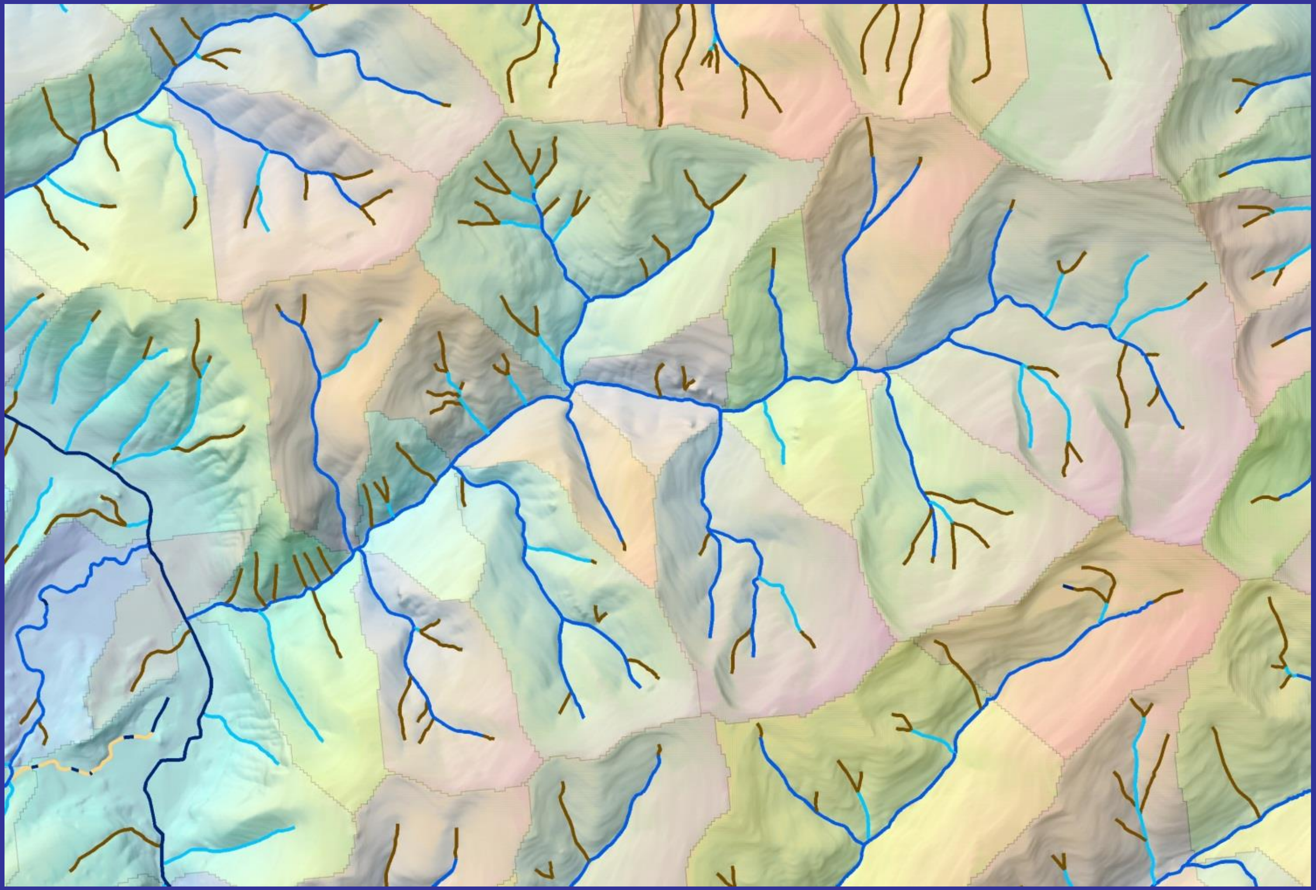
The High Resolution NHDPlus

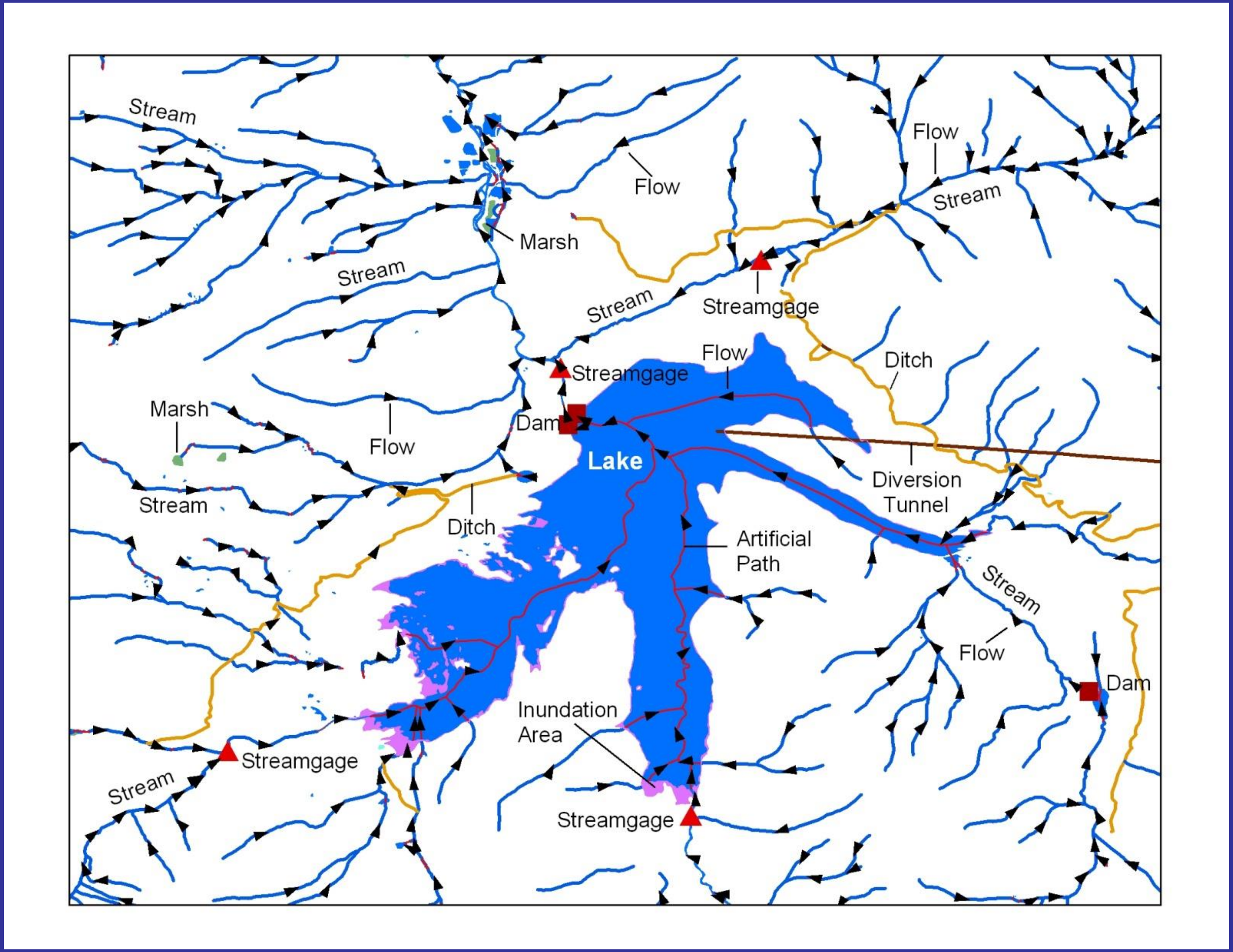


Esri Southwest User Conference
Jeff Simley
U.S. Geological Survey

USGS

What is the National Hydrography Dataset?

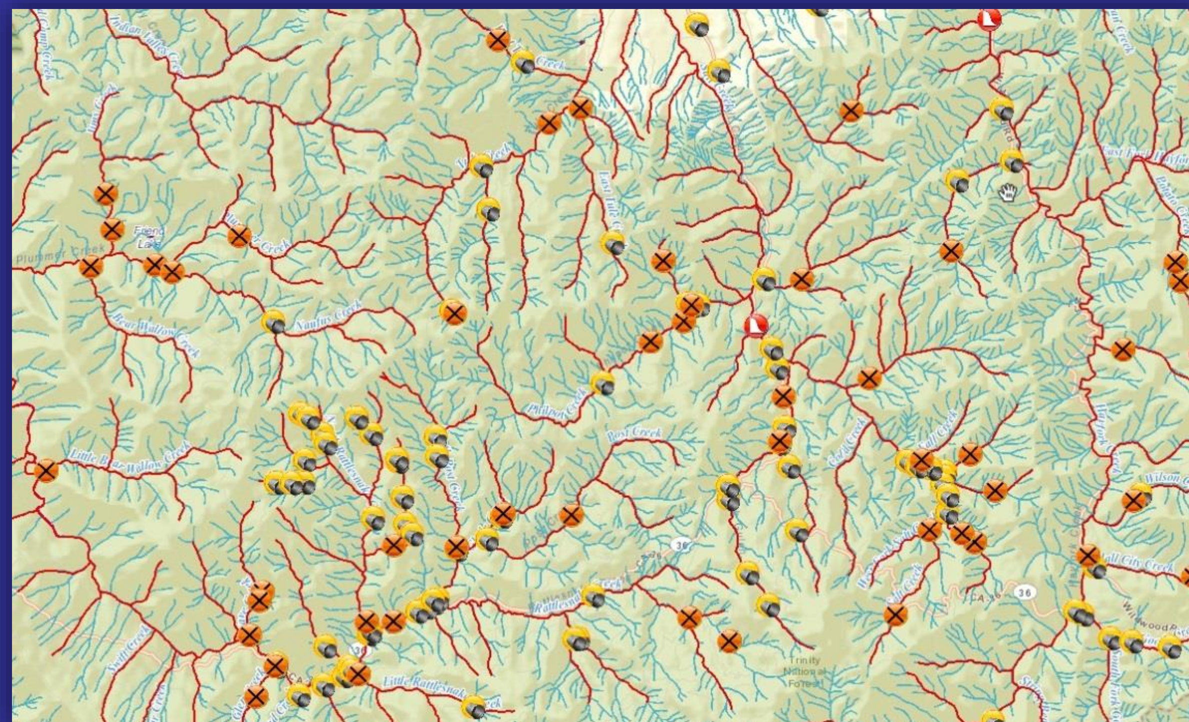
Essentially the surface water features found on topographic maps



USGS

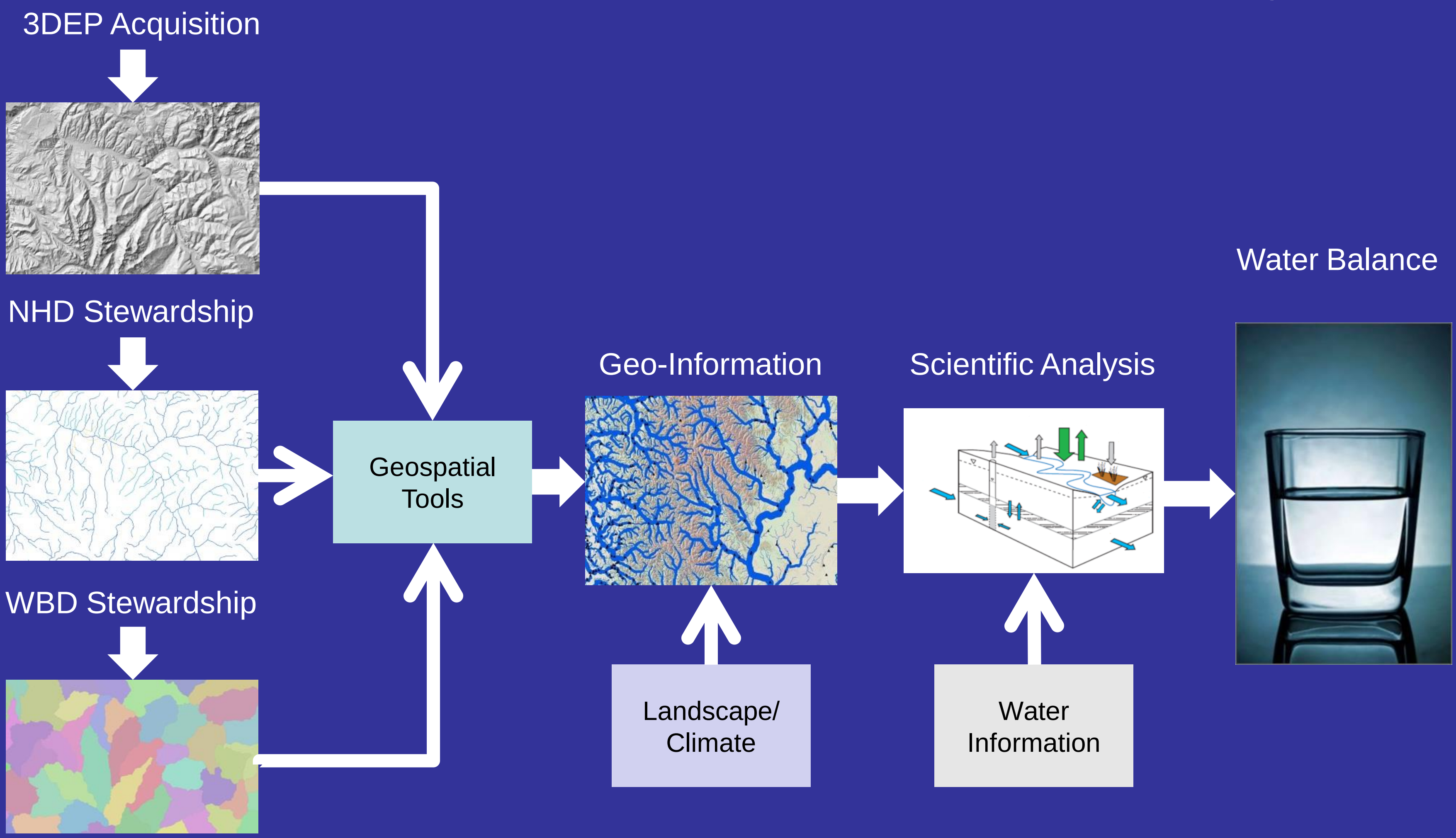
NHD as a framework for a water information system

- U.S. Geological Survey - the NHD represents the nation's surface water features and drainage network
- U.S. Forest Service- additional streams and other features provided as NHD stewards
- Environmental Protection Agency – data on impaired waters (red lines)
- U.S. Army Corps of Engineers - dams (red dot)
- U.S. Fish and Wildlife Service - data on streams flowing through culverts (yellow symbols) and waterfalls (orange dots), which were assembled by the State of California

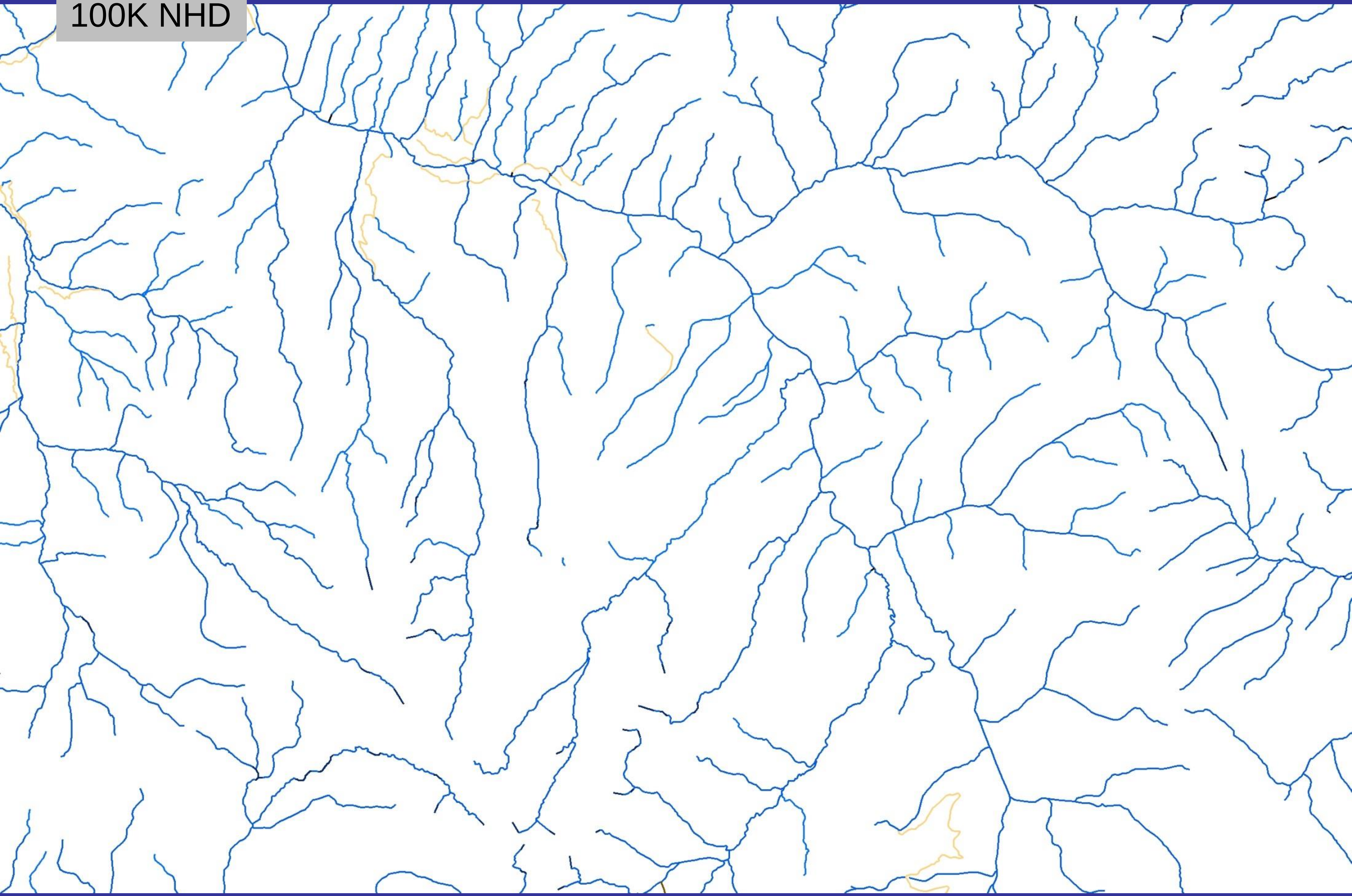


Dams, culverts, and waterfalls can act as barriers to fish passage; the USFWS and others use these data to support studies to improve fish migration to spawning grounds

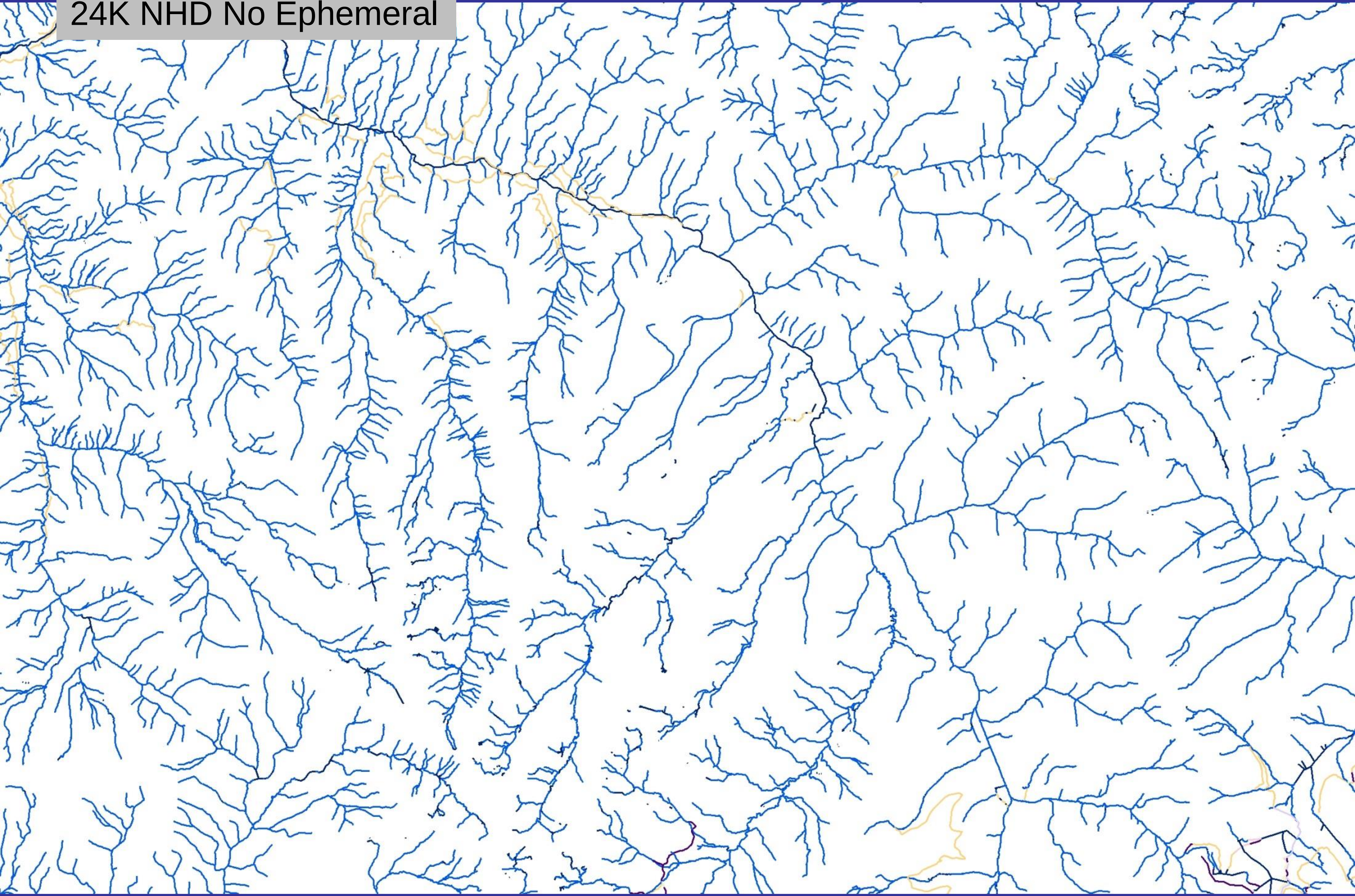
The Role of Geospatial Data in Meeting National Needs for Water Availability



