OLD STATE ROAD 267 FEH MITIGATION ALONG WHITE LICK CREEK

Prepared for:

Indiana University and the Indiana Office of Community and Rural Affairs (OCRA) in Support of the Development of the Indiana Fluvial Erosion Hazard Mitigation Manual, an Indiana Silver Jackets Initiative

October 2018

Prepared by:

Christopher B. Burke Engineering, LLC
115 West Washington Street, Suite 1368 South
Indianapolis, Indiana 46204

CBBEL Project No. 14-0014.00000

Table of Contents

List of Tables and Figures

List of Exhibits

List of Appendices

EXECUTIVE SUMMARY

This report documents the results and methodology used by Christopher B. Burke Engineering, LLC (CBBEL) to mitigate an existing fluvial erosion hazard (FEH) at a site along White Lick Creek near the intersection of Old State Road 267 and SR-267 in Hendricks County, Indiana. This assessment and preparation of this document was conducted in support of the development of the Indiana Fluvial Erosion Hazard Mitigation Manual, which was an initiative of the Indiana Silver Jackets, made possible through a grant from the Indiana Office of Community and Rural Affairs (OCRA). A FEH mitigation study was completed to identify the stressors leading to channel instability issues and to develop conceptual mitigation solutions.

White Lick Creek is a major tributary to the West Fork White River; the watershed includes the western portion of the Indianapolis Metropolitan Area, Brownsburg, Avon, Plainfield, Danville, and Pittsboro. Channel instability and migration have been an issue with White Lick Creek for many years, including near Old State Road 267 in Plainfield.

A system assessment of White Lick Creek was completed by CBBEL to identify the root causes of the erosion that occurs near Old State Road 267. The system assessment included review of previous studies and analysis of available data that was focused primarily on the project reach. The system assessment determined that four major factors are most responsible for the current channel instability and migration issues.

1. **Highly mobile channel material:** Observations made during site visits revealed a large amount of the channel material is highly erodible sand and gravel.
2. **Sediment 'sinks':** Four gravel pits along the stream near Old State Road 267 may currently be contributing to channel instability and will likely cause more severe channel instability in the future.
3. **Channel incision and inadequate floodplain connectivity:** Confinement of the flow in the channel and the lost floodplain connectivity have resulted in significant erosion risk.
4. **Increased flow rates and flow volume:** Higher peak flow and more flow volume have resulted in longer-lasting and more erosive flows that destabilize the stream.

The assessment revealed that White Lick Creek has exhibited moderate to severe lateral migration since the surrounding region was settled. The continued development in the watershed will continue to alter the hydrology of the system, potentially leading to heightened instability without preventative, passive management measures. The passive measures are not expected to eliminate the instability at the FEH site subject to this study or other FEH sites along the stream, but rather to reduce the destabilizing trend caused by development.

Because establishing stability in the overall system is not feasible in the short term, CBBEL evaluated localized strategies for mitigating the FEH at Old State Road 267. The improvements include toe protection, reducing the bank slope, and minor channel realignment; the anticipated cost to implement the improvements is approximately $315,000. The dynamic nature of the stream causes the timing of implementation to be a concern; should a significant flooding / erosion event occur, the extent, cost, and difficulty of the improvements could be greatly increased. It is recommended that stakeholders meet to discuss next steps and the overall implementation strategy.

CHAPTER 1 PROJECT OVERVIEW

1.1 INTRODUCTION

This report documents the results and methodology used by Christopher B. Burke Engineering, LLC (CBBEL) to identify the need and ability to mitigate an existing fluvial erosion hazard (FEH) at a site along White Lick Creek near the intersection of Old State Road 267 and SR-267 in Hendricks County, Indiana. This assessment and preparation of this document was conducted in support of the development of the Indiana Fluvial Erosion Hazard Mitigation Manual. The development of the Manual was an initiative of the Indiana Silver Jackets, made possible through a grant from the Indiana Office of Community and Rural Affairs (OCRA). A FEH mitigation approach was used to identify the stressors leading to channel instability issues to aide in the development of conceptual mitigation solutions.

1.2 PROJECT HISTORY

Figure 1: Unstable Reach of White Lick Creek

White Lick Creek is a major tributary to the West Fork White River, with a drainage area (DA) of 291 square-miles (mi^2). White Lick Creek begins in Boone County and extends south through Hendricks County, into Morgan County where it joins the West Fork White River. The watershed primarily includes the main stem with two primary tributaries, the West Fork (DA = 63.4 mi^2) and the East Fork (DA = 51.9 mi^2), which combine with the main channel in the lower portion of the watershed. The West Fork joins White Lick Creek in Hendricks County just below Plainfield, and the East Fork joins the main channel at Mooresville. The White Lick Creek Watershed includes the western portion of the Indianapolis Metropolitan Area, including Brownsburg, Avon, Plainfield, Danville, and Pittsboro. A map of the study area is shown in Exhibit 1. Flooding and channel migration have been reported as a consistent issue with White Lick Creek for many years, most notably after the June 2008 flooding. Multiple bank stabilization and stream stabilization projects have been completed; however, the flooding and instability issues in the system have continued or worsened, most notably near Old State Road 267 (Center Street).

1.3 PROJECT PURPOSE

Figure 2: FEH Site

The purpose of the study is to determine a means of reducing the risk of damage to Old State Road 267 in Plainfield, Indiana due to erosion along White Lick Creek. A better understanding of White Lick Creek is required to determine the current characteristics of the channel and watershed, to identify the root causes of the channel instability, and to determine what, if any, mitigation strategies are warranted, applicable, and able to be implemented without detrimental impact to adjacent stream reaches.

1.4 ANALYSIS PROCESS

The project was completed in several successive phases. Phase I of the project included a significant data gathering effort. The information acquired during the data collection phase included local testimony collected during meetings from the 2015 CBBEL study, previous studies, observations from site visits, historical aerial photography, streamflow data, rainfall data, soils information, and land use data.

The second phase of the project consisted of the assimilation and processing of the data collected during Phase I to determine the major themes of the current morphologic condition of the river system affecting the site. The processed data were then used to identify the watershed- and local-scale stressors acting on the river system.

Phase III involved the development of conceptual solutions for the stressors identified in Phase II of the project. An implementation sequence of the recommended strategies was also developed during this portion of the work.

CHAPTER 2 DATA GATHERING

Existing data and previous studies, where available, were used as supporting information for the FEH mitigation study. Additional data and observations were collected to provide a more comprehensive understanding of the physical processes at work within the river system. The following sections detail the origin and use of existing datasets and applicable previous studies, as well as the type and extent of additional information gathered.

2.1 SOURCES OF DATA

Topography Data

The analysis of the White Lick Creek corridor and watershed required detailed topographic information for various calculations. The 2012IndianaMap Digital Elevation Model (DEM) was used as the source of topographic data for regional bankfull width approximation, floodplain connectivity considerations, and as the terrain source for a two-dimensional hydraulic model. The IndianaMap DEM covers the entire White Lick Creek Watershed with a 5-foot cell resolution and is sufficient for producing 1-foot contours. A topographic map of the assessment reach is provided in Exhibit 2.

A limited site survey was completed by SJCA on May 31, 2017 to allow for more accurate topographic data of the FEH site and for channel classification and confirmation of the 2012 DEM accuracy.

Soil & Land Use Data

Information concerning the properties of the soils as well as the types and extent of land use practices in the area were necessary for a portion of the analysis. Soil information was obtained from the National Resource Conservation Service's (NRCS) Soil Survey Geographic Database (SSURGO).

Land use information was gathered from the 2011 National Land Cover Dataset (NLCD). Aerial photography from the 2012 IndianaMap Framework Dataset was inspected to generally confirm the land uses shown in the NLCD data.

The characterization of channel bed and bank material was completed using visual observation and the Quaternary Map of Indiana (Gray, 1989).

Rainfall Data

Rainfall information was gathered from several weather stations from the National Climatic Data Center (NCDC). This information was used to examine the changes in storm frequency, duration, and intensity over time.

Streamflow Data

Streamflow information served as a critical component to the hydrologic analysis completed as a part of this study. All streamflow information was obtained from the United States Geological Survey's (USGS) online portal.

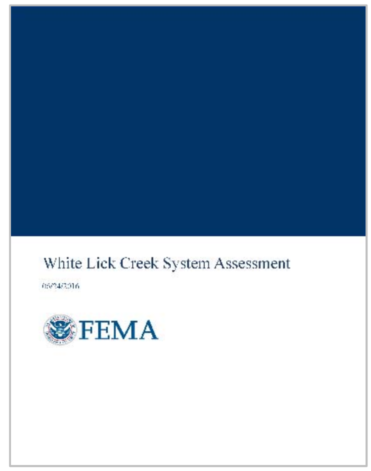
Aerial Photography

Aerial photography of the White Lick Creek Watershed was obtained from multiple sources. The primary source of aerial photography information was the 2012 IndianaMap Orthophotography. Historical aerial imagery was collected from Google Earth, as well as the Indiana Historical Society archives.

2.2 PREVIOUS STUDIES

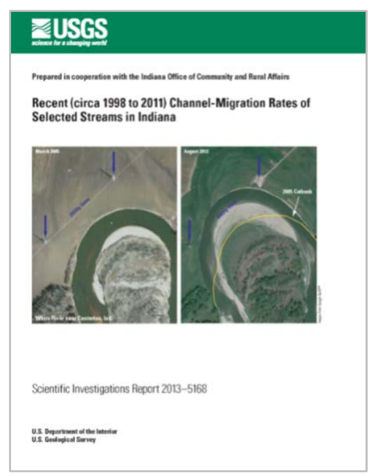
The review of previous studies in the White Lick Creek Watershed was limited to hydrologic and hydraulic analyses, as well as a small number of other reports of significance to fluvial stability and flooding considerations.

White Lick Creek System Assessment (CBBEL, 2015)
A system assessment of White Lick Creek was completed by CBBEL for Federal Emergency Management Agency (FEMA) as part of the FEMA RiskMap Mitigation Grant to identify the root causes of the widespread flooding and erosion that occurs in the along the watercourse. The system assessment included review of previous studies and analysis of available data and focused primarily on the main stem. The assessment was developed to serve as supporting information for potential future flood risk reduction or fluvial erosion hazard mitigation projects. The analysis included in the assessment is directly applicable to the current study and is therefore heavily referenced, but not repeated, in this document.



Recent (circa 1998 to 2011) Channel Migration Rates of Selected Streams in Indiana (USGS, 2013)

A total of 42 stream reaches in Indiana were measured to determine observed lateral migration rates of the streams, or how much a channel's banks shift relative to the surrounding land features. Lateral migration rates can be used as a surrogate for overall stream stability. The analysis completed by the USGS revealed that of the streams considered, White Lick Creek has the 3rd highest lateral migration rate. The channel moves at a rate of almost 10 feet per year on average, with the maximum migration rate reaching a value of almost 26 feet per year.



Regional Bankfull Channel Dimensions of Non-Urban Wadeable Streams in Indiana (USGS, 2013)

Regionally-based relationships for channel dimensions were developed by analyzing data from streams throughout Indiana. The data was obtained from 81 streams that are non-urban, wadeable, and pristine or naturalized. The regional equations can be used to determine a channels departure from the expected dimensions as well as to aid in channel restoration design processes.

CHAPTER 3 FEH MITIGATION STUDY

The FEH mitigation study included consideration of the findings of previous studies, an extensive site investigation, and the contributing watershed area to the main stem of White Lick Creek. The FEH mitigation study was broken into three major categories of observations and analysis, including site assessment, watershed-scale assessment, and reach-scale assessment. The following paragraphs provide an overview of each component of the FEH mitigation study.

3.1 IDENTIFICATION OF ASSESSMENT REACH

The preliminary identification of an assessment reach is necessary to determine the extent of the stream that will be evaluated during the site assessment, to establish the portion of the overall watershed that should be considered during the watershed-scale assessment, and to provide an initial estimate of the extent of the reach-scale assessment.

A preliminary assessment reach is centered on the FEH location and extends a minimum of 12 bankfull widths in the upstream and downstream direction. The anticipated bankfull width of White Lick Creek at the location of the FEH was determined by applying the contributing drainage area at that point in the stream (124 mi^2) to the reginal bankfull equations for the Central Till Plain in Indiana. An approximate bankfull width of 131 feet was determined. The preliminary assessment reach identified for the FEH site is shown in Figure 3.

Figure 3: Preliminary Assessment Reach

3.2 SITE ASSESSMENT

On April 25, 2017, an assessment of environmentally regulated areas along the project reach was performed at which time no wetlands were identified or delineated. Wetland delineations were conducted using methods identified in the Regional Supplement to the Corps of Engineers Delineation Manual: Midwest Region (Version 2.0) (August 2010). However, White Lick Creek was identified as a “Waters of the U.S.” and falls under both state and federal jurisdiction. See Appendix 2 for the White Lick Creek Wetland Delineation Report.

A site visit was also conducted on May 31, 2017 to observe the river corridor along the preliminary assessment reach to determine the characteristics of the channel and to help identify the physical processes occurring in the channel. Photographs from the site visit are provided in Appendix 1. The site observations focused on measuring key dimensions of the channel and locating signs of morphological change, or changes in the channel, such as scoured and/or failed streambanks, significant upland erosion, and sediment deposition.

Observations and representative measurements were made to allow for the assessment reach to be classified. White Lick Creek is a C4 stream according to Rosgen Classification of Natural Rivers. A C4 stream is a slightly entrenched stream with moderate to high sinuosity, gentle slope, and gravel streambed. A copy of the field measurements and stream classification form is provided in Appendix 2.

The exposed soil profiles in the eroded streambanks through the assessment reach were observed to be primarily formed of sandy, gravelly, mobile material. The toe of the slope near the FEH site is composed of dense, erosion resistant till material. The presence of highly erodible material above the toe of the slope suggests that instability in the upper bank of the FEH site will likely continue.

3.3 WATERSHED-SCALE ASSESSMENT

A comprehensive watershed-scale assessment was completed as a part of the 2015 CBBEL study. The assessment included an evaluation of the contributing watershed to determine if there are systemic issues contributing to the instability noted at the FEH site. This study concluded that there were significant systemic issues present. Excerpts from the 2015 CBBEL Watershed-scale Assessment are provided in Appendix 3. The assessment provided the following factors as the primary evidence of systemic, watershed-scale issues:

Rainfall Analysis

The average annual precipitation in the White Lick Creek Watershed has been increasing over the last 25 years by approximately 0.2 inches per year. The intensity of heavy rainfall events has also increased over the last 30 years by 12% to 24%, depending on the duration of the event; however, the data suggested that the rainfall intensities are essentially the same or only slightly greater than they were 50 years ago. The discussion of the rainfall analysis clarified that the use of a single gaging station does not necessarily reflect climatic trends of an entire region but cited a previous study of National Weather Service data from 1958 to 2016 that shows the Midwest has seen the amount of precipitation during the heaviest 1% of storms increase by 42%. Figure 4 shows the 15-year moving average trends for the annual rainfall depth and the depth of the 95th-percentile 24-hour storm rainfall intensity.

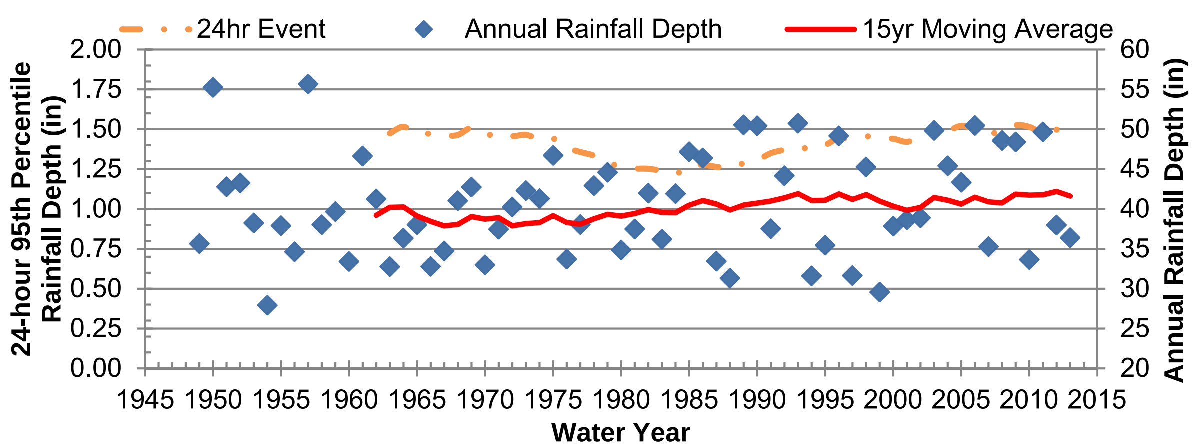


Figure 4: Annual Rainfall and Rainfall Intensity 15-year Moving Average Trends

Land Use Change

One of the most significant causes for systemic issues noted in the 2015 study was the drastic shift in the proportion of agricultural and urban lands that occurred between 1992 and 2001 and continued to a lesser extent to 2011 and beyond. The rapid development was noted to correspond with the population boom in Danville, Brownsburg, Plainfield, and Avon during that period. Figure 5 shows a visual of the land use conversions that occurred between 1992 and 2011. Increasing land use intensity has significant implications on the way that the watershed responds to rainfall, which is highlighted by the following discussion of the evaluation of watershed hydrology.

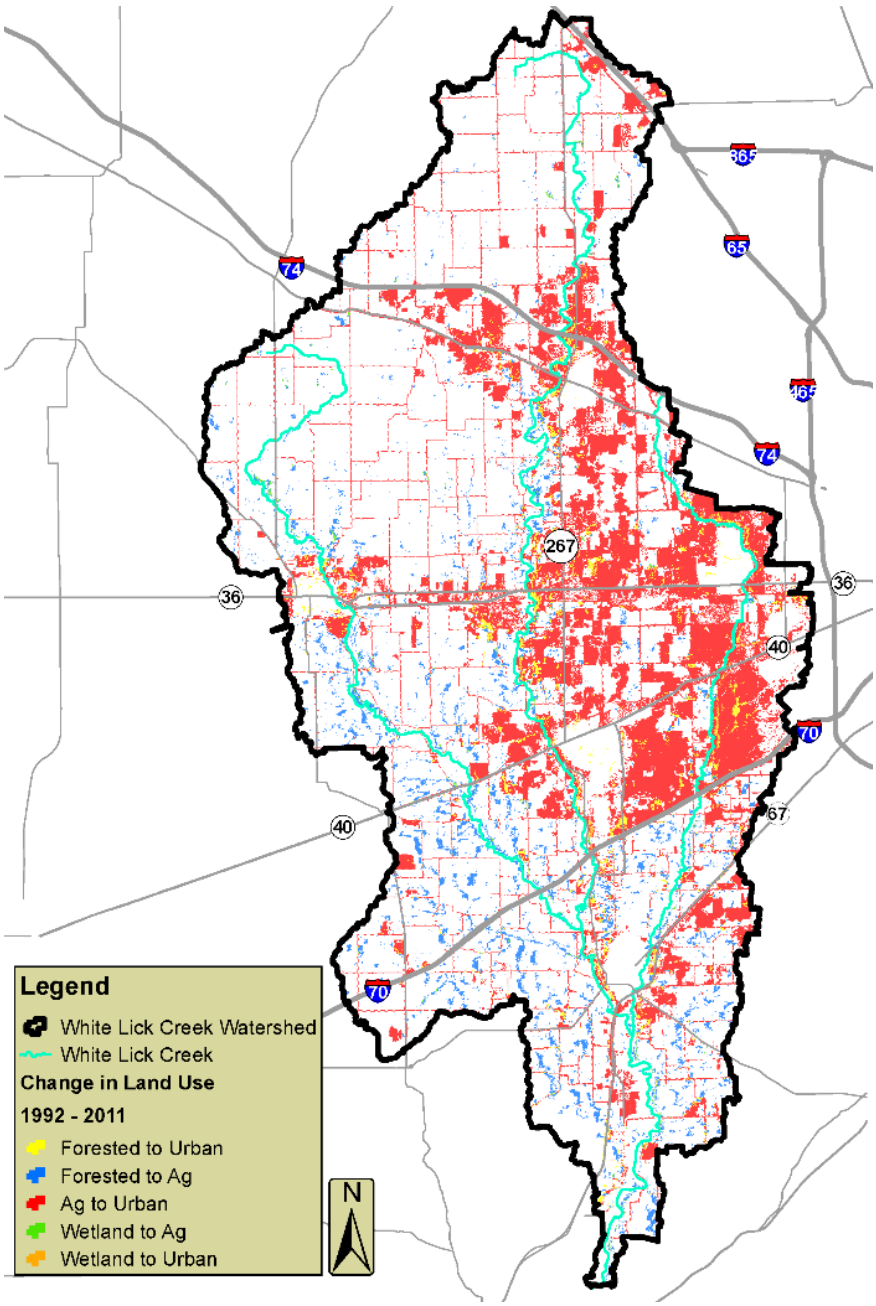


Figure 5: Land Use Conversion from 1992 - 2011

Watershed Hydrology

An analysis of the White Lick Creek streamflow gage in Mooresville, Indiana showed that the 15-year average peak annual flow rate has been increasing since 1985 The most dramatic shift occurred between 1992 and 2001, during which time the average peak annual flow was increased from 8,800 cubic-feet per second (cfs) to almost 11,000 cfs; which equates to an average of 1% increase each year for the past 22 years. The 2015 CBBEL study noted that the increase in average peak annual flow supports the validity of complaints of increased flooding in the communities along White Lick Creek each year. The trendline for the peak annual flow rate is provided in Figure 6.

A significant upward trend in the volume of runoff was also noted and attributed to the increased annual rainfall depth as well as the expansion of impervious and drained areas. The analysis showed that the average daily flow volume for White Lick Creek increased from 460 ac-ft in 1992 to 580 ac-ft in 2014, a 26% increase in flow volume. The 15-year moving average for the average daily flow volume is shown in Figure 6.

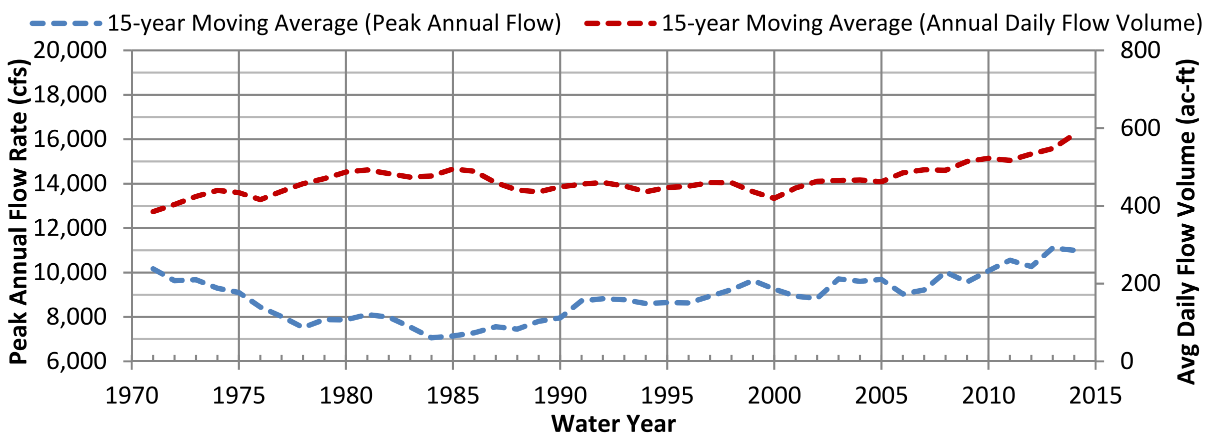


Figure 6: 15-year Moving Average for Peak Annual Flow and Daily Flow Volume

The 2015 CBBEL study also included an evaluation of the frequency of the bankfull discharge by completing a statistical analysis of the White Lick Creek gage data. The analysis concluded that the 1.5-year flow rate (approximately 7,000 cfs) has been occurring more frequently and for a longer duration since 1992 and now occurs [on average] for a full day each year, rather than for only a few hours every other year. Figure 7 provides a plot of the annual frequency of bankfull flows, as well as the trendline for the duration of bankfull flows measured in hours per year.

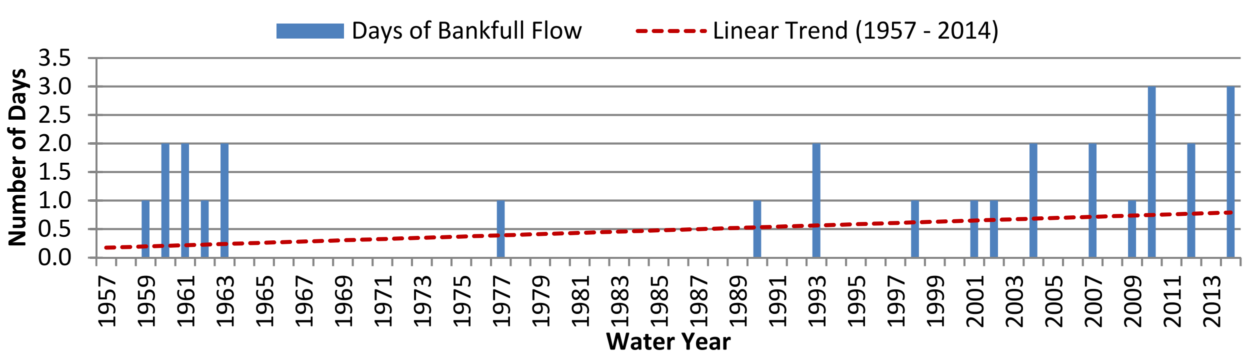


Figure 7: Annual Frequency and 15-year Moving Average of Duration of Bankfull Flow

Comparison of Channel Dimensions to Regional Curves

The 2015 CBBEL study noted a significant departure from the anticipated bankfull width of the channel in most locations along the Creek by completing an approximate determination of the bankfull width using the IndianaMap DEM. Seven of the nine measurement locations showed a deviation of more than 10% from the bankfull width suggested by the Indiana regional curves; two locations showed more than a 25% difference. The analysis noted that the significant departure from the expected values was only present where White Lick Creek passes through an alluvial deposit.

