to Monroe County on the south) (Ohio Department of Natural Resources, 2015b).

Because of rapidly changing water-use demands, there is an increasing need by regulators and potential water users to quickly estimate the cumulative quantity of upstream water uses (total withdrawals) at specific stream locations within Ohio. In addition, there is a need to be able to estimate net withdrawals (that is, total withdrawals minus the amount of the withdrawal returned to the stream) because net withdrawals reflect the amount of the total withdrawal actually consumed, thereby depleting streamflows. To help meet those needs, the U.S. Geological Survey (USGS), in cooperation with the Ohio Water Development Authority and the Muskingum Watershed Conservancy District, agreed to complete a pilot study to enhance the Ohio StreamStats application (Koltun and others, 2006) by adding the ability to obtain estimates of total and consumptive water use in a portion of Ohio.

Description of Study Area

The pilot study area covers more than 11,250 square miles (mi^2) in Ohio and includes all or part of the following counties: Ashland, Ashtabula, Belmont, Carroll, Columbiana, Coshocton, Crawford, Cuyahoga, Erie, Geauga, Guernsey, Harrison, Holmes, Huron, Jefferson, Lake, Lorain, Mahoning, Medina, Monroe, Muskingum, Noble, Portage, Richland, Seneca, Stark, Summit, Trumbull, Tuscarawas, and Wayne (fig. 1). In 2010, a total of about 4.9 million people lived in the counties listed above; Cuyahoga County, the most populous county, had a 2010 population of about 1.28 million people (United States Census Bureau, 2014). The dominant land cover in the study area is forest (38.4 percent), followed by agriculture (35.0 percent), and then developed areas (19.8 percent), as determined from the National Land Cover Database 2011 (Homer and others, 2015). The average annual precipitation and temperature in the study

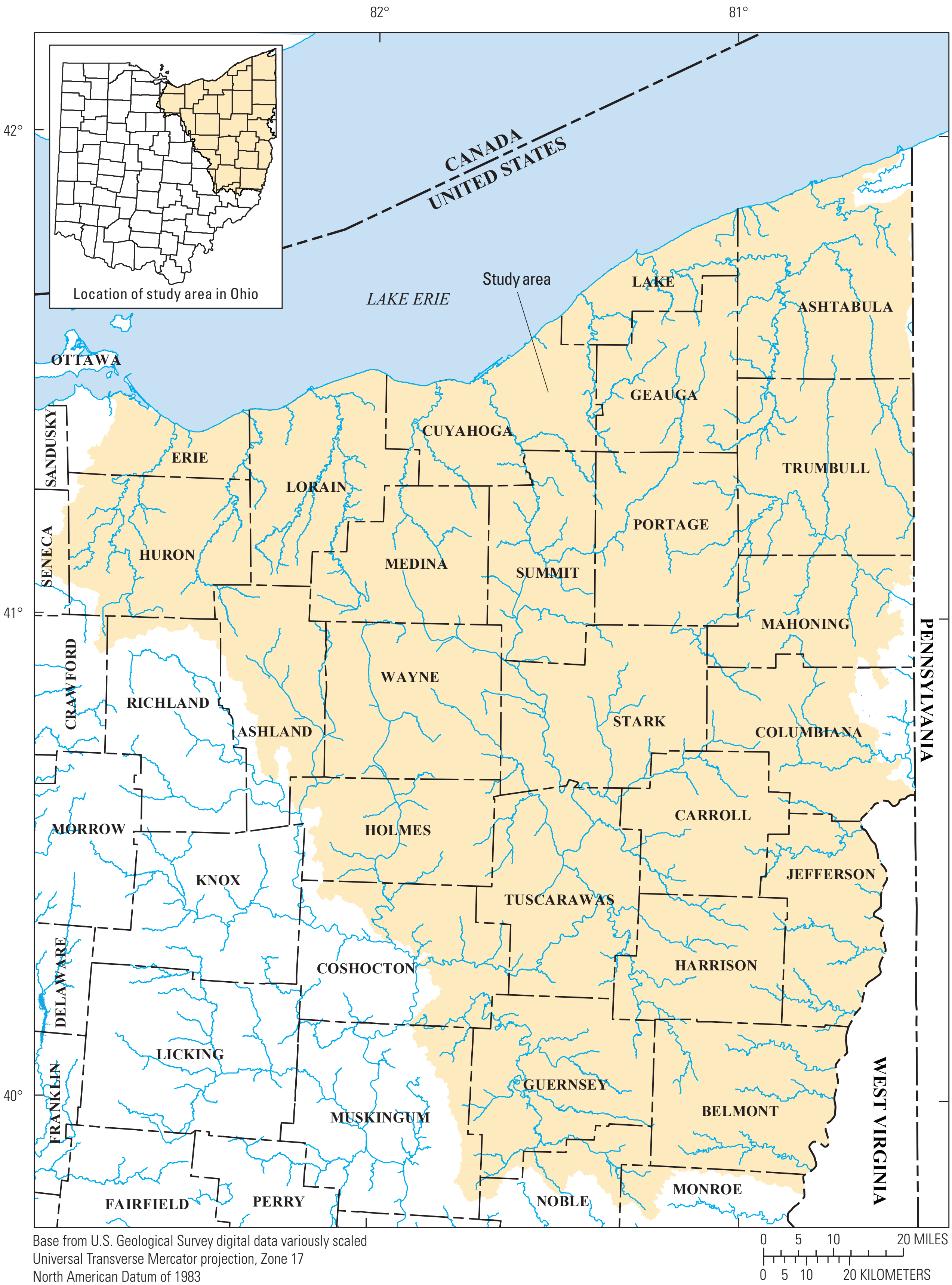

Figure 1. Map showing study area where Ohio water-use information is available through StreamStats.

area from 1981–2010 were 39.7 inches and 50.1 °F, respectively, as determined from Parameter-Elevation Regressions on Independent Slopes Model (PRISM) datasets (PRISM Climate Group, 2015). Some of the larger basins whose drainages lies entirely within the study area include the Black River Basin, Chagrin River Basin, Cuyahoga River Basin, Grand River Basin, and Tuscarawas River Basin.

Purpose and Scope

This report describes the analytical methods and results of a pilot study to add the ability to obtain water-use information for a portion of Ohio from the Ohio StreamStats application. The existing Ohio StreamStats application is a Web-based, interactive geographic information system that permits a user to locate points of interest on streams, delineate the basin boundary, compute selected basin characteristics, and obtain estimates of a variety of streamflow statistics associated with those locations. The capabilities added in this study allow StreamStats to provide information on average monthly and average annual water uses (including total withdrawals, returns, and net withdrawals) associated with areas draining to the selected locations. This study was done to pilot the water-use information retrieval process for Ohio and so was limited to providing information for only a portion of Ohio where water demands have been changing rapidly.

Approach

Monthly and annual water-use data (with the exception of data on domestic water use) for the study area were obtained from the ODNR. The data provided by the ODNR were collected as part of the Water Withdrawal Facilities Registration Program (WWFRP) that was established in 1988 by the Ohio General Assembly. Section 1521.16 of the Ohio Revised Code requires owners of facilities (or a combination of facilities) with the capacity to withdraw water at a quantity greater than 100,000 gallons per day (gal/d) to register such facilities with the ODNR, Division of Soil and Water Resources. It is important to note that registration under the WWFRP does not constitute a permit to withdraw water, nor does it impose any restrictions on withdrawals.

