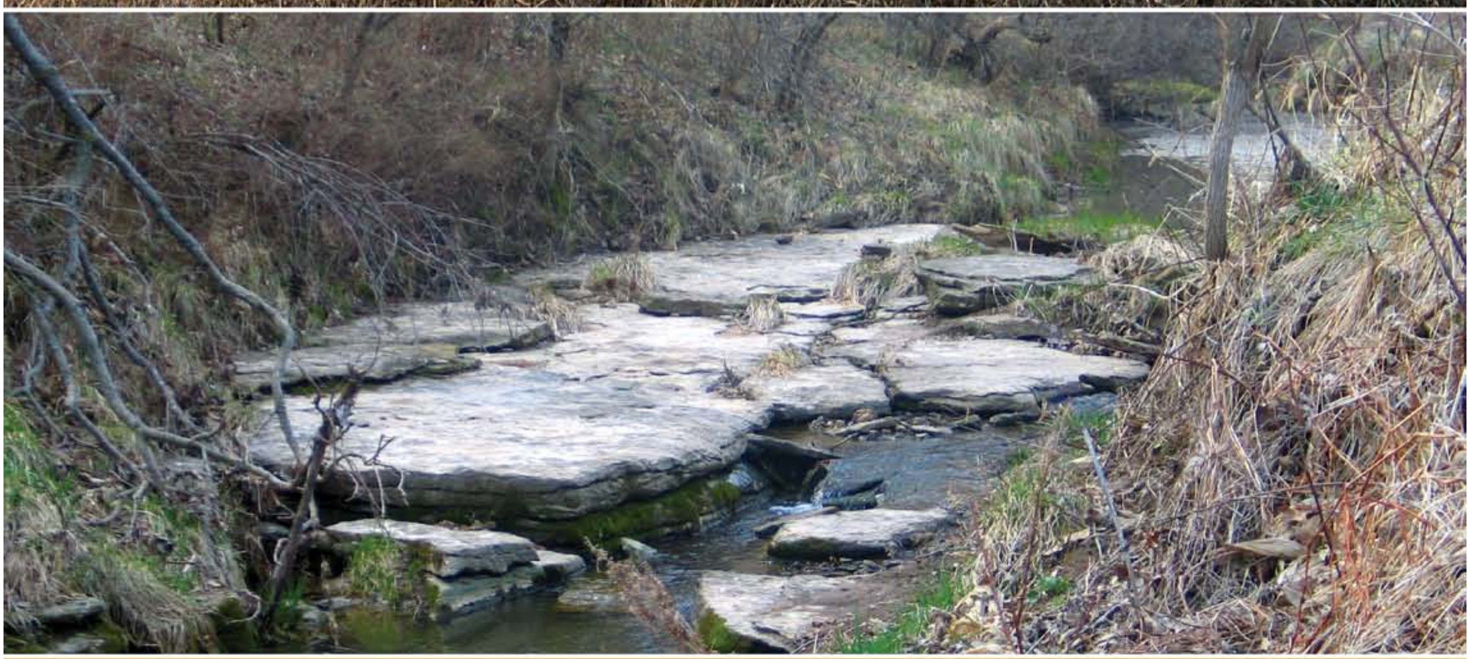

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Geomorphic Assessment of the Middle and Lower Swan Lake Watershed, Calhoun Division of Two Rivers National Wildlife Refuge

Laura Keefer and Erin Bauer

Illinois State Water Survey
Institute of Natural Resource Sustainability
University of Illinois at Urbana-Champaign

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by

Laura Keefer, M.S.
Fluvial Geomorphologist
And
Erin Bauer, M.S.
Watershed Specialist

Illinois State Water Survey
Institute of Natural Resource Sustainability
University of Illinois at Urbana-Champaign
Champaign, IL

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Champaign, IL

Introduction

Swan Lake is part of a complex of backwater lakes along the Illinois River and the one closest to the confluence with the Mississippi River (Figure 1). These backwater lakes were created as a result of significant and complicated glacial activities in recent geologic history. During this period the Mississippi River shifted from its former position, which is currently the Illinois River Valley between Hennepin and Grafton, Illinois, to its current location. This valley was made even wider due to even much larger flows in pre- and post-glacial times resulting in an oversized valley for the relatively lower flows of the current Illinois River. Other marked changes have taken place in the region over the last two centuries due to human influence. Agricultural land uses have almost completely replaced the pre-settlement upland and bottomland forests and the construction of major lock and dams have permanently influenced water levels in the backwater lakes.

During the late-1990s through early-2000s the Swan Lake Habitat Rehabilitation and Enhancement Project (HREP) (Theiling et al., 1995) focused on improving the unique and diverse ecological communities found in this bottomland. One of the significant HREP projects was the segmentation of Swan Lake into three units referred to as Upper, Middle, and Lower Swan Lake. Middle and Lower Swan Lake is within the Calhoun Lake Division of Two Rivers National Wildlife Refuge in Calhoun County, Illinois with a surface area of 10 km^2. The watershed draining to these two units have a combined area of approximately 54 km^2. The watersheds are drained by Metz Creek, Lower Metz Creek, and Deer Plain Creek with a total stream length of 46.7 km (Figure 1).

Because changes in Illinois River water levels and sedimentation have degraded this backwater lake, most of the Swan Lake HREP efforts focused on projects to control water levels and sedimentation from the Illinois River. The HREP also installed practices such as ponds, wetland cells, filter strips, water and sediment control traps, and grade stabilization in the local watersheds on the west side of the lake. However, it appears that sedimentation may still be an issue for Middle and Lower Swan Lake as evident in the formation of deltas at the mouth of the local watershed streams. Understanding and reducing sediment inputs that have contributed to the deltas remains a major long-term challenge (Heitmeyer and Westphall, 2007). Therefore, determining the sources of sedimentation in the lake is an important first step toward developing a watershed management plan to improve the ecological viability in Middle and Lower Swan Lake.

Scope and Objectives

In general, watersheds supply water and sediment to stream channels and floodplains. As the water and sediment supply changes, channels and floodplains continuously adjust to convey and deliver water and sediment downstream. The geologic setting, soils, slope, depositional environments, and bedrock are some of the controlling factors in this adjustment feedback process. Natural and human factors influence changes in water and sediment supply and can occur anywhere in the watershed at anytime. Changes in factors such as climate, vegetation, land use, and channelization can slow or accelerate water movement thereby influencing the energy water has to erode and transport a sediment particle down hillslopes and along stream channels. Accordingly, a watershed and the associated stream channels are constantly dynamically adjusting to maintain a balance between streamflow/channel slope and sediment load/particle size thereby adjusting over time. It is when considerable natural or human changes in the watershed or stream channels cause an imbalance in this process that increased rates of erosion and/or sedimentation are observed (Federal Interagency Stream Restoration Working Group, 1998).

To better understand the watershed and channel adjustment processes responsible for erosion and sedimentation, a geomorphic assessment that ranges from individual stream channel reaches to the entire watershed is useful. By evaluating stream channel character in the context of the watershed landscape over time, the fluvial processes responsible for these interactions can be determined. The assessment framework is provides a systematic, geomorphic evaluation of the fluvial processes for guiding management activities. Components of the assessment are organized into a framework that endeavors to determine the past and current fluvial geomorphic processes through an analysis that compares available data over time and space. Evaluating channel response processes to disturbances responsible for the current channel character is instrumental for formulating future management activities. The assessment also provides long-term datasets to monitor and study future channel adjustments as well as to conduct post-project appraisals for adaptive management opportunities (Downs and Kondolf, 2002).

The objective of this study was to conduct a geomorphic-based watershed assessment focusing on fluvial processes (hereafter referred to as a geomorphic assessment) of the Middle and Lower Swan Lake watershed by the Illinois State Water Survey, Center for Watershed Science (Keefer, 2006). The objective of the assessment was to determine the prevailing erosion processes possibly responsible for the sedimentation in Swan Lake. It is anticipated that if these processes are documented through investigation of the stream channel character within the context of the watershed, the U.S. Fish and Wildlife Service (USFWS) can then collaborate with local, state, and federal agencies to develop a more targeted watershed management plan to reduce the local sedimentation in Middle and Lower Swan Lake to meet ecological rehabilitation and enhancement objectives.

Acknowledgements

This study was funded by the U.S. Fish and Wildlife Service, Calhoun Division of Two Rivers National Wildlife Refuge and the USFWS Region 3 Challenge Cost Share Program. The Illinois State Water Survey supported this study through the regular duties of the principal investigator. Curt McMurl was the U.S. Fish and Wildlife Service project manager and his support, cooperation, and assistance throughout this study is greatly appreciated. Appreciation is also given to Debbie Kuhn – Two Rivers National Wildlife Refuge.

