Stream Restoration: Nature-Based Solution for Flood Risk Mitigation and Watershed Resiliency

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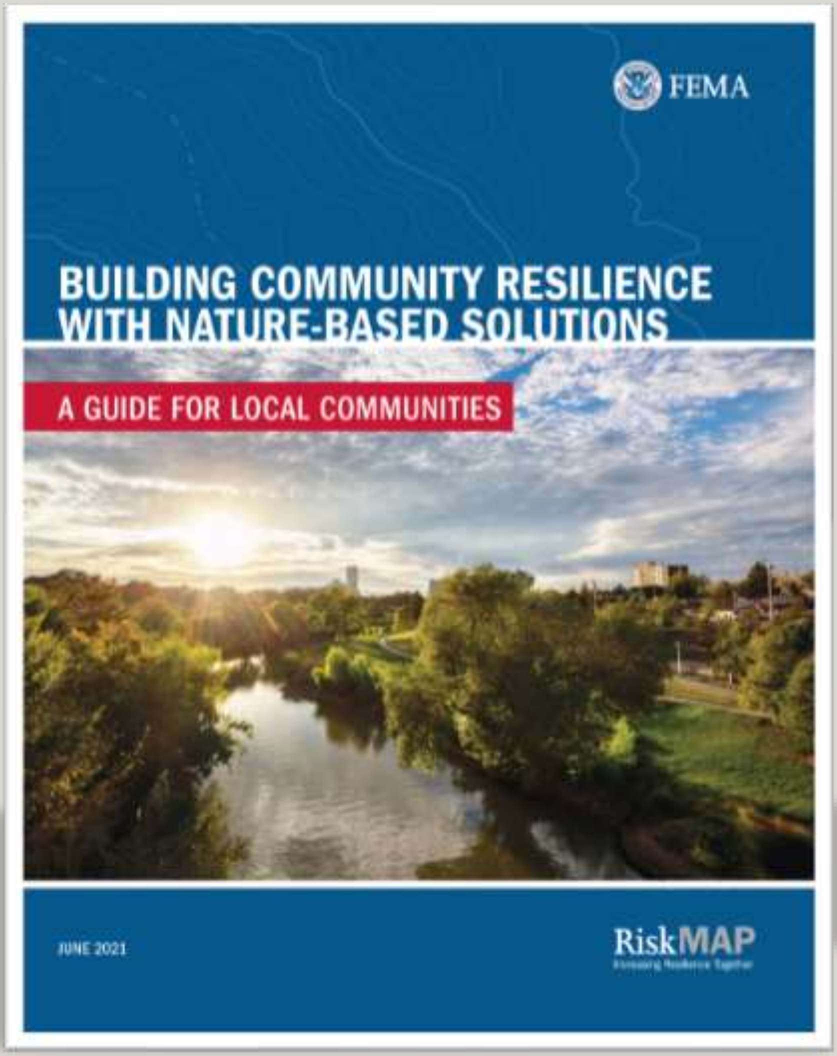
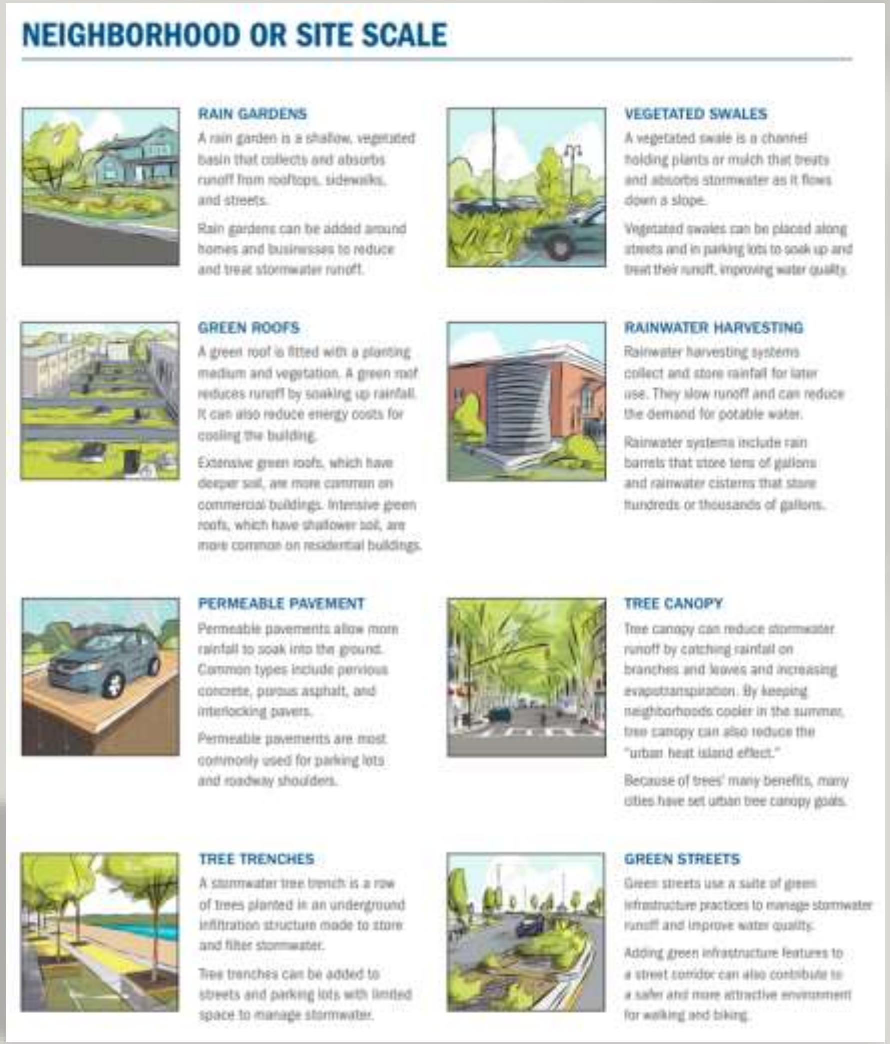
Nature-Based Solutions' (NBS) Emerging Role in U.S.

- FEMA's five Hazard Mitigation Assistance (HMA) Programs emphasize NBS for building community/watershed resilience and mitigating impacts of natural hazards
  - Hazard Mitigation Grant Program (HMGP)
  - Building Resilient Infrastructure and Communities (BRIC)
  - Flood Mitigation Assistance (FMA)
  - HMGP Post-Fire
  - Pre-Disaster Mitigation (PDM)

- HUD Community Development Block Grant (CDBG) grantees required to account for resilience to natural hazard risks in Consolidated Plans, including NBS
- Major federal funding for NBS infrastructure/climate resiliency project planning & implementation
  - Infrastructure Investment and Jobs Act (IIJA) = $47B
  - Inflation Reduction Act (IRA) = $6B
- Biden Administration released $25B NBS Roadmap at COP 27 (2022)

Federal Guidance on NBS - FEMA





NEIGHBORHOOD OR SITE SCALE

RAIN GARDENS

A rain garden is a shallow, vegetated basin that collects and absorbs runoff from rooftops, sidewalks, and streets.

Rain gardens can be added around homes and businesses to reduce and treat stormwater runoff.

VEGETATED SWALES

A vegetated swale is a channel holding plants or mulch that treats and absorbs stormwater as it flows down a slope.

Vegetated swales can be placed along streets and in parking lots to soak up and treat their runoff, improving water quality.

GREEN ROOFS

A green roof is fitted with a planting medium and vegetation. A green roof reduces runoff by soaking up rainfall. It can also reduce energy costs for cooling the building.

Extensive green roofs, which have deeper soil, are more common on commercial buildings. Intensive green roofs, which have shallower soil, are more common on residential buildings.

RAINWATER HARVESTING

Rainwater harvesting systems collect and store rainfall for later use. They slow runoff and can reduce the demand for potable water.