Water-withdrawal facilities typically report monthly and annual withdrawals for a given calendar year by March of the following calendar year. Withdrawals are reported in units of million gallons per day (Mgal/d) rounded to two decimal places. While some facilities have flow meters to determine withdrawals, other facilities estimate withdrawals by other means. Consequently, the accuracy of reported withdrawals varies among facilities. The ODNR does some quality assurance checks on data, including having data entry checked by someone other than the person who entered the data into the database and comparing reported water-use values against values reported in previous years (Michael Hallfrisch, Ohio Department of Natural Resources, written commun., 2016). The ODNR reports that they have greater than 97 percent compliance in reporting of water use by facilities by the time they finalize their database (Michael Hallfrisch, Ohio Department of Natural Resources, written commun., 2016).

Sources and Processing of Water-Use Data

Water-use data obtained from the ODNR were entered into the USGS Site-Specific Water-Use Data System (SWUDS) for Ohio. Only data for facilities that were active between 2005 and 2012 were entered into SWUDS. Records were checked for completeness and rudimentary accuracy. If provided, the Standard Industrial Classification (SIC[1]) code or North American Industry Classification System (NAICS[2]) code reported by the facilities were used to assign water-use categories (public supply, commercial, industrial, thermoelectric, mining, livestock, aquaculture, or irrigation). Otherwise, other sources of information (for example, Internet searches) were used to assign a water-use category. In some cases, a facility can have multiple water-uses associated with it (for example, a public water supply may serve industries as well as the resident population). In those cases, a primary water-use category was determined for later use in assigning consumptive-use coefficients.

Although the ODNR collects information on withdrawals for individual wells and intakes used by facilities, only aggregate groundwater and (or) surface-water withdrawal data are entered into their WWFRP database. Because some Ohio water-use data previously had been entered into SWUDS, an effort was made to match facilities in the ODNR WWFRP database with facilities already entered into SWUDS. Matching was done on the basis of facility location, facility name, and (or) facility purpose. If the facility was not found in SWUDS, a new facility entry was created.

SWUDS was designed to use a conveyance-based model of the water-use network. Such models can describe complex water-use networks, such as a facility that has many groundwater wells and (or) surface-water intakes that supply it. Conveyances are used to describe the connections and flow paths associated with a facility. Because the water-use data in the WWFRP database were aggregated, those aggregate water uses (rather than water-uses associated with the individual wells or intakes) were associated with facilities using conveyances (fig. 2).

Withdrawal rates (in Mgal/d) were computed by dividing monthly and annual withdrawal volumes (in Mgal) reported in the WWFRP database by the number of days in the month and year, respectively (accounting for the leap day in 2008 and 2012), and entered into the SWUDS database. Entry of negative withdrawals is not permitted in SWUDS, although in one instance, a facility reported a small negative withdrawal for one month. The reason for reporting a negative withdrawal could not be determined, so a withdrawal of 0 Mgal/d was substituted.

[1]See http://www.sec.gov/info/edgar/siccodes.htm for more information on SIC codes.

[2]See http://www.census.gov/cgi-bin/sssd/naics/naicsrch?chart=2012 for more information on NAICS codes.

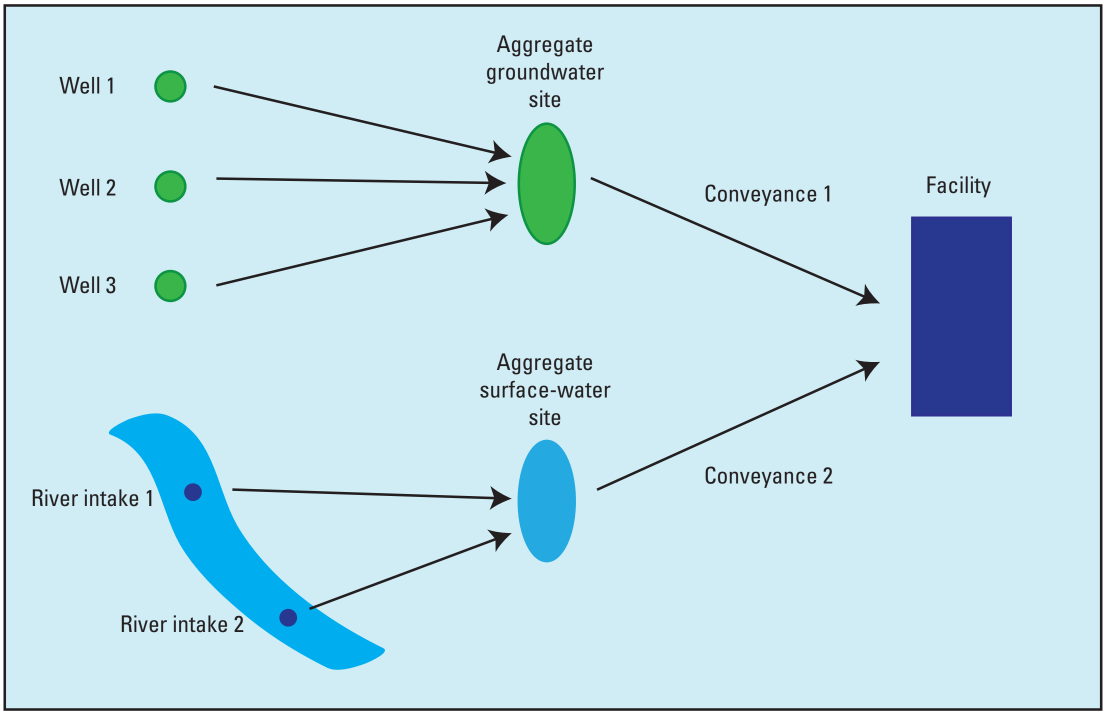

Figure 2. Illustration of conveyances used to model aggregate water-use data in the Site-Specific Water-Use Data System (SWUDS).

The WWFRP does not mandate that facilities report return flows (water that is withdrawn and returned to the environment), but some facilities do so. Return-flow data (when available) were not entered into SWUDS because reporting of return flows is not mandatory (and so may be incomplete) and because return flows that are reported have the potential to include water from sources other than withdrawals (for example, water that infiltrates into return pipes). Instead, return flows are estimated by multiplying total withdrawals by 1 minus a consumptive-use coefficient[3] associated with the specific primary water-use category assigned to the facility (table 1). Net withdrawals are estimated by subtracting the estimated return flows from the total reported withdrawals.

Data from SWUDS were extracted into an intermediate relational database using a Visual Basic for Applications (VBA) program that maintains a link-node topology consistent with the original SWUDS concept of water conveyances. Positional and other metadata on water uses from the intermediate database were imported into an Arc Hydro StreamStats geodatabase using the ArcMap GIS software (Esri, 2013) and the Arc Hydro Data Model and Tools (Maidment, 2002). Monthly data associated with aggregate water uses were loaded into the Arc Hydro StreamStats geodatabase as time series.

