# The N-EWN Knowledge Series

## A Continuing Education Series about Engineering with Nature



*Mr. Eddie Brauer*

## Engineering With Nature® Engineering Practice Guide for Floodplain Benching Projects

*US Army Corps of Engineers Research and Development Center*



*Dr. Joanna Curran*

Restoration and nature-based solutions are increasingly recognized as sustainable infrastructure, yet practitioners charged with delivering them often lack the design criteria and procedures that are routine for conventional "gray" infrastructure. Technical guidance for natural infrastructure (NI) remains limited in both content and organization, which slows adoption, complicates review, and inflates perceived risk.

USACE is addressing this through Engineering Practice Guides (EPGs), developed in alignment with the Engineering With Nature Guiding Principles and structured to follow the standard project design process. The Floodplain Benching EPG addresses reconnection in alluvial systems of any size, targeting flood attenuation, channel dynamics, sediment transport, margin hydraulics, and surface water-groundwater exchange, emphasizing self-forming and self-maintaining designs. Within the EPG, we describe site characterization, engineering design criteria, and design considerations. The focus is on moving from preliminary to detailed design, emphasizing hybrid approaches that combine gray with green and blue solutions.

**Save the date!**

**Upcoming webinars will take place the 3rd Thursday of the month.**

**Sep. 17 12:30pm ET**

*Mr. Edward Brauer and Dr. Joanna Curran, USACE-ERDC*

*Engineering With Nature® Engineering Practice Guide for Floodplain Benching Projects*

**Oct. 15 12:30pm ET**

*Dr. Matt Bilskie, University of Georgia*

*Nature-Based Coastal Resilience at Marine Corps Recruit Depot Parris Island: From Concept to Long-Term Monitoring*

**Nov. 19 12:30pm ET**

*Leigh Langley, USACE-ERDC*

*Dune Stabilization for Coastal Flood Protection*

**Register here: https://bit.ly/3gR9ADL** **or scan:**

**1 Continuing Education Credit (CEC) is available to attendees**

**Recorded webinars will be posted online at: https://n-ewn.org/resources/n-ewn-knowledge-seminars/**

**Presented by:**

NETWORK FOR ENGINEERING WITH NATURE

LimnoTech Water Environment Scientists Engineers

UNIVERSITY OF GEORGIA

ERDC

**Questions? Please contact:**
**Alex Curwin, LimnoTech**
**acurwin@limno.com**

# EWN Engineering With Nature®

EWN is the intentional alignment of natural and engineering processes to efficiently and sustainably deliver economic, environmental and social benefits through collaboration.

**Policy development**
- Engagement with policymakers
- Policy/procedure “Modernization

**Engagement, Partnering and teaming**
- Within USACE, e.g., EWN Proving Grounds
- With other organizations inside and outside government

**On-the-ground projects and demos**
- Across the spectrum of applications and project development (i.e., from planning to operations
- Scaling up nature-based solutions

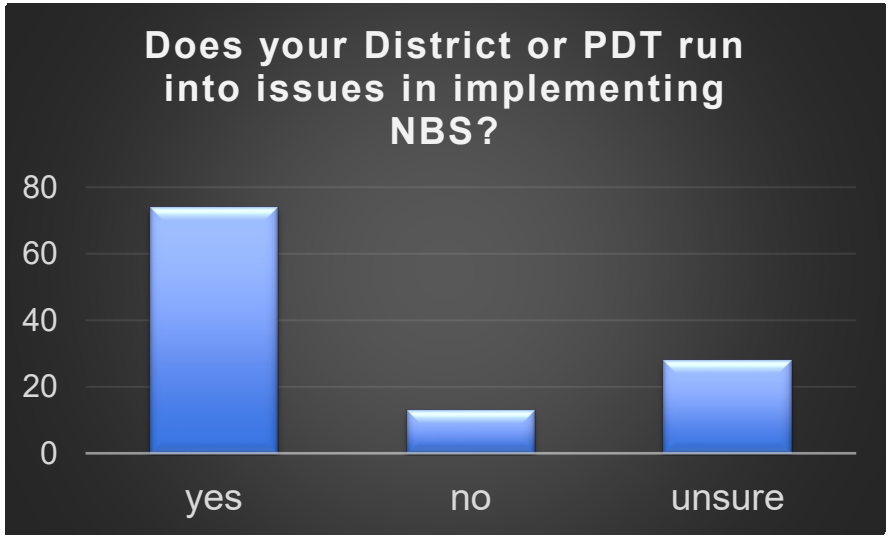


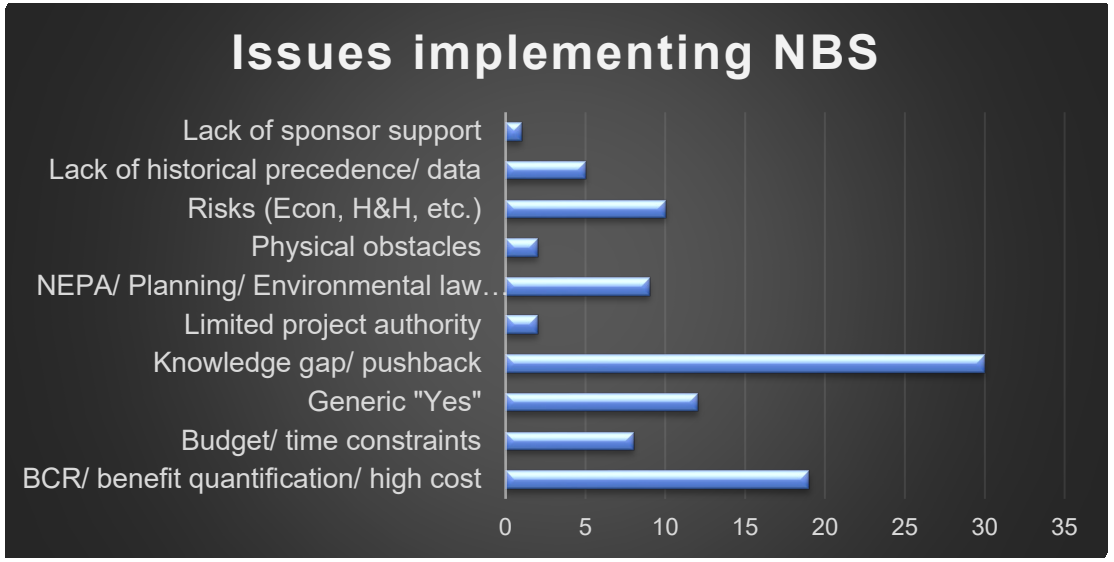
**Innovation**
- Creating a vison of the future
- Establishing goals, targets and conditions
- New science and engineering tools for delivery

**Strategic Communications**
- Individual research papers
- Communication tools, e.g., EWN Atlas Vol 1, 2, and 3
- Education, e.g., academic curricula, training

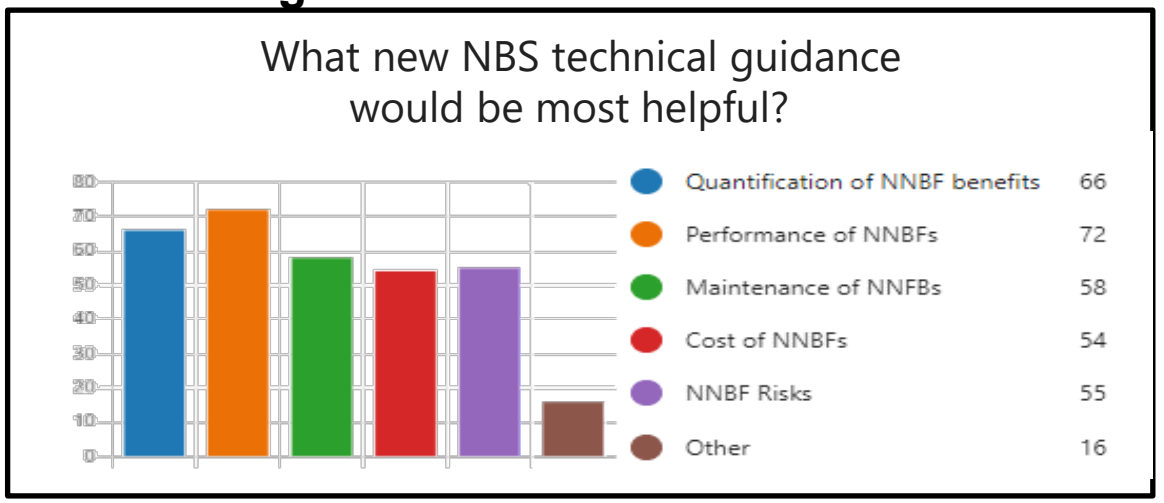
# 2021 and 2022 Poll Results: Issues in NI Implementation

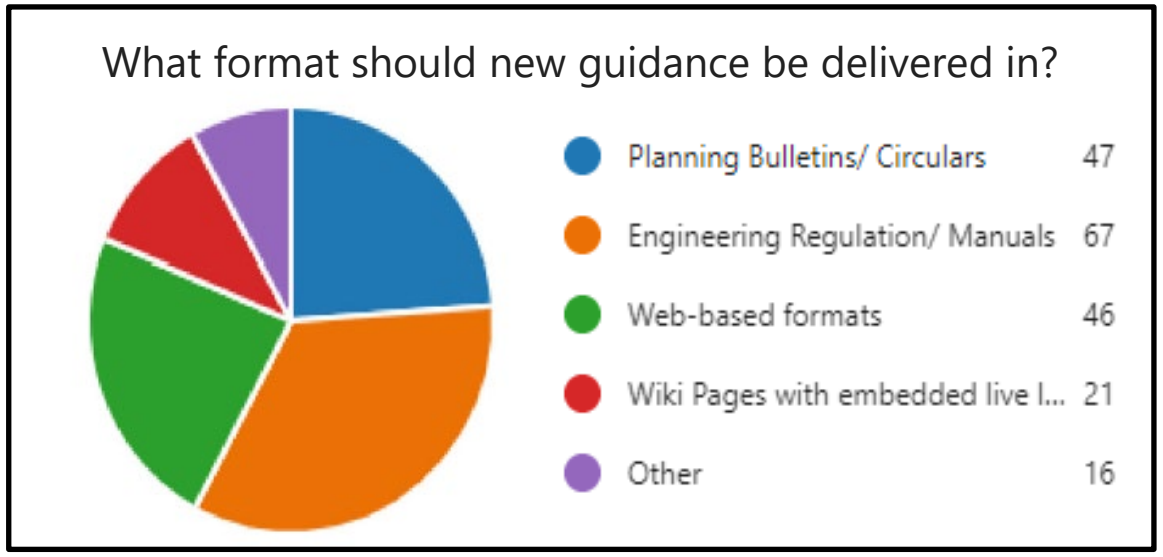
## 2021 Polling:




## 2022 Polling:




**OBSERVATION:** USACE PDT's face multiple challenges in quantifying NBS benefits, and in technical design construction guidance.

**RECOMMENDATION:** USACE should facilitate NBS implementation assistance based on PDTs' needs.

# 2022 Questionnaire: Facilitating NI Implementation

*Input from questionnaire helps to better understand the needs of the USACE EWN/NBS practitioners regarding NBS guidance*

What section(s) in existing USACE policy need clarification to be more helpful in implementing EWN/NBS in USACE projects?

"**Policy example - ER 1105-2-100 (pg. 2-19):**
**(5) Public Use and its Relation to Federal Participation.**
Do the same public access/ownership requirements that dictate federal participation/cost-sharing for beaches apply to marshes and back-bay shorelines?"

**"EM 1110-1-1601**
rewrite, include section on EWN, NNBFs focused on engineering analysis/basis of design minimums OR new EM (Hydraulic Design of NNBFs and Ecosystem Restoration projects"

"**ER 1105-2-100**
Consistency on the level of incremental analysis needed for NBS features that better aligns on their project purpose and their system function ex. dune and beach features"

**ER 1165-2-130, pg. 15 (3) d. and e.**
NBS that may require future periodic placement of sediment (e.g. marsh nourishment), are the future placements considered "continuing construction" (as periodic beach renourishment is) or "maintenance," which would be a 100% non-federal cost?

**"EM 1110-2-1416 & EM 1110-2-1205**
…Outdated…."

**"EM 1110-2-4000**
Update as it covers a lot of the deficiencies in EM 1110-2-141"

**"No USACE agency guidance currently exists for implementation of NBS."**

**"Coastal Engineering Manual"**

**"ER 1110-2-1150**
Update to highlight what level of detail and data collection are expected during recon, feasibility and PED"

**"ER 1105-2-100 3-9 Multipurpose Studies**
Embrace both AAHUs as well as BCR for AER & FRM benefits then we are really leveraging the power of the NNBF measures in our studies. Some standardization of how much detail is enough"

"**ER 1165-2-501**
differentiate between form vs process objectives, targeted on desired outcomes (success metrics)."

**"ER 1165-2-26**
A great document but does not get used as reason to include EWN/NNBFs. All the principals and objectives are consistent with EWN and NNBFs. EC or similar highlighting how these are linked would be nice."

**"ER 1110-2-1150**
Include a paragraph or section or appendix on expected level of data collection and engineering analysis for NNBFs by project phase in next updates with references to relevant guidance."

**"ER 500-1-1**
Allow projects to combine structural-nonstructural measures under one rehab plan to facilitate NBS in PL 84-99"

# Obstacles in Guidance Development

**USACE Guidance**

- **Time** - Development of guidance in USACE is a slow and tedious process.
- **Money** - There is limited funding for Guidance Development. Competing with other USACE guidance needs.
- **Flexibility** –
  - Updating existing guidance is difficult, time consuming and expensive
  - Many NI projects require site specific considerations.

**Natural Infrastructure Knowledge**

- New pilot projects that inform knowledge/research are being constructed regularly.
- New information is being published regularly.
- New applications are being identified with new solutions.

# Solution

- EWN working with Jacobs Engineering in collaboration with USACE Headquarters, E&C Directorate to develop **Engineering Practice Guides for NI**
- Support the forward momentum of Natural Infrastructure solutions in the field of engineering and design.

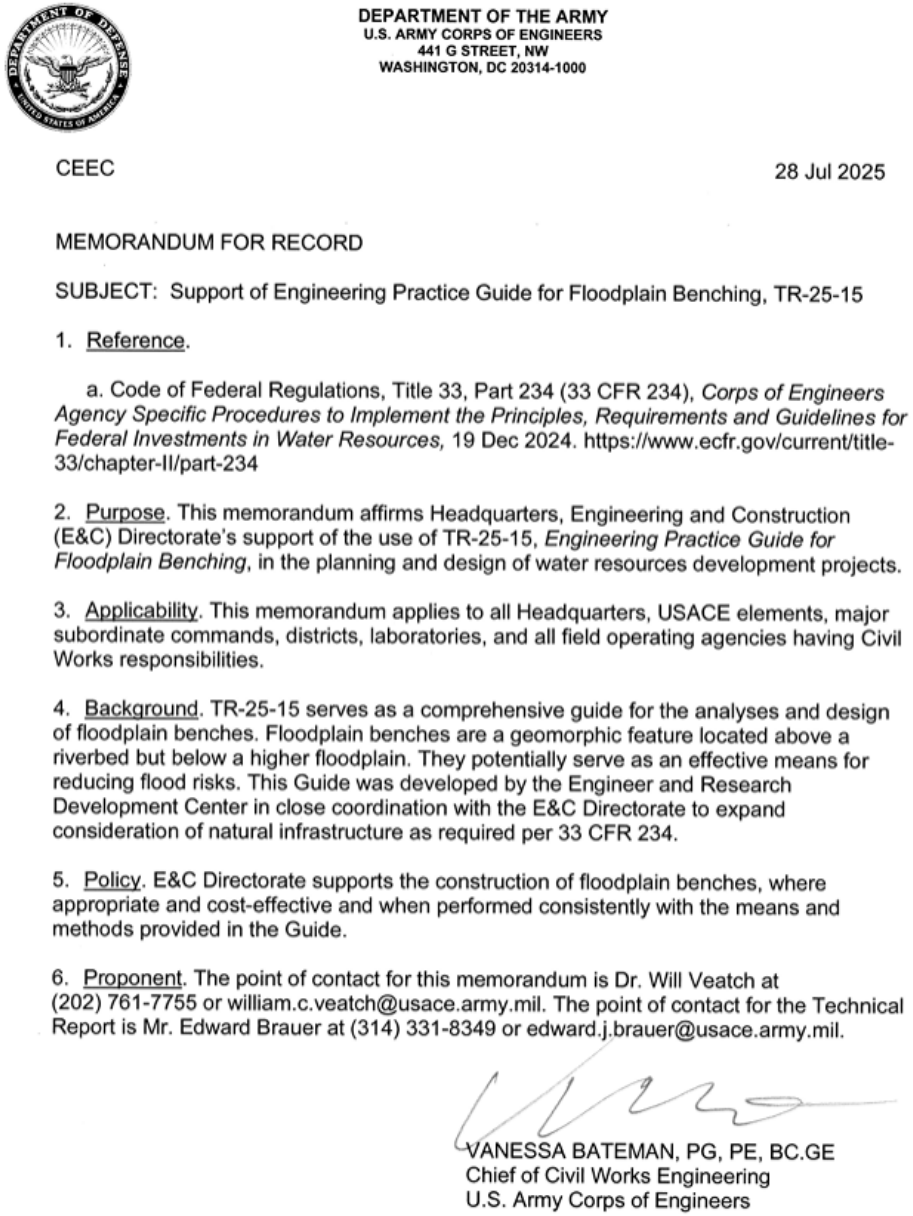
## Key Collaborative Moments

- Scoping - September 2022 *Engineering Guidance for Nature-Based Solutions: Defining Requirements and Products* workshop in Dallas, TX
- Kickoff - May 2023 *Developing Engineering Guidance for Design of NbS* workshop in Washington, DC
- Teams include SMEs from across ERDC, USACE Districts, Jacobs Engineering and other AEs, Academia.



# EWN/E&C Engineering ‘guidance’

- EWN working with USACE E&C and Jacobs Engineering to develop an Engineer Manual and Engineering Practice Guides
- EPGs are tiered off of the EM.
- All EPGs include a MFR from E&C that the *E&C Directorate supports the construction of each measure where appropriate and cost-effective and when performed consistently with the means and methods in the EPGs.*



DEPARTMENT OF THE ARMY
U.S. ARMY CORPS OF ENGINEERS
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WASHINGTON, DC 20314-1000

CEEC

28 Jul 2025

MEMORANDUM FOR RECORD

SUBJECT: Support of Engineering Practice Guide for Floodplain Benching, TR-25-15

1. Reference.

a. Code of Federal Regulations, Title 33, Part 234 (33 CFR 234), *Corps of Engineers Agency Specific Procedures to Implement the Principles, Requirements and Guidelines for Federal Investments in Water Resources,* 19 Dec 2024. https://www.ecfr.gov/current/title-33/chapter-II/part-234

2. Purpose. This memorandum affirms Headquarters, Engineering and Construction (E&C) Directorate's support of the use of TR-25-15, *Engineering Practice Guide for Floodplain Benching*, in the planning and design of water resources development projects.

3. Applicability. This memorandum applies to all Headquarters, USACE elements, major subordinate commands, districts, laboratories, and all field operating agencies having Civil Works responsibilities.

4. Background. TR-25-15 serves as a comprehensive guide for the analyses and design of floodplain benches. Floodplain benches are a geomorphic feature located above a riverbed but below a higher floodplain. They potentially serve as an effective means for reducing flood risks. This Guide was developed by the Engineer and Research Development Center in close coordination with the E&C Directorate to expand consideration of natural infrastructure as required per 33 CFR 234.

5. Policy. E&C Directorate supports the construction of floodplain benches, where appropriate and cost-effective and when performed consistently with the means and methods provided in the Guide.

6. Proponent. The point of contact for this memorandum is Dr. Will Veatch at (202) 761-7755 or william.c.veatch@usace.army.mil. The point of contact for the Technical Report is Mr. Edward Brauer at (314) 331-8349 or edward.j.brauer@usace.army.mil.

VANESSA BATEMAN, PG, PE, BC.GE
Chief of Civil Works Engineering
U.S. Army Corps of Engineers

# Engineering Manual (EM)

Traditional USACE Engineering document. "Guidance or reference of a continuing nature that may be standard or informational". Will specify that specific guidance is in TRs

TRs Can be developed quickly and updated regularly as new information becomes available. ERDC product vs. E&C Product

When appropriate, mid-level TRs can be produced with when additional information is needed between the planning actions and design actions.