Rainwater systems include rain barrels that store tens of gallons and rainwater cisterns that store hundreds or thousands of gallons.

PERMEABLE PAVEMENT

Permeable pavements allow more rainfall to soak into the ground. Common types include pervious concrete, porous asphalt, and interlocking pavers.

Permeable pavements are most commonly used for parking lots and roadway shoulders.

TREE CANOPY

Tree canopy can reduce stormwater runoff by catching rainfall on branches and leaves and increasing evapotranspiration. By keeping neighborhoods cooler in the summer, tree canopy can also reduce the "urban heat island effect."

Because of trees' many benefits, many cities have set urban tree canopy goals.

TREE TRENCHES

A stormwater tree trench is a row of trees planted in an underground infiltration structure made to store and filter stormwater.

Tree trenches can be added to streets and parking lots with limited space to manage stormwater.

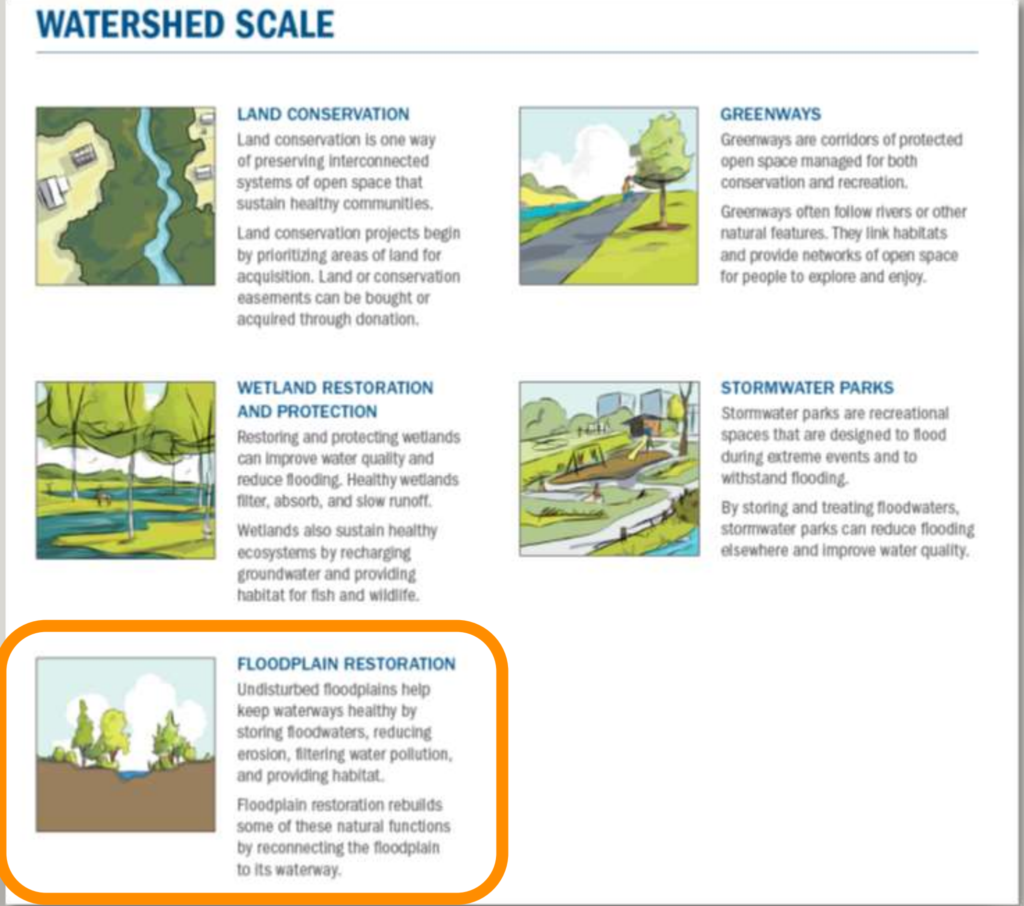
GREEN STREETS

Green streets use a suite of green infrastructure practices to manage stormwater runoff and improve water quality.

Adding green infrastructure features to a street corridor can also contribute to a safer and more attractive environment for walking and biking.

Federal Guidance on NBS - FEMA

- Provide NBS solutions across the watershed <u>except</u> in the streams themselves
- Implies NBS BMP opportunities stop when stormwaters outfall to the stream, as though the stream channels themselves are fixed components with no capacity to improve or degrade flood risk mitigation and resiliency



WATERSHED SCALE

LAND CONSERVATION

Land conservation is one way of preserving interconnected systems of open space that sustain healthy communities.

Land conservation projects begin by prioritizing areas of land for acquisition. Land or conservation easements can be bought or acquired through donation.

GREENWAYS

Greenways are corridors of protected open space managed for both conservation and recreation.

Greenways often follow rivers or other natural features. They link habitats and provide networks of open space for people to explore and enjoy.

WETLAND RESTORATION AND PROTECTION

Restoring and protecting wetlands can improve water quality and reduce flooding. Healthy wetlands filter, absorb, and slow runoff.

Wetlands also sustain healthy ecosystems by recharging groundwater and providing habitat for fish and wildlife.

STORMWATER PARKS

Stormwater parks are recreational spaces that are designed to flood during extreme events and to withstand flooding.

By storing and treating floodwaters, stormwater parks can reduce flooding elsewhere and improve water quality.

FLOODPLAIN RESTORATION

Undisturbed floodplains help keep waterways healthy by storing floodwaters, reducing erosion, filtering water pollution, and providing habitat.

Floodplain restoration rebuilds some of these natural functions by reconnecting the floodplain to its waterway.

NOTE: Streams addressed only through Floodplain Restoration

Federal Guidance on NBS – HUD/CDBG

- Two documents - reader is referred to other federal agency, NGO, & international agency guidance documents
- Streams are mentioned in 2 sections:

INLAND FLOODING

- "promote stream and wetland restoration to ensure adequate retention, drainage, and diversion of stormwater"
- "encourage participants to re-establish natural floodplains"

EROSION

- "encourage the use of natural bank stabilization techniques"

- Promotes stream restoration as NBS, but implies that "natural bank stabilization techniques" are the key to stream restoration and stability to mitigate "erosion" and provide "adequate drainage"

