

Fluvial Erosion Hazard Mitigation

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Road School 2019





WHAT IS A FLUVIAL EROSION HAZARD?



Bean Creek in Indianapolis, IN

WHAT IS A FLUVIAL EROSION HAZARD?

Sugar Creek in Crawfordsville, IN



WHAT IS A FLUVIAL EROSION HAZARD?

West Fork Whitewater River near Brookville, IN





WHAT IS A FLUVIAL EROSION HAZARD?

Fluvial Erosion Hazards are:

The suite of risks to structures, property, and infrastructure elements that are brought about by the natural processes of stream-bank erosion and stream-channel meandering



FEH CONCEPTS

Rivers are not static. They change:

- Dimension (cross-section)



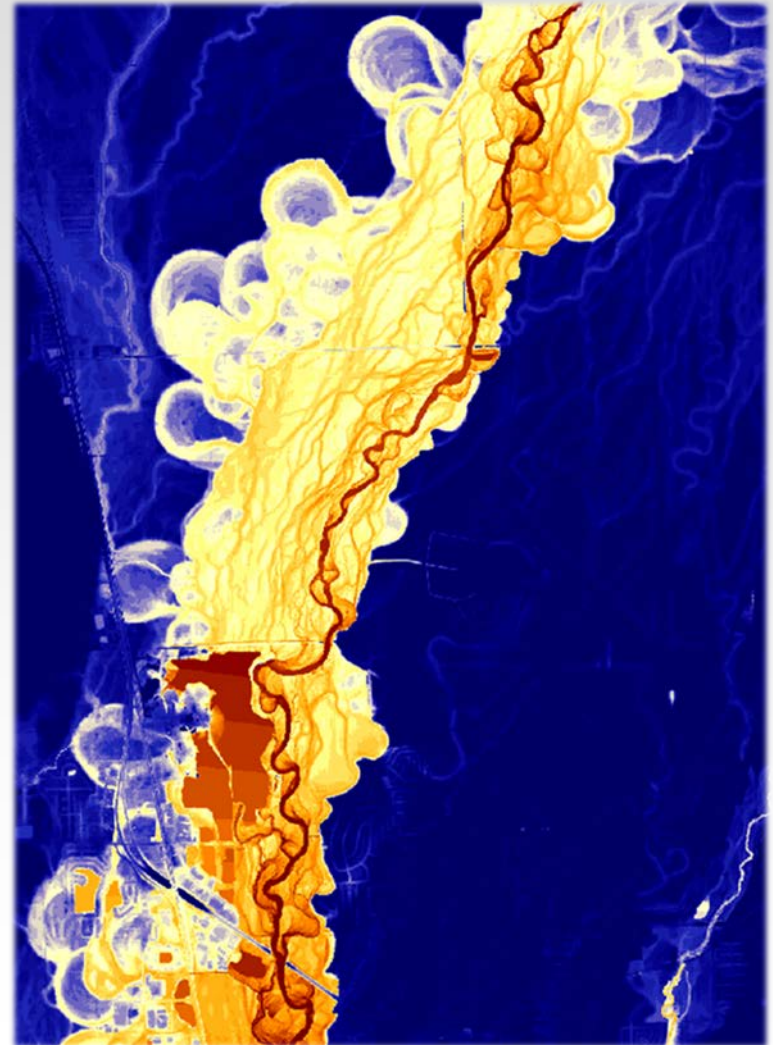
West Fork White River in Muncie, IN



FEH CONCEPTS

Rivers are not static. They change:

- Dimension(cross-section)
- Pattern (alignment from an aerial view)



Flatrock River near Columbus, IN

FEH CONCEPTS

Rivers are not static. They change:

- Dimension (cross-section)
- Pattern (alignment from an aerial view)
- Profile (bed elevation)

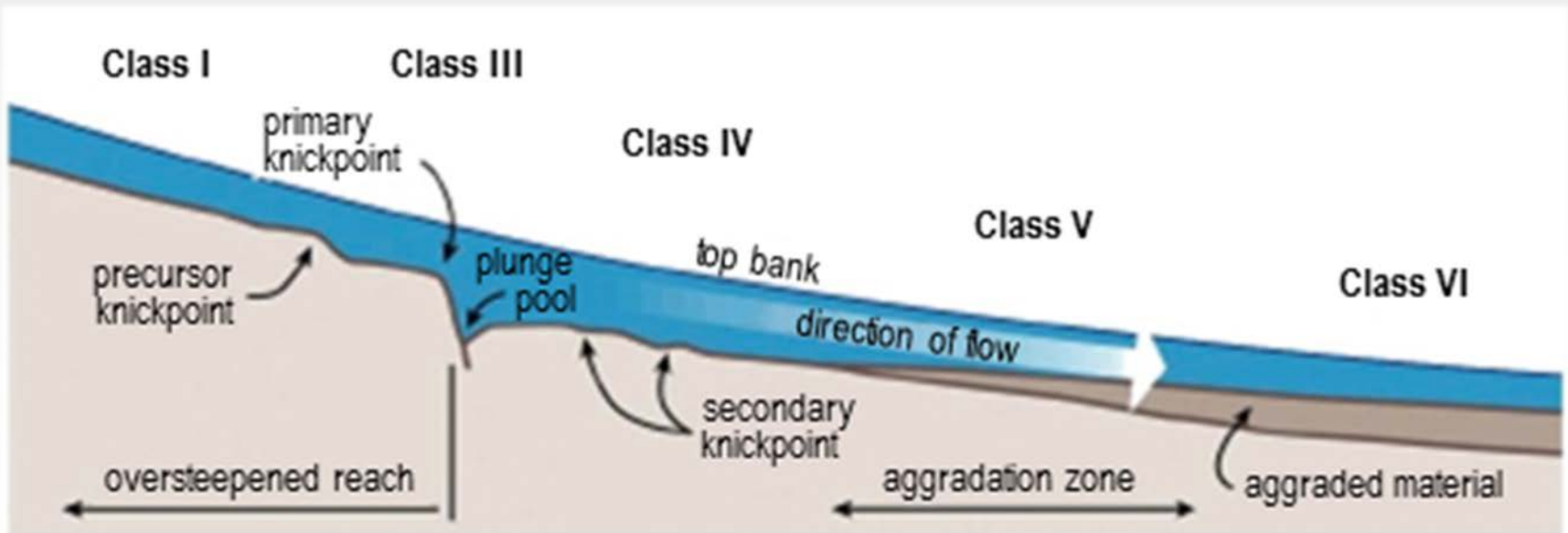


Image: Schumm et al, after USACE



FEH CONCEPTS

Stability is defined as a river or stream's ability in the present climate to transport the stream-flows and sediment of its watershed over time in such a manner that the channel maintains its dimension, pattern, and profile without either aggrading or degrading

(Rosgen, 1996, 2001).

- Fluvial erosion hazards can result from both stable and unstable rivers, though it is more common with unstable rivers.

INDIANA FEH PROGRAM

Federal and National Partners

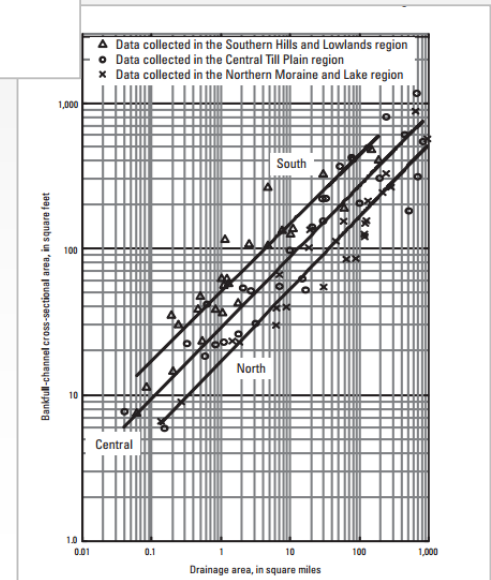


State, Local, and Educational Partners



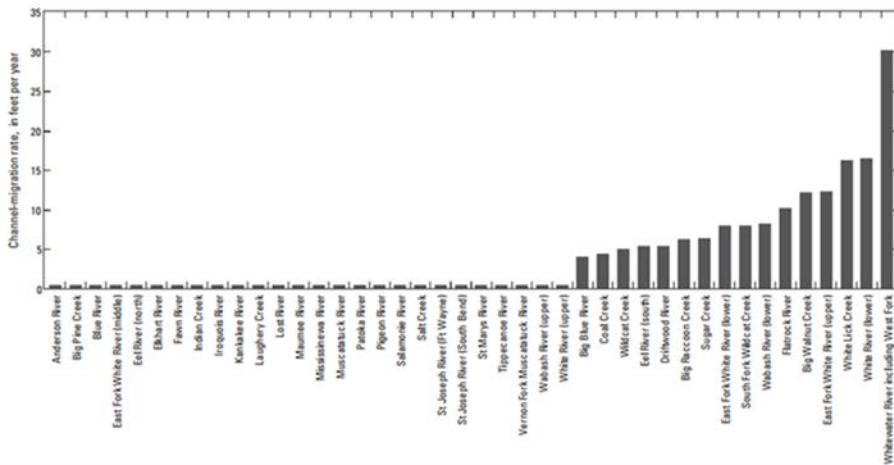

INDIANA FEH PROGRAM: PREVIOUS PHASES

- Phase I:
Develop regionally-based channel dimensions for stable Indiana streams