The Design Guidance TR provides **detailed design and construction guidance** on a specific NBS.

**ERDC TR**
Alternative Bank Protection

**ERDC TR**
Analysis of Potential Actions to Enhance Floodplain Connectivity

**ERDC TR**
Tidal Flow Restoration for Wetlands

**ERDC TR**
Oyster Reefs

**ERDC TR**
Floodplain Benching

**ERDC TR**
Wood-Based Riverbank Stabilization

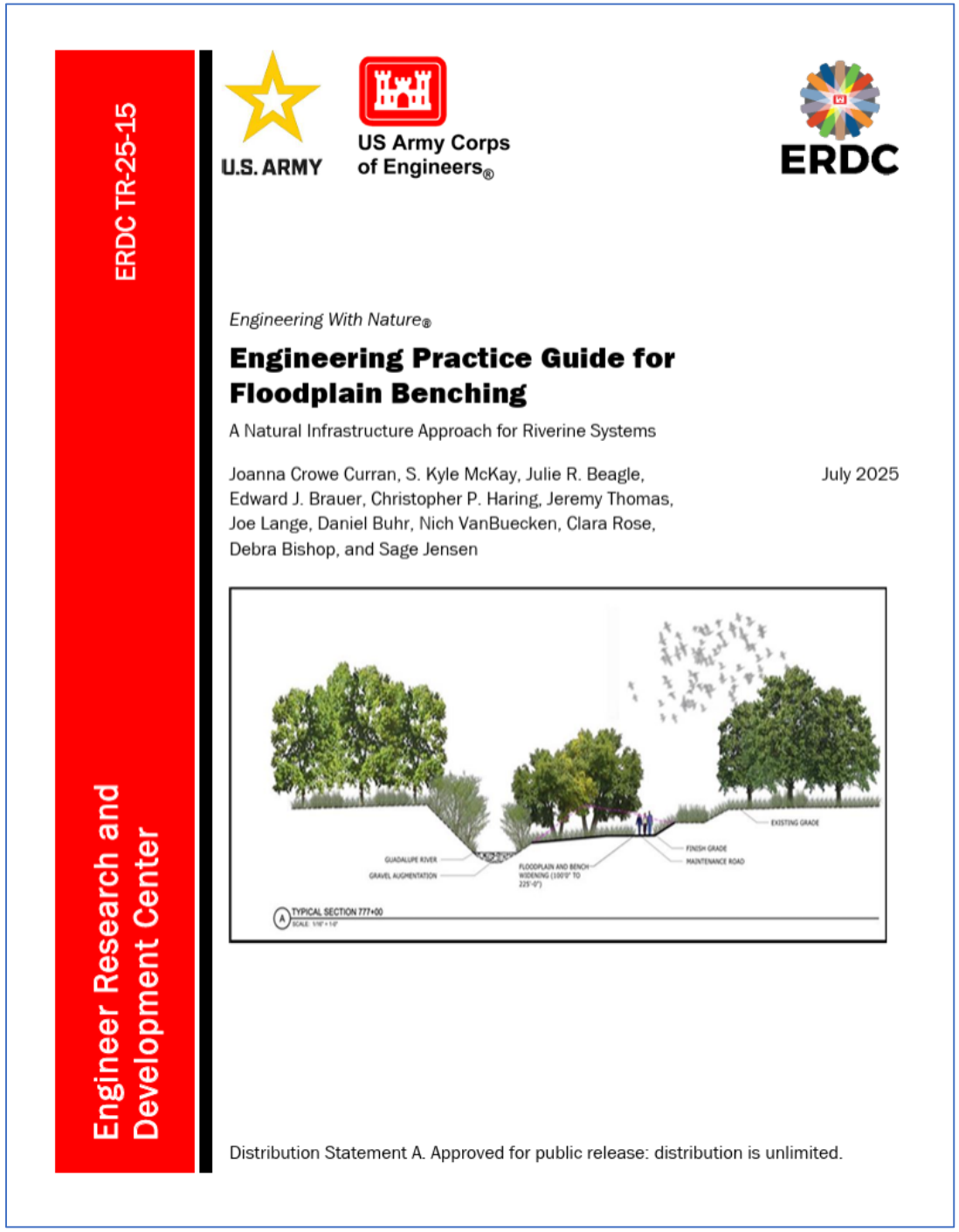
**ERDC TR**
Cobble and Gravel Beach Design

**ERDC TR**
Vegetated Bank Biostabilization

**ERDC TR**
Leaky Structures

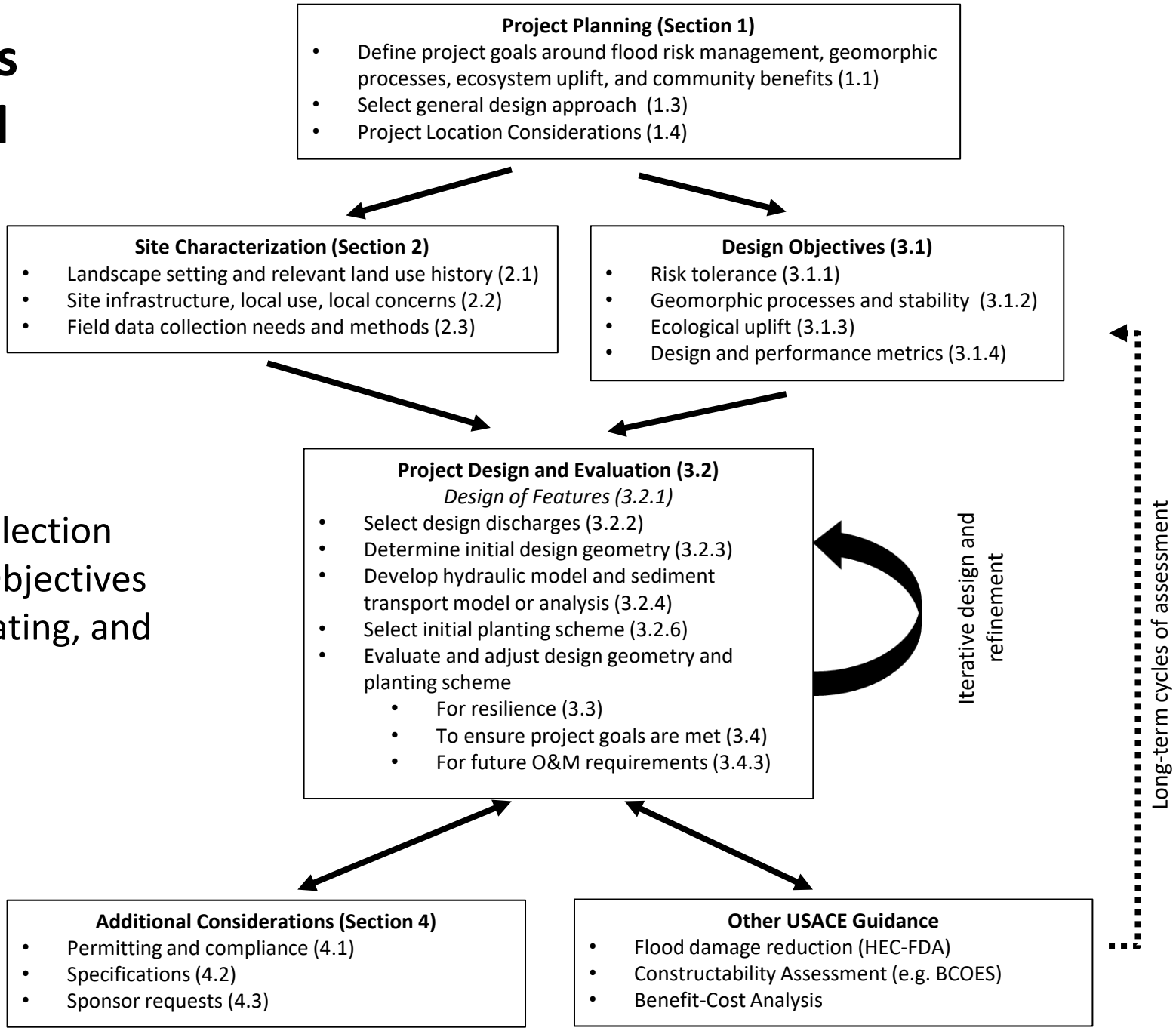
# Status of Engineering Practice Guides

- **Engineering Manual (in review)**
  - Civil Works Design: Leveraging Natural Infrastructure
- **Published EPGs**
  - Floodplain Benching
  - Oyster Reefs
  - Wood- Based Riverbank Stabilization (in review, publication Q1FY27)
  - Analysis of Potential Actions to Enhance Floodplain Connectivity (in review, publication in Q1FY27)
- **EPGs in Development**
  - Leaky Structures
  - Vegetated Bank Biostabilization
  - Tidal Flow Restoration for Wetlands
  - Cobble and Gravel Beach Design
- **Future EPG Topics**
  - Re-meandering
  - Coastal Hybrid Approaches



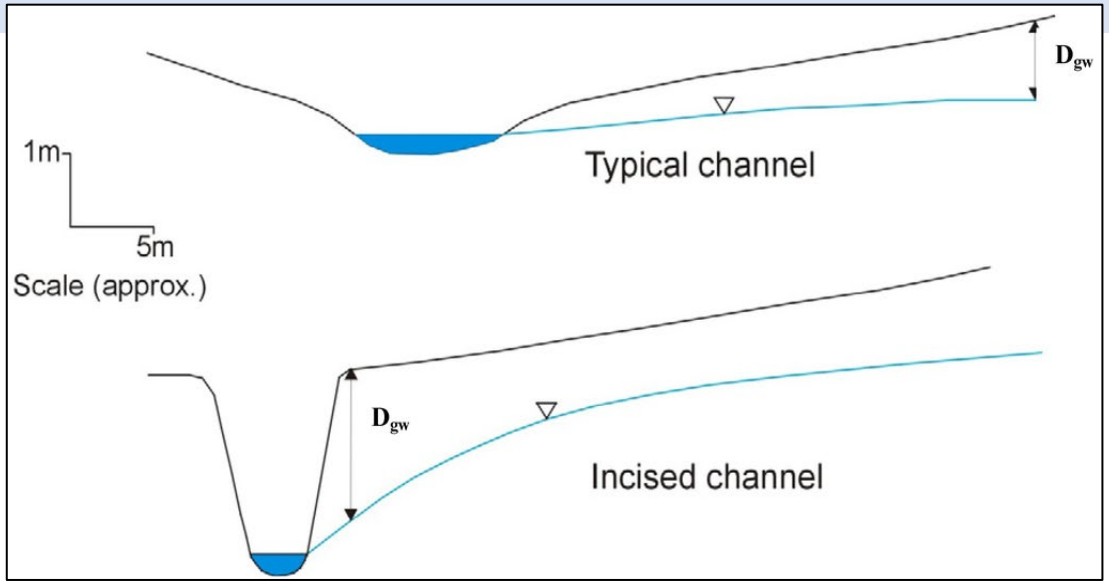
# Practice Guide Follows the Workflow Defined for Designing a Floodplain Bench

1. Planning and Site Selection
2. Desktop and Field Data Collection
3. Setting Goals and Design Objectives Creating the Design, Evaluating, and Iterating to a Final Design



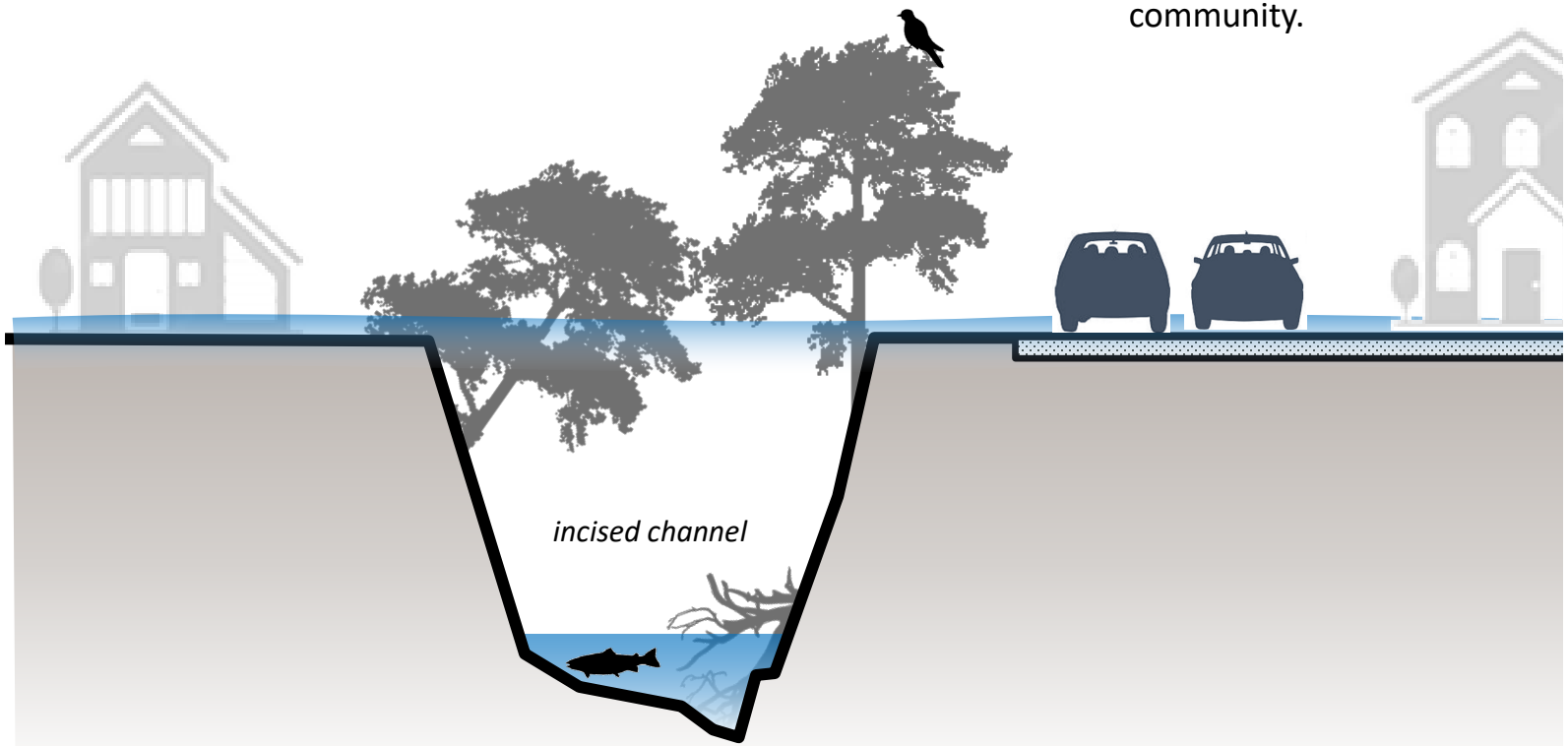
# For inland river systems where incision causes riparian flows to occur only during floods to the community

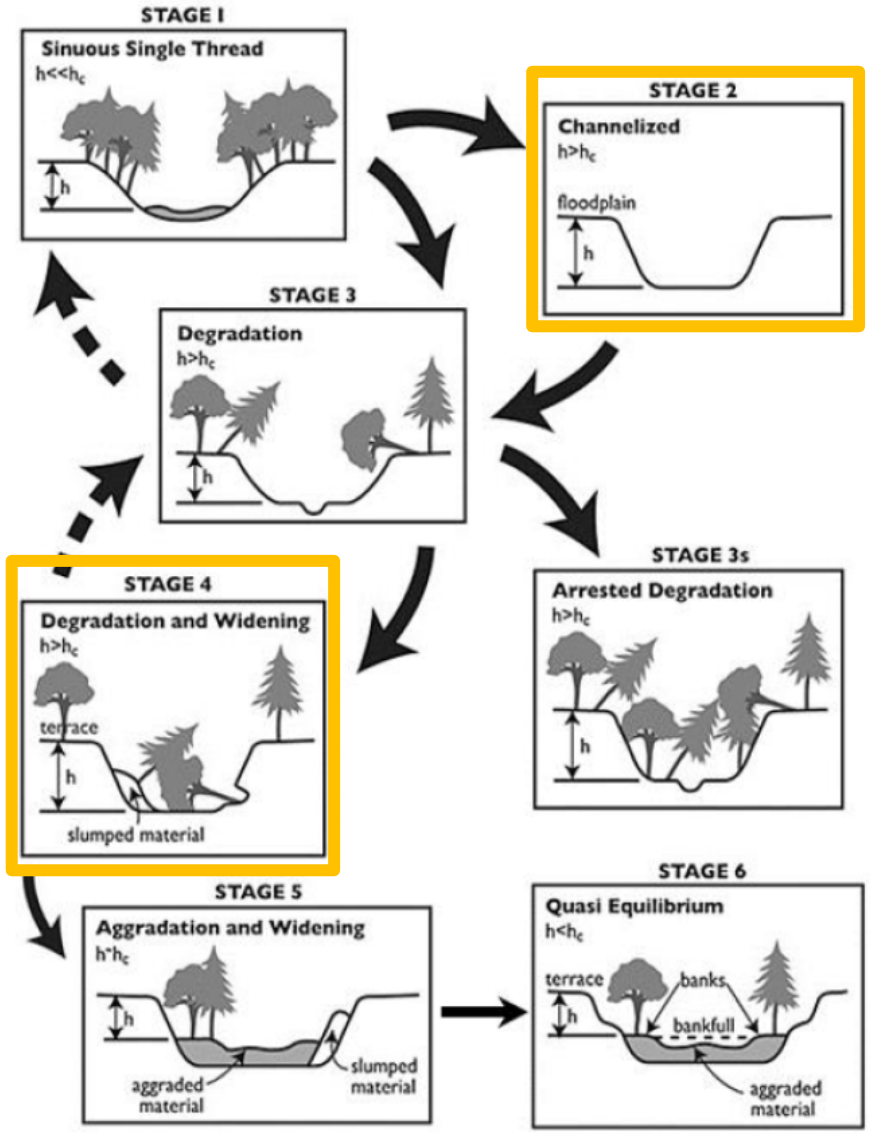
- Vertical erosion and a lack of overbank flow can lead to a lowered water table, drying floodplain soils
- Intervene where channel incision is a result of changes in flow or sediment supply and planform is stable
- Where an engineered solution is needed






