FINAL REPORT

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ABSTRACT

Maintaining aquatic ecosystem health is critical for the conservation of a number of rare and imperiled freshwater mussel and fish species. This project employed Geographic Information System (GIS) models to rapidly evaluate and broadly describe streams based upon systemizing up-to-date statewide multi-scale spatial data capable of characterizing aquatic species habitats. Main data sets that were used to attribute the stream network included climate, ecoregions, ecological drainage units, watersheds, surficial geology, landforms, soils, vegetation and land cover.

We developed a statewide stream habitat classification GIS data layer that is necessary for the identification of existing and potential habitats of aquatic species. The classification scheme used a set of hierarchical stream habitat abiotic characteristics presumably correlated with the fine-scale stream characteristics important for aquatic species. The scheme involved the application of the stream habitat classification framework, developed by the Missouri Resource Assessment Partnership, to attribute the flowlines of the 1:24,000-scale National Hydrologic Dataset (NHD, or digital stream network) for Florida. The NHD quality was significantly improved by extending the network through modeling missing streams and refining overall geometry, connectedness, and flow direction of flow-lines representing centerlines of the streams. The final Florida Stream Dataset (FSD) contains 3,106,943 stream segments with the total length of approximately 165,000 km. The nested aquatic classification system describes each of those segments crossing landscape-level ecosystem/hydrologic units for freshwater areas. The freshwater aquatic habitat classification provides adequate detail for conducting ecological GIS modeling and large- scale statewide and ecoregional assessments, finer watershed level assessments, as well as assessments at a scale of individual stream segments.

ACKNOWLEDGEMENTS

This project was initiated by Theodore Hoehn. The initial pilot study and testing of available classification tools was performed by Michelle Mayo during the first 6 months of the project. Michelle also worked with Florida Geological Survey on simplifying their environmental geology data layer to derive straight-forward descriptions of surficial geology types applicable to stream substrate types. During the first year of the project, Luke Bell concentrated on production of the Digital Elevation Model (DEM). Aaron Podey devoted his time to the National Hydrography Dataset enhancement and to production of the Ecological Drainage Units. This project could not have been completed without technical help provided by FWC OPS employees, Jason Fuller, Dusty Powel, and Matt Sumner, who worked on manual editing of hydrologic networks. We also thank 2 FWC volunteers, Bryan Schoonard and Bjorn Nilsson, who assisted with searching for and downloading available ancillary data sources. This project was supported by the Florida Wildlife Legacy Initiative program of the Florida Fish and Wildlife Conservation Commission and the U.S. Fish and Wildlife Service‘s State Wildlife Grants Program (T-3, SWG-9100-256-2167).

TABLE OF CONTENTS

INTRODUCTION

The identification of habitats of rare and imperiled species is a requirement of the State Comprehensive Wildlife Conservation Strategy (CWCS) (FWC 2005). These aquatic ecosystems are particularly critical to the conservation of a number of rare and imperiled freshwater mussel and fish species. Before this project was initiated, Geographic Information System (GIS) databases that could be used to rapidly evaluate streams based upon system type, stream order, or habitat type did not exist. Florida is currently experiencing significant development pressures as timberland and agricultural land are converted to residential development. As development projects are proposed, an evaluation tool will be needed to assess potential impacts to rare and imperiled species as a function of changes in system/habitat type and land use.

This project builds on the previous State Wildlife Grant (SWG)-funded project, *Florida Imperiled Fish Species Investigation*. The objective of this project is to develop a digital stream habitat classification data layer that can be used to identify existing and potential habitats of rare and imperiled fish and other aquatic species. The classification system defines habitats within macro-habitat units in a nested aquatic classification system across landscape-level ecosystem/hydrologic units for freshwater areas (CWCS requirement 2). The resulting GIS dataset can be readily updated whenever there are changes in “quality” of the general landscape. This is due to the combination of physical and ecological factors that will define environmental “quality” associated with the stream macro-habitats. The stream habitat classification framework was applied to the National Hydrologic Dataset (NHD, digital stream network) for Florida from the Perdido River to the Everglades.

The GIS-based stream habitat data layer allows for identification of existing and potential but unsampled habitats of rare and imperiled fishes, refinements of the distributions of these fishes, and identification of stream segments that may be threatened by development or in need of restoration (CWCS requirement 1 and 2). For these purposes, 2 concurrent 1-year projects were initiated: Florida‘s State Wildlife Grants Programs (SWG) *Florida Freshwater and Tidal Stream Fish Distribution Mapping: Phase I – Panhandle,* and Florida‘s Conserve Wildlife Tag Fund Grant (CWT) *Mapping Threats to Florida Freshwater Habitats*. This SWG-funded project, *Florida Stream Habitat Classification,* is a part of a bigger initiative for comprehensive conservation planning and management of aquatic ecosystems, referred to as Florida's Aquatic Gap Analysis Project (Fig. 1).

Initially we intended to use the NHD with the coarse standard geographic resolution of 1:100,000 which was aggregated according to the 8-digit sub-basin level Hydrologic Unit Code (HUC), as mapped by the U.S. Geological Survey (USGS 2005). The Florida Department of Environmental Protection (DEP) is in the process of developing and certifying a finer level (1:24,000 scale) version of the NHD at the 12-digit HUC, or sub-watershed level. The product of this refinement process was not available at the time of this project; therefore, additional efforts were dedicated to enhance the 1:24,000-scale NHD to a level where the stream-habitat classification framework could be built on the finer scale NHD. The finer scale NHD is more appropriate for the classification and its multiple applications, including more detailed aquatic ecological assessments. The DEP is working on the Florida NHD, which should not be confused with the FWC Florida Stream Dataset (FSD), which was developed concurrently and contains added habitat values.

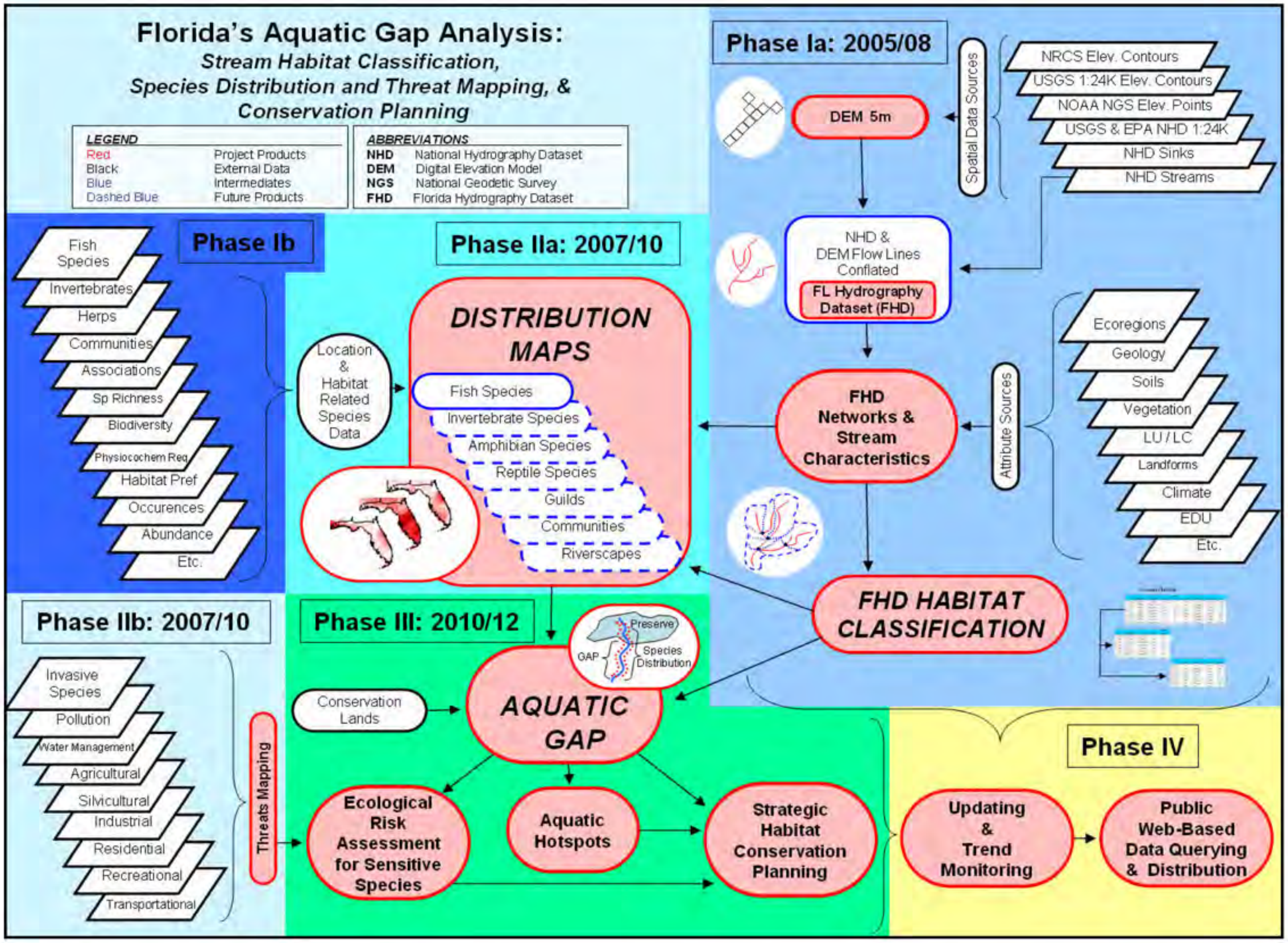

Figure 1. Conceptual steps to the 4 phases of Florida's Aquatic Gap Analysis Project. This project *Florida Stream Habitat Classification* is represented by Phase Ia. Note the Florida Stream Dataset is referred to as the Florida Hydrography Dataset (FHD) in this diagram.

Originally, it was proposed to build the stream-habitat classification framework using the methodology developed and used by the Missouri Resource Assessment Partnership (MoRAP) and EPA Region 7 (Sowa et al. 2005). Their methodology was based on attributing the 1:100,000-scale NHD at 4 hierarchical levels (Annis et al. 2002):

1) *Aquatic Subregions* – Aquatic Subregions stratify Aquatic Regions. Large drainages with relatively distinct climate and physiography, which generally correspond to broad vegetation regions. In Missouri, Aquatic Subregions largely correspond to Bailey's Ecoregional Provinces.
2) *Aquatic Ecological Drainage Units (EDU)* – Zoogeographic subunits of Aquatic Subregions. EDU's are delineated using multivariate statistics to aggregate hydrologic units that share relatively distinct aquatic assemblages.
3) *Aquatic Ecological System Types (AES)* – Hydrologic subunits of EDU's with similar physiographic settings, basin morphometry and position within the larger drainage (e.g., located in the headwaters versus near the drainage outlet). These were delineated using groupings of 14-digit hydrologic units.
4) *Valley Segment Types (VST)* – Hydrogeomorphic units defined by local physical factors and their position in the stream network. Valley segment types stratify stream networks into major functional components that define broad similarities in fluvial processes, sediment transport, riparian interactions, and thermal regime. These were delineated using the 1:100,000 scale NHD stream coverage. Size typically ranges from 1 – 10 kilometers in length.

We used the MoRAP methodology as a general approach. Where applicable we followed their methods using equivalent data sources; however, we did make necessary modifications to account for current GIS capabilities, new available data sources, and Florida specific requirements. The MoRAP project was created on a much less detailed NHD framework. In Florida, we concentrated on producing a detailed and reliable stream network that will serve as a base for incorporating habitat values and allowing updates. The Florida stream network was coded with major stream parameters at multiple scales. However, some parameters found in MoRAP, such as gradient, were not included due to the predominantly flat terrain in Florida. Additionally, we did not cluster the collected local physical factors into combined classes, such as the MoRAP‘s Valley Segment Types. These classifications have to be subject-specific, addressing particular species and their assemblages. The Florida dataset provides the necessary information which can be aggregated and augmented according to specific goals of a particular assessment.

The stream-habitat classification framework is based upon 4 key assumptions regarding the biological community and its connections with habitat structure: 1) large-scale physiographic and climatic patterns influence the distribution of aquatic organisms, and can be used to predict expected range of community types within these large zones; 2) aquatic communities exhibit distributional patterns that can be predicted from the physical structure of aquatic ecosystems; 3) although aquatic habitats are continuous, reasonable generalizations can be made about discrete patterns in habitat use; and 4) by nesting small classification units (biological communities, macrohabitats) within the large climate and physiographic zones, community diversity that is difficult to observe or measure can be accounted for (Higgins et al. 1998, 1999). The framework incorporates abiotic components to describe river reaches along with ecoregional modifiers and regional ―quality” parameters. Local stream habitat variables predicted from larger scale characteristics, such as catchment basins, are useful for predicting fish distribution (Mugodo et al. 2006). The abiotic components describe physical features like stream order, reach or geomorphologic position (landform). These components are also delineated across ecoregional province and section, climate regions, land-cover types, and groundwater level and substrate type (based on surficial geology and soil types).

METHODS

A general overview of the entire process used in this project is presented in a flowchart (Fig. 2). The process involved 3 major steps with each being completed in approximately 12 months: 1) producing a 5-m resolution DEM for the area of 8 NHD subregions; 2) enhancing the NHD using modeled flowlines derived from the DEM; and 3) calculating morphometric and positional parameters of the resultant Florida Stream Dataset (FSD), and coding it with aquatic characteristics at multiple scales using external and internally developed data sources.

Data Sources

The major dataset for the stream framework was obtained from USGS and consisted of a set of 14-digit coded flowlines within the 8 4-digit 1:24,000-scale NHD subregions covering Florida and parts of Georgia and Alabama (subregions 0307–0314) (Fig. 3). The regions outside of Florida were needed to correctly assess stream order and distance to the sources. The NHD dataset is routinely updated by USGS every 2-3 months. A version of the dataset dated October 2005 was used for initial DEM production. A second version from June 2006 served as the base upon which dataset improvements and extensions were made. Finally, the March 2007 version was used in the final editing and coding phase. The three versions of the NHD were downloaded on the referenced dates. The first and second downloaded datasets were used primarily to generate and model flowlines and not for actual editing, while the third NHD download served as the basis for modifications and improvements. Since the first two downloads were not edited

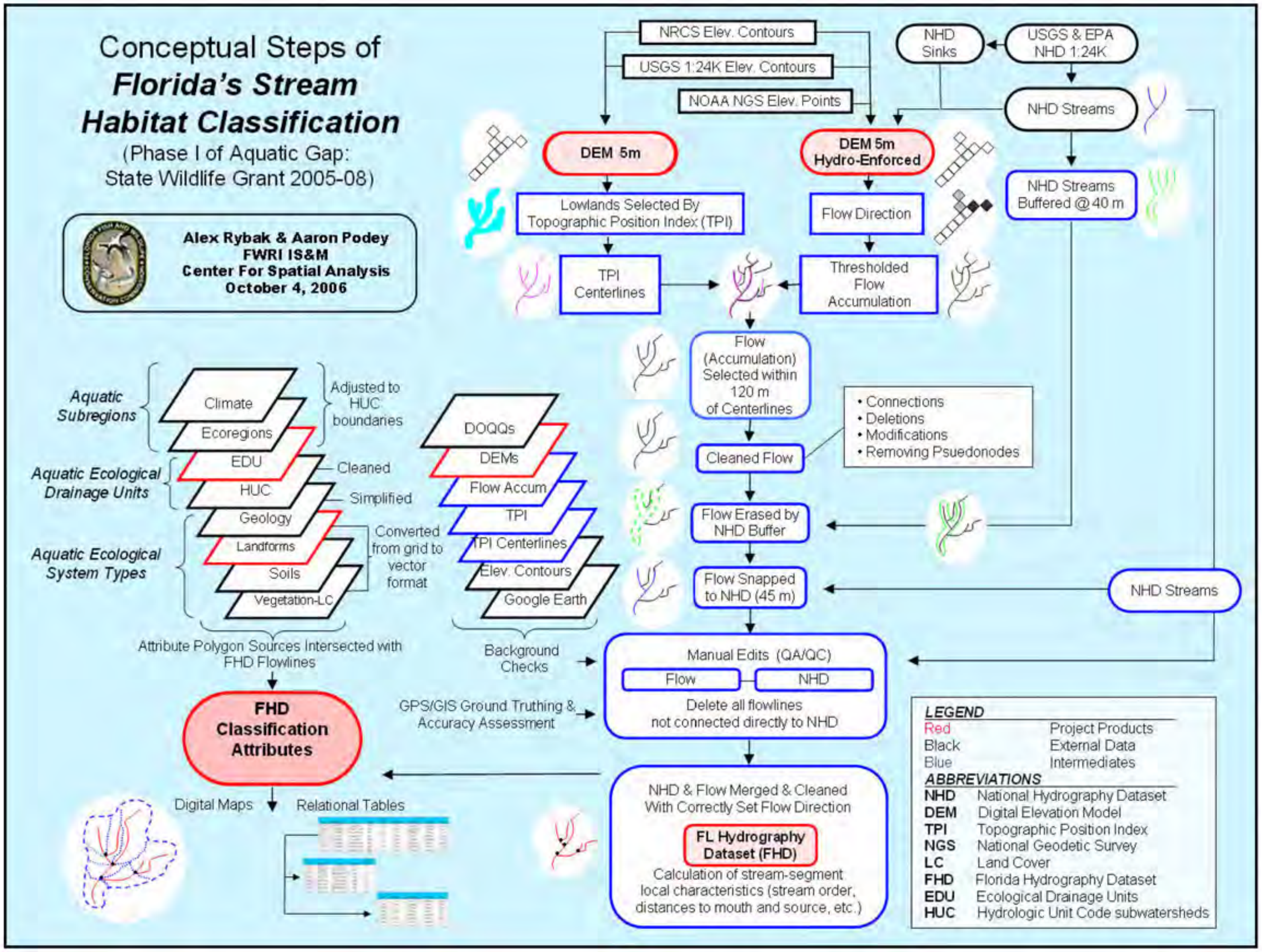

Figure 2. Flowchart of Florida Stream Habitat Classification project. Note the Florida Stream Dataset (FSD) is referred to as the Florida Hydrography Dataset (FHD) in this diagram.

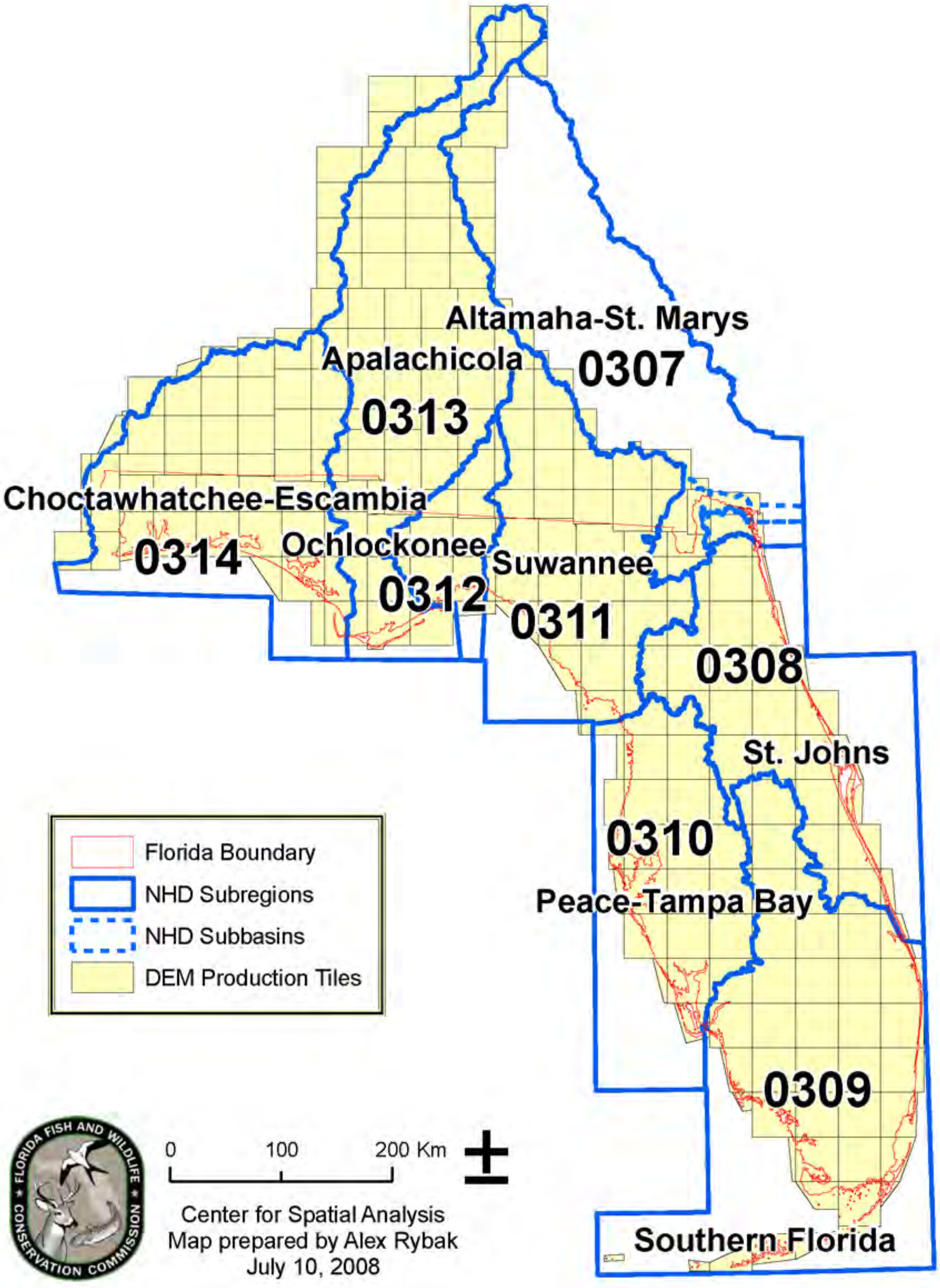

Figure 3. The NHD subregions 0307–0314 and 240 DEM production tiles. Only two NHD subbasins of the subregion 0307 (dashed blue lines) were used in this project.

directly, there was no duplication of effort during the editing process. The flowlines developed in the earlier stages of the project were combined with the third downloaded dataset and modified to produce a combined set of improved NHD and added flowlines.

Another important dataset was from the DEP and consisted of HUCs at the subwatershed level (12-digit, or HUC-12). We received the dataset in August 2007 with a disclaimer that this was a –working" version of the 1:24,000 scale of the Watershed Boundary Dataset (WBD). The WBD is being developed by the USDA Natural Resources Conservation Service (NRCS), along with many other federal agencies and national associations, under the leadership of the Subcommittee on Spatial Water Data, which is part of the Advisory Committee on Water Information (ACWI) and the Federal Geographic Data Committee (FGDC). After editing the polygons, the HUC-12 dataset contained 1,575 subwatersheds within Florida and the closest contributing areas in Georgia and Alabama (Fig. 4).

It should be noted that currently the USGS14-digit NHD flowlines and the NRCS 12-digit HUC identifiers do not always match by code and position; although both datasets were prepared by digitizing the same source data—the USGS 1:24,000 topographic maps. The coding system is designed by 2-digit sequential representations: region (the first–second digits), subregion (third–fourth), basin (fifth–sixth), subbasin (seventh–eighth), watershed (ninth-tenth), subwatershed (eleventh–twelfth), and the thirteenth–fourteenth level units.

For the stream network improvements, we developed 5-meter resolution digital elevation models (DEMs). The DEMs were based on the USGS 1:24,000-scale elevation contours, which had been refined for Florida by Florida Geological Survey (FGS) and DEP. The elevation intervals of the contours varied from 5 to 10 feet among the more than 1,000 USGS 7.5-minute quads (series map sheets) covering the State of Florida. Contour data for those areas outside of

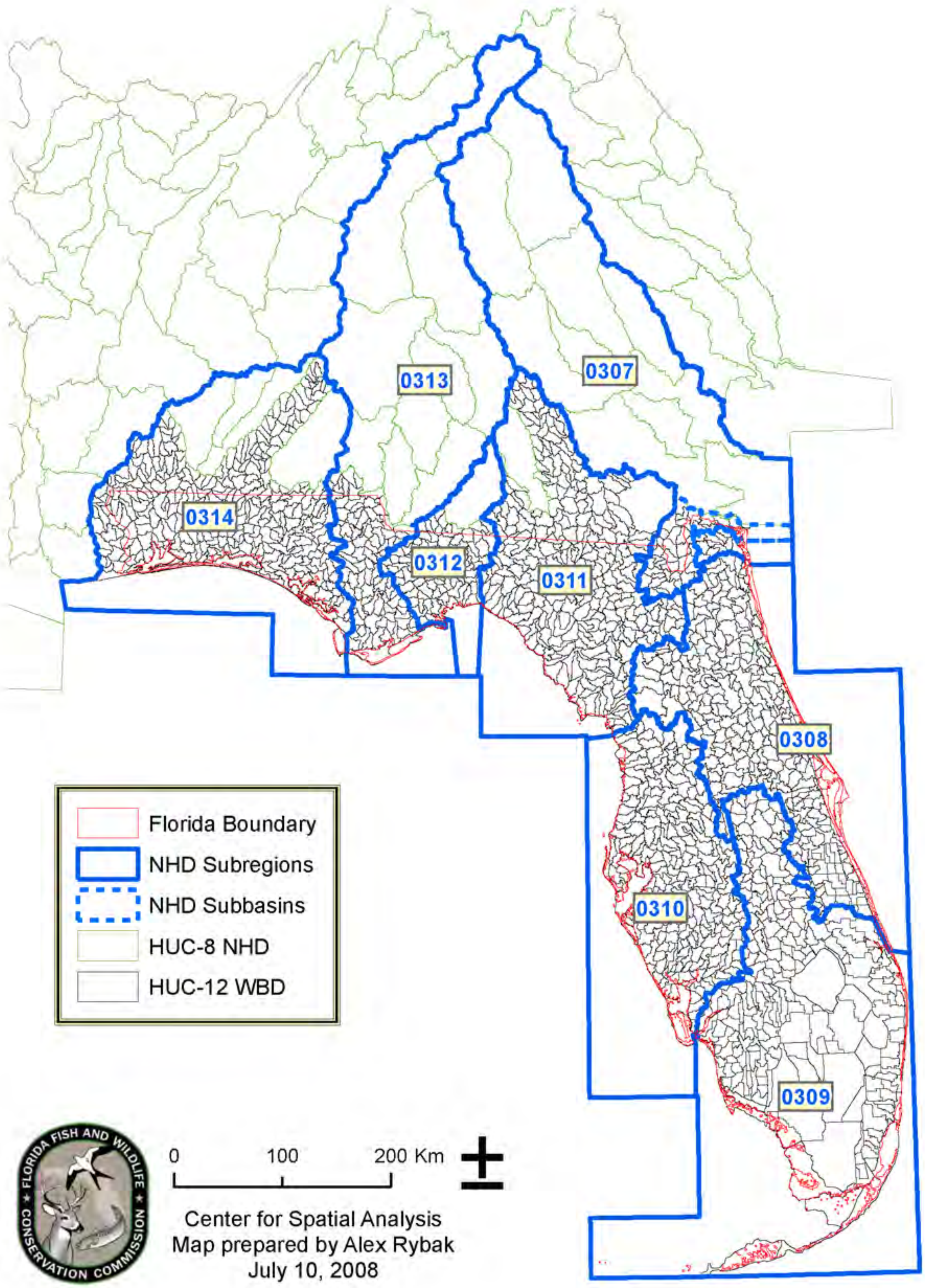

Figure 4. The NRCS/USGS HUC-12 subwatersheds (1,575) Watershed Boundary Dataset (WBD) (black lines), NHD HUC-8 subbasins (131) (green lines).

Florida was obtained from the Natural Resources Conservation Service (NRCS) through their Gateway website (http://datagateway.nrcs.usda.gov). In addition to contours, we used elevation points for the DEM production. The elevation point data consisted of 42,382 vertical geodetic control points (GCP), developed by NOAA's National Geodetic Survey in 2004 and 48,398 South Florida Information Access (SOFIA) high-accuracy elevation points collected by USGS and South Florida Water Management District for the Everglades region (Desmond 2003, Desmond et al. 2005) (Fig 5). The SOFIA points were very useful as they filled the gaps between widely spaced contours and GCP points in southern Florida. Additionally, 5,378 GCP and 4,710 SOFIA independent points were used to assess the accuracy of the DEM.

Other data layers that were used in the classification at the Aquatic Subregions level included: 7 Florida climate divisions subdivided by county boundaries developed by University of Florida (Fraisse et al. 2004) (Fig. 6, Table 1), and 3 ecoregions and 14 eco-subregions of Florida developed by EPA and DEP (Griffith et al, 1994) (Fig. 7). For the second hierarchical classification level, the freshwater fish distribution data across 42 drainage basins of the Southeastern US (Swift et al. 1986) served as a major information source for the production of a layer of Ecological Drainage Units (EDU), 9 within Florida and 9 outside of Florida (Sowa et al. 2005) (Fig. 8).