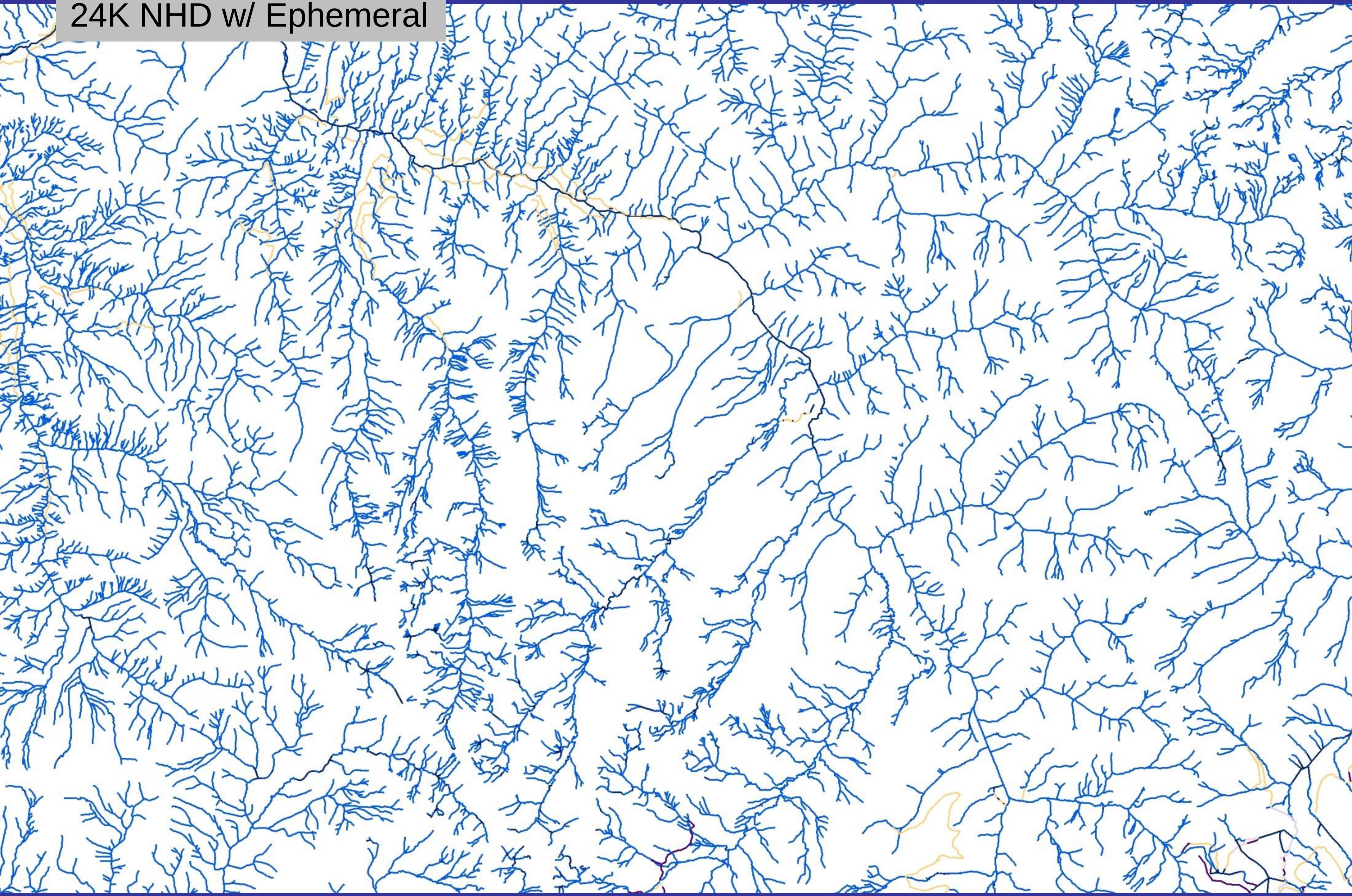
USGS


100K NHD

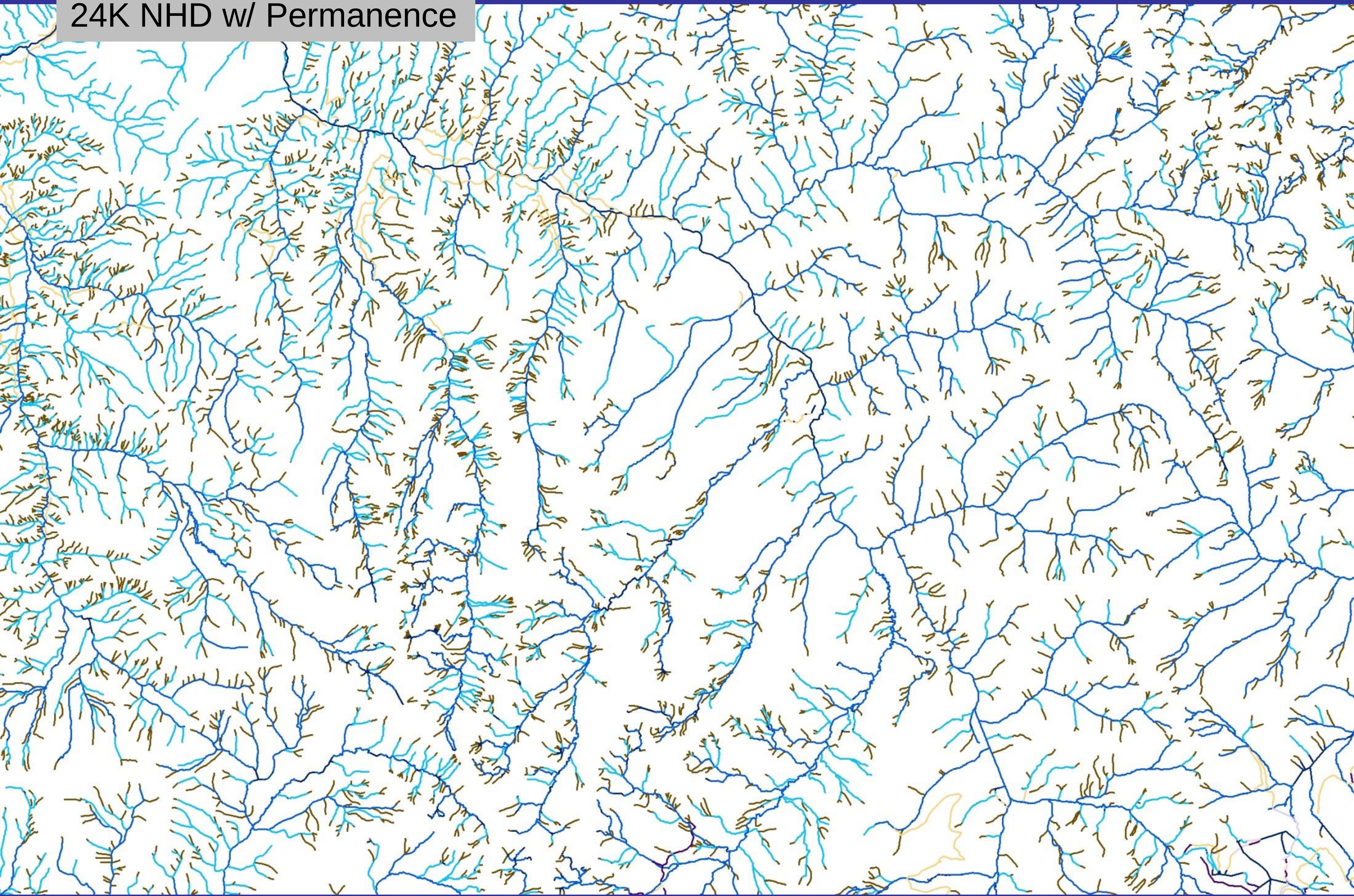
24K NHD No Ephemeral



24K NHD w/ Ephemeral



24K NHD w/ Permanence



USGS
science for a changing world

Ariel Bates[1], Jeff Simley[1], Tommy Dewald[2], Tim Bondelid[3]

Natural Stream Flow Estimates for Washington

Using the NHDPlus Unit Runoff Method

Purpose

This map presents the methodology and results of the NHDPlus Unit Runoff Method (UROM) calculations for modeling natural streamflow in Washington. The map does not represent actual streamflow, but rather modeled streamflow based on the UROM model. The intent of the map is to show the characteristics of Washington's drainage network and how the tributary system converges into larger and larger arteries to form the major rivers that drain the state. By reviewing this drainage pattern it is possible to better understand Washington's drainage.

The Map

The stream lines come from NHDPlus, a joint U.S. Environmental Protection Agency (USEPA)-U.S. Geological Survey (USGS) program to develop enhancements to the 1:100,000-scale National Hydrography Dataset. The line weights represent ranges in mean annual streamflow measured in cubic feet per second (cfs). Streams with a UROM streamflow less than 1.0 cfs are not shown. This eliminates approximately half of the 1:100,000-scale streams from being shown and results in good map clarity at the map scale of 1:767,000 (as shown).

NHDPlus

NHDPlus is an integrated suite of application-ready geospatial data sets that incorporates many of the best features of the National Hydrography Dataset (NHD), and National Elevation Dataset (NED). NHDPlus includes a stream network based on the medium resolution NHD, improved networking, name attributes, and "value-added attributes" (VAA's) providing additional flowline characteristics. Flowlines are the basic linear hydrologic features in the NHD, such as streams, rivers, etc. NHDPlus also includes elevation-derived catchments (flowline-based drainage areas) produced using a drainage enforcement technique dubbed "The New-England Method". This technique modifies the National Elevation Dataset (NED) by "burning-in" the 1:100,000-scale NHD, and when available, building "walls" using the national Watershed Boundary Dataset (WBD). The resulting modified Digital Elevation Model (DEM) is used to produce hydrologic derivatives that agree with the NHD and WBD. Over two years an interdisciplinary team from the USGS and USEPA found this method to produce the best quality catchments feasible in a relatively short time frame.

Unit Runoff Method

The UROM stream flow estimates are calculated using flowline catchment areas and unit runoff (cfs/km^2) values from associated 8-digit hydrologic subbasins. The USGS streamgages in the Hydro Climatic Data Network (HCDN) were selected for developing the unit runoff values because they represent relatively natural hydrologic conditions and are not influenced by controlled releases from reservoirs. Further, only gages with a drainage area less than the drainage area of the subbasin where the gage is located were selected so that the discharge data represents runoff for only that subbasin. For example, a gage on the Mississippi River at St. Louis would not be representative of the unit runoff from that subbasin. At the national level, a total of 1,338 HCDN gages were selected for this dataset.

UROM Calculations

Using streamflow data from the selected gages, mean annual and mean summer unit runoffs (ft^3/sec/km^2) were calculated for each subbasin. The nearest HCDN gages were identified using a 200-mile maximum search radius from the centroid of a subbasin. In most subbasins, five gages were selected but some had fewer than five within the 200-mile search radius. Mean annual and mean summer unit runoffs for each subbasin were calculated using a weighted-average technique based on the square of the distance of the selected HCDN gages from the centroid of the subbasin. The computations are defined as follows:

$$Q_{CU\_MA} = \Sigma(Q_{HCDN\_MA} \times 1/D^2_{CU\_HCDN})/\Sigma(1/D^2_{CU\_HCDN})$$

Where

Q_{CU_MA} = estimated mean annual unit discharge for the 8-digit Subbasin of interest,

Q_{HCDN_MA} = mean annual unit discharge for the selected HCDN gage,

$D^2_{CU\_HCDN}$ = square of distance from the selected HCDN gage to the centroid of the 8-digit Subbasin of interest.

Flows for each NHDPlus flowline were then calculated as follows:

IncrFlowU is the incremental flow at the bottom of flowline, computed as:

$$IncrFlowU = A * CU\_MA$$

Where

A = Drainage Area of the catchment (km^2), and

CU_MA = Unit Runoff for the 8-digit Subbasin (cfs/ km^2)

The UROM based mean annual flow for each flowline (MAFlowU) is computed as:

$MAFlowU = \sum_{i=1 \text{ to } n} (IncrFlowU_i)$ for each i to n upstream flowline.

UROM Tuning Using Intermittent Flow Adjustment Factors

The UROM was developed as part of the National Water Pollution Control Assesment Model (NWPCAM) (Research Triangle Institute, 2001). For hydrologic regions west of the Mississippi, initial UROM estimates of routed discharge generally were observed to be greater than the HCDN gage flow values. Consequently, for the western hydrologic regions, a method was developed to better relate discharge estimates to observed flow data. The discharge estimates were lowered (tuned) by incorporating only a percentage of the reach-specific runoff for intermittent stream reaches. The method calculates discharge estimates assuming various contributions (e.g., 100, 50, 25, 10, and 1 percent) of the unit runoff for intermittent flowlines. The method proved successful in improving the match between actual gage flows and UROM-based flow estimates and it was employed in the western hydrologic regions in NHDPlus. The best fit is selected based on graphical analyses that compare the UROM flow estimates to the HCDN gage flow data.

Explanation

▲ Stream Gage

Mean Annual Flow (cfs)

1- 25	5001 - 10000
26 - 50	10001 - 25000
51 - 100	25001 - 50000
101 - 500	50001 - 130000
501 - 1000	130001 - 200000
1001 - 5000	200001 - 300000

Scale 1:767,000
Lambert Conformal Conic Projection
Central Meridian -119.50

0 25 50 100
Miles

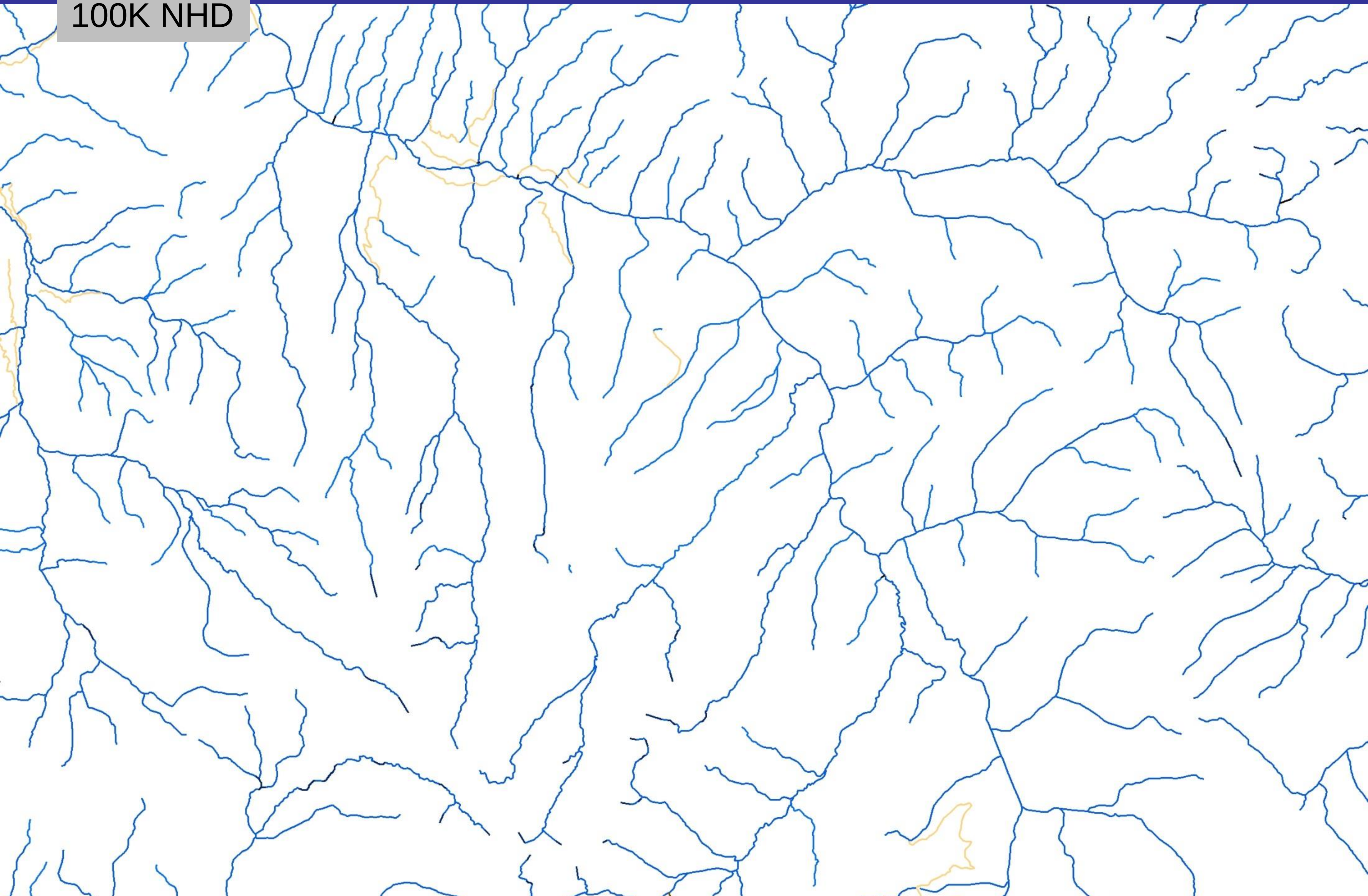
N W E S

Additional Information:
http://www.epa.gov/WATERS
http://nhd.usgs.gov
http://www.horizon-systems.com/nhdplus/
http://pubs.usgs.gov/of/1992/ofr92-129/

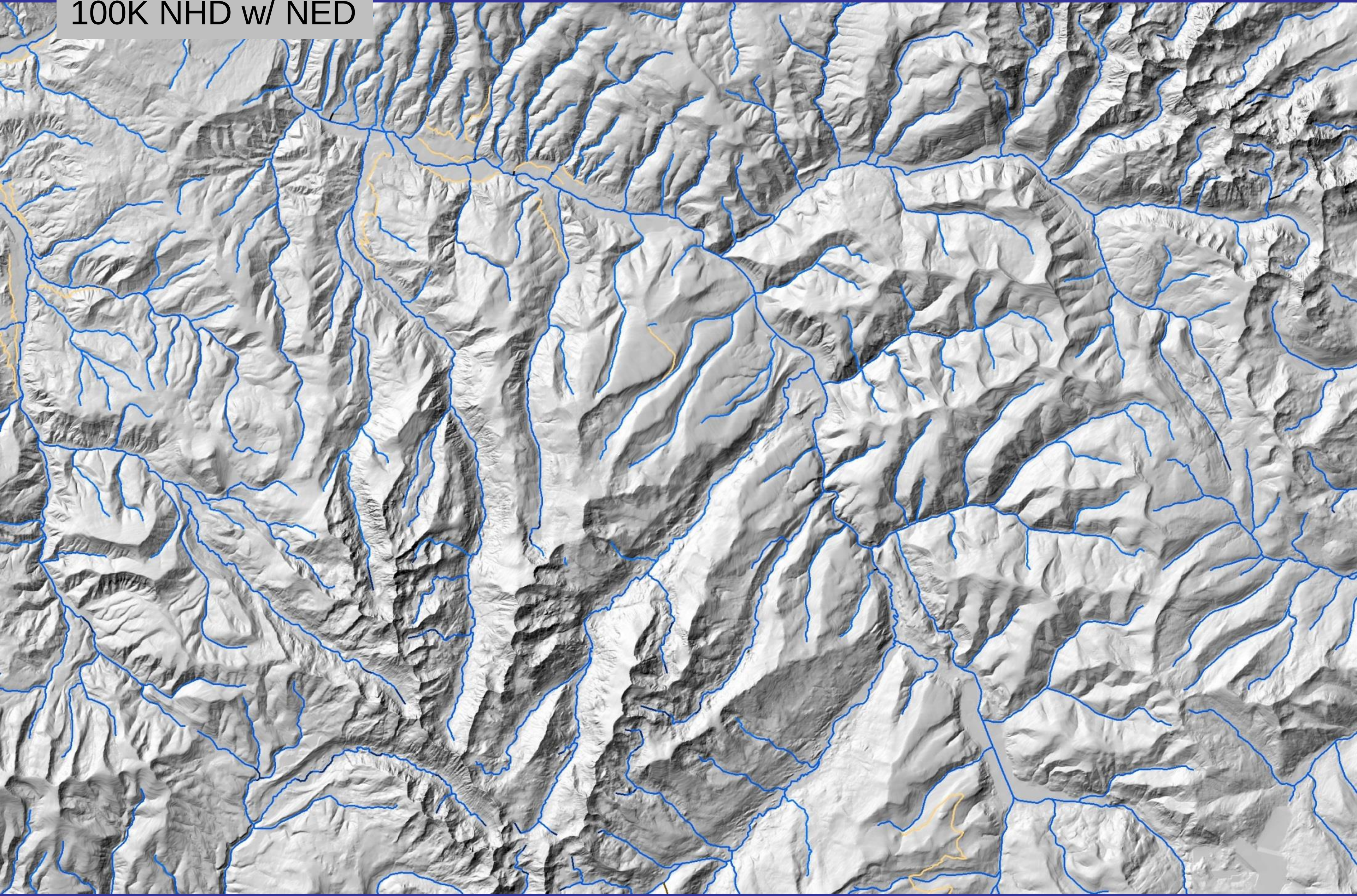
1 U.S. Geological Survey, National Geospatial Programs Office
2 U.S. Environmental Protection Agency, Office of Water
3 U.S. Environmental Protection Agency

Department of the Interior
U.S. Geological Survey

November 2008


100K NHD

100K NHD w/ NED



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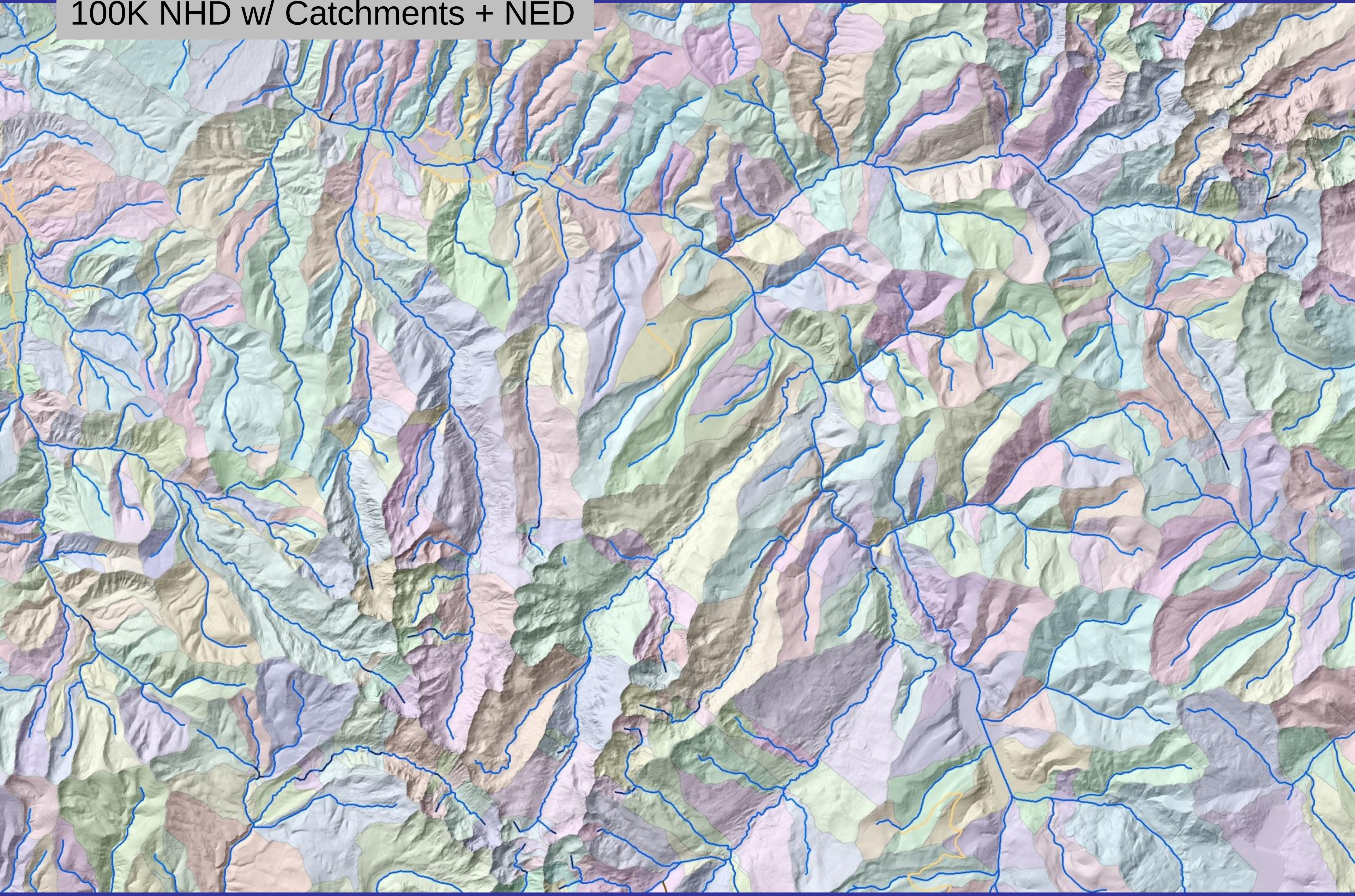
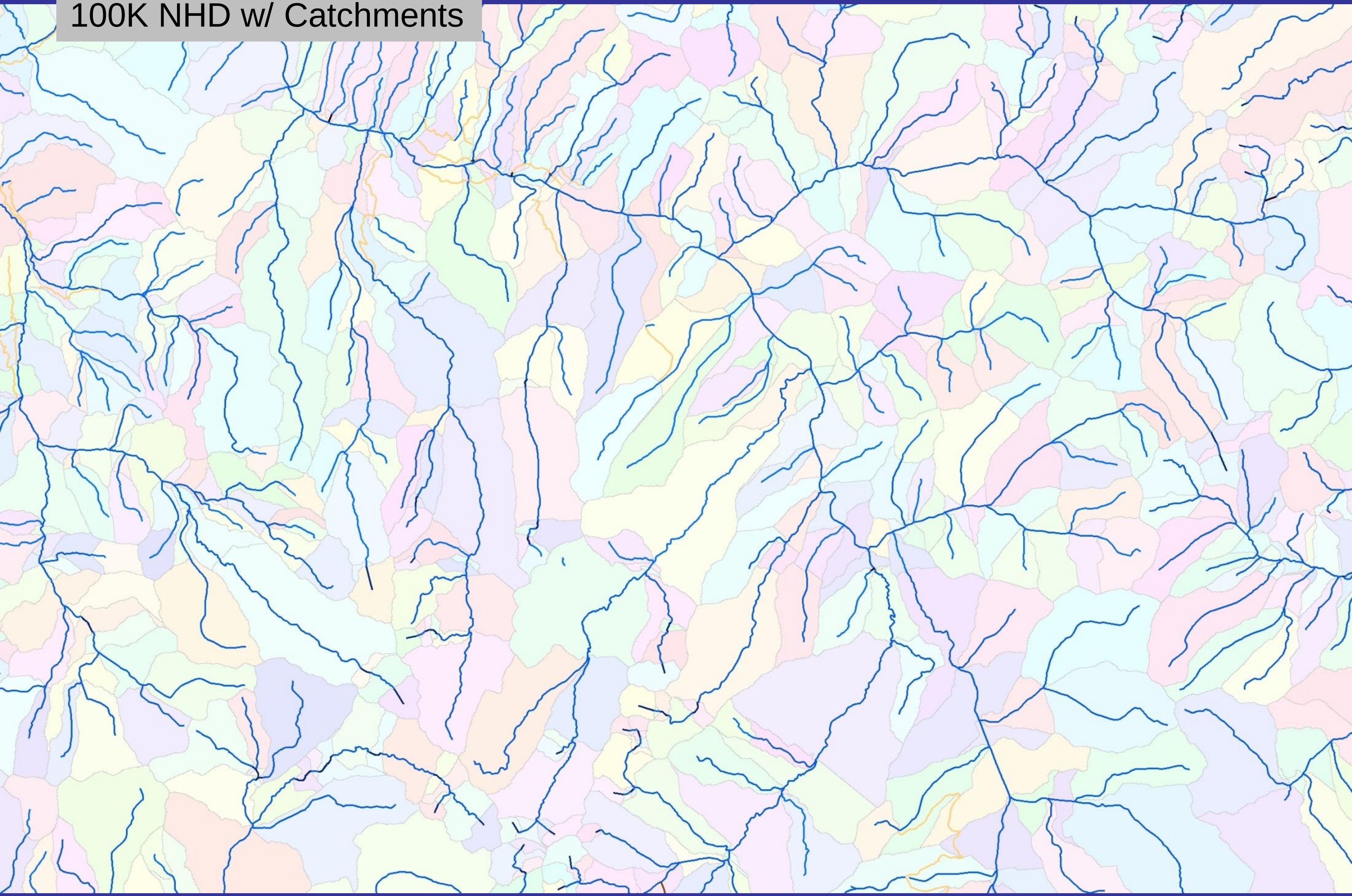
100K NHD w/ Catchments + NED

