ILLINOIS NATURAL HISTORY SURVEY
PRAIRIE RESEARCH INSTITUTE

Hierarchical Framework for Wadeable Stream Management and Conservation: Annual Report 2013

Leon C. Hinz Jr.,
Brian A. Metzke,
and
Jodi Vandermyde

Illinois Natural History Survey
Prairie Research Institute
University of Illinois

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Prairie Research Institute, University of Illinois at Urbana Champaign
William Shilts, Executive Director

Illinois Natural History Survey
Brian D. Anderson, Director
1816 South Oak Street
Champaign, IL 61820
217-333-6830

Annual Summary Report 2013

Project Title:
Hierarchical Framework for Wadeable Stream Management and Conservation.

Project Number: T-75-R-001

Contractor information:

University of Illinois at Urbana/Champaign
Prairie Research Institute
Illinois Natural History Survey
1816 South Oak Street
Champaign, IL 61820

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Principle Investigator:

Leon C. Hinz Jr., Ph.D.
Associate Research Scientist in Stream Ecology
Illinois Natural History Survey
One Natural Resources Way,
Springfield, IL 62702-1271
217-785-8297
leon.hinz@illinois.gov

Prepared by: Leon C. Hinz Jr.

Goals/ Objectives: (1) Develop Ecological Drainage Units for Illinois Streams; (2) Define Aquatic Ecological Systems for Illinois Streams; (3) Develop and Classify Illinois' Stream Valley Segments; (4) Define Natural Community Types for Illinois Streams; and (5) Develop and submit a list of candidate sites for INAI listing under Category I (High Quality and Significant Natural Communities) and revised Category VI (Unusual Concentrations of Fauna) criteria for streams.

Project Title:

Hierarchical Framework for Wadeable Stream Management and Conservation.

Narrative:

Efforts during this reporting period include refining Illinois' Ecological Drainage Units (EDUs) using fish and mussel distribution similarities. Draft EDUs have been developed and are available for review. In addition Valley Segment Types (VSTs) have been delineated based on stream size, summer temperatures, and low flow water yield. VSTs are also available for review by the working group.

Considerable effort was expended on defining Illinois' Aquatic Ecological Systems (AESs) within the draft Ecological Drainage Units (EDUs). AES polygons have been defined and we have begun attribution of geology, soils, landform, and ground water potential has begun for use in describing AES types. Biological data are also being prepared to characterize fish and mussel assemblages within AES types in a manner similar to what we have done with Valley Segment Types (VSTs).

We have consolidated and mapped biological information associated with existing criteria for INAI listing of wadeable streams. Threatened and Endangered species locations, fish Index of Biotic Integrity and Mussel Community Index values, and Mussel Species Richness from recent statewide surveys that meet existing criteria for INAI listing have been consolidated and mapped. Additional efforts were made toward developing standard methods for classifying and rating INAI Category I and Category VI sites.

Work on this project continued with one full time research scientist and one part-time research scientist during the reporting period. We hired and added a second full time staff member near the end of the reporting period to focus on completion of Jobs 2 and 3. Our part-time graduate student worker completed georeferencing and quality assurance of Illinois EPT collections data that is now available for our use. Efforts to define AES polygons uncovered two unexpected but related issues with our existing GIS database system. A large number of very small areas (often < 1 meter wide but sometimes miles long) within the state had not been incorporated into the system. Secondly, some watershed polygons were found to have been misattributed to adjacent watersheds. These areas were generally at the boundaries of the processing units that were used in the initial database development. Identifying, incorporating, and attributing these areas has taken considerable time and delayed work on defining AESs (Job 3).

Job 1: Compile and update databases.

Integration of biological assemblage data with our existing GIS system continued during this reporting period and has been expanded to take advantage of additional available information on aquatic insects. Data sources for fish include IDNR Monitoring (Fisheries Database, Natural Heritage BIOTICS Database) and Collections Data (INHS, University of Michigan Natural History Museum). Fisheries data integration has been completed with 3,995,952 IDNR records available statewide from 1910-2011. These records are from 100s of stations located throughout the state. Mussel data through the 2012 collecting season were made available in the last quarter of the reporting period from the INHS Collections and IDNR Mussels database (T-53).

We worked with INHS research teams to include information on stoneflies (DeWalt et al. 2009), caddisflies and mayflies (DeWalt et al. 2011) to georeference and QA/QC all EPT records in the INHS collections database. Over 4500 records are now georeferenced and available within the system.

Compilation and integration of biological assemblage data with hydrologic, geomorphic, and geologic data within our existing GIS system has been completed for data available through 2011. However, we have restricted most analysis to using records from biological samples through the calendar year 2010. This job has been completed.
Additional work during this reporting period included the incorporation of 1000s of small landscape units into the GIS system (see Job 3 below). We are further integrating local watershed units that drain into Illinois from Wisconsin into the GIS system.

Job 2: Develop Ecological Drainage Units (EDUs).

Work on refining the existing Illinois' EDUs using information on fish, mussel, and EPT distributions has continued. Biological information for fish and mussels within draft EDUs has been compiled, summarized, and mapped. We summarized species richness for native fish (Figure 2.1) and mussels (Figure 2.2) at HUC-8 watersheds statewide.

The USGS 8-digit Hydrologic Unit Codes (HUC8) were used as the baselayer for delineating EDUs. Next, prevalence of each fish and mussel species were spatially linked to USGS HUC8s by compiling a state-wide georeferenced database using existing community samples. Fish community samples were compiled in a recent study (T-68) including samples from Illinois Department of Natural Resources Fisheries Division (IDNR Lake Stations, IDNR River Miles/Stations, IDNR Stream Stations, IDNR Stations-NRM), IDNR Natural Heritage Database (Biotics), Illinois Natural History Survey (Long Term ElectroFishing (LTEF) Program, INHS Collections, Long-Term Resource Monitoring Program (LTRMP)), and the fisheries collection of the University of Michigan Museum of Zoology (UMMZ). Mussel community samples were from Illinois Natural History Survey recent state-wide study (T-53; 2009-2011 survey collection). HUC8s that were split by state boundaries were merged with the most appropriate nearby HUC8 based on drainage (i.e., Sugar - Pecatonica, Upper Rock - Lower Rock, and Middle Wabash/Little Vermilion - Vermilion/Wabash). For the initial set of analyses (MDS and CLUSTER, PRIMER v6), fish and mussel assemblages were analyzed separately and examined with and without common and/or rare species presence. Little difference was observed when common and/or rare species were removed from analyses, so all species were included in the final analysis.

The resulting data matrix (all native species presence by HUC8) was used as the input data for a series of multivariate analyses that assessed the relative similarity of fish and mussel assemblages among HUC8s. Native fish and mussel assemblages were analyzed separately and together to compare relative similarity among HUC8s using non-metric multidimensional scaling and clustering dendrograms (MDS and CLUSTER, PRIMER v6). Draft EDUs were developed from HUC8s with relatively similar fish and mussel assemblages (Bray-Curtis 70% similarity; PRIMER v6). Draft EDUs were then analyzed separately to assess similarity of HUC8s within the defined EDUs and dissimilarity among EDUs to verify appropriate placement of HUC8s (SIMPER, PRIMER v6). Aquatic Subregions for Illinois (Laurentian Great Lakes, Upper Mississippi, Lower Mississippi, and Teays-Old Ohio; http://www.feow.org/ecoregions/browse) were also referred to during the development of EDUs. Eleven EDUs were defined for Illinois based on similarity analyses and drainage boundaries (Great Lakes, Upper Illinois River, Illinois River, Rock River, Mississippi River North, Mississippi River Central, Mississippi River South, Kaskaskia River, Middle Wabash River, Wabash River, and Ohio River).

