Illinois Natural History Survey

Ecological Classification of Rivers for Environmental Assessment and Management: Stream Attribution and Model Preparation

Final Project Report 2005

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TABLE OF CONTENTS

List of Tables

List of Figures

INTRODUCTION

Illinois streams vary dramatically from low gradient, coastal plain-like systems to more rocky, boulder-laden systems. Describing the driving factors or characteristics that make these systems different from one another is difficult given the vast number of river systems and their inherent variability. This is further complicated by the fact that much of Illinois' landscape and it's river systems have been altered, thus confounding our understanding of a system's driving variables.

At several different scales, our terrestrial colleagues can describe habitat types with much clarity. For example, when one refers to an upland forest, dolomite prairie, or emergent wetland, other terrestrial ecologists understand the system being described. Each named community has specific features that are unique to that system. Stream ecologists on the other hand, have few tools available that integrate physical and biological features to describe stream types. There are a few classifications used in Illinois, but they do not integrate all of the factors that we know are important in shaping biology. For example, geomorphic classifications such as Rosgen (1994) and the channel evolution model (Schumm et al. 1984) are widely used across the United States. The premise of these classifications is that channels evolve in set pattern and can be classified as to their current state. Although channel stage is important, purely geomorphic classifications do not capture variations in key ecological factors such as chemistry, hydrology, and temperature that also strongly shape the aquatic biota. Further, purely biological classification, such as the Biological Stream Characterization (BSC; Bertrand et al. 1996), does not take into account habitat when rating streams. BSC ratings are assigned to a stream reach primarily based on the fish community sampled at a site. Therefore, resource managers need a tool that will integrate ecological, biological, and geomorphic factors in a way that aquatic systems can be described in a standardized fashion.

River conditions are the product of landscape and climatic conditions in the upstream catchment (i.e., watershed), local valley constraints, and unique ecological properties of the site. Factors at all of these scales work in concert with each other to shape biotic communities. Examples of two factors that shape stream biota are size and connectivity. Headwater streams support fewer fish species than mainstems because certain habitat types like deep pools are not frequently present. Further, even streams of the same size support different fish communities depending on what size stream each is connected to. Streams that are connected to lakes or reservoirs also frequently support different fish than streams of the same size that are connected to other streams. Another example of a factor influencing stream biota is gradient. Although compared to montane states, Illinois' topography is flat. Yet several glaciations have resulted in diverse topographic conditions across the state, such as the presence of a driftless area in north-west Illinois and a series of end moraines in east-central Illinois. Gradient plays a major role in determining how fast water flows through a stream system (velocity), which in turn affects the substrate, dissolved oxygen, etc. Aquatic biota respond to these abiotic conditions of the system. These examples are not an exhaustive list, rather they are meant to provide some background of the types of factors to be considered for inclusion in a classification system.

The motivation behind trying to classify streams from an ecological standpoint was to account for as many of the ecological, biological, and geomorphic factors as reasonably possible. In order to adequately define stream types, scale becomes an important factor. Using several variables at a very fine scale would create a huge, logically impractical dataset with which to work. Further, this project was designed to support the Comprehensive Wildlife Conservation Planning (CWCP) process. Therefore, we constrained the focus to existing data. Finally, the purpose of the classification is to simplify the natural variability that exists in streams, thereby providing a tool to identify unique communities and stream types in need of protection and restoration. Too broad of a scale would not help users distinguish between stream reaches. Alternatively, too fine a scale would result in information overload and would create a system in which every stream was different from the next. Therefore, the final classification will be based on an intermediate spatial scale, which is comprised of stream units 10's to 100's of km in length. To achieve this scale, we concentrated on smaller sections of stream, i.e., stream arcs, which can be aggregated into larger units during the next phase of this project.

Given the selected intermediate spatial scale, we faced a challenge of selecting variables that address multiple scales of influence, (i.e., landscape and climatic conditions in the upstream catchment, local valley constraints, and unique ecological factors at the site) from several different disciplines (e.g., chemistry, hydrology, temperature, geomorphology, and biology). To help ensure that the selected variables were meaningful, we collaborated with researchers from Wisconsin and Michigan in a project funded by a federal EPA STAR grant (see http://sitemaker.umich.edu/riverclassproject for more information). This group decided to describe streams by using a suite of ecologically-relevant attributes (e.g., landuse, gradient, surficial geology) at three different scales (i.e., stream channel, riparian zone, watershed). After the attribution phase was completed, we chose three variables to use in an initial stream typing effort. The result of this effort demonstrates the process and usefulness of combining attributes into a meaningful number of stream types and lays the framework for the final classification that will occur in the next phase of work.