Several staff from the Calhoun County Soil and Water Conservation District were extremely helpful in contacting landowners in the watershed to obtain permission to access their property for the field survey of the creeks: Crystal Nance, District Conservationist; Kandy Gress, Soil Conservation Technician; Jane Brangenburg, Administrative Coordinator; and Marsha Presley, Resource Conservationist. The authors are deeply grateful to the land owners in the watershed for graciously allowing access to their property for this study, which would not have been possible without their cooperation.

We appreciate the assistance of David Grimley and Mary Seid of the Illinois State Geological Survey, Institute of Natural Resource Sustainability, University of Illinois, for providing an understanding of the complicated geology in this portion of Calhoun County through their extensive experience in the region. The authors wish to acknowledge the significant contributions of the following ISWS project staff: Field crew – Long Duong, Joy Miller, and Jon Rodsater; Database development – Mary Richardson and Brad Larson; GIS database & map development – Brad Larson. Sara Olson created the report cover and supervised figure development; Lisa Sheppard edited the report; and Patti Hill assisted in compiling and formatting the final report.

Geomorphic Assessment

Assessment Approach

The geomorphic assessment framework developed by the Illinois State Water Survey (Keefer, 2006) has three levels of investigation: watershed-scale characterization, reach-scale characterization, and evaluation/assessment. The assessment involves collection and analysis of past and current data at watershed- and reach-scales. To understand any underlying factors and events leading to the existing channel character it is essential to assess over time and space. Historical information on watershed and channel conditions, existing data on geologic, topographic, and hydrologic attributes that govern stream dynamics, and field data on current channel conditions are used to establish the temporal context of the watershed. By evaluating the disturbance history, watershed-scale controls, and current channel conditions, it is possible to infer the causal mechanisms producing the channel conditions.

Watershed-scale characterization: The objective of the watershed-scale characterization is to establish the physical character of the watershed and stream channels over time and space to determine the prevailing erosion processes responding to changes in the watershed or channels. This is accomplished by performing a historical analysis and field survey. The historical analysis gathers, synthesizes, and contrasts available historical and recent information to establish the physical character of the watershed, identify disturbances that possibly triggered changes in water and sediment supply, and correlate the data with associated observed channel character so it can be assessed in the context of the identified disturbances. Table 1 lists the typical data sources used in the watershed-scale characterization. The field survey supplements the historical analysis by establishing current channel conditions throughout the watershed. Also, the field survey rapidly measures basic channel geometry as well as ranks channel stability and biological habitat characteristics.

The field survey uses the Channel-Stability Ranking Scheme (CSRS), Bank Height/Slope Measurements (BHS), and Biological/Habitat Ranking Scheme (BHRS) field forms which can be found in Appendix A. The CSRS is a rapid assessment adapted from a method developed at the USDA-ARS National Sedimentation Laboratory (Simon and Downs, 1995; Kuhnle and Simon, 2000; Simon et al., 2002) and ranks channel characteristics into a channel-stability index (CSI). The principal use of the CSI is to determine the relative distribution of the stability rankings between sites to detect possible system-wide channel adjustment processes. The index has a possible maximum score of 36. The general guideline for assessing the scores is: <10 – stable; >20 – likely instability; 10-20 – potential for instability depending on indexes bounding the site, and the higher the index score the more unstable the reach (personal communication; Simon, June 2003; Simon, Bingner et al., 2002).

Table 1. Data Types in Historical Analysis of Watershed-Scale Characterization

Watershed Physical Character	Identification of Potential Disturbances	Hydraulic & Channel Geometry
Physiographic Divisions	Maps/Aerial & Ground Photography	Streamflow records
Geology (bedrock)	Drainage projects, roadway/causeway construction plans	Sediment data
Surficial materials (glacial)	Bathymetric surveys	Channel geometry
Soil character	Climate	Channel gradient
Climate	Land use/cover	Drainage projects, roadway/causeway construction plans
Land use/cover	Past scientific studies, travel accounts, news media/interviews	

A rapid Biological/Habitat Ranking Scheme (BHRS) is also adapted from the National Sedimentation Laboratory (Kuhnle and Simon, 2000) and is based on a USEPA method by Barbour et al., 1999). The BHRS will also be used at each field site to establish habitat conditions in the context of the prevailing channel conditions. A Biological/ Habitat Index (BHI) has a total possible score of 40 which represents good biological habitat conditions. The approach by Barbour et al. (1999) specifies that a ratio between the score for the site in question and the score of a reference condition in the area (percent comparability) be computed. This way a station is classified with respect to reference conditions in a particular region. However, in this geomorphic assessment, the overall interpretation of the channel reach is assessed by the inverse relationship between the CSI and BHI scores. This avoids the need to define, locate, and establish reference conditions and instead focus on the fluvial processes at work in the watershed.

The results of the watershed-scale characterization are examined in the context of the historical analysis and assesses whether 1) only discrete local adjustments are occurring, which would conclude the geomorphic assessment, 2) system-wide adjustments are present with possible associated causes with a necessity to continue to the reach-scale characterization level, or 3) results are inconclusive and further data collection options need to be determined.

Reach-scale characterization: The objective of a reach-scale characterization is to document the current character of stream channels in the watershed by collecting more detailed field data on channel morphology. It also collects data that spatially coincides with any historical site data compiled in the watershed-scale characterization which allows for temporal evaluation of the reach. The objectives are accomplished by collecting and recording detailed, quantitative data at a subset of sites drawn from the initial field survey. These sites, hereafter referred to as "reconnaissance sites", will have information recorded on data sheets to serve as a permanent, standardized record of a site reach, as well as provide supporting information for a final evaluation of the stream dynamics. Most of the information on the data sheets is qualitative in nature, such as sketches of bed and bank forms and photographs of channel features for documentation, but is more focused and detailed than data collected in the initial field survey. The quantitative information includes instrument-surveyed channel cross-sections, collection of bed and bank material for particle size distribution analysis, and estimates on the extent and type of riparian vegetation. The Geomorphic Assessment Stream-Evaluation (GASE) data sheet used for the reach-scale characterization can be found in Appendix A.

Evaluation and Assessment: The objective of the evaluation and assessment component is to analyze the changes in channel character over time to determine potential future adjustments of the stream channel throughout the fluvial system. The watershed- and reach-scale characterizations concentrate on documenting past conditions and current character of a channel. The temporal and spatial elements are compiled from both of these characterizations to evaluate the channel responses to natural and human disturbances to date and, if sufficient data is available, extrapolate trends in channel adjustments to infer the type and magnitude of future channel adjustments. Trends are determined by converging multiple types of characterizations forming a representation of expected channel adjustment morphologies. This process increases the likelihood of overcoming absences or limitations of data such that reasonable inferences of future channel character and associated potential for erosion or sedimentation can be made

Watershed-Scale Characterization

Historical Analysis

An extensive review of the physical character of the Calhoun and Gilbert Lake Divisions of Two Rivers National Wildlife Refuge is covered in a report by Heitmeyer and Westphall, 2007. Therefore, except for brief summaries, information found in that report will not be repeated here and the reader will be referred there as needed. For this study the geomorphic assessment was intended to isolate the physical characteristics of the watersheds located to the west of lower and middle Swan Lake that are outside the Calhoun Division Refuge boundaries. This section identifies and describes those physical characteristics that play a role in erosive and resistive forces in the watershed fluvial processes. Table 2 lists available data that was located and retrieved for the historical analysis.

Table 2. Available Data Types for Swan Lake Historical Analysis (shown as underlined)

Watershed Physical Character	Identification of Potential Disturbances	Hydraulic & Channel Geometry
<u>Physiographic Divisions</u>	<u>Maps/Aerial & Ground Photography</u>	Streamflow records
<u>Geology (bedrock)</u>	Drainage projects, roadway/causeway construction plans	Sediment data
<u>Surficial materials (glacial)</u>	<u>Bathymetric surveys</u>	Channel geometry
<u>Soil character</u>	<u>Climate</u>	Channel gradient
<u>Climate</u>	<u>Land use/cover</u>	Drainage projects, roadway/causeway construction plans
<u>Land use/cover</u>	Past scientific studies, travel accounts, news media/interviews	

The analysis is divided into three sections (watershed physical character, potential disturbances, and hydraulic and channel geometry) where each associated data type is presented and discussed. The physical character section establishes the natural physical controlling factors present in the watershed. The geology, land cover, and climate determine the effect of erosional forces of water movement. For example, a channel that is adjusting through the process of incising and widening in a watershed covered with 4 meters of loess underlain by limestone bedrock, is assumed to take a longer period of time to reach the bedrock than if there was only 1 meter of loess. Once there, the stream power would redirect the erosive energy from the resistant bedrock to more extensive bank widening or increase in meander amplitude. Knowing this time difference would be useful in determining future restoration measures. Identifying potential disturbances assists in determining if significant historical human or natural activities have changed the energy balance of the watershed, usually by increasing or decreasing the erosional resistance. For example, removing meander bends, converting forest to urban land covers or row agriculture, clearing woody vegetation from stream channel banks, or constricting streamflow with a bridge. Finally, hydraulic and channel geometry establishes rates of channel degradation or aggradation and compares that to identified disturbances. Also, the rates can give insight to the expected future erosion conditions, thereby providing more information for compiling a watershed management plan.