EDUs have been defined using drainage affinity and presence of fish and mussel species and are ready for review by the working group (Figure 2.3). The eleven EDUs we have defined for Illinois differ only slightly from the EDUs currently being used by the National Fish Habitat Partnership. However, we believe that these refinements better reflect existing and historical patterns of ecological connectivity. Further refinements are possible after review by the working group.

Job 3: Define Aquatic Ecological Systems (AES).

Work on this Job was delayed while draft EDUs (Job 2) were being refined using the biological assemblage data. Summaries for physiographic and anthropogenic disturbance variables have been derived for HUC 8 and HUC 12 watersheds throughout Illinois. These attributes will be used to assist with identifying areas with less "natural" conditions. We have assembled the appropriate data for typing and delineating AES units using the procedure outlined in Sowa et al. (2006). However, since our existing GIS attributes had not been summarized at the appropriate scale for this analysis we continued efforts to develop polygons for AES units delineated for small, medium, and large river stream segments. Attributes within these polygons will be aggregated and used to describe the character of AES units.

AES polygons were developed from 30-meter DEM local watersheds within the 1:100,000 stream arc coverage for Illinois. All stream segments classified as headwater or small stream (VST size code 1 and 2) were removed from the stream network. Valley Segment Type size codes > 3 (drainage area > 81 km^2) and selected null values (stream segments not coded but connected to larger streams) were used to create a digital stream network that contained only streams classified as medium stream, large stream, or large river (Figure 3.1). AES polygons were given a unique identifier that corresponded with the major stream segment that it contained. We developed an automated process within GIS to delineate AES polygons. Errors such as unidentified gaps and overlaps between polygons were discovered within and between some AES polygons. These were inspected individually and merged with the most appropriate AES polygon based on patterns of drainage. We also identified unattributed “slivers” and other small areas that were not included in the existing database system. These unattributed areas were generally small (e.g., one foot wide and a mile long) and occurred along the boundaries of the original processing units used to develop summaries for the existing database system. These areas were merged into adjoining AES polygons based on drainage patterns. A total of 1085 AES polygons were delineated within Illinois and are being reviewed (Figure 3.2). Local watersheds for stream segments that occur in Wisconsin and Indiana that are tributary to streams in Illinois are being incorporated into AES polygons where appropriate.

AES polygons will be used for calculating landscape summaries and classifying distinct AES types. Attribution of geology, soils, landform, and groundwater potential for each AES polygon has begun. We will conduct a cluster analysis (MDS and CLUSTER, Primer v6) on these data to group hydrologic units sharing similar percentages of selected physical variables (geology, soils, landform, groundwater inputs) into AES types. Unanticipated effort associated with previously unattributed areas within the existing GIS framework has delayed completion of this Job. This work is ongoing.

Job 4: Classify stream segments as valley segment types (VSTs).

The pre-project valley segment groupings were reviewed and attributed to the statewide stream linework (1:100,000). This valley segment delineation was developed in 2007 with the approach described in Brenden et al. (2008) using catchment area, link number, catchment slope, and two surficial geology summaries associated with different expectations for infiltration and runoff (bedrock, coarse sand). During this reporting period we used existing data summaries and analysis (Holtrop et al. 2006, Hinz et al. 2011, Seelbach et al. 2011) to develop Illinois specific categories describing summer stream temperature, stream size, and low flow water yield (Table 4.1). Based on this work we attributed all stream arcs and the Valley Segment Affinity Search Technique (VAST; Brenden et al. 2008) was used to delineate a new iteration of valley segments by joining similar stream arcs. VAST output was used to attribute stream arcs with unique valley segment identifiers throughout the state.

Stream size (width, drainage area, link magnitude), modeled exceedance flow discharge and modeled water temperature were examined to classify stream arcs in Illinois. To approximate stream size we used width measurements from IDNR FAS database and field data from T-25 (Sass et al. 2010). We also attributed stream arcs with size and gradient classes as defined within INAI guidelines (IDNR 2006) and used the regional upper stream size thresholds for the Illinois Fish IBI to define wadeable stream segments in Illinois (Figure 4.1).

We examined our stream size class breaks using the distributions of fish species with preference for small (brook stickleback, Southern Redbelly Dace), medium (Largescale stoneroller, fantail darter, orangethroat darter, redfin shiner, silverjaw minnow), or large (freshwater drum, smallmouth buffalo, bullhead minnow, emerald shiner, longnose gar) stream channels. Size classes associated with these species were similar to those previously developed.

Similarly, we examined thresholds between stream gradient and fish distributions of species with habitat preferences associated with low gradients (black bullhead, blackstripe topminnow, grass pickerel, sand shiner, silverjaw minnow) or higher gradients (southern redbelly dace, central stoneroller, largescale stoneroller, striped shiner, orangethroat darter). There appears to be a threshold at 0.1% slope between primarily lentic (i.e., low gradient) and lotic (i.e., high gradient) species assemblages in Illinois streams.

Thermal classes were examined using representative fish distributions for coolwater species (southern redbelly dace, fantail darter, blacknose dace, common shiner, brook stickleback), warm transitional species (smallmouth bass, stonecat), and warmwater species (red shiner, longear sunfish, green sunfish, blackstripe topminnow, yellow bullhead, gizzard shad) that had been described in a previous project (Hinz et al. 2011). Thermal breaks using these species were similar to those previously defined.

Classification of existing valley segments into types has continued using characteristics associated with watershed based conditions for stream reaches. The dominant condition from the arc-based attributes has been used to reattribute the Valley Segments for typing. We reviewed VSEC references, examined size relationships between drainage area – link magnitude – stream width, and developed an attribution of stream size & gradient for stream arcs statewide using INAI defined criteria using size and gradient (Figure 4.1b). After completing attribution of the existing INAI approach using size and gradient we explored alternative attributes for stream classification (Figure 4.3, Figure 4.4, Figure 4.5). We determined that a typing based on stream size, water temperature, and low flow water yield better described the range of stream characteristics observed in Illinois' wadeable streams. Valley Segment Types (VSTs) are ready to be reviewed (Figure 4.6). Further refinements are possible after review by the working group.

To determine if VSTs are associated with defined native fish assemblages we are performing cluster analysis (MDS and CLUSTER, Primer v6) of VSTs and fish assemblages within each EDU. Fish presence/absence data was compiled from IDNR Fisheries database and linked to stream segments (PUGAP codes) so that fish assemblages can be associated with VSTs within the same stream segment. Only fisheries database were used because we required community samples associated with stream segments. Similar data were compiled from the IDNR Mussel database. The resulting data matrix (species presence by stream segment) will be used as the input data for a series of multivariate analyses that assess the relative similarity of fish and mussel assemblages among VSTs within an EDU. This work is ongoing.

Job 5: Define Natural Community Types (NCTs).

We continued to review INAI guidelines for Category I and Category VI designations and the grading applicable to streams. Regional fish (Figure 2.1) and mussel richness (Figure 2.2) has been estimated statewide from recent surveys at the HUC8 level. We are investigating the use of species richness levels, and the range of species collected during individual sampling events, to index regional (EDU) biodiversity expectations as a standard reference level for Category VI.

We also investigated using NatureServe S (subnational or state) ranks for fish or mussels as a Category I or VI designation criteria in a manner similar to what is used for Cave Communities in the INAI. Unfortunately, while this approach has promise the Illinois NatureServe rankings have not been updated since they were initially developed (< 1997) and are painfully out of date. Information from T-68 and T-53 could be used to update the state S rankings but this is beyond the scope of our current project. This work is ongoing.

Job 6: Produce a list of candidate sites for INAI using existing data.

No work was scheduled for this Job during this reporting cycle.

Fish and mussel collection locations of T&E species were georeferenced and mapped for evaluation as INAI Category III (suitable habitat for T&E species) sites. We have also obtained and mapped locations that would qualify under the existing criteria as INAI Category VI sites based on fish IBI and Mussel Community Index scores, and high Mussel Richness. During this reporting period we continued investigating using fish species richness measures for potential as an INAI criterion for Category VI. This work is ongoing.

