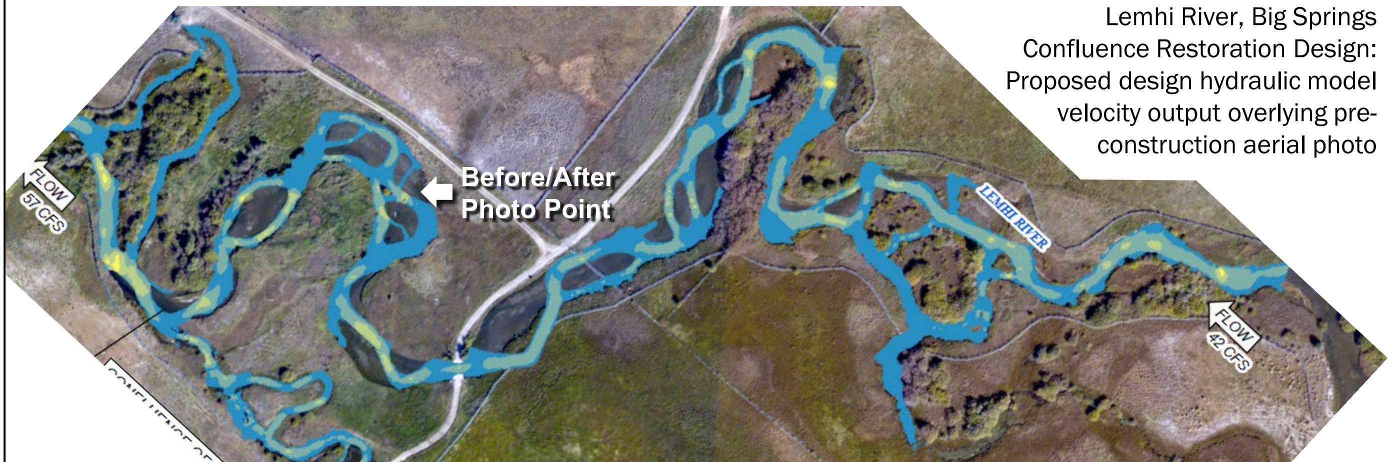
Treatment: Side Channels
Type: Reconnection and Restoration



Lemhi River, Big Springs Confluence Restoration Design: Proposed design hydraulic model velocity output overlying pre-construction aerial photo

Application

- Reconnect existing low-lying topography
- Excavate/create side channels where geomorphically appropriate
- Create diverse off-channel habitat with cover and access to the main channel

Biological Considerations

- Frequent, short/narrow side channels (less than 35% flow split, up to 800 ft long) preferred to less frequent, long/wide side channels
- Habitat units should be proportionally smaller and more frequent compared to the larger main stem
- Winter/summer rearing for Chinook and steelhead

Geomorphic Considerations

- Spring-fed hydrology and/or limited bedload systems tend toward lower width-to-depth, sinuous, side channels with few/no exposed bars maintained by dense riparian vegetation
- Snowmelt hydrology and/or high bedload systems tend toward less sinuous, island-braided systems maintained by instream structure (esp. log jams)

Design Considerations

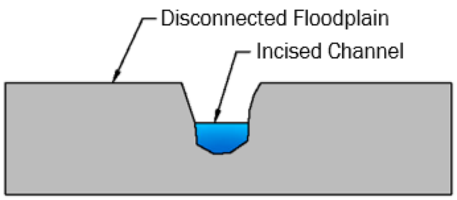
- Channel inlet/outlet located in pools or glides, generally upstream of riffles
- High (close to 90°) angle inlets may limit bedload entering the side channel
- Use natural scour/deposition to form side channels with limited earthwork where geomorphic processes and risk allow

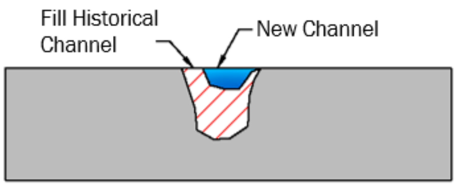
Lemhi River, ID; Over-widened, single-thread channel; average channel width over 100 ft.

