

Prepared in cooperation with the Idaho Department of Environmental Quality and the Bureau of Reclamation

Estimated Perennial Streams of Idaho and Related Geospatial Datasets



Data Series 412

Cover: U.S. Geological Survey stream-gaging station on Corral Creek near Challis, Idaho. The watershed drainage area is 10.7 square miles. Streamflow was measured at 6.03 cubic feet per second (ft^3/s) the day this photograph was taken. The 7-day 2-year low flow ($7Q_2$) estimated for this site is 1.37 ft^3/s . The stream at this location was classified as perennial by the model described in this report. (Photograph taken by James L. Schaefer, U.S. Geological Survey, June 30, 2005.)

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By Alan Rea and Kenneth D. Skinner

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Data Series 412

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

U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
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Conversion Factors, Datums, and Abbreviations and Acronyms

Conversion Factors

Multiply	By	To obtain
cubic foot per second (ft ³ /s)	0.02832	cubic meter per second (m ³ /s)
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
square mile (mi ²)	2.590	square kilometer (km ²)

Datums

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

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

Altitude, as used in this report, refers to distance above the vertical datum.

Abbreviations and Acronyms

Abbreviation or Acronym	Definition
7Q ₂	7-day, 2-year low flow
AML	Arc Macro Language
DEM	Digital Elevation Model
EDNA	Elevation Derivatives for National Applications
FGDC	Federal Geographic Data Committee
HUC	Hydrologic Unit Code
NED	National Elevation Dataset
NHD	National Hydrography Dataset
NHD Hi-Res	National Hydrography Dataset High Resolution
NHD Med-Res	National Hydrography Dataset Medium Resolution
NHDPlus	National Hydrography Dataset Plus
TMDL	Total Maximum Daily Load
USGS	U.S. Geological Survey
WBD	Watershed Boundary Dataset
XML	Extensible Markup Language

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Estimated Perennial Streams of Idaho and Related Geospatial Datasets

By Alan Rea and Kenneth D. Skinner

Abstract

The perennial or intermittent status of a stream has bearing on many regulatory requirements. Because of changing technologies over time, cartographic representation of perennial/intermittent status of streams on U.S. Geological Survey (USGS) topographic maps is not always accurate and (or) consistent from one map sheet to another. Idaho Administrative Code defines an intermittent stream as one having a 7-day, 2-year low flow ($7Q_2$) less than 0.1 cubic feet per second. To establish consistency with the Idaho Administrative Code, the USGS developed regional regression equations for Idaho streams for several low-flow statistics, including $7Q_2$. Using these regression equations, the $7Q_2$ streamflow may be estimated for naturally flowing streams anywhere in Idaho to help determine perennial/intermittent status of streams. Using these equations in conjunction with a Geographic Information System (GIS) technique known as weighted flow accumulation allows for an automated and continuous estimation of $7Q_2$ streamflow at all points along a stream, which in turn can be used to determine if a stream is intermittent or perennial according to the Idaho Administrative Code operational definition.

The selected regression equations were applied to create continuous grids of $7Q_2$ estimates for the eight low-flow regression regions of Idaho. By applying the 0.1 ft³/s criterion, the perennial streams have been estimated in each low-flow region. Uncertainty in the estimates is shown by identifying a “transitional” zone, corresponding to flow estimates of 0.1 ft³/s plus and minus one standard error.

Considerable additional uncertainty exists in the model of perennial streams presented in this report. The regression models provide overall estimates based on general trends within each regression region. These models do not include local factors such as a large spring or a losing reach that may greatly affect flows at any given point. Site-specific flow data, assuming a sufficient period of record, generally would be considered to represent flow conditions better at a given site than flow estimates based on regionalized regression models. The geospatial datasets of modeled perennial streams are considered a first-cut estimate, and should not be construed to override site-specific flow data.

Introduction

The perennial or intermittent status of a stream has bearing on many regulatory requirements. For example, the application of Total Maximum Daily Load (TMDL) requirements for Idaho depends on whether the relevant stream reach is perennial or intermittent. Because of changing technologies over time, cartographic representation of perennial/intermittent status of streams on U.S. Geological Survey (USGS) topographic maps is not always accurate and (or) consistent from one map sheet to another. This can be problematic because USGS topographic maps often are used to determine the perennial or intermittent status of specific streams. Because of this, the USGS, in cooperation with the Idaho Department of Environmental Quality and the Bureau of Reclamation, is attempting to better estimate and map the perennial and intermittent streams in Idaho.

Idaho Administrative Code IDAPA 58.01.02 (State of Idaho, 2006) defines an intermittent stream as one having an unregulated 7-day, 2-year low flow ($7Q_2$) of less than 0.1 ft³/s. The $7Q_2$ is the annual minimum mean streamflow over 7 consecutive days that has a 50 percent probability of not being exceeded in any one year. The USGS has developed regional regression equations for Idaho streams for several low-flow statistics, including $7Q_2$ (Hortness, 2006). Using these regression equations, the $7Q_2$ streamflow may be estimated for naturally flowing streams anywhere in Idaho, based on measurements of certain basin and climatic characteristics.

Using this approach to estimate perennial streams, however, in most cases entails using the regression equations far outside the range of values used to develop the regression models. Such extrapolation cannot be avoided because of a lack of stream-gaging station data for such small streams. This can result in unreasonable flow estimates, as well as unreasonable spatial patterns in the modeled stream networks when extrapolating to estimate flows in streams with small drainage areas. As described in Wood and others, 2008, the spatial patterns resulting from continuous estimation of $7Q_2$ flows using the equations by Hortness (2006) were used to evaluate regression models for $7Q_2$, and alternative models determined to be more appropriate for estimating perennial streams were selected for five of eight low-flow regression regions.

Background

The only sources of information available regarding the perennial or intermittent status of streams often are the USGS 7.5-minute topographic maps for the area in question. Streams shown on these maps have been digitally captured into the National Hydrography Dataset High-Resolution (NHD Hi-Res). According to the (draft) Standards for the National Hydrography Dataset-High Resolution (U.S. Environmental Protection Agency and U.S. Geological Survey, 1999), an intermittent stream “Contains water for only part of the year, but more than just after rainstorms and at snowmelt.” A perennial stream “Contains water throughout the year, except for infrequent periods of severe drought.” Similar standards and procedures were used to develop the National Hydrography Dataset Medium Resolution (NHD Med-Res) from 1:100,000-scale topographic maps. The NHD Med-Res was used as the basis for the NHDPlus, which will be discussed later in this report. In this report, the term “NHD” is used to describe the National Hydrography Dataset in a generic sense when it is not important to distinguish between the NHD Hi-Res and NHD Med-Res.

Although the information represented on USGS topographic maps generally was field verified at the time of map compilation, it was not always possible to verify the perennial or intermittent status of every stream. Additionally, the various topographic maps were compiled over many decades, using varying technologies and standards. Therefore, adjacent topographic maps may have been developed under quite different time frames, using different standards and technologies. Finally, errors sometimes occurred in the process of digitally capturing the topographic map information and incorporating it into the NHD. The NHD originally was processed by 8-digit Hydrologic Units, known as subbasins. The result is that the streams shown in the NHD sometimes reflect unrealistic changes in perennial or intermittent status at quadrangle (topographic map) or hydrologic-unit boundaries. [Figure 1](#) shows the spatial distribution of streams identified as perennial in an area of northern Idaho. Several unrealistic density differences are visible following quadrangle or hydrologic-unit boundaries.

Idaho Definition of Perennial Streams

The State of Idaho does not specifically define perennial streams in its water-quality rules; instead, it applies definitions of ephemeral and intermittent waters. Ephemeral waters are on the drier end of the spectrum of flow from intermittent waters; perennial waters, therefore, are all streams having more flow than intermittent waters. Idaho’s water-quality rules define intermittent waters thus:

Intermittent Waters. A stream, reach, or water body which naturally has a period of zero (0) flow for at least one (1) week during most years. Where flow records are available, a stream with a $7Q_2$ hydrologically-based unregulated flow of less than one-tenth (0.1) cubic feet per second (cfs) is considered intermittent. Streams with natural perennial pools containing significant aquatic life uses are not intermittent. (IDAPA 58.01.02.010.45)

This project focused on the $7Q_2$ less than 0.1 ft³/s criterion as one that can be estimated from existing flow records at established gaging stations. The 1-week duration of no flow criterion and the possible persistence of perennial pools in non-flowing streams were not used in this project. The definition specifies that the basis for classifying streamflow is the natural (unregulated) flow; therefore, this project was concerned with classifying stream segments as perennial or non-perennial based on estimates of unregulated $7Q_2$. This classification is of interest to the State of Idaho because permanence of flow has bearing on monitoring and methods of assessing water quality, application of water quality standards, and determination of appropriate use designations, and affects the extent of authority under the Clean Water Act to regulate water quality.

Purpose and Scope

This report describes the datasets and procedures used to create a geospatial dataset of perennial streams in Idaho. A by-product of the effort to model perennial streams is an integrated suite of geospatial datasets derived from 10-m resolution Digital Elevation Models (DEMs) and 1:24,000-scale NHD. These improved datasets also are described in this report, and will be incorporated into the Idaho StreamStats application in the future. (More information about StreamStats is available at <http://streamstats.usgs.gov/>.) This report provides links to Federal Geographic Data Committee (FGDC)-compliant metadata (Federal Geographic Data Committee, 1998) that describe these new geospatial datasets and to distribution information that describe how to obtain the datasets.

Some shortcomings of previous datasets of perennial streams in Idaho and qualitative improvements in the spatial patterns of modeled perennial streams are described. Quantitative analysis of these data improvements by comparison to field data is described by Wood and others (2008).

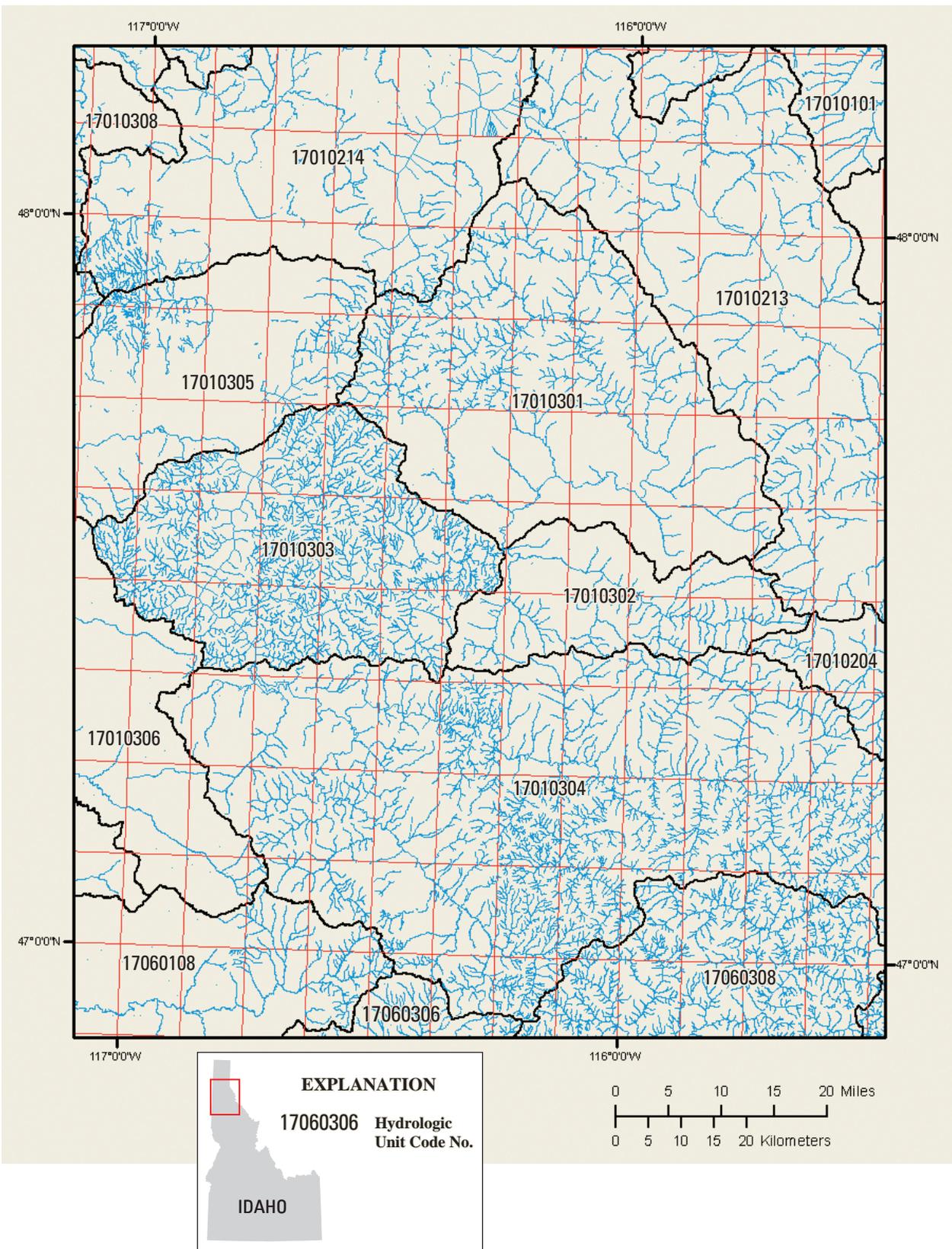


Figure 1. Spatial distribution of perennial streams (blue) and subbasins (black) from National Hydrography Dataset High-Resolution, and 7.5-minute quadrangle boundaries (red) in northern Idaho.