INDIANA FEH PROGRAM: PREVIOUS PHASES

- Phase I:
Develop regionally-based channel dimensions for stable Indiana streams
- Phase II:
Determine channel migration rates to identify mobile streams and establish statewide FEH corridors

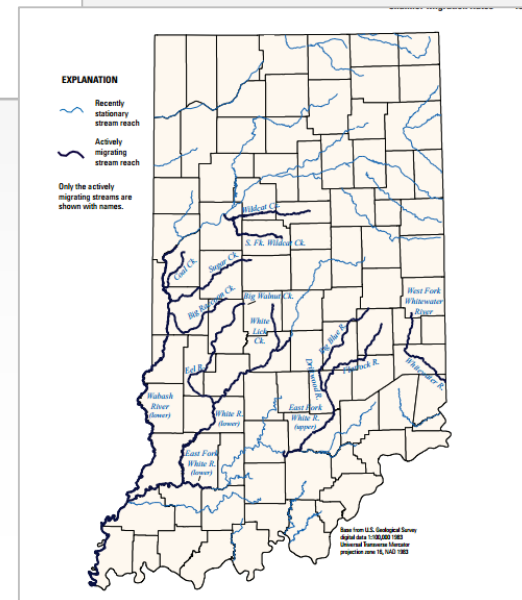
Prepared in cooperation with the Indiana Office of Community and Rural Affairs

Recent (circa 1998 to 2011) Channel-Migration Rates of Selected Streams in Indiana



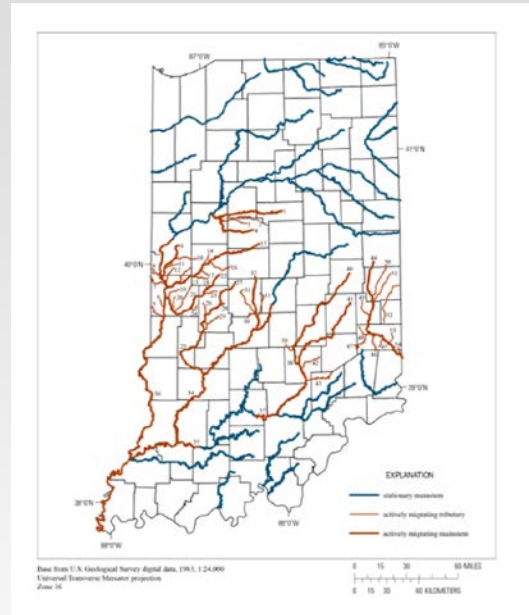
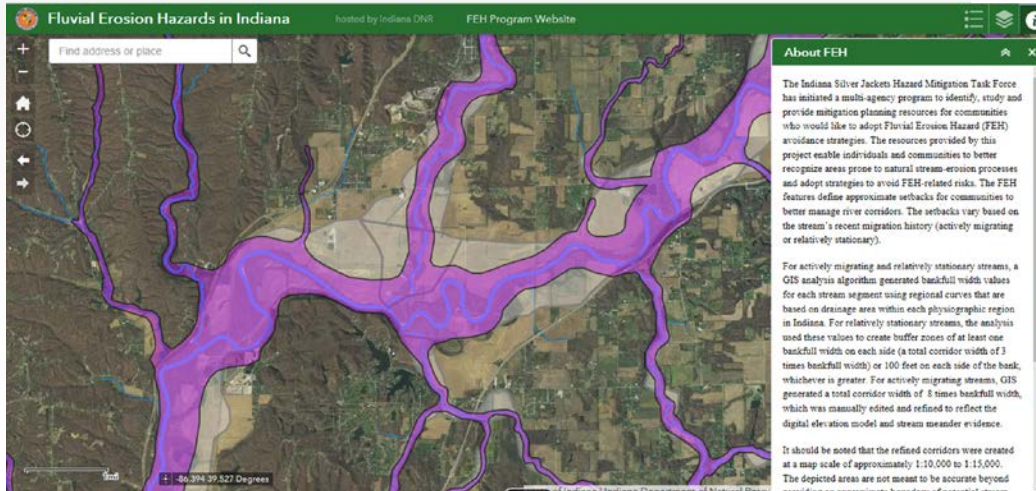
Scientific Investigations Report 2013-5168

U.S. Department of the Interior
U.S. Geological Survey



INDIANA FEH PROGRAM: PREVIOUS PHASES

- Phase I:
Develop regionally-based channel dimensions for stable Indiana streams
- Phase II:
Determine channel migration rates to identify mobile streams and establish statewide FEH corridors

Fluvial Erosion Hazards in Indiana hosted by Indiana DNR FEH Program Website

Find address or place

About FEH

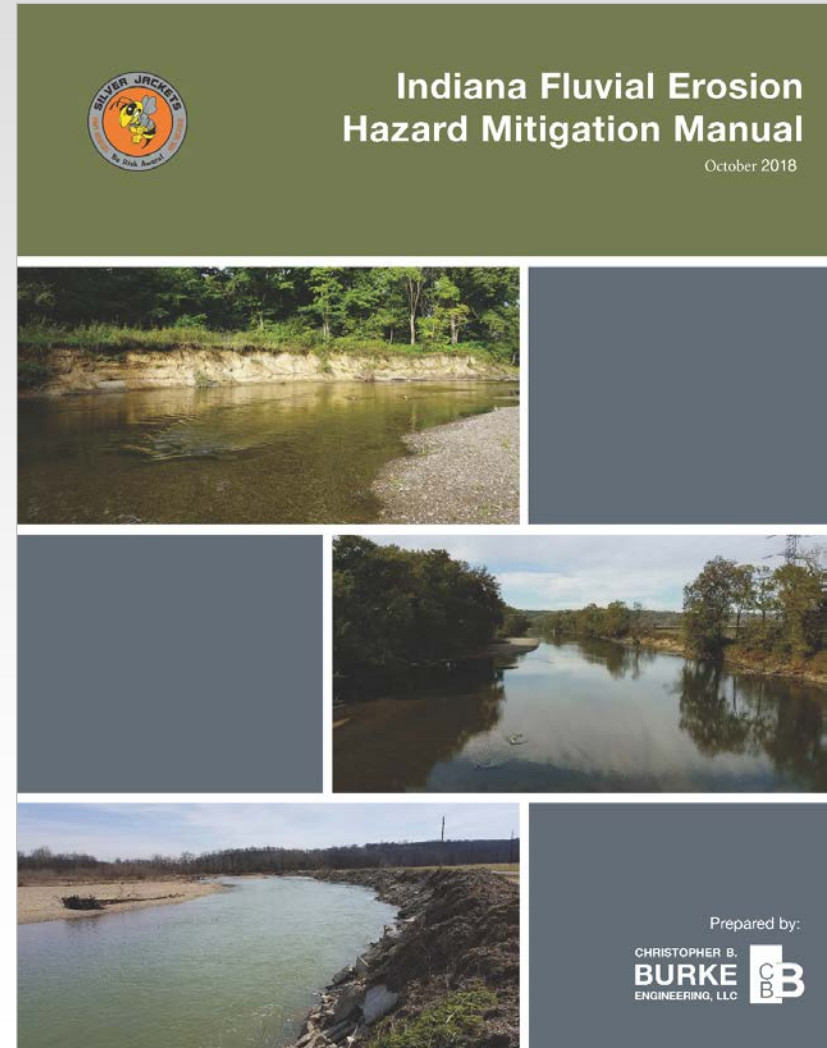
The Indiana Silver Jackets Hazard Mitigation Task Force has initiated a multi-agency program to identify, study and provide mitigation planning resources for communities who would like to adopt Fluvial Erosion Hazard (FEH) avoidance strategies. The resources provided by this project enable individuals and communities to better recognize areas prone to natural stream-erosion processes and adopt strategies to avoid FEH-related risks. The FEH features define approximate setbacks for communities to better manage river corridors. The setbacks vary based on the stream's recent migration history (actively migrating or relatively stationary).

For actively migrating and relatively stationary streams, a GIS analysis algorithm generated bankfull width values for each stream segment using regional curves that are based on drainage area within each physiographic region in Indiana. For relatively stationary streams, the analysis used these values to create buffer zones of at least one bankfull width on each side (a total corridor width of 3 times bankfull width) or 100 feet on each side of the bank, whichever is greater. For actively migrating streams, GIS generated a total corridor width of 5 times bankfull width, which was manually edited and refined to reflect the digital elevation model and stream meander evidence.