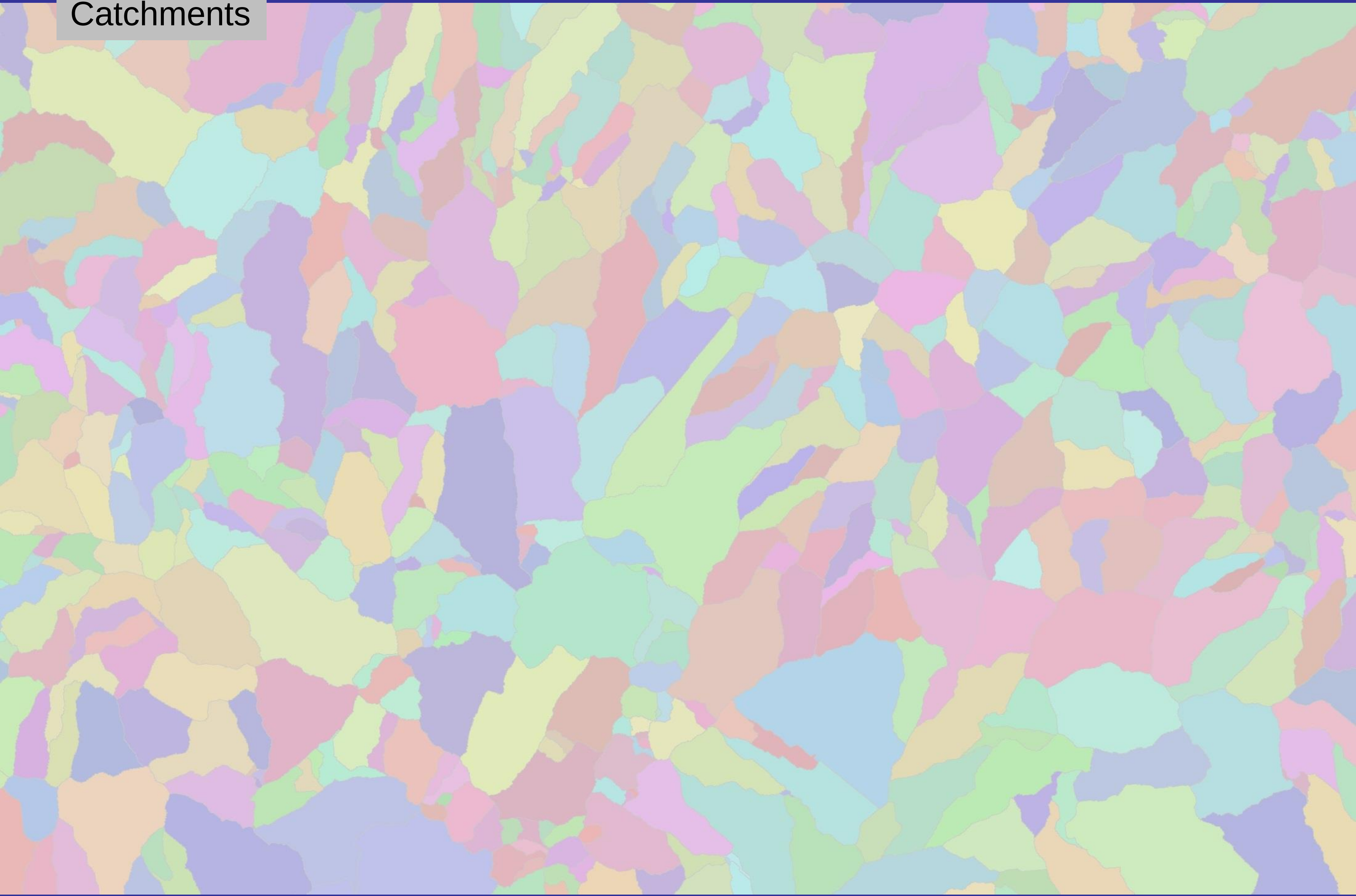


USGS

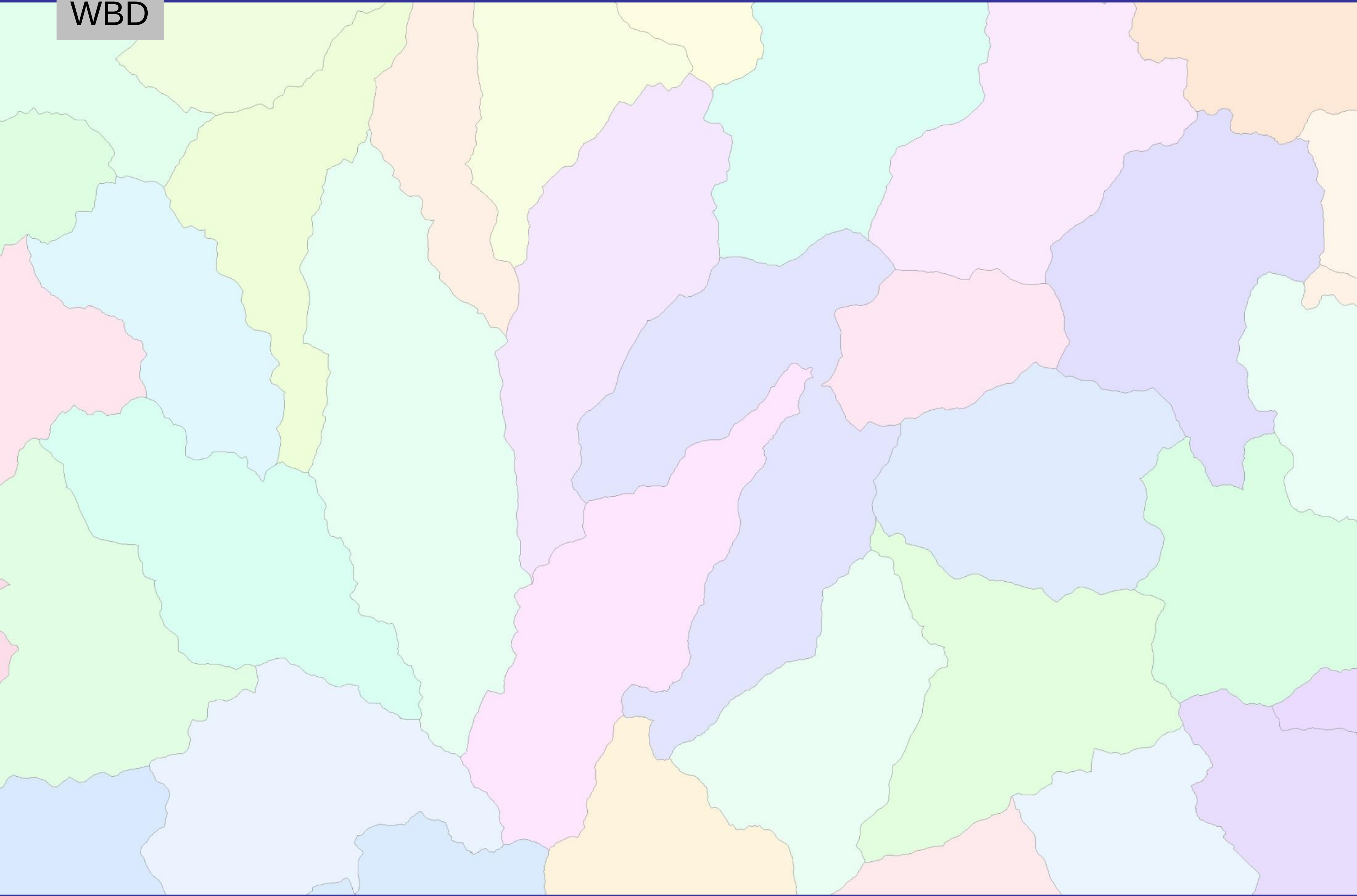
100K NHD w/ Catchments



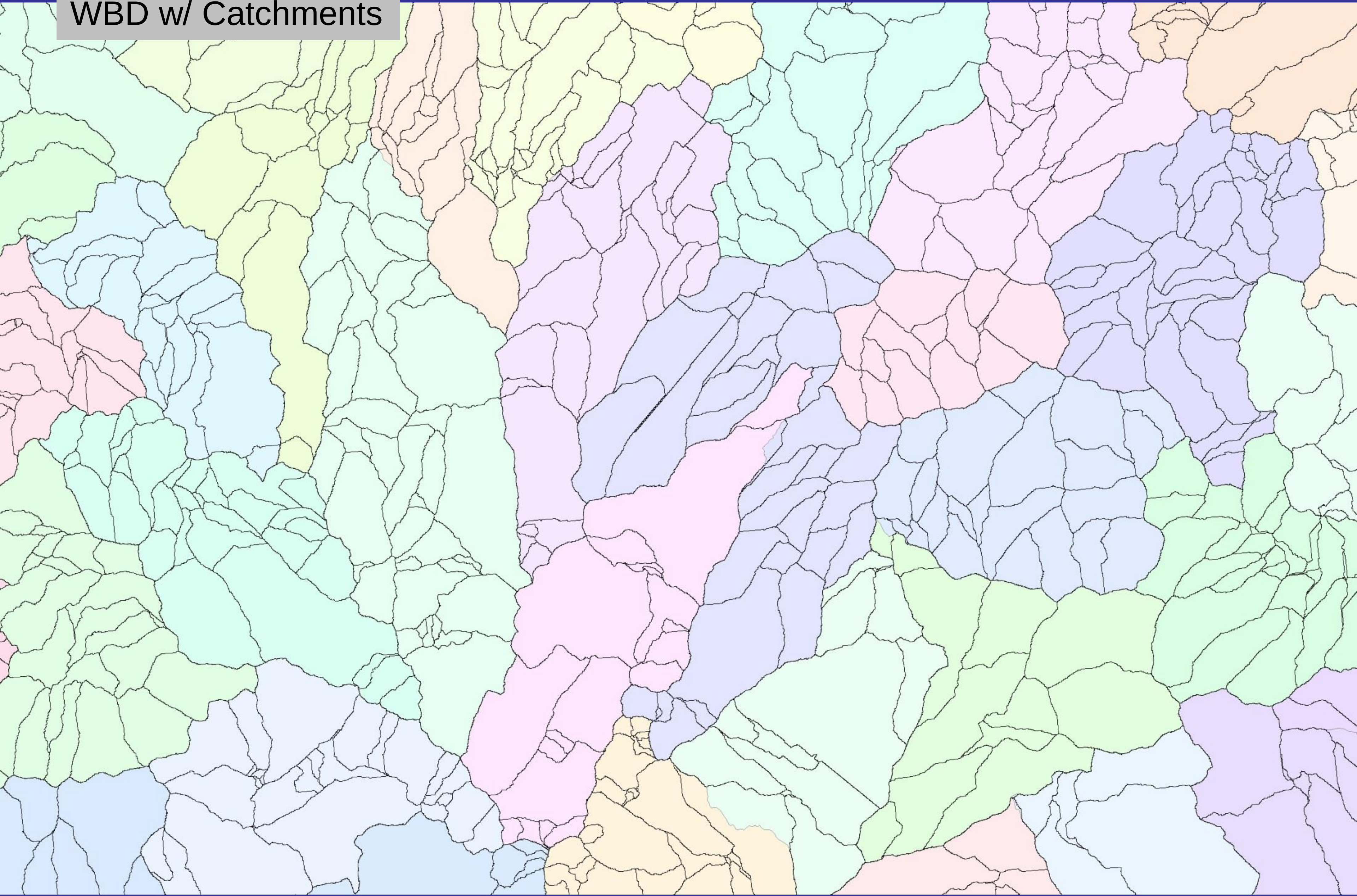
Catchments



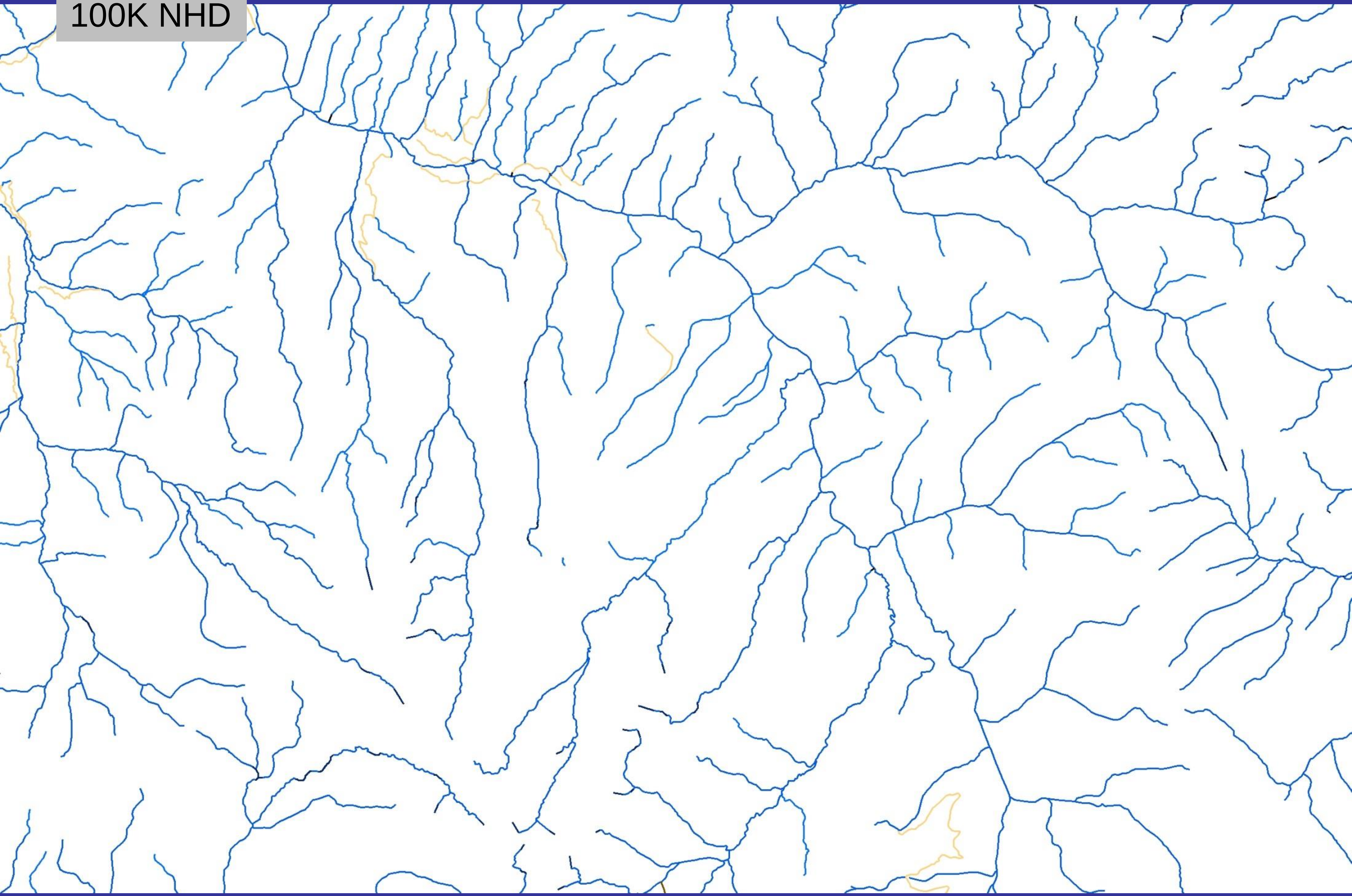
WBD



WBD w/ Catchments

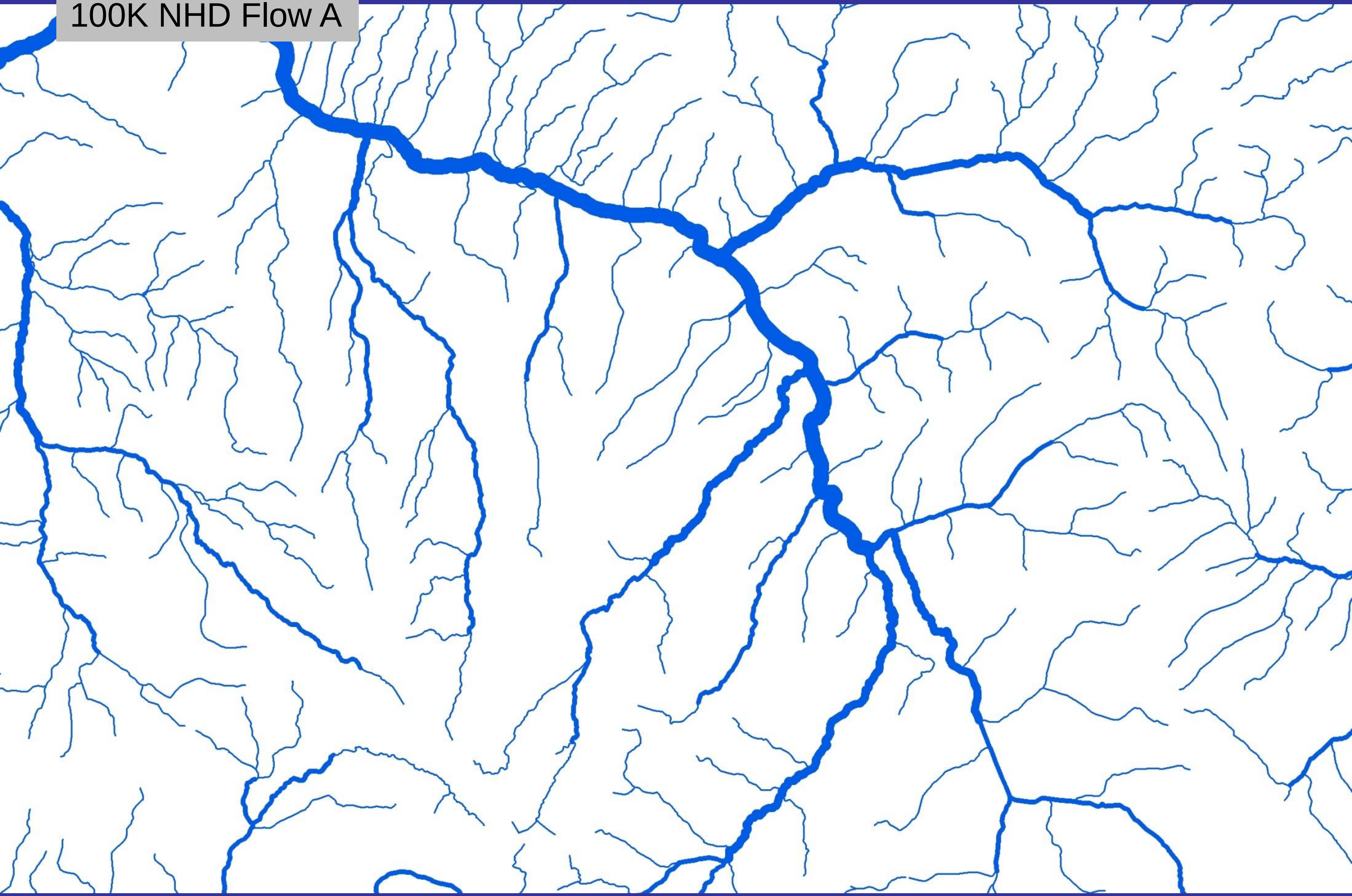


100K NHD



USGS

100K NHD Flow A

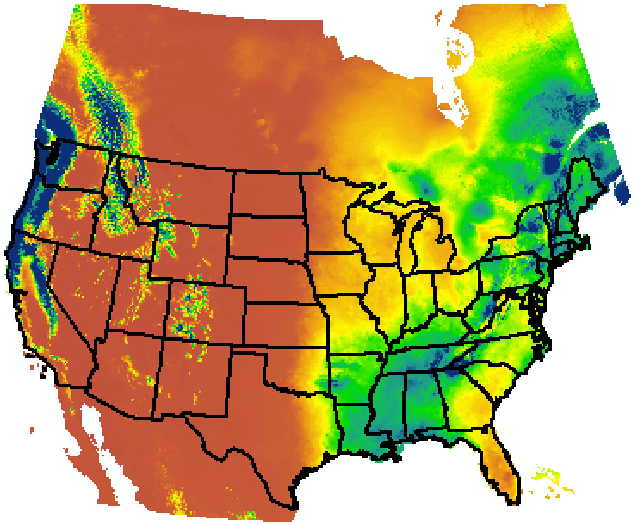


Enhanced Unit Runoff Method (EROM) Flow Estimation

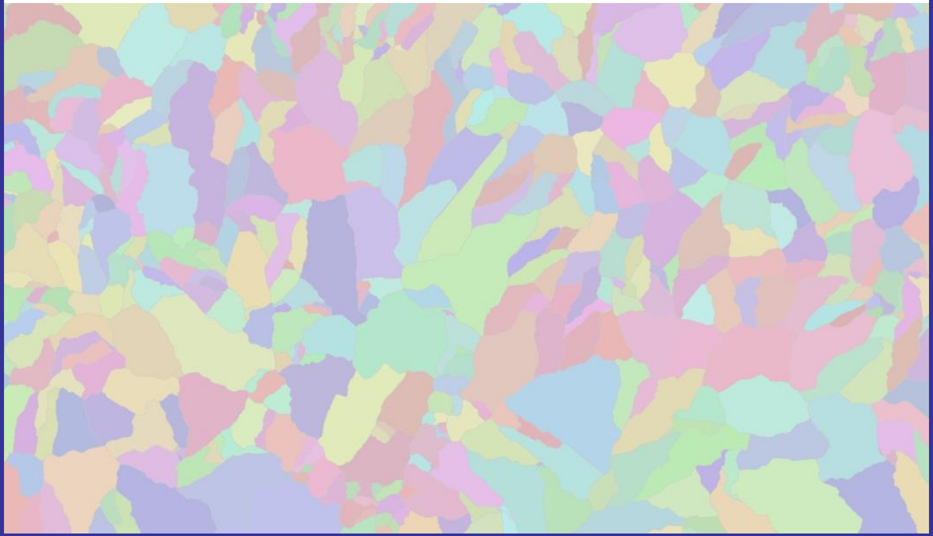
Mean Annual Flow

1. Q0001A – Unit runoff from flow balance model. Uses the mean annual (MA) runoff grids as the baseline runoff values. The water balance approach:
   1. Precipitation
   2. Potential evapotranspiration
   3. Evapotranspiration
   4. Soil moisture storage

Mean Annual Runoff Grid



Intersect with catchments



Enhanced Unit Runoff Method (EROM) Flow Estimation

Mean Annual Flow

1. Q0001A – Unit runoff from flow balance model.
2. Q0001B – Takes "Excess Evapotranspiration" into account. This is streamflow that is "lost." May be 0. Designed to take instream losses into account due to natural hydrologic processes. This loss of instream flow is a significant, observed phenomenon, especially in areas west of the Mississippi River. Was introduced to overcome a major problem in the NHDPlusV1 flow estimates, which tended to over-estimate flows in dry, hot areas.