# Consider Current Channel Morphology



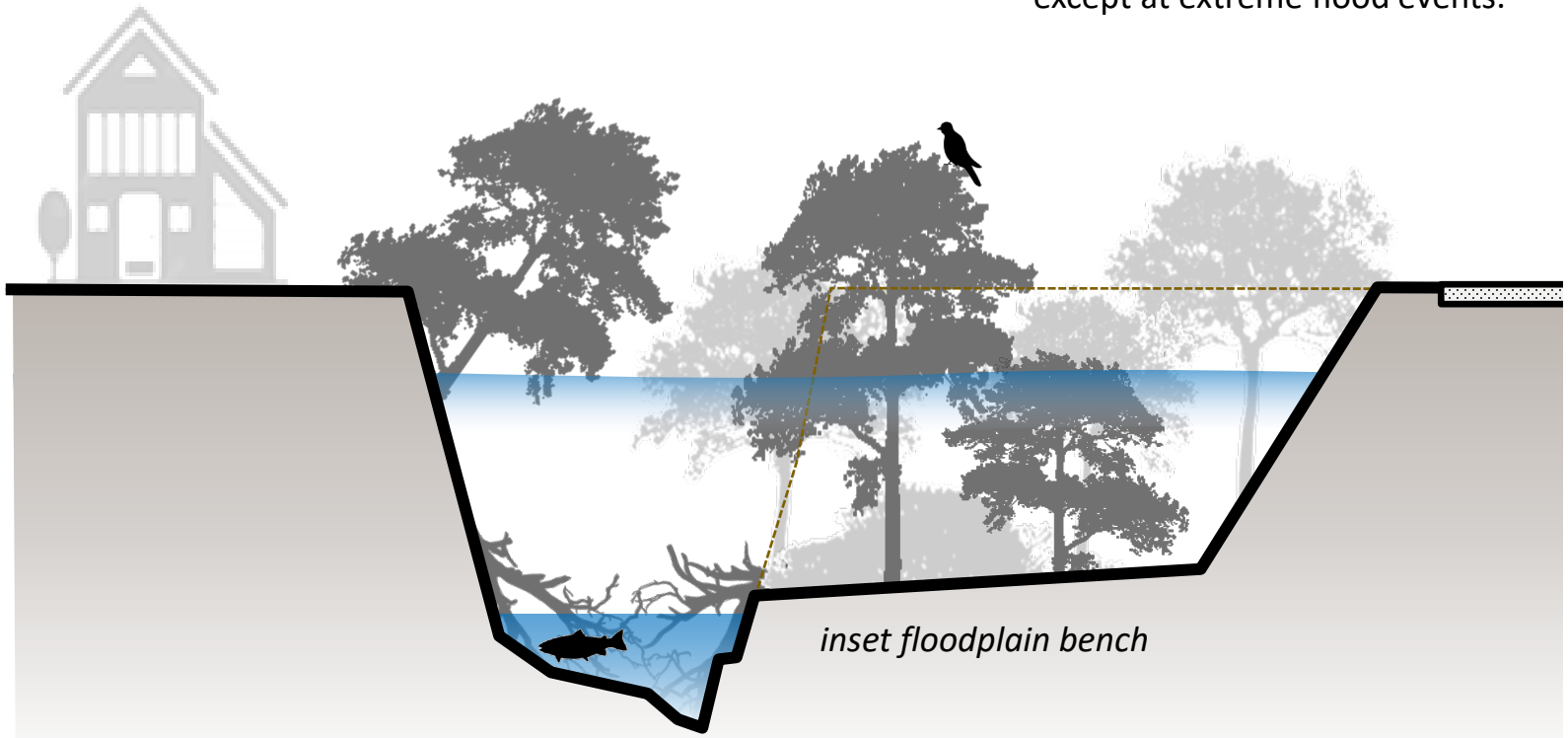



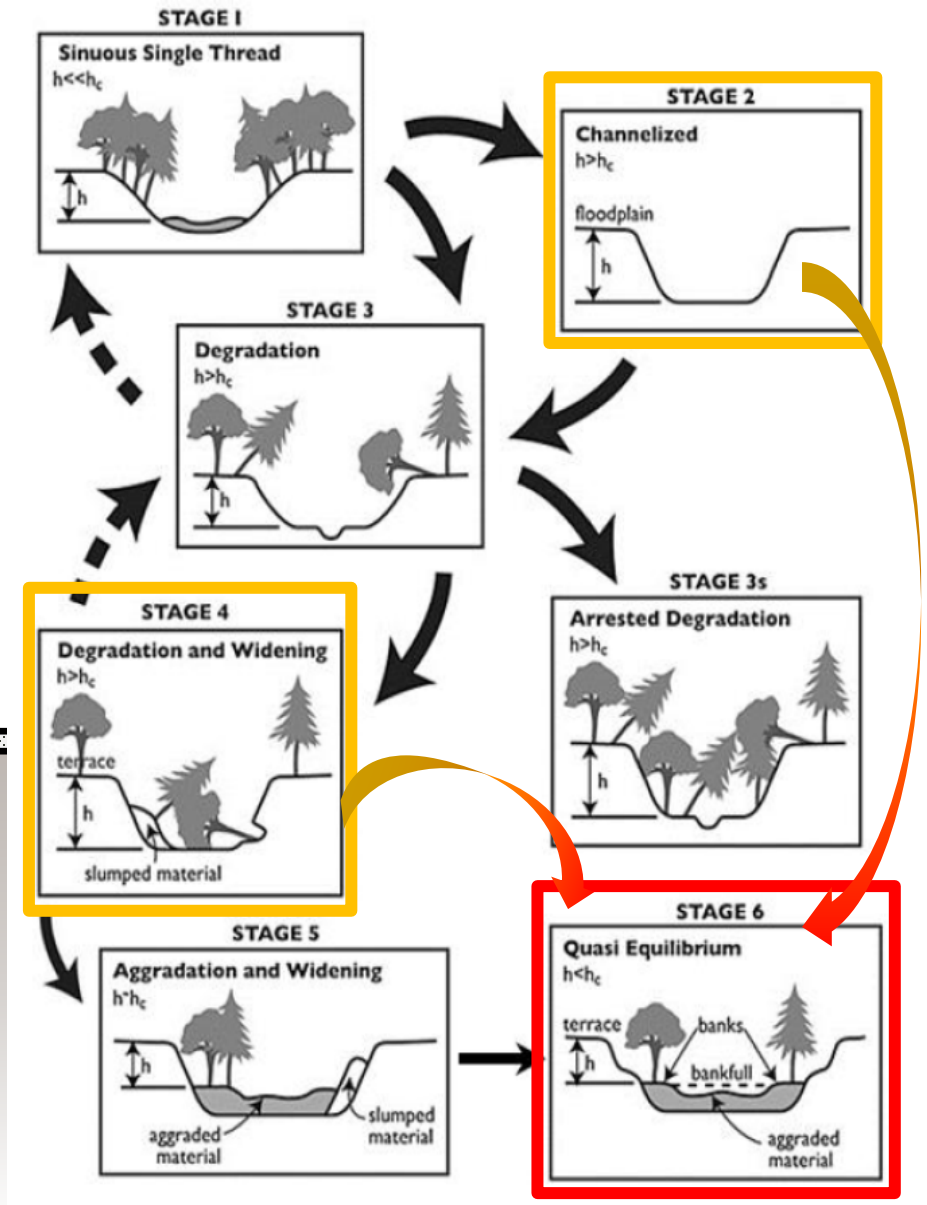

*Case study: Pajaro River FRM — USACE San Francisco District (J. Beagle)*

# Define Desired Channel Morphology

**A floodplain benching project skips in-between stages of river adjustment**

River contained within the banks except at extreme flood events.




*Case study: Pajaro River FRM — USACE San Francisco District (J. Beagle)*

# Goals Define the Project Purpose
# All Goals are Given Equal Weight and Importance

Flood Risk Management (1.1.1) —space for low-level flooding, lower flood peaks and velocities downstream, maintain or reduce flood risk

Geomorphic Function (1.1.2) — a channel geometry matched to current and future flow and sediment regimes for geomorphic equilibrium

Ecological Uplift (1.1.3) —aquatic and terrestrial habitat benefits within a larger riparian corridor with greater hydraulic diversity

Community Benefits (1.1.4) —recreation, access; the priorities of the sponsor and neighbors bring to the project



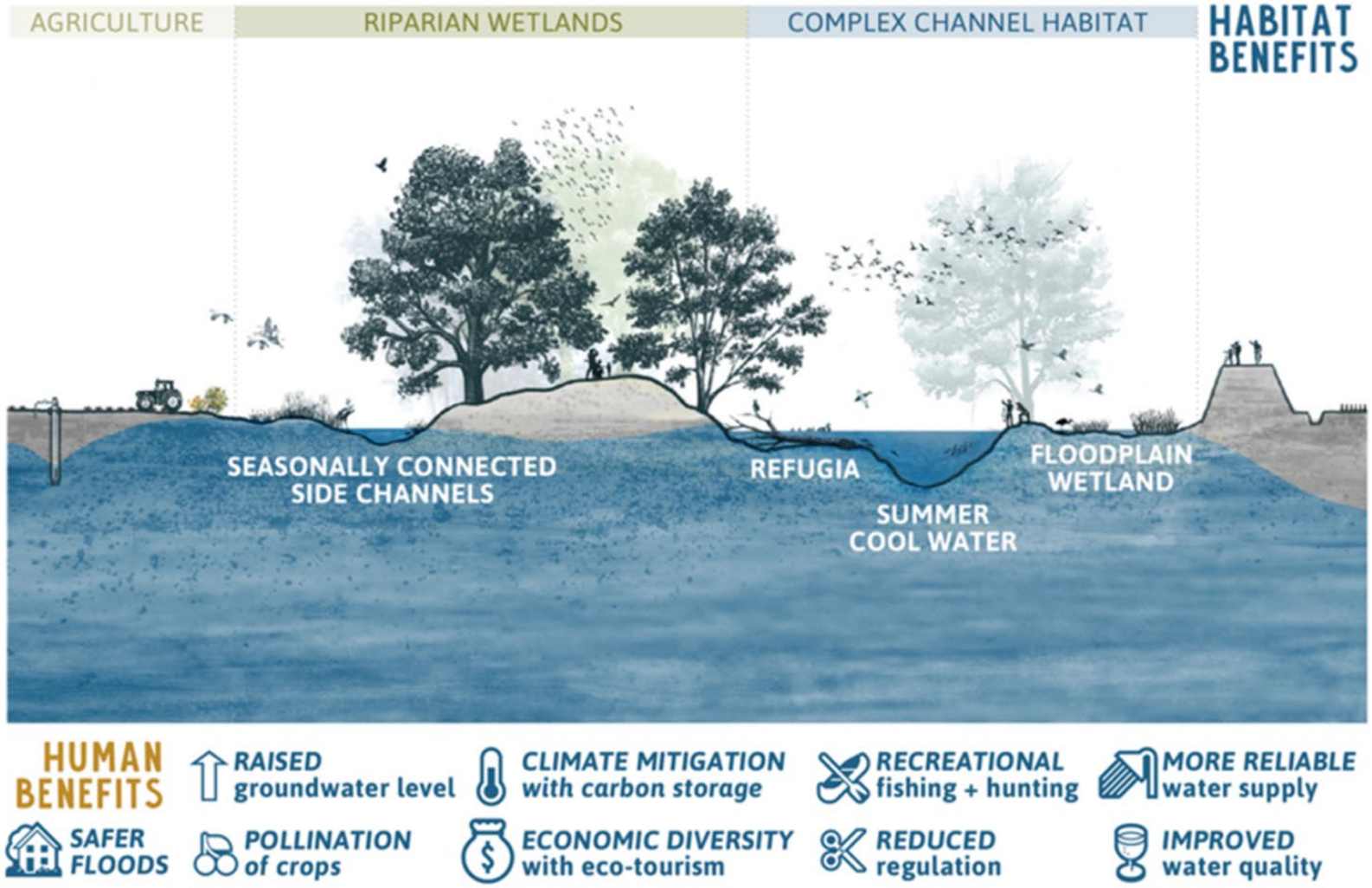
# Equal Goal Consideration Created a Multiple Purpose Project

Existing conditions
- Incised flashy system
- Narrow, encroached riparian corridor

As a Single Purpose FRM Project:
- Build a levee away from river
- Plan to truck in borrow material needed for construction

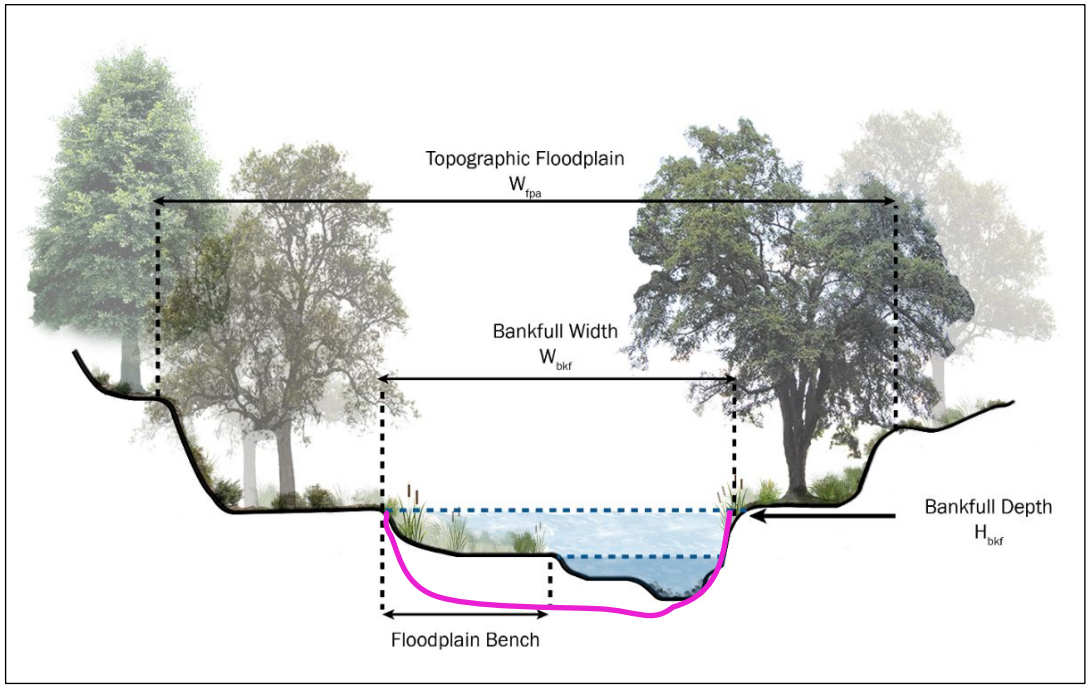
Community needs:
- Ground water depletion in valley
- Special status species needs
- Recreation
- FRM

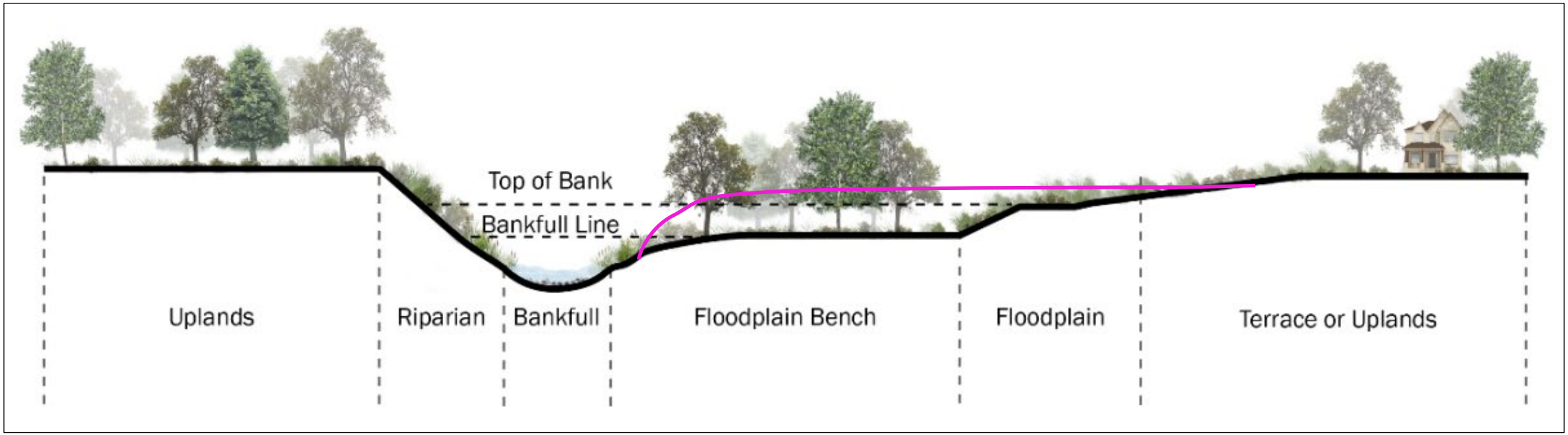
With Benching Project Added:
- Excavated bench supplies borrow material
- Riparian corridor with floodplain wetland
- Raised groundwater table and increased groundwater recharge



# Two general methods to create bench

- Build a bench within the existing channel cross section
- Lower the adjacent floodplain to create a bench and wider total cross section

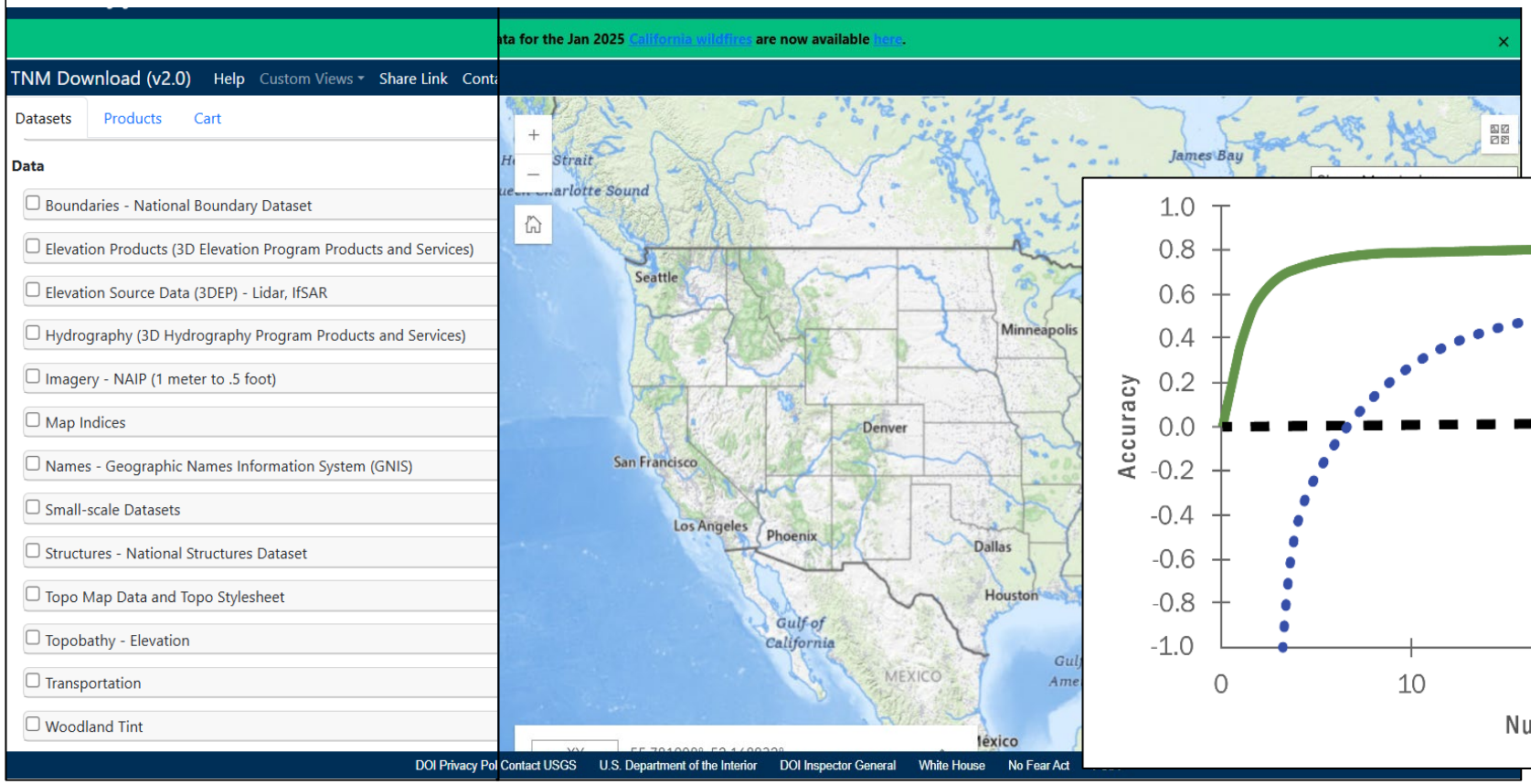


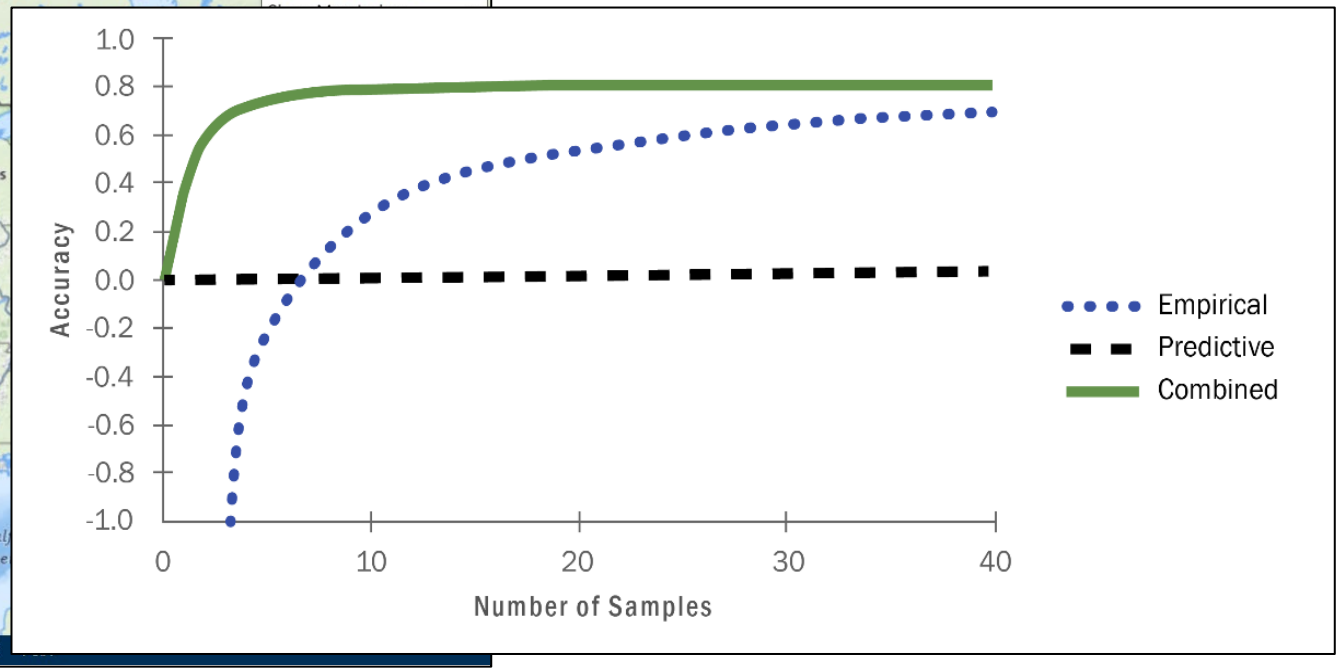



# Identify Site Constraints and Available Data, and Begin Collecting Field Data

- 2.1 Desktop — gather what already exists and narrow the reach
- 2.2 Societal — past and future land use, infrastructure, and who to talk to
- 2.3 Field — collect only what the desktop work could not tell you





# Ignoring Sediment Is a Common Driver of Failure

Is it a sand or gravel bed channel?