Job 7: Prepare manuscripts and reports.

Four quarterly reports for IDNR and this annual report were prepared. No other work was scheduled for this Job.

Literature Cited:

Brenden, T.O., L. Wang, P.W. Seelbach, R.D. Clark Jr., M.J. Wiley, B.L. Sparks-Jackson. 2008. A Spatially constrained clustering program for river valley segment delineation from GIS digital river networks. Environmental Modelling & Software 23: 638-649.

Clarke, K.R. and R.N.Gorley. 2006. PRIMER v6: User Manual/Tutorial. PRIMER-E, Plymouth.

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DeWalt, R. E., S. Grubbs, Y. Cao, L. Hinz, and T. Tweddale. 2009. Using Museum Records and Distribution Models to Reconstruct the Historical Assemblage for Midwest Plecoptera. NSF DEB 09-18805

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Sass L. L., L.C. Hinz Jr., J. Epifanio and A. M. Holtrop. 2010. Developing a multi-metric habitat index for wadeable streams in Illinois. Final Report to the Illinois Department of Natural Resources. Illinois Natural History Survey Technical Report 2010/21.

Seelbach, P.W., L.C. Hinz, M.J. Wiley, and A.R. Cooper. 2011. Use of multiple linear regression to estimate flow regimes for all rivers across Illinois, Michigan, and Wisconsin. Michigan Department of Natural Resources and Environment. Fisheries Division Research Report No. 2095. Ann Arbor.

Sowa, S.P. and D.D. Diamond. 2006. Using GIS and an aquatic ecological classification system to classify and map distinct riverine ecosystems throughout EPA region 7. Final Report, submitted to US EPA Landscape Ecology Branch, Environmental Photographic Interpretation Center, Reston, VA. 242 pp.

Table 4.1. Stream segment attributes used to develop Valley Segment Types. Stream Size is the total upstream drainage area at the downstream end of the stream segment (Holtrop et al. 2006), Mean Daily July Temperature is based on predicted temperatures from a state-wide multiple linear regression model (Hinz et al. 2011), and Low Flow Yield was defined as the annual 90% exceedance flow discharge [m^3s^{-1}] / drainage area [km^2] based on a state-wide multiple linear regression model (Seelbach et al. 2011).

Code	Stream Size (stream size class name)
1	<15 km^2 (headwaters)
2	15-80 km^2 (small streams)
3	81-600 km^2 (medium streams)
4	601-35,000 km^2 (large streams)
5	>35,000 km^2 (major rivers)

Code	Mean Daily July temperature (thermal class name)
1	<21.5 ^oC (cool)
2	21.5-23.5 ^oC (warm transitional)
3	>23.5 ^oC (warm)

Code	Modeled Low Flow Yield
1	0 - 0.00000242 m^3s^{-1}/km^2
2	0.00000243 - 0.00015835 m^3s^{-1}/km^2
3	> 0.00015835 m^3s^{-1}/km^2

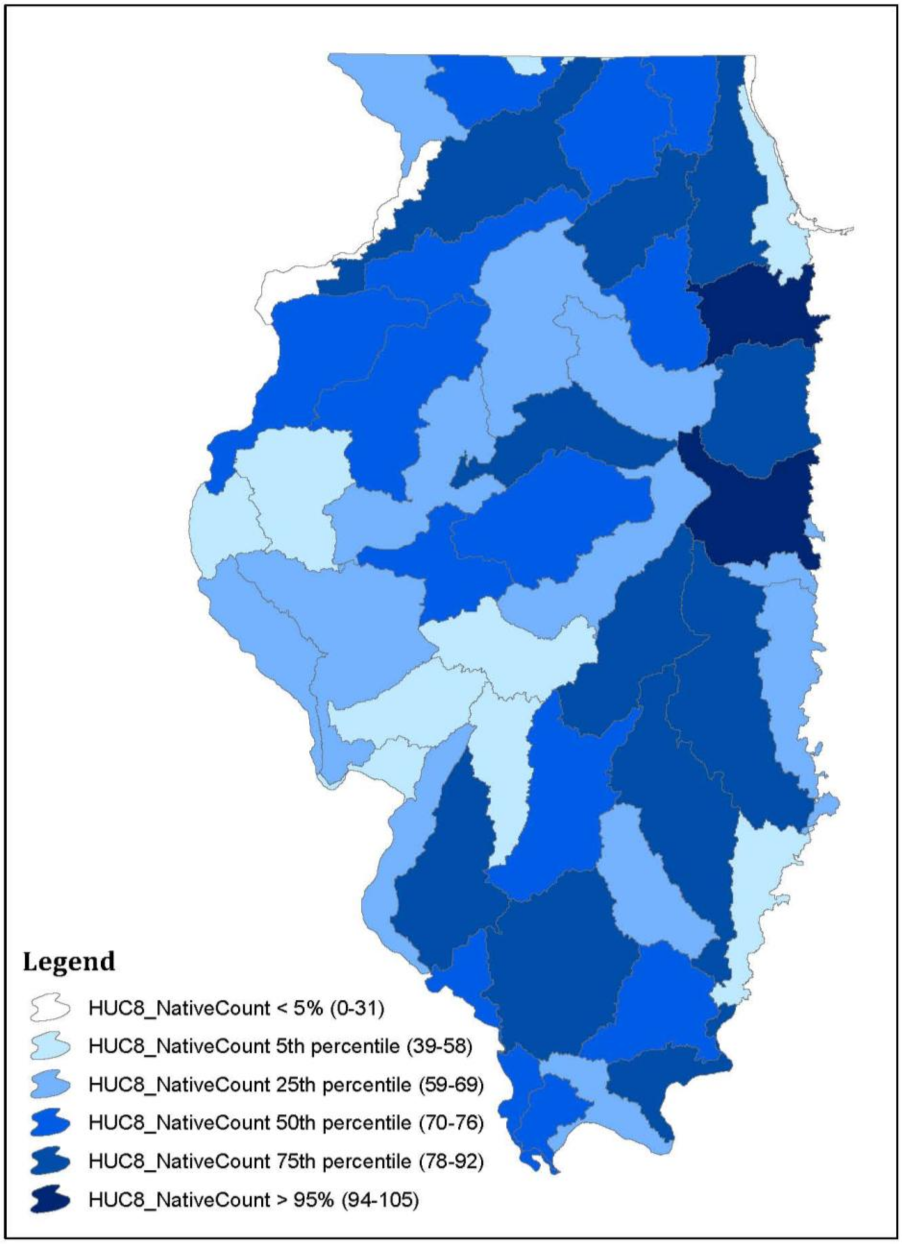

Figure 2.1. Number of native fish species within HUC8 watersheds in Illinois.