A database table, separate from those exported from SWUDS, was created in the Arc Hydro StreamStats geodatabase to hold the more ephemeral and dynamic water-use registrations reported by the ODNR for hydraulic fracturing. Water-use registrations for hydraulic fracturing are categorized as "temporary water-use registrations" because the water uses associated with those registrations are not expected to be needed after the hydraulic fracturing process has been completed. In addition to location data, this table contains total intake and (or) well capacity for each location and an indicator of whether those registrations are considered active (meaning the associated withdrawal capacity could be used at any time). Only registrations marked as active are included in water-use tallies. It is anticipated that the temporary water-use registration table will be updated monthly in StreamStats from data provided by the ODNR, whereas the more persistent water uses retrieved from the WWFRP will be updated not more than annually.

The WWFRP does not contain data on domestic water uses. Consequently, the most recent (2010) county-level estimates of domestic water uses (U.S. Geological Survey, 2015) were used in this pilot study. To facilitate estimation of domestic water uses at a subbasin level, gridded datasets were developed in a geographic information system (GIS) wherein each 30 meter by 30 meter grid cell in a county was assigned a water-use equal to the estimated 2010 county-level domestic water use (in Mgal/d) divided by the number of grid cells within the county. Consequently, the value assigned to each grid cell equals the amount of the county's total domestic water use associated with the area in that grid cell. The underlying assumption associated with the grids is that domestic water use occurs uniformly in space and time across the county; in reality, that is unlikely to be true. Determining the true spatial and temporal distribution of domestic water use was not possible with the data available.

[3]Consumptive-use coefficients represent the fraction of the total withdrawal consumed and thus not returned to the source. Consumptive-use coefficients used in this study were determined and provided by the ODNR (Mike Hallfrisch, Ohio Department of Natural Resources, written commun., 2013).

Table 1. Consumptive-use coefficients, by water-use category, used to estimate return flows in the Site-Specific Water-Use Data System (SWUDS) for Ohio.

[misc., miscellaneous; ODNR, Ohio Department of Natural Resources; USGS, U.S. Geological Survey; consumptive-use coefficients determined and provided by the ODNR (Mike Hallfrisch, written commun., 2013)]

Water-use category	Consumptive-use coefficient	ODNR primary-use designations	USGS water-use subtype code
Mining and quarry dewatering	0.00	Mining	Mining (MI) minus the hydraulic fracturing component.
Industrial cooling (once-through)[1]	0.01	Power	Thermoelectric power, once-through cooling (PO).
Industrial cooling (closed-cycle)[1]	0.10	Power	Thermoelectric power, closed-cycle cooling (PC).
Industrial processing	0.10	Industry	Industry (IN).
Public water supply	0.15	Public	Water Supply (WS).
Domestic, commercial, & institutional	0.15	Misc. public	Commercial (CO).
Livestock watering	0.80	Agriculture	Livestock (LV).
Fish hatchery	0.80	Misc.	Aquaculture (AQ).
Wetland augmentation	0.80	Misc.	Commercial (CO).
Irrigation	0.90	Agriculture, Golf course	Irrigation (IR).
Hydraulic fracturing	1.00	Hydraulic fracturing	Only the hydraulic fracturing component of Mining (MI).

[1]This category is predominately cooling water used in the generation of electricity; however, some other industrial cooling processes are included.

Description of Water-Use Web Services and Linkage to StreamStats

Web services are client and server applications that communicate over the Internet using the Hypertext Transfer Protocol (HTTP) and transfer information using JavaScript Object Notation (JSON), Extensible Markup Language (XML), or other machine-readable file formats. A water-use Web service was developed that uses Visual Basic .NET (Microsoft, 2013) ArcObjects to process previously compiled water-use data within an ArcGIS Server software environment. In this case, the Ohio StreamStats application starts a client application that (after interaction with the user) sends a JSON object containing the name of a personal geodatabase (which contains the coordinates of a basin polygon and the mean October streamflow [$\bar{Q}_{10}$] determined by StreamStats for a user-selected location) along with a user-specified date range to the water-use Web service. The water-use Web service obtains the basin polygon from the personal geodatabase, uses it to select water-use facilities within the basin's interior, and then retrieves time series of water-use records within the specified date range for the selected facilities. It also uses the basin polygon to identify the previously described domestic water-use grid cells whose centroids lie within its interior, and then it sums the water-uses associated with those cells to obtain estimates of domestic water use. The water-use Web service then computes selected water-use statistics from the time-series records and returns results (in JSON format) to the StreamStats client application, where they are tabled and graphed.

The water-use Web service computes average total withdrawals, estimated returns and net withdrawals, and water-use-category-specific withdrawals, by calendar month, for the user-selected period. The period used to compute averages is a user-specified contiguous period with start and end dates ranging from calendar years 2005 to 2012. The net withdrawals that are computed equal the differences between the total withdrawals and the estimated returns, and the net withdrawals, as such, represent the consumptive water uses. It is worth noting that the net withdrawals are assumed to affect streamflows only in the selected basin and locations downstream. Although that may not be strictly true in all cases (for example, some groundwater withdrawals could affect streamflows outside the basin boundary), this assumption is required given the aggregate nature of the water-use data and the inability to make more informed decisions without expending appreciably more effort and resources.

In addition to monthly results, , the water-use Web service computes the following statistics: (1) the average annual withdrawals originating from groundwater and surface-water sources; (2) temporary water-use registrations (total as well as grouped by groundwater and surface-water sources), and (3) water-use indices computed with and without temporary water-use registrations included (that is, computed by dividing the average annual net withdrawal with and without temporary water-use registrations, respectively, by the estimated mean October streamflow[4] [converted to units of Mgal/d] returned from StreamStats). The water-use indices are intended to provide metrics of

[4]The estimated mean October streamflow is computed by StreamStats, assuming no or minimal anthropogenic sources of streamflow regulation. The estimated mean October streamflow was chosen for use in computing the water-use indices because October typically has the lowest or second lowest average flow of all months for unregulated streams in Ohio.

potential consumptive water use. An example illustrating the computation of water-use indices is shown below. Assume the following were computed for a subbasin:

Average annual net withdrawal ($\overline{W}_n$) = 14.364 Mgal/d

Temporary water-use registrations (R_T) = 225.856 Mgal/d

Mean October streamflow ($\overline{Q}_{10}$) = 575 ft^3/s

The water-use index without temporary registrations (I) would be computed as follows:

$$I = \frac{\overline{W}_n}{\left(\overline{Q}_{10} \times 0.6463 \frac{\text{Mgal/d}}{\text{ft}^3/\text{sec}}\right)} = \frac{14.364}{(575 \times 0.6463)} = 0.0387 \qquad (1)$$

The water-use index with temporary registrations (I_T) would be computed as follows:

$$I_T = \frac{(\overline{W}_n + R_T)}{\left(\overline{Q}_{10} \times 0.6463 \frac{\text{Mgal/d}}{\text{ft}^3/\text{s}}\right)} = \frac{(14.364 + 225.856)}{(575 \times 0.6463)} = 0.6464 \qquad (2)$$

In some basins, the sum of average annual net withdrawals and temporary water-use registrations may exceed the estimated mean October streamflow, resulting in a water-use index with temporary registrations greater than 1.0. That can occur in part because there is no set suspense date assigned to temporary registrations. Consequently, it is assumed that temporary registrations can be used at any time until those registrations are flagged as inactive by the ODNR. As water-use indices approach or exceed a value 1.0 for a given location, extra scrutiny is warranted when considering future additional water uses.