- Implications for field data collection methods

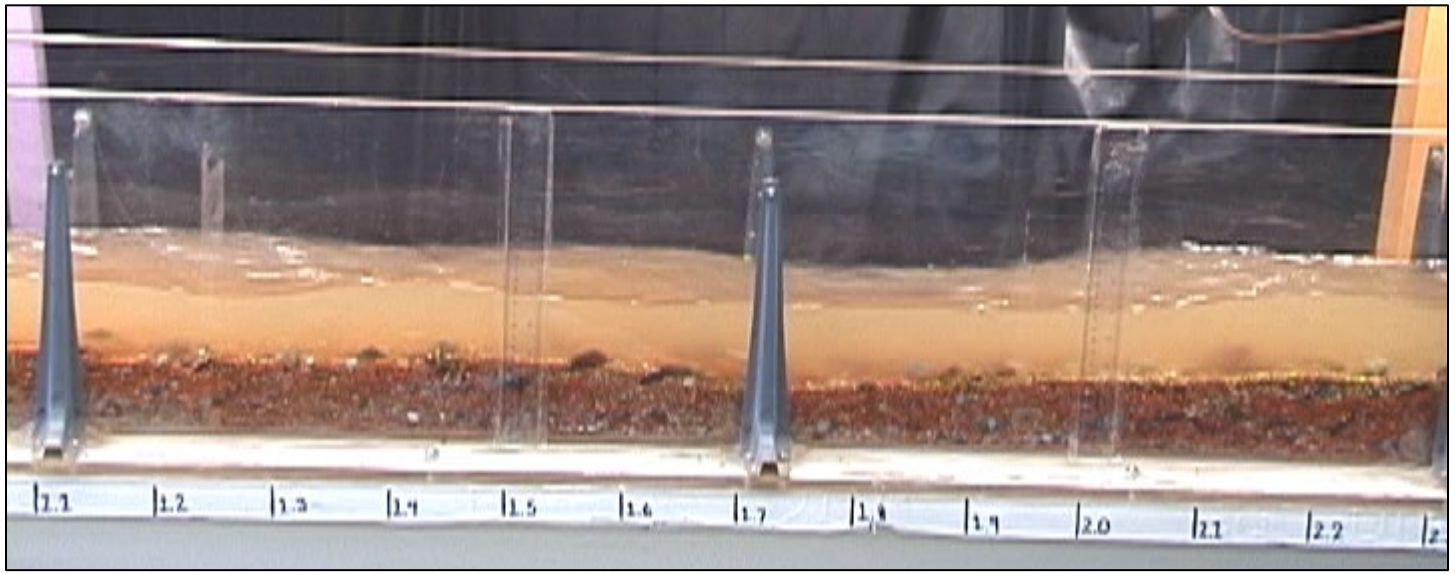
Will the bench elevation alter bedload transport?

- Implications for design





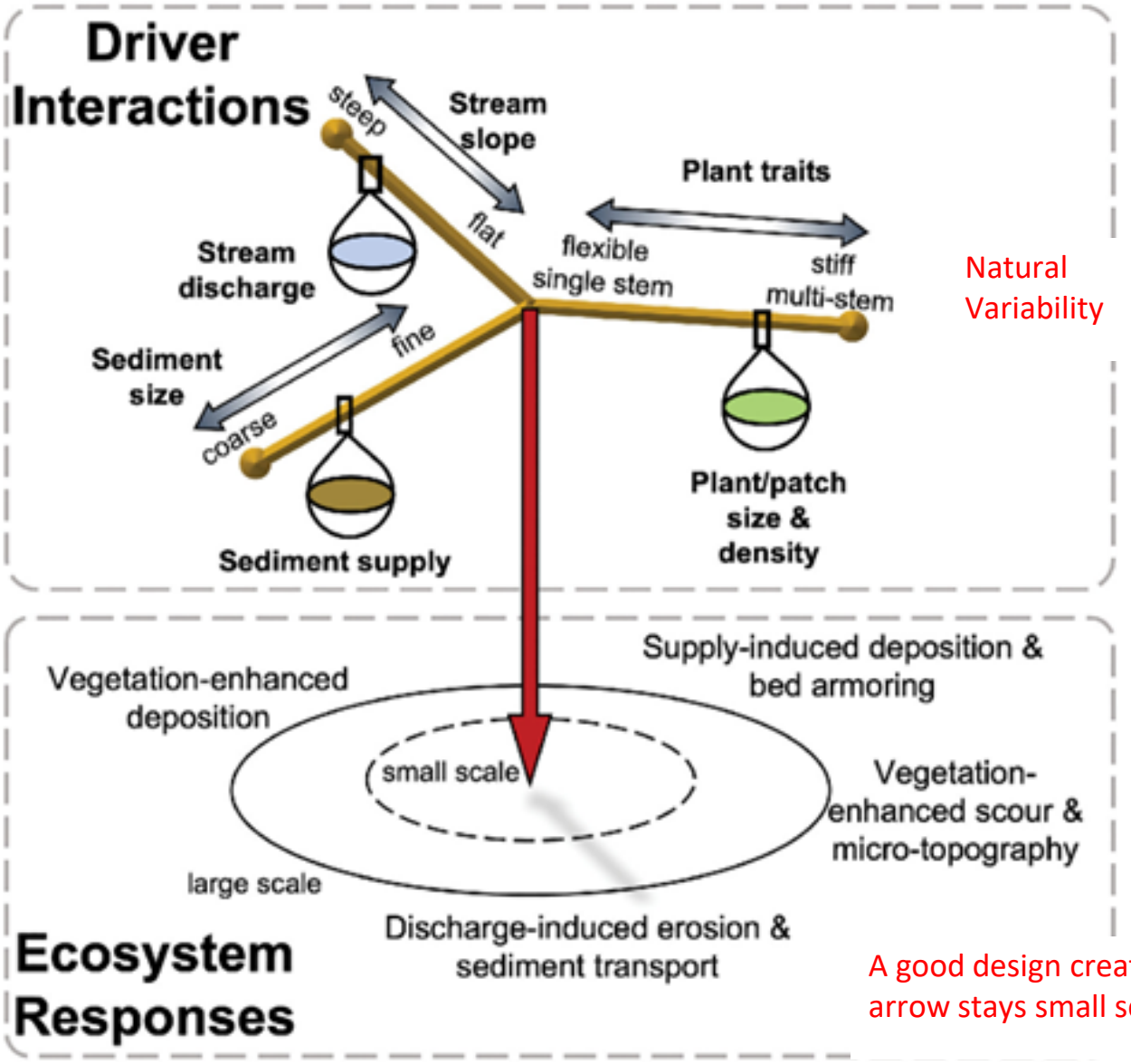




# Table 1 — Data checklist at the end of Section 2

| Question to Answer from Collected Data | Desktop | Field |
|---|---|---|
| What is the social context for floodplain benching (users, community needs, cultural context, societal motivations)? | 2.2 | |
| How does site physiography matter for project design? | 2.1.1, 2.1.2 | |
| How has the channel changed over recent history (10 years, 100 years)? | 2.1.1, 2.1.3, 2.1.5 | |
| What is the stage of channel evolution? | 2.1.1, 2.1.3 | 2.3.1 |
| What are estimated to be future levels of stability or dynamism under current channel geometry (pre-project)? | 2.1.1, 2.1.3, 2.1.4 | |
| How large is the floodplain? | 2.1.4 | |
| What are the channel width and longitudinal profile? | 2.1.3 | 2.3.1 |
| What are current uses of the floodplain? Are there notable societal assets to consider? | 2.1.3, 2.2 | verify |
| What aspects of historical or cultural significance should be considered in design? | 2.2.3 | |
| Is there infrastructure in the area that could impact design or the amount of acceptable risk? | 2.2.1, 2.2.2 | verify |
| Are there plant or animal species of concern or interest in the area? | 2.1.5 | 2.3.6 |
| What are the native forms of vegetation in the region? | 2.1.5 | 2.3.5, 2.3.6 |
| What soils are at the site, and what does that mean for excavation? | 2.1.1 | 2.3.4 |
| What is the grain size distribution of sediment on the channel bed? | 2.1.2 | 2.3.2 |
| What is the sediment supply? | | 2.3.3 |
| What are the range of flows at the site and the different flow frequencies (10%, 50%, 90% flows)? | 2.1.4 | |

# Design Objectives are Defined so Project Meets Design Goals




Risk tolerance (3.1.1)
Geomorphic processes and stability (3.1.2)
Ecological uplift (3.1.3)

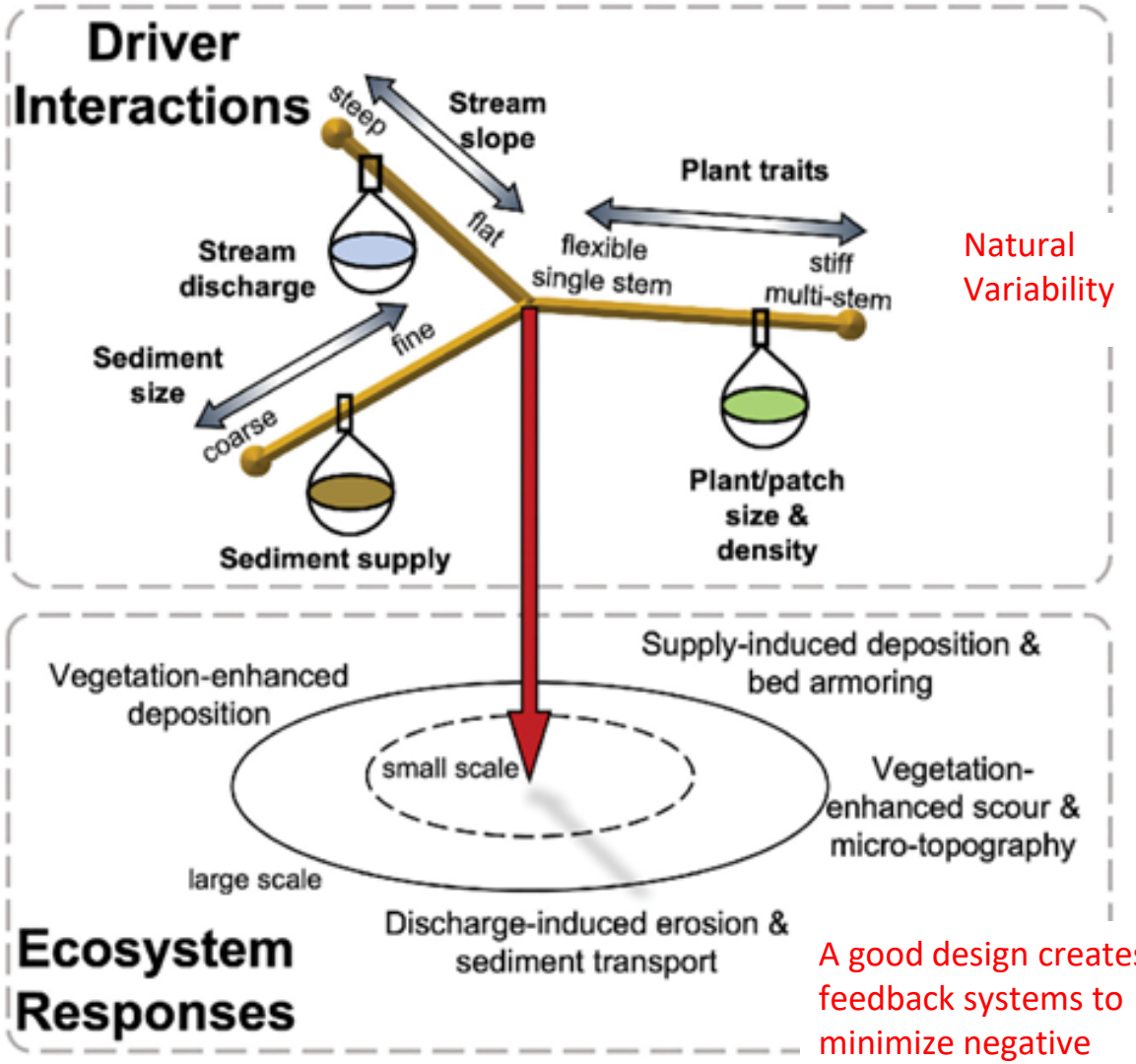
Design objectives connect to project goals and help define the risks that could lead to failure

- Bench erodes — too dry for the ecosystem goal
- Channel incises — bench floods too rarely
- Bank erosion upstream or downstream of the bench
- Bench aggrades — flood risk goal not met
- Invasives take over — habitat and conveyance lost
- Deposition or erosion reaches infrastructure or private property

A good design creates resilience so arrow stays small scale

Image from Bywater-Reyes, Diehl, Wilcox, Stella, and Kui. 2022. ESP&L, 47 (10): 2410–36. https://doi.org/10.1002/esp.5385.

# Metrics Quantify Project Objectives and Build in Resilience




A good design creates feedback systems to minimize negative impacts

Metrics:

- define how much change can occur before project objectives are at risk
- reflect acceptable risk and natural variability
- identify what is more and less critical in the design
- establish criteria for evaluating the design
- set up future O&M
- set threshold for adaptive management

What is the tolerance level for erosion or deposition on the bench for the vegetation to survive and FRM met?

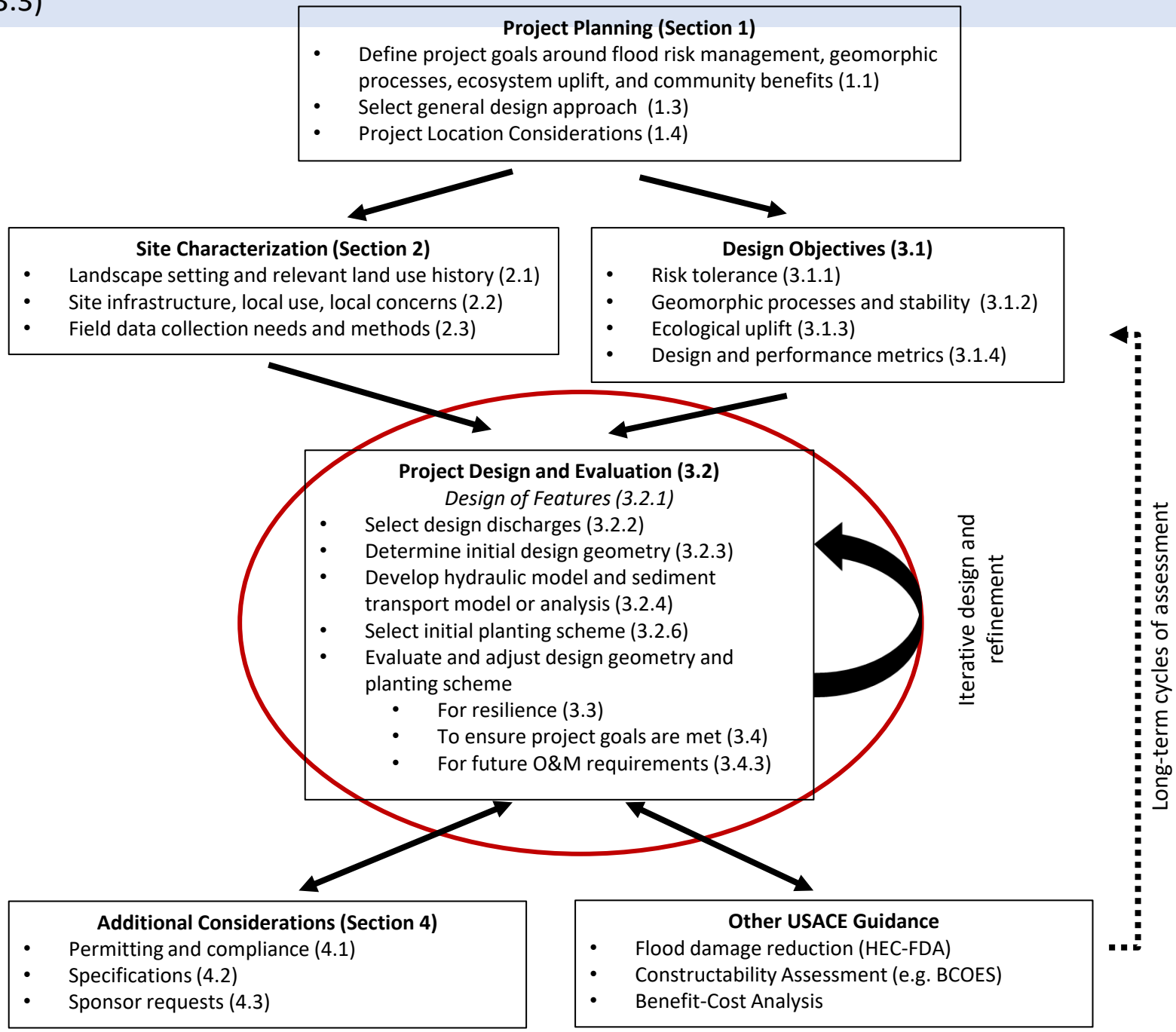
How much can the channel bed elevation change and the flows continue to inundate at the desired frequency and level before risking project goals?

What is the limit to planform change before impacting infrastructure or private property?