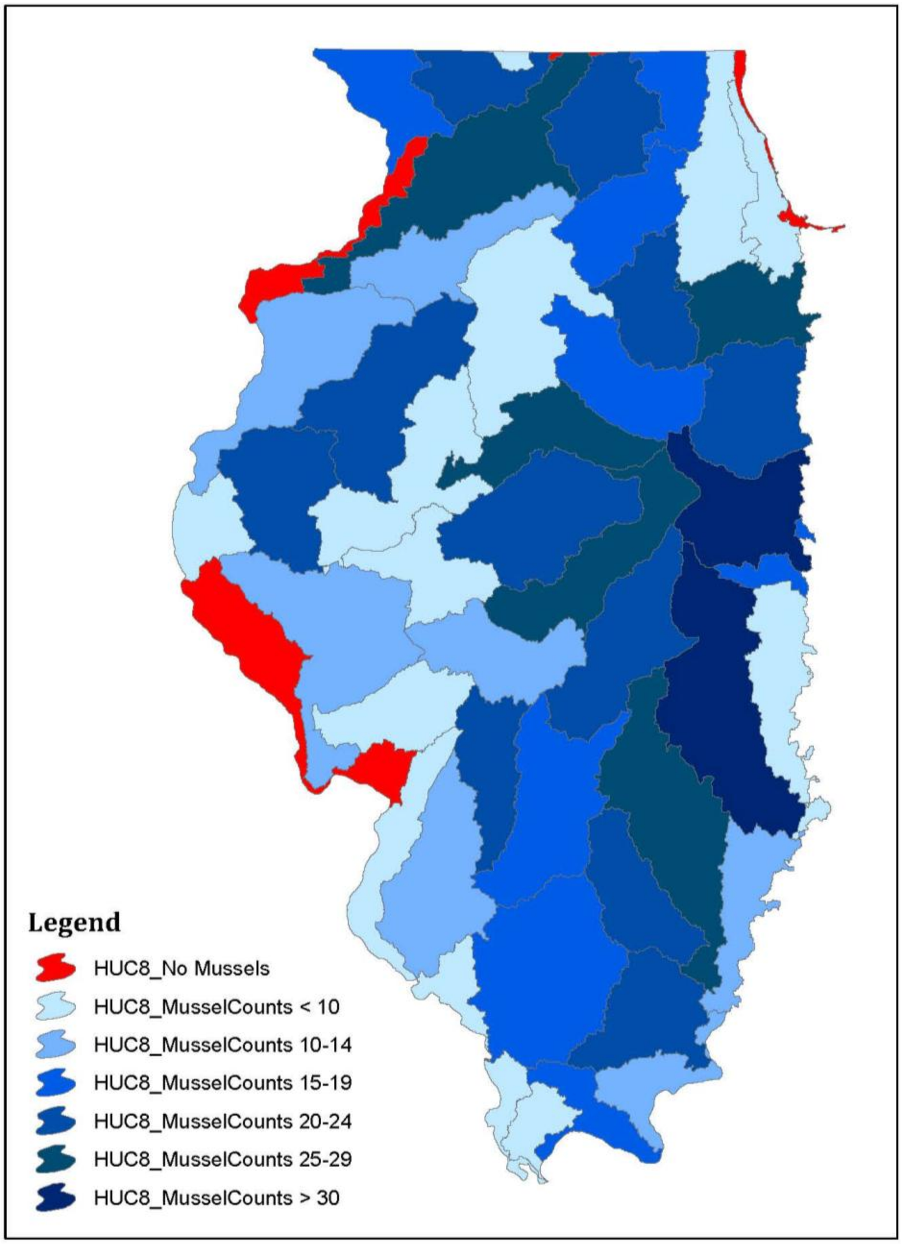

Figure 2.2. Number of native mussel species within HUC8 watersheds in Illinois. Areas with "No Mussels" have not been as extensively surveyed and do not include mussel records from the Mississippi River Mainstem or the Great Lakes.

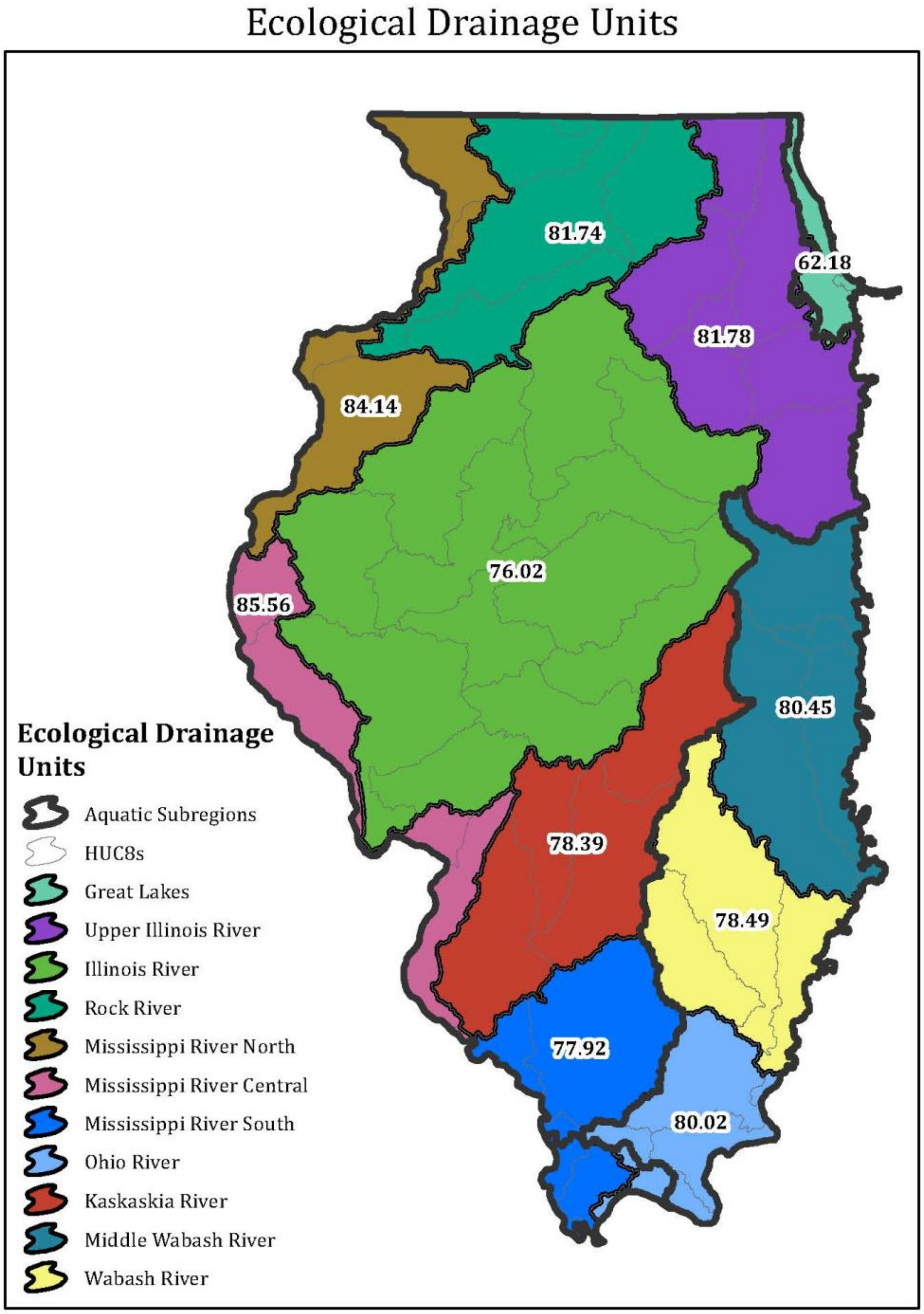

Figure 2.3. Draft Ecological Drainage Units (EDU) for Illinois were derived using drainages and HUC8s with relatively similar fish and mussel species assemblages. Values correspond to the Bray-Curtis similarity of the combined fish and mussel assemblages between HUC8s within each EDU (SIMPER, Bray-Curtis 70% similarity; PRIMER v6).

