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ABSTRACT

This paper describes the work done to develop average annual streamflow estimates and power potential for the states of Alaska and Hawaii. The Elevation Derivatives for National Applications (EDNA) database was used, along with climatic datasets, to develop flow and power estimates for every stream reach in the EDNA database. Estimates of average annual streamflows were derived using state-specific regression equations, which were functions of average annual precipitation, precipitation intensity, drainage area, and other elevation-derived parameters. Power potential was calculated through the use of the average annual streamflow and the hydraulic head of each reach, which is calculated from the EDNA digital elevation model. In all, estimates of streamflow and power potential were calculated for over 170,000 stream segments in the Alaskan and Hawaiian datasets.

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ACRONYMS

CONUS Conterminous United States

The area of the United States comprising 48 states not including the states of Alaska and Hawaii.

DEM Digital Elevation Model

A database of elevation data represented by a regularly spaced set of geographic coordinates each with an associated elevation distance measured from a defined datum.

EDNA Elevation Derivatives for National Applications

EDNA is a multi-layered database derived from a version of the National Elevation Dataset (NED) that has been hydrologically conditioned for improved hydrologic flow representation (http://edna.usgs.gov).

EROS Earth Resources Observation Systems

GIS Geographical Information Systems

A software system that allows geographical information to be displayed using maps. Such information consists of raster data (bitmaps) and vector data (line drawings). Information can be displayed as separate layers (overlays or coverages). Raster data can be used to perform analyses. GIS data are usually stored using a relational database.

IDW Inverse Distance Weighting

A method of extrapolating spatial variables that uses a linearly weighted combination of a set of sample points. The weight is a function of inverse distance.

INEEL Idaho National Engineering and Environmental Laboratory

NED National Elevation Dataset

The NED is a new raster product assembled by the USGS. The NED is designed to provide national elevation data in a seamless form with a consistent datum, elevation unit, and projection. Data corrections were made in the NED assembly process to minimize artifacts, permit edge matching, and fill sliver areas of missing data. (http://ned.usgs.gov)

SAIC Science Applications International Corporation

USGS United States Geological Survey

NOMENCLATURE

Average annual streamflow	The statistical mean of the flow rates occurring at a particular location during the course of 1 year. The streamflow regression equations used in this study estimate the mean of the annual mean flow rates that occurred over a period of many years. The annual mean flow rate in any given year will usually differ from the value predicted by the equations.
Bilinear	A method of resampling raster data sets that uses the four nearest input cell resampling centers to the location of the center of an output cell on the input grid. The new value for the output cell is a weighted average determined by the value of the four nearest input cell centers and their relative position or weighted distance from the location of the center of the output cell in the input grid.
Catchment	That portion of a drainage basin supplying runoff to a particular stream reach.
Drainage area	The total surface area of a drainage basin.
Drainage basin	The geographic area supplying potential runoff to a particular point on a stream.
EDNA stream	Those locations on the land surface (as represented by the DEM) that have a network minimum upstream drainage area of 4.5 sq. km. This dataset is derived in a raster framework and is converted to a vector representation for use with GIS.
EDNA stream node	An EDNA stream node is defined at every confluence and terminal location (upstream and downstream terminal streams) in the EDNA stream network.
EDNA stream reach	That portion of the EDNA stream network between two EDNA stream nodes.
Elevation range	The difference between the minimum and maximum elevations.
Flow accumulation	The number of upstream cells that flow, as determined by the flow direction grid, into each cell in the DEM. This is essentially a representation of the upstream drainage area of each cell in the DEM.
Flow direction	The direction of flow out of each cell of a DEM. The direction of flow is determined by finding the direction of steepest descent or maximum drop from each cell to its eight neighbors. The eight direction flow algorithm used assumes that all flow is in one of the eight cardinal directions.
Isopluvial Maps	A map depicting a line on the surface of the earth, connecting all points of equal precipitation.
Leeward	The direction to which the wind is blowing.
Pour Point	The minimum elevation in an EDNA drainage basin. This is the location at which water would exit the drainage basin.

Step-wise regression	An iterative regression approach in which a list of several potential explanatory variables are available. This list is repeatedly searched for variables that should be included in the model. The best explanatory variable is used first, then the second best, and so on.
Windward	The direction from which the wind is coming.

Estimation of Average Annual Streamflows and Power Potentials for Alaska and Hawaii

1. INTRODUCTION

The Idaho National Engineering and Environmental Laboratory (INEEL) has been tasked by the U.S. Department of Energy to assess the water energy resources of the United States with the principal focus being the power potential of low hydraulic head (less than 30 ft)/low power (less than 1 MW) resources. To fulfill this requirement, the INEEL funded the U.S. Geological Survey (USGS) to produce estimates of power potential for the conterminous United States (CONUS) in fiscal year 2003. Follow-on funding for fiscal year 2004 was received to complete a similar analysis for Alaska and Hawaii. This paper reports on the work done to develop the Alaskan and Hawaiian power potential estimates.

The Elevation Derivatives for National Applications (EDNA) database (Verdin 2000) was used to develop low-head/low-power estimates for the states of Alaska and Hawaii. This work followed the successful completion of estimates for the CONUS in fiscal year 2003. As opposed to the EDNA data for the CONUS, for which the initial EDNA data processing had been completed in 2001, the EDNA data for Alaska and Hawaii needed to be produced before the power potential analysis could be performed.

The power potential calculation was performed for every stream segment in the EDNA databases for Alaska and Hawaii. Power potential is a function of the amount of water flowing through a stream segment and the hydraulic head of the segment. Therefore, in order to assess the power for every stream segment, development of estimates of flow in every stream segment, along with the hydraulic head of the segment, were needed. The EDNA Digital Elevation Model (DEM) was used to determine elevations at the up and downstream ends of the stream segments. The difference of these two elevations is the hydraulic head of the stream segment. To estimate the streamflows, we used regression equations developed by the USGS Water Resources Division (Parks and Madison 1985; Yamanaga 1972). Regression equations for the prediction of mean annual streamflow for Alaska have as independent variables only drainage area and mean annual precipitation. The independent variables used in the regressions for Hawaii, however, are drainage area, mean annual precipitation, precipitation intensity of the 24-hour storm with a return period of 2 years, mean elevation of the basin, and the range of elevation within the basin.

EDNA's stream layer was used to provide the modeling framework. The framework for the contribution of flow from Canada was provided by the USGS's HYDRO1k database (Verdin and Jenson 1996). EDNA's elevation layer was used to provide the elevation-based input parameters (hydraulic head, mean elevation, and elevation range). Several climatological layers were used to provide the required precipitation inputs. All these data layers are discussed in the data section of this report.

In many ways, the power potential analyses for Alaska and Hawaii were similar to the techniques used for the CONUS. However, there were several significant differences in the procedures.

- The resolution of the EDNA raster layers for Alaska and Hawaii were different than that for the CONUS. Whereas a 30-meter cell size was used in developing EDNA for the CONUS (corresponding to a National Elevation Dataset [NED] cell size of 1 arc-second), Alaska's EDNA was developed with a 60-meter cell size and the EDNA for Hawaii has a 10-meter cell size. The 60-meter cell size for Alaska corresponds to the input NED's cell size of 2 arc-seconds. Ten-meter resolution was possible in Hawaii because of the high quality of the 1/3-arc-second NED.