In contrast to the upper levels consisting of regional unique mapping units, we based the third more detailed AES level on typological data source classifications allowing for the identification of classes in multiple locations. Upon our request, the FGS specialists simplified their surficial geology map (Arthur 1997) into 28 classes of the uppermost sediments representing combinations of clay, silt, sand, and gravel (Fig. 9). The Soil Survey Geographic database (SSURGO, Henderson 2007) with 3,641 mapping units in Florida was developed by

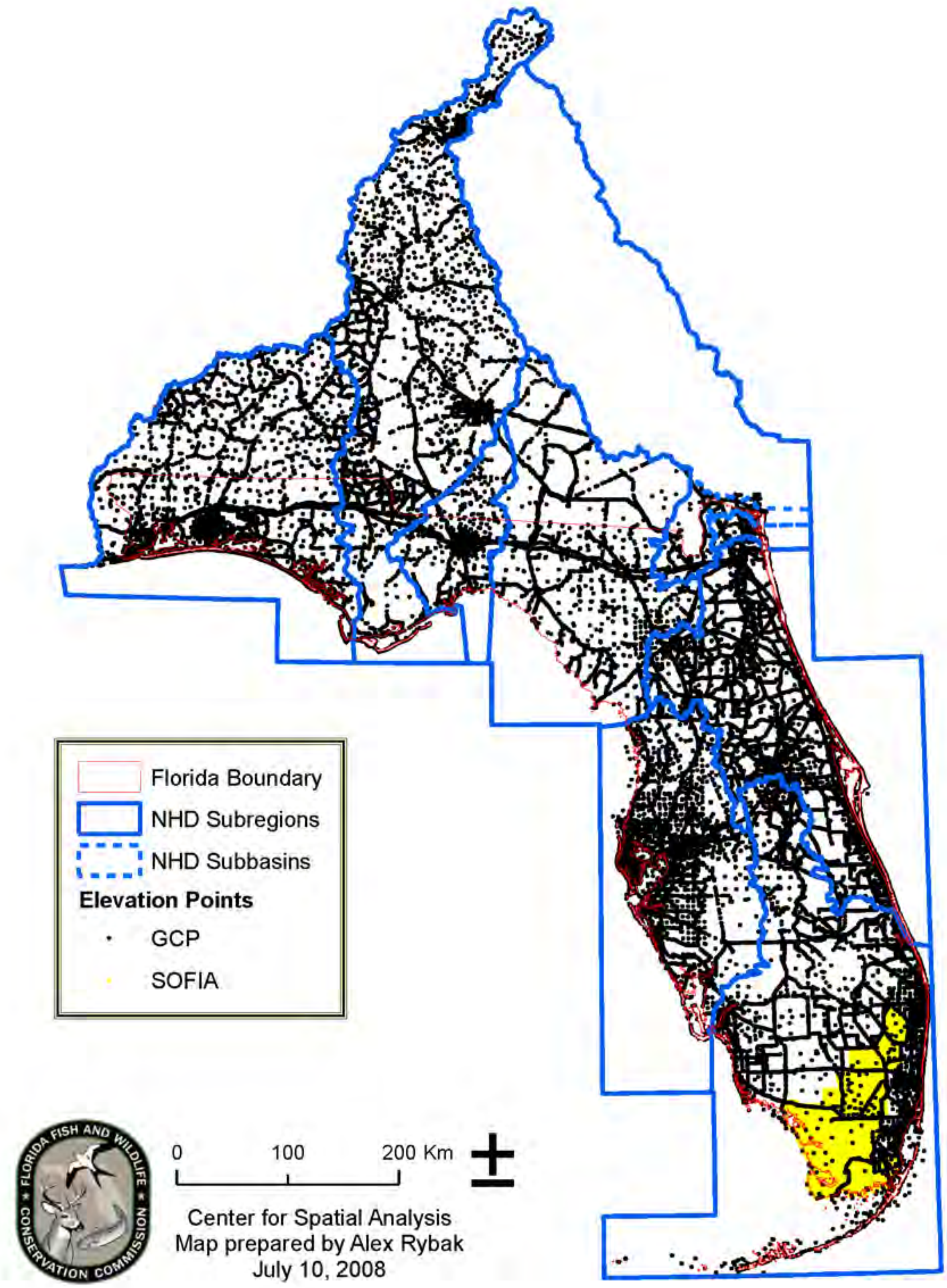

Figure 5. NOAA National Geodetic Survey vertical geodetic point control (GCP, 42,382 black dots) and Florida Information Access (SOFIA, 48,398 red dots) 90,780 elevation points used in DEM production.

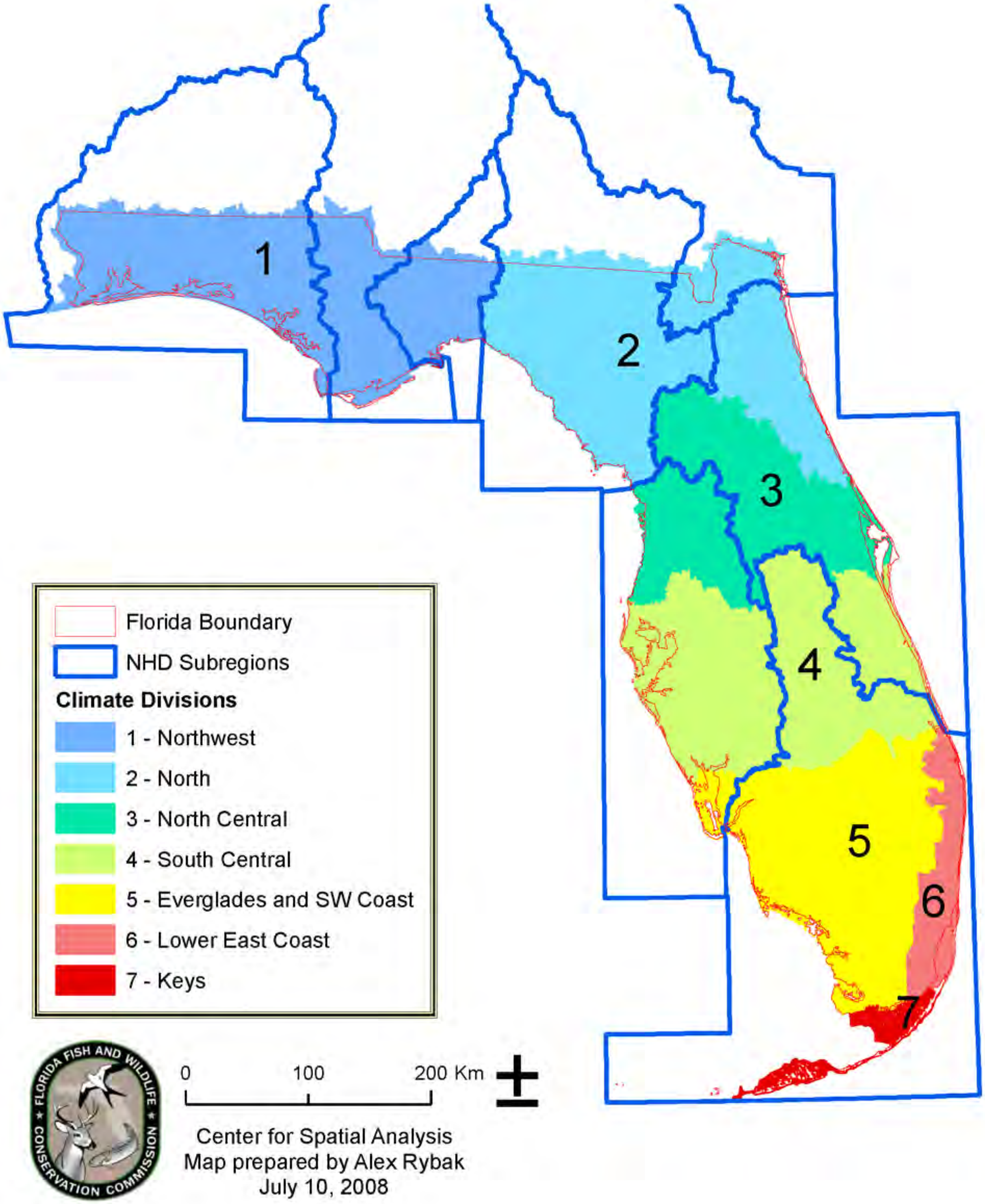

Figure 6. Florida 7 Climate divisions subdivided by county boundaries (University of Florida, Fraisse et al. 2004) adjusted to the WBD HUC boundaries.

Table 1. Rainfall and temperature averages by month for each climate division in Florida (Fraisse et al 2004).

Climate Division	**Average Rainfall Totals (in)**												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1 – Northwest	5.74	4.73	6.29	3.76	4.32	6.13	7.95	6.66	5.73	3.53	4.20	4.09	63.13
2 – North	4.20	3.43	4.48	3.10	3.30	6.16	6.73	7.22	5.81	3.34	2.55	3.03	53.35
3 – North Central	3.20	2.92	3.96	2.56	3.64	6.87	6.94	7.12	6.21	3.02	2.58	2.56	51.58
4 – South Central	2.58	2.69	3.32	2.23	3.65	7.03	7.24	7.54	6.81	3.29	2.43	2.27	51.08
5 – Everglades and Southwest Coast	2.19	2.02	2.60	2.27	4.31	8.34	7.27	7.69	7.08	3.50	2.28	1.71	51.26
6 – Lower East Coast	2.62	2.44	2.91	3.33	5.67	8.51	6.14	7.70	8.15	5.81	3.97	2.41	59.66
7 – Keys	2.39	1.66	2.14	1.97	3.53	5.63	3.35	5.29	6.06	4.89	2.71	2.05	41.67
Climate Division	**Mean Temperature (°F)**												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg.
1 – Northwest	50.5	54.3	60.4	66.3	73.7	79.4	81.4	80.9	77.4	67.9	60.0	52.7	67.0
2 – North	53.6	57.3	62.9	67.9	74.7	79.7	81.6	81.2	78.3	70.4	63.0	55.8	68.6
3 – North Central	58.3	61.2	66.1	70.2	76.1	80.3	81.7	81.6	79.9	73.5	66.9	60.5	71.1
4 – South Central	61.2	63.7	67.8	71.4	76.8	80.6	81.9	82.0	80.7	75.4	69.2	63.3	72.5
5 – Everglades and Southwest Coast	63.8	65.9	69.6	72.9	77.6	81.1	82.3	82.4	81.5	77.0	71.5	66.0	74.2
6 – Lower East Coast	67.1	68.6	71.7	74.5	78.4	81.3	82.5	82.8	81.9	78.7	73.9	69.4	75.4
7 – Keys	69.8	70.5	73.3	76.6	80.3	82.9	84.3	84.2	83.0	79.7	75.8	71.4	77.7

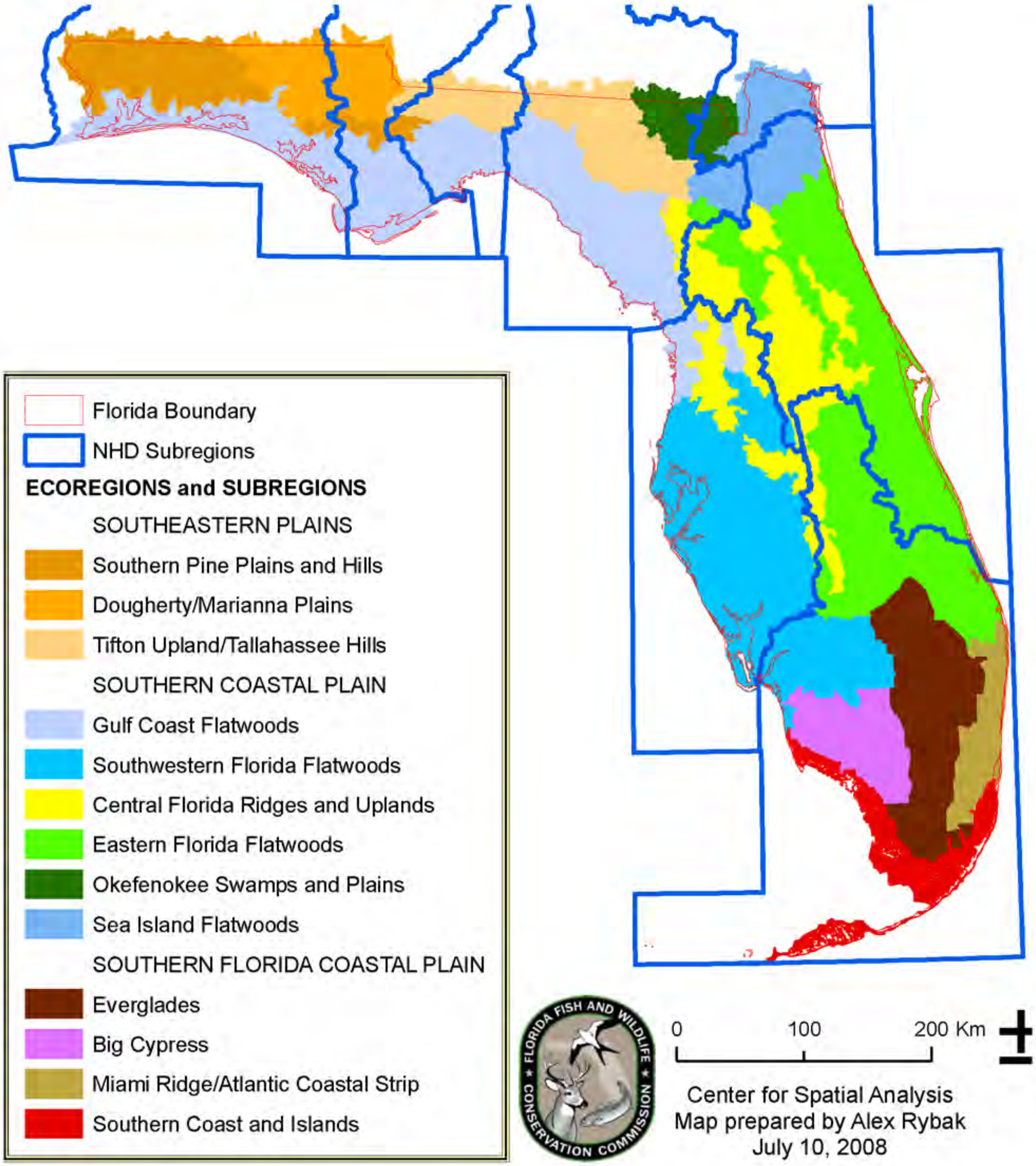

Figure 7. EPA/DEP 14 Eco-subregions of Florida adjusted to the WBD HUC boundaries.

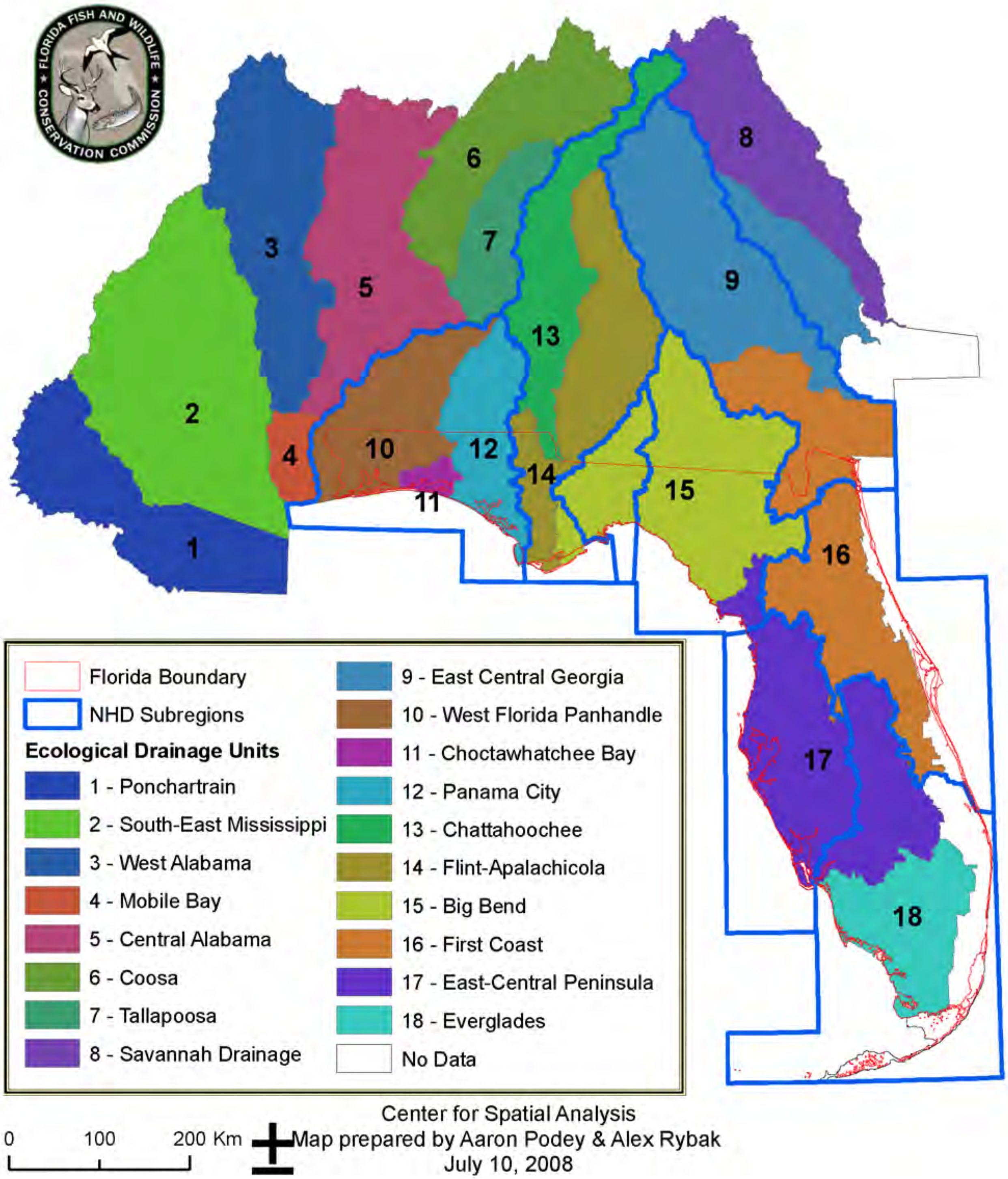

Figure 8. Ecological Drainage Units: 9 in Florida and 9 outside of it.

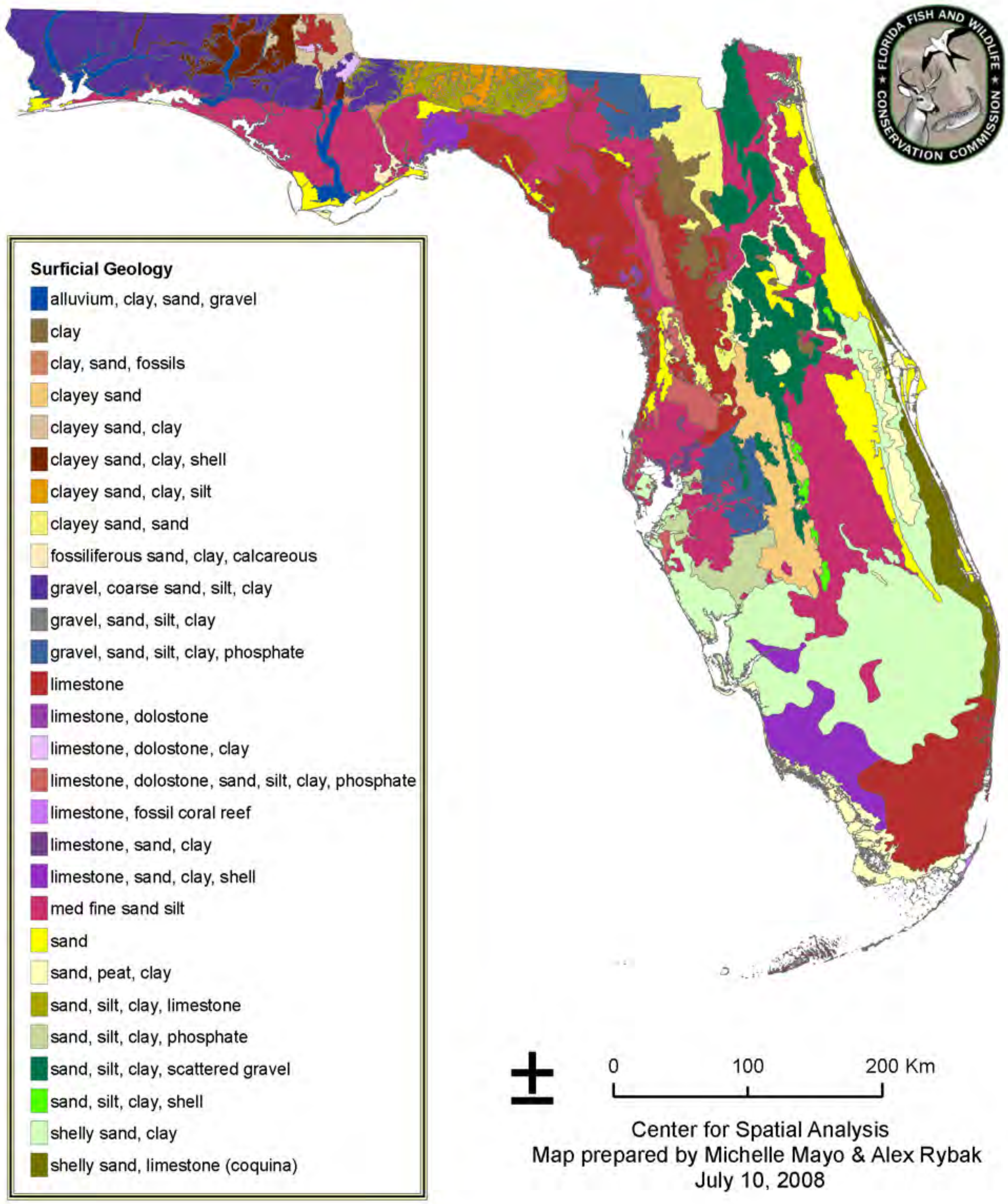

Figure 9. The FGS 28 classes of simplified surficial geology indicating stream bottom types.

NRCS (Fig. 10). We used the FWC Florida vegetation and land cover dataset (Stys et al. 2004) (Fig. 11). This dataset is in 30-m grid format and contains 43 types, including 26 natural and semi-natural vegetation types, 16 types of disturbed lands (such as agriculture, urban, and mining), and one water class. We performed the landform classification using methods describe by Weiss (2001) and Jenness (2006), developing a digital grid data layer of 10 landform classes (Fig. 12). The classes were derived from the 10-meter resolution DEM, which was derived from the 5-meter DEM using bilinear interpolation (see ―DEM Production" below for more details).

As the data sources were developed by different agencies at different times and at varying scales and with different levels of precision, the layers had different geographic extents. For example, the soils layer covers more area along the coast than the geology layer, while the geology layer extends further to the north. These unavoidable extent differences led to missing values in the stream classification in areas of incomplete overlay.

If the individual data layers consisted of multiple pieces, they were merged and transformed into ESRI shapefiles. The shapefiles were projected to the standard FWC Albers Conic Equal Area projection and the geometry of the shapefiles was cleaned if necessary. North Florida was chosen as a start point due to the availability of existing datasets and the presence of high aquatic biological diversity.

DEM Production

Fine-scale elevation data were needed to enhance the 1:24,000 scale NHD. Because existing elevation datasets for Florida were too coarse (30 meter grid), we created two 5-meter resolution DEMs for Florida, including lands within Florida‗s sub-basins that extend into Georgia and Alabama. We used the ArcInfo TOPOGRID procedure to generate the DEMs into

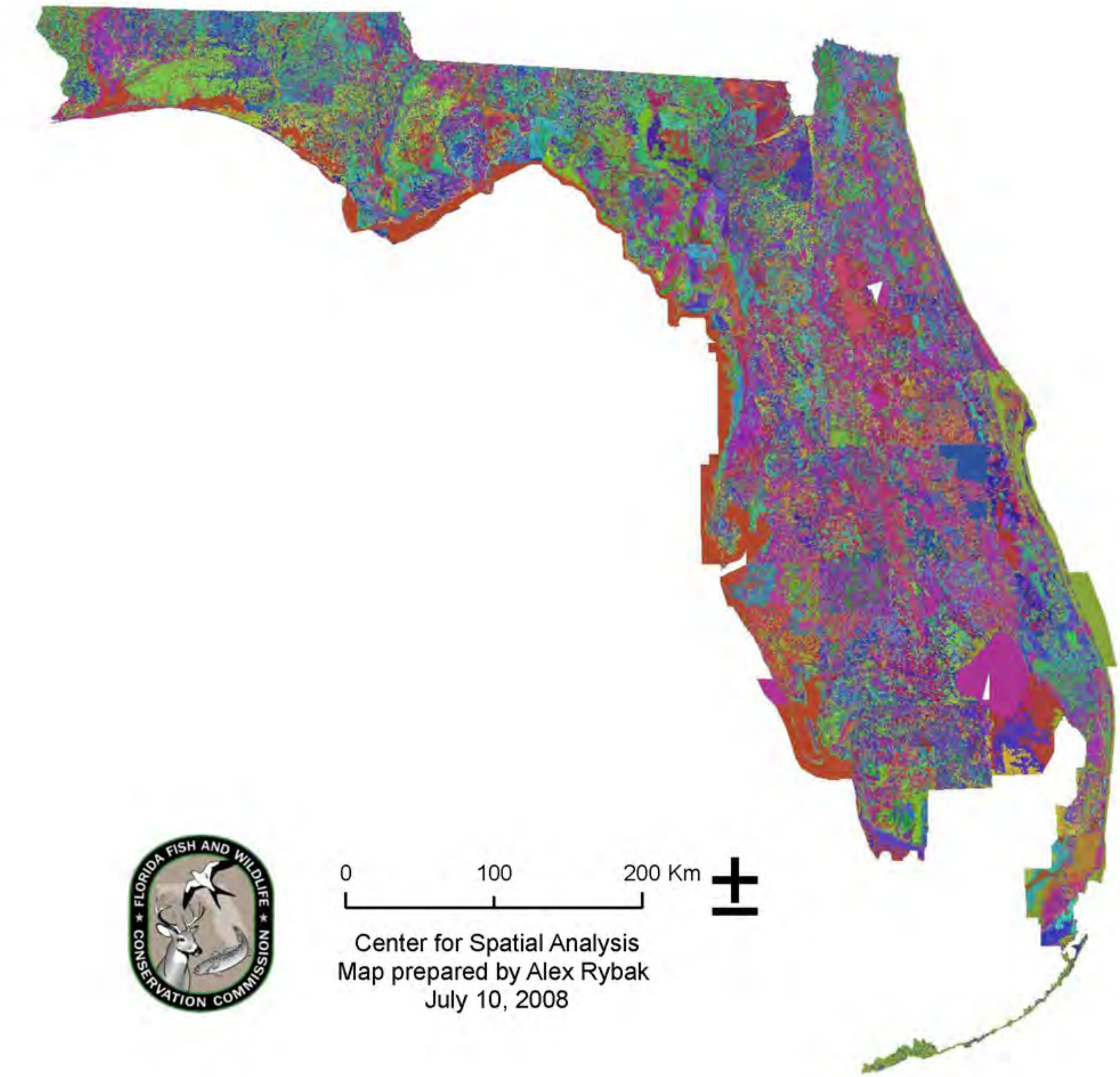

Figure 10. NRCS Soil Survey Geographic (SSURGO) 3,641 mapping units in Florida. Notice a gap in data in the southern Florida. SSURGO data collection was organized county by county, and artifacts of that are still visible on the map. Legend for this map with only unit names is too big to be displayed. The SSURGO database contains not a single but multiple attributes and multiple related tables. The FSD can be related to the database through a common field *mukey*.

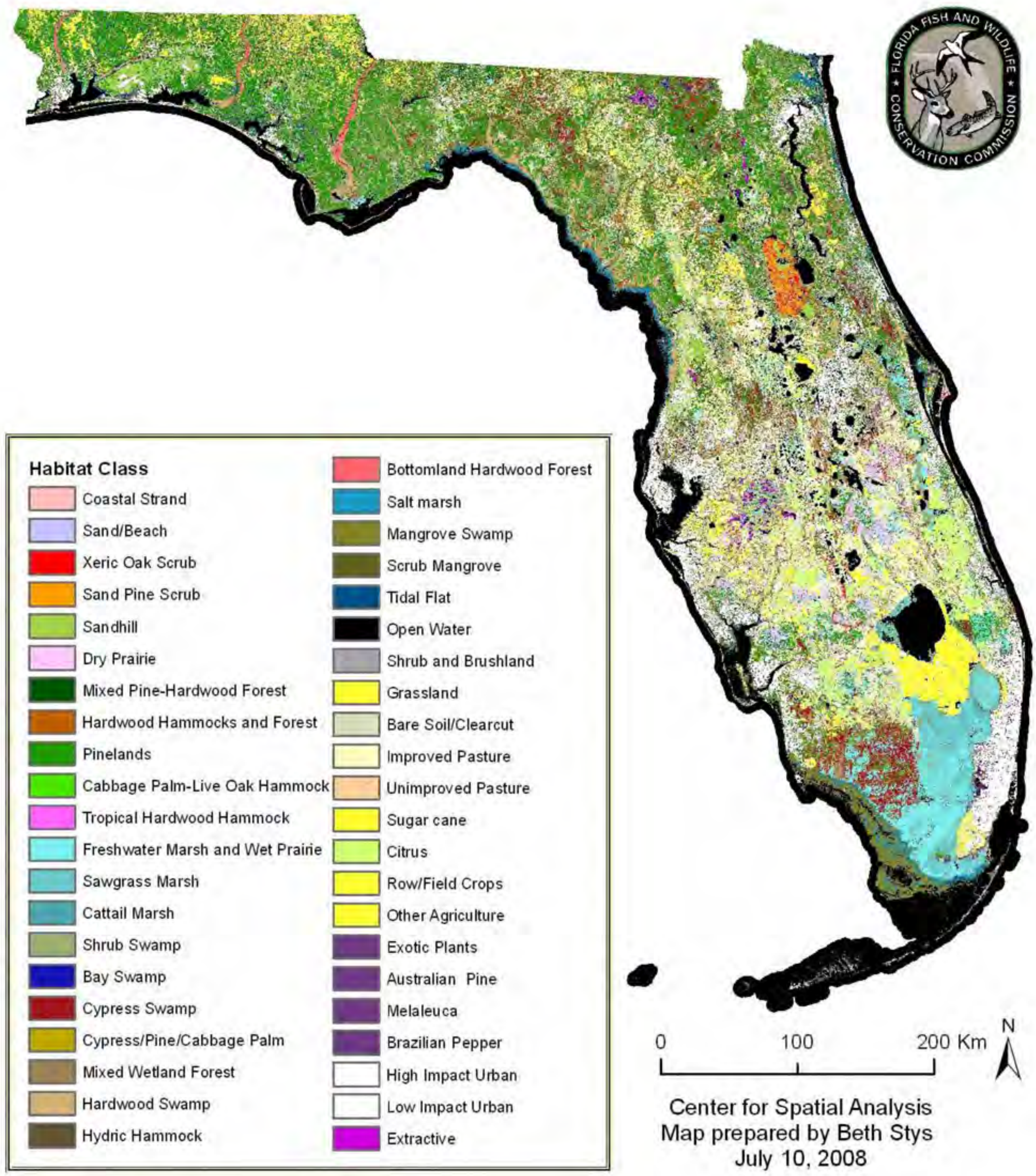

Figure 11. FWC 43 Florida vegetation and land cover types based on 2001–2003 Landsat ETM satellite imagery.