Obtaining Water-Use Summaries from the Ohio StreamStats Web Application

The Ohio StreamStats application can be accessed from the national StreamStats introduction page at http://water.usgs.gov/osw/streamstats/. The introduction page has a link to the interactive map that, when selected, opens a Web page showing the StreamStats initial user interface (fig. 3). The remainder of this section describes the steps for obtaining water-use information with StreamStats and provides details about the result displays.

In order to obtain water-use information, the user must first zoom in to the general area of interest. Once the display is zoomed in far enough, one or more buttons will be displayed on the left of the interface, allowing the user to select Ohio as the state of interest (for example, see fig. 4). Once the Ohio application is selected, a streamflow accumulation grid will be displayed when the zoom level equals or exceeds 15 (a scale of 1:18,055 or larger) and a "Delineate" button (a button on the left of the interface) is activated (fig. 5). After selecting the "Delineate" button, the user must position the cursor over

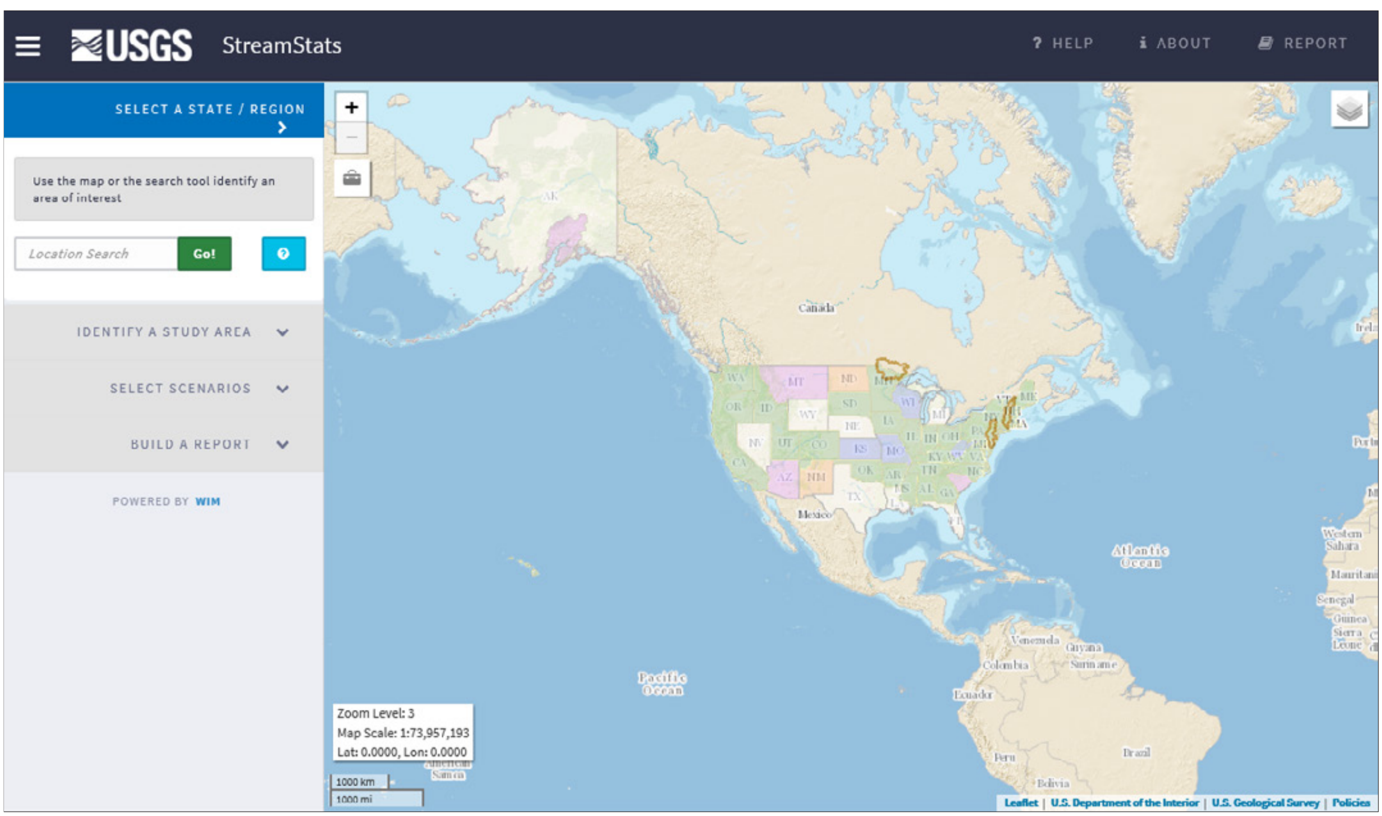

Figure 3. StreamStats initial user interface.