Given the current data that are available, there are several important factors that likely drive biota, yet we have not accounted for them with the current variables chosen to describe stream channels, riparian zones, and watersheds. For example, several species of fish have specific temperature tolerances. Groundwater plays a role in not only regulating flow, but also keeping water cool enough to support cool-water fish communities. Information regarding soil permeability and elevation is available, and therefore ground water potential can be modeled. There are several other factors, such as hydrology (i.e., flow), water temperature, and biota (e.g., fish and macroinvertebrates) where some data exist, but certainly not from every stream. Therefore, the second objective of this project was to develop datasets for use in statistical models that will predict riverine site habitats and biota from mapped landscape and local variables.

Job 2.1. To describe stream reaches and their catchments with a suite of ecologically-relevant attributes (e.g., landuse, gradient, surficial geology).

The second required element of the CWCP is to describe locations and relative conditions of key habitats and community types essential to species in greatest need of conservation. Although habitat types can be described with much clarity from a terrestrial perspective, stream ecologists have few tools available to uniformly describe stream types. Because resource managers in Illinois face characterizing an almost infinite number of physiographically diverse riverine sites, there is a need to simplify the natural variability that exists in stream systems. River conditions are the product of landscape and climatic conditions in the upstream catchment (i.e., watershed), local valley constraints, and unique ecological properties of the site. Therefore, the following paragraphs describe an effort to describe stream reaches by using a suite of ecologically-relevant attributes (e.g., landuse, gradient, surficial geology) at three different scales (i.e., stream channel, riparian zone, watershed). After the attributes were generated, an initial stream typing effort was undertaken to demonstrate the potential for describing location of stream types in a standardize manner statewide.

Linework Pre-Processing

The 1:100,000-scale, flow-validated, National Hydrography Dataset (NHD) was used as the base linework for this project. It is based upon the content of USGS Digital Line Graph (DLG) hydrography data integrated with reach-related information from the EPA Reach File Version 3 (RF3) (USGS 2004). The NHD data for Illinois and portions of adjacent states contributing flow to Illinois' were downloaded as individual subbasins (formally referred to as USGS eight-digit hydrologic cataloging units) from the USGS website (http://nhd.usgs.gov/data.html). After decompressing the files, all NHD files were reprojected to Lambert Conformal Conic.

In order for future processing to occur correctly, processing units (PUs) were created to include all subbasins (i.e., individual NHDinARC workspaces) that drain to a common location, referred to as a pour point. An Arc Macro Language (AML) program, append_NHD.aml (available at: http://nhd.usgs.gov/tools.html#append), was used to properly combine multiple NHDinARC workspaces into a single workspace covering a larger geographic area. The NHD data set is very complex, thus append_NHD.aml was used because it properly integrates multiple coverages and feature classes, several related tables, and metadata from the input workspaces into the final workspace. Further, it detects and properly resolves duplicate features (e.g, a duplicate stream/river feature that touches sub-basin boundaries) into a single instance of each feature (USGS 2000). Following the append process, a final set of 22 PUs was created for Illinois (Figure 1).

Additional NHD editing included reconnecting or deleting disconnected stream arcs and removing loops. When possible, Digital Raster Graphics (DRGs; ISGS 2004) were used to evaluate if a connection should be made, or if the disconnected stream arc should be deleted. If a connection could be justified, then a node from the disconnected stream arc was moved and snapped to the desired stream arc. If needed, then vertices on the newly connected stream arc were moved to closely match the stream lines as they appear on the DRGs. Next, all loops including braids, interconnecting drains, and interconnecting headwaters were deleted from the NHD linework. Loops (i.e., polygons) were identified by using the "build as poly" command in ArcInfo workstation. To the extent possible, DRGs were used to decide which feature of each loop was 1) the secondary flow channel, or 2) more incorrect. The secondary or incorrect channel was coded for removal and deleted. Once all loops were removed, an arc macro language program was used to orient all upstream arcs in the same direction relative to a selected drain point. If needed, the program was run twice to orient all arcs downstream.

The final pre-processing step involved assigning a unique code to each stream arc. The field name "gap code" severed this purpose and allowed us to assign data from multiple sources and data tables to each unique arc. The following section describes the development of data sets at three scales (i.e., channel, riparian, and watershed), which describe stream systems and can be used in future modeling and classification.