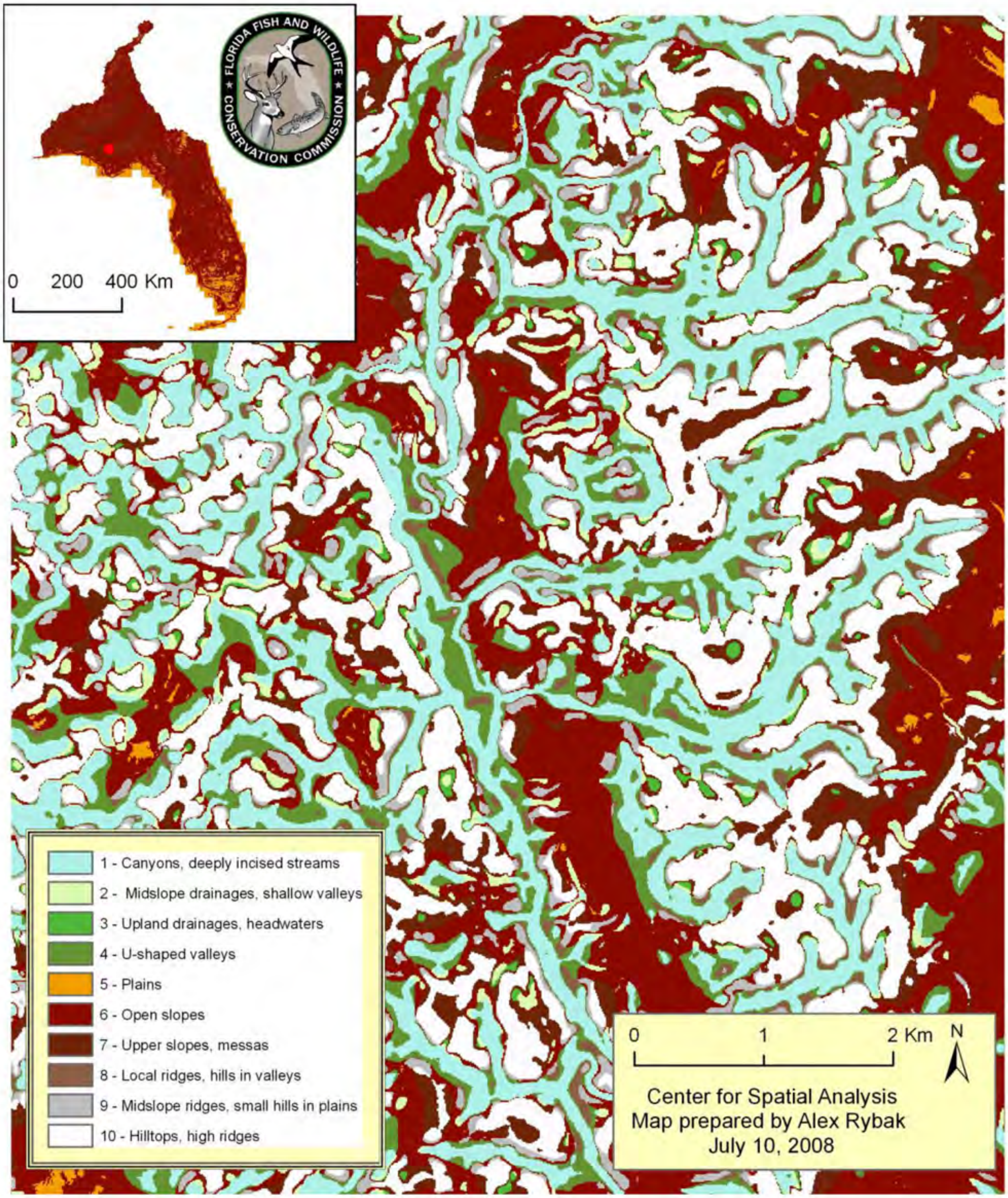

Figure 12. Landform classes within the NHD subregions 0307–0314. The overview map in the upper-left corner shows the general extent of the coverage without landform details. The details can be seen on the inset map at a finer scale. The location of the place is shown on the overview map by the red dot.

small overlapping tiles (Fig. 3), which were then mosaiced into 5 regional tiles, and these were then merged into a single grid covering all 8 NHD subregions. The smaller tiles, overlapping each other by 500 meters, measured approximately 35 to 40 kilometers per side. To prevent erroneous calculations at the edges of the tiles, elevation calculations were based on areas larger than the tiles themselves. These larger areas included 5-10 km margins outside of the borders of the tiles. Ranges of DEM tile cell values were constrained by restricting the cell values to within 3 m of the range extremes (minimum and maximum) of the contour elevation values for the entire area within the tile's margins. These small tile sizes were necessary due to the limitations of the software. TOPOGRID has an ArcInfo software limitation of being able to produce DEMs no larger than 80,820,100 cells at a time. We developed an ArcInfo Macro Language (AML) script and ran it in loops for 30-40 tiles per run (Appendix A).

The first DEM version was hydrologically enforced, meaning that the TOPOGRID program used an algorithm to mimic erosion and river systems. The DEM was built using point, line, and polygon coverages including: tile boundaries, 5-10-foot elevation contours, marine shoreline contours (the NHD coastline assigned with zero value and added to the elevation contours, which were missing the zero elevations), surface elevation points (GCP and SOFIA), point coverage representing known topographic depressions (developed by FGS and DEP), and the NHD streams. This DEM was used to create a drainage system representation by flowline patterns. Each flowline corresponds to the centerline of a stream regardless of its width.

The second DEM was generated running an identical AML program but with 2 modifications: the DEM was not hydrologically enforced and it was based on elevation contours only. This non-hydro-enforced DEM was used to identify topographic depressions, or lower slope lands and bottomlands, which we called "lowlands." The TOPOGRID procedure is sensitive to the character and number of input data sources and to the hydro-enforcement parameter being used.

The targeted products derived from the DEMs dictated our choice of procedures: hydrologically accurate flowlines at the bottoms of valleys and gullies as opposed to generally contiguous lowland areas. Both DEM products had advantages and disadvantages for modeling flowlines. Flow-accumulation lines from the hydro-enforced DEM were exactly at the very bottoms of topographic depressions, as they ought to be. However, an unrealistically high density of the flowlines at valley bottoms, in the flat areas, and in extended headwater parts were disadvantages of this modeling method. A higher threshold of the area of contributing watershed could resolve those problems, but in that case, the flowlines would not only be shorter but also more disconnected. On the other hand, centerlines of the lowlands derived from the non-hydro-enforced DEM were not exactly at the valley bottoms, but their general “skeleton” was much cleaner than the “skeleton” of the flow-accumulation lines. As will be described in more detail below, we combined advantages of both methods to achieve a higher probability of representing aquatic habitats.

The 2 resultant versions of 240 DEM tiles in floating-point data format (meters, 14 significant digits) were then converted into integer format (centimeters without decimal places) to reduce file size. Next, they were mosaiced to form 5 contiguous regional DEMs encompassing from 1 to 3 four-digit HUC subregions. The flow-accumulation lines and lowland centerlines were derived from each of those DEMs to add missing flowlines to the NHD, subregion by subregion (see more details below).

The ocean and lake areas were rarely represented by bathymetric contours. Nevertheless, the TOPOGRID program was producing topographic depressions as a continuation of slopes surrounding ocean or lake areas. We did not replace ocean and lake areas with flat surfaces representing sea level or lake water level. Compared to using the depressions, the flat surfaces were not the better choice for flowline modeling because the flow-accumulation method creates too many unrealistic lines within flat areas.

The 5 regional DEMs were mosaiced into one DEM of the entire area of Florida plus contributing watersheds beyond the state (Fig. 13). The final 5 m resolution DEM was resampled to a 10 m DEM using bilinear interpolation. Each cell of the 10 m DEM covered 4 cells of the 5 m DEM. Elevation of each 10 m DEM cell was calculated as the distance-weighted mean of the 4 cells. The coarser resolution of the10 m DEM smoothed small imperfections of the surface modeling and made the layer closer in resolution and details to the other AES GIS datasets. The 10 m DEM was also better for processing due to its smaller file size. Additionally, the 10-m DEM was necessary to derive the landform classes as one of the stream classification attributes (see more details below).

DEM Accuracy Assessment

The original elevation GCP and SOFIA points used for the DEM production were obtained, saved and reprojected to FWC Albers. This projection has less area distortions than UTM or State Plane based projections. The SOFIA points had high positional and vertical accuracy. We selected the GCP points which had high accuracies as well (Bossler 1984, National Geodetic Survey 2005). The GCP points used had the following selection criteria:

- position source – adjusted (least-squares adjustment, rounded to 5 decimal places);
- elevation source – adjusted (direct digital output from least-squares adjustment of precise leveling, rounded to 3 decimal places);

- position order – 1, A, or B (minimum distance accuracy, or the ratio of the relative positional error of a pair of control points to the horizontal separation of those points, is 1:100,000); and
- vertical elevation order – 1 (maximum elevation difference accuracy, or the relative elevation error between a pair of control points that is scaled by the square root of their horizontal separation traced along existing level routes, is 0.7).

Each set of points was quality-checked. Those points that had an elevation value that was more than ±5 m different from closest contour (about 8,000) were rejected. It was determined that these points, for the most part, represented the tops of man-made structures such as buildings, towers and bridges. Approximately 600 of these points were checked and verified. The remaining points were and then split into “training” and “test” subsets in a 9:1 proportion using the ESRI ArcGIS Geostatistical Analyst extension (ESRI, Redlands, CA). The training points were used for the DEM production while the test points were reserved and used to assess the accuracy of the DEM.

We selected 42,382 GCP points and 48,398 SOFIA points (90,780, 90% of the total) to create the DEMs; and 5,378 GCP and 4,710 SOFIA independent points (10,088, or 10% of the total) remained and were used to assess the accuracy of the DEMs. For the accuracy assessment, we used a traditional measure of the Root Mean Square Error (RMSE), which is the square root of the average of the squared differences between the test point and DEM elevations.

NHD Framework Enhancement

Enhancements to the NHD were necessary due to its limitations and lack of stream network detail. Some of the limitations of the NHD flowlines included incorrect geometry and

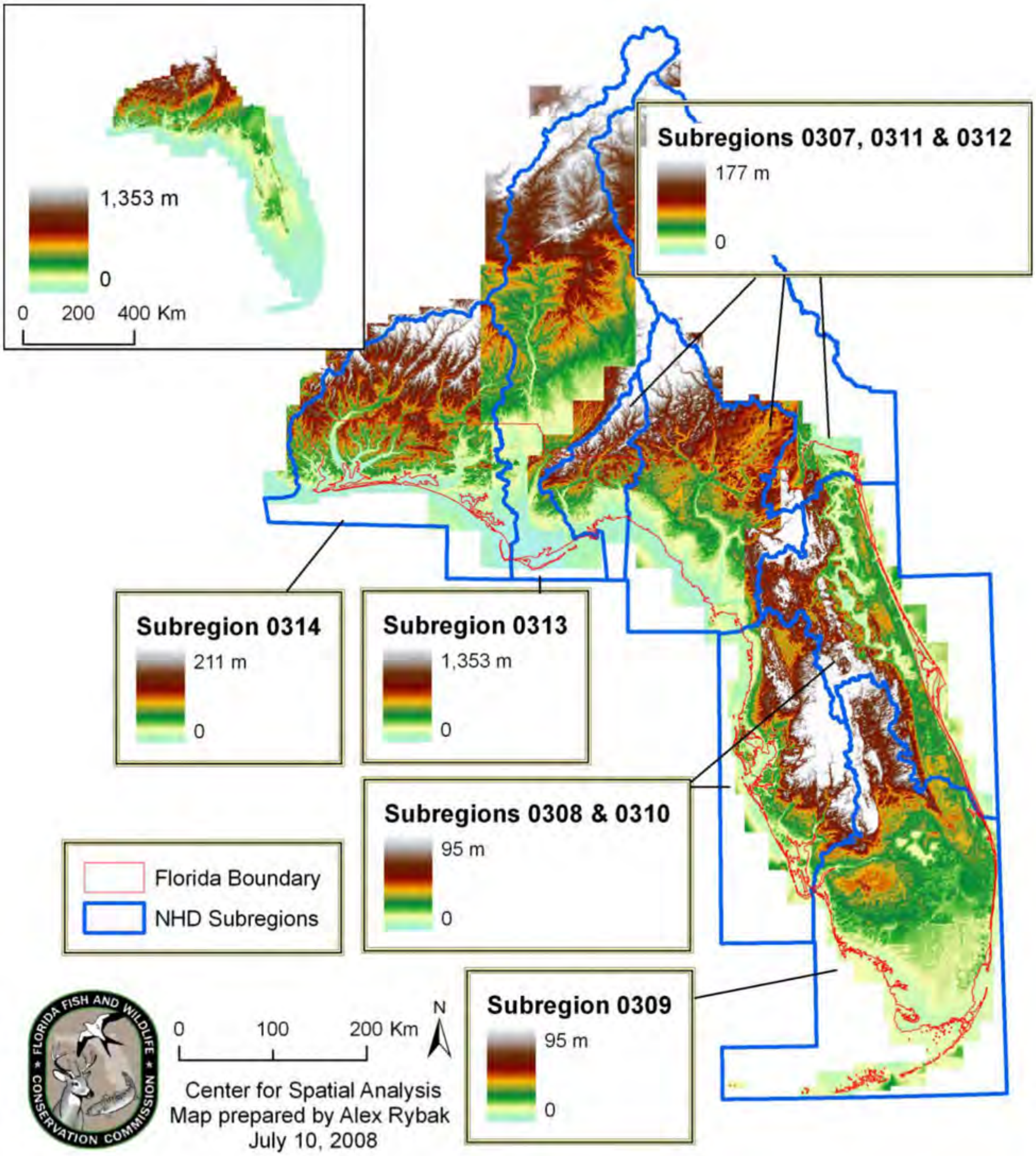

Figure 13. The hydro-enforced 5-m resolution DEM mosaiced from small tiles to form 5 regions encompassing the 4-digit HUC subregions and then mosiaced together to form Florida and adjacent connecting areas (shown on the overview map at a coarse scale). Land areas outside of HUCs had elevation contour data up to at least 5 km.

topology, incomplete and disconnected networks, erroneous and undefined directionality, double-digitized lines, and miscoded flowline types.

We identified streams using 2 criteria: large flow accumulation area and low topographic position. Streams derived from a fine-resolution DEM using only flow accumulation are usually overrepresented. Restricting the flow accumulation lines to lowlands reduces the overestimates. The hydro-enforced DEM was used to derive flow accumulation while the lowlands were identified using Topographic Position Index (TPI, Jenness 2006) calculated on the hydro-unenforced DEM:

TPI **=** **X** – **Y**, where

X is the cell value of DEM, and

Y is the focal mean DEM value in a 30-m radius circle neighborhood.

We converted the flow accumulation (> 500 cells) and TPI (< -0.6 m) into centerlines using R2V 5.5.4 software (Able Software Corp., Lexington, MA, USA) to produce the TPI centerlines from the lowland areas in the grids. Flow accumulation grids represented flow with 1-cell width; therefore, we were able to use ESRI GIS software for the grid-vector conversion. Only those flow accumulation lines that were within a distance of 120 m from the TPI lines were used for further analyses. The flow lines were generalized and cleaned. The small stream lines (<= 25 m) and unconnected stream lines (<= 75m) were deleted.

The NHD lines (excluding the coastlines and pipelines) were treated as having precedence over the modeled flow lines. Due to this assigned precedence, we deleted the flow lines within 40 m from the NHD lines. The remaining “truncated” flow lines were connected by the shortest distance to the NHD lines by adding straight segments. Thus, we added the missing flowlines from the NHD segments using only those flow-accumulation lines from the hydro-

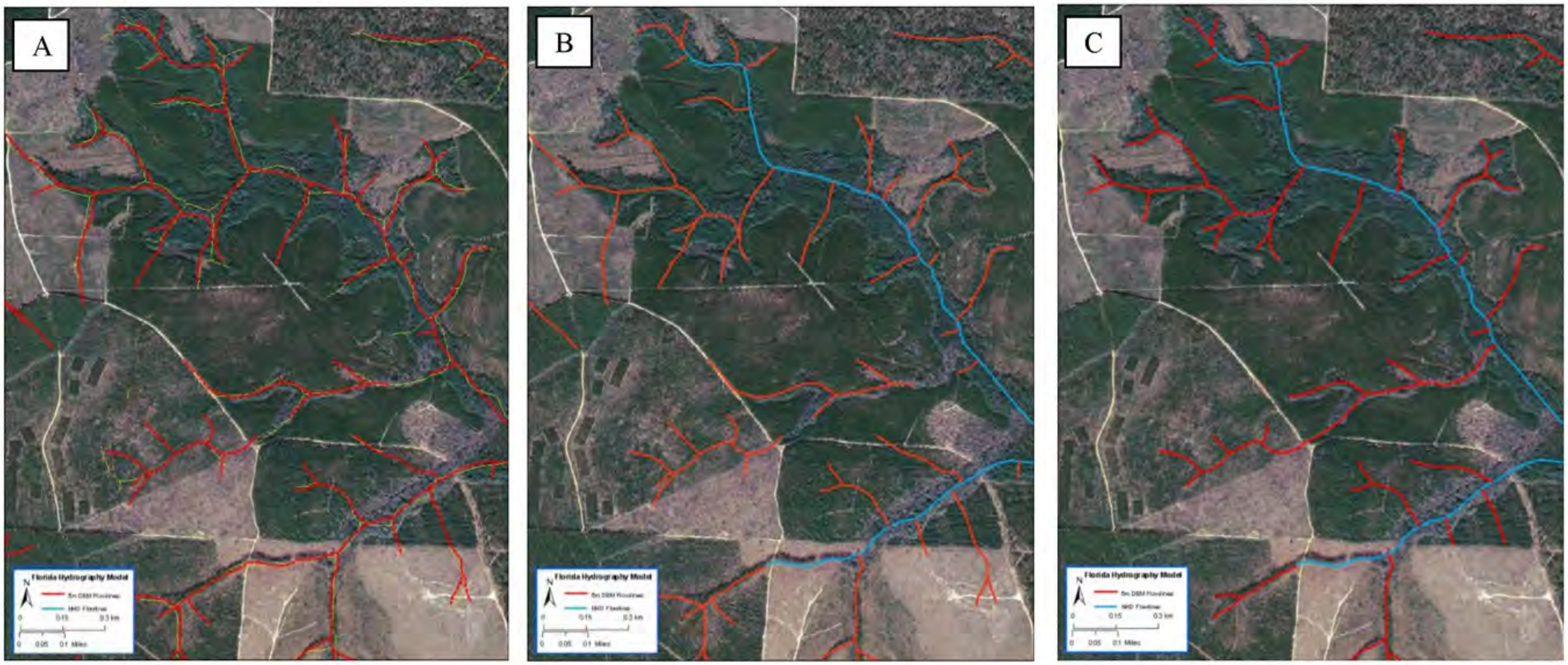

Figure 14. An example of streams (red lines) derived from 5-m Digital Elevation Models (DEM), selected using lowland centerlines (yellow lines), and joined to the National Hydrography Dataset (1:24,000 scale, blue lines). The map depicts the area around Lighter Knot Creek, a tributary of the Blackwater River, Santa Rosa County, FL. The background is an aerial photo taken in 2004 (1-m resolution, color Digital Orthophoto Quarter Quadrangle). A - Flow accumulation (> 500 cells) and Topographic Position Index (< -0.6 m) centerlines were derived from the DEMs. B - Flow accumulation lines were selected within a distance of 120 m from the Topographic Position Index lines; flow lines were generalized and cleaned; pseudo-nodes, dangles <= 25 m, and unconnected arcs <= 75 m were deleted; flow lines within 40 m from the NHD lines were deleted; and finally, flow lines were snapped to the NHD lines. C - Derived flow lines were visually inspected and manually edited where needed.

enforced DEM that were within the lowlands. These added parts were hydrologically modeled tributaries or connectors. This process was automated using an AML (Fig. 14, Appendices B and C).

The prorgamatically derived flow lines were visually inspected and manually edited for correct geometry where necessary. In 3 very flat southern NHD subregions with a dominance of canal networks (0308, 0309, and 0310), the flowline modeling did not produce satisfactory results and the additions were not included in the final dataset. Visual editing operations for the remaining 5 northern NHD subregions were conducted by examining the stream network at 1:8,000 scale and zooming in when necessary. The flow-lines were manually edited (separately from the NHD lines) with 1992-2005 high-resolution aerial photography (1-2 meter Digital Orthophoto Quarter Quadrangles, DOQQs; LABINS 2004).

Other ancillary data sets used for quality control included digital layers of elevations, waterbodies, land use/land cover, and satellite imagery. Quality control and editing was performed on geometry (intersections, loops, dangles, and duplicates), connectivity, directionality, and flow-types within the NHD subregions 0307, 0311, 0312, 0313, 0314, and partially 0308, 0309 and 0310. Examples of this intermediate work are shown on Figures 14–16.

After this step, we conflated the edited flowlines with the NHD again in an integrated dataset, the Florida Stream Dataset (FSD). The FSD inherited from the NHD the following attributes:

COMID – permanent common ID,

GNIS_NAME Geographic Names Information System name of the hydrologic feature,

LENGTHKM – length of the stream in km,

REACHCODE – the 14-digit reach code, maybe reassigned in newer NHD versions, FTYPE – the 3-digit flow type,

FTYPENAME flow type name,

FCODE – the 6-digit flow code, and

FCODENAME – flow code name, more detailed than the FTYPENAME.

The NHD flow type and code descriptions can be found in Table 2.

Flowlines Accuracy Assessment and FSD Final Editing

The modeled and post-processed flowlines substantially enhanced the 1:24,000 NHD. Based on a GPS ground-truthing survey in North Florida within 5 NHD subregions, the modeled flowlines were found in 87% of survey locations and within an average of 27 m from their predicted locations (Hvozda et al. 2007). However, the majority of segment types (64%) were classified as dry ditches, indicating that although they might be important in the overall hydrologic integrity of the system, they may not provide permanent habitat for fish and other aquatic species. This intermediate finding justified our conservative decision to eliminate all modeled streams from the FSD, except those which directly connect the NHD parts.

Next, the final FSD flowlines were cleaned and quality checked. These procedures were applied by subregion to ensure that the integrated stream networks are topologically correct. Various errors were identified using the RivEx 4.5 extension to ESRI ArcGIS tools (Hornby 2008). Types of errors included: zero (null) length polylines, multi-part polylines, self-intersecting polylines, closed polylines, small polylines composed of only 2 vertices, disconnected polylines, double-digitized polylines, intersecting polylines, and wrong flow direction (polylines with zero value stream orders, which are the result of polylines pointing from a mouth to source direction). The identified errors were resolved individually. During the editing process other issues with polylines were resolved by re-coding, modifying, deleting,

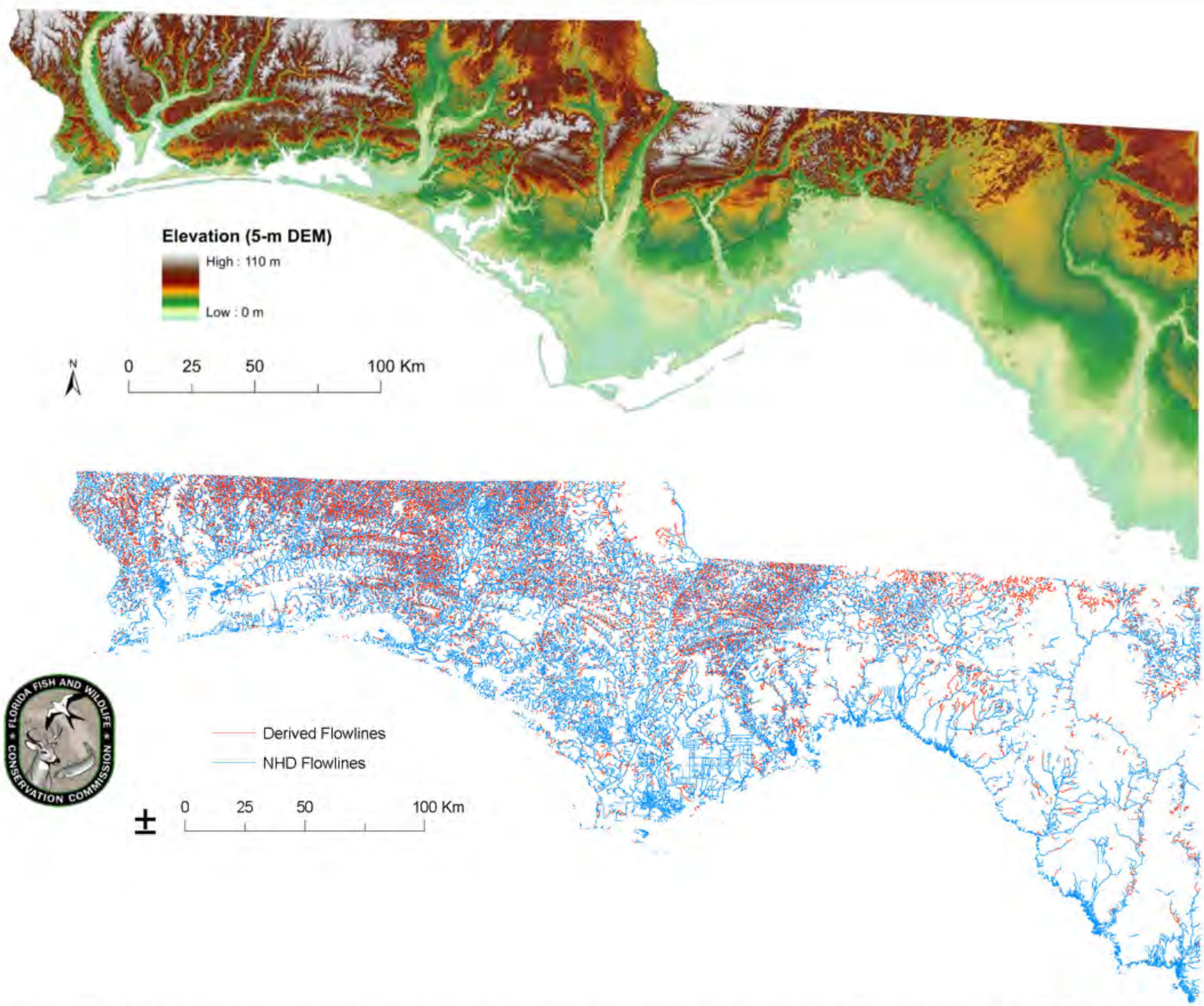

Figure 15. NHD framework enhancement from the Florida Panhandle: Using ArcInfo TOPOGRID, the hydro-enforced 5-m Digital Elevation Model (DEM), along with the unenforced DEM, was created to model flowlines.

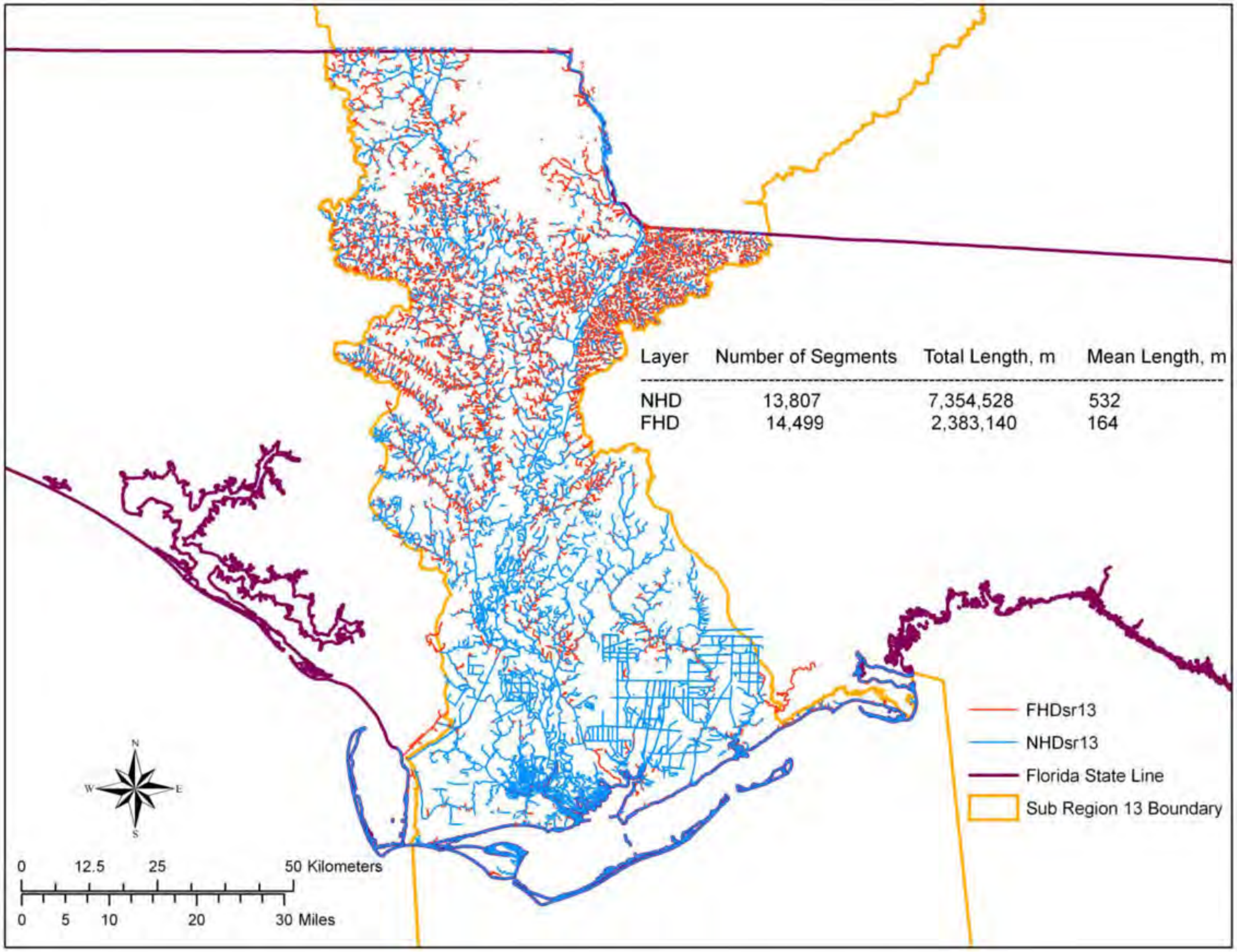

Figure 16. NHD framework enhancement: an example from subregion 0313 within Florida.

