City of Columbia

701 East Broadway, Columbia, Missouri 65201

Agenda Item Number: B 304-15
Department Source: Utilities-Sewer/Stormwater
To: City Council
From: City Manager & Staff
Council Meeting Date: 10/19/2015
Re: Hinkson Creek Collaborative Adaptive Management (CAM) Studies Intergovernmental Agreement for Cost Sharing

Documents Included With This Agenda Item

Council memo, Resolution/Ordinance, Exhibits to Resolution/Ordinance
Supporting documentation includes: None

Executive Summary

Authorizing the City Manager to execute an Intergovernmental Cooperative Agreement Partial Performance Acknowledgement of Hinkson Creek Physical Habitat Assessment, between the City of Columbia, the County of Boone, and the Curators of the University of Missouri. This agreement addresses projects initiated in the Collaborative Adaptive Management (CAM) process in response to a Total Maximum Daily Load (TMDL) for the Hinkson Creek, as issued by the Federal Environmental Protection Agency (EPA). The projects addressed by this agreement include: Physical Habitat Assessment, Forum Level Spreader Monitoring and Combined Flow and Suspended Sediment Study.

Discussion

On April 1, 2013, Council authorized an Intergovernmental Cooperative Agreement between the City of Columbia, the County of Boone, and the Curators of the University of Missouri with regard to how the Parties will contribute to projects that are initiated in the CAM process to address the TMDL. In that agreement it states that for research, study, or monitoring-type projects, the three entities will each be responsible for one-third of the project cost. It also states that for construction projects, the cost shall be borne by the entity within whose boundaries the project is located. For each project the parties shall agree in writing to the project. This agreement fulfills that obligation for the following projects.

One project initiated in that CAM process (Physical Habitat Assessment) has now been completed, and another project (Forum Level Spreader) partially completed. The proposed Intergovernmental Cooperative Agreement Partial Performance Acknowledgement of Hinkson Creek Physical Habitat Assessment, acknowledges the progress of the aforementioned projects and addresses a third project known as “Combined Flow and Suspended Sediment Proposal”, and outlines the costs associated with the three projects as follows:

Physical Habitat Assessment - This project consisted of two phases. The first phase was a geographical information systems (GIS) data development project conducted at a cost of $6,665.59.

The second phase was a field assessment. A grant was sought for this phase of the project which would have reduced the cost to the parties; however, the grant was not awarded. The contribution amount is adjusted in the proposed agreement and identifies the contribution amounts the parties are responsible for. The extra cost is shared equally among the three parties. The City's share of this project was $22,000 and has already been paid.

Combined Sediment and Flow Study - A new project to analyze five years of existing data that will provide basic information to help steer the CAM process and inform future projects. The City's share of this project will not exceed $70,147.08.

Forum Level Spreader Monitoring - A large level spreader (a stormwater treatment device) was installed at the Forum Nature area last year by the City. Per the agreement, all construction costs were paid by the City. However, the parties agree to share the cost of monitoring the effectiveness of the practice equally. The City's share of the monitoring portion of this project will not exceed $20,750.

This proposed agreement fits within the framework of the April 2013 Intergovernmental Cooperation Agreement between the City of Columbia, the County of Boone, and the Curators of the University of Missouri for sharing the costs of the CAM projects.

Fiscal Impact

Short-Term Impact: The City's share of the CAM projects yet to be paid is $90,897.08 and will be paid over the next three years (the life of the projects).

Long-Term Impact: Cost to maintain the level spreader is expected to be less than $1000 per year over the life of the practice (~50 years). These studies are expected to identify projects to improve and protect Hinkson Creek, and other creeks in Columbia, more effectively, and thus reduce the long term costs to achieve that objective.

Vision, Strategic & Comprehensive Plan Impact

Vision Impact: Environment
Strategic Plan Impact: Not Applicable
Comprehensive Plan Impact: Environmental Management

Suggested Council Action

Authorize the City Manager to execute an Intergovernmental Cooperation Agreement Partial Performance Acknowledgement of Hinkson Creek Physical Habitat Assessment, between the City of Columbia, the County of Boone, and the Curators of the University of Missouri.

Legislative History

4/1/13 (Ord 51646) Authorizing an intergovernmental cooperative agreement with Boone County,

City of Columbia
701 East Broadway, Columbia, Missouri 65201

Missouri and the Curators of the University of Missouri as it relates to the collaborative adaptive management implementation (CAM) process to address the total maximum daily load (TMDL) for Hinkson Creek.

Department Approved

City Manager Approved

Introduced by ____________________________

First Reading ______________________ Second Reading ______________________

Ordinance No. _____________________ Council Bill No. ______B 304-15________

AN ORDINANCE

authorizing an Intergovernmental Cooperative Agreement Partial Performance Acknowledgement of Hinkson Creek Physical Habitat Assessment with the County of Boone and The Curators of the University of Missouri as it relates to the collaborative adaptive management implementation (CAM) process to address the total maximum daily load (TMDL) for Hinkson Creek; and fixing the time when this ordinance shall become effective.

WHEREAS, a Total Maximum Daily Load (TMDL) for Hinkson Creek was issued by the Federal Environmental Protection Agency (EPA) in 2011; and

WHEREAS, the City of Columbia, County of Boone, and The Curators of the University of Missouri are partners in a Municipal Separate Storm Sewer System (MS4) permit issued by the Missouri Department of Natural Resources, which is affected by the TMDL; and

WHEREAS, the City, County, and University entered an agreement with the EPA and the Missouri Department of Natural Resources (DNR) to address the TMDL with a Collaborative Adaptive Management (CAM) process.

NOW, THEREFORE, BE IT ORDAINED BY THE COUNCIL OF THE CITY OF COLUMBIA, MISSOURI, AS FOLLOWS:

SECTION 1. The City Manager is hereby authorized to execute an Intergovernmental Cooperative Agreement Partial Performance Acknowledgement of Hinkson Creek Physical Habitat Assessment with the County of Boone and The Curators of the University of Missouri as it relates to the collaborative adaptive management implementation (CAM) process to address the total maximum daily load (TMDL) for Hinkson Creek. The form and content of the agreement shall be substantially as set forth in "Exhibit A" attached hereto and made a part hereof as fully as if set forth herein verbatim.

SECTION 2. This ordinance shall be in full force and effect from and after its passage.

PASSED this __________ day of ________________________, 2015.

ATTEST:

_________________________________ _________________________________

City Clerk Mayor and Presiding Officer

APPROVED AS TO FORM:

____

City Counselor

EXHIBIT A

INTERGOVERNMENTAL COOPERATIVE AGREEMENT PARTIAL PERFORMANCE ACKNOWLEDGEMENT OF HINKSON CREEK PHYSICAL HABITAT ASSESSMENT

The parties hereto are the City of Columbia, Missouri, a Constitutional charter city of the State of Missouri (the "City"), the County of Boone, a first class non-charter county and political subdivision of the State of Missouri by and through its County Commission (the "County"), and The Curators of the University of Missouri (University) and those parties enter this Partial Performance Acknowledgement (Acknowledgement) this ___ day of ____________, 2015, by stating as follows:

Whereas, the parties entered an Intergovernmental Cooperation Agreement, attached hereto as Addendum A, on April 2, 2013; and

Whereas, in that Agreement the parties acknowledged their mutual obligations in certain projects initiated under a Collaborative Adaptive Management (CAM) process emanating from a Municipal Separate Storm Sewer System (MS4) permit issued by the Missouri Department of Natural Resources; and,

Whereas, the first two projects initiated in that CAM process have now been completed; and,

Whereas, the parties now wish to acknowledge those projects' completion and affirm and restate their full performance of their respective obligations under these two projects,

Whereas, the parties also wish to agree to the scope and details and costs of a third project known as the "Combined Flow and Suspended Sediment Proposal".

NOW, THERFORE, in consideration of the mutual covenants in this Acknowledgement, the parties agree that:

1. The University has directed the completion of the Physical Habitat GIS Data Development, as described in the attached Addendum B, and the parties affirm and restate that the scope of the project and the amounts not to be exceeded are acceptable as the University has been fully compensated by the City and the County with each of them contributing $6,665.59.

2. The University has also directed the completion of the Physical Habitat Data Development, Project 2013MO142B, as described in the attached Addendum C. The parties affirm and restate the scope of the project.

3. The initial proposed cost of the project described in the attached Addendum C to be shared by the parties, $66,001.00, was to have been reduced to $44,001.00 by an anticipated federal grant. That grant, however, failed to issue, leaving the final cost to be shared by the parties at $66,001.00.

4. The City affirms and restates that the project and amount not to be exceeded are acceptable to the parties, and the University agrees it has been fully compensated by the City by the City's payment of the City's proportionate one third share of $22,000.00.

5.. The County agrees to pay to the University $22,000.00, upon the execution of this acknowledgement, which the University agrees will constitute the County's full performance of its obligations for the projects described in Addenda B and C, the completed portions of Addendum A, the Intergovernmental Cooperation Agreement and this is acceptable to the parties.

6.. The parties now agree to the scope and details of the next project known as the "Combined Flow and Suspended Sediment Proposal" as described in the attached Addendum D. This project has a total not to exceed amount of $280,000.00; however the University agrees that it will pay the full cost of the first year of the project without contribution by the City or the County, with a first year estimated cost of $69,916.50. As set forth in Addendum D the total cost to be shared by the parties in the following three years is $210, 441.24; with each of the parties proportionate one third costs not to exceed $23,320.78 in year two; $23,320.15 in year three; and $23,506.15 in year four. The proportionate payments shall be subject to the appropriations of the each of the Parties. Subject to appropriation, the City Manager will have the authority make payment on behalf of the City to the University, after receiving an invoice for the proper amounts as set forth herein. Subject to appropriations, the University and County shall take whatever individual actions they deem appropriate to make payment for the proper amounts as set forth herein.

7. The parties also now agree to the scope and details of the next project known as the "Forum Nature Area Level Spreader Monitoring Proposal", as described

in the attached Addendum E. This project has a total not to exceed amount of $62,250.00, with each of the parties' total proportionate one-third costs not to exceed $ 20,750.00, or $7,416.67 in year one and $3,333.33 for each of years two through five. The proportionate payments shall be subject to the appropriations of the each of the Parties. Subject to appropriation, the City Manager will have the authority make payment on behalf of the City to the University, after receiving an invoice for the proper amounts as set forth herein. Subject to appropriations, the University and County shall take whatever individual actions they deem appropriate to make payment for the proper amounts as set forth herein. Further, Dr. Enos Inniss, will assume Dr. Jason Hubbart's responsibilities as project director.

8. No party may assign or transfer any of its rights or obligations under this Agreement to any other person or entity without the prior, written consent of the other parties.

9. This Agreement is for the sole benefit of parties, and nothing in this Agreement is intended to confer any rights or remedies on any third party.

10. Nothing in this Agreement will be deemed or construed by the parties, nor by any other entity or person, as creating any principal and agent relationship, or partnership, or joint venture, between the parties.

11. This Agreement will be governed by the laws of the State of Missouri, and any action relating to this Agreement will be brought in the Circuit Court of Boone County, Missouri.

12. The covenants, agreements, and obligations in this Agreement will extend to, bind, and inure to the benefit of the parties and their respective successors and approved assigns.

13. Each person signing this Agreement on behalf of any of the parties represents that he or she has been duly authorized and empowered, by order, ordinance, or otherwise, to execute this Agreement and that all necessary action on behalf of that party to effectuate that authorization has been taken and done.

14. The Parties state that this Agreement, together with its attached Addenda A through E, contains the entire agreement between the Parties, and there are no other oral, written, express, or implied promises, agreements, representations, or inducements not specified herein.

IN WITNESS WHEREOF the parties hereto have caused this Agreement to be executed by their duly-authorized officers on day and year indicated by their signature below.

The Curators of the University of Missouri

____

By:

____

Date:

BOONE COUNTY, MISSOURI

BY:______________________
Dan Atwill, Presiding Commissioner

ATTEST:

____

Wendy S. Noren, County Clerk

APPROVED AS TO LEGAL FORM:

____

C.J. Dykhouse, County Counselor

Boone County Auditor Certification:
I hereby certify that a sufficient, unencumbered appropriation balance exists and is available to satisfy the obligation arising from this contract. (Note: Certification of this contract is not requiredif the terms of this contract do not create a measurable county obligation at this time.)

____

County Auditor Date

CITY OF COLUMBIA, MISSOURI

By: ______________________________
Mike Matthes, City Manager

____
Date

ATTEST:

____
Sheela Amin, City Clerk

APPROVED AS TO FORM:

____
Nancy Thompson, City Counselor

I hereby certify that this Contract is within the purpose of the appropriation to which it is to be charged, that is, account 558-6688-881.49-90 and that there is an unencumbered balance to the credit of such account sufficient to pay therefore.

____
John Blattel, Director of Finance

ADDENDUM
A

INTERGOVERNMENTAL COOPERATION AGREEMENT

This intergovernmental cooperation agreement (the "Agreement") is entered into on this 2ND day of APRIL, 2013, by and between the City of Columbia, Missouri, a Constitutional charter city of the State of Missouri (hereinafter referred to as the "City"), and the County of Boone in the State of Missouri (hereinafter referred to as "County"), and The Curators of the University of Missouri (hereinafter referred to as "University"); and may collectively be referred to as the "Parties."

WHEREAS, a Total Maximum Daily Load (TMDL) for Hinkson Creek was issued by the Federal Environmental Protection Agency (EPA) in 2011; and

WHEREAS, the City, County, and University are partners in a Municipal Separate Storm Sewer System (MS4) permit issued by the Missouri Department of Natural Resources, which is affected by the TMDL; and

WHEREAS, the City, County, and University entered into an agreement with the EPA and the Missouri Department of Natural Resources (DNR) to address the TMDL with a Collaborative Adaptive Management (CAM) process; and

WHEREAS, the City, County, and University wish to enter into an agreement with regard to how the Parties will contribute to projects that are initiated in the CAM process to address the TMDL.

NOW, THEREFORE, the parties agree as follows:

1 **TYPES OF PROJECTS**. The Parties will contribute to projects which are initiated in the CAM process to address the TMDL for research, study, or monitoring-type projects and for construction projects.

For research, study, or monitoring-type projects, the three entities will each be responsible for one-third of the project cost. The University shall coordinate research, study, or monitoring-type projects on behalf of the parties. Before any research, study, or monitoring-type project is started, the Parties shall agree in writing regarding the scope and details of the project, including a not-to-exceed amount for each project.

For construction projects, each entity will exercise discretion and control over projects and be responsible for the costs of projects conducted on its own property unless otherwise agreed between the parties in writing.

2. **APPROPRIATIONS.** All types of projects shall be subject to the appropriations of the Parties who shall pay for the projects. Subject to these appropriations, the Parties shall each delegate in writing a person who shall be responsible for implementing this agreement and any associated documents or contracts to give this agreement effect.

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COL. CITY
CAM PROJ HINKSON CREEK

3. **TERM.** The effective date of this Agreement is the date the last party executes the Agreement and provides original executed documents to the other Parties. Any of the Parties may terminate this Agreement at any time by providing the other Parties written notice of their intent to terminate at least thirty (30) days in advance of the intended termination date

4. **ASSIGNMENT.** None of the Parties may assign or transfer any of its rights or obligations under this Agreement to any other person or entity without the prior, written consent of the other Parties.

5. **SOLE BENEFIT OF PARTIES.** This Agreement is for the sole benefit of the City, County and University. Nothing in this Agreement is intended to confer any rights or remedies on any third party.

6. **ENTIRE AGREEMENT.** The Parties state that this Agreement contains the entire agreement between the Parties, and there are no other oral, written, express or implied promises, agreements, representations or inducements not specified herein.

7. **AUTHORITY.** The signatories to this Agreement warrant and certify that they have obtained the necessary authority, by resolution or otherwise, to execute this Agreement on behalf of the named party for whom they are signing.

[SIGNATURES ON THE FOLLOWING PAGES]

IN WITNESS WHEREOF, the Parties hereto have been duly authorized to execute this Agreement as of the day and year first above written.

CITY OF COLUMBIA, MISSOURI

By: ______________________
Mike Matthes, City Manager

ATTEST:

____
Sheela Amin, City Clerk

APPROVED AS TO FORM:

____
~~Fred Boeckmann~~, City Counselor
Cavanaugh Noce

BOONE COUNTY, MISSOURI

By: ______________________
Dan Atwill, Presiding Commissioner

ATTEST:

____
Wendy Noren, County Clerk

APPROVED AS TO FORM:

____
C.J. Dykhouse, County Attorney

THE CURATORS OF THE
UNIVERSITY OF MISSOURI

By: ______________________
Lisa S. Wimmenauer
Assoc. Director, Business Services

ATTEST:

Approved By

MAR 0 5 2013
PJH
General Counsel via EMAIL

Introduced by McDavid

First Reading 3-18-13 Second Reading 4-1-13

Ordinance No. 021646 Council Bill No. B 78-13

AN ORDINANCE

authorizing an intergovernmental cooperation agreement with Boone County, Missouri, and The Curators of the University of Missouri as it relates to the collaborative adaptive management implementation (CAM) process to address the total maximum daily load (TMDL) for Hinkson Creek; and fixing the time when this ordinance shall become effective.

BE IT ORDAINED BY THE COUNCIL OF THE CITY OF COLUMBIA, MISSOURI, AS FOLLOWS:

SECTION 1. The City Manager is hereby authorized to execute an intergovernmental cooperation agreement with Boone County, Missouri, and The Curators of the University of Missouri as it relates to the collaborative adaptive management implementation (CAM) process to address the total maximum daily load (TMDL) for Hinkson Creek. The form and content of the agreement shall be substantially as set forth in "Exhibit A" attached hereto and made a part hereof as fully as if set forth herein verbatim.

SECTION 2. This ordinance shall be in full force and effect from and after its passage.

PASSED this 1st day of April, 2013.

ATTEST:

[signature]
City Clerk

[signature]
Mayor and Presiding Officer

APPROVED AS TO FORM:

[signature]
City Counselor

ADDENDUM

B

Hinkson Creek Watershed Restoration Project

Collaborative Adaptive Management (CAM)

Physical Habitat GIS Data Development Technical Report

July 31, 2013

Prepared by: Ronnie Lea
GIS/RS Specialist
Missouri Resource Assessment Partnership (MoRAP)
School of Natural Resources
University of Missouri-Columbia
lear@missouri.edu

Missouri Resource Assessment Partnership Staff Contributors

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David Diamond, Ph.D., MoRAP Director
Clayton Blodgett, Ph.D., Remote Sensing Coordinator
Dyan Pursell, GIS Technician
Kim Mabry, GIS Technician

Hinkson CAM Science Team Collaborators

Paul Blanchard, Ph.D., Missouri Department of Conservation
Joe Engeln, Ph.D., Missouri Department of Natural Resources
Robb Jacobson, Ph.D., United States Geological Survey
Jason Hubbart, Ph.D., University of Missouri

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1 Executive Summary

As part of the Hinkson Creek Restoration project, we used GIS and Remote Sensing techniques to create basic information on the geomorphology of Hinkson Creek and the distribution of land cover within the valley and watershed. Basic input data, which included air photos, LiDAR, a stream center line, and fine spatial resolution land cover for about 75% of the watershed, were provided by partners (Boone County and City of Columbia). Staff from our partners, which included members of the Hinkson CAM Science team, viewed progress and provided input on interim products so that modifications could be made at regular intervals. The Hinkson Creek Restoration team partners (Boone County, City of Columbia, and University of Missouri) will use this information for a variety of initiatives, including selection of field data sampling sites and stand-alone analyses, such as the influence of land cover on the geomorphology and biology of the stream. The information is fine-resolution and will serve as input for analyses at multiple scales of resolution.

Data sets developed include: (1) stream centerline update, (2) spatially explicit sample points at 50 m (and multiples of 50 m) intervals on the centerline of the stream, (3) bankfull boundaries on the stream, (4) valley boundaries along the stream, (5) new fine spatial resolution land use/landcover (LULC) for 25% of the study area, (6) attribution of physical data to spatially specific points within the stream at multiple scales (i.e., LULC composition, bankfull width, valley width, slope, sinuosity, and distance to valley wall), (7) sand/gravel bar delineation, and (8) Hinkson Creek road crossings.

2 Data Development

2.1 Introduction

Missouri Resource Assessment Partnership (MoRAP) was contracted to create a number of geospatial datasets, requested by the Hinkson Collaborative Adaptive Management (CAM) Science Team, which would aid in the analysis of the physical, ecological, and geomorphic conditions of Hinkson Creek and its eight main tributaries. The study area extends from the headwaters of Hinkson Creek to its confluence with Perche Creek and includes the following watersheds: County House Branch, Flat Branch, Grindstone Creek, Hinkson Creek, Hominy Branch, Merideth Branch, Mill Creek, Nelson Creek, and Varnon Branch (Figure 1).