Methods

The methods used in this project consisted of the following steps:

1. Development of $7Q_2$ regression models,
2. Development of hydro-enforced DEMs,
3. Computation of continuous parameter grids,
4. Computation of continuous $7Q_2$ estimates, and
5. Transfer of regression model results to NHD

Each step is described in detail in the following sections.

Development of $7Q_2$ Regression Models

Regression models from Hortness (2006) were modified to enable extrapolation beyond the limits of available data from streamflow-gaging stations. The evaluation and comparisons of alternative regression models for $7Q_2$ is more completely described by Wood and others (2008). The final $7Q_2$ regression equations selected for modeling perennial streams in Idaho are shown in [table 1](#). The regression regions are shown on [figure 2](#). New regression models were selected for five of the eight regions; the original equations by Hortness (2006) were retained for regions 2, 4, and 6. These regression equations were applied to create continuous grids of $7Q_2$ estimates for the eight regression regions of Idaho. No equations are given for the undefined region in the Eastern Snake River Plain area, so no estimates of $7Q_2$ are possible, and no perennial streams are indicated in that area.

Table 1. Regression equations for the $7Q_2$ low-flow statistic for unregulated streams in regions 1–8 in Idaho.

[$7Q_2$ regression equation: A , drainage area, in square miles; P , mean annual precipitation, in inches; E , mean elevation, in feet. **Abbreviation:** $7Q_2$, 7-day, 2-year low flow]

Region	$7Q_2$ regression equation	Standard error of prediction	
		\log_{10}	Percent
1	$7Q_2 = 0.300A^{0.879}$	0.271	+86.7 to -46.4
¹ 2	$7Q_2 = 0.000153A^{1.04}P^{1.92}$	.253	+78.9 to -44.1
3	$7Q_2 = 0.0214A^{0.971}$	.277	+236 to -70.2
¹ 4	$7Q_2 = 0.0000215A^{1.04}P^{2.41}$	.341	+119 to -54.4
5	$7Q_2 = 0.334A^{0.963}$	.249	+77.3 to -43.6
¹ 6	$7Q_2 = 0.000133A^{1.05}P^{2.10}$	.243	+75.0 to -42.9
7	$7Q_2 = 0.0000115A^{0.837}(E/1000)^{4.658}$	.577	+277 to -73.5
8	$7Q_2 = 0.00181A^{0.981}P^{1.515}$	.331	+116 to -53.4

¹ Denotes original Hortness (2006) equation.

Development of Hydro-Enforced Digital Elevation Models

The datasets used in this project primarily were derived from the 10-m resolution DEMs produced by the USGS, and the 1:24,000-scale NHD Hi-Res. Previous experience with 30-m resolution DEM data processed with standard methods (see Elevation Derivatives for National Applications (EDNA) <http://edna.usgs.gov>) identified many shortcomings that we wished to avoid in the development of these datasets. Moore and others (2004) described a process used to produce a hydrologically conditioned DEM, referred to in this report as the “HydroDEM.” The HydroDEM process was further refined as part of this study, and subsequently was used to develop data for many USGS StreamStats web sites. The process also became the basis for the elevation-derived components of the NHDPlus. More information on the NHDPlus is available at <http://www.horizon-systems.com/nhdplus/>.

The source DEM was obtained from the 1/3-arc-second resolution National Elevation Dataset (NED) and was projected into the Idaho Transverse Mercator projection based on the North American Datum of 1983 (known as IDTM83) for each 8-digit Hydrologic Unit Code (HUC), (also known as “Subbasin”) in Idaho. A buffer area 100-m wide was included around each 8-digit HUC area.

The NHD vector streams were integrated into the raster NED data, using a process often referred to as “stream burning” (Saunders, 2000). These modifications were needed because the drainage path defined by the NED surface often does not closely match the 1:24,000-scale NHD streams. The stream locations in the NHD, coming from the topographic maps, ultimately were derived from aerial photo interpretation and field verification. The drainage path derived from the NED surface, however, is sensitive to blockages at culverts and dams, and under sampling of tight channels in the rasterization process. In addition, in areas of low relief the NED surface often does not retain enough detail to represent stream channels accurately. [Figure 3A](#) illustrates a common example of the differences in the horizontal positions of NHD streams and NED-derived streams. Where this offset distance is greater than one grid-cell width, some cells may not be identified as being upslope from the NHD stream segment; therefore, cells would be erroneously excluded from watersheds or catchments (the area draining to a particular stream reach) delineated using these data ([fig. 3B](#)). For these reasons, the stream-burning process was used to give the NHD streams preference over the NED-derived streams. [Figure 3C](#) shows that the stream-burning process corrects for DEM flow path displacement errors.

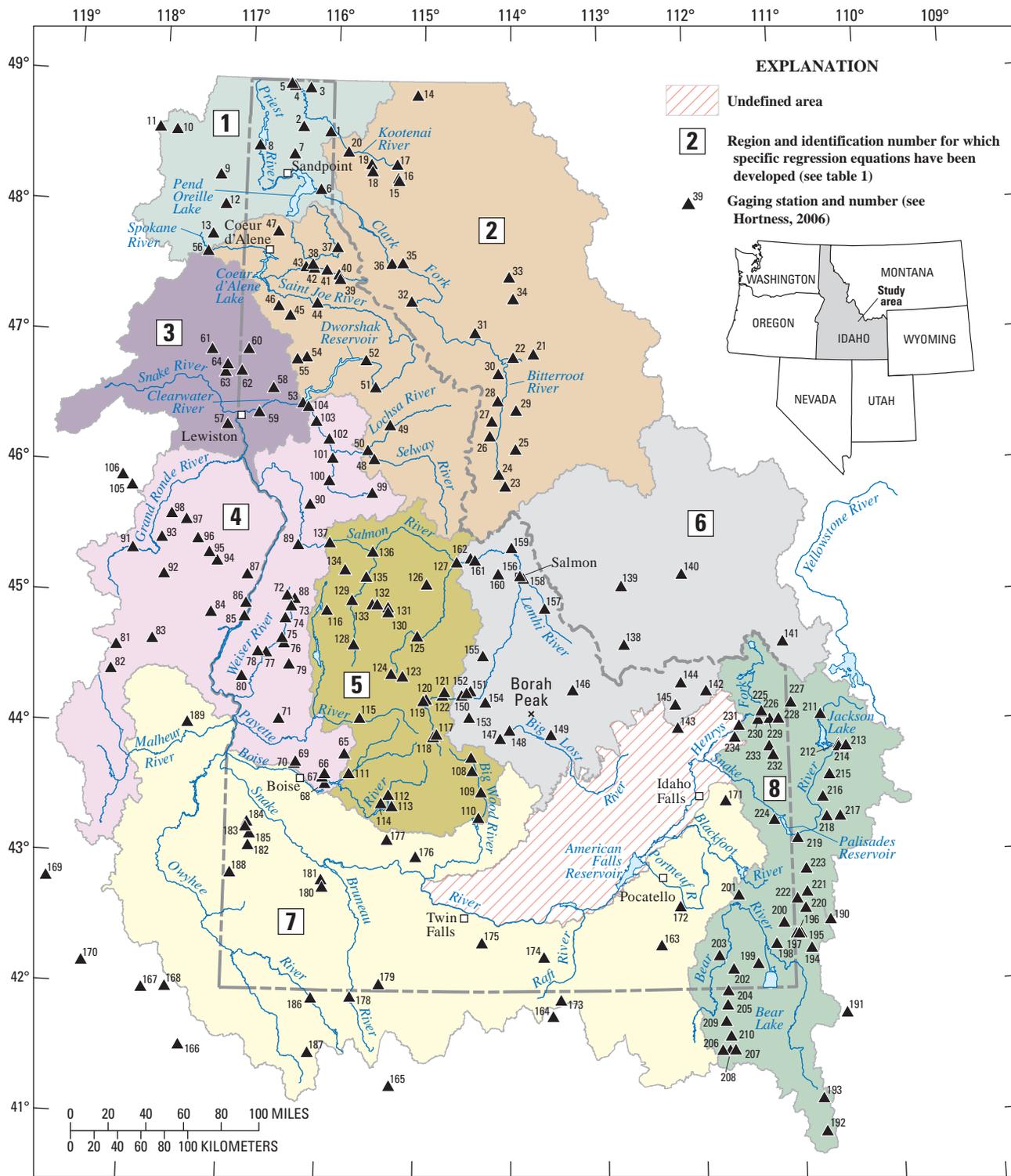


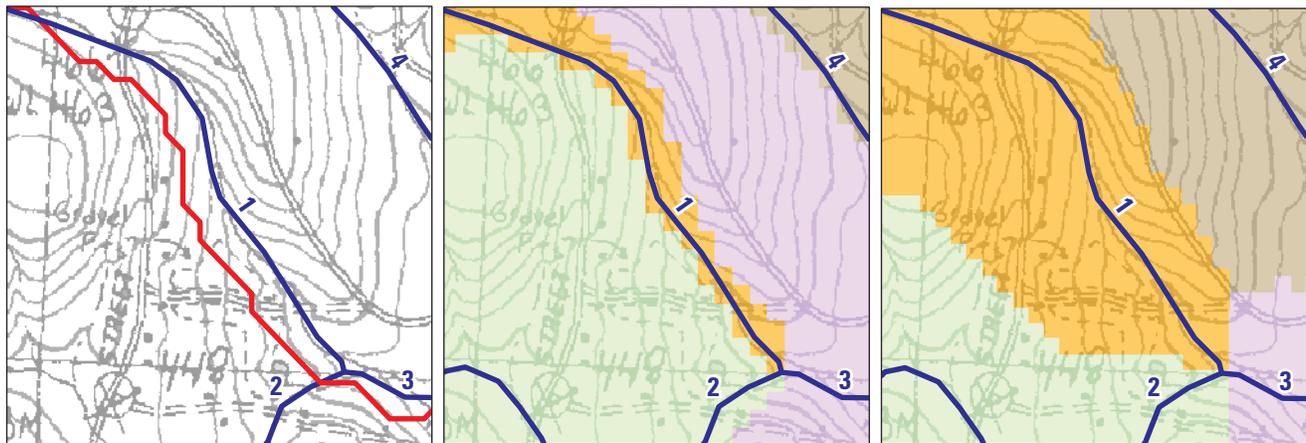
Figure 2. Location of study area, streamflow-gaging stations, and eight regions used to estimate low-flow frequency statistics for unregulated streams in Idaho (adapted from Hortness, 2006).

6 Estimated Perennial Streams of Idaho and Related Geospatial Datasets

A. Horizontal displacement between NHD flowline and NED-derived stream

B. NHD flowline catchments generated from NED-derived flow directions

C. NHD flowline catchments generated from HydroDEM



Base from U.S. Geological Survey Digital Raster Graphic, Stoddard, N.H., 1:25,000, 1984

EXPLANATION

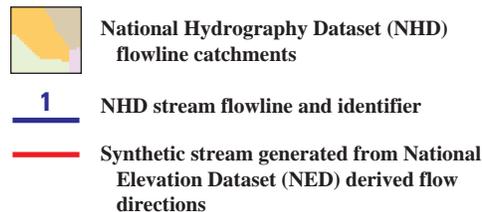


Figure 3. Stream locations determined by (A) differences in drainage between the NHD and flow paths of a NED-derived stream, (B) resultant NHD catchment delineations using unmodified NED digital elevation model (DEM) data, and (C) resultant NHD catchment delineations using the HydroDEM. (Modified from C.M. Johnston, U.S. Geological Survey, written commun., 2008.)