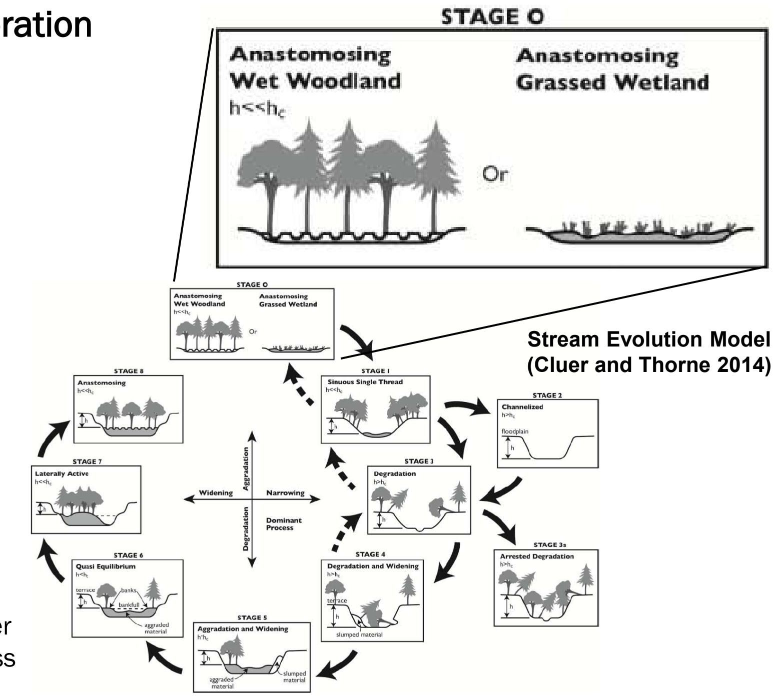
Lemhi River, 1.5 years after construction of multi-threaded channel network using various bank treatments and instream structure to split flow into many, short, narrow side channels; average width less than 20 ft.

Lemhi River, during construction; including FESL, brush bank, and LWD with sod mats and potted plants.

Treatment: Floodplain Reconnection – Fill or Raise the Channel
Type: Reconnection and Restoration







Stream Evolution Model (Cluer and Thorne 2014)

Application

- Raise the water surface with channel fill, constructed riffles, increased sinuosity (i.e., lower gradient), narrower channel, increased roughness and/or other means to inundate the floodplain more frequently

Biological Considerations

- Provides high-flow refuge for juvenile salmonids

Geomorphic Considerations

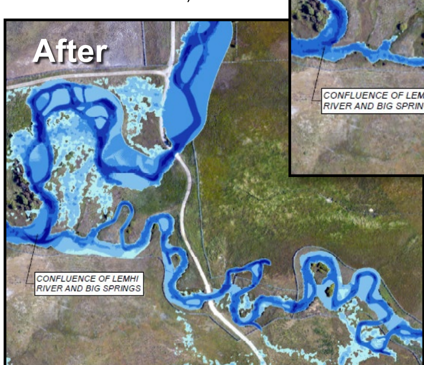
- Dissipates flood energy
- Deposits fine sediment in the floodplain
- Improves hydrologic connectivity for riparian areas and wetlands

Design Considerations

- Promote over-bank flow in densely vegetated areas
- Significant roughness is often required in frequently inundated floodplain areas to prevent avulsion and undesired channel response resulting in low sinuosity and/or channel incision
- Complete channel commonly referred to as "stage-zero restoration" after Cluer and Thorn (2014) stream evolution model