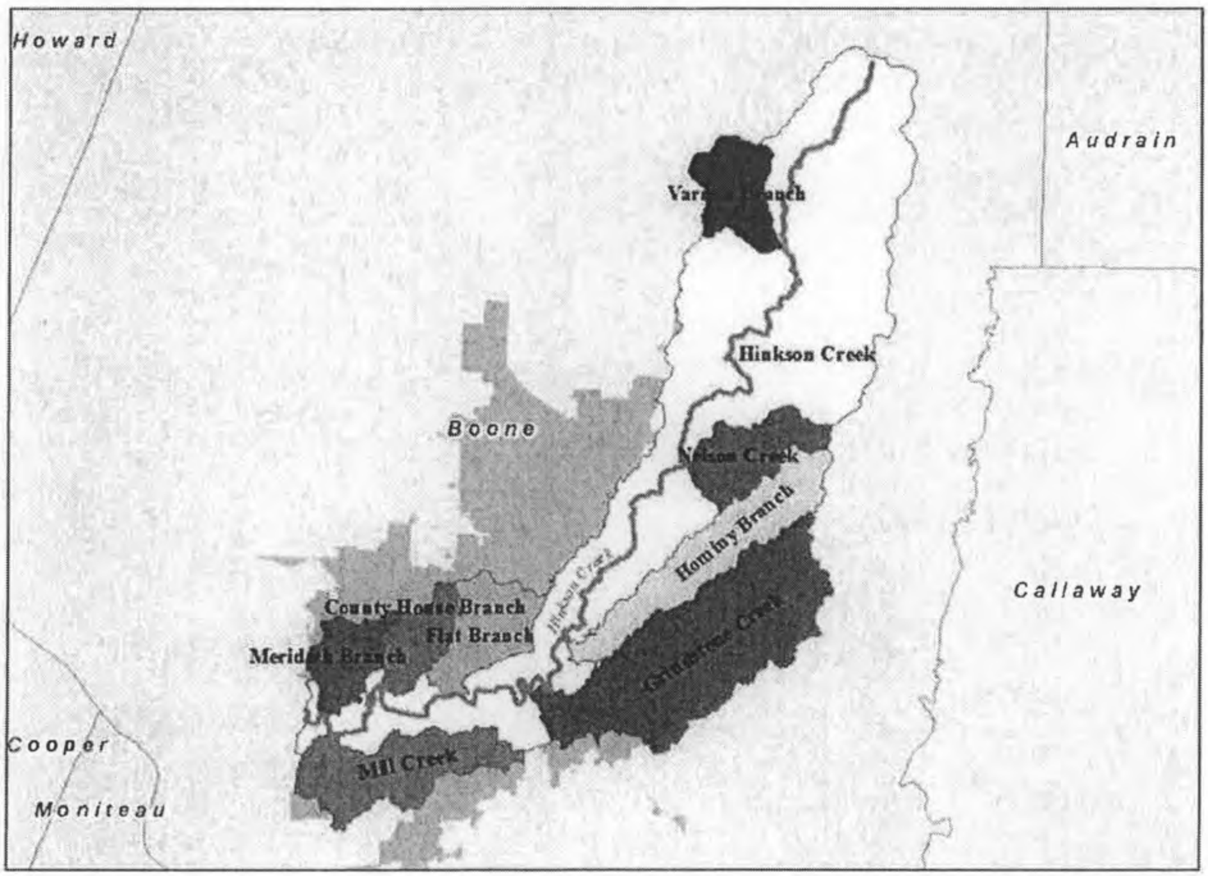

Figure 1. Watersheds that define the study area cover much of the Columbia metro area in central Boone County, Missouri.

2.2 Data Collaboration

Boone County and the City of Columbia shared critical geospatial data with MoRAP (Table 1). The shared data was used only for this project and a GIS data agreement was signed prior to MoRAP receiving data.

2.2.1 Data Used

Table 1. List of GIS data provided by partners to develop physical habitat products.

Data Name	Source	Description	Use
2009 1 foot DEM	Boone County	Digital elevation raster model derived from 2009 LiDAR data	Stream centerline update, bankfull, valley delineation, sand and gravel bar delineation, and % slope
2009 1 foot Hill Shade	Boone County	Hill shade raster derived from 2009 1 foot DEM	Stream centerline update, bankfull, valley delineation, sand and gravel bar delineation, and % slope
Hydro_lines	Boone County	Hydrography lines based on 2007 ortho-imagery	Source for Hinkson Creek centerline, though centerline was updated by MoRAP
2011 6 inch Leaf-off Aerial Photography	Boone County	6 inch, leaf-off, 3-band, true color, aerial photography	Stream centerline update, sand or gravel bar delineation, MoRAP LULC, Hinkson road crossings
2007 Natural Resources Inventory (NRI)	City of Columbia	6 class vector Land Use/Land Cover data set for City of Columbia	Used to determine LULC and impervious surface composition throughout study area and as training data source for MoRAP LULC of study area not covered by NRI
Watersheds	City of Columbia	Watershed vector layer used to define study area	Study area delineation and LULC statistics
2010 1 meter leaf-on NAIP	MSDIS	1 meter, leaf-on, 4-band, CIR, NAIP. Used original, non-compressed, quads	MoRAP LULC

2.3 Subject Matter Expert/Science Team Collaboration

Multiple meetings with subject matter experts Dr. Robb Jacobson - United States Geological Survey, Dr. Paul Blanchard – Missouri Department of Conservation, and Dr. Jason Hubbart – University of Missouri were conducted to identify GIS data products that would be useful to the overall Hinkson Creek restoration effort. Additionally, meetings with a wider audience were held to review GIS data during the data development process to ensure that the data was on track with what was requested and that all parties had similar expectations. By working in a collaborative manner and conducting meetings throughout the data development process, we were able to capitalize on expert information to improve the final products.

2.4 Data Development Methodologies

2.4.1 Study Area Extent

The study area consists of 57,338 acres in central Boone County, Missouri and is centered on Hinkson Creek. The watersheds included are: County House Branch, Flat Branch, Grindstone Creek, Hinkson Creek, Hominy Branch, Merideth Branch, Mill Creek, Nelson Creek, and Varnon Branch (see Figure 1).

2.4.2 Projection

The standard projection used for all datasets was Missouri State Plane Central, NAD 83, FIPS 2402, U.S. Survey feet. Distances in tables are feet unless otherwise noted.

2.4.3 Stream Centerline Update

The Hinkson Creek stream centerline (Hydro_Lines) provided by Boone County was based on 2007 ortho-imagery and upon visual inspection, discrepancies between the centerline and stream channel in the 2009 LiDAR hillshade (provided by Boone County) and the 2011, 6 inch, leaf-off aerial photography (provided by Boone County) were observed. As a result, MoRAP manually edited the Hinkson Creek stream centerline at a 1:1000 scale to reflect its location based on 2009 LiDAR hillshade and the 2011 imagery (Figure 2). Additionally, in some locations the 2009 LiDAR and 2011 imagery did not match due to bank and stream channel geomorphologic changes. In these situations, the stream centerline was modified to more closely correspond with LiDAR, which was used to develop several other datasets.

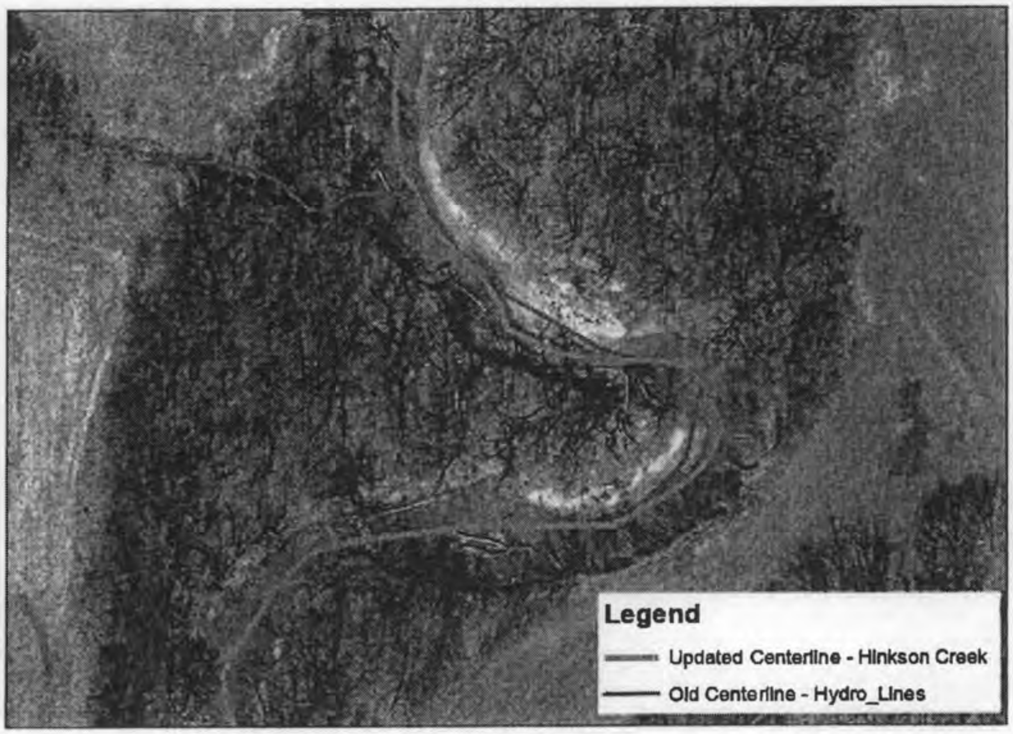

Figure 2. The centerline for Hinkson Creek was updated (blue) in places where 2007 line work (red) did not reflect stream conditions in 2011.

2.4.4 Top of Bank/Bankfull

A bankfull, or top of bank, dataset was created to identify the slope break between the narrower stream channel and the broader floodplain. Theoretically, this is the point at which water will flow over the banks into the surrounding floodplain. It should be noted that top of bank, as determined via GIS data, may not represent modern hydrologic bankfull width because of down cutting of the channel and limitations of the spatial resolution of the imagery. Hydrologic bankfull width is the channel width at bankfull discharge.

Several methods of delineating bankfull were explored, including the automated River Bathymetry Toolkit (RBT). The data for the study area proved to be too cumbersome for the RBT and the results on sample areas were not satisfactory. MoRAP was able to develop a straightforward and effective method of delineating bankfull. Image objects, or polygons, were created for a buffered extent of the Hinkson Creek centerline based on elevation and slope from the 2009 1 foot LiDAR DEM using Ecognition software. Polygons were generated to encompass textural, tonal, and statistical homogeneity in the data. Due to data file size restrictions, the study area was divided into 22 tiles and image objects were created for each tile. The image object tiles were merged together to create one file encompassing the total study area.

Polygons that delineated top of bank/bankfull were manually selected at a scale of 1:1000. All polygons between steep slope breaks at the top of banks on both sides of the creek were selected (Figure 3). Two foot elevation contours based on the LiDAR DEM were also used to aid in top of bank/bankfull delineation where one bank was higher than the other. This was especially useful in cases where one of the banks was a bluff or high valley wall with a continuous steep slope on one side of the creek. In these instances the elevation break point on the lower bank was used to determine where the bankfull line should be placed on the higher bank.

Image objects were based on raster data, resulting in squared and pixelated-looking polygons. To improve aesthetic appearances, a smoothing technique was applied to the polygons after bankfull delineation was complete (Figure 3 A and B). The polygon shapefile was smoothed in ArcMap using the PAEK smoothing algorithm with a 25 feet tolerance, and all other defaults were retained. This smoothing technique was also applied to valley boundaries and sand/gravel bar boundaries, which were also developed using image objects based on raster data.

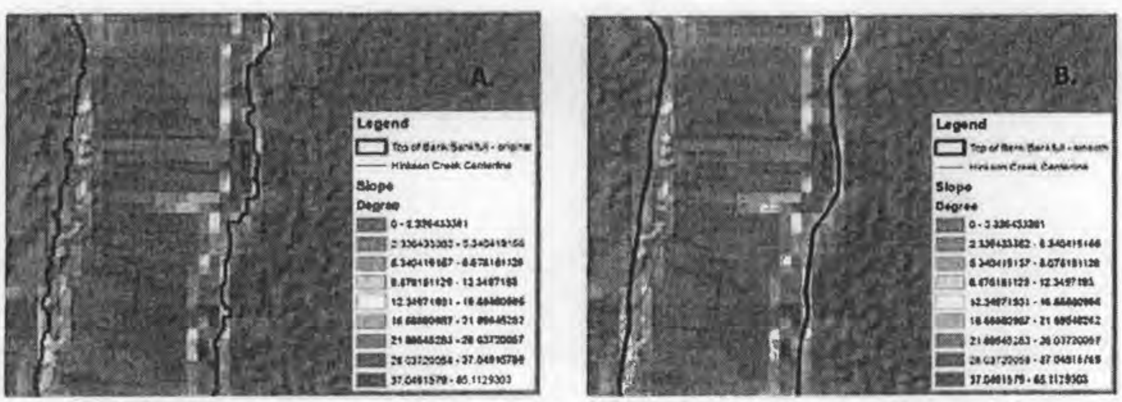

Figure 3. A) The original, pixel based polygon delineation of bankfull where the surrounding valley begins to slope down into stream channel. B) Smoothed bankfull polygon.

2.4.5 Valley Delineation

The initial Hinkson Creek valley delineation concept was designed to define the stream valley from bluff to bluff, including the entire bottomland area and all recent as well as historic floodplain terraces. After initial review by, and advice from, the subject matter experts, a second version of the valley was delineated based on modern constrictions to flow (e.g. levees, roads, etc.; Figure 4).

The constricted modern floodplain concept attempts to limit the delineation to the modern active floodplain and accounts for the impacts of modern structures such as levees, built-up roads, and bridge abutments. This delineation was somewhat subjective, but a single MoRAP staff member did all of the delineation to ensure consistency. Results were viewed and vetted by members of our subject matter expert panel.

The valley boundaries delineated in this project are distinct and different from the FEMA floodplain dataset. The FEMA dataset was developed to identify flood hazards and will be a useful tool in future analyses. The valley bottom datasets created here are not intended for use in flood hazard assessment.

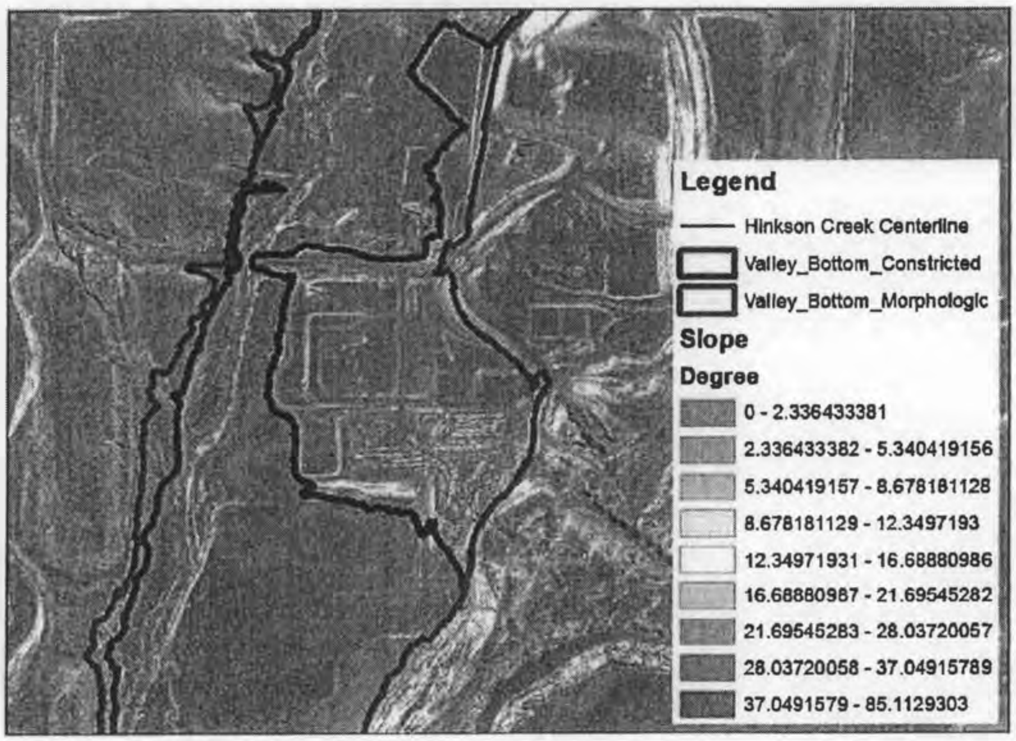

Figure 4. Location within the valley where constricted (black) valley is narrowed due to levees and elevated road beds. Morphological valley (blue) is considerably wider in some areas.

2.4.5.1 Morphological Valley Delineation

The morphological valley boundary broadly circumscribes the bottomland between bluffs (Figure 5). The same image objects created for top of bank/bankfull were used to delineate the morphological valley. Image objects that intersected with alluvial bottomland/valley soils defined by digital county soil surveys were initially selected. The valley boundary was refined using a subjective manual process, generally at a scale of 1:1000. The image objects were compared against the 2009 1 foot LiDAR hillshade and slope to identify the final boundary of the valley. Valley boundary identification was clear at bluff/bottomland intersections. However, a more subjective approach was often required in areas with more subtle valley slope breaks. In such cases, the valley boundary line was often drawn where incised lateral drainages on slopes intersected with smooth, flat valley bottoms.

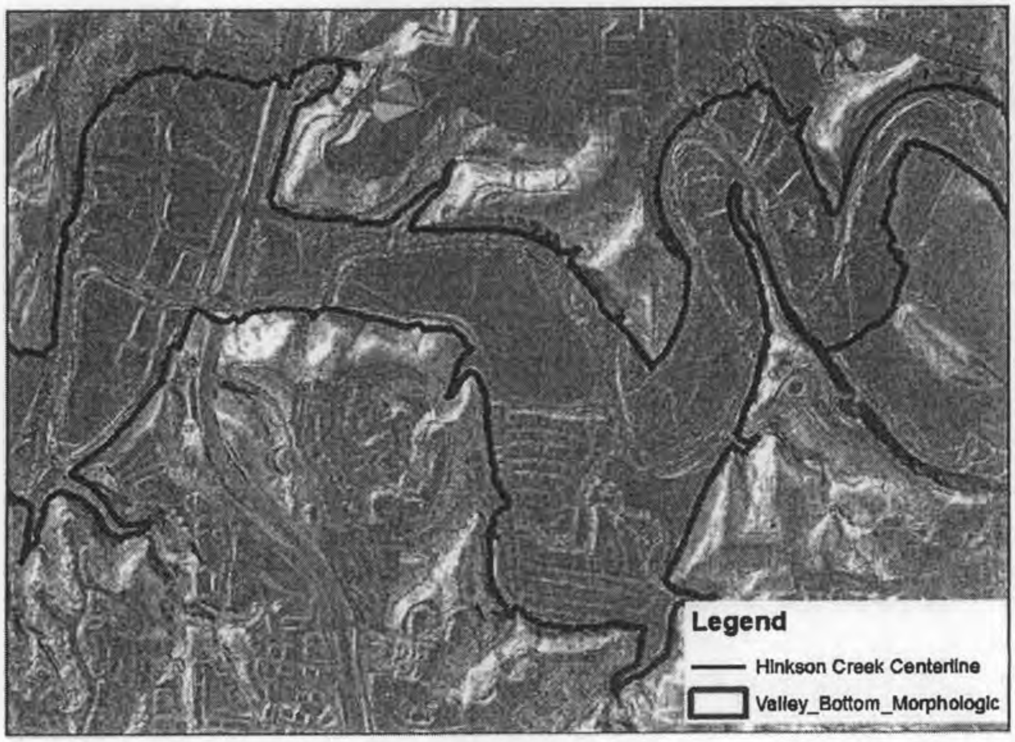

Figure 5. Morphological valley delineating bluff to bluff boundary.

2.4.5.2 Constricted Valley Delineation

The constricted valley is often defined by anthropomorphic built-up impedances, such as roads, bridges, trails, levees, and neighborhoods. In some areas without built-up impedances, the constricted valley boundary is drawn at gentle inflections in the landscape that may correspond with the boundary between modern versus older floodplain terrace soils. The same image objects generated for top of bank/bankfull and morphological valley boundary were used to delineate the constricted valley (Figure 6). This process was also a manual and subjective process that was completed at an average scale of 1:1000.

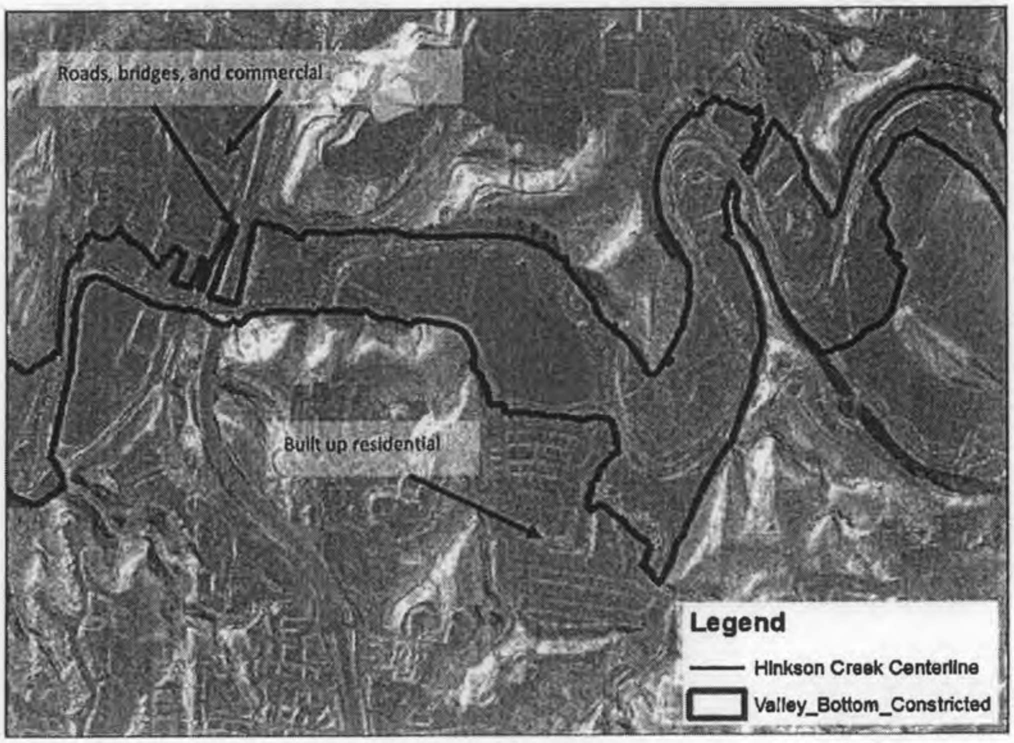

Figure 6. Valley is constricted due to roads, bridges, and built up residential and commercial properties.