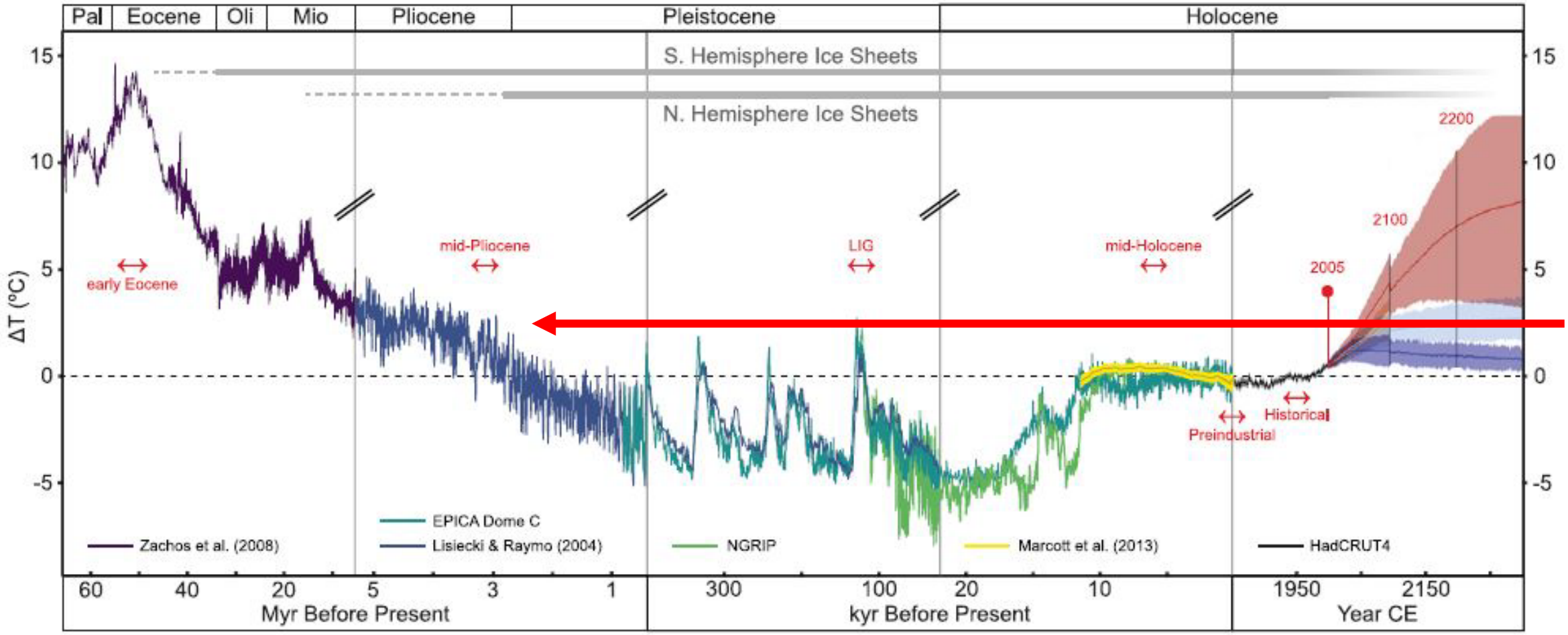
Define the minimum expected level of ecosystem diversity and abundance, FRM, and community benefits that need to be maintained

# Design: Develop Floodplain Bench Design (Section 3.2-3.3)

| Design Phase | Design Aspect | Specific Criteria | Data | Design |
|---|---|---|---|---|
| **Establish Goals and Objectives** | Risk Management | Inclusive of flood risk management and setting the criteria defining risk to project success | 1.2.1 | 3.1.1 |
| | Geomorphic Processes and Stability | Inclusive to those processes that can be improved as a result of changes to the independent parameters. | 1.2.2 | 3.1.2 |
| | Ecological Lift | Inclusive of all habitat and ecosystem features that can be improved with the project | 1.2.3 | 3.1.3 |
| | Community Benefits | Inclusive of the benefits to the surrounding community and future O&M at the project | 1.2.4 | 3.4.1, 3.4.3 |
| **Develop Initial Design** | Design discharge | Determine the discharges to be used in design | 2.1.4, 2.1.3 | 3.2.2 |
| | Bench width | Set an initial width to accommodate anticipated sediment supply and grain size distribution | 2.3.2, 2.3.3. | 3.2.3, 3.2.5 |
| | Bench elevation | Set for inundation frequency and duration using the stage-discharge curve and the flow frequencies | 2.3.1 | 3.2.3, 3.2.7 |
| | Bench side slope | Set to avoid fish stranding, generally similar to existing floodplain slope or 5H:1V | 2.3.1, 2.3.4 | 3.2.3, 3.2.8 |



# Develop Initial Design for Current and Anticipated Future Flow and Sediment Supply Conditions



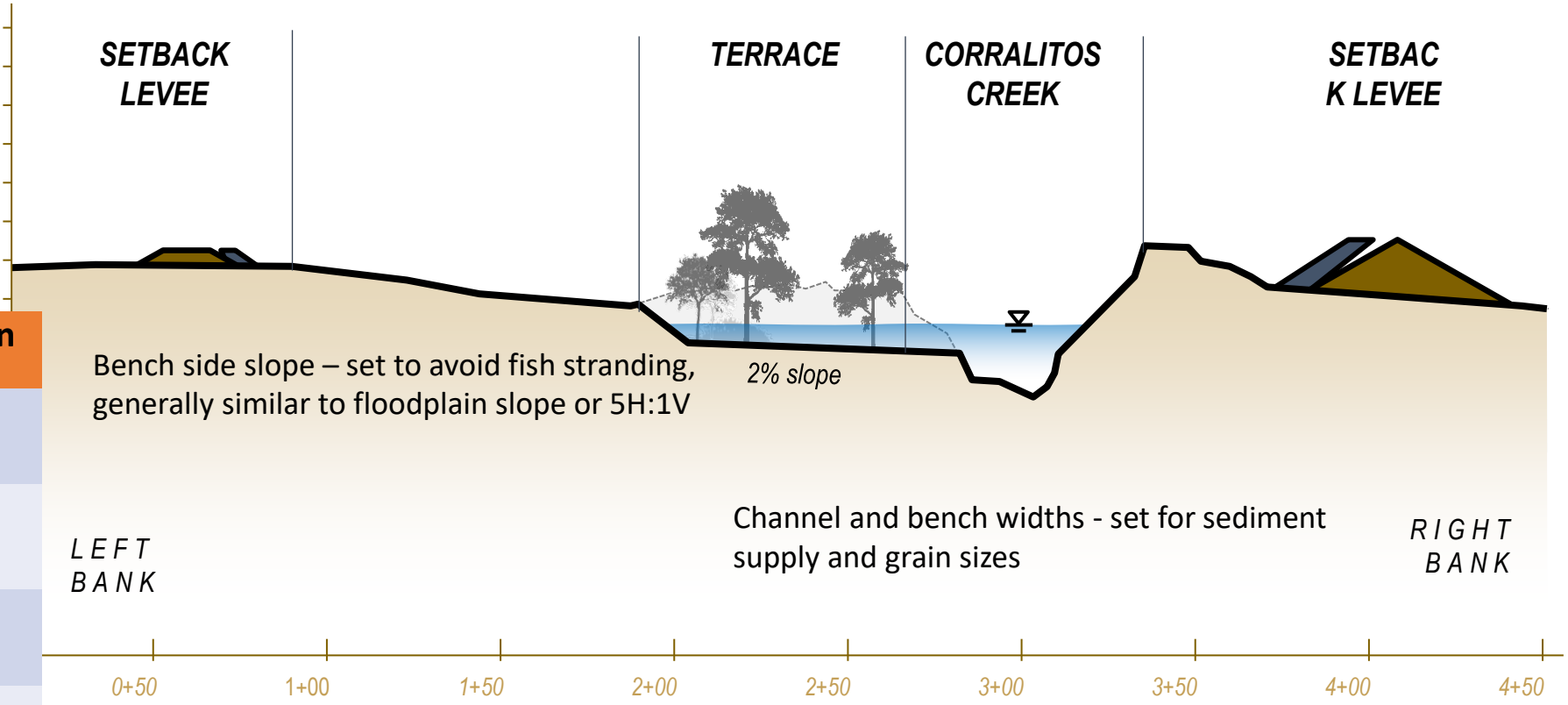

Burke et al., 2018, PNAS 115 (52): 13289

# Initial Design Uses Design Discharges

Design discharges may include bankfull, recurrence interval, ecological, effective flow rates

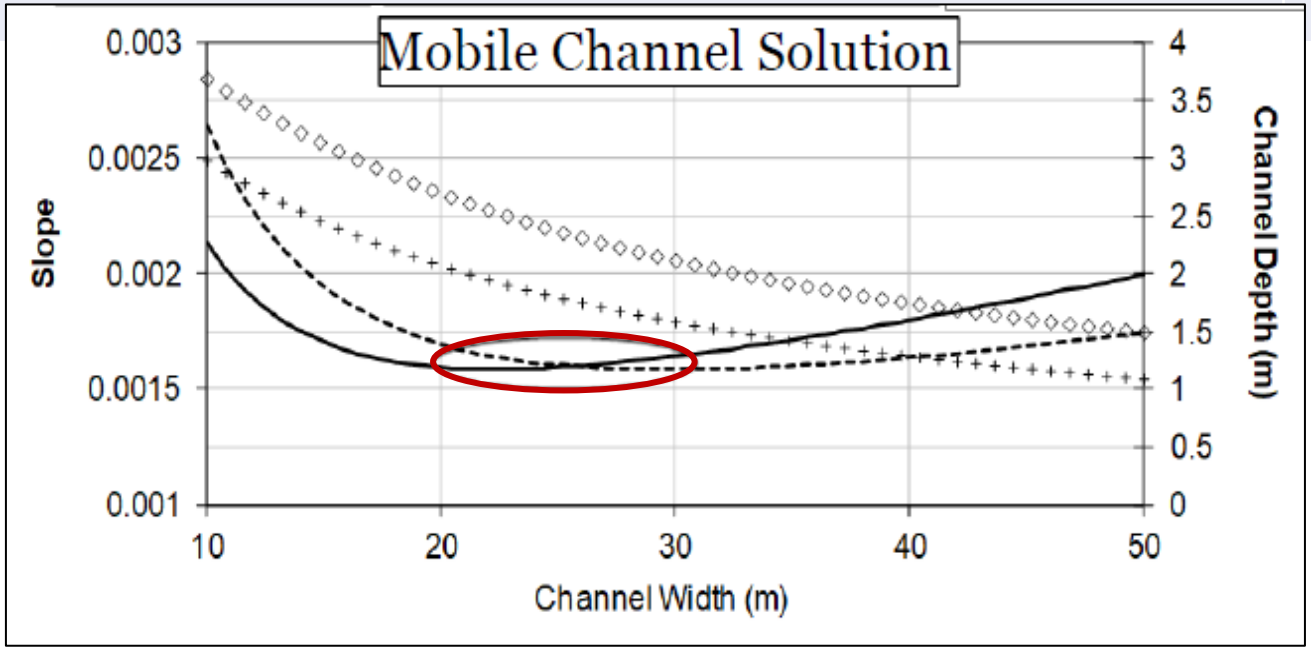
| Design Aspect | Data | Design |
|---|---|---|
| Design discharge | 2.1.4, 2.1.3 | 3.2.2 |
| Bench width | 2.3.2, 2.3.3 | 3.2.3, 3.2.5 |
| Bench elevation | 2.3.1 | 3.2.3, 3.2.7 |
| Bench side slope | 2.3.1, 2.3.4 | 3.2.3, 3.2.8 |
| Bench longitudinal slope | 2.3.1 | 3.2.3 |
| Channel side slopes | 2.3.1, 2.3.4 | 3.2.3, 3.2.8 |

**Corralitos Creek Example**



| Design Phase | Design Aspect | Specific Criteria | Data | Design |
|---|---|---|---|---|
| **Evaluate Design** | Hydraulic performance | Evaluate over multiple hydrographs that reflect existing and anticipated flow rates of importance for project success and to ensure flood risk management | 2.1.4 | 3.2.4 |
| | Sediment transport | Determine sediment sizes in transport above the bench elevation and if transport will affect bedload transport in the main channel; can be evaluated from the $D_{50}$ on the bench and bed surface over multiple hydrographs | 2.3.2, 2.3.3 | 3.2.5 |
| | Deposition / erosion | Evaluate over multiple hydrographs to ensure topography changes are within risk tolerance | | 3.2.5, 3.2.6 |
| | Flow velocities on bench | Ensure velocities on the bench surface will not prevent vegetation growth (typically less than 4 feet per second), which may be species-, season-, or life-stage dependent | | 3.2.6 |
| | Seasonal vegetation | Evaluate over different seasons using roughness values to reflect anticipated level of growth | 2.3.5, 2.3.6 | 3.2.6, 3.2.7 |
| | Future resilience | Evaluate over multiple hydrographs and sediment supplies to evaluate design resilience to future change | | 3.3 |

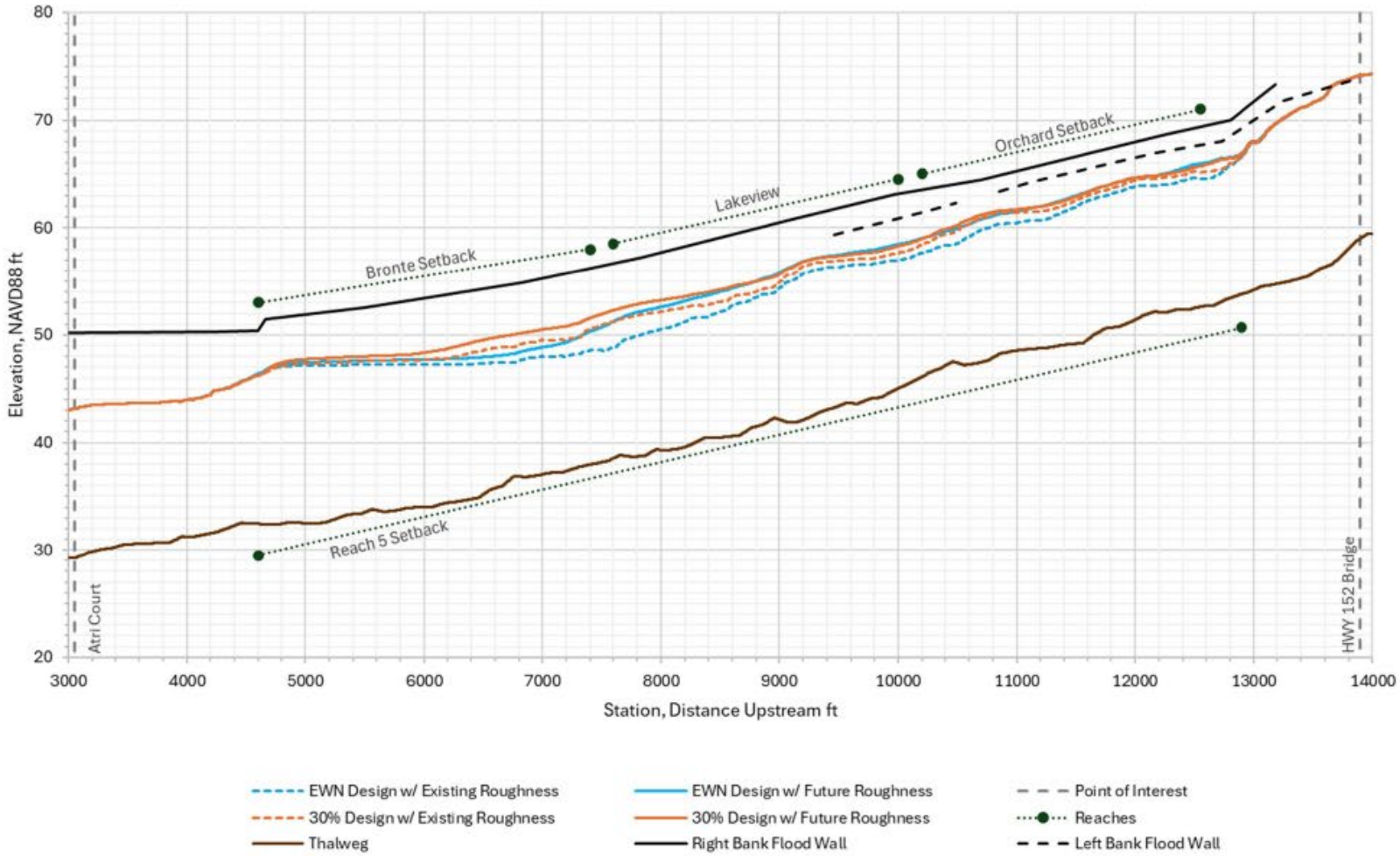
Iterate to find the channel and bench widths that create the geometry most resilient to changes in flow and sediment supply



# Reach 5: Hydrodynamic Results

Hydrodynamic modeling results:

- The EWN design reduced WSE compared to the 30% design for existing roughness
  - EWN project design features increased the channel cross-sectional area with the proposed grading.
- Under future roughness, WSE reductions were similar in the Bronte and downstream Lakeview reaches, while the upstream Lakeview and Orchard reaches showed no change.

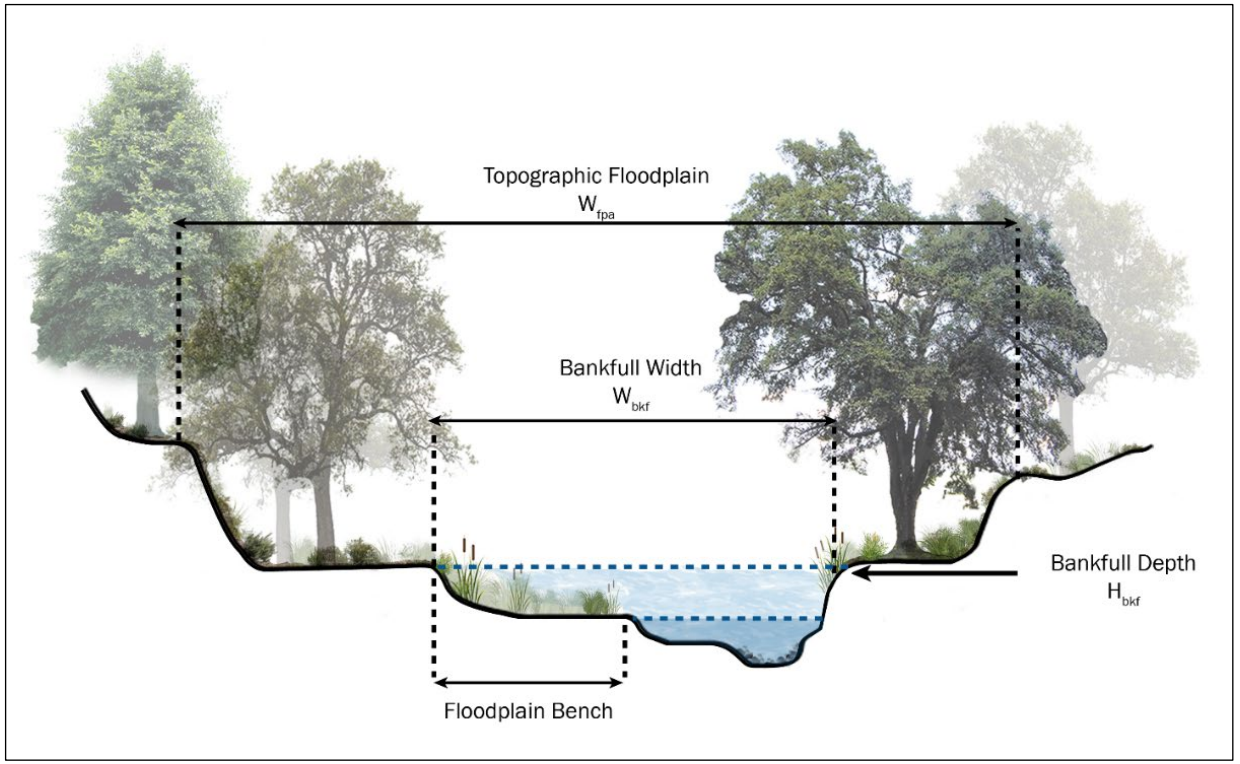



*Case study: Pajaro River FRM — USACE San Francisco District (J. Beagle)*

| Design Phase | Design Aspect | Specific Criteria | Data | Design |
|---|---|---|---|---|
| **Refine Design Iteratively** | Bench width and elevation | Adjust to remain within risk tolerances | | 3.2.4 |
| | Planting | Adjust species and distribution for risk tolerances | | 3.2.7, 3.4.2 |
| | Bank and bench side slopes | Adjust with knowledge of planting and accompanying stability from planting | | 3.2.7, 3.2.8 |
| | Bank Protection | Utilize bioengineering to enhance bank stability as needed in final design | | 3.2.8 |
| | Ecological features | Add habitat features (bat boxes, topographic variability) to enhance ecological outcomes | | 3.2.7, 3.4.1 |
| | Social features | Adjust design to accommodate use of the site by the surrounding communities | | 3.3.2, 3.4.1, 3.4.4 |

Other Benefits:

- Walking or Biking Paths
- Benches
- Park Space
- Increase local pollinator populations
- Attract birds of interest to bird watchers
- Optimized geometry and plants to encourage pollutant bioretention
- Reuse excavated materials in support of other infrastructure development