Identification of At-Risk Infrastructure

The fluvial erosion hazard corridor along White Lick Creek near the FEH site was used to identify the at-risk area which infrastructure would need to be evaluated. Each location within the assessment reach where significant infrastructure was located within the corridor was examined to determine the migration rate of the channel and the perceived risk level given the anticipated detrimental impact if the infrastructure was compromised, as shown in Figure 8. The risk level was determined according to the criteria Table 1. Table 2 provides a summary of the at-risk infrastructure identified during the assessment, including the risk level and contributing factors.

Table 1: Risk Level Criteria

Risk Level	Stability Level	Impact to Public if Infrastructure is Compromised
High	Unstable	Minor Disruption → Severe risk to public health or loss of critical infrastructure
	Recently Stable / Transitional	Moderate Disruption → Severe risk to public health or loss of critical infrastructure
	Stable	Severe risk to public health or loss of critical infrastructure
Moderate	Unstable	Minor Disruption → Significant disturbance to daily commute/activities
	Recently Stable / Transitional	Moderate Disruption → Significant disturbance to daily commute/activities
	Stable	Significant disturbance to daily commute/activities
Low	Unstable	No disruption → Minor disruption to localized areas
	Recently Stable / Transitional	No disruption → Minor disruption to localized areas
	Stable	Minor disruption to localized areas

Table 2: Identification of Fluvial Erosion Hazards

Location	FEH Description	Impact of Compromised Infrastructure	Risk Level
WLC1	Road (SR 267)	Significant disturbance to daily commute/activities	Moderate
WLC2	Structure	Potential loss of life and homes	Low[1]
WLC3	Gravel Pit	Potential destabilization of US & DS channel	Moderate
WLC4	Structure	Potential loss of life and homes	Low[2]
WLC5	Gravel Pit	Potential destabilization of US & DS channel	Moderate
WLC6	Road (SR 267)	Significant disturbance to daily commute	High
WLC7	Gravel Pit	Potential destabilization of US & DS channel	Moderate
WLC8	Natural Gas Line	Potential disruption of industrial operations	Low
WLC9	Gravel Pit	Potential destabilization of US & DS channel	Moderate
WLC10	Structure	Potential loss of life and homes	Low[1]
WLC11	Structure	Potential loss of life and homes	Low[1]
WLC12	Structure	Potential loss of life and homes	Low[1]

[1] These structures (homes) are within the Fluvial Erosion Hazard Zone but are more than 200 feet away from the stream and within a stable reach of the stream. Therefore, there is a low potential of risk.

[2] This structure (house) is within the Fluvial Erosion Hazard Zone but is within a stable reach of the stream with a low migration rate. Therefore, there is a low potential of risk.

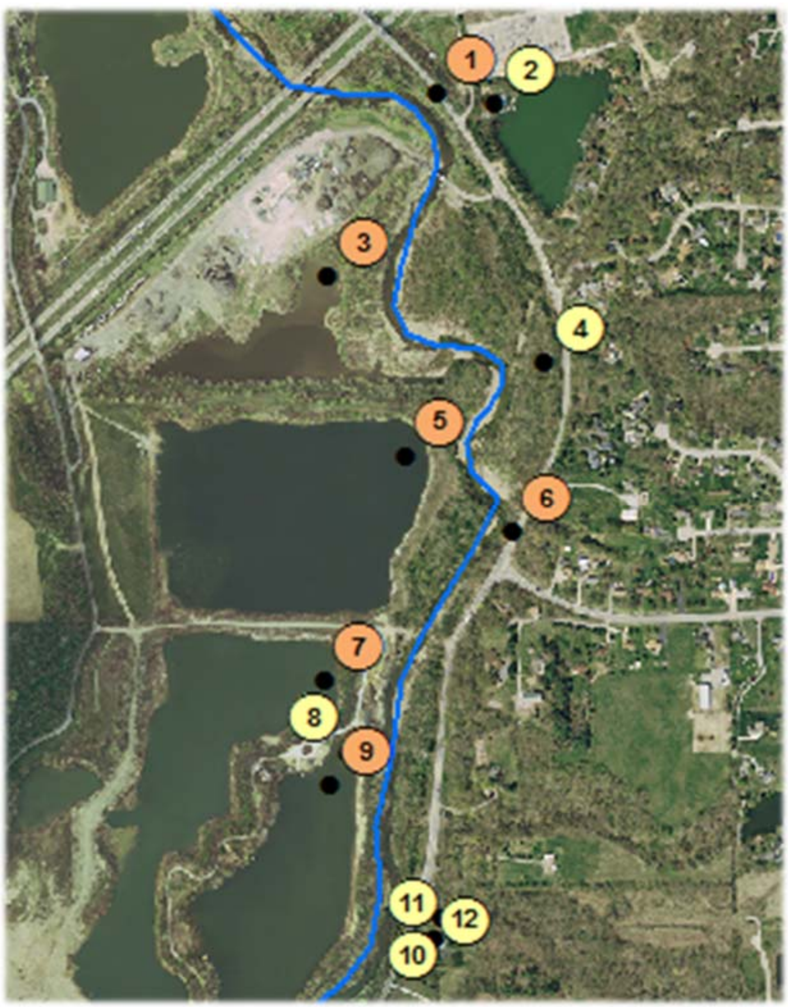


Figure 8: At-Risk Infrastructure

3.4 REACH-SCALE ASSESSMENT

A more detailed evaluation of the assessment reach was completed to quantify the parameters needed to develop conceptual active management solutions. The analyses were also used to further improve the understanding of the local system. The following paragraphs summarize the additional analyses completed for the reach-scale assessment.

3.4.1 Refined Assessment Reach

The preliminary assessment reach extent was evaluated to determine if the detailed analyses should cover the entirety of the reach or if analysis and evaluation efforts needed to be amended. Figure 9 shows the extent of the preliminary assessment reach and the refined assessment reach.

The refined assessment reach was extended upstream of the assessment reach to account for flow through the gravel pits and downstream of the gravel pits due to the impact of the four gravel pits on the hydrology and flow conditions through the reach during larger events.

Figure 9: Preliminary Reach Limits vs. Refined Analysis Extent

3.4.2 Channel Forming and Maintenance Flows

The channel forming discharge was evaluated using two different methods, a gage analysis of the Mooresville USGS stream gage utilizing the Advisory Committee on Water Information (ACWI) B17C guidelines, and a site assessment determination of bankfull discharge. The results of the B17C and bankfull discharge analysis are provided in Appendix 4. The channel forming discharge at the site was estimated to be 5,190cfs, based on the results of the combined analyses, which corresponds to the 1.3-year flow event.

3.4.3 Hydraulic Analysis

A two-dimensional hydraulic model was developed for the refined assessment reach to determine the speed and direction of flow in the channel near Old State Road 267 and through the gravel pits. The hydraulic model was configured to consider flows that ranged from baseflow conditions up to flows that overtop the channel banks. Additional information concerning the hydraulic model is provided in Appendix 4.

The results from the hydraulic model indicate that the maximum flow velocity in the refined assessment reach ranges from 1.5 to 9 feet per second (ft/s) for the flows considered. They are sufficient to mobilize the soil forming the channel banks due to the small particle size and lack of sufficient cohesion. The outside bend is likely to continue experiencing erosion, causing continued migration of the meander bend.

During more severe flow events, the hydraulic model indicates that the flow leaves the channel and overtops into the gravel pits along the left bank as shown in Figure 10. The velocities where the flow leaves the channel range from 3 to 5 ft/s for events up to the 100-year flow.

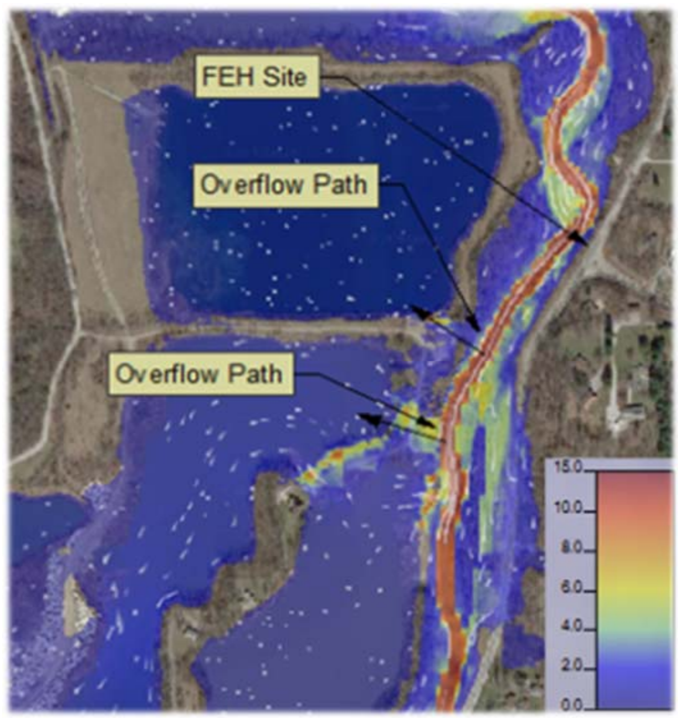


Figure 10: Overflow Path near FEH Site

The hydraulic model also included the gravel pits and the overflow paths between the gravel pits and White Lick Creek and the area downstream of the assessment reach to reduce the impact of boundary condition assumptions. The high conveyance capacity of the gravel pit causes the flow to accelerate through the upstream and downstream overflow paths in the gravel pit barrier. The increased velocities at the overflow paths have the potential to degrade the main channel bed and initiate or continue head-cutting in the upstream direction, potentially to, or beyond, the location of Old State Road 267. The diversion of flow through the gravel pits also produces a reduction of main channel velocity in the bypassed segment of the White Lick Creek. This reduction in velocity has the potential to increase sedimentation, which may lead to the abandonment of the reach over time.

3.4.4 Scour Evaluation

The results of the hydraulic model were used to compute general scour and bend scour at the FEH site. The general scour calculations were completed using the Blodgett and Pemberton and Lara methods; bend scour was computed using the methodology outlined in the National Engineering Handbook Part 654 Chapter 9. The results of the analyses show that the maximum scour depth near the FEH site is expected to range from 2 to 10 feet for general scour, and from 2 to 5 feet for bend scour. Long-term channel degradation is not accounted for in the above-mentioned scour depths; however, it will likely be a significant factor due to the capture of the gravel pits. Scour calculations are provided in Appendix 4.

An evaluation of long-term channel degradation was completed to evaluate the potential for the channel bed to be naturally armored by particles that are large enough that they are not mobilized. The smallest armoring-particle size was determined using Borah's method from TS-14B of Part 654 of the National Engineering Handbook. Figure 11 shows the relationship between the flow rate in the channel and the largest mobile particle on the channel bed. Sediment competence calculations are provided in Appendix 4.

Due to the fact that less than 65% of the channel materials are not of sufficient size to resist mobilization during the 1-year event (about 2,000 cfs), it does not appear likely that the channel will be naturally armored; channel degradation will likely continue until the channel reaches the equilibrium slope. An equilibrium slope was not evaluated as the gravel pit causes any determination to be highly speculative.

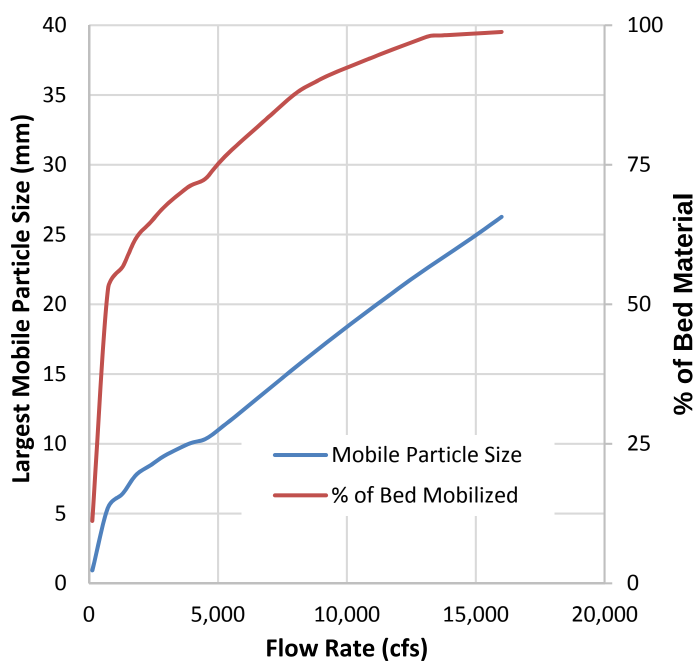


Figure 11: Sediment Competence Curve

3.5 KEY FINDINGS OF FEH MITIGATION STUDY

The most significant factors affecting the stability of the channel through the assessment reach identified during the 2015 CBBEL study and the current FEH mitigation study are described in the following paragraphs. All the stressors identified are affected by at least one of the other stressors, creating a compounding effect that reduces the overall stability of the river.

Highly Mobile Channel Material

The material forming the bed and banks of the channel is primarily gravel-sized sediment with a significant amount of sand. Soil profiles in the banks (see Figure 12) and large gravel bars within the stream suggest that the material was previously and is currently highly-mobile, as confirmed by the sediment competence evaluation discussed in Section 3.4.4. The prevalence of erodible materials means that the stream will likely continue to be mobile for the foreseeable future due to the fact that it is infeasible to protect the entirety of the stream against erosion. The mobility of the channel sediments given the inputs of water and sediment from the watershed should be considered the primary cause of the streams instability.

Figure 12: Erodible Channel Materials

Figure 13: Gravel Pits near FEH Site

Sediment ‘Sinks’

Locations in a system that have essentially no capacity to carry sediment are referred to as sediment ‘sinks’. Sediment sinks can result in massive instabilities in streams with high sediment loads, such as White Lick Creek. The large gravel pits near White Lick Creek, along and just downstream of the assessment reach, as shown in Figure 13 serve as enormous sediment sinks when intercepted. Once the flow enters the gravel pit, the sediment transport capacity vanishes, allowing nearly all the sediment being carried to be deposited. Deposition will continue to occur until the gravel pit is filled to a level that is at or above the natural stream bed. This creates a tremendous imbalance in the sediment capacity and sediment supplied to the reach immediately downstream of the gravel pit. Once the flow re-enters the downstream channel the sediment capacity increases dramatically. The sediment supplied from the upstream reach (i.e. the gravel pit) is essentially non-existent leaving the sediment capacity to be harvested from the channel bed and banks. This is often referred to as the stream being ‘hungry’, as the bed and banks are rapidly eaten away. This type of stressor also leads to degradation of the channel bed upstream of the gravel pit, as described in Section 3.4.4.

Channel Incision

The long-term degradational trend for White Lick Creek has caused the channel to become incised and disconnected from the natural floodplain; an example of this issue is shown in Figure 14. The result of the channel incision and floodplain disconnection is that in many places the flow is confined to the channel and does not have the ability to be stored in a floodplain during a ‘bankfull’ event. In healthy streams, the channel and floodplain are connected. This has significant benefit during flooding, as excess flow and sediment can exit the channel and be stored in the floodplain.

Figure 14: Incised Channel with Detached Floodplain
(White Lick Creek near Old State Road 267)

Increased Flow Rates and Flow Volume

The hydrologic analysis of the watershed discussed in Section 3.3 indicates that there is a significant amount of destabilizing activity in the watershed. The analysis of stream gage data shows a dramatic upward trend in the peak annual flow rate and also indicates a gradual climb in flow volume. Analysis of rainfall data shows that the rainfall depth and intensity have also increased, though not enough to completely explain the strong upward trend in flow rate and volume. There has been significant urbanization in the watershed between the early 1990’s and 2000s. The watershed produces more runoff and produces it more quickly now than in 1992.

The increased peak annual flow and flow volume may not be the primary factor affecting the stability of the assessment reach; however, longer-lasting and more erosive flows work to destabilize a stream. The magnitude and volume of the flow are detrimental in terms of increasing the sediment load of the stream, but the changing nature of those conditions often leads to instability, sometimes severe. Using Lane’s Balance, shown in Figure 15, one can determine the effect of increased flow rates and flow volume. If the amount of water is increased on the right-hand side of the scale, it will tip, leading to degradation of the channel. Degradation should be expected to occur unless the channel boundary sediments coarsen, which the analysis of scour and bed armoring in Section 3.4.4 suggests is not likely.

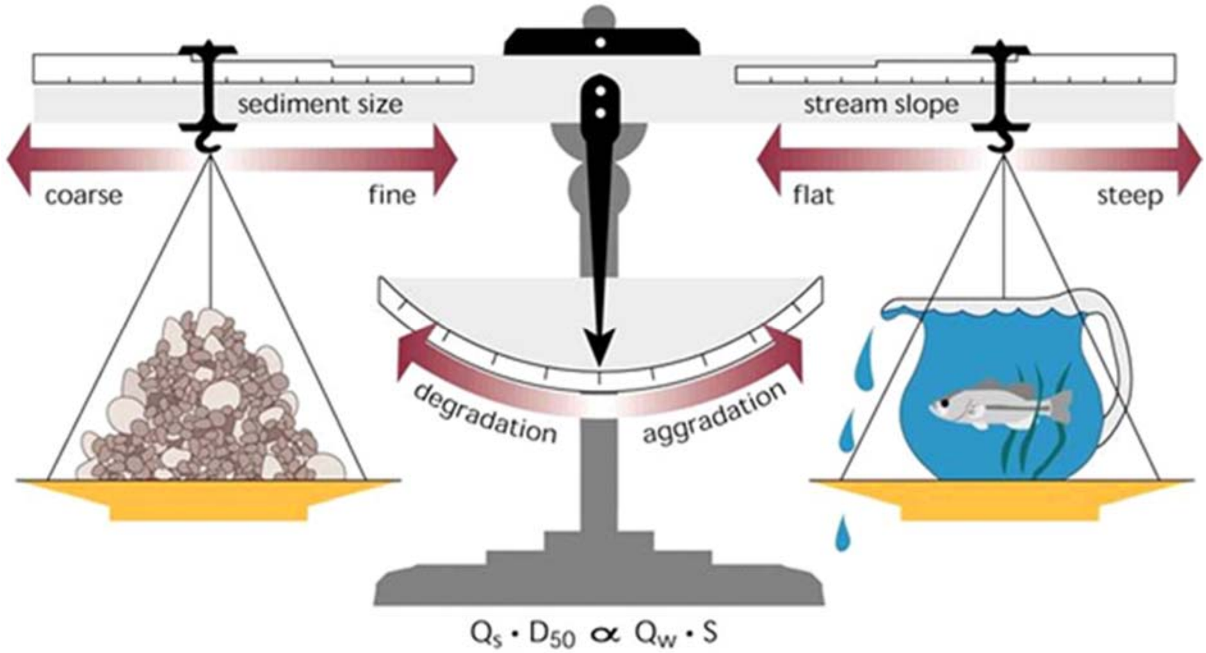


Figure 15: Lane's Balance
(USFWS, after Lane, 1955)

CHAPTER 4 STAKEHOLDER INPUT AND MITIGATION OBJECTIVES

The identification of the overall mitigation objectives is critical to the development of mitigation strategies and the success of the project. Establishing a clear decision-making process, evaluating the impairments to be addressed, and considering the potential improvements using a merit-based system is imperative to a prudent design. It is also important to identify what will constitute 'project success'. These factors should be considered by appropriate stakeholders.

4.1 DECISION MAKING PROCESS

The decision to proceed with a design of mitigation features will ultimately lie with the Town of Plainfield, state officials, and adjacent landowners. The conceptual improvements identified later in Chapters 5 and 6 were determined by the designer using the objectives noted below with consideration of the impairments to be mitigated and the likelihood of mitigation success.

4.2 MITIGATION OBJECTIVES

Conversations with Plainfield officials revealed concern over the long-term stability of Old State Road 267 due to observations of severe streambank erosion. The following objectives were implied:

1. Prevent the stream from compromising the roadway embankment
2. Reduce the long-term FEH risk
3. Low maintenance need for improvements
4. Cost efficient construction

4.2.1 Impairments to be Mitigated

The FEH site has several impairments that must be considered to meet the mitigation objectives. The impairments are primarily systemic instabilities that have been manifested proximate to the FEH. The following issues must be addressed by the design:

1. Channel migration leading to poorly aligned flow
2. General scour at the site, largely attributable to a highly erodible bed material
3. Peak annual flow rates that are on a significant increasing trend
4. Potential channel degradation due to the interaction and capture of the gravel pits within the refined assessment reach

4.2.2 Functional Lift

The relatively small extent of the FEH of interest and the confining objectives for the project reduce the potential for providing functional lift to the stream reach.

It may be possible to increase the stability of the immediately adjacent streambanks by better aligning flow during flooding events; however, unless the improvements extend well beyond the FEH site, negligible benefits should be expected elsewhere.

The amount of sediment load reduction or habitat construction possible for an FEH mitigation project in the assessment reach is not expected to provide significant benefit to the overall stream.

4.3 PRIORITIZED MITIGATION OBJECTIVES& PERFORMANCE METRICS

The mitigation objectives identified in Section 4.2 were provided in the order of priority that was understood from conversations with local stakeholders. The specific mitigation objectives have been expanded in the list below and are accompanied by designer-specified performance objectives intended to achieve the stated objectives:

1. **Prevent the stream from compromising the roadway embankment:**

   This mitigation objective will require active management strategies to effectively stop erosion near the roadway embankment. Prudent performance metrics for the improvements near the roadway include:

   A. Flow velocity during the 100-year event must be below the acceptable performance threshold of the surface cover/protection to prevent erosion during all but the most extreme of flow events.
   B. Flow vectors during the full range of flow events should be well aligned with the surface contouring inundated by and adjacent to the flow.

2. **Reduce the long-term FEH risk**

   This mitigation objective may include passive or active management strategies to reduce the risk of erosion near the roadway embankment, the likelihood that negative effects from the gravel pits would compromise the integrity of the implemented improvements at the FEH site and help to reduce the overall level of instability in the stream. Specific performance metrics are as follows:

   A. Protect against long-term degradation, ideally by addressing the issue at the source (i.e. the gravel pits)
   B. Mitigation measures implemented in and adjacent to the stream should consider the potential for the peak annual flow rate to continue to rise for the engineering life-span of the project

   C. Local regulations should be amended to help reduce the rapidity and volume of runoff being produced by the existing and new development within the watershed.

3. **Low maintenance need for improvements**

   Low maintenance requirements hinge on the types of improvements designed and the types of materials selected. Maintenance need is heavily dependent on uncontrolled variables (e.g. severity and frequency of flooding, debris strikes, etc). As a result, performance metrics are limited to anticipated outcomes rather than results of detailed analyses:

   A. Maintenance activities should be required no more frequently than once, annually.
   B. Material selections should have a long (20+ year) life-span to reduce or prevent the need to replace components of the project.

4. Cost efficient construction

Minimizing the project implementation cost requires evaluation of the materials and active management stabilization methods used. Though the overall cost of the improvements cannot be accurately predicted or determined prior to the selection of active management treatments, generalized goals can be established:

A. The overall project cost should be less than $1000 per foot of stabilized streambank.

B. The complexity of the design should be minimized to reduce installation costs and materials should be locally available and cost efficient.

CHAPTER 5 PASSIVE MANAGEMENT CONSIDERATIONS

Passive management strategies are most effective for addressing systemic issues that are watershed-based, or site-specific issues for a location that does not have a large contributing drainage area. As a result, the use of passive management strategies for mitigation of the FEH of interest is not a standalone solution to the problem; however, passive measures can often provide an increased benefit to the design of site-specific measures.

The apparent severity of the hydrologic stressors in the contributing watershed (e.g. increased rainfall, more frequent high flows, more runoff volume, etc) suggests that efforts should be made to promote more conservative and environmentally friendly drainage practices, particularly when new urban development occurs. Incentivizing green infrastructure, using more restrictive detention standards, and constructing flood control facilities to address the cumulative effect of past development could be used to help reduce runoff volume and peak flow rates.

The anticipated timeframe and inability to implement passive management improvements that completely resolve the issue at Old State Road 267 do not match up well with the project objectives, particularly the interest in immediately protecting the left bank at Old State Road 267. As a result, the implementation of passive measures would be required to occur under a parallel effort to the implementation of FEH mitigation measures.

CHAPTER 6 ACTIVE RIVER MANAGEMENT ANALYSIS

Active river management includes modifications to the stream corridor that directly combat or eliminate the instabilities that are present. Various types of active management strategies can be combined to create robust improvements to specific portions of the channel or the entire channel through a given reach. Active river management methods must address both vertical and lateral instability to be effective.

6.1 VERTICAL STABILITY CONSIDERATIONS

Improvements to the FEH mitigation site will need to address two potential sources of vertical instability: scour along the toe of the bank during significant flow events and the potential long-term degradation or head-cutting caused by the gravel pits.

Toe protection measures are typically necessary for FEH mitigation sites that have vertical or horizontal stability issues due to the fact that a bank is not likely to remain stable if the toe is eroded. Toe protection usually comes in the form of large stone, concrete, or wooden revetment that is designed to be immobile, even during high flow events. For streams with sand as a large portion of the bed material, large, loosely-placed rock is not a suitable means of toe protection as the material can shift out of position when smaller materials are evacuated from around the unfiltered edges of the stone placement. If the revetment stone is effectively restrained, filtered, and installed to a sufficient depth, it can provide adequate toe protection. Toe wood is a bank stabilization technique suitable for streams with sandy beds; the method uses large woody materials (trees, branches, etc) to protect the toe of the bank, while also providing redirection of the flow. An example of each type of toe protection measure is shown in Figure 16.

Figure 16: Toe Protection Measures
Riprap toe protection (top); soil lifts above toe wood (middle); toe wood (bottom)

Grade control structures are often used to prevent the process of channel degradation, or the gradual lowering of the channel invert due to erosion downstream propagating upstream. Grade control structures can be made of large, immobile stone, concrete, or sheet piling and span the width of the channels to stop the upstream migration of a headcut.