Channel Attribution

Following editing and preprocessing of the NHD linework, channel processing began. The initial description of stream channels was based on arc segments. Arc segments are defined as a line between two nodes or pseudonodes; arcs comprise the base of the NHD dataset. Several attributes were used to describe stream arcs. First, sinuosity was based on Rosgen (1994) and was calculated by dividing Euclidean length by total length of stream arc. Secondly, gradient was calculated by dividing the change in elevation of the upstream and downstream nodes by the length of the stream arc. Elevation was determined from a 30 m digital elevation model (DEM) produced by the National Elevation Dataset (NED; USGS 2003). The NED was chosen because it is consistent across state lines, thereby supporting collaboration among the states involved with the EPA STAR grant. Thirdly, depth to bedrock in the channel was extracted from regional Soller bedrock maps (1998). Before surficial or bedrock geology type in the channel was identified, the Surficial Geology of Illinois (Lineback 1979) and Bedrock Geology of Illinois (Willman et al. 1967) maps were reclassified to match classes agreed upon by staff working on the EPA STAR Grant (see Figures 2 and 3 for reclassified maps respectively). The standardization of geology classes across Michigan, Wisconsin, and Illinois allows resource managers to investigate biotic distributions across a broader landscape in the future. After the maps were reclassified, the NHD linework was overlain on surficial geology and bedrock geology maps. The underlying surficial and bedrock geology type was then assigned to each arc. Finally, two measures of stream size were used to describe stream channel, Strahler stream order (Strahler 1957) and Shreve link number (Shreve 1967). When calculating Strahler stream order (Strahler 1957), headwater streams are assigned a one for first order streams. When two first order streams join, a second order stream is formed. Similarly, when two second order streams join, a third order stream is formed. Order numbers continue to be assigned throughout the drainage network. Shreve link order is defined as the number of first order streams upstream of a given stream arc (Shreve 1967). For each arc, the stream order and link number of the next arc immediately downstream were also identified. Downstream order and d-link number (Osborne and Wiley 1992) provided a measure of connectivity by identifying the size stream to which each arc was connected.

Riparian Delineation & Attribution

The second scale of attribution was a 150 m riparian buffer around each arc. The buffer size of 150 m was determined by selecting two 30 m grid cells on each side of stream channel (i.e., channel equals one cell), thereby creating a buffer of five cells (5 cells x 30 m/per cell = 150 m buffer). In addition to the local buffer around each arc, an upstream buffer comprising all buffers upstream of a given arc was created. Each attribute was used to describe an arc's local and upstream riparian zone. In addition to describing stream channels, depth to bedrock, surficial geology, and bedrock geology were also used to describe riparian zones. Illinois' land cover (IDNR 1996) was standardized with Wisconsin and Michigan in a similar manner to the process described above for surficial and bedrock geology. After land cover classes were reclassified (Figure 4), proportions of each land cover type in the riparian buffer were identified. Soil permeability in the riparian zone was extracted from the state soil geographic (STATSGO) data base for the conterminous United States (Schwarz and Alexander 1995). Finally, slope represents the rate of maximum change in elevation value from each digital elevation model (DEM) grid cell within the riparian zone.

There are several important factors that influence biotic distributions and shape stream habitats that have yet to be accounted for in the channel and riparian attributes. For example, several species of fish have specific temperature tolerances. Groundwater plays a role in not only regulating flow, but also keeping water cool enough to support cool-water fish communities. Because we had information on soil permeability and elevation, we were able to model ground water potential by using Darcy's law (Figure 5). Darcy's law states that ground water velocity is proportional to local hydraulic head (slope) times the hydraulic conductivity of the underlying materials (Dunne and Leopold 1978; Wehrly et al. 1997). Slope data were calculated from the 30 m digital elevation model (DEM) produced by the National Elevation Dataset (NED; USGS 2003). Conductivity values for surficial geology classes were taken published hydraulic conductivity values used by Wehrly et al. (1997). Finally, surficial geology data were obtained from Lineback (1979), USGS (2004b), IGS (2002b). The resulting map of potential ground water velocity was summarized as the mean velocity within each riparian zone.

Watershed Delineation & Attribution

Although several watershed coverages exist for Illinois, none provided a unique watershed for each arc. Therefore, we developed a process to delineate unique watersheds for each arc by using a digital elevation model (DEM). Similar to the data used when calculating gradient and slope, the National Elevation Dataset (NED) was used as the base DEM for this process. Before the DEM could be used to create watershed boundaries, it had to be cleaned and conditioned. The first step in the DEM conditioning process was to fill "sinks" to create a more uniform slope

(Figure 6). Ridges along known watershed boundaries (i.e., HUC 12; NRCS 2003) were exaggerated. Because DEMs are large files, important points representing peaks and valleys along the flow path (i.e., very important points; VIP) were identified and extracted. These points were used in a topogrid analysis using Arc Info (2001). The result of the topogrid step is a new "conditioned" DEM that can be used for watershed delineation (Figure 6). By using an Arc Macro Language (AML) program within Arc Info (2001), unique watersheds for each arc were created. In addition to the local watershed for each arc, an upstream watershed comprising all contributing land upstream of a given arc was created.