2.4.6 Sand or Gravel Bar Delineation

Sand or gravel bars within Hinkson Creek channel were delineated based on 2011 6 inch, 3-band, true color, leaf-off aerial photography provided by Boone County (Figure 7). Image objects were generated based on the 2011 photography using Ecognition software. Due to data file size restrictions, the imagery was divided into seven tiles. Image objects, or polygons, were generated based on the textural and tonal homogeneity of the imagery. The image object tiles were merged into a single file for sand or gravel bar delineation. Polygons that circumscribed sand or gravel bars were manually selected and modified at a scale of 1:1000, as needed, by scanning the entire length of Hinkson Creek from the confluence to the headwaters. No distinction between sand versus gravel bars was possible due to limitations of the imagery. Accordingly, the resultant dataset is a record of sand or gravel bars that existed in the spring of 2011.

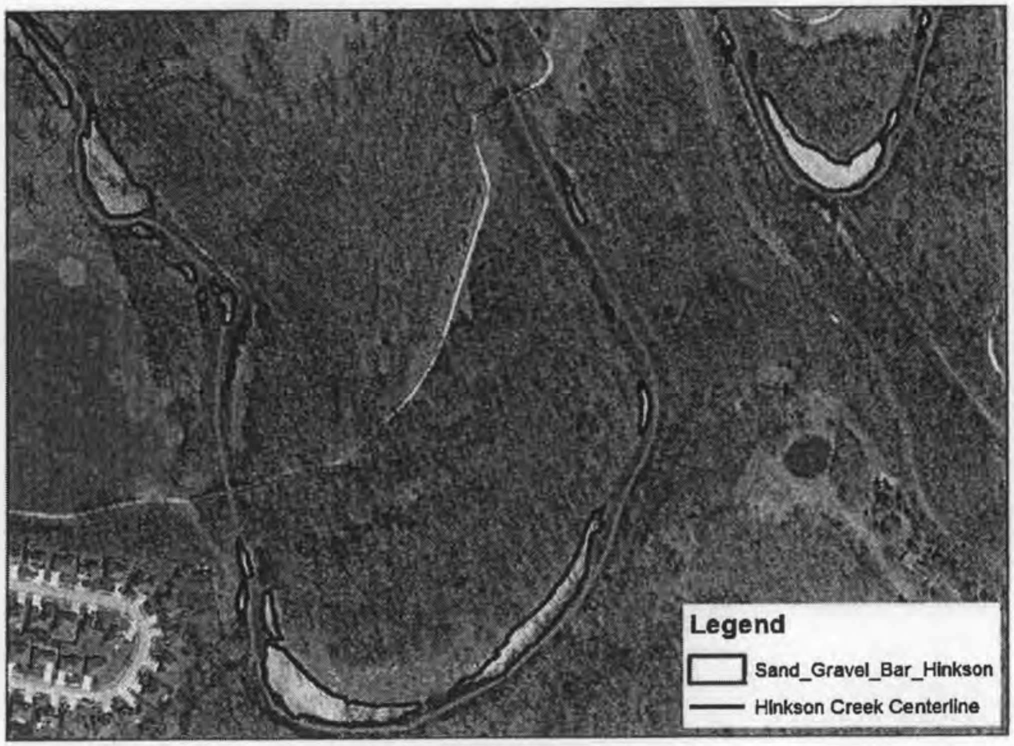

Figure 7. Sand or gravel bars were identified based on 2011 6 inch, 3-band, true color, leaf-off imagery.

2.4.7 Land Use/Landcover - LULC

Land Use/Landcover (LULC) data were used to determine the composition of vegetation and impervious surface within the study area. LULC from the City of Columbia's 2007 Natural Resources Inventory (NRI), a 6 class vector LULC based on 2007 6 inch, 4-band, leaf-on, aerial photography covered approximately 75% of the study area. The remaining 25%, mainly north of the city of Columbia, was not covered by high spatial resolution LULC. MoRAP developed a NRI-like LULC to fill in the gap (Figure 8).

The MoRAP NRI-like LULC is based on 2011 6 inch, 3-band, leaf-off aerial photography (provided by Boone County), 2010 1 meter, 4-band, leaf-on NAIP imagery, 2009 LiDAR DEM derivatives slope and aspect, and a LiDAR digital surface model (DSM). All datasets used in classification were resampled to 1 meter spatial resolution. A supervised classification approach was employed to map the 6 NRI LULC classes (forest, grass, impervious, sparsely vegetated, crop, and water). A total of 3,000 training samples from the NRI dataset, 500 per class, were used to classify and map LULC in raster format. Image objects were generated using Ecognition software based on the 2011 and 2010 imagery to approximate the shape and size of the NRI polygons. Each polygon was attributed with the majority LULC value based on the raster LULC dataset. The NRI and MoRAP NRI-like LULC vector datasets were merged together to create a seamless, high spatial resolution vector LULC dataset that covers over 99% of the study area (Figure 9). There were approximately 100 acres not covered by LULC due to lack of data at the time of classification.

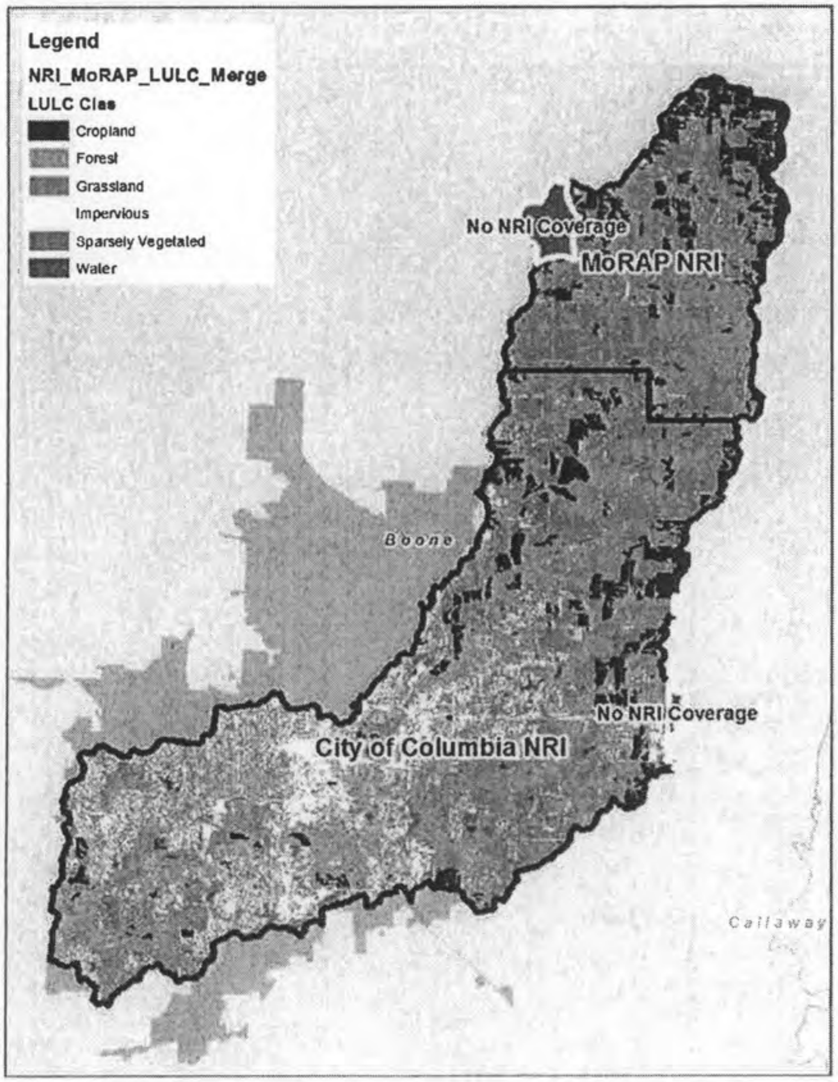

Figure 8. MoRAP created NRI-like LULC for the northern portion of the study area. The areas in red indicate where no LULC exists.

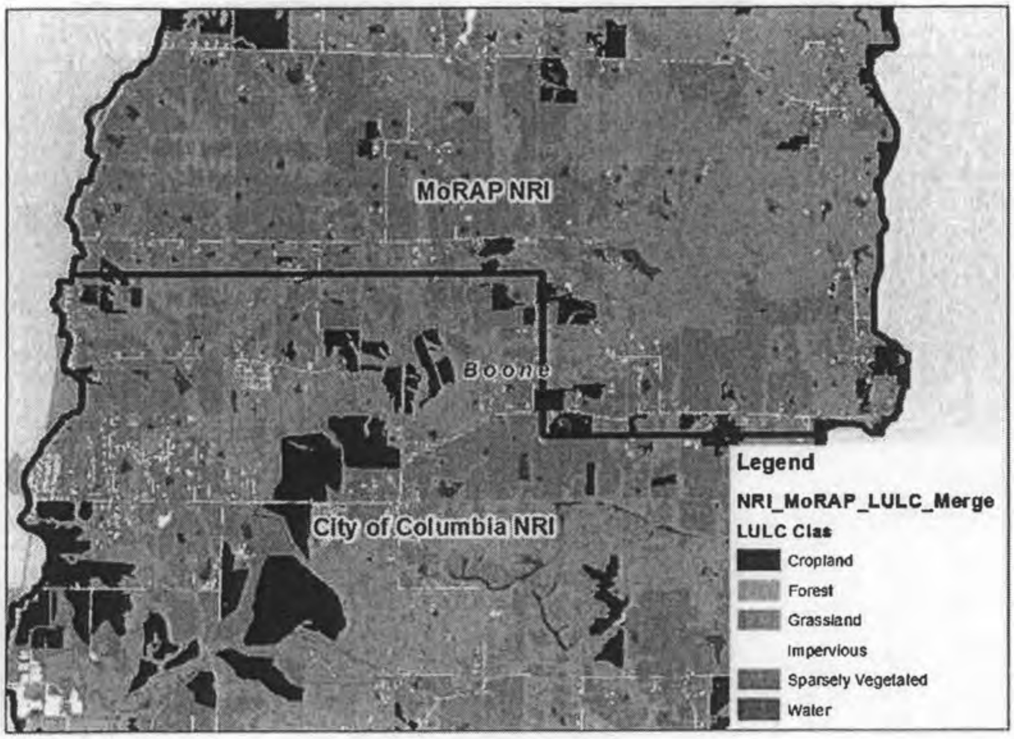

Figure 9. The addition of the MoRAP created LULC provided a virtually seamless LULC for the study area.

2.4.8 Stream Points

Points were generated along the Hinkson Creek centerline at 50 meter intervals to facilitate data summaries and on-the-ground sampling (Figure 10). Ground data will be collected at intervals defined by points generated here, and field data can be compared with GIS-generated data. Attributes applied to the points were percent slope, sinuosity, bankfull width, morphological and constricted valley width, and distance to valley wall. Summaries were provided at intervals of 50, 100, 250, 500, 1000, 2000, and 4000 meters. All points at an interval greater than 50 meters were based on the 50 meter points. Physical stream attributes at multiple scales allow fine- and broad-scale views of the stream. The unique identification number for each set of points begins at 0 at the confluence of Perche and Hinkson Creeks and increases incrementally upstream to the headwaters.

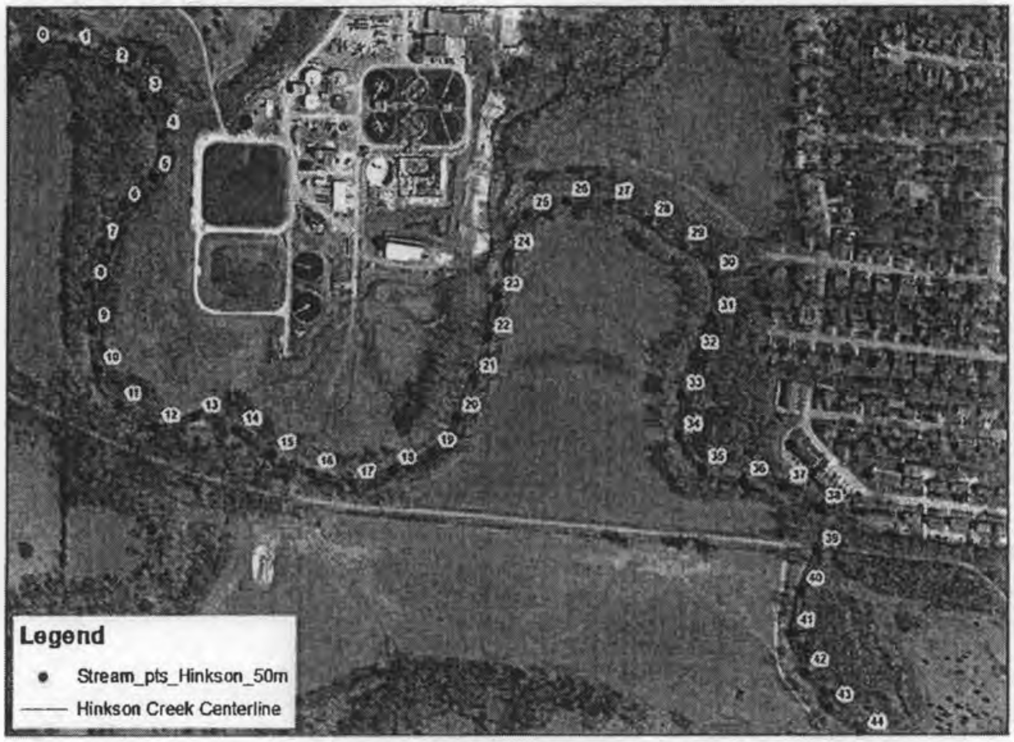

Figure 100. Shown are points at 50 meter intervals along the Hinkson Creek centerline, beginning at the confluence with Perche Creek. Physical attributes were summarized for these points (i.e. slope, sinuosity, bankfull width, valley width, etc.).

2.4.8.1 Percent Slope

Slope is a measure of stream gradient or steepness and was based on the surface water elevation of the stream at the time of LiDAR DEM (provided by Boone County) data acquisition, March 18 and 19, 2009. Average stream discharge during the period of data acquisition was 19 cubic feet per second (waterdata.usgs.gov). Percent slope between stream points along the centerline was calculated at all point intervals. Calculation of slope began at the confluence of Hinkson and Perche Creeks and ended at the headwaters. Slope was calculated by first extracting the elevation for each point from the LiDAR DEM, then calculating the elevation difference between the adjacent points to determine the rise value. The elevation difference was divided by the stream distance to produce a percent slope value.

% slope = (elevation difference/stream line distance) x 100

2.4.8.2 Sinuosity

Sinuosity is a measure that indicates the degree to which a stream meanders. It is the ratio between the stream distance and Euclidean, or straight-line, distance between two points. A value of 1 indicates a straight stream. As values increase a more sinuous, or meandering, stream is indicated (Figure 11). Sinuosity was calculated between points at all stream point intervals and began at the confluence of Hinkson and Perche Creeks and ended at the headwaters (Figure 12).

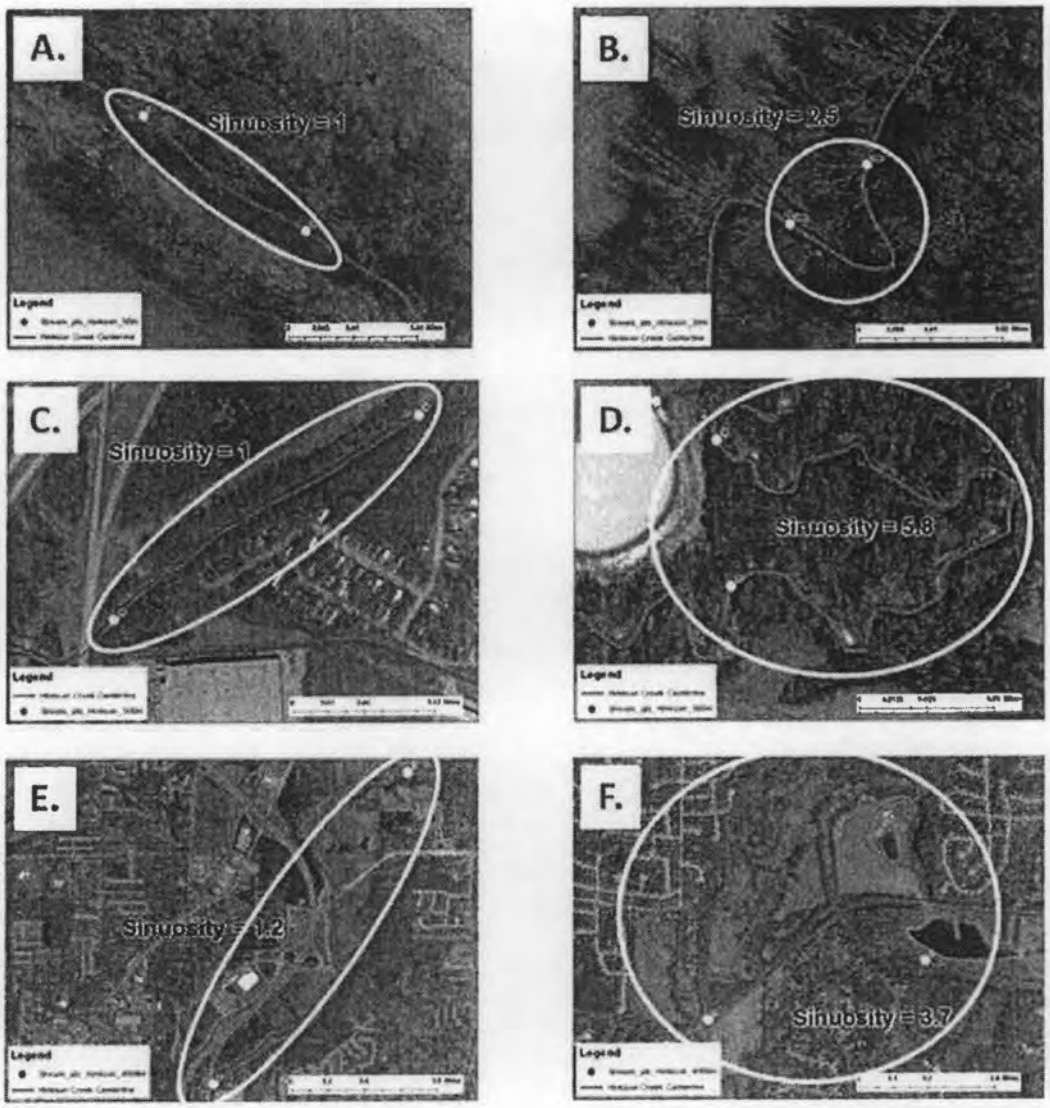

Figure 11. Shown is sinuosity at various scales. A) Sinuosity value of 1 between 50 meter points, indicating a straight section of the creek. B) Maximum sinuosity value of 2.5 within the 50 meter point dataset. C) Sinuosity value of 1 between 500 meter points. D) Maximum sinuosity value of 5.8 within the 500 meter point dataset. E) Sinuosity value of 1.2 between 4000 meter points. F) Maximum sinuosity value of 3.7 within the 4000 meter point dataset.

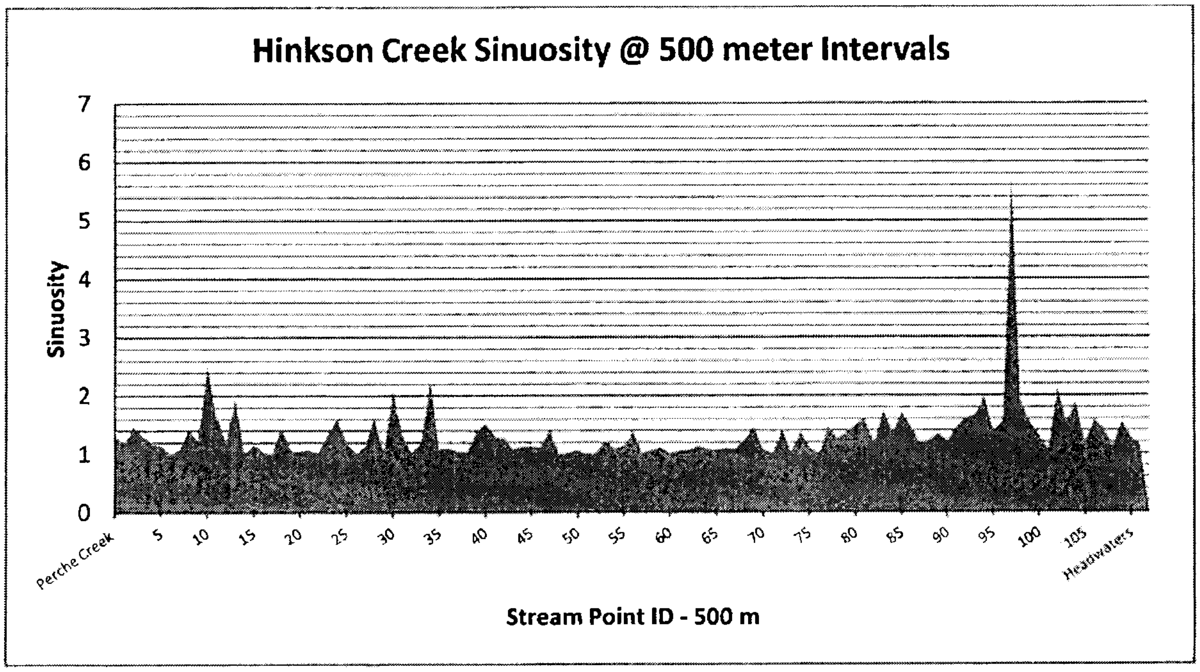

Figure 122. Longitudinal plot of sinuosity measures of Hinkson Creek at 500 meter point intervals. See Figure 23 for locator map of points at 500 meter intervals.