Current Physical Character of Watershed

Physiography (geomorphology, geology, surficial materials). The western watersheds of middle and lower Swan Lakes lie in the northern segment of the Salem Plateau section of the Ozark Plateaus Province (Figure 2). The Salem Plateau section is characterized by a mature dissected landscape dominated by a central ridge that runs from the Cap au Grès flexure in the north to the Shawnee Hills to the south (Leighton et al., 1948). This area was not glaciated by the pre-Illinoian and Illinoian ice sheets. The uplands are underlain by limestone bedrock which is covered with a thick layer of loess of up to 6 meters (20 feet) (Figures 3 and 4). Alluvial and stratified lake deposits accumulated after each glacier surge forming the terraces in the lowlands, most recently during the Wisconsinan glacial episode (Seid and Devera, 2008).

The middle and lower Swan Lake watersheds are bounded on the west by Dividing Ridge which lies between the Illinois and Mississippi Rivers (Figure 5) (Rubey, 1952). The northern boundary of the watershed, Metz Creek watershed, is the Cap au Grès Faulted Flexure. To the south, the Deer Plain Creek watershed is bounded by the low-lying areas of Deer Plain and Calhoun Point, a sliver of land between the Mississippi and Illinois Rivers. Figure 6 is a 10m x 10m Digital Elevation Model (DEM) of the Swan Lake region. Land surface elevations within the study watershed ranged from 127.7 m (491 ft) at Swan Lake to 207.9 m (682 ft) in the upland hills (Dividing Ridge). The elevation of the Illinois River is 127.7 m (419 ft) within the pool of Lock and Dam 26 on the Mississippi River. The natural elevation of the lake, prior to commissioning of Lock and Dam 26 in 1938 was ~125.6 m (412 ft).

Inspection of the DEM, shows the Middle and Lower Swan Lake tributaries draining from the upland Dividing Ridge to the floodplain. The main tributaries have wider valleys than the secondary stream branches and have elevations closer to the lowland near the lake than the uplands. To determine the magnitude and distribution of stream elevation, the DEM was used to estimate percent stream slopes every 100m of stream length and is presented in Figure 7a. Except for minor occurrences of 1 – 2 percent slopes, a stream slope of <1.0 percent dominates significant stream distances and slopes of >2 percent are located in the extreme headwater portions of the stream network. Figure 7b further illustrates the slopes by showing the elevation profile of all three creeks with a vertical scale exaggeration of approximately 39:1.

Figure 8 illustrates three distinct geomorphic (landform sediment assemblage) features in the study area. Landform Sediment Assemblage (LSA) units were generalized to more easily distinguish the features. The LSA units describe the distribution, type, and age of geologic deposits and landforms along the Illinois Valley as reported by Hajic (2000) using geomorphic maps and available subsurface information. Along Swan Lake, the first geomorphic feature is the floodplain including the alluvial fans along the lake. The floodplain was previously covered by bottomland forest and bottomland prairie (Heitmeyer and Westphall, 2007). Currently, levees divide the floodplain into cropland, wildlife conservation prairie, and bottomland forest. Floodplain elevations range from 127.7 m at the lake to approximately 131 m at the second feature, Deer Plain Terrace. The western boundary of the Refuge roughly follows the nearly linear transition between floodplain and Deer Plain Terrace. Deer Plain Terrace surface elevations range from 131 to 140m. The savanna-like surface is easily recognized as paralleling the Illinois and Mississippi Rivers and is intersected occasionally by the active tributaries to Swan Lake. Deer Plain Terrace and uplands to the west were previously covered by upland forest until converted to agricultural production beginning in the 1800s (Heitmeyer and Westphall, 2007).

Climate. Precipitation data were retrieved from the Midwest Climate Center for climate stations at Grafton, Illinois and St. Charles, Missouri. The St. Charles station is approximately 22 km southeast of Brussels, IL and the Grafton station is approximately 14 km east of Brussels. The 30-year (1971-2000) annual mean precipitation for both stations are presented in Table 3, as well as the maximum and minimum annual precipitation for the entire data record for each station.

Table 3. St. Charles, MO and Grafton, IL 30-yr Annual Mean Precipitation with Station Record Annual Maximum and Minimum Precipitation

Station	Period of Record (years)	30-year Mean Precipitation (1971-2000)	Record Maximum Precipitation	Record Minimum Precipitation
			cm (inches)	
Grafton, IL	1894-1999	97.13 (38.24)	*1942* 142.04 (55.92)	*1953* 50.11 (19.73)
St. Charles, MO	1894-2009	101.93 (40.13)	*2008* 155.68 (61.29)	*1930* 48.41 (19.06)

Both station records began in 1894 and the St. Charles station continues to present, whereas the Grafton record closed in 1999. The 30-yr mean annual precipitation (1971-2000) is similar between stations (97.13 and 101.93 cm) and might be closer if the Grafton station included 2000 annual data. The St. Charles station is more complete and has the annual precipitation for the period of record illustrated in Figure 9. The lowest annual precipitation occurred in 1930 whereas the highest was 2008. An 11-year moving average of the annual data appears to show three periods of high annual precipitation around 1910, 1945, and 1998 with two lower periods near 1935 and mid-1950s to late 1970s (Figure 9). A sustained increase in annual precipitation appears from the late 1970s to late-1990s.

The monthly precipitation data for the St. Charles station was divided into wet (January – June) and dry (July – December) seasons to examine the character of precipitation within a year and is shown in Figure 10. The 1910 and 1945 periods of high annual precipitation appears to coincide with occurrences of peak wet and dry season precipitation. The 1998 period appears to be due to extreme wet season precipitation and inversely related decrease in annual dry season precipitation. The dry season period during this time peaked around 1990, 8 years prior to the wet season peak. From 1998 to the mid-2000s, there is a decline in wet season annual precipitation with an increase in dry season. However, inspection of annual precipitation in Figure 9 shows an extreme increase in 2008 and 2009 annual precipitation.

Land Use/Cover. In recent years, several sources of digital land cover information are available. These data can be selected for specific areas of interest and have been available for approximately the last 10 years. The United States Department of Agriculture (USDA), National Agricultural Statistics Service (NASS) Cropland Data Layer (CDL) is a raster, geo-referenced, categorized land cover data layer developed from satellite imagery that focuses on cropland but all land covers are recorded. NASS uses broad land use categories to define land that is not under cultivation, including non-agricultural, pasture/rangeland, water, woods, and farmstead. A detailed description of the USDA-NASS Illinois CDLs can be found in the Illinois Geospatial Clearinghouse at the Illinois State Geological Survey (http://www.isgs.illinois.edu/nsdihome/webdocs/landcover/index.html). The Calhoun County land cover data for 1999 and 2008 were retrieved for this study. It is noted that there were different technologies and interpretation techniques used to develop the 1999 and 2008 surveys. Therefore, it is more reasonable to make relative comparisons between land uses rather than making interpretations on exact areas covered.

Figure 11 shows the 1999 and 2008 NASS land use categories for Calhoun County. The 1999 NASS survey had fewer categories than the 2008 survey. For comparison over time it was possible to match most categories except for the 1999 "non-agricultural" category. The 1999 pasture/grass category is markedly different from the 2008 survey. It is assumed that the 2008 pasture/grass category equivalent is spread between the pasture/grass, developed/open space, and pasture/hay categories which would increase 2008 to near the 1999 figures. For both 1999 and 2008 corn, soybeans, open water, and deciduous forest are the predominant land uses in Calhoun County with open water (11 percent), wetlands (11 percent), and deciduous forest (43 percent) occupying a total of 65 percent of the county. Agricultural production is approximately 30 percent.

The 1925-2008 NASS Illinois Agricultural Statistics database contains area of crops harvested for Calhoun County (hectares). Figure 12 shows area of crops harvested for corn, barley, hay, oats, sorghum, soybeans, and wheat. In general, harvested corn, hay, and wheat were relatively steady over the 86 year period with soybeans increasing from 1927 to present and somewhat equaling the area of corn harvested from 1995 to 2006. Oats were harvested more often during 1940-1960 and have not been harvested in the county since 1990. Total crop area harvested was relatively steady from 1925 through the 1970s then increased by approximately 5,000 ha through 2006 (7 percent of the total county land area), and decreased to previous levels. The 1925-2008 average percent of agricultural crop area harvested in the county is 24 percent and a maximum of 32 percent in the mid-1990s. This is a similar percent to the agriculture production area estimated in the 1999 and 2008 NASS surveys.