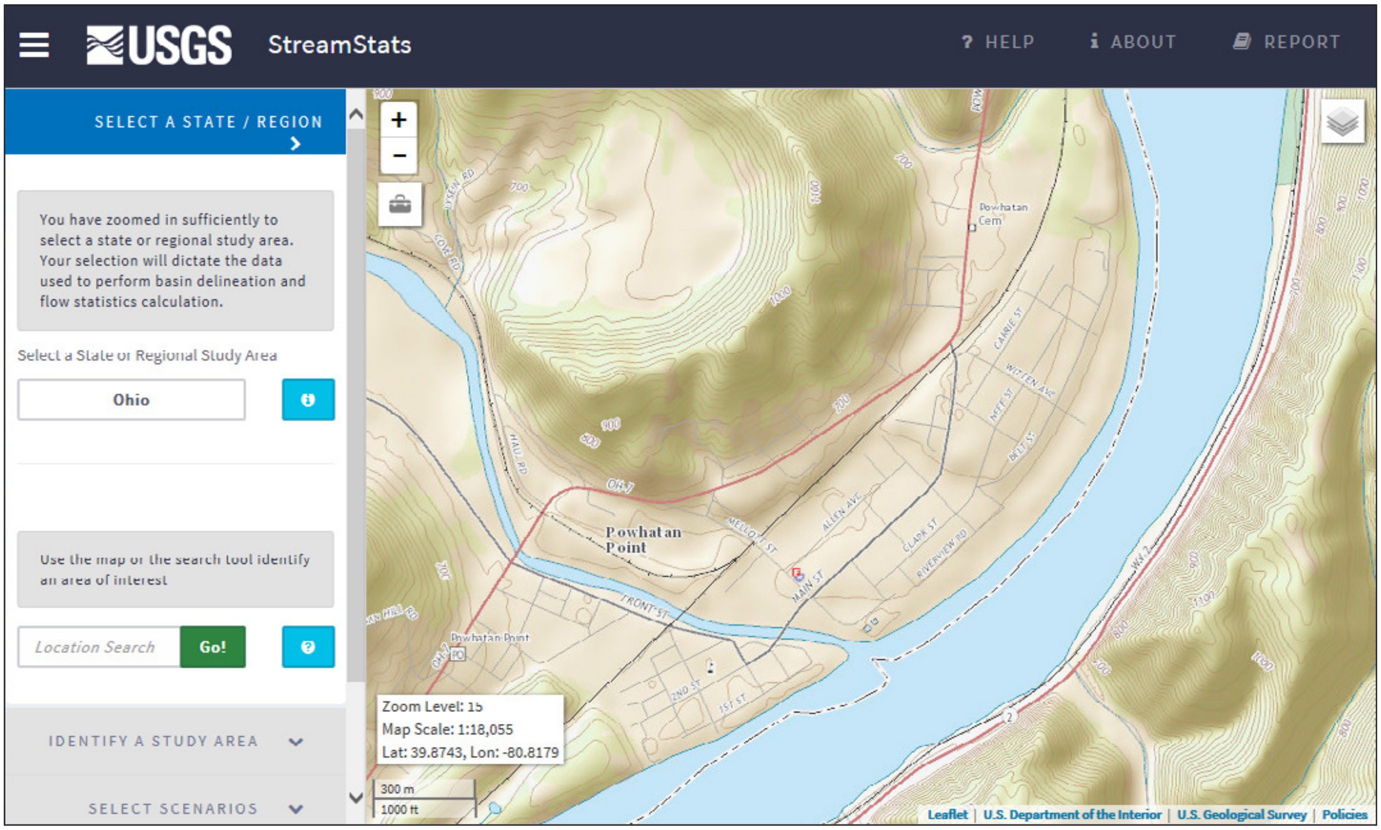

Figure 4. Example StreamStats display showing Ohio application selection button.

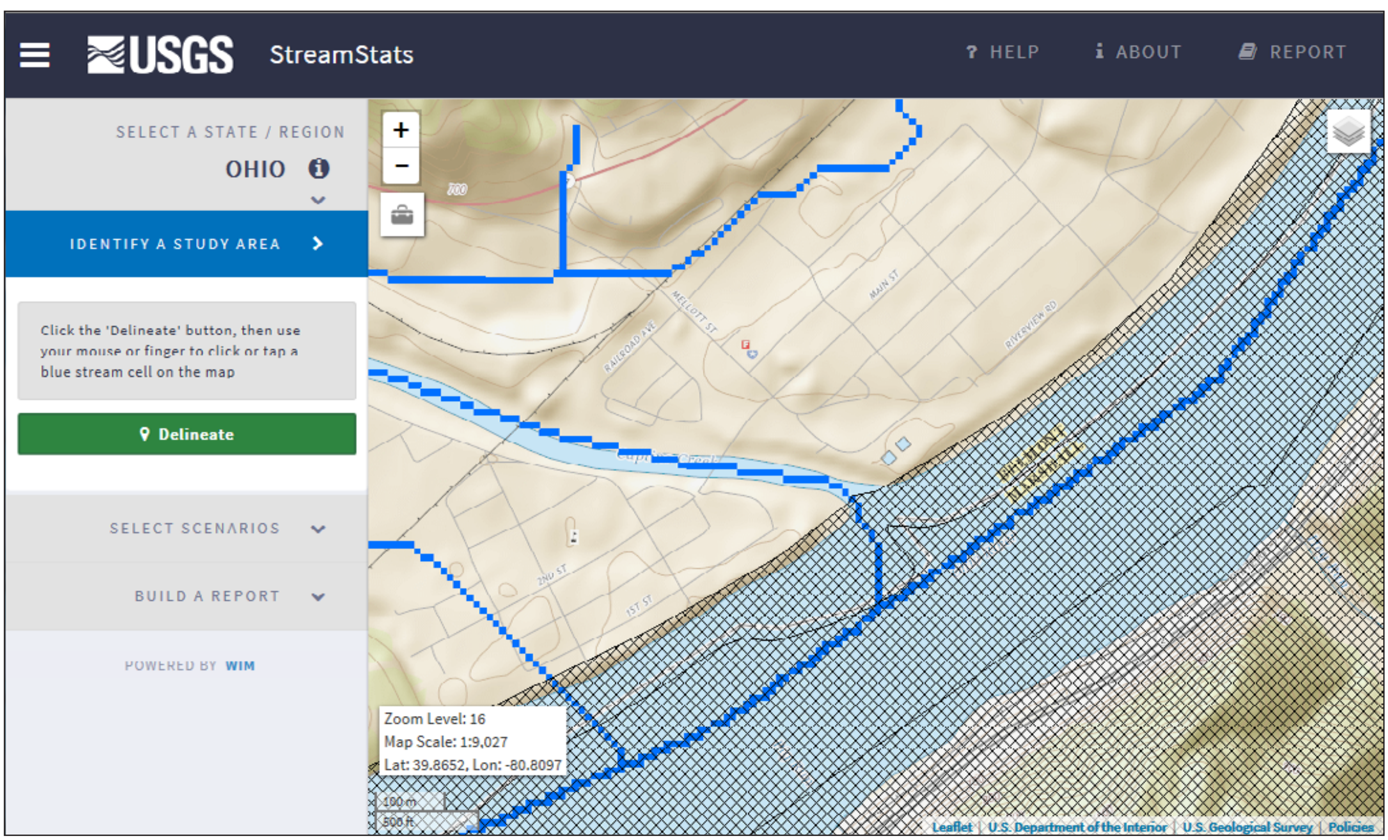

Figure 5. Example StreamStats display showing “Delineate” button and streamflow accumulation grid after selecting Ohio state application.

the streamflow accumulation grid at the point of interest and then select that point (using their mouse or other pointing device). Once the point is selected, the StreamStats application will delineate the basin boundary and display it on the Web page (for example, see fig. 6). It is recommended that the basin boundary be checked for accuracy before proceeding. StreamStats provides tools for editing the basin boundary, if required. Once the user is satisfied with the boundary, the user must select the "Check for Water Use" button (located on the left side of the interface, fig. 6) to obtain water-use data. When the "Check for Water Use" button is selected, StreamStats will open a new window (fig. 7) with water-use selection criteria. The user must select starting and ending years for averaging (either by typing four-digit years in the indicated boxes or by using the slider buttons) then select the "Get water use" button. Once that is done, StreamStats will (1) query the water-use Web service, which determines the water uses within the basin, (2) compute statistics, and (3) return the results. The results window has two tabs: one for graphical displays and the other for tabular results.

The graphical display ("Water-Use Graph" tab) includes a pie chart of average annual water use by source (fig. 8) and bar charts of average monthly water uses by water-use category and estimated average monthly returns (fig. 9). Water-use categories on bar charts are color coded as shown in the explanation above the bar chart. Numerical information on the amount of water use for a specific source or category can be obtained by positioning the pointer over a slice or bar, which causes a display to pop up that lists the value associated with that slice or bar. Values listed to the right of bars are the sum of the water uses shown in the bar. All water uses are reported in units of Mgal/d.

The tabular display ("Water-Use Table" tab) contains tables with annual and monthly water-use summaries. The top portion of the annual table (fig. 10) lists average withdrawals and returns for the user-selected period, the middle portion of the table shows the temporary water-use registrations (expected to be updated approximately monthly), and the lower portion of the table shows the water-use indices computed with and without the temporary registrations.