2.4.8.3 Bankfull and Valley Width

Top-of-bank/bankfull and valley widths were measured at each point for all point intervals. A transect perpendicular to the stream centerline was generated for each point and clipped to bankfull, morphological valley, and constricted valley boundaries (Figures 13, 14, 15, and 16). The Geospatial Modeling Environment (GME) "sampleperpointsalonglines" function was used to generate points perpendicular to the stream centerline at 50 meter intervals. Transects were generated at a distance of 300 feet on each side for bankfull width and 10,000 feet for valley widths. A Python script was written to convert the endpoints for transects into polylines. The polylines were clipped to bankfull, morphological valley, and constricted valley boundaries. Extraneous lines remaining as a result of clipping the polylines to boundaries were removed. Line distance, in feet, was calculated for the remaining polylines. A spatial join was performed to apply transect lengths for bankfull and valley widths to each set of stream points.

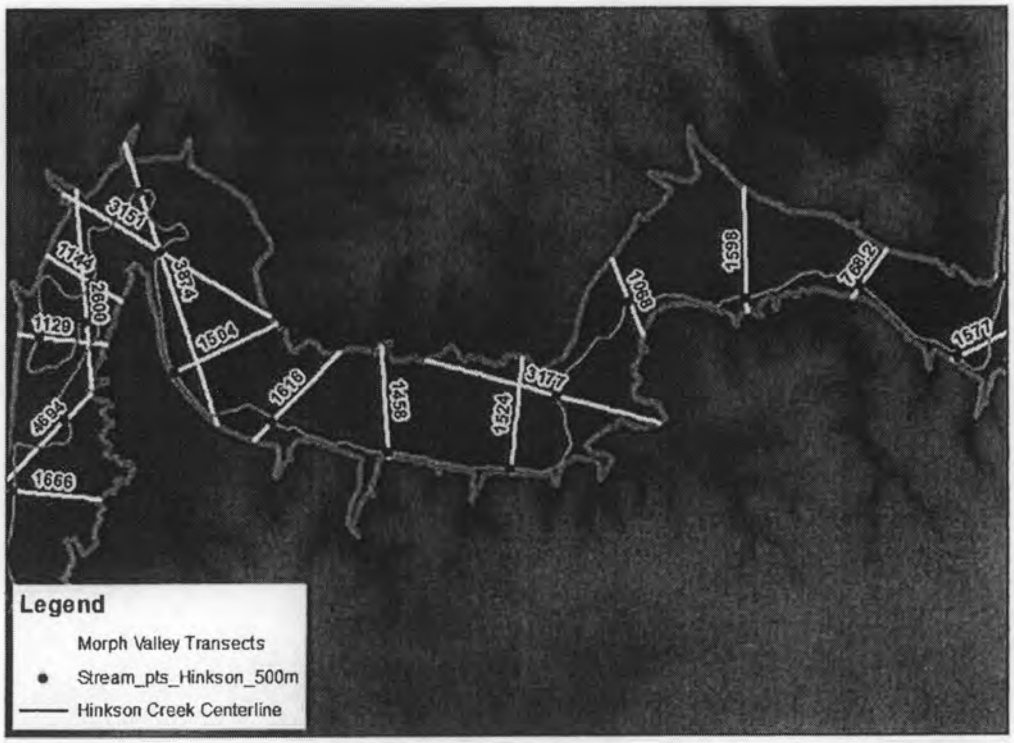

Figure 133. Transects perpendicular to the stream centerline were calculated for each point and clipped to morphologic and constricted valley boundaries and the bankfull boundary to calculate width and then applied to each point. Shown are transects clipped to the morphological valley boundary with width distances in feet on the transect lines. Due to stream sinuosity within the valley, these values may be more or less meaningful.

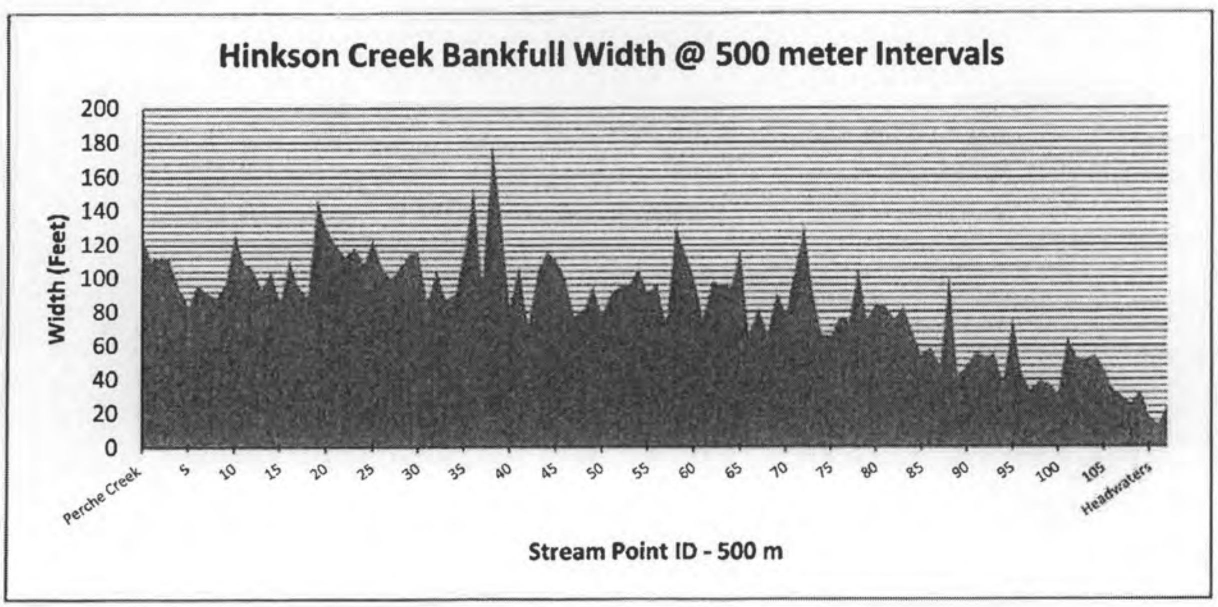

Figure 14. Longitudinal profile of Hinkson Creek bankfull width at 500 meter intervals shows decreasing width from the confluence at Perche Creek upstream to the headwaters. See Figure 23 for locator map of points at 500 meter intervals.

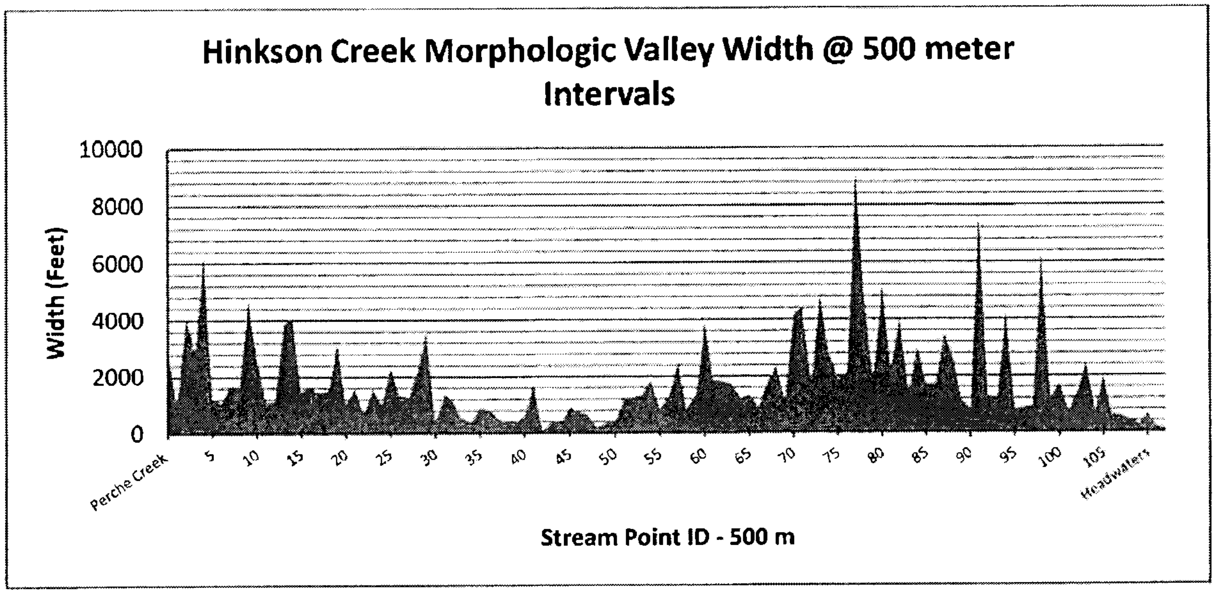

Figure 145. Width of Hinkson Creek morphologic valley at 500 meter intervals. See Figure 23 for locator map of points at 500 meter intervals.

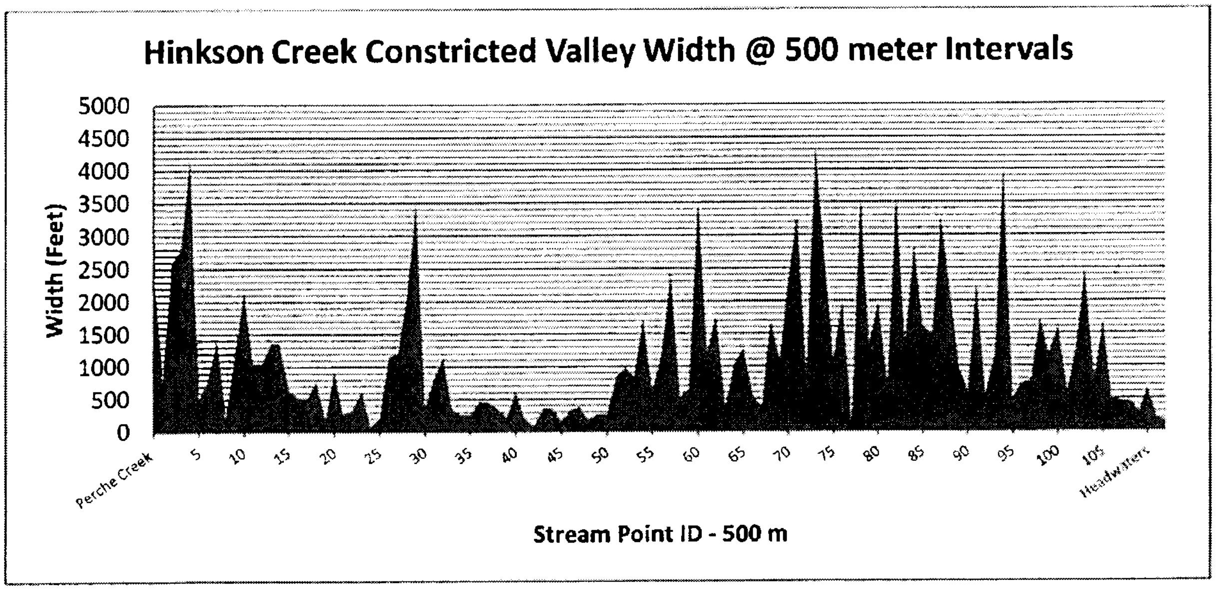

Figure 156. Width of Hinkson Creek constricted valley at 500 meter intervals. See Figure 23 for locator map of points at 500 meter intervals.

2.4.8.4 Distance to Valley Wall

Distance to morphologic and constricted valley walls were calculated and applied to points for all point intervals. Transects used to measure valley width were split at the stream centerline, and the length of the remaining transects for each side of the stream was calculated (Figures 17, 18, and 19). Two distance values were assigned for each point, one for distance to valley wall/boundary edge on one side of the stream, and one for distance on the opposite side. Right and left sides of the stream were assigned as if navigating upstream from the confluence of Hinkson and Perche Creeks.

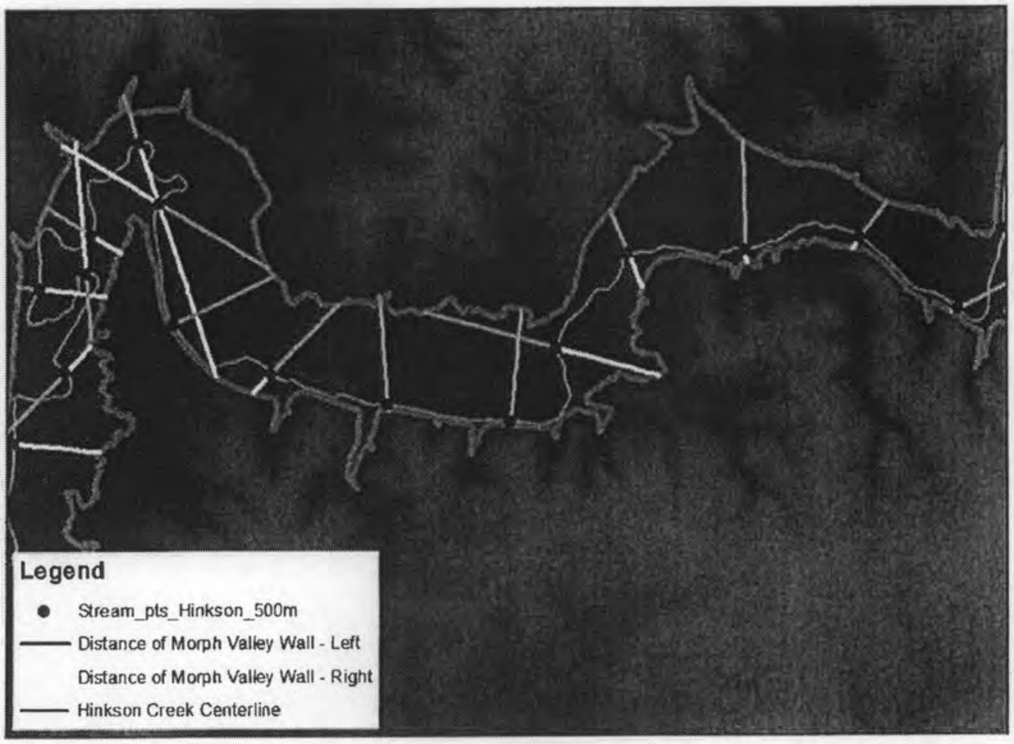

Figure 167. Perpendicular transects used to calculate valley widths were split using the stream centerline. Distance from centerline to right and left side valley boundaries were calculated and applied to each point. Due to sinuosity within the valley, these values may be more or less meaningful.

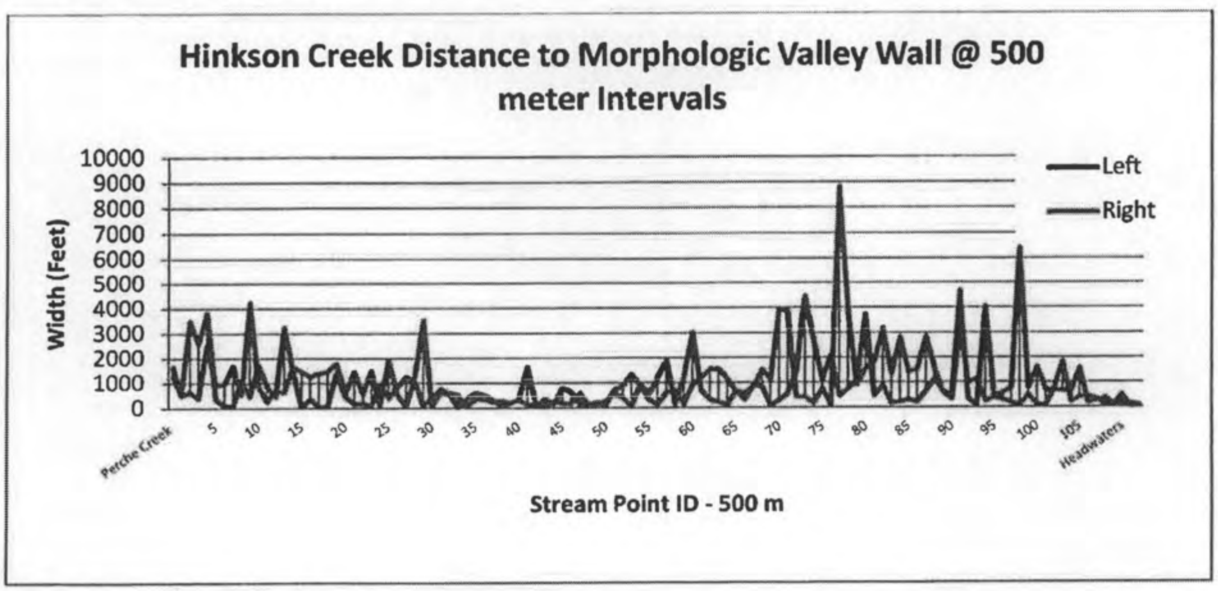

Figure 18. Distance to morphologic valley wall from Hinkson Creek centerline at 500 meter intervals. Red line represents distance from right side of stream to valley boundary and blue line represents distance from left side of stream to valley boundary based on navigation upstream from confluence of Hinkson and Perche Creeks. See Figure 23 for locator map of points at 500 meter intervals.

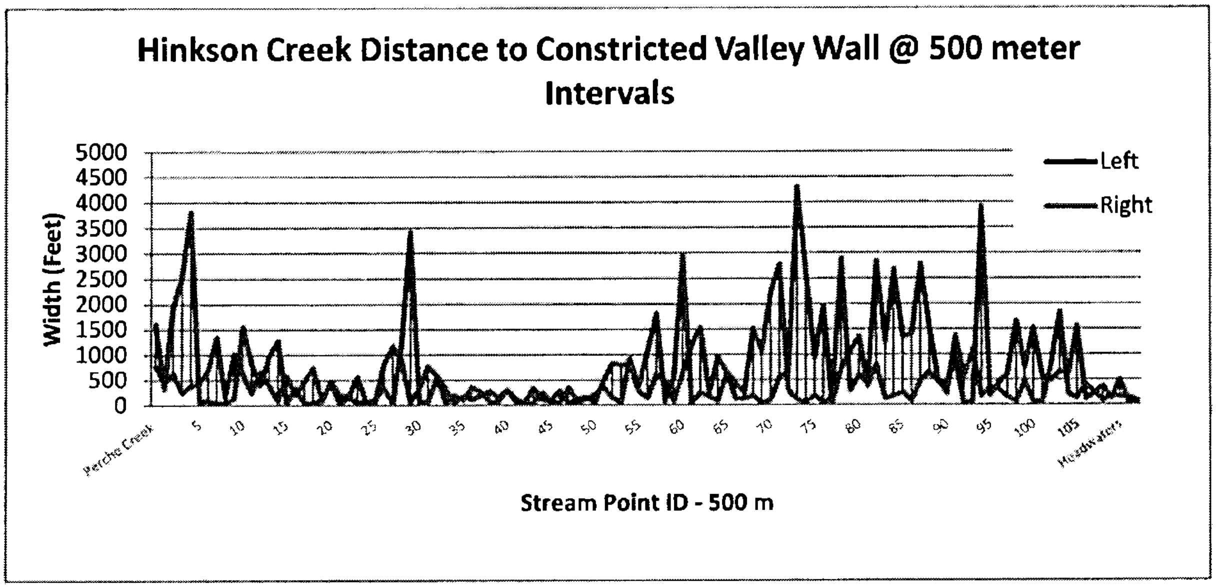

Figure 19. Distance to constricted valley wall from Hinkson Creek centerline at 500 meter intervals. Red line represents distance from right side of stream to valley boundary and blue line represents distance from left side of stream to valley boundary based on navigation upstream from confluence of Hinkson and Perche Creeks. See Figure 23 for locator map of points at 500 meter intervals.

2.4.8.5 Thiessen Polygon LULC Summary

Thiessen polygons represent areas, or zones, around a set of points where any location associated with a given point is closer to that point than any other point. A set of Thiessen polygons was generated for stream points at all intervals in order to associate the surrounding LULC with a spatially specific location within the stream. The polygons were clipped to both the morphologic and constricted valley boundaries and LULC composition was summarized (total area and % area of each class) for every polygon within each dataset. This resulted in two sets of polygons for each stream interval. A caveat to comparing LULC values for a given point is that the size of the area within polygons associated with any given point can vary greatly. The shorter the stream centerline interval between points, the more varied in size the area within polygons. Polygons based on 50 meter interval stream points have a coefficient of variance (CV) of roughly 0.91 (Figure 20). They become less variable at 500 meters, where CV was 0.49 (Figure 21). The lowest CV of 0.41 occurred at 2000 meters.