Table 2. The NHD flow type and code names. The pipelines and coastlines were not included in the FSD.

FTYPE	FTYPENAME	FCODE	FCODENAME
334	Connector	33400	Connector
336	Canal/Ditch	33600	Canal/Ditch
336	Canal/Ditch	33601	Canal/Ditch: Canal/Ditch Type = Aqueduct
428	Pipeline	42800	Pipeline
428	Pipeline	42801	Pipeline: Pipeline Type = Aqueduct; Relationship to Surface = At or Near
428	Pipeline	42802	Pipeline: Pipeline Type = Aqueduct; Relationship to Surface = Elevated
428	Pipeline	42803	Pipeline: Pipeline Type = Aqueduct; Relationship to Surface = Underground
428	Pipeline	42804	Pipeline: Pipeline Type = Aqueduct; Relationship to Surface = Underwater
428	Pipeline	42805	Pipeline: Pipeline Type = General Case; Relationship to Surface = At or Near
428	Pipeline	42806	Pipeline: Pipeline Type = General Case; Relationship to Surface = Elevated
428	Pipeline	42807	Pipeline: Pipeline Type = General Case; Relationship to Surface = Underground
428	Pipeline	42808	Pipeline: Pipeline Type = General Case; Relationship to Surface = Underwater
428	Pipeline	42809	Pipeline: Pipeline Type = Penstock; Relationship to Surface = At or Near
428	Pipeline	42810	Pipeline: Pipeline Type = Penstock; Relationship to Surface = Elevated
428	Pipeline	42811	Pipeline: Pipeline Type = Penstock; Relationship to Surface = Underground
428	Pipeline	42812	Pipeline: Pipeline Type = Penstock; Relationship to Surface = Underwater
428	Pipeline	42813	Pipeline: Pipeline Type = Siphon
428	Pipeline	42814	Pipeline: Pipeline Type = General Case
428	Pipeline	42815	Pipeline: Pipeline Type = Penstock
428	Pipeline	42816	Pipeline: Pipeline Type = Aqueduct
460	Stream/River	46000	Stream/River
460	Stream/River	46003	Stream/River: Hydrographic Category = Intermittent
460	Stream/River	46006	Stream/River: Hydrographic Category = Perennial
460	Stream/River	46007	Stream/River: Hydrographic Category = Ephemeral
558	Artificial Path	55800	Artificial Path
566	Coastline	56600	Coastline

adding, and flipping the lines to run downhill and to maintain the whole network topology, connectedness, and flow direction. An example of how connected lines were identified is presented in Appendix D. The edits included additions, deletions and modifications in both geometry and attribution. The final FSD was used as a framework for identifying ecological, geomorphologic, and hydrologic parameters of streams and watersheds important for freshwater stream habitat classification.

Local Parameters of the FSD

Stream ordering is the classic example of stream network analysis and is an important part of stream network classification. Many environmental variables correlate to stream order (Hornby 2008). Strahler (1957) and Shreve (1966) proposed stream ordering methods for identifying and classifying types of streams based on their number of tributaries. In both methods, an order of 1 is assigned to the headwater segments. In the Strahler method, stream order increases when streams of the same order intersect. However, the orders are additive for all interior links in the Shreve method. These 2 methods complement each other, and both are included in the Florida‘s stream classification dataset. Using the RivEx and ESRI ArcInfo tools, we calculated and assigned the following values to each stream reach of the FSD network subregion-by-subregion, starting at headwaters from outside of Florida down to the Keys:

- sr – NHD subregion code, from 07-14 (the preceding ‗03‘ indicating the NHD region was omitted as it is the same for all subregions in the dataset);
- FHID – stream ID within a subregion (was assigned by RivEx at the final run, before cutting off flowlines outside of Florida), before intersecting with polygons of all classification layers;
- FNODE – from-node, starting node of the unsplit stream;

- TNODE – to-node, end node of the unsplit stream;
- LENGTH – stream length (in meters), after intersecting with polygons of all classification layers, after cutting off flowlines outside of Florida;
- STRAHLER – Strahler order, before cutting off flowlines outside of Florida;
- SEGMENT – segment number (1 segment for each Strahler reach; RivEx uses the method of Gleyzer et al. 2004), before the cut;
- SHREVE – Shreve order, before the cut;
- US_ACCUM – sum of upstream lengths up to the source (in meters), including the length of the link itself, before intersecting with polygons of all classification layers;
- LINK_TYPE – type of link (E – exterior; I – interior; and O – outlet), before the intersection and the cut;
- CATCHID – catchment ID within a subregion, a unique number for a set of connected polylines that flow to a single node (the mouth), the number used for the catchment ID is an incremental counter. In the final FSD, which combines all subregions in 1 FSD line dataset, we added to this number ($sr * 10^6$) in order to have unique identifiers across subregions;
- MAINCHAN - main channel (1 for main channel and 0 otherwise), defined as the route taken from the furthest polyline upstream to the mouth node within a catchment. For braids or multi-threading channels, RivEx chooses a single route based upon the order of the polylines as they are stored in the dataset. This means that the chosen route may not necessarily be the main channel within the threading river section;
- DIST2MTH – distance from network mouth (in meters), including the length of the link itself, before the intersection. No consistent path through braiding sections can

be guaranteed as each dataset is uniquely digitized. If there are multiple mouths within a catchment, only 1 is chosen. The mouth is usually at the coastline or at the sink. There also could be erroneous mouths due to disconnects in the network or complicated multiple connections at a confluence, especially when a stream intersects a 1-directional canal.

Some of these attributes (Shreve and main channel) were not assigned to the polylines of the southern subregions 0308, 0309, and 0310 because it was not possible to make a logical system of flow directions in a region made up predominantly of canals. Stream ordering on artificial grid-like channels can produce some very strange results and should be interpreted with extreme caution.

After calculating and assigning the local parameters to all polylines, the lines extending far beyond Florida‘s borders were deleted from the shapefiles. The flowlines within each subregion were split by classification attributes, and were assigned an identifier *FID_sr*. The subregional polylines were merged into 1 FSD shapefile. An additional unique *str_ID* identifier was assigned to each segment of the entire network after further splitting by classification polygon layers.

FSD Classification Attributes

The FSD line segments also received attribution based upon the Climate divisions, Ecosubregions, Ecological Drainage Units, and Aquatic Ecological System Types (Sowa et al. 2005; Figs. 6–12). Once the corresponding source layers were prepared as described below, they were intersected with the FSD using the ESRI ArcTool ―Identity”. This operation split the FSD lines by the intersecting areas, and at the same time, the classification attributes were added to the FSD. The Climate divisions, Ecosubregions, Ecological Drainage Units, and HUC-12 were also overlaid with each other, and the resultant polygon layer ―HECE.shp" was linked to the FSD through a common field *FID_HECE*.

Aquatic Subregions. – Climate divisions and Ecosubregions boundaries were adjusted to HUC-8 boundaries in most of the cases (Figs. 6 and 7). In cases where this was not possible, the more detailed HUC boundaries served for the adjustments of the Aquatic Subregions.

Ecological Drainage Units (EDUs). – The idea of the Ecological Drainage Units (EDUs) was based on the EDUs from ―A Gap Analysis for Riverine Ecosystems of Missouri" Final Report (Sowa et al. 2005). The data for the EDUs came from Swift et al. (1986). The 6 species of introduced fish were not included in analyses because the intent of the layer was to locate historical fish assemblages.

A total of 256 fish species (Appendix E), by 42 drainages of the Southeastern United States, was imported into Primer 5 version 5.2.9 (PRIMER-E Ltd, Roborough, Plymouth, UK), a multivariate statistics package for ecologists (Clarke and Gorley 2001). All of the species present in a basin class (native freshwater species, native freshwater species and possibly introduced, euryhaline species, and suspected records without known museum records or other substantiation) were given a score of 1 in the table and all empty cells, indicating absence of the species, were given a 0 score. The Bray-Curtis similarity matrix (Bray and Curtis 1957) was created for the drainages. A hierarchical cluster analysis with a dendrogram (Fig. 17) and a multidimensional scaling (MDS) plot (Fig. 18) were preformed on the similarity index. The index was used to make a decision of how to combine the drainages into EDUs.

HUC-12 Cleaning. – The original HUC-12 shapefile with more than 4,000 polygons contained many gaps and overlays. We used the ET Geowizard ArcGIS extension to clean the layer of overlays and eliminate the gaps by joining them to the largest adjacent HUC. Remaining

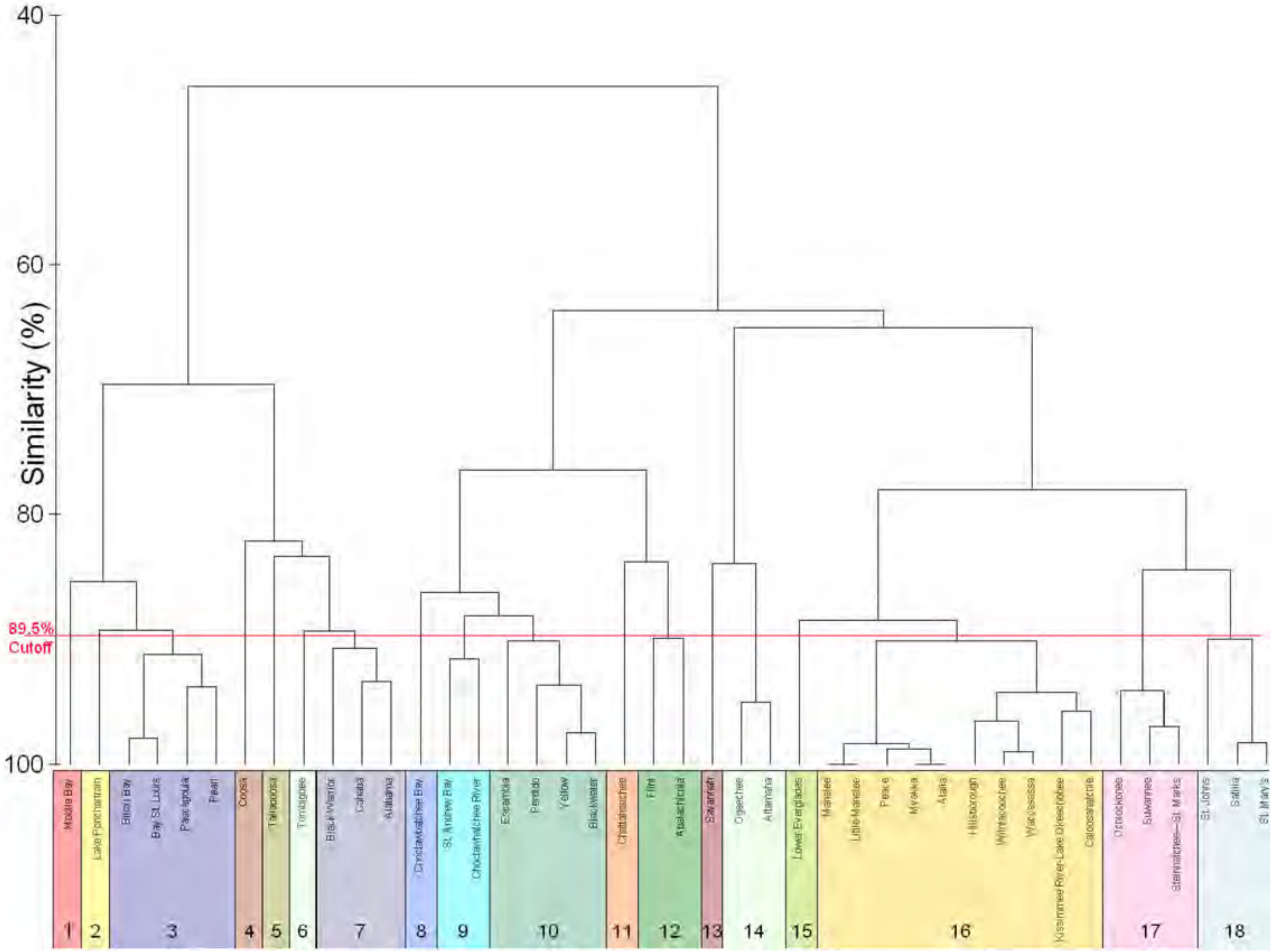

Figure 17. Ecological Drainage Unit (EDU) similarity dendrogram of 42 freshwater fish basins of the Southeastern United States. The 18 EDUs are combining the basins using the similarity index cutoff of 89.5%.

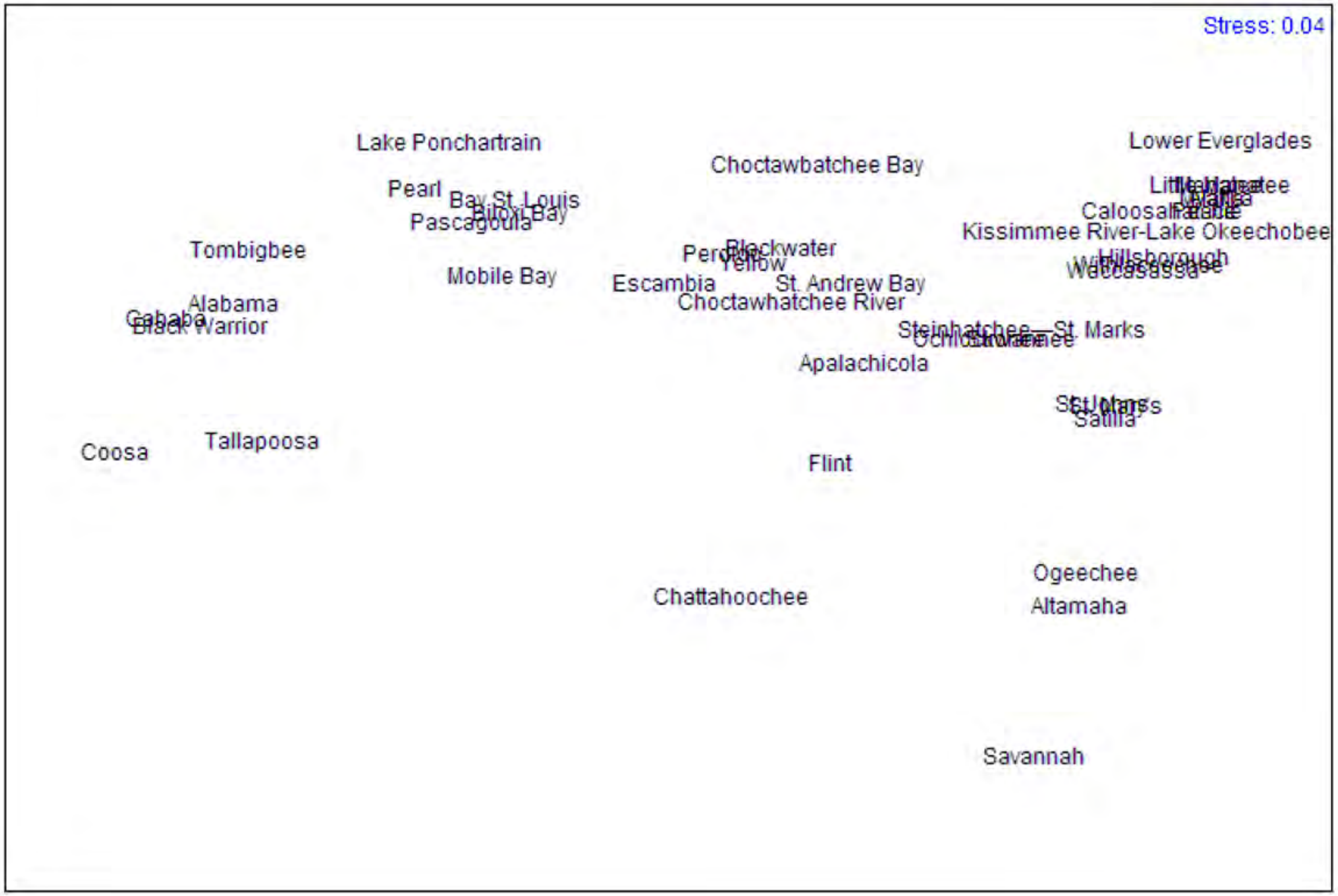

Figure 18. A multidimensional scaling (MDS) plot of 42 freshwater fish basins of the Southeastern United States.

small sliver polygons were deleted using a 0.1 m tolerance. This process reduced the number of polygons to 1,575. After joining to it the NHD HUCs-8 encompassing the Southeastern US EDUs, there were 1,706 polygons in the HECE shapefile (Fig. 4).

HUC-12 Linkage to 'Threats to Florida Freshwater Habitats' Dataset. – A companion project, ―*Mapping Threats to Florida Freshwater Habitats*" (Ricketts and Stys 2008) (Conserve Wildlife Tag Grant), was being completed concurrently with this project. It was collecting information by the same subwatersheds used in the HECE. As described above, the HUC-12 has a hydrologically-based hierarchical structure. Its smallest mapping unit, subwatershed, falls right in between the EDU and AES classification levels. The subwatershed is a convenient way of aggregating area-wide habitat data, which is associated with all streams within a watershed. Our dataset was connected to the Threats dataset by a common field *FLHUA_ID*. From the *Threats* dataset, we used 1 table LULC_PERC, which characterizes land cover of riparian zones at 3 levels, 0, 30, and 90 m, as a part of an overall assessment of threats to freshwater habitats in Florida. This dataset represents a HUC-12 level assessment of land cover in riparian areas of Florida based on the FWC's Florida Vegetation and Land Cover 2004 classification. For each HUC-12 unit 13 categories of land cover (aggregated from 43 habitat classes of the 2004 data) are summarized within the 3 distances from fresh waterbodies. Percent values of each land cover class represent the percent of the total land within the particular buffer zone distance, not the percent of the total land within the entire HUC 12 unit.

Aquatic Ecological System Types (AES). – A set of ―quality" attributes was added to the FSD by overlaying it with polygon data layers. The set included simplified surficial geology types, landforms, land cover, and soil types (Figs. 9–12). The simplified geology polygons were ready to use as they were revised by FGS and were assigned directly to the FSD lines. The

SSURGO polygons were ready to use after merging the county files into a statewide file. Through the *mukey* field, the FSD table was also connected to the SSURGO soil database. We used only the summary SSURGO table *muaggatt*, or ‗Mapunit Aggregated Attribute' (Appendix F). The full version of the table with 40 fields under the name *mukey* was put into an MS Access database *soil_mukey* for direct use with the FSD. An abbreviated version of the table was also included in the database, named *mukey_ab.* It contains the 23 attributes deemed most relevant to habitat assessment. In future applications, the multiple soil mapping unit attributes of other SSURGO tables can also be linked by the *mukey* field.

The landform grid was created and converted to polygons. The grid-vector conversion was done to the land-cover grid as well. The conversion was done with a tolerance of 15 m for the 10 m resolution landform grid, and with a tolerance of 45 m for the 30 m resolution land-cover grid. These 2 layers in polygon shapefile format were too large for the overlay operation with the FSD flowlines, so the layers were split by NHD subregions and subbasins to carry the overlay on smaller areas.

Landforms. – The Landform classification grid was calculated from 2 TPIs derived from the 10-m DEM, plus an additional slope classification criteria grid. Weiss (2001) and Jenness (2006) provided examples demonstrating how 2 TPI grids at different scales and a slope grid can be used to identify canyons, mid-slope drainages, U-shaped valleys, plains, open slopes, upper slopes, mesas, mid-slope ridges and mountain tops. The combination of TPI values from different scales suggests various landform types. For example, a high TPI value in a small neighborhood, combined with a low TPI value in a large neighborhood, would be classified as a local ridge or hill in a larger valley, while a low small-neighborhood TPI plus a high large-neighborhood TPI would be classified as an upland drainage or depression.

The small-neighborhood TPI grid was calculated within a 100 m radius circle and the large-neighborhood TPI was created within a 300 m radius circle. The grids were converted into integer format. We slightly modified the classification criteria and names of the landform categories. We used $\pm$0.25 SD as the splitting criteria of the standardized TPI grids, slope of 5^{o} to differentiate surfaces with TPI values near 0 into Plains and Opens Slopes, and class 10 —Mountain tops, High ridges” was renamed to —Hilltops, High ridges” (Fig. 12, Tables 3 and 4).

Table 3. Landform classification criteria for the Southeastern United States. TPI is 10-m resolution Topographic Position Index (Weiss, 2001, Jenness, 2006).

SD of TPI at 300-m Radius Circle Neighborhood	SD of TPI at 100-m Radius Circle Neighborhood		
	<= -0.25	> -0.25 & < 0.25	>= 0.25
<= -0.25	1. Canyons, Deeply incised streams	4. U-shaped valleys	8. Local ridges, Hills in valleys
> -0.25 & < 0.25	2. Midslope drainages, Shallow valleys	5. Plains (slope <= 5^{o}) 6. Open Slopes (slope > 5^{o})	9. Midslope ridges, Small hills in plains
>= 0.25	3. Upland drainages, Headwaters	7. Upper slopes, Mesas	10. Hilltops, High ridges

Table 4. Landform classes and sizes (in 10-m cell) in the NHD subregions 0307-0314.

Class	Number of Cells	Landform
1	368,272,485	Canyons, Deeply incised streams
2	71,869,931	Midslope drainages, Shallow valleys
3	27,395,130	Upland drainages, Headwaters
4	121,810,041	U-shaped valleys
5	687,965,616	Plains
6	975,017,470	Open slopes
7	128,062,920	Upper slopes, Mesas
8	36,686,226	Local ridges, Hills in valleys
9	93,597,701	Midslope ridges, Small hills in plains
10	377,921,953	Hilltops, High ridges

RESULTS AND DISCUSSION

These multi-step GIS operations resulted in the completion of the FSD digital stream layer, the initial stream order and stream linkage calculations and associations, and attribution of the FSD line segments with the stream habitat classification (Fig. 2).

The enhancement of the NHD was based on production of the fine scale DEMs with accuracy compliant with the USGS standard. The standard is ½ of the data source contour interval, meaning that it is 0.76 m for 5 ft contours and 1.52 m for 10 ft contours. Overall accuracy of our DEMs was 0.91-0.92 m, and in Florida, it was 0.78-0.81 m (Table 5). The DEMs cover the area within 1,038 USGS 7.5‘ quads in the State of Florida, and an additional 384 quads in Georgia and 215 quads in Alabama (Fig. 13).

Basins that had the similarity index of 89.5% or greater were considered as belonging to a particular EDU (Fig. 3). This means that an EDU had basins that were 89.5% similar in species composition (Appendix G). The 89.5% cutoff combined the 42 original basins into 18 distinctive Ecological Drainage Units of the Southeastern United States (Fig. 8). The EDUs were included in HUCs-8 not only in Florida but also from Lake Ponchartrain to the River within NHD subregions 0306, 0315–0318, 0807 and 0809. The NHD HUC-8 boundaries outside of Florida were adjusted to the HUC-12 boundaries. There were 9 EDUs in Florida (with a gap along the Atlantic coast, for which there was no source data, Fig. 8). Overall, there are 53 combinations of Ecosubregions/Climate/EDU in Florida. However, there are only 44 complete combinations because 9 are missing fish data for the EDUs along the east coast.

After putting together pieces of streams and capturing additional connectivity in Florida, the FSD digital stream layer had 3,106,943 flowline segments with different combinations of classification attributes. The length in meters of the mapped streams included in the final dataset was as follows (Fig. 19):

Minimum:	0.0001
Maximum:	11,718.5932
Sum:	165,042,790.7200
Mean:	53.1206
Standard Deviation:	91.1653

There are so many segments because the reaches are split by multiple polygons (NHD segments, HUCs, EDUs, climate divisions, soils, geology, landforms, and land cover). The majority of flowlines (3,071,413) are from the NHD with only a small portion (35,530) resulting from the added ―connectors” of missing parts in the 5 northern subregions. These 2 parts (original NHD and added connectors) are distinguished by an added attribute source (with ‗N‘ for NHD and ‗F‘ for modeled flowlines). There still might be some duplicate features, which we were not able to

Table 5. Accuracy assessment of the 5- and 10-m DEMs by independent datasets of testing points with known elevations. RMSE is root mean square error. GCP is a testing subset of vertical geodetic point control data developed by NOAA National Geodetic Survey in 2004. SOFIA is an additional testing subset of South Florida Information Access high-accuracy elevation points 2005 collected by USGS and South Florida Water Management District for Everglades region (Desmond 2003).

Dataset	DEM RMSE (m)		*n*
	5-m	10-m	
Overall	0.905	0.922	10,088
GCP, FL	1.136	1.168	3,920
SOFIA, FL	0.350	0.354	5,378
GCP & SOFIA, FL	0.784	0.805	9,298
GCP, AL & GA	1.795	1.800	790

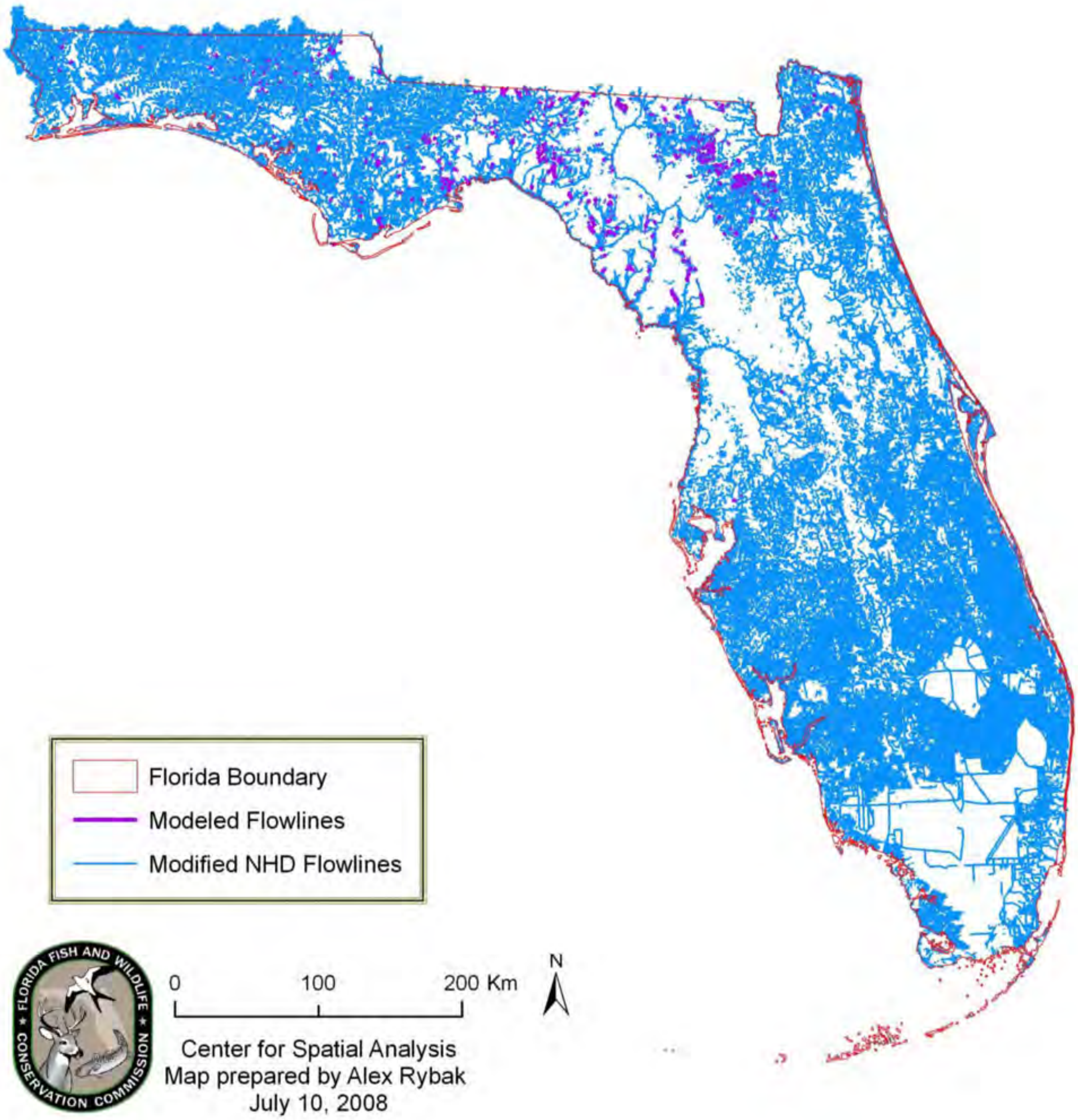

Figure 19. Florida Stream Dataset flowlines. Coastlines are not included.

detect and delete. There also may be about 5–10% of stream flowlines that are still missing. Based on the results of the ground-truthing (Hvozda et. al 2007), 64% of the modeled streams were eliminated. It was impossible to decide a-priori which tributaries had to be deleted and which ones had to stay, although it was clear that the modeled streams filling the gaps in the disconnected NHD network had to be a part of the FSD. As a result, from 52,906 new unsplit flowlines with total length of 12,833.8 km, only a comparatively few were used, with a total length of 1,670.7 km (Table 6).

The total length of the final FSD is approximately 165,000 km. The level of new details provided exceeds previous and recent estimates. Moreover, the final FSD line topology, configuration, connectedness and directionality are much cleaner than they were in the original NHD. The high quality of the FSD allowed proper stream ordering and attribution, which were not possible with the draft NHD.