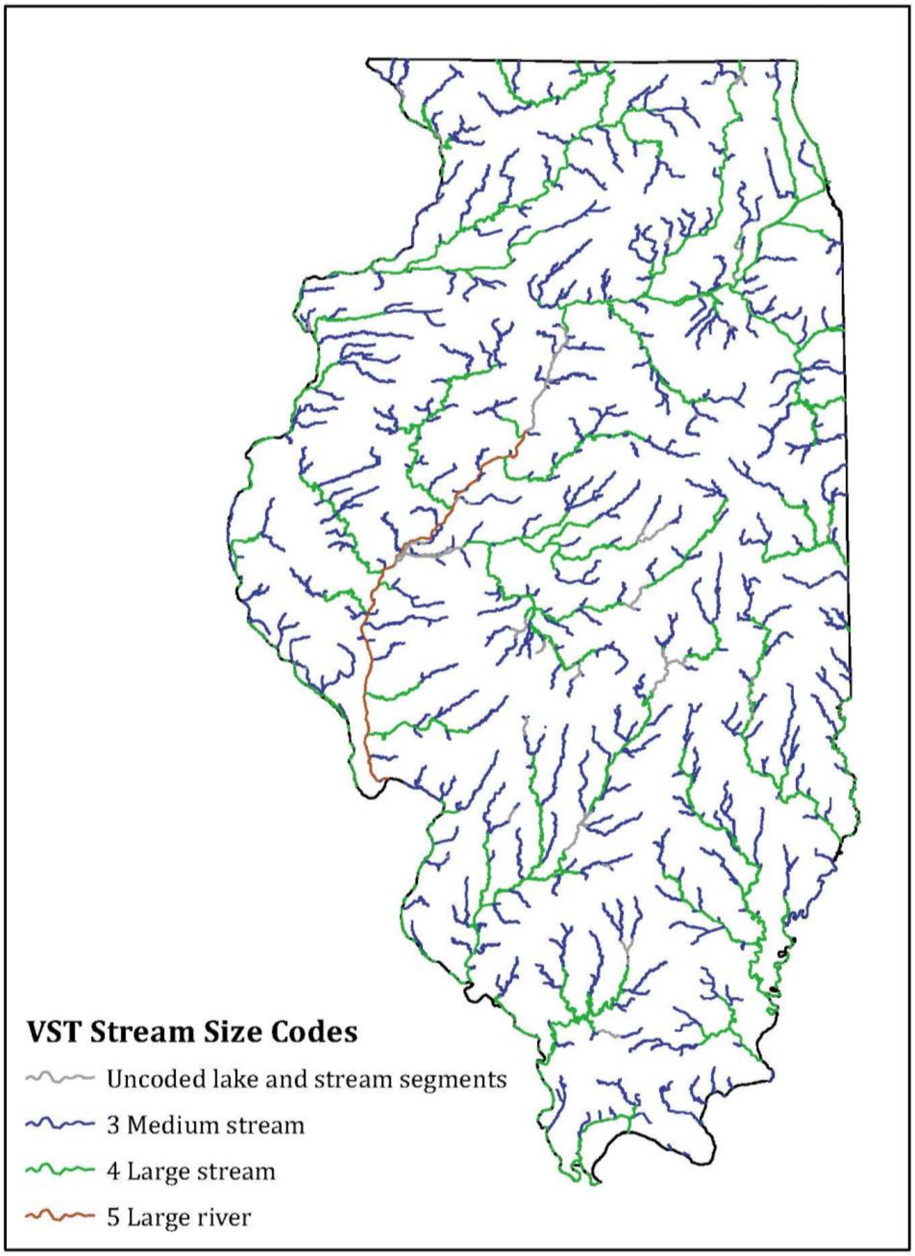

Figure 3.1. Illinois stream network containing only medium sized and larger stream segments used for developing watershed boundaries associated with Aquatic Ecological Systems. Great River (i.e., Mississippi River, Ohio River, Wabash River) segments on Illinois' borders with other states have not been coded for these efforts.

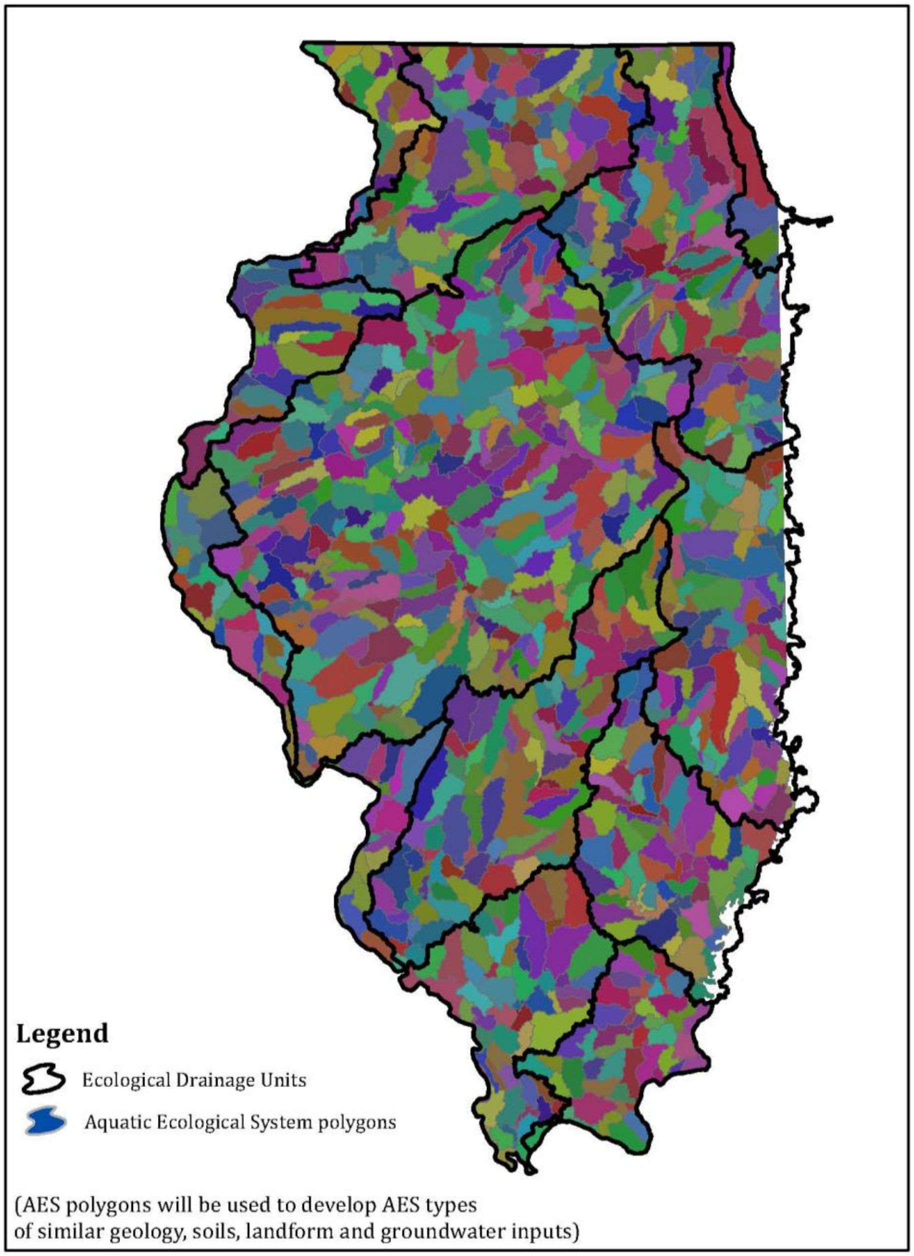

Figure 3.2. Draft watershed boundaries for Aquatic Ecological Systems for Illinois streams. Great River (i.e., Mississippi River, Ohio River, Wabash River) segments on Illinois' borders with other states have not been coded for these efforts.