Enhanced Unit Runoff Method (EROM) Flow Estimation

Mean Annual Flow

1. Q0001A – Unit runoff from flow balance model.
2. Q0001B – Takes excess evapotranspiration into account.
3. Q0001C – Adjust for bias using reference gages. Steps 1 and 2 could fairly consistently under-estimate flows. Based on the knowledge and experience of the USGS hydrologists, it was hypothesized that steps 1 and 2 may "miss" a key part of the natural stream flow, which could produce an underlying negative bias in base flow. Additional analyses using gages that are primarily "natural flow" (known as the "GAGES II Reference Gages") reinforced this point.

Steps 1, 2 and 3 are designed to provide "best estimates" of natural flow.

USGS

Enhanced Unit Runoff Method (EROM) Flow Estimation

Mean Annual Flow

1. Q0001A – Unit runoff from flow balance model.
2. Q0001B – Takes excess evapotranspiration into account.
3. Q0001C – Adjust for bias using reference gages.
4. Q0001D – Adjust for withdrawals, augmentation, and transfers. Table "PlusFlowAR" provides a place for flow additions, removals, and transfers of flow to be taken into account.

Enhanced Unit Runoff Method (EROM) Flow Estimation

Mean Annual Flow

1. Q0001A – Unit runoff from flow balance model.
2. Q0001B – Takes excess evapotranspiration into account.
3. Q0001C – Adjust for bias using reference gages.
4. Q0001D – Adjust for withdrawals, augmentation, and transfers.
5. Q0001E – Adjust streamflow based on observed gaging station data. A way to (1) provide much better flow estimates upstream of gages, and (2) "adjust" flow estimates downstream of gages to better reflect flow alterations not taken into account in the first four steps.

Steps 1 through 5 are designed to provide "best estimates" of streamflow.

USGS

Enhanced Unit Runoff Method (EROM) Flow Estimation

Mean Annual Flow

1. Q0001A – Unit runoff from flow balance model.
2. Q0001B – Takes excess evapotranspiration into account.
3. Q0001C – Adjust for bias using reference gages.
4. Q0001D – Adjust for withdrawals, augmentation, and transfers.
5. Q0001E – Adjust streamflow based on observed gaging station data.
6. Q0001F – Adjust streamflow as in Step 5 but randomly remove 20% of the gages. Running this step multiple times could provide an estimate of how well Step 5 improves the streamflow estimates. These flows are used for QA/QC purposes only and are not as good as the Step 5 streamflows.

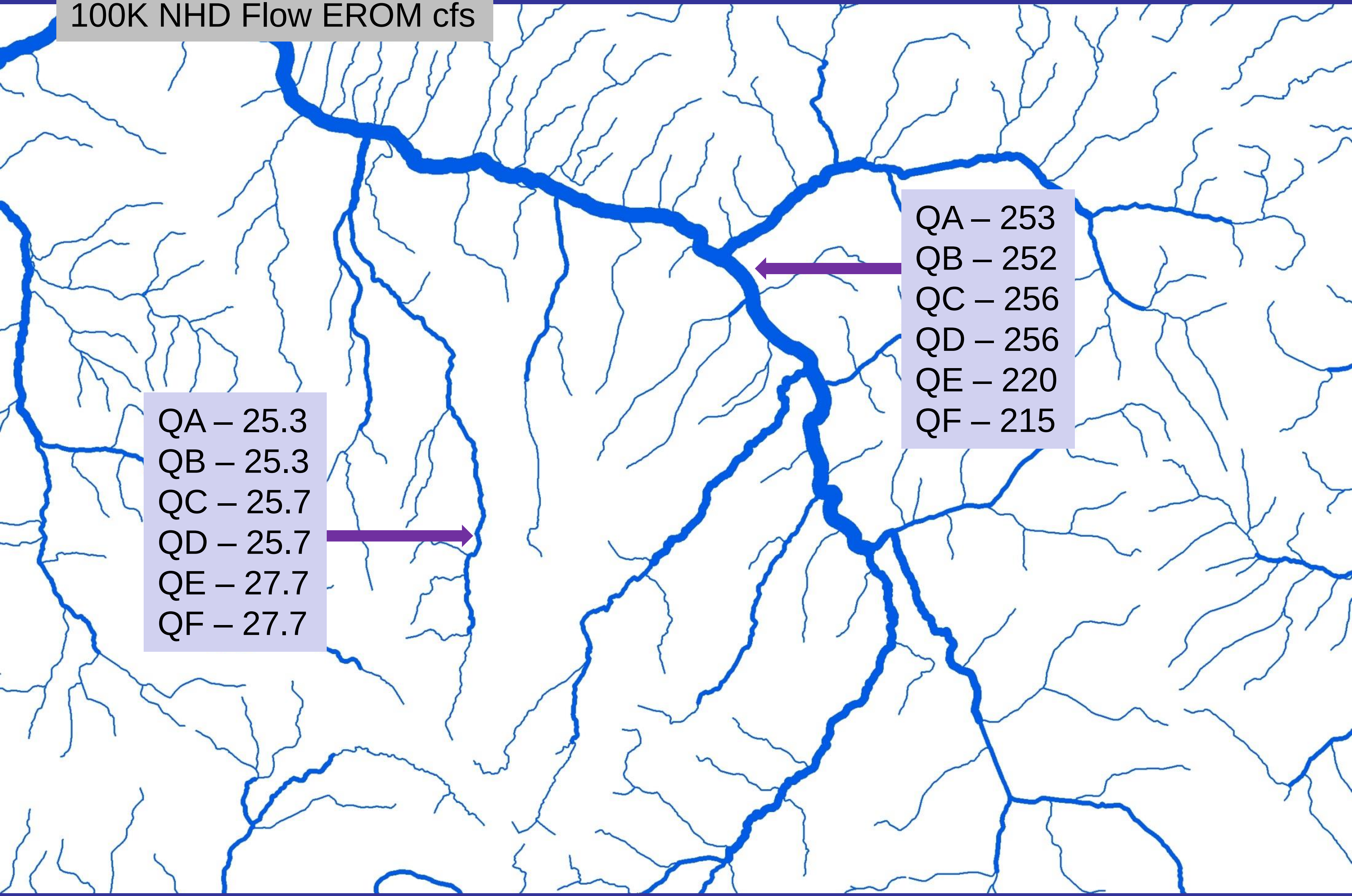
USGS

Enhanced Unit Runoff Method (EROM) Flow Estimation

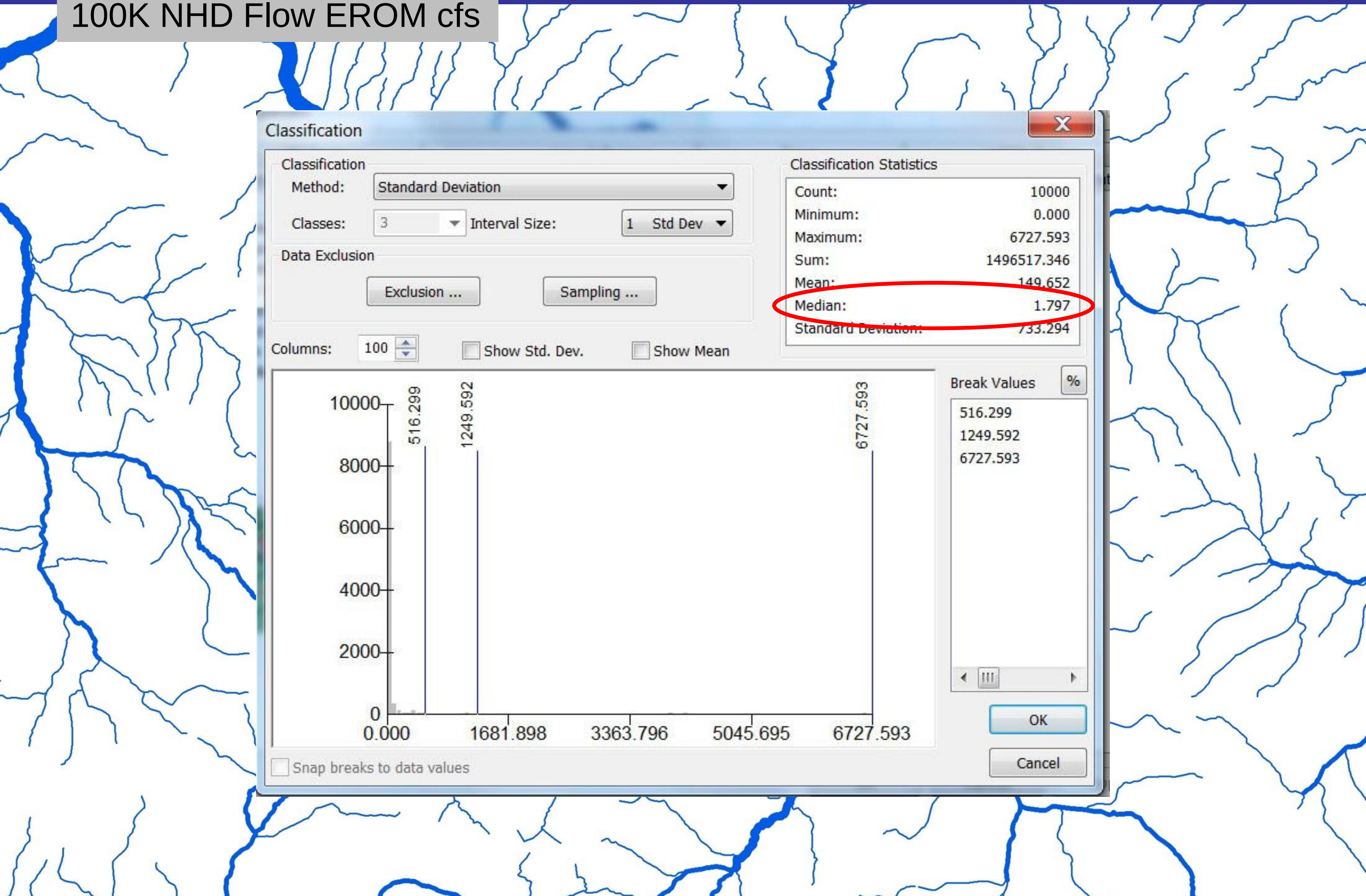
Mean Annual Flow measured in cubic feet per second

1. Q0001A – Unit runoff from flow balance model.
2. Q0001B – Takes excess evapotranspiration into account.
3. Q0001C – Adjust for bias using reference gages.
4. Q0001D – Adjust for withdrawals, augmentation, and transfers.
5. Q0001E – Adjust streamflow based on observed gaging station data.
6. Q0001F – A QA/QC step using a subset of observed gaging station data.

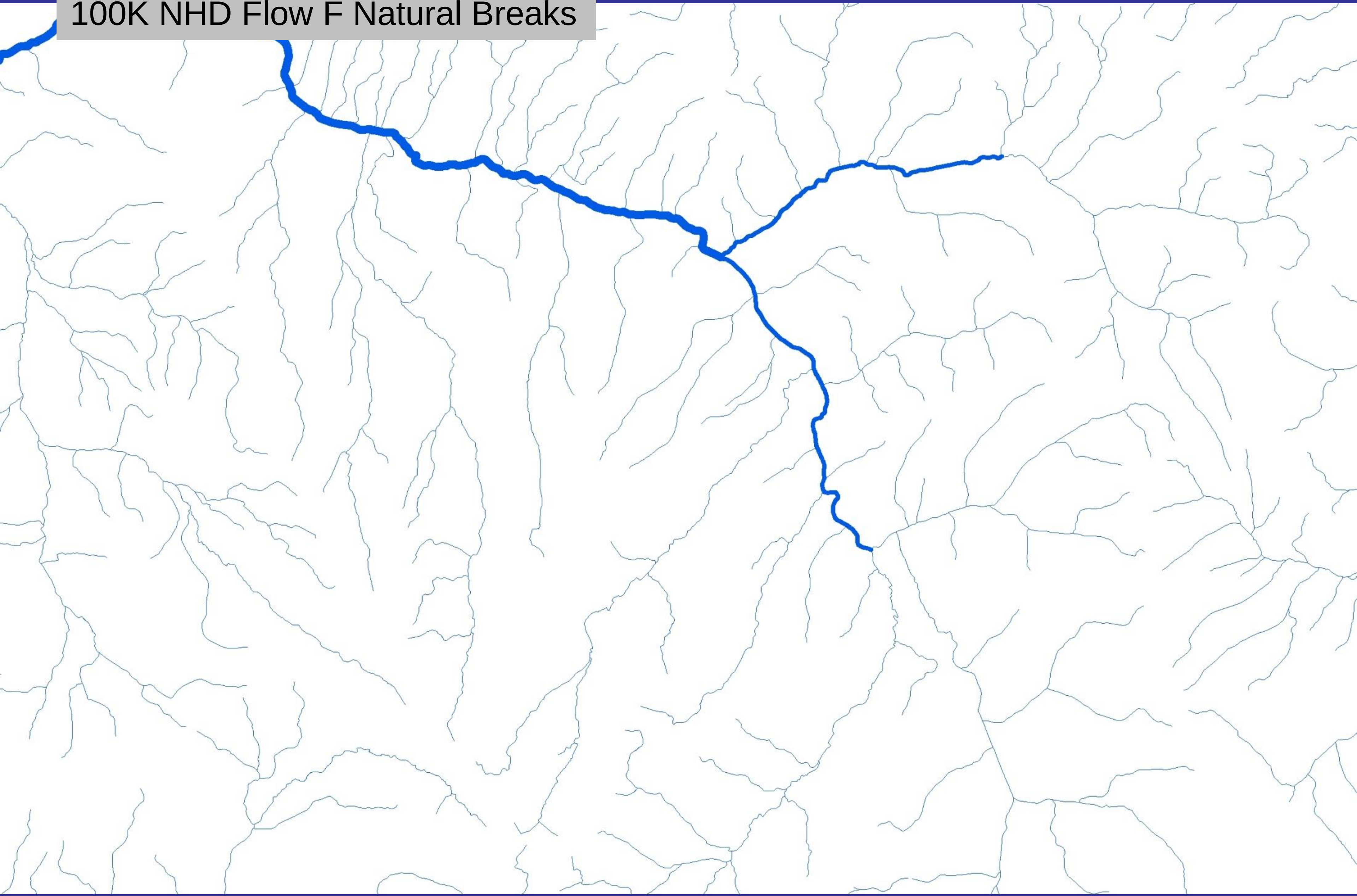
100K NHD Flow EROM cfs



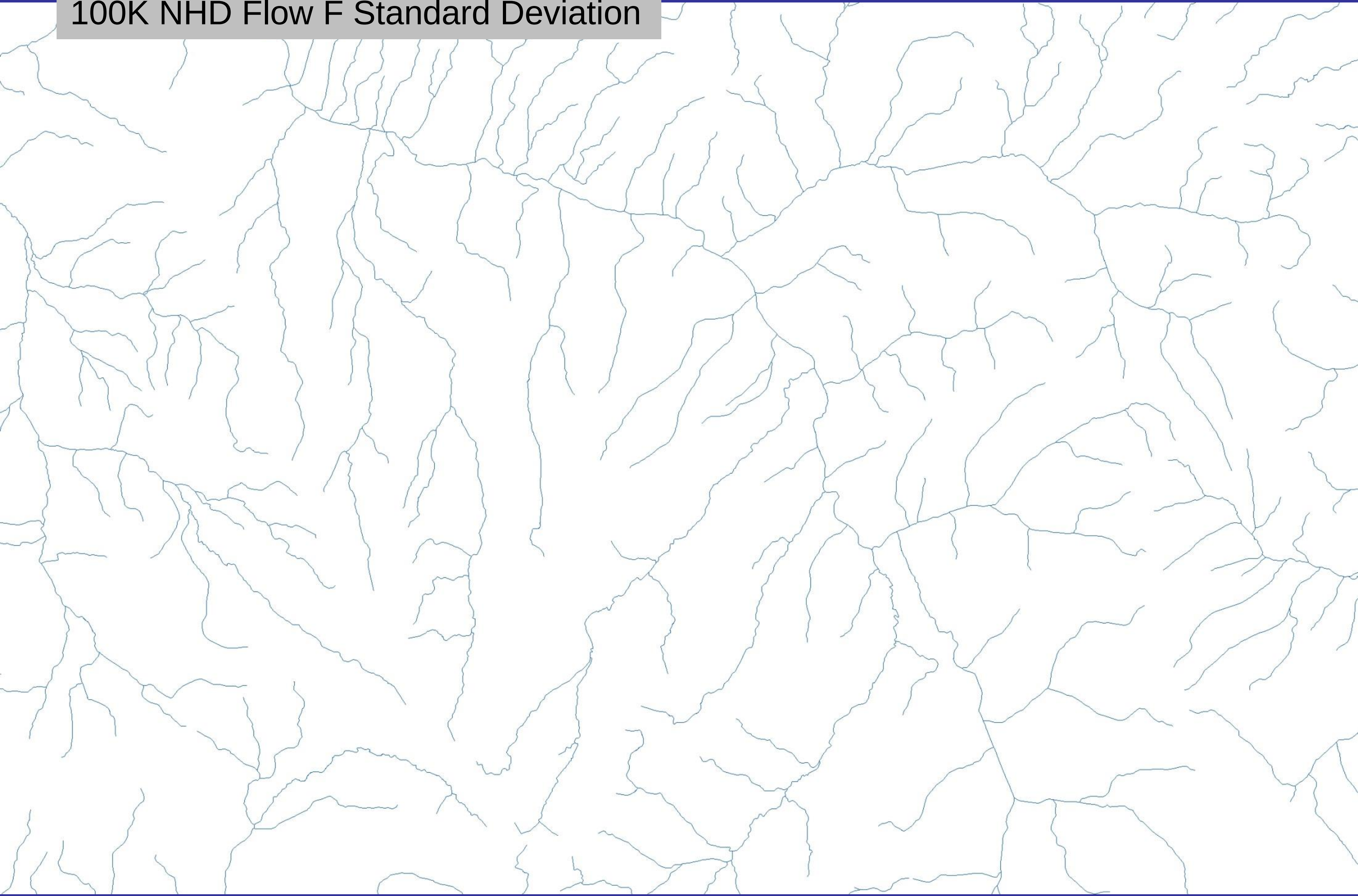
100K NHD Flow EROM cfs



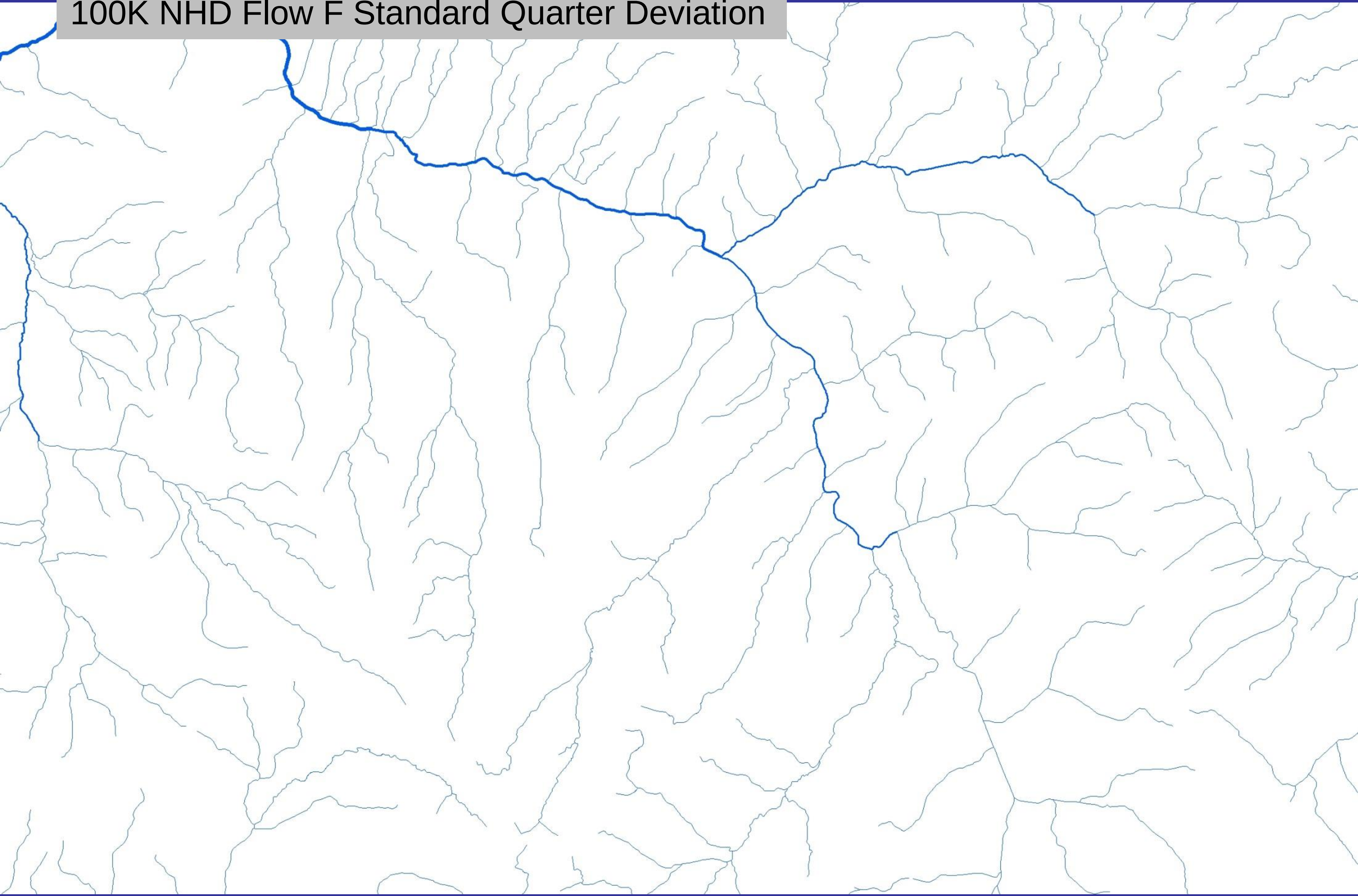
100K NHD Flow F Natural Breaks



100K NHD Flow F Standard Deviation



100K NHD Flow F Standard Quarter Deviation



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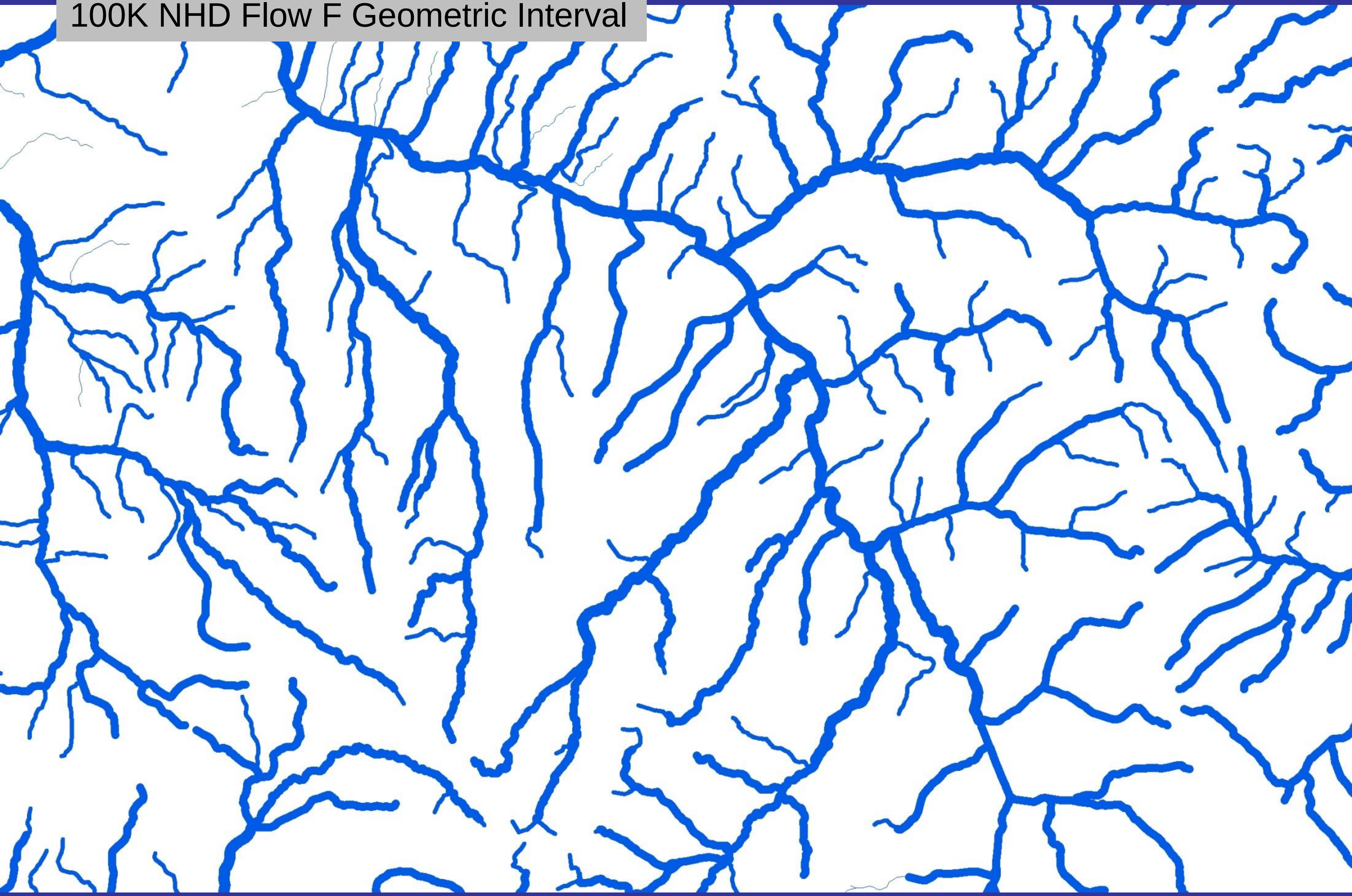
100K NHD Flow F Geometric Interval