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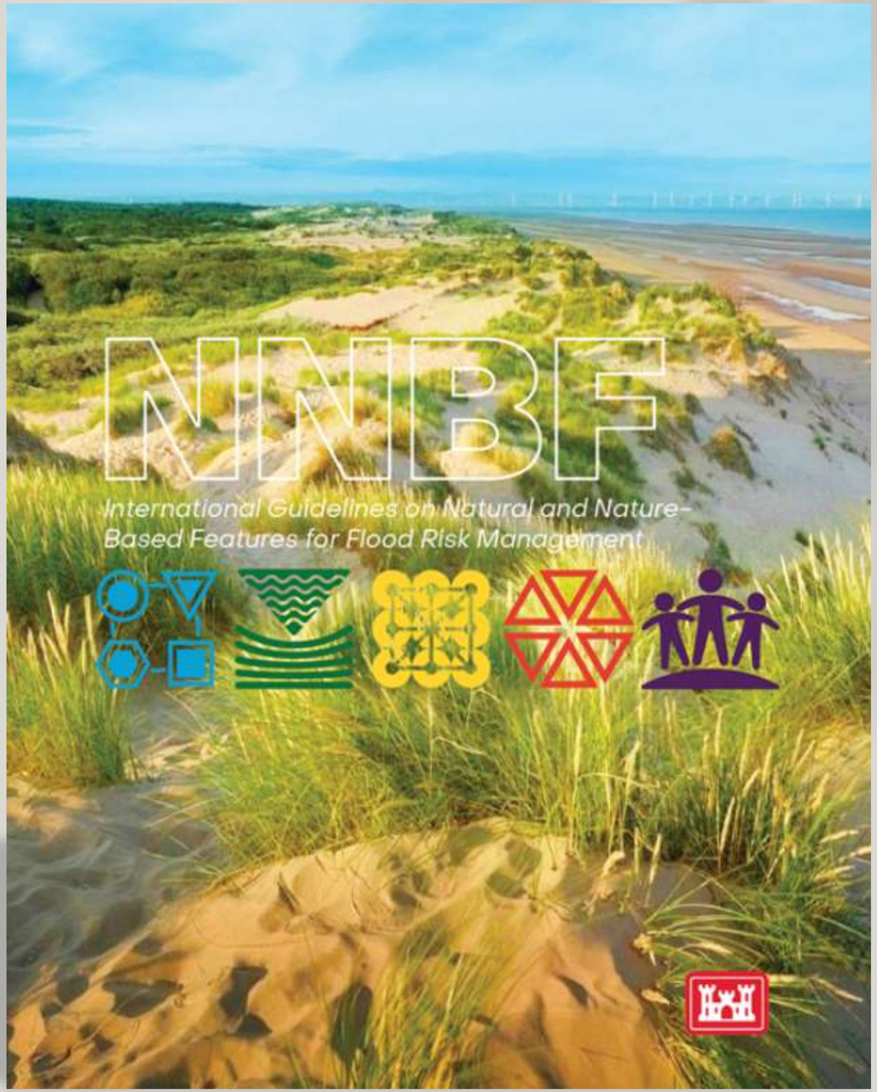
Federal Guidance on NBS – USACE

- ERDC Engineering with Nature® Initiative and subsequent development of:
- 2022 "International Guidelines on Natural and Nature-Based Features for Flood Risk Management" (IGNNBFFRM)
  - Most holistic guidelines and 1st time Stream Restoration is mentioned BEYOND floodplain connection & bank stabilization!!!
  - Chapters 15 thru 19 focus on Fluvial Systems, which includes rivers, floodplains, and wetlands
  - Focus on a holistic approach (i.e., all stream reaches/floodplains/wetlands are connected and affected by other reaches /floodplains/ wetlands and watershed hydrology)



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Federal Guidance on NBS – USACE

15.1 | Objectives for NNBF in Fluvial Settings

The primary objective in applying NNBF in fluvial settings is to reduce flood risk by restoring, enhancing, or mimicking natural hydraulic, morphological, and ecological functions and processes (Lane 2017). Although the scale and physiography of watersheds vary, there are common reasons to apply NNBF, such as the following:

- **To capture, retain, slow, or disperse floodwaters throughout the upper and middle watershed, using native vegetation where possible to capture and retain water and sediment and to slow erosion.** NNBF help dissipate flood energy, mitigate land loss to erosion, and reduce channel incision and aggradation.
- **To improve the connectivity and interaction of the watercourse with the floodplain (creating space for water and room for the river)—especially where open spaces are also designated floodways.** This approach should decrease the need for interventions to maintain conveyance, such as dredging or clearing vegetation.
- **To preserve or restore sediment balance (Wohl et al. 2015) to maintain not only stream channel geomorphology but also floodplains and deltas through appropriate sediment-building processes.** Work with natural processes to provide resilient and sustainable designs.
- **To restore or maintain lowland and river delta functions in ways that replicate or mimic natural features or processes.** This includes naturalizing and balancing channel capacity and conveyance to provide channel stability, aquatic restoration, and flood-control alternatives.

Incorporating NNBF that have these functions into watershed planning and engineering helps economically mitigate local and downstream flood peaks and impacts while providing ecosystem service co-benefits, such as the following:

- Groundwater recharge and drought amelioration
- Water quality improvement and greater freshwater availability
- Biodiversity enhancement and habitat improvement
- Improved aesthetics compared to conventional infrastructure
- Human health, welfare, and recreational opportunities

- Holistic summary finally promotes overall watershed restoration, including streams, in terms of the inter-connectivity and inter-dependence of uplands, wetlands, floodplains, streams, and deltas

- Acknowledgement and understanding of ecosystem service co-benefits is critical to public buy-in/consensus building and fair/accurate benefit/cost analysis relative to project evaluation and selection

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Streams in Urban & Suburban Settings

- 80% of U.S. population lives in urban areas (2020 U.S. Census)
- Majority of urban areas are associated with plains & floodplain areas for many reasons (river transport, infrastructure & structure constructability, arable land)
- These settings are dominated by larger alluvial streams/ rivers and their alluvial tributaries commonly with little to no bedrock or armored riffles (i.e., D_{50} = Sand)

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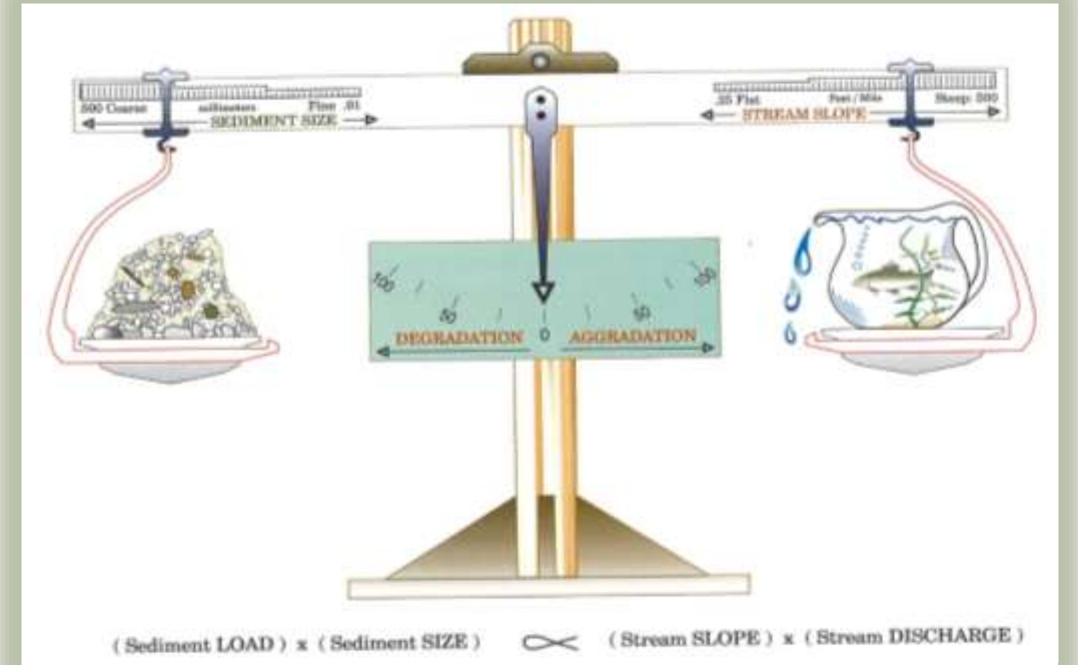
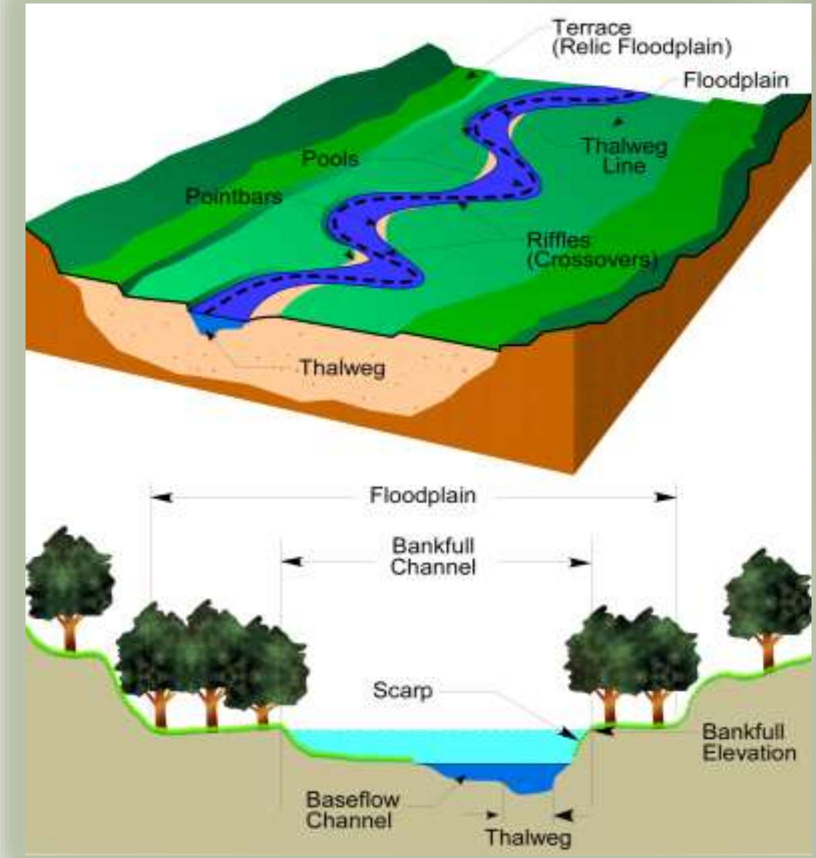
Dynamic Equilibrium in Alluvial Streams