- Whereas the PRISM (Parameter-elevation Regressions on Independent Slopes Model) precipitation layers were used for the CONUS and Hawaii, the precipitation layer used in the Alaska portion of the analysis was developed from isopluvial maps. While the PRISM data are available for Alaska, the isopluvial map was chosen as the preferred input, because it was more representative of the precipitation period used in developing the streamflow regression equations.
- The streamflow regression equations for Hawaii and Alaska were quite different than those developed for the CONUS. In both the Hawaii and Alaska equations, temperature was not an independent variable. Other variables, such as elevation, were included in the Hawaiian equations.

2. DATA

Various data layers were used in developing the power potential estimates for Alaska and Hawaii. The underlying framework, providing the stream network and connectivity, was the EDNA database (Verdin 2000). The EDNA is a hydrologic derivative database, which was developed from a version of the NED (Gesch et al. 2002). EDNA's multiple raster data layers include a hydrologically conditioned DEM, flow directions, flow accumulations, and slope. Vector layers include synthetic streamlines and a corresponding reach catchment layer. This multi-layer dataset provided the framework for the analysis.

While the raster layers for the EDNA data for the CONUS were developed at a 30-meter spacing (corresponding to the input NED's resolution of 1 arc-second), the layers for Alaska were created at 60-meter spacing (corresponding to a NED resolution of 2 arc-second). The high quality of the underlying NED in Hawaii allowed these same layers to be developed at 10-meter spacing. Both datasets for Alaska and Hawaii were developed in an Albers equal area projection. The projection information for the EDNA layers is presented in Table 1.

Table 1. Projection parameters for the Alaskan and Hawaiian EDNA layers.

	Alaska	Hawaii
Projection	Albers	Albers
Datum	NAD27	NAD83
Units	Meters	Meters
1st Standard Parallel	55°0'0"	20°0'0"
2nd Standard Parallel	65°0'0"	22°0'0"
Central Meridian	-154°0'0"	-157°30'0"
Latitude of Projection	50°0'0"	3°0'0"
False Easting	0	0
False Northing	0	0

Alaska is not a self-contained drainage system. It receives a significant portion of its drainage from Canada. The EDNA database does not extend into Canada. Therefore, the Canadian portion of the drainage basin was provided by the HYDRO1k database (Verdin and Jenson 1996). The HYDRO1k DEM was projected into the Alaskan Albers projection and was reprocessed to fill spurious sinks, which may have been introduced during the projection procedure. Locations in the EDNA that receive flow from Canada were identified, and an appropriate HYDRO1k basin was delineated for each point. Shown in Figure 1 is the Alaskan drainage area including that area drained from Canada.

Inputs to the regression equations for mean annual streamflow were derived from various data sources:

1. Area: The drainage area, required for both the Alaskan and Hawaiian regressions, is easily derived from the EDNA layers. It is represented in the flow accumulation values associated with each pixel.

2. Elevation: Both the mean elevation and the range in elevations were required inputs to the Hawaiian regression equations. Both were derived from the EDNA DEM.

3. Mean annual precipitation (Alaska): In order to produce a mean annual precipitation layer for Alaska, the precipitation as represented in the Environmental Atlas of Alaska (Hartman and Johnson 1978) was used. These precipitation data, representative of the period over which the regression equations were developed, were in the form of an isopluvial map and were digitized for use within a Geographic Information System (GIS) (Figure 2). Precipitation data for the Canadian portions of the drainage basins were obtained from the Global Temperature and Precipitation Climatologies (Willmott and Matsuura 2001). In order to be useful within the GIS, the isopluvial data needed to be converted into a raster format and also needed to be merged with the Canadian data. This was done by converting both the isopluvial data and the Canadian precipitation data into point datasets (Figure 3) and using the Inverse Distance Weighting technique to create a raster precipitation surface.

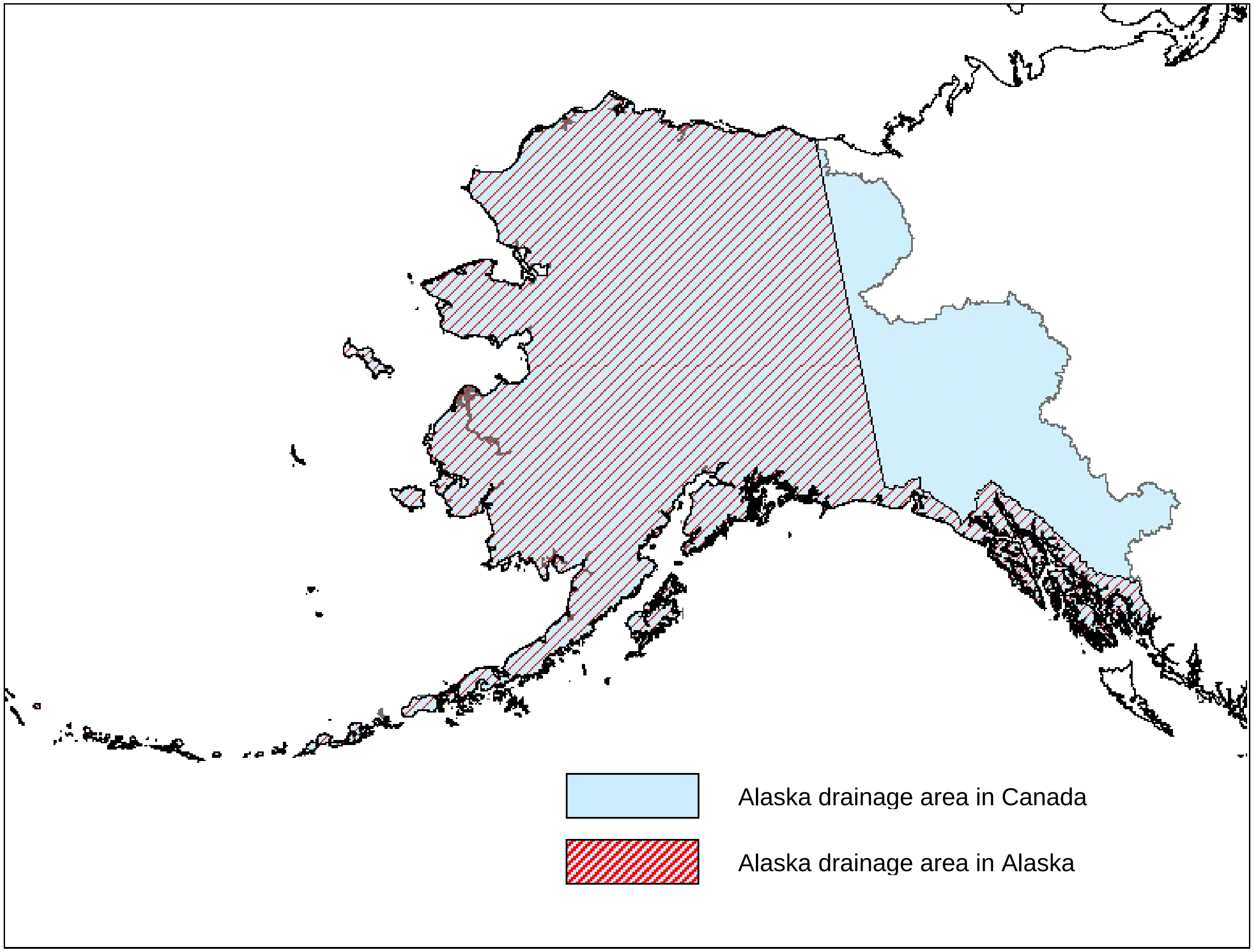


Figure 1. Drainage area for the State of Alaska.