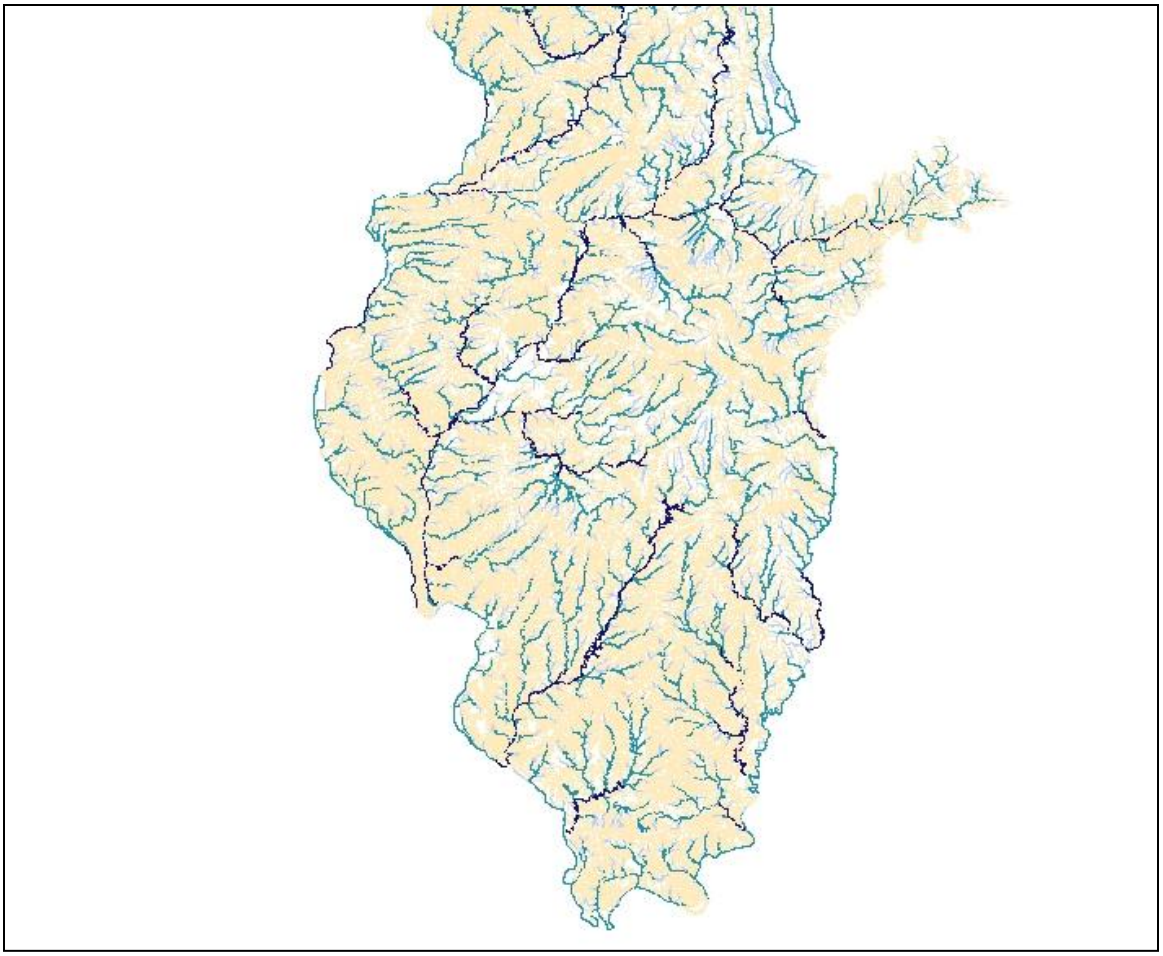

Figure 4.1. Size classification based on INAI Framework developed using association between drainage area and stream width. Very small streams (<10 ft, 0-37 km^2) are tan, small streams (10-20 ft, , 38-80 km^2) are light blue, medium streams (21-100 ft, 81-2150 km^2) are green, and large streams (>100 ft, > 2150 km^2) are dark blue. [Note: Major Rivers (i.e., Mississippi, Ohio, Wabash) are not fully classified on this Figure; Some portions of Indiana are included where they connect with Illinois' waters.]

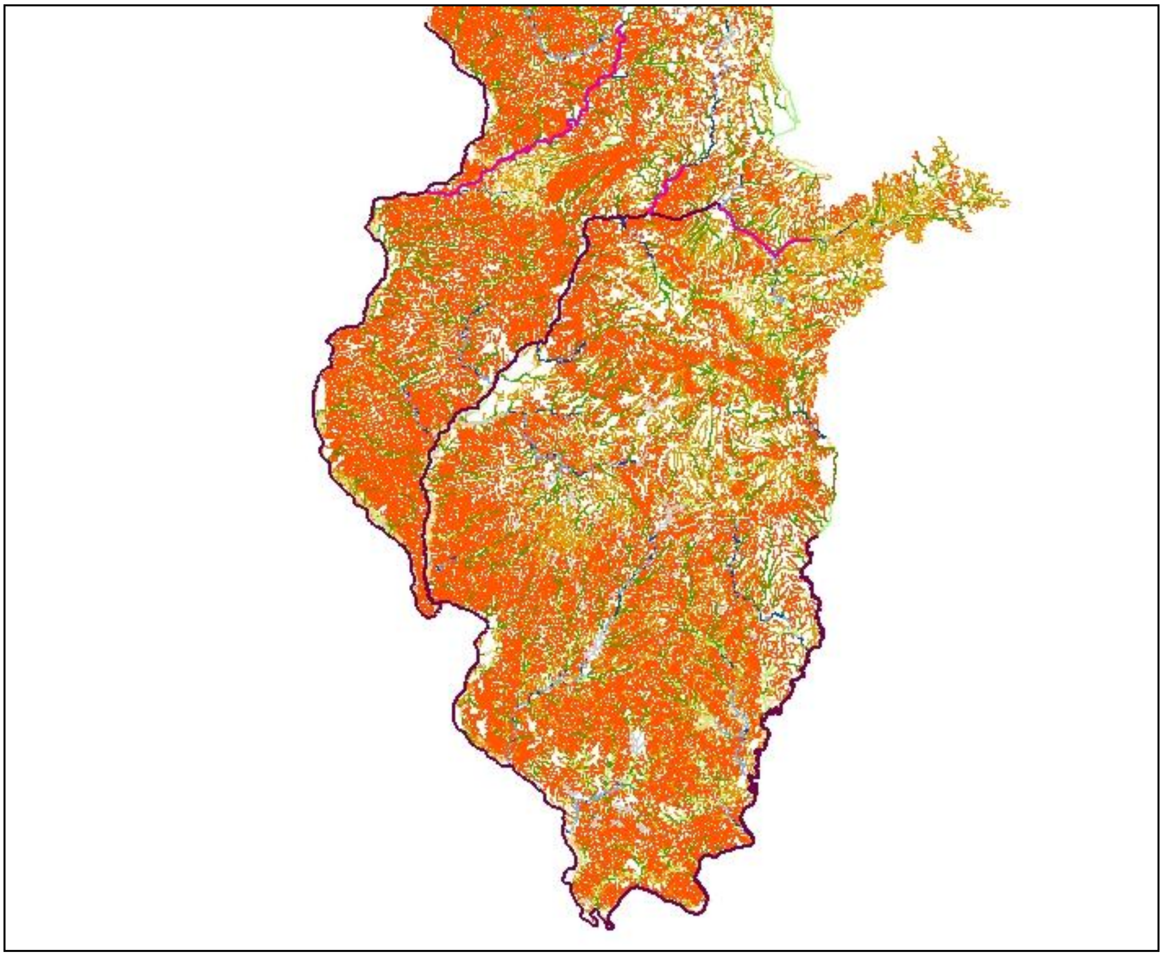

Figure 4.2. Size and Gradient Classification defined within the current INAI framework. Colors represent different combinations of size and gradient.