Each attribute was used to describe an arc's local and upstream watershed. In addition to describing stream channels and/or riparian zones, depth to bedrock, surficial geology, bedrock geology, land cover, soil permeability, slope, and ground water potential were also used to describe watersheds. Additional watershed attributes include drainage area and stream length per watershed. Further, three climate attributes were used to describe watersheds. These attributes included precipitation, growing degree days, and air temperature. In order to ensure data compatibility across state lines, STAR grant collaborators used grant funds to purchase these climate data from the Spatial Climate Analysis Service (2000).

Stream Type Delineation

In this phase of work, our objectives were to describe stream reaches and their catchments with a suite of ecologically-relevant attributes and to develop datasets for use in statistical models. Ultimately in phase two, the compiled attributes will be used with model output to classify Illinois streams into a set of stream types. However in this phase of work, we wanted to establish a process for classifying arcs into a series of types and to create an interim product for use in the writing of the CWCP. After all attributes had been compiled, it was obvious that the number of variables used to "type" each stream arc must be reduced. For the purpose of supporting the CWCP, three variables that seemed to affect biotic distributions and were easily summarized were chosen (i.e., gradient, connectivity, and size). The remaining attributes not used in this initial stream typing will be considered for the modeling efforts and future stream classification after the models are complete. Provided below is an overview of the three variables used in the initial stream typing effort.

Gradient - Channel slope was interpreted from a Digital Elevation Model (DEM) as 1 of 3 broad categories. These broad categories were similar to those used by Seelbach et al. (1997) and Miller et al. (1998).

- 1 - very low valley slope, roughly 4 ft/mi (<0.00076 %). These slopes are typical of headwaters in the Green River and parts of east-central Illinois, as well as larger water bodies throughout the state (Figure 7). Channel habitats include runs and pools.

- 2 - low slope, roughly 4-10 ft/mi (0.00076 - 0.0019%). These slopes are most common in east-central Illinois. However, they are also common in intermediate-sized streams and streams statewide (Figure 8). Channel habitats include some riffles present.

- 3 - moderate slope, roughly >10 ft/mi (>0.0019%). These slopes comprise most headwaters in northern, western, and southern Illinois (Figure 9). Channel habitats are typically alternating riffle-pool sequences.

Connectivity codes - Connectivity was defined as the link number of the immediate downstream stream arc (i.e., d-link). The selected broad categories were based on Miller et al. (1998). See Figure 10 for a distribution of d-link classes.

- 1 - connected downstream to a headwater stream (link numbers of 1 - 10).
- 2 - connected downstream to a intermediate sized stream (link numbers of 11 - 50)
- 3 - connected downstream to a stream (link numbers of 51 - 200)
- 4 - connected downstream to a river (link numbers of 210 - 700)
- 5 - connected downstream to a large river (link number > 700)
- 6 - connected downstream to a lake
- 99 - pour point of a processing unit

Size codes - Size was defined as the link number (i.e., number of first order streams upstream of a given point on the arc). The selected broad categories were based on Miller et al. (1998). See Figure 11 for the distribution of link classes.

- 1 - headwater stream (link numbers 1 - 10)
- 2 - intermediate stream (link numbers 11 - 50)
- 3 - stream (link numbers 51 - 200)
- 4 - river (link numbers of 201 - 700)
- 5 - large river (link numbers >700)

Unique combinations of these three variables yielded a possible 69 stream types for Illinois streams. In an effort to reduce the number of stream types, we conducted a principal components analysis (PCA; McCune and Mefford 1999). Cumulatively, 74% of the total variance among stream types was explained by the first two principal components (i.e., principal component 1 = 41%; principal component 2 = 33%). Principal component 1 was positively related to link class and d-link class. Principal component 2 was positively related to gradient class. The plot resulting from the PCA was used to identify stream types that could be grouped, thereby reducing the number of stream types present statewide (Figure 12). Further, original types that included a d-link value of “99" were reviewed and grouped with the broader types developed from the PCA. D-link values of “99" were limited to pour point arcs in each processing unit, and were simply the product of analyzing areas separately rather than statewide. Therefore, the values of “99" were manually replaced by actual d-link values gathered from adjacent processing units, thereby allowing ten addition stream types to be combined with other types. These steps reduced the original 69 classes to 15 (Table 1). A final class, great river/unclassified, was used to describe arcs of the Mississippi, Ohio, and Wabash Rivers that could not be classified because their entire upstream drainage was not used in our analysis. Therefore, the data generated for size and connectivity were not accurate.