Figure 13 shows the 2008 percent area of NASS land use categories for Metz, Lower Metz, and Deer Plain Creek watersheds. The predominant land use categories across all three watersheds are corn, soybeans, open space, deciduous forest, pasture/hay, and woody wetlands. This was similar to the county wide NASS survey data. The main observations are that the Metz Creek watershed generally had higher percent area in corn and soybeans than deciduous forest and pasture/hay, whereas Lower Metz Creek watershed was the opposite. In 2008 the Deer Plain Creek watershed had significantly more area in corn than soybeans and more area in pasture/hay than deciduous forest. Also, in comparison, 45 percent of the area for all three watersheds is approximately used for agriculture and 17 percent in deciduous forest, whereas Calhoun County is 30 percent agriculture and 43 percent deciduous forest. Figure 14 shows the distribution of the 2008 NASS survey land use categories for the Swan Lake watersheds. The wetlands, woody wetlands, and deciduous forests are predominantly in the Deer Plain Terrace area, the uplands is mostly covered by pasture/grass and deciduous forest, and the area between is predominantly row crop agriculture.

Potential Direct and Indirect Disturbances

Topographic maps, aerial photography, ground-based photography. Changes in channel planform over time can be an indicator of disturbances in the channel or watershed. Adjustments in channel planform are determined by comparing stream channel planforms between discrete time periods. The stream channel is digitized by using Geographic Information System (GIS) techniques from georectified historical and recent aerial photography or satellite imagery. Figure15 shows the stream channel planforms and open-water shorelines of Swan Lake in the 1940s and recent times. The oldest aerial photographs in Illinois were taken during 1938-41 and many have been scanned and geo-rectified through a program at the Illinois State Geological Survey (http://www.isgs.uiuc.edu/nsdihome/webdocs/ilhap/). The present day planform was determined from the 2007 USGS Digital Ortho-Quadrangles (DOQs) (Illinois Geospatial Clearinghouse; http://www.isgs.uiuc.edu/nsdihome/ISGSindex.html). The spatial extent of open water in Swan Lake was digitized and is presented as shoreline in Figure 15. In addition, the 1931 and 1940 shorelines were determined using Lower Alton Pool aerial photography obtained from the Upper Midwest Environmental Sciences Center (http://www.umesc.er.usgs.gov) and 2007 shoreline using USDA-FSA imagery. As seen in Figure 15, there have been virtually no lateral channel adjustments in the uplands area due to the mature dissected character of the watershed. The only observable changes in stream channel planform are in Deer Plain Terrace and the alluvial fan areas nearest Swan Lake partly due to alluvial fan (delta) extension since 1940 and recent HREP restoration efforts.

Planform changes of any physical features in a watershed are also useful in determining potential disturbances or observing natural adjustments over time. Table 4 lists 11 sets of imagery retrieved for Swan Lake and surrounding areas between 1902-04 and 2009. Because several of the older resources did not cover the entire study watershed, this investigation focused on the Swan Lake, floodplain, and Deer Plain Terrace areas. Figures 16a and 16b illustrate the 1904 Woermann maps and the 2009 National Agricultural Imagery Program (NAIP) digital ortho quarter quads (DOQQ), respectively. Both figures show the present and 1940 open-water shorelines and stream channels, floodplain boundary (demarcation between the floodplain and Deer Plain Terrace), 1931 open-water shoreline, and, for reference, location of the Calhoun Division of Two Rivers National Wildlife Refuge office (Refuge Office). Additionally, the 1904 map (Figure 16a) has the Swan Lake/stream channels delineated as well as the western edge of timber and brush that was noted on the map. The 1931 (purple) and 1940 (red) open-water shoreline information is included to represent the extent of open water before and after the construction of the Alton Lock & Dam on the Mississippi River.

As seen in Figure 16a, in 1904 (green line) the lower section of Swan Lake was narrower and located on the eastern border of its current location, paralleling the Illinois River. Based on the 1904 contour lines, all three creeks appear to have been developing deltas extending beyond Deer Plain Terrace on to the floodplain. Metz Creek (labeled Fuller Creek on the original map) and Lower Metz Creek were determined by the U.S. Army Corps of Engineers Woermann maps (Woermann, 1904) to have a conveyance channel all the way to Swan Lake, whereas Deer Plain Creek does not. Lower Metz Creek is labeled a “ditch” from the floodplain border, beyond its delta, and out to Swan Lake. However, these channels are hidden in the tree canopy in the 1931 photos. The 1931 open-water shoreline boundary shows Swan Lake slightly more narrow with the addition of an isolated open water body in what is now known as the lower segment of Swan Lake. The profound effect of the Alton Lock & Dam is evident from the 1940 open-water shoreline. It is located slightly west of the 2007 open-water shoreline and somewhat inundated the deltas as represented by the 1904 contour lines. The 1940 stream channels appear not to be connected with the larger Swan Lake. Thick tree canopy make it difficult to determine a defined channel near the lake. Upon closer inspection of the photography, there appears to be small braided channels fanning out over the delta area to the lake. Since the previous timber and brush areas are now inundated, it is assumed the previous channels were submerged and the creeks were in the process of adjusting their course under this higher base elevation. Finally, the 2007 open-water shoreline shows some delta expansion for all three creek outlets. The present stream channels have also shifted their outlet positions most likely due to HREP activities. Figure 16b shows the 2009 imagery with the 1931, 1940, and 2007 open-water shoreline and stream channels for reference. At the time the 2009 imagery was collected the USFWS was in a period of managed draw down for segments of Swan Lake. Full page-size images of Figure 16 as well as the other images listed in Table 4 can be found in Appendix B.

Table 4. List of Maps and Aerial Imagery of Swan Lake and Immediate Area

Year (Date)	Source Agency/Program	Type Media
1902-1904	Woermann - USCOE	Drawn maps
1931 (Oct. 25)	USCOE	Drawn maps (updated with 1931 aerial photography)
1931 (Oct. 25)	Upper Midwest Environmental Science Center, Wisconsin	Aerial photography
1940 (Jun. 19)	Upper Midwest Environmental Science Center, Wisconsin	Aerial Photography
1974 (Dec. 9)	Contracted by ISWS for Illinois River	Aerial Photography
1999 (Mar. 25)	USGS	Digital Ortho Quads
2004, 2005, 2006, 2007, and 2009 (Agricultural growing season)	USDA – National Agricultural Imagery Program (NAIP)	Digital Ortho Quarter Quads

Drainage projects, road and causeway construction plans, and bathymetric surveys. Most projects or construction activities that have influenced drainage in Swan Lake and watershed occurred either in the floodplain and Deer Plain Terrace or Illinois River and downstream on the Mississippi River. Some of these activities are associated with HREP restoration of the ecology of the Swan Lake complex and are extensively documented in Heitmeyer and Westphall (2007). They also have a discussion on the flow regime alterations that have affected Swan Lake in the Illinois and Mississippi River since pre-settlement.

Lake sedimentation surveys can be useful in estimating the contribution of sediment from tributaries over long periods of time. Because Swan Lake receives sediment from the watershed tributaries and Illinois River floodwaters, it would be complicated to determine the discrete contributions from each. However, absolute sedimentation rates could be useful for long-term management purposes. Investigations discovered two extensive bathymetric surveys performed for Swan Lake. The first was by Woermann in 1904. Since that time sedimentation of backwater lakes along the Illinois River were investigated by the Illinois State Water Survey in 1975 (Lee and Stall, 1976) and again after the 1993 flood (Demissie, 1996). Lee and Stall (1976) performed a small reconnaissance sedimentation survey which cannot be used to accurately determine the average depth of the lake in 1975. In 1994, a sedimentation survey was performed and a comparative evaluation with the Woermann 1904 map topography (Demissie, 1996) provided information on the sedimentation rate in Swan Lake. Depth plots of 1904 and 1994 cross-sections, "show that as much as 5 feet of sediment has accumulated on the lake bottom since 1904." (Demissie, 1996). Figure 17 shows a cross section of the Swan Lake bed profiles from both surveys. The average depth of Swan Lake in 1994 was calculated at 1.2 feet (Demissie, 1996). Average annual sedimentation rates using Cesium-137 dating techniques were estimated at 1.2 cm/yr from 1962-1994. This average is considered somewhat inflated due to deposition from the 1993 flood. Additional evidence of high sedimentation for land areas adjacent to Swan Lake is noted by Demissie (1996):

> "During the recovery of the horizontal control monumentation from the 1988 MECO [Metropolitan Engineering Company, of Collinsville, Illinois] survey, monuments described in 1988 as exposed by 6 inches were either flush with the soil surface or buried, indicating that these exposed sediments continue to accumulate during high water periods."