The stream-burning process uses computer algorithms in an Arc Macro Language (AML) program called AGREE, developed by Hellweger and Maidment (1997). [Figure 4](#) shows that AGREE “burns” a “canyon” into the NED-based DEM by subtracting a specified vertical distance from the elevation cells beneath the NHD vector streamlines. The vertical exaggeration of the canyon is controlled by specifying a “Sharp Drop Distance.” A negative “sharp” drop distance (-500 m) was used.

AGREE also “smooths” the elevation adjacent to NHD stream cell locations in the DEM within a buffer distance specified by the AGREE program user. Typically, the buffer distance used is related to a common horizontal displacement error between NHD and NED-derived streams; this distance is seldom exceeded. For this project, the buffer distance was set to 60 m on each side of the NHD flowline. The smoothing process changes the DEM grid-cell elevations within the buffer area to create a downward sloping gradient towards the canyon created beneath the NHD streams. The steepness of the

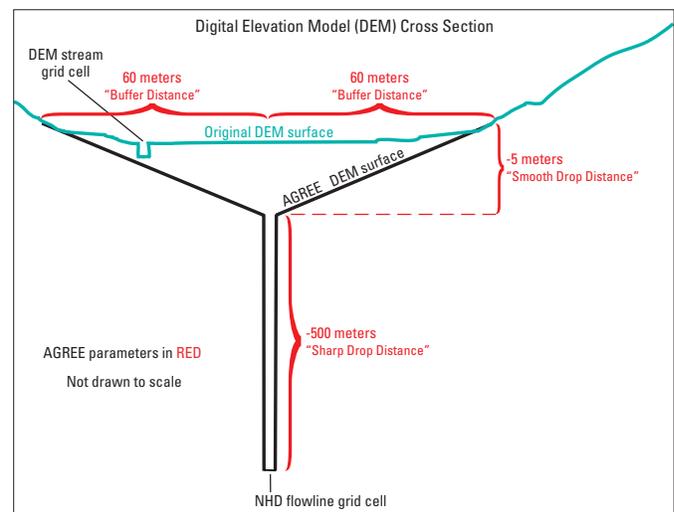


Figure 4. Schematic diagram of AGREE process in a Digital Elevation Model cross section.

slope within the buffer is controlled by the AGREE “Smooth Drop/Raise Distance” option. A smooth drop distance of -5 m was specified for this project. [Figure 4](#) illustrates how AGREE changes the original DEM surface using all the specified parameters of AGREE.

The use of AGREE’s 60 m smooth drop buffer distance of the NHD streams potentially may cause problems at headwater flowlines that begin at or near drainage divides in the DEM. The 60 m buffer distance at these headwater streams may extend across the DEM drainage divides and into the adjacent basin area, thereby including areas outside the true catchment area. Input datasets were inspected to ensure this situation did not exist in relation to the 8-digit HUC boundaries, and if it did, the NHD streams were trimmed back from the divides.

Because the DEM and derived gridded datasets are large, the data were divided into tiles based on the 8-digit Hydrologic Units, also known as “Subbasins,” of the National Watershed Boundary Dataset (WBD). A dataset of Subbasin boundaries was developed and digitized for this project. These boundaries became the first draft (June 2005) of the WBD Subbasin boundaries for Idaho. Further refinements to these boundaries have been made, but these refinements were not reflected in the datasets used for this project. Current status and updated draft WBD datasets for Idaho are available at <http://www.idwr.idaho.gov/watersheds/default.htm> (Idaho Department of Water Resources, 2008).

The Subbasin boundaries were used to generate simulated “walls” around each Subbasin, by raising the elevation of grid cells by 1,000 m in a 50-m buffer around each Subbasin. The NHD hydrography was edited to ensure it crossed this “wall” only at the designated outlet of the Subbasin. The grid was then processed so that the NHD cut a narrow slot through the “wall” at the outlet. This procedure ensured that no grid cell within the Subbasin would receive a flow direction that crossed the Subbasin boundary anywhere except at the outlet. In this manner, the NED DEM and derived datasets could be processed independently for each Subbasin.

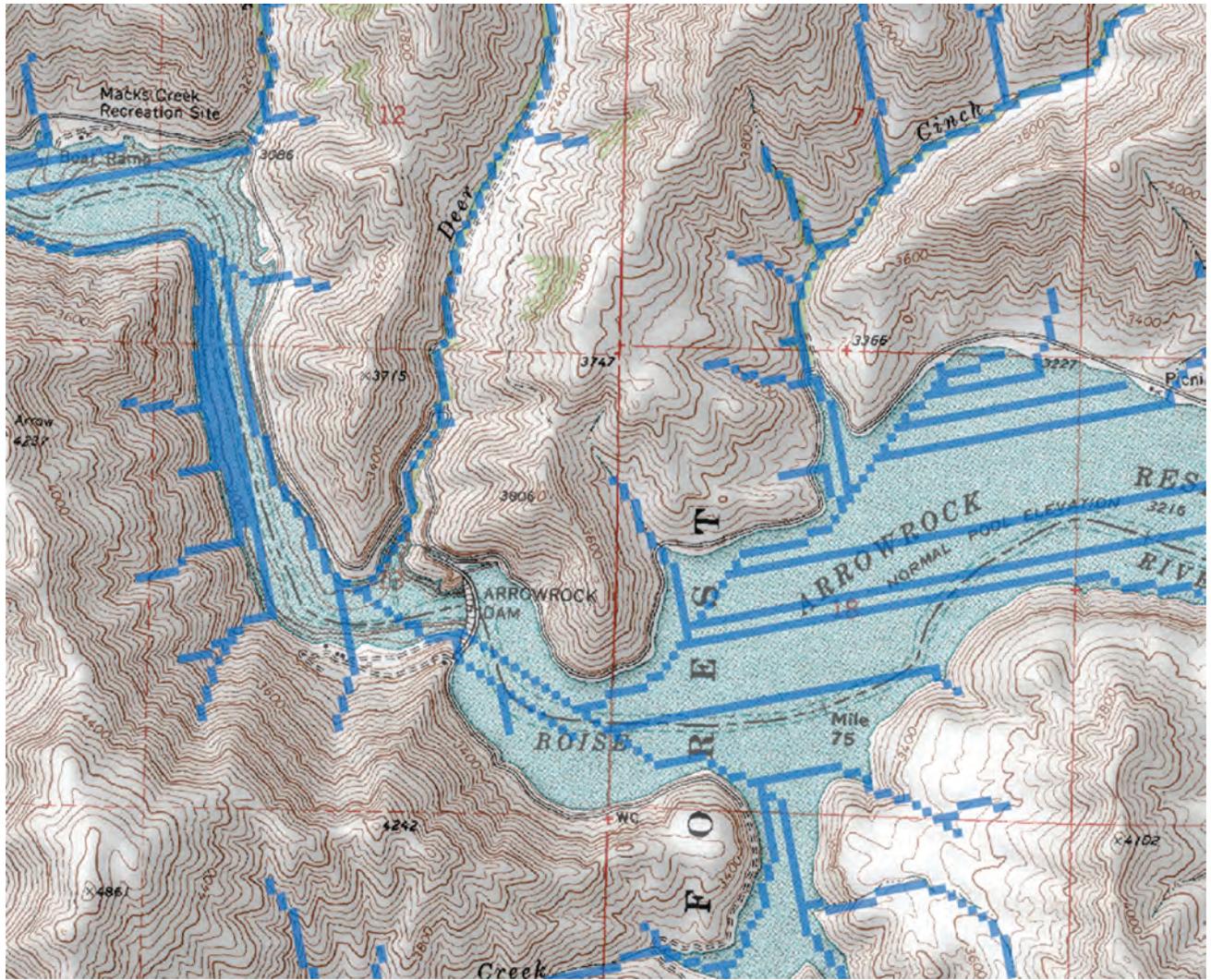
The process was further refined by imposing a “bathymetric gradient” within wide rivers and lakes or ponds. The bathymetric gradient ensured that the surface

sloped toward the artificial-path flowlines of the NHD, which generally follow the centerlines of these NHD water-body features. The gradient was applied prior to running AGREE. The bathymetric gradient process applied algorithms similar to those used in AGREE, to create a gently sloping gradient from water-body shorelines toward the artificial path flow lines. The result of this process was flow routed across these areas, which were perfectly flat in the original DEM, closely matched the pattern of the artificial-path flowlines. The resulting synthetic drainage pattern matched the NHD drainage network much more closely than the parallel synthetic drainage lines that often are produced from standard DEMs. This greatly improves the usability of the surface for watershed and catchment delineations. [Figures 5A](#) and [5B](#) show the improvement resulting from the bathymetric gradient process.

The last step in the process creates a “filled” DEM surface grid with the ARC/INFO GRID command “FILL,” which removes depressions. This step ensured all elevation cells in the basin had a defined drainage direction. A flow direction grid then was produced from the filled DEM surface. This flow-direction grid was the foundation for developing a flow-accumulation grid and other hydrologic derivatives, using the techniques described by Jenson and Domingue (1988).

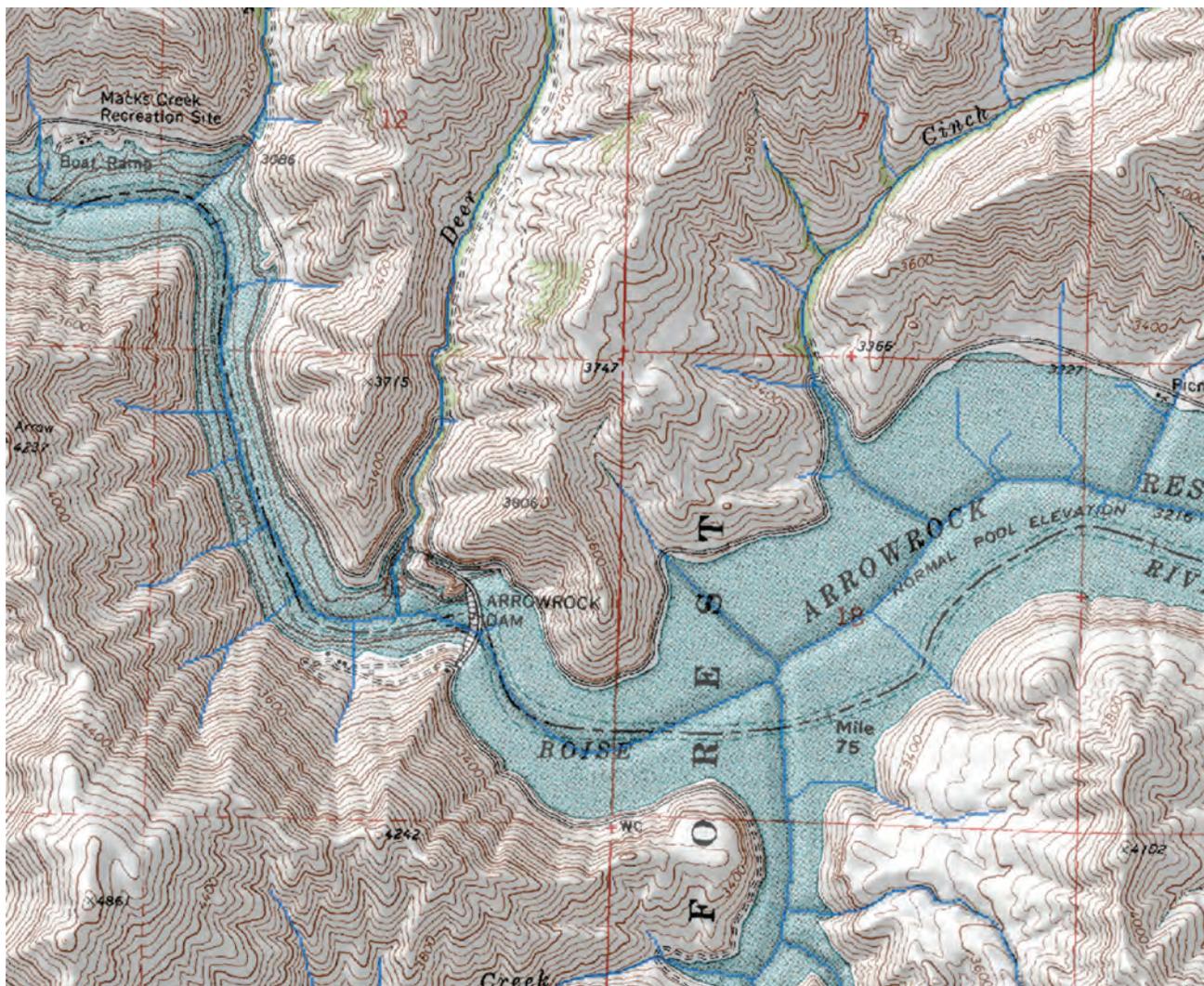
[Figures 5](#) through [7](#) illustrate some of the improvements made in the DEM hydrologic derivatives as a result of this project. [Figure 5](#) shows the area around the outlet of Arrowrock Reservoir. [Figure 5A](#) shows the shaded relief and synthetic drainage network (dark blue pixels) derived from 30-m NED DEMs, using the standard processes described by Jenson and Domingue (1988). Known as EDNA, these data have been the basis for the Idaho StreamStats web application since its development. [Figure 5B](#) shows the shaded relief and improved synthetic drainage network derived from the 10-m HydroDEM specially processed for this project. [Figures 6A](#) and [6B](#) show similar images for an area in which the surface has been modified by placer mining.