It should be noted that the refined corridors were created at a map scale of approximately 1:10,000 to 1:15,000. The depicted areas are not meant to be accurate beyond providing an approximate boundary of potential stream

INDIANA FEH PROGRAM: PHASE III

- Phase I:
Develop regionally-based channel dimensions for stable Indiana streams
- Phase II:
Determine channel migration rates to identify mobile streams and establish statewide FEH corridors
- Phase III:
Develop a manual to provide guidance on how to address FEHs





FEH MITIGATION MANUAL

- Purpose

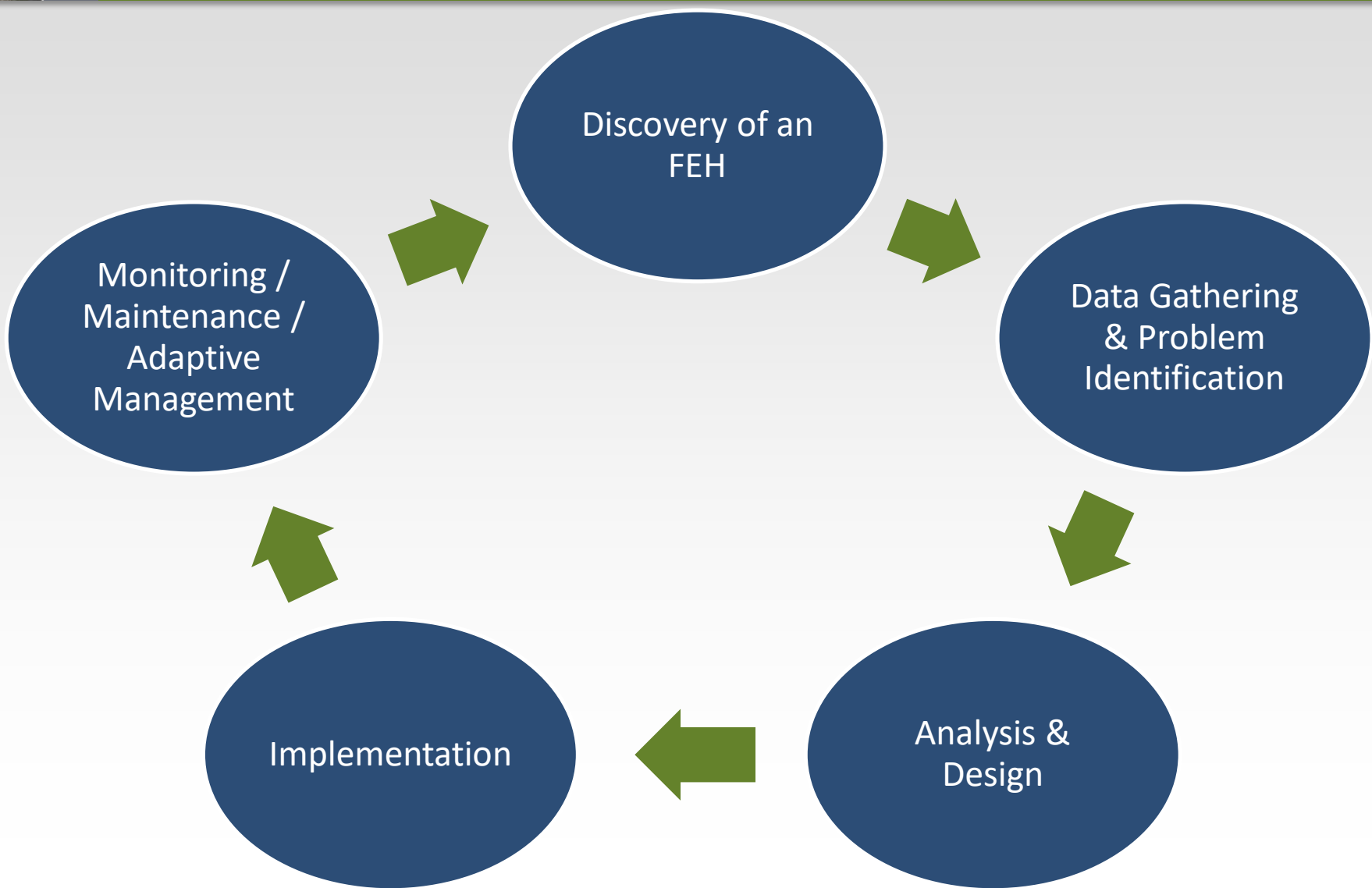
Focus on how to best mitigate the fluvial erosion hazard in areas where avoidance is not feasible, acceptable, or is cost prohibitive, and how to evaluate best methods for protecting structures and infrastructure, while striving to minimize impacts on the stream system.

- Appropriate Use / Limitations

This manual is directed to project engineers, technical professionals, and owners involved in the design and construction of fluvial erosion hazard mitigation projects, also referred to as bank stabilization or rehabilitation. The intent of this manual is to provide direction to experienced design professionals so that any modifications made to the stream maintain or improve the stability of the waterway and protect the interests of the owner. The majority of information given in this document is general and provides many of the technical principles used throughout the country. The designer must be a suitably educated and trained professional that has experience in this field to properly apply these guidelines to the specifics of the site and the needs of the owner.

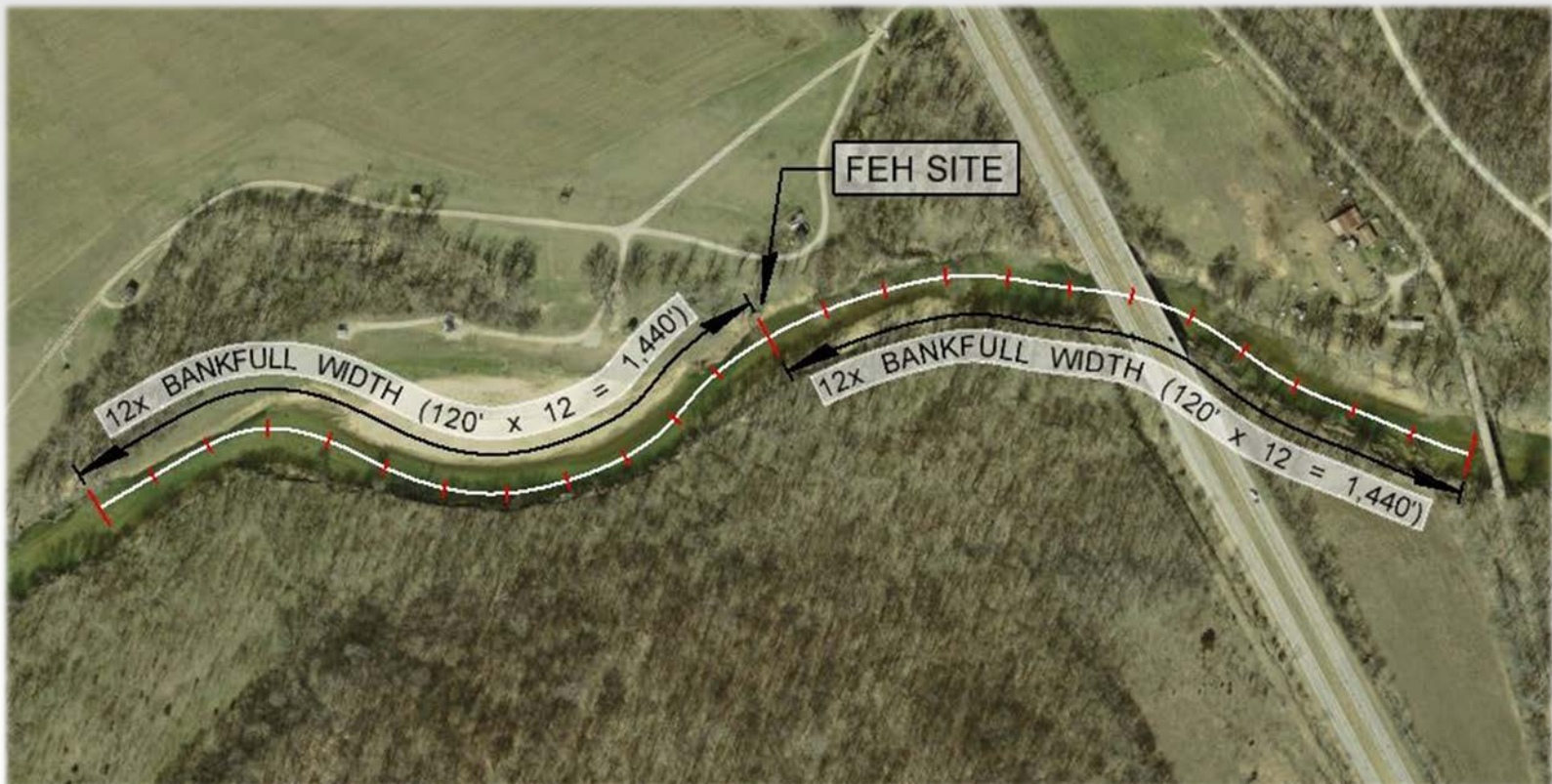


FEH MITIGATION MANUAL: OUTLINE / PROCESS



FEH MITIGATION MANUAL: DATA GATHERING

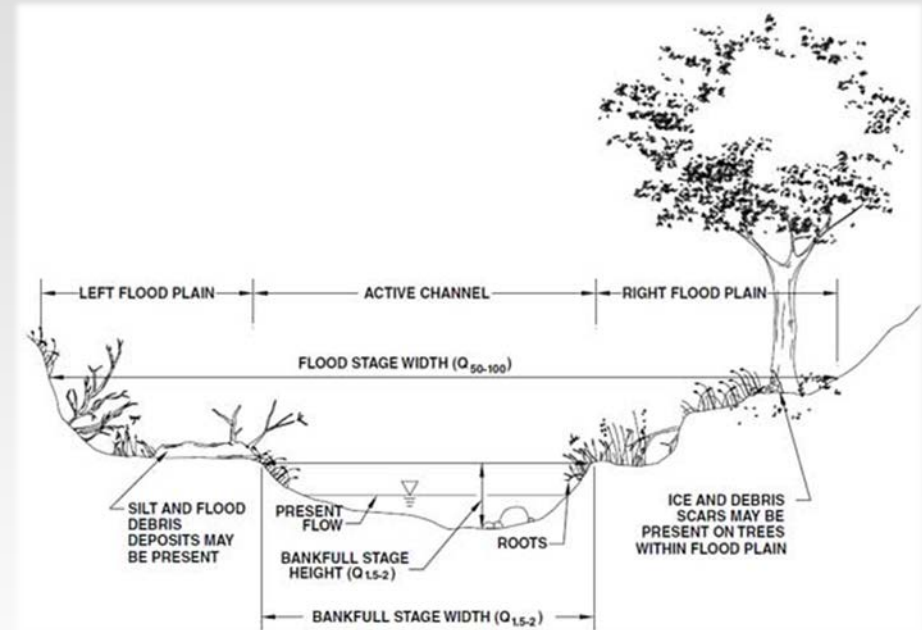
- Site Assessment
 - Establish assessment reach limits