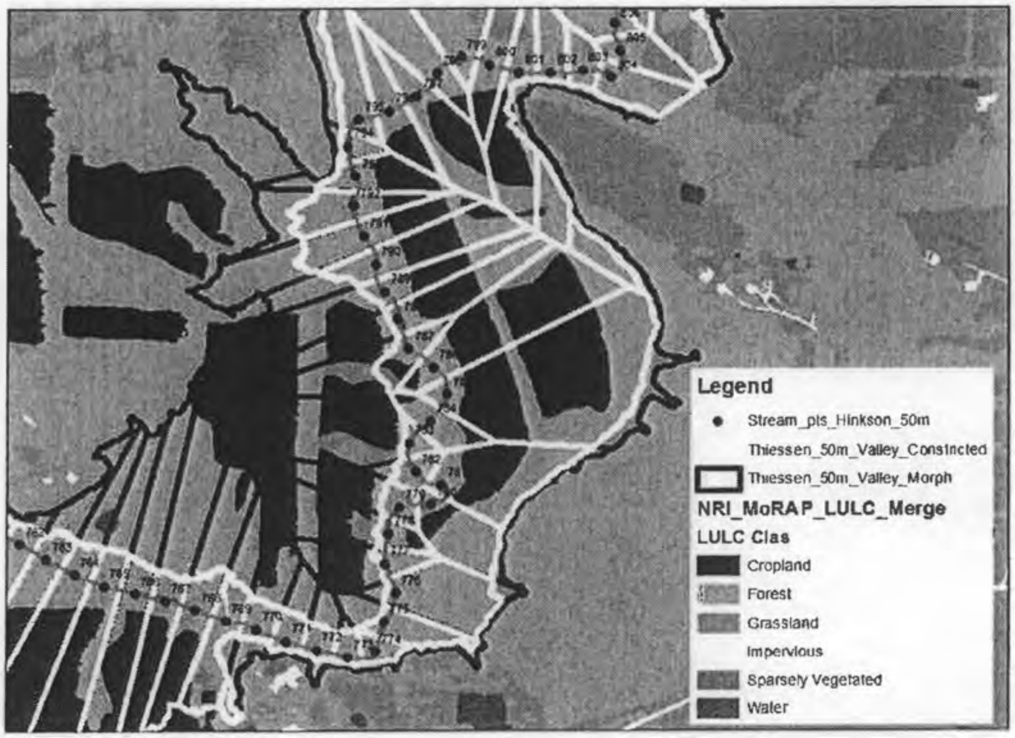

Figure 20. Theissen polygons based on stream points at 50 meter intervals vary greatly in size. Thiessen polygons were clipped to morphological (black) and constricted (white) valley boundaries.

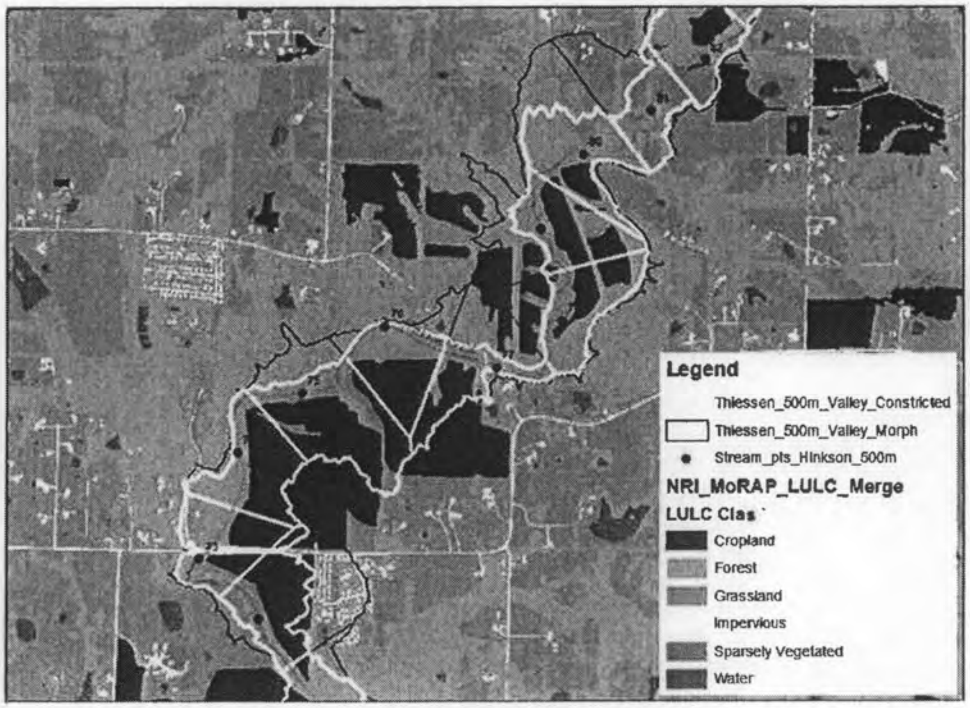

Figure 21. Theissen polygons based on stream points at 500 meter intervals were much more uniform in size compared to 50 meter intervals (Figure 20). Thiessen polygons were clipped to morphologic (black) and constricted (white) valley boundaries.

2.4.9 Hinkson Road Crossings

A point file was created indicating where roads, bridges, trails, cart paths, etc. cross Hinkson Creek (Figure 22). A point was manually placed on the stream centerline at the location of a stream crossing based on visual inspection of the 2011 6 inch, leaf-off imagery provided by Boone County at a scale of 1:1000. This is a record of stream crossings visible in 2011 aerial photography.

Figure 172. A point file of road crossings was manually created by marking any road, bridge, trail, or low water crossing along the stream centerline visible in Spring 2011.

3 Results

3.1 LULC Analysis

3.1.1 LULC – Theissen Polygons - Morphologic Valley

Land Use/Landcover (LULC) values can be analyzed in a number of ways to help evaluate contribution to stream conditions at multiple scales. LULC summarized by Thiessen polygons at 500 meter stream intervals, clipped to the morphologic valley extent, show spikes in impervious at the lower reaches of Hinkson Creek (Figures 23 and 24). Forest and grass comprise the majority of LULC throughout much of the valley, except at the lower reach where impervious cover increases and at the upper middle portion of the reach, between points 61 and 72, where crop increases (Figures 23 and 24).

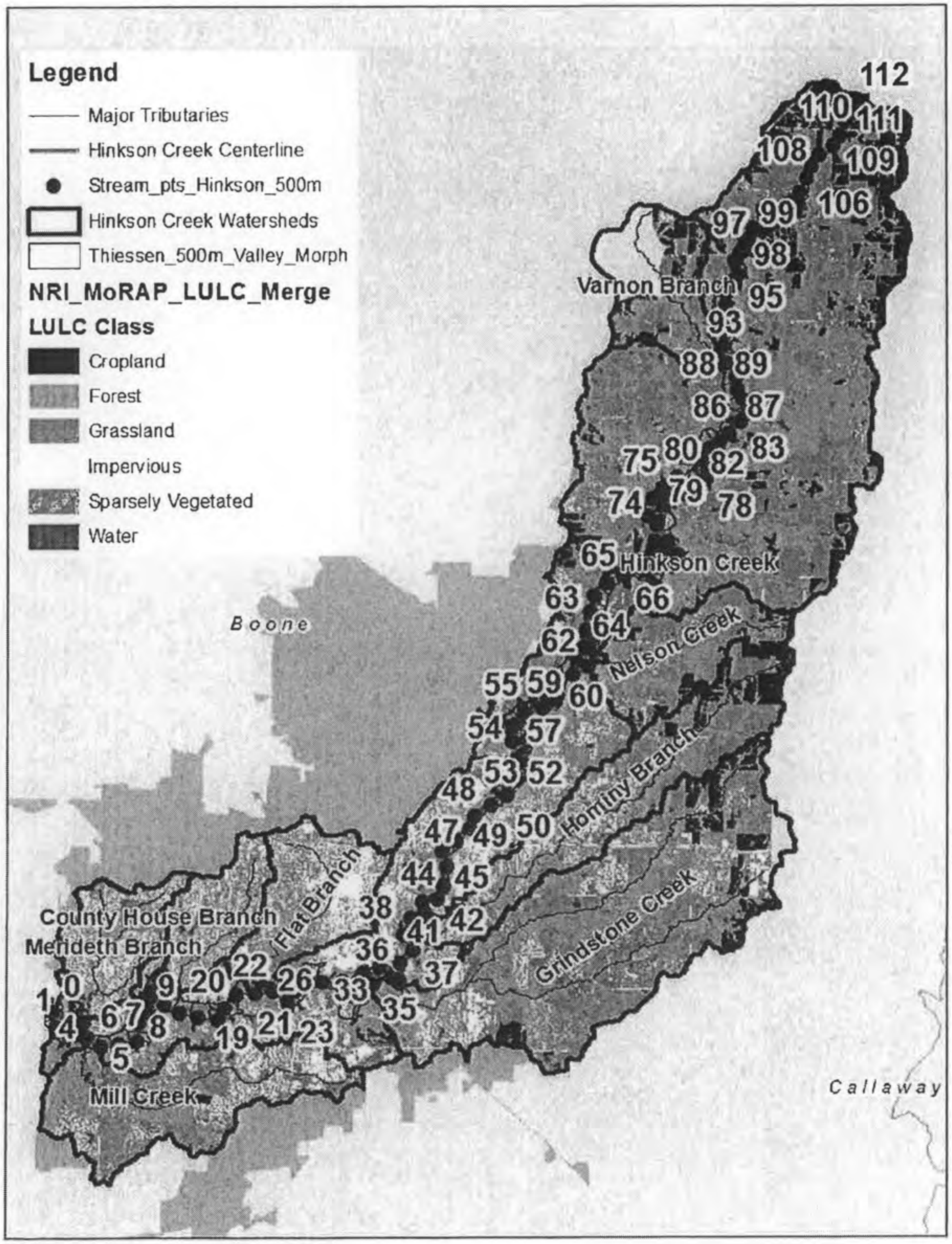

Figure 183. Numbers represent unique ID of stream points and Thiessen polygons at 500 meter intervals along stream centerline.

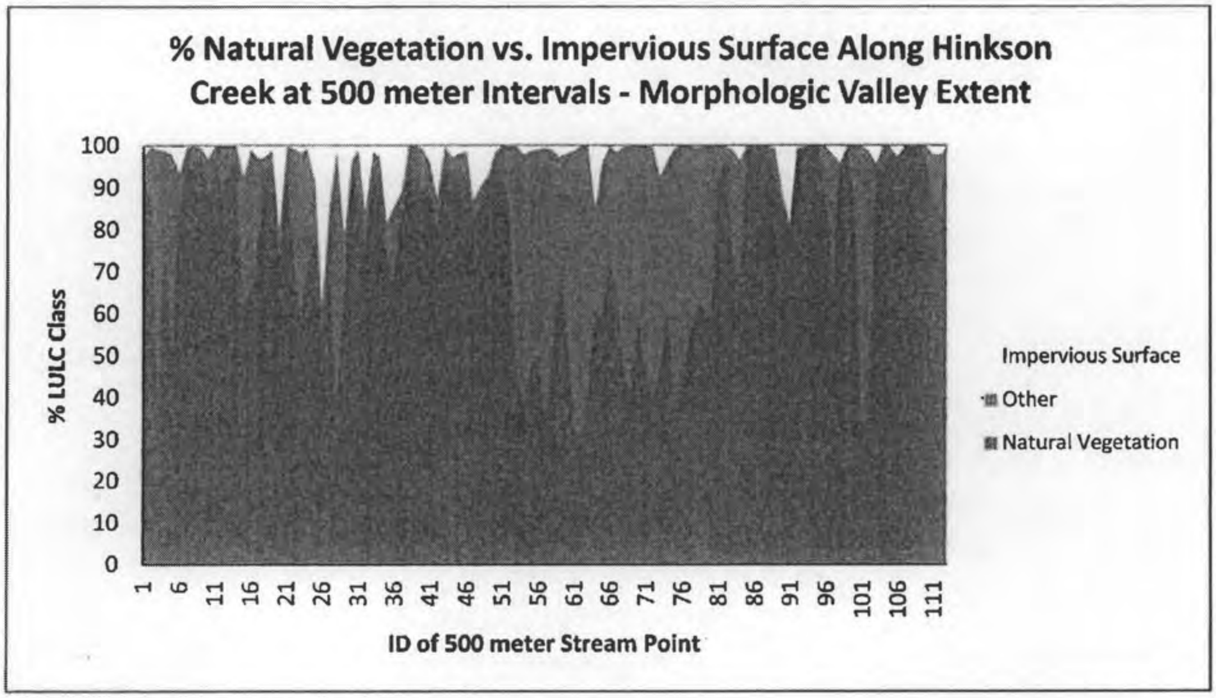

Figure 194. Chart illustrating LULC composition within Thiessen polygons at 500 meter intervals within the morphologic valley. Spikes in impervious surface mostly occur along lower portions of stream, between points 16 and 51. While natural vegetation (grass and forest) drops just below the mid-point of the stream, it typically comprises the majority of LULC within the morphologic valley. Points along the x-axis correspond to spatially explicit points along Hinkson Creek (Figure 25), beginning at the confluence and ending at the headwaters.

3.1.2 LULC – Watershed

At a broader scale, LULC composition within each watershed is illustrated in Figures 25, 26, and 27. Hinkson Creek watershed has the most total area in all cover classes (Figure 26) based on its overall larger size. Forest and grass are the predominant cover types in all watersheds. Flat Branch watershed has the highest percentage of impervious of all watersheds, at 31%, followed by Meredith Branch, at 23%.

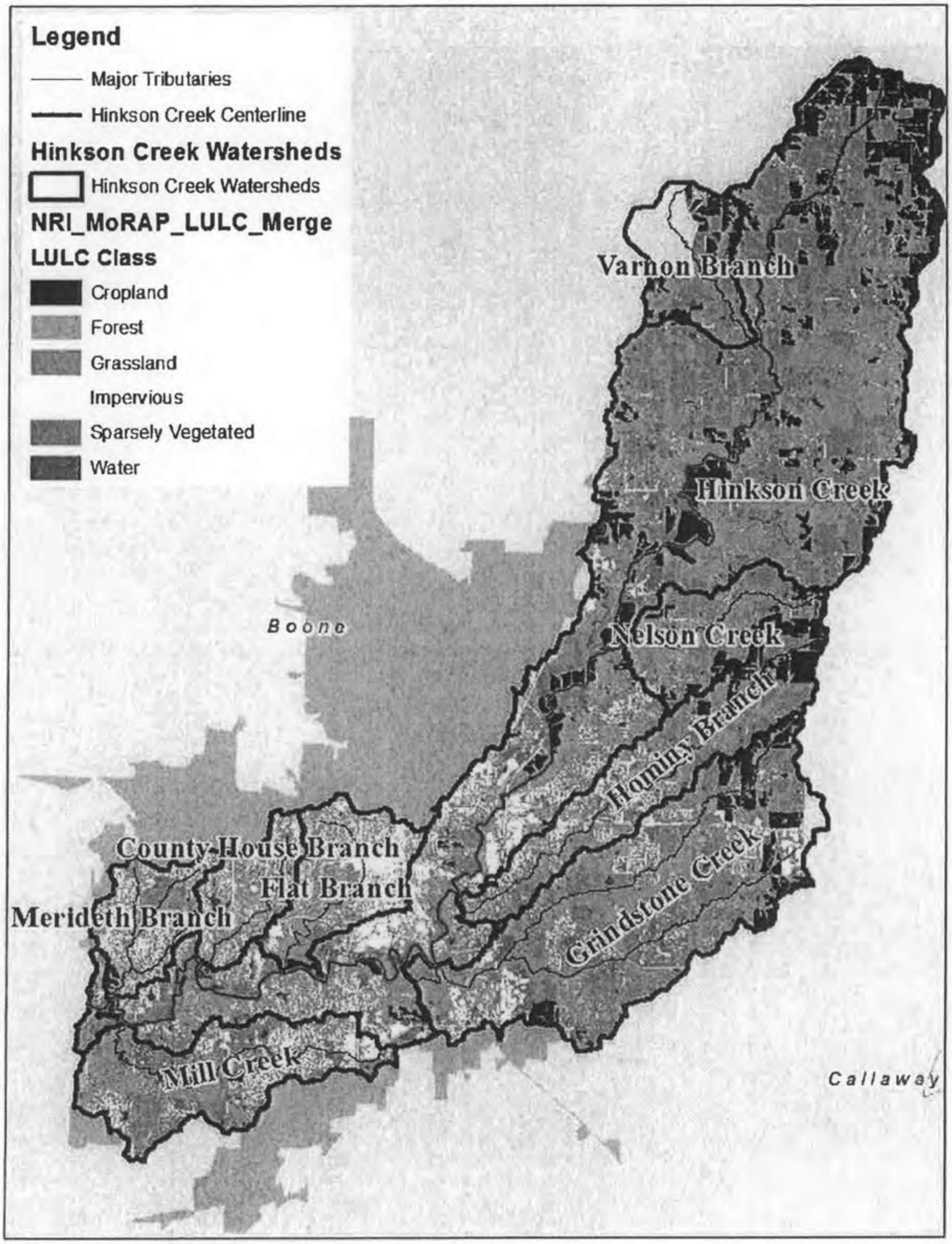

Figure 205. Watersheds and LULC within Hinkson Creek study area.

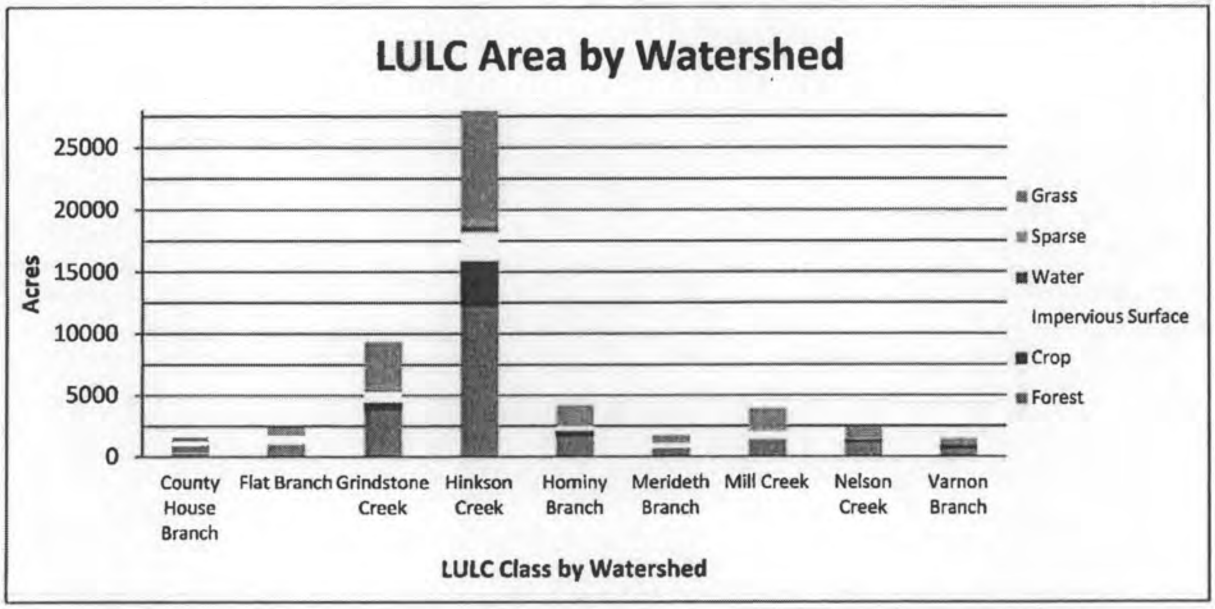

Figure 216. Area of LULC within each watershed in acres.

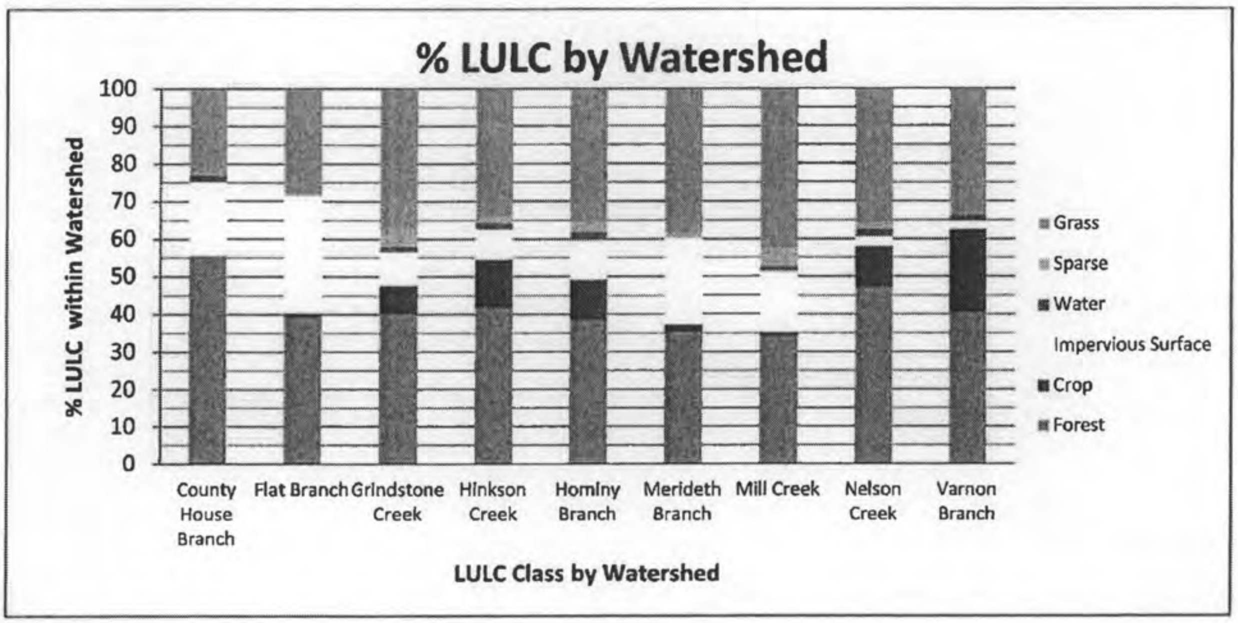

Figure 227. Percent LULC class within each watershed.

3.1.3 LULC – Cumulative Upstream Catchments

To quantify the cumulative upstream composition of LULC at each major tributary, the watershed was divided into hydrologic drainage catchments that roughly correspond with the watershed layer. The Hinkson Creek watershed was subdivided at the confluence of major tributaries. Break lines were drawn based on Hinkson Creek basin hydrologic catchments generated from 30 m DEMs (Figure 28). Catchments were numbered from 1 to 8, starting at the headwaters, with each major tributary resulting in a break point.