The final FSD line and HECE polygon datasets were organized by the relationship scheme shown in Figure 20. The open structure of the entire FSD dataset and its linkages to NHD, SSURGO and Threats databases make the dataset very flexible and will provide opportunity for future growth. It aggregates the most important attributes from the NHD flowlines, calculates local stream characteristics, and incorporates the Valley Segment Type ‗quality‘ attributes (surficial geology *SURGEONAME*, landform *LANDFCLASS,* and vegetation and land cover class *LULC_CLASS*). An example of attribute values associated with an elementary FSD line segment is presented on Figure 21. A user would know that this particular 37-m long (*LENGTH)* stream segment belongs to a bigger 2.8-km-long (*LENGTHKM*) perennial river (*FCODENAME*) called Wiggins Branch (*GNIS_NAME*) within subwatershed internal

Table 6. Final Florida Stream Dataset flowlines length as a result of combination and editing the NHD and modeled flowlines.

Subregion	NHD		Modeled Flowlines				Total in Final FSD	
	Before Deletion and Split		Before Deletion		After Deletion and Split			
	n	Length (m)	*n*	Length (m)	*n*	Length (m)	*n*	Length (m)
0307	14,090	4,744,349.6	882	390,654.8	1,190	56,545.3	66,179	3,480,133.4
0308	103,522	32,753,844.1	-	-	-	-	603,355	32,040,448.2
0309	169,262	63,588,947.7	-	-	-	-	1,028,001	60,993,666.6
0310	96,418	26,817,195.2	-	-	-	-	608,551	26,815,603.3
0311	76,858	24,087,282.3	5,829	2,313,803.8	22,359	1,070,271.3	211,206	10,253,157.0
0312	23,323	9,239,150.9	9,753	147,589.4	4,151	197,476.5	96,704	5,322,689.2
0313	113,508	62,641,019.3	4,831	1,527,268.4	3,133	155,068.2	118,440	6,849,274.0
0314	131,198	50,613,455.6	31,611	8,454,478.4	4,537	183,665.6	374,507	19,287,819.1
Total	728,179	274,485,244.7	52,906	12,833,794.9	35,370	1,663,026.9	3,106,943	165,042,790.7

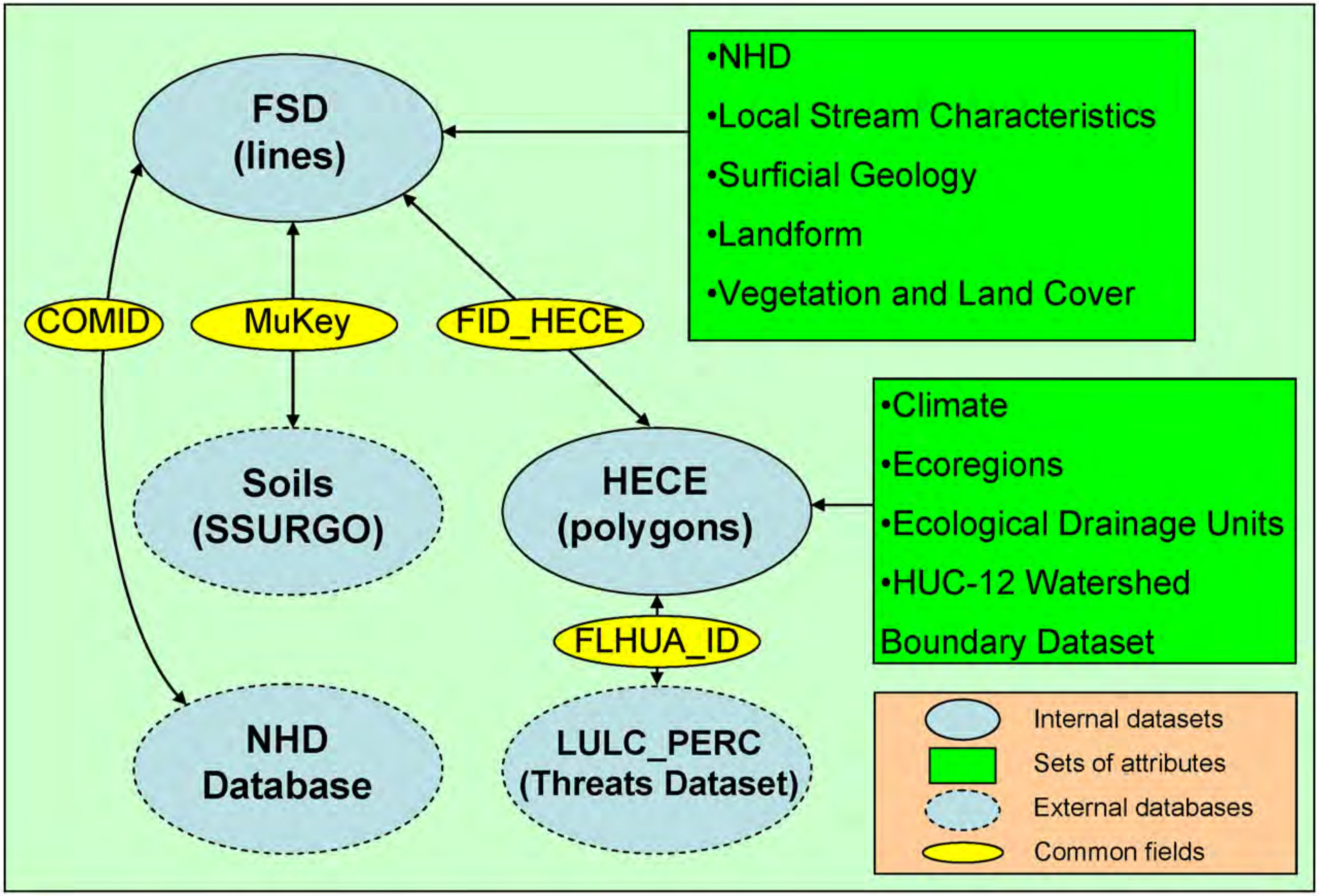

Figure 20. Relationship scheme of the Florida Stream Dataset.

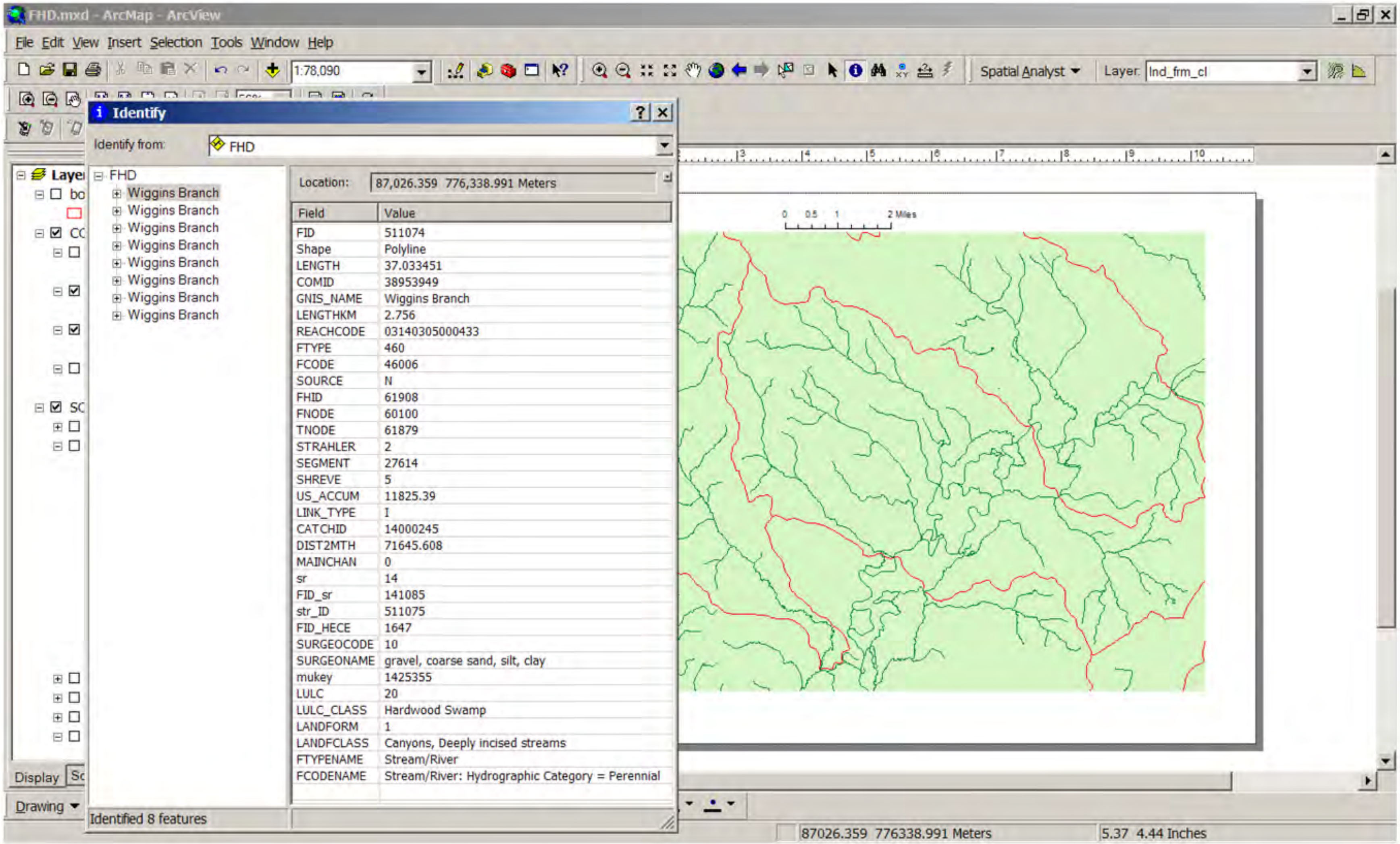

Figure 21. An example of attribute values associated with an elementary FSD line segment (green lines). Red lines delineate HECE polygons based on HUC-12 subwatersheds.

1647 (FID_HECE), within catchment # 14,000,245 (*CATCHID*), within NHD subregion 0314 (sr). This reach is positioned aside from the main channel (*MAINCHAN*), internal (*LINK_TYPE*), distance to source is 11.8 km (*US_ACCUM*), distance to mouth is 71.6 km (*DIST2MTH*), Shreve order is 2, Segment is 27,614, Shreve order is 5. The stream is deeply incised in topography (*LANDFCLASS*), goes through Hardwood Swamp (*LULC_CLASS*), and has substrate with gravel, coarse sand, silt, and clay (*SURGEONAME*).

An example of what data can be retrieved from the soil database is shown on Figure 22. In addition to the main core FSD information, a user would have more detailed soils information, including the following: ‗Dorovac muck and Fluvaquents, frequently flooded' *muname*, dominant slope gradient 1%, weighted average slope gradient 1%, annual and April- June minimum water table depth is 8 cm, floods are frequent, 15-49% of the map is subject to water being ponded on the soil surface, specifics of available to plants water storage (AWS) by layers, the natural drainage condition – very poorly drained, hydrologic Group D – soils have high runoff potential when thoroughly wet, irrigated capability 100%, non-irrigated capability 85%, relative potential erosion hazard when used as a site for forest roads and trails – very severe, and partially hydric class.

Figure 23 gives an example of HECE polygon attribute values associated with an elementary FSD line segment. This particular stream is within North Climate division, Southern Pine Plains and Hills ecological subregion, West Florida Ecological Drainage Unit. An example of additional land-cover percent data averaged by riparian zones can be linked to the HECE subwatershed polygons (Figure 24).

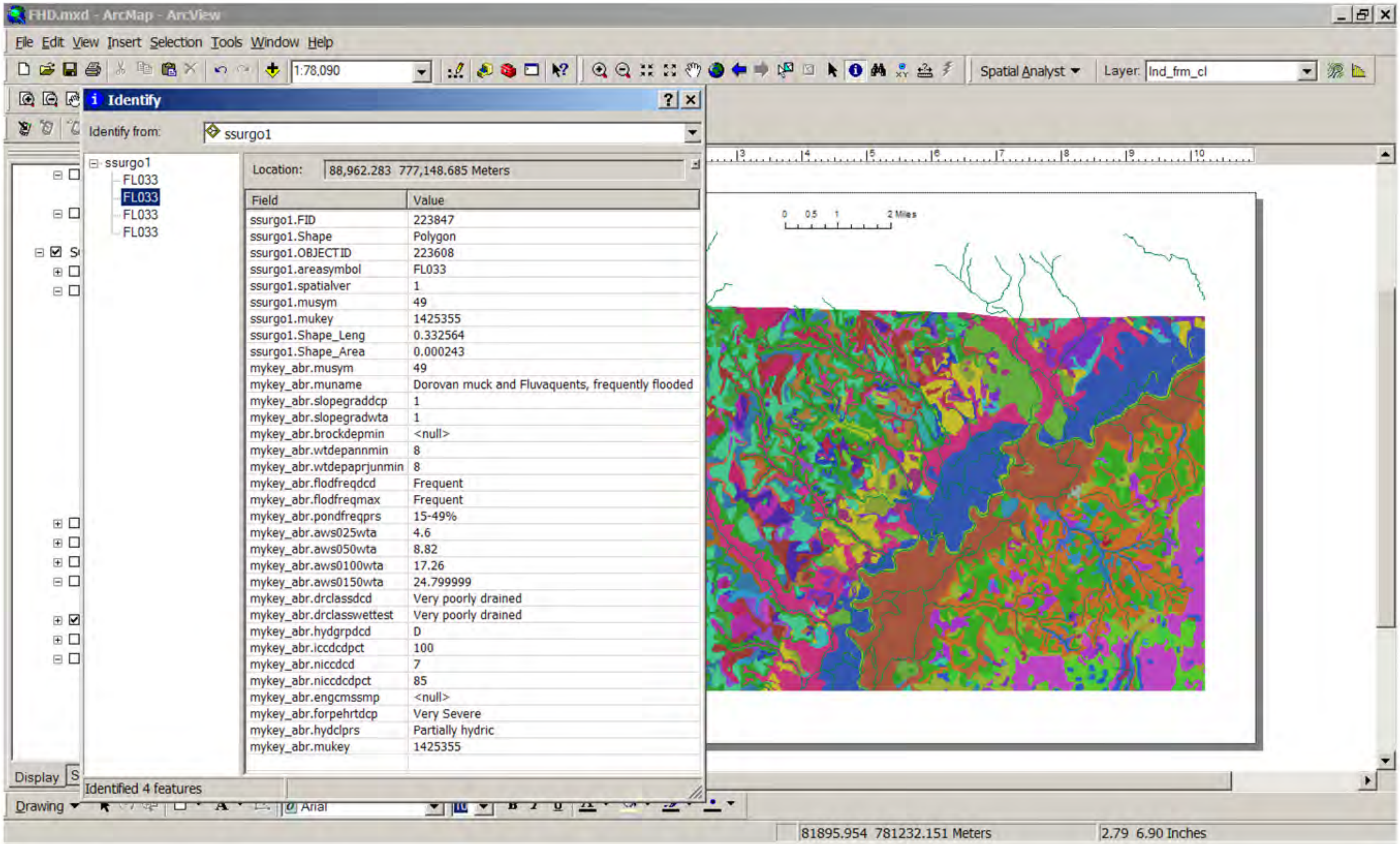

Figure 22. An example of soil SSURGO attribute values associated through *mukey* field with an elementary FSD line segment (green lines).

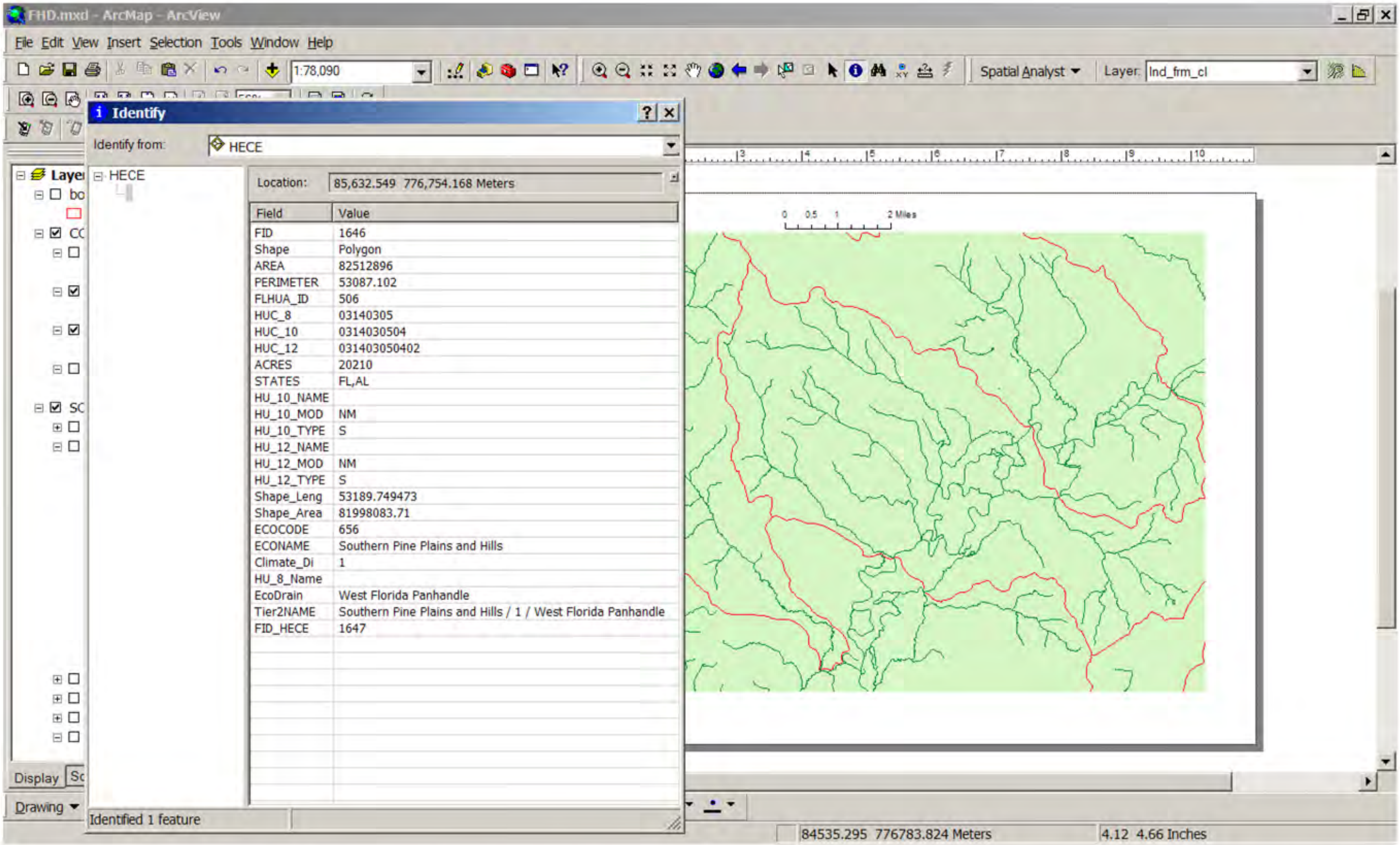

Figure 23. An example of HECE polygon (delineated by red line) attribute values associated with an elementary FSD line segment (green lines).

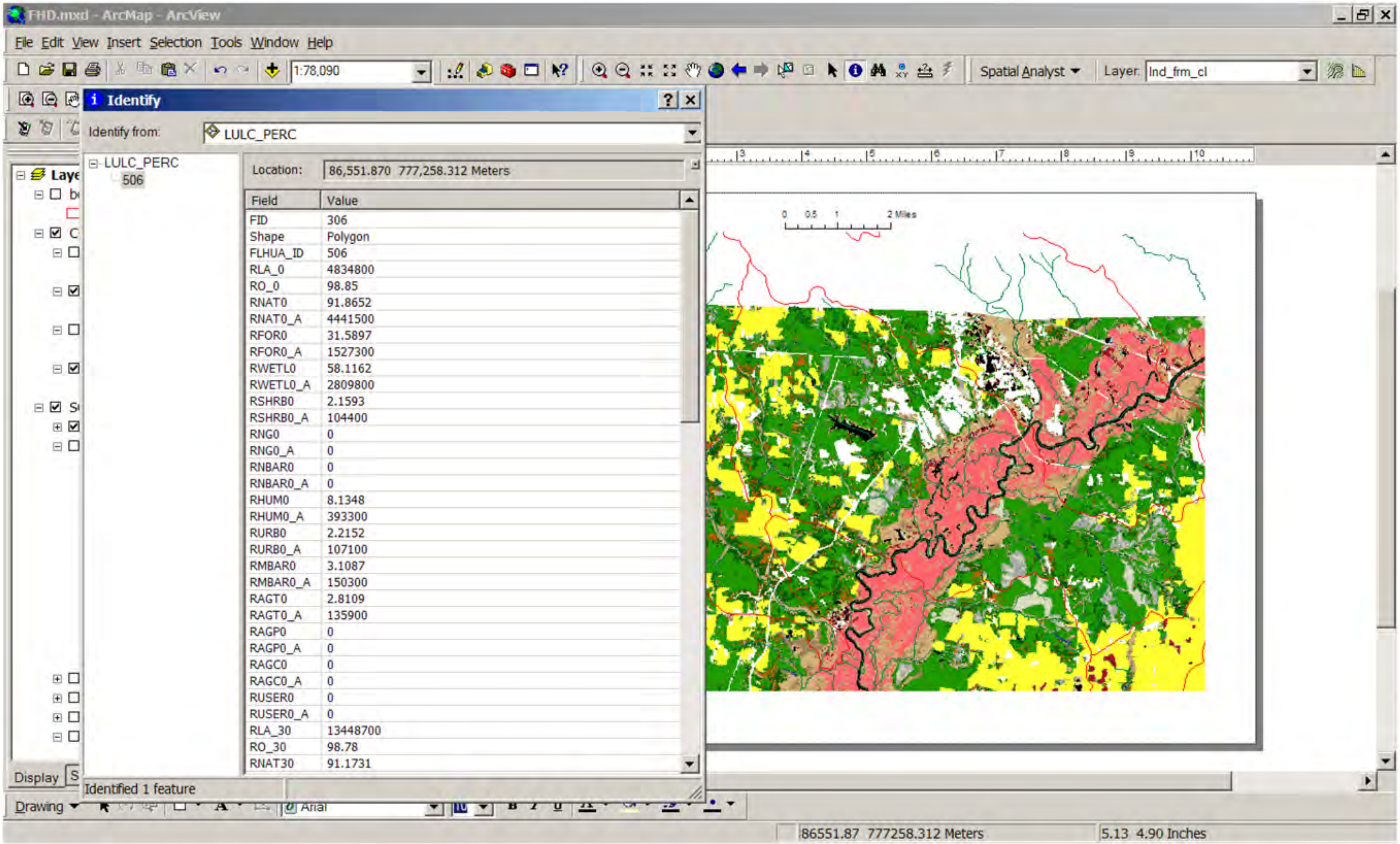

Figure 24. An example of additional land-cover percent data averaged by riparian zones of linked to the HECE subwatershed polygons (delineated by red lines). The elementary FSD line segments (green lines) are linked to the HECE as well.

MANAGEMENT IMPLICATIONS

The previous SWG-funded project, *Florida Imperiled Fish Species Investigation*, collected specific stream habitat characteristics and digital photographs for many stream locations throughout Florida. This information may serve as an additional filter in the ground-truthing of the classification. As HUCs are completed, they can provide updated information for the threats and conservation goals analysis that is being developed by The Nature Conservancy‘s SWG03 ―*Identifying Priority Areas for Freshwater Conservation Action in Florida*" and ―*Problem and conservation action identification using The Nature Conservancy's planning process*" projects. Some of the products can be integrated into the Dynamic Solutions Group (DSG) tasks C3- ―Regions and key habitat types" and C5- ―Species of greatest conservation need, priorities, regions, and key habitats" and into future versions of the CWCS.

This project will form the basis for several ongoing and future projects including: creation of potential habitat models for more than 100 species of freshwater fishes, identification of priority aquatic conservation sub-areas, and establishment of comprehensive conservation strategies for these areas. Additionally, the FSD dataset can be submitted to the DEP for review in close collaboration with the Florida Water Management Districts and local hydrologists to ensure we were making the proper decisions concerning the corrections. After that, the FSD may become a part of approved National Hydrography Dataset.

FWC should work closely with environmental agencies and organizations in neighboring states of Georgia and Alabama on coordinating research, monitoring, and management of aquatic resources because eco-hydrological units do not stop at the states‘ borders.

CONCLUSIONS

Overall, the total length of approximately 165,000 km of flowlines representing Florida streams was thoroughly compiled, cleaned, and checked for quality. The extensive grouping constitutes the preliminary abiotic classification of the freshwater aquatic system. It includes up-to-date digital delineations by Climate divisions, Ecosubregions, Ecological Drainage Units, and Aquatic Ecological System Types, such as surficial geology types, landforms, land cover, and soil types. Moreover, the set incorporates NHD and HUC attributes as well as a suite of calculated positional characteristics associated with stream ordering.

Because the FSD is at a scale of 1:24,000, the freshwater aquatic habitat classification provides adequate detail for deriving extensive information about each river segment. This information can be extracted for all streams within a watershed or any other area of interest. The FSD information has the potential to be used by many researchers and organizations for conducting modeling and large scale statewide and ecoregional assessments, finer watershed level assessments, and assessments at a scale of individual stream segments.

The open structure of the entire FSD dataset and its linkages to NHD, WBD, SSURGO and Threats databases (Fig. 20) make the dataset very flexible and provides opportunities for future growth. The growth and improvements can go in two directions: 1) adding to geometrical network of streams; and 2) adding to the classification database.

A systematic process of continuous collection of paired biological and physical habitat data will establish large data sets growing out from the FSD. This will make future monitoring more effective, ecological assessment more informative, and conservation decisions more focused spatially at specific targets while considering multiple levels of the hydro-ecological system depicted by this project‘s dataset.

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APPENDIX A – ArcInfo AML for producing a series of 5-meter hydro-enforced DEM tiles.

```
/* This script will perform TOPOGRID on multiple tiles defined by
/* XYLIMITS of input polygons box*.
/* Created by: Alex Rybak, FWC.
/* Date: Jan 31, 2006.

&watch createdem_5.wat

&type ZMIN was set to original (without enforcing it to be = 0)

&messages &on
&severity &warning &ignore
&severity &error &ignore

&type
&type This script will perform TOPOGRID on multiple squares defined by
&type XYLIMITS of input polygons box* and ZLIMITS of contours inside the box.

precision double double

&s covers := [listfile f5_* -cover -polygon]
&if [null %covers%] &then
  &return No polygon coverages exist.
&s num := [token %covers% -count]
&do I := 1 &to %num%

   &s cov1 := [extract %i% %covers%]
   &s cov := [before %cov1% _buff]
   &type Extracting XY limits for %cov1%
   &describe %cov1%

   &lv DSC$XMIN
   &lv DSC$YMIN
   &lv DSC$XMAX
   &lv DSC$YMAX

   &s xmin1 := [round %DSC$XMIN%]
   &s ymin1 := [round %DSC$YMIN%]
   &s xmax1 := [round %DSC$XMAX%]
   &s ymax1 := [round %DSC$YMAX%]

   &s xmin2 := [MOD %xmin1% 5]
   &s ymin2 := [MOD %ymin1% 5]
   &s xmax2 := [MOD %xmax1% 5]
   &s ymax2 := [MOD %ymax1% 5]
```

```
  &s xmin := [calc %xmin1% - %xmin2%]
  &s ymin := [calc %ymin1% - %ymin2%]
  &s xmax := [calc %xmax1% - %xmax2%]
  &s ymax := [calc %ymax1% - %ymax2%]

&type
  &type Calculating MARGIN for %cov1%
  &type   44950

  &s x := [calc %xmax% - %xmin%]
  &s y := [calc %ymax% - %ymin%]
  &s xy := [calc %x% * %y%]
  &s x2 := [calc 2 * %x%]
  &s y2 := [calc 2 * %y%]
  &s xpy := [calc %x2% + %y2%]
  &s q2xpy := [calc %xpy% * %xpy%]
  &s d := [calc %xy% - 2020502500]
  &s d2 := [calc 16 * %d%]
  &s d3 := [calc %q2xpy% - %d2%]
  &s a2 := [sqrt %d3%]
  &s a := [calc %a2% - %xpy%]
  &s marg := [calc %a% / 8]

  &s xmin3 := [round [calc %xmin% - %marg%]]
  &s ymin3 := [round [calc %ymin% - %marg%]]
  &s xmax3 := [round [calc %xmax% + %marg%]]
  &s ymax3 := [round [calc %ymax% + %marg%]]


  &type Extracting Z limits for %cov1%
  &type

  generate b
  polygons
  %i%, AUTO
  %xmin3%, %ymin3%
  %xmax3%, %ymin3%
  %xmax3%, %ymax3%
  %xmin3%, %ymax3%
  %xmin3%, %ymin3%
  end
  end
  q

  build b poly
```

```
ap
  mapextent poly b
  resel cont5 arcs mapextent
  sort cont5 arcs elevmeters ascending
  &s zmin1 := [show select cont5 arc 1 item elevmeters]
  sort cont5 arcs elevmeters descending
  &s zmax1 := [show select cont5 arc 1 item elevmeters]
  &s zmin := [calc [truncate %zmin1%] - 3]
  &s zmax := [calc [round [calc %zmax1% + 0.5]] + 3]

  clearselect cont5 arcs
  q

  &type Creating DEM for %cov1%
  topogrid dem5%cov% 5
  contour cont5 elevmeters
  datatype contour
  enforce on
  iterations 40
  margin %marg%
  outputs sink5%cov% drain5%cov% diag5%cov%
  point gcp_all_tr elevmeters
  sink sink
  stream streams
  tolerances 1.5 2.0 0
  xyzlimits %xmin% %ymin% %xmax% %ymax% %zmin% %zmax%
  end
```

APPENDIX B. AML conflating the NHD and flowaccumulation selected using TPI centerlines.