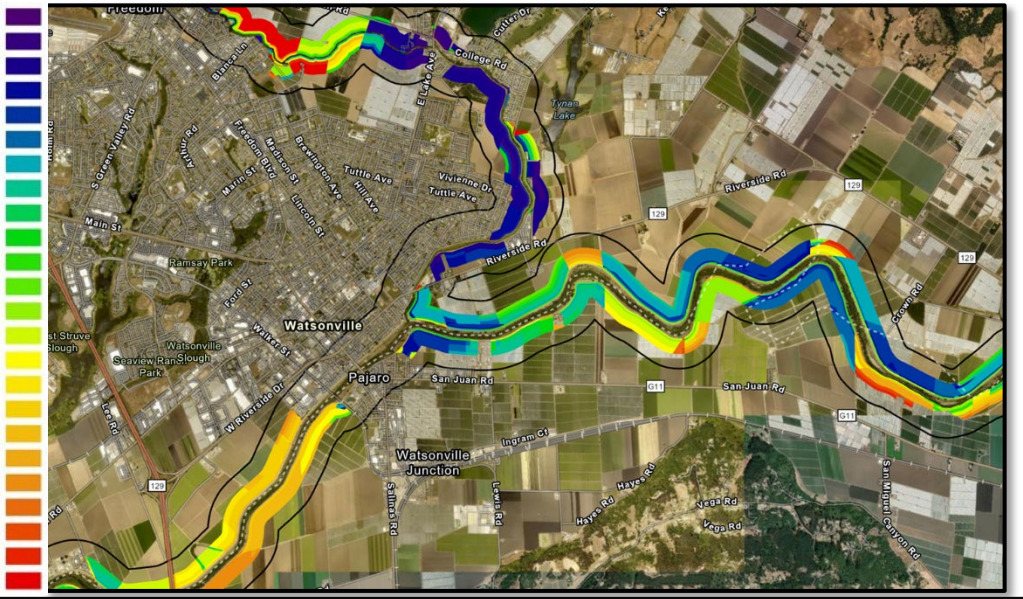


# Optimize the project

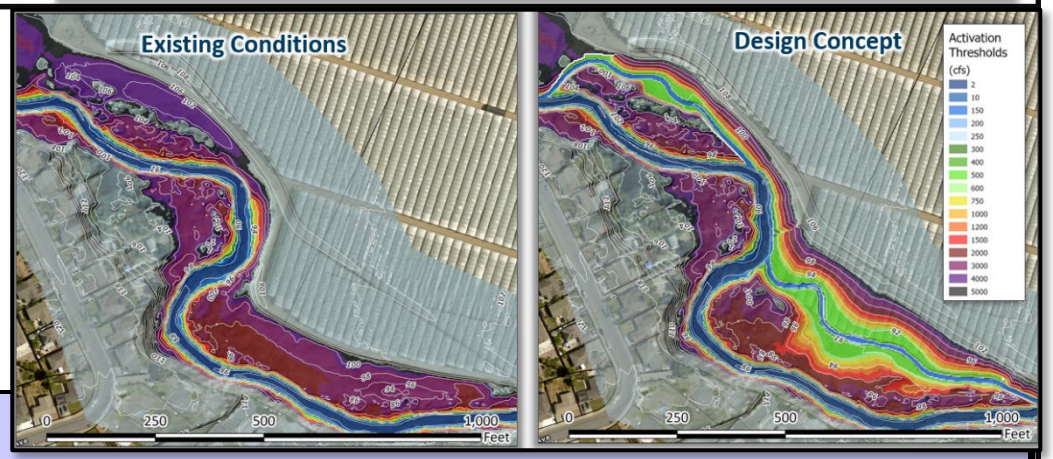
## Where does floodplain reconnection make sense to maximize benefits to ecosystem and communities

https://storymaps.arcgis.com/stories/f899bf3c36a2403d9e0bd3c70dc2dfc5

Identification, Analysis, and Prioritization




From Ideas to Implementation



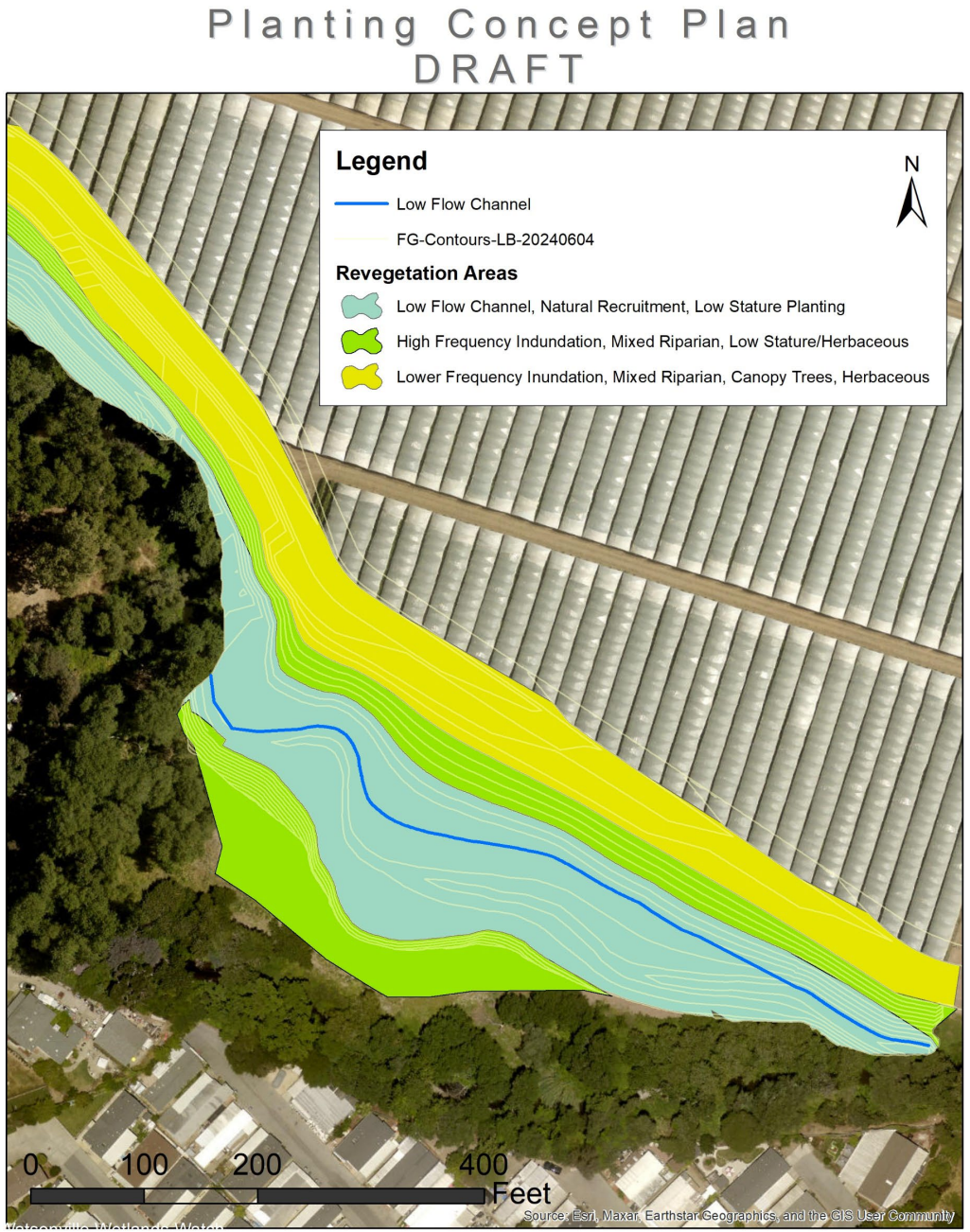

| Metric | Baseline (EG) | Concept (FG) | Difference (FG - EG) |
|---|---|---|---|
| Inundation (Acre-days / WY) | 1409 | 1416 | 7 |
| Habitat (Acre-days / WY) | 397 | 399 | 2 |
| Recharge (Acre-feet / WY) | 589 | 617 | 28 |

# Future O&M requirements
# Excavated sediment reuse
# Sponsor requests

Set expectations for the first five years

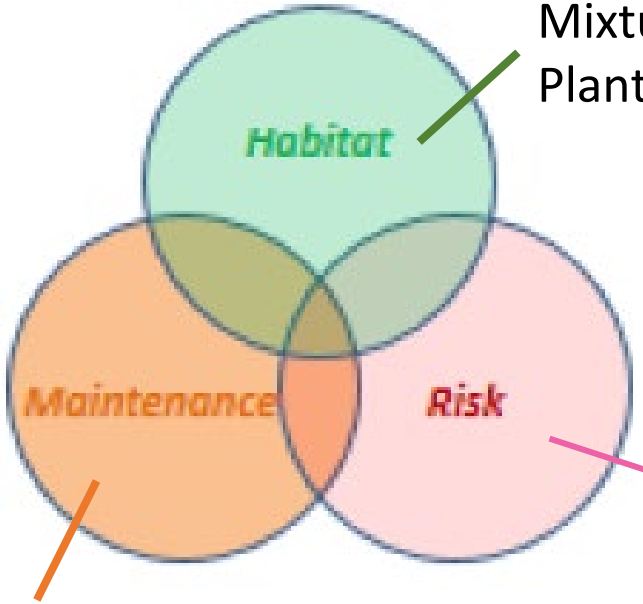
- Monitor bench elevation and width against geomorphic stability thresholds and risk tolerances
- Monitor channel and bench vegetation and habitat development
- Maintain and irrigate plantings for the first 3–5 years
- Expect channel adjustment and monitor around defined project metrics

Pajaro Example



# Key Take Aways

Goal: floodplain benches with managed, native plant communities that recover ecological, societal, and engineering benefits of a healthy river while improving flood risk management




Mixture of Plants

Floodplain Bench Reduces Flood Risk

Require Equal or Less Maintenance

Set yourself and your project up for success

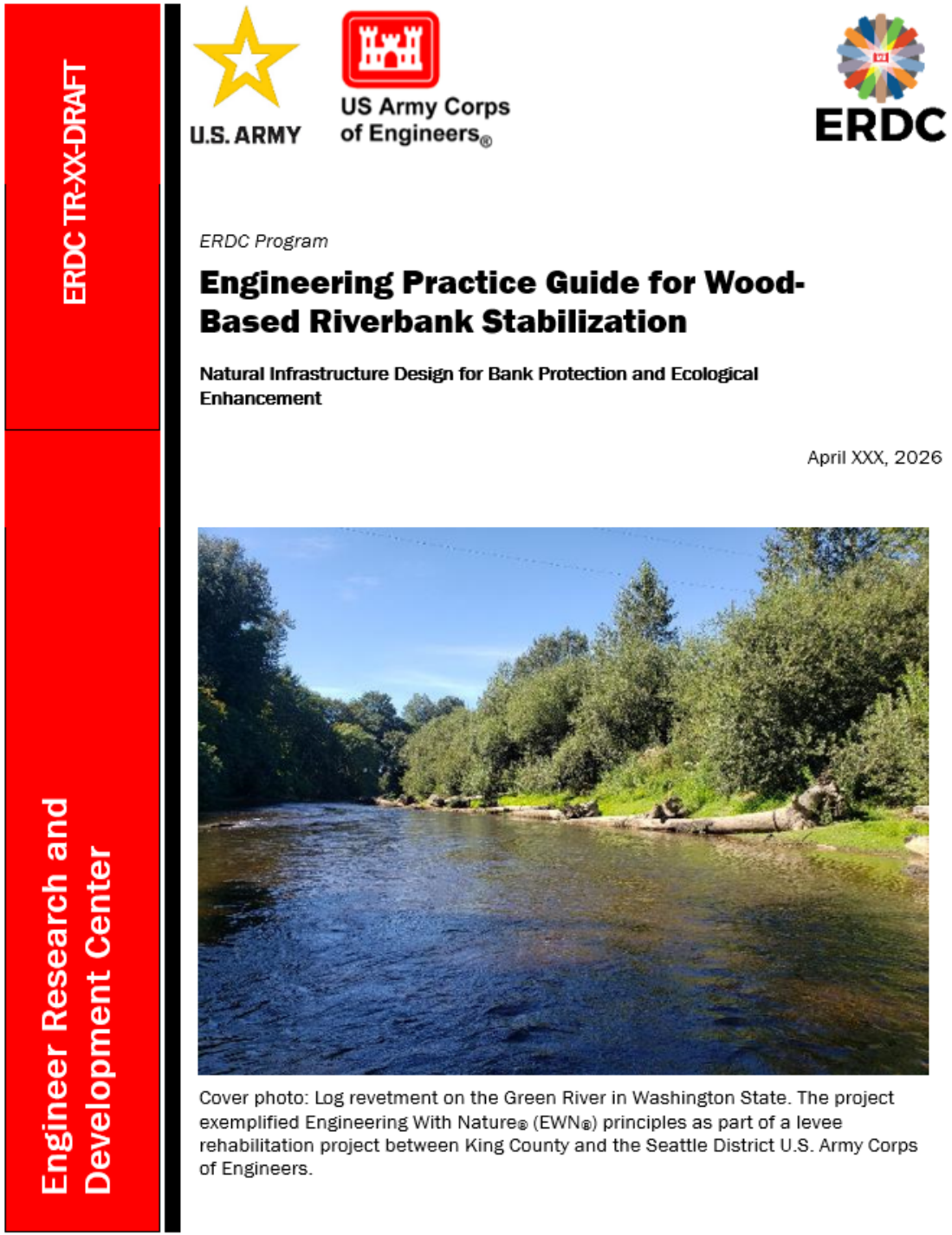
- Know your river first — sand or gravel
- Do the desktop work before the field work; it focuses your field time
- If bedload matters, get that data while you are in the field
- Design for natural geomorphic resilience
- Work with the sponsor to fulfill local goals and community benefits
- Plan for adaptive management and set metrics to identify when it is needed



# Riverine Engineering Practice Guide for Wood-Based Bank Toe Protection

Joanna Crowe Curran, PhD, PE, LG
Seattle District
Chris Haring, PhD, PE, CFM
ERDC-CHL
Edward Brauer, PE
St. Louis District

https://ewn.erdc.dren.mil/engineering-practice-guides/



# Practice Guide Follow a Similar Workflow – Adjusted for Designing Bank Toe Protection Using Wood



**Project Planning (Section 1)**
- Define project goals around flood risk management, geomorphic processes, and ecological uplift (1.1 and 1.2)
- Identify processes causing site instability and erosion (1.3)
- Select geneal design approach (1.4)

**Site Characterization (Section 2)**
- Landscape setting and relevant land use history (2.1)
- Site infrastructure, local use, local concerns (2.2)
- Field data collection needs and methods (2.3)

**Design Objectives and Metrics (3.1)**
- Risk tolerance (3.1.1)
- Geomorphic stability (3.1.2)
- Ecological uplift (3.1.3)

**Project Design and Evaluation (3.3 - 3.5)**
- Determine initial design type (3.3)
- Select design discharges (3.4.1)
- Develop hydraulic and bank models (3.4.2)
- Evaluate and adjust for stability (3.4.3)
- Evaluate sediment transport using design and site appropriate level of effort (3.4.4)
- Adjust for ecological uplift goals (3.4.5)
- Enusre community benefits and boater safety (3.5.1 and 3.5.3)
- Evaluate final design resilience (3.5.4)

Iterative design and refinement

Long-term cycles of assessment

**Additional Considerations (Section 4)**
- Permitting and compliance (4.1)
- O&M requirements (4.2)
- Monitoring and adaptive management (4.3)

**Other USACE Guidance**
- Floodplain Benching Engineering Practice Guide
- National Large Wood Manual
- Cost Effectiveness and Incremental Cost Analysis

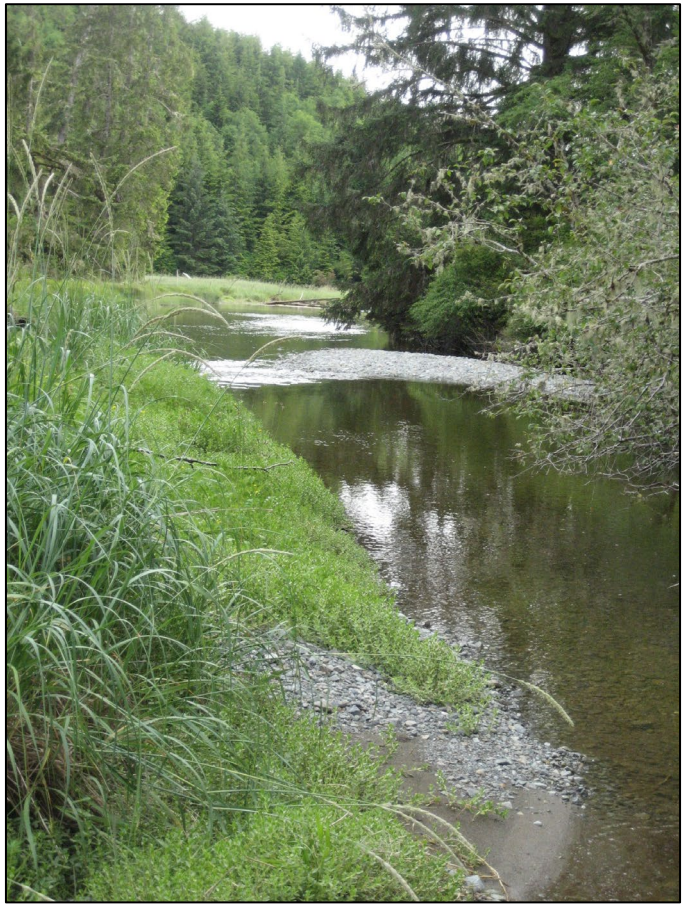
*Set Project Goals, Define Success Metrics, Collect Data, Initiate Design, and Refine to a Final Design*

# Section 1.1: Removes Community Benefits
# Define Equal Project Goals around Flood Risk Management, Geomorphic Processes, and Ecological Uplift

**Bank Stabilization:**
Intentionally modify the bank profile, which alters near bank hydraulics in a manner that reduces the erosive forces acting on bank sediment, stabilizes the bank, and reduces rates of fluvial erosion further erosion

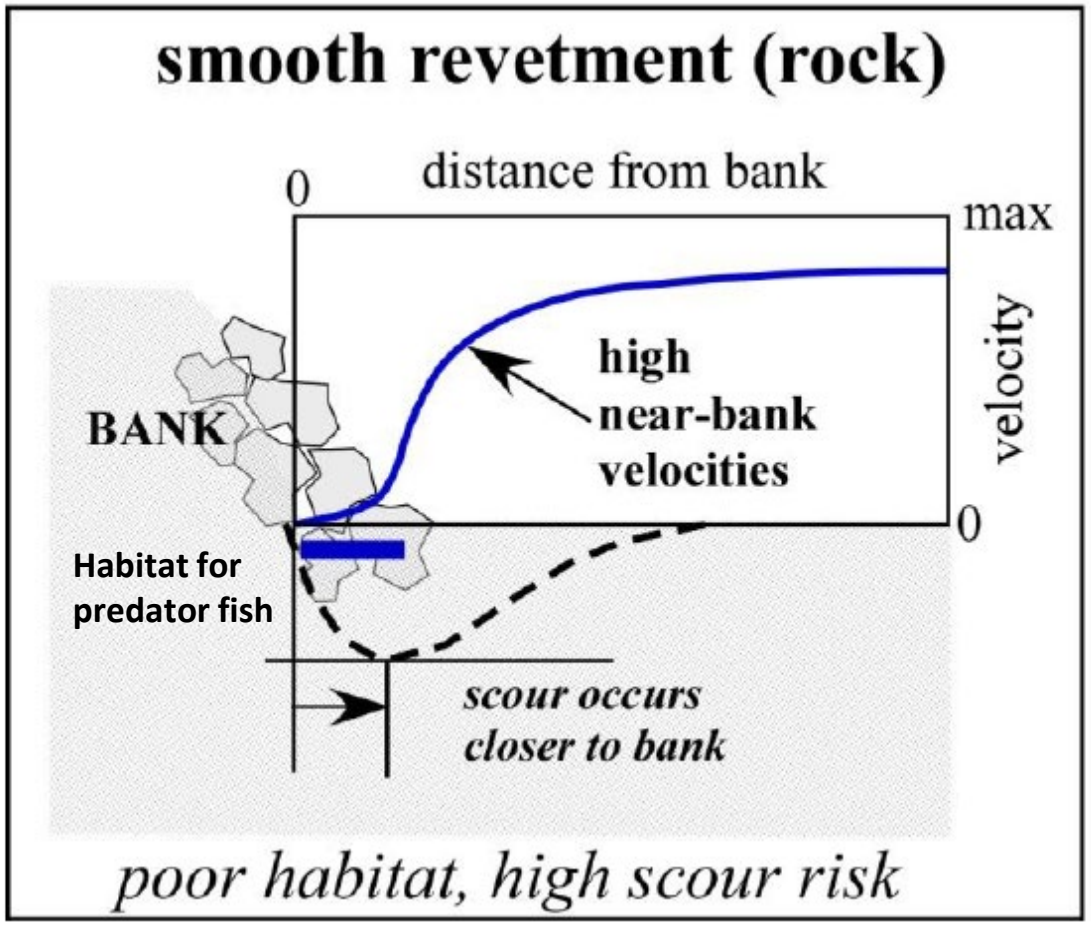
**Geomorphic Processes:**
Alters turbulent flow patterns and  local roughness, which create backwater or pool areas or combine to reduce near-bank flow velocities, increase deposition, and encourage vegetation growth