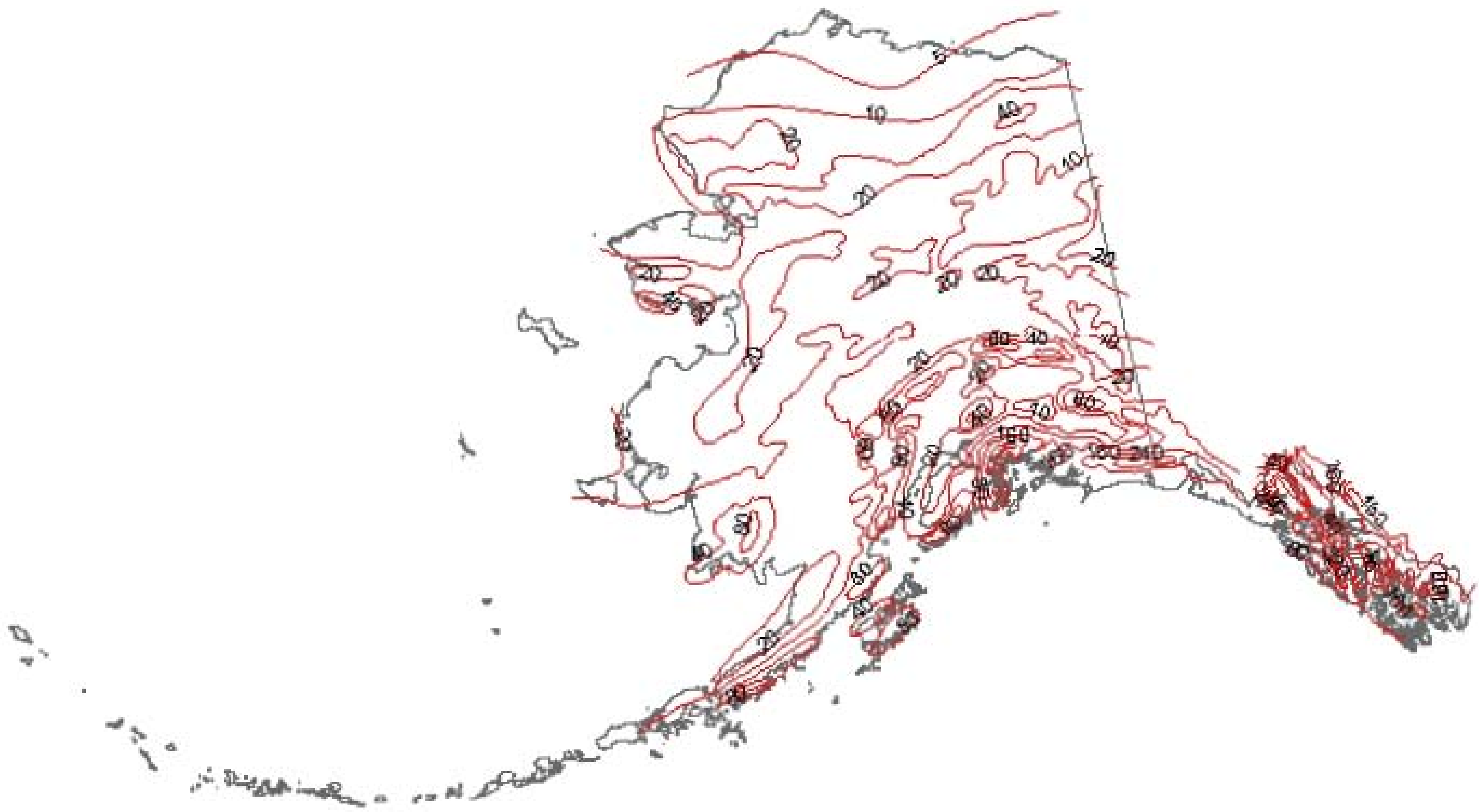


Figure 2. Mean annual precipitation (inches) for Alaska.

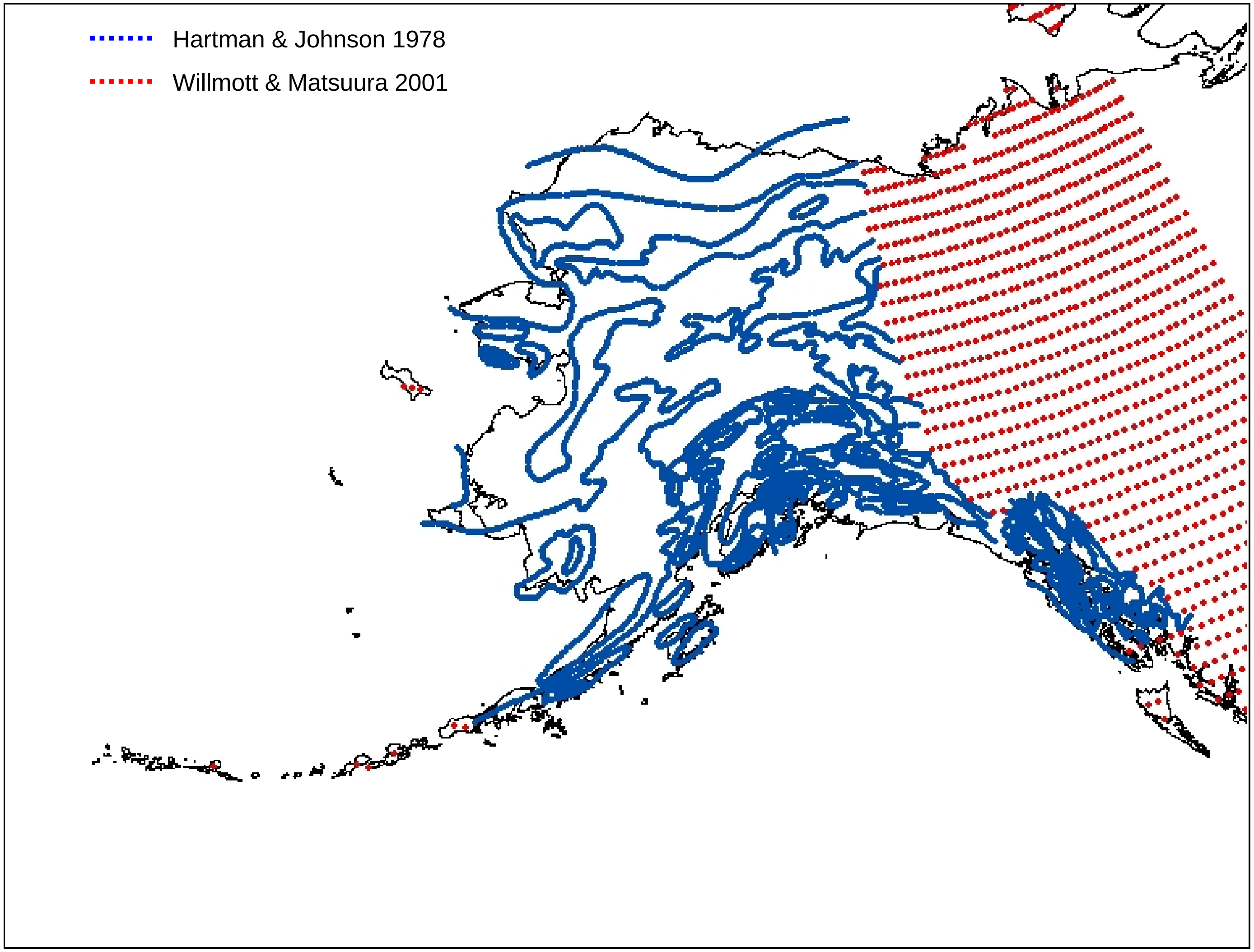


Figure 3. Precipitation points used in development of the average annual precipitation surface for Alaska.

