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StreamStats: A Water Resources Web Application

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Introduction

Streamflow statistics, such as the 1-percent flood, the mean flow, and the 7-day 10-year low flow, are used by engineers, land managers, biologists, and many others to help guide decisions in their everyday work. For example, estimates of the 1-percent flood (the flow that is exceeded, on average, once in 100 years and has a 1-percent chance of being exceeded in any year, sometimes referred to as the 100-year flood) are used to create flood-plain maps that form the basis for setting insurance rates and land-use zoning. This and other streamflow statistics also are used for dam, bridge, and culvert design; water-supply planning and management; water-use appropriations and permitting; wastewater and industrial discharge permitting; hydropower facility design and regulation; and the setting of minimum required streamflows to protect freshwater ecosystems. In addition, researchers, planners, regulators, and others often need to know the physical and climatic characteristics of the drainage basins (basin characteristics) and the influence of human activities, such as dams and water withdrawals, on streamflow upstream from locations of interest to understand the mechanisms that control water availability and quality at those locations. Knowledge of the streamflow network and downstream human activities also is necessary to adequately determine whether an upstream activity, such as a water

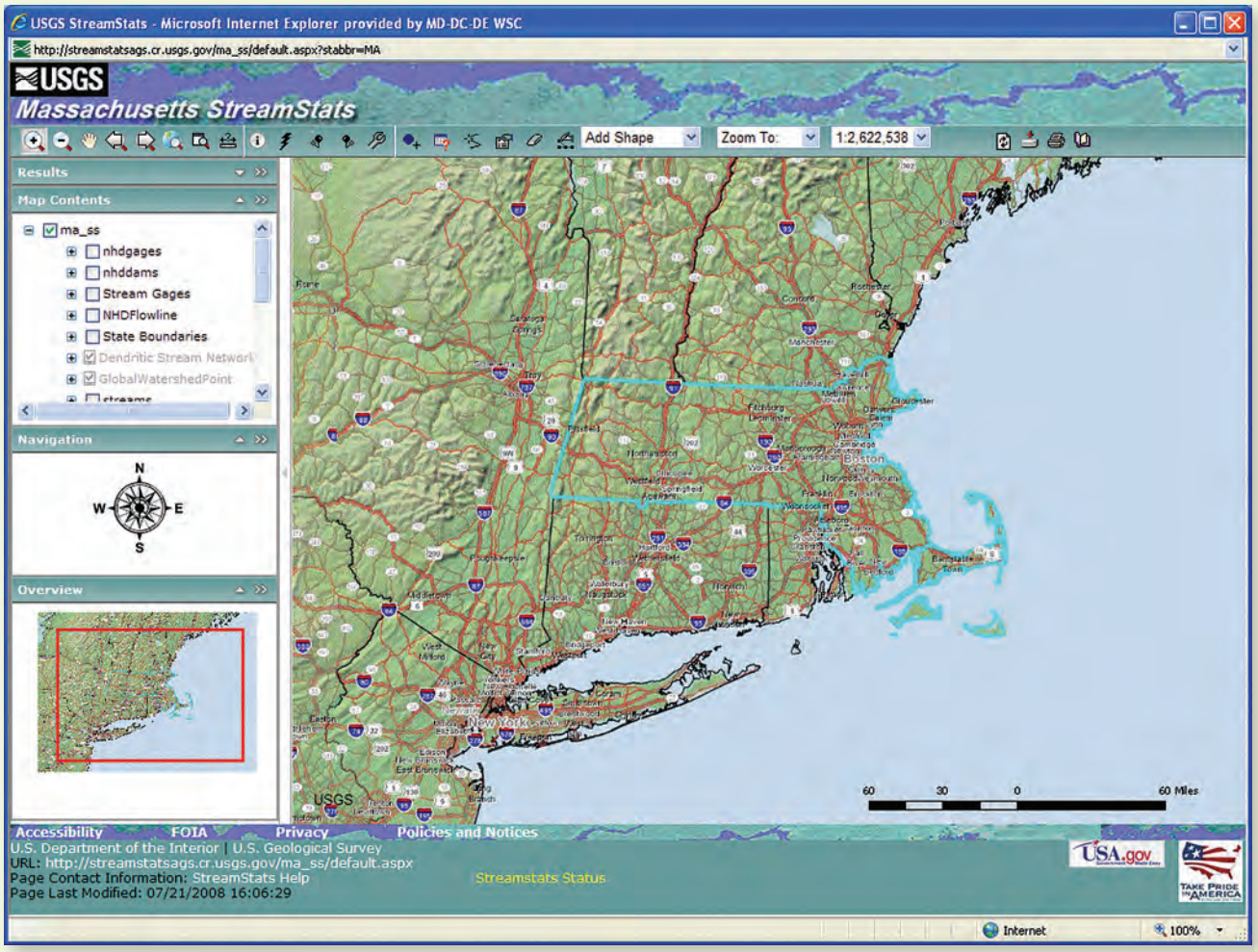

Figure 1. View of the StreamStats user interface for Massachusetts.

withdrawal, can be allowed without adversely affecting downstream activities.