[Figures 7A](#) and [7B](#) show similar images for a relatively flat, valley location. Similar improvements are available in the datasets statewide.



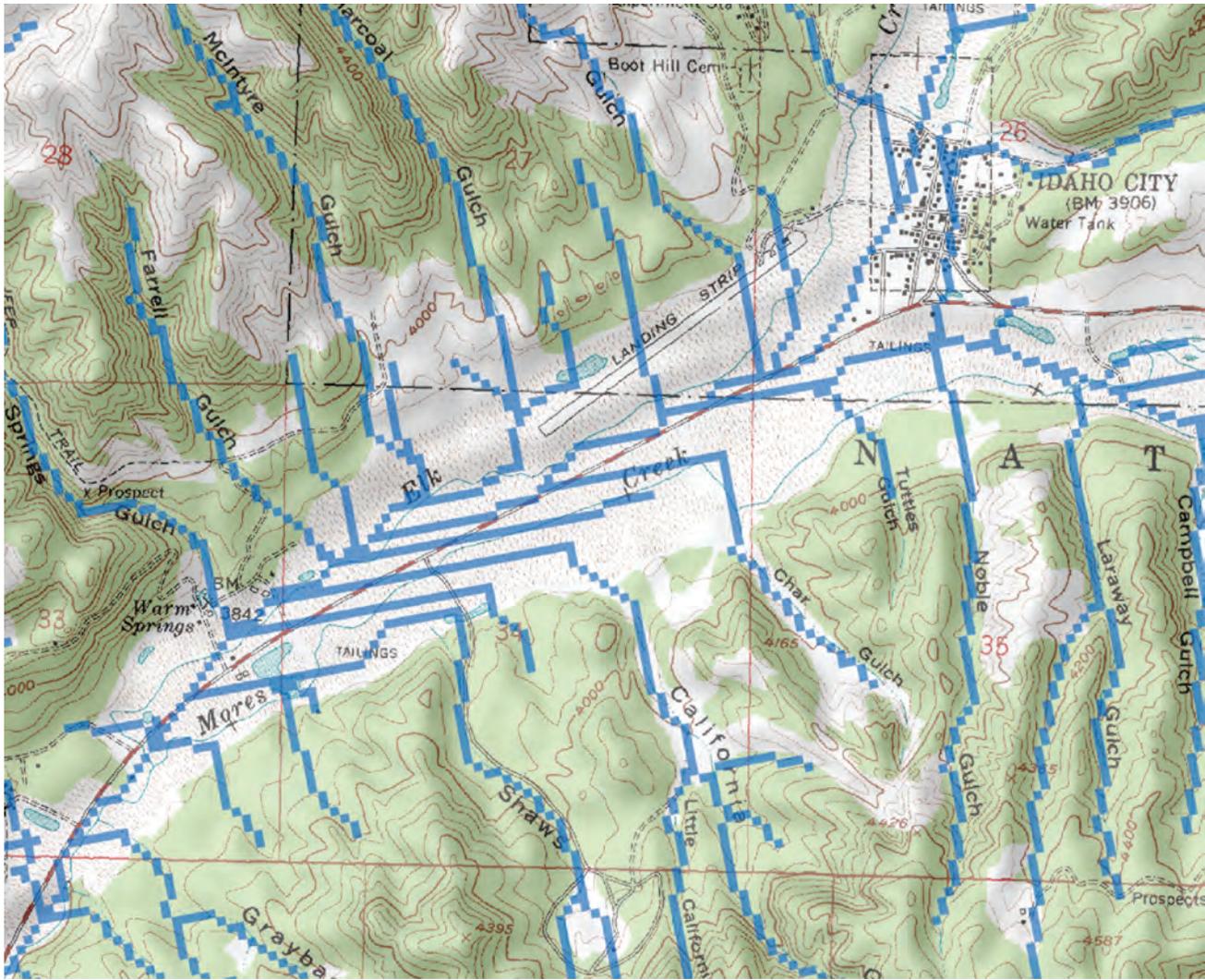
A. EDNA

Figure 5. Screen captures showing (A) shaded-relief view of Elevation Derivatives for National Applications (EDNA) data near Arrowrock Dam, and (B) shaded-relief view of modified HydroDEM with burning of NHD streams near Arrowrock Dam, in Idaho.



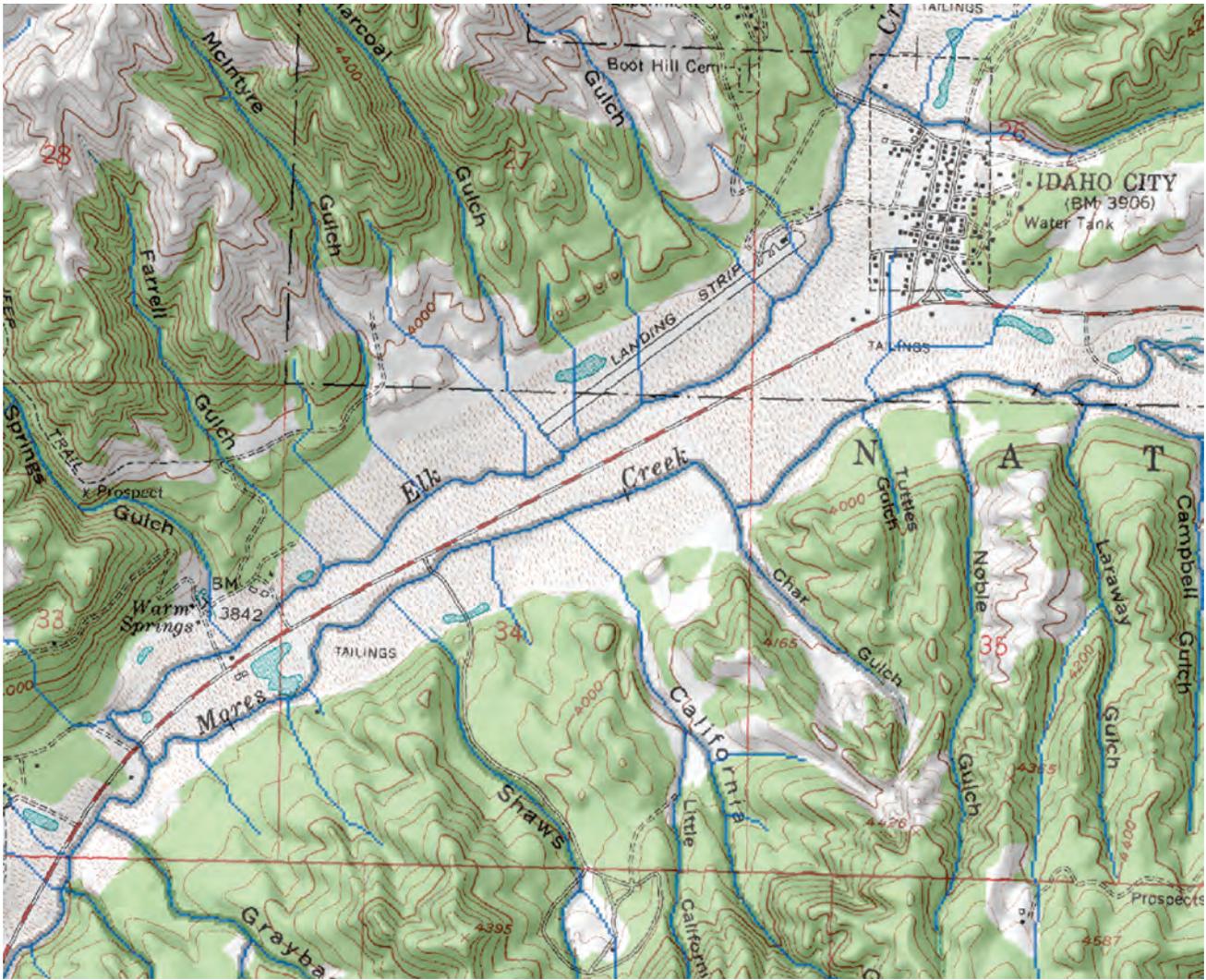
B. HydroDEM

Figure 5.—Continued.



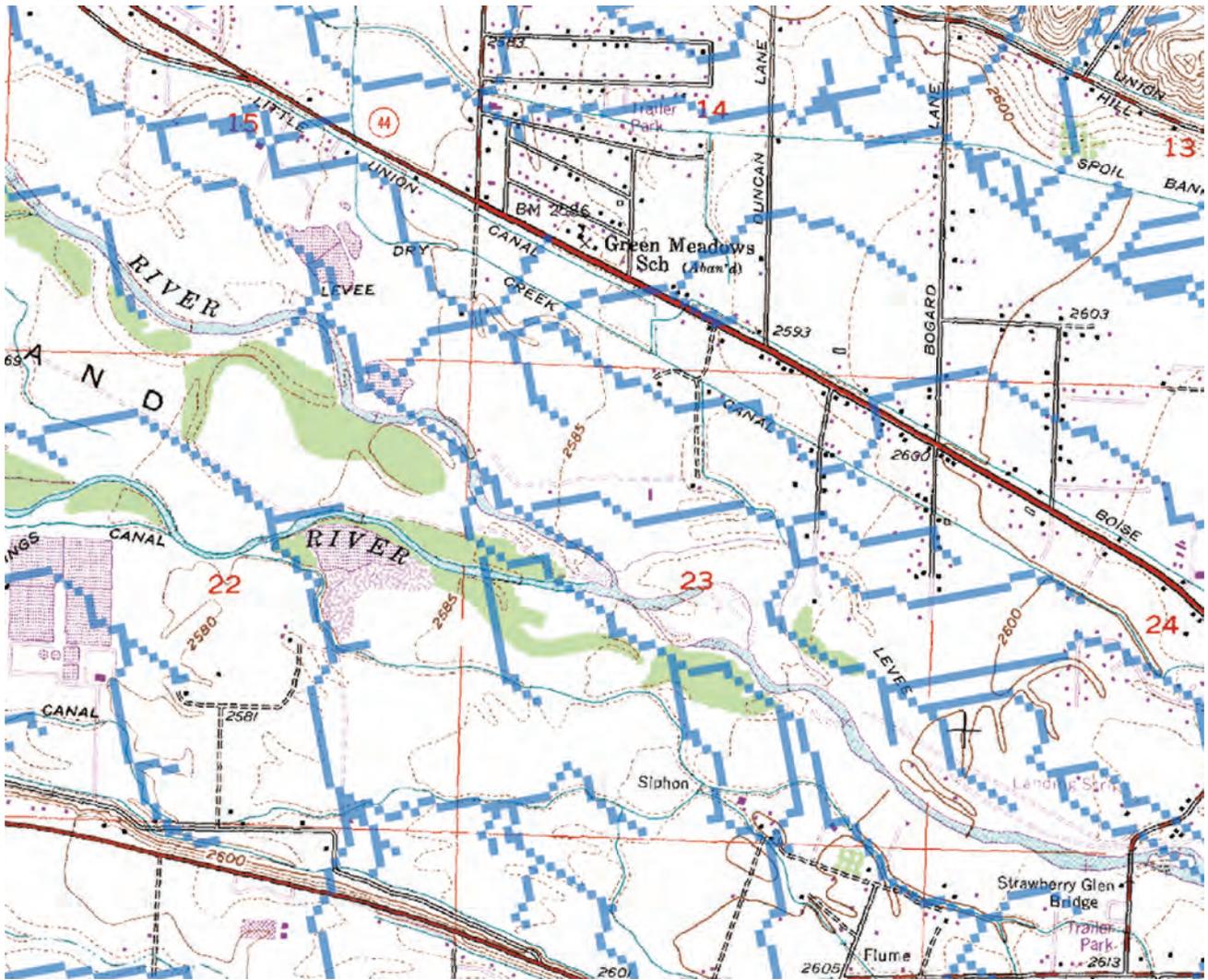
A. EDNA

Figure 6. Screen captures showing (A) shaded-relief view of Elevation Derivatives for National Applications (EDNA) data in an area of placer mining, and (B) shaded-relief view of modified HydroDEM with burning of NHD streams in an area of placer mining in Idaho.