4. Mean annual precipitation (Hawaii): Mean annual precipitation for Hawaii was taken from the PRISM Spatial Climate Layers for the United States (Daly et al. 1997). The PRISM dataset contains climatological data in multiple layers. Annual precipitation (in mm) was used in this analysis. Data are distributed at a resolution of 1.25 arc minutes in a geographic projection using a WGS72 datum. To facilitate compatibility with the EDNA framework, the PRISM data were reprojected into the Hawaiian Albers Equal Area Conic projection using bilinear resampling. The cell size of the dataset was allowed to default to 448 meters.

5. Precipitation intensity: Precipitation intensity of the 24-hour storm with a return period of 2 years was a required input to the Hawaiian regression equations. These data were derived from isopluvial maps available in the Rainfall-Frequency Atlas of the Hawaiian Islands (U.S. Weather Bureau 1962). Again, these data were digitized for use within a GIS (Figure 4). Conversion to a raster layer was achieved by using the Inverse Distance Weighting technique.

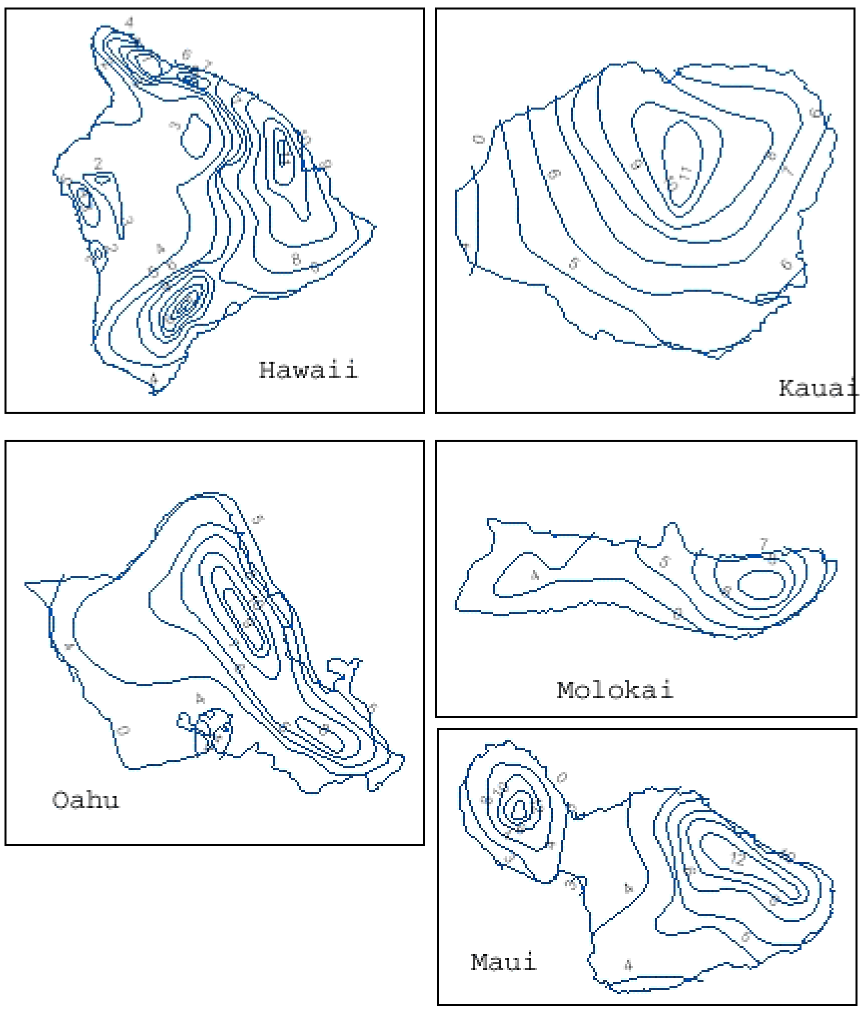


Figure 4. Hawaii precipitation intensity isohyets of the 2-year, 24-hour rainfall (inches).

3. METHODS

The ultimate aim of this work was the development of power potential for the States of Alaska and Hawaii. Power potential is a function of the amount of water flowing through a stream segment and the hydraulic head of the segment. We used:

$$P = ((Q_{in} + Q_{out}) / 2) * H/11.8 \qquad (1)$$

where

P = power potential (kilowatts)

Q_{in} = mean annual flow at the from-node of the stream segment (ft^3/sec)

Q_{out} = mean annual flow at the pour point of the catchment (ft^3/sec)

H = hydraulic head of the stream segment (ft).

In order to evaluate this equation for every stream segment in the EDNA dataset, estimates of mean annual streamflow at the upstream and downstream ends of the stream segment were needed along with the change in elevation along the segment. As stated previously, the mean annual streamflow estimates were developed through the use of regression equations.

For Alaska, regression equations for estimation of mean annual streamflow (Parks and Madison 1985) were developed using only upstream drainage area and mean annual precipitation as independent variables. For the State of Alaska, six distinct regions (see Figure 5) were defined and unique regression equations were developed for each region. The regression equations are of the general form:

$$\mathrm{Log}(Q) = \log(a) + b*\log(DA) + c*\log(P) \text{ or} \qquad (2)$$

$$Q = (10^a)*(DA^b)*(P^c) \qquad (3)$$

where

Q = mean annual flow (cfs)

DA = total upstream drainage area (mi^2)

P = mean annual precipitation for the upstream drainage area (inches).

The constants a, b, and c are developed through regression techniques for each region.

The regression equations for each region along with the standard errors of estimate associated with each equation are summarized in Table 2.

Mean annual streamflow regression equations for Hawaii were taken from a USGS Open-File Report (Yamanaga 1972). These regression equations were developed using a step-wise technique that found that the variables of significance varied depending on the windward/ leeward orientation of the drainage basin. Therefore, separate regressions were developed for the windward and leeward sides of the islands. For the windward areas, the significant variables were found to be drainage area, mean annual precipitation, and the precipitation intensity of the 24-hour/2-year storm. The equation for the leeward areas had the same independent variables, but also included the mean elevation and the elevation range for the basin. The regression equations are summarized in Table 3.

The windward and leeward sides of the islands were determined from Yamanaga (1972) and digitized for use within a GIS. The windward and leeward sides of the islands are shown in Figure 6.