$Q_{Sed} \times D_{50} \qquad S \times Q_{Water}$

The Lane Relationship for "Stable Channel Balance"

- Alluvial streams and their floodplains form in a "dynamic equilibrium" balance to do the work of moving water and sediments through the system most efficiently in response to watershed hydrology and sediment loads



- Cross-sectional dimension, pattern on the landscape, and longitudinal profile are all critical to maintaining "dynamic equilibrium"

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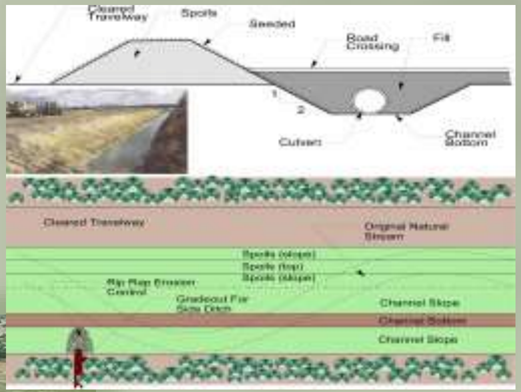
Hydromodification in Urban & Suburban Settings

Landscape

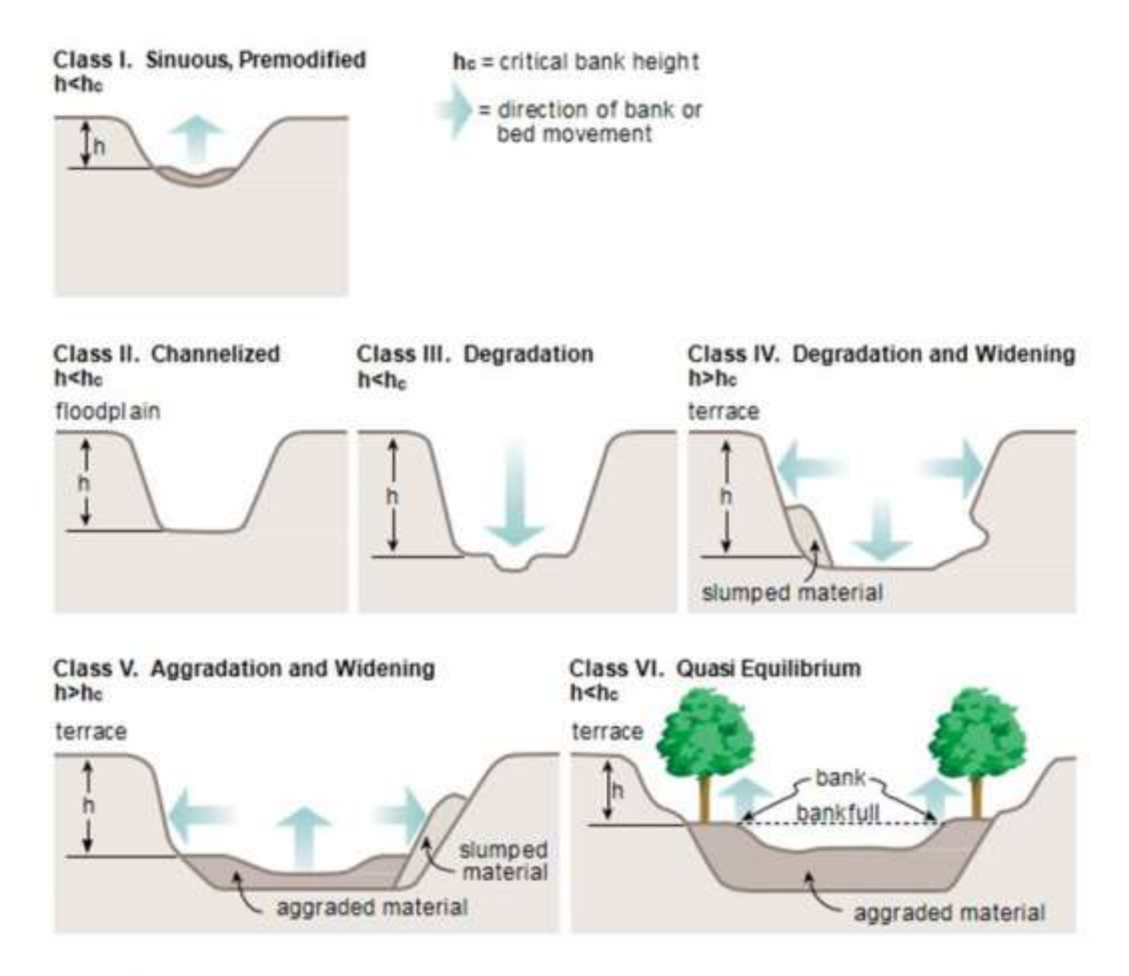




In-Stream


Stream Response to Hydromodification



Simon's (1989) model of channel response in disturbed alluvial channels

- All alluvial streams respond in the same gravity-driven process to any form of hydromodification (landscape or in-channel), as described by Simon's (1989) model of channel response in disturbed alluvial channels
- Streams in our cities must evolve through natural channel evolution in response to hydromodification of the past 200 years & continued hydromodification from continued development and climate change