In the example shown in figure 10, the water-use index computed without including temporary registrations is 0.006, which indicates that the estimated consumptive water use without temporary registrations constitutes only 0.6 percent of the estimated mean October streamflow. However, when temporary registrations are included, the index is 3.890. This indicates that if all of the water associated with temporary registrations were actually used in addition to the estimated existing consumptive water use, then that total would constitute almost 390 percent of the estimated mean October streamflow. While it is unlikely that all of the water-use associated with temporary registrations would occur at the same time, the index suggests that there would not be sufficient water to meet that demand during an average October

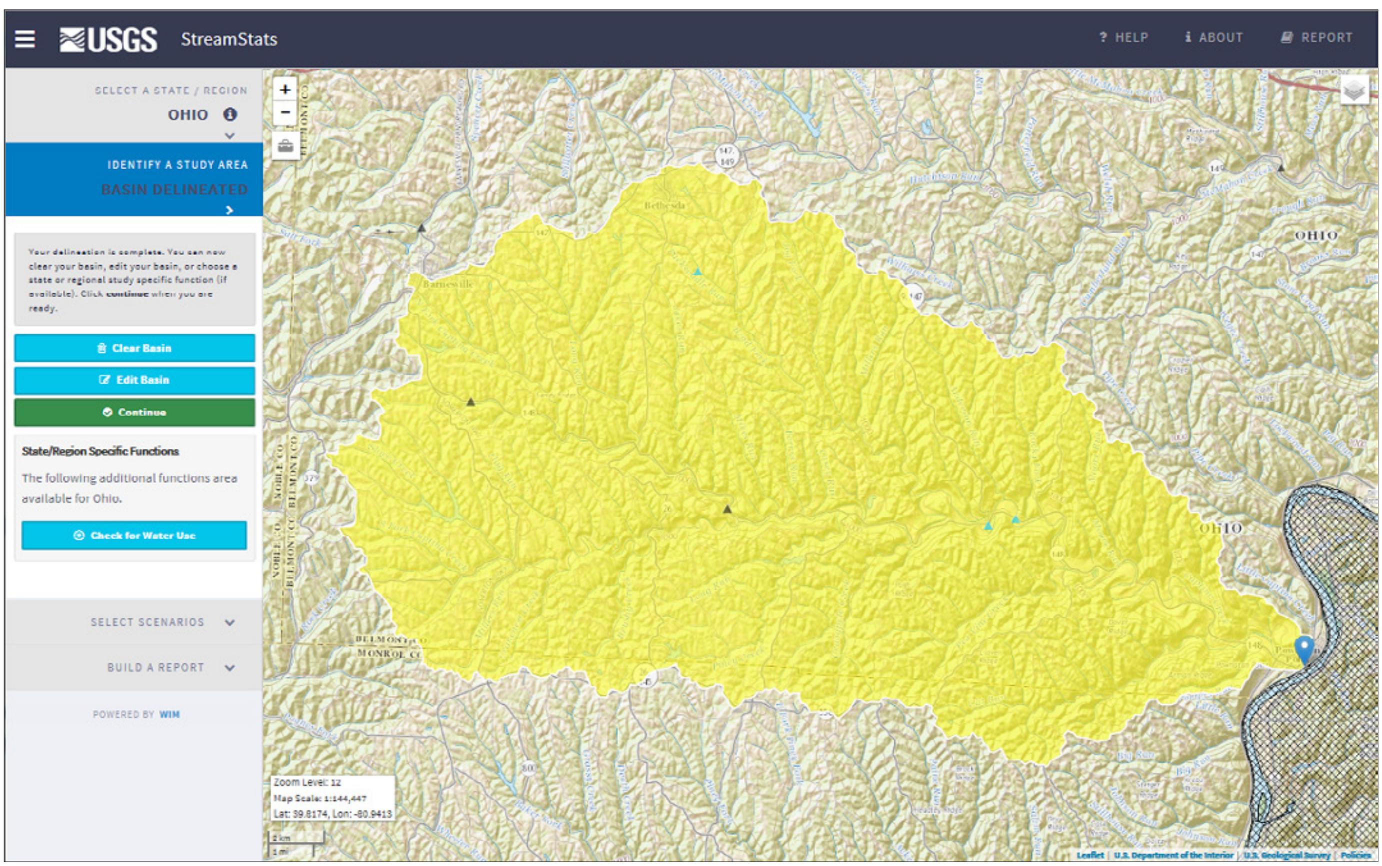

Figure 6. Example StreamStats basin boundary delineation results window.

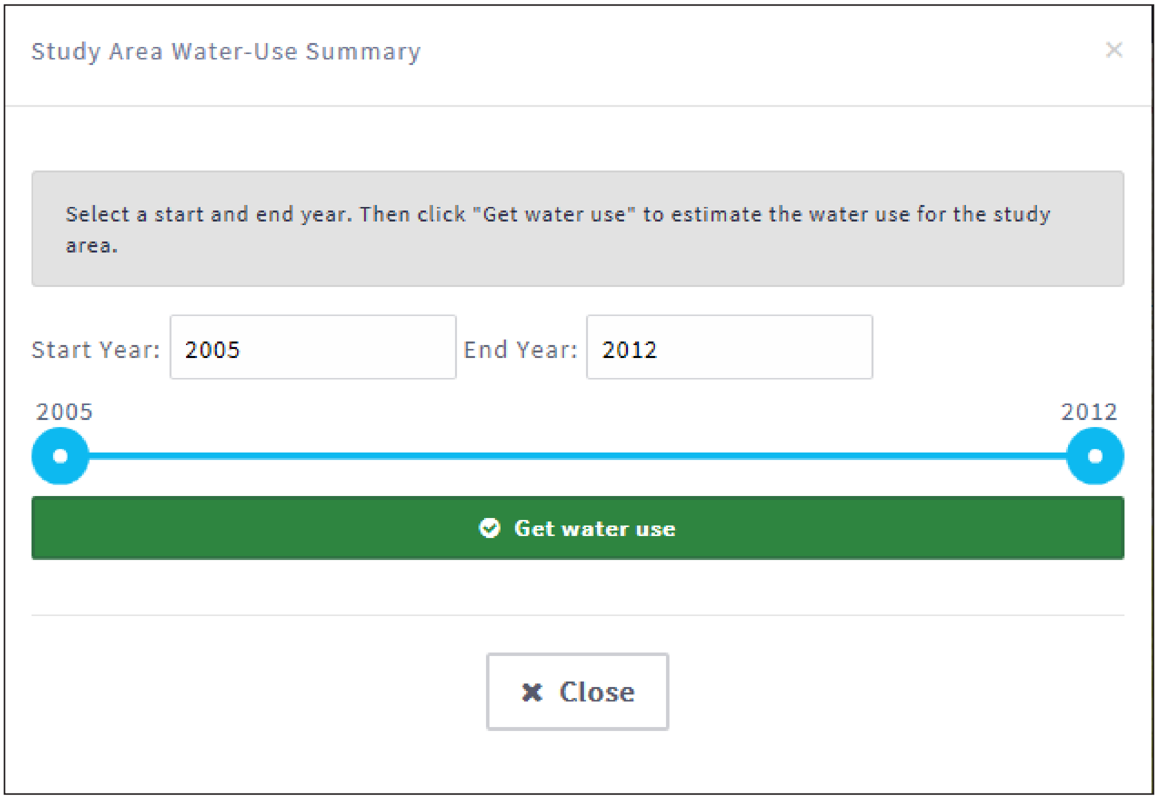

Figure 7. Initial water-use selection pop-up window in StreamStats.