Streamflow statistics could be needed at any location along a stream. Most often, streamflow statistics are needed at ungaged sites, where no streamflow data are available to compute the statistics. At U.S. Geological Survey (USGS) streamflow data-collection stations, which include streamgaging stations, partial-record stations, and miscellaneous-measurement stations, streamflow statistics can be computed from available data for the stations. Streamflow data are collected continuously at streamgaging stations. Streamflow measurements are collected systematically over a period of years at partial-record stations to estimate peak-flow or low-flow statistics. Streamflow measurements usually are collected at miscellaneous-measurement stations for specific hydrologic studies with various objectives.

StreamStats is a Web-based Geographic Information System (GIS) application (fig. 1) that was created by the USGS, in cooperation with Environmental Systems Research Institute, Inc. (ESRI)[1], to provide users with access to an assortment of analytical tools that are useful for water-resources planning and management. StreamStats functionality is based on ESRI's ArcHydro Data Model and Tools, described on the Web at *http://support.esri.com/index.cfm?fa=downloads.dataModels.filteredGateway&dmid=15*. StreamStats allows users to easily obtain streamflow statistics, basin characteristics, and descriptive information for USGS data-collection stations and user-selected ungaged sites. It also allows users to identify stream reaches that are upstream and downstream from user-selected sites, and to identify and obtain information for locations along the streams where activities that may affect streamflow conditions are occurring. This functionality can be accessed through a map-based user interface that appears in the user's Web browser (fig. 1), or individual functions can be requested remotely as Web services by other Web or desktop computer applications. StreamStats can perform these analyses much faster than historically used manual techniques.

StreamStats was designed so that each state would be implemented as a separate application, with a reliance on local partnerships to fund the individual applications, and a goal of eventual full national implementation. Idaho became the first state to implement StreamStats in 2003. By mid-2008, 14 states had applications available to the public, and 18 other states were in various stages of implementation.

Functionality

A previous Fact Sheet (Ries and others, 2004) described the development, functionality, and limitations of the initial version of StreamStats. In 2008, StreamStats was enhanced to provide additional functionality and access to some functionality through Web services. Additional enhancements are planned for the future. Current functionality (2008) for all state applications includes the ability to:

- View a range of base-map features, such as roads, streams, political boundaries, and USGS topographic maps in the user interface map frame for navigation purposes;
- Re-center the map on a user-specified point;
- Zoom in or out to a different map scale based on input of (1) a user-drawn rectangle, (2) a place name, (3) coordinates of longitude and latitude, (4) a specified scale, (5) a National Hydrography Dataset (NHD) reach address, or (6) the full extent of the state;
- Get information on the various map layers shown in the interface;
- Get previously published streamflow statistics, basin characteristics, and descriptive information for USGS data-collection stations, and link to the USGS National Water Information System (NWIS) Web site that provides access to the data collected at the selected stations;
- Delineate the drainage-basin boundary for a user-selected ungaged site;
- Edit the basin boundary;
- Measure basin characteristics, such as drainage area and stream slope, and determine the NHD reach address for the selected site;
- Estimate streamflow statistics and provide indicators of the accuracy of the estimates for the site;
- Search upstream or downstream along the stream from a selected

Figure 2. The StreamStats link frame that appears on each Web page.

[1] The use of trade, product, or firm names in this report is for descriptive purposes only and does not imply endorsement by the U.S. Government.

site to identify connected stream reaches and to locate and provide information on natural or manmade features, such as dams and wastewater discharges, that may affect the quantity or quality of the flow in the stream;
- Download the basin boundary for use in other applications, along with any basin characteristics and streamflow statistics that have been computed for the site; and
- Print whatever is showing in the user interface map frame.

In addition to the standard functionalities listed above, some state applications also have custom functionalities.