6.2 LATERAL STABILITY CONSIDERATIONS

Failed, over-steepened, and undermined banks are unstable due to an inability to support the weight of the soil forming the bank. Where banks suffer from this type of geotechnical instability, a simple and cost-effective means of correcting the issue is to reduce the slope to a more stable angle, typically in the range of 3-feet horizontal to 1-foot vertical (3H:1V), or flatter.

Figure 17: Armored Channel in Indianapolis, IN

Natural, healthy streams in Indiana typically meander and gradually move back and forth across their floodplain. In certain situations, such as this one, allowing the movement of the stream can endanger infrastructure. Utilizing an armoring system on the channel banks can help to prevent the natural erosion processes that allow the channel to move or change its shape in meaningful ways. Channel armoring is accomplished by installing a system that can withstand the flow velocity in the channel with negligible loss of bank and bed material over time; riprap, turf reinforcement mats, soil cement, etc. are examples of common armoring systems. An example of an armored channel is provided in Figure 17. The high lateral migration rate that is common throughout White Lick Creek poses an unusual concern for channel armoring. Attempting to constrain a highly mobile channel to a fixed location can result in increased instability in other areas of the stream.

Flow redirection includes altering the flow patterns that develop in a channel. The flow velocity through meander bends is typically higher around the outside of the bend along the bank. This creates a situation where weaker, unprotected bank materials can become significantly eroded and develop into what is known as a cut-bank. Cut-banks are areas along the outside of a meander bend that often suffer bank failures and are characterized by over-steepened or even vertical banks. The purpose of flow redirection is to realign flow that is directed toward the bank and to reduce the flow velocity along the bank. Flow redirection can be achieved by installing specialized structures, or by regrading the channel banks.

6.3 PROPOSED MITIGATION MEASURES

The type of mitigation techniques used to improve the stability of a stream is dependent on the type of instability present in the channel. White Lick Creek exhibits various forms of instability, including bank scour, vertical instability, and a large amount of lateral migration through the assessment reach. The proposed mitigation techniques and the portions of the stream to which the strategies are applicable are discussed below.

6.3.1 Evaluation of and Selection of Improvement Alternatives

There are different treatment methods available to address the different types of instability presented at the mitigation site. For vertical instability, treatments that provide toe protection are the most applicable. These treatments include toe wood, interlocking concrete jacks, and gabion baskets. For lateral instability, treatments that provide channel armoring are the most applicable. These treatments include gabion baskets, live stakes, and erosion control blanket systems. Each of the three types of toe protection were considered in conjunction with live stakes and erosion control blankets.

A triple bottom line comparison was completed for the three channel improvement alternatives to evaluate the economic costs, social benefits, and environmental benefits. A summary of the triple bottom line comparison is provided in Table 3. The complete triple bottom line decision matrix is included in Appendix 5.

Table 3: Triple Bottom Line Comparison of Improvement Alternatives

Improvement Alternative	Economic Score	Social Score	Environmental Score	Total Score
Toe Wood	2.6	1.3	3.2	**7.1**
Interlocking Concrete Jacks	2.2	1.0	2.8	**6.0**
Gabion Wall	1.8	1.0	2.5	**5.3**

Toe wood had the highest economic score because it was the least expensive and have low to moderate lifecycle cost. Gabion baskets were the most expensive and have moderate to high lifecycle cost. The interlocking concrete jacks have a low to moderate lifecycle cost but have a higher installation cost than toe wood.

Toe wood had the highest score for potential social benefits. All the protection types had a moderate to high benefit to public health and safety. Toe wood is expected to offer a limited benefit to quality to life due to the potential improvement for recreational use; the other two protection types provide no meaningful benefit beyond public health and safety. None of the protection types are expected to provide widespread benefit to properties or reduced flooding/drainage problems.

Toe wood had the highest environmental benefit score due to the potential for moderate to high improvement and/or protection to stream habitat; the other alternatives are not expected to meaningfully change the stream habitat. All the protection types provided a robust level of protection and did little to restore or protect the floodplain function of the stream. Gabion baskets could have some minor negative impacts to the adjacent stream reach due to a lack of energy dissipation.

6.3.2 Description of Improvements

Toe wood is a proven mitigation technique that can be used to reinforce the toe of an over-steepened streambank or to protect the outside of a meander bank. The toe wood application can be made to adjust the bankfull dimensions of the channel, as well as to create floodplain benches. Toe wood had a triple bottom line score of 7.1, which was the highest of the treatments.

A schematic layout of the potential improvements is provided in Exhibit 3. As can be seen in the exhibit, significant impacts to the stream are required to install the treatments. It is anticipated that armoring the streambank would require the acquisition of the following environmental permits, at a minimum:

IDNR Construction in a Floodway

IDEM Section 401 Water Quality Certification

USACE Section 404 Dredge & Fill Permit

IDEM Rule 5 Permit

The recommended bank armoring detail, or any other stabilization method, should not be used indiscriminately along the channel to ‘fix’ the banks. The installation of bank armoring can result in increased erosion and instability downstream of the project that impacts adjacent properties. Strategic integration of the improvements into the stream corridor is paramount to project success.

The cost of designing, permitting, and constructing these improvements is expected to be approximately $315,000. A detailed breakdown of the anticipated project cost is provided in Appendix 5.

6.3.3 Anticipated Performance

The improvements are expected to stabilize the streambank along Old State Road 267. Reinforcing the toe of the bank and adjusting the bank to provide a stable slope should provide sufficient resistance to erosion and prevent further migration. An evaluation of the mitigation objectives using the previously identified performance metrics is as follows:

1. **Prevent the stream from compromising the roadway embankment:**

   The anticipated maximum flow velocity during the 100-year event is 9 ft/s in the channel. Toe wood is a particularly robust system that is capable of withstanding velocities in excess of 8 ft/s. Most erosion control blanket systems have a performance threshold of up to 9 ft/s in an unvegetated state. This performance metric is met, as both erosion prevention systems have adequate erosion resistance during the 100-year event.

   The adjustment of the channel alignment and inclusion of a small shelf to improve the transition to the point bar cause the flow vectors to be much more well-aligned with the bank during the full range of flow events.

2. **Reduce the long-term FEH risk**

   The FEH site is protected against long-term degradation by using toe wood, which remains stable even when the structure is slightly undercut. Without acquiring the gravel pit property or establishing an agreement with the owner, designing significant improvements, and identifying a funding source for the remediation of the captured gravel pit, the problem cannot be addressed at the source. As a result, this performance metric is only partially met.

   The enlargement of the channel cross-section above the bankfull elevation increases the flow capacity in the immediate vicinity of the FEH site. As a result, the mitigation measures accommodate the potential for the peak annual flow rate to continue to rise to the greatest extent practicable given the improvements.

3. **Low maintenance need for improvements**

   The use of mitigation measures that are only vegetative on the surface reduces the difficulty of the required maintenance activities; in fact, the grass species used in conjunction with the erosion control blankets can be selected such that they do not need to be mowed to maintain a vigorous stand.

   When installed correctly, toe wood has an indefinite lifespan, as wood does not rot when continuously submerged in water. The use of non-degradable erosion control blankets and vegetation as reinforcement reduce the likelihood that the system would need to be augmented or replaced. Toe wood is also particularly tolerant of channel degradation and slight undermining of the structure. While this reduces the overall risk to the FEH site from the captured gravel pit downstream, it does not eliminate the issue.

4. **Cost efficient construction**

The overall construction cost for the improvements is anticipated to be approximately $315,000. The total length of stabilized streambank is 520 feet, resulting in a unit cost of $605 per foot.

The proposed methods are cost efficient and the materials should be locally available. Installing toe wood is an involved process that requires an experienced contractor to successfully implement; however, the overall goal is achieved.

CHAPTER 7 RECOMMENDATIONS

The results of the stream assessment described in Section 3.0 and the key factors influencing the stability of White Lick Creek described in Section 3.5 suggest that the issues are likely to persist and cannot be solved by correcting a problem in a specific location. However, Old State Road 267 serves as an important thoroughfare to Plainfield and should therefore be protected against damage from fluvial erosion. Monitoring the channel conditions at the FEH site and near the gravel pits will be a critical component to mitigating the fluvial erosion hazards through this reach of White Lick Creek.

7.1 GRAVEL PIT ANALYSIS

The potential impact of White Lick Creek having captured the gravel pits downstream of the FEH site could be severe. Interception of the gravel pits has and will likely lead to more channel degradation that radiates in the upstream and downstream directions, further destabilizing the streambanks. It is recommended that a more detailed analysis of the gravel pit and proximate areas be conducted to determine what precautionary measures are warranted and would be sufficient to prevent further destabilization of White Lick Creek.

7.2 IMPROVEMENT IMPLEMENTATION

Adjusting the channel alignment and armoring approximately 520 feet of both banks at the FEH site is expected to prevent erosion from compromising the roadway embankment. Reinforcing the toe of the bank, adjusting the upper portion of the bank to provide a stable slope, and realignment of the channel should provide sufficient resistance to erosion to prevent further migration. Exhibit 3 shows a typical section of the recommended method of bank armoring. Additional methods and treatments that are applicable for bank armoring exist; however, the recommended method was selected based on limiting the risk of failure while being sensitive to overall project cost.

7.3 MONITORING

Once the improvements have been constructed, the condition of the reconstructed bank at the FEH site should be monitored on an annual basis, and/or after significant flooding events. If the improvements are damaged or the embankment is threatened by stream migration, remedial action should be completed as soon as possible.

The gravel pits should also be monitored on a regular basis to identify new or worsening breaches in the berms, the trend in the erosion and deposition, changes to the local hydrology of the assessment reach, as well as the apparent impact to the upstream channel. Should conditions suggest that a wave of channel incision is occurring, additional analysis and evaluation of the instability should be completed, as discussed in Section 7.1.

7.4 NEXT STEPS

The following steps are recommended to reduce the fluvial erosion hazard risk at the Old State Road 267 in Plainfield:

1. Meet with CBBEL to discuss the findings and recommendations of this report.
2. Complete a master plan for the gravel pits to determine the precautionary measures necessary to prevent further destabilization of White Lick Creek.
3. Move forward with the detailed design and permitting of the proposed FEH mitigation measures for Old State Road 267 and additional areas proximate to the gravel pits, as recommended by the gravel pit master plan.
4. Following construction, establish a monitoring plan that records the condition and location of the streambanks and other significant changes to the channel at the identified fluvial erosion hazard location, the gravel pits, and any additional FEH locations that may become a concern in the future.

CHAPTER 8 REFERENCES

Chow, V. T. (1959). Open-Channel Hydraulics. Caldwell: The Blackburn Press.

Leopold, L.B., Wolman, M.G., and Miller, J.P. (1964) Fluvial Processes in Geomorphology. Freeman, 522 p.

National Oceanic and Atmospheric Administration (NOAA). National Climatic Data Center (NCDC). *Hourly Rainfall Data for Indianapolis International Airport*. Available http://gis.ncdc.noaa.gov/map/viewer/. Accessed April 6, 2016.

Robinson, B.A., 2013, Recent (circa 1998 to 2011) channel-migration rates of selected streams in Indiana: U.S. Geological Survey, Scientific Investigations Report 2013–5168, 14 p. plus 1 app., http://pubs.usgs.gov/sir/2013/5168/.

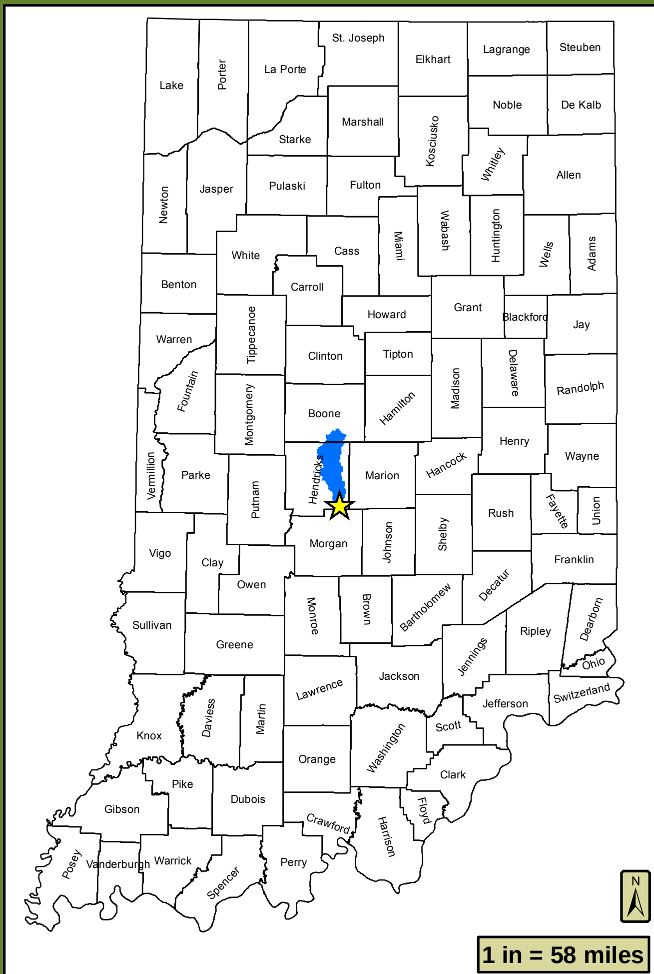
Robinson, B.A., 2013, Regional bankfull-channel dimensions of non-urban wadeable streams in Indiana: U.S. Geological Survey, Scientific Investigations Report 2013-5078, 33 p.

Rosgen, D, L. (1996) Applied River Morphology. Wildland Hydrology, variously paged.

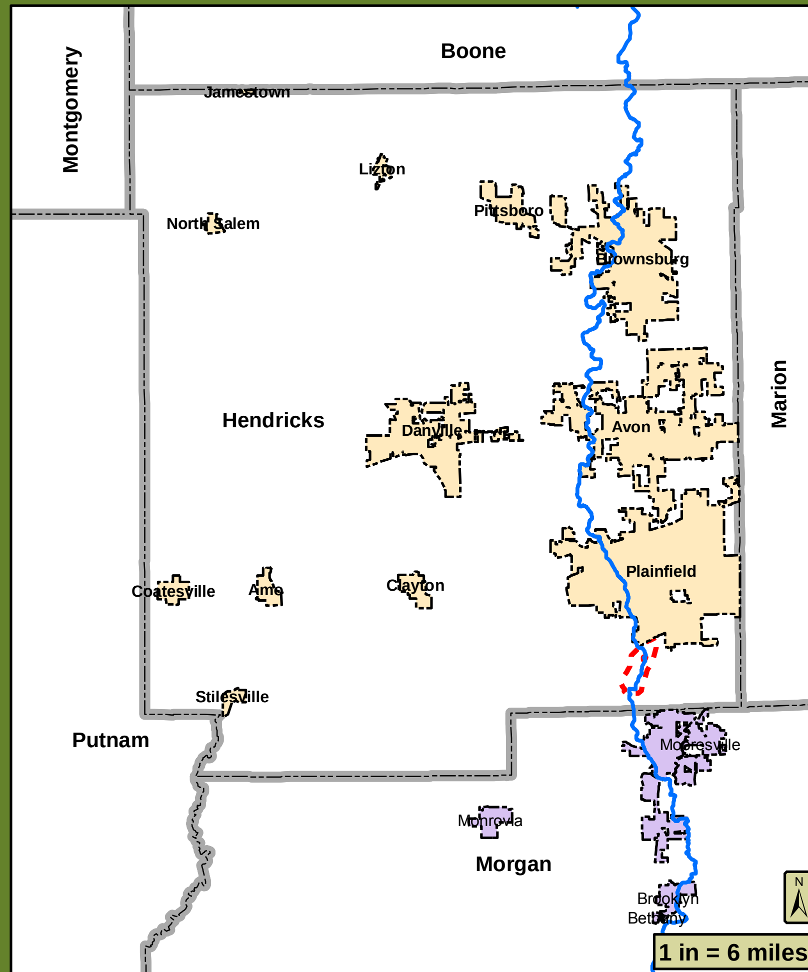
United States Department of Agriculture. Natural Resources Conservation Service. Urban Hydrology for Small Watersheds (Technical Release 55). June 1986.

United States Geological Survey. Stream Gage Data for Station 03353800 White Lick Creek AT MOORESVILLE, IN. Available http://maps.waterdata.usgs.gov/mapper. Accessed February 8, 2016.

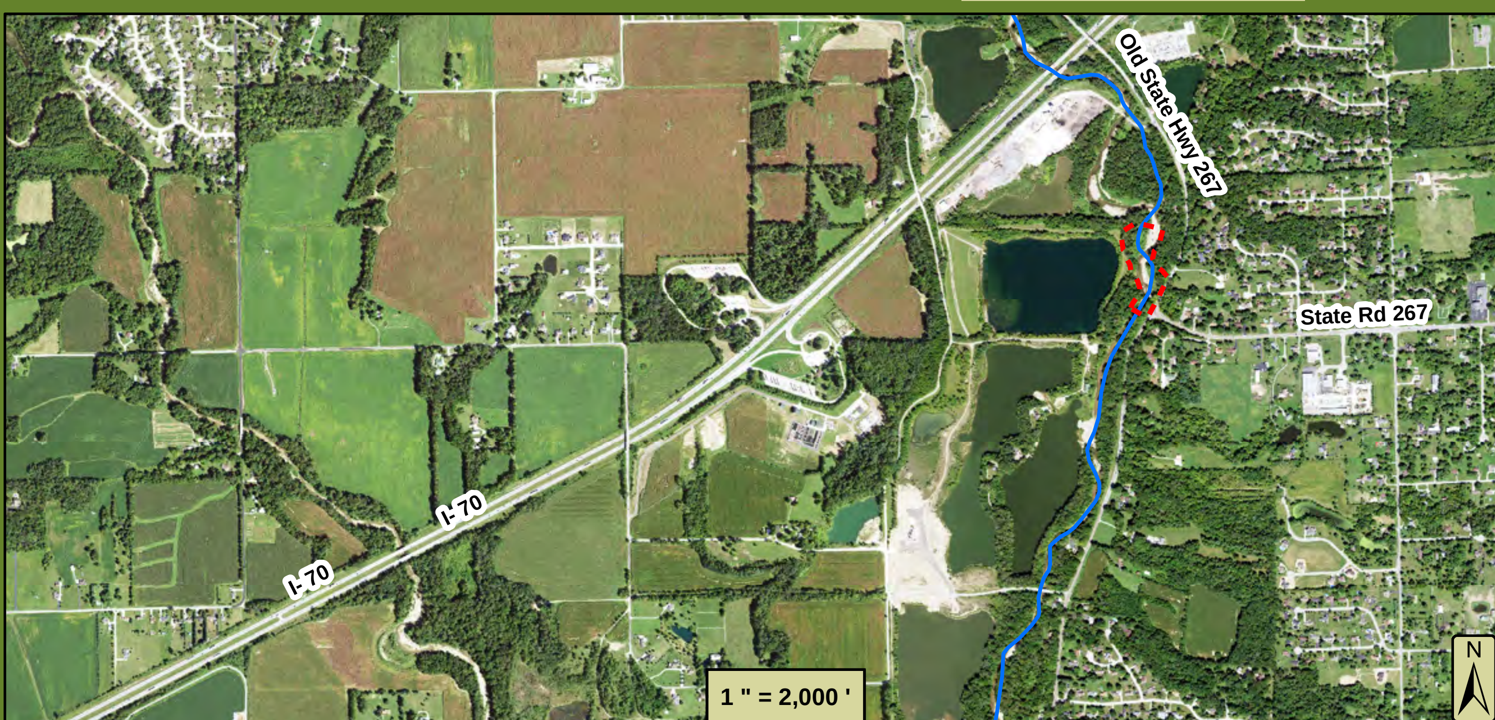
Exhibits



STATE MAP



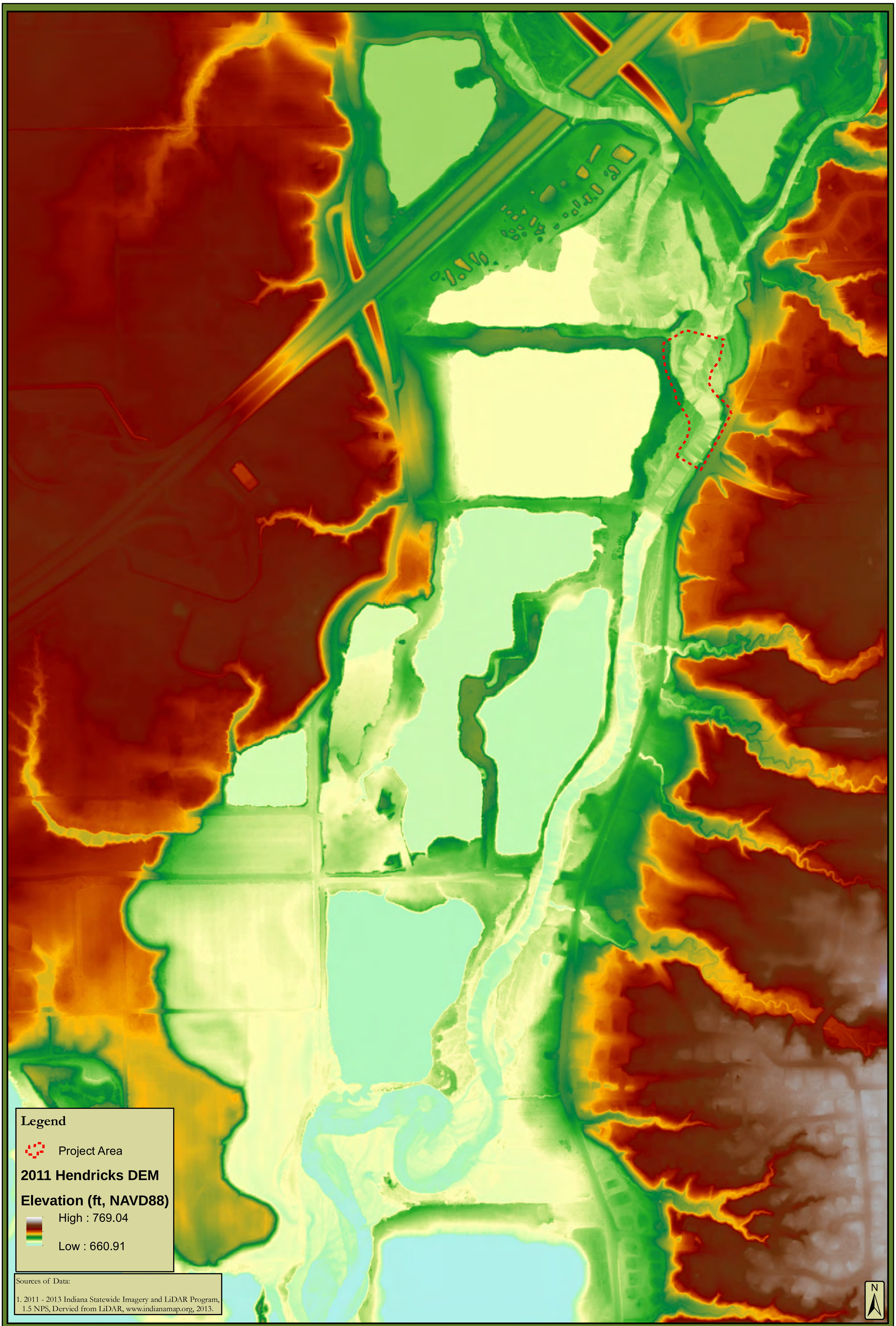
VICINITY MAP



STUDY AREA MAP

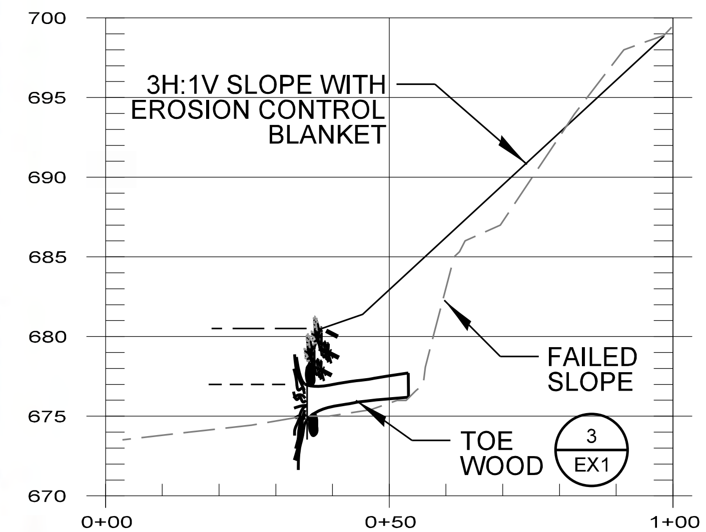
Christopher B. Burke Engineering, LLC
PNC Center, Suite 1368 South
115 West Washington Street
Indianapolis, Indiana 46204
(t) 317.266.8000 (f) 317.632.3306

PROJECT: White Lick Creek FEH Mitigation Assessment		PROJECT NO. 14-0014	APPROX. SCALE As Shown
TITLE: Study Area Map			DATE: 10/2018
			EXHIBIT 1