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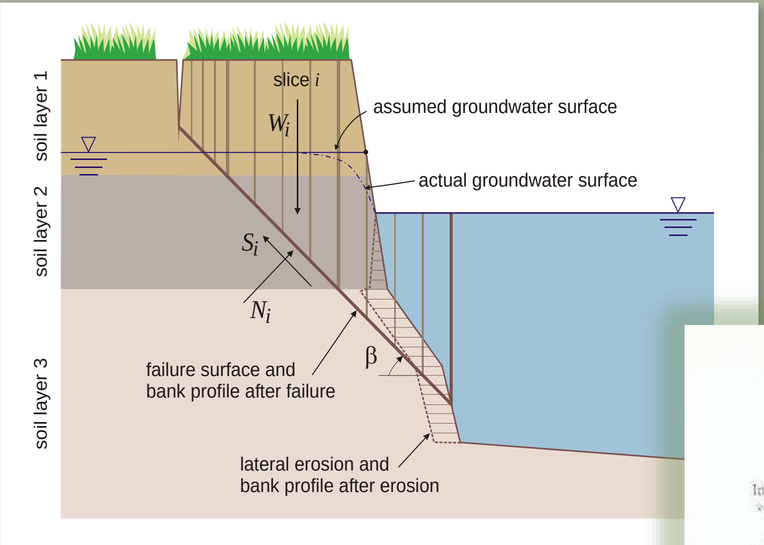
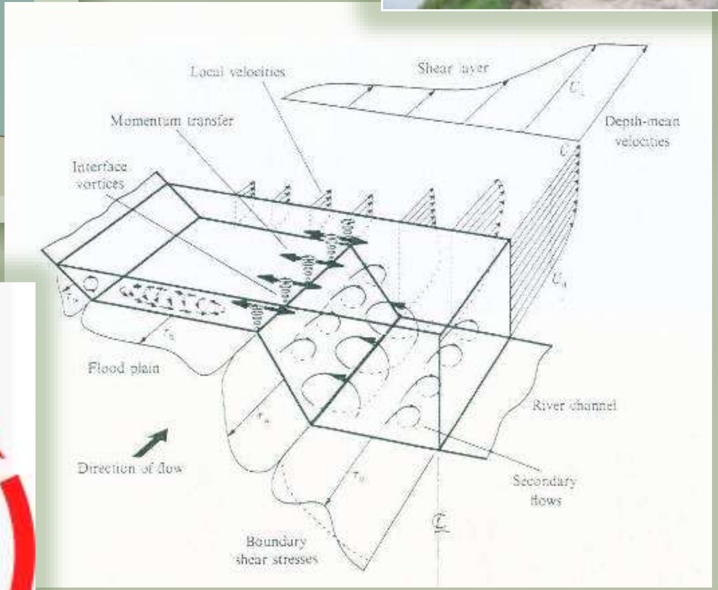
Stream Response to Hydromodification in Urban & Suburban Settings

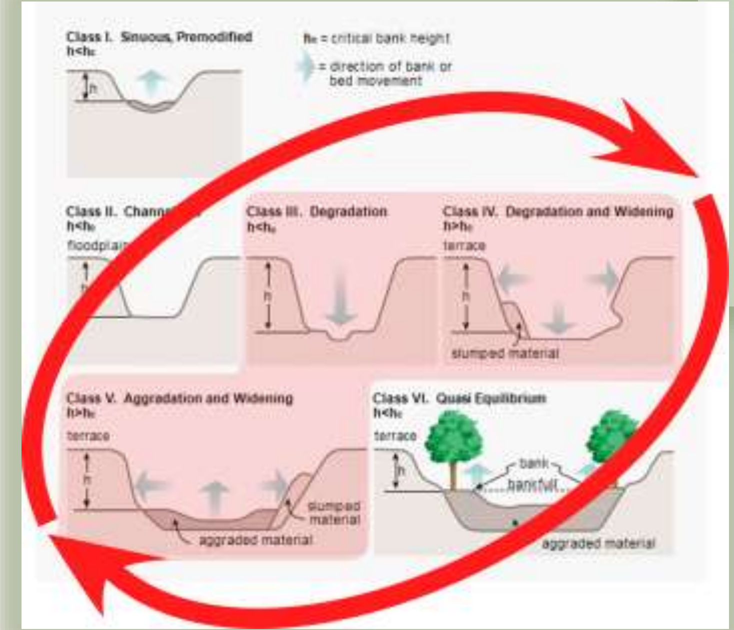
- Consider that alluvial streams:
  - Seldom have natural cobble/boulder/bedrock riffle armoring to protect against channel incision
  - Often have sand/silt/clay banks which provide minimal resistance to bank shear stresses
- Consider that flows ≥ channel-forming flows only occur from 5 to 15 times/year in thunderstorm-driven systems
- Can't achieve new quasi-equilibrium (Class VI) before additional hydromodification re-starts channel evolution process

→ Endless loop in unstable degradation/ widening/aggrading phases of channel evolution process

- The re-establishment of stable streams via natural channel evolution would take decades or centuries if hydrologic conditions could be "frozen" across these catchments, which is not even possible







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Challenges to Resiliency in Urban & Suburban Streams

- Resiliency is extremely difficult without pro-active stream restoration or stabilization using NCD methods

15.1 | Objectives for NNBF in Fluvial Settings

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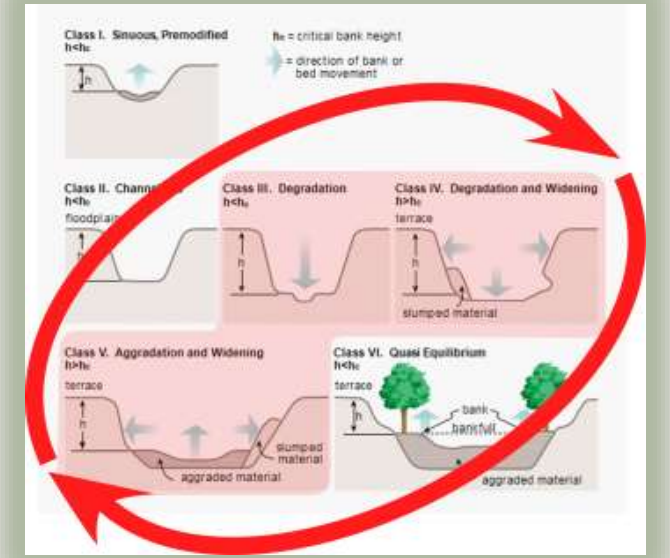

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Solutions for Alluvial Stream Restoration Projects in Urban & Suburban Settings

- Priority Approach:
  - Rosgen Priority 1 Restoration wherever possible (e.g.,headwaters)
  - Rosgen Priority 2 Restoration everywhere else if possible,
  - Rosgen Priority 3 with grade control & minimal floodplain in laterally constrained reaches

- Keys to Resiliency:
  - Grade control (use threshold/immobile grade control structures…even if not fully natural analogs!)
  - Floodplain connectivity at bankfull discharge
  - Outside meander channel bank toe armoring (toewood, boulders…even if not fully natural analogs!)
  - Vegetation management through root maturity