Although only three variables were used to create stream types, the results provide a reasonable and workable framework on which to begin statewide conservation planning. Figure 13 shows five categories of streams based on size, which are further stratified by gradient (i.e., 15 total types plus an unclassified/great river type). As expected, headwater streams (i.e., link numbers 1 - 10) comprised the majority of stream arcs in this classification; 81.4% of arcs fell into this size class (Table 1; Figure 13). As stream size increased, fewer arcs comprised each size class (10.3% intermediate streams, 4.2% streams, 2.2% rivers, 1.3% rivers, and 0.6% great river).

Of the arcs classified as headwaters, most (59.8%) had moderate gradients. The areas of headwaters with very low or low gradients are reflective of geological processes on the landscape. For example, the headwaters of the Green River reflect extensive sand deposits of the historic Mississippi River valley, which provides a stark contract to the surrounding moderate gradient headwaters reflective of areas outside of the historic river valley (Figure 14). A second example is in east-central Illinois, which is fairly low relief (Figure 15). However, patches of low to moderate gradient headwaters in this area reflect end moraines from various glaciations that contribute to a more diverse landscape than generally recognized. Generally statewide, as stream size increased, the proportion of streams with moderate gradients decreased and low to very-low gradient streams became dominant (Figures 13 - 17).

The stream types generated in this analysis demonstrate the potential for simplifying the natural variability of lotic systems into a meaningful number of stream types. Further, the resulting types reflect a realistic view of the landscape. Therefore, the attributes compiled during this phase of work should be sufficient input variables into models that will be developed in phase II. Additionally, the resulting models and final classification to be completed in phase II should continue to provide a realistic view of the landscape and to provide resource managers with a useful tool for implementing the IDNR’s CWCP.

Job 2.2. To develop datasets for use in statistical models that will predict riverine site habitats and biota from mapped landscape and local variables.

The first required element for Illinois' CWCP is to provide information on the distribution and abundance of species of wildlife that are indicative of the diversity and health of Illinois' wildlife. From the aquatic perspective, this is difficult because comprehensive survey data are not available for all river reaches. Therefore, some modeling approach is required for extrapolating data from sampled to unsampled river reaches. In preparation for modeling that will be undertaken in phase II, we gathered the following datasets.

Fish

The Fisheries Analysis System (FAS) database that resides within the IDNR - Office of Resource Conservation is a comprehensive database that stores information such as, sampling gear and duration, stream conditions on the day of sampling, fish species counts, and other information. We queried the database for all samples that occurred between 1990 and 2000; 1427 samples were identified. The next step was to limit these sample to those that occurred in wadeable or semi-wadeable streams. Although the electric seine is the primary gear used to sample wadeable streams (Day et al. 2003), boat and backpack electrofishers are also used. Minnow seine hauls were only included in our dataset if they occurred in conjunction with boat electrofishing.

Most of the fish data in FAS were collected as part of the IDNR's cooperative Basin Surveys with the Illinois Environmental Protection Agency (IEPA). Typical protocol for the Basin Survey Program requires IDNR to collect fish, whereas IEPA collects semi-quantitative instream habitat information as well as macroinvertebrates. We anticipate that instream habitat data will be important to the fish model, therefore, we limited our dataset to include only those fish samples with corresponding IEPA habitat data. This criteria reduced the possible dataset to 696 samples.

The IDNR typically samples watersheds throughout Illinois on a five year rotation. Therefore, several sites were sampled more than once during the ten year period to which we restricted our dataset. Remaining samples were quickly reviewed to ensure that each sample adequately represented the fish community sampled. In cases where more than one sample existed for a sampling site, the one that was considered to most adequately represented the fish community was retained. Our final dataset comprised 444 samples (Figure 18).

Locations of the final fish sampling sites were linked to the NHD linework and a subset of GIS attributes were extracted.

Macroinvertebrates

The Illinois Environmental Protection Agency extracted 600 qualitative macroinvertebrate samples from their database and standardized the identification of each taxa to genus level or higher. In addition to taxonomic name, sampling and station information, and site-specific habitat data were extracted. Locations of these macroinvertebrate sites (Figure 19) will be linked to the NHD linework and a subset of GIS attributes will be extracted. At this time, however, we are unsure of the modeling approach and what GIS attributes will be needed for the model.

Flow

A flow model for Illinois will be created by contractual staff at the University of Michigan as part of the EPA STAR Grant. To support the development of Illinois' flow model, we were asked to provide flow data for gages with at least 20 years of flow record. The United States Geological Survey provided us with a CD of data for water year 2002, which we forwarded to the contractor at the University of Michigan. Gages were excluded if they were close to and downstream of dams; listed in water book as having flow regulated by dams (including powerplants, lake outflows, or mill dams); had effluent additions, diversion, or mine pumpage; had diurnal fluctuations at low flow (or other wise); or were canals. Gages that had 20 years or more of data and with a near continuous record that included the 1995 water year (or more recent) were included. Based on these criteria, 67 gages could be used in developing Illinois' flow model (Table 2). In addition to the water data, we were asked to provide a GIS shapefile of catchments for each gage location. The catchments were provided to us by staff at the USGS office in Champaign. A subset of GIS attributes described in Job 2.1 were clipped based on each catchment boundary and were provided to the contractor.