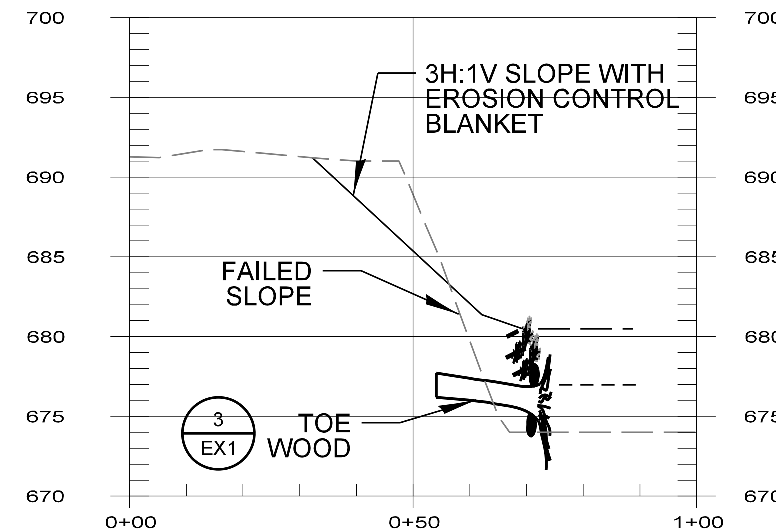


Christopher B. Burke Engineering, LLC
PNC Center, Suite 1368 South
115 West Washington Street
Indianapolis, Indiana 46204
(t) 317.266.8000 (f) 317.632.3306

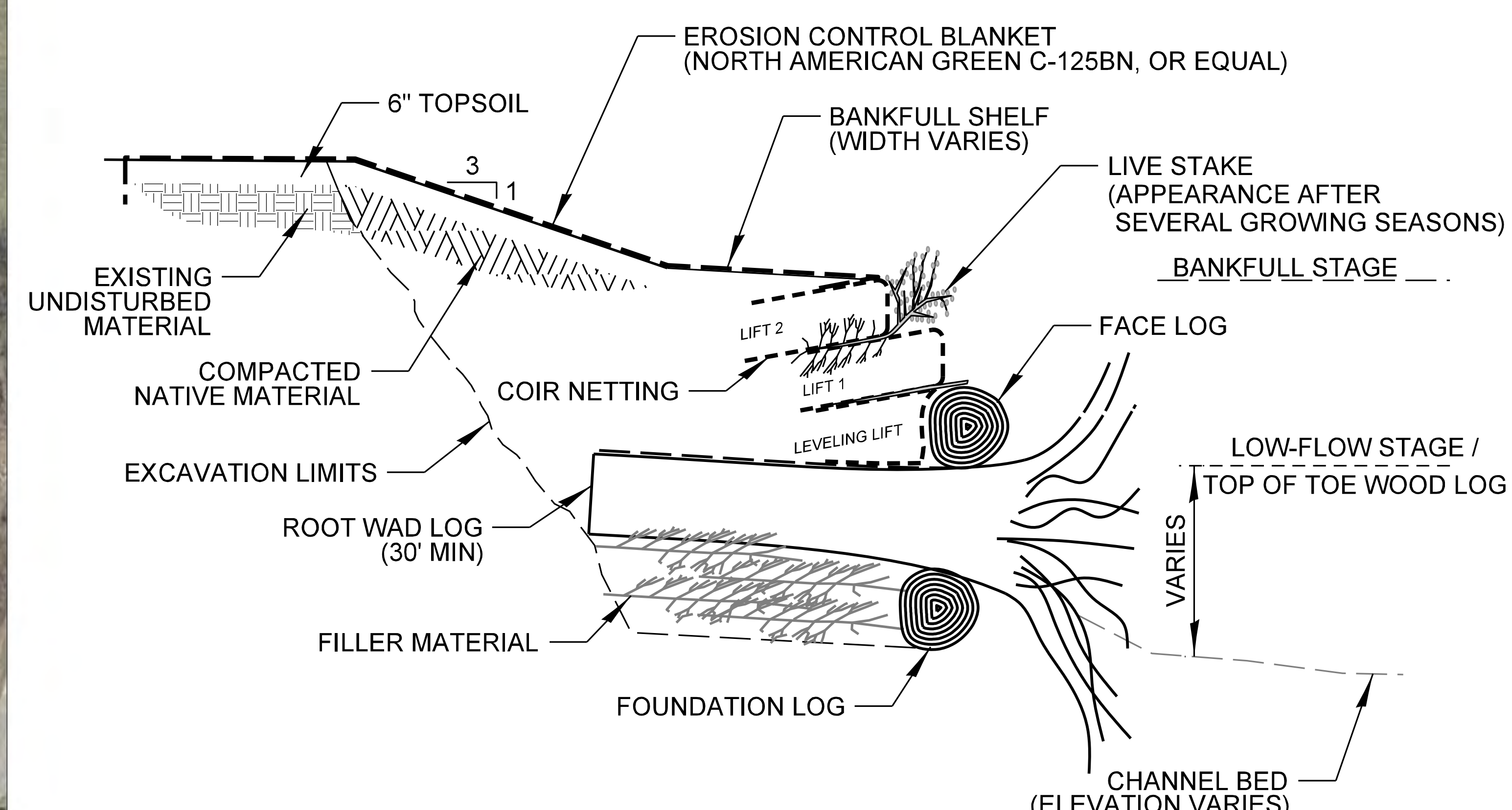
PROJECT:	PROJECT NO.	APPROX. SCALE
White Lick Creek FEH Mitigation Assessment	14-0014	1"=600'
TITLE: Topographic Map of White Lick Creek Watershed		DATE: 10/2018
		EXHIBIT 2



1 CONCEPTUAL DETAIL
TOE WOOD AT GRAVEL PIT
NOT TO SCALE



2 CONCEPTUAL DETAIL
TOE WOOD AT OLD SR 267
NOT TO SCALE



3 TYPICAL MITIGATION DETAIL
NOT TO SCALE

CHRISTOPHER B. BURKE ENGINEERING, LLC
PNC Center, Suite 1368 South
115 West Washington Street
Indianapolis, Indiana 46204
(317) 266-8000 FAX: (317) 632-3306

CERTIFIED: PRELIMINARY NOT FOR CONSTRUCTION	TITLE: OLD SR 267 EROSION MITIGATION	PROJECT NO. 19.R140014.00000	SHEET 1 OF 1
	PROJECT: WHITE LICK CREEK FEH MITIGATION ASSESSMENT	DRAWING NO. EX3	

Appendix 1:Site Observation Photographs

Christopher B. Burke Engineering, LLC
PNC Center, Suite 1368 South
115 West Washington Street
Indianapolis, Indiana 46204
(t) 317.266.8000 (f) 317.632.3306

PROJECT: White Lick Creek FEH Mitigation Assessment		PROJECT NO. 14-0014	APPROX. SCALE 1"=400'
			DATE: 10/2018
TITLE: Photo Location Map			EXHIBIT A1.1

Photo 1: White Lick Creek near FEH site (looking upstream)

Photo 2: Erosion at the FEH site

(Note eroded slope and lack of vegetation)

Photo 3: Sand Bar near FEH site

Photo 4: Debris along bank at FEH site

Photo 5: Non-vegetated slope at FEH site

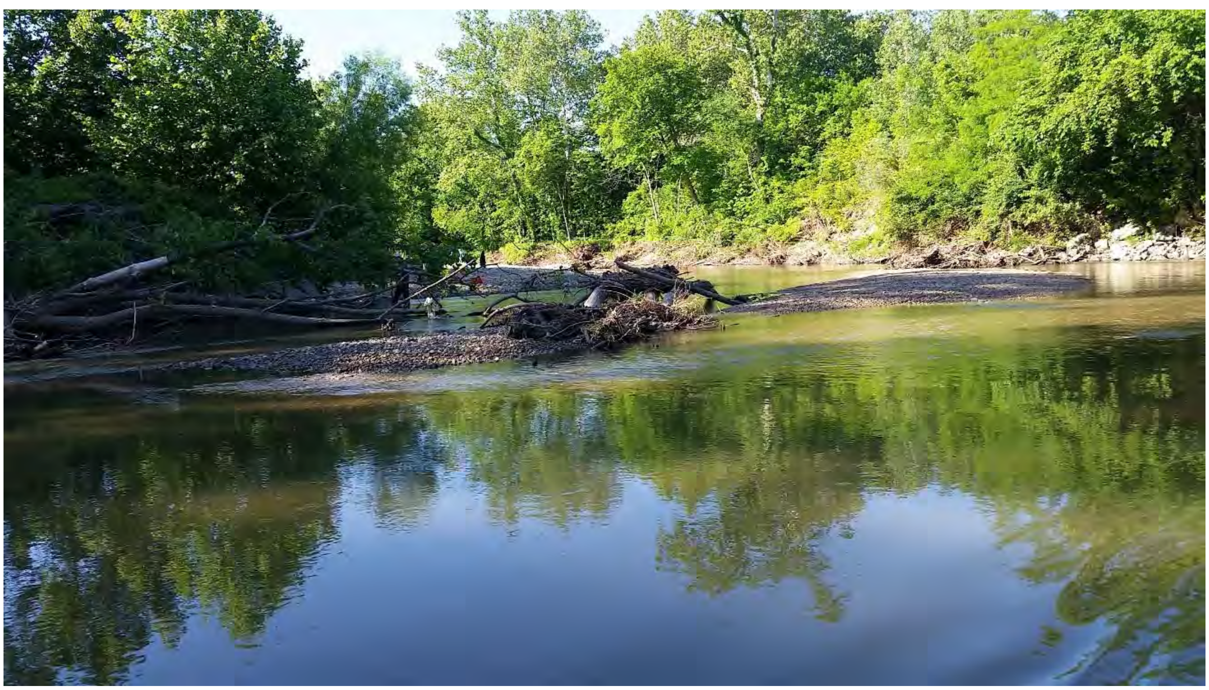


Photo 6: White Lick Creek at FEH site

Photo 7: White Lick Creek at FEH site

Photo 8: White Lick Creek along FEH site

Photo 9: White Lick Creek along FEH site

Appendix 2:Site Assessment Data & Calculations

Wetland Delineation Report

CHRISTOPHER B.
BURKE
ENGINEERING, LLC

White Lick Creek

Wetland Delineation Report

Plainfield, IN | April 2017

TABLE OF CONTENTS

TABLES

EXHIBITS

APPENDICES

JURISDICTIONAL WATERS AND WETLAND DELINEATION REPORT
WHITE LICK CREEK SITE
HENDRICKS COUNTY, INDIANA

EXECUTIVE SUMMARY

Christopher B. Burke Engineering, LLC (CBBEL) staff conducted an onsite field investigation of the White Lick Creek site in Hendricks County, Indiana. Field work was conducted on April 25, 2017 during which time no (0) wetlands and one (1) stream were identified onsite. Wetland delineations were conducted using methods identified in the Regional Supplement to the Corps of Engineers Delineation Manual: Midwest Region (Version 2.0) (August 2010).

Table 1 is a summary of the "waters"/wetland sites identified, including acreage or linear footage and our opinion of federal regulatory jurisdiction.

Table 1: Summary of Waters/Wetlands in Project Area

Site	Wetland/Stream Type	Acreage/Liner Footage (within project limits)	Jurisdiction
White Lick Creek	Perennial	1,075	State/Federal

1.0 STUDY AREA

On April 25, 2017, Christopher B. Burke Engineering, LLC (CBBEL) completed a Wetland/"Waters" of the U.S field investigation of the White Lick Creek Site in Hendricks County, Indiana (**Exhibit 1**). This report was prepared to document our findings and to determine if the on-site "waters"/wetland areas are jurisdictional under Sections 404/401 of the Clean Water Act (CWA) or under current Indiana Regulations. The project site includes both banks of an approximate 1,075-foot reach of White Lick Creek, located west of the intersection of Old State Highway 267 and Black Rock Road in Plainfield, Indiana. Specifically, the project is located in Section 14, of Township 14 North, Range 1 East on the Plainfield 7.5 Minute Quadrangle Map.

Wetland/"waters" boundaries were delineated in accordance with the Midwest Region methodology established by the USACE. The delineated wetlands/"waters" and data points are shown on **Exhibit 6**. Information collected on site is listed in the attached data forms (**Appendix B**).

2.0 METHODOLOGY

2.1 WETLAND DETERMINATION METHODOLOGY

Wetland determinations were conducted using the methodology from the *Regional Supplement to the Corps of Engineers Delineation Manual: Midwest Region (Version 2.0),* dated August 2010. The Midwest Regional Supplement identifies the mandatory technical criteria for wetland identification. The three essential characteristics of a wetland are hydrophytic vegetation, hydric soils and wetland hydrology as described below:

Hydrophytic Vegetation: The hydrophytic vegetation criterion is based on a separation of plants into five basic groups:

(1) Obligate wetland plants (OBL) almost always occur (estimated probability >99%) in wetlands under natural conditions;

(2) Facultative wetland plants (FACW) usually occur in wetlands (estimated probability 67-99%), but occasionally are found in non-wetlands;

(3) Facultative plants (FAC) are equally likely to occur in wetlands or nonwetlands (estimated probability 34-66%);

(4) Facultative upland plants (FACU) usually occur in non-wetlands (estimated probability 67-99%), but occasionally are found in wetlands (estimated probability 1-33%); and

(5) Obligate upland plants (UPL) almost always occur (estimated probability >99%) in non-wetlands under natural conditions.

***Indicator 1 - Rapid Test for Hydrophytic Vegetation*:** The rapid test for hydrophytic vegetation is met if all dominant species across all strata are OBL or FACW, or a combination of the two, based on a visual assessment.

Indicator 2 - Dominance Test: If greater than 50% of the plants present are FAC, FACW, or OBL the subject area is considered to be wetland in terms of vegetation, and no further vegetation analysis is required.

Indicator 3 - Prevalence Index: This test is conducted if the plant community fails the Dominance Test, but indicators of hydric soil and wetland hydrology are both present. The Prevalence Index is a weighted-average (based on percent cover) wetland indicator status of all plant species in the sampling plot, where each indicator status category is given a numeric value (OBL=1, FACW=2, FAC=3, FACU=4, and UPL=5). If the Prevalence Index is less than or equal to 3.0, then the hydrophytic vegetation criteria has been met.

Indicator 4 - Morphological Adaptations: This test is conducted if the plant community fails the prevalence test, but indicators of morphological adaptations for life in wetlands, on otherwise upland plant species, are present. If more than 50 percent of FACU species have morphological adaptations for life in wetlands, this species is considered a hydrophyte and is re-assigned an indicator of FAC. The Dominance Test and Prevalence Test should be re-calculated, and the hydrophytic vegetation criteria is satisfied if either test is satisfied.

Hydric Soils: Hydric soils are defined in the Midwest Regional Supplement as "soils that have formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part." Field indicators include matrix color, redox depletions and concentrations, sulfate reduction and resultant odor, organic matter accumulation, gleying, and soil texture. Specific types of hydric soils in the Midwest Region include, Histosols, Sandy Soils, Muck or Peat, and Loam or Clay Soils. Within these soil groups, there are many indicators specific to each type of soil.

Wetland Hydrology: The wetland hydrology criterion is often the most difficult to determine. Typically, the presence of water for a week or more during the growing season creates anaerobic conditions. Anaerobic conditions lead to the prevalence of wetland plants and soils. In the Midwest Regional Supplement, hydrology indicators are divided into four groups; Group A. Observation of Surface Water or Saturated Soils, Group B. Evidence of Recent Inundation, Group C. Evidence of Current or Recent Soil Saturation, and Group D. Evidence from Other Site Conditions or Data. Within each group, indicators are divided into two categories, *Primary* and *Secondary*. In the absence of a primary indicator, two or more secondary indicators from any group are required to conclude that wetland hydrology is present. Some indicators of wetland hydrology are surface water, saturation, water marks, sediment deposits, water stained leaves, drainage patterns, sulfide odor, crayfish burrows, stunted or stressed plants, or geomorphic position.

2.2 STREAM METHODOLOGY

The location of potentially jurisdictional channels was determined using the Hendricks County Soil Survey, the USGS Quadrangle Map, and aerial photography. An onsite evaluation determined if additional channels, not shown on any existing mapping, were present within the project limits. There was one jurisdictional stream documented within the project limits.

3.0 RESULTS AND DISCUSSION

3.1 IDENTIFIED WETLAND AREAS

There were no wetlands identified within the project limits.

3.2 NON-WETLAND DATA POINTS

Data Point 1: Data Point 1 is located within a forested area along the east bank of White Lick Creek. Vegetation at this data point consists of silver maple (*Acer saccharinum*, FACW), eastern cottonwood (*Populus deltoides*, FAC), box edler saplings (*Acer negundo*, FAC), black raspberry (*Rubus occidentalis*, NI), and riverbank wild-rye (*Elymus riparius*, FACW). The soil at this site has a matrix color of 10YR 4/4 and did not exhibit any redox concentrations. This area exhibited one secondary indicator of wetland hydrology; therefore, this data point does not qualify as wetland.

Data Point 2: Data Point 2 is located within an open area along the west bank of White Lick Creek. Vegetation at this data point consists of honey locust (*Gleditsia triacanthos*, FACU), American sycamore (*Platanus occidentalis*, FAC), and black raspberry (NI). The soil at this site has a matrix color of 10YR 3/3 and did not exhibit any redox concentrations. This area did not exhibit any indicators of wetland hydrology; therefore, this data point does not qualify as wetland.

Data Point 3: Data Point 3 is located within a forested area along the west bank southwest of Data Point 2. Vegetation at this data point consists of silver maple (FACW), eastern cottonwood (FAC), bush honeysuckle (*Lonicera maackii*, UPL), and garlic mustard (*Allaria petiolata*, FAC). The soil at this site has a matrix color of 10YR 4/2 and did not exhibit any redox concentrations. This area exhibited two secondary indicators of wetland hydrology. Although this data point has hydrophytic vegetation and hydrology, it does not have hydric soil; therefore, this data point does not qualify as wetland.

Data Point 4: Data Point 4 is located in a forested area along the west bank of White Lick Creek within the southern portion of the prjoject limits. Vegetation at this data point consists of Ohio buckeye (*Aesculus glabra*, FAC), American sycamore (FACW), bush honeysuckle (UPL), garlic mustard (FAC), Virginia waterleaf (*Hydrophyllum virginianum*, FAC), and red trillium (*Trillium erectum*, UPL). The soil at this site has a matrix color of 10YR 4/2 and did not exhibit any redox concentrations. This area exhibited one secondary indicator of wetland hydrology; therefore, this data point does not qualify as wetland.

Data Point 5: Data Point 5 is located within a forested area along the east bank of White Lick Creek within the southern portion of the project limits. Vegetation at this data point consists of sugar maple (*Acer saccharum*, FACU), American sycamore (FACW), bush honeysuckle (UPL), riverbank wild-rye (FACW), and tall scouring rush (Equisetum hyemale, FACW). The soil at this site has a matrix color of 10YR 3/2 and did not exhibit any redox concentrations. This area exhibited one secondary indicator of wetland hydrology; therefore, this data point does not qualify as wetland.

3.3 OTHER JURISDICTIONAL WATERS

White Lick Creek is a perennial stream that flows south through the project site. The Ordinary High Water Mark (OHWM) of the channel was measured at approximately 6-feet above the bed of the channel. The channel width ranged from approximately 10 feet wide to 100-feet wide within the project limits. Dominant substrates include sand, gravel, and cobble.

It is our opinion that this stream should be considered "Waters of the U.S." and, therefore, under federal jurisdiction. Any work within the channel will require Clean Water Act approval from the USACE and the IDEM. Additionally, an IDNR Construction in a Floodway permit will be required if there is any work within regulatory floodway.

4.0 REFERENCE MATERIALS

4.1 EXHIBIT REFERENCES

The following reference materials were reviewed and used to assist in the "Waters"/Wetland field reconnaissance. They are included as Exhibits 1-6.

EXHIBIT 1 –Site Location Map

The project site includes both banks of an approximate 1,075-foot reach of White Lick Creek, located west of the intersection of Old State Highway 267 and Black Rock Road in Plainfield, Indiana. Specifically, the project is located in Section 14, of Township 14 North, Range 1 East on the Plainfield 7.5 Minute Quadrangle Map.

EXHIBIT 2- National Wetlands Inventory Map

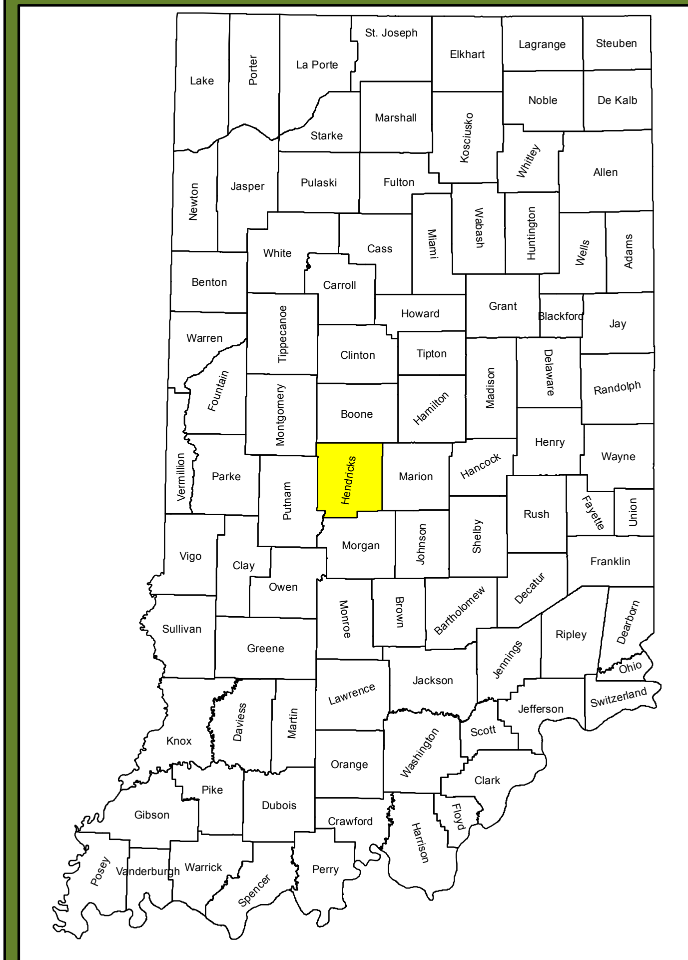
The National Wetland Inventory (NWI) does indicate wetlands within the project limits; however, the NWI serves only as a large-scale guide; actual wetland locations and types often vary from that mapped. The NWI map may also predate the development of the subject wetland.

EXHIBIT 3 – Soils Map
The Soil Survey of Hendricks County, Indiana (1970) was reviewed to determine the location of hydric soils on site. Mapped hydric soil can be indicative of wetland conditions. Genesee Silt Loam (Gn) and Genesee Sandy Loam (Gs) are mapped throughout the project limits and are not considered a hydric soils.

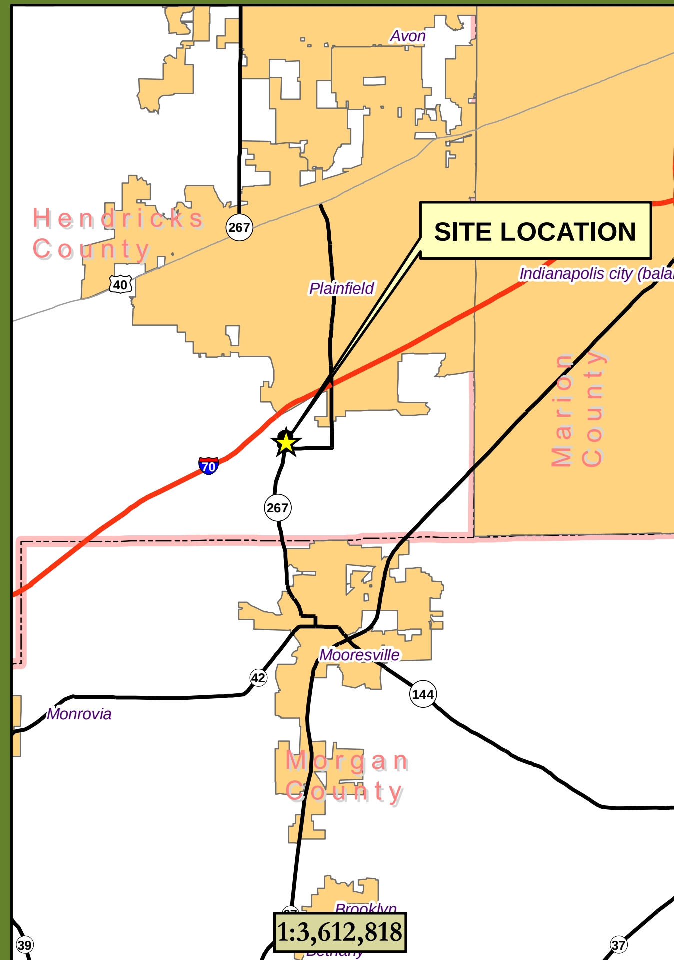
EXHIBIT 4 –Topography Map
U.S.G.S. 7.5-Minute Quadrangle Map, Plainfield, 1992 was reviewed to determine the local drainage pattern. The map indicates sloping terrain to white Lick Creek throughout the project limits.

EXHIBIT 5 – DFIRM
The Digital Flood Insurance Rate Map (DFIRM), Effective, September 25, 2009, was reviewed to determine the location of floodplain or floodway within the study area. Mapped floodplains can be indicative of wetland hydrology. The FIRM indicates regulatory floodway throughout the project limits.