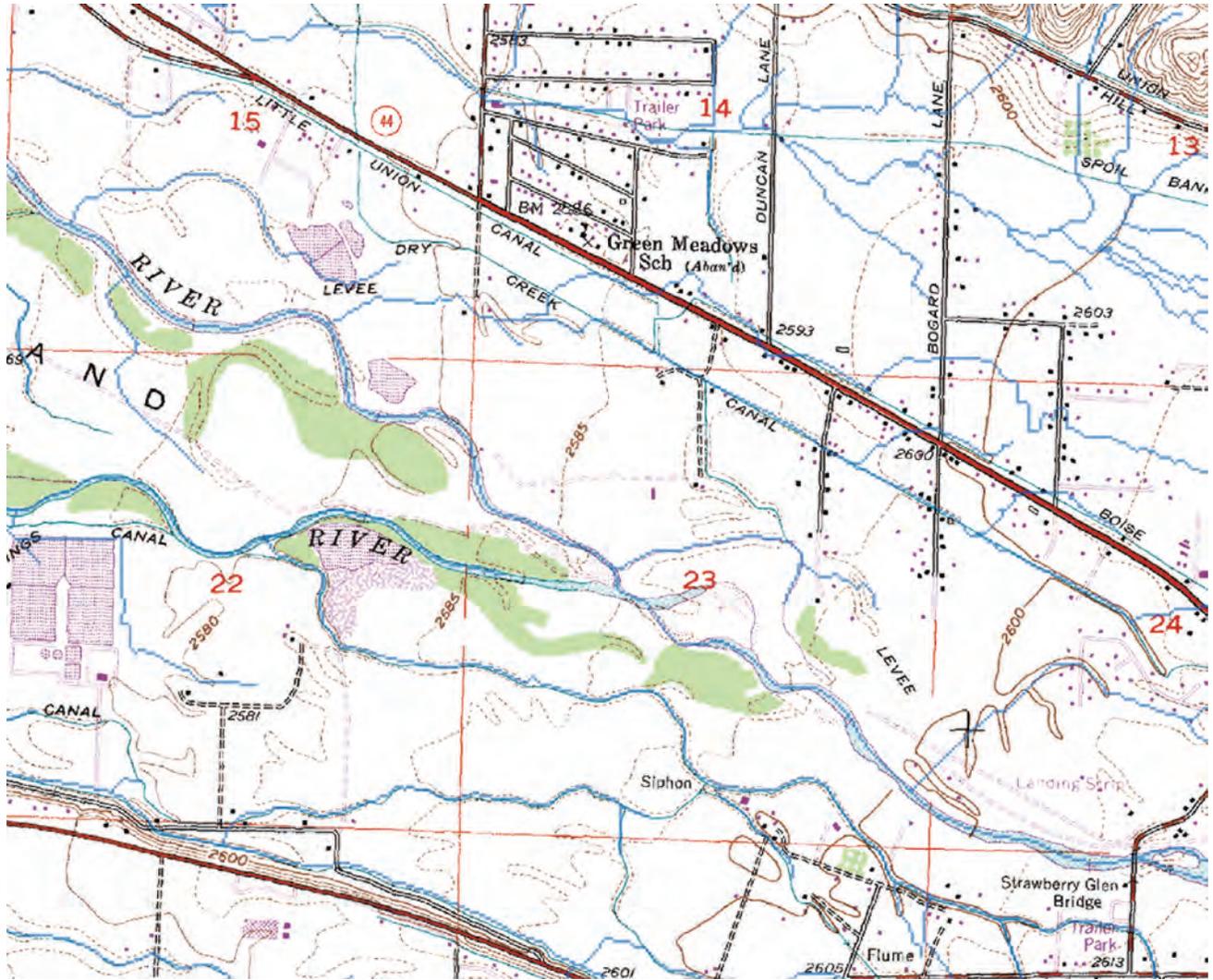
B. HydroDEM

Figure 6.—Continued.



A. EDNA

Figure 7. Screen captures showing (A) view of Elevation Derivatives for National Applications (EDNA) data in a relatively flat, valley location, and (B) view of modified HydroDEM with burning of NHD streams in a relatively flat, valley location in Idaho.



B. HydroDEM

Figure 7.—Continued.

Computation of Continuous Parameter Grids

Verdin and Worstell (2008) describe a method using a weighted flow accumulation function to compute continuous parameter grids. In this discussion, a grid where each cell contains the value of some parameter, measured for the entire drainage area upstream of that cell is referred to as a continuous parameter grid. The flow-accumulation grid described by Jenson and Domingue (1988) is the most basic continuous parameter grid. Each cell in a flow-accumulation grid contains the number of cells upstream of that cell. The upstream drainage area may be determined by multiplying the number of cells by the area of a cell. This area should be adjusted by adding the area of the cell of interest, because the flow accumulation grid does not include this cell.

The ARC/INFO GRID flow accumulation function (Environmental Systems Research Institute, Inc., 1999) allows the use of an optional “weight” grid. When using a weight grid, the flow accumulation function sums values from the weight grid for each cell as it accumulates values downstream. Using a precipitation grid for a weight grid, for example, the weighted flow accumulation function sums the precipitation depths from all upstream cells, producing a grid that represents—after appropriate unit conversions—the total volume of precipitation in the watershed upstream of each cell. In contrast, if no weight grid is given, the flow accumulation function simply totals the *number* of upstream cells, a process called “unweighted flow accumulation” in this report. The weighted flow accumulation value, divided by the unweighted flow accumulation value, gives the average of the weight grid upstream of any grid cell. Adjusting to include the cell of interest, the formula given in equation 1 may be used to compute the mean value of a weight grid for the watershed above and including the cell.

$$P_i = (facWp_i + p_i) / (fac_i + 1) \quad (1)$$

where

- P_i is the average value of parameter P in the watershed of cell i .
- $facWp_i$ is the weighted flow accumulation at cell i ,
- p_i is the value of the parameter grid P at cell i ,
and
- fac_i is the value of the unweighted flow accumulation at cell i .

Equation 1 may be used with continuous-value parameters, such as elevation or precipitation, which may be expressed as a grid of real values. Equation 1 also may be used with single-value categorical grids. For example, using a grid containing 1 for every cell categorized as forested in a land-cover dataset, and 0 for every other cell, equation 1 may be used to compute the fraction of the watershed area for grid cell i that is forested.

The basic assumption of equation 1 is that the quantity of interest may be determined by an area-weighted average of the upstream cell values in the weight grid. Therefore, equation 1 may not be used with maximum, minimum, or range type parameters, or parameters that depend on the geometric shape of the entire watershed or stream channel.

Computation of Continuous $7Q_2$ Estimates

Equation 1 gives us the ability to compute most, though not necessarily all, basin characteristics on a continuous basis, for every grid cell. If all parameters of a regression equation can be computed in this manner, then the result of the regression equation also may be computed continuously, for every grid cell. In this manner, equations described by Wood and others (2008) may be used to compute estimates of the $7Q_2$ for every 10 by 10 m grid cell in Idaho. By comparing these estimates to the criterion of 0.1 ft³/s to determine perennial flows, a map of perennial streams may be developed.

The $7Q_2$ low-flow values were calculated for each grid cell of the eight regions using the corresponding regression equation listed in [table 1](#). Vector stream lines then were created from the $7Q_2$ grids using cells with a $7Q_2$ value of 0.1 ft³/s or greater to represent perennial streams. Because these representations of perennial streams are derived from the gridded elevation model, they are referred to in this report as “synthetic streams.” Because no equations are given for the undefined region in the Eastern Snake River Plain area, no estimates of $7Q_2$ are possible, and no perennial streams are modeled in that area.

The continuous parameter grid computations use the flow accumulation locally within each HUC. For HUC’s downstream of other HUC’s, the parameter estimates and, therefore, the flow estimates, for main-stem streams do not take into account the flows entering from upstream HUC’s. For this project, the assumption was made that any streams downstream of one or more entire 8-digit HUCs are perennial; these stream segments were given PerCode attribute values of 3.

To provide an approximation of the level of uncertainty of the regression equations, synthetic stream lines were created from the $7Q_2$ grids using the $0.1 \text{ ft}^3/\text{s}$ criterion plus and minus the standard error of prediction range. This range of $7Q_2$ values provides a spatial context to the level of uncertainty in the regression equations and may approximate the transitional reach in which a stream transitions from intermittent to perennial. The transitional reach represents the part of the stream that, given annual climate fluctuations and inherent statistical uncertainty, is assumed to contain the point where a stream changes from perennial to intermittent. In other words, flow in reaches upstream of the top of the transitional reach is considered intermittent, and flow in reaches downstream of the bottom of the transitional reach is considered perennial. Within the transition zone, flow could be perennial or intermittent. However, few data points are available to verify the regression models in this low-flow regime, and extrapolation of the regression models was necessary. More data are needed in the low-flow regime to verify the statistical confidence of these estimates. The synthetic stream line dataset contains lines coded in the PerCode attribute field, with value “1” for the error range less than $0.1 \text{ ft}^3/\text{s}$, “2” for the error range greater than $0.1 \text{ ft}^3/\text{s}$ (these two error ranges together represent the transitional reach), and “3” for $7Q_2$ values greater than the error ranges. Additional statistical analysis of the perennial streams model is available in Wood and others (2008).

Figure 8 shows the synthetic stream line dataset for lines having $7Q_2$ values greater than $0.1 \text{ ft}^3/\text{s}$ for the area shown in figure 1. The model has corrected many of the most obvious drainage-density problems in the NHD version; however, in some areas the model appears to overestimate perennial streams.

Transfer of Regression Model Results to National Hydrography Dataset

Although the synthetic streams derived from the regression models provide a consistent, connected representation of the stream network, many users need the

results referenced to the NHD, the commonly recognized hydrography framework. An initial attempt to reference the synthetic streams linearly to the NHD by matching synthetic streams to NHD flowlines resulted in a large number of errors. These errors mostly were due to minor deviations between the synthetic streams and the NHD flowlines, and caused numerous breaks in the connectivity of the resulting network. To provide a better matchup, an alternative procedure was used to snap transition points to the NHD network, and then to trace downstream of these points, selecting all the downstream NHD flowline features. A detailed description of the following general procedure is available in the metadata for the “ds412_PerennialStreamsEvents” dataset.

Points were generated on the synthetic streams wherever the flow category changed (for example, from PerCode 1 to 2 or 3). In effect, this identified all stream segments with estimated $7Q_2$ flows of $0.1 \text{ ft}^3/\text{s}$ or greater. These points were snapped to the nearest 1:100,000-scale NHDPlus flowlines, using a snapping tolerance of 100 m. Points were not snapped if they were farther than 100 m from any NHDPlus flowline. This resulted in some segments of synthetic streams modeled as perennial not being transferred onto the NHD. The snapped points were inserted as junctions into a geometric network, splitting the flowline features. The ArcMap geometric network “Trace Downstream” task in ArcMap 9.2 (Environmental Systems Research Institute, Inc., 2006) was used to trace downstream of 53,219 points, and to select the traced flowline features. These selected features then were converted to a “linear event table” (ds412_PerennialStreamsEvents.dbf).

Extensive checking or editing of the resulting dataset was beyond the scope of this project. Features estimated to be perennial streams in the synthetic streams dataset may have no corresponding feature in the 1:100,000-scale NHDPlus flowline feature class, often, due to scale generalization in the NHD. No attempt was made to address these discrepancies. The synthetic streams dataset (ds412_SyntheticPerennialStreams.shp) represents a more complete representation of the model simulation results; however, it does not provide any direct linkage to the NHD.