Figure 29 shows the percent LULC within each catchment. Forest and grass comprise the majority cover in all catchments, while percent crop decreases and impervious increases downstream. Catchment 5 (Flat Branch) is 28% impervious, which is the highest percentage of all the catchments. Catchment 1 (Varnon Branch) has the highest percentage of crop, at 30%. The highest percentage of forest is found in catchment 6 (County House Branch), at 54% of the catchment. The percent cover by catchment portrays a more accurate longitudinal LULC trend, following the course of Hinkson Creek, than the watersheds. This is due to the subdivision of the Hinkson Creek watershed at major tributaries.

Cumulative upstream LULC depicts the composition of LULC above each major tributary. Forest, grass, and impervious steadily increase downstream, while the percentage of crop levels off at catchment 4, the Grindstone Creek confluence (Figure 30). A spike in impervious occurs between catchments 2 (Nelson Creek) and 3 (Hominy Branch), where the total jumps from 0.8% to 3.3%, and continues to increase up to the confluence with Perche Creek. The second highest spike in impervious occurs between catchments 4 (Grindstone Creek) and 5 (Flat Branch), where the value increases from 5% to 7.3%. Ninety-five percent of all crop occurs between catchments 1 (Varnon Branch) and 4 (Grindstone Creek), and 70% of crop is accounted for in catchments 1 (Varnon Branch) and 2 (Nelson Creek). The most significant jump in forest and grass cover is from catchment 1 (Varnon Branch) to 2 (Nelson Creek), with 13% and 11% increases, respectively.

Percent LULC cover type relative to total area of a given cover type helps to identify the spatial distribution of cover types by catchment. Figure 31 shows that roughly 32% of all forest is within catchment 2 (Nelson Creek), 36% of all crop is within catchment 1 (Varnon Branch), and 60% of impervious surface is within catchments 3 through 5. Catchment 3 (Hominy Branch) has the highest value for impervious at 23%. More than 31% of grass exists in catchment 2 (Nelson Creek). These values are influenced by the size of the catchments, but nonetheless paint a picture of the distribution of land cover within the study area.

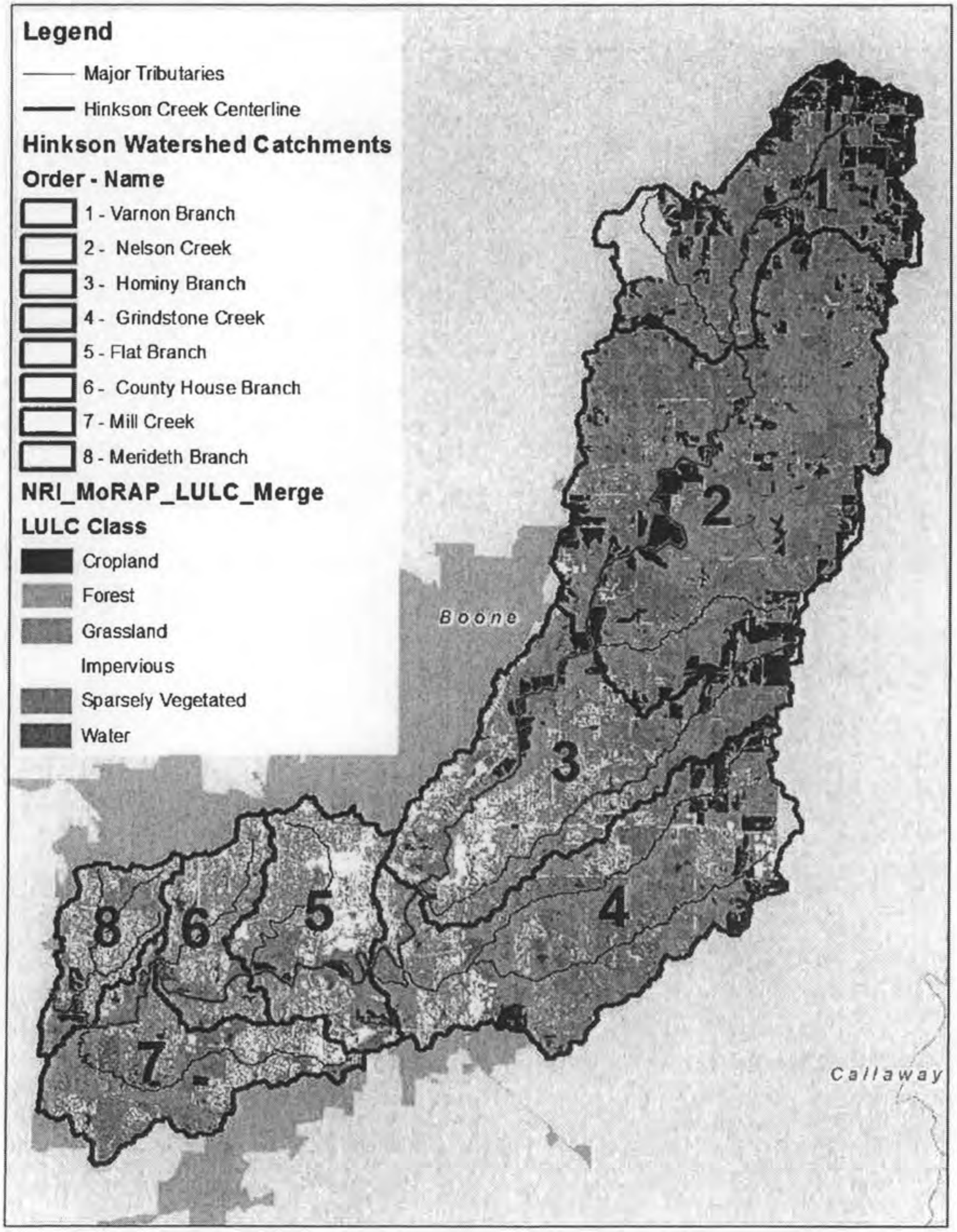

Figure 28. "Catchments" developed to calculate cumulative upstream LULC composition statistics at major tributaries of Hinkson Creek. Watersheds were divided at major tributaries based on fine scale catchments and lumped into broader watershed catchments. Catchments were numbered starting at #1 for the headwaters and increasing downstream.

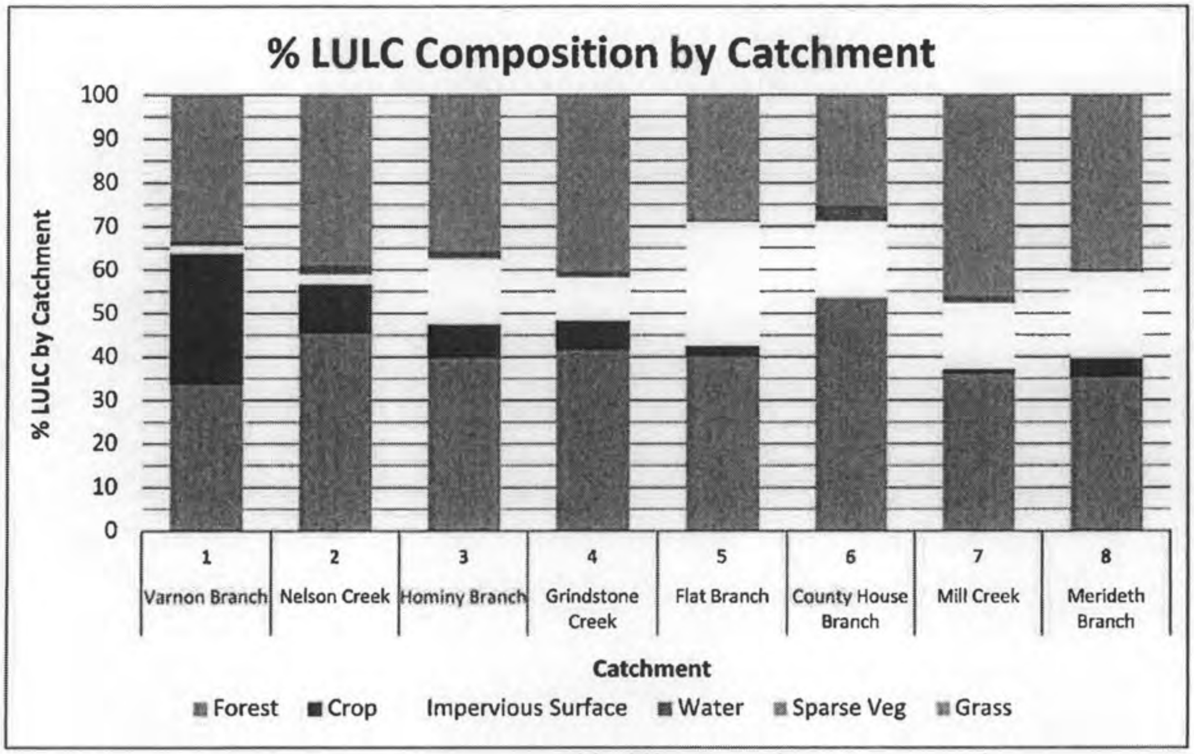

Figure 29. Percent LULC composition within each catchment. Note the dominance of the forest and grass cover types in all catchments, the increase in impervious cover from catchments 3 to 8, and decrease in crop cover type from catchments 1 through 8.

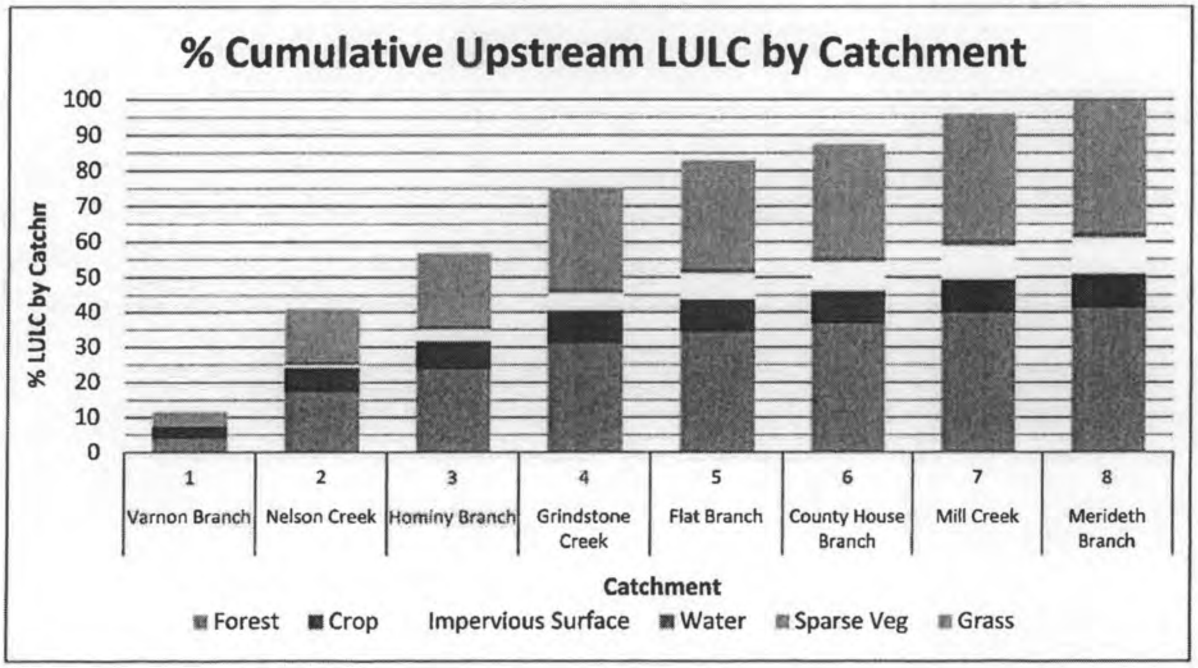

Figure 30. Percent cumulative upstream LULC by catchment shows the contribution of each catchment toward total land cover values for the entire watershed, progressively moving downstream. Note the gradual addition of all forest, grass, and impervious in a downstream direction. Crop, water, and sparse vegetation cover level off before catchment 8.

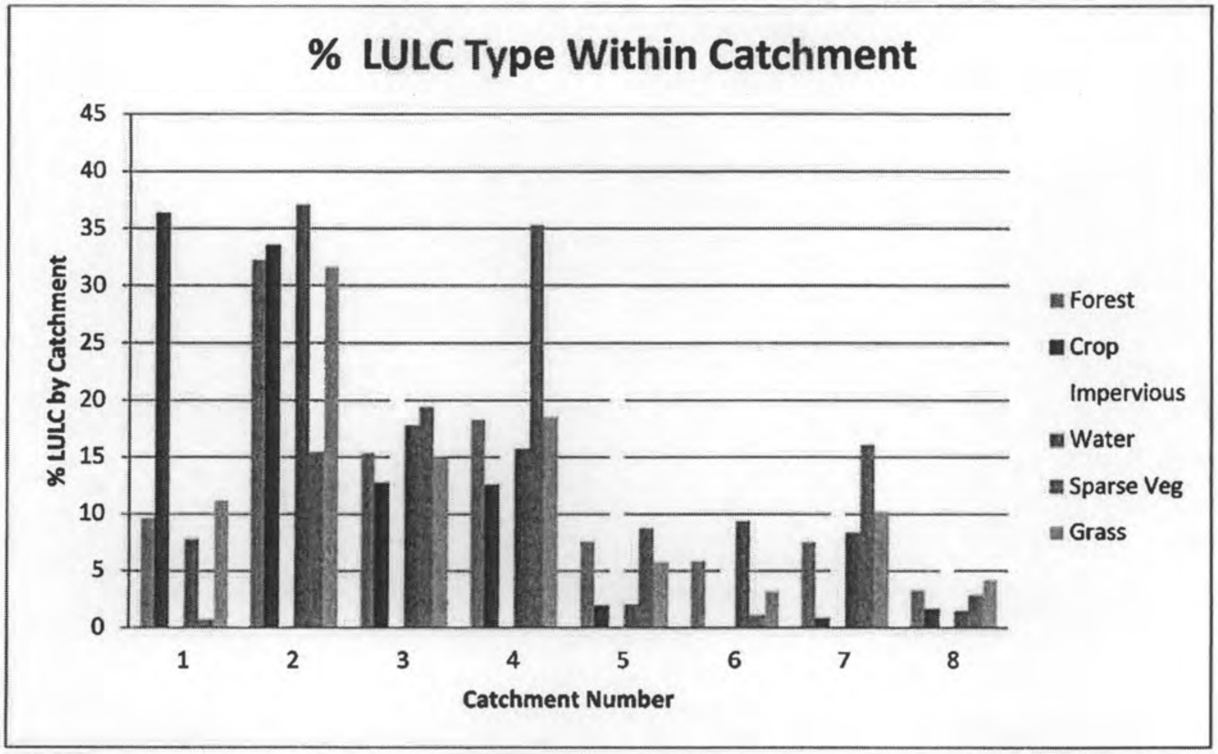

Figure 31. Percent of each LULC type by catchment relative to total area for each LULC type. This chart illustrates the percentage of the total area of a single cover type that exists within each catchment. Note that over 35% of all crop exists in catchment 1 and over 60% of all impervious surface can be found in catchments 3 thru 5.

ADDENDUM

C

II

State:	MO
Project Number:	2013MO142B
Title:	Increase in Water Quality Through the Study of Longitudinal Variations in Physical Habitats
Project Type:	Research
Focus Category:	Management and Planning, Ecology, Conservation
Keywords:	impaired water bodies, habitat characterisitcs, Collaborative Adaptiave Management (CAM), Management and Planning, habitat assessment, channel dimension, floodplain geometry,
Start Date:	3/1/2013
End Date:	2/28/2014
Congressional District:	4
PI:	Hubbart, Jason email:Hubbartj@missouri.edu
Co-PI(s):	Hubbart, Jason email:Hubbartj@missouri.edu

Abstract

Increase in Water Quality Through the Study of Longitudinal Variations in Physical Habitats Jason A. Hubbart, Ph.D. School of Natural Resources, Department of Forestry, 203-Q ABNR Building, Columbia, MO 65211

ABSTRACT

Many decisions related to restoration, management, monitoring, and evaluation of impaired water bodies require an understanding of longitudinal variation of physical habitat characteristics. Variation in characteristics such as channel morphology, floodplain width, floodplain sediments, and riparian vegetation can affect medium-term channel change and indicate where specific management or restoration actions will be most effective. Hinkson Creek is located in Boone County, central Missouri, USA. The Missouri Department of Natural Resources (MDNR) placed Hinkson Creek on the state s list of impaired streams under section 303(d) of the Clean Water Act (CWA) in 1998. A Collaborative Adaptive Management (CAM) process has been initiated in the watershed that uses a science-based approach guided by local stakeholder committees. Presently, no comprehensive inventory of physical habitat characteristics exists for Hinkson Creek to guide spatial understanding of restoration, management, monitoring, and evaluations. The primary objectives of the current proposal include assessing the entire stream system to supply information that will better inform the CAM process and supply needed information to watershed stakeholders, with the ultimate goal of restoring the biological community to fully supporting and eventual removal of the creek from the 303(d) list of impaired waters. This current effort will be a primarily field-based campaign designed to complement a current geographic information system effort. A student undergraduate team will be assembled, that will be directly supervised by a graduate student assistant (GSA). The entire team and project will be supervised by the PI. The field team will start their field campaign starting in May 2013, and will conduct physical habitat assessment starting in Hinkson Creek headwaters at intervals of approximately every 50 meters. Stream physical habitat data will include observations of erosion and depositional processes, changes in channel and floodplain geometry, and riparian and land-use cover alterations. Data collected will include channel dimension, pattern, profile and sediments (i.e. bed composition and apparent depth). Data (quantitative and observation) gathered from the proposed work will be of great value as the CAM process and current and ongoing research in the watershed continues. Data from the current work will be distributed to the City of Columbia, Public Works Department, Boone County, the University of Missouri Campus Facilities, the Missouri Department of Natural Resources, the Missouri Department of Conservation and other state, Federal and public entities upon request within four months of project completion (i.e. December 2013).

ABSTRACT

Title:

A Mizzou Undergraduate Team Physical Habitat Assessment for Hinkson Creek

Principle Investigator

Jason A. Hubbart, Ph.D. School of Natural Resources, Department of Forestry, 203-Q ABNR Building, Columbia, MO 65211.

Many decisions related to restoration, management, monitoring, and evaluation of impaired water bodies require an understanding of longitudinal variation of physical habitat characteristics. Variation in characteristics such as channel morphology, floodplain width, floodplain sediments, and riparian vegetation can affect medium-term channel change and indicate where specific management or restoration actions will be most effective. Hinkson Creek is located in Boone County, central Missouri, USA. The Missouri Department of Natural Resources (MDNR) placed Hinkson Creek on the state's list of impaired streams under section 303(d) of the Clean Water Act (CWA) in 1998. A Collaborative Adaptive Management (CAM) process has been initiated in the watershed that uses a science-based approach guided by local stakeholder committees. Presently, no comprehensive inventory of physical habitat characteristics exists for Hinkson Creek to guide spatial understanding of restoration, management, monitoring, and evaluations. The primary objectives of the current proposal include assessing the entire stream system to supply information that will better inform the CAM process and supply needed information to watershed stakeholders, with the ultimate goal of restoring the biological community to *fully supporting* and eventual removal of the creek from the 303(d) list of impaired waters. This current effort will be a primarily field-based campaign designed to complement a current geographic information system effort. A student undergraduate team will be assembled, that will be directly supervised by a graduate student assistant (GSA). The entire team and project will be supervised by the PI. The field team will start their field campaign starting in May 2013, and will conduct physical habitat assessment starting in Hinkson Creek headwaters at intervals of approximately every 50 meters. Stream physical habitat data will include observations of erosion and depositional processes, changes in channel and floodplain geometry, and riparian and land-use cover alterations. Data collected will include channel dimension, pattern, profile and sediments (i.e. bed composition and apparent depth). Data (quantitative and observation) gathered from the proposed work will be of great value as the CAM process and current and ongoing research in the watershed continues. Data from the current work will be distributed to the City of Columbia, Public Works Department, Boone County, the University of Missouri Campus Facilities, the Missouri Department of Natural Resources, the Missouri Department of Conservation and other state, Federal and public entities upon request within four months of project completion (i.e. December 2013).

PRE-PROPOSAL

Title

A Mizzou Undergraduate Team Physical Habitat Assessment for Hinkson Creek

Principle Investigator

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Nature, Scope and Objectives of Research

Introduction and Problem Statement

Land use practices including agriculture, forest harvesting, and urbanization, can have profound impacts on receiving water bodies (Allen 2004). Impacts can include alteration of flow, sediment, thermal regimes, stream geomorphology, aquatic and riparian habitat, the addition of pollutants and nutrients, and a reduction of aquatic species richness and diversity (Allan et al. 2007). For example, agriculture can result in excess nutrient loading that can lead to eutrophication and anoxia (Morgan et al. 2006). In addition, habitat degradation associated with riparian forest clearing, channel straightening and sedimentation, is often present in agricultural streams, and can lead to substantially degraded aquatic faunal assemblages (Heatherly et al. 2007, Reid et al. 2010, Stone et al. 2005). Urbanization can lead to increased sedimentation, increased channel erosion, and consequent habitat degradation (Boothe and Jackson 1997), changes in riparian vegetation (White and Greer 2006), and increases in hydrologic disturbance (Coleman et al. 2011). These effects are often cumulative, resulting in confounding research outcomes, confusing management practices, and misallocations of millions of tax payer dollars.