FEH MITIGATION MANUAL: DATA GATHERING

- **Site Assessment**

- Establish assessment reach limits
- **Channel dimensions**
- Signs of erosion/deposition
- Evaluate channel forming discharge & other flows
- Document morphologic processes
- Infrastructure & site constraints
- Identify reach-scale stressors



FEH MITIGATION MANUAL: DATA GATHERING

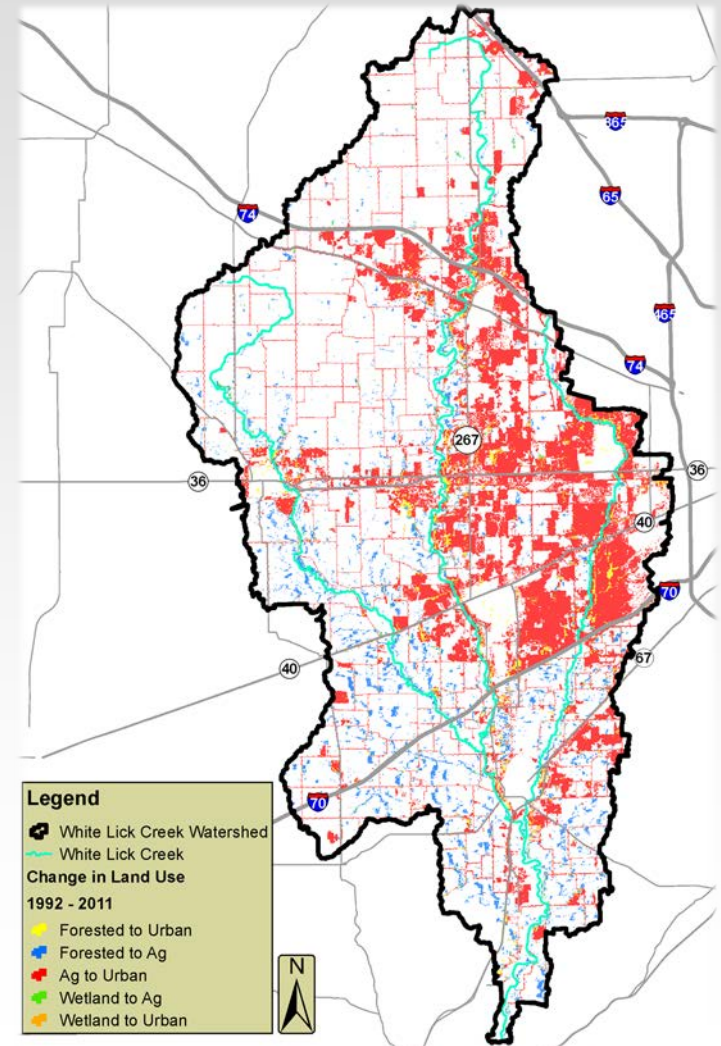
- **Site Assessment**

- Establish assessment reach limits
- Channel dimensions
- Signs of erosion/deposition
- Evaluate channel forming discharge & other flows
- Document morphologic processes
- Infrastructure & site constraints
- Identify reach-scale stressors



FEH MITIGATION MANUAL: DATA GATHERING

- Watershed Assessment
 - Land use analysis (composition & trends)
 - Rainfall analysis (trends)
 - Upstream drainage network analysis (composition & trends)
 - Streamflow Gage analysis (trends)



FEH MITIGATION MANUAL: DATA GATHERING

- Stakeholder Input
 - Federal, State, Local, & Project Team
 - Establish decision making process
 - Convey/acknowledge constraints and limitations based on site assessment

- Mitigation Objectives
 - Create list of stressors
 - List & prioritize desired stream functions
 - Evaluate social, environmental, and O&M factors
 - Identify additional information needs



Photo courtesy: MakProSVC



Photo courtesy: EMH&T

FEH MITIGATION MANUAL: ANALYSIS & DESIGN

- Analysis Methods
 - Channel forming flows

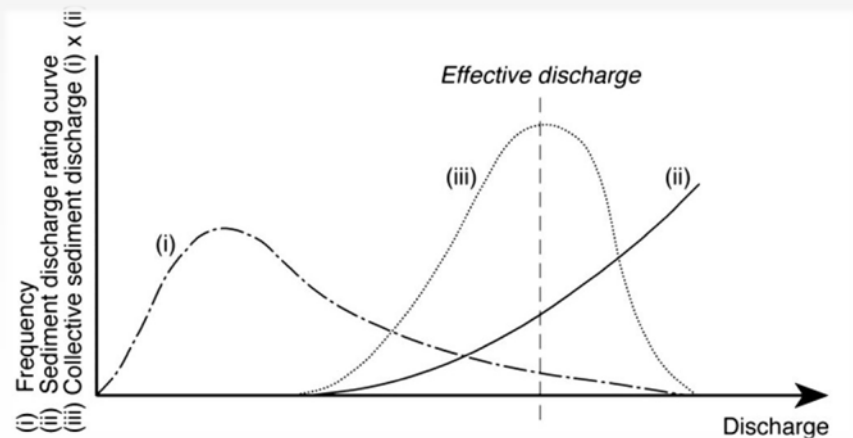
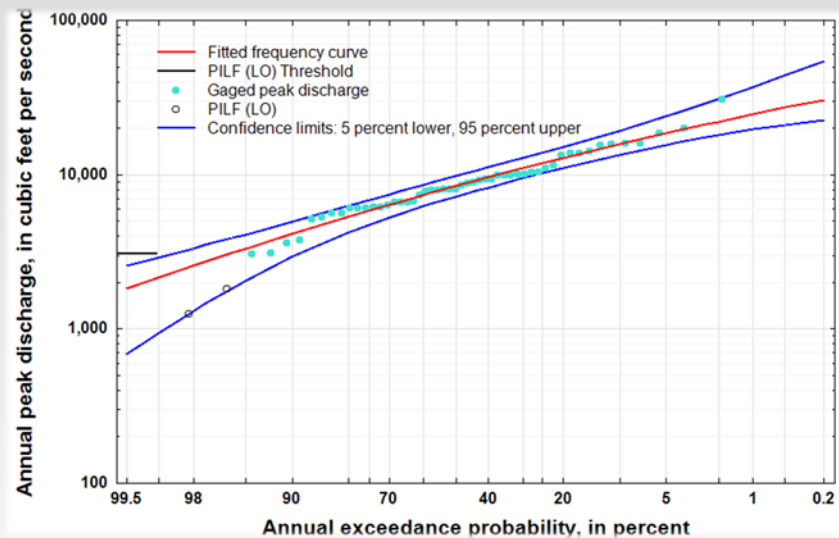
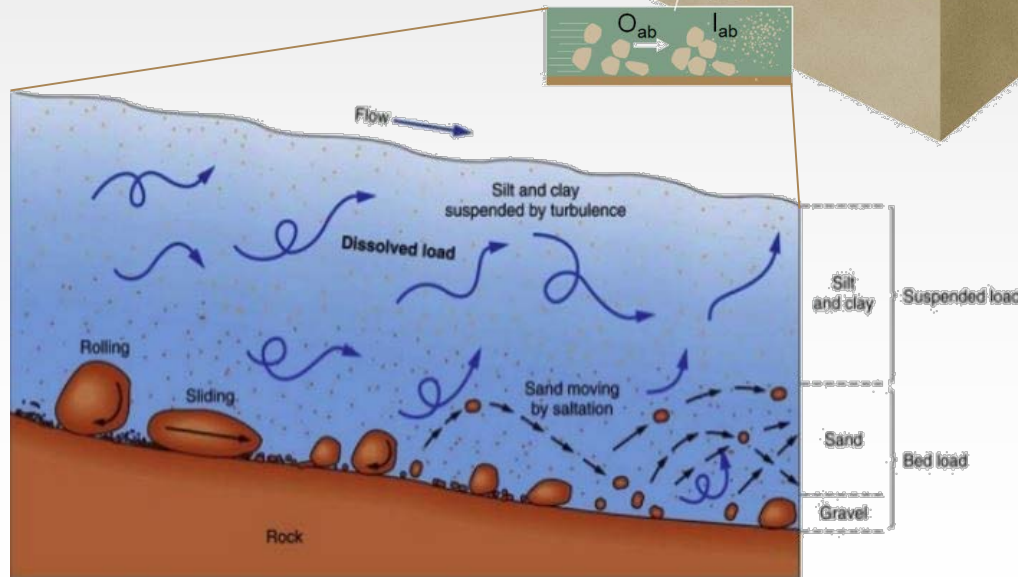
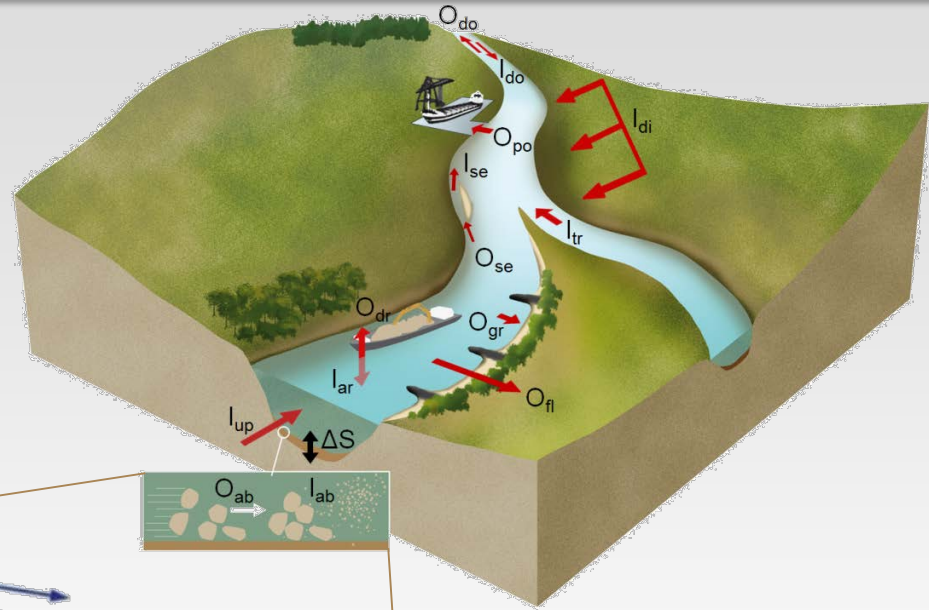