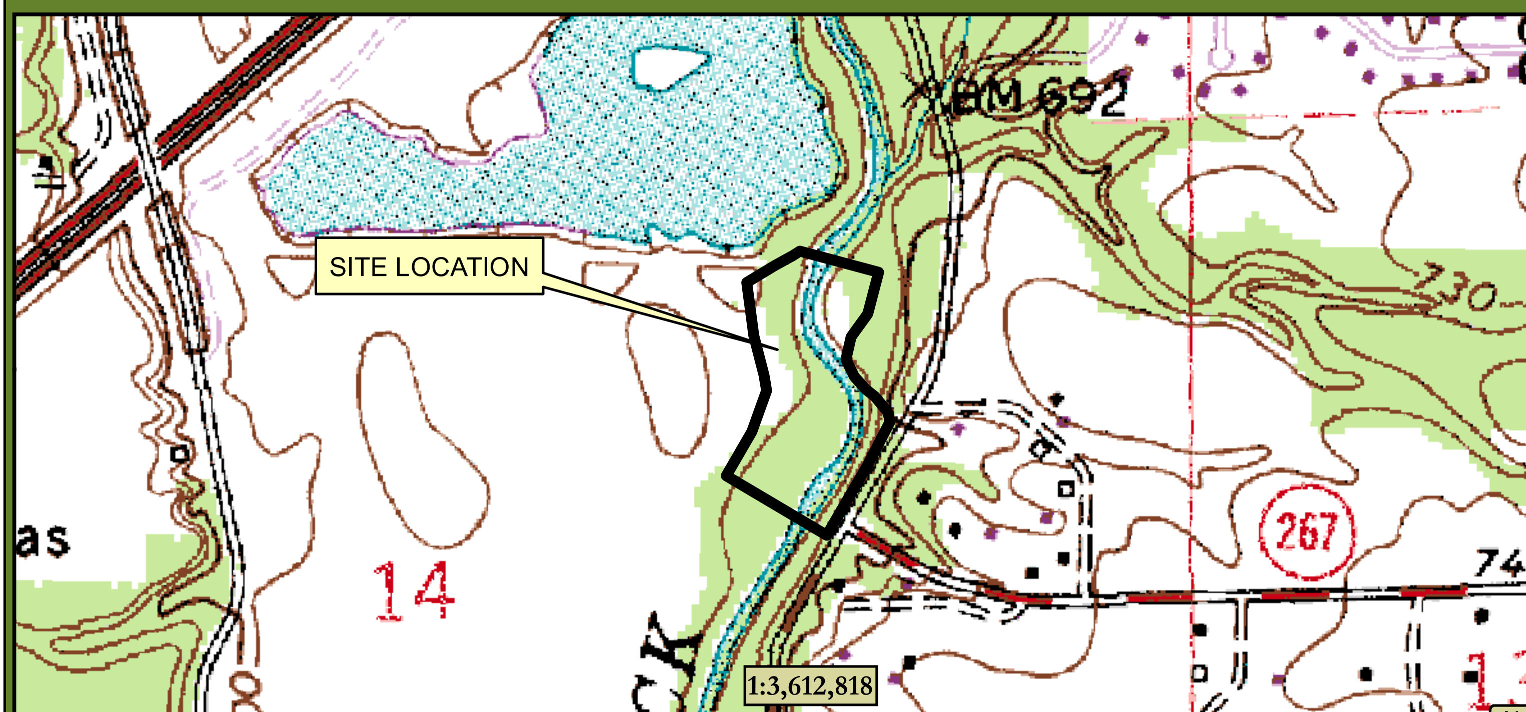
EXHIBIT 6 –Delineated Wetlands/"Waters", Data Points & Photo Stations
The aerial photograph of the site was reviewed to determine drainage patterns and identify poorly drained areas, or note changes in vegetation. The data points and photo stations are overlaid on the aerial photograph.



STATE MAP

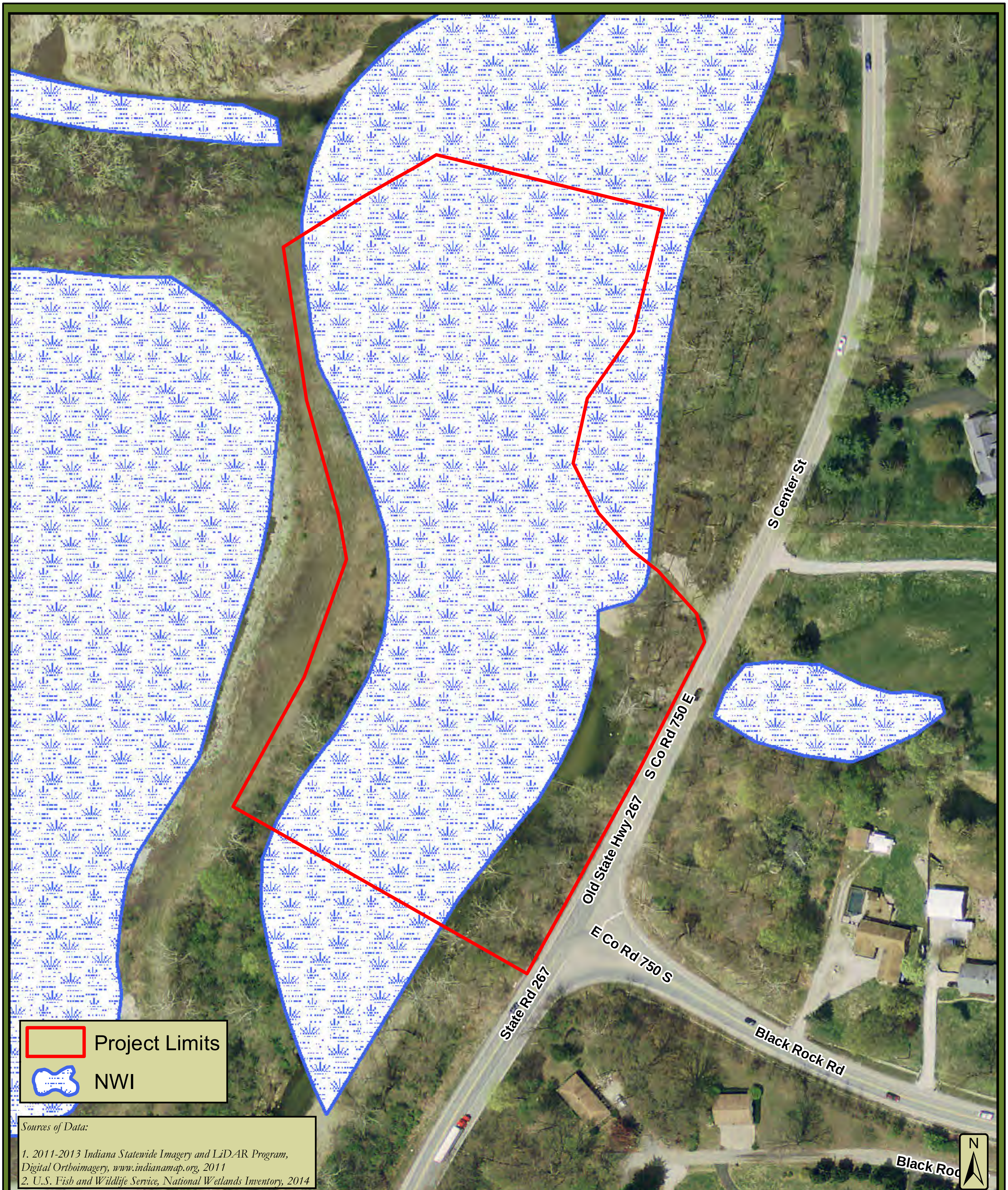


VICINITY MAP



AREA MAP

Christopher B. Burke Engineering, LLC PNC Center, Suite 1368 South 115 West Washington Street Indianapolis, Indiana 46204 (t) 317.266.8000 (f) 317.632.3306	PROJECT: White Lick Creek	PROJECT NO. 14-0014	APPROX. SCALE as shown
	TITLE: SITE LOCATION		DATE: 04/2017 EXHIBIT 1

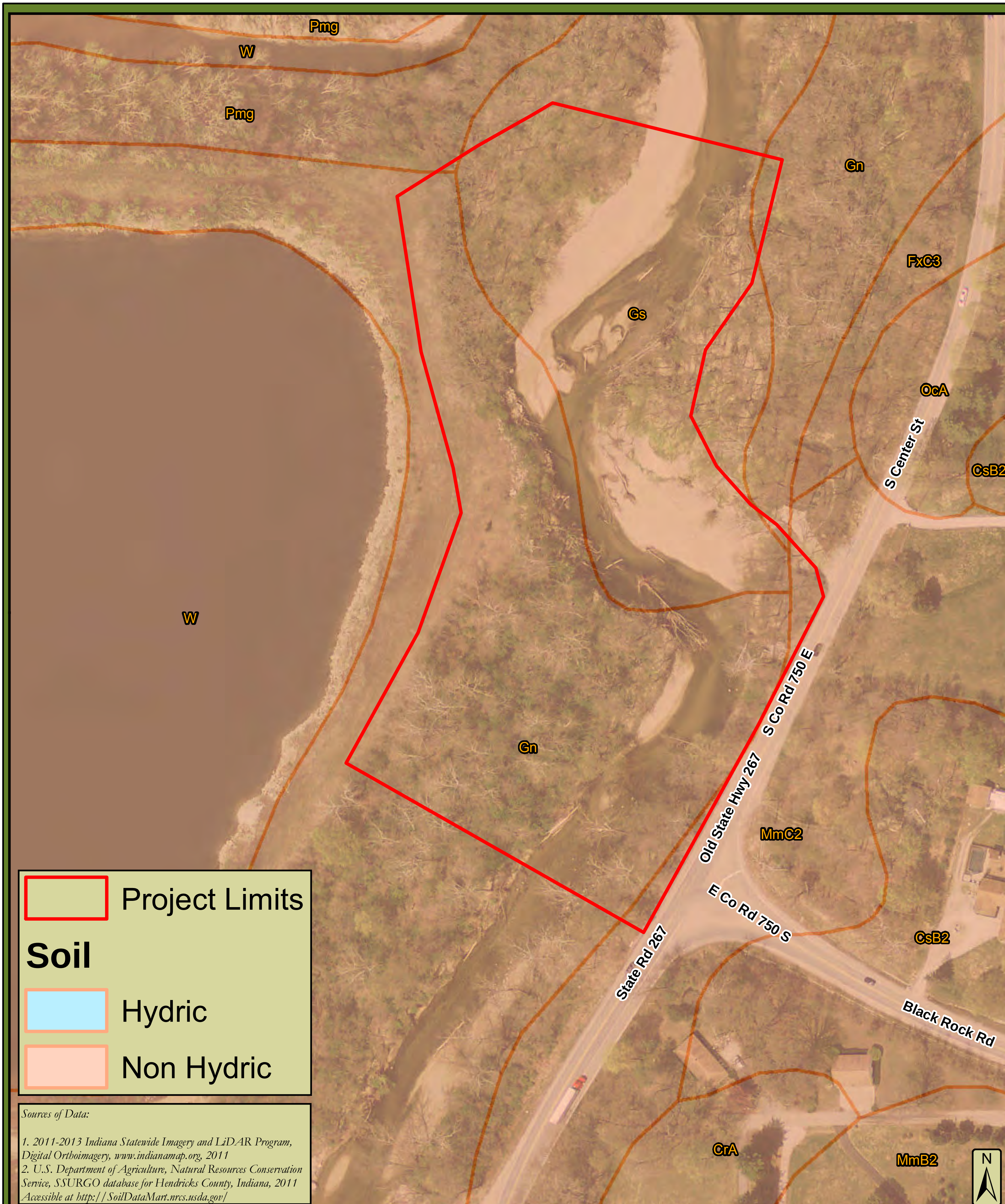


Sources of Data:

1. 2011-2013 Indiana Statewide Imagery and LiDAR Program, Digital Orthoimagery, www.indianamap.org, 2011
2. U.S. Fish and Wildlife Service, National Wetlands Inventory, 2014

Christopher B. Burke Engineering, LLC
PNC Center, Suite 1368 South
115 West Washington Street
Indianapolis, Indiana 46204
(t) 317.266.8000 (f) 317.632.3306

PROJECT:	PROJECT NO.	APPROX. SCALE
White Lick Creek	14-0014	1"=150'
TITLE: NWI		DATE: 04/2017
		EXHIBIT 2

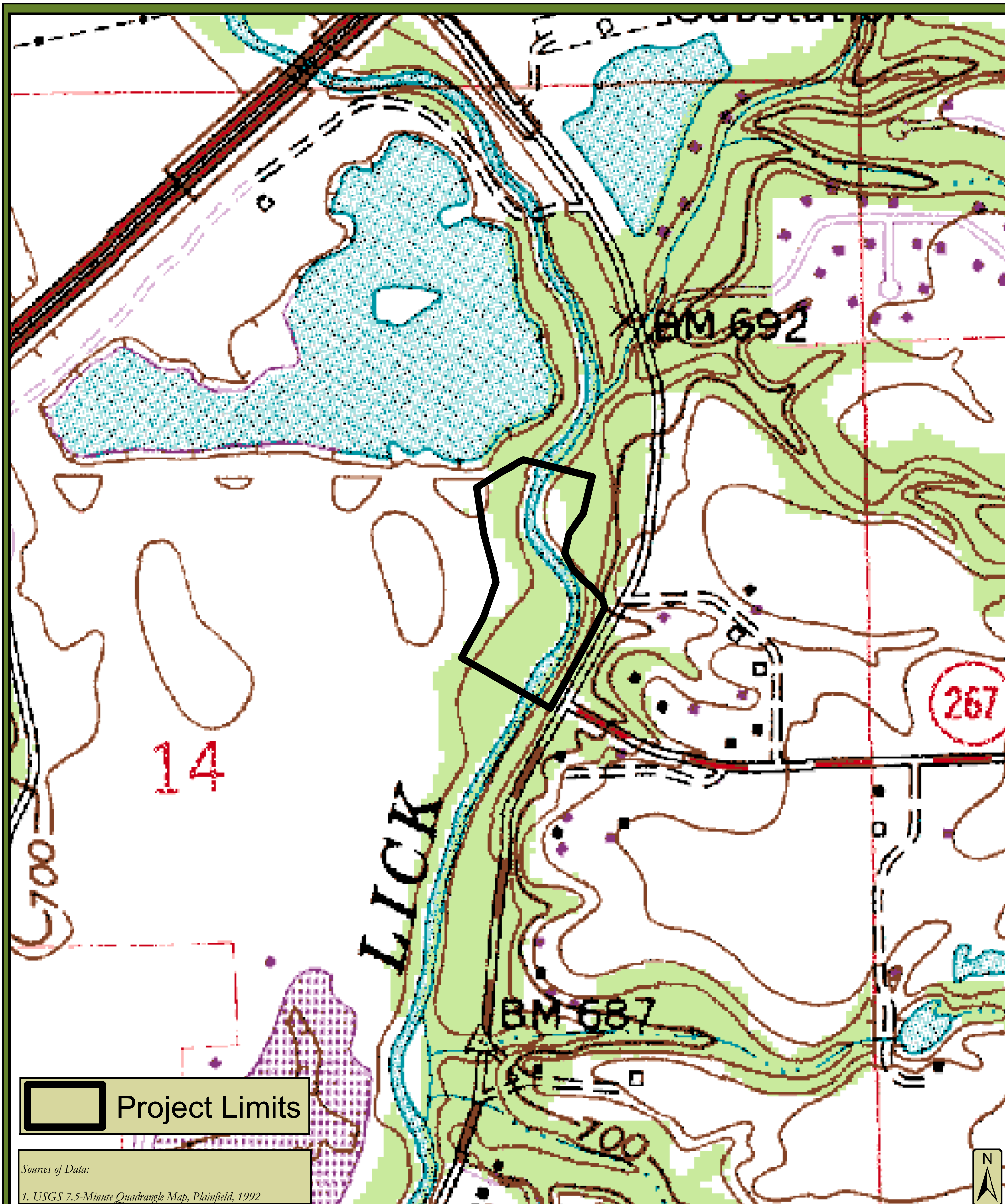


Sources of Data:

1. 2011-2013 Indiana Statewide Imagery and LiDAR Program, Digital Orthoimagery, www.indianamap.org, 2011
2. U.S. Department of Agriculture, Natural Resources Conservation Service, SSURGO database for Hendricks County, Indiana, 2011 Accessible at http://SoilDataMart.nrcs.usda.gov/

Christopher B. Burke Engineering, LLC
PNC Center, Suite 1368 South
115 West Washington Street
Indianapolis, Indiana 46204
(t) 317.266.8000 (f) 317.632.3306

PROJECT: White Lick Creek		PROJECT NO. 14-0014	APPROX. SCALE 1"=150'
TITLE: SOIL			DATE: 04/2017
			EXHIBIT 3



Christopher B. Burke Engineering, LLC
PNC Center, Suite 1368 South
115 West Washington Street
Indianapolis, Indiana 46204
(t) 317.266.8000 (f) 317.632.3306

PROJECT: White Lick Creek	PROJECT NO. 14-0014	APPROX. SCALE 1"=500'
TITLE: TOPO		DATE: 04/2017
		EXHIBIT 4

Christopher B. Burke Engineering, LLC
PNC Center, Suite 1368 South
115 West Washington Street
Indianapolis, Indiana 46204
(t) 317.266.8000 (f) 317.632.3306

PROJECT: White Lick Creek	PROJECT NO. 14-0014	APPROX. SCALE 1"=150'
TITLE: DFIRM		DATE: 04/2017
		EXHIBIT 5

Christopher B. Burke Engineering, LLC
PNC Center, Suite 1368 South
115 West Washington Street
Indianapolis, Indiana 46204
(t) 317.266.8000 (f) 317.632.3306

PROJECT:	PROJECT NO.	APPROX. SCALE
White Lick Creek	14-0014	1"=150'
TITLE: DELINEATED WETLANDS/"WATERS", DATA POINTS, & PHOTO STATIONS		DATE: 04/2017
		EXHIBIT 6

Appendix A – Project Photos

	PROJECT:	PROJECT NO:	APPROX. SCALE:
CHRISTOPHER B. BURKE ENGINEERING, LLC. PNC Center, Suite 1368 South 115 West Washington Street Indianapolis, Indiana 46204 TEL (317)266-8000 FAX (317)632-3306	White Lick Creek Wetland Delineation	14-0014	N/A
	TITLE: PROJECT PHOTOGRAPHS April 25, 2017		DATE: 04/2017 **SITE 1&2**

CHRISTOPHER B. BURKE ENGINEERING, LLC.
PNC Center, Suite 1368 South
115 West Washington Street
Indianapolis, Indiana 46204
TEL (317)266-8000 FAX (317)632-3306

PROJECT:	PROJECT NO:	APPROX. SCALE:
White Lick Creek Wetland Delineation	14-0014	N/A
TITLE: PROJECT PHOTOGRAPHS April 25, 2017		DATE: 04/2017
		SITE 3&4

CHRISTOPHER B. BURKE ENGINEERING, LLC.
PNC Center, Suite 1368 South
115 West Washington Street
Indianapolis, Indiana 46204
TEL (317)266-8000 FAX (317)632-3306

PROJECT:	PROJECT NO:	APPROX. SCALE:
White Lick Creek Wetland Delineation	14-0014	N/A
TITLE: PROJECT PHOTOGRAPHS April 25, 2017		DATE: 04/2017
		SITE 5&6

CHRISTOPHER B. BURKE ENGINEERING, LLC. PNC Center, Suite 1368 South 115 West Washington Street Indianapolis, Indiana 46204 TEL (317)266-8000 FAX (317)632-3306	**PROJECT:** White Lick Creek Wetland Delineation	**PROJECT NO:** 14-0014	**APPROX. SCALE:** N/A
	TITLE: PROJECT PHOTOGRAPHS April 25, 2017		**DATE:** 04/2017 **SITE 7&8**

CHRISTOPHER B. BURKE ENGINEERING, LLC. PNC Center, Suite 1368 South 115 West Washington Street Indianapolis, Indiana 46204 TEL (317)266-8000 FAX (317)632-3306	**PROJECT:** White Lick Creek Wetland Delineation	**PROJECT NO:** 14-0014	**APPROX. SCALE:** N/A
	TITLE: PROJECT PHOTOGRAPHS April 25, 2017		**DATE:** 04/2017 **SITE 9**

Appendix B – Data Sheets

WETLAND DETERMINATION DATA FORM – Midwest Region

Project/Site: White Lick Creek- Wetland Delineation   City/County: Plainfield/Hendricks   Sampling Date: 4/25/17

Applicant/Owner: IUPUI   State: IN   Sampling Point: DP1

Investigator(s): Sarah Wright; Jamie Furgason   Section, Township, Range: Section 14, Township 14 North, Range 1 East

Landform (hillslope, terrace, etc.): ______   Local relief (concave, convex, none): none

Slope (%): ______   Lat: 39.6551   Long: -86.3841   Datum: NAD83

Soil Map Unit Name: Gs- Genesee Sandy Loam   NWI classification: PFO1A

Are climatic / hydrologic conditions on the site typical for this time of year? Yes ◉ No ○ (If no, explain in Remarks.)

Are Vegetation ☐, Soil ☐, or Hydrology ☐ significantly disturbed?   Are "Normal Circumstances" present? Yes ◉ No ○

Are Vegetation ☐, Soil ☐, or Hydrology ☐ naturally problematic?   (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes ◉ No ○	Is the Sampled Area within a Wetland?	Yes ○ No ◉
Hydric Soil Present?	Yes ○ No ◉		
Wetland Hydrology Present?	Yes ○ No ◉		

Remarks:

VEGETATION – Use scientific names of plants.

Tree Stratum (Plot size: 30ft.)	Absolute % Cover	Dominant Species?	Indicator Status
1. Acer saccharinum	35	Yes	FACW
2. Populus deltoides	45	Yes	FAC
3.			
4.			
5.			
	80	= Total Cover	
Sapling/Shrub Stratum (Plot size: 15ft.)			
1. Acer negundo	20	Yes	FAC
2. Rubus occidentalis	50	Yes	NI
3.			
4.			
5.			
	70	= Total Cover	
Herb Stratum (Plot size: 5ft.)			
1. Elymus riparius	5	No	FACW
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
	5	= Total Cover	
Woody Vine Stratum (Plot size: 5ft.)			
1.			
2.			
	0	= Total Cover	

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 3 (A)

Total Number of Dominant Species Across All Strata: 4 (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: 75 (A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species		x 1 =
FACW species		x 2 =
FAC species		x 3 =
FACU species		x 4 =
UPL species		x 5 =
Column Totals:	0 (A)	(B)

Prevalence Index = B/A = ______

Hydrophytic Vegetation Indicators:

- ☐ 1 - Rapid Test for Hydrophytic Vegetation
- ☑ 2 - Dominance Test is >50%
- ☐ 3 - Prevalence Index is ≤3.0[1]
- ☐ 4 - Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
- ☐ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? Yes ◉ No ○

Remarks: (Include photo numbers here or on a separate sheet.)

SOIL

Sampling Point: DP1

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox Features %	Type[1]	Loc[2]	Texture	Remarks
0-16	10YR 4/4	100					Sand	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ☐ Histosol (A1)
- ☐ Histic Epipedon (A2)
- ☐ Black Histic (A3)
- ☐ Hydrogen Sulfide (A4)
- ☐ Stratified Layers (A5)
- ☐ 2 cm Muck (A10)
- ☐ Depleted Below Dark Surface (A11)
- ☐ Thick Dark Surface (A12)
- ☐ Sandy Mucky Mineral (S1)
- ☐ 5 cm Mucky Peat or Peat (S3)
- ☐ Sandy Gleyed Matrix (S4)
- ☐ Sandy Redox (S5)
- ☐ Stripped Matrix (S6)
- ☐ Loamy Mucky Mineral (F1)
- ☐ Loamy Gleyed Matrix (F2)
- ☐ Depleted Matrix (F3)
- ☐ Redox Dark Surface (F6)
- ☐ Depleted Dark Surface (F7)
- ☐ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ☐ Coast Prairie Redox (A16)
- ☐ Dark Surface (S7)
- ☐ Iron-Manganese Masses (F12)
- ☐ Very Shallow Dark Surface (TF12)
- ☐ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic

Restrictive Layer (if observed):

Type: ____________

Depth (inches): ____________

Hydric Soil Present? Yes ○ No ◉

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ☐ Surface Water (A1)
- ☐ High Water Table (A2)
- ☐ Saturation (A3)
- ☐ Water Marks (B1)
- ☐ Sediment Deposits (B2)
- ☐ Drift Deposits (B3)
- ☐ Algal Mat or Crust (B4)
- ☐ Iron Deposits (B5)
- ☐ Inundation Visible on Aerial Imagery (B7)
- ☐ Sparsely Vegetated Concave Surface (B8)
- ☐ Water-Stained Leaves (B9)
- ☐ Aquatic Fauna (B13)
- ☐ True Aquatic Plants (B14)
- ☐ Hydrogen Sulfide Odor (C1)
- ☐ Oxidized Rhizospheres on Living Roots (C3)
- ☐ Presence of Reduced Iron (C4)
- ☐ Recent Iron Reduction in Tilled Soils (C6)
- ☐ Thin Muck Surface (C7)
- ☐ Gauge or Well Data (D9)
- ☐ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ☐ Surface Soil Cracks (B6)
- ☐ Drainage Patterns (B10)
- ☐ Dry-Season Water Table (C2)
- ☐ Crayfish Burrows (C8)
- ☐ Saturation Visible on Aerial Imagery (C9)
- ☐ Stunted or Stressed Plants (D1)
- ☐ Geomorphic Position (D2)
- ☑ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present? Yes ○ No ◉ Depth (inches): ____________

Water Table Present? Yes ○ No ◉ Depth (inches): ____________

Saturation Present? (includes capillary fringe) Yes ○ No ◉ Depth (inches): ____________

Wetland Hydrology Present? Yes ○ No ◉

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

WETLAND DETERMINATION DATA FORM – Midwest Region

Project/Site: White Lick Creek- Wetland Delineation City/County: Plainfield/Hendricks Sampling Date: 4/25/17

Applicant/Owner: IUPUI State: IN Sampling Point: DP2

Investigator(s): Sarah Wright; Jamie Furgason Section, Township, Range: Section 14, Township 14 North, Range 1 East

Landform (hillslope, terrace, etc.): ______ Local relief (concave, convex, none): none

Slope (%): ______ Lat: 39.6557 Long: -86.3845 Datum: NAD83

Soil Map Unit Name: Gs- Genesee Sandy Loam NWI classification: PFO1A

Are climatic / hydrologic conditions on the site typical for this time of year? Yes ⦿ No ○ (If no, explain in Remarks.)

Are Vegetation ☐, Soil ☐, or Hydrology ☐ significantly disturbed? Are "Normal Circumstances" present? Yes ⦿ No ○

Are Vegetation ☐, Soil ☐, or Hydrology ☐ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes ○ No ⦿	Is the Sampled Area within a Wetland?	Yes ○ No ⦿
Hydric Soil Present?	Yes ○ No ⦿		
Wetland Hydrology Present?	Yes ○ No ⦿		

Remarks:

VEGETATION – Use scientific names of plants.