Advantage was made of the continuous parameterization technique (Verdin and Greenlee 2003) to aggregate several area-dependent variables. In essence, this methodology makes use of the EDNA flow direction matrix to develop continuous surfaces of variables of interest. Most raster GIS users are familiar with the flow accumulation grid. In fact, it is one of the basic data layers in the EDNA database. The flow accumulation grid is derived from the flow direction grid and is, essentially, a grid in which each cell holds a value equal to the number of cells upstream of that location plus one to account for the cell itself. This can be thought of as the cell's "drainage area." The "continuous parameterization" technique uses this simple function. But, instead of counting every pixel equally, we count the pixels weighted by a spatial parameter. After accumulating or counting these values, we obtain a grid of the total of the spatial parameter within the "drainage

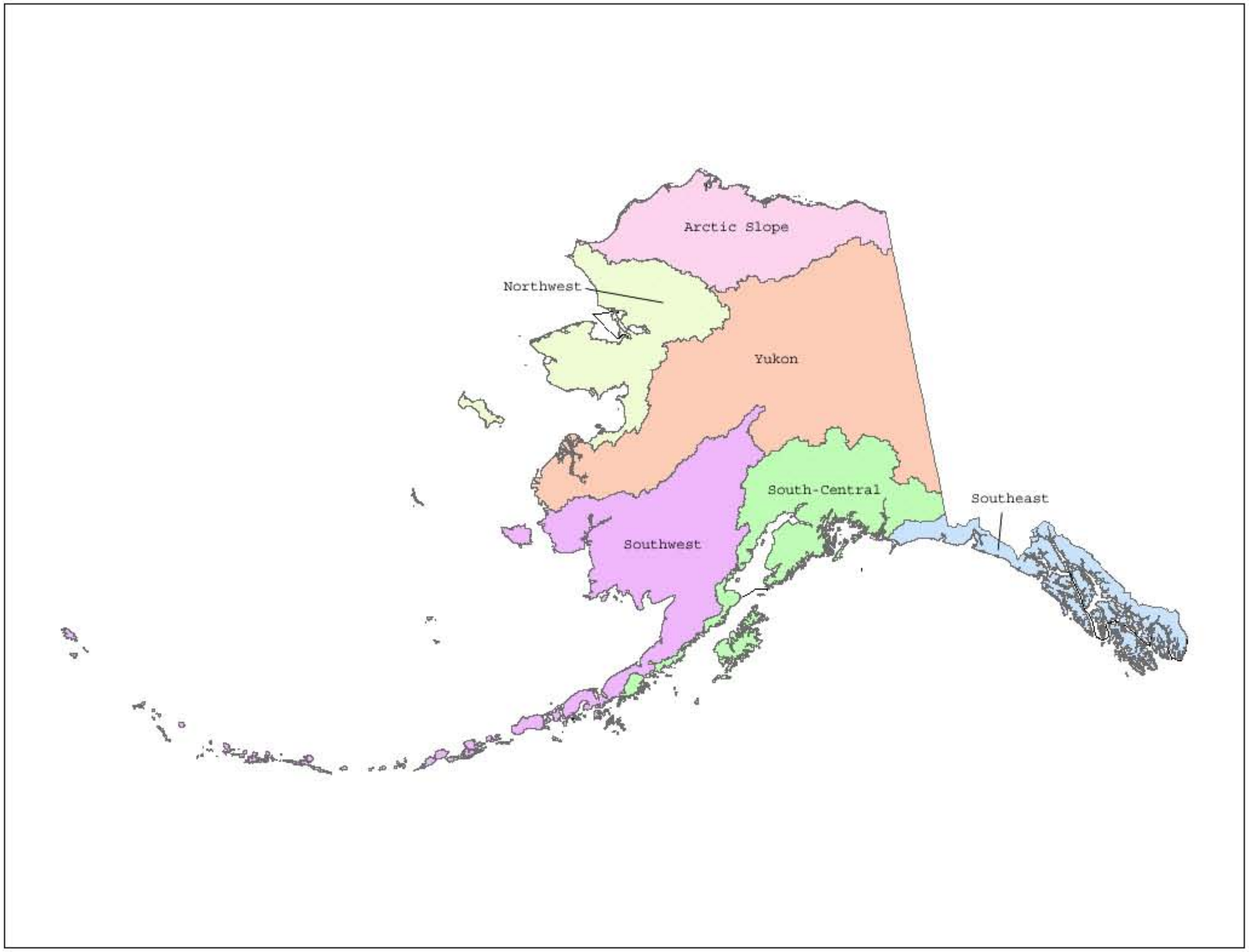


Figure 5. Regional boundaries used for the development of streamflow regression equations.

Table 2. Regression equations used in estimating mean annual streamflow for Alaska.

Region	Mean Annual Flow (cfs)	N	R^2	SE (%)
Southeast	$Q = (10^{-0.46})*(DA^{1.01})*(P^{0.68})$	66	0.92	-28 to +38
South-Central	$Q = (10^{-1.33})*(DA^{0.96})*(P^{1.11})$	56	0.97	-31 to 45
Southwest	$Q = (10^{-1.38})*(DA^{0.98})*(P^{1.13})$	10	0.99	-29 to +41
Yukon	$Q = (10^{-2.04})*(DA^{1.05})*(P^{1.39})$	32	0.99	-21 to +26
Arctic Slope and Northwest[a]	$Q = (10^{-1.51})*(DA^{0.98})*(P^{1.19})$	172	0.98	-29 to +41

where

Q = mean annual flow in cubic feet/second

DA = drainage basin area in square miles

P = mean annual precipitation in inches/year

N = number of observations used in developing the regression equations

R^2 = coefficient of determination

SE = standard error of estimate

a. Arctic Slope and Northwest region used the statewide regression equation.

Table 3. Regression equations used in estimating mean annual streamflow for Hawaii.

	Annual Mean Flow Rate (cfs)	SE (%)
Windward Areas	$Q = 0.015*(DA^{0.949})*(P^{0.588})*(PI^{0.850})$	±34
Leeward Areas	$Q = 6.93E\text{-}08*(DA^{0.746})*(E^{1.057})*(R^{0.154})*(P^{2.783})*(PI^{-1.588})$	±28

where

Q = mean annual flow in cubic feet/second

DA = drainage basin area in square miles

P = mean annual precipitation in inches/year

PI = precipitation intensity in inches (maximum rainfall during a 24-hour period having a recurrence interval of 2 years)

E = mean drainage basin elevation in feet

R = difference between minimum and maximum elevations occurring in the drainage basin in feet