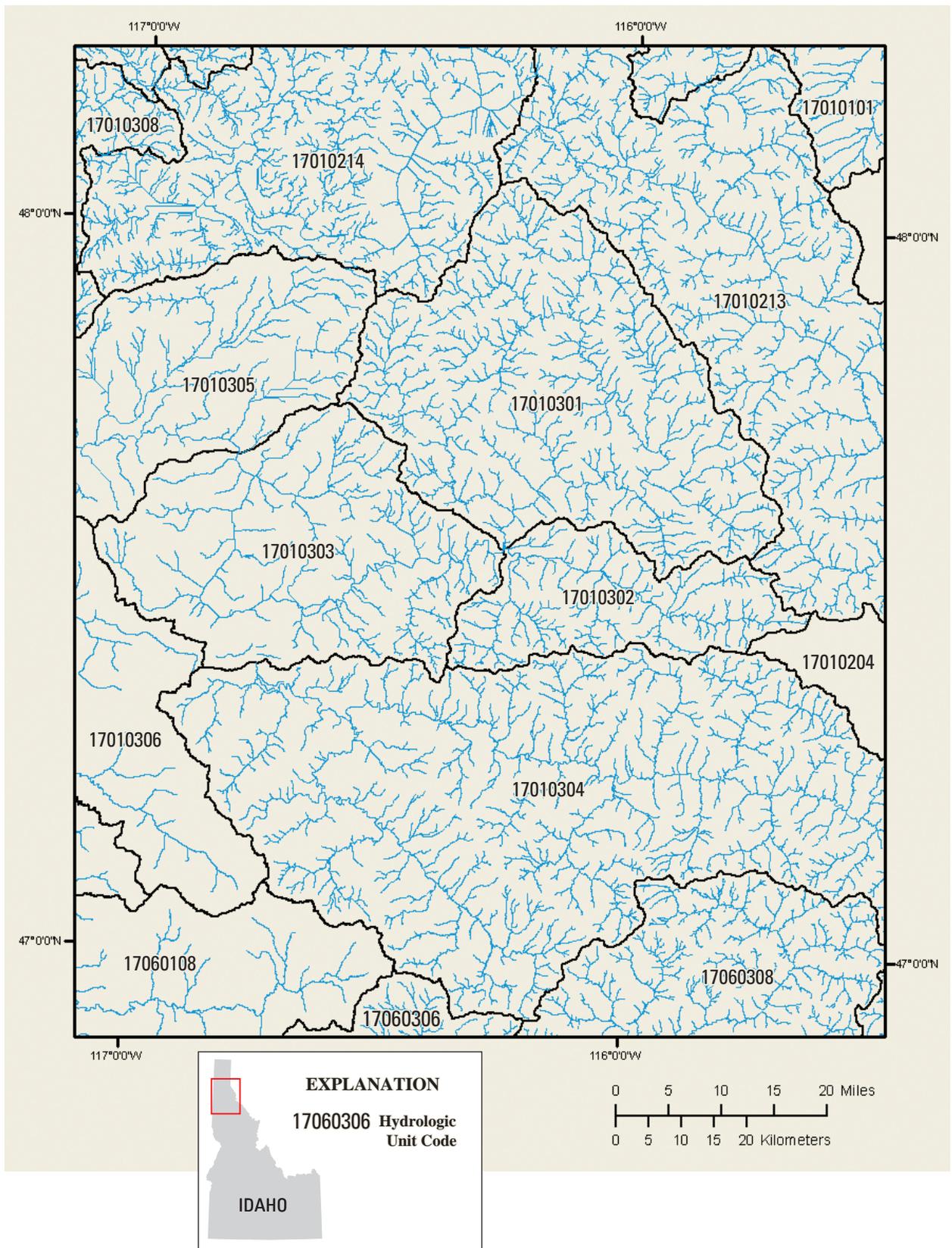


Figure 8. Spatial distribution of modeled perennial streams (blue) and subbasins (black) in northern Idaho. (See [figure 1](#) for comparison.)

Description of Geospatial Dataset Products

A suite of geospatial datasets have been compiled for estimating streamflow statistics in Idaho, to support statistical modeling of perennial streams and to support the Idaho StreamStats web application. Since the initial prototype application was developed in 2003, Idaho StreamStats has been based on 30-m resolution EDNA data. The new datasets developed for modeling perennial streams are well suited to providing an improved foundation of datasets for Idaho StreamStats, and will be used on the web site in the near future. Links are provided for metadata for the datasets. The metadata includes distribution information on obtaining these datasets for use outside the Idaho StreamStats web application.

Data-File Versioning System

In a collection as large as these geospatial datasets, errors may be detected and the data may need to be updated. Therefore, the data are distributed using a versioning system. Each download .ZIP file contains the version information in the filename in the form of “Vnn,” where “nn” is the data version number. In this manner, each data component may be versioned and distributed independently. The data is distributed in .ZIP files, one per 8-digit HUC, plus one .ZIP file for the ArcHydro Global dataset, one for the statewide layers, and separate files for the synthetic perennial streams shapefile and for the perennial streams event table. For example, the file “IDSS_17060201_V01.zip” would contain the entire folder for HUC 17060201. A file named “IDSS_17060201_V02.zip” would indicate that data have been updated, and that version 02 data should be used. If a change to one dataset results in the need to change others (adjacent datasets, for example,) all affected datasets will be updated, and the data distribution site will be maintained so it includes a complete set of compatible dataset versions.

Each .ZIP file includes a text file that indicates the version of the accompanying data component. For example, the “IDSS_17060201_V02.zip” file would contain a file named “IDSS_17060201_V02.txt,” which will extract into the archydro\17060201 folder. The name of this file will indicate the version of the data in the folder. The file itself contains an explanation of the versioning system, and a summary of edits made since the first version of the dataset was released.

When the .ZIP files are uncompressed, each file should be extracted to the same location. This ensures that all data files and version files are extracted to the appropriate locations relative to each other. If a new version of a data component is available, the previous component should first be deleted in its entirety before the new version is extracted. The examples in [table 2](#) show how to remove each type of data component. In the examples, all original data components are assumed to have been extracted to the D:\id_ss\ folder.

Table 2. Example instructions for deleting data components from geospatial datasets.

[HUC#, 8-digit Hydrologic Unit Code; D:\id_ss], disk location where ZIP file archives were extracted]

Component	Delete
ArcHydroGlobal	D:\id_ss\archydro\global.mdb
StatewideLayers	D:\id_ss\statewide\ (delete entire folder)
Huc#	D:\id_ss\archydro\Huc# (delete entire folder)

Digital Elevation Model and Derivatives Used by ArcHydro Tools

Idaho StreamStats uses the ArcHydro Tools, developed by ESRI and enhanced under contract by ESRI for StreamStats. The ArcHydro Tools are available as a free download at <http://support.esri.com/index.cfm?fa=downloads.dataModels.filteredGateway&dmid=15> (Environmental Systems Research Institute, Inc., 2007). The tools include documentation and a tutorial.

The Idaho ArcHydro datasets are organized and tiled by 8-digit HUC. These units also are known as subbasins in the WBD nomenclature. Some 8-digit HUC boundaries have changed since these datasets were developed, so these datasets should not be used as a substitute for WBD. The data structure within each HUC tile is identical, and consists of an ESRI personal geodatabase named for the HUC and several ESRI Grid-format datasets. The dataset structure for each HUC is listed in [table 3](#).

A “global” database also is available for Idaho in the file “global.mdb.” This database contains the information needed to link the HUCs together to delineate watersheds that span more than one HUC. Selected data elements of the ArcHydro global geodatabase are shown in [table 4](#).

To use these data with the ArcHydro Tools, users need to download the ds412_ArcHydroGlobal.zip and ds412_StatewideLayers.zip files, plus any 8-digit HUC datasets that overlap their area of interest. The 8-digit HUC datasets needed may be determined by overlaying the user’s area of interest with the “hucpoly” polygon feature class in the global geodatabase contained in the ds412_ArcHydroGlobal.zip file. A new folder should be created and all .ZIP files should be extracted into this folder. This procedure will ensure that the datasets are in their proper locations relative to one another.

Create a fresh ArcMap document (identified by the “.MXD” file extension) by starting ArcMap, loading the “Layers” feature dataset (including all component feature classes) from the global.mdb file, and saving the document with a new file name. The ArcHydro Tools use configuration information stored in Extensible Markup Language (XML) to define basin characteristics and other configuration options.

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Table 3. ArcHydro datasets tiled by 8-digit Hydrologic Unit Code.

[**Abbreviations:** NED, National Elevation Dataset; IDTM83, Idaho Transverse Mercator projection based on North American Datum of 1983; m, meter; DEM, Digital Elevation Model]

Dataset name	Description
Basic grids used by ArcHydro Tools	
<i>cat</i>	Catchment grid.
<i>dem</i>	Digital elevation model, from NED, projected to IDTM83 projection, 10-m resolution, elevations in centimeters.
<i>fac</i>	Flow accumulation grid.
<i>fac_global</i>	Global flow accumulation grid (includes upstream HUCs). Present only for HUCs downstream of others.
<i>fdr</i>	Flow direction grid.
<i>lnk</i>	Link grid.
<i>str</i>	Stream grid used to define catchments.
<i>str900</i>	Dense stream grid used for display and to guide delineation, 900-cell threshold.
Geodatabase feature classes used by ArcHydro Tools	
<i>Catchment</i>	Polygon version of <i>cat</i> grid.
<i>AdjointCatchment</i>	Polygons representing aggregated catchments upstream of each non-headwater catchment.
<i>DrainageLine</i>	ArcHydro drainage line feature class.
<i>DrainagePoint</i>	ArcHydro drainage point feature class.
<i>LongestFlowPathCat</i>	Longest flowpath in each catchment, computed by ArcHydro.
<i>LongestFlowPathAdjCat</i>	Longest flowpath in each adjoint catchment, computed by ArcHydro.
Basin characteristic grids	
<i>bsldem10m</i>	Basin slope based on a 10-m DEM.
<i>nfs130</i>	Grid of cells with north-facing slopes greater than or equal to 30 percent.
<i>slop30</i>	Grid of cells with slopes greater than or equal to 30 percent.
Continuous parameter grids of basin characteristics	
<i>bsld10_cpg</i>	Average upstream basin slope based on a 10-m DEM for every cell.
<i>elev_cpg</i>	Average upstream basin elevation in feet for every cell.
<i>forest_cpg</i>	Average upstream percent forested area for every cell.
<i>nfs130_cpg</i>	Average upstream percentage of cells with north-facing slopes greater than or equal to 30 percent for every cell.
<i>precip_cpg</i>	Average upstream basin precipitation in 10ths of 1 inch for every cell.
<i>slop30_cpg</i>	Average upstream basin percentage of cells with slopes greater than or equal to 30 percent for every cell.

XML code for the Idaho StreamStats configuration has been incorporated into versions of the ArcHydro Tools released after February 1, 2009. The ArcHydro Tools Configure Function Parameters tool may be used to load the configuration for StreamStats, using the configuration named "Idaho_10m." This will load the XML configuration designed to work with these data. The Local Point Delineation or Global

Point Delineation tools from the ArcHydro Tools may be used to delineate watersheds. The Compute Local Parameters or Compute Global Parameters menu options then may be used to compute watershed characteristics. For further explanation of the functions of the above datasets, and for instructions on using the tools, see the ArcHydro Tools documentation, available on the ArcHydro Tools download site.

Table 4. Selected data elements stored in the ArcHydro global geodatabase for Idaho.

[Abbreviations: DEM, Digital Elevation Model; HUC, Hydrologic Unit Code]

Data element name	Description
<i>hucpoly</i>	DEM-derived “synthetic” HUC polygon feature class. These polygons constitute an index to the data tiles. (Note: Recent changes to the 8-digit HUC boundaries are not reflected. This dataset is not a substitute for WBD.)
<i>Streams3D</i>	Three-dimensional streams network that ties together the hucpoly polygons.
<i>HUCLongestFlowPath</i>	Longest flow path within a hucpoly polygon.
<i>Point3D</i>	Points on the Streams3D network that become junctions in the HUC_Net geometric network.
<i>HUC_Net</i>	Geometric network composed of Point3D and Streams3D, which ties together the hucpoly polygons.
<i>HUCHasJunction</i>	Relationship class that establishes a link between hucpoly and Point3d via the JunctionID field.
<i>HUCPeakFlowRegions</i>	Table listing the drainage areas in each region by hucpoly polygon.