Tree Stratum (Plot size: 30ft.)	Absolute % Cover	Dominant Species?	Indicator Status
1. Gleditsia triacanthos	25	Yes	FACU
2. Platanus occidentalis	20	Yes	FACW
3.			
4.			
5.			
	45	= Total Cover	
Sapling/Shrub Stratum (Plot size: 15ft.)			
1. Rubus occidentalis	70	Yes	NI
2.			
3.			
4.			
5.			
	70	= Total Cover	
Herb Stratum (Plot size: 5ft.)			
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
	0	= Total Cover	
Woody Vine Stratum (Plot size: 5ft.)			
1.			
2.			
	0	= Total Cover	

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 1 (A)

Total Number of Dominant Species Across All Strata: 3 (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: 33 (A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species		x 1 =
FACW species	20	x 2 = 40
FAC species		x 3 =
FACU species	25	x 4 = 100
UPL species		x 5 =
Column Totals:	45 (A)	140 (B)

Prevalence Index = B/A = 3.11

Hydrophytic Vegetation Indicators:

- ☐ 1 - Rapid Test for Hydrophytic Vegetation
- ☐ 2 - Dominance Test is >50%
- ☐ 3 - Prevalence Index is ≤3.0[1]
- ☐ 4 - Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
- ☐ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? Yes ○ No ⦿

Remarks: (Include photo numbers here or on a separate sheet.)

SOIL

Sampling Point: DP2

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox Features %	Type[1]	Loc[2]	Texture	Remarks
0-16	10YR 3/3	100					Sand	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ☐ Histosol (A1)
- ☐ Histic Epipedon (A2)
- ☐ Black Histic (A3)
- ☐ Hydrogen Sulfide (A4)
- ☐ Stratified Layers (A5)
- ☐ 2 cm Muck (A10)
- ☐ Depleted Below Dark Surface (A11)
- ☐ Thick Dark Surface (A12)
- ☐ Sandy Mucky Mineral (S1)
- ☐ 5 cm Mucky Peat or Peat (S3)
- ☐ Sandy Gleyed Matrix (S4)
- ☐ Sandy Redox (S5)
- ☐ Stripped Matrix (S6)
- ☐ Loamy Mucky Mineral (F1)
- ☐ Loamy Gleyed Matrix (F2)
- ☐ Depleted Matrix (F3)
- ☐ Redox Dark Surface (F6)
- ☐ Depleted Dark Surface (F7)
- ☐ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ☐ Coast Prairie Redox (A16)
- ☐ Dark Surface (S7)
- ☐ Iron-Manganese Masses (F12)
- ☐ Very Shallow Dark Surface (TF12)
- ☐ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: ____________

Depth (inches): ____________

Hydric Soil Present? Yes ○ No ◉

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ☐ Surface Water (A1)
- ☐ High Water Table (A2)
- ☐ Saturation (A3)
- ☐ Water Marks (B1)
- ☐ Sediment Deposits (B2)
- ☐ Drift Deposits (B3)
- ☐ Algal Mat or Crust (B4)
- ☐ Iron Deposits (B5)
- ☐ Inundation Visible on Aerial Imagery (B7)
- ☐ Sparsely Vegetated Concave Surface (B8)
- ☐ Water-Stained Leaves (B9)
- ☐ Aquatic Fauna (B13)
- ☐ True Aquatic Plants (B14)
- ☐ Hydrogen Sulfide Odor (C1)
- ☐ Oxidized Rhizospheres on Living Roots (C3)
- ☐ Presence of Reduced Iron (C4)
- ☐ Recent Iron Reduction in Tilled Soils (C6)
- ☐ Thin Muck Surface (C7)
- ☐ Gauge or Well Data (D9)
- ☐ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ☐ Surface Soil Cracks (B6)
- ☐ Drainage Patterns (B10)
- ☐ Dry-Season Water Table (C2)
- ☐ Crayfish Burrows (C8)
- ☐ Saturation Visible on Aerial Imagery (C9)
- ☐ Stunted or Stressed Plants (D1)
- ☐ Geomorphic Position (D2)
- ☐ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present? Yes ○ No ◉ Depth (inches): ____________

Water Table Present? Yes ○ No ◉ Depth (inches): ____________

Saturation Present? (includes capillary fringe) Yes ○ No ◉ Depth (inches): ____________

Wetland Hydrology Present? Yes ○ No ◉

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

WETLAND DETERMINATION DATA FORM – Midwest Region

Project/Site: White Lick Creek- Wetland Delineation City/County: Plainfield/Hendricks Sampling Date: 4/25/17

Applicant/Owner: IUPUI State: IN Sampling Point: DP3

Investigator(s): Sarah Wright; Jamie Furgason Section, Township, Range: Section 14, Township 14 North, Range 1 East

Landform (hillslope, terrace, etc.): ______ Local relief (concave, convex, none): none

Slope (%): ______ Lat: 39.6552 Long: -86.3851 Datum: NAD83

Soil Map Unit Name: Gn- Genesee Silt Loam NWI classification: PFO1A

Are climatic / hydrologic conditions on the site typical for this time of year? Yes ⦿ No ○ (If no, explain in Remarks.)

Are Vegetation ☐, Soil ☐, or Hydrology ☐ significantly disturbed? Are "Normal Circumstances" present? Yes ⦿ No ○

Are Vegetation ☐, Soil ☐, or Hydrology ☐ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes ⦿ No ○	Is the Sampled Area within a Wetland? Yes ○ No ⦿
Hydric Soil Present?	Yes ○ No ⦿	
Wetland Hydrology Present?	Yes ⦿ No ○	

Remarks:

VEGETATION – Use scientific names of plants.

Tree Stratum (Plot size: 30ft.)	Absolute % Cover	Dominant Species?	Indicator Status
1. Acer saccharinum	30	Yes	FACW
2. Populus deltoides	30	Yes	FAC
3.			
4.			
5.			
	60	= Total Cover	
Sapling/Shrub Stratum (Plot size: 15ft.)			
1. Lonicera maackii	60	Yes	UPL
2.			
3.			
4.			
5.			
	60	= Total Cover	
Herb Stratum (Plot size: 5ft.)			
1. Alliaria petiolata	15	No	FAC
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
	15	= Total Cover	
Woody Vine Stratum (Plot size: 5ft.)			
1.			
2.			
	0	= Total Cover	

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 2 (A)

Total Number of Dominant Species Across All Strata: 3 (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: 66 (A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species		x 1 =
FACW species		x 2 =
FAC species		x 3 =
FACU species		x 4 =
UPL species		x 5 =
Column Totals:	0 (A)	(B)

Prevalence Index = B/A = ______

Hydrophytic Vegetation Indicators:

- ☐ 1 - Rapid Test for Hydrophytic Vegetation
- ☑ 2 - Dominance Test is >50%
- ☐ 3 - Prevalence Index is ≤3.0[1]
- ☐ 4 - Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
- ☐ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? Yes ⦿ No ○

Remarks: (Include photo numbers here or on a separate sheet.)

SOIL

Sampling Point: DP3

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Color (moist)	Redox %	Type[1]	Loc[2]	Texture	Remarks
0-16	10YR 4/2	100					Clay	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ☐ Histosol (A1)
- ☐ Histic Epipedon (A2)
- ☐ Black Histic (A3)
- ☐ Hydrogen Sulfide (A4)
- ☐ Stratified Layers (A5)
- ☐ 2 cm Muck (A10)
- ☐ Depleted Below Dark Surface (A11)
- ☐ Thick Dark Surface (A12)
- ☐ Sandy Mucky Mineral (S1)
- ☐ 5 cm Mucky Peat or Peat (S3)
- ☐ Sandy Gleyed Matrix (S4)
- ☐ Sandy Redox (S5)
- ☐ Stripped Matrix (S6)
- ☐ Loamy Mucky Mineral (F1)
- ☐ Loamy Gleyed Matrix (F2)
- ☐ Depleted Matrix (F3)
- ☐ Redox Dark Surface (F6)
- ☐ Depleted Dark Surface (F7)
- ☐ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ☐ Coast Prairie Redox (A16)
- ☐ Dark Surface (S7)
- ☐ Iron-Manganese Masses (F12)
- ☐ Very Shallow Dark Surface (TF12)
- ☐ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: ______

Depth (inches): ______

Hydric Soil Present? Yes ○ No ◉

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ☐ Surface Water (A1)
- ☐ High Water Table (A2)
- ☐ Saturation (A3)
- ☐ Water Marks (B1)
- ☐ Sediment Deposits (B2)
- ☐ Drift Deposits (B3)
- ☐ Algal Mat or Crust (B4)
- ☐ Iron Deposits (B5)
- ☐ Inundation Visible on Aerial Imagery (B7)
- ☐ Sparsely Vegetated Concave Surface (B8)
- ☐ Water-Stained Leaves (B9)
- ☐ Aquatic Fauna (B13)
- ☐ True Aquatic Plants (B14)
- ☐ Hydrogen Sulfide Odor (C1)
- ☐ Oxidized Rhizospheres on Living Roots (C3)
- ☐ Presence of Reduced Iron (C4)
- ☐ Recent Iron Reduction in Tilled Soils (C6)
- ☐ Thin Muck Surface (C7)
- ☐ Gauge or Well Data (D9)
- ☐ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ☐ Surface Soil Cracks (B6)
- ☐ Drainage Patterns (B10)
- ☐ Dry-Season Water Table (C2)
- ☐ Crayfish Burrows (C8)
- ☐ Saturation Visible on Aerial Imagery (C9)
- ☐ Stunted or Stressed Plants (D1)
- ☑ Geomorphic Position (D2)
- ☑ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present? Yes ○ No ◉ Depth (inches): ______

Water Table Present? Yes ○ No ◉ Depth (inches): ______

Saturation Present? (includes capillary fringe) Yes ○ No ◉ Depth (inches): ______

Wetland Hydrology Present? Yes ◉ No ○

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

WETLAND DETERMINATION DATA FORM – Midwest Region

Project/Site: White Lick Creek- Wetland Delineation City/County: Plainfield/Hendricks Sampling Date: 4/25/17

Applicant/Owner: IUPUI State: IN Sampling Point: DP4

Investigator(s): Sarah Wright; Jamie Furgason Section, Township, Range: Section 14, Township 14 North, Range 1 East

Landform (hillslope, terrace, etc.): ______ Local relief (concave, convex, none): none

Slope (%): ______ Lat: 39.6537 Long: -86.3851 Datum: NAD83

Soil Map Unit Name: Gn- Genesee Silt Loam NWI classification: PFO1A

Are climatic / hydrologic conditions on the site typical for this time of year? Yes ◉ No ○ (If no, explain in Remarks.)

Are Vegetation ☐, Soil ☐, or Hydrology ☐ significantly disturbed? Are "Normal Circumstances" present? Yes ◉ No ○

Are Vegetation ☐, Soil ☐, or Hydrology ☐ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes ◉	No ○
Hydric Soil Present?	Yes ○	No ◉
Wetland Hydrology Present?	Yes ○	No ◉

Is the Sampled Area within a Wetland? Yes ○ No ◉

Remarks:

VEGETATION – Use scientific names of plants.

	Absolute % Cover	Dominant Species?	Indicator Status
Tree Stratum (Plot size: 30ft.)			
1. Aesculus glabra	30	Yes	FACW
2. Platanus occidentalis	30	Yes	FAC
3.			
4.			
5.			
	60 = Total Cover		
Sapling/Shrub Stratum (Plot size: 15ft.)			
1. Lonicera maackii	60	Yes	UPL
2.			
3.			
4.			
5.			
	60 = Total Cover		
Herb Stratum (Plot size: 5ft.)			
1. Alliaria petiolata	20	Yes	FAC
2. Hydrophyllum virginianum	20	Yes	FAC
3. Trillium erectum	15	No	UPL
4.			
5.			
6.			
7.			
8.			
9.			
10.			
	55 = Total Cover		
Woody Vine Stratum (Plot size: 5ft.)			
1.			
2.			
	0 = Total Cover		

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 4 (A)

Total Number of Dominant Species Across All Strata: 5 (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: 80 (A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species		x 1 =
FACW species		x 2 =
FAC species		x 3 =
FACU species		x 4 =
UPL species		x 5 =
Column Totals:	0 (A)	(B)

Prevalence Index = B/A = ______

Hydrophytic Vegetation Indicators:

☐ 1 - Rapid Test for Hydrophytic Vegetation
☑ 2 - Dominance Test is >50%
☐ 3 - Prevalence Index is ≤3.0[1]
☐ 4 - Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
☐ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? Yes ◉ No ○

Remarks: (Include photo numbers here or on a separate sheet.)

SOIL

Sampling Point: DP4

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox Features %	Type[1]	Loc[2]	Texture	Remarks
0-16	10YR 4/2	100					Clay	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ☐ Histosol (A1)
- ☐ Histic Epipedon (A2)
- ☐ Black Histic (A3)
- ☐ Hydrogen Sulfide (A4)
- ☐ Stratified Layers (A5)
- ☐ 2 cm Muck (A10)
- ☐ Depleted Below Dark Surface (A11)
- ☐ Thick Dark Surface (A12)
- ☐ Sandy Mucky Mineral (S1)
- ☐ 5 cm Mucky Peat or Peat (S3)
- ☐ Sandy Gleyed Matrix (S4)
- ☐ Sandy Redox (S5)
- ☐ Stripped Matrix (S6)
- ☐ Loamy Mucky Mineral (F1)
- ☐ Loamy Gleyed Matrix (F2)
- ☐ Depleted Matrix (F3)
- ☐ Redox Dark Surface (F6)
- ☐ Depleted Dark Surface (F7)
- ☐ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ☐ Coast Prairie Redox (A16)
- ☐ Dark Surface (S7)
- ☐ Iron-Manganese Masses (F12)
- ☐ Very Shallow Dark Surface (TF12)
- ☐ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: ______

Depth (inches): ______

Hydric Soil Present? Yes ○ No ◉

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ☐ Surface Water (A1)
- ☐ High Water Table (A2)
- ☐ Saturation (A3)
- ☐ Water Marks (B1)
- ☐ Sediment Deposits (B2)
- ☐ Drift Deposits (B3)
- ☐ Algal Mat or Crust (B4)
- ☐ Iron Deposits (B5)
- ☐ Inundation Visible on Aerial Imagery (B7)
- ☐ Sparsely Vegetated Concave Surface (B8)
- ☐ Water-Stained Leaves (B9)
- ☐ Aquatic Fauna (B13)
- ☐ True Aquatic Plants (B14)
- ☐ Hydrogen Sulfide Odor (C1)
- ☐ Oxidized Rhizospheres on Living Roots (C3)
- ☐ Presence of Reduced Iron (C4)
- ☐ Recent Iron Reduction in Tilled Soils (C6)
- ☐ Thin Muck Surface (C7)
- ☐ Gauge or Well Data (D9)
- ☐ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ☐ Surface Soil Cracks (B6)
- ☐ Drainage Patterns (B10)
- ☐ Dry-Season Water Table (C2)
- ☐ Crayfish Burrows (C8)
- ☐ Saturation Visible on Aerial Imagery (C9)
- ☐ Stunted or Stressed Plants (D1)
- ☐ Geomorphic Position (D2)
- ☑ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present? Yes ○ No ◉ Depth (inches): ______

Water Table Present? Yes ○ No ◉ Depth (inches): ______

Saturation Present? (includes capillary fringe) Yes ○ No ◉ Depth (inches): ______

Wetland Hydrology Present? Yes ◉ No ○

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

WETLAND DETERMINATION DATA FORM – Midwest Region

Project/Site: White Lick Creek- Wetland Delineation City/County: Plainfield/Hendricks Sampling Date: 4/25/17

Applicant/Owner: IUPUI State: IN Sampling Point: DP5

Investigator(s): Sarah Wright; Jamie Furgason Section, Township, Range: Section 14, Township 14 North, Range 1 East

Landform (hillslope, terrace, etc.): ______ Local relief (concave, convex, none): none

Slope (%): ______ Lat: 39.6535 Long: -86.3844 Datum: NAD83

Soil Map Unit Name: Gn- Genesee Silt Loam NWI classification: None

Are climatic / hydrologic conditions on the site typical for this time of year? Yes ⦿ No ○ (If no, explain in Remarks.)

Are Vegetation ☐, Soil ☐, or Hydrology ☐ significantly disturbed? Are "Normal Circumstances" present? Yes ⦿ No ○

Are Vegetation ☐, Soil ☐, or Hydrology ☐ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes ⦿ No ○	Is the Sampled Area within a Wetland? Yes ○ No ⦿
Hydric Soil Present?	Yes ○ No ⦿	
Wetland Hydrology Present?	Yes ○ No ⦿	

Remarks:

VEGETATION – Use scientific names of plants.

Tree Stratum (Plot size: 30ft.)	Absolute % Cover	Dominant Species?	Indicator Status
1. Acer saccharum	40	Yes	FACU
2. Platanus occidentalis	45	Yes	FACW
3.			
4.			
5.			
	85	= Total Cover	
Sapling/Shrub Stratum (Plot size: 15ft.)			
1. Lonicera maackii	20	Yes	UPL
2.			
3.			
4.			
5.			
	20	= Total Cover	
Herb Stratum (Plot size: 5ft.)			
1. Elymus riparius	20	Yes	FAC
2. Equisetum hyemale	20	Yes	FACW
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
	40	= Total Cover	
Woody Vine Stratum (Plot size: 5ft.)			
1.			
2.			
	0	= Total Cover	

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 3 (A)

Total Number of Dominant Species Across All Strata: 5 (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: 60 (A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species		x 1 =
FACW species		x 2 =
FAC species		x 3 =
FACU species		x 4 =
UPL species		x 5 =
Column Totals:	0 (A)	(B)

Prevalence Index = B/A = ______

Hydrophytic Vegetation Indicators:

- ☐ 1 - Rapid Test for Hydrophytic Vegetation
- ☑ 2 - Dominance Test is >50%
- ☐ 3 - Prevalence Index is ≤3.0[1]
- ☐ 4 - Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
- ☐ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? Yes ⦿ No ○

Remarks: (Include photo numbers here or on a separate sheet.)

SOIL

Sampling Point: DP5

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox Features %	Type[1]	Loc[2]	Texture	Remarks
0-16	10YR 3/2	100					Clay	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ☐ Histosol (A1)
- ☐ Histic Epipedon (A2)
- ☐ Black Histic (A3)
- ☐ Hydrogen Sulfide (A4)
- ☐ Stratified Layers (A5)
- ☐ 2 cm Muck (A10)
- ☐ Depleted Below Dark Surface (A11)
- ☐ Thick Dark Surface (A12)
- ☐ Sandy Mucky Mineral (S1)
- ☐ 5 cm Mucky Peat or Peat (S3)
- ☐ Sandy Gleyed Matrix (S4)
- ☐ Sandy Redox (S5)
- ☐ Stripped Matrix (S6)
- ☐ Loamy Mucky Mineral (F1)
- ☐ Loamy Gleyed Matrix (F2)
- ☐ Depleted Matrix (F3)
- ☐ Redox Dark Surface (F6)
- ☐ Depleted Dark Surface (F7)
- ☐ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ☐ Coast Prairie Redox (A16)
- ☐ Dark Surface (S7)
- ☐ Iron-Manganese Masses (F12)
- ☐ Very Shallow Dark Surface (TF12)
- ☐ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: ______

Depth (inches): ______

Hydric Soil Present? Yes ○ No ◉

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ☐ Surface Water (A1)
- ☐ High Water Table (A2)
- ☐ Saturation (A3)
- ☐ Water Marks (B1)
- ☐ Sediment Deposits (B2)
- ☐ Drift Deposits (B3)
- ☐ Algal Mat or Crust (B4)
- ☐ Iron Deposits (B5)
- ☐ Inundation Visible on Aerial Imagery (B7)
- ☐ Sparsely Vegetated Concave Surface (B8)
- ☐ Water-Stained Leaves (B9)
- ☐ Aquatic Fauna (B13)
- ☐ True Aquatic Plants (B14)
- ☐ Hydrogen Sulfide Odor (C1)
- ☐ Oxidized Rhizospheres on Living Roots (C3)
- ☐ Presence of Reduced Iron (C4)
- ☐ Recent Iron Reduction in Tilled Soils (C6)
- ☐ Thin Muck Surface (C7)
- ☐ Gauge or Well Data (D9)
- ☐ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ☐ Surface Soil Cracks (B6)
- ☐ Drainage Patterns (B10)
- ☐ Dry-Season Water Table (C2)
- ☐ Crayfish Burrows (C8)
- ☐ Saturation Visible on Aerial Imagery (C9)
- ☐ Stunted or Stressed Plants (D1)
- ☐ Geomorphic Position (D2)
- ☑ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present? Yes ○ No ◉ Depth (inches): ______

Water Table Present? Yes ○ No ◉ Depth (inches): ______

Saturation Present? (includes capillary fringe) Yes ○ No ◉ Depth (inches): ______

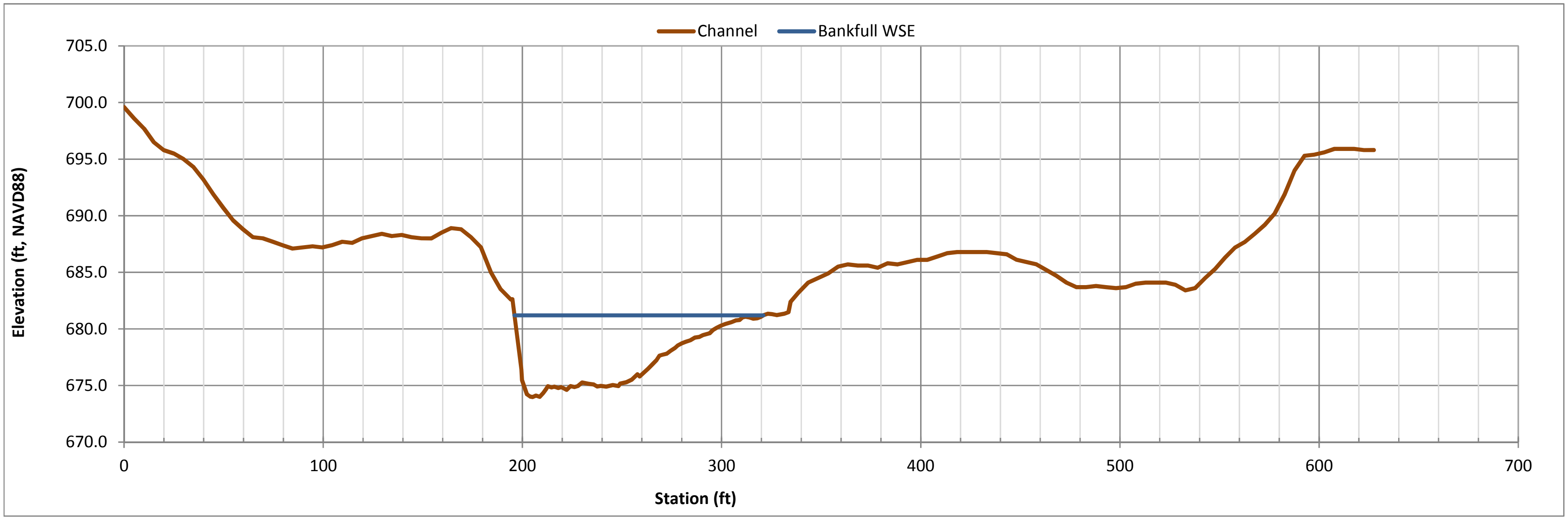
Wetland Hydrology Present? Yes ◉ No ○

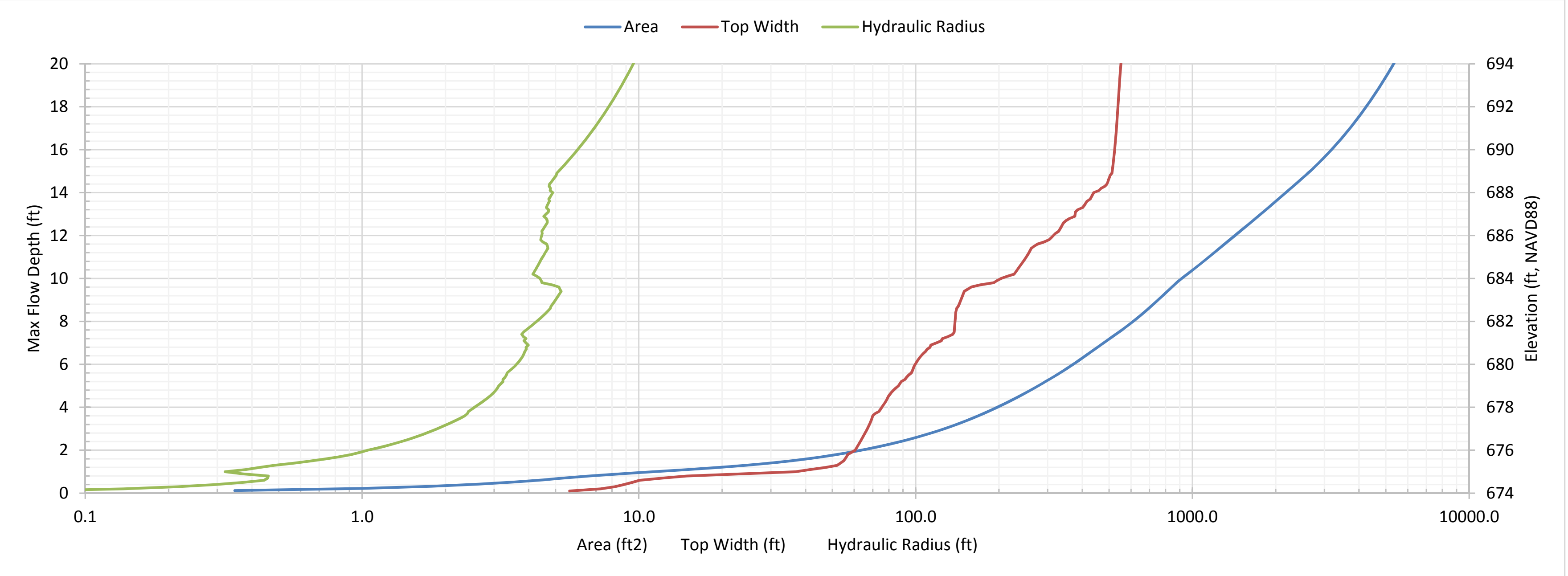
Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

Bankfull Cross Section Plot

Bankfull Channel Cross-section Properties





Stream Classification Sheet

Channel Classification

Worksheet 2-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen and Silvey, 2005).