Web Site

The StreamStats home page is at *http://streamstats.usgs.gov*. This page provides a brief description of the application. A gray box to the left of the page (fig. 2) provides links to other pages that document and provide access to the application. This gray box is duplicated on all other StreamStats Web pages for easy navigation.

The **State Applications** link is used to access the individual state applications. It presents a map of the United States with individual states shown in different colors depending on their implementation status. Users can access an introductory page for an individual state by selecting the state from a scroll list at the top of the page, or by selecting an implemented state shown as green or purple on the map.

Each state introductory page (1) identifies the area in which StreamStats is implemented, if the entire state is not available, (2) identifies the streamflow statistics for which there are regression equations available for estimating those statistics for ungaged sites, (3) identifies and provides links to the reports that describe the development of the equations, (4) provides a link to the state application, (5) describes any special functionality or limitations for use of the application, and (6) identifies the other agencies that cooperated with the USGS in implementing the application. Clicking on the **Interactive Map** link causes a new Web browser window to appear on the user's computer desktop that contains the application user interface for the state.

It is highly recommended that users read the information on the **StreamStats Description**, **User Instructions**, and **Limitations** pages before attempting to use the application. Users who plan to use StreamStats to estimate streamflow statistics for ungaged sites should also review the reports listed on the state introductory pages to understand how the regression equations were developed, how they should be applied, and to view any special instructions for estimating streamflow statistics for ungaged sites in the state.

StreamStats User Interface

The StreamStats user interface (fig. 1) allows users to locate, select, and obtain information for gaged and ungaged sites of interest. The largest part of the interface consists of the Map Frame, which displays default and selected digital map layers. The Console, to the left of the map, allows control of the display of map layers and map navigation, and provides information about the map. The Toolbar above the map frame contains a series of buttons (tools) that are used to change the scale (zooming in and out) and the center (panning) of the map, and that allow users to initiate the various StreamStats functions.

This Fact Sheet does not fully describe all of the available functions. The *Help* button, located at the far right of the Toolbar, gives access to brief directions for use of each of the buttons. Complete documentation can be accessed through the links provided on the main and other StreamStats Web pages.

Streamflow Statistics for Data-Collection Stations

StreamStats provides convenient access to descriptive information, basin characteristics, and streamflow statistics for USGS data-collection stations. Users can zoom in to the location of a data-collection station in the user interface, click on the *Gaging Station Information* button, and then click on the station symbol to obtain a report that contains available information for the station. A national application that is accessible through the **USGS Station Statistics** Web page provides access to this functionality for data-collection stations in all states. Similar functionality also is available in the applications for each implemented state.

Descriptive information provided in the StreamStats output for the data-collection stations includes: the USGS station identification number, station name, station type, period of record, latitude, longitude, hydrologic unit code (HUC), major drainage basin name, county, U.S. Census Bureau Minor Civil Division (MCD) name, directions to locate the station, and remarks indicating any effects of human impacts or other pertinent information about the stations. Only previously published basin characteristics and streamflow statistics are available from StreamStats. Content varies among stations depending on station type and the interests of local cooperators who may have shared in the cost of computing the statistics. The outputs contain citations to the original source reports that explain the methods used to determine the information. The **Definitions** links from the StreamStats homepage define the **Streamflow Statistics** and **Basin Characteristics** provided in the output.

Streamflow Statistics for Ungaged Sites

StreamStats can estimate streamflow statistics for ungaged sites either on the basis of regional regression equations or on the basis of the known flows for nearby stream-gaging stations. Both methods are discussed below.

The USGS has developed numerous regression equations that can be used to estimate various streamflow statistics for locations on ungaged streams throughout the Nation. Regression equations are developed by statistically relating the streamflow statistics to the basin characteristics for a group of data-collection stations within a region. Estimates of streamflow statistics for ungaged sites can then

Regression Equations

The USGS has developed equations to estimate peak-flow frequency statistics, such as the 100-year flood, for ungaged sites in every state. Regression equations also have been developed to estimate other types of streamflow statistics for many states. As an example, the equation for estimating the 100-year flood for ungaged sites in part of northern Idaho is:

$$Q_{100} = 5.39\ DA^{0.874}(E/1{,}000)^{-1.13}\ P^{1.18}$$

where

Q_{100} is the peak flow that occurs, on average, once in 100 years (1-percent chance of occurrence in any year), in cubic feet per second;

DA is the drainage area, in square miles;

E is the mean basin elevation, in feet; and

P is the mean annual precipitation, in inches.