It should be noted that the 1993 flood occurred between the 1988 and 1994 surveys. Outside of a study by the Illinois Natural History Survey (Garvey et al., 2007) there has not been another complete lake sedimentation survey performed since 1994. The survey methodology used by Garvey and others (2007) was for a separate purpose and is not comparable to the ISWS 1994 survey. Therefore, sedimentation rates since 1994 cannot be determined at this time.

Climate and Land Use. Fluctuations in precipitation influence runoff and vegetation patterns, which can effect transport capacity and sediment supply of rivers (Knighton, 1998). The long-term (1894-2009) annual mean precipitation at the St. Charles station is 96.8 cm, slightly below the 101.93cm 30-year mean. As seen in Figure 9, an 11-year moving average on the 116-year record showed three wet periods around

1910, 1945, and 1998 with two dryer periods near 1935 and mid-1950s to late 1970s. Further analysis of relationships between wet and dry seasons (Figure 10) showed similar cycles. In general, cycles between wetter and dryer periods can generally be attributed to parallel increases or decreases in wet and dry season precipitation. The 25-year period from 1990 to the mid-2000s is marked by an inverse relationship. The period from 1988 to 1991 shows an increase in wet and dry season precipitation, whereas in 1991 the wet season precipitation continues to increase over 7 cm higher than the highest recorded (1901) whereas the dry season precipitation peaks at this time then decreases. This recent inverse relationship can have the effect of creating conditions where the watershed and stream channels are either very saturated or very dry within any year. Saturated conditions increase runoff from the hillslopes and contribute to higher velocities and out-of-bank conditions in the stream channel. Also, these periods of extreme wet conditions cause flooding in the Illinois River, as well as the Mississippi River, contributing to extended backwater conditions in the floodplain and Deer Plain Terrace reaches of the three Swan Lake tributaries. Very dry conditions stress and weaken vegetation that absorbed rainfall, increase infiltration, and stabilize stream channels. Sediment can then be dislodged and transported downstream when conditions become wetter.

Land use practices and various land covers affect runoff rates in a watershed, which influences transport capacity in streams. In an urban setting, impermeable surfaces can significantly increase runoff rates. Forest, grasslands, pastures and wetlands increase infiltration and reduce runoff. Rowcrop agriculture tends to have higher runoff rates than small grain production, however, conservation tillage and increases in crop residue promote increased infiltration. Documenting trends in land uses and land cover can reveal potential indirect disturbances in a fluvial system.

Land cover in the watershed during the 1800s was dominated by forest in the uplands and Deer Plain Terrace areas, prairie in the floodplains, and forest in Swan Lake (Illinois Natural History Survey, 2002). Figures 11-14 show that currently the types of land uses in the Swan Lake watersheds and Calhoun County are similar. Most agricultural crop production is in corn and soybeans with much of the remaining land area covered by deciduous forests and open water. However, 45 percent of the Swan Lake watersheds are in agricultural production as opposed to 30 percent for the county, whereas deciduous forest covers 17 percent of the watersheds and 43 percent of the county. It is not clear why there is a higher percentage of agricultural production area in the Swan Lake watersheds than the county, as well as a higher percent of deciduous forest in the county than the watersheds. It is clear that the area of Calhoun County north of the Cap au Gres flexure can be as much as 50-70m higher in elevation with steeper hillslopes than the Swan Lake watersheds, which occupy most of the county south of the flexure. This feature alone would make it more conducive to agricultural production in the Swan Lake watersheds.

Based on the similarity of types of crop production between Swan Lake watersheds and Calhoun County, it is reasonable to assume that the same trends in crop area harvested in the county apply to the watersheds. However, the Illinois Agriculture Statistics and the 1999 and 2008 NASS data do not provide a perspective on land in orchards for which this region of the State of Illinois has a long reputation. Orchards typically have a ground cover of grass/sod which is known for stabilizing erodible soils as opposed to row crop agriculture with a higher potential for erosion (U. S. Department of Agriculture, 1989). The Census of Agriculture for Calhoun County reports area in orchards was 21,398 acres in 1930 and steadily decreased to 6940 acres in 1945, 848 acres in 1987, and 546 acres in 2007. This is a drop from 13 percent of the county to 0.3 percent. For further analysis, the 1940 and 2007 imagery were visually investigated for orchards and then digitized (Figure 18a). In 1940, the Swan Lake watersheds had 1,755 acres of land in orchard and 219 acres in 2007, representing 12 and 40 percent of the entire county area in orchard, respectively. The land in orchards during 1940 occupied 13 percent of the Swan Lake watershed area, whereas orchards in 2007 represent less than 2 percent of the watershed area. Figure 18b shows that a significant portion of the 1940 land in orchards were located on the higher elevations of the uplands region of the watersheds. A visual inspection of the 1940 orchards with the 2008 NASS land cover information determined that much of the land formerly in orchards is currently in row crop agriculture but there are several instances where it was converted to deciduous forest or pasture. It is not conclusive that conversion of 11 percent of watershed area from orchard has directly contributed to increase in erosion.

Hydraulic and Channel Geometry

Streamflow records, sediment data, channel geometry. Historical or current records/data for streamflow, suspended sediment, or stream channel geometry are not available for the study area. An attempt was made to determine previous channel geometry using the 1904 Woermann contour maps to the extent of the map. The map contours extended less than 1000 meters upstream in the Swan Lake tributaries. Once these cross sections were constructed they were compared with basic channel geometry measurements made at the nearest field survey station from this geomorphic assessment. Results showed that the1904 channels were once very wide and shallow which correlates with the deltaic environment observed in the Woermann maps. However, the current channels are more ditch-like due to man-made drainage modification. Therefore, this change in channel geometry is not useful in elucidating information on natural channel adjustment morphology.

Field survey

Geomorphic assessment sites for the field survey were selected first based on stream reaches that were likely to be perennial in flow character and then a regular spacing interval. The field site spacing started at the mouth of the tributaries with Swan Lake and sites were located approximately every 600 meters upstream. This initially resulted in 69 field sites for the assessment. Due to backwater flooding from the Illinois River during a portion of the field season, several sites near the mouth of Metz Creek were under water and could not be evaluated. Approximately 7 sites were discovered to be ephemeral with no distinct channel form. Opportunities were taken to add several sites during the course of the field work and at least 2 were not visited due to lack of landowner permissions. This resulted in a total of 58 field sites for the geomorphic assessment field survey (Figure 19).

The basic channel morphology data and scores for each variable from the Channel-Stability Ranking Scheme (CSRS) (Figure 20) were entered into a database and mapped using a GIS system to view the spatial distribution of the field variables. Tables and maps illustrating individual CSRS variables are available in Appendix C. Basic channel morphology data consisted of reach length, average channel width and depth, angle of both banks, and descriptions of bed and bank material. Slope of the reach was obtained through the DEM analysis (Figure 7). The data were estimated using a laser rangefinder, hand level or rangefinder/hypsometer, and hand-held particle size analyzer.

The Biological/Habitat Ranking Scheme (BHRS) scores for each of the variables were also entered into a database and mapped. The BHRS had two versions of the form depending on whether the field site stream reach was low or high gradient (Figure 21a and 21b). Prior to this study only one version of the form was used which combined low/high gradient reach conditions. Due to the anticipated higher gradients in this watershed it was decided to break out the appropriate variables and create two versions (low and high gradient). This created a confusing situation in the field with the result of forms being irregularly applied to field sites. Therefore, only those variables common to both BHRS form versions are presented and discussed in this report. Those variables are: availability of favorable habitat, active streambed/bar deposition, percent streambed exposure, degree of "hard" channel alteration, percent bank instability, vegetative bank protection (bank face), and riparian-zone width (out from edge of water). Based on this experience, the geomorphic assessment protocol will return to one combined BHRS form. Tables and maps illustrating these individual BHRS variables are available in Appendix D.

The assessment maps used to illustrate the spatial distribution of the CSRS and BHRS variables are broad representations to facilitate analysis and comparisons between variables. Each field site is labeled on the map along with a variable represented by color shaded lines that extend half the distance upstream and downstream between sites. The reach length assessed at field sites ranged from 50 to 100 meters and the average distance between field sites was 600 meters. The extension of the shaded lines does not necessarily infer that those reach conditions between field sites are of the same character as the shorter assessed reaches. The extensions are only a visual tool to more easily analyze variable distribution and relationships between stations in a spatial context. However, many times it was possible to traverse the creek in one direction and assess field sites in sequence. This allowed the field crew to observe the representativeness of the field site in context of the upstream/downstream field sites and bounding reaches. Based on these traverses, field sites were added when the field crew suspected something markedly different in the channel character. Nonetheless, the extensions are not to be interpreted as possessing the same values as the variables for assessed field site reaches. To facilitate relationships and interpretations, shaded lines may be of varying widths in order to superimpose variables in the same stream line. Also, seven variables in the CSRS and BHRS were delineated by left and right bank. In these cases, the shaded lines are longitudinally halved to represent those variable conditions for each bank. Left and right banks are determined by an observer facing in the downstream direction of the stream.