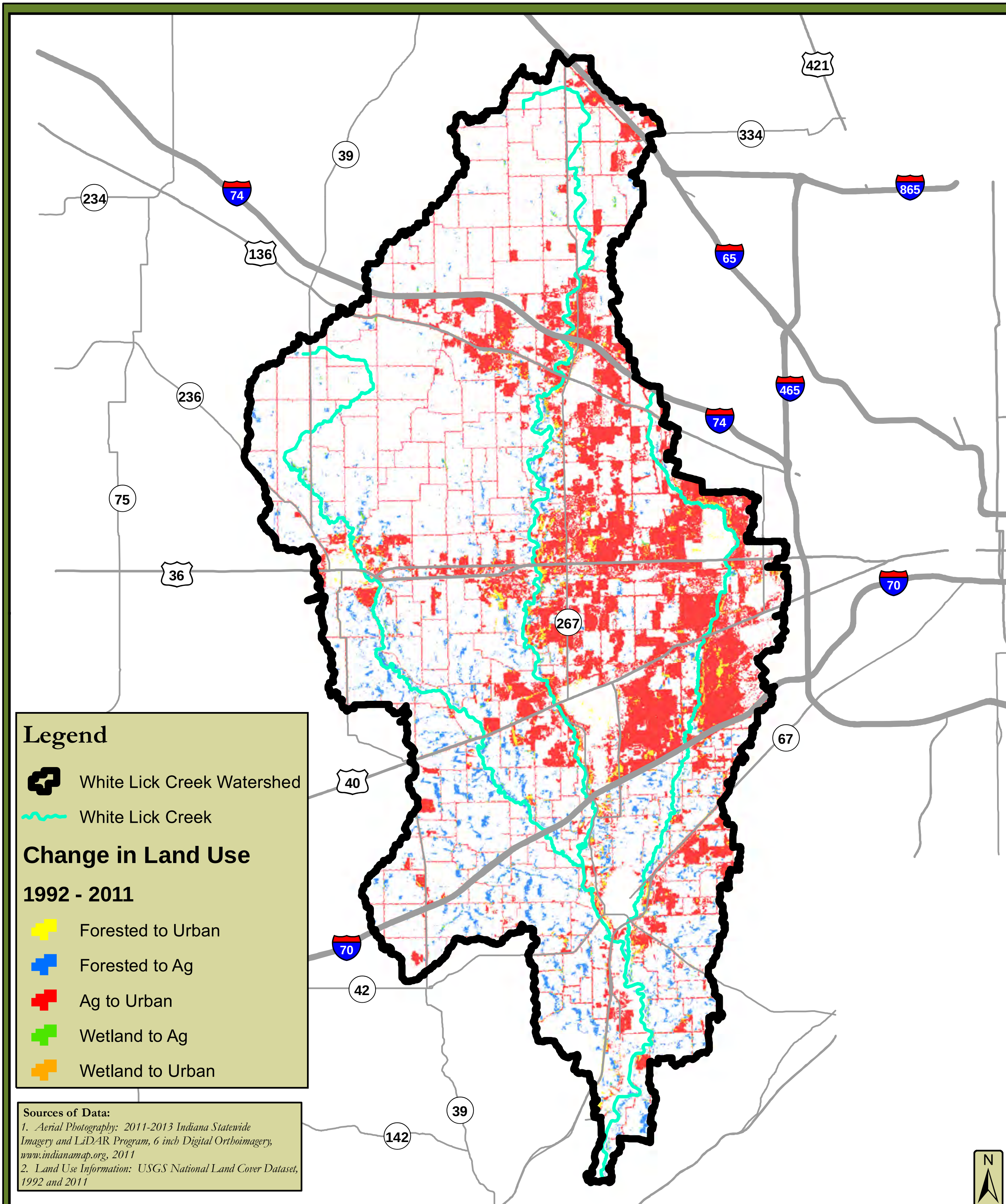
Stream:	**White Lick Creek**				
Basin:	**White Lick Creek**	Drainage Area:	**79,684** acres	**124.5**	mi^2
Location:	**Plainfield, IN**				
Twp.&Rge:		Sec.&Qtr.:			
Cross-Section Monuments (Lat./Long.):				Date:	**5/31/2017**
Observers:	**BJM, JDF, BWM, DRH**			Valley Type:	**U-GL-TP**

Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**131**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**3.95**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**517.2**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**33.2**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**7.32**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or ($2 \times d_{mbkf}$) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**398**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**3.0**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**4.7**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.00119**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**1.24**	

Stream Type **C4** (See **Figure 2-14**)

Appendix 3:Excerpts from 2015 CBBEL Watershed-scale Assessment

Land Use Change Map and Tabular Summary



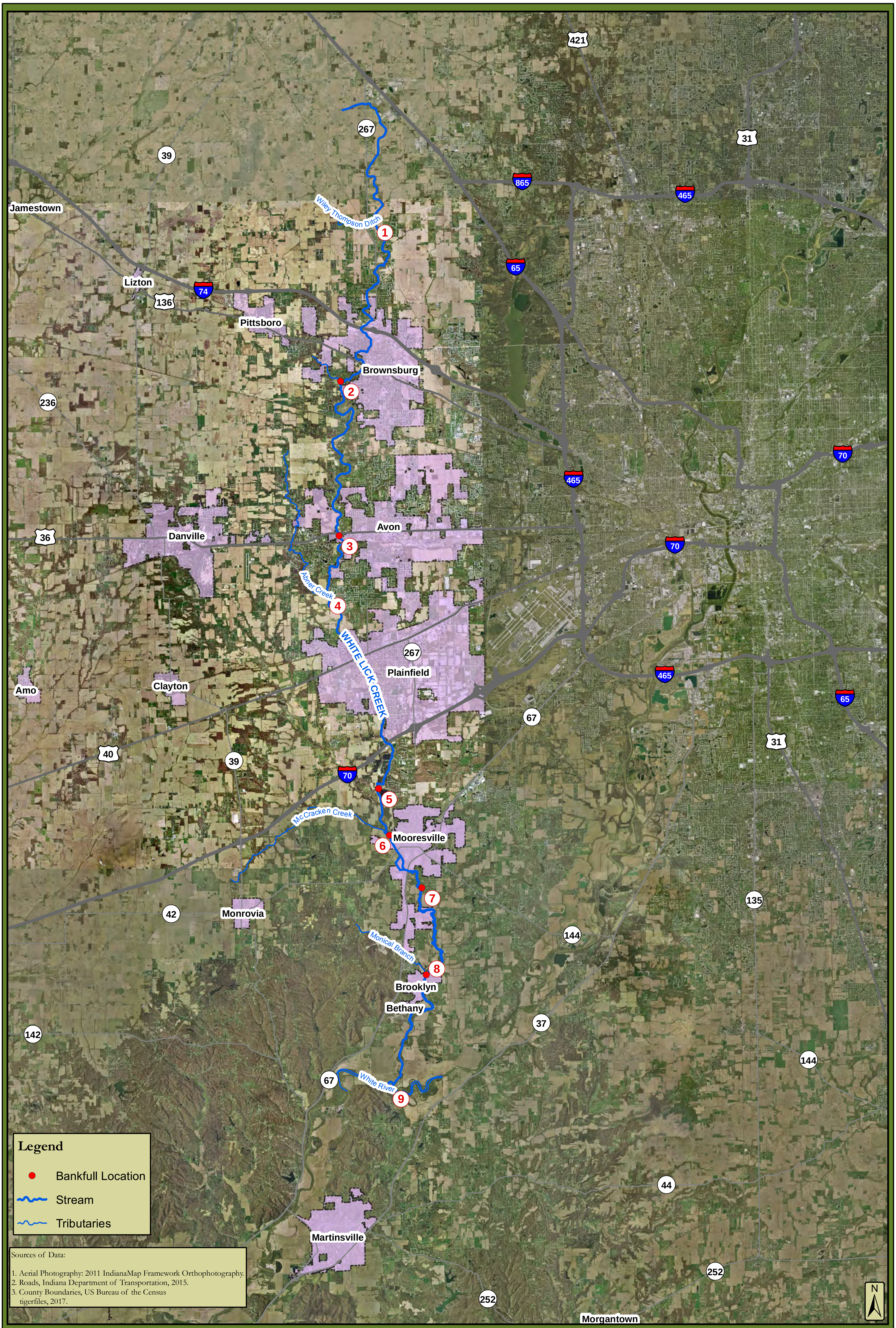
Christopher B. Burke Engineering, LLC
PNC Center, Suite 1368 South
115 West Washington Street
Indianapolis, Indiana 46204
(t) 317.266.8000 (f) 317.632.3306

PROJECT: White Lick Creek FEH Site Assessment	PROJECT NO. 14-0014	APPROX. SCALE 1"=20,000'
TITLE: Land Use Change Map		DATE: 10/2018
		EXHIBIT A3.1

Watershed Land Use by Year (%)				
Land Use Classification	**1992**	**2001**	**2006**	**2011**
Open Water	0.4%	0.5%	0.5%	0.5%
Urban	8.5%	24.1%	27.8%	29.9%
Barren / Rock	0.1%	0.0%	0.1%	0.0%
Forested	7.5%	10.1%	10.0%	9.9%
Shrub / Scrub	0.0%	0.1%	0.1%	0.1%
Grassland / Herbaceous	0.0%	1.1%	1.0%	1.0%
Agricultural	83.2%	63.9%	60.4%	58.4%
Wetland	0.4%	0.1%	0.1%	0.1%
Total	100.0%	100.0%	100.0%	100.0%

Population by Community				
Community	**1992**	**2001**	**2006**	**2011**
Danville	4,722	6,982	7,949	9,133
Brownsburg	8,514	15,946	18,827	22,136
Plainfield	16,453	21,926	26,263	28,395
Avon	1,156	8,877	10,535	12,969
Total Population	30,845	53,731	63,574	72,633
Population Increase	-	74%	18%	14%

Approximate Bankfull Location Map and Bankfull Dimension Comparison



Christopher B. Burke Engineering, LLC
PNC Center, Suite 1368 South
115 West Washington Street
Indianapolis, Indiana 46204
(t) 317.266.8000 (f) 317.632.3306

PROJECT: White Lick Creek FEH Mitigation Assessment	PROJECT NO. 14-0014	APPROX. SCALE 1"=15,000'
TITLE: Approximate Bankfull Location Map		DATE: 10/2018
		EXHIBIT A3.2

Bankfull Dimension Comparison

Miles from Mouth (mi)	Drainage Area (sq. mi.)	Approximate Bankfull Width* (ft)	Predicted Bankfull Width** (ft)	Predicted Bankfull Depth** (ft)	Predicted Bankfull Area** (ft^2)	Departure from Expected Bankfull Width (ft [%])	Description of Stream at Measurement Location
Main Stem							
42.4	20.2	50	49	2.6	124	1 ft [3%]	Loam Till
33.9	34.6	50	58	2.8	162	-8 ft [-14%]	Loam Till
25.8	80.2	84	76	3.2	244	8 ft [10%]	Alluvium
23.2	95.3	90	81	3.3	265	9 ft [11%]	Alluvium
13.9	124.2	134	88	3.4	301	46 ft [52%]	Alluvium
	208.5	114	104	3.7	388	10 ft [9%]	Alluvium
9.9	234.2	135	108	3.8	411	27 ft [25%]	Alluvium
5.3	299.4	129	117	4.0	463	12 ft [10%]	Alluvium
0	311.1	139	119	4.0	471	20 ft [17%]	Alluvium

* Approximate bankfull width measured from cross-sections of the IndianaMap DEM. The channel width was measured at an elevation that was the predicted bankfull depth above the invert of the cross-section. This method is expected to produce bankfull widths that will be slightly higher than those that would be measured in the field (if bankfull indicators could be reasonably identified).

** Predicted bankfull width and depth determined using the Central Till Plain Region regression equations published by the USGS in Regional Bankfull-Channel Dimensions of Non-Urban Wadeable Streams in Indiana.

Appendix 4:Reach-scale Assessment Data & Calculations

Stream Gage Analysis

PEAKFQ_03353800

```
1
  Program PeakFq           U. S. GEOLOGICAL SURVEY           Seq.002.000
  Version 7.2        Annual peak flow frequency analysis      Run Date / Time
  3/28/2018                                                    08/17/2018 08:50

                          --- PROCESSING OPTIONS ---

                     Plot option         = Graphics device
                     Basin char output   = None
                     Print option        = Yes
                     Debug print         = No
                     Input peaks listing = Long
                     Input peaks format  = WATSTORE peak file

                     Input files used:
                        peaks (ascii)  - R:\2014\14-0014.00000\Worksheets\White
Lick Creek\PEAKFQ_03353800.TXT
                        specifications - R:\2014\14-0014.00000\Worksheets\White
Lick Creek\PKFQWPSF.TMP
                     Output file(s):
                        main - R:\2014\14-0014.00000\Worksheets\White Lick
Creek\PEAKFQ_03353800.PRT


  ***  User responsible for assessment and interpretation of the following analysis
***

1


  Program PeakFq           U. S. GEOLOGICAL SURVEY           Seq.001.001
  Version 7.2        Annual peak flow frequency analysis      Run Date / Time
  3/28/2018                                                    08/17/2018 08:50

            Station - 03353800  WHITE LICK CREEK AT MOORESVILLE, IN


                     TABLE 1 - INPUT DATA SUMMARY

               Number of peaks in record           =       62
               Peaks not used in analysis          =        0
               Gaged peaks in analysis             =       61
               Historic peaks in analysis          =        1
               Beginning Year                      =     1950
               Ending Year                         =     2017
               Historical Period Length            =       68
               Skew option                         =   WEIGHTED
               Regional skew                       =   -0.393
                    Standard error                 =    0.550
                    Mean Square error              =    0.303
               Gage base discharge                 =      0.0
               User supplied high outlier threshold =   --
               User supplied PILF (LO) criterion    =   --
               Plotting position parameter         =     0.00
               Type of analysis                      BULL.17B
               PILF (LO) Test Method                     MGBT
               Perceptible Ranges              =   Not Applicable
               Interval Data                   =   Not Applicable


    TABLE 2 - DIAGNOSTIC MESSAGE AND PILF RESULTS
```

```
    WCF134I-NO SYSTEMATIC PEAKS WERE BELOW GAGE BASE.                0.0
    EMA003I-LOW OUTLIERS WERE DETECTED USING MULTIPLE GRUBBS-BECK TEST       2
4260.0
      THE FOLLOWING PEAKS (WITH CORRESPONDING P-VALUES) WERE DROPPED:
          1940.0    (0.0474)
          2670.0    (0.0367)
    WCF156I-17B HI-OUTLIER TEST SUPERSEDED BY MIN HIST PK   30300.0
    WCF165I-HIGH OUTLIERS AND HISTORIC PEAKS ABOVE HHBASE. 14  1    12000.0
  **WCF171W-NUMBER HI-OUT/HIST PKS EXCEEDS 10PCT OF SYS PKS.     15     61
    WCF002J-CALCS COMPLETED.  RETURN CODE =  2
```

Kendall's Tau Parameters

	TAU	P-VALUE	MEDIAN SLOPE	No. of PEAKS
GAGED PEAKS	0.073	0.408	29.494	61

1

```
  Program PeakFq            U. S. GEOLOGICAL SURVEY              Seq.001.002
  Version 7.2          Annual peak flow frequency analysis      Run Date / Time
  3/28/2018                                                       08/17/2018 08:50
```

Station - 03353800 WHITE LICK CREEK AT MOORESVILLE, IN

TABLE 3 - ANNUAL FREQUENCY CURVE PARAMETERS -- LOG-PEARSON TYPE III

	FLOOD BASE		LOGARITHMIC		
	DISCHARGE	EXCEEDANCE PROBABILITY	MEAN	STANDARD DEVIATION	SKEW
SYSTEMATIC RECORD	0.0	1.0000	3.9349	0.2125	-0.435
BULL.17B ESTIMATE	0.0	0.9668	3.9413	0.1866	-0.014

BULL.17B ESTIMATE OF MSE OF AT-SITE SKEW   0.0820

TABLE 4 - ANNUAL FREQUENCY CURVE -- DISCHARGES AT SELECTED EXCEEDANCE PROBABILITIES

			<-- FOR BULLETIN 17B ESTIMATES -->		
ANNUAL EXCEEDANCE PROBABILITY	BULL.17B ESTIMATE	SYSTEMATIC RECORD	LOG VARIANCE OF EST.	CONFIDENCE INTERVALS 5% LOWER	CONFIDENCE INTERVALS 95% UPPER
0.9950		2002.	--	--	--
0.9900		2365.	--	--	--
0.9500	4301.	3641.	----	3670.0	4878.0
0.9000	5033.	4515.	----	4387.0	5630.0
0.8000	6086.	5782.	----	5423.0	6718.0
0.6667	7265.	7190.	----	6573.0	7962.0
0.5000	8744.	8919.	----	7979.0	9583.0
0.4292	9440.	9713.	----	8623.0	10370.0
0.2000	12540.	13080.	----	11360.0	14080.0
0.1000	15140.	15680.	----	13540.0	17370.0
0.0400	18490.	18760.	----	16240.0	21800.0
0.0200	21040.	20910.	----	18240.0	25280.0

0.0100	23630.	22940.	----	20230.0	28890.0
0.0050	26270.	24870.	----	22230.0	32660.0
0.0020	29860.	27290.	----	24900.0	37890.0

1

Program PeakFq　　U. S. GEOLOGICAL SURVEY　　Seq.001.003
Version 7.2　　Annual peak flow frequency analysis　　Run Date / Time
3/28/2018　　08/17/2018 08:50

Station - 03353800 WHITE LICK CREEK AT MOORESVILLE, IN

TABLE 5 - INPUT DATA LISTING

WATER YEAR	PEAK VALUE	PEAKFQ CODES	REMARKS
-1950	12000.0	H	
1957	13400.0		
1958	7580.0		
1959	11400.0		
1960	11400.0		
1961	14100.0		
1962	11500.0		
1963	18000.0		
1964	13600.0		
1965	5620.0		
1966	2670.0		
1967	6250.0		
1968	11000.0		
1969	12000.0		
1970	6590.0		
1971	7320.0		
1972	5440.0		
1973	8250.0		
1974	5660.0		
1975	8440.0		
1976	4260.0		
1977	5150.0		
1978	10600.0		
1979	19000.0		
1980	5330.0		
1981	6310.0		
1982	4440.0		
1983	4320.0		
1984	4780.0		
1985	7810.0		
1986	9520.0		
1987	9480.0		
1988	6630.0		
1989	11000.0		
1990	10700.0		
1991	15800.0		
1992	6560.0		
1993	9940.0		
1994	16400.0		
1995	5980.0		
1996	6090.0		
1997	8950.0		
1998	8790.0		
1999	10900.0		
2000	1940.0		

2001	4860.0
2002	7880.0
2003	19900.0
2004	9360.0
2005	12000.0
2006	5980.0
2007	9270.0
2008	22000.0
2009	9740.0
2010	13500.0
2011	13200.0
2012	4670.0
2013	21400.0
2014	9250.0
2015	11600.0
2016	9100.0
2017	11800.0

Explanation of peak discharge qualification codes

PeakFQ CODE	NWIS CODE	DEFINITION
D	3	Dam failure, non-recurrent flow anomaly
G	8	Discharge greater than stated value
X	3+8	Both of the above
L	4	Discharge less than stated value
K	6 OR C	Known effect of regulation or urbanization
H	7	Historic peak

- Minus-flagged discharge -- Not used in computation
  -8888.0 -- No discharge value given
- Minus-flagged water year -- Historic peak used in computation

1

Program PeakFq   U. S. GEOLOGICAL SURVEY   Seq.001.004
Version 7.2   Annual peak flow frequency analysis   Run Date / Time
3/28/2018   08/17/2018 08:50

Station - 03353800 WHITE LICK CREEK AT MOORESVILLE, IN

TABLE 6 - EMPIRICAL FREQUENCY CURVES -- WEIBULL PLOTTING POSITIONS

WATER YEAR	RANKED DISCHARGE	SYSTEMATIC RECORD	B17B ESTIMATE
2008	22000.0	0.0161	0.0145
2013	21400.0	0.0323	0.0290
2003	19900.0	0.0484	0.0435
1979	19000.0	0.0645	0.0580
1963	18000.0	0.0806	0.0725
1994	16400.0	0.0968	0.0870
1991	15800.0	0.1129	0.1014
1961	14100.0	0.1290	0.1159
1964	13600.0	0.1452	0.1304
2010	13500.0	0.1613	0.1449
1957	13400.0	0.1774	0.1594
2011	13200.0	0.1935	0.1739

-1950	12000.0	--	0.1884
1969	12000.0	0.2097	0.2029
2005	12000.0	0.2258	0.2174
2017	11800.0	0.2419	0.2328
2015	11600.0	0.2581	0.2492
1962	11500.0	0.2742	0.2655
1959	11400.0	0.2903	0.2818
1960	11400.0	0.3065	0.2982
1968	11000.0	0.3226	0.3145
1989	11000.0	0.3387	0.3309
1999	10900.0	0.3548	0.3472
1990	10700.0	0.3710	0.3636
1978	10600.0	0.3871	0.3799
1993	9940.0	0.4032	0.3962
2009	9740.0	0.4194	0.4126
1986	9520.0	0.4355	0.4289
1987	9480.0	0.4516	0.4453
2004	9360.0	0.4677	0.4616
2007	9270.0	0.4839	0.4780
2014	9250.0	0.5000	0.4943
2016	9100.0	0.5161	0.5106
1997	8950.0	0.5323	0.5270
1998	8790.0	0.5484	0.5433
1975	8440.0	0.5645	0.5597
1973	8250.0	0.5806	0.5760
2002	7880.0	0.5968	0.5924
1985	7810.0	0.6129	0.6087
1958	7580.0	0.6290	0.6250
1971	7320.0	0.6452	0.6414
1988	6630.0	0.6613	0.6577
1970	6590.0	0.6774	0.6741
1992	6560.0	0.6935	0.6904
1981	6310.0	0.7097	0.7068
1967	6250.0	0.7258	0.7231
1996	6090.0	0.7419	0.7394
1995	5980.0	0.7581	0.7558
2006	5980.0	0.7742	0.7721
1974	5660.0	0.7903	0.7885
1965	5620.0	0.8065	0.8048
1972	5440.0	0.8226	0.8212
1980	5330.0	0.8387	0.8375
1977	5150.0	0.8548	0.8538
2001	4860.0	0.8710	0.8702
1984	4780.0	0.8871	0.8865
2012	4670.0	0.9032	0.9029
1982	4440.0	0.9194	0.9192
1983	4320.0	0.9355	0.9356
1976	4260.0	0.9516	0.9519
1966	2670.0	0.9677	0.9682
2000	1940.0	0.9839	0.9846

1

End PeakFQ analysis.

```
   Stations processed :       1
   Number of errors   :       0
   Stations skipped   :       0
   Station years      :      62
```

Data records may have been ignored for the stations listed below.
(Card type must be Y, Z, N, H, I, 2, 3, 4, or *.)

(2, 4, and * records are ignored.)

For the station below, the following records were ignored:

FINISHED PROCESSING STATION: 03353800   USGS WHITE LICK CREEK AT MOORESVIL

For the station below, the following records were ignored:

FINISHED PROCESSING STATION:

Bankfull Discharge Calculations

Worksheet 5-2. Computations of velocity and bankfull discharge using various methods (Rosgen and Silvey, 2005).