Statewide Datasets

A separate folder named “statewide” is created by extracting the DS412_StatewideLayers.zip file, and contains a personal geodatabase containing exclusion polygons, grids of the regression regions, and two grids used to compute basin characteristics. The peak flows regression regions grid is named “id_pkreg.” The regions grid for low flows, mean-annual, and monthly flow statistics is named “id_lowreg.” These grids are more detailed versions of the region maps in Hortness and Berenbrock (2001), Berenbrock (2002), Hortness and Berenbrock (2003), Hortness (2006), and Wood and others (2008). The grids named “forestg” and “precip_combo” may be used to compute percentage of forested area and mean annual precipitation, respectively, for watershed datasets edited by the user after the automated delineation process. (Continuous parameter grids in each HUC folder are available for unedited watershed datasets.)

The exclusion polygons in the ExcludePolys.mdb geodatabase are areas for which delineation is restricted in StreamStats, or for which additional information is provided. These exclusions consist of areas where software limits are exceeded and watershed delineation is not possible, and areas downstream of Canada, where no data were included, and the

delineations are not valid. Also included are the Eastern Snake River Plain, an area for which no regression equations were developed, and a polygon covering the area outside a 1-km buffer of the state of Idaho, in which flow estimates may be computed, but are considered not valid.

Modeled Perennial Streams of Idaho

Estimated perennial streams developed as described above are provided in ESRI shapefile format in two separate datasets. The dataset named “DS412_SyntheticPerennialStreams.shp” contains the synthetic streams in ESRI shapefile format. The dataset named “DS412_PerennialStreamsEvents.dbf” contains linear event data indexed to the NHDPlus Version 01_02 (schema version 1, data version 2), in dBase format. See the NHDPlus User Guide (Horizon Systems Corporation, 2008) for more information about NHDPlus versions. The DS412_PerennialStreamsEvents.dbf file is known as an “event table.” The data in an event table are referenced to a route system to give them spatial context. The records in DS412_PerennialStreamsEvents.dbf should be used in conjunction with the flowline route system in the NHDPlus Version 01_02.

Geospatial Data Files Available for Download

Digital geospatial datasets are available for download as part of this report by following hyperlinks. The hyperlinks point to FGDC-compliant metadata for the datasets. Links in the Distribution_Information section of the metadata provide access to the download files.

DEM and Derivatives Used by ArcHydro Tools

http://water.usgs.gov/lookup/getspatial?ds412_archydrohucs

http://water.usgs.gov/lookup/getspatial?ds412_archydroglobal

Statewide Datasets

http://water.usgs.gov/lookup/getspatial?ds412_statewidelayers

Modeled Perennial Streams of Idaho

http://water.usgs.gov/lookup/getspatial?ds412_syntheticperennialstreams

http://water.usgs.gov/lookup/getspatial?ds412_perennialstreamsevents

Summary and Conclusions

Regionalized linear regression models for estimating the 7-day, 2-year low flow ($7Q_2$) statistic with a 0.1 ft³/s cutoff criterion may be used to estimate perennial streams in Idaho. Regression equations were applied to create continuous grids of $7Q_2$ estimates for eight regression regions of Idaho. By applying the 0.1 ft³/s criterion, the perennial streams have been estimated in each low-flow region. To measure estimate uncertainty, a “transitional” zone was identified that corresponded to flow estimates of 0.1 ft³/s plus and minus one standard error. Although the regression models provide overall estimates based on the general trends within each regression region, additional estimate uncertainty exists. Local factors such as a large spring or a losing reach are not included in these regression models, and these factors may greatly affect flows at any given point. Site-specific flow data with a sufficient period of record generally would better represent flow conditions at a given site than flow estimates based on regionalized regression models. The geospatial dataset of perennial streams of Idaho is considered a first-cut estimate, and should not be construed to override site-specific flow data. The modeled perennial streams are provided in this report in two different forms: a shapefile of estimated synthetic perennial streams, and an event table that may be used with the flowline route system in the NHDPlus Version 01_02. Additional datasets designed to work with the ArcHydro Tools also are included. These datasets may be used to delineate watersheds, compute basin characteristics, and compute streamflow estimates throughout the state of Idaho. These datasets will be used by the Idaho StreamStats web application in the future, and represent a significant improvement over the data currently being used for Idaho StreamStats.

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Appendix A. HydroDEM Program Source Code

The following Arc Macro Language (AML) program was run to batch-process all the HUCs for this project. The program originally consisted of three separate programs, which were combined after initial processing and testing for a final run of all the data. The program file was named “totalbatch_mergeNED_hydrodem_rerun92.aml”. This

program accomplished the majority of the data processing which could be done in AML. Subsequent steps included running the “Batch Terrain Preprocessing 9” tool in the ArcHydro Tools with the “Catchment Processing Only” option, and building the basin characteristics and global datasets.

```

/* This is a combination of the mergeNED, SetupHydroDEM, and hydrodem amls.
/* run the aml from a top directory.
/* The HUC lists need to be updated for each of the 3 embedded amls if they
/* are to be run.
/* Kenneth Skinner
/* 5/3/06
/* The original amls are kept intact even though some sections have been
/* commented out. A couple routines had to be renumbered.

/* &args huc

/*&if [null %huc%] &then &do
/* &call usage
/* &return
/* &end /* of if-null-huc-then-do
&do huc &list 17040208 17060205 17040209 17060206 17040210 17060207 17040211 17060208 ~
17040212 17060209 17040213 17060210 17040214 17060301 17040215 17060302 17040216 17060303 ~
17040217 17060304 17040218 17060305 17040219 17060306 17040220 17060307 17040207 17060204 ~
16010204 17050104 16020309 17050105 17010101 17050106 17010103 17050107 17010104 17050108 ~
17010105 16010102 17040221 17060308 16010201 17050101 16010202 17050102 16010203 17050103 ~
17050111 17010213 17050112 17010214 17050113 17010215 17050114 17010216 17050115 ~
17010301 17050120 17010302 17050121 17010303 17050122 17010304 17050123 17010305 17050124 ~
17010306 17050201 17010308 17060101 17040104 17060103 17040105 17060106 17040201 17060107 ~
17040202 17060108 17040203 17060109 17040204 17060201 17040205 17060202 17040206 17060203

/* **** LOCAL INSTALLATION CUSTOMIZATIONS below this line ****
&setvar indir D:\hydrodem10
&setvar srcdir D:\hydrodem10\amls /* local directory for source files
&setvar prjfile = %srcdir%\idtm83_newparams.prj /* Default projection file
&sv outdir = D:\hydrodem10%\%huc%
&sv huccov = D:\miscproj\ned10m\hucsidtm
&sv tilesc = D:\miscproj\ned10m\tilescov
&sv snapg = D:\miscproj\ned10m\snapg
&sv topdir = D:\miscproj\ned10m
/* **** LOCAL INSTALLATION CUSTOMIZATIONS above this line ****

/* set some default names and settings--these are similar to prototype EDNA
&setvar cellsz = 10 /* NED cell size is 1/3 arc second, approx. 10 meters
&setvar nedmeta = metacov
&setvar metatext = metatext
&setvar tempdem = tempdem
&setvar origdem = dem
&setvar buffdist = 100

```

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```
&workspace %indir%
/* Make new workspace, if not already existing
&if ^ [exists %outdir% -directory] &then
    createworkspace %outdir%

/* Clean up grids and coverages from previous runs if they exist
&call cleanup1

/* Select HUC and buffer it
reselect %huccov% %outdir%\huc8 poly
res huc = %huc%
[unquote ``]
n
n

&wo %outdir%
buffer huc8 hucbuff # # %buffdist% 10 poly

grid
verify off
setcell %cellsz%
setwindow hucbuff %topdir%/snapg
buffg = polygrid (hucbuff)
setmask buffg

/* Find the tiles that overlap the buffered HUC poly
reselect %tilesc% poly overlap hucbuff poly
cursor cur declare %tilesc% poly ro
cursor cur open

/* For each selected poly in tiles cover, add path to strg
&sv strg = %topdir%/dem10m/%:cur.tilepath%/demcm
cursor cur next
&do &while %:cur.aml$next% /* while true, still have records to do
    /* build string list of dems
    &sv strg = %strg%, %topdir%/dem10m/%:cur.tilepath%/demcm
    cursor cur next
&end /* of do-while-cur.aml$next (cursor loop through all records)

/* merge tiles to create seamless dem
%origdem% = merge( %strg% )
quit /*leave Grid

/* set PRJs of all data sets
projectdefine grid buffg
&r %prjfile%
projectdefine cover huc8
&r %prjfile%
projectdefine cover hucbuff
&r %prjfile%

&workspace .. /* return to directory in which we started
&call cleanup2

&end /* end of do HUC list
```

```

/* hydrodem.aml -- This aml is used by the National StreamStats Team as the optimal
/* approach for preparing a state's physiographic datasets for watershed delineations.
/* It takes as input, a 10-meter (or 30-foot) DEM, and enforces this data to recognize
/* NHD hydrography as truth. WBD can also be recognized as truth if available for a
/* given state/region. This aml assumes that the DEM has first been projected to a
/* state's projection of choice. This aml prepares data to be used in the Archydro
/* data model (the GIS database environment for National StreamStats).

/* A document describing how to prepare NHD, WBD and dem data for input into this aml
/* can be found on the NHD web site: http://nhd.usgs.gov/watershed/watershed\_tool\_inst\_TOC.html

/* hydrodem.aml supports dem input with either of the following 2 sets of projection parameters:
/* 1. units = meters, cellsize = 10, zunits = 100
/* 2. units = feet, cellsize = 30, zunits = 100
/* hydrodem.aml will reject any other options unless, of course, users modify the aml.
/* zunits is an optional parameter in projection files, but needs to be specified in the input dem
/* before running this aml. zunits represents a value 100 times the 'units' value of the input dataset
/* (if dem input is in meters, the zunits would therefore be centimeters... if dem input is in feet,
/* the zunits values represent 1/100th of a foot. this aml calls agree.aml

&do huc &list 17040208 17060205 17040209 17060206 17040210 17060207 17040211 17060208 ~
17040212 17060209 17040213 17060210 17040214 17060301 17040215 17060302 17040216 17060303 ~
17040217 17060304 17040218 17060305 17040219 17060306 17040220 17060307 17040207 17060204 ~
16010204 17050104 16020309 17050105 17010101 17050106 17010103 17050107 17010104 17050108 ~
17010105 16010102 17040221 17060308 16010201 17050101 16010202 17050102 16010203 17050103 ~
17050111 17010213 17050112 17010214 17050113 17010215 17050114 17010216 17050115 ~
17010301 17050120 17010302 17050121 17010303 17050122 17010304 17050123 17010305 17050124 ~
17010306 17050201 17010308 17060101 17040104 17060103 17040105 17060106 17040201 17060107 ~
17040202 17060108 17040203 17060109 17040204 17060201 17040205 17060202 17040206 17060203