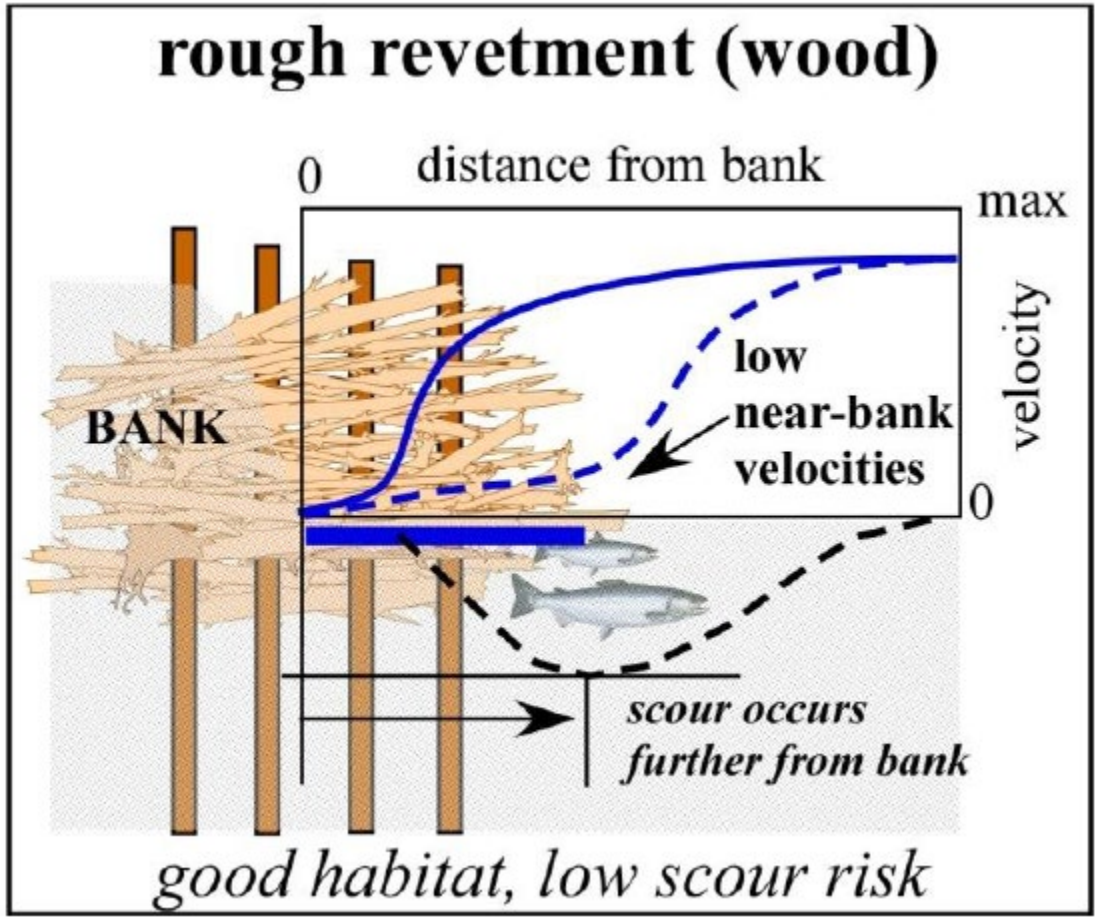
**Water Quality Impacts:**
Wood and wood surface biofilms regulates nutrient, organic matter, and fine sediment inputs and control rate of nutrient export; a food source for grazing invertebrates



*Wood designs can mimic natural bank processes — combined with engineering analysis, it can stabilize and enhance*

# Section 1.1:
# Equal Goal Consideration Creates a Multiple Purpose Project
# EPG Focuses Solution on Use of Wood in an Engineered Bank Protection




*Conventional hard armoring protects infrastructure — but sacrifices the ecological functions that keep rivers resilient.*

# Section 1.3:
# Determine Dominant Erosional Process:
# Natural Variability or Watershed Alteration

Natural process and beneficial for channel planform shape and complexity



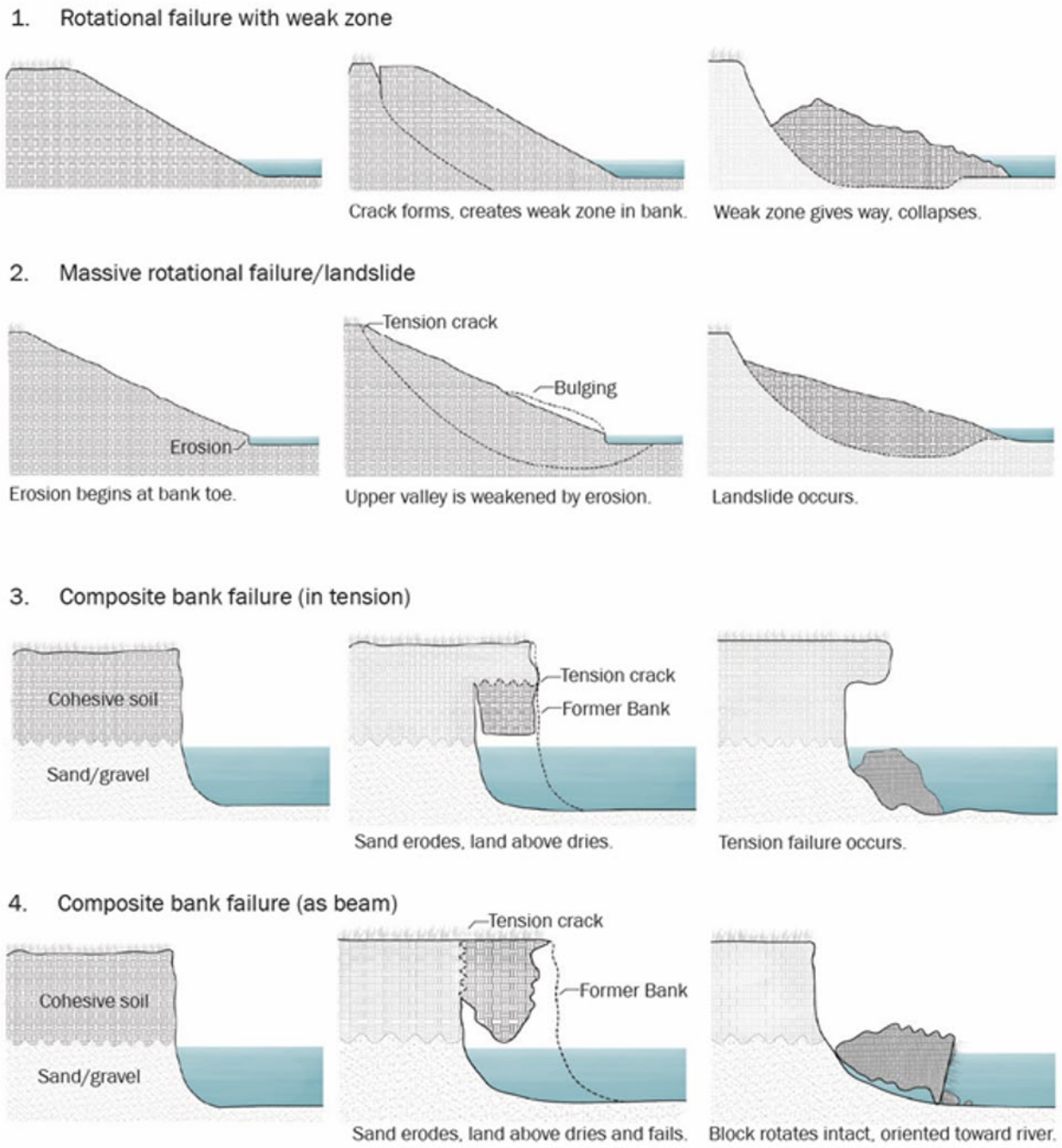
Erosion may be driven by hydromodification or undesirable due to nearby structures



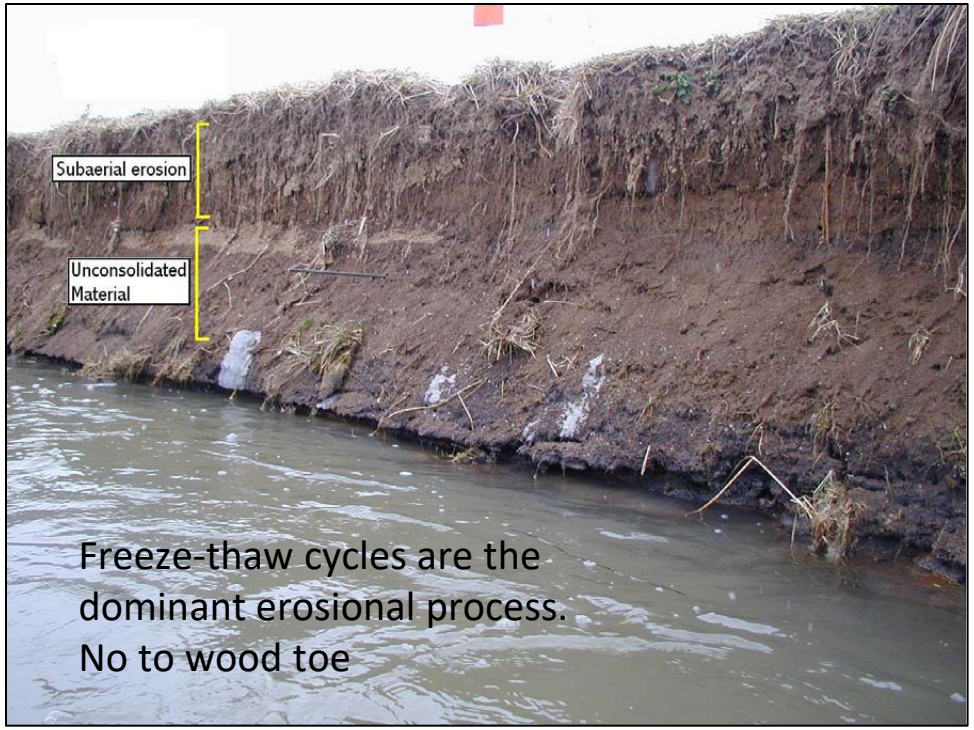
# Section 1.3: Determine Dominant Erosional Process

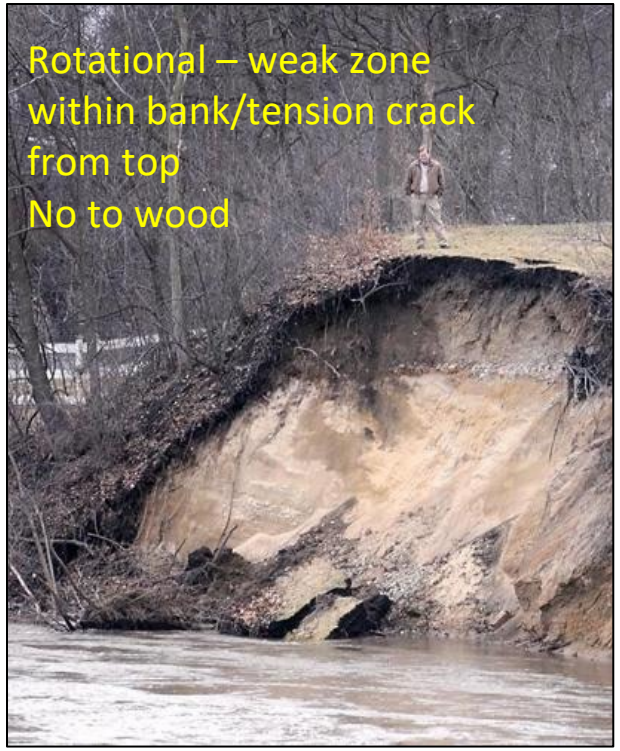
## Added Importance to Understanding What is Causing the Erosion

## Can it be alleviated with toe structures?



Is this site appropriate or not for wood based bank toe protection









Composite bank failure (in tension)
Yes for wood toe
Not needing more – other than land use change, riparian, etc

# Section 1.4: Select General Design Approach













EPG includes methods that can be employed in a range of physiographic regions

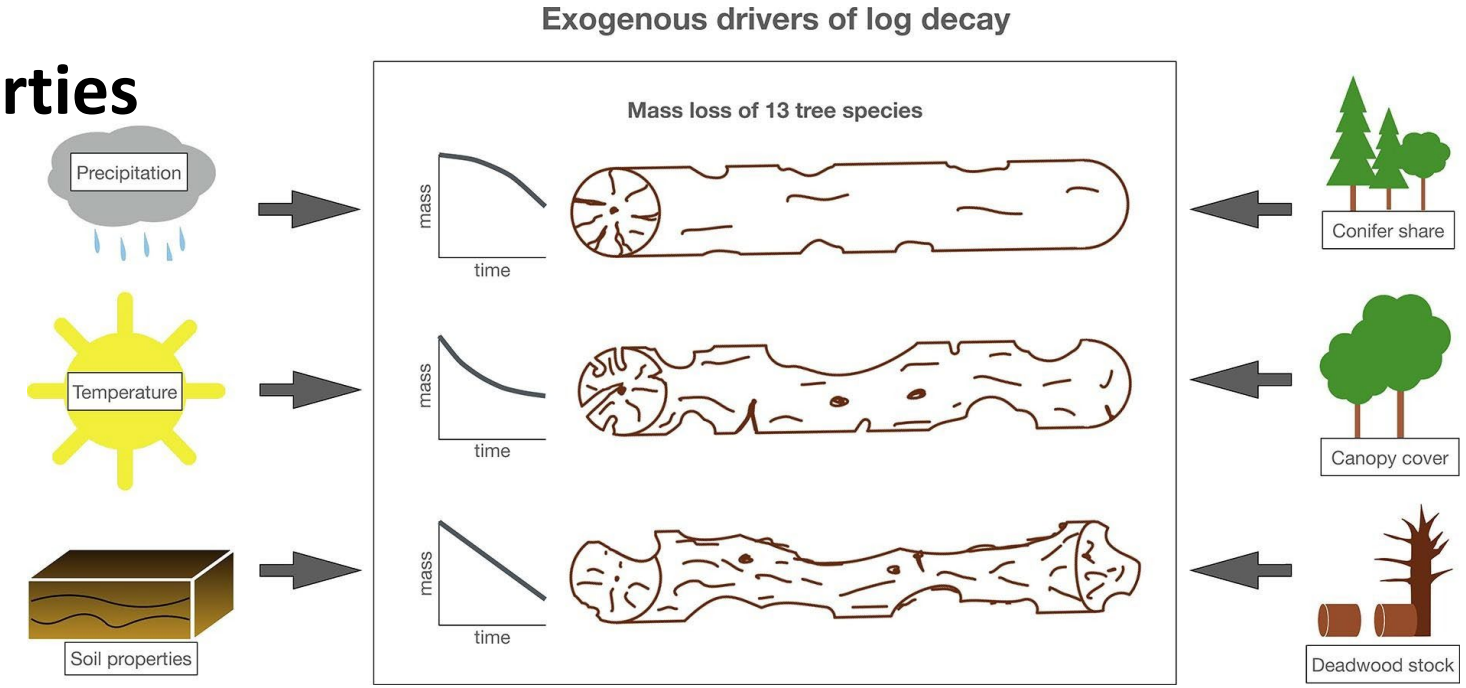
# Section 1.4:
# Select General Design to Counter Erosional Process

Each technique differs in installation requirements, structural performance, ecological benefits, and long-term maintenance considerations, making proper method selection critical to project success.

| Process Causing Erosion | Intervention |
|---|---|
| Reduction in sediment supply and increase in extended duration low flows | Log revetment<br>Bank embedded logs - with and without rootwads |
| Persistent change in flow patterns and rates (for example, from an increase in the number of large flow events each year) has led to lower bank or bank toe erosion and overall bank collapse | Bank embedded logs - with and without rootwads |
| Increased overland flow due to change in local land use has led to bank collapse and channel widening | Log deflectors –logs can extend into the channel<br>Log revetment –logs need to remain aligned with the bank |
| Persistent reduction in sediment supply or increase in flow rate has eroded the bank face as well as the toe. Often caused by boat wakes or nearby infrastructure causing expansion and contraction of flows and altering sediment transport processes | Timber bank crib –logs cannot extend into the channel<br>Log deflectors– boat wakes have concentrated erosion closer to the toe and logs can extend in the channel |

# Section 2.1: Desktop Analysis
# Added Section on Wood Properties

- Gather existing information on the possible project reaches and use it to define the project as much as possible.
- Occurs prior to the fieldwork because it will inform and focus the data collection.
- Includes determining the wood species available and species properties




Edelmann et al., 2023

Appendix A: Table of wood species specifics.