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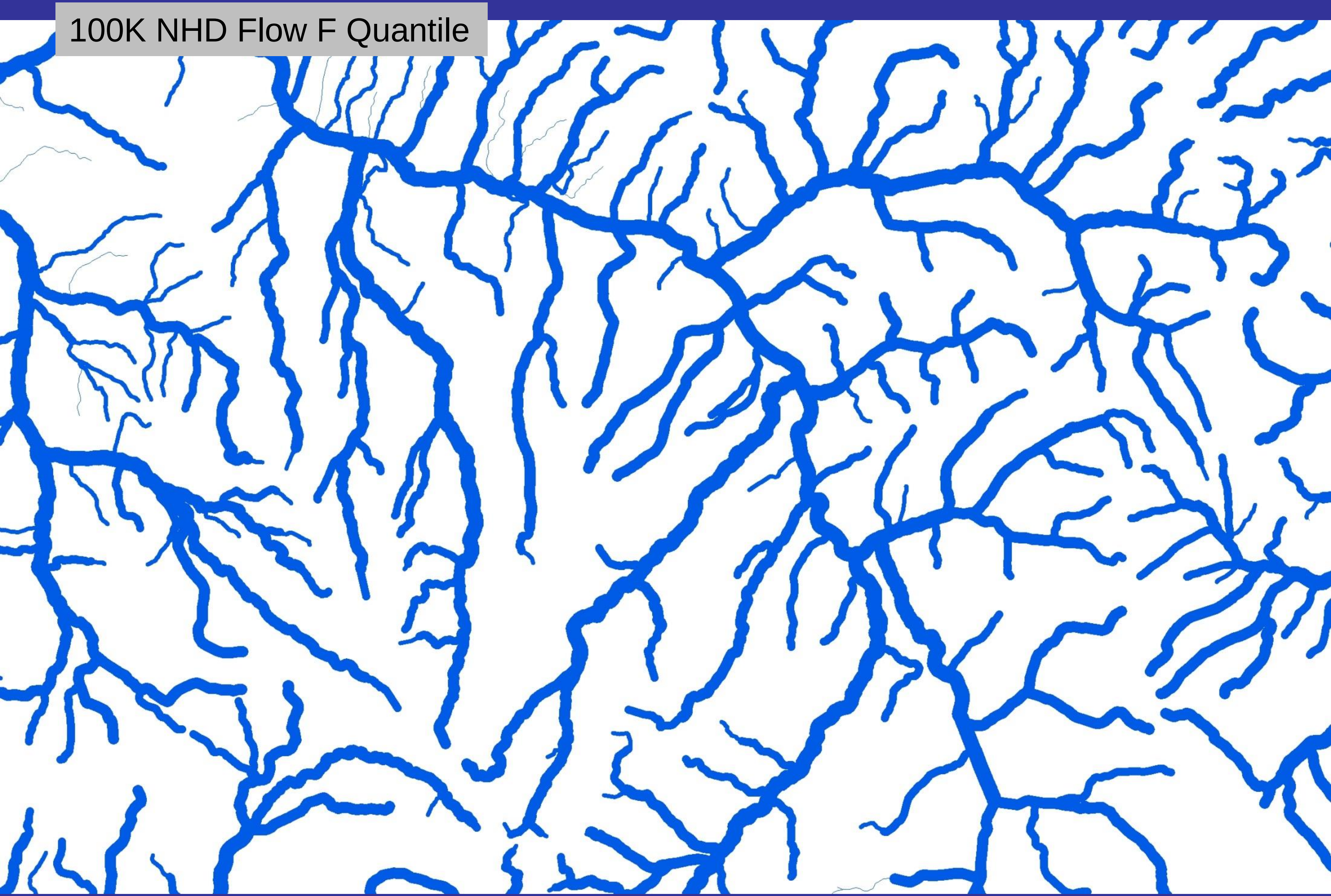
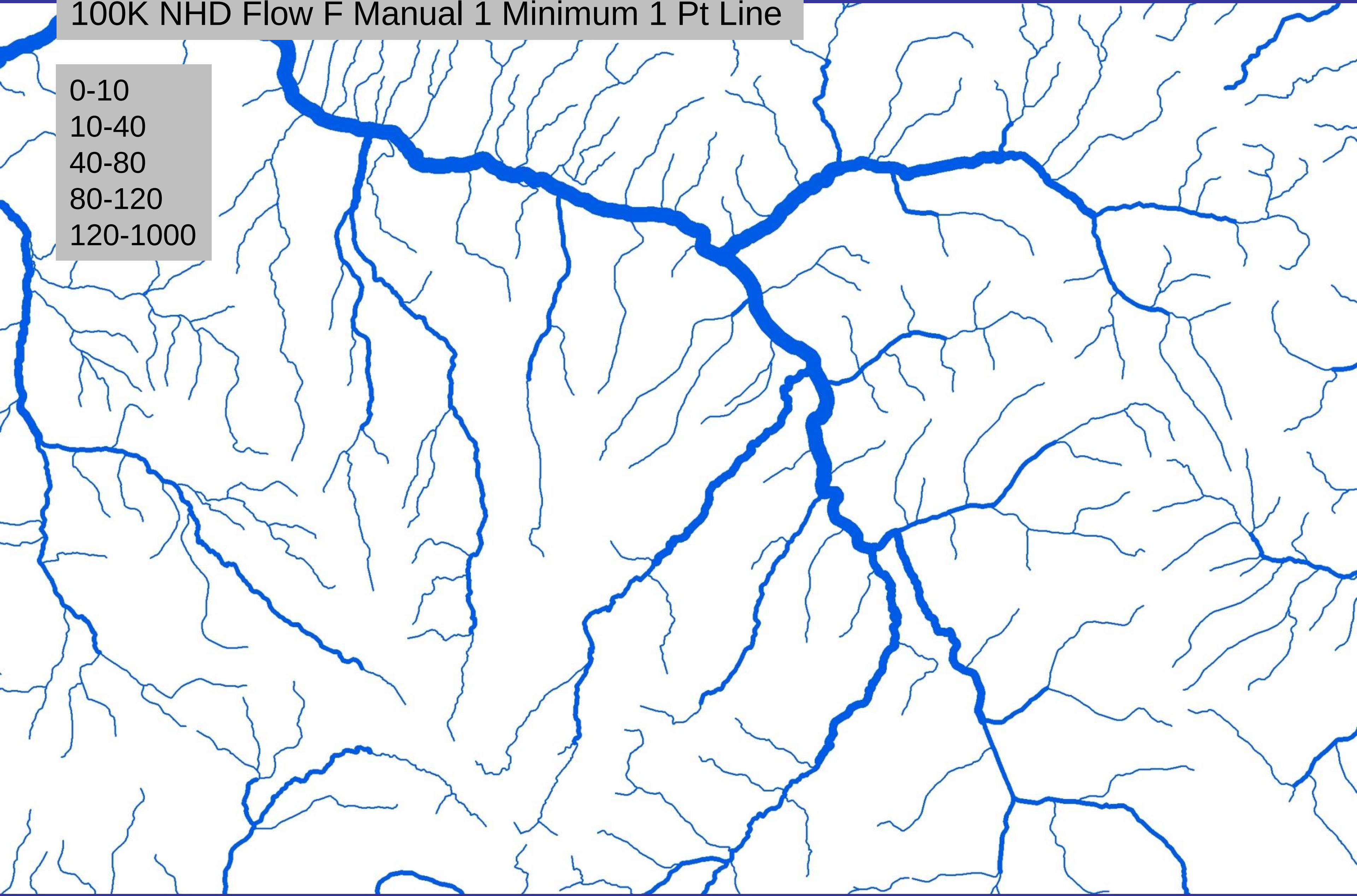
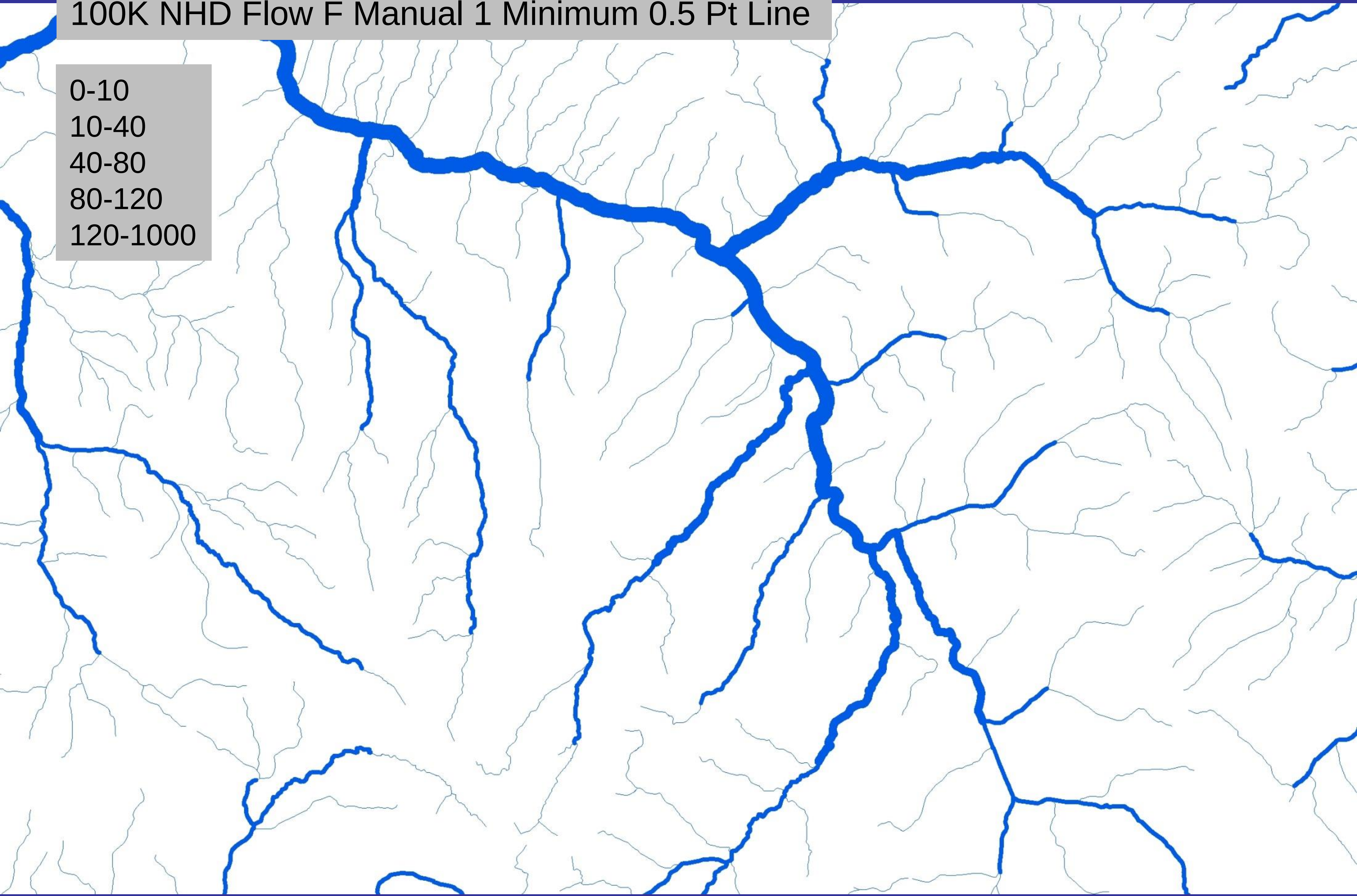

100K NHD Flow F Quantile

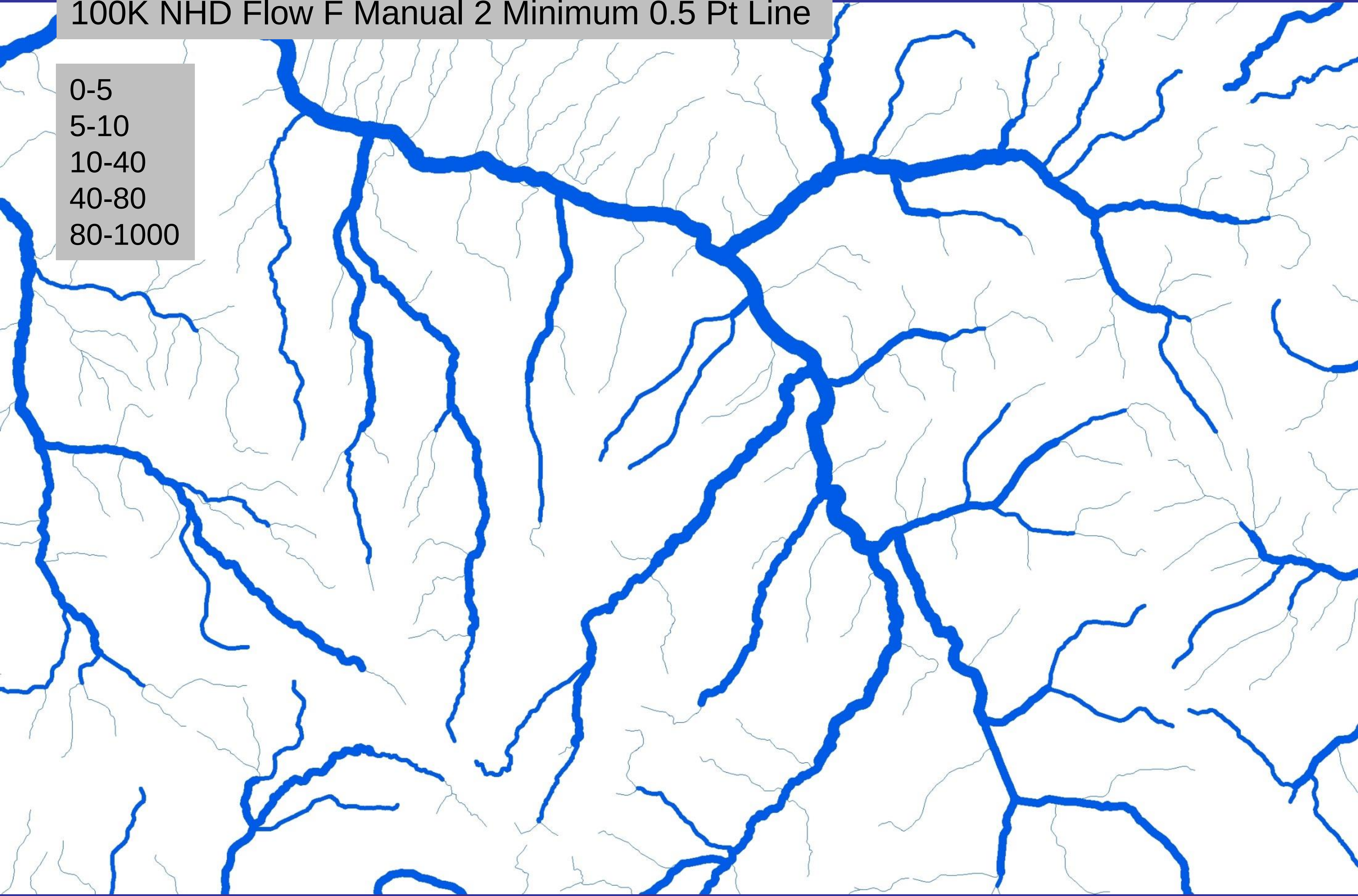
100K NHD Flow F Manual 1 Minimum 1 Pt Line



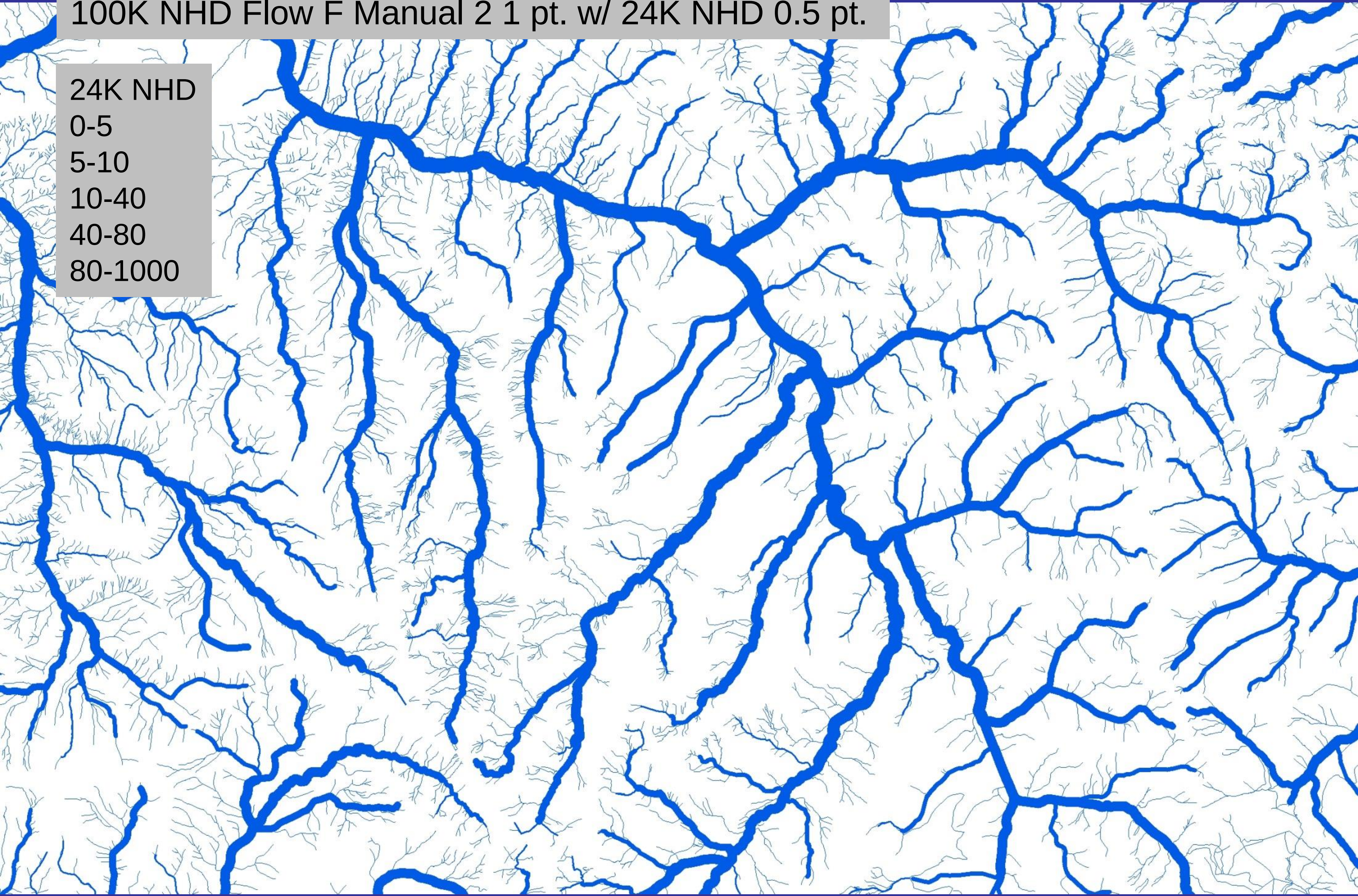
100K NHD Flow F Manual 1 Minimum 0.5 Pt Line



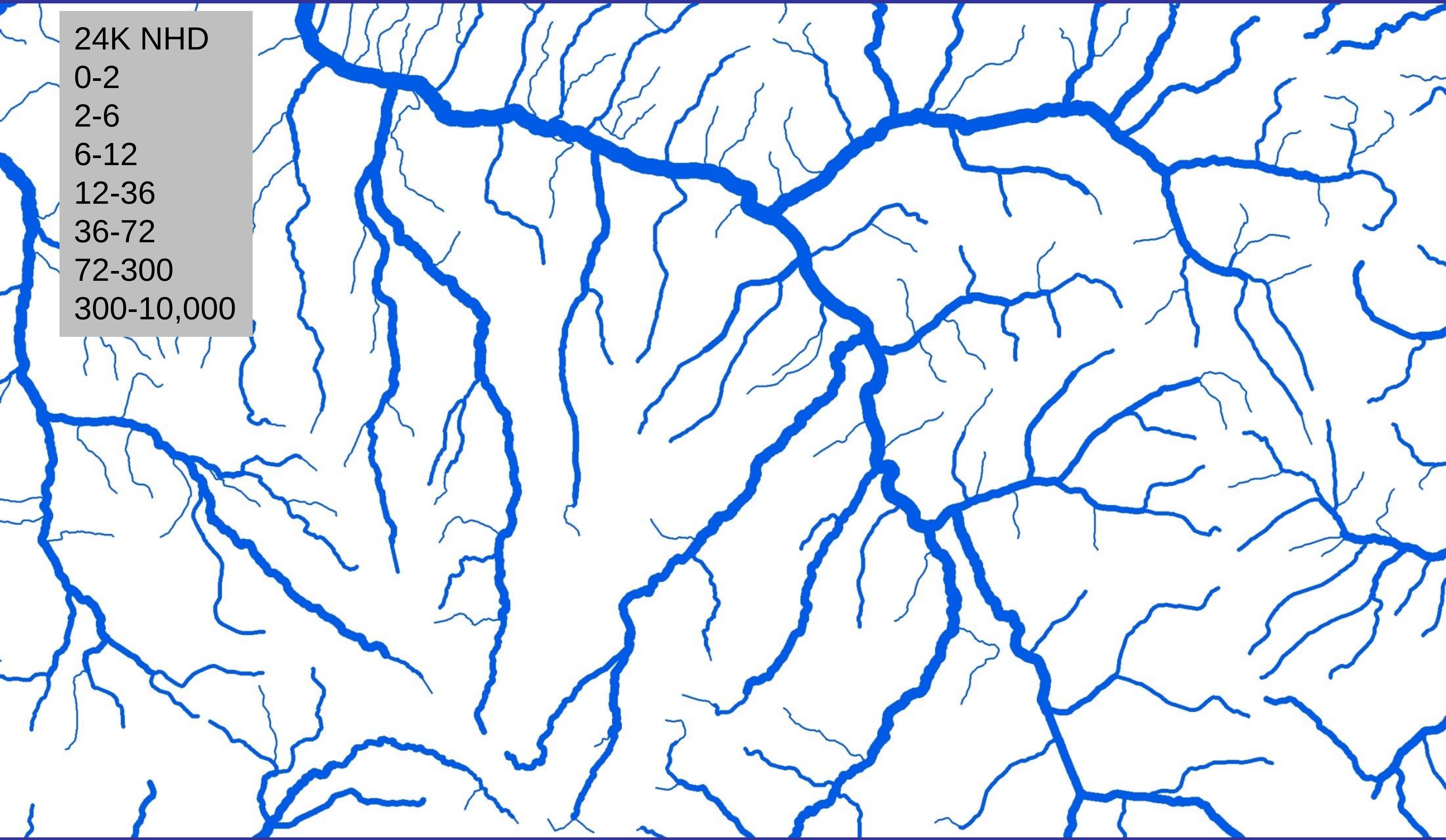
100K NHD Flow F Manual 2 Minimum 0.5 Pt Line



100K NHD Flow F Manual 2 1 pt. w/ 24K NHD 0.5 pt.