Image courtesy: Soar & Thorne, 2001

FEH MITIGATION MANUAL: ANALYSIS & DESIGN

- Analysis Methods
 - Channel forming flows
 - Sediment continuity



(Adapted from the International Commission for the Hydrology of the Rhine Basin [above]
Little Geological Consulting [below])

FEH MITIGATION MANUAL: ANALYSIS & DESIGN

- Analysis Methods
 - Channel forming flows
 - Sediment continuity
 - Stable channel geometry

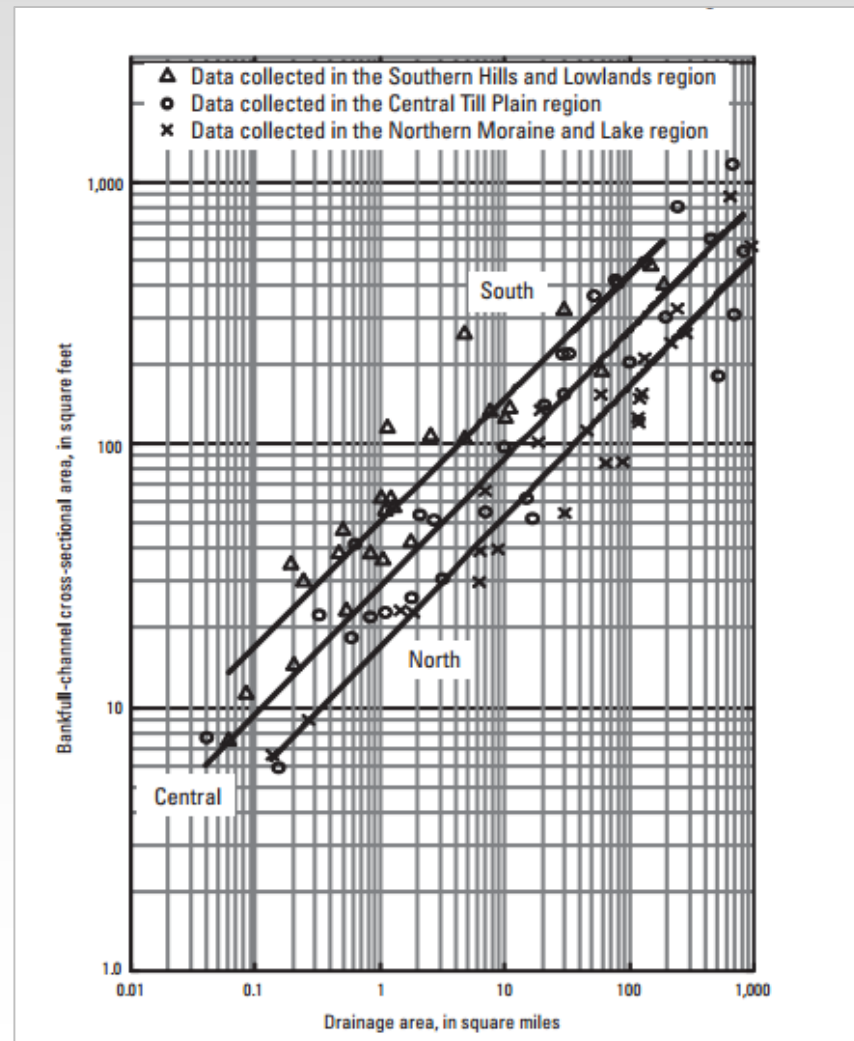


Image courtesy: USGS, 2013

FEH MITIGATION MANUAL: ANALYSIS & DESIGN

- Analysis Methods

- Channel forming flows
- Sediment continuity
- Stable channel geometry
- Scour

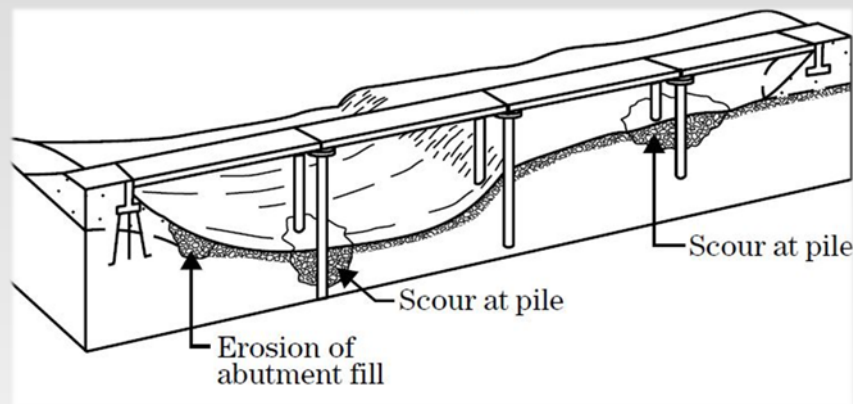


Image courtesy: USDA

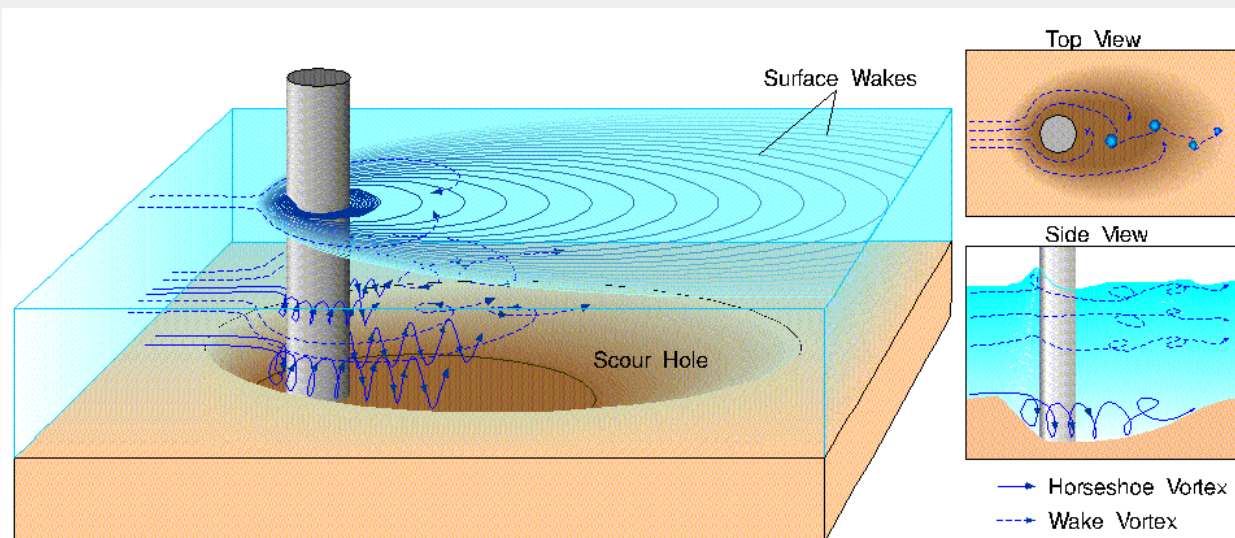


Image courtesy: USGS

FEH MITIGATION MANUAL: ANALYSIS & DESIGN

- Analysis Methods
 - Channel forming flows
 - Sediment continuity
 - Stable channel geometry
 - Scour
 - Habitat quality & availability



Collection of Field Data for QHEI in White Lick



Invasive Species
(Top: Missouri Dept. of Conservation, 2017)
(Middle: Purdue Ext. Entomology, 2018)
(Bottom: Circle of Blue, 2016)

FEH MITIGATION MANUAL: ANALYSIS & DESIGN

- Passive River Management (Agricultural)