Index Scores

Table 5 lists the station (field site) number and the CSI and BHI scores. The maximum possible score for the CSI is 36 and BHI is 40. The CSI scores for each creek ranged as follows: Metz – 5(15)-28; L. Metz – 15-26.5; and Deer Plain – 17-28. Metz Creek had one field site with a CSI of 5 and the next lowest was 15. For each creek, the percentage of field sites that had a CSI ranking of 20 or greater were 76, 64, and 91, respectively, and the percentage with a CSI of 25 or greater were 24, 55, and 32. Figure 22 maps the CSI in all three watersheds. Station 122 in Deer Plain Creek had the CSI of 5; otherwise the other stations are predominantly in the CSI range of 20-25 with isolated lower and higher indices. This range indicates that many of the reaches are on the lower end of being unstable. Many of the most unstable reaches (CSI greater than 25) are located in the downstream segments of all three creeks generally in the Deer Plain Terrace and floodplain regions. The BHI in all three watersheds is mapped in Figure 23 and shows most stations scoring 20 or greater, which indicates a moderate quality of biological habitat. The slightly better than moderate biological habitat (BHI greater than 25) are located in the upland region reaches. Figure 24 shows the BHI scores overlying the CSI scores. In many cases both indices have the same score especially in the 20 to 25 range. In the reaches closest to Swan Lake, the BHI is lower than the CSI indicating the reach has low habitat value in a fairly unstable channel.

Table 5. Station Number and CSI and BHI Scores for Metz Creek, Lower Metz Creek, and Deer Plain Creek

Metz Creek			Lower Metz Creek			Deer Plain Creek		
Station Number	CSI	BHI	Station Number	CSI	BHI	Station Number	CSI	BHI
101	25	22	201	24	21.5	378	23	23.75
102	22.25	25.5	202	26.5	16	379	21	26
103	28	17	203	26	19	380	23	23.5
104	26.5	19	204	25	21	381	21.5	25
105	26	20	205	25	21	382	24	22.5
106	19	28	206	15	28.5	383	20	26.5
107	20	27	208	25	20.5	384	21.5	24.5
108	19	27.5	209	16	22.5	385	24	22
109	27	17.5	210	25	19	386	22	24.5
110	22	26	212	19	22	387	23	23.5
111	21	27	213	19.5	21.5	388	25.5	21
112	24	22.5				389	25.5	20.5
113	20.5	27				390	26	20.5
114	23	23.5				391	26.5	20
115	18.5	28				392	28	20
116	21	27				393	22	24
118	21.5	26.5				394	25	21.5
119	17	28.5				395	23.5	23
120	15	29				396	17	27
121	22.5	25				397	17.5	27
122	5	29				398	25	21
124	22.5	24				399	24.75	22
125	23	23						
126	25	22						
127	23	22.5						

To better evaluate the relationship between the CSI and BHI, Figure 24 highlights each stream segment with a yellow line and is labeled according to the name of the creek and given an arbitrary number (ex. first stream segment for Metz Creek from Swan Lake to head waters is labeled “M1”). A stream segment begins at its headwaters and ends at Swan Lake. Figures 25, 26, and 27 compare the CSI and BHI scores for stream segments of Metz, Lower Metz, and Deer Plain Creeks in longitudinal profile from Swan Lake to the headwaters. Each stream segment is represented by a colored line and is paired with the CSI score as a solid line whereas the BHI score is a dashed line. To compare between creeks the stream distances were computed from a starting point (zero distance) at the Illinois River Road, which is located in the uplands and roughly parallels the Deer Plain Terrace boundary downstream of the road. Distances were computed upstream and downstream from the road, where positive distances are upstream toward the headwaters and negative are downstream toward Swan Lake. The overall interpretation is based on the inverse relationship between the CSI and BHI scores in context with surrounding reaches. It should be noted that the differences between the scores were not large but it is the relationship between them that is being evaluated. The Channel Evolution Model (CEM) stage (Simon and Hupp, 1992) is also plotted to determine if the profile corresponds with this model of systemic channel adjustments by incising and widening.

CSI and BHI stream segments for Metz Creek are shown in Figure 25. Segment M1 (brown) shows that the channel downstream of Illinois River Road (IRR) as critically unstable (>25 CSI) with low biological habitat conditions (<22 BHI). The scores in these reaches are the inverse of one another. Upstream of IRR the condition is generally reversed (BHI scores are higher than the CSI scores), except for near the headwaters. The CSI and BHI scores are <25 and >22, respectively. The best CSI scores were 17 and 17.5 (potentially unstable). Segment M4 (Pohlman Creek) had unstable channel CSI scores peak downstream of IRR and steadily improve upstream. The BHI scores (low habitat conditions) were lowest near Swan Lake and the headwaters but generally better than the CSI score for the remainder of the reaches. Segments M2 and M3 were similar to M1 and M2 downstream of IRR but had high instability and low habitat scores for the middle reaches. Segment M2 had lower channel stability and lower biological habitat conditions (20-22) at the headwater reaches, whereas M3 headwater reaches had higher improving habitat with lower channel instability. In general, except for some issues in segment M2, most issues appear to be downstream of IRR.

Lower Metz Creek is a single segment and is represented by identifier LM1. Figure 26 shows that LM1 has a similar CSI/BHI relationship to the segment of Metz Creek downstream of IRR. The CSI scores hover around 25 and the BHI score is very low (16) and increases almost to IRR but is still less than the CSI score. The relation reverses upstream of IRR showing improved habitat and channel conditions. Conditions oscillate further upstream at the headwaters.

As seen in Figure 27, Deer Plain Creek has the longest profile of the three creeks and has five stream segments. In general, most stream segments exhibited the same conditions downstream of IRR as Metz and Lower Metz Creeks; unstable channels with low biological habitat rankings. Unlike Metz and Lower Metz Creeks, Deer Plain Creek was surveyed at a time when the Illinois River was not flooding upstream, which made it easier to evaluate these lower reaches. Just downstream of IRR, the scores reverse with higher habitat scores than channel stability scores. All segments upstream of IRR, except one reach in segment DP1, maintained the higher habitat to lower channel stability score relationship. Overall, the best CSI and BHI scores were in Deer Plain Creek.

Ranking Scheme Variables

Each of the remaining variables from the CSRS and BHRS were mapped and are presented in Figures 28-37.

The primary streambed material observed was silt/clay in Deer Plain Creek, gravel in Lower Metz Creek, and a mix of gravel and silt/clay in Metz Creek with an isolated area of limestone bedrock in the upper reaches. However, the gravel was loose and did not offer protection from possible downcutting. Except for the reaches with bedrock beds, the primary bank material was silt to sandy silt. This indicates most of the stream channels in all three creeks could be susceptible to downcutting and widening. Types of bank erosion are classified into either none, fluvial, or mass wasting. Fluvial erosion is the gradual wearing away of the banks, whereas mass wasting is the dislodging of large masses of bank material. Mass wasting is a possible indicator of significant channel adjustments and a source for large amounts of sediment to be carried downstream. Figure 28 shows that almost all of the reaches had some type of erosion and most of those are of the fluvial type. There may have been minor portions of a bank mass wasting at a field site but the observed dominant type of erosion was fluvial. Three groups of reaches that indicated erosion by mass wasting were identified, outlined, and labeled A, B, and C for discussion purposes. These same groups are labeled on Figure 29, as well as subsequent figures, which show the percent of the channel bank that is actively eroding. Because large amounts of sediment can be transported downstream when the dominant form of erosion is mass wasting and a significant percentage of a bank is actively eroding, the following discussions focus on comparing CSI and BHI variables within and outside these three groups.

In general, groups A and C had less than 50% of their banks mass wasting and a few reaches with more significant percent of the banks eroding. Group B had greater than 76 percent of the banks actively eroding. The remaining reaches had been identified as slowly eroding by fluvial processes and many of those banks had more than 76 percent of the banks actively eroding, which can slowly deliver substantial sediment downstream over a long period of time. This was the case for Metz and Lower Metz Creeks, whereas the middle reaches of Deer Plain Creek had less than 25 percent eroding banks.