This AML calls a supporting AML (Appendix 3).

```
/* Conflate 3 coverages, i.e. NHD, Centerline, and FlowaccLine in a subregion.
/* usage: &r con#a.aml # (# = # of subregion)
/* Input: nhd_s# fac_s# cen_s# shapefiles (run them thru TOPOLOGY in ArcMap)
/* Created by Alex Rybak & Aaron Podey
/* 10/02/06
/* "/*" = notes & old runs; "/**" = commands needed for further runs; quoted temporally

/* Output by sequence:              # of arcs   # of seg    FUZZY_TOL
/* Numbers of ARCs etc. - do not apply!!!

/*              nhd_s (repair geometry)        shapefile
/*          fac_s
/*          cen_s
/*          sr13buf2k (BND_S)       shapefile
/* 1    H       nhd
/*          (with replaced shore)   110,853     2,501,789       27.6
/* 2    H       fac                 2,376,092   20,632,186      29.8
/*          Have to clip grid to create fac_s.shp beforehand
/* 3    H       cen                 464,865             10,635,905      28.1

/* 4    nothing
/* 5    H       fac_mid    /* >13 hrs
/* 6    H       f2c (120)           861,410             8,684,631       29.8


/* 7    H       f2c_gen (2)         861,410             2,602,250       29.8

/* 8    H       f2c_c (0, 0.0000001)  1,005,488   2,746,306    0.0000001
/* 9    H       f2c_cn (0, 12)      733,026             2,227,240       12
/* 10           f2c_cln (0, 0.1)    738,796             2,479,476       0.1
/* 11           f2c_uns                     640,806             2,479,476       0.1

/* 12           f2c_ln (0, 0.1)     653,863             2,472,808       0.1
/* 13       f2c_dng (25)            602,275             2,415,456       0.1
/* 14           f2c_del (unconn & <75)      583,528             2,379,760       0.1

/* 15           nhd_cn (0, 0.0000001)
/* 16           nhd_cln (0, 0.1)    113,663             2,504,103       0.1

/* 17           nhd_buf (40, 0.1)   2,987 (POLYs)       578 buffers     0.34

/* 18           f2c_idn       (0.1)         771,546             2,567,071       0.1
```

```
/* 19         f2c_trm (<>100 = 40) 398,331              1,349,565     0.1


/* 20       nhd_45b (45, 0.1)       3,018 (polys)  561 buffers    0.38
/* 21       f2c_45n (identity 0.1)  577,572                1,528,163     0.1

/* 22         fc2n (41, str, seg)   576,429                1,524,018     0.1

/* 23         fc2n_uns              377,460                1,524,018     0.1
/* 24         fc2n_cln (0, 0.1)     377,434                1,522,967     0.1
/* 25         fc2n_dng (5)          375,411                1,520,848     0.1
/* 26         f (drop items from fc2n_dng)
/* 27         n (copy of nhd_cln)

/*        nc (shape from n)
/*        fc (shape from f)

/*        manual editing of nc (mostly deleting) & fc (del, add, connect, modify)
/*        manual adding of lakes/ponds/reservoirs & springs
/*        merge nce & fce => fh_s (shape)
/*        geometry repair of fh_s
/*        add source = f
/*        del useless fields
/*        convert fh_s.shp to fh cov (check TOL)

/* 28       fh
/* 29         fh_cn (0, 0.0000001)
/* 30       fh_ln (0, 0.1)
/* 31       fh_uns
/* 32         fh_dng (5)
/* 33       fhd (clean 0, 0.1)


&severity &error &ignore
&severity &warning &ignore

&args sr

&if [NULL %sr%] &then &do
  &ty;&ty Usage: CON#.AML <SubRegion#>
  &return
&end


&watch conf%sr%.wat &append &commands
```

```
&ty
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
+++++++++++++++++++++++++++
&ty


&ty ######
&ty [date -full]
&ty ######



precision double double
lc

/* - update NHD from the web: 8/31/06 and later / saved in c:\alex\gis_data\nhd\nhd_sep06
/* - sel all flowlines exc. pipeline and shore/coast; replace NHD_shore with FWC_shore  =>
nhds.shp

&sv t1 := [date -full]


&ty - convert nhd_s shapefile into coverage <NHD>
&ty

ap
layer define x shapefile nhd_s%sr% line
layerexport x coverage nhd%sr% line

&sv t2 := [date -full]

&ty - convert shape fac_s%sr% into cov fac%sr%
&ty

layer define y shapefile fac_s%sr% line
layerexport y coverage fac%sr% line

&sv t3 := [date -full]

&ty - convert shape cen_s%sr% into cov cen%sr%
&ty

layer define z shapefile cen_s%sr% line
layerexport z coverage cen%sr% line
q
```

```
&ty ######
&ty [date -full]
&ty ######


&ty - build nhd%sr%, fac%sr%, and cen%sr% lines and nodes
&ty

build nhd%sr% line
build fac%sr% line
build cen%sr% line

build nhd%sr% node
build fac%sr% node
build cen%sr% node

renode nhd%sr% node
renode fac%sr% node
renode cen%sr% node



&sv t5 := [date -full]

&ty ######
&ty [date -full]
&ty ######


&ty - add attrib SOURCE to NHD cov
&ty

lc

additem nhd%sr%.aat nhd%sr%.aat source 5 6 c

&ty
&ty - calc attribs
&ty

tables
sel nhd%sr%.aat
calc source = 'n'
commit
nsel
q
```

```
&ty - Finding <fac_cln> near <cen>
&ty
&ty - Start selecting fac_cln%sr% arcs having their centers within 120 m from cen%sr%
&ty
&ty - finding middle point of FAC_cln%sr%
&ty

&ty ######
&ty [date -full]
&ty ######

&sv t6 := [date -full]

&r find_middle_pnt fac%sr% fac_mid%sr%

&ty ######
&ty [date -full]
&ty ######

&ty - computing the distance from each point in coverage fac_mid%sr%
&ty - to the nearest arc in cen%sr%
&ty - within 120 m

near fac_mid%sr% cen%sr% line 120

&ty ######
&ty [date -full]
&ty ######

&ty - joining the attributes (fields) "CEN%sr%#" and "DISTANCE"
&ty - of fac_mid%sr% points to fac_cln%sr% lines
&ty

joinitem fac%sr%.aat fac_mid%sr%.pat fac%sr%.aat $RECNO

&ty ######
&ty [date -full]
&ty ######

&sv t7 := [date -full]

&ty - creating a new <F2C> cov from arcs in <FAC%sr%> which doesn't NOT have
CEN%sr%# = 0
&ty
```

```
reselect fac%sr% f2c%sr% line
res cen%sr%# <> 0
~
n
n

&ty - adding NODE topology to <F2C>
&ty

&ty ######
&ty [date -full]
&ty ######

build f2c%sr% line
build f2c%sr% node
renode f2c%sr%

&ty - GENERALIZE <F2C> => <F2C_gen>
&ty

&sv t8 := [date -full]

generalize f2c%sr% f2c_gen%sr% 2

&ty ######
&ty [date -full]
&ty ######

&ty - adding NODE topology to <F2C_gen>
&ty

build f2c_gen%sr% line
build f2c_gen%sr% node
renode f2c_gen%sr%

&ty - CLEAN <F2C_gen> => <F2C_c> 0, 0.0000001
&ty

&sv t9 := [date -full]

clean f2c_gen%sr% f2c_c%sr% 0 0.0000001 line
build f2c_c%sr% node
renode f2c_c%sr%

&ty ######
&ty [date -full]
```

```
&ty ######

&ty - CLEAN <F2C_c> => <F2C_cn> 0, 12
&ty

&sv t10 := [date -full]

clean f2c_c%sr% f2c_cn%sr% 0 12 line
build f2c_cn%sr% node
renode f2c_cn%sr%

&ty ######
&ty [date -full]
&ty ######

&ty - CLEAN <F2C_cn> => <F2C_cln> 0, 0.1
&ty

&sv t11 := [date -full]

clean f2c_cn%sr% f2c_cln%sr% 0 0.1 line
build f2c_cln%sr% node
renode f2c_cln%sr%

&ty ######
&ty [date -full]
&ty ######

&ty - remove pseudo-nodes from <F2C_cln> using ArcEdit UNSPLIT => <F2C_uns>
&ty

&sv t12 := [date -full]

copy f2c_cln%sr% f2c_uns%sr%

ae
ec f2c_uns%sr%
ef arc
sel all
unsplit none
save
unselect all
q

&ty ######
&ty [date -full]
```

```
&ty ######


&ty - adding NODE topology to <F2C_UNS>
&ty

build f2c_uns%sr% line
build f2c_uns%sr% node
renode f2c_uns%sr%

&ty - CLEAN <F2C_uns> {out_cover} {dangle_length} {fuzzy_tolerance} {POLY | LINE}
&ty - => <F2C_LN>
&ty

&sv t13 := [date -full]

clean f2c_uns%sr% f2c_ln%sr% 0 0.1 line
build f2c_ln%sr% node
renode f2c_ln%sr%

&ty ######
&ty [date -full]
&ty ######

&ty - removing dangles from <f2c_ln> -> <f2c_dng>
&ty

&sv t14 := [date -full]

copy f2c_ln%sr% f2c_dng%sr%

ae
ec f2c_dng%sr%
ef arc
sel dangle
asel dangle
resel length <= 25
delete
save
unselect all
q

&ty ######
&ty [date -full]
&ty ######
```

```
&ty - adding NODE topology to <F2C_dng>
&ty

build f2c_dng%sr% line
build f2c_dng%sr% node
renode f2c_dng%sr%

&ty - delete unconnected and <75 m arcs in <F2C_dng> => <F2C_DEL>
&ty

&sv t15 := [date -full]

copy f2c_dng%sr% f2c_del%sr%

ae
ec f2c_del%sr%
ef arc
sel length < 75
sel connect
asel connect
asel connect
asel connect
asel connect
asel connect
asel connect
asel connect
asel connect
asel connect
asel connect
asel length >= 75
asel connect
asel connect
nsel
delete
save
unselect all
q

&ty ######
&ty [date -full]
&ty ######


&ty - adding NODE topology to <F2C_DEL>
&ty
```

```
build f2c_del%sr% line
build f2c_del%sr% node
renode f2c_del%sr%

&ty - Cleaning <nhd> => <NHD_CN> 0 0.0000001
&ty

&sv t16 := [date -full]

clean nhd%sr% nhd_cn%sr% 0 0.0000001 line
build nhd_cn%sr% node
renode nhd_cn%sr%

&ty ######
&ty [date -full]
&ty ######

&ty - Cleaning <nhd_cn> => <NHD_CLN> 0 0.1
&ty

&sv t17 := [date -full]

clean nhd_cn%sr% nhd_cln%sr% 0 0.1 line
build nhd_cln%sr% node
renode nhd_cln%sr%

&ty ######
&ty [date -full]
&ty ######


&ty - buffering <NHD_CLN> by 40 using end type ROUND and
&ty - fuzzy tolerance of 0.1 => <NHD_buf> nhd_buf%sr%
&ty

&sv t18 := [date -full]

buffer nhd_cln%sr% nhd_buf%sr% # # 40.0 0.1 line

&ty ######
&ty [date -full]
&ty ######

build nhd_buf%sr% poly
```

```
&ty - identify <F2C_del> by <NHD_BUF> => <F2C_IDN>
&ty

&sv t19 := [date -full]

identity f2c_del%sr% nhd_buf%sr% f2c_idn%sr% line 0.1
build f2c_idn%sr% line
build f2c_idn%sr% node
renode f2c_idn%sr%

&ty ######
&ty [date -full]
&ty ######


&ty - resel inside <> 100 from <F2C_IDN> => <F2C_trm>
&ty

&sv t20 := [date -full]

reselect f2c_idn%sr% f2c_trm%sr% line
res inside <> 100
~
n
n

&ty ######
&ty [date -full]
&ty ######


&ty - adding NODE topology to <F2C_trm>
&ty

build f2c_trm%sr% line
build f2c_trm%sr% node
renode f2c_trm%sr%

&ty - BUFFER <NHD_CLN> @ 45 => nhd_45b (45, 0.1)
&ty - buffer nhd_cln%sr% nhd_45b%sr% # # 45.0 0.1 line round full
&ty

&sv t21 := [date -full]

buffer nhd_cln%sr% nhd_45b%sr% # # 45.0 0.1 line
```

```
&ty ######
&ty [date -full]
&ty ######

build nhd_45b%sr% poly

&ty - Add nodes on <F2C_TRM> @ 45 m from <NHD_CLN> using IDENTITY =>
<F2C_45n>
&ty

&sv t22 := [date -full]

identity f2c_trm%sr% nhd_45b%sr% f2c_45n%sr% line 0.1
build f2c_45n%sr% line
build f2c_45n%sr% node
renode f2c_45n%sr%


&ty ######
&ty [date -full]
&ty ######

&ty - snapcover <F2C_45n> to <NHD_cln> @ 41 => <FC2N>
&ty

&sv t23 := [date -full]

snapcover arc f2c_45n%sr% arc nhd_cln%sr% fc2n%sr% 41 straight segment

&ty ######
&ty [date -full]
&ty ######


&ty - adding NODE topology to <FC2N>
&ty

build fc2n%sr% line
build fc2n%sr% node
renode fc2n%sr%

&ty - remove pseudo-nodes from <FC2N> using ArcEdit UNSPLIT => <FC2N_uns>
&ty

&sv t24 := [date -full]
```

```
copy fc2n%sr% fc2n_uns%sr%

ae
ec fc2n_uns%sr%
ef arc
sel all
unsplit none
save
unselect all
q

&ty ######
&ty [date -full]
&ty ######


&ty - adding NODE topology to <FC2N_UNS>
&ty

build fc2n_uns%sr% line
build fc2n_uns%sr% node
renode fc2n_uns%sr%

&ty - CLEAN <FC2N_uns> => <FC2N_cln>
&ty

&sv t25 := [date -full]

clean fc2n_uns%sr% fc2n_cln%sr% 0 0.1 line

&ty ######
&ty [date -full]
&ty ######


build fc2n_cln%sr% line
build fc2n_cln%sr% node
renode fc2n_cln%sr%

&ty - deleting useless attribs shape_leng and shape_len in <NHD_CLN>
&ty

dropitem nhd_cln%sr%.aat nhd_cln%sr%.aat shape_leng shape_len

&sv t26 := [date -full]
```

```
&ty - delete dangles < 5 m in fc2n_cln => fc2n_dng
&ty

copy fc2n_cln%sr% fc2n_dng%sr%

ae
ec fc2n_dng%sr%
ef arc
sel dangle
asel dangle
resel length <= 5
delete
save
unselect all
q

&ty ######
&ty [date -full]
&ty ######

&ty - dropitems from fc2n_dng%sr% => <F>
&ty
copy fc2n_dng%sr% f%sr%
dropitem f%sr%.aat f%sr%.aat F2C_TRM%sr%# ~
F2C_TRM%sr%-ID ~
F2C_DEL%sr%# ~
F2C_DEL%sr%-ID ~
ID ~
AREA ~
PERIMETER ~
FAC_MID%sr%# ~
FAC_MID%sr%-ID ~
CEN%sr%# ~
DISTANCE ~
NHD_BUF%sr%# ~
NHD_BUF%sr%-ID ~
INSIDE ~
NHD_45B%sr%# ~
NHD_45B%sr%-ID

copy nhd_cln%sr% n%sr%

&ty - Convert cov to shape: <N> => <NC> & <F> => <FC>
&ty
ap
layer define j cover n%sr% line
```

```
layerexport j shapefile nc%sr%

layer define i cover f%sr% line
layerexport i shapefile fc%sr%
q

&ty ######
&ty [date -full]
&ty ######

&sv t27 := [date -full]

lc

&describe nhd%sr%
&sv a_arc := %DSC$ARCS%
&sv a_seg := %DSC$SEGMENTS%
&sv a_fuz := %DSC$FUZZY%

&describe fac%sr%
&sv b_arc := %DSC$ARCS%
&sv b_seg := %DSC$SEGMENTS%
&sv b_fuz := %DSC$FUZZY%

&describe cen%sr%
&sv c_arc := %DSC$ARCS%
&sv c_seg := %DSC$SEGMENTS%
&sv c_fuz := %DSC$FUZZY%

&describe fac_mid%sr%
&sv f_arc := %DSC$ARCS%
&sv f_seg := %DSC$SEGMENTS%
&sv f_fuz := %DSC$FUZZY%

&describe f2c%sr%
&sv g_arc := %DSC$ARCS%
&sv g_seg := %DSC$SEGMENTS%
&sv g_fuz := %DSC$FUZZY%

&describe f2c_gen%sr%
&sv h_arc := %DSC$ARCS%
&sv h_seg := %DSC$SEGMENTS%
&sv h_fuz := %DSC$FUZZY%

&describe f2c_c%sr%
&sv i_arc := %DSC$ARCS%
```

```
&sv i_seg := %DSC$SEGMENTS%
&sv i_fuz := %DSC$FUZZY%

&describe f2c_cn%sr%
&sv j_arc := %DSC$ARCS%
&sv j_seg := %DSC$SEGMENTS%
&sv j_fuz := %DSC$FUZZY%

&describe f2c_cln%sr%
&sv k_arc := %DSC$ARCS%
&sv k_seg := %DSC$SEGMENTS%
&sv k_fuz := %DSC$FUZZY%

&describe f2c_uns%sr%
&sv l_arc := %DSC$ARCS%
&sv l_seg := %DSC$SEGMENTS%
&sv l_fuz := %DSC$FUZZY%

&describe f2c_ln%sr%
&sv m_arc := %DSC$ARCS%
&sv m_seg := %DSC$SEGMENTS%
&sv m_fuz := %DSC$FUZZY%

&describe f2c_dng%sr%
&sv n_arc := %DSC$ARCS%
&sv n_seg := %DSC$SEGMENTS%
&sv n_fuz := %DSC$FUZZY%

&describe f2c_del%sr%
&sv o_arc := %DSC$ARCS%
&sv o_seg := %DSC$SEGMENTS%
&sv o_fuz := %DSC$FUZZY%

&describe nhd_cn%sr%
&sv p_arc := %DSC$ARCS%
&sv p_seg := %DSC$SEGMENTS%
&sv p_fuz := %DSC$FUZZY%

&describe nhd_cln%sr%
&sv q_arc := %DSC$ARCS%
&sv q_seg := %DSC$SEGMENTS%
&sv q_fuz := %DSC$FUZZY%

&describe nhd_buf%sr%
&sv r_arc := %DSC$ARCS%
&sv r_seg := %DSC$SEGMENTS%
```

```
&sv r_fuz := %DSC$FUZZY%

&describe f2c_idn%sr%
&sv s_arc := %DSC$ARCS%
&sv s_seg := %DSC$SEGMENTS%
&sv s_fuz := %DSC$FUZZY%

&describe f2c_trm%sr%
&sv t_arc := %DSC$ARCS%
&sv t_seg := %DSC$SEGMENTS%
&sv t_fuz := %DSC$FUZZY%

&describe nhd_45b%sr%
&sv u_arc := %DSC$ARCS%
&sv u_seg := %DSC$SEGMENTS%
&sv u_fuz := %DSC$FUZZY%

&describe f2c_45n%sr%
&sv v_arc := %DSC$ARCS%
&sv v_seg := %DSC$SEGMENTS%
&sv v_fuz := %DSC$FUZZY%

&describe fc2n%sr%
&sv w_arc := %DSC$ARCS%
&sv w_seg := %DSC$SEGMENTS%
&sv w_fuz := %DSC$FUZZY%

&describe fc2n_uns%sr%
&sv x_arc := %DSC$ARCS%
&sv x_seg := %DSC$SEGMENTS%
&sv x_fuz := %DSC$FUZZY%

&describe fc2n_cln%sr%
&sv y_arc := %DSC$ARCS%
&sv y_seg := %DSC$SEGMENTS%
&sv y_fuz := %DSC$FUZZY%

&describe fc2n_dng%sr%
&sv z_arc := %DSC$ARCS%
&sv z_seg := %DSC$SEGMENTS%
&sv z_fuz := %DSC$FUZZY%

&ty
&ty
********************************************************************************
*
```

```
&ty COV                    [format '%1,-15% %2,-12% %3,-10% %4,-24%' ARCS SEGS
FUZ Start_TIME]
&ty ____               [format '%1,-15% %2,-12% %3,-10% %4,-24%' ______ _________
__________ _________]
&ty NHD%sr%_____ [format '%1,-10% %2,-12% %3,-10% %4,-24%' %a_arc% %a_seg%
%a_fuz% %t1%]
&ty FAC%sr%_____ [format '%1,-10% %2,-12% %3,-10% %4,-24%' %b_arc% %b_seg%
%b_fuz% %t2%]
&ty cen%sr%_____    [format '%1,-10% %2,-12% %3,-10% %4,-24%' %c_arc% %c_seg%
%c_fuz% %t3%]
&ty fac_mid%sr%            [format '%1,-10% %2,-12% %3,-10% %4,-24%' %f_arc%
%f_seg% %f_fuz% %t6%]
&ty f2c%sr%_____    [format '%1,-10% %2,-12% %3,-10% %4,-24%' %g_arc% %g_seg%
%g_fuz% %t7%]
&ty f2c_gen%sr%            [format '%1,-10% %2,-12% %3,-10% %4,-24%' %h_arc%
%h_seg% %h_fuz% %t8%]
&ty f2c_c%sr%__            [format '%1,-10% %2,-12% %3,-10% %4,-24%' %i_arc%
%i_seg% %i_fuz% %t9%]
&ty f2c_cn%sr%_            [format '%1,-10% %2,-12% %3,-10% %4,-24%' %j_arc%
%j_seg% %j_fuz% %t10%]
&ty f2c_cln%sr%            [format '%1,-10% %2,-12% %3,-10% %4,-24%' %k_arc%
%k_seg% %k_fuz% %t11%]
&ty f2c_uns%sr%            [format '%1,-10% %2,-12% %3,-10% %4,-24%' %l_arc%
%l_seg% %l_fuz% %t12%]
&ty f2c_ln%sr%_            [format '%1,-10% %2,-12% %3,-10% %4,-24%' %m_arc%
%m_seg% %m_fuz% %t13%]
&ty f2c_dng%sr%            [format '%1,-10% %2,-12% %3,-10% %4,-24%' %n_arc%
%n_seg% %n_fuz% %t14%]
&ty f2c_del%sr%            [format '%1,-10% %2,-12% %3,-10% %4,-24%' %o_arc%
%o_seg% %o_fuz% %t15%]
&ty nhd_cn%sr%_            [format '%1,-10% %2,-12% %3,-10% %4,-24%' %p_arc%
%p_seg% %p_fuz% %t16%]
&ty nhd_cln%sr%            [format '%1,-10% %2,-12% %3,-10% %4,-24%' %q_arc%
%q_seg% %q_fuz% %t17%]
&ty nhd_buf%sr%            [format '%1,-10% %2,-12% %3,-10% %4,-24%' %r_arc%
%r_seg% %r_fuz% %t18%]
&ty f2c_idn%sr%            [format '%1,-10% %2,-12% %3,-10% %4,-24%' %s_arc%
%s_seg% %s_fuz% %t19%]
&ty f2c_trm%sr%            [format '%1,-10% %2,-12% %3,-10% %4,-24%' %t_arc%
%t_seg% %t_fuz% %t20%]
&ty nhd_45b%sr%            [format '%1,-10% %2,-12% %3,-10% %4,-24%' %u_arc%
%u_seg% %u_fuz% %t21%]
&ty f2c_45n%sr%            [format '%1,-10% %2,-12% %3,-10% %4,-24%' %v_arc%
%v_seg% %v_fuz% %t22%]
&ty fc2n%sr%____    [format '%1,-10% %2,-12% %3,-10% %4,-24%' %w_arc% %w_seg%
%w_fuz% %t23%]
```

```
&ty fc2n_uns%sr%     [format '%1,-10% %2,-12% %3,-10% %4,-24%' %x_arc% %x_seg%
%x_fuz% %t24%]
&ty fc2n_cln%sr%     [format '%1,-10% %2,-12% %3,-10% %4,-24%' %y_arc% %y_seg%
%y_fuz% %t25%]
&ty fc2n_dng%sr%     [format '%1,-10% %2,-12% %3,-10% %4,-24%' %z_arc% %z_seg%
%z_fuz% %t26%]
&ty end                          [format '%1,-15% %2,-12% %3,-10% %4,-24%' ______
_________ __________ %t27%]
&ty
&ty
*****************************************************************************
*

&dv *

&ty Done

&ty
&ty
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
+++++++++++++++++

&watch &off

&stop
&return
```

APPENDIX C. AML finding the middle point for each arc (Joy Hu, 1998). The script was downloaded from ESRI support web-site http://arcscripts.esri.com/details.asp?dbid=10131.

```
/* FIND_MIDDLE_PNT.AML
/* find middle point for each arc in an arc coverage and write middle
/* points out to a point coverage. the point takes the arc attributes
/* 12/2/98

&severity &error &routine BAILOUT
&args incov outcov

&if [NULL %incov%] &then &do
  &ty;&ty Usage: FIND_MIDDLE_PNT.AML <in_cover> <out_cover>
  &return
&end
&if [NULL %outcov%] &then &do
  &ty;&ty Usage: FIND_MIDDLE_PNT.AML <in_cover> <out_cover>
  &return
&end

/* check that the coverage exists

&if ^ [EXISTS %incov% -COVER] &then &do
  &ty;&ty Coverage %incov% does not exist in this workspace.;&ty
  &return
&end
&if [EXISTS %outcov% -COVER] &then &do
  &ty;&ty Coverage %outcov% already exists.;&ty
  &return
&end

/* check that the coverage has arcs

&describe %incov%
&if %DSC$ARCS% = 0 &then &do
  &ty;&ty ERROR: coverage %incov% does not contain arcs.;&ty
  &return
&end

&s oldincov
/* if double precision, convert to single
&if [translate %DSC$PRECISION%] = DOUBLE &then &do
   &if ^ [exists xx%incov%s -cover] &then
      copy %incov% xx%incov%s single
   &s oldincov = %incov%
   &s incov := xx%incov%s
```

```
&end

&s genfile := xxgen.txt
&s ungenfile := xx%incov%.ungen
/* ungenerate the arc coverage
&if [exists %ungenfile%] &then
  &return File %ungenfile% already exists.
ungenerate line %incov% %ungenfile%

/* open ungenerated file for input

&s amlunit1 := [open %ungenfile% openstat1 -READ]
&if %openstat1% NE 0 &then
  &return Error opening file, error code: %openstat1%

/* open a file for output point x,y
&if [exists %genfile% -file] &then
  &return File %genfile% already exists.

&s amlunit2 := [open %genfile% openstat2 -WRITE]
&if %openstat2% NE 0 &then
  &return Error opening file, error code: %openstat2%

/* read file and find middle point for each arc

&s record := [read %amlunit1% readstat]
&do &while %readstat% = 0
  &if [translate %record%] NE END &then &do
     &s lineid = %record%
     /* read next record
     &s record := [read %amlunit1% readstat]
     &s number := 0 /* number of segments in each arc
     &s middlenumber := 1 /* keep track of which segment the middle point is on
     &s x%number% := [extract 1 [unquote %record%]]
     &s y%number% := [extract 2 [unquote %record%]]
     &s length := 0  /* length on the segment, from middle point to the beginning vertex
     &s record := [read %amlunit1% readstat]
     &do &while [translate %record%] NE END
        &s number := %number% + 1
        &s x%number% := [extract 1 [unquote %record%]]
        &s y%number% := [extract 2 [unquote %record%]]
        &s deltax := [calc [value x%number%] - [value x[calc %number% - 1]]]
        &s deltay := [calc [value y%number%] - [value y[calc %number% - 1]]]

        /* length of current segment
        &s length%number% := [sqrt [calc %deltax% * %deltax% + %deltay% * %deltay%]]
```

```
      /* check where the middle point is located
      &s length := [calc %length% + [calc 0.5 * [value length%number%]]]
      &do &while %length% > [value length%middlenumber%]
        &s length := [calc %length% - [value length%middlenumber%]]
        &s middlenumber := %middlenumber% + 1
      &end

      &s record := [read %amlunit1% readstat]

    &end /* end &do &while

    /* calculate the coordinates of the middle point on current arc
    &s deltax = [calc [value x%middlenumber%] - [value x[calc %middlenumber% - 1]]]
    &s deltay = [calc [value y%middlenumber%] - [value y[calc %middlenumber% - 1]]]
    &s ratio = [calc %length% / [calc [value length%middlenumber%] + 0.1]]
    &s middlex := [calc %ratio% * %deltax% + [value x[calc %middlenumber% - 1]]]
    &s middley := [calc %ratio% * %deltay% + [value y[calc %middlenumber% - 1]]]
    &s writestat := [write %amlunit2% %lineid%,%middlex%,%middley%]

  &end /* end &if

  &s record := [read %amlunit1% readstat]

&end /* end &do &while

&s writestat := [write %amlunit2% end]

&s closestat1 := [close %amlunit1%]
&s closestat2 := [close %amlunit2%]

generate %outcov%
input %genfile%
points
q
build %outcov% point

/* define projection
projectdefine cover %outcov%
projection albers
datum hpgn
units meters
spheroid grs1980
parameters
24 0 0.000000
31 30 0.000000
```

```
-84 0 0.000000
24 0 0.000000
400000.000000
0.000000

/* get attributes from the arc coverage
&s itemlist := [unquote [after [quote [listitem %incov%.aat -info]] [upcase %incov%#]]]
&if [exists xxjoin.tab -info] &then
   killinfo xxjoin.tab
pullitems %incov%.aat xxjoin.tab
&do item &list %itemlist%
  %item%
&end
END
&data ARC INFO
  ARC
  SELECT XXJOIN.TAB
  ALTER [upcase %incov%]-ID,[upcase %outcov%]-ID,,,,,,,
  Q STOP
&end
joinitem %outcov%.pat xxjoin.tab %outcov%.pat %outcov%-id
killinfo xxjoin.tab

&ty Done.

/* clean up
&call EXIT

&return

/*--------------------------
&ROUTINE EXIT

&s cl := [close -all]
&if [exists %genfile% -file] &then
  &s d := [delete %genfile%]
&if [exists %ungenfile% -file] &then
  &s d := [delete %ungenfile%]
&if [exists xxjoin.tab -info] &then
  killinfo xxjoin.tab
&if ^ [NULL %oldincov%] &then
  kill xx%oldincov%s all
&return

/*----------------------------
&ROUTINE BAILOUT
```

```
&severity &error &ignore

&call EXIT

&return &error Bailing out of AML FIND_MIDDLE_PNT.AML
```

APPENDIX D. AML finding connected segments in a network, assigning them with a unique value and count of segments.

```
&severity &error &ignore
&severity &warning &ignore

&args file

&if [NULL %file%] &then &do
  &ty;&ty Usage: &run CONNECT.AML <FILE>
  &return
&end

&watch %file%_con.wat &append &commands

&ty
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
++++++++++++++++++++++++++
&ty


&ty ######
&ty [date -full]
&ty ######



precision double double
lc


additem %file%.aat %file%.aat group 8 10 F 0
additem %file%.aat %file%.aat group_seg 8 10 F 0

ae
ec %file%
ef arc

&sv n = 1
&sv num_con_bef = 0
&sv num_con_aft = 1
&sv nomore = 1

sel all

&do &until %nomore% = 0
```

```
 &sv rec_1 = [show select 1]
 unselect all
 sel $RECNO = %rec_1% and group = 0
 asel connect

   &do &until %num_con_bef% = %num_con_aft%

     &sv num_con_bef = [show number select]
     asel connect
     &sv num_con_aft = [show number select]
     &ty MINILOOP

   &end


  calc group = %n%
  calc group_seg = %num_con_aft%

  &ty BIGLOOP # %n% done!
  &ty BIGLOOP # %n% done!
  &ty BIGLOOP # %n% done!

  &sv n = %n% + 1

  save

  unselect all

  sel group = 0

  &sv nomore = [show number select]

&end

save
unselect all
q

&ty Done

&watch &off

&stop
&return
```

APPENDIX E. List of 256 fish species by 30 families included in the Ecological Drainage Unite analysis of the Southeastern United States.