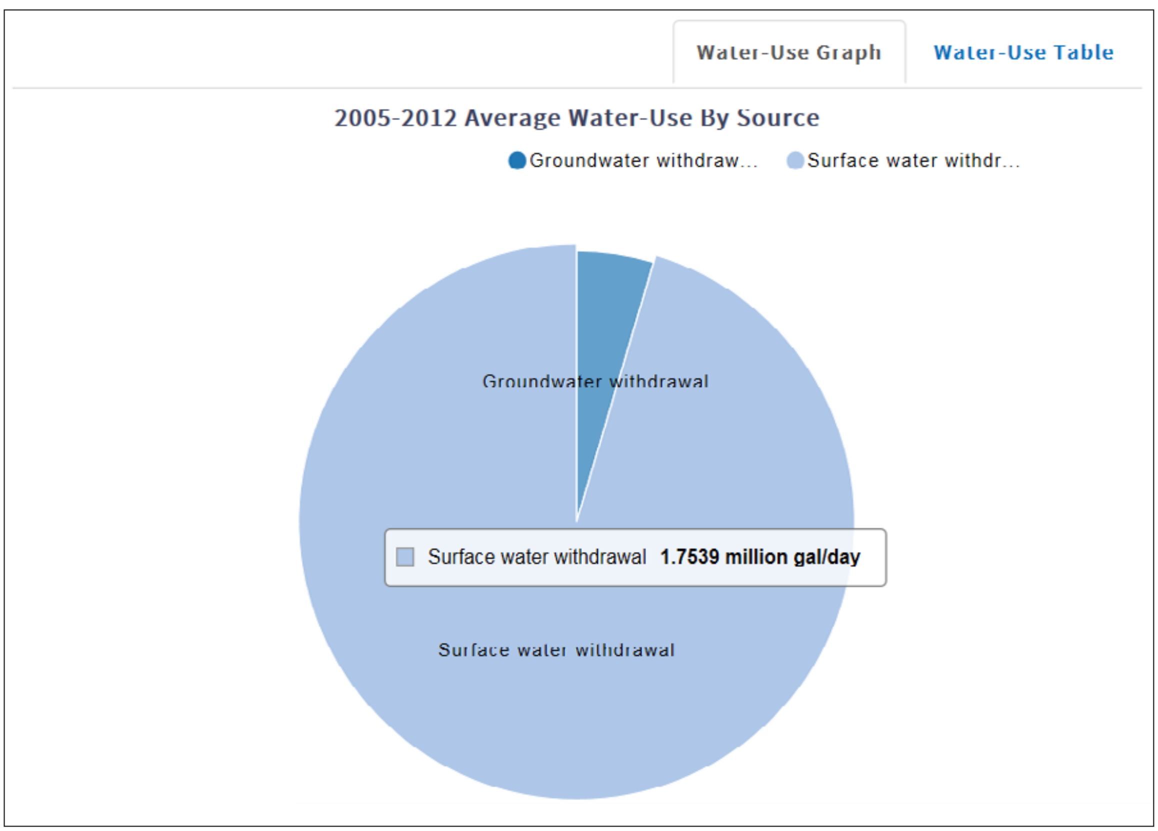

Figure 8. Example "Water-Use Graph" tab display in Streamstats showing pie chart of average water use by source with detailed water-use pop-up display.

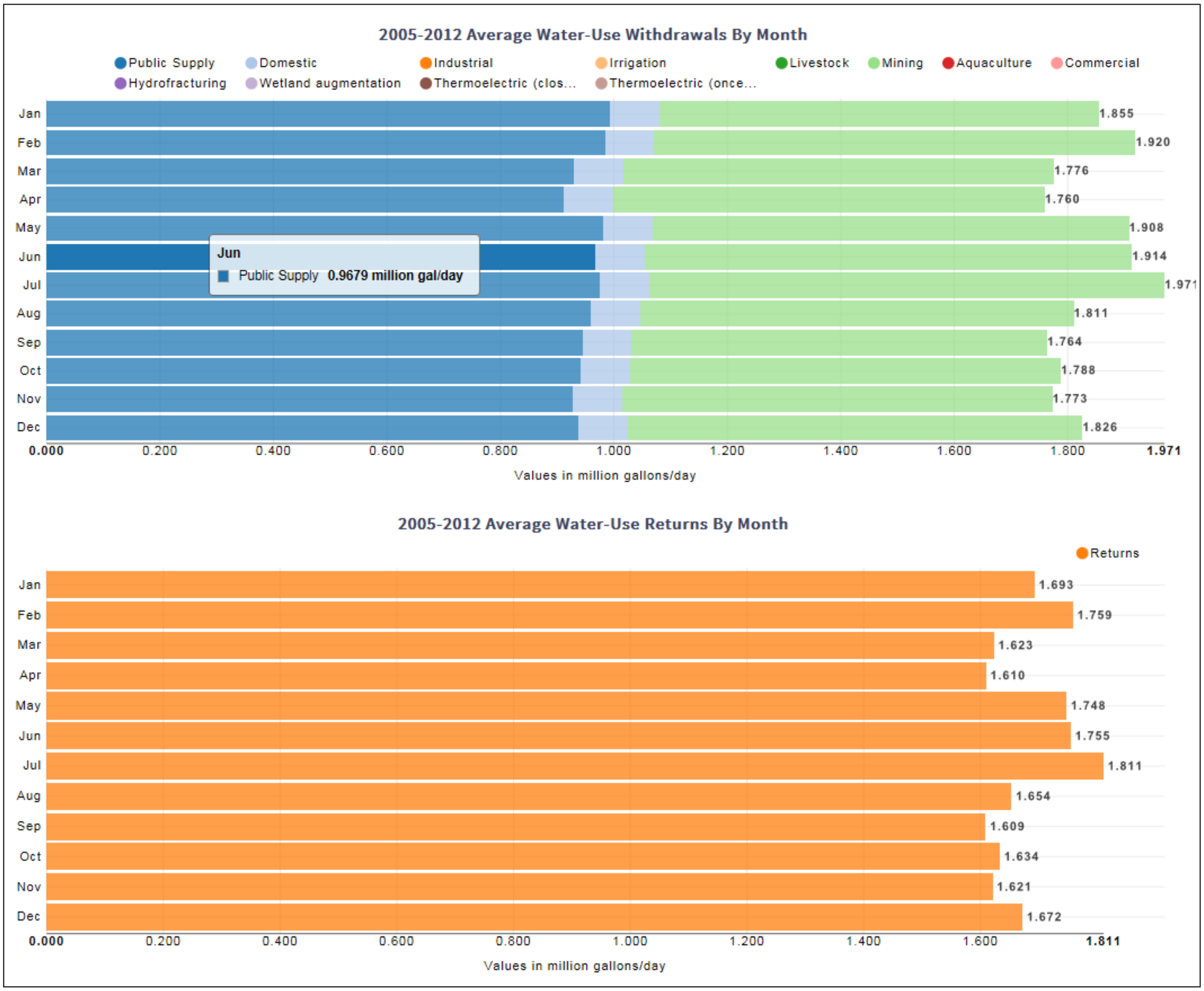

Figure 9. Example of “Water-Use Graph” tab display showing bar chart of average monthly water use by use category and estimated average monthly returns.