Temperature

Continuous water temperature is not routinely collected in Illinois. Therefore, we lacked adequate data at the start of this project and had to initiate a data collection effort. In order to identify sites representing the range of temperatures in Illinois streams, we compiled existing data that influence differences in water temperature among sites (i.e., cfs, width, depth, canopy cover, and water temperature) and conducted a principle components analysis (McCune and Mefford 1999). Cumulatively, 63% of the total variance among sampling sites was explained by the first two principal components (i.e., principal component 1 = 43%; principal component 2 = 20%). Principal component 1 was negatively related to cfs, width, and depth (Table 3). Principal component 2 was negatively related to canopy but positively related to water temperature. The plot resulting from the PCA was used to identify sites representing the range of conditions in Illinois streams (Figure 20). To make the plot more interpretable, the results were differentiated by IBI regions and a series of regional plots were made (Figure 21).

Forty-four temperature loggers were purchased by the University of Michigan with EPA STAR Grant funds and were placed in Illinois streams in June - July 2003. Each logger was programmed to collect hourly stream temperature. Data were downloaded from each logger in October 2003 and then again in June - July 2004 when the loggers were removed. During the attempted summer retrival, several loggers were unrecovered. The loggers that were recovered were reset and placed in new streams during June - July 2004. Additionally, several new loggers were purchased to replace the unrecovered loggers from 2003; these were programmed and placed in streams during June - July 2004. As part of phase II, these data will be summarized into daily mean, daily maximum, and daily minimum as well as other summaries (e.g., 7-day mean, maximum, and minimum) and will be used to develop models to predict spring and summer water temperatures.

DISCUSSION:

This project supports the development of an Illinois river classification system, which will be a vital tool for consistently describing aquatic habitat statewide. The classification will allow resource managers to identify unique or critical habitats in need of protection or management. Phase II of this work will build upon this work by linking ecological valley-segment units to a Land Transformation Model, which will create a physical framework for assessing current status of river reaches and forecasting the river segments at risk for future species loss due to development. The ultimate product will be a GIS-based river classification and modeling system that simplifies the natural complexity of Illinois' rivers and allows resource mangers to model a suite of habitat and biological traits at specific, often unsampled, river locations across the state over time.

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BUDGET SUMMARY:

Category Description	Amount Budgeted	Amount Spent
Subcontracts		
Personnel	$72,000	
Fringe	$20,671	
Travel	$5,000	
Materials and Supplies	$7,000	
Contractual	$900	
Total Direct Costs____	$105,571	
_Indirect Costs (20% of total direct costs)	$21,114	
TOTAL FEDERAL COST	$126,685	
State of Illinois Match		
University match (contracts to U of I)	$42,228	
TOTAL STATE MATCH	$42,228	
TOTAL PROJECT COSTS	$168,913	

Table 1. Unique combinations of link, d-link, and gradient classes (called "Grad Class" below) generated 69 possible stream types. These types were reduced to 15 types ("combo type" below) based on the results of a principal components analysis. Arcs that originally had a d-link = 99 were replaced by actual d-link values (see text for additional explanation) and were subsequently added to one of the new combo types, thereby eliminating the original types highlighted below. Count below refers to the number of arcs in each stream type. Because some arcs comprising the Mississippi, Ohio, and Wabash Rivers were later coded as combo type = 16 (i.e., unclassified/mainstem), the counts listed below do not match exactly the percentages referenced in the text.

Link Class	D-link Class	Grad Class	Type	Count	Combo Type
1	1	1	1	3928	1
1	2	1	4	846	1
1	3	1	7	262	1
1	4	1	10	176	1
1	5	1	13	120	1
1	6	1	16	454	1
1	1	2	2	4296	2
1	2	2	5	969	2
1	3	2	8	277	2
1	4	2	11	151	2
1	5	2	14	67	2
1	6	2	17	198	2
1	1	3	3	24274	3
1	2	3	6	4384	3
1	3	3	9	1560	3
1	4	3	12	744	3
1	5	3	15	408	3
1	6	3	18	1154	3
2	2	1	21	2420	4
2	3	1	24	193	4
2	4	1	27	71	4
2	5	1	30	26	4
2	6	1	33	78	4
2	2	2	22	1539	5
2	3	2	25	142	5
2	4	2	28	41	5
2	5	2	31	26	5
2	6	2	34	28	5
2	2	3	23	941	6
2	3	3	26	57	6
2	4	3	29	28	6
2	5	3	32	23	6
2	6	3	35	22	6

Table 1. Cont.