- Land cover & tillage
- Grazing
- Soil compaction
- Drainage
- Nutrients



Extensive tile drainage

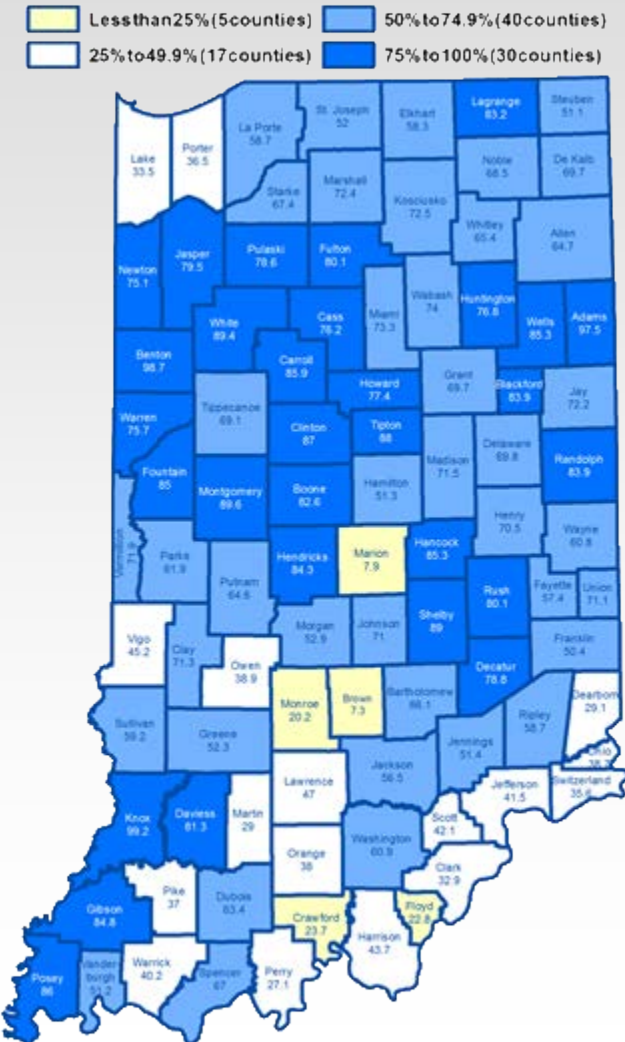


Image after USDA, 2012

FEH MITIGATION MANUAL: ANALYSIS & DESIGN

- Passive River Management (Urban)
 - Green infrastructure (including LID)
 - Pollutants of concern



Photo courtesy: AAES, 2015

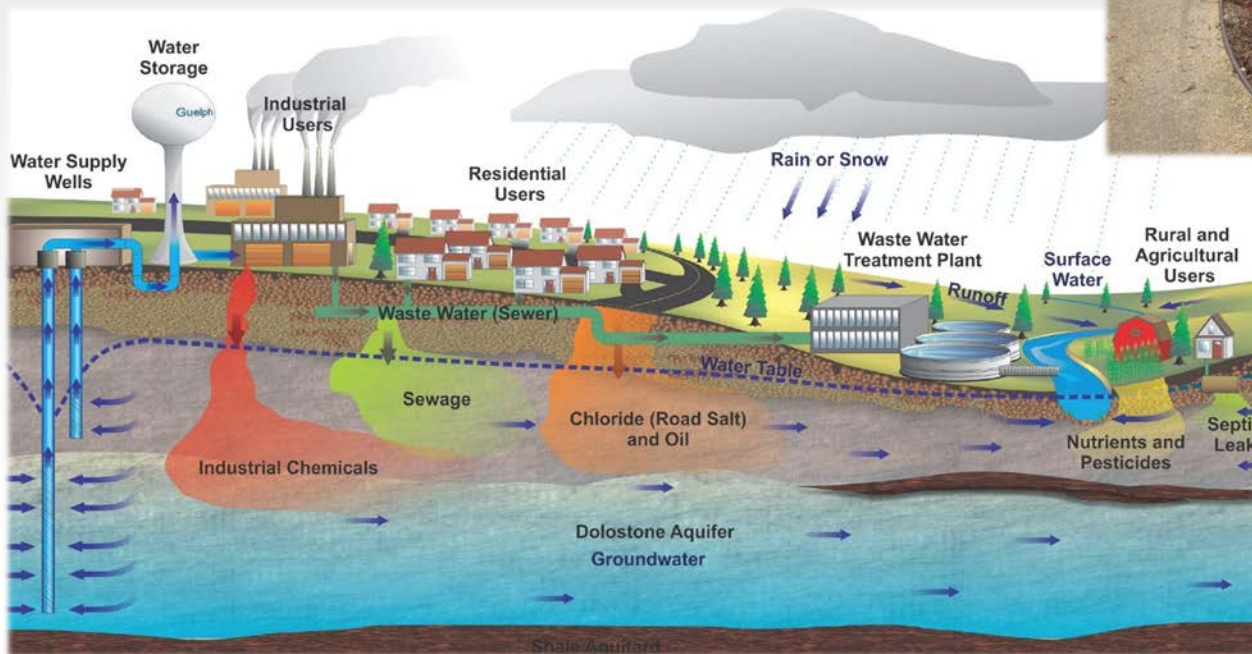


Photo courtesy: Institute for Groundwater Research

FEH MITIGATION MANUAL: ANALYSIS & DESIGN

- Active River Management
 - Vertical stability
 - Floodplain reattachment
 - Grade control structures
 - Bed armoring

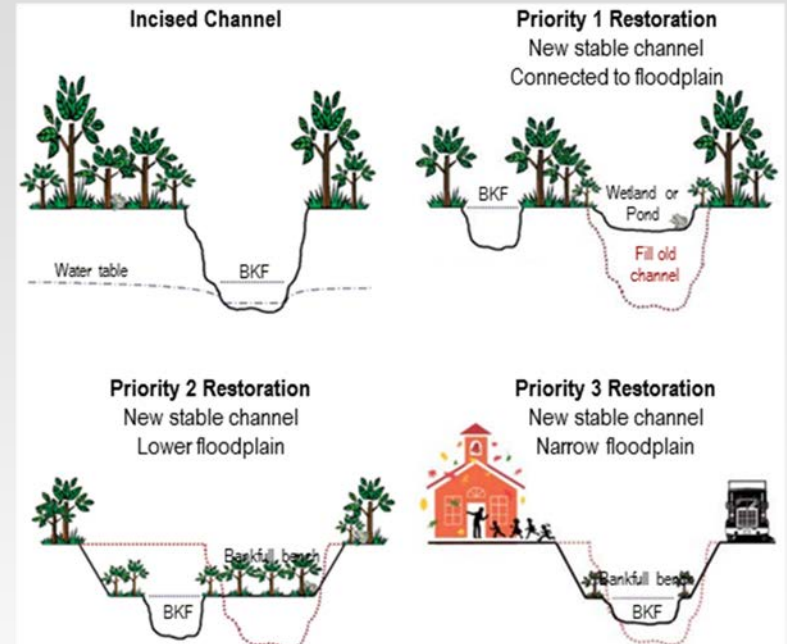


Image courtesy NCSU, 2017



Bean Creek in Indianapolis, IN



Photo courtesy USACE

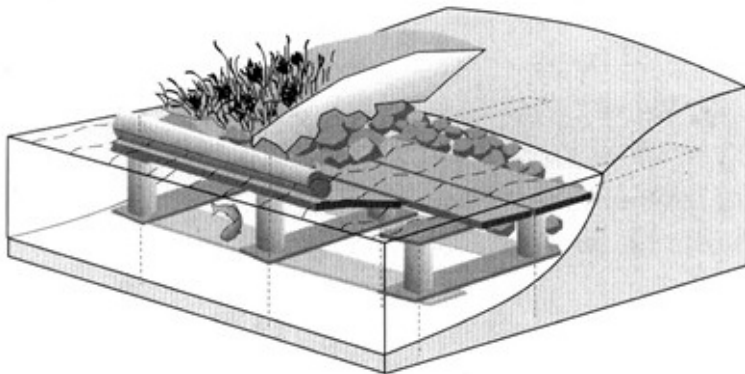
FEH MITIGATION MANUAL: ANALYSIS & DESIGN

- Active River Management
 - Lateral stability
 - Toe protection
 - Bank armoring
 - Flow redirection
 - Channel augmentation