SE = standard error of estimate

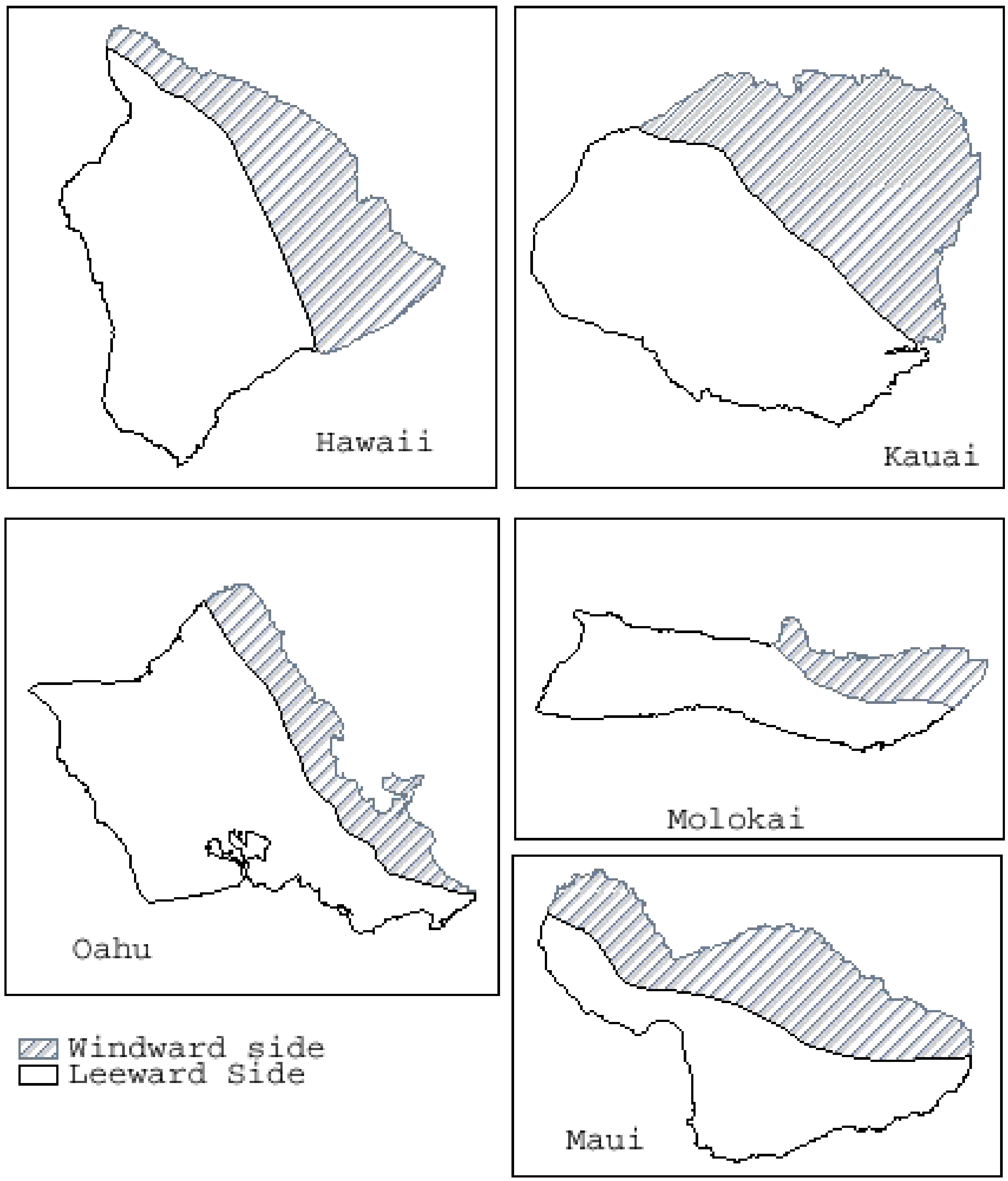


Figure 6. Windward/leeward subdivisions of the major Hawaiian Islands.

area" for each cell. To obtain the average of each spatial parameter, such as average precipitation as used in the regression equations for Alaska and Hawaii, we divide the accumulated total for each cell by the total number of cells in its "drainage area" from the flow accumulation grid.

Figure 7 provides an example of the continuous parameterization technique applied to precipitation for a very small area. Figure 7a shows a hypothetical flow direction grid. This grid is used in generating the standard flow accumulation grid shown in Figure 7b. The standard flow accumulation function counts each cell upstream equally, giving each cell an equal weight. Use of other weights, such as precipitation (Figure 7c), can easily produce a continuous surface of accumulated precipitation as shown in Figure 7d. To derive average precipitation for the "drainage area" associated with each cell, the accumulated precipitation (Figure 7d) is divided by the flow accumulation grid (Figure 7b), which yields the average precipitation values shown in Figure 7e.

The flow direction grid and associated flow accumulation function are used to "accumulate" any spatial variable above any location. The drainage area above the location, DA, was calculated simply by translating the flow accumulation value (in pixels) into an appropriate area in square miles. Use of the function in this way assumes that the weight given the flow accumulation function is one. All upstream pixels are counted or weighted in the same manner. The climatological variables, such as precipitation and temperature, were accumulated by using the techniques illustrated in Figure 7 and converted to averages for use in the regression equations by dividing the number of cells draining into each location (i.e., the flow accumulation value).

Several other independent variables in the Alaskan and Hawaiian regression equations were obtained with EDNA through the application of the flow accumulation function using different weights. The variables required for the Hawaiian and Alaskan average annual streamflow regression equations are shown in Table 4. Five of the six parameters were derived through the continuous parameterization technique.

Table 4. Independent variables needed for evaluation of the mean annual streamflow regression equations for Alaska and Hawaii.

Required Variable	Flow Accumulated	Weight
Drainage Area	Yes	None
Mean Annual Precipitation (Alaska)	Yes	Gridded precipitation maps
Mean Annual Precipitation (Hawaii)	Yes	PRISM precipitation
Precipitation Intensity	Yes	Gridded precipitation intensity
Mean Elevation	Yes	EDNA DEM
Elevation Range	No	—

The only independent variable that did not lend itself to evaluation using the continuous parameterization technique was the elevation range. This variable was derived in the standard manner—for each stream segment, the upstream drainage area was defined and a zonalmax function was applied to the EDNA DEM to derive the maximum elevation in the basin. The minimum elevation occurred at the pour point. The elevation range was calculated as a simple difference between the two. The delineation of the upstream drainage area was greatly expedited through the use of the Pfafstetter codes (Verdin and Verdin 1999).

In order to generate an average streamflow for each stream segment, a streamflow value was generated at both the upstream and downstream ends of the segment. These streamflow values were averaged, and this average value was used in the power equation (Equation (1)).

The streams data layer in both the Alaskan and Hawaiian EDNA databases were attributed with the information required to evaluate the mean annual streamflow regressions. Examples of the attribute tables for the Alaskan and Hawaiian stream datasets are shown in Figures 8 and 9, respectively. Different variable requirements for the regression equations necessitated different attributes on the two datasets. In order to evaluate the streamflow at the upstream and downstream end of the segment, attributes were required defining the parameters at both ends of the segment. For example, the Alaskan streams dataset has the attributes of area_sqmi_up and area_sqmi_down describing the drainage areas above the upstream and downstream ends of the stream segment. Using this variable along with the average precipitation above the upstream and downstream ends of the segment (avg_precip at the downstream end and precip_in at the upstream end of the segment) results in an estimate of streamflow at both ends of each stream segment (q_cfs_up and q_cfs_down). Following the attribution of the stream segments with the necessary information, calculation of streamflow and resulting power were simple calculations carried out within an ARC/INFO's TABLES environment.

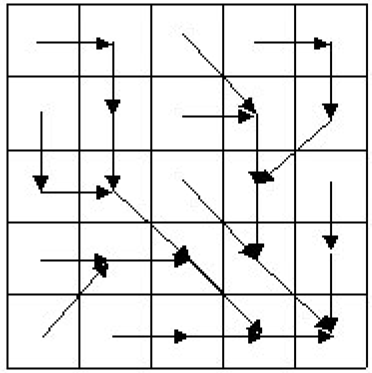


Figure 7a. Flow direction grid for a small area. Arrows show down-slope direction.

1	2	1	1	2
1	3	1	3	3
2	6	1	7	1
1	3	10	9	2
1	1	2	13	25

Figure 7b. Flow accumulation counts for each cell inclusive.