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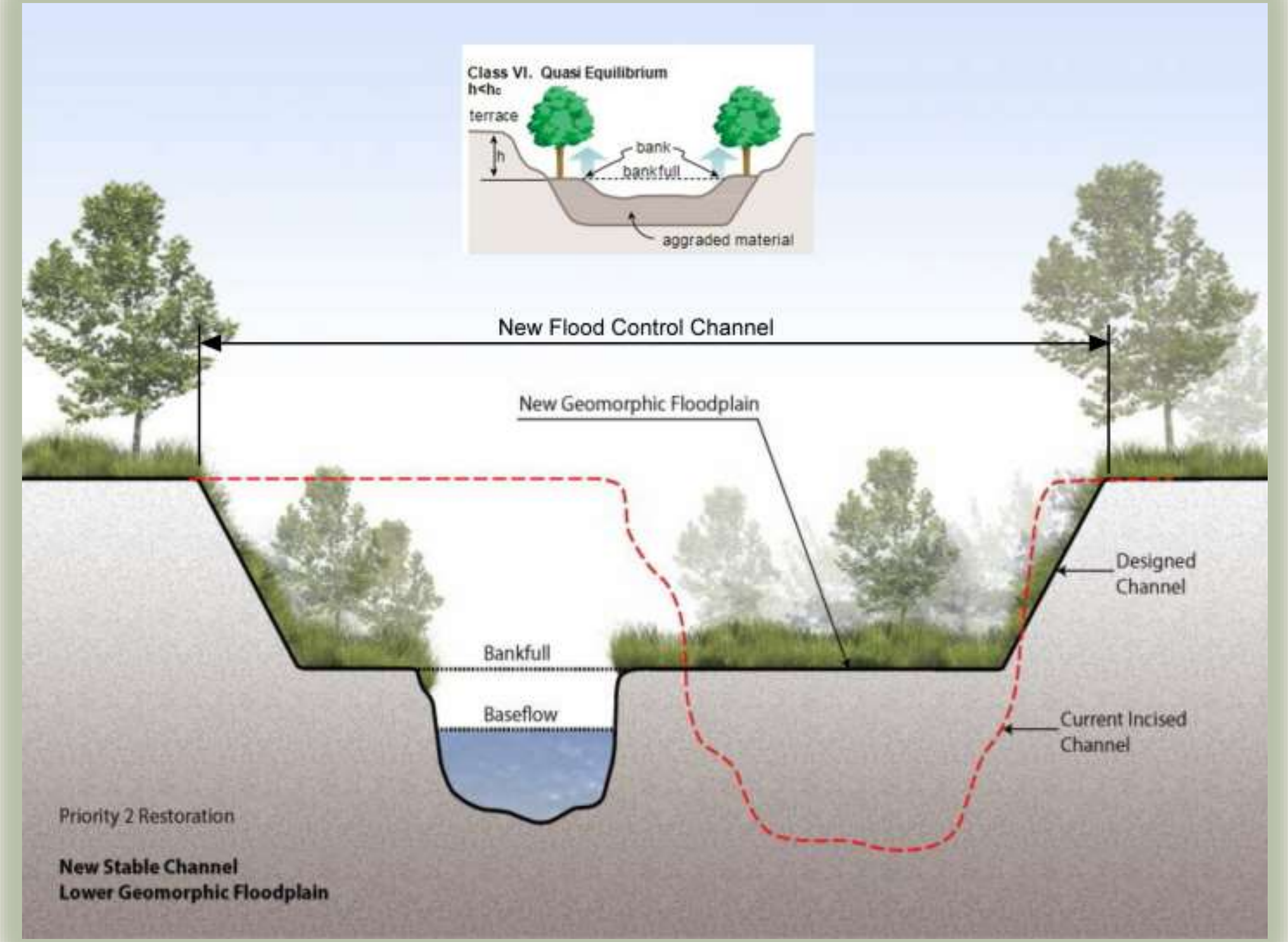
Priority 2 Restoration Components



Images courtesy of HCFCD & Lane

- Establish equilibrium at lower elevation

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Priority 2 Restoration Components

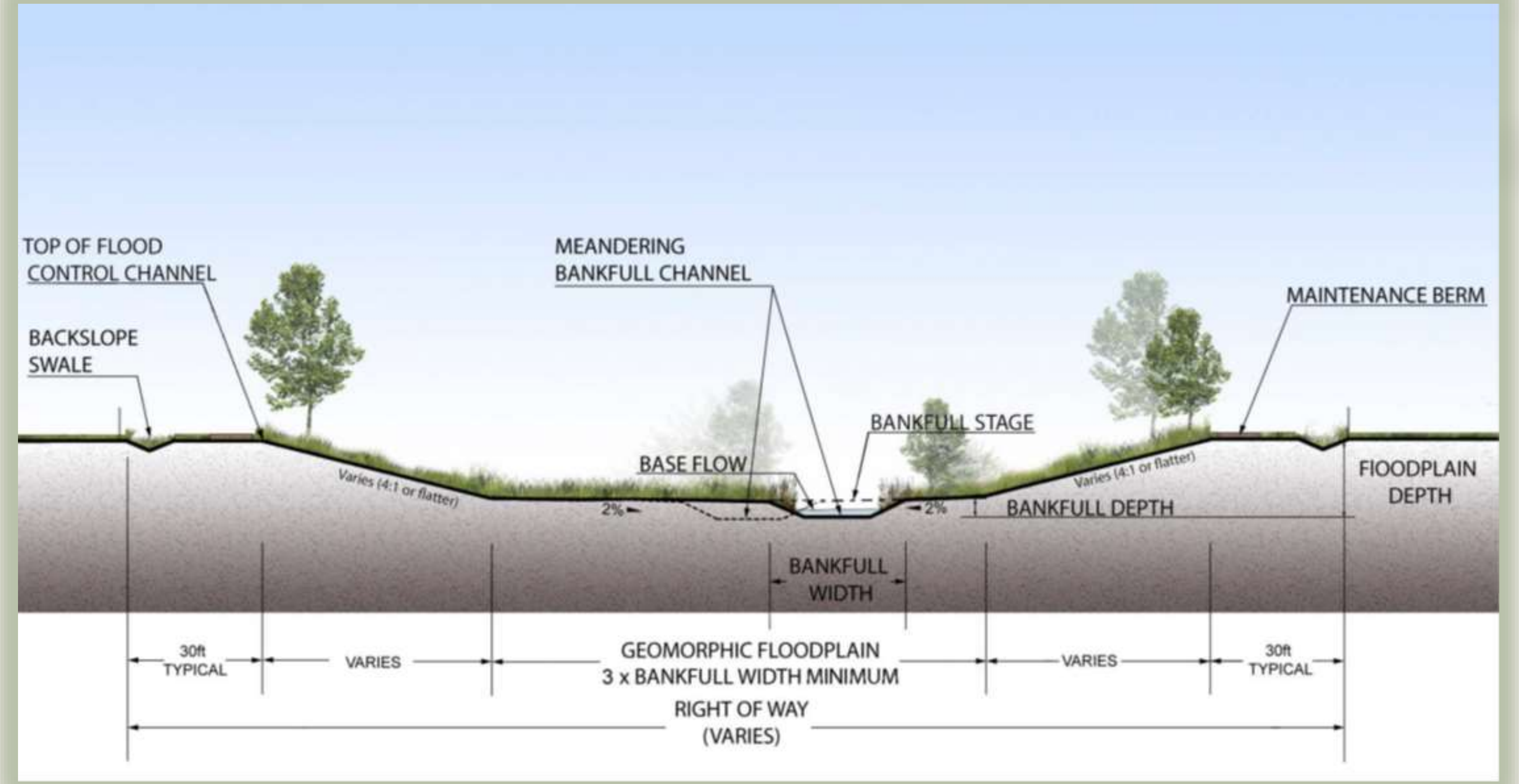

Image courtesy of HCFCD

- Rosgen C channels (with possible transition to E channel)
- Nominal bankfull floodplain bench (Min: 3 x WBKF)

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Priority 2 Restoration Components