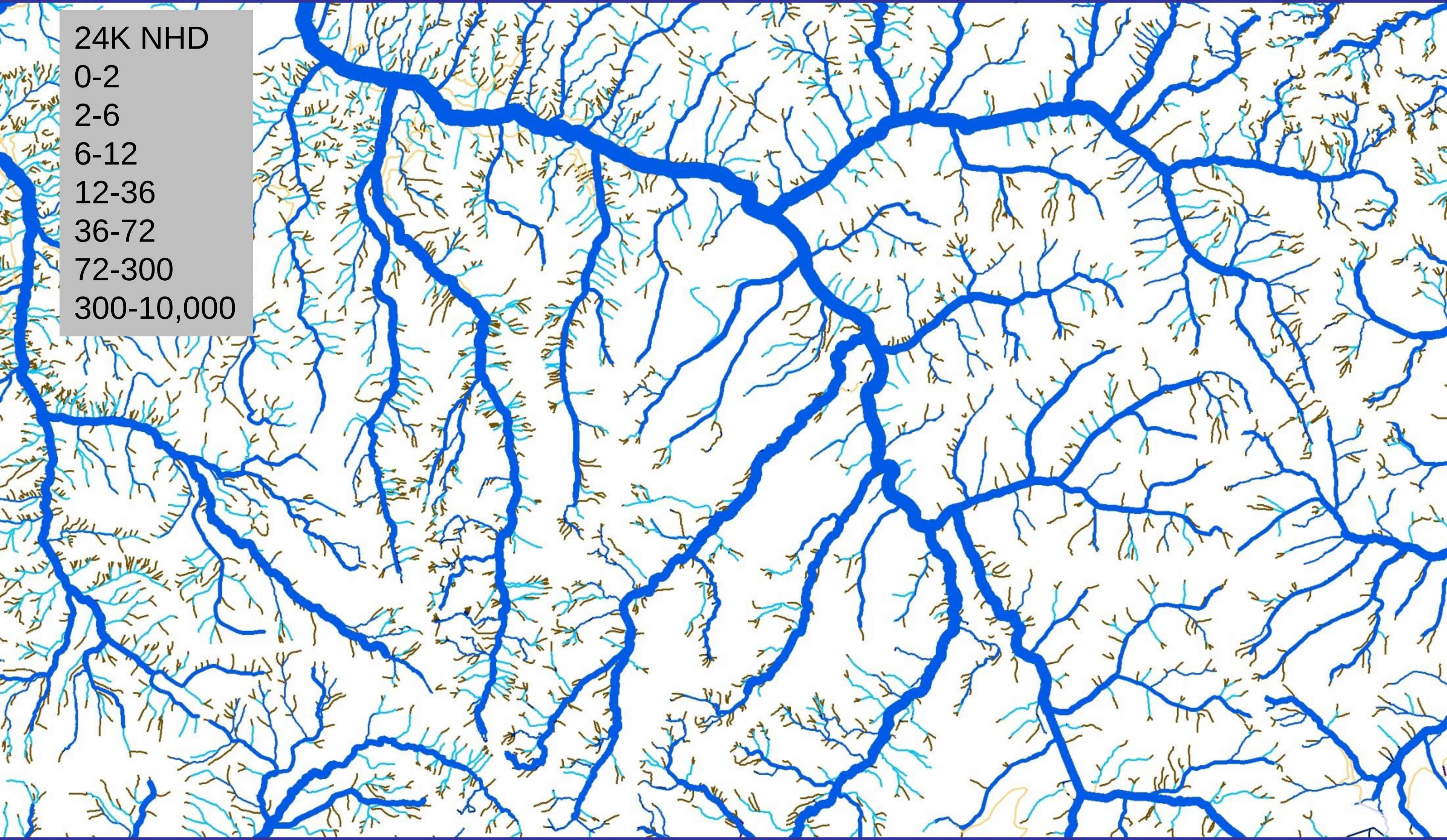


100K NHD Flow E Manual 4 1 pt.



USGS

100K NHD Flow E Manual 4 1 pt. w/ 24K



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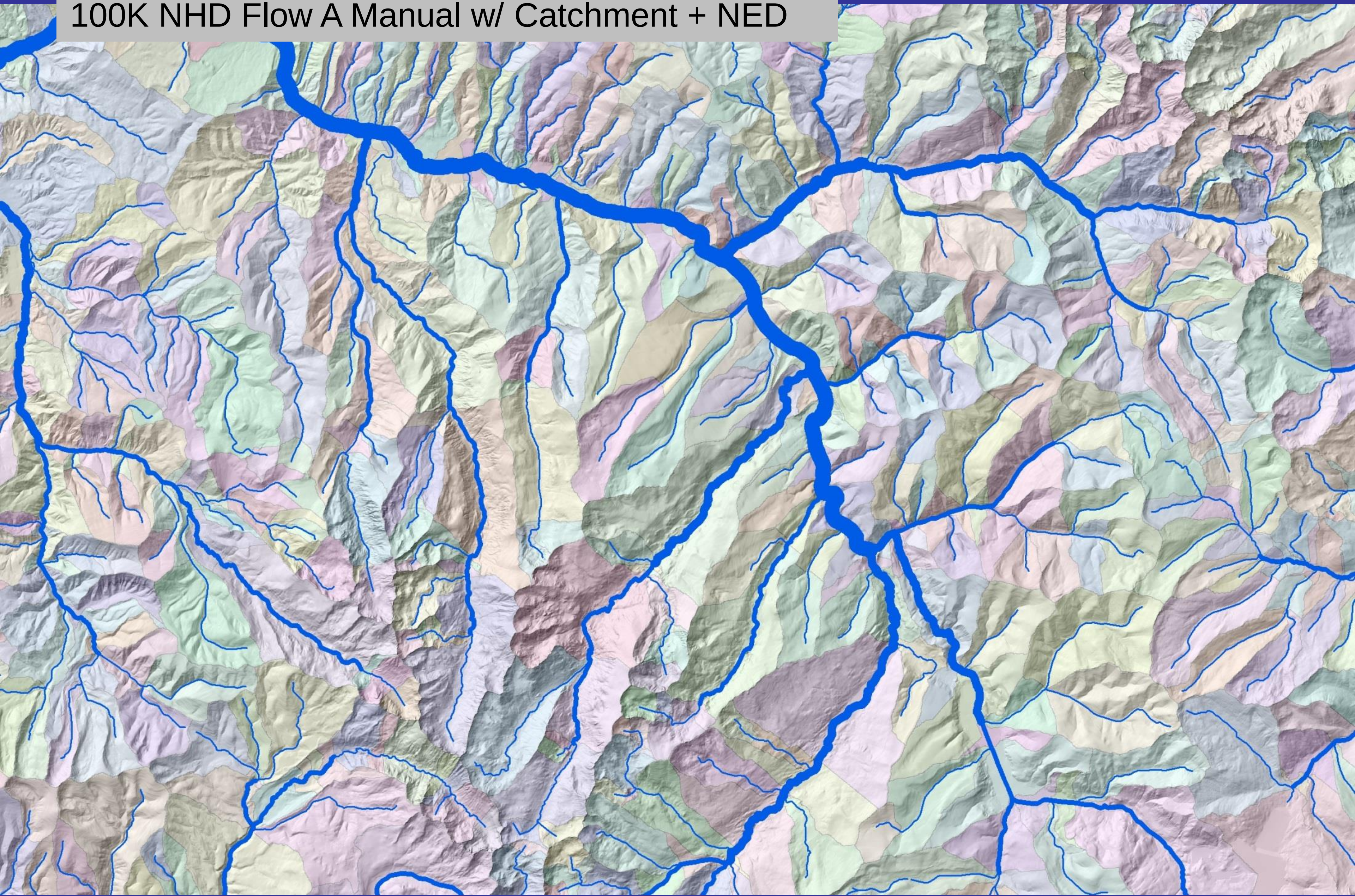
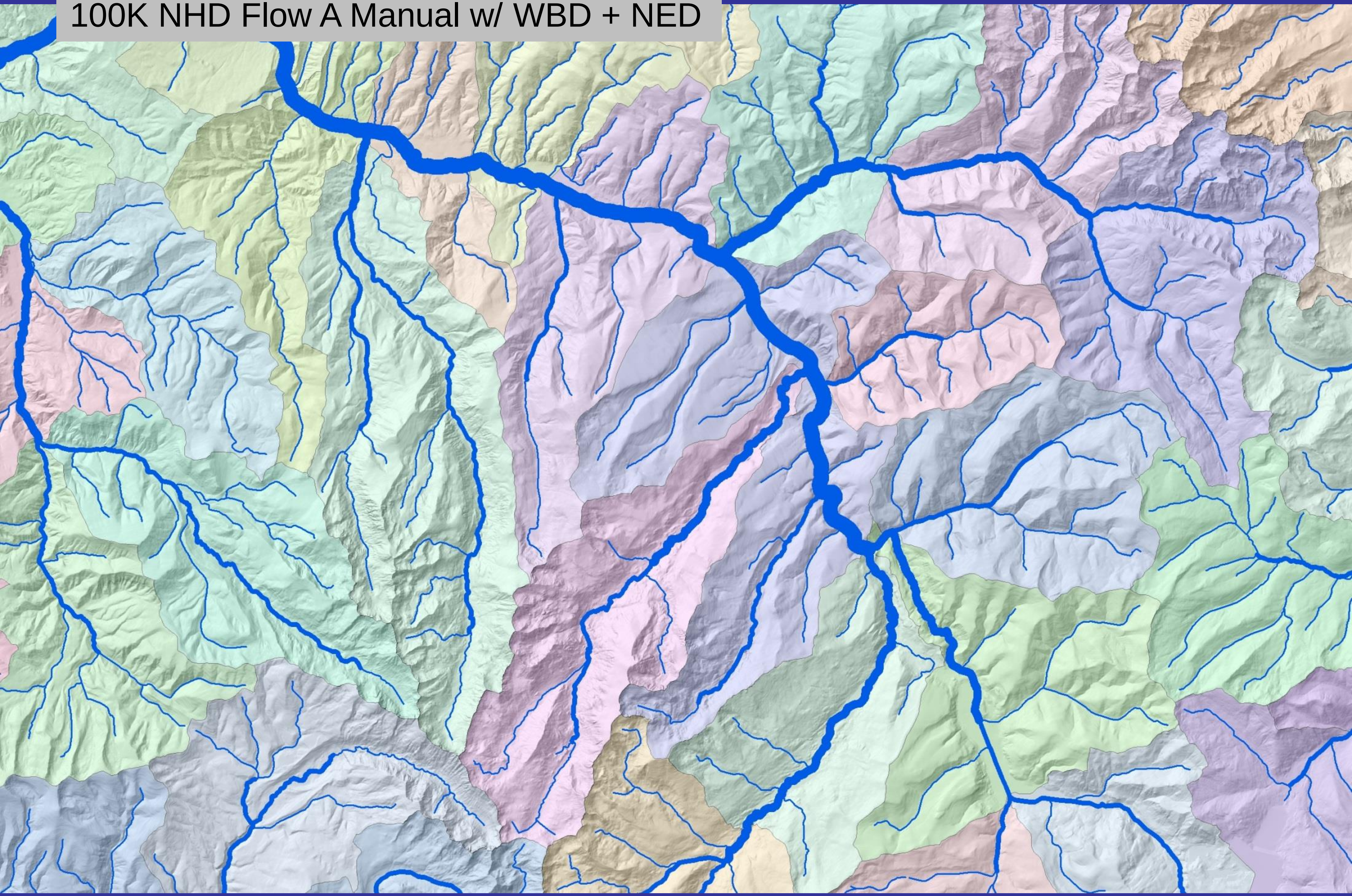
100K NHD Flow A Manual w/ Catchment + NED

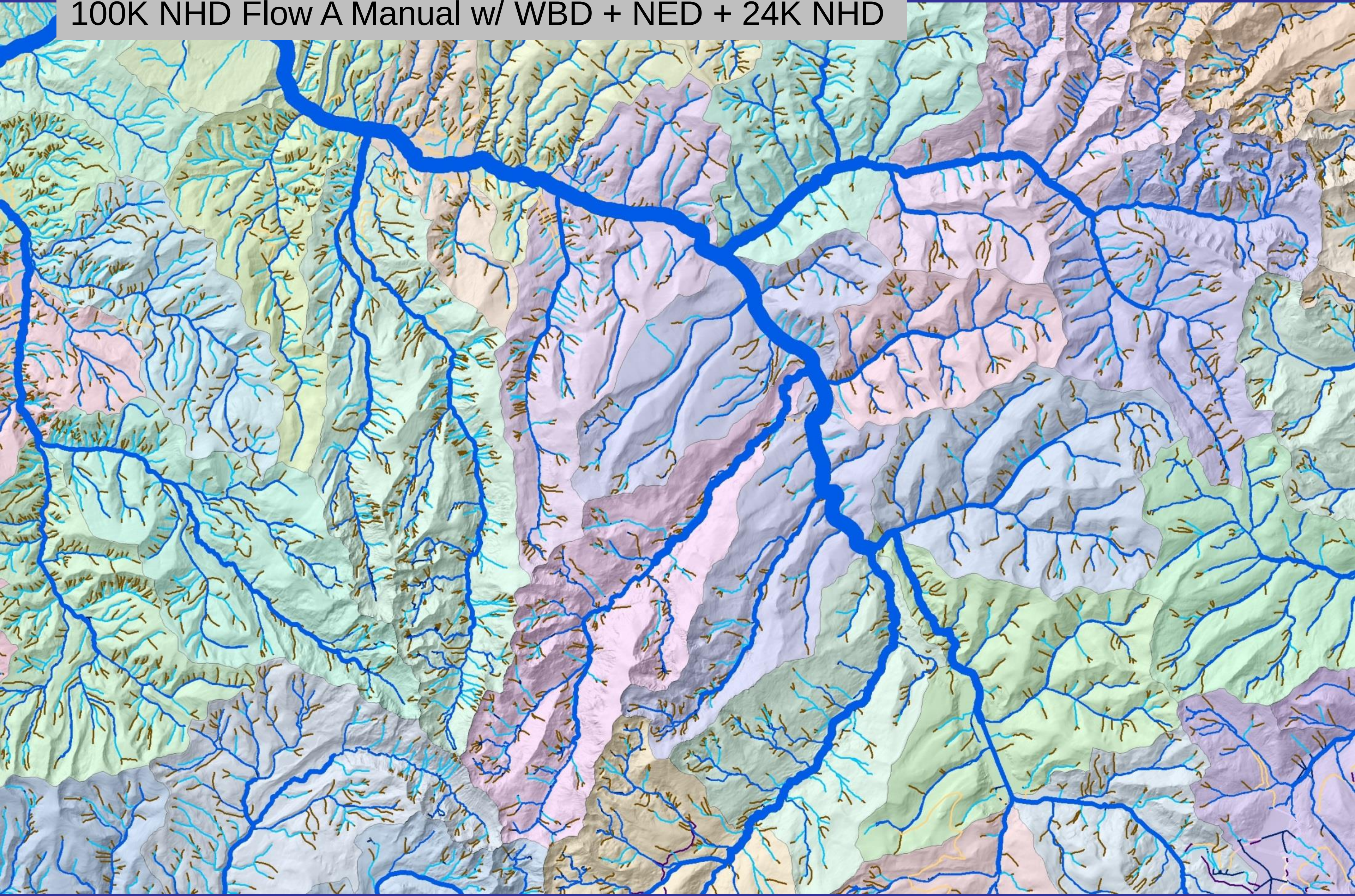


USGS

100K NHD Flow A Manual w/ WBD + NED



100K NHD Flow A Manual w/ WBD + NED + 24K NHD



USGS

Velocity

Velocity measured in feet per second.

V0001A, V0001B, V0001C, V0001D, V0001E

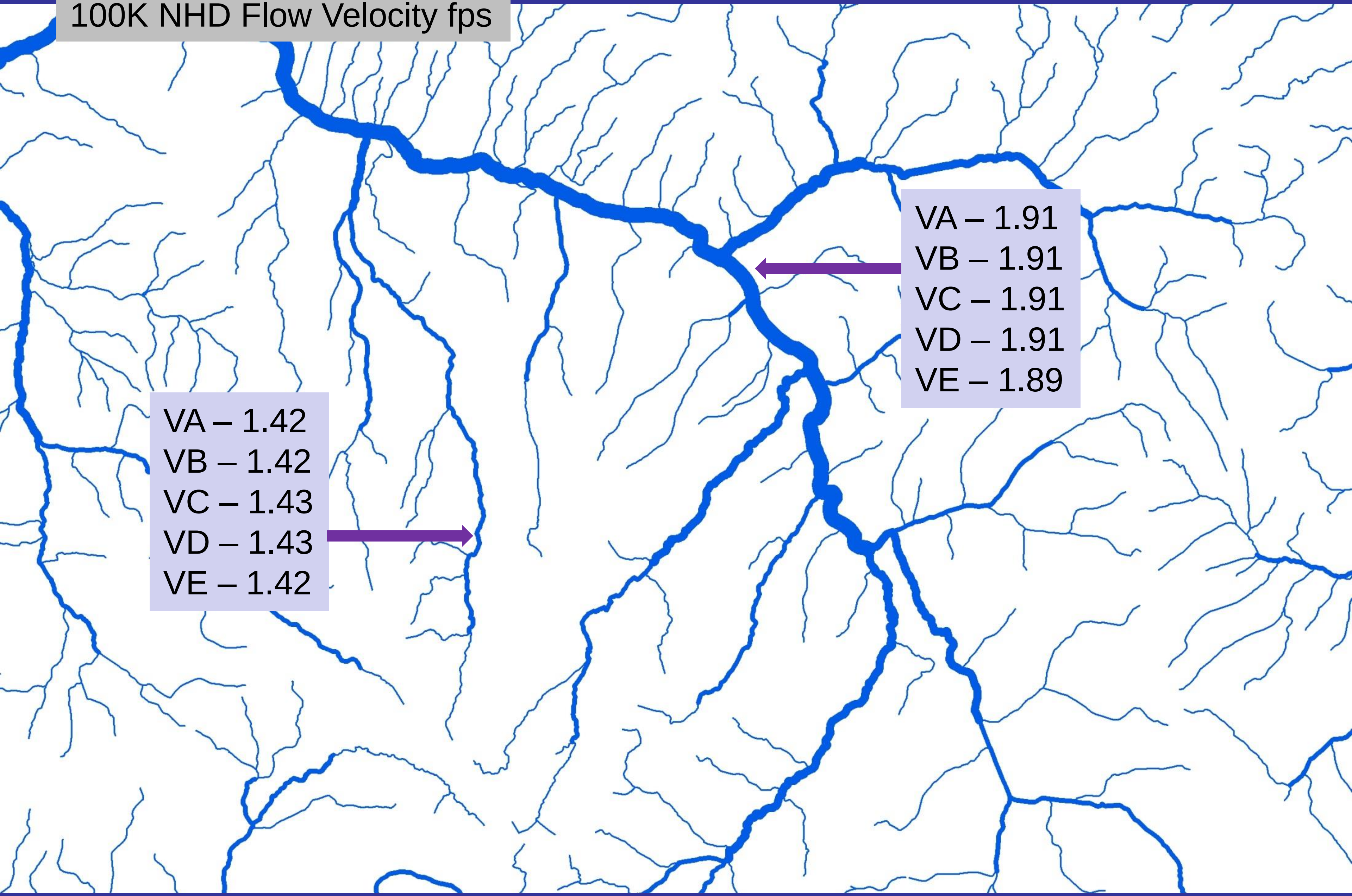
Velocities are estimated for mean annual flows using the work of Jobson (1996). This method uses regression analyses on hydraulic variables for over 980 time-of-travel studies, which represent about 90 different rivers in the U.S. These rivers represent a range of sizes, slopes, and channel geometries.

Four principal NHDFlowline feature variables are used in the Jobson methods:

1. drainage area,
2. NHDFlowline feature slope,
3. mean annual discharge,
4. discharge at the time of the measurement.

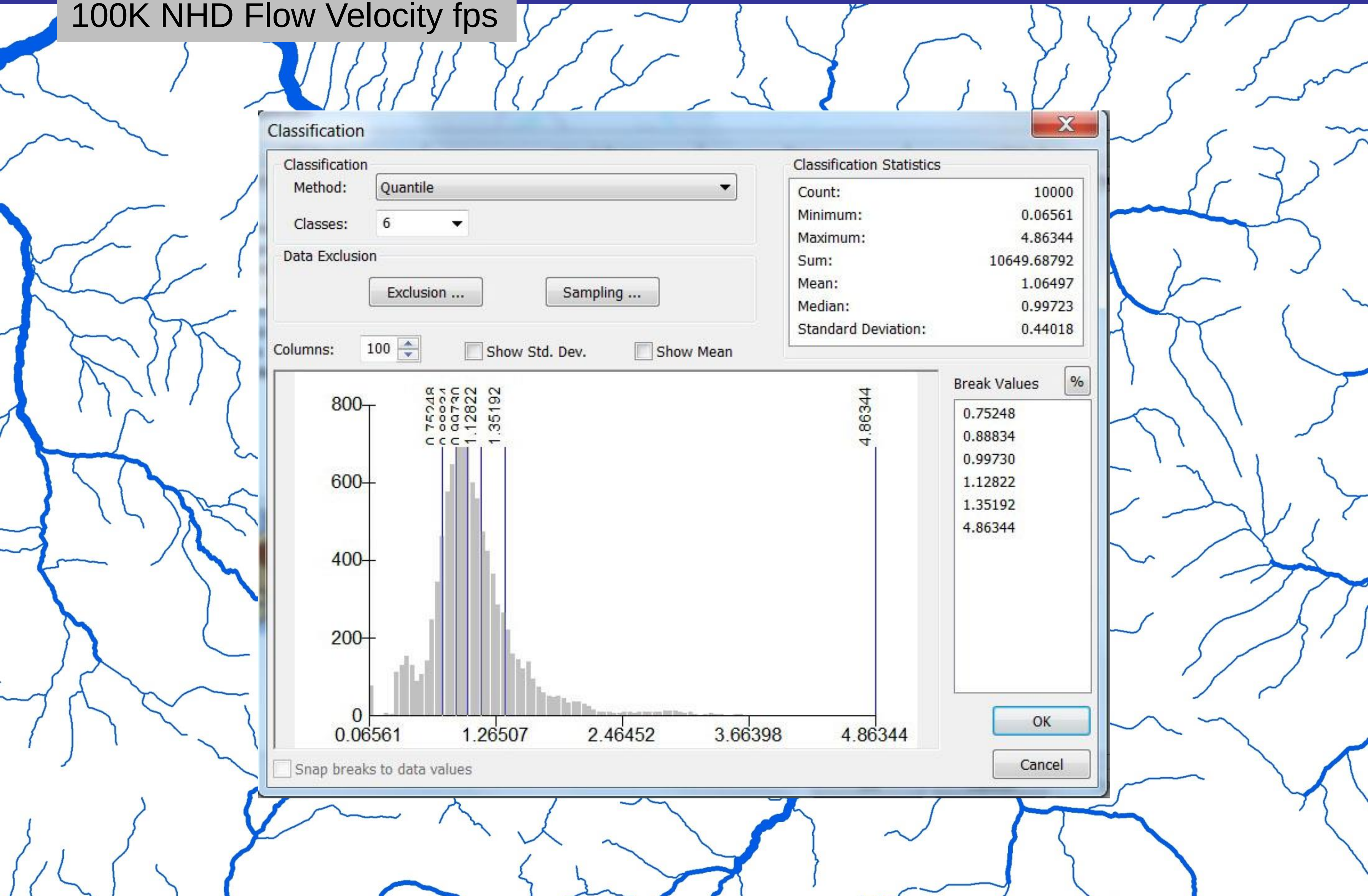
The Velocity Module computes velocities for either the EROM or Vogel flow estimates.