Many decisions related to restoration, management, monitoring, and evaluation of impaired water bodies require at least a basic understanding of the longitudinal variation of physical habitat characteristics. Longitudinal variation in hard constraints such as bedrock in the bed or banks, hard infrastructure, channel network structure, and sources of coarse sediment will control how much the channel can migrate or adjust to stresses or restoration activities (Piegay and Schumm, 2003; Elliott et al., 2009). Variation in characteristics such as channel morphology, floodplain width, floodplain sediments, and riparian vegetation can affect medium-term channel change and indicate where specific management or restoration actions will be most effective (Jacobson et al., 2010). An additional class of characteristics can be considered short-term physical responses that may also vary substantially along the channel. Examples include (but are not limited to) gravel or sand bar extent, large woody debris, root mats, and sedimentological characteristics of the bed (Jacobson and Gran, 1999). The association of response factors in relation to the first two classes may indicate sources of stress and response in given water body and therefore provide direction for short term physical response investigations.

Hinkson Creek is located in Boone County, central Missouri, USA. The Missouri Department of Natural Resources (MDNR) placed Hinkson Creek on the state's list of impaired streams under section 303(d) of the Clean Water Act (CWA) in 1998. The cause of impairment was listed as unknown (EPA 2011). Subsequent bioassessment studies of Hinkson Creek indicated that sections of the creek were not fully supporting of aquatic life, but water quality analyses and follow-up studies were unable to determine a specific cause of impairment (MDNR 2002, 2004, 2005, 2006). In 2011 a TMDL was proposed, the design of which would reduce runoff from the stream's surrounding area as a surrogate for unidentified pollutants (Hubbart et al., 2010; USEPA, 2011). More recently a Collaborative Adaptive Management (CAM) process has been initiated in the watershed that uses a science-based approach guided by local stakeholder committees. To learn more pertaining to the HCW CAM process the reader is referred to: http://helpthehinkson.org/CollaborativeAdaptiveManagement.htm. The primary objectives of the current proposal include assessing the entire stream system, including the creek and terrestrial portions of the watershed, with the goal of restoring the biological community to *fully supporting* and eventual removal of the creek from the 303(d) list of impaired waters.

Presently, no comprehensive inventory of physical habitat characteristics exists for Hinkson Creek to guide spatial understanding of restoration, management, monitoring, and evaluations. A physical habitat assessment of the main stem of Hinkson Creek was identified by several members of the CAM Science Committee and subsequently approved by the CAM Stakeholder Committee as an essential first step towards improved management of Hinkson Creek and its eventual removal from the CWA 303(d) list. Currently, a number of biological and chemical parameters are measured on a regular basis at specific sites. However, those sites have not been placed in the context of the range of physical variability along Hinkson Creek and the physical attributes that influence or provide habitat for macro invertebrates and other aquatic biota throughout the Hinkson Creek drainage have not been thoroughly investigated.

Recent and Ongoing Work in Hinkson Creek

In November of 2008, permanent gauging stations were established at 5 locations along Hinkson Creek using a nested scale experimental watershed study design (Figure 2) (Hubbart et al. 2010). The objectives of studies conducted using the experimental watershed study design included analyses of suspended sediment (Hubbart and Freeman 2010, Hubbart and Gebo 2010, Freeman 2011), monitoring and modeling the flow regime (Scollan 2011) and investigations of nutrient loading (articles in prep). Future anticipated analyses after year seven will include water yield, peak flow and other land-use flow, and pollutant transport analyses. A number of interim studies have been published including Hubbart and Freeman (2010) who collected and analyzed water samples for particle size class distribution during March, 2010. They identified a sharp increase in the concentration of fine particles in urban reaches of Hinkson Creek comparing pre and post-precipitation event conditions and identified a 450% increase in the concentration of the smallest particle size class (2.06 μm). Thus, with a doubling of streamflow (1.4 m^3/s to 2.9 m^3/s), the concentration of fine sediment was more than quadrupled. This relationship can be attributed to a number of natural in-stream or overland processes; however, urban influence was indicated to potentially impact their results. Freeman (2011) showed that suspended sediment concentrations were greater at urban sites relative to rural sites but that the difference was not statistically significant. His results also showed smaller mean particle sizes of the suspended sediment at urban sites which was attributed to both in-stream weathering processes and land use (Freeman 2011). Kellner et al. (article in submission) followed up on the work of Hubbart and Freeman (2010) and Freeman (2011) by analyzing terrestrial stormwater samples for suspended sediment size class distribution and compared 17 urban stormwater monitoring sites (n = 272) and 3rd and 4th order receiving water bodies. Urban stormwater samples had lower total concentration (205.11 μl/l) relative to receiving water bodies (3rd order = 318.77 μl/l, 4th order = 323.26 μl/l), containing approximately 35% less total suspended sediment. Ultimately, results to date indicate a disproportionate contribution of fine suspended sediment from the urban environment. In other research conducted in the HCW, Huang (2012) conducted a study of streambank erosion and found that bank erosion can contribute as much as 67% of suspended sediment material in the reach of Hinkson Creek that was investigated. These studies show very clearly the effects of land use and implications for hydrogeomorphological alteration, and therefore aquatic habitat. Arguably, alterations to the flow regime including peak flows and base flows may greatly influence in-stream processes. Hubbart and Zell (in submission) used two dissimilar automated baseflow separation algorithms, and Monte Carlo techniques to evaluate urban baseflow and estimation uncertainty using data from the Hinkson Creek USGS gauging station. Three uncertainties affecting trend determinations were assessed including, algorithm structure, precipitation – runoff relationships, and baseflow algorithm parameterization. Results indicated that despite ongoing population growth and development in the HCW, annual streamflow metrics did not significantly increased or decreased ($p \leq 0.05$) from 1967 to 2010. However, several streamflow metrics featured shallow insignificant ($p > 0.05$) slopes in the direction hypothesized for an urbanizing (less pervious) watershed, including a downward slope for baseflow index (BFI) and increases in runoff volume coefficient. Median annual baseflow estimations differed by 29% between techniques (85.3 vs. 118.9 mm yr^{-1}). Obviously, there is a great deal of information still needed in the HCW to better understand current and projected development impacts. Given the work to date, and need for additional physical investigation of the stream channel, the current proposed project will supply a great deal of information inexpensively, while also training future water resources professionals.

Approach and Study Outcomes

Two scales of effort were identified by the CAM Science Committee for the physical habitat assessment. The first scale involves compilation of data that can be readily acquired through photo-interpretation and analysis of existing geographic information system (GIS) data (Elliott and Jacobson, 2006; Elliott and others, 2009). The second scale of effort and the impetus for the current proposed work involves field measurements of characteristics that cannot be measured from remotely sensed data. This second scale of effort could be more open-ended as many potentially relevant characteristics could be measured in the field. Therefore, for the current effort parameters will be selected to maximize utility compared to cost. The Hinkson Creek Science Team members identified relevant parameters for the effort, sampling intervals, and budget needs. The field measurements habitat assessment is anticipated to start as early as spring 2013 and will provide higher spatial coverage of the stream system and more detailed data to support both analyses and future actions within the watershed.

It is anticipated that the scales of habitat assessment proposed here will be followed by more detailed, reach-scale assessments in the future, including measurements of channel morphology, substrate, riparian vegetation characteristics and discharge-determined habitat availability over distances of 10-20 channel widths or multiple riffle/pool sequences (Fitzpatrick and others, 1998; Panfil and Jacobson, 2001; Jacobson and others, 2004; Kaufmann, 2006). However, as mentioned above the data and other information gathered from the proposed work will be of incalculable value as the CAM process and current and ongoing research in the watershed continues. Data from the current work will be distributed to the City of Columbia, Public Works Department, Boone County, the University of Missouri Campus Facilities, the Missouri Department of Natural Resources, the Missouri Department of Conservation and other state, Federal and public entities upon request within four months of project completion (i.e. December 2013). The project will also result in a interpretive report and student poster presentations of results.

Methods

Hinkson Creek is located in the Lower Missouri-Moreau River basin (HUC 10300102) in central Missouri and is approximately 42 km long. The Hinkson Creek Watershed (HCW) spans approximately 231 km^2 (MDNR 2006). Soils in the upper reaches of the watershed are Keswick-Hatton-Winnegan Association, characterized as loamy till with a well-developed clay pan. Soils in the lower portion of the watershed are of the Weller-Bardley-Clinkenbeard Association and are characterized as thin cherty clay and silty to sandy clay (USDA 2001). Land use in the upper watershed is mostly agricultural and forested and becomes increasingly urban further downstream.

This will be a primarily field-based effort. A student undergraduate team will be assembled, that will be directly supervised by a graduate student assistant (GSA). The entire team and project will be supervised by the PI (please see Training Potential below). The field team will start their field campaign starting in May 2013, and will conduct physical habitat assessment starting in Hinkson Creek headwaters with repetition approximately every 50 meters. Stream physical habitat data will generally include observations of erosion and depositional processes, changes in channel and floodplain geometry, and riparian and land-use cover alterations. Data collected will include channel dimension, pattern, profile and sediments (i.e. bed composition and apparent depth). Field data sheets will be prepared in advance of the start of the field season by the PI and GSA. All field equipment will be assembled and prepared for field deployment for the undergraduate field team prior to the start of the field season. Field training will be scheduled for two days prior to the field season to train all students (graduate and undergraduate). Other specific information/data collected at each stream cross section will include:

- *Presence of bedrock in banks and bed*: Bedrock can have very strong controls on channel form and process by presenting non-erodible materials, and influencing particle size and bed roughness. Zones where bedrock constrains lateral or vertical movement of the stream channel will be documented by mapping upstream and downstream locations where bedrock is present in the bed and banks.
- *Bank stabilization structures*: Bank stabilization structures consist of rip-rap, gabion baskets, and other engineered structures intended to prevent bank erosion and retreat. Zones where bank stabilization structures constrain lateral movement of the stream channel will be mapped by locating upstream and downstream extents of each structure.

- *Infrastructure* not adequately mapped in GIS resources (including pipes, outfalls, and discharge control structures. Utilities and infrastructure will be incorporated into the habitat assessment because they represent hard structures that can constrain channel movement (for example pipelines in the bed, bridge abutments) as well as potential hazards (for example leaking sewers). Locations of all infrastructure elements intersecting the bank or beds will be determined.
- *Disturbance features*: including erosion gullies, debris fans, slumps, bank failures, debris piles. Relatively small geomorphic features adjacent to the channel can be sources of disturbance or changes in channel morphology or substrate. An example would be a high-gradient gully delivering boulders to the channel or a bank slump that delivers fine sediment directly to the channel. Locations of all relevant geomorphic features affecting the channel will be determined.
- *Bank height and slope*: Stream bank height and angle will be determined at every stream survey site and/or every 50 m using a clinometer (Biedenharn et al., 1997). The vertical height can be determined by knowing one angle and one side of right triangle (Gordon et al., 2004).
- *Photographic journal*: Digital cameras will be used to create a photo journal of each survey site. Photo's will be collected in multiple locations including a mandatory set of photos taken from the center of the streambed in the four cardinal directions as well as upwards (canopy cover), directly down (streambed composition), directly upstream, downstream and perpendicularly towards each streambank.
- *GPS*: Coordinates will be collected at each survey site including streambanks, streambeds and major objects (i.e. woody debris, public utilities, engineered structures, erosional gullies, bank failures, debris piles, and other obvious habitat altering features.
- *Canopy cover*: A convex canopy densiometer will be used to quantify forest canopy cover. Canopy cover is defined as the proportion of the forest floor covered by the vertical projection of the tree crowns (Jennings et al. 1999). Canopy cover has been shown to be a multipurpose ecological indicator that is useful for distinguishing different plant and animal habitats, assessing forest floor microclimate and light conditions, and estimating functional variables like the leaf area index (LAI) that quantifies the photosynthesizing leaf area per unit ground area (Jennings et al. 1999).

Data accuracy will be assured through data review and documentation conducted by each undergraduate team member and the GRA. Team members will be responsible for reviewing data daily and evaluating field assessments. Performing daily data inspections will ensure data are not missing, inconsistent with the protocols, or otherwise problematic, and whether there is a need for reevaluation (i.e. revisiting previous sites). Data will be checked in the field by multiple individuals to assure information reliability and replicability as well as to make sure data are properly detailed in data sheets, which will later need to be transcribed to digital formats. Microsoft Excel® databases will be developed to support the collection and storage of data collected at each phase of assessment. Data will be entered by the GRA, and reviewed by both the GRA and PI for completeness and accuracy as it is entered and then again prior to submission to stakeholders at the end of the project. To assist in reviewing data for accuracy and consistency, standard reports and tables will be generated reflecting data at the watershed, reach, segment, and site level (as necessary). Reports and tables will also help with determining where additional information should be collected and where future phases of assessments may be appropriate.

Related Research

There are currently no related studies in Hinkson Creek as that proposed here. It is however, worth mentioning that the outcomes of the proposed habitat assessment will prove invaluable to land managers (City of Columbia, Boone County, University of Missouri, Campus Facilities, and others) and researchers (Missouri Department of Conservation, Missouri Department of Natural Resources, University of Missouri, and others) engaged and peripheral to the Hinkson Creek Collaborative Adaptive Management process now and for at least the next 10 years at which time the work should have been repeated to document any changes as per the CAM process.

Training Potential

Training is the first step in starting an assessment. Learning how to use the protocols and evaluate the different parameters is necessary for completing an accurate and consistent assessment. Carefully following the protocols is one way of ensuring that repeatable and consistent sets of data are collected. Completing a quality assurance (QA) at the end of each day and/or phase of habitat assessment is also part of the tracking process. Training will be arranged by the PI and other CAM Science Committee members. Training of all members of the field crew (i.e. graduate or undergraduate) will be viewed as mandatory by the PI to assure field work efficiency and data quality. The GSA will receive additional training by supervising the undergraduate field crew, maintaining field protocols and data collection procedures in the field. The GSA will also be responsible for preliminary organization and analysis of the database, a process overseen and reviewed by the PI. All students involved in this project will be expected to present results at the annual Missouri Natural Resources conference in 2014, thereby showcasing the funding agency, MU WRRC and demonstrating the impacts of the project.

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RELEVANCE OF PROJECT

Relevance of research to Missouri needs, as well as regional and national significance, and potential users

The Missouri Department of Natural Resources (MDNR) placed Hinkson Creek on the state's list of impaired streams under section 303(d) of the Clean Water Act (CWA) in 1998. The stream was listed as impaired by unknown pollutants based on analyses of the stream's microinvertebrate community at eleven sites within the creek. In 2011 a Total Maximum Daily Load (TMDL) was proposed by EPA that used runoff from the stream's surrounding area as a surrogate for the unidentified pollutants (Hubbart et al., 2010; USEPA, 2011). In response to the TMDL, the EPA, Missouri Department of Natural Resources and the three local entities that shared responsibility for the storm water permit, Boone County, the City of Columbia, and the University of Missouri entered into a precedent-setting agreement in 2012 to address the water quality concerns. The agencies agreed to use a Collaborative Adaptive Management (CAM) process in the watershed that uses a science-based approach guided by a local stakeholder committee because of the significant uncertainties inherent in this watershed. This represents the first time such an approach has been formally agreed upon to address water quality issues in a watershed. The stakeholder committee is supported by a group of engineers from the city, county and university who will examine potential actions within the watershed and a team of scientists that will serve to guide the process and provide scientific advice to the stakeholders. The habitat assessment currently proposed was the first priority identified by the science team to help inform future decisions in the watershed because alteration or loss of habitat in response to alterations in hydrologic regime are considered potential causes of impairment. It will serve two major purposes: A) identify areas where suitable habitat for one or more of the species groups used in the macroinvertebrate sampling is missing; and B) direct actions to those reaches of the stream where changes in management practices or restoration activities might best benefit the species and overall water quality. These data and analyses have immediate value as they will be used by the science and action teams as well as stakeholders to guide future decision-making in the Hinkson Creek watershed. Data and an interpretive report from the current work will be distributed to the City of Columbia, Public Works Department, Boone County, the University of Missouri Campus Facilities, the Missouri Department of Natural Resources, the Missouri Department of Conservation, the US Geological Survey and other state, Federal and public entities upon request within four months of project completion (i.e. December 2013). These data will also be incorporated as a project into the County GIS system to promote their availability to all citizens.

Potential of future research and funding following completion

It is anticipated that the proposed work will supply information that will result in a follow up investigation that includes more detailed, reach-scale assessments. Reach-scale assessments typically involve measurements of channel morphology, substrate, riparian vegetation characteristics and discharge-determined habitat availability over distances of 10-20 channel widths or multiple riffle/pool sequences (Fitzpatrick and others, 1998; Panfil and Jacobson, 2001; Jacobson and others, 2004; Kaufmann, 2006). Possible funding sources for ongoing studies including follow on studies to the current proposed work include the National Science Foundation, US Department of Agriculture National Institute of Food and Agriculture, the Environmental Protection Agency, the Missouri Department of Natural Resources.

Student involvement

In the spring of 2013 a call will go out for undergraduate applications for a four person field team that will work through the summer of 2013 on this project. Applicants will be chosen based on background, interests, course work and grades and their cover letter. This will be a competitive process and a prestigious opportunity for highly qualified undergraduate to obtain field experience, understand the research process and present results at the 2014 Missouri Natural Resources conference by means of poster presentations.

Previous Grant Support from the Water Center

NONE.

RELEVANCE OF PROJECT

Relevance of research to Missouri needs, as well as regional and national significance, and potential users

The Missouri Department of Natural Resources (MDNR) placed Hinkson Creek on the state's list of impaired streams under section 303(d) of the Clean Water Act (CWA) in 1998. The stream was listed as impaired by unknown pollutants based on analyses of the stream's microinvertebrate community at eleven sites within the creek. In 2011 a Total Maximum Daily Load (TMDL) was proposed by EPA that used runoff from the stream's surrounding area as a surrogate for the unidentified pollutants (Hubbart et al., 2010; USEPA, 2011). In response to the TMDL, the EPA, Missouri Department of Natural Resources and the three local entities that shared responsibility for the storm water permit, Boone County, the City of Columbia, and the University of Missouri entered into a precedent-setting agreement in 2012 to address the water quality concerns. The agencies agreed to use a Collaborative Adaptive Management (CAM) process in the watershed that uses a science-based approach guided by a local stakeholder committee because of the significant uncertainties inherent in this watershed. This represents the first time such an approach has been formally agreed upon to address water quality issues in a watershed. The stakeholder committee is supported by a group of engineers from the city, county and university who will examine potential actions within the watershed and a team of scientists that will serve to guide the process and provide scientific advice to the stakeholders. The habitat assessment currently proposed was the first priority identified by the science team to help inform future decisions in the watershed because alteration or loss of habitat in response to alterations in hydrologic regime are considered potential causes of impairment. It will serve two major purposes: A) identify areas where suitable habitat for one or more of the species groups used in the macroinvertebrate sampling is missing; and B) direct actions to those reaches of the stream where changes in management practices or restoration activities might best benefit the species and overall water quality. These data and analyses have immediate value as they will be used by the science and action teams as well as stakeholders to guide future decision-making in the Hinkson Creek watershed. Data and an interpretive report from the current work will be distributed to the City of Columbia, Public Works Department, Boone County, the University of Missouri Campus Facilities, the Missouri Department of Natural Resources, the Missouri Department of Conservation, the US Geological Survey and other state, Federal and public entities upon request within four months of project completion (i.e. December 2013). These data will also be incorporated as a project into the County GIS system to promote their availability to all citizens.

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Previous Grant Support from the Water Center

NONE.

ADDENDUM

D

HINKSON CREEK COLLABORATIVE ADAPTIVE MANAGEMENT RESEARCH PROPOSAL: FY2015

Combined Flow and Suspended Sediment Proposal

Total Budget (Not to Exceed):
$280,000.00 (Please see Budget Details)

Submitted To:
Hinkson Creek Watershed Collaborative Adaptive Management
Stakeholders, Actions and Science Teams

Date:
March 19, 2014

Project Title:
Hinkson Creek: Quantifying Stream Flow and Suspended Sediment Response to Urbanization using a Scale-Nested Experimental Watershed Study Design

Principle Investigator:
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Background

Hinkson Creeks listing on the Clean Water Act (CWA) 303(d) list as impaired due to unknown pollutants in 1998 (MDNR, 2011; USEPA, 2011) came about due to many problems suspected by State and Federal agencies, and local residents including (but not limited to), (1) larger and more frequent floods, (2) lower base flows; (3) increased soil erosion in construction and development areas with subsequent transport of the soil to streams (i.e. altered suspended sediment regimes); (4) water contamination from urban storm water flows; (5) degradation of habitat for aquatic organisms due to thc concerns listed above; and (6) degradation of aquatic habitat due to the physical alteration of stream channels and adjacent streamside (riparian) corridors (MDNR, 2009). In November of 2008, with initial funding ($634,000) provided by the MDNR 319 program and USDA Ag Experimental Station, the PI began instrumenting Hinkson Creek with a nested-scale experimental watershed study design (Hubbart et al. 2010) to investigate the suspected problems that led to the 1998 listing and improve understanding of contemporary land-use and urbanization effects on hydrologic processes (stream response, water yield), water quality, and biological community health. Nested watershed study designs use a series of sub-basins inside a larger watershed to examine environmental variables. Sub-basins are often determined based on dominant land use and characteristics of the hydrologic system. A nested watershed study design enables quantitative characterization of influencing patterns and processes observed at each location (Hubbart et al., 2010). Each nested monitoring site of Hinkson Creek is designed to monitor water stage and a complete suite of climate variables. Multiple additional water quality variables (e.g. suspended sediment, nitrogen, phosphorus, chloride, pH, and other constituents) have been monitored at the nested sites since shortly after implementation of the study. A United States Geological Survey gauging station (USGS-06910230) has collected stage data intermittently since 1966 and provides flow data for site 4 (Figure 1).