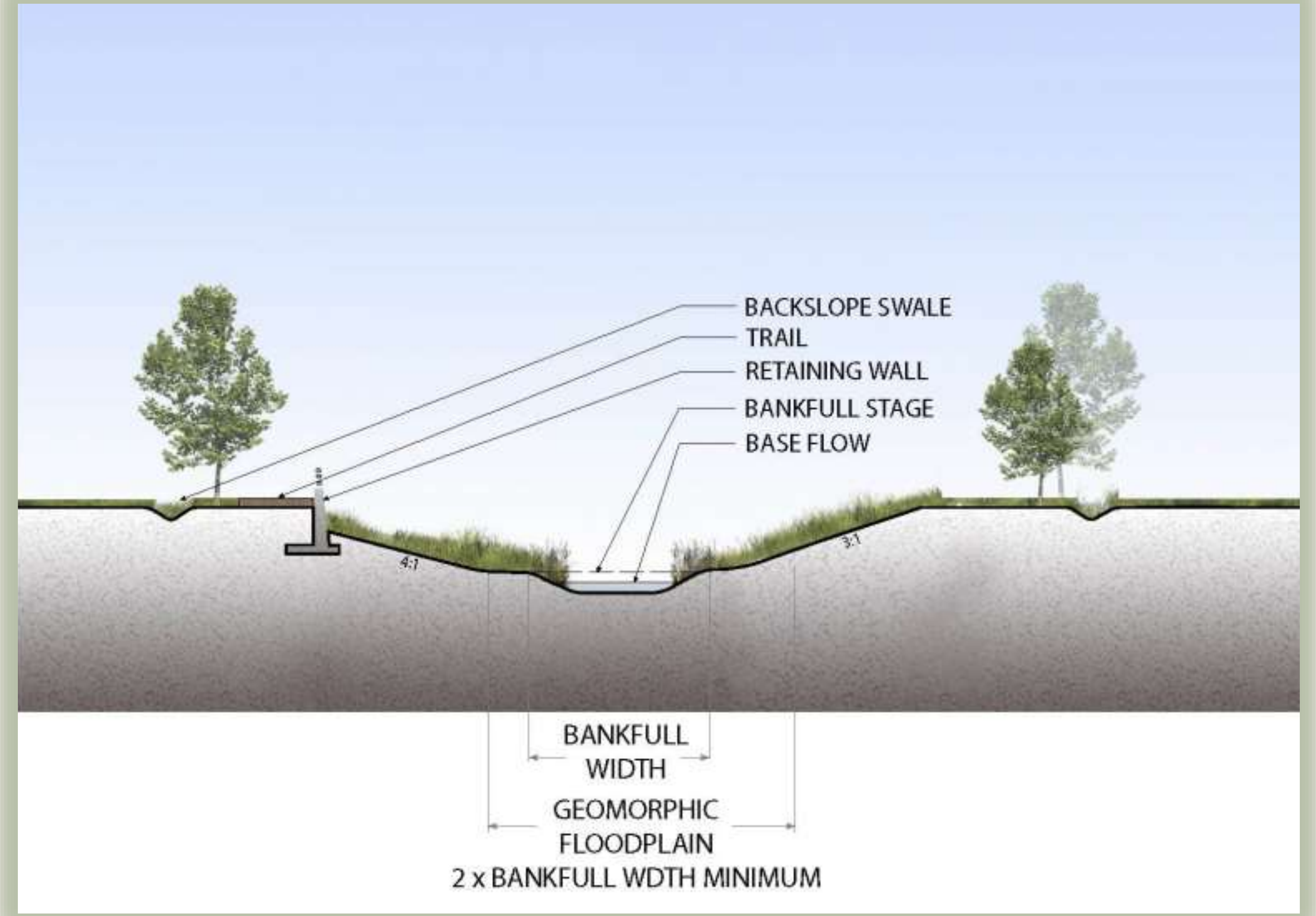

Image courtesy of HCFCD

- Rosgen Bc (step-pool) channels where lateral constraints or slopes require
- Nominal bankfull floodplain bench (Min: 2 x WBKF)

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Priority 2 Restoration Components

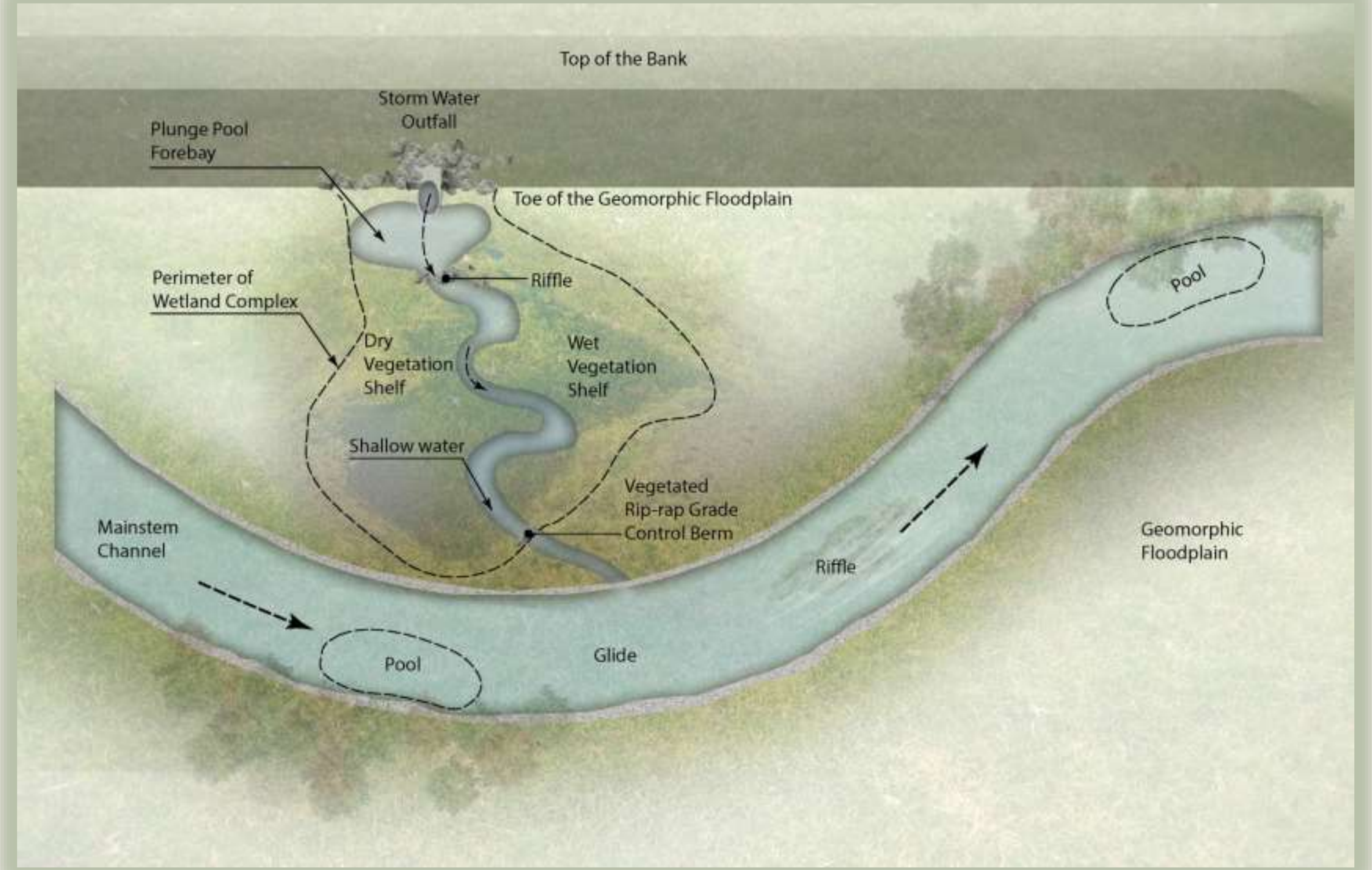

Image courtesy of HCFCD

- Stormsewer outfall energy dissipation & waters quality wetlands on geomorphic floodplain