1). Acipenseridae
1. Acipenser brevirostrum
2. A. fulvescens
3. A. oxyrhynchus
4. Scaphirhynchus platorynchus
2). Amblyopsidae
5. Chologaster cornuta
6. Typhlichthys subterraneus
3). Amiidae
7. Amia calva
4). Anguillidae
8. Anguilla rostrata
5). Atherinidae
9. Labidesthes sicculus
10. Menidia beryllina
6). Belonidae
11. Strongylura marina
7). Catostomidae
12. Carpiodes velifer
13. Catostomus commersoni
14. Cycleptus elongatus
15. Erimyzon oblongus
16. E. sucetta
17. E. tenuis
18. Hypentelium etowanum
19. H. nigricans
20. Ictiobus bubalus
21. Minytrema melanops
22. Moxostoma anisurum
23. M. carinatum
24. M. duquesnei
25. M. erythrurum
26. M. Iachneri
27. M. poecilurum
28. M. robustum
29. M. rupiscartes
30. Moxostoma sp.
8). Centrarchidae
31. Acantharchus pomotis
32. Ambloplites ariommus
33. Centrarchus macropterus
34. Elassoma evergladei
35. E. okefenokee
36. E. zonatum
37. Enneacanthus chaetodon
38. E. gloriosus
39. E. obesus
40. Lepomis auritus
41. L. cyanellus
42. L. gulosus
43. L. humilis
44. L. macrochirus
45. L. marginatus
46. L. megalotis
47. L. microlophus
48. L. punctatus
49. L. symmetricus
50. Micropterus coosae
51. M. notius
52. M. punctulatus
53. M. salmoides
54. Micropterus sp.
55. Pomoxis annularis
56. P. nigromaculatus
9). Clupeidae
57. Alosa aestivalis
58. A. alabamae
59. A. chrysochloris
60. A. mediocris
61. A. sapidissima
62. Dorosoma cepedianum
63. D. petenense
10). Cottidae
64. Cottus bairdi
65. C. carolinae
66. C. pygmaeus
11). Cyprinidae
67. Campostoma anomalum
68. C. pauciradii
69. C. oligolepis
70. Clinostomus funduloides
71. Ericymba buccata
72. Hemitremia flammea
73. Hybognathus hayi
74. H. nuchalis
75. H. regius
76. Hybopsis aestivalis
77. H. lineapunctata
78. H. rubrifrons
79. H. storeriana
80. H. winchelli
81. Nocomis leptocephalus
82. N. micropogon
83. Notemigonus crysoleucas
84. Notropis altipinnis
85. N. ardens
86. N. asperifrons
87. N. atherinoides
88. N. atrapiculus
89. N. baileyi
90. N. bellus
91. N. caeruleus
92. N. callisema
93. N. callistius
94. N. callitaenia
95. N. camurus
96. N. candidus
97. N. chalybaeus
98. N. chrosomus
99. N. chrysocephalus
100. N. coccogenis
101. N. cummingsae
102. N. edwardraneyi
103. N. emiliae
104. N. euryzonus
105. N. fumeus
106. N. galacturus
107. N. gibbsi
108. N. harperi
109. N. hudsonius
110. N. hypselopterus
111. N. hypsilepis
112. N. leedsi
113. N. leuciodus
114. N. lirus
115. N. Iongirostris
116. N. lutipinnis
117. N. maculatus
118. N. niveus
119. N. petersoni
120. N. roseipinnis
121. N. rubricroceus
122. N. scepticus
123. N. signipinnis
124. N. spectrunculus

APPENDIX E. Continued.

125. Notropis stilbius
126. N. texanus
127. N. trichroistius
128. N. uranoscopus
129. N. venustus
130. N. volucellus
131. N. welaka
132. N. whipplei
133. N. xaenocephalus
134. N. xaenurus
135. N. zonistius
136. Notropis sp. I
137. Notropis sp. 2
138. Notropis sp. 3
139. Phenacobius catostomus
140. Pimephales notatus
141. P. vigilax
142. Rhinichthys atratulus
143. R. cataractae
144. Semotilus atromoculatus
12). Cyprinodontidae
145. Cyprinodon variegatus
13). Esocidae
146. Esox americanus
147. E. niger
14). Fundulidae
148. Fundulus catenatus
149. F. cingulatus
150. F. dispar
151. F. escambiae
152. F. euryzonus
153. F. notatus
154. F. notti
155. F. olivaceus
156. F.seminolis
157. F. stellifer
158. Jordanella fioridae
159. Leptolucania ommata
160. Lucania goodei
161. L. parva
15). Gobiidae
162. Awaous tajasica
16). Hiodontidae
163. Hiodon tergisus
17). Ictaluridae
164. Ictalurus brunneus
165. I. furcatus
166. I. melas
167. I. natalis
168. I. nebulosus
169. I. platycephalus
170. I. punctatus
171. I. serracanthus
172. Noturus funebris
173. N. gyrinus
174. N. insignis
175. N. leptacanthus
176. N. miurus
177. N. munitus
178. N. nocturnus
179. Pylodictis olivaris
18). Lepisosteidae
180. Atractosteus spatula
181. Lepisosteus oculatus
182. L. osseus
183. L. platyrhincus
19). Mugilidae
184. Agonostomus monticola
185. Mugil cephalus
20). Percichthyidae
186. Morone mississippiensis
187. M. saxalilis
21). Percidae
188. Ammocrypta asprella
189. A. beani
190. A. bifascia
191. A. meridiana
192. A. vivax
193. Etheostoma chlorosomum
194. E. coosae
195. E. davisoni
196. E. ditrema
197. E. edwini
198. E. fricksium
199. E. fusiforme
200. E. gracile
201. E. histrio
202. E. hopkinsi
203. E. inscriptum
204. E. jordani
205. E. nigrum
206. E. nuchale
207. E. okaloosae
208. E. olmstedi
209. E. parvipinne
210. E. proeliare
211. E. rupestre
212. E. serriferum
213. E. stigmaeum
214. E. swaini
215. E. trisella
216. E. whipplei
217. E. zonale
218. E. zoniferum
219. Etheostoma sp. 1
220. Etheostoma sp. 2
221. Etlieostoma sp. 3
222. Etheostoma sp. 4
223. Etheostoma sp. 5
224. Perca flavescens
225. Percina antesella
226. P. aurolineata
227. P. lenticula
228. P. maculata
229. P. nigrofasciata
230. P. ouachitae
231. P. palmaris
232. P. sciera
233. P. shumardi
234. Percina sp. 1
235. Percina sp. 2
236. Percina sp. 3
237. Peicina sp. 4
238. Percina sp. 5
239. Percina sp. 6
240. Percina sp. 7
241. Stizostedion vitreum
22). Petromyzotidae
242. lchthyomyzon castuneus
243. I. gagei
244. Lampetra aepyptera
245. Petromyzon marinus
23). Poeciliidae
246. Gambusia affinis
247. G. rhizophorae
248. Heterandria formosa
249. Poecilia Iatipinna
24). Polyodontidae
250. Polyodon spathula
25). Rivulidae
251. Rivulus marmoratus
26). Salmonidae
252. Salvelinus fontinalis
27). Sciaenidae
253. Aplodinotus grunniens
28). Soleidae
254. Trinectes maculatus
29). Syngnathidae
255. Syngnathus scovelli
30). Umbridae
256. Umbra pygmaea

APPENDIX F. Description of the summary SSURGO table *muaggatt*, or ‗Mapunit Aggregated Attribute'

NRCS SSURGO Metadata Version: 2.2.3, pp. 77-81 (soildatamart.nrcs.usda.gov/documents/SSURGOMetadataTables.pdf).

SSURGO Metadata - Table Column Descriptions

Table Physical Name: **muaggatt** Table Label: Mapunit Aggregated Attribute

Column Physical Name: **musym** Column Label: Mapunit Symbol
The symbol used to uniquely identify the soil mapunit in the soil survey.

Column Physical Name: **muname** Column Label: Mapunit Name
Correlated name of the mapunit (recommended name or field name for surveys in progress).

Column Physical Name: **mustatus** Column Label: Status – dropped in MUKEY_ABR
Identifies the current status of the map unit.
As of SSURGO version 2.1, values for this attribute are no longer provided. This attribute will be dropped from the next major SSURGO version.

Column Physical Name: **slopegraddcp** Column Label: Slope Gradient - Dominant Component
The difference is elevation between two points, expressed as a percentage of the distance between those points. This column displays the slope gradient of the dominant component of the map unit based on composition percentage.

Column Physical Name: **slopegradwta** Column Label: Slope Gradient - Weighted Average
The difference is elevation between two points, expressed as a percentage of the distance between those points. This column displays the weighted average slope gradient of all components in the map unit.

Column Physical Name: **brockdepmin** Column Label: Bedrock Depth - Minimum
The distance from the soil surface to the top of a bedrock layer, expressed as a shallowest depth of components whose composition in the map unit is equal to or exceeds 15%.

Column Physical Name: **wtdepannmin** Column Label: Water Table Depth - Annual - Minimum
The shallowest depth to a wet soil layer (water table) at any time during the year expressed as centimeters from the soil surface, for components whose composition in the map unit is equal to or exceeds 15%.

Column Physical Name: **wtdepaprjunmin** Column Label: Water Table Depth - April - June - Minimum
The shallowest depth to a wet soil layer (water table) during the months of April through June expressed in centimeters from the soil surface for components whose composition in the map unit is equal to or exceeds 15%.

Column Physical Name: **flodfreqdcd** Column Label: Flooding Frequency – Dominant Condition
The annual probability of a flood event expressed as a class. This column displays the dominant flood frequency class for the map unit, based on composition percentage of map unit components whose composition in the map unit is equal to or exceeds 15%.

Column Physical Name: **flodfreqmax** Column Label: Flooding Frequency - Maximum
The annual probability of a flood event expressed as a class. This column displays the highest probability class assigned to an individual component of the map unit whose composition in the map unit is equal to or exceeds 15%.

Column Physical Name: **pondfreqprs** Column Label: Ponding Frequency - Presence
The percentage of the map unit that is subject to water being ponded on the soil surface, expressed as one of four classes; 0-14%, 15-49%, 50-74% or 75-100%.

Column Physical Name: **aws025wta** Column Label: Available Water Storage 0-25 cm - Weighted Average
Available water storage (AWS). The volume of water that the soil, to a depth of 25 centimeters, can store that is available to plants. It is reported as the weighted average of all components in the map unit, and is expressed as centimeters of water.
AWS is calculated from AWC (available water capacity) which is commonly estimated as the difference between the water contents at 1/10 or 1/3 bar (field capacity) and 15 bars (permanent wilting point) tension, and adjusted for salinity and fragments.

Column Physical Name: **aws050wta** Column Label: Available Water Storage 0-50 cm - Weighted Average
Available water storage (AWS). The volume of water that the soil, to a depth of 50 centimeters, can store that is available to plants. It is reported as the weighted average of all components in the map unit, and is expressed as centimeters of water.
AWS is calculated from AWC (available water capacity) which is commonly estimated as the difference between the water contents at 1/10 or 1/3 bar (field capacity) and 15 bars (permanent wilting point) tension, and adjusted for salinity and fragments.

APPENDIX F. Continued

Column Physical Name: **aws0100wta** Column Label: Available Water Storage 0-100 cm - Weighted Average *Available water storage (AWS). The volume of water that the soil, to a depth of 100 centimeters, can store that is available to plants. It is reported as the weighted average of all components in the map unit, and is expressed as centimeters of water.*
AWS is calculated from AWC (available water capacity) which is commonly estimated as the difference between the water contents at 1/10 or 1/3 bar (field capacity) and 15 bars (permanent wilting point) tension, and adjusted for salinity and fragments.

Column Physical Name: **aws0150wta** Column Label: Available Water Storage 0-150 cm - Weighted Average
Available water storage (AWS). The volume of water that the soil, to a depth of 150 centimeters, can store that is available to plants. It is reported as the weighted average of all components in the map unit, and is expressed as centimeters of water.
AWS is calculated from AWC (available water capacity) which is commonly estimated as the difference between the water contents at 1/10 or 1/3 bar (field capacity) and 15 bars (permanent wilting point) tension, and adjusted for salinity and fragments.

Column Physical Name: **drclassdcd** Column Label: Drainage Class - Dominant Condition
The natural drainage condition of the soil refers to the frequency and duration of wet periods. This column displays the dominant drainage class for the map unit, based on composition percentage of each map unit component.

Column Physical Name: **drclasswettest** Column Label: Drainage Class - Wettest
The natural drainage condition of the soil refers to the frequency and duration of wet periods. This column displays the wettest drainage class assigned to an individual component of the map unit whose composition in the map unit is equal to or exceeds 15%.

Column Physical Name: **hydgrpdcd** Column Label: Hydrologic Group – Dominant Conditions
Hydrologic Group is a grouping of soils that have similar runoff potential under similar storm and cover conditions. This column displays the dominant hydrologic group for the map unit, based on composition percentage of each map unit component.

Definition. The complete definition and official criteria for hydrologic soil group is available online at http://directives.sc.egov.usda.gov/media/pdf/H_210_630_7.pdf (U.S. Department of Agriculture, Natural Resources Conservation Service. 2007. National Engineering Handbook, Title 210-VI, Part 630, Chapter 7, Hydrologic Soil Groups. Washington, DC.).

Group A—Soils in this group have low runoff potential when thoroughly wet.
Group B—Soils in this group have moderately low runoff potential when thoroughly wet.
Group C—Soils in this group have moderately high runoff potential when thoroughly wet.
Group D—Soils in this group have high runoff potential when thoroughly wet.
Dual hydrologic soil groups—Certain wet soils are placed in group D based solely on the presence of a water table within 60 centimeters [24 inches] of the surface even though the saturated hydraulic conductivity may be favorable for water transmission. If these soils can be adequately drained, then they are assigned to dual hydrologic soil groups (A/D, B/D, and C/D) based on their saturated hydraulic conductivity and the water table depth when drained. The first letter applies to the drained condition and the second to the undrained condition. For the purpose of hydrologic soil group, adequately drained means that the seasonal high water table is kept at least 60 centimeters [24 inches] below the surface in a soil where it would be higher in a natural state.

Column Physical Name: **iccdcd** Column Label: Irrigated Capability Class – Dominant Condition - dropped in MUKEY_ABR
The broadest category in the land capability classification system for soils. This column displays the dominant capability class, under irrigated conditions, for the map unit based on composition percentage of all components in the map unit.

Column Physical Name: **iccdcdpct** Column Label: Irrigated Capability Class – Dominant Condition Aggregate Percent
The percent composition of the map unit that has the capability class displayed in the Irrigated Capability Class.

Column Physical Name: **niccdcd** Column Label: Non-Irrigated Capability Class - Dominant Condition
The broadest category in the land capability classification system for soils. This column displays the dominant capability class, under nonirrigated conditions, for the map unit based on composition percentage of all components in the map unit.

Column Physical Name: **niccdcdpct** Column Label: Non-Irrigated Capability Class - Dominant Condition Aggregate Percent
The percent composition of the map unit that has the capability class displayed in the Non-Irrigated Capability Class - Dominant Condition column.

Column Physical Name: **engdwobdcd** Column Label: ENG - Dwellings W/O Basements - Dominant Condition - dropped in MUKEY_ABR
The rating of the map unit as a site for dwellings without basements, expressed as the dominant rating class for the map unit, based on composition percentage of each map unit component.

Column Physical Name: **engdwbdcd** Column Label: ENG - Dwellings with Basements - Dominant Condition Condition - dropped in MUKEY_ABR

APPENDIX F. Continued.

The rating of the map unit as a site for dwellings with basements, expressed as the dominant rating class for the map unit, based on composition percentage of each map unit component.

Column Physical Name: **engdwbll** Column Label: ENG - Dwellings with Basements - Least Limiting Condition - dropped in MUKEY_ABR

The rating of the map unit as a site for dwellings with basements, expressed as the least limiting rating class for the map unit, based on the evaluation of each component in the map unit.

Column Physical Name: **engdwbml** Column Label: ENG - Dwellings with Basements - Most Limiting Condition - dropped in MUKEY_ABR

The rating of the map unit as a site for dwellings with basements, expressed as the most limiting rating class for the map unit, based on the evaluation of each component in the map unit.

Column Physical Name: **engstafdcd** Column Label: ENG - Septic Tank Absorption Fields - Dominant Condition Condition - dropped in MUKEY_ABR

The rating of the map unit as a site for septic tank absorption fields, expressed as the dominant rating class for the map unit, based on composition percentage of each map unit component.

Column Physical Name: **engstafll** Column Label: ENG - Septic Tank Absorption Fields - Least Limiting Condition - dropped in MUKEY_ABR

The rating of the map unit as a site for septic tank absorption fields, expressed as the least limiting rating class for the map unit, based on the evaluation of each component in the map unit.

Column Physical Name: **engstafml** Column Label: ENG - Septic Tank Absorption Fields - Most Limiting Condition - dropped in MUKEY_ABR

The rating of the map unit as a site for septic tank absorption fields, expressed as the most limiting rating class for the map unit, based on the evaluation of each component in the map unit.

Column Physical Name: **engsldcd** Column Label: ENG - Sewage Lagoons – Dominant Condition Condition - dropped in MUKEY_ABR

The rating of the map unit as a site for sewage lagoons, expressed as the dominant rating class for the map unit, based on composition percentage of each map unit component.

Column Physical Name: **engsldcp** Column Label: ENG - Sewage Lagoons – Dominant Component Condition - dropped in MUKEY_ABR

The rating of the map unit as a site for sewage lagoons, expressed as the rating class for the dominant component in the map unit, based on composition percentage of each map unit component.

Column Physical Name: **englrsdcd** Column Label: ENG - Local Roads and Streets - Dominant Condition Condition - dropped in MUKEY_ABR

The rating of the map unit as a site for local roads and streets, expressed as the dominant rating class for the map unit, based on composition percentage of each map unit component.

Column Physical Name: **engcmssdcd** Column Label: ENG - Construction Materials; Sand Source - Dominant Condition Condition - dropped in MUKEY_ABR

The rating of the map unit as a source of sand, expressed as the dominant class for the map unit, based on composition percentage of each map unit component.

Column Physical Name: **engcmssmp** Column Label: ENG - Construction Materials; Sand Source - Most Probable Condition -
The rating of the map unit as a source of sand, expressed as the most probable class for the map unit, based on the evaluation of each component whose composition in the map unit is equal to or exceeds 15%.

Column Physical Name: **urbrecptdcd** Column Label: URB/REC - Paths and Trails - Dominant Condition Condition - dropped in MUKEY_ABR

The rating of the map unit as a site for paths and trails, expressed as the dominant rating class for the map unit, based on composition percentage of each map unit component.

APPENDIX F. Continued.

Column Physical Name: **urbrecptwta** Column Label: URB/REC - Paths and Trails - Weighted Average Condition - dropped in MUKEY_ABR

The relative rating of the map unit for use as paths and trails, expressed as a weighted average of numerical ratings for individual soil components in the map unit. The ratings are on a scale of 0.0 to 1.0, with the higher values indicating more limitations.

Column Physical Name: **forpehrtdcp** Column Label: FOR - Potential Erosion Hazard (Road/Trail) - Dominant Component
The relative potential erosion hazard for the map unit when used as a site for forest roads and trails, expressed as the rating class for the dominant component in the map unit, based on composition percentage of each map unit component.

Column Physical Name: **hydclprs** Column Label: Hydric Classification - Presence
An indication of the proportion of the map unit, expressed as a class, that is "hydric", based on the hydric classification of individual map unit components.

Column Physical Name: **awmmfpwwta** Column Label: AWM - Manure and Food Processing Waste - Weighted Average Condition - dropped in MUKEY_ABR

The relative rating of the map unit for use as a disposal site of Manure and Food Processing Wastes, expressed as a weighted average of numerical ratings for individual components in the map unit. The ratings are on a scale of 0.0 to 1.0, with the higher values indicating increasing limitations.

Column Physical Name: **mukey** Column Label: Mapunit Key
The unique identifier of a record in the Mapunit table. It also serves as the non-connotative string of characters used to uniquely identify a record in the Mapunit Aggregated Attribute table as there is a one-to-one relationship between records in these two tables. Use this column to join the Mapunit Aggregated Attribute table to the Mapunit table.

Seq	Column Physical Name	Column Label Logical Data Type	Not Null?	Size	Prec	Min	Max	Units of Measure	Domain
1	musym	Mapunit Symbol String	Yes	6					
2	muname	Mapunit Name String	No	175					
3	mustatus	Status Choice	No	254					mapunit_status
4	slopegraddcp	Slope Gradient - Dominant Component Float	No		1			percent	
5	slopegradwta	Slope Gradient - Weighted Average Float	No		1			percent	
6	brockdepmin	Bedrock Depth -Minimum Integer	No					centimeters	
7	wtdepannmin	Water Table Depth -Annual - Minimum Integer	No					centimeters	
8	wtdepaprjunmin	Water Table Depth -April - June - Minimum Integer	No					centimeters	
9	flodfreqdcd	Flooding Frequency - Dominant Choice Condition	No	254					flooding_frequency_class
10	flodfreqmax	Flooding Frequency - Maximum Choice	No	254					flooding_frequency_class
11	pondfreqprs	Ponding Frequency - Presence Choice	No	254					ponding_frequency_map_legend
12	aws025wta	Available Water Storage 0-25 cm - Weighted Average Float	No		2			centimeters	
13	aws050wta	Available Water Storage 0-50 cm - Weighted Average Float	No		2			centimeters	
14	aws0100wta	Available Water Storage 0-100 cm - Weighted Average Float	No		2			centimeters	
15	aws0150wta	Available Water Storage 0-150 cm - Weighted Average Float	No		2			centimeters	
16	drclassdcd	Drainage Class - Dominant Condition Choice	No	254					drainage_class
17	drclasswettest	Drainage Class -Wettest Choice	No	254					drainage_class
18	hydgrpdcd	Hydrologic Group - Dominant Choice Conditions	No	254					hydrologic_group
19	iccdcd	Irrigated Capability Class - Dominant Choice Condition	No	254					capability_class
20	iccdcdpct	Irrigated Capability Class - Dominant Integer Condition Aggregate Percent	No			0	100		
21	niccdcd	Non-Irrigated Capability Class - Choice Dominant Condition	No	254					capability_class
22	niccdcdpct	Non-Irrigated Capability Class - Integer Dominant Condition Aggregate Percent	No			0	100		

APPENDIX F. Continued.

Seq	Column Physical Name	Column Label	Logical Data Type	Not Null?	Size	Prec	Min	Max	Units of Measure	Domain
23	engdwobdcd	ENG - Dwellings W/O Basements - Dominant Condition	String	No	254					
24	engdwbdcd	ENG - Dwellings with Basements - Dominant Condition	String	No	254					
25	engdwbll	ENG - Dwellings with Basements - Least Limiting	String	No	254					
26	engdwbml	ENG - Dwellings with Basements - Most Limiting	String	No	254					
27	engstafdcd	ENG - Septic Tank Absorption Fields - Dominant Condition	String	No	254					
28	engstafll	ENG - Septic Tank Absorption Fields - Least Limiting	String	No	254					
29	engstafml	ENG - Septic Tank Absorption Fields - Most Limiting	String	No	254					
30	engsldcd	ENG - Sewage Lagoons - Dominant Condition	String	No	254					
31	engsldcp	ENG - Sewage Lagoons - Dominant Component	String	No	254					
32	englrsdcd	ENG - Local Roads and Streets - Dominant Condition	String	No	254					
33	engcmssdcd	ENG - Construction Materials; Sand Source -Dominant Condition	String	No	254					
34	engcmssmp	ENG - Construction Materials; Sand Source -Most Probable	String	No	254					
35	urbrecptdcd	URB/REC - Paths and Trails - Dominant Condition	String	No	254					
36	urbrecptwta	URB/REC - Paths and Trails - Weighted Average	Float	No		2				
37	forpehrtdcp	FOR - Potential Erosion Hazard (Road/Trail) - Dominant Component	String	No	254					
38	hydclprs	Hydric Classification - Presence	Choice	No	254					hydric_classification_map_legend
39	awmmfpwwta	AWM - Manure and Food Processing Waste - Weighted Average	Float	No		2				
40	mukey	Mapunit Key	String	Yes	30					

APPENDIX G. List of fish species of 18 Ecological Drainage Unites (EDUs) of the Southeastern United States.

EDU 1: Big Bend (62 species)

Acantharchus pomotis
Acipenser oxyrhynchus
Alosa alabamae
Amia calva
Anguilla rostrata
Centrarchus macropterus
Cyprinodon variegatus
Dorosoma cepedianum
D. petenense
Elassoma evergladei
E. okefenokee
E. zonatum
Enneacanthus gloriosus
E. obesus
Erimyzon sucetta
Esox americanus
E. niger
Etheostoma fusiforme
Fundulus cingulatus
F. lineolatus
F. seminolis
Gambusia affinis
Heterandria formosa
Ictalurus natalis
I. nebulosus
I. punctatus
I. serracanthus
Jordanella fioridae
Labidesthes sicculus
Lepisosteus osseus
L. platyrhincus
Lepomis auritus
L. gulosus
L. macrochirus
L. marginatus
L. microlophus
L. punctatus
Leptolucania ommata
L. parva
Menidia beryllina
Micropterus salmoides
Minytrema melanops
Morone saxalilis
Mugil cephalus
Notemigonus crysoleucas
Notropis chalybaeus
N. emiliae
N. hypselopterus
N. maculatus
N. petersoni
N. texanus
N. venustus
Noturus gyrinus
N. leptacanthus
Percina nigrofasciata
Poecilia Iatipinna
Pomoxis nigromaculatus
Semotilus atromoculatus
Strongylura marina
Syngnathus scovelli
Trinectes maculatus
Umbra pygmaea

EDU 2: Central Alabama (108 species)

Acipenser oxyrhynchus
Alosa alabamae
A. chrysochloris
Ambloplites ariommus
Amia calva
Ammocrypta beani
A. meridiana
Anguilla rostrata
Aplodinotus grunniens
Atractosteus spatula
Campostoma oligolepis
Carpiodes velifer
Centrarchus macropterus
Cottus carolinae
Dorosoma cepedianum
D. petenense
Elassoma zonatum
Ericymba buccata
Erimyzon oblongus
E. sucetta
E. tenuis
Esox americanus
E. niger
Etheostoma nigrum
E. parvipinne
E. proeliare
E. rupestre
E. stigmaeum
E. swaini
E. whipplei
E. zoniferum
Etheostoma sp. 1
Etheostoma sp. 2
Etheostoma sp. 3
Etheostoma sp. 4
Etheostoma sp. 5
Fundulus olivaceus
Gambusia affinis
Hiodon tergisus
Hybognathus hayi
H. nuchalis
Hybopsis aestivalis
H. storeriana
H. winchelli
Hypentelium etowanum
Ictalurus furcatus
I. melas
I. natalis
I. nebulosus
I. punctatus
I. bubalus

APPENDIX G. Continued.

EDU 2: Central Alabama (Continued)

Labidesthes sicculus
Lampetra aepyptera
lchthyomyzon gagei
Lepisosteus oculatus
L. osseus
Lepomis cyanellus
L. gulosus
L. humilis
L. macrochirus
L. marginatus
L. megalotis
L. microlophus
L. punctatus
Micropterus coosae
M. punctulatus
M. salmoides
Minytrema melanops
Morone saxalilis
Moxostoma carinatum
M. duquesnei
M. erythrurum
M. poecilurum
Mugil cephalus
Nocomis leptocephalus
Notemigonus crysoleucas
Notropis asperifrons
N. atherinoides
N. baileyi
N. bellus
N. callistius
N. chrosomus
N. chrysocephalus
N. edwardraneyi
N. stilbius
N. texanus
N. venustus
N. volucellus
Notropis sp. 1
Notropis sp. 3
Noturus funebris
N. gyrinus
N. leptacanthus
N. nocturnus
Percina lenticula
P. maculata
P. nigrofasciata
P. shumardi
Percina sp. 3
Pimephales notatus
P. vigilax
Polyodon spathula
Pomoxis annularis
P. nigromaculatus
Pylodictis olivaris
Scaphirhynchus platorynchus
Semotilus atromoculatus
Stizostedion vitreum

EDU 3: Chattahoochee (89 species)

Acipenser oxyrhynchus
Alosa alabamae
A. chrysochloris
Ambloplites ariommus
Amia calva
Anguilla rostrata
Campostoma pauciradii
Catostomus commersoni
Centrarchus macropterus
Cottus bairdi
C. carolinae
Dorosoma cepedianum
D. petenense
Elassoma okefenokee
E. zonatum
Enneacanthus gloriosus
E. obesus
Ericymba buccata
Erimyzon oblongus
E. sucetta
Esox americanus
E. niger
Etheostoma edwini
E. fusiforme
E. parvipinne
E. swaini
Fundulus catenatus
F. cingulatus
F. olivaceus
F. stellifer
Gambusia affinis
Heterandria formosa
Hybopsis winchelli
Hypentelium etowanum
H. nigricans
Ictalurus brunneus
I. natalis
I. nebulosus
I. punctatus
I. serracanthus
Labidesthes sicculus
lchthyomyzon gagei
Lepisosteus oculatus
L. osseus
Lepomis auritus
L. gulosus
L. macrochirus
L. marginatus
L. megalotis
L. microlophus
L. punctatus
Leptolucania ommata
Micropterus coosae
M. salmoides
Micropterus sp.
Minytrema melanops
Morone saxalilis
Moxostoma Iachneri
M. robustum
Moxostoma sp.
Mugil cephalus
Nocomis leptocephalus
Notemigonus crysoleucas
Notropis atrapiculus
N. callitaenia
N. cummingsae

APPENDIX G. Continued.