The percent of sediment accreting on a stream bank or bar is an indication of a system balancing the sediment load upstream to downstream, removing all material through a degrading process, or depositing most of the material through an aggrading process. Too little or too much sediment in a channel indicates unstable channel adjustment processes in the stream network and not necessarily at that particular reach. In Figure 30 many of the reaches had less than 10 percent sediment accretion, whereas groups A and C show a range of 11 to 50 percent and 0 to 75 percent, respectively.

Group B had less than 25 percent sediment accretion except for the reaches in the delta which had 26 to 50 percent accretion. The delta reaches are dominated by backwater influences from Illinois River flooding and could have accretion for this reason. The Deer Plain Creek reaches in the areas of Deer Plain Terrace and the floodplain also indicated sand for primary bed material which is dropped out of suspension and deposited under these types of backwater conditions.

Vegetation with woody characteristics, such as small trees and brush, increase stream bank resistance (roughness) and offer protection from erosion. Also, depending on the plant, vegetation can offer some protection to the bank face. Figures 31 and 32 show the percent of established woody cover on banks (CSRS) and vegetative bank protection (BHRS), respectively. Group B had the least woody cover or vegetative protection and group C was somewhat better with 25 to 75 percent of the banks in woody cover and 50-70% of the banks covered by some vegetation. Two of the three reaches in group A had greater than 90% of the bank protected by vegetation, whereas the third had high disruption of vegetative protection. Group A woody cover was mixed between 11 and 75%. The riparian zone width (Figure 33), measured out from the edge of the water for each bank, was usually less than 5 meters for most of the reaches including groups A and C. The riparian zone width ranged from less than 5 to greater than 20 meters for 2 reaches in group B. At times it was observed that sediment accumulated along the edge of agricultural fields along the narrow riparian zones. Also, there was a discontinuity of riparian zones along the streams.

In some cases it was observed that wild-grape vines were present and dominated some timbered riparian zones. The vines ranged from young to mature and covered many trees, especially the large, older trees. It was assumed that long-term shading of the vines had weakened the trees. Many vine-covered trees fell either into the stream channel or the root ball of a tree located on the bank was ripped out; both scenarios causing flow deflection or outright destruction of a bank causing "mass wasting" types of bank erosion. Timbered riparian zones that did not have wild-grape vines had stable banks with minor or natural fluvial erosion, hardy and established tree rootballs along streambanks, and natural meandering characteristics. There were a few cases where some clearing of timber on the edges of riparian zones were observed. The cleared trees were then forced into the riparian zone or on stream banks causing flow deflection.

The Channel Evolution Model (CEM) variable can signify fluvial system-wide channel adjustments through channel incision and widening processes (Simon, 1989). This channel adjustment model identifies six conceptual stages of channel cross-section shape, longitudinal profile, and adjustment processes from pre-modification (Stage I) to restabilization (Stage VI). Stage III represents a downcutting and upstream headcut progression with increasing stages of channel evolution (Stage IV, V, and VI) occurring in the downstream direction of the headcut. Stage III (headcut) will continue upstream until it reaches a resistant geologic material, reduction in erosive runoff, or reduction in slope (energy) (Federal Interagency Stream Restoration Working Group, 1998). The approach to assigning a CEM stage during the field survey is thoughtfully done due to the fact that the variable is also part of the overall CSI score. The best interpretation of the channel character and cross-section associated with CEM stages is made during the site visit even if this adjustment process does not appear to be present in the network. The relative relationship of the stages between stations in the stream longitudinal profile is evaluated to determine whether a reasonable sequence of the CEM stages is observed in the stream network or an isolated section of the stream exhibits disturbed channel morphology. The longitudinal profiles of the Channel Evolution Model (CEM) stages were presented in Figures 25-27 and the spatial distribution of CEM stages is mapped in Figure 34. Some field sites were observed to exhibit Stage VI channel morphology that would be consistent with a channel that had previously undergone this process but now appears to be established enough to be considered a relic feature. Based on the profiles and maps there does not appear to be any CEM stage sequences between field survey sites that would indicate a systemic channel adjustment process throughout the channel network.

Basic Field Measurements

Figures 35-37 present the bank height, channel width, and left/right bank angles for the three creeks, respectively. Bank heights were generally below 6 meters with a few exceptions where the channel might have been positioned along a steep hill. Group C seems to have more reaches with bank heights 3-6 meters, whereas groups A and C were mixed between <3 and 3-6 meters. Channel widths were larger in reaches that have been channelized, particularly in Deer Plain Creek nearest Illinois River Road and Lower Metz Creek in field site #204. Groups B and C had most reaches between 9 and 15 meters wide and group A were between 3 and 9 meters. Bank angle data is collected to determine the existence of steep banks which tend to be unstable in loess when bank heights are high. Also, similar left/right bank angles can be indicative of incised or maintained channels and steep versus shallow bank angles are a sign of natural meanders with cutbanks and inside bars that suggest variety and effective transport of sediment downstream. Groups A, B, and C exhibit a variety of left/right bank angles as well as the remaining reaches. Similar bank angles do appear in known channelized reaches, particularly reaches nearest Swan Lake.

Results of Watershed-Scale Characterization

The watershed-scale characterization established that the geology and surface materials are the dominant controlling features in the watersheds. The uplands are capped in thick loess which were covered in forest during pre-settlement times. Changes in the watersheds including the conversion of the uplands from pre-settlement forest to agricultural production most likely set into motion the hillslope erosion and gully development in the high sloping uplands. This assumed increase in runoff due to land conversion appears to have incised some of the upper reaches as evidenced by the observation of old Stage V & VI channels. The main tributary channels have lower slopes and can effectively transport upland sediment downstream but may have only slightly adjusted laterally due to narrow valley widths. This is supported by limited sediment bank/bar accretion and the planform analysis between 1940 and 2007 that showed no lateral shifts in channel position throughout the upland areas. The only major lateral channel shifts were documented in the Deer Plain Terrace and floodplain areas and is attributed to some historic channelization and recent HREP activities.

The lower reaches of the tributaries and floodplain areas are dominated by Illinois River backwater flooding which deposits sand and silt in Swan Lake as well as the tributary channels. Backwater can reach upstream in the channels of the three tributaries past Deer Plain Terrace. Deposition of this material and the long-term saturation of streambanks in these backwater prone reaches can make them heavy, unstable, and contribute or rework sediment delivered to Swan Lake. The construction of the Alton Lock & Dam in the 1940s raised the Illinois River surface water elevations near Swan Lake by over 2 meters (7 feet). In terms of changes in the hydrologic and channel character of the lower tributary reaches, the Alton Lock & Dam has an indisputable, profound effect.

Another change in the region is an apparent increase in annual precipitation since the 1970s as noted by the St. Charles, MO climate station 11-year moving average. An investigation into wet and dry season precipitation showed this increase was due to a simultaneous increase in wet and dry season precipitation and, until recently, the continued increase of wet season precipitation. Without streamflow records it is not possible to determine the magnitude this increased precipitation had on runoff and stream power, although it is reasonable to assume there was some effect.

With regard to long-term changes in land use since the pre-settlement conversion of forest, there have been minor changes. For the last 20 years, agricultural land use has been steady and is dominated by production of corn and soybeans, pasture, and some orchards, with sporadic tracks of forest. Also, based on the Illinois Agricultural Statistics for Calhoun County, soybean production has made the biggest change in the region. Soybeans were harvested in earnest by 1940 and increased through the 1950s. There were a couple of marked increases during the 1970s and 1990s and then peaked in 2005. Assuming these county trends were similar for these watersheds, it is unclear if these changes affected runoff without knowing the tillage and conservation practices used throughout this period.

The field survey results reveal no systemic channel adjustments for all three creeks that would account for an apparent increased delivery of sediment to Swan Lake as observed by delta growth in the lake. However, in general the observed channel characteristics exhibit less than ideal stability or biological habitat conditions. Three groups of reaches were initially identified as potential areas of high sediment production due to mass wasting erosion mechanisms. However, the portion of the banks eroding in this manner was less than the portion of banks that were observed to be eroding due to slower fluvial processes. Riparian zone widths were generally less than 5 meters for all creeks, except for some head water areas. Many reaches had less than 10% banks covered in stabilizing woody vegetation. Several reaches, both left and right banks, exhibited 50 percent or less of the banks with high disturbance of any vegetative cover but only one group of reaches, group B, was also observed to have mass wasting of the banks.