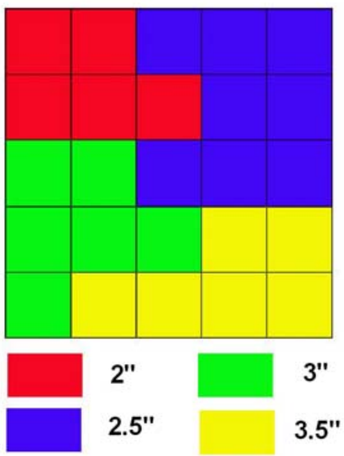


Figure 7c. Precipitation grid for small area with values from 2 to 3.5 inches.

2	4	2.5	2.5	5
2	6	2	7	7.5
5	14	2.5	17	2.5
3	9	26	23	6
3	3.5	7	36.5	69

Figure 7d. Flow-accumulated precipitation. The count for each cell is the sum of the upstream precipitation values (in inches).

2	2	2.5	2.5	2.5
2	3	2	2.33	2.5
2.5	2.33	2.5	2.43	2.5
3	9	2.6	2.56	3
3	3.5	7	2.81	2.76

Figure 7e. The average precipitation for the drainage area above each cell in inches.

Figure 7. Illustration of the concept behind the flow-accumulated variable technique.

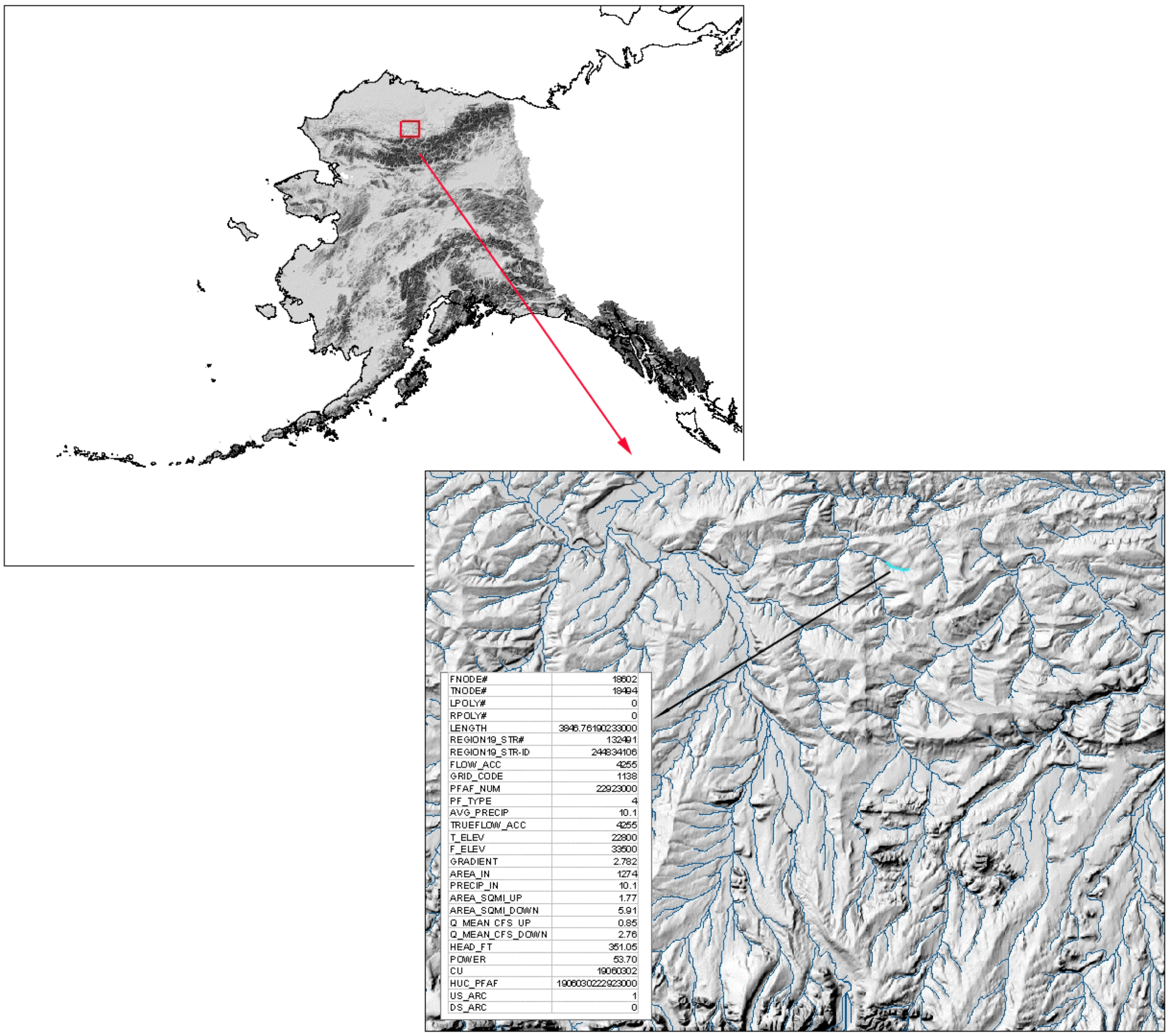
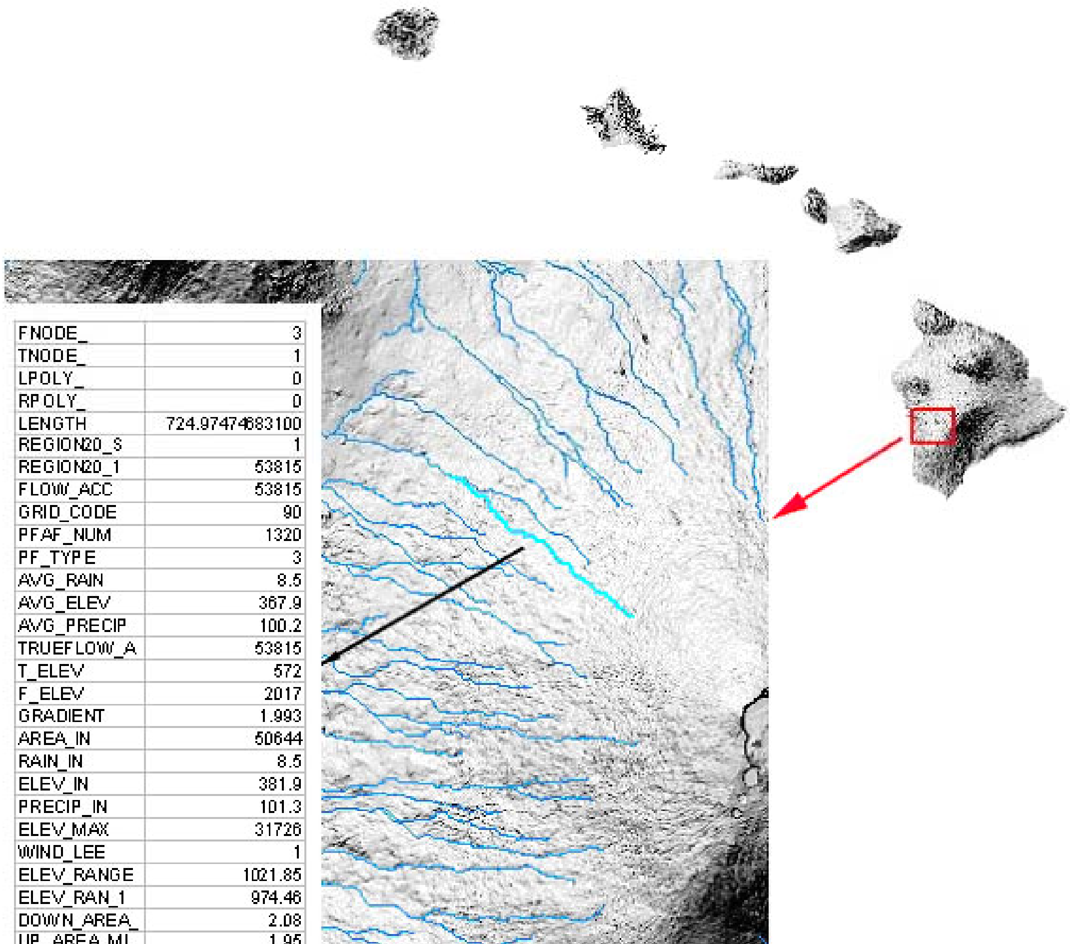


Figure 8. Example of attribute table for Alaska streams dataset.