EDU 3: Chattahoochee (Continued)

Notropis emiliae
N. euryzonus
N. harperi
N. hudsonius
N. hypselopterus
N. hypsilepis
N. Iongirostris
N. lutipinnis
N. maculatus
N. petersoni
N. texanus
N. venustus
N. welaka
N. zonistius
Noturus gyrinus
N. leptacanthus
Percina nigrofasciata
Pomoxis nigromaculatus
Rhinichthys atratulus
Salvelinus fontinalis
Semotilus atromoculatus
Strongylura marina
Trinectes maculatus

EDU 4: Choctawhatchee Bay (68 species)

Alosa alabamae
A. chrysochloris
Ambloplites ariommus
Amia calva
Anguilla rostrata
Atractosteus spatula
Awaous tajasica
Centrarchus macropterus
Cyprinodon variegatus
Dorosoma cepedianum
D. petenense
Elassoma evergladei
El. zonatum
Enneacanthus gloriosus
Ericymba buccata
Erimyzon sucetta
Esox americanus
E. niger
Etheostoma fusiforme
E. okaloosae
E. parvipinne
Etheostoma sp. 5
Fundulus cingulatus
F. olivaceus
Gambusia affinis
Heterandria formosa
Ictalurus natalis
I. nebulosus
I. punctatus
Labidesthes sicculus
lchthyomyzon gagei
Lepisosteus oculatus
L. osseus
Lepomis gulosus
L. macrochirus
L. marginatus
L. megalotis
L. microlophus
L. punctatus
Leptolucania ommata
L. parva
Lucania goodei
Menidia beryllina
Micropterus punctulatus
M. salmoides
Minytrema melanops
Moxostoma poecilurum
Mugil cephalus
Notemigonus crysoleucas
Notropis emiliae
N. harperi
N. hypselopterus
N. Iongirostris
N. petersoni
N. signipinnis
N. texanus
N. venustus
N. welaka
Noturus funebris
N. gyrinus
N. leptacanthus
Percina nigrofasciata
Percina sp. 2
Poecilia Iatipinna
Pomoxis nigromaculatus
Semotilus atromoculatus
Syngnathus scovelli
Trinectes maculatus

APPENDIX G. Continued.

EDU 5: Coosa (129 species)

Acipenser fulvescens
A. oxyrhynchus
Alosa alabamae
A. chrysochloris
Ambloplites ariommus
Amia calva
Ammocrypta asprella
A. beani
Ammocrypta meridiana
Anguilla rostrata
Aplodinotus grunniens
Atractosteus spatula
Campostoma oligolepis
Carpiodes velifer
Catostomus commersoni
Centrarchus macropterus
Cottus bairdi
C. carolinae
C. pygmaeus
Cycleptus elongates
Dorosoma cepedianum
Elassoma zonatum
Ericymba buccata
Erimyzon oblongus
Esox americanus
E. niger
Etheostoma coosae
E. ditrema
E. jordani
E. nigrum
E. parvipinne
E. rupestre
E. stigmaeum
E. swaini
E. trisella
E. whipplei
E. zoniferum
Etheostoma sp. 1
Etheostoma sp. 2
Etheostoma sp. 3
Etheostoma sp. 4
Etheostoma sp. 5
Fundulus catenatus
F. olivaceus
F. stellifer
Gambusia affinis
Hemitremia flammea
Hiodon tergisus
Hybognathus hayi
H. nuchalis
Hybopsis aestivalis
H. lineapunctata
H. storeriana
H. winchelli
Hypentelium etowanum
Ictalurus furcatus
I. melas
I. natalis
I. nebulosus
I. punctatus
Ictiobus bubalus
Labidesthes sicculus
Lampetra aepyptera
lchthyomyzon castuneus
l. gagei
Lepisosteus oculatus
L. osseus
Lepomis cyanellus
L. gulosus
L. macrochirus
L. marginatus
L. megalotis
L. microlophus
L. punctatus
Micropterus coosae
M. punctulatus
M. salmoides
Minytrema melanops
Morone saxalilis
Moxostoma carinatum
M. duquesnei
M. erythrurum
M. poecilurum
Mugil cephalus
Nocomis leptocephalus
Notemigonus crysoleucas
Notropis asperifrons
N. atherinoides
N. baileyi
N. bellus
N. caeruleus
N. callistius
N. chrosomus
N. chrysocephalus
N. lirus
N. lutipinnis
N. sp. 3
N. stilbius
N. texanus
N. trichroistius
N. venustus
N. volucellus
N. xaenocephalus
Noturus funebris
N. gyrinus
N. leptacanthus
N. munitus
Percina antesella
P. aurolineata
P. lenticula
P. maculata
P. nigrofasciata
P. palmaris
Percina sp. 3
Percina sp. 4
Percina sp. 5
Percina sp. 7
Phenacobius catostomus
Pimephales notatus
P. vigilax
Polyodon spathula
Pomoxis annularis
P. nigromaculatus
Pylodictis olivaris
Rhinichthys atratulus
Salvelinus fontinalis
Semotilus atromoculatus
Stizostedion vitreum
Typhlichthys subterraneus

APPENDIX G. Continued.

EDU 6: East Central Georgia (77 species)

Acantharchus pomotis
Acipenser brevirostrum
A. oxyrhynchus
Alosa aestivalis
A. mediocris
A. sapidissima
Amia calva
Anguilla rostrata
Centrarchus macropterus
Chologaster cornuta
Cyprinodon variegates
Dorosoma cepedianum
Elassoma evergladei
E. zonatum
Enneacanthus chaetodon
E. gloriosus
E. obesus
Erimyzon oblongus
E. sucetta
Esox americanus
E. niger
Etheostoma fusiforme
E. hopkinsi
E. inscriptum
E. olmstedi
E. serriferum
Fundulus lineolatus
Gambusia affinis
Heterandria formosa
Hybognathus regius
Hybopsis rubrifrons
Ictalurus brunneus
I. natalis
I. nebulosus
I. platycephalus
I. punctatus
Labidesthes sicculus
Lepisosteus osseus
L. platyrhincus
Lepomis auritus
L. gulosus
L. macrochirus
L. marginatus
L. microlophus
L. punctatus
Leptolucania ommata
L. parva
Lucania goodei
Menidia beryllina
Micropterus salmoides
Minytrema melanops
Morone saxalilis
Moxostoma anisurum
M. robustum
Mugil cephalus
Nocomis leptocephalus
Notemigonus crysoleucas
Notropis callisema
N. chalybaeus
N. cummingsae
N. emiliae
N. hudsonius
N. hypselopterus
N. leedsi
N. lutipinnis
N. maculatus
N. petersoni
Noturus gyrinus
N. leptacanthus
Percina nigrofasciata
Petromyzon marinus
Poecilia Iatipinna
Pomoxis nigromaculatus
Semotilus atromoculatus
Strongylura marina
Trinectes maculatus
Umbra pygmaea

EDU 7: East-Central Peninsula (40 species)

Amia calva
Anguilla rostrata
Cyprinodon variegatus
Dorosoma cepedianum
Elassoma evergladei
Enneacanthus gloriosus
Erimyzon sucetta
Esox americanus
E. niger
Etheostoma fusiforme
Fundulus cingulatus
F. lineolatus
F. seminolis
Gambusia affinis
Heterandria formosa
Ictalurus natalis
I. nebulosus
I. punctatus
Jordanella fioridae
Labidesthes sicculus
Lepisosteus osseus
L. platyrhincus
Lepomis gulosus
L. macrochirus
L. marginatus
L. microlophus
L. punctatus
Leptolucania ommata
Lucania goodei
Micropterus salmoides
Mugil cephalus
Notemigonus crysoleucas
Notropis chalybaeus
N. maculatus
N. petersoni
Noturus gyrinus
Poecilia Iatipinna
Pomoxis nigromaculatus
Strongylura marina
Trinectes maculatus

APPENDIX G. Continued.

EDU 8: Everglades (42 species)

Amia calva
Anguilla rostrata
Cyprinodon variegatus
Dorosoma cepedianum
D. petenense
Elassoma evergladei
Enneacanthus gloriosus
Erimyzon sucetta
Esox americanus
E. niger
Etheostoma fusiforme
Fundulus lineolatus
F. seminolis
Gambusia affinis
G. rhizophorae
Heterandria formosa
Ictalurus natalis
I. nebulosus
I. punctatus
Jordanella fioridae
Labidesthes sicculus
Lepisosteus osseus
L. platyrhincus
Lepomis gulosus
L. macrochirus
L. microlophus
L. punctatus
Leptolucania ommata
L. parva
Lucania goodei
Menidia beryllina
Micropterus salmoides
Mugil cephalus
Notemigonus crysoleucas
Notropis maculatus
N. petersoni
Noturus gyrinus
Poecilia Iatipinna
Pomoxis nigromaculatus
Rivulus marmoratus
Strongylura marina
Trinectes maculatus

EDU 9: First Coast (58 species)

Acantharchus pomotis
Acipenser brevirostrum
A. oxyrhynchus
Alosa aestivalis
A. mediocris
A. sapidissima
Amia calva
Anguilla rostrata
Centrarchus macropterus
Cyprinodon variegatus
Dorosoma cepedianum
D. petenense
Elassoma evergladei
E. okefenokee
E. zonatum
Enneacanthus gloriosus
E. obesus
Erimyzon sucetta
Esox americanus
Esox niger
Etheostoma fusiforme
Etheostoma olmstedi
Fundulus cingulatus
F. lineolatus
Gambusia affinis
Heterandria formosa
Ictalurus natalis
I. nebulosus
I. punctatus
Labidesthes sicculus
L. osseus
L. platyrhincus
Lepomis auritus
L. gulosus
L. macrochirus
L. marginatus
L. microlophus
L. punctatus
Leptolucania ommata
Leptolucania parva
Menidia beryllina
Micropterus salmoides
Morone saxalilis
Mugil cephalus
Notemigonus crysoleucas
Notropis chalybaeus
N. emiliae
N. hypselopterus
N. maculatus
N. petersoni
Noturus gyrinus
Noturus leptacanthus
Petromyzon marinus
Poecilia Iatipinna
Pomoxis nigromaculatus
Strongylura marina
Trinectes maculatus
Umbra pygmaea

APPENDIX G. Continued.

EDU 10: Flint-Apalachicola (67 species)

Acipenser oxyrhynchus
Alosa alabamae
A. chrysochloris
Ambloplites ariommus
Amia calva
Anguilla rostrata
Centrarchus macropterus
Dorosoma cepedianum
D. petenense
Elassoma okefenokee
E. zonatum
Enneacanthus gloriosus
E. obesus
Ericymba buccata
Erimyzon sucetta
Esox americanus
E. niger
Etheostoma edwini
E. fusiforme
E. parvipinne
E. swaini
Fundulus cingulatus
Gambusia affinis
Heterandria formosa
Hybopsis winchelli
Ictalurus brunneus
I. natalis
I. nebulosus
I. punctatus
I. serracanthus
Labidesthes sicculus
lchthyomyzon gagei
Lepisosteus oculatus
L. osseus
Lepomis auritus
L. gulosus
L. macrochirus
L. marginatus
L. microlophus
L. punctatus
Leptolucania ommata
Micropterus salmoides
Minytrema melanops
Morone saxalilis
Moxostoma Iachneri
Moxostoma sp.
Mugil cephalus
Notemigonus crysoleucas
Notropis callitaenia
N. chalybaeus
N. emiliae
N. harperi
N. hypselopterus
N. Iongirostris
N. maculatus
N. petersoni
N. texanus
N. venustus
N. welaka
N. zonistius
Noturus gyrinus
Noturus leptacanthus
Percina nigrofasciata
Pomoxis nigromaculatus
Semotilus atromoculatus
Strongylura marina
Trinectes maculatus

EDU 11: Mobile Bay (99 species)

Acipenser oxyrhynchus
Alosa alabamae
A. chrysochloris
Ambloplites ariommus
Amia calva
Ammocrypta beani
Anguilla rostrata
Aplodinotus grunniens
Atractosteus spatula
Carpiodes velifer
Centrarchus macropterus
Cyprinodon variegates
Dorosoma cepedianum
D. petenense
Elassoma zonatum
Erimyzon sucetta
E. tenuis
Esox americanus
E. niger
Etheostoma chlorosomum
E. fusiforme
E. histrio
E. parvipinne
E. proeliare
E. stigmaeum
E. swaini
Etheostoma sp. 1
Etheostoma sp. 2
Etheostoma sp. 3
Etheostoma sp. 4
Etheostoma sp. 5
Fundulus notatus
F. notti
F. olivaceus
Gambusia affinis
Heterandria formosa
Hiodon tergisus
Hybognathus hayi
H. aestivalis
H. storeriana
H. winchelli
Ictalurus furcatus
I. melas
I. natalis
I. nebulosus
I. punctatus
Ictiobus bubalus
Labidesthes sicculus
lchthyomyzon gagei
Lepisosteus oculatus
L. osseus

APPENDIX G. Continued.

EDU 11: Mobile Bay (Continued)

Lepomis cyanellus
L. gulosus
L. humilis
L. macrochirus
L. marginatus
L. megalotis
L. microlophus
L. punctatus
Leptolucania parva
Menidia beryllina
Micropterus punctulatus
M. salmoides
Minytrema melanops
Morone mississippiensis
M. saxalilis
Moxostoma poecilurum
Mugil cephalus
Nocomis leptocephalus
Notemigonus crysoleucas
Notropis chalybaeus
N. emiliae
N. hypselopterus
N. maculatus
N. petersoni
N. roseipinnis
N. signipinnis
N. texanus
N. venustus
N. volucellus
N. welaka
Notropis sp. 1
Notropis sp. 3
Noturus funebris
N. gyrinus
N. leptacanthus
N. nocturnus
Percina nigrofasciata
Pimephales notatus
P. vigilax
Poecilia Iatipinna
Polyodon spathula
Pomoxis annularis
P. nigromaculatus
Pylodictis olivaris
Scaphirhynchus platorynchus
Semotilus atromoculatus
Syngnathus scovelli
Trinectes maculatus

EDU 12: Panama City (71 species)

Acipenser oxyrhynchus
Alosa alabamae
A. chrysochloris
Ambloplites ariommus
Amia calva
Anguilla rostrata
Atractosteus spatula
Centrarchus macropterus
Cyprinodon variegatus
Dorosoma cepedianum
D. petenense
Elassoma evergladei
E. okefenokee
E. zonatum
Enneacanthus gloriosus
E. obesus
Ericymba buccata
Erimyzon sucetta
Esox americanus
E. niger
Etheostoma edwini
E. fusiforme
E. parvipinne
E. swaini
Fundulus cingulatus
F. olivaceus
Gambusia affinis
Heterandria formosa
Hybopsis winchelli
Ictalurus natalis
I. nebulosus
I. punctatus
Labidesthes sicculus
lchthyomyzon gagei
Lepisosteus oculatus
L. osseus
Lepomis auritus
L. gulosus
L. macrochirus
L. marginatus
L. megalotis
L. microlophus
L. punctatus
Leptolucania ommata
Leptolucania parva
Lucania goodei
Menidia beryllina
Micropterus punctulatus
M. salmoides
Minytrema melanops
Mugil cephalus
Notemigonus crysoleucas
Notropis chalybaeus
N. emiliae
N. harperi
N. hypselopterus
N. Iongirostris
N. maculatus
N. petersoni
N. signipinnis
N. texanus
N. venustus
Noturus funebris
N. gyrinus
N. leptacanthus
Poecilia Iatipinna
Pomoxis nigromaculatus
Semotilus atromoculatus
Strongylura marina
Syngnathus scovelli
Trinectes maculatus

APPENDIX G. Continued.

EDU 13: Ponchartrain (100 species)

Acipenser oxyrhynchus
Alosa alabamae
A. chrysochloris
Ambloplites ariommus
Amia calva
Anguilla rostrata
Aplodinotus grunniens
Atractosteus spatula
Carpiodes velifer
Centrarchus macropterus
Cyprinodon variegatus
Dorosoma cepedianum
D. petenense
Elassoma zonatum
Erimyzon oblongus
E. sucetta
E. tenuis
Esox americanus
E. niger
Etheostoma chlorosomum
E. fusiforme
E. gracile
E. histrio
E. parvipinne
E. proeliare
E. stigmaeum
E. swaini
E. zonale
Fundulus euryzonus
F. notatus
F. notti
F. olivaceus
Gambusia affinis
Heterandria formosa
Hiodon tergisus
Hybognathus hayi
H. nuchalis
Hybopsis aestivalis
H. storeriana
H. winchelli
Hypentelium nigricans
Ictalurus furcatus
I. melas
I. natalis
I. nebulosus
I. punctatus
L. symmetricus
Labidesthes sicculus
lchthyomyzon castuneus
lchthyomyzon gagei
Lepisosteus oculatus
L. osseus
Lepomis cyanellus
L. gulosus
L. humilis
L. macrochirus
L. marginatus
L. megalotis
L. microlophus
L. punctatus
Leptolucania parva
Menidia beryllina
Micropterus punctulatus
M. salmoides
Minytrema melanops
Morone mississippiensis
M. saxalilis
Moxostoma poecilurum
Mugil cephalus
Nocomis leptocephalus
Notemigonus crysoleucas
Notropis atherinoides
N. chrysocephalus
N. emiliae
N. fumeus
N. Iongirostris
N. roseipinnis
N. texanus
N. venustus
N. volucellus
Noturus gyrinus
N. leptacanthus
N. nocturnus
Notropis sp. 1
Percina maculata
P. nigrofasciata
P. ouachitae
P. sciera
Percina sp. 1
Percina sp. 6
Pimephales notatus
P. vigilax
Poecilia Iatipinna
Polyodon spathula
Pomoxis annularis
P. nigromaculatus
Pylodictis olivaris
Semotilus atromoculatus
Syngnathus scovelli
Trinectes maculatus

APPENDIX G. Continued.

EDU 14: Savannah Drainage (100 species)

Acantharchus pomotis
Acipenser brevirostrum
A. oxyrhynchus
Alosa aestivalis
A. mediocris
Alosa sapidissima
Amia calva
Anguilla rostrata
Campostoma anomalum
Carpiodes velifer
Catostomus commersoni
Centrarchus macropterus
Chologaster cornuta
Clinostomus funduloides
Cottus bairdi
Cyprinodon variegatus
Dorosoma cepedianum
Elassoma evergladei
E. zonatum
Enneacanthus chaetodon
E. gloriosus
Enneacanthus obesus
Erimyzon oblongus
E. sucetta
Esox americanus
E. niger
Etheostoma fricksium
E. fusiforme
E. hopkinsi
E. inscriptum
E. olmstedi
E. serriferum
E. zonale
Fundulus lineolatus
Gambusia affinis
Heterandria formosa
Hybognathus regius
Hybopsis rubrifrons
Hypentelium nigricans
Ictalurus brunneus
I. natalis
I. nebulosus
I. platycephalus
I. punctatus
Labidesthes sicculus
Lepisosteus osseus
L. platyrhincus
Lepomis auritus
L. gulosus
L. macrochirus
L. marginatus
L. microlophus
L. punctatus
Leptolucania parva
Menidia beryllina
Micropterus coosae
M. salmoides
Minytrema melanops
Morone saxalilis
Moxostoma anisurum
Moxostoma robustum
Moxostoma rupiscartes
Mugil cephalus
Nocomis leptocephalus
Nocomis micropogon
Notemigonus crysoleucas
Notropis altipinnis
N. chalybaeus
N. coccogenis
N. cummingsae
N. emiliae
N. galacturus
N. hudsonius
N. hypselopterus
N. hypsilepis
N. leedsi
N. leuciodus
N. lutipinnis
N. maculatus
N. niveus
N. petersoni
N. rubricroceus
N. scepticus
N. spectrunculus
N. zonistius
Noturus gyrinus
N. insignis
N. leptacanthus
Perca flavescens
Percina nigrofasciata
Petromyzon marinus
Poecilia Iatipinna
Pomoxis nigromaculatus
R. cataractae
Rhinichthys atratulus
Salvelinus fontinalis
Semotilus atromoculatus
Strongylura marina
Trinectes maculatus
Umbra pygmaea

APPENDIX G. Continued.

EDU 15: South-East Mississippi (94 species)

Acipenser oxyrhynchus
Alosa alabamae
A. chrysochloris
Ambloplites ariommus
Amia calva
Ammocrypta beani
A. vivax
Anguilla rostrata
Atractosteus spatula
Centrarchus macropterus
Cyprinodon variegatus
Dorosoma cepedianum
D. petenense
Elassoma zonatum
Ericymba buccata
Erimyzon oblongus
E. sucetta
E. tenuis
Esox americanus
E. niger
Etheostoma chlorosomum
E. fusiforme
E. histrio
E. parvipinne
E. proeliare
E. stigmaeum
E. swaini
E. zonale
Fundulus notatus
F. notti
F. olivaceus
Gambusia affinis
Heterandria formosa
Hiodon tergisus
Hybognathus hayi
Hybopsis aestivalis
H. winchelli
Ictalurus furcatus
I. melas
I. natalis
I. nebulosus
I. punctatus
Labidesthes sicculus
lchthyomyzon gagei
Lepisosteus oculatus
L. osseus
Lepomis cyanellus
L. gulosus
L. humilis
L. macrochirus
L. marginatus
L. megalotis
L. microlophus
L. punctatus
Leptolucania parva
Menidia beryllina
Micropterus punctulatus
M. salmoides
Minytrema melanops
Morone saxalilis
Moxostoma poecilurum
Mugil cephalus
Nocomis leptocephalus
Notemigonus crysoleucas
Notropis atherinoides
N. chalybaeus
N. chrysocephalus
N. emiliae
N. Iongirostris
N. maculatus
N. roseipinnis
N. signipinnis
N. texanus
N. venustus
N. volucellus
N. welaka
Notropis sp. 1
Noturus funebris
N. gyrinus
N. leptacanthus
N. nocturnus
Percina nigrofasciata
Percina sp. 1
Percina sp. 6
Pimephales notatus
P. vigilax
Poecilia Iatipinna
Polyodon spathula
Pomoxis annularis
P. nigromaculatus
Pylodictis olivaris
Semotilus atromoculatus
Syngnathus scovelli
Trinectes maculatus

APPENDIX G. Continued.

EDU 16: Tallapoosa (109 species)

Acipenser oxyrhynchus
Alosa alabamae
A. chrysochloris
Ambloplites ariommus
Amia calva
Ammocrypta asprella
A. beani
Ammocrypta meridiana
Anguilla rostrata
Aplodinotus grunniens
Atractosteus spatula
Campostoma oligolepis
Carpiodes velifer
Centrarchus macropterus
Cottus carolinae
Dorosoma cepedianum
Elassoma zonatum
Ericymba buccata
Erimyzon oblongus
E. sucetta
E. tenuis
Esox americanus
E. niger
Etheostoma chlorosomum
E. jordani
E. nigrum
E. parvipinne
E. rupestre
Etheostoma sp. 2
Etheostoma sp. 5
E. stigmaeum
E. swaini
E. whipplei
E. zoniferum
Fundulus catenatus
F. cingulatus
F. olivaceus
F. stellifer
Gambusia affinis
Hiodon tergisus
Hybognathus hayi
Hybognathus nuchalis
Hybopsis aestivalis
H. lineapunctata
H. storeriana
H. winchelli
Hypentelium etowanum
Ictalurus furcatus
I. melas
I. natalis
I. nebulosus
I. punctatus
Labidesthes sicculus
lchthyomyzon gagei
Lepisosteus oculatus
L. osseus
Lepomis auritus
L. cyanellus
L. gulosus
L. macrochirus
L. marginatus
L. megalotis
L. microlophus
L. punctatus
Micropterus coosae
M. punctulatus
M. salmoides
Minytrema melanops
Morone saxalilis
Moxostoma carinatum
M. duquesnei
M. erythrurum
M. poecilurum
Mugil cephalus
Nocomis leptocephalus
N. micropogon
Notemigonus crysoleucas
Notropis baileyi
N. bellus
N. callistius
N. chrysocephalus
N. emiliae
N. gibbsi
N. stilbius
N. texanus
N. uranoscopus
N. venustus
N. volucellus
N. xaenocephalus
Noturus funebris
N. gyrinus
N. leptacanthus
N. nocturnus
Percina lenticula
P. maculata
P. nigrofasciata
P. ouachitae
P. palmaris
P. shumardi
Percina sp. 3
Phenacobius catostomus
Pimephales notatus
P. vigilax
Polyodon spathula
Pomoxis annularis
P. nigromaculatus
Pylodictis olivaris
Salvelinus fontinalis
Semotilus atromoculatus

APPENDIX G. Continued.

EDU 17: West Alabama (125 species)

Acipenser oxyrhynchus
Alosa alabamae
A. chrysochloris
Ambloplites ariommus
Amia calva
Ammocrypta asprella
A. beani
A. meridiana
Anguilla rostrata
Aplodinotus grunniens
Atractosteus spatula
Campostoma oligolepis
Carpiodes velifer
Centrarchus macropterus
Cycleptus elongatus
Dorosoma cepedianum
D. petenense
Elassoma evergladei
E. zonatum
Ericymba buccata
Erimyzon oblongus
E. sucetta
E. tenuis
Esox americanus
E. niger
Etheostoma chlorosomum
E. histrio
E. nigrum
E. parvipinne
E. proeliare
E. rupestre
E. stigmaeum
E. swaini
E. whipplei
E. zoniferum
Etheostoma sp. 1
Etheostoma sp. 2
Etheostoma sp. 3
Etheostoma sp. 4
Etheostoma sp. 5
Fundulus dispar
F. notatus
F. notti
F. olivaceus
Gambusia affinis
Hiodon tergisus
Hybognathus hayi
H. nuchalis
Hybopsis aestivalis
H. storeriana
H. winchelli
Hypentelium etowanum
Ictalurus furcatus
I. melas
I. natalis
I. nebulosus
I. punctatus
Ictiobus bubalus
Labidesthes sicculus
Lampetra aepyptera
lchthyomyzon castuneus
l. gagei
Lepisosteus oculatus
L. osseus
Lepomis cyanellus
L. gulosus
L. humilis
L. macrochirus
L. marginatus
L. megalotis
L. microlophus
L. punctatus
Micropterus punctulatus
M. salmoides
Minytrema melanops
Morone mississippiensis
M. saxalilis
Moxostoma carinatum
M. erythrurum
M. poecilurum
Mugil cephalus
Nocomis leptocephalus
Notemigonus crysoleucas
Notropis asperifrons
N. atherinoides
N. baileyi
N. bellus
N. callistius
N. candidus
N. chalybaeus
N. chrysocephalus
N. edwardraneyi
N. emiliae
N. maculatus
N. signipinnis
N. stilbius
N. texanus
N. trichroistius
N. venustus
N. volucellus
N. welaka
Notropis sp. 1
Notropis sp. 3
Noturus funebris
N. gyrinus
N. leptacanthus
N. munitus
N. nocturnus
Perca flavescens
Percina lenticula
P. maculata
P. nigrofasciata
P. ouachitae
P. sciera
P. shumardi
Percina sp. 1
Percina sp. 3
Pimephales notatus
P. vigilax
Polyodon spathula
Pomoxis annularis
P. nigromaculatus
Pylodictis olivaris
Semotilus atromoculatus
Stizostedion vitreum

APPENDIX G. Continued.

EDU 18: West Florida Panhandle (73 species)

Acipenser oxyrhynchus
Alosa alabamae
A. chrysochloris
Ambloplites ariommus
Amia calva
Ammocrypta bifascia
Anguilla rostrata
Atractosteus spatula
Centrarchus macropterus
Cyprinodon variegatus
Dorosoma cepedianum
D. petenense
Elassoma evergladei
E. zonatum
E. gloriosus
Ericymba buccata
Erimyzon sucetta
E. tenuis
Esox americanus
E. niger
Etheostoma edwini
E. fusiforme
E. parvipinne
E. stigmaeum
E. swaini
Etheostoma sp. 5
Fundulus cingulatus
F. olivaceus
Gambusia affinis
Heterandria formosa
Ictalurus natalis
I. nebulosus
I. punctatus
Labidesthes sicculus
lchthyomyzon gagei
Lepisosteus oculatus
L. osseus
Lepomis gulosus
L. macrochirus
L. marginatus
L. megalotis
L. microlophus
L. punctatus
Leptolucania ommata
Leptolucania parva
Menidia beryllina
Micropterus punctulatus
M. salmoides
Minytrema melanops
Morone saxalilis
Moxostoma poecilurum
Mugil cephalus
Notemigonus crysoleucas
Notropis chalybaeus
N. emiliae
N. hypselopterus
N. Iongirostris
N. maculatus
N. petersoni
N. signipinnis
N. texanus
N. venustus
N. welaka
Noturus funebris
N. gyrinus
N. leptacanthus
Percina nigrofasciata
Percina sp. 2
Poecilia Iatipinna
Pomoxis nigromaculatus
Semotilus atromoculatus
Syngnathus scovelli
Trinectes maculatus