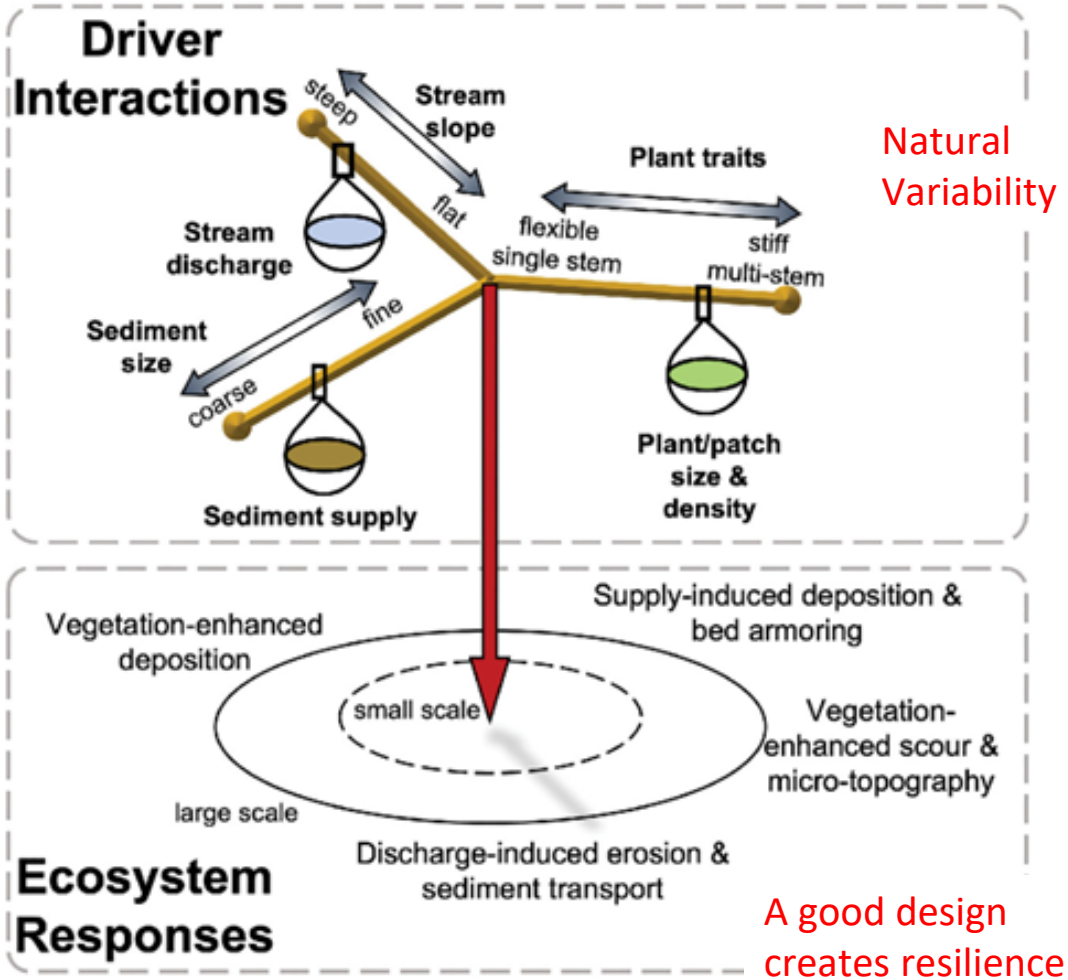
| Wood Species (Scientific Name) | Common Name | Decay Rate (years to 50% loss) | Climate | Average Log Diameter (in) | Source Document |
|---|---|---|---|---|---|
| Acer rubrum | Red Maple, Swamp Maple, Scarlet Maple | 10 | Temperate | 7.2 | Russell et al., 2014 |
| Acer saccharinum | Silver Maple | 9 | Temperate | 7.2 | Russell et al., 2014 |
| Acer saccharum | Sugar Maple | 10 | Temperate | 7.2 | Russell et al., 2014 |
| Alnus incana | Speckled Alder, European Gray Alder | 6.8 | Subarctic | 2 | Freschet et al., 2011 |
| Betula alleghaniensis | Yellow Birch, Golden Birch, Swamp Birch | 11 | Temperate | 7.2 | Russell et al., 2014 |
| Carpinus betulus | European Hornbeam | ~5 | Temperate | 12.2 | Kahl et al., 2017 |

*Decay rates depend on species and local climate*

# End of Section 2 has a table to check through during data collection

| Question to Answer from Collected Data | Desktop | Field |
|---|---|---|
| Is there a nearby source for wood and ballast rock? | 2.1.2, 2.1.4 | |
| How does site physiography matter for project design? | 2.1.2, 2.1.4 | |
| Does the channel have floodplain access or is the channel incised? | 2.1.2, 2.1.3 | |
| Are wood-based structures appropriate for the site? | 1.5 | |
| How has the channel changed over recent history (10 years, 100 years)? | 2.1.1, 2.1.2, 2.1.3 | |
| What are the channel and reach planform patterns and are they the same? | 2.1.2 | |
| What are current uses of the channel? Are there current channel uses that could impact design? | 2.2.3, 2.2.4, 2.2.5 | 2.3 (verify) |
| Is there infrastructure in the area that could impact design or the amount of acceptable risk? | 2.2.1, 2.2.2 | 2.3 (verify) |
| What is the bank profile geometry in eroded and non-eroded reaches? | 2.1.2 | 2.3.1 |
| What is the primary mechanism of bank erosion at the site? | 1.3, 2.1.2 | 2.3.1 |
| Are bank soils consistent? Are they cohesive, non-cohesive, or a mix? | | 2.3.5 |
| What are the bank soil layer and soil properties? | 2.1.1 | 2.3.5 |
| What are the range of flows at the site and the different flow frequencies (10%, 50%, 90% flow exceedance probability flows)? | 2.1.3 | |
| What are the top of bank and bankfull flows? | | 2.3.1 |
| Are there plant or animal species of concern or interest in the area? | 2.1.5 | 2.3.6 |
| What are the native forms of vegetation in the region? | 2.1.5 | 2.3.6 |
| What is the grain size distribution of sediment on the channel bed? | | 2.3.2 |
| What is the sediment supply (if applicable)? | | 2.3.4 |
| Is there a need to create scour pools? | 2.1.5 | 2.3.6 |
| Is there a need to narrow the channel? | 2.2.1 | 2.3.1 |
| Has anyone already built a hydraulic model of the area? | 2.1.1 | |
| Is there wood present in the channel and riparian area? | 2.1.2 | 2.3.3 |

# Section 3.1:
# Design Objectives are Defined to Project Meets Design Goals
# Metrics Quantify Project Objectives and Build in Resilience




A good design creates resilience and erosion risk remains reduced

**What could happen to risk long-term success of project goals?**

- Excessive amounts of sediment are deposited, burying the wood and aggrading the lower bank to a higher elevation
- Excessive amounts of organic matter and wood are deposited on the structure, increasing hydraulic stresses on the structure
- Wood is not appropriately ballasted and transports downstream
- Project alters the hydraulics and the bank upstream or downstream of the site erodes
- Bank erosion continues due to processes not associated with fluvial erosion and bank line retreat eventually strands the wood structure in the channel
- Changes to land use upstream alter hydraulics and sediment supply leading to erosion that threatens existing infrastructure or private property

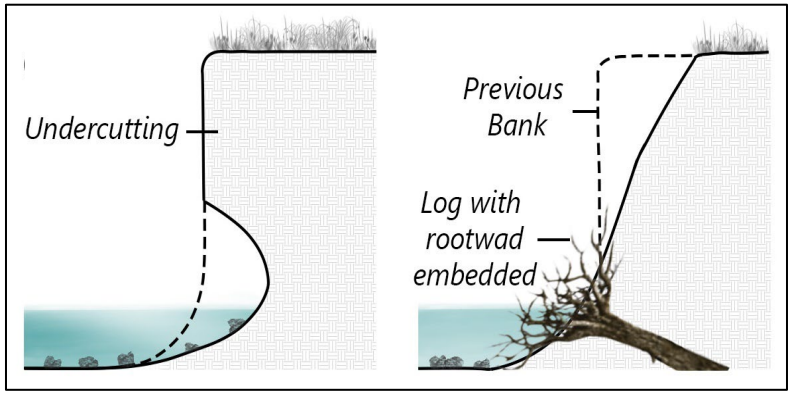
**Define how much post project change is acceptable**

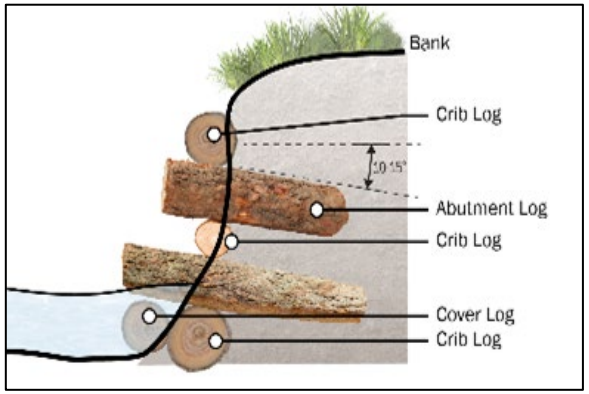
- What is the tolerance level for bank erosion or near-bank deposition before risking project goals?
- How much of the structure can be non-functional (eroded logs or ballast rock, log or rootwad burial, log or rootwad not engaged with flow) before risking project goals?

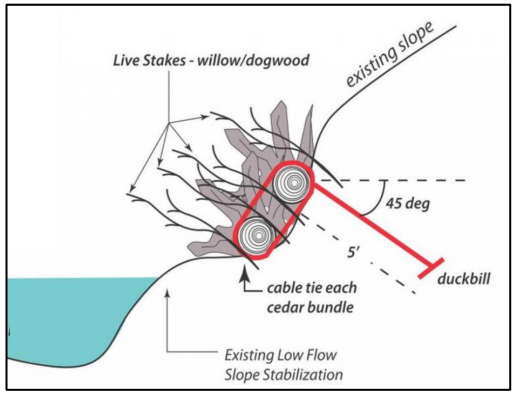
# Section 3.3 Select Design Type

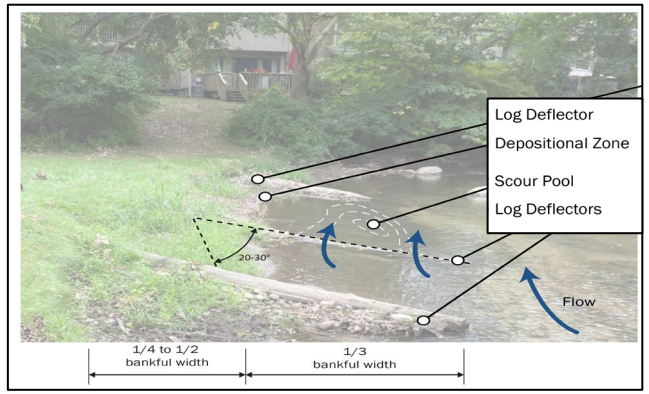
| Process Causing Erosion | Intervention |
|---|---|
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| Persistent reduction in sediment supply or increase in flow rate has eroded the bank face as well as the toe. Often caused by boat wakes or nearby infrastructure causing expansion and contraction of flows and altering sediment transport processes | Timber bank crib –logs cannot extend into the channel<br>Log deflectors– boat wakes have concentrated erosion closer to the toe and logs can extend in the channel |

| Design Phase | Design Aspect | Specific Criteria | Data | Design |
|---|---|---|---|---|
| **Section 3.3: Develop Initial Design** | Identify Design Type | Determine the dominant process responsible for bank erosion and the appropriate type of protection design | 1.3 | 3.3 |
| | Bank Embedded Log | Determine use of rootwads, log spacing, and log location in bank profile | 1.4.2 | 3.3.1 |
| | Timber Bank Crib | Determine length and height, appropriate planting | 1.4.3 | 3.3.2 |
| | Log Revetment | Determine location relative to bank toe, height and complexity of structure, and inclusion of any rootwads | 1.4.4 | 3.3.3 |
| | Log Deflector | Determine orientation, length, and distance of log into the flow. Orient deflector to create one or two scour and deposition locations | 1.4.5 | 3.3.4 |



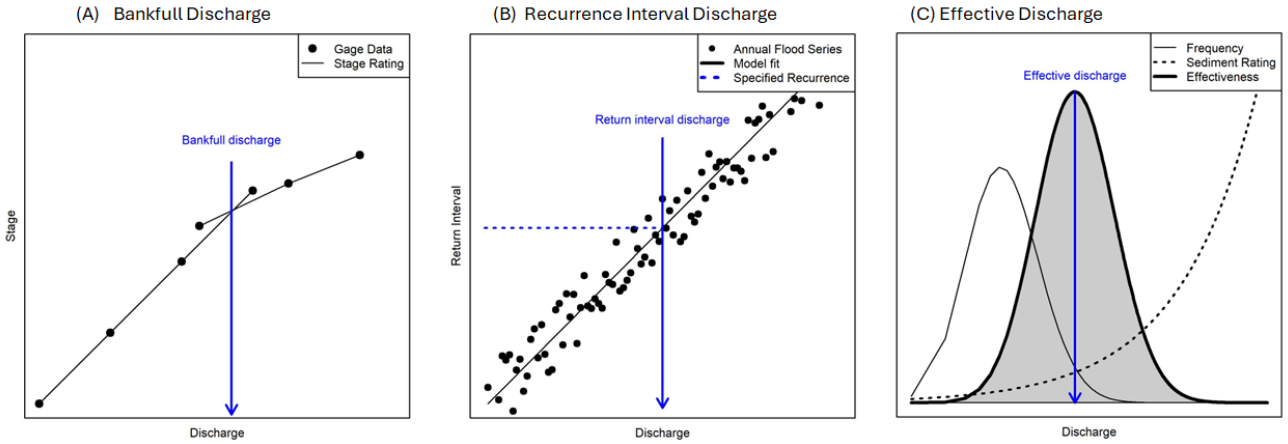

Ensure that initial design from planning is appropriate intervention for erosional drivers (e.g. overland flow widened bank, boat wave action, reduced sediment supply, upstream flow control)

| Design Phase | Design Aspect | Specific Criteria | Data | Design |
|---|---|---|---|---|
| **Section 3.4 Evaluate Design** | Design Discharge | Determine the discharges to use in design | 2.1.3 | 3.4.1 |
| | Hydraulic performance | Calibrate to the events that created erosion. Then, evaluate over multiple hydrographs and design flows that reflect existing and anticipated flow rates | 2.1.3 | 3.4.2 |
| | Bank Process | Evaluate risk of bank failure under a range of flows and designs | 2.3.1, 2.3.4 | 3.4.2 |
| | Project Stability | Evaluate forces acting on design and adjust for needed anchoring and/or ballast to fulfill structural stability goals. Evaluate design over multiple hydrographs and future bank lines | — | 3.4.3 |
| | Sediment transport | Evaluate impact of bank embedded log design on near-bank aggradation and erosion, including the potential for scour. Use either a sediment transport rating curve or sediment transport model, depending on project risk. | 2.3.2, 2.3.4 | 3.4.4 |

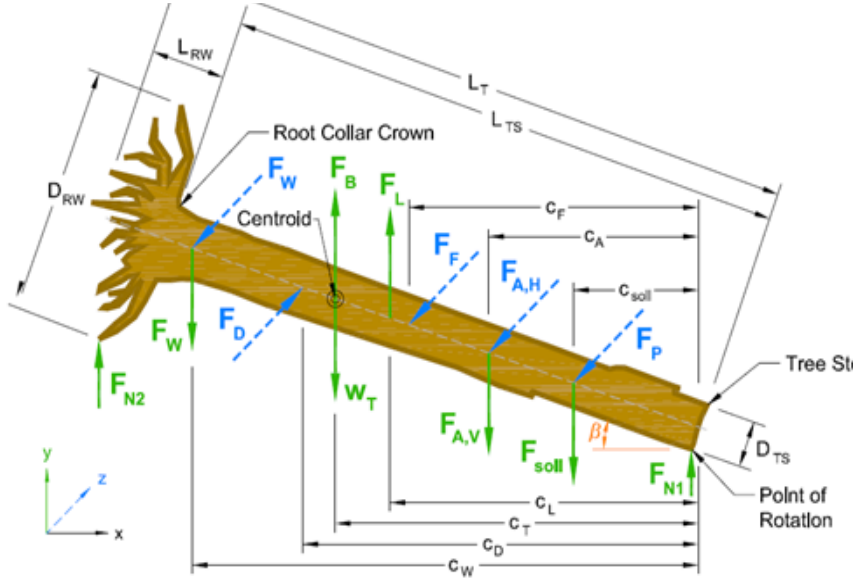
Choose multiple design discharges
Model to the degree needed for the risk

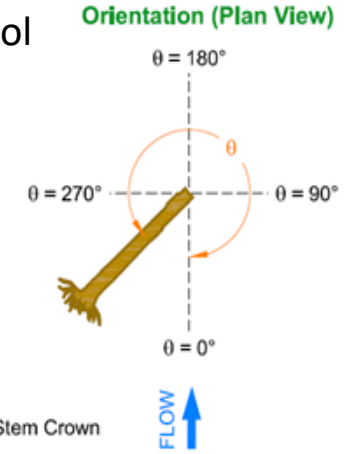
Drag force acting on the wood

$$F_D = \frac{1}{2}\rho C_D^{app} u^2 A \sin\Theta$$

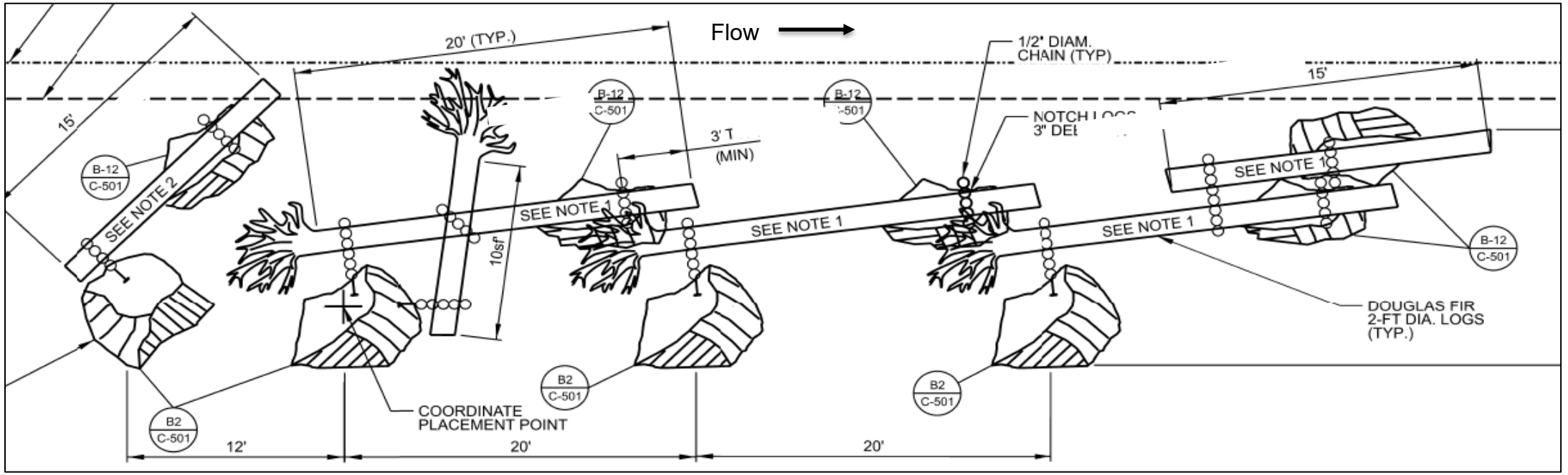



Force diagram from Rafferty (2017) tool



| Design Phase | Design Aspect | Specific Criteria | Data | Design |
|---|---|---|---|---|
| **Sections 3.4-3.5: Refine Design** | Ecosystem Uplift | Adjust log orientations, angles, and other details to ensure plans for generating shade, increasing organic matter, and altering near-bank hydraulics will have the anticipated increase in ecological benefits | 2.1.5, 2.3.6 | 3.4.5 |
| | Structure stability | Ensure stability as design becomes finalized with species and orientations | | 3.4.3 |
| | Anticipate Vegetation | Select plants beneficial to the local ecosystem where part of design and set O&M expectations for opportunistic vegetation at the bank, particularly where deposition is expected | 2.1.5 | 3.5.2 |
| | Community Benefits | Adjust design to accommodate recreational, access, or cultural uses of the site | 2.2.5 | 3.5.1 |
| | Safety | Adjust to ensure recreational safety | 2.2.4 | 3.5.3 |
| | Design Resilience | Evaluate proposed design for resilience against expected changes with seasonality, and potential changes in upstream landuse. | — | 3.5.4 |



# The N-EWN Knowledge Series

## A Continuing Education Series about Engineering with Nature



*Mr. Eddie Brauer*

## Engineering With Nature® Engineering Practice Guide for Floodplain Benching Projects

*US Army Corps of Engineers Research and Development Center*



*Dr. Joanna Curran*

Restoration and nature-based solutions are increasingly recognized as sustainable infrastructure, yet practitioners charged with delivering them often lack the design criteria and procedures that are routine for conventional "gray" infrastructure. Technical guidance for natural infrastructure (NI) remains limited in both content and organization, which slows adoption, complicates review, and inflates perceived risk.

USACE is addressing this through Engineering Practice Guides (EPGs), developed in alignment with the Engineering With Nature Guiding Principles and structured to follow the standard project design process. The Floodplain Benching EPG addresses reconnection in alluvial systems of any size, targeting flood attenuation, channel dynamics, sediment transport, margin hydraulics, and surface water-groundwater exchange, emphasizing self-forming and self-maintaining designs. Within the EPG, we describe site characterization, engineering design criteria, and design considerations. The focus is on moving from preliminary to detailed design, emphasizing hybrid approaches that combine gray with green and blue solutions.

**Save the date!**

**Upcoming webinars will take place the 3rd Thursday of the month.**

**Sep. 17 12:30pm ET**

*Mr. Edward Brauer and Dr. Joanna Curran, USACE-ERDC*

*Engineering With Nature® Engineering Practice Guide for Floodplain Benching Projects*

**Oct. 15 12:30pm ET**

*Dr. Matt Bilskie, University of Georgia*

*Nature-Based Coastal Resilience at Marine Corps Recruit Depot Parris Island: From Concept to Long-Term Monitoring*

**Nov. 19 12:30pm ET**

*Leigh Langley, USACE-ERDC*

*Dune Stabilization for Coastal Flood Protection*

**Register here: https://bit.ly/3gR9ADL** **or scan:**

**1 Continuing Education Credit (CEC) is available to attendees**

**Recorded webinars will be posted online at: https://n-ewn.org/resources/n-ewn-knowledge-seminars/**

**Presented by:**

NETWORK FOR ENGINEERING WITH NATURE

LimnoTech Water Environment Scientists Engineers

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