Lost Creek, OR, before channel fill

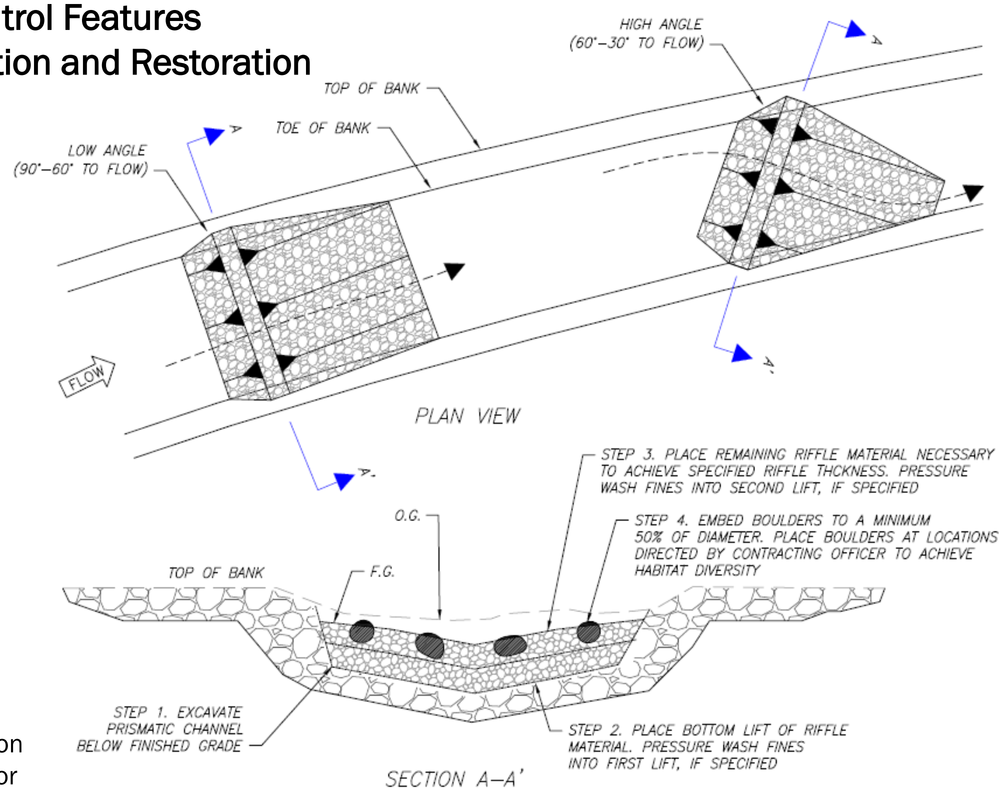
5-yr Flood Model of Lemhi River and Big Springs Creek Confluence, ID



Narrower channel, increased sinuosity, grade control and hydraulic roughness increased floodplain connection in restored channel

Jackson Creek, OR, immediately after channel fill

Treatment: Grade Control Features
Type: Reconnection and Restoration



Application

- Raise the streambed elevation
- Abate channel incision and/or knickpoint

Biological Considerations

- Adult and juvenile fish often feed in riffles due to macroinvertebrate abundance
- Proximity to cover and pool refuge is an important consideration

Geomorphic Considerations

- Can be used to backwater floodplain and/or side channel areas, activating off-channel habitat
- Flow passes over the riffle crest perpendicular to the crest angle; a high-angle riffle crest can be used to direct flow toward the bank
- Temporary storage of transient bedload

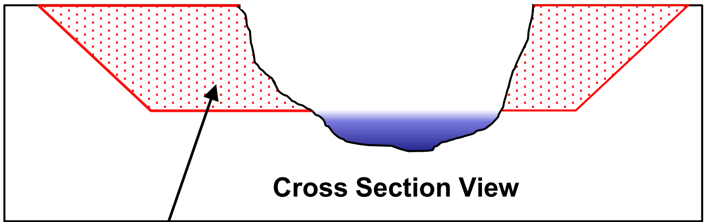
Design Considerations

- Must understand channel migration trends to ensure channel does not migrate off the riffle before the system has stabilized
- Material sizes should be comparable to the native substrate and should be keyed into the bank to prevent short-term flanking
- Constructed riffles are elongated features that can range in slope from 0.1–5%, while drop structures (step pools) are singular features that control vertical grade and can be used to develop pool habitat
- Roughened chutes are a combination of step pools incorporated into longer reinforced riffles and are typically placed in channels with steeper slopes (>5%)
- Selection of material is important to stability
- A concave cross section may be necessary to focus low-flow water sufficiently to provide adequate depth for seasonal fish passage
- Downstream pool formation and upstream backwater conditions often occur