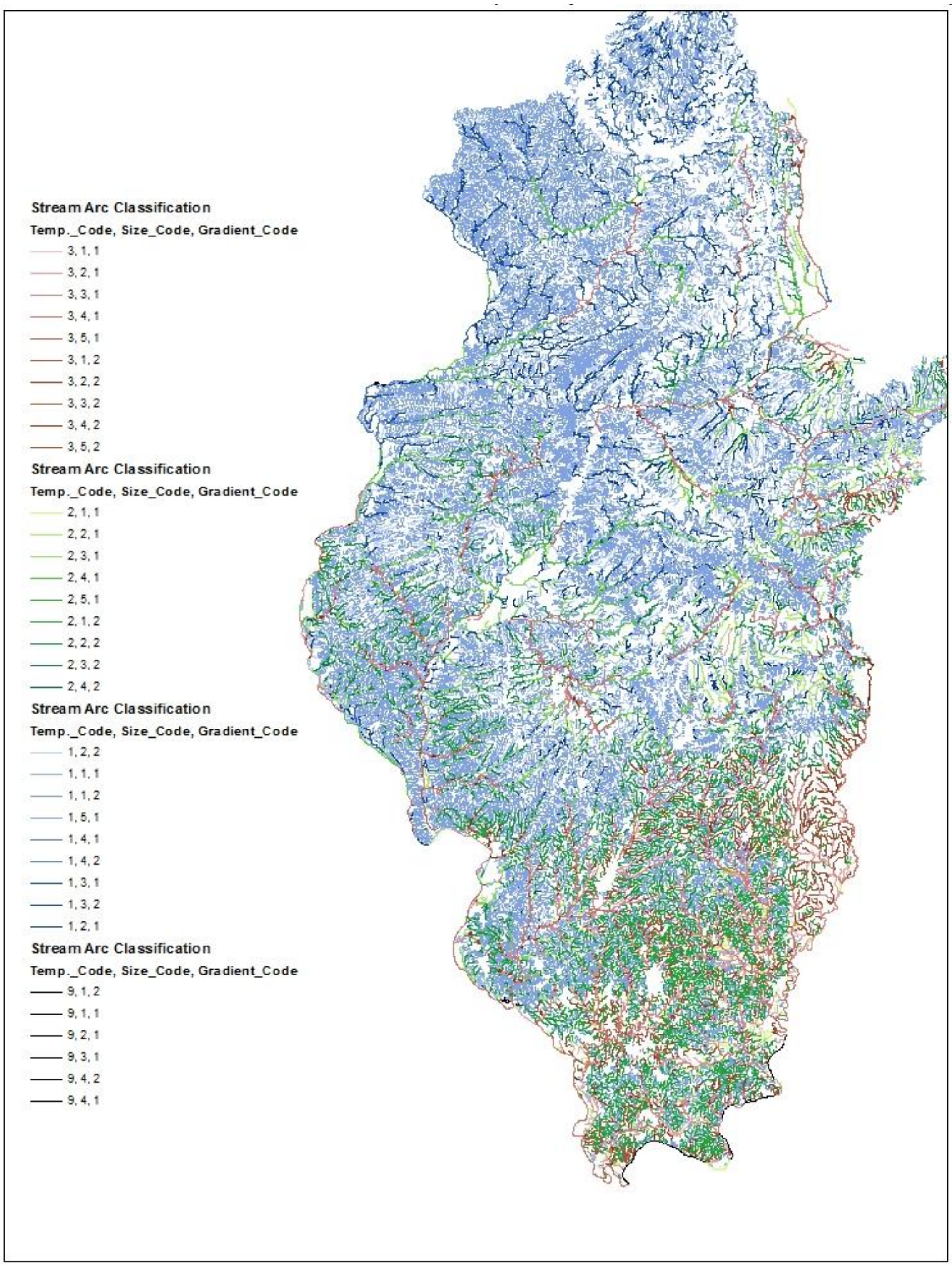

Figure 4.3. Draft Classification of stream reaches based on temperature, size, and gradient. This is essentially the existing INAI classification with a thermal attribute added.

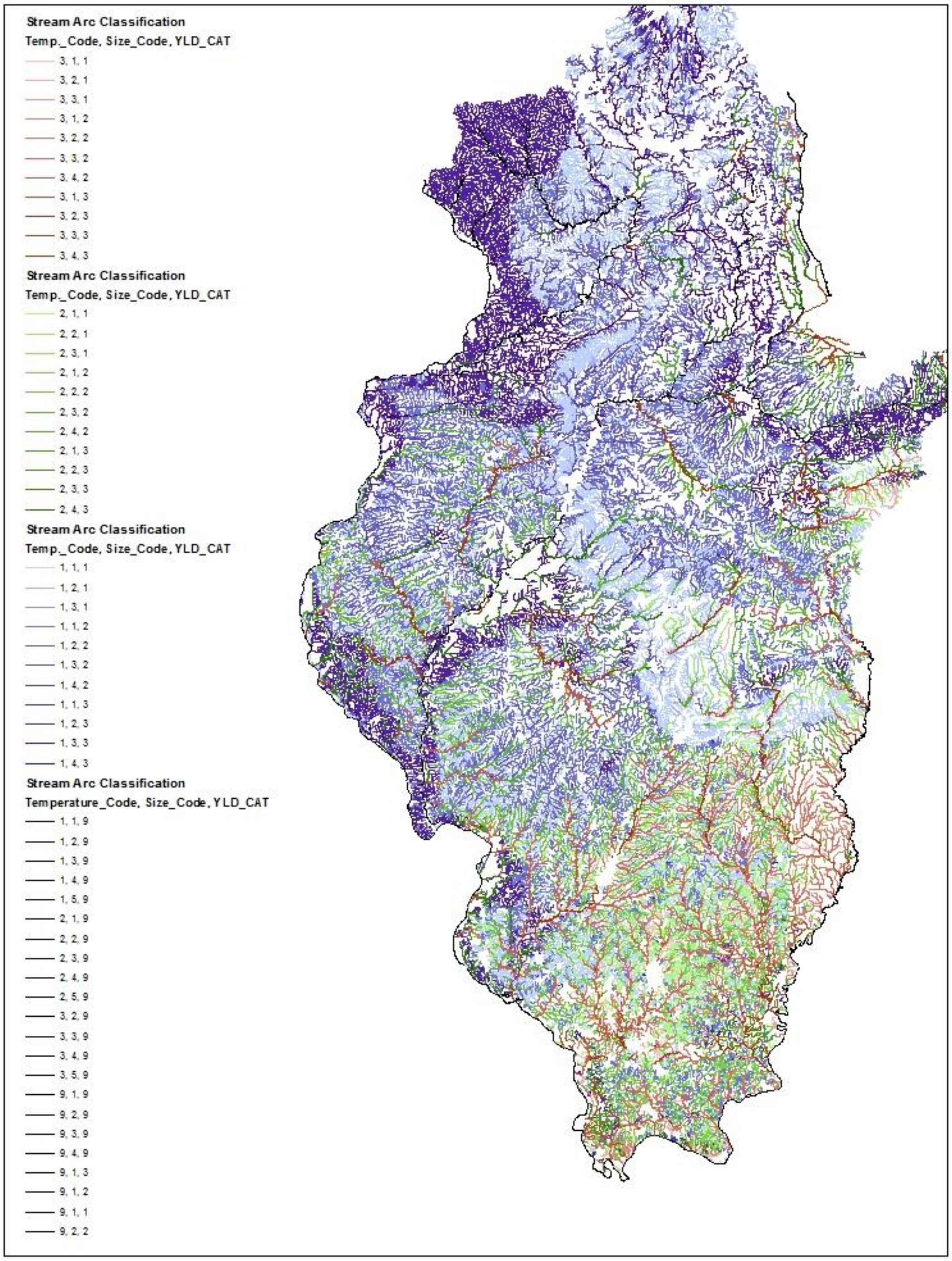

Figure 4.4. Stream classification based on summer temperature, stream size, and water yield.