100K NHD Flow Velocity fps

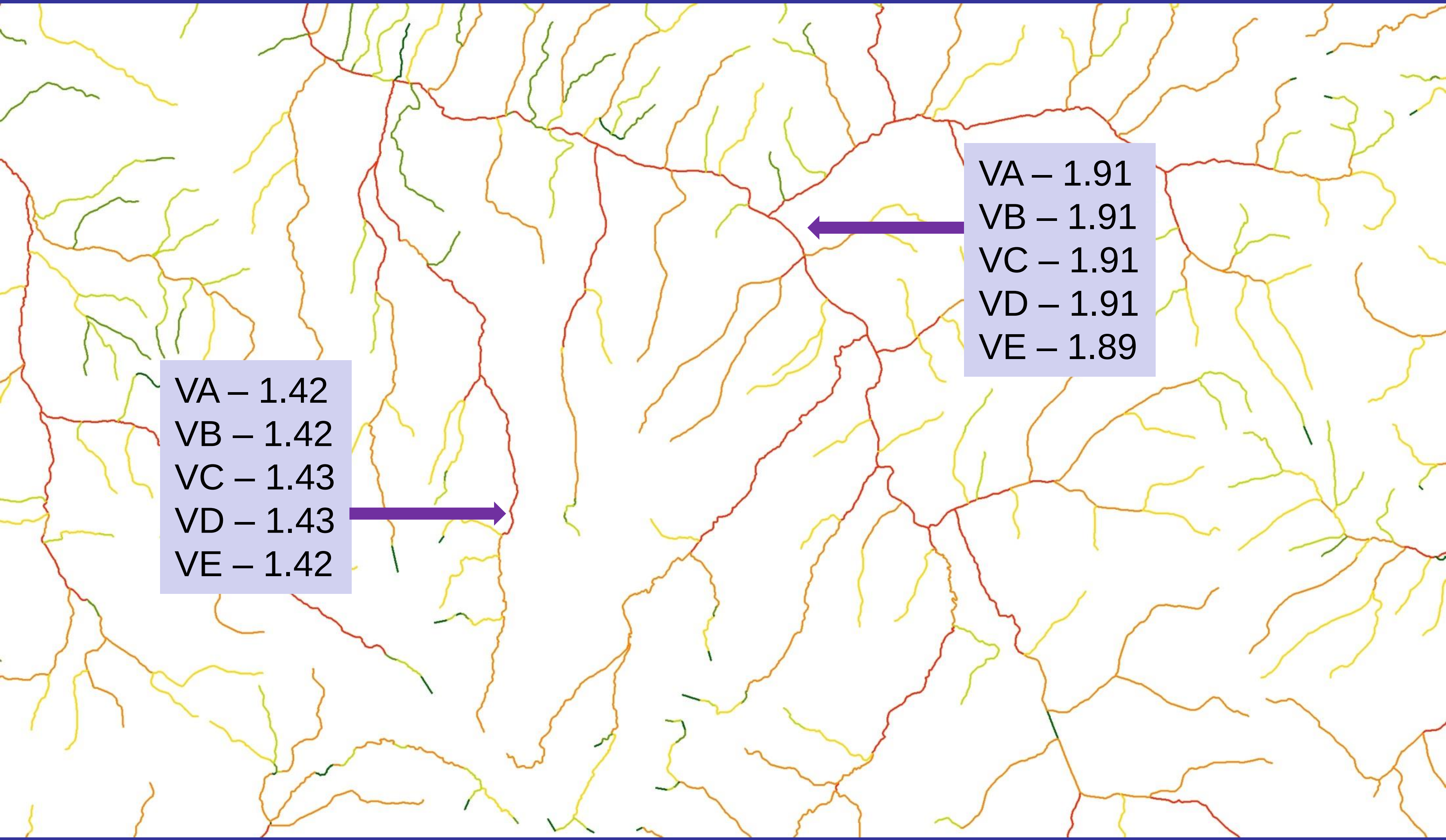


USGS

100K NHD Flow Velocity fps



100K NHD Flow Velocity fps



USGS

Vogel Mean Annual Flow Estimation

Mean Annual Flow measure in cubic feet per second

Mean annual flow estimates for the Continental United States (Hydrologic Regions 01 to 18) are computed based on the work of Vogel et al., 1999. This method uses a log-log regression approach based on

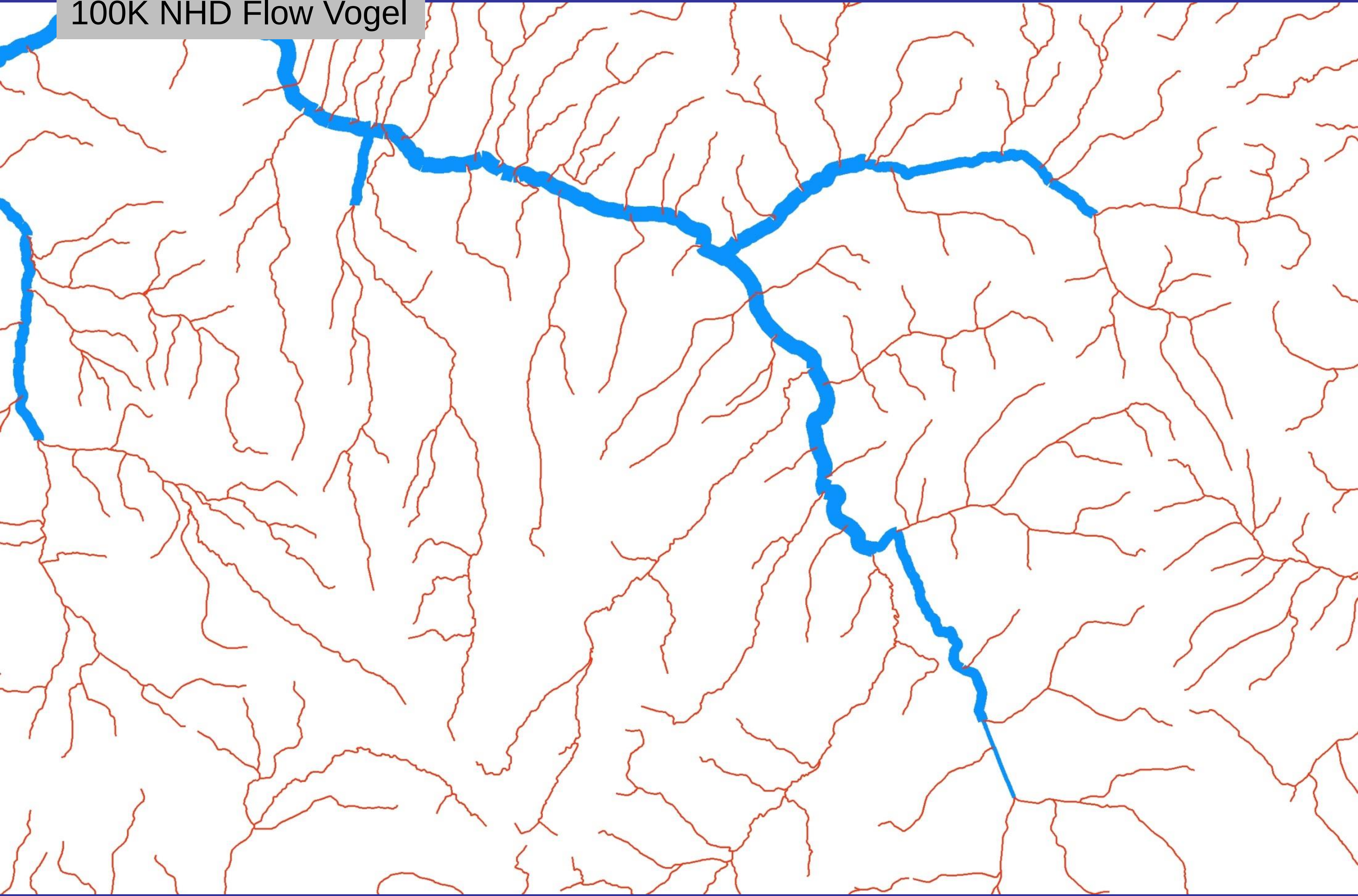
1. Drainage area
2. Precipitation
3. Temperature

data using mean annual flow values from the HydroClimatic Data Network (HCDN) of gages. These gages are defined as minimally affected by human activities, such as major reservoirs, intakes, and irrigation withdrawals. Therefore, the “Vogel” mean annual flow estimates are most representative of “natural” flow conditions.

Valid only within the ranges of the original data used for computing the regressions. For cumulative drainage areas that fall outside of these ranges, the Vogel flows and velocities are set to missing values (-9999).