Reference

Berenbrock, Charles, 2002, *Estimating the magnitude of peak flows at selected recurrence intervals for streams in Idaho: U.S. Geological Survey Water-Resources Investigations Report 02–4170, 59 p.*

be obtained by measuring the basin characteristics for the ungaged site and inserting them into the regression equations. (See inset above.)

StreamStats automates the process of measuring the basin characteristics and solving the applicable regression equations for ungaged sites. Depending on the size of the basin and the types of basin characteristics measured, this automated process can save an hour to a few days of the labor that would be needed to do the work manually. Users need to (1) locate their ungaged site of interest on the map, (2) use the *Point Delineation* tool to obtain the drainage basin for the site, and then (3) use the *Generate Flow Statistics* tool to obtain the estimates. When the process is complete, a Web browser window will appear that reports the time of the analysis, the location of the site, the basin characteristics, the estimated streamflow statistics, and indicators of the errors associated with the estimates for the site.

StreamStats determines the drainage-basin boundary for a selected site by use of a Digital Elevation Model (DEM), which is a regularly spaced grid of elevation points, and a digital representation of the stream network. When a user selects a site along the digital stream network, the site location is transferred to a point in the DEM, and the DEM is then used to determine the drainage boundary. The DEM for most states has been enhanced by a process that ensures conformity with the stream network and a dataset of pre-existing drainage boundaries. As a result, delineations obtained from StreamStats usually are of greater accuracy than delineations obtained from a standard DEM.

The process for obtaining estimates of flow statistics for an ungaged site based on the known flows for nearby streamgaging stations is similar to that for obtaining estimates from regression equations. Users still need to locate sites of interest and delineate the drainage boundaries. The *Generate Flows Based on Similar Gages* tool is then used to obtain the flow estimates. When this tool is used, StreamStats searches upstream and downstream along the stream network to locate nearby streamgaging stations. Usually, streamgaging stations will be used as the basis for estimating streamflow statistics for the ungaged site if the drainage area for the ungaged site is within 0.5 and 1.5 times the drainage area for the streamgaging station. This range of drainage-area ratios can vary by state. The streamflow statistics and the drainage area for the station with the drainage-area ratio closest to one will be retrieved from a database and the flow per unit area will be computed for each statistic. These flows per unit area will then be multiplied by the drainage area for the ungaged site to obtain the estimates. If another station in the opposite direction along the stream network also has a drainage-area ratio within the specified limits, then it also will be used to estimate streamflow statistics for the ungaged site. If both an upstream and a downstream station were used for estimation, then final estimates will be determined by weighting the upstream and downstream estimates by a process explained in Ries and Dillow (2006).

Limitations for Ungaged Site Estimates

Estimates of streamflow statistics that are obtained from regression equations are based on the assumption of natural flow conditions at the ungaged site. If human activities such as dam regulation and water withdrawals substantially affect the timing, magnitude, or duration of flows at a selected site, the regression-equation estimates provided by StreamStats should be adjusted by the user to account for those activities.

StreamStats can be used to obtain regression-equation estimates of streamflow statistics for USGS data-collection stations. Users should understand that there are errors associated with estimates determined from available data for the stations as well as estimates determined from regression equations, and some disagreement between the two sets of estimates is expected. If the flows at the stations are affected by human activities, then users should not assume that the differences between the data-based estimates and the regression-equation estimates are equivalent to the effects of human activities on streamflow at the stations.

When StreamStats is used to obtain regression-equation estimates for sites with basin characteristics outside the ranges of those for the sites used to develop the regression equations, the estimates are extrapolated. Errors associated with these estimates are unknown and may be very large. StreamStats provides a warning when extrapolation occurs.

When the *Generate Flows Based on Similar Gages* tool is used to obtain estimates for ungaged sites, StreamStats users can specify whether to include only stations with natural flow conditions in the analysis or to also include stations that are affected by flow regulations. This decision must be made carefully. If users choose