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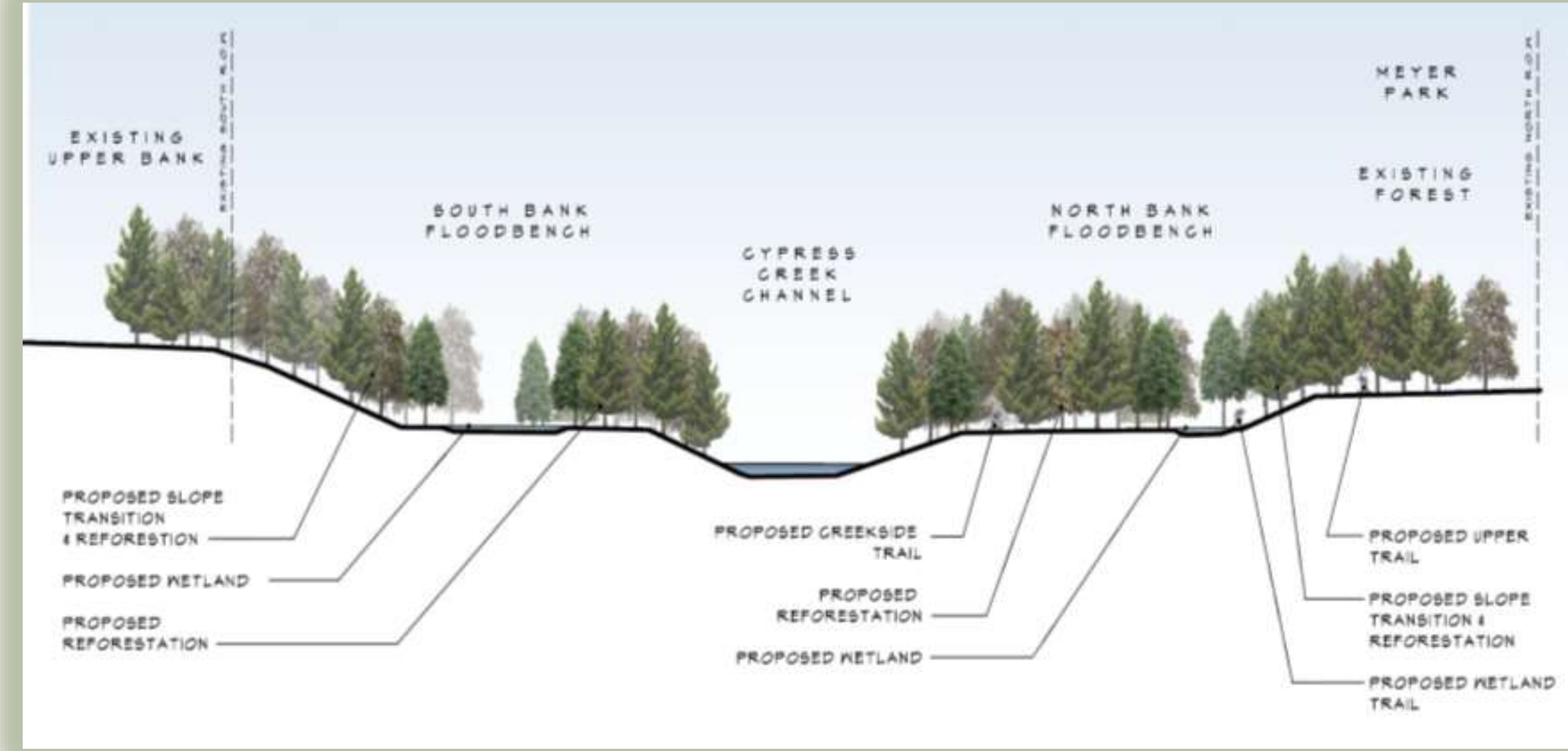
Priority 2 Restoration Components



- Greenway trails on bankfull bench

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Cypress Creek @ Mayer Park, Houston

- 189 mi^2 drainage area
- $Q_{BKF} = 1{,}853$ cfs
- $W_{BKF} = 120'$, $D_{BKF} = 11'$
- Sand bed & banks
- Natural, but majority of reaches in area had been dredged in the past
- Unstable reaches upstream sending large sediment loads through project reach
- Incision and overwidening via channel evolution process threatened park infrastructure and stormsewer outfalls

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Cypress Creek @ Mayer Park, Houston

Reach 1 Improvements

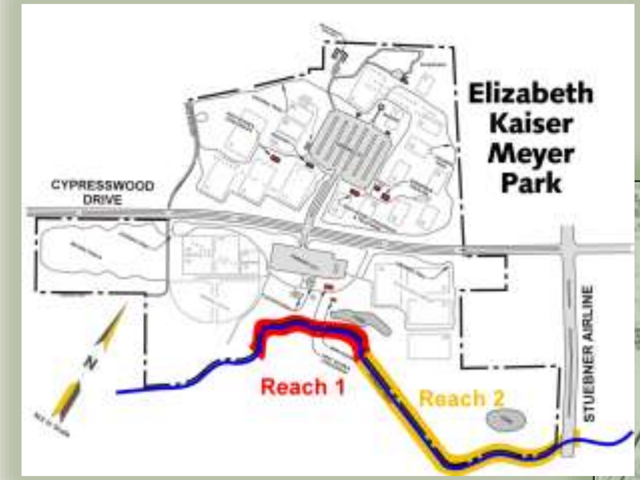
- 800' Relocated Priority 2 NCD Meander Bend
- Riprap Armored Channel Toe (Both Banks)

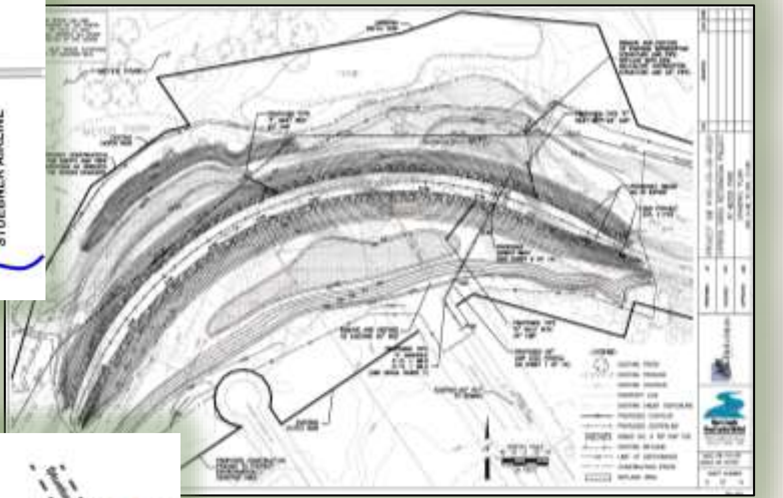
Reach 2 Improvements

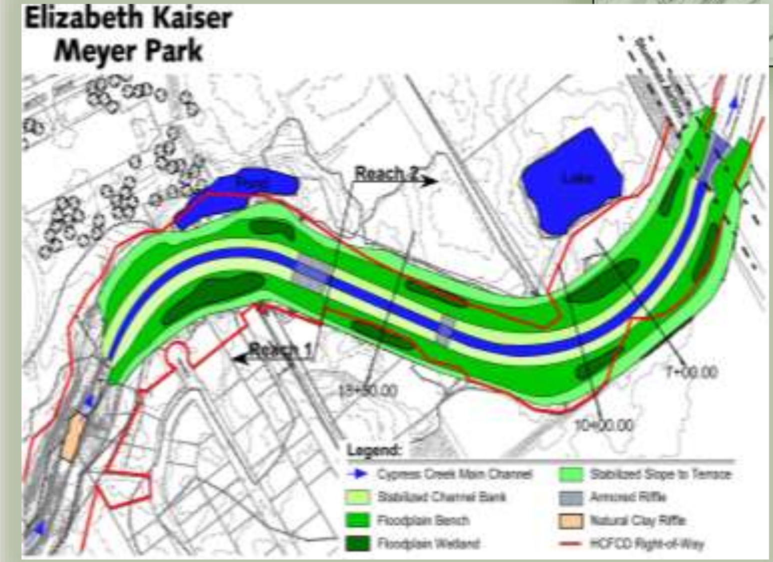
- 2,000' Relocated Priority 2 NCD Channel
- Constructed Threshold Boulder Grade Control Riffles

Reach 1 & 2 Common Improvements

- Constructed Floodplain Bench
- Stabilized and Vegetated Flood Control Channel Slopes
- Grass, Forb, Shrub & Tree Plantings
- Armored Stormsewer Outfalls
- Floodplain SWQ Wetlands
- Greenway & Park Trail Alignments







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Reach 1 Before & After Construction (2009)

BEFORE

AFTER

- Stable and self-improving after 8 bankfull events

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Reach 1 & 2 After Construction (2017)




- Stable and self-improving after Memorial Day Flood (2015), Tax Day Flood (2016), and Hurricane Harvey (2017)

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Thank you!!!
Questions?