3	3	1	37	1677	7
3	4	1	40	82	7
3	5	1	43	18	7
3	6	1	46	47	7
3	3	2	38	382	8
3	4	2	41	14	8
3	5	2	44	6	8
3	6	2	47	7	8
3	3	3	39	139	9
3	4	3	42	3	9
3	5	3	45	5	9
3	6	3	48	5	9
4	4	1	51	1054	10
4	5	1	54	27	10
4	6	1	57	19	10
4	4	2	52	133	11
4	5	2	55	1	11
4	6	2	58	6	11
4	4	3	53	46	12
4	5	3	56	2	12
4	6	3	59	1	12
5	1	2	62	1	13
5	5	2	64	39	13
5	5	1	63	659	14
5	6	1	66	7	14
5	5	3	65	17	15
1	99	1	19	2	
1	99	3	20	1	
2	99	2	36	1	
3	99	1	49	3	
3	99	3	50	1	
4	99	1	60	7	
4	99	3	61	5	
5	99	1	67	4	
5	99	2	68	1	
5	99	3	69	2	

Table 2. Potential gages for use in Illinois' flow model. HUC unit refers to the USGS' hydrological unit code, which identifies the major watershed in which the gage resides. DA refers to drainage area (in km^2). Mean slope was extracted for the GIS attributes provided to the contractor.

USGS Gage	Site Name	HUC Unit	DA (km^2)	Mean Slope
3336645	MIDDLE FORK VERMILION RIVER ABOVE OAKWOOD, IL	5120109	1106.64	0.4151
3343400	EMBARRAS RIVER NEAR CAMARGO, IL	5120112	475.36	0.1564
3345500	EMBARRAS RIVER AT STE. MARIE, IL	5120112	3869.58	0.5913
3346000	NORTH FORK EMBARRAS RIVER NEAR OBLONG, IL	5120112	814.35	0.7882
3378000	BONPAS CREEK AT BROWNS, IL	5120113	584.66	1.3111
3379500	LITTLE WABASH RIVER BELOW CLAY CITY, IL	5120114	2898.18	0.6532
3382100	SOUTH FORK SALINE RIVER NR CARRIER MILLS, IL	5140204	375.73	2.8997
3384450	LUSK CREEK NEAR EDDYVILLE, IL	5140203	109.83	5.4170
5414820	SINSINAWA RIVER NEAR MENOMINEE, IL	7060005	103.59	3.3237
5435500	PECATONICA RIVER AT FREEPORT, IL	7090003	3412.43	3.8730
5438500	KISHWAUKEE RIVER AT BELVIDERE, IL	7090006	1391.94	0.5396
5439000	SOUTH BRANCH KISHWAUKEE RIVER AT DEKALB, IL	7090006	199.50	0.1609
5439500	SOUTH BRANCH KISHWAUKEE RIVER NR FAIRDALE IL	7090006	994.03	0.3435
5440000	KISHWAUKEE RIVER NEAR PERRYVILLE, IL	7090006	2834.32	0.4960
5444000	ELKHORN CREEK NEAR PENROSE, IL	7090005	373.07	1.7969
5447500	GREEN RIVER NEAR GENESEO, IL	7090007	2562.75	0.7840
5466000	EDWARDS RIVER NEAR ORION, IL	7080104	397.95	1.3295
5466500	EDWARDS RIVER NEAR NEW BOSTON, IL	7080104	1140.38	1.7500
5469000	HENDERSON CREEK NEAR OQUAWKA, IL	7080104	1114.43	1.0595
5495500	BEAR CREEK NEAR MARCELLINE, IL	7110001	894.11	1.4492
5518000	KANKAKEE RIVER AT SHELBY, IND.	7120001	4565.33	0.3706
5519000	SINGLETON DITCH AT SCHNEIDER, IND.	7120001	315.87	0.6004
5520500	KANKAKEE RIVER AT MOMENCE, IL	7120001	5893.80	0.3717
5524500	IROQUOIS RIVER NEAR FORESMAN, IND.	7120002	1152.34	0.2160
5525000	IROQUOIS RIVER AT IROQUOIS, IL	7120002	1759.42	0.2023
5525500	SUGAR CREEK AT MILFORD, IL	7120002	1146.88	0.2344
5526000	IROQUOIS RIVER NEAR CHEBANSE, IL	7120002	5352.95	0.2016
5527800	DES PLAINES RIVER AT RUSSELL, IL	7120004	314.91	0.7767
5528500	BUFFALO CREEK NEAR WHEELING, IL	7120004	50.44	0.9184
5529000	DES PLAINES RIVER NEAR DES PLAINES, IL	7120004	924.35	0.7371
5529500	MC DONALD CREEK NEAR MOUNT PROSPECT, IL	7120004	20.28	0.2677
5530000	WELLER CREEK AT DES PLAINES, IL	7120004	33.81	0.2215
5532000	ADDISON CREEK AT BELLWOOD, IL	7120004	46.72	0.2643
5534500	NORTH BRANCH CHICAGO RIVER AT DEERFIELD, IL	7120003	50.60	0.3487
5535000	SKOKIE RIVER AT LAKE FOREST, IL	7120003	29.67	0.3489
5535070	SKOKIE RIVER NEAR HIGHLAND PARK, IL	7120003	50.62	0.4108
5536255	BUTTERFIELD CREEK AT FLOSSMOOR, IL	7120003	60.05	0.4381
5536340	MIDLOTHIAN CREEK AT OAK FOREST, IL	7120003	30.95	0.6155
5536500	TINLEY CREEK NEAR PALOS PARK, IL	7120003	28.86	0.8462
5537500	LONG RUN NEAR LEMONT, IL	7120004	53.59	1.2585
5539000	HICKORY CREEK AT JOLIET, IL	7120004	275.40	0.8647
5545750	FOX RIVER, WI	7120006	2072.45	1.3683
5548280	NIPPERSINK CREEK NEAR SPRING GROVE, IL	7120006	493.72	0.9216
5551200	FERSON CREEK NEAR ST. CHARLES, IL	7120007	132.86	0.9622
5555300	VERMILION RIVER NEAR LEONORE, IL	7130002	3221.25	0.2232
5556500	BIG BUREAU CREEK AT PRINCETON, IL	7130001	500.52	0.5807
5568800	INDIAN CREEK NEAR WYOMING, IL	7130005	162.05	1.2837
5569500	SPOON RIVER AT LONDON MILLS, IL	7130005	2742.36	1.5034
5570000	SPOON RIVER AT SEVILLE, IL	7130005	4193.09	1.5822
5570910	SANGAMON RIVER AT FISHER, IL	7130006	615.52	0.3558