Bankfull VELOCITY / DISCHARGE Estimates

Site	White Lick Creek			Location	Plainfield, IN
Date	4/14/17	Stream Type	C4	Valley Type	U-GL-TP
Observers	BJM, JDF			HUC	

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Cross-section AREA	517.2	A_{bkf} (SqFt)	Bankfull Mean DEPTH	3.95	D_{bkf} (Ft)
Bankfull WIDTH	131.0	W_{bkf} (Ft)	Wetted PERIMETER $\sim 2 * d_{bkf} + W_{bkf}$	135.20	W_{Pbkf} (Ft)
D84 @ Riffle	14.1	Dia. (mm)	D84 mm / 304.8 =	0.05	D84 (Ft)
Bankfull SLOPE	0.00119	S (Ft / Ft)	Hydraulic RADIUS A_{bkf} / W_{Pbkf}	3.83	R (Ft)
Gravitational Acceleration	32.2	g (Ft /Sec²)	Relative Roughness R (ft) / D84 (ft)	82.7	
Drainage AREA	124.5	DA (SqMi)	Shear Velocity $u^* = \sqrt{gRS}$	0.3829	u* (Ft / Sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [2.83 + 5.66\text{Log}\{R / D84\}]u^*$	5.2	Ft / Sec	2709	CFS
2. Roughness Coefficient: a) Manning's 'n' from friction factor / relative roughness. (Figs. 5-6, 5-7) $u = 1.4895*R^{2/3}*S^{1/2}/n$ n = 0.025	10.0	Ft / Sec	5185	CFS
2. Roughness Coefficient: $u = 1.4895*R^{2/3}*S^{1/2}/n$ b) Manning's 'n' from Jarrett (USGS): $n = 0.39S^{.38}R^{-.16}$ n = Note: This equation is for applications involving **steep, step-pool, high boundary roughness, cobble-boulder-dominated stream systems**; i.e., for stream types A1, A2, A3, B1, B2, B3, C2 and E3.		Ft / Sec		CFS
2. Roughness Coefficient: $u = 1.4895*R^{2/3}*S^{1/2}/n$ c) Manning's 'n' from Stream Type n = 0.025	10.0	Ft / Sec	5185	CFS
3. Other Methods, ie. Hydraulic Geometry (Hey, Darcy-Weisbach, Chezy C, etc.)		Ft / Sec		CFS
3. Other Methods, ie. Hydraulic Geometry (Hey, Darcy-Weisbach, Chezy C, etc.)		Ft / Sec		CFS
4. Continuity Equations: a) USGS Gage: u = Q / A Return Period for Bankfull Discharge (Yr.) Q = 1.3		Ft / Sec	5400	CFS
4. Continuity Equations: b) Regional Curves u = Q / A		Ft / Sec		CFS

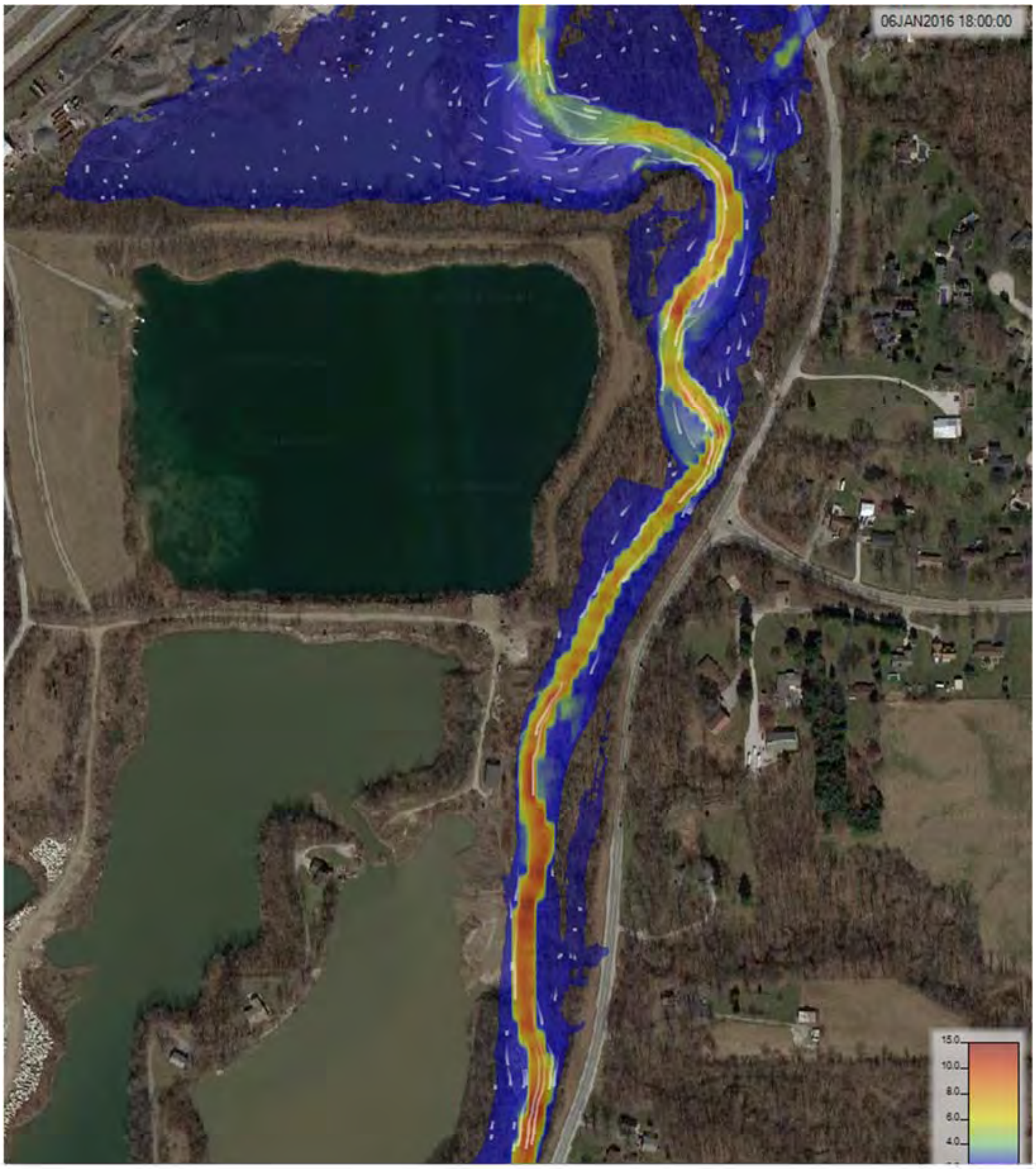
Options for using the D84 term in the **relative roughness relation** (R/D84), when using estimation method 1.

Option 1. For **sand-bed** channels: measure the **"protrusion height"** (h_{sd}) of sand dunes above channel bed elevations. Substitute an average sand dune protrusion height (h_{sd} in feet) for the D84 term in estimation method 1.

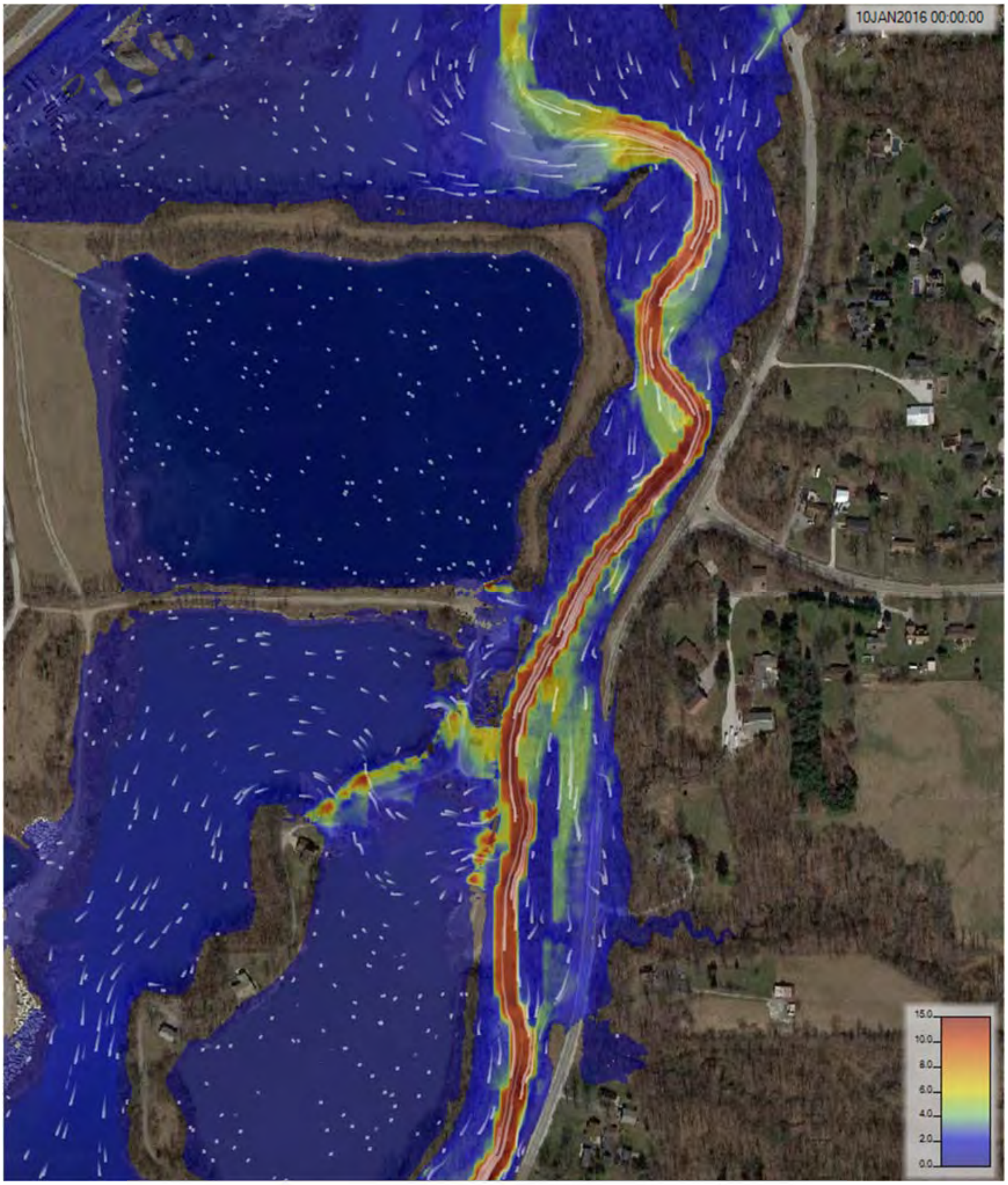
Option 2. For **boulder-dominated** channels: measure several **"protrusion heights"** (h_{bo}) of boulders above channel bed elevations. Substitute an average boulder protrusion height (h_{bo} in feet) for the D84 term in estimation method 1.

Option 3. For **bedrock-dominated** channels: measure several **"protrusion heights"** (h_{br}) of rock separations/steps/joints/ uplifted surfaces above channel bed elevations. Substitute an average bedrock protrusion height (h_{br} in feet) for the D84 term in estimation method 1.

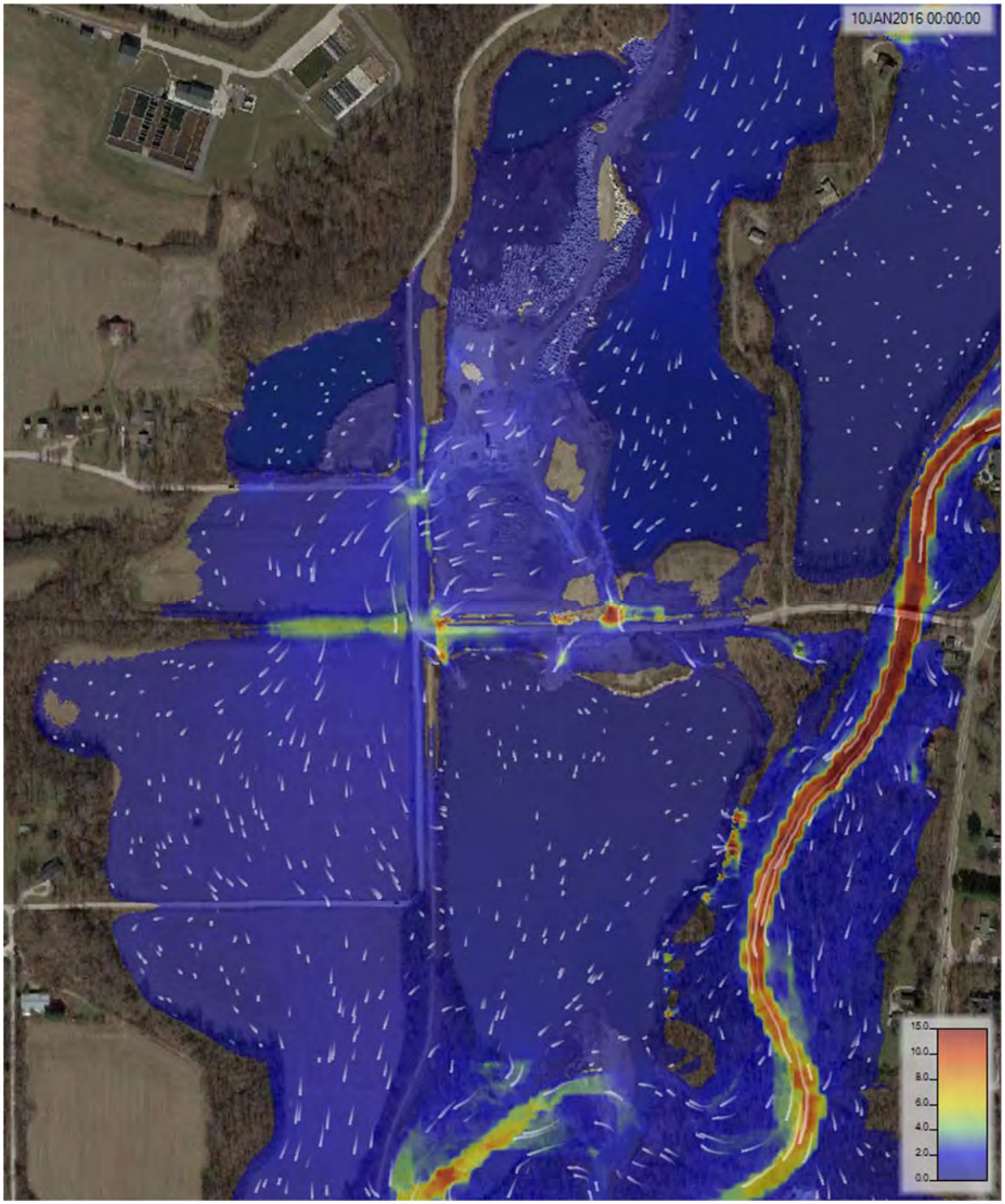
Flow Velocity Grids



Bankfull Velocity Grid w/flowlines



100-Year Velocity Grid w/flowlines



100-Year Velocity Grid w/flowlines of Gravel Pit overflows

Scour and Sediment Competence Calculations

Scour and Sediment Competence Evaluation for White Lick Creek

Date: 10/18/2019
Project No.: 14-0014

General Scour:

Blodgett Method:

z_t (mean) = $KD^{-0.115}$ D = D_{50}

z_t (max) = $KD^{-0.115}$

where:
z_t (mean) = best fit curve, ft

z_t (max) = enveloping curve, ft

D_{50} = median size of bed material, ft

K = 1.42 for z_t mean
K = 6.5 for z_t max

D_{50} (from site visit) = 5.7 mm
D_{50} (from site visit) = 0.019 ft

z_t (mean) = 2.24 ft

z_t (max) = 10.27 ft

Pemberton and Lara Method (Using Blench and Lacey Constants)

$z_t = KQ^aW^bD^c$

$Q = Q_d$
$W = W_f$
$D = D_{50}$

where:

z_t = maximum scour depth, ft
K = coefficient (see table below)
Q_d = design discharge, ft^3/s
W_f = flow widt at design discharge, ft

D_{50} = median size of bed material, mm
a, b, c = exponents (see table below)

Q_d = 4,950 cfs
W_f = 319.5 ft
D_{50} = 5.7 mm

Condition	Lacey				Blench			
	K	a	b	c	K	a	b	c
Moderate bend	0.195	1/3	0	- 1/6	0.530	2/3	- 2/3	-0.1092
Severe bend	0.292	1/3	0	- 1/6	0.530	2/3	- 2/3	-0.1092

Moderate bend, Lacey:

z_t = 2.49 ft

Severe bend, Lacey:

z_t = 3.72 ft

Moderate bend, Blench:

z_t = 2.72 ft

Severe bend, Blench:

z_t = 2.72 ft

Bend Scour:

NEH654.09 Method:

$z_b = y\,(y_{max}/y - 1)$

where:
y = average flow depth in the bend (ft)
y_{max} = maximum flow depth in the bend (ft)

y = 3 ft
$y_{max}/y = 1.5 + 4.5\,(W_i/Rc)$

where:
W_i = channel width at bend inflection point, ft
Rc = bend radius of curvature, ft

W_i = 98 from aerial photograph
Rc = 479 from aerial photograph

y_{max}/y = 2.42 ft

z_b = 4.56 ft

Flow Probability						Sediment Competence		Degradation Prior to Channel Armoring		
Bin Number	Min Flow Rate (cfs)	Max Flow Rate (cfs)	Frequency	Probability of Occurrence (%)	Average Flow Rate (cfs)	Mobile Sediment Size (mm)	% of Riffle Mobile (%)	Armor Particle Size (mm)	Degradation to Armor (ft)	% of Riffle Mobile (%)
1	0	534	19373	90.76	122	0.929	11.18	0.79	0.00	10.98
2	533	1067	1163	5.45	729	5.414	52.72	4.25	0.03	48.13
3	1067	1600	395	1.85	1288	6.403	56.62	4.84	0.03	50.44
4	1600	2133	132	0.62	1823	7.775	61.88	5.61	0.04	53.54
5	2133	2667	77	0.36	2384	8.470	64.70	5.98	0.05	55.00
6	2667	3200	53	0.25	2901	9.119	67.40	6.33	0.05	56.32
7	3200	3733	43	0.20	3440	9.637	69.55	6.60	0.06	57.36
8	3733	4267	19	0.09	3931	10.048	71.26	6.81	0.06	58.17
9	4267	4800	18	0.08	4507	10.341	72.48	6.96	0.06	58.75
10	4800	5333	18	0.08	5040	11.042	75.40	7.31	0.07	60.11
11	5333	5867	8	0.04	5584	11.831	77.88	7.70	0.08	61.62
12	5867	6400	8	0.04	6074	12.571	79.92	8.07	0.08	63.03
13	6400	6933	9	0.04	6681	13.491	82.41	8.51	0.09	64.87
14	6933	7467	10	0.05	7168	14.228	84.41	8.86	0.10	66.33
15	7467	8000	3	0.01	7840	15.244	87.17	9.34	0.12	68.31
16	8000	8533	5	0.02	8296	15.923	88.66	9.96	0.14	70.75
17	8533	9067	3	0.01	8710	16.528	89.68	10.81	0.18	74.00
18	9067	9600	3	0.01	9307	17.396	91.08	11.93	0.24	78.18
19	9600	10133	1	0.00	10100	18.521	92.59	12.67	0.28	80.18
20	10133	10667	1	0.00	10500	19.086	93.34	13.04	0.31	81.19
21	10667	11200	0	0.00	10933	19.680	94.14	13.43	0.34	82.24
22	11200	11733	0	0.00	11467	20.411	95.11	13.91	0.38	83.54
23	11733	12267	1	0.00	12100	21.262	96.23	14.46	0.44	85.05
24	12267	12800	0	0.00	12533	21.836	96.96	14.84	0.50	86.06
25	12800	13333	1	0.00	13200	22.716	98.06	15.41	0.57	87.60
26	13333	13867	0	0.00	13600	23.205	98.17	15.73	0.63	88.24
27	13867	14400	0	0.00	14133	23.856	98.30	16.15	0.70	89.08
28	14400	14933	0	0.00	14667	24.508	98.44	16.58	0.77	89.93
29	14933	15467	0	0.00	15200	25.205	98.58	17.03	0.86	90.59
30	15467	16000	1	0.00	16000	26.270	98.80	17.72	1.00	91.51

Worksheet 5-15. Sediment competence calculation form to assess bed stability.

Stream:	**Big Walnut Creek**		Stream Type:		
Location:	**Brazil, IN**		Valley Type:		
Observers:	**BJM, JDF**		Date: **4/17/17**		
Enter required information					
4.00	D_{50}	Riffle bed material D_{50} (mm)			
1.25	$\hat{D}_{50}$	Bar sample D_{50} (mm)			
0.15	D_{max}	Largest particle from bar sample (ft)	**45.0**	**(mm)**	304.8 mm/ft
0.00063	S	Existing bankfull water surface slope (ft/ft)			
4.04	d	Existing bankfull mean depth (ft)			
1.65	γ_s	Submerged specific weight of sediment			
Select the appropriate equation and calculate critical dimensionless shear stress					
0.030	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1:	$\tau^* = 0.0834\,(D_{50}/\hat{D}_{50})^{-0.872}$	
	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2:	$\tau^* = 0.0384\,(D_{max}/D_{50})^{-0.887}$	
0.030	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:	**Eq. 1**	
Calculate bankfull mean depth required for entrainment of largest particle in bar sample					
11.7	d	Required bankfull mean depth (ft)	$d = \dfrac{\tau^* \gamma_s D_{max}}{S}$		
	Check: ☐ Stable ☐ Aggrading ☐ Degrading				
Calculate bankfull water surface slope required for entrainment of largest particle in bar sample					
0.00182	S	Required bankfull water surface slope (ft/ft)	$S = \dfrac{\tau^* \gamma_s D_{max}}{d}$		
	Check: ☐ Stable ☐ Aggrading ☐ Degrading				
Sediment competence using dimensional shear stress					
0.2	Bankfull shear stress $\tau = \gamma d S$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d)				
39.3	Moveable particle size (mm) at bankfull shear stress **(Figure 5-54)**				
2.4	Predicted shear stress required to initiate movement of D_{max} (mm) **(Figure 5-54)**				
7.7	Predicted mean depth required to initiate movement of D_{max} (mm)	$d = \dfrac{\tau}{\gamma S}$			
0.00508	Predicted slope required to initiate movement of D_{max} (mm)	$S = \dfrac{\tau}{\gamma d}$			

Appendix 5: Triple Bottom Line & Cost Estimate Calculations

Alternative Name, Treatment Type, or Other Project Metric	**Cummulative Score (15)**	ECONOMIC				SOCIAL					ENVIRONMENTAL				
		Capital Cost	**Lifecycle O&M Cost**	**Shared Funding**	Score (5)	**Widespread Benefit (# of properties)**	**Reduce Flooding Drainage Problems**	**Benefit to Public Health & Safety**	**Benefit to Quality of Life**	Score (5)	**Level of Protection for Threatened Features**	**Impact to Adjacent Stream Reaches**	**Restore/ Protect Floodplain Function**	**Improve/ Protect Stream Habitat**	Score (5)
	Weighting Factor=	*0.45*	*0.20*	*0.35*	*1.00*	*0.25*	*0.25*	*0.25*	*0.25*	*1.00*	*0.40*	*0.30*	*0.20*	*0.10*	*1.00*
	0=	*> $1000/ft*	*very high*	*none*		*0*	*none*	*none*	*none*		*added risk*	*significant (-)*	*no change*	*no change*	
	1=	*>$750/ft <$1000/ft*	*high*	*100% Owner*		*1-10*	*limited*	*limited*	*limited*		*no change*	*minor (-)*	*limited*	*limited*	
	2=	*>$500/ft <$750/ft*	*mod-high*	*75% Owner*		*11-30*	*limited-mod*	*limited-mod*	*limited-mod*		*minimal*	*no change*	*limited-mod*	*limited-mod*	
	3=	*>$250/ft <$500/ft*	*moderate*	*50% Owner*		*31-100*	*moderate*	*moderate*	*moderate*		*moderate*	*minor (+)*	*moderate*	*moderate*	
	4=	*>$100/ft <$250/ft*	*low-mod*	*75% Other*		*101-300*	*mod-high*	*mod-high*	*mod-high*		*high*	*moderate (+)*	*mod-high*	*mod-high*	
	5=	*<$100/ft*	*low*	*100% Other*		*300+*	*high*	*high*	*high*		*robust*	*significant (+)*	*high*	*high*	
Toe Wood	**7.1**	4	4	0	2.6	0	0	4	1	1.3	5	2	1	4	3.2
Interlocking Concrete Jacks	**6.0**	3	4	0	2.2	0	0	4	0	1.0	5	2	1	0	2.8
Gabion Wall	**5.3**	3	2	0	1.8	0	0	4	0	1.0	5	1	1	0	2.5

Opinion of Probably Cost for White Lick Creek FEH Mitigation Project

Toe Wood Improvements

Line	Description	Estimated Quantities	Units	Unit Price	Estimated Cost (Rounded)
1	**Demolition**				
2	Strip & Stockpile Topsoil	300	CY	$ 7	$ 2,000
3	Selective Tree Clearing, Grubbing, & Hauling	0.8	AC	$ 25,000	$ 20,000
4			Estimated Demolition Cost		$ 22,000
5	**Channel Improvements**				
6	Mass Excavation	1,600	CY	$ 7	$ 11,000
7	Place & Compact Fill Material	1,600	CY	$ 7	$ 12,000
8	Install Toe Wood	510	LF	$ 76	$ 39,000
9	Install Soil Lifts	1,020	SF	$ 19	$ 20,000
10	Install Live Willow Stakes	1,020	EA	$ 3	$ 3,000
11	Topsoil Placement	3,500	SY	$ 2	$ 8,000
12	Finish Grading	3,800	SY	$ 1	$ 4,000
13	Seeding	3,800	SY	$ 2	$ 8,000
14	Install Erosion Control Blankets	3,500	SY	$ 3	$ 11,000
15		Estimated Channel Improvements Cost			$ 116,000
16	**Miscellaneous**				
17	Dewatering	1	LS	$ 1,000	$ 1,000
18	Erosion and Sediment Control	1	LS	$ 1,000	$ 1,000
19	Construction Surveying	1	LS	$ 2,000	$ 2,000
20	Construction Mobilization/Demobilization	1	LS	$ 8,000	$ 8,000
21	Project Administration & Unforeseen Additional Costs (50%)	1	LS	$ 69,000	$ 69,000
22			Estimated Miscellaneous Cost		$ 81,000
23					
24			**Total Construction Cost**		**$ 219,000**
25					
26	**Professional Services**				
27	Topographic Site Survey	1	LS	$ 5,000	$ 5,000
28	Geotechnical Engineering Investigation	1	LS	$ 5,000	$ 5,000
29	Engineering Design	1	LS	$ 66,000	$ 66,000
30	Construction Observation	1	LS	$ 18,000	$ 18,000
31		Estimated Professional Services Cost			$ 94,000
32					
33		**Estimated Total Cost for Project**			**$ 313,000**

Notes and Assumptions

1 All costs are estimates based on the engineer's knowledge of common construction methods and materials. Christopher B. Burke Engineering does not guarantee that the actual bid price will not vary from the costs used with this estimate.
2 All costs are in 2018 dollars.
3 Estimated costs have been rounded.
4 This estimate does not include unforeseen costs increases that may result from shortages in fuel and materials as a result of a natural or man-made disaster.
5 Costs have been estimated without the benefit of survey data, utility coordination, or design. This estimate is intended for planning level consideration, and should only be used for such purposes.
6 This estimate does not include easement, right-of-way, or land acquisition costs that may be necessary to construct the proposed alternative.
7 This estimate does not include the cost of environmental mitigation, which may be necessary as a result of project impacts