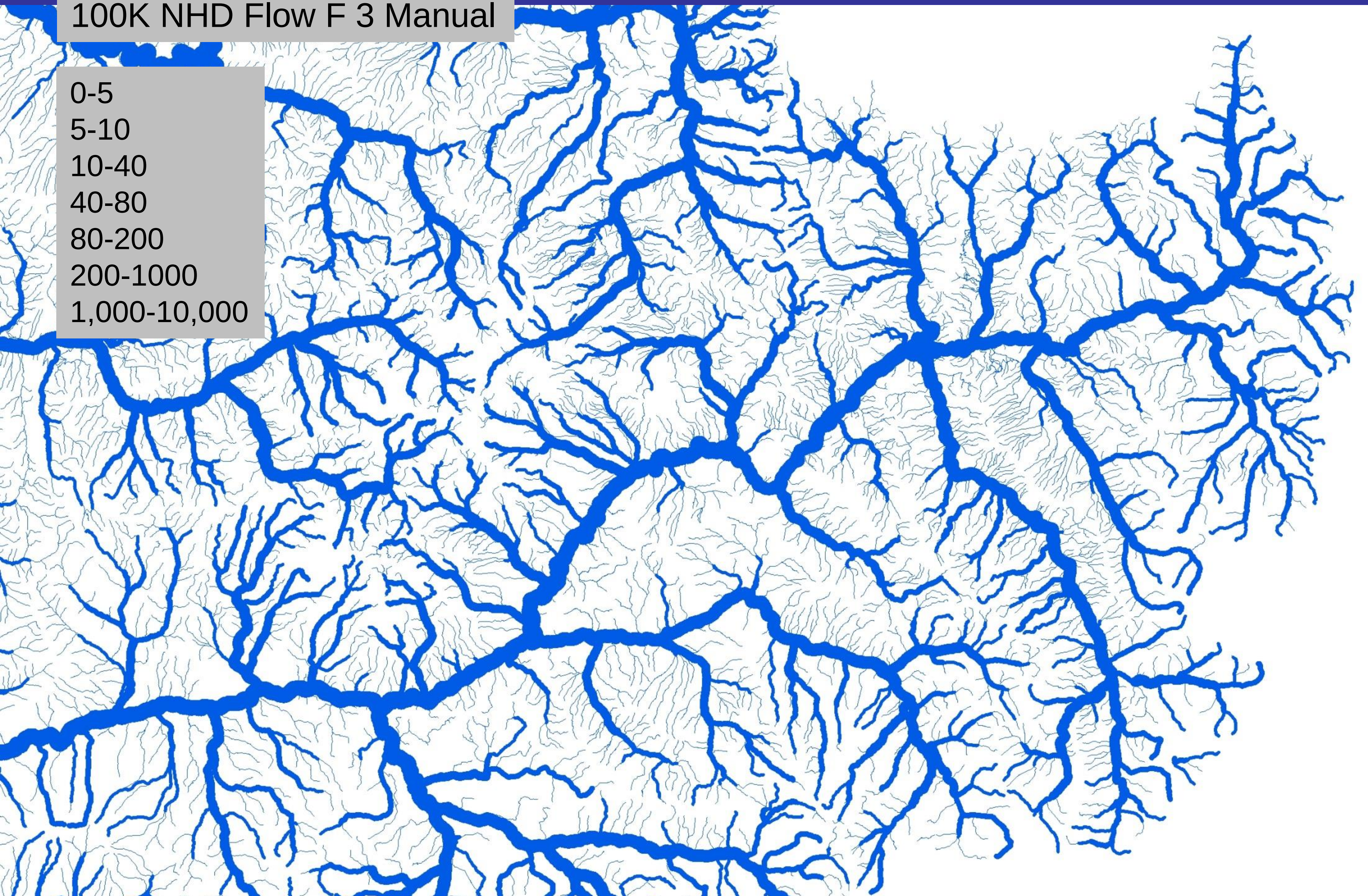
USGS

100K NHD Flow Vogel

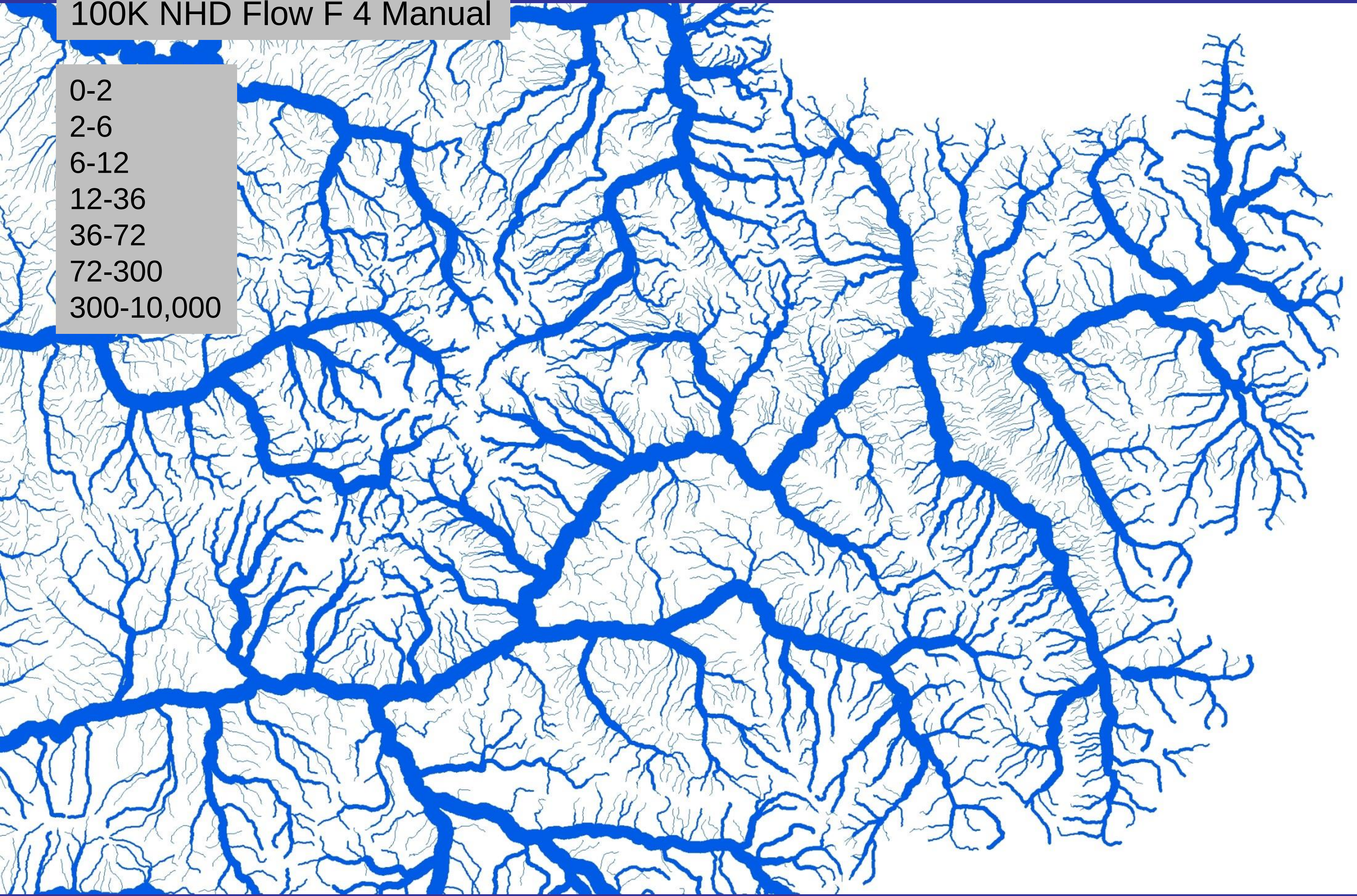


USGS

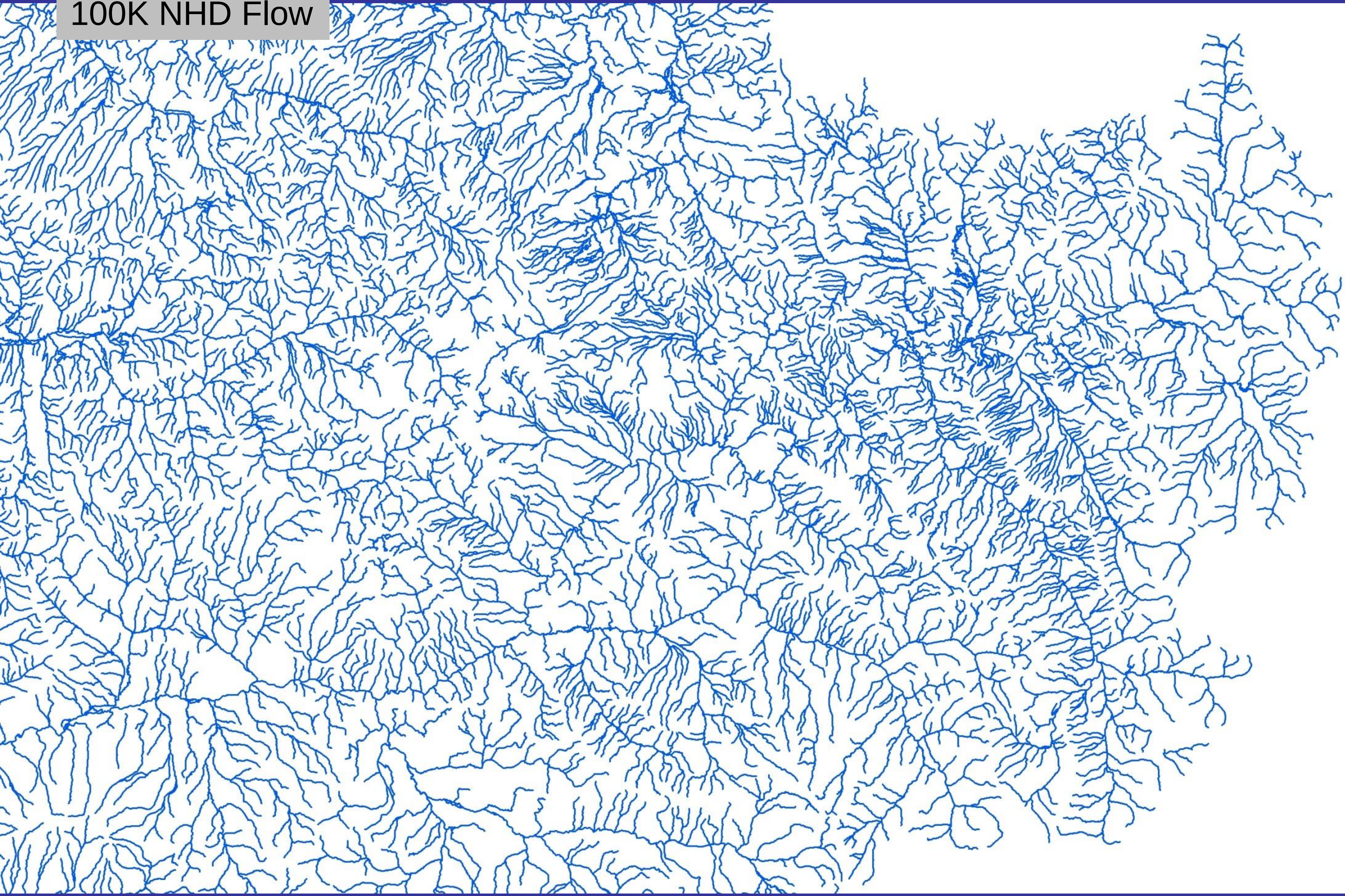
100K NHD Flow F 3 Manual



100K NHD Flow F 4 Manual

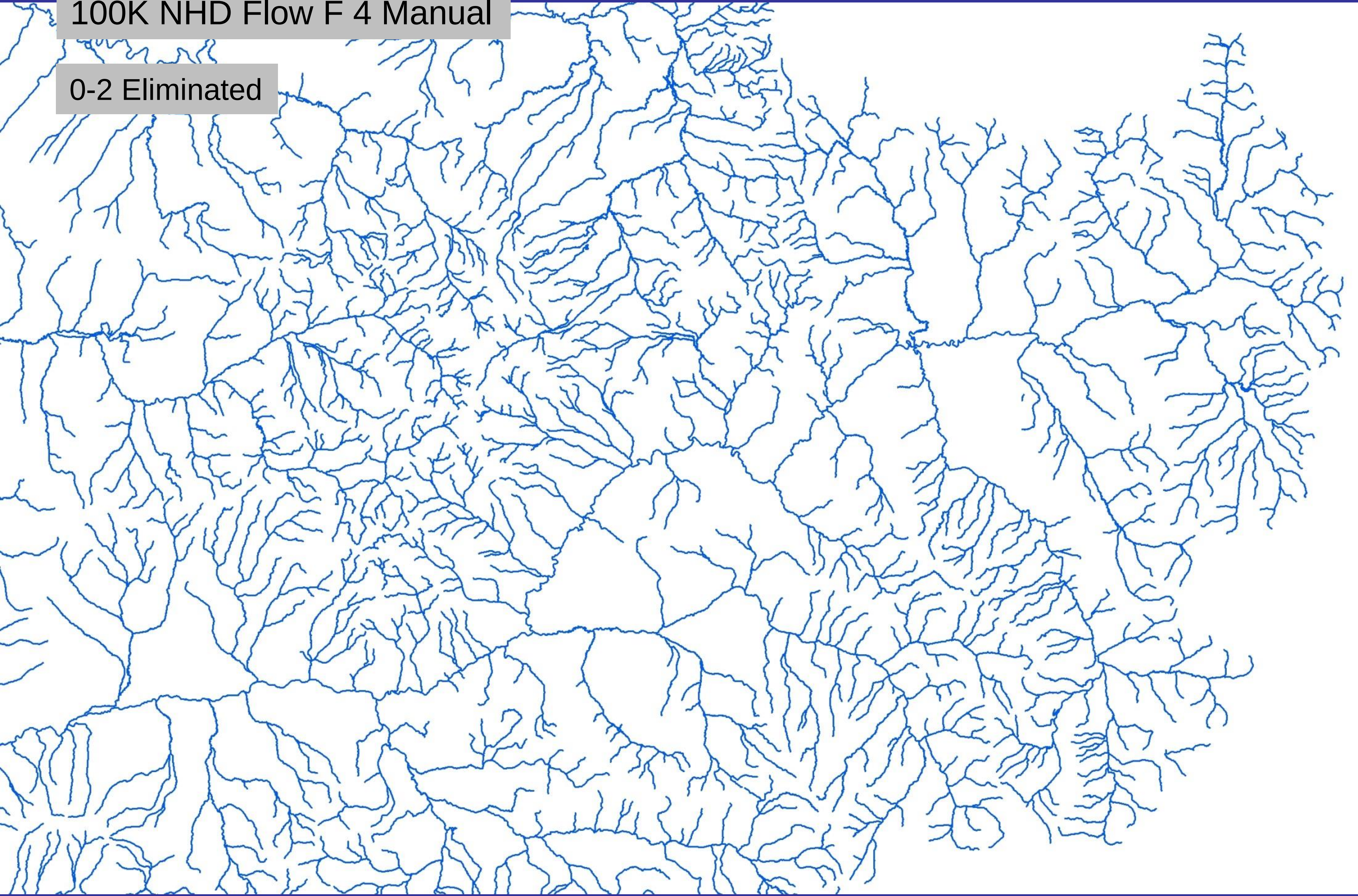


100K NHD Flow



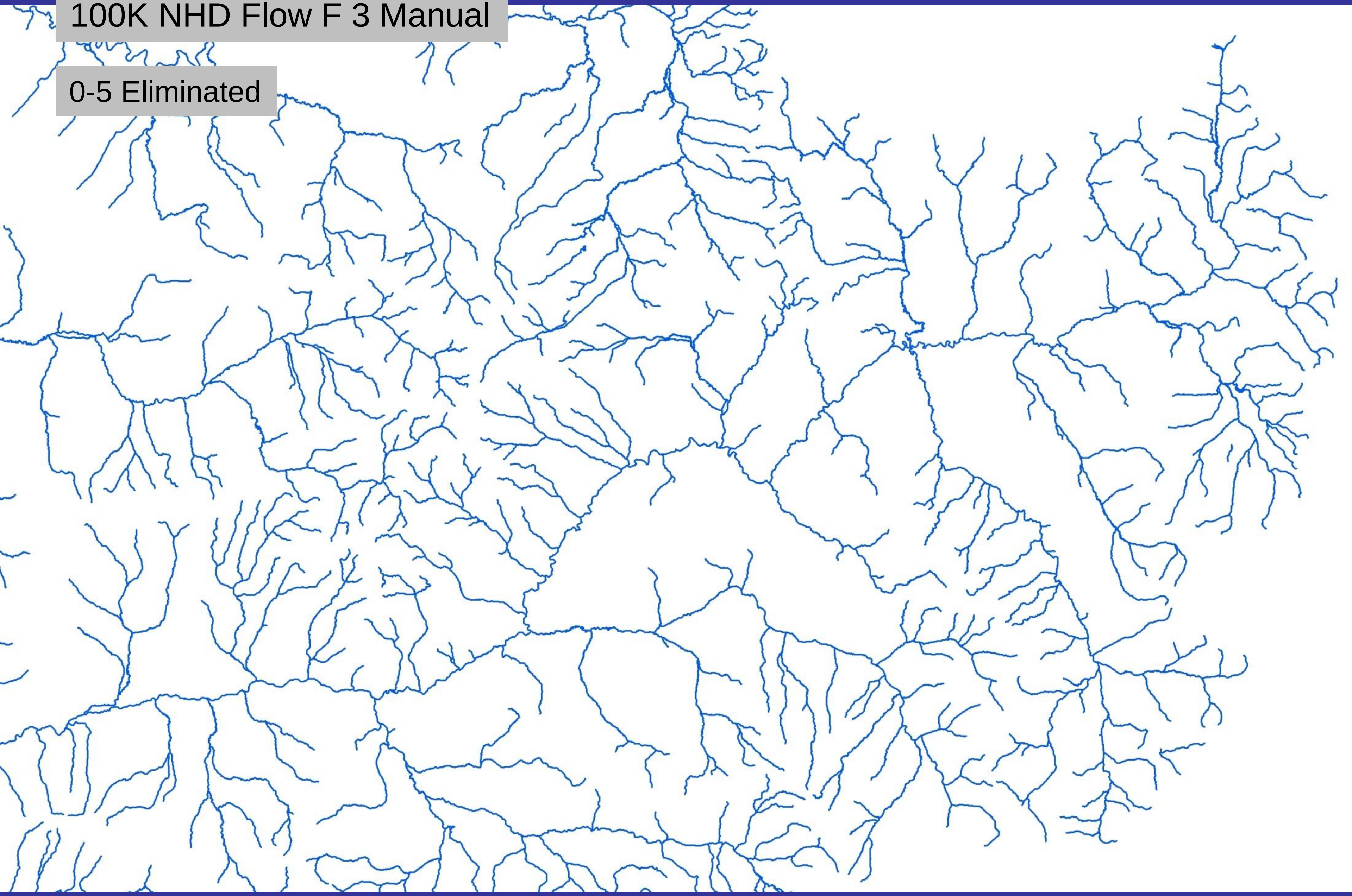
100K NHD Flow F 4 Manual

0-2 Eliminated



100K NHD Flow F 3 Manual

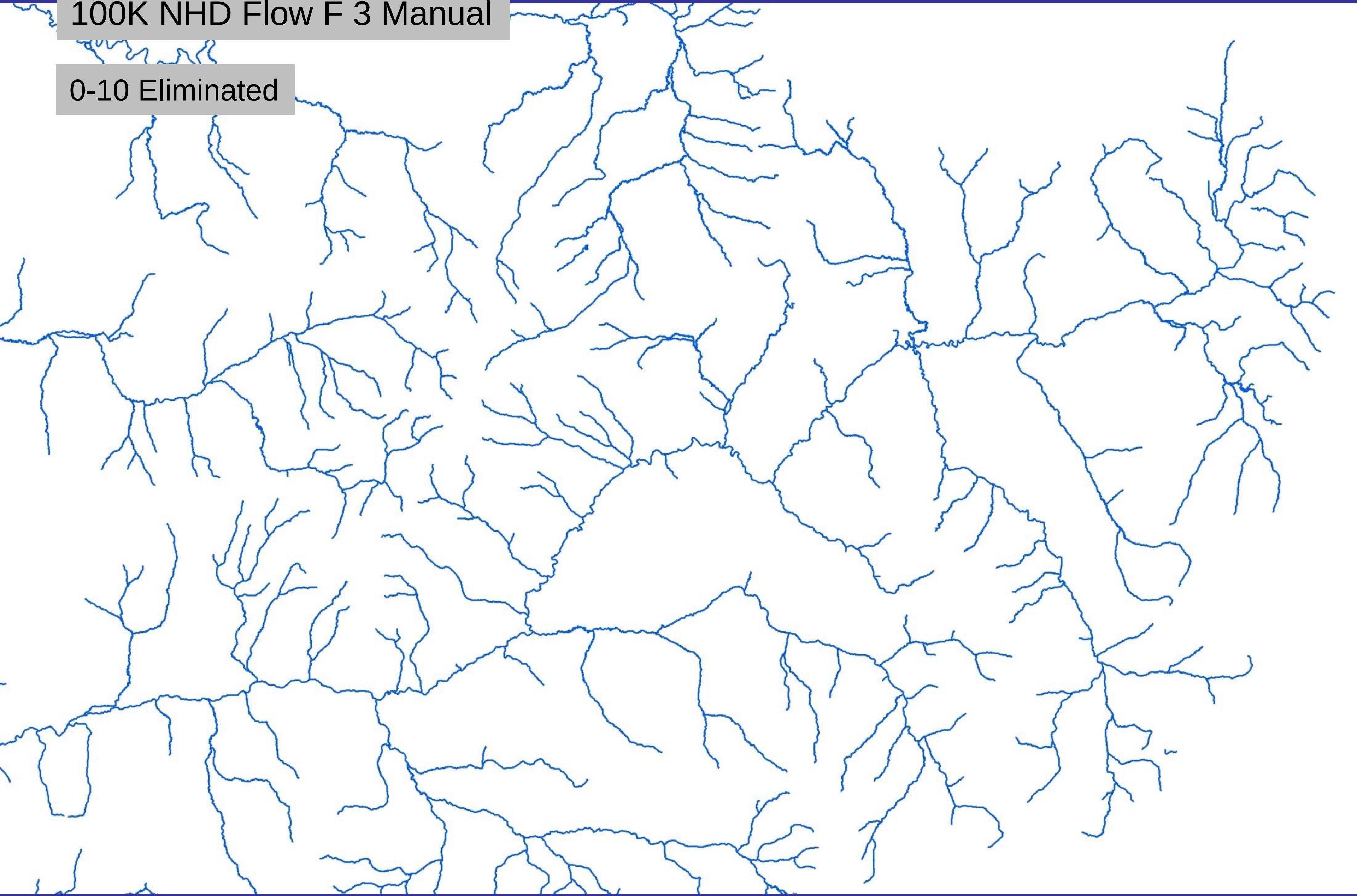
0-5 Eliminated



USGS

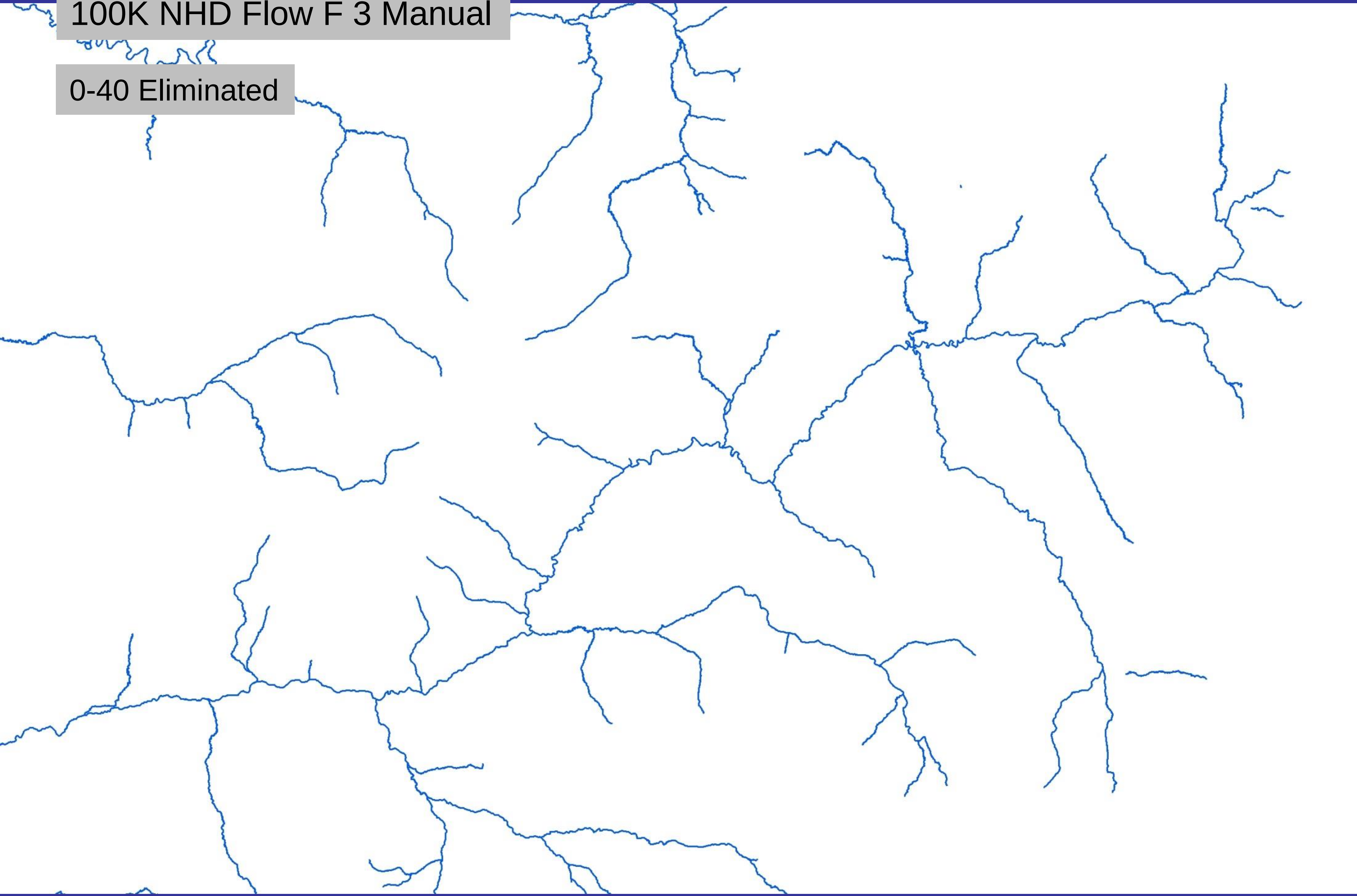
100K NHD Flow F 3 Manual

0-10 Eliminated



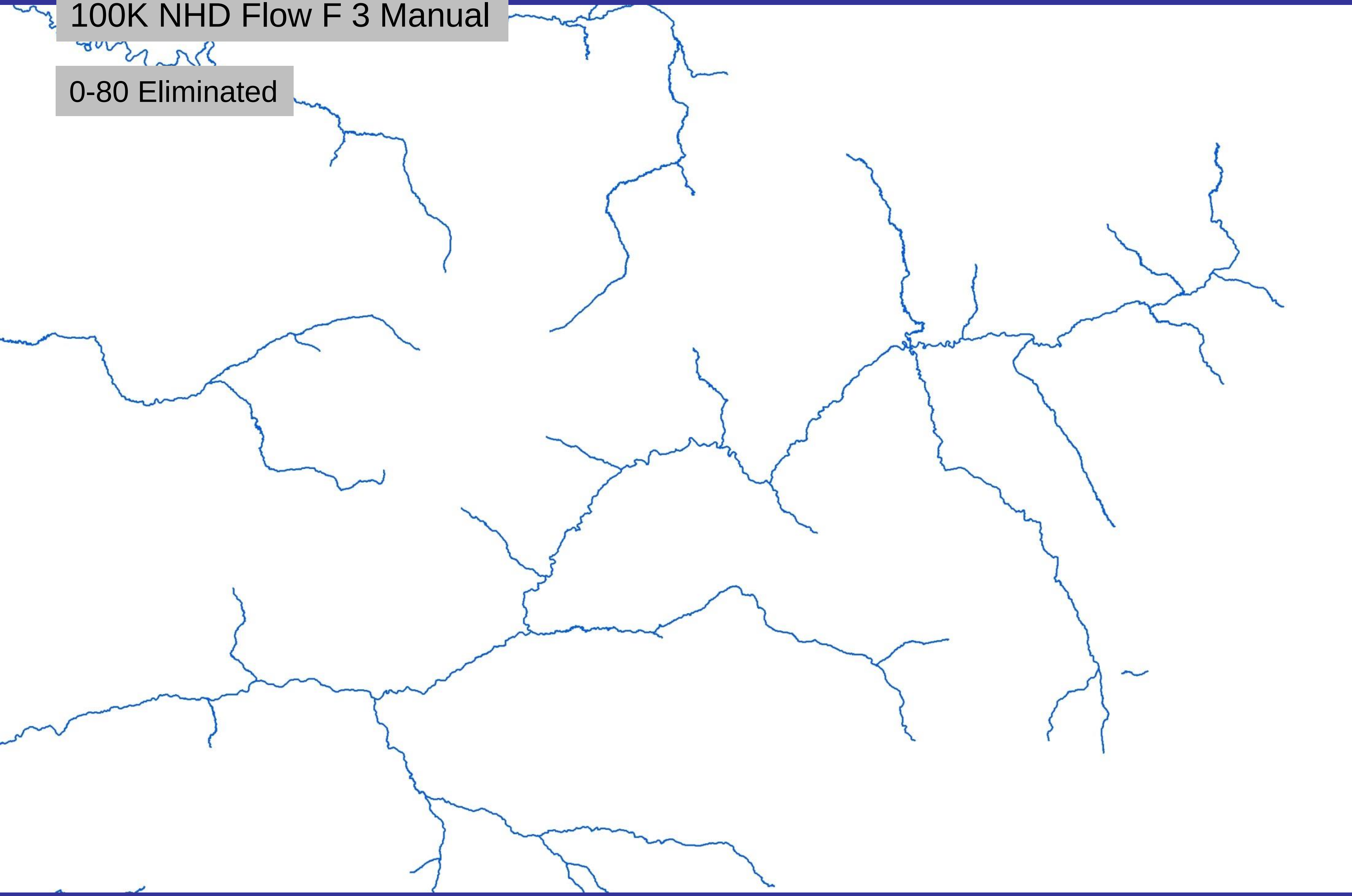
100K NHD Flow F 3 Manual

0-40 Eliminated



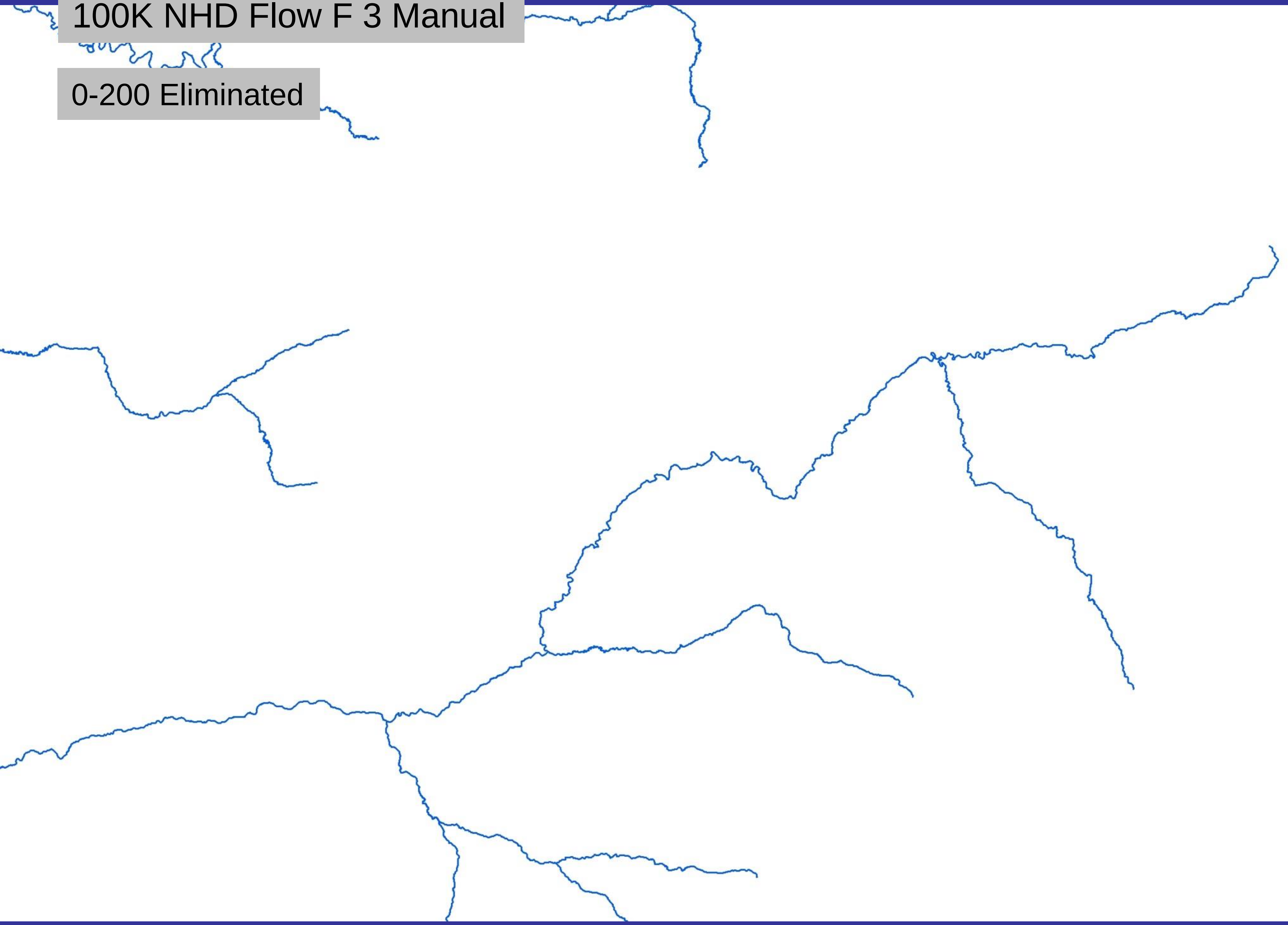
100K NHD Flow F 3 Manual

0-80 Eliminated



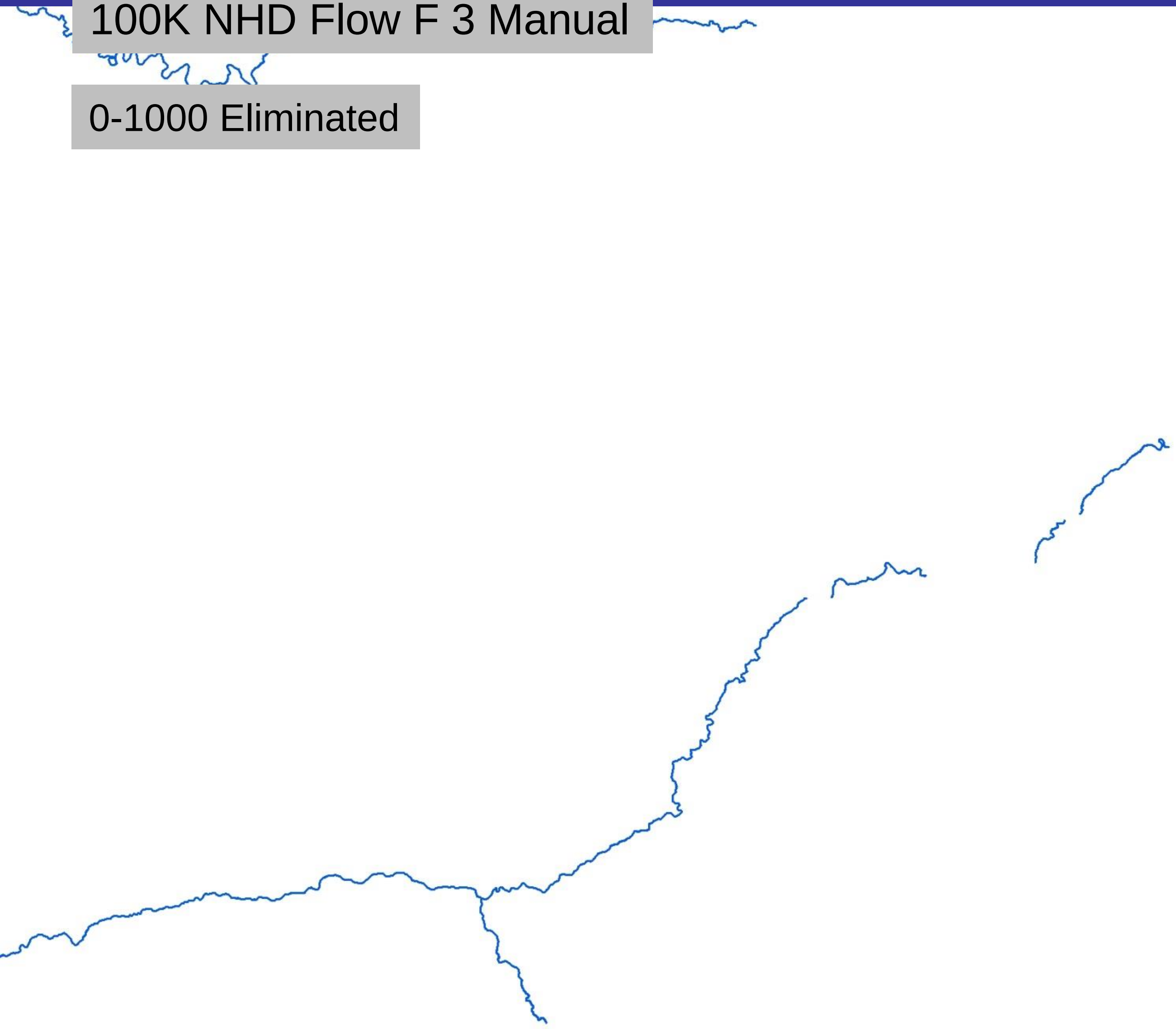
100K NHD Flow F 3 Manual

0-200 Eliminated



100K NHD Flow F 3 Manual

0-1000 Eliminated



100K NHD Flow A Manual

0-1000 Eliminated