FEH MITIGATION MANUAL: ANALYSIS & DESIGN

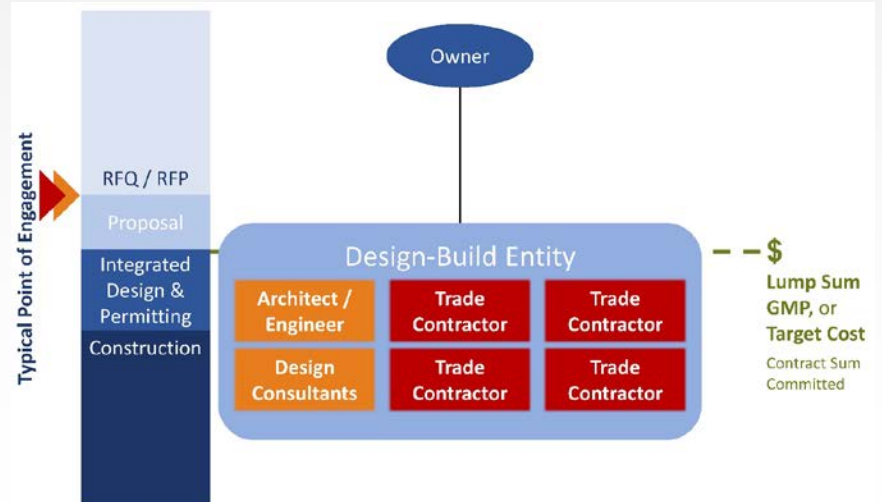
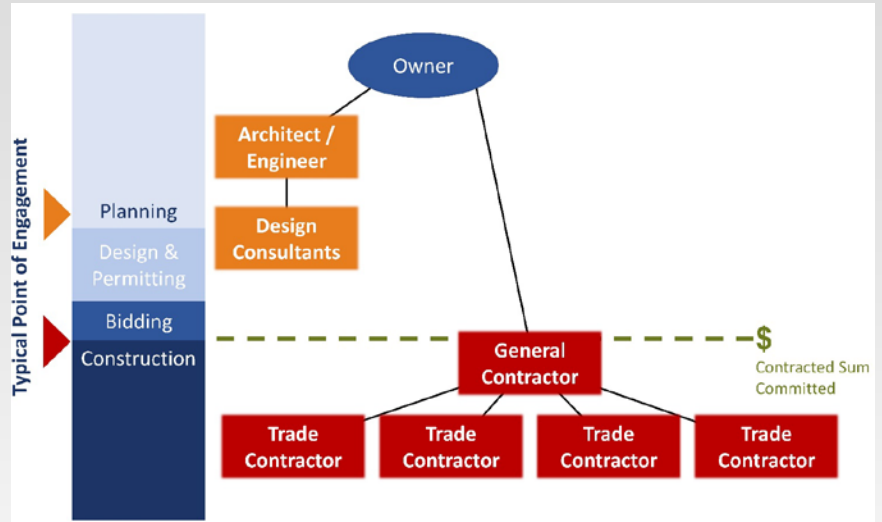
- Active River Management
 - Habitat
 - Water quality
 - Constructed habitat & habitat rejuvenation



Lunker Structure
Image courtesy ESenSS, 2014

FEH MITIGATION MANUAL: ANALYSIS & DESIGN

- Project Implementation Considerations
 - Project Delivery
 - Design-Bid-Build
 - Design-Build



Images adapted from DBIA, 2015

FEH MITIGATION MANUAL: ANALYSIS & DESIGN

- Project Implementation Considerations
 - Constructability & timing



Toe wood installation along Yellow River near Knox, IN



Poor initial establishment of vegetation due to timing along Yellow River near Knox, IN

FEH MITIGATION MANUAL: ANALYSIS & DESIGN

- Project Implementation Considerations
 - Environmental impact



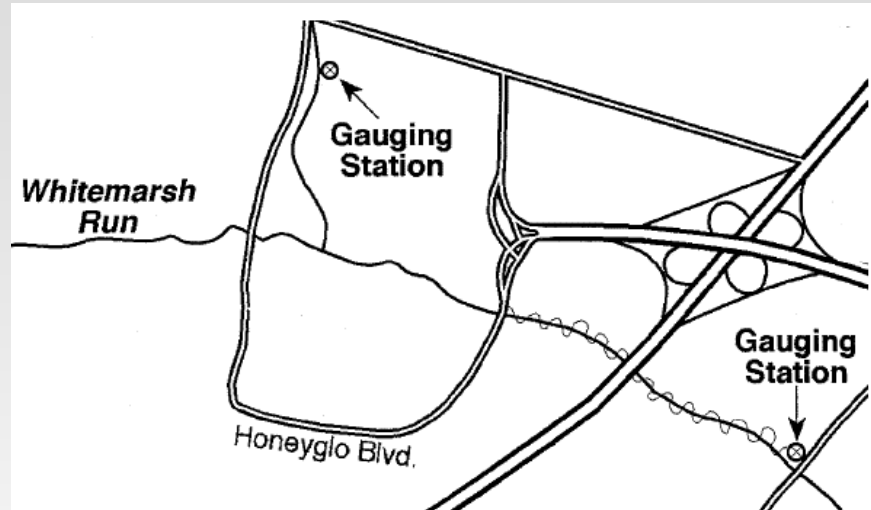
Photo courtesy of City of Golden Valley, 2018



Native seeding over toe wood along Yellow River near Knox, IN

FEH MITIGATION MANUAL: ANALYSIS & DESIGN

- Project Implementation Considerations
 - Natural variability



Top: Sinuosity inconsistent with surrounding reaches, Soar and Thorne, 2001
Bottom: Project nearly indistinguishable from natural reaches, Google Earth, 2015

FEH MITIGATION MANUAL: ANALYSIS & DESIGN

- Project Implementation Considerations
 - Anticipated longevity
 - Maintenance



Lack of maintenance/management results in slope failure
White Lick Creek in Avon, IN



Robust materials protecting critical infrastructure in a flashy stream
Bean Creek in Indianapolis, IN



FEH MITIGATION MANUAL: ANALYSIS & DESIGN

- Project Implementation Considerations

- Project cost
 - Delivery method
 - Alternative materials
 - Scope reduction
 - Prioritization of key project components

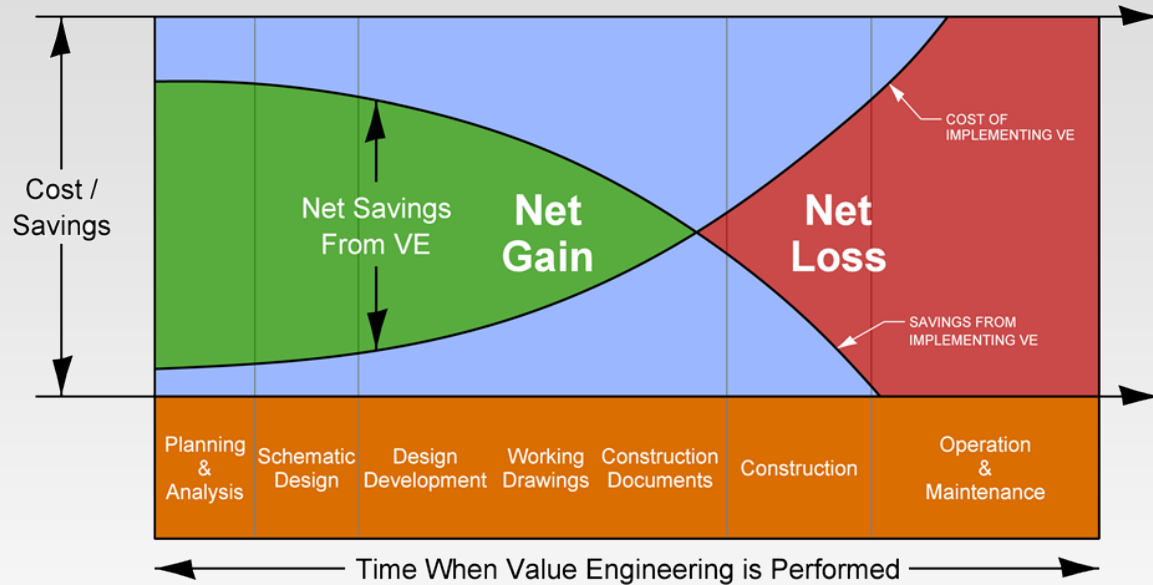


Image adapted from Whole Building Design Guide



FEH MITIGATION MANUAL: ANALYSIS & DESIGN

- Project Implementation Considerations
 - Performance evaluation
 - Selection of alternative
 - Develop design documents

| Alternative Name, Treatment Type, or Other Project Metric | Cumulative 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= | | > \$10M | very high | none | | 0 | none | none | none | | added risk | significant (-) | no change | no change | |
| 1= | | >\$5M <\$10M | high | 100% Owner | | 1-10 | limited | limited | limited | | no change | minor (-) | limited | limited | |
| 2= | | >\$1M <\$5M | mod-high | 75% Owner | | 11-30 | limited-mod | limited-mod | limited-mod | | minimal | no change | limited-mod | limited-mod | |
| 3= | | >\$500K <\$1M | moderate | 50% Owner | | 31-100 | moderate | moderate | moderate | | moderate | minor (+) | moderate | moderate | |
| 4= | | >\$100K <\$500K | low-mod | 75% Other | | 101-300 | mod-high | mod-high | mod-high | | high | moderate (+) | mod-high | mod-high | |
| 5= | | <\$100K | low | 100% Other | | 300+ | high | high | high | | robust | significant (+) | high | high | |
| Alternative 1 / Treatment 1 | 8 | 0 | 3 | 3 | 1.7 | 5 | 4 | 2 | 3 | 3.5 | 4 | 0 | 4 | 4 | 2.8 |
| Alternative 2 / Treatment 2 | 10 | 3 | 3 | 4 | 3.4 | 5 | 5 | 0 | 3 | 3.3 | 5 | 1 | 3 | 1 | 3.0 |
| Alternative 3 / Treatment 3 | 6 | 4 | 0 | 4 | 3.2 | 2 | 0 | 1 | 3 | 1.5 | 3 | 0 | 0 | 3 | 1.5 |



FEH MITIGATION MANUAL: IMPLEMENTATION

- Passive Measures
 - Programs Available
 - NRCS
 - TNC (and other non-governmental organizations)
 - Wetland and tree mitigation for regulatory permits
 - Duration & Deed Restriction
 - Required participation duration for voluntary programs varies
 - Mitigation for regulatory permits are typically in perpetuity



FEH MITIGATION MANUAL: IMPLEMENTATION

- Active Measures
 - Funding
 - Regulatory permitting
 - Communication during construction



Pre-construction meetings and meetings about critical project elements are a key to successful implementation

FEH MITIGATION MANUAL: ADAPTIVE MANAGEMENT

- Post-construction Activities
 - Mgmt Plan objectives & approach
 - Proper performance of in-stream structures and stabilization measures
 - Changes in channel morphology
 - Response by ecological/biological resources
 - Monitoring
 - Channel geometry
 - Channel materials
 - Water quality
 - Habitat & Flora/Fauna



FEH mitigation projects are generally most vulnerable immediately following construction, particularly when bio-engineering methods are used.