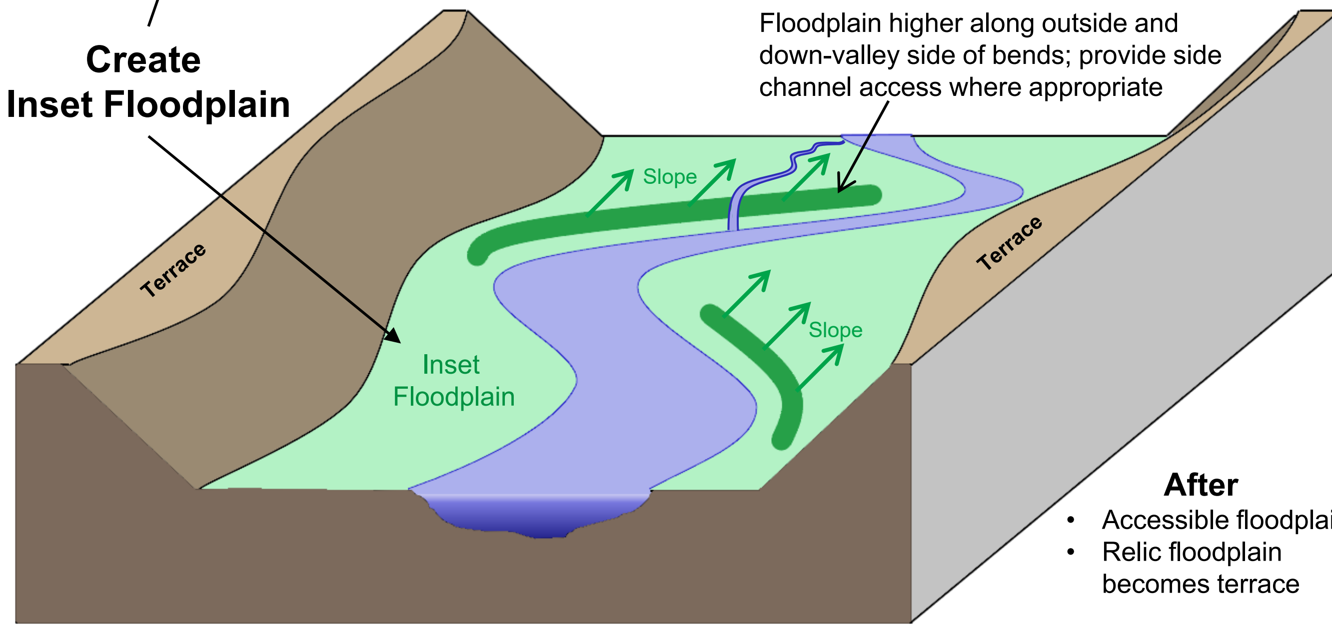
Constructed riffle during construction; LWM bank structure installed on left bank (right side of photo) to reduce over-widened channel width; Lemhi River, ID

Constructed riffle immediately after construction; Lemhi River, ID

Treatment: Floodplain Reconnection – Create Inset Floodplain
Type: Reconnection and Restoration



Before
- Incised channel
- Poor floodplain connection
- Concentrated flow
- No high-flow refugia



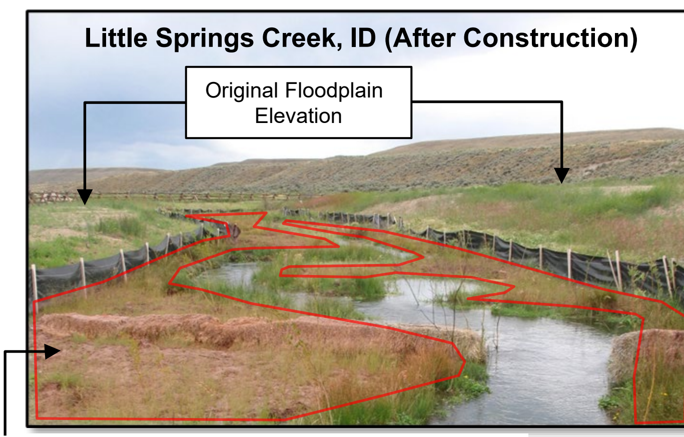
After
- Accessible floodplain
- Relic floodplain becomes terrace