/* **** LOCAL INSTALLATION CUSTOMIZATIONS below this line ****
&sv srcdir = D:\hydrodem10\amls
&sv work = D:\hydrodem10\%huc%
&sv outdir = G:\outdirs\%huc% /* this will be the workspace where all 'local' Archydro
/* workspaces reside.
&sv huc8cov = %work%/huc8 /* the name of the single polygon huc8 coverage
&sv inwall = %work%/inwall /* the name of the coverage of basin boundaries inside the huc8 used for
/* walling this coverage could include gage boundaries and
/* other non-WBD-12-digit boundaries
&sv dendrite = %work%/nhdrch /* the name of the modified nhd reach coverage
&sv origdem = %work%/dem /* the name of the input dem
&sv bowl_polys = %work%/nhd_wbg /* pre-processed NHD water bodies for bowling
&sv bowl_lines = %work%/wb_srcg /* pre-processed NHD centerlines in water bodies
&sv snap_grid = %work%/dem
/* *** REA 5/27/05 added drainplug
&sv drainplug = %work%/drain_plug
/* **** LOCAL INSTALLATION CUSTOMIZATIONS above this line ****

```

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```
/* set some default names and settings--these are similar to prototype EDNA and ArchHydro
&setvar cellsz = 10          /* NED cell size is 1/3 arc second, approx. 10 meters
                             /* this variable is changed to 30 below if the units are in feet

&setvar thresh = 150000    /* cell-number threshold for stream initiation and catchments

&setvar thresh2 = 900      /* used to create a stream grid which is later merged with all
                             /* other huc900 grids in the state and converted to shape. This
                             /* shapefile is used in the StreamStats interface for viewing
                             /* and selecting locations on streams.

&setvar filldem = fil      /* final fill grid
&setvar fdirg = fdr       /* final flow direction grid
&setvar faccg = fac       /* final flow accumulation grid

&setvar fsinkg = sinks     /* for QA error check on filled sinks (grid)
&setvar fsinkc = sinks_poly /* for QA error check on filled sinks (poly)

&setvar buffdist = 50      /* value used to buffer the huc8 boundary
&setvar inwallbuffdist = 15 /* value used to buffer the inner walls
&setvar inwallht = 50000   /* inner wall (huc12) height... this variable changed to 150000 (below)
                             /* if units are in feet
&setvar outwallht = 100000 /* outer wall (huc8) height (cm)... this variable changed to 300000
                             /* (below)
                             /* if units are in feet
&setvar bowldepth = 2000   /* The value 2000 (20m) may need to be increased for very wide water
                             /* bodies.

&sv agreebuf = 60         /* agree.aml default value for buffer (when in meters)
&sv agreesmooth = -500    /* agree.aml default value for smooth depth (when in units meters and
                             /* zunits = cm)
&sv agreesharp = -50000   /* agree.aml default value for sharp depth (when in meters)

/* ***** PROJECTION PARAMETER CHECKS BELOW THIS LINE *****
&workspace %work%
&describe %origdem%

&if %PRJ$UNITS% = METERS &then &DO
&if %GRD$DX% = 10 &then &do
&sv cellsz = 10
&sv inwallht = 50000 /* (zunits = cm)
&sv outwallht = 100000 /* (zunits = cm)
&sv agreebuf = 60
&sv agreesmooth = -500 /* (zunits = cm)
&sv agreesharp = -50000 /* (zunits = cm)
&sv buffdist = 50
&sv inwallbuffdist = 15
&end
&else &return if the units are in meters, the cellsize must be 10
&end

&if %PRJ$UNITS% = FEET &then &DO
&if %GRD$DX% = 30 &then &do
&sv cellsz = 30
&sv inwallht = 150000 /* (zunits of 1/100th of a foot)
&sv outwallht = 300000 /* (zunits of 1/100th of a foot)
```

```

&sv agreebuf = 180
&sv agreesmooth = -1500 /* (zunits of 1/100th of a foot)
&sv agreesharp = -150000 /* (zunits of 1/100th of a foot)
&sv buffdist = 150
&sv inwallbuffdist = 45
&end
&else &return if the units are in feet, the cellsize must be 30
&end

&if %PRJ$UNITS% ne FEET and %PRJ$UNITS% ne METERS &then &do
&return units must be in feet or meters
&end

&sv zunits = [quote %PRJ$ZUNITS%]
&if %zunits% ne [quote 100] &then &do
&return zunits must be set and must be 100 times the units of the input dem
&end

/* ***** PROJECTION PARAMETER CHECKS ABOVE THIS LINE *****

/* Clean up grids and coverages from previous runs if they exist
&call cleanup3

&if ^ [exists %outdir% -workspace] &then
    createworkspace %outdir%

&wo %outdir%
buffer %huc8cov% hucbuff # # %buffdist% 1 poly

grid
verify off
setcell %cellsz%
setwindow hucbuff %snap_grid%
buffg = polygrid (hucbuff)
setmask buffg

/* "burning & ridging"

&r %srcdir%/agree.aml %origdem% %dendrite% %agreebuf% %agreesmooth% %agreesharp% /* creates a new
    /* elevation grid -- elevgrid

nhdgrd = linegrid(%dendrite%, #, #, #, %cellsz%)

/* Creates the ridged DEM at a height of the DEM + %outwallht%
ridge_n1 = polygrid(%huc8cov%, #, #, #, %cellsz%) /* creates a grid of the huc boundaries
ridge_exp = expand(ridge_n1, 2, list, 2) /* expands the present huc grid by 2 cells
/* The next function basically subtracts the previous 2 grids resulting in just the
/* expanded cells representing the wall.
ridge_w = setnull((not isnull(ridge_n1) and not isnull(ridge_exp)), ridge_exp)
dem_ridge8 = elevgrid + con(( not isnull(ridge_w) and isnull(nhdgrd)), %outwallht%, 0)
/* The above statement adds the wall to the original dem except for where streams cross

/* NHD water body 'bowling'
/* NHD streams intersected with water bodies to be used as a source grid.
/* use preexisting water body grid (%bowl_polys%) and source grid (%bowl_lines%).
eucd = setnull(isnull(%bowl_polys%), eucdistance(%bowl_lines%))

```

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```
dem_ridge8wb = dem_ridge8 - con( not isnull(eucd), (%bowldepth% / (eucd + 1)), 0)

/* inner wall processing below
&if [exists %inwall% -line] &then &do /* *** REA 6/1/05
  arc buffer %inwall% inwallbuf # # %inwallbuffdist% 1 line
  inwallg_tmp = polygrid(inwallbuf,inside,#,#,%cellsz%)
  inwallg = con(inwallg_tmp == 100,0) /* needed to remove trapped polys inside buffer areas
  /* ("1" values)
  dem_enforced = dem_ridge8wb + con(( not isnull(inwallg) and isnull(nhdgrd)), %inwallht%, 0)
&end /* of if-exists-inwall-then-do /* *** REA 6/1/05
&else /* *** REA 6/1/05
  dem_enforced = dem_ridge8wb /* *** REA 6/1/05
/* end of inner wall processing

/* Do fill, flowdirection, flowaccumulation
setwindow hucbuff %snap_grid%
setcell %origdem%

/* *** REA 5/27 insert drainplug (NODATA holes)
&sv drainplug = %work%/drain_plug
/* If optional drainplug cover given, make its polygons NODATA in DEM before running FILL
&if [exists %drainplug% -polygon] &then &do
  dpg = polygrid (%drainplug%)
  detmp = con(isnull(dpg),dem_enforced)
  kill dem_enforced
  rename detmp dem_enforced
&end /* of if-exists-drainplug-then-do

fill dem_enforced %filldem% sink # %fdirg%
setmask ridge_nl /* mask back to huc only
%fdirg%msk = %fdirg%
kill %fdirg% all
rename %fdirg%msk %fdirg%

%faccg% = int( flowaccumulation ( %fdirg% ))

/* Identify filled sinks -- look at filled sinks for QA
%fsinkg% = con ( %filldem% gt %origdem%, 1)
%fsinkc% = gridpoly( %fsinkg%)
kill %fsinkg% all

/* Delineate synthetic streams
str = con ( %faccg% ge %thresh%, 1)
lnk = streamlink ( str, %fdirg% )
str900 = con ( %faccg% ge %thresh2%, 1)

/* Delineate catchments from each synthetic reach
cat = watershed (fdr, lnk )

quit /*leave Grid

hillshade dem_enforced shd # # # 0.01
```

```

kill dem_enforced all
kill dem_ridge8 all
kill dem_ridge8wb all
kill elevgrid all
kill eucd all
kill ridge_exp all
kill ridge_nl all
kill ridge_w all

&end /* end of do HUC list

&return /* end of main routine

&routine cleanup3

&do covs &list %fsink% hucbuff inwallbuf
  &if [exists %outdir%/%covs% -cover] &then kill %outdir%/%covs% all
&end

&do grds &list %fdirg% %faccg% %fsinkg% shd ~
buffg cat dem_ridge8 dem_ridge8wb elevgrid nhdgrd ridge_w ~
str str400 ridge_nl ridge_exp eucd lnk ~
inwallg dem_enforced inwallg_tmp dem_ridge12
  &if [exists %outdir%/%grds% -grid] &then kill %outdir%/%grds% all
&end

&return /* end of cleanup3 routine

&routine cleanup1

&do infile &list zstat_flowacc
  &if [exists %infile% -info] &then &sv delst [delete %infile% -info]
&end

&do covs &list %nedmeta% huc8 hucbuff
  &if [exists %outdir%/%covs% -cover] &then kill %outdir%/%covs% all
&end

&do grds &list %tempdem% %origdem% buffg
  &if [exists %outdir%/%grds% -grid] &then kill %outdir%/%grds% all
&end

&if [exists %outdir%/%metatext% -directory] &then &sv delst [delete %outdir%/%metatext% -directory]
&return /* end of cleanup1 routine

&routine cleanup2

&do infile &list zstat_flowacc
  &if [exists %infile% -info] &then &sv delst [delete %infile% -info]
&end

&do grds &list %tempdem%
  &if [exists %outdir%/%grds% -grid] &then kill %outdir%/%grds% all
&end
&return /* end of cleanup2 routine

```

Appendix B. Program Source Code for Computing Continuous Parameter Grids

The following is an Arc Macro Language (AML) program used to compute continuous parameter grids.

```

/* outdirs2archydrodirs.aml -- Copies relevant datasets from HydroDEM outdirs
/* and computes continuous parameter grids.
/* Run this aml from a top directory.
/* The HUC list may need to be updated for each run, if it does not run to completion.
/*
/* Al Rea 06/06/2008

&do huc &list 17040208 17060205 17040209 17060206 17040210 17060207 17040211 17060208 ~
17040212 17060209 17040213 17060210 17040214 17060301 17040215 17060302 17040216 17060303 ~
17040217 17060304 17040218 17060305 17040219 17060306 17040220 17060307 17040207 17060204 ~
16010204 17050104 16020309 17050105 17010101 17050106 17010103 17050107 17010104 17050108 ~
17010105 16010102 17040221 17060308 16010201 17050101 16010202 17050102 16010203 17050103 ~
17050111 17010213 17050112 17010214 17050113 17010215 17050114 17010216 17050115 ~
17010301 17050120 17010302 17050121 17010303 17050122 17010304 17050123 17010305 17050124 ~
17010306 17050201 17010308 17060101 17040104 17060103 17040105 17060106 17040201 17060107 ~
17040202 17060108 17040203 17060109 17040204 17060201 17040205 17060202 17040206 17060203

/* **** LOCAL INSTALLATION CUSTOMIZATIONS below this line ****
&sv topdir = E:\id_archydro10m
&setvar indir E:\id_archydro10m\outdirs\%huc%
&sv outdir = E:\id_archydro10m\archydro\%huc%
&setvar forestw = E:\id_archydro10m\statewide\forestg
&setvar precipw = E:\id_archydro10m\statewide\precip_prj
/* **** LOCAL INSTALLATION CUSTOMIZATIONS above this line ****

&workspace %indir%

/* Make new workspace, if not already existing
&if ^ [exists %outdir% -directory] &then
    createworkspace %outdir%

/* copy datasets from indir to archydro folders

&do dataset &list cat dem fac fac_mod2 fdr lnk str str900
    &if [exists %indir%\%dataset% -grid] &then copy %indir%\%dataset% %outdir%\%dataset%
&end /* of do-dataset-list

```

```

&do dataset &list %huc%.mdb
  &if [exists %indir%\%dataset% -file] &then &sv cptest [copy %indir%\%dataset% %outdir%\%dataset%]
&end /* of do-dataset-list

/* go to output archydro folder
&wo %outdir%

grid
verify off
setcell dem
setwindow dem dem

/* compute continuous parameter grids for elev, forest, precip
elev_cpg = int(((dem + flowaccumulation(fdr, dem)) / (fac + 1)) * 0.03281 + 0.5)
forest_cpg = int((((%forestw% + flowaccumulation(fdr, %forestw%)) / (fac + 1)) * 100) + 0.5)
precip_cpg = int((((%precipw% + flowaccumulation(fdr, %precipw%)) / (fac + 1)) * 10) + 0.5)

/* compute slope grids
bsldem10m = slope (dem, 0.01, PERCENTRISE)
slop30 = con (bsldem10m ge 30, 1, 0)
aspectg = aspect (dem)
setmask slop30
nfsl30 = con (slop30 gt 0 and (aspectg lt 60 or aspectg gt 300), 1, 0)
setmask off

/* compute continuous parameter grids for mean slope, slopes ge 30, north-facing slopes ge 30
bsld10_cpg = int((bsldem10m + flowaccumulation(fdr, bsldem10m))/(fac + 1)) + 0.5)
slop30_cpg = int((((slop30 + flowaccumulation(fdr, slop30))/(fac + 1)) * 100) + 0.5)
nfsl30_cpg = int((((nfsl30 + flowaccumulation(fdr, nfsl30))/(fac + 1)) * 100) + 0.5)

/* clean up
kill aspectg all

quit /* out of grid

&workspace %topdir%

&end /* end of do HUC list

```

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