FEH MITIGATION MANUAL: ADAPTIVE MANAGEMENT

- Post-construction Activities
 - Maintenance
 - Correct settlement
 - Failed/inadequate vegetation
 - Repair minor erosion
 - Final Inspection & Termination
 - Confirm objectives are met and the project is self-sustaining
 - Nature-based vs. engineered solutions



FEH MITIGATION MANUAL: APPENDIX INFORMATION

BMP Fact Sheets

APPENDIX 3: BEST MANAGEMENT PRACTICES- FACT SHEETS

1.1.1 Rock W-weirs

1.2.1 Toe Wood

Notes:

1. Foundation logs shall face the downstream direction of ice angle on the banks having 75% or greater.
2. Approximately 20% of the foundation logs shall be secured with the toe-roping practice and shall be kept in place until the water has receded.
3. Foundation logs shall be spaced 10 to 15 feet apart and shall be secured with toe-roping practice.
4. Foundation logs shall be secured with toe-roping practice and shall be kept in place until the water has receded.
5. The second or other foundation logs shall be secured with toe-roping practice and shall be kept in place until the water has receded.
6. Toe-roping practice shall be placed on top of the logs and shall be secured with toe-roping practice.
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| No. | Mitigation Measure | Primary Category | Secondary Category |
|--------|-----------------------------------|--------------------------|--------------------------|
| 1.1.1 | Rock W-weirs | Grade Control Structures | Flow Redirection |
| 1.1.2 | Step-pools | Grade Control Structures | Floodplain Reattachment |
| 1.1.3 | Log drops and V-log drops | Grade Control Structures | Floodplain Reattachment |
| 1.1.4 | Newbury Riffle | Grade Control Structures | Bed Armoring |
| 1.2.1 | Toe wood | Toe Protection | Habitat Improvements |
| 1.2.2 | Rock-toe revetments | Toe Protection | |
| 1.2.3 | Interlocking concrete jacks | Toe Protection | |
| 1.2.4 | Boulder revetments | Toe Protection | Bank Armoring |
| 1.3.1 | Branch layering | Bank Armoring | |
| 1.3.2 | Natural fiber rolls | Bank Armoring | |
| 1.3.3 | Brush mattresses | Bank Armoring | Channel Augmentation |
| 1.3.4 | Gabion baskets | Bank Armoring | Toe Protection |
| 1.3.5 | Gabion mattresses | Bank Armoring | Bed Armoring |
| 1.3.6 | Live stakes | Bank Armoring | Habitat Improvements |
| 1.3.7 | Live fascines | Bank Armoring | Habitat Improvements |
| 1.3.8 | Live soil lifts | Bank Armoring | Channel Augmentation |
| 1.3.9 | Natural fiber matting / TRM / ECB | Bank Armoring | |
| 1.3.10 | Riprap bank armoring | Bank Armoring | |
| 1.3.11 | Articulating concrete blocks | Bank Armoring | |
| 1.4.1 | Rock cross-vanes | Flow Redirection | Grade Control Structures |
| 1.4.2 | J-hook vanes | Flow Redirection | Grade Control Structures |
| 1.4.3 | Rock vanes | Flow Redirection | |
| 1.4.4 | Log vanes | Flow Redirection | |
| 1.5.1 | Constructed riffle-pool series | Channel Augmentation | Habitat Improvements |
| 1.5.2 | Bank regrading/shaping | Channel Augmentation | Flow Redirection |
| 1.5.3 | Cut-off sills | Channel Augmentation | Floodplain Reattachment |
| 1.5.4 | Boulder clusters | Channel Augmentation | Habitat Improvements |



FEH MITIGATION MANUAL: APPENDIX INFORMATION

- FEH Mitigation Case Studies
 - Analysis
 - Design
 - Implementation

APPENDIX 2: FEH MITIGATION CASE STUDIES

BEAN CREEK – DESIGN OF A THRESHOLD CHANNEL REACH

APPENDIX 2: FEH MITIGATION CASE STUDIES

SUGAR CREEK – A HIGH BANK SCENARIO

APPENDIX 2: FEH MITIGATION CASE STUDIES

YELLOW RIVER – SYSTEM ASSESSMENT

APPENDIX 2: FEH MITIGATION CASE STUDIES

YELLOW RIVER – IMPLEMENTING MITIGATION MEASURES

APPENDIX 2: FEH MITIGATION CASE STUDIES

BIG WALNUT CREEK – FEH MITIGATION STUDY

APPENDIX 2: FEH MITIGATION CASE STUDIES

WHITE LICK CREEK – FEH MITIGATION STUDY

APPENDIX 2: FEH MITIGATION CASE STUDIES

EAGLE CREEK – FEH MITIGATION STUDY

...the City of Bean servable erosion event caused determined a 48" interceptor pipe were bank erosion resulted from this utility responded temporarily designed solution

...and the loss of States Geological was identified Considering this tion has and will

...to stabilize the t; the critical the complex flow model accounted and the sanitary etion and design stabilize the critical hancing the

...to stabilize the river from future ventionation of the due to scar. If's were used to

...erikake Marsh, a lated States, The 435-square-miles, r watershed history of d has been se primary nt into the

...ad sediment input lers in St. Joseph ations were than nuous suspended many sources of Marshall County

...of recommended stream reaches with practices are e streams. In the plan recommends of State County food and channel of modifying the

...ion - May 2017 of investigation to site assessment, assessment. The r have led to the

...October 2017 the issue of the effective sediment peobis anticipated

...item assessment nished-scale and ents from the following four determined to be for the current mitigation issues: uvent material, and inlet incision and in storage, and ad flow volumes. A mitigation study stem-wide issues historically, were development and ce of a problem. intended to be FEH site and near y.

...ation study : Issues have e worsened late change, diess of the ction of a

...rk migration rate nstoring program nk near the gravel reducing the bank- to complicated by

...A combination of FEH mitigation measures will be necessary to maintain the integrity of the levee system, a critical flood control structure for the City of Indianapolis. Recommended improvements along the channel banks include reinforcing the toe and adjustment of the upper bank to create a more stable slope. Passive mitigation measures are typically best for addressing the type of systemic issues present in Eagle Creek; however, the dam heavily dampens the inputs from the watershed, which will negate potential positive changes in the watershed.

Once the improvements have been constructed, the condition of the reconstructed bank at the site should be monitored on an annual basis, and/or after significant flooding events addressing damaged banks or migrating stream as soon as possible.

EAGLE CREEK – FEH MITIGATION STUDY

A system assessment was completed to evaluate options for reducing the risk of ongoing slope failure along the existing levee system downstream of Eagle Creek Reservoir in Indianapolis, IN. The headwaters of Eagle Creek are located in the northwest portion of Hamilton County and flow generally south through Boone and Marion Counties to its confluence with the White River on the west side of Indianapolis. Upstream of the reservoir, the Eagle Creek corridor is primarily agricultural, transitioning to urban as it approaches the Marion County border. The assessment reach was located downstream of the reservoir, where much of Eagle Creek is leveed.

Passive mitigation measures are typically best for addressing the type of systemic issues present in Eagle Creek; however, the dam heavily dampens the inputs from the watershed, which negates positive changes in the watershed.

- Artificial hydrology and sediment barrier caused by Eagle Creek Dam
- Channel incision and inadequate floodplain



FEH Site along Eagle Creek – September 2016

Once the improvements have been constructed, the condition of the reconstructed bank at the site should be monitored on an annual basis, and/or after significant flooding events addressing damaged banks or migrating stream as soon as possible.



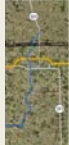
Appendix 2 | FEH Mitigation Case Studies



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FEH MITIGATION MANUAL: EXAMPLE DOCUMENTS


- FEH Mitigation Study Example Reports



**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

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CBBEL Project No. 14-0014.00000



**DANDY TRAIL SITE
FEH MITIGATION ALONG EAGLE 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
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October 2018

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CBBEL Project No. 14-0014.00000



**CITY OF BRAZIL WELLFIELD FEH MITIGATION
ALONG BIG WALNUT 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



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FEH MITIGATION MANUAL

Indiana Fluvial Erosion Hazard Mitigation Manual

Available for download at:

<http://feh.iupui.edu/resources/>

Indiana Fluvial Erosion Hazard Mitigation Manual

Indiana Fluvial Erosion Hazard Mitigation Manual (FINAL)

Indiana Fluvial Erosion Hazard Mitigation Program: Big Walnut Creek Fluvial Erosion Hazard Assessment

Big Walnut Creek FEH Mitigation Assessment_Feb 2019

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