The overall evaluation of the watershed-scale characterization gives reasonable evidence that system-wide channel adjustments are not active in the Middle and Lower Swan Lake watershed. However, there is some evidence of historical channel adjustments. Local channel disturbances due to weakened timber in riparian zones with wild grape vines seem to be an area for improved management. There are minor (fluvial) but wide-spread channel instabilities in the watersheds but are most likely delivering, on the average, some sediment load over a long period of time. The observed delta growth in Swan Lake exhibits a sustained delivery of sediment. However, there is no data to determine actual yields, let alone what yields would be reasonably expected for this region. It is hypothesized that the increase in wet season precipitation could be an exacerbating factor on these processes by transporting higher sediment loads during high intensity precipitation events. The reaches for all three creeks closest to Swan Lake in the floodplain area seem the deepest and more unstable than the upstream reaches. Due to the apparent discrete local nature of highly unstable reaches and the lack of evidence for active system-wide channel adjustment processes, there is no cause to proceed to the reach-scale level of this geomorphic assessment.

Evaluation and Assessment

The objective of the evaluation and assessment component is to analyze the changes in channel character over time to determine potential future adjustments of the stream channel throughout the fluvial system. The type of fluvial and physical environment in the Swan Lake watersheds was investigated by the watershed-scale characterization. The characterization results showed that there are no profound system-wide channel adjustments of the type to produce significant short-term sediment delivery to Swan Lake. The dominant process of channel erosion has been through fluvial processes. However, it should be noted that the CSI and BHI scores were less than ideal and that this type of erosion over a long period of time can still deliver significant sediment downstream. Swan Lake and tributary watersheds naturally delineate into four fluvial environments (areas): upland, Deer Plain Terrace, floodplain, and Swan Lake.

In the upland area, headwater hillsides are high sloping (10-15 percent) and tributary valleys are narrow but have a lower one percent slope. Characteristic of a maturely dissected area where sediment delivered from the steeper valley walls is transported downstream or deposited as overbank material, possibly captured by the narrow riparian zones, to be reworked or eroded at a later time by extreme streamflow events. Gullies were observed in some agricultural fields which are expected to periodically develop due to extreme precipitation events.

The Deer Plain Terrace area is a feature from Wisconsinan glacial deposition and for the most part the land surface is not inundated by current day Illinois River floods. However, the tributary channels that cut through the terrace are influenced by Illinois River flooding which causes sediment to deposit in the stream channels. Post-flood rainfall events can then move the material to the lake. Also, an extended, elevated water surface in the channels can saturate and weaken the banks. Because the channels in these reaches are typically engineered for drainage and trapezoidal in shape, the backwater and depositional conditions that occur make the banks particularly vulnerable to instabilities. The floodplain area is obviously inundated by Illinois River flooding. This creates a complicated depositional situation where sediment from floodwaters and upstream tributaries meet and deposit sediment in these tributary reaches. Also saturated conditions and deposition of sediment throughout this area create an unstable environment. Vegetation seems to only survive on top of the banks and not on the bank face where the drainage channels convey water at more efficient velocities. This can leave banks vulnerable to added fluvial erosion and more efficiently transport tributary sediment load to the lake.

Swan Lake itself has undergone significant disturbances, particularly by the construction of the Alton Lock & Dam on the Mississippi River. Prior to the dam, the Swan Lake open-water surface area was much smaller, narrower in shape, and located closer to the Illinois River. Timber was observed in 1904 between the lake and the current floodplain boundary. The 1904 bathymetric survey also showed elevated delta-like areas in the current location of the Metz, Lower Metz, and Deer Plain Creek mouths with Swan Lake. However, in the pre-dam imagery, the creeks do not appear to have definable outlets but rather appear to be braided and hidden under the timber canopy to connect with Swan Lake in a diffused manner at the 1904 open-water shoreline. It is undetermined whether these deltas were a feature of natural pre-settlement erosion rates or a result of the initial land use conversion. Post-dam construction inundated the previous timbered areas resulting in the demise of the timber (Heitmeyer and Westphall, 2007). Currently, delta growth is observed at the same locations seen in the 1904 bathymetry and each creek has a defined channel connection with the current open-water shoreline. HREP efforts were focused on addressing sediment issues mostly due to Illinois River influences as a result of the pool created by Alton Lock & Dam. Assuming that the current watershed erosion processes have been similar for some time, it is apparent that the pool and subsequent backwater flooding have disturbed the channels in the lower tributary reaches as well.

Recommendations

Based on the geologic and fluvial environment and unlikely shifts in future watershed land use and Illinois River backwater flooding, it seems that the channel character and tributary sediment delivery to Swan Lake will continue as currently observed. Precipitation appears to be the outlier in this assessment, as demonstrated by an apparent increase in annual and wet season rainfall in the last 20 years (Figures 9 and 10). Any changes in annual totals or intensity of rainfall can have an effect on the current fluvial and sediment conditions in the watershed, for better or worse, depending on the trend.

The geomorphic assessment found that there were no profound system-wide channel adjustment processes of the type to produce significant sediment delivery in short periods of time to Swan Lake. The assessment and evaluation recognized four fluvial environments: upland, Deer Plain Terrace, floodplain, and Swan Lake. Significant historical or past disturbances that were found to have influenced the study area are the conversion of land from pre-settlement forest to agricultural production, construction of the Alton Lock & Dam, and recent increase in annual precipitation. The Swan Lake Habitat Rehabilitation and Enhancement Project (HREP) was the most recent land management activity in the area.

Based on the evaluation and assessment, the following are general observations and recommendations for each fluvial environment. These are provided as a tool and represent only a part of the information needed for a broader discussion on the development and implementation of future natural resource management strategies by stakeholders in Swan Lake and its watershed.

- Uplands: Higher runoffs from steep hillsides produce higher velocity runoff. These velocities have more energy to dislodge sediment particles from hillsides due to land cover that is not resistant enough to overcome it. Practices that reduce runoff velocities to levels that a land cover can resist the erosive energy can subsequently reduce stream velocities and fluvial erosion of the channels. The potential reduction of hillslope and channel erosion could have long-term benefits for sustainable crop production in the uplands and decrease in sediment loads to Swan Lake. Any expansion of current best management practice programs that are focused on further reducing runoff from areas with high sloping hillsides could improve channel stability by reducing the energy that drives the fluvial erosion processes observed in the stream channels.

  A survey of the extent and magnitude of wild grape vines in the timbered riparian zones (randomly located in isolated reaches of upland, Deer Plain Terrace, and floodplain areas) would be useful to determine how to control the species. The development of management plans for these timber stands could convert them to stable channel reaches thereby reducing local sediment supplies.

- Deer Plain Terrace/Floodplain: The channel reaches affected by backwater flooding in Deer Plain Terrace and floodplain areas will continue to be influenced by the hydrology and hydraulics of the Illinois River and cannot be addressed by this study. During backwater conditions the water level is held at a higher elevation for extended periods of time which saturates the channel thereby adding surplus weight to the banks. The elevated water level holds the banks up until it recedes; then the banks cannot dewater fast enough and fail due to the banks exceeding their critical height for the saturated weight. However, some types of channel geometries and shallower bank slopes that are more stable under these backwater conditions could be investigated for application in these reaches. Also, an investigation is suggested to determine types of vegetation that further stabilizes these banks but does not appreciably increase the roughness and reduce the efficient conveyance of upstream runoff during non-backwater conditions. It also appeared that some road crossings over stream channels in these reaches may be constricting flow and exacerbating backwater conditions.

- Swan Lake: The increase in pool elevation since 1940 is the defining disturbance in Swan Lake and lower tributary reaches. Based on the assumption that the currently observed steady rate of fluvial erosion in the upstream tributary channels will continue into the foreseeable future, consideration could be given to understanding the role this sediment delivery to the lake could play in accomplishing long-term goals and vision of the Swan Lake Habitat Rehabilitation and Enhancement Project (HREP) and Two Rivers Comprehensive Conservation Plan.

As seen in the 1904 Woermann bathymetric survey (Appendix B), the pre-dam tributaries developed delta-type landforms extending past the floodplain boundary into the timber which surrounded Swan Lake. The pre-dam 1931 aerial photography showed the hydrologic connection between the tributaries and Swan Lake appeared diffused as the streams entered the timber; most likely becoming braided under the tree canopy. As seen in the 1940 aerial photo, the increased pool elevation by the Alton Lock & Dam (1940 shoreline) partially inundated the 1904-mapped delta landforms. The currently observed deltas (2007 shoreline) are located on the previous deltas (1904 bathymetric contour lines) and extend further into Swan Lake. It is hypothesized that delta forming loads are continuing and those depositional processes are still building the deltas but at a higher elevation due to the higher pool. However, as opposed to pre-dam conditions, the tributaries now have a direct connection to Swan Lake thereby depositing upstream sediment load into open-water instead of the pre-dam bottomland timber areas. A study into the feasibility of providing near shore depositional environments for tributaries to deposit their sediment load sooner may help reestablish bottomland timber areas and reduce suspended sediment deposited in the deeper open-water areas of Swan Lake.

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