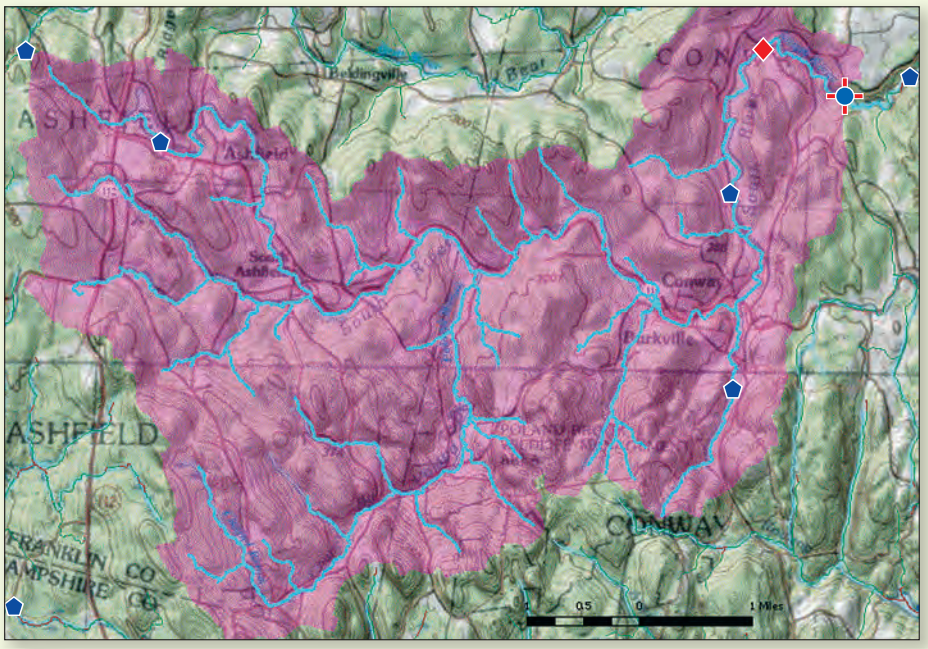

Figure 3. View of the StreamStats map frame showing an upstream network trace for a user-selected point on a stream in Massachusetts where the upstream stream network is light blue, the selected point is a dark blue circle with a red cross behind it, the drainage area is shaded magenta, dams are dark blue pentagons, and streamgaging stations are red diamonds.

to allow use of regulated stations, then they should consider how the effects of regulation could change between the streamgaging station and the ungaged site. For example, if a regulated station is downstream from the ungaged site, it is possible that the stream is not affected by regulation at the ungaged site, and therefore the streamflow statistics estimated on the basis of the flow per unit area at the station will not be representative of the flow conditions at the ungaged site. Conversely, if the regulated station is upstream from the ungaged site, streamflow from tributaries entering between the station and the ungaged site may dampen the effects of the regulation at the station and cause the estimated streamflow statistics to be unrepresentative of conditions at the ungaged site.

Stream Network Navigation

StreamStats has the ability, known as "stream network navigation," to analyze the stream network upstream and downstream from a user-selected point and to identify and obtain information for other points of interest that are located along the network. An explanation of stream networks, focusing on the NHD, is needed before this functionality can be fully understood and utilized.

A stream network is a digital representation of streams and constructed channels for a given area as would be seen on an aerial photograph or on a topographic map. As with photographs and maps, stream networks can be shown at various scales, with smaller scales having less detail than larger scales. In a digital stream network, connecting lines are drawn through lakes, wetlands, bridges, culverts, and any other features where the stream channel is not visible from maps or photographs, thus eliminating any breaks in the network.

In a stream network, reaches are segments of surface water with similar hydrologic characteristics. Reaches are commonly defined by a length of stream between two confluences, or a lake or pond. Each reach is assigned a unique reach code, flow direction, reach length, reach type, and other characteristics that are stored as reach attributes. In addition, points of interest along a network, such as the locations of dams, streamgaging stations, and effluent discharges, can be assigned a reach address, which consists of a reach code and the percentage distance along the reach from the downstream end. These points of interest are called point events. This stream network data structure allows users to navigate upstream or downstream from a user-selected point on a stream to locate and obtain information for the associated reaches and point events.

The NHD was developed cooperatively by the USGS and the U.S. Environmental Protection Agency (USEPA). A medium-resolution version of the NHD is available nationally at a scale of 1:100,000. A high-resolution version of the NHD is also available for nearly the entire Nation at a scale of 1:24,000. In addition, some State and local agencies are creating local-resolution versions of the NHD at various scales with finer resolution than the high-resolution NHD. Detailed information on the NHD and access to available data can be found on the Web at *http://nhd.usgs.gov*.