FNODE_	3
TNODE_	1
LPOLY_	0
RPOLY_	0
LENGTH	724.97474683100
REGION20_S	1
REGION20_1	53815
FLOW_ACC	53815
GRID_CODE	90
PFAF_NUM	1320
PF_TYPE	3
AVG_RAIN	8.5
AVG_ELEV	367.9
AVG_PRECIP	100.2
TRUEFLOW_A	53815
T_ELEV	572
F_ELEV	2017
GRADIENT	1.993
AREA_IN	50644
RAIN_IN	8.5
ELEV_IN	381.9
PRECIP_IN	101.3
ELEV_MAX	31726
WIND_LEE	1
ELEV_RANGE	1021.85
ELEV_RAN_1	974.46
DOWN_AREA_	2.08
UP_AREA_MI	1.95
Q_UP_CFS	2.63
Q_DOWN_CFS	2.78
HEAD_FT	47.41
POWER	10.87
CU	20070000
HUC_PFAF	200700001320000
US_ARC	1
DS_ARC	1

Figure 9. Example of attribute table for Hawaii streams dataset.

4. RESULTS

The final product was a series of ARC/INFO datasets that were delivered to the scientists at the INEEL. The Alaska dataset contained almost 173,000 stream segments, each with an associated catchment. Hawaii was a much smaller dataset, containing 1,700 stream segments. For both states, tarred export coverages of the EDNA streams and catchment datasets were delivered. In addition, a tarred export coverage of the National Hydrography Dataset for each state was provided to the scientists at the INEEL for use in their validation work.

Table 5 details the value-added attributes added to the Alaskan dataset, while Table 6 details the same information for Hawaii. Each stream in the datasets was linked to its catchment through the use of the HUC_PFAF parameter.

Table 5. Value-added attributes found in the Alaskan streams dataset.

Attribute	Description	Units
Area_in	Drainage area above the from-node of the stream segment	Pixels
Area_sqmi_down	Area of the drainage basin upstream of the pour point of the stream. Calculated by: Area_sqmi_up = Trueflow_acc ∗ 3600 / 2,589,988	Square miles
Area_sqmi_up	Area of the drainage basin upstream of the from-node of the stream. Calculated by: Area_sqmi_up = Area_in ∗ 3600 / 2,589,988	Square miles
Avg_precip	Average annual precipitation of the drainage area above the pour point of the stream	Inches
CU	Cataloging Unit of the stream segment	N/A
F_elev	Elevation of the from-node of the stream segment	Centimeters
Gradient	Slope of the stream segment calculated using rise over run. Rise is determined by differencing the F_elev and T_elev elevation values. The run is taken from the length attribute.	Percent
Head_ft	Difference in elevation between the from-node and the to-node of the stream. Calculated as: Head_ft = [(f_elev – t_elev) / 100] ∗ 3.280883	Feet
Huc_pfaf	Unique number linking the stream segment with its associated catchment. Developed by concatenating the CU number with the Pfaf_num	N/A
Length	Length of the stream segment from the from-node to the to-node.	Meters
Pf_type	Local Pfafstetter stream type of the segment	N/A
Pfaf_num	Local Pfafstetter code of the stream	N/A
Power	Mean power potential of the reach. Calculated using the average streamflow along the reach as: Power = [(q_mean_cfs_up + q_mean_cfs_down)/2] ∗ head_ft / 11.8	Kilowatts
Precip_in	Average annual precipitation of the drainage area above the from-node of the stream	Inches
Q_mean_cfs_down	Mean annual streamflow at the pour point of the stream	Cubic feet per second
Q_mean_cfs_up	Mean annual streamflow at the from-node of the stream	Cubic feet per second
T_elev	Elevation of the to-node of the stream segment	Centimeters
Trueflow_acc	Drainage area above the pour point of the stream segment	Pixels

Table 6. Value-added attributes found in the Hawaiian streams dataset.

Attribute	Description	Units
Area_in	Drainage area above the from-node of the stream segment	Pixels
Avg_elev	Average elevation for the drainage basin above the pour point of the stream	Feet
Avg_precip	Average annual precipitation of the drainage area above the pour point of the stream	Inches
Avg_rain	Average precipitation intensity for the drainage basin above the pour point of the stream	Inches
CU	Cataloging Unit of the stream segment	N/A
Down_area_mi	Area of the drainage basin above the pour point of the stream segment	Square miles
Elev_in	Average elevation for the drainage basin above the from-node of the stream	Feet
Elev_max	Maximum elevation of the drainage basin above the pour point of the stream	Feet
Elev_range	Range of elevations found in the drainage basin above the pour point of the stream segment.	Feet
Elev_range_up	Range of elevations found in the drainage basin above the from-node of the stream segment.	Feet
F_elev	Elevation of the from-node of the stream segment	Centimeters
Gradient	Slope of the stream segment calculated using rise over run. Rise is determined by differencing the F_elev and T_elev elevation values. The run is taken from the length attribute.	Percent
Head_ft	Difference in elevation between the from-node and the to-node of the stream. Calculated as: Head_ft = [(f_elev – t_elev) / 100] ∗ 3.280883	Feet
Huc_pfaf	Unique number linking the stream segment with its associated catchment. Developed by concatenating the CU number with the Pfaf_num	N/A
Length	Length of the stream segment from the from-node to the to-node.	Meters
Pf_type	Local Pfafstetter stream type of the segment	N/A
Pfaf_num	Local Pfafstetter code of the stream	N/A
Power	Mean power potential of the reach. Calculated using the average streamflow along the reach as: Power = [(q_up_cfs + q_down_cfs)/2] ∗ head_ft / 11.8	Kilowatts
Precip_in	Average annual precipitation of the drainage area above the from-node of the stream	Inches
Q_down_cfs	Mean annual streamflow at the pour point of the stream	Cubic feet per second
Q_up_cfs	Mean annual streamflow at the from-node of the stream	Cubic feet per second

Table 6. (continued).

Attribute	Description	Units
Rain_in	Average precipitation intensity for the drainage basin above the from-node of the stream	Inches
T_elev	Elevation of the to-node of the stream segment	Centimeters
Trueflow_acc	Drainage area above the pour point of the stream segment	Pixels
Up_area_mi	Area of the drainage basin above the from node of the stream segment	Square miles
Wind_lee	Windward/Leeward nature of the island. 1 indicates windward.	N/A

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