2005-2012 Average Annual Water-Use
reported in million gallons/day

	Average Return	Average Withdrawal
Surface Water	---	1.754
Groundwater	---	0.085
Total	1.682	1.838
Temporary water-use registrations (surface water)		99.160
Temporary water-use registrations (groundwater)		0.000
Temporary water-use registrations (total)		99.160
Water-use index (dimensionless) without temporary registrations:		0.006
Water-use index (dimensionless) with temporary registrations:		3.890

Figure 10. Example of “Water-Use Table” tab display showing table of average annual water uses, temporary water-use registrations, and water-use indices.

and that serious streamflow deficiencies could occur even if only a portion of the registration amounts were used. The bottom table (fig. 11) lists the average water uses by month. Depending on the size of the browser window, a horizontal scroll bar (at the bottom of the window) may need to be used to view the entire water-use table. It is worth noting that this table reports both total and net withdrawals. Net withdrawals are the differences between the total withdrawals and the corresponding estimated returns, and the net withdrawals, as such, represent estimates of the water consumed.

Limitations for Estimates of Water Use

Because of the pilot nature of this study, the Ohio StreamStats application has been populated with water-use information for only a portion of Ohio (fig. 1). Water uses quantified in the Ohio StreamStats application only include those reported to the ODNR WWFRP for calendar years ranging from 2005 to 2012, active temporary water-use registrations for hydraulic fracturing reported by the ODNR, and estimated 2010 domestic water uses. The WWFRP does not capture water-use information from low-capacity water users, so total water uses may be underrepresented in some cases. Water uses within a basin (other than domestic water uses) are selected by identifying facilities and (or) temporary registrations located within the basin boundary. Domestic water uses are estimated from grids developed for this study whose individual grid cells represent the area-weighted portion of the total domestic water use (estimated for 2010) for the county in which they fall. Domestic water uses are assumed to be uniform both in time and in space within a given county.

The portions of total water uses within the basin that are consumed (that is, the net withdrawals) are estimated by application of water-use-specific consumptive-use coefficients. Net withdrawals are assumed to affect only streamflows in the delineated basin and locations downstream. That assumption may not be strictly true in all cases (for example, some groundwater withdrawals could affect streamflows outside the basin boundary).

Water-use indices are computed by dividing net withdrawals (with and without temporary water-use registrations) by the estimated mean October streamflow for the selected location computed by StreamStats. The estimate of the mean October streamflow computed by StreamStats is for streams with no or minimal streamflow regulation. Should the basin that is selected have appreciable flow regulation (for example, a basin that has an actively controlled dam), the computed mean October streamflow may poorly reflect the actual mean October streamflow, making the indices invalid for their intended use. Because StreamStats does not explicitly report the presence of upstream regulation, it is the user's responsibility to determine whether regulation occurs and is sufficient to invalidate the intent of the water-use indices. For more

2005-2012 Average Water-Use by Month

reported in million gallons/day

	Returns	Withdrawals											
Month	Total	Total	Net	Public Supply	Domestic	Industrial	Irrigation	Livestock	Mining	Aquaculture	Commercial	Hydrofracturing	Wetland augmentation
Jan	1.693	1.855	0.162	0.993	0.087	0.000	0.000	0.000	0.775	0.000	0.000	0.000	0.000
Feb	1.759	1.920	0.161	0.984	0.087	0.000	0.000	0.000	0.848	0.000	0.000	0.000	0.000
Mar	1.623	1.776	0.153	0.930	0.087	0.000	0.000	0.000	0.759	0.000	0.000	0.000	0.000
Apr	1.610	1.760	0.150	0.911	0.087	0.000	0.000	0.000	0.762	0.000	0.000	0.000	0.000
May	1.748	1.908	0.160	0.981	0.087	0.000	0.000	0.000	0.840	0.000	0.000	0.000	0.000
Jun	1.755	1.914	0.158	0.968	0.087	0.000	0.000	0.000	0.859	0.000	0.000	0.000	0.000
Jul	1.811	1.971	0.159	0.976	0.087	0.000	0.000	0.000	0.908	0.000	0.000	0.000	0.000
Aug	1.654	1.811	0.157	0.960	0.087	0.000	0.000	0.000	0.764	0.000	0.000	0.000	0.000
Sep	1.609	1.764	0.155	0.944	0.087	0.000	0.000	0.000	0.732	0.000	0.000	0.000	0.000
Oct	1.634	1.788	0.154	0.941	0.087	0.000	0.000	0.000	0.760	0.000	0.000	0.000	0.000
Nov	1.621	1.773	0.152	0.927	0.087	0.000	0.000	0.000	0.759	0.000	0.000	0.000	0.000
Dec	1.672	1.826	0.154	0.937	0.087	0.000	0.000	0.000	0.802	0.000	0.000	0.000	0.000

Figure 11. Example of "Water-Use Table" tab display showing table of average monthly water use by use category.

information on other limitations of StreamStats, see http://water.usgs.gov/osw/streamstats/disclaimer.html.

The estimates of mean October streamflow and water uses contain uncertainty. The approximate average standard error of prediction for estimates of the mean October streamflow is 50.8 percent (Koltun and Whitehead, 2002). The uncertainty in the water-use estimates cannot be readily quantified; however, factors that affect that uncertainty include the accuracy of water uses reported by the facilities, the accuracy of consumptive-use coefficients for the various water-use categories, and uncertainty associated with simplifying assumptions related to where and how the water uses affect streamflows within the delineated basins. As a consequence of these uncertainties, water-use estimates and water-use indices computed by the Ohio StreamStats application can be inexact.

Summary

This report describes the analytical methods and results of a pilot study to add the ability to obtain water-use information for selected areas in Ohio from the Ohio StreamStats application. The area for which water-use information can be obtained covers about 11,250 square miles and includes portions of 30 counties in the northeast quadrant of Ohio.

Water-use estimates are determined in the Ohio StreamStats application through a multistep process. To begin the process, a user selects a point on a stream, and StreamStats determines the drainage boundary associated with that point. Water-use estimates can then be obtained by clicking on the "Check for Water Use" button, which causes a new window to open in which the user must first select beginning and ending years for averaging and then select the "Get water use" button. When the "Get water use" button is selected, selected information is sent to a water-use Web service that ultimately computes the water-use statistics and returns the results back to StreamStats for display.

Water-use data used to develop the Ohio StreamStats water-use application were obtained from the following sources: the Ohio Department of Natural Resources (ODNR) Water Withdrawal Facilities Registration Program (WWFRP), temporary registrations for hydraulic fracturing reported monthly by the ODNR, and 2010 county-wide estimates of self-supplied domestic water use compiled by the U.S. Geological Survey (USGS). With the exception of domestic water uses, monthly time series of water uses reported to the WWFRP for 2005–2012 are used to calculate average monthly and average annual withdrawals. Domestic water use is estimated from USGS 2010 county-wide estimates, assuming that water use is distributed uniformly in space and time. Consumptive-use coefficients are used to estimate net withdrawals and facilitate computation of return flows.

Temporary water-use registrations for hydraulic fracturing are tabulated separately from the other water uses. Water-use indices are computed by dividing average annual net withdrawals (with and without temporary registrations) by the mean October streamflow estimated with StreamStats. The water-use indices are intended to provide metrics of potential consumptive water use.

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