The StreamStats Toolbar contains three tools for network navigation. The network may be a version of the NHD or any other stream network that is available in StreamStats. The *Config* tool is used to specify the network upon which tracing (searching upstream or downstream) will be done, the direction of the trace, and the map layers of point events that will participate in the trace. Tracing can be done either by first delineating a drainage basin for a selected site and then using the *Config* tool and the *Trace from Outlet* tool in sequence, or by first using the *Config* tool and then using the *Perform and Ad Hoc Trace* tool and selecting any point on a stream to begin the trace. When the process is complete, a window will appear that contains a table that lists the reaches and point events found from the trace. Items in the table usually will contain links from the items to additional information about them. In addition, the map frame will redraw, with the stream reaches identified in the trace highlighted.

A view of the StreamStats Map Frame that illustrates the results of an

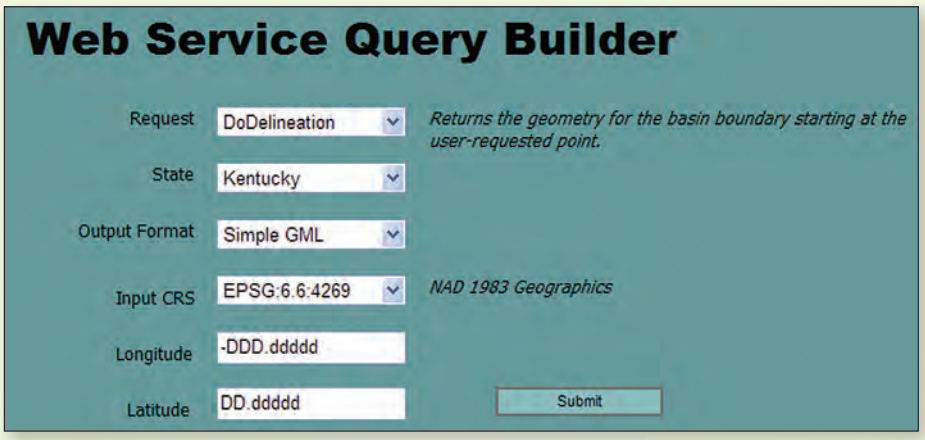

Figure 4. The Web Service Query Builder form set to provide a drainage area delineation in Kentucky.

upstream trace for a user-selected point on a stream in Massachusetts is shown in figure 3. A user has selected a point (dark blue dot with a red cross behind it) and used the *Point Delineation* tool to delineate the drainage basin (shaded magenta area) for the point. The *Config* button was then used to select the NHD Flowline data layer and the upstream direction for tracing. As a result, StreamStats has highlighted the reaches (in light blue) that were found in the trace. These reaches include the reach on which the selected point is located and all upstream reaches. A streamgaging station, represented as a red diamond, and three dams, represented as dark blue pentagons, were also found in the trace. The report produced as a result of the trace (not shown) provides information for each of the reaches and the point events identified in the trace.

The primary benefit of the trace functionality is to understand how the flow at a particular site may be affected by upstream activities or how downstream flow may be affected by existing or proposed activities at the selected site. The USEPA and many State and local agencies have worked to associate their water-related data to the NHD, and many similar efforts are underway. Dams and USGS streamgaging stations have also been associated to the NHD. The layers that are associated to stream networks in StreamStats will vary by state and with time.

Web Services

Some StreamStats functionality is available through Web services, meaning that other remote computer applications or Web sites can initiate a request for a particular function over the Internet, and StreamStats can perform that function and deliver the result back to the remote application. As an example, a user may be using a desktop mapping application to identify a location for which the drainage-basin boundary is needed. If the desktop application does not have the ability to delineate boundaries, the user may request the boundary from the StreamStats Web service.

A Web-based form has been created to aid developers in building StreamStats Web Services (fig. 4). The user first selects the type of query from the top scroll list in the form. The display then changes depending on the requested service. In this example, a basin delineation is requested. The user selects the desired state, output format, and map coordinate system from the scroll lists, and then enters the coordinates (in this case, latitude and longitude) for the site of interest and submits the information. The query builder will then output a Web address that can be submitted through the user's application, causing StreamStats to return the basin boundary in the format that was requested in the form.

Web services that are available include drainage area delineation, use of regression equations to estimate streamflow statistics, and determination of NHD reach and measure; and for Kentucky, estimation of daily precipitation time series for selected basins. Additional Web services are planned for the future. Readers who are interested in making use of any of these services or in having more services added should contact GS-W_StreamStats_help@usgs.gov.

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Ries III, K.G., and Dillow, J.J.A., 2006, Magnitude and frequency of floods on nontidal streams in Delaware: U.S. Geological Survey Scientific Investigations Report 2006–5146, p. 31.

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