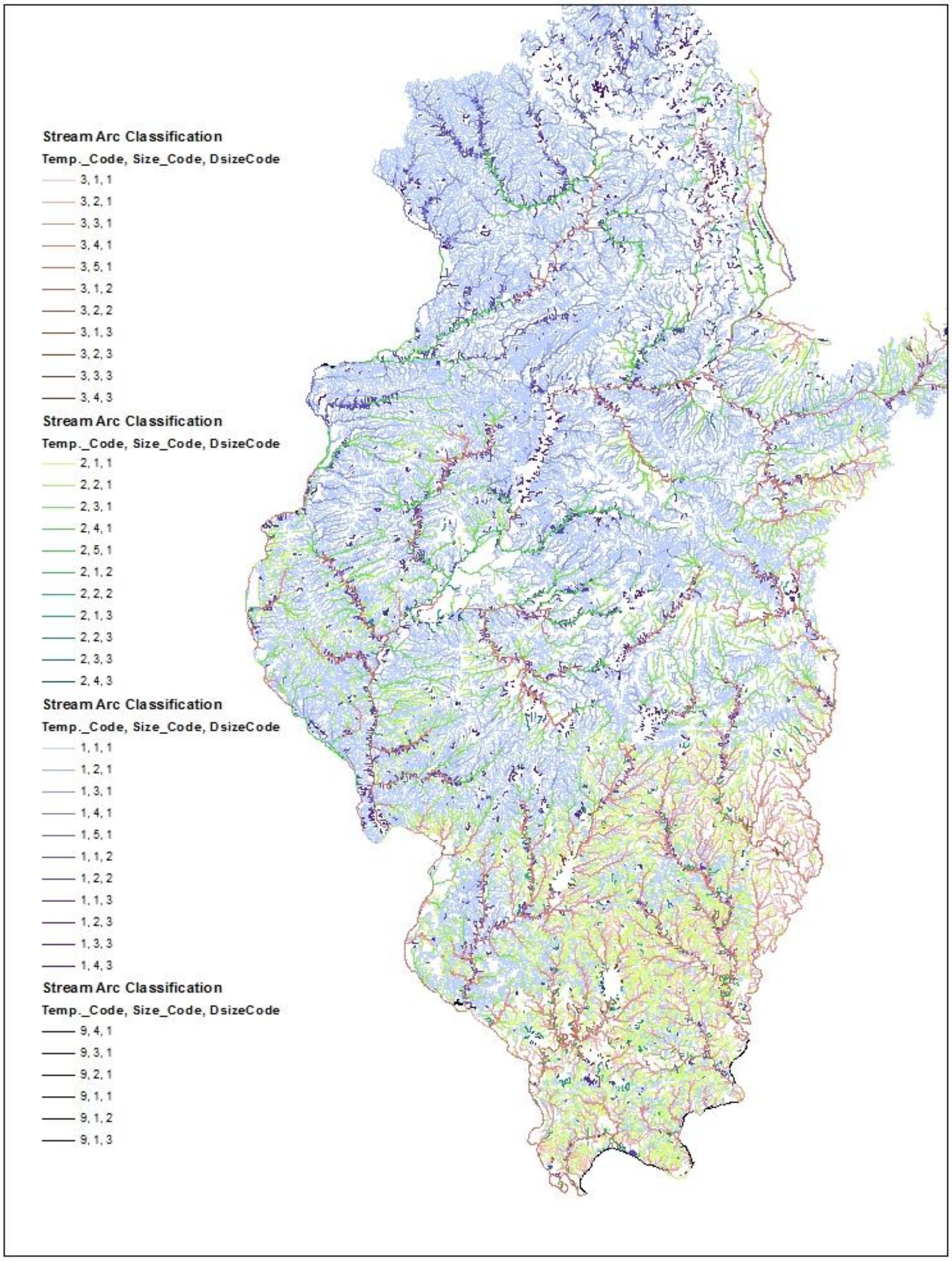

Figure 4.5. Stream classification based on temperature, stream size, and size of downstream segment.

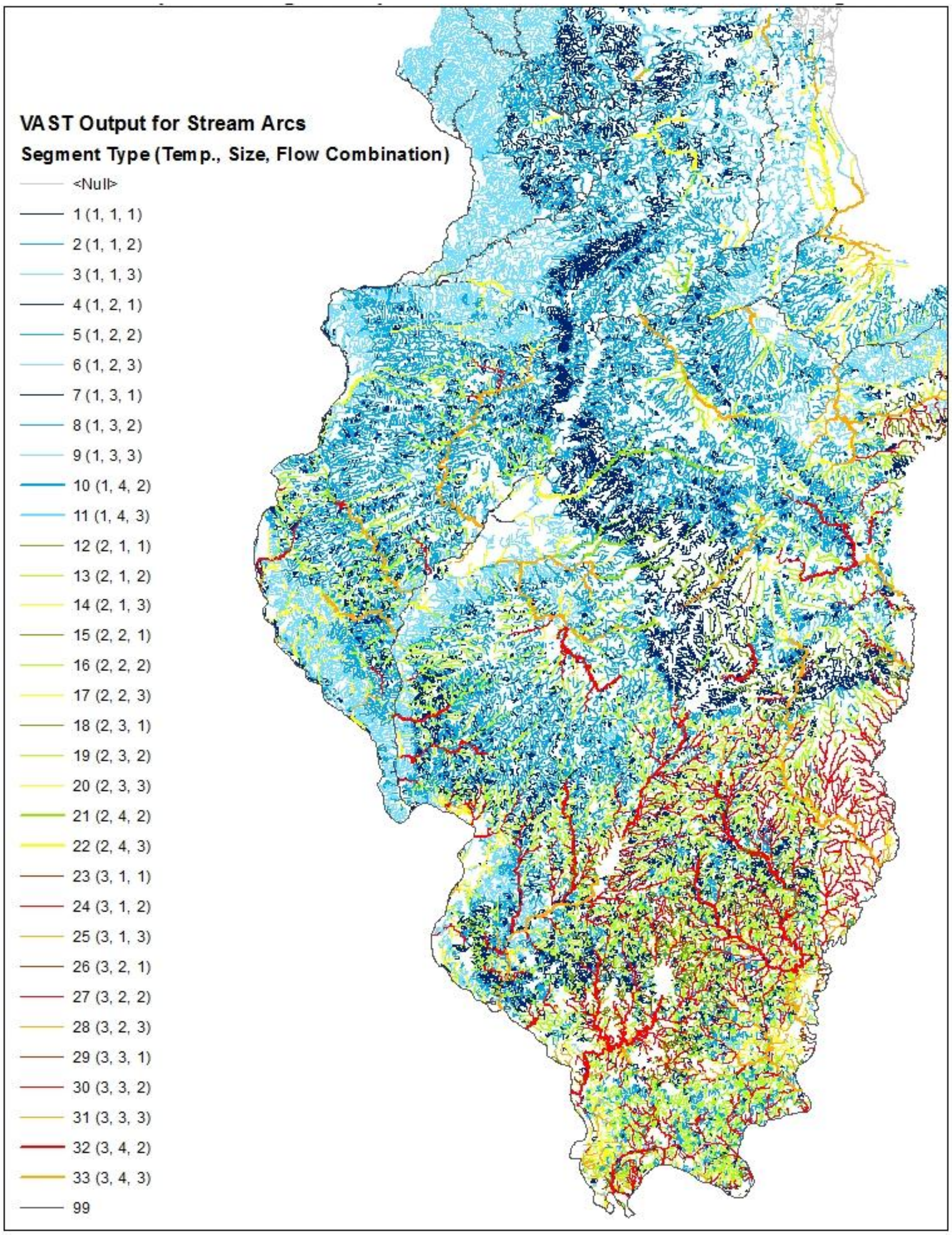

Figure 4.6. Draft Valley Segment Classification of stream reaches based on summer water temperature, stream size, and water yield. Temperature, Size, and Flow characteristics are described in Table 4.1.