Table 2. Cont.

5572000	SANGAMON RIVER AT MONTICELLO, IL	7130006	1411.49	0.3835
5579500	LAKE FORK NEAR CORNLAND, IL	7130009	547.03	0.2500
5582000	SALT CREEK NEAR GREENVIEW, IL	7130009	4622.26	0.4782
5583000	SANGAMON RIVER NEAR OAKFORD, IL	7130008	13045.47	0.4649
5584500	LA MOINE RIVER AT COLMAR, IL	7130010	1678.21	1.1018
5585000	LA MOINE RIVER AT RIPLEY, IL	7130010	3319.76	1.4936
5587000	MACOUPIN CREEK NEAR KANE, IL	7130012	2216.52	1.0124
5587900	CAHOKIA CREEK AT EDWARDSVILLE, IL	7140101	540.31	1.4025
5588000	INDIAN CREEK AT WANDA, IL	7140101	95.78	1.1478
5591550	WHITLEY CREEK NEAR ALLENVILLE, IL	7140201	95.15	0.2015
5592800	HURRICANE CREEK NEAR MULBERRY GROVE, IL	7140202	388.71	0.9912
5592900	EAST FORK KASKASKIA RIVER NEAR SANDOVAL, IL	7140202	288.82	0.7392
5593520	CROOKED CREEK NEAR HOFFMAN, IL	7140202	651.65	0.4654
5593575	LITTLE CROOKED CREEK NEAR NEW MINDEN, IL	7140202	214.09	0.2914
5594450	SILVER CREEK NEAR TROY, IL	7140204	395.49	0.6630
5594800	SILVER CREEK NEAR FREEBURG, IL	7140204	1193.88	0.8000
5595730	RAYSE CREEK NEAR WALTONVILLE, IL	7140106	234.13	0.7289

Table 3. Results from the Principal Components Analysis (PCA) used to assess similarity in stream habitat variables among sites. Values in the table represent factor loading coefficients; bold values within a column indicate variables that were most highly correlated with the respective principal component (i.e., PC 1 and PC 2).

Habitat Variable	Principal Component	
	1	2
CFS	**-0.6015**	-0.0373
Mean wetted width	**-0.5989**	0.0600
Mean wetted depth	**-0.4893**	-0.0625
Percent canopy cover	0.1607	**-0.6609**
Water temperature	0.1197	**0.7445**