Urbanization can significantly impact stream hydro-ecosystems. In particular by means of stream flow response to precipitation and runoff events. Increased impervious surface areas in urban watersheds, including roadways, rooftops, and parking lots, act to reduce or eliminate soil infiltration and increase the amount of stormwater runoff delivered to stream channels (Bledsoe and Watson 2001, Rose and Peters 2001, Jennings and Jarnagin 2002, Burns et al. 2005, Cianfrani et al. 2006, Xiao et al. 2007). Watershed imperviousness also reduces stormwater transit time, shortening the "lag time" between peak precipitation and peak flow (Galster et al. 2008). Vegetation removal and urban development also increases runoff volumes due to reduced evapotranspiration and canopy interception of precipitation (Hornbeck et al. 1997, Rose and Peters 2001, Im et al. 2003).

Stormwater flow serves as an important transport mechanism for non-point source pollutants, including suspended solids, nutrients, turf fertilizers, bacteria, and trace metals (Tsihrintzis and Hamid 1998, Xiao et al. 2007). Impervious surfaces serve as conduits for flow, replacing soils and vegetation that would otherwise attenuate runoff and transport of pollutants (Tabacchi et al. 2000). Urban peak discharge events also degrade water quality through physical alterations to the stream channel. Channels typically broaden and deepen in response to increased volume, velocity, and frequency of peak discharge in urban environments (Bledsoe and Watson 2001, Galster et al. 2008), leading to channel instability and accelerated channel erosion (Olsen et al. 1997). Changes in the timing, frequency, and magnitude of stream flow have significant impacts on freshwater ecosystem function (Postel 2000). Channel simplification as a consequence of increased peak discharge frequency also degrades stream habitat diversity and biotic integrity (Cianfrani et al. 2006). In nearly every region, peak discharge magnitude has been shown to increase in response to watershed urbanization. In the southeastern United States, Rose and Peters (2001) documented 30 to 100 percent increases in the magnitude of peak flows in urban watersheds relative to rural watersheds. Despite available information, little is known in urbanizing watersheds of the central U.S. where there is similarly no multi-use (including urban) experimental watershed studies underway from which to draw inference. Thus, the experimental watershed study design implemented in the HCW will provide a great deal of information both locally and regionally in terms of urban land-use effects on peak flow and other stream response characteristics.

A primary transport material of receiving waters is suspended sediment. Suspended sediment is a primary cause of freshwater impairment (USEPA, 2006) affecting the biological, chemical, and physical health of aquatic ecosystems (Uri, 2001). Excess sediment is associated with a host of aquatic ecosystem impacts including reduced transmission of sunlight, which can inhibit photosynthesis and primary productivity (Campbell et al., 2005). Too much suspended sediment can abrade or clog the gills of aquatic organisms, inhibit the feeding efficiency of filter feeders (i.e. mussels), obstruct sight-feeders (i.e. applies to most fish species), and adversely affect macroinvertebrate communities by filling streambed interstitial void spaces (Owens et al., 2005). Suspended sediment also serves as a transport mechanism for many water quality constituents (Keyes and Radcliffe, 2002).

Objectives

The objectives of this project are to improve understanding of the impairment of Hinkson Creek and to assess implications for recovery strategies. Study outcomes will identify land-use related impacts to flow, thus informing the CAM process, respond to original concerns (re: 1998 303(d) listing) in Hinkson Creek related to altered flow processes, and better inform the appropriateness of the formerly proposed volume-based flow reduction TMDL approach. The experimental watershed study design (presented above) in the HCW and associated flow and sediment data collected over the past four years will be used to improve quantitative understanding of stream responses to water –input events (i.e. precipitation) and the transport of sediment and sediment loading in Hinkson Creek. This analysis is a substantial undertaking and investment. For example, flow and precipitation data have been collected at 5-minute intervals during the entire time period (approximately 421,000 data points) and multiple grants have been obtained by the PI to maintain instrumentation and a graduate student labor force (~$1.5million). Sub-objectives of the current proposed analyses include estimating the interactions of land use type (forested, agriculture, sub-urban, urban) on stream response characteristics such as peak discharge, event flow hydrographs (or effective water input), storm duration, hydrograph rise, response lag, time to peak, response time, time of concentration and other stream responses characteristics (Dingman, 2002) (as appropriate, as analyses progress) will be evaluated at and between each nested monitoring site. These relationships where practicable will be evaluated with observed suspended sediment concentrations. Observed data and analyses will then be used to calibrate a hydrological model (such as the soil water assessment tool, SWAT), and/or a water resources planning and management analytical tools (e.g. StreamStats, USGS). A calibrated hydrological model will allow us to assess sensitivity of Hinkson Creek streamflow characteristics to a wide range of past and future land-use changes in the watershed.

Study Rationale

1. Quantifying stream response to rainfall events and associated transport of suspended sediment will provide understanding of how these processes vary with stream distance and land-use in Hinkson Creek. Thus, the potential causes of water quality concerns related to physical habitat will become more apparent through this study.
2. This study, coupled to the Physical Habitat Assessment (PHA) results, will help inform decisions on possible actions to improve habitat and water quality in Hinkson Creek by showing where important changes in suspended sediment dynamics occur relative to location (i.e. land-use) in the watershed.

By comparing Hinkson Creek flow data with that from other streams in both urbanized and rural settings, it may be possible to estimate how altered Hinkson Creek has become as a result of land-use practices (e.g. urbanization). This provides a critical measure for determining what might be possible in terms of "restoration" of Hinkson Creek and to better estimate *realistic* extents of action needed to mitigate current and future development impacts.

Methods

Streamflow Metrics

Discharge at gauge sites 1, 2, 3, and 5 will be measured at designated stream cross-sections using the velocity-area method (Rantz 1982, Jones 1997, Dingman 2002, Chen and Chiu 2004). Cross-section discharge estimates will be used to create rating curve equations that will adjust stage measurements (5-minute intervals) from gauge sites. Stream response characteristics will be assessed based on a suite of metrics that may include but are not limited to mean annual flows, 7-day low flows in winter and summer, peak discharges due to rainfall as well as number of flow days with high and extreme flow rates greater than the mean plus one or two standard deviations, respectively (Novotny and Stefan, 2007), or upper confidence limits (CL) to detect significant differences in peak discharge (e.g. 90% CL) as per methods such as Beschta et al. (2000). There may also be some basis for considering precipitation and/or flow return periods in the analysis. Simple regression analysis (Hirsch et al., 1993), and/or statistics such as (but not limited to) Mann-Kendal non-parametric tests will be used to detect significant trends over time and between streamflow monitoring sites. The current work should not be considered all-encompassing or exhaustive, but will be focused on the most meaningful information that will most effectively assist the CAM process.

Suspended Sediment

Suspended sediment concentrations have been quantified using two standardized methods, 1) mass (or gravimetric, mg/l) concentration by wet sieving (ASTM, 1999: Edward and Glysson, 1999; Davis, 2005), and 2) laser diffraction analysis (ul/l). Wet sieving produces Total Suspended Sediment (TSS), or Suspended Sediment Concentration (SSC) information. The main difference between the TSS and SSC method is that TSS generally analyzes an aliquot of a total sample, whereas SSC analyzes the entire sample. Recent advances in suspended sediment monitoring include *in situ* fully automated devices that sense and log suspended sediment and particle size classes (Gray and Gartner, 2009). Laser diffraction instruments often provide volumetric estimates of sediment concentration as opposed to a mass concentration (Agrawal and Pottsmith, 2000) because the optical power distribution is converted to an area distribution. The LISST-Streamside (Sequoia Scientific Inc.), used in the current work utilizes laser diffraction technology to estimate suspended sediment and particle size class concentration metrics (Hubbart and Freeman, 2010). Both methods were used in the current work because each method has its advantages. For example, questions of sediment loading and yield may be most appropriately addressed using mass/gravimetric methods since the studies concern transfers of mass between systems (Walling 1999; Walling and Fang 2003; Wass and Leeks 1999). Conversely, water quality questions, such as the effects of excess sediment concentrations on aquatic biota, may be more aptly addressed via volumetric methods since the method quantifies relative proportions of a given constituent within a water body (Nichols, 2013).

Regardless of the method used, sample collection and laboratory analyses are expensive, and labor intensive (Gray and Gartner, 2009). The collection and labor involved with laboratory analysis will be complete on March 1, 2014. This proposal includes analysis of these data to provide information on how suspended sediment concentrations, loads, and particle-size distributions vary over time in Hinkson Creek.

Study Outcomes: Product(s) and Recommendations for CAM Process

Distinct products are listed as follows for flow and sediment. However, it is worth mentioning that sediment analysis cannot be concluded without flow, so combination of the two studies is a logical course of action.

Flow

Results of data analysis will provide quantitative estimates of stream response characteristics (such as those listed above) in Hinkson Creek. Products will include:

- Annual estimates of stream response metrics at all 5 nested monitoring sites in the HCW.
- Seasonal and event based estimates of stream response metrics at all 5 nested monitoring sites in the HCW.
- Modeled vs. observed stream response metrics (for example, peak flow) processes using a process based model such as (but not limited to) the Soil Water Assessment Tool (SWAT).

Stream response metrics will be compared to land use types in the overall watershed and in each respective sub-catchment (n=5, Figure 1) of the HCW. Modeling results will be very important for this phase of the work to understand land-use impacts on flow processes. Study results will be synthesized with respect to overall implications for the severity and causes of impairment of Hinkson Creek. Results from Hinkson Creek will be compared with similar studies in other urban areas to provide insight on controlling factors.

The combination of flow dynamics, land use characteristics, and hydroclimatic data will provide detailed, quantitative information that will provide evidence to support, or refute hypotheses about causes for altered stream flow regimes in Hinkson Creek. That information will help guide decision makers in terms of management plans in terrestrial and aquatic environments to mitigate any detected alterations. Study outcomes will identify land-use related impacts to flow dynamics that will inform the CAM process and respond to original concerns in Hinkson Creek related to altered flow processes. Results will also help target most effective locations for BMP implementation projects, and better inform the appropriateness of the formerly proposed volume-based flow reduction TMDL approach.

Suspended Sediment

Results of flow analysis will provide transport relationships to improve quantitative estimates of:

1. Annual suspended sediment loads at all 5 nested monitoring sites in the HCW.
2. Quantitative estimates of fine particle size class concentrations between sites, as an indicator of sediment source or the type of sediment-related stress. For example, urban stormwater runoff may contribute disproportionate quantities of fine sediment to receiving water bodies, while simultaneously starving watercourses of total sediment concentration.
3. Modeled vs. observed suspended sediment loading using the Soil Water Assessment Tool (SWAT).

Total loading and particle size class analysis results will be compared to land use practices in the overall watershed and in each respective sub-catchment (n=5, Figure 1) of the HCW to provide relations between existing land use and suspended sediment. Modeling will be important in this phase of the work to help describe land-use practice impacts to sediment dynamics through 1) providing estimates of background sediment yield under pre-urban conditions and 2) providing a means to assess sensitivity of sediment loading to various land-use scenarios. Study results will be synthesized with respect to overall implications for the severity and causes of impairment of Hinkson Creek. Results from Hinkson Creek will be compared with similar studies in other urban areas to provide insight on controlling factors.

The combination of sediment loads, concentrations, and size distributions, compared with land use characteristics and hydroclimatic data, will provide detailed, quantitative information that will provide evidence to support, or refute hypotheses about causes for altered suspended sediment regimes in Hinkson Creek and thus guide decision makers accordingly in terms of management plans to mitigate any detected alterations in the receiving water body. Thus, study results will inform the CAM process by identifying whether or not suspended sediment is a problem in Hinkson Creek, and if so, where, and by how much.

Products will include annual reports to CAM teams and at least 6 publications in the peer reviewed literature addressing the numbered bullets above.

Not to Exceed Budget

The proposed work will support a post-doctoral research associate (PDA) in the Interdisciplinary Hydrology Laboratory of the PI. The PDA will post-process and analyze data, conduct modeling and report results that will supply improved understanding of land-use impacts on stream response, and management recommendations in Hinkson Creek.

Post-doctoral research associate stipend, benefits and analysis and modeling software, office supplies, consumables: \$70k/yr x 4 yrs = \$280k

Tentative Budget

	Year 1	Year 2	Year 3	Year 4	Total
Salary Post-Doc	\$ 45,000.00	\$47,250.00	\$49,612.50	\$52,093.13	\$193,955.63
Benefits	\$ 15,916.50	\$16,712.33	\$17,547.94	\$18,425.34	\$ 68,602.10
Analyis and Modeling Software	\$5,000	\$3,000	\$1,000	\$0	\$ 9,000.00
Travel	4000	3000	1800	0	\$ 8,800.00
Total Direct Costs	\$ 69,916.50	\$69,962.33	\$69,960.44	\$70,518.46	\$280,357.73
				Grand Total:	\$280,357.73
Funding Source and Amount					
University of Missouri	\$ 69,916.50	\$23,320.78	\$23,320.15	\$23,506.15	\$140,063.58
City of Columbia		\$23,320.78	\$23,320.15	\$23,506.15	\$ 70,147.08
Boone County		\$23,320.78	\$23,320.15	\$23,506.15	\$ 70,147.08
				Grand Total:	\$280,357.73

Based on the tentative budget above, each of the three CAM partners are requested to fund approximately \$23,320 for year each year following the first year (2, 3, and 4).

Tentative Schedule

Tasks/Accomplishments	Year 1				Year 2				Year 3				Year 4			
	F	W	Sp	Su	F	W	Sp	Su	F	W	Sp	Su	F	W	Sp	Su
Post-Doc Secured for Project	X	X														
Data post processing		X	X	X	X	X	X	X	X	X	X	X	X	X		
Report #1, Article #1, and 2 Submission				X	X											
Report #2, Article #3, and 4 Submission								X	X							
Report #3, Article #5 and 6 Submission												X	X			
Work Completed															X	X

Reports are distributed to CAM teams.

Timeline assumes post-doc appointment at noted date (could be delayed depending on qualified applicants)

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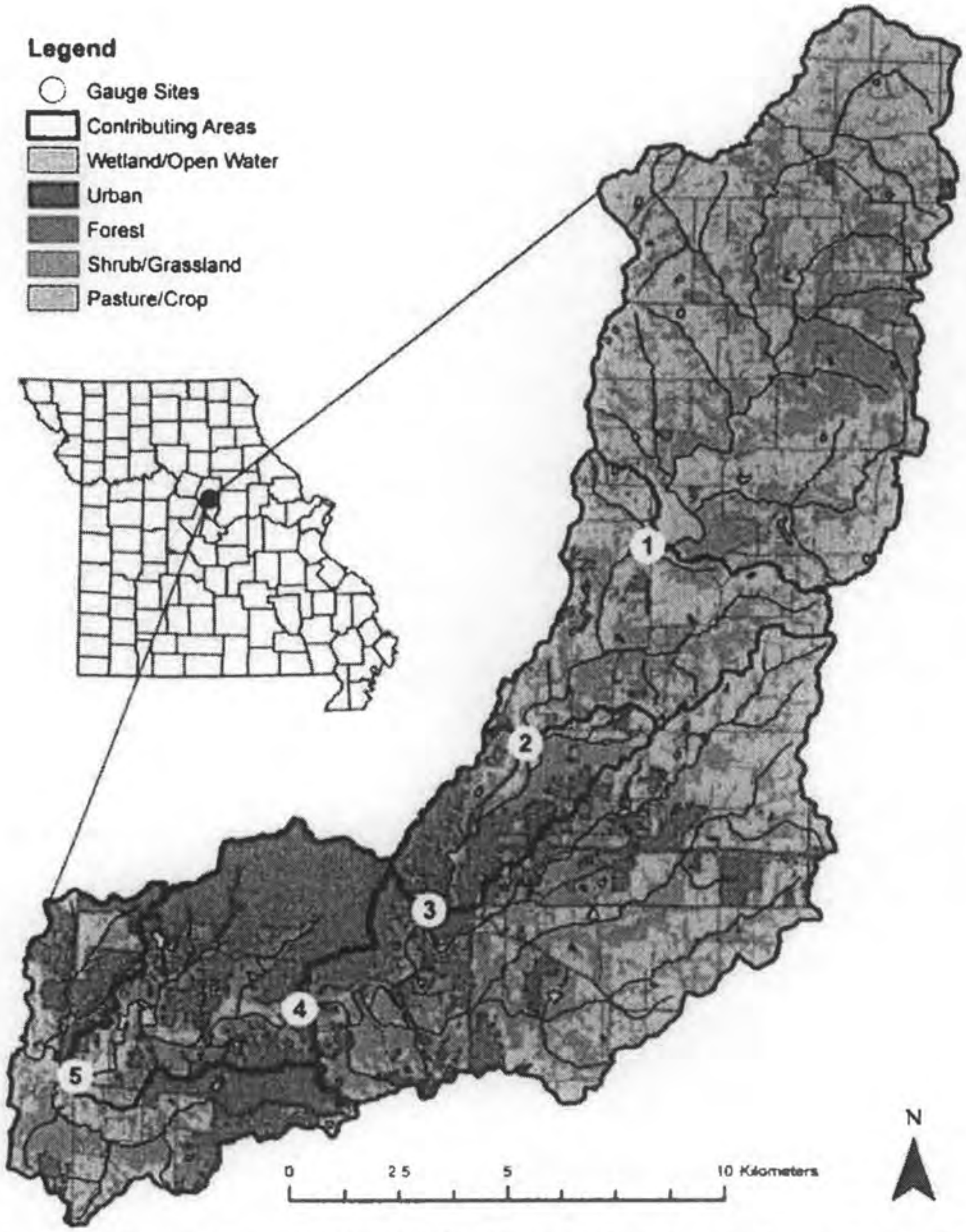

Figure 1. Hinkson Creek Watershed (HCW) nested-scale experimental watershed study design (site 4 is the USGS gauging station).

ADDENDUM

E

Forum Nature Area Level Spreader Monitoring Project

Total Budget:
$62,250.00
(Please see Budget Details)

Submitted To:
Tom Wellman: City of Columbia Public Works

Submission Date:
August 30, 2014

Principle Investigator:
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Background

Stormwater flow serves as an important transport mechanism for non-point source pollutants, including suspended solids, nutrients, fertilizers, bacteria, and trace metals (Tsihrintzis and Hamid 1998, Xiao et al. 2007). Impervious surfaces serve as conduits for flow, replacing soils and vegetation that would otherwise attenuate runoff and transport of pollutants (Tabacchi et al. 2000). Urban peak discharge events also degrade water quality through physical alterations to the stream channel. Channels typically broaden and deepen in response to increased volume, velocity, and frequency of peak discharge in urban environments (Bledsoe and Watson 2001, Galster et al. 2008), leading to channel instability and accelerated channel erosion (Olsen et al. 1997). Changes in the timing, frequency, and magnitude of stream flow have significant impacts on freshwater ecosystem function (Postel 2000). Channel simplification as a consequence of increased peak discharge frequency also degrades stream habitat diversity and biotic integrity (Cianfrani et al. 2006).

There is a broadly recognized need to improve the state of knowledge related to Best Management Practices (BMP) efficacy to enhance land managers ability to recommend appropriate and cost effective BMP solutions for slowing, storing, and bioremediation of stormwater in rapidly urbanizing areas. With this in mind, and as part of the ongoing Collaborative Adaptive Management (CAM) process in Hinkson Creek Watershed, a Level Spreader was installed in 2014 to divert water from a small un-named tributary to Hinkson Creek (approximately 115-acre drainage area) and spread the water over an area of Hinkson Creek Floodplain in the Forum Nature Area. The area where the water is spread has been replanted with trees that will improve infiltration and increase transpiration (consumptive water use). The intent of this BMP is to focus on smaller runoff events (i.e. 1-yr storms). It is anticipated that the BMP will a) clean the water, b) reduce immediate runoff to Hinkson Creek, and c) increase localized baseflow to the creek.

Objectives

As per the original CAM Proposal, http://helpthehinkson.org/documents/ProjectProposal1.pdf, a monitoring project will be implemented to study the long-term efficacy of the level spreader BMP. The monitoring project will use multiple sensors to determine a) the amount of water flowing through the level spreader, b) the overflow from the level spreader, and c) an array of soil moisture sensors to quantitatively characterize the change in soil infiltration, and soil moisture over time as the small floodplain forest becomes reestablished. While the initial monitoring period is planned for 5 years, a much longer period of time is recommended (i.e. 10 or more years).

Study Outcomes

Study outcomes will provide quantitative information about level spreader efficacy, which will better inform the City and HCW stakeholders the appropriateness of this relatively low cost solution to urban runoff peak flows and water quality.

Not to Exceed Budget

The PI will provide approximately $2500 worth of instrumentation for the initial installation of the hydroclimate site, including a tri-pod, guy kit, and cross arm and bracket (not included in budget below). The PI will also take his fall 2014 Hydrologic Measurement Techniques course students to the site where they will map the site, create a grid design, and quantify a) infiltration capacity, compaction, and soil water content (and possibly other variables) during the semester. This work may be repeated at interim points and the end of the study to quantify any changes over time. This constitutes a great deal of savings in terms of instrumentation that the PI already possesses, and student labor.

The proposed work will provide support for a field technician, or partial salary for a Graduate Research Assistant, or other research associate in the Interdisciplinary Hydrology Laboratory of the PI. The research associate will help with instrument installations, weekly to bi-weekly site visits and maintenance, data collection, post-processing and data analysis, modeling and / or provide interim reports (upon request up to twice annually).

Budget	Yr1	Yr2	Yr3	Yr4	Yr5	Total
Hydrometeorological Station	$ 10,000	$ -	$ -	$ -	$ -	$ 10,000
Pressure Transducers (flow)	$ 2,250	$ -	$ -	$ -	$ -	$ 2,250
Instrument Maintenance	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 10,000
Student Labor	$ 8,000	$ 8,000	$ 8,000	$ 8,000	$ 8,000	$ 40,000
Total	$ 22,250	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 62,250

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