Application
- Selective earthwork to create a new, lower, inset floodplain to enable more frequent inundation

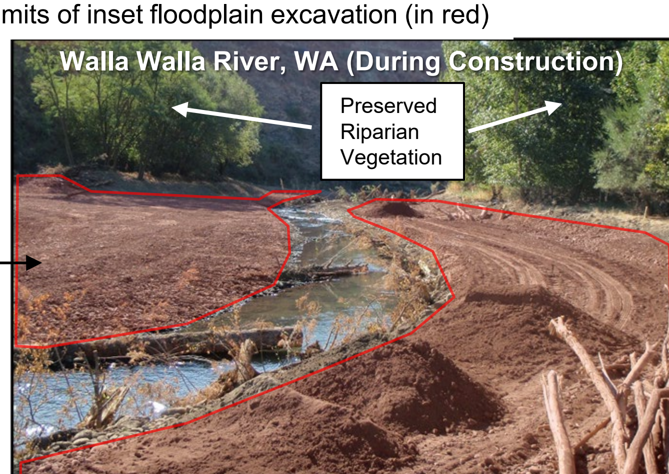
Biological Considerations
- Provides high-flow refuge for juvenile salmonids
- Creates a floodplain surface near the groundwater table to enable/enhance riparian vegetation

Geomorphic Considerations
- Dissipates flood energy
- Deposits fine sediment in the floodplain
- Improves hydrologic connectivity for riparian areas
- Reduces flooding elevations by increasing capacity within the inset floodplain
- Does not address the cause of incision
- Results in "Arrested Degradation" stage of channel evolution (Stage 3s – Cluer and Thorne 2014)

Design Considerations
- Consider constructing new banks and floodplain surfaces slightly higher on the outside and down-valley side of bends and islands, sloping slightly down-valley to limit avulsion risk while still providing large areas of flood backwater inundation
- Floodplain width (i.e., meander belt width) should be at least as wide as the maximum calculated meander amplitude
- Can often require disposal site for excavated floodplain material



Limits of inset floodplain excavation (in red)



Treatment: Reduce Channel Width
Type: Restoration

Big Springs Creek, ID; Before construction; Over-widened channel with plane-bed and poor habitat diversity

Big Springs Creek, ID; 1 year after construction; Reduced channel width, increased sinuosity, improved shade, and hydraulic diversity using a variety of bank fill treatments (FESL, brush mat, willow clumps, post-line willow-weave, gravel placement

Application

- Reduce channel width where over-widened to meet geomorphic targets
- Excavate new channel(s) and/or fill portions of the existing channel

Biological Considerations

- Install habitat structures and cover; plant riparian vegetation to maintain habitat diversity and shade

Geomorphic Considerations

- Relocate the channel against existing, mature vegetation where possible to provide immediate structure, cover, and shade

Design Considerations

- Add sinuosity, side channels, and/or floodplain connection to compensate for increased velocity associated with narrower channel width to achieve desired instream conditions across a variety of flows
- Detailed hydraulic modeling required; compare existing vs. proposed hydraulic diversity using histogram outputs of velocity and depth area distributions to confirm increased hydraulic variability and habitat suitability
- Provide variability in width by providing areas of contraction and expansion
- Use a variety of bank treatments; provide topographic variability in floodplain areas

Treatment: Channel Realignment
Type: Restoration

Channel realignment and side channel creation during construction, Catherine Creek, OR

Application

- Create a new, more geomorphically appropriate channel network with improved habitat
- Used to relocate a new channel away from negative response areas and/or toward positive response areas

Biological Considerations

- Redirect channel to areas with improved floodplain connection, mature riparian vegetation, and/or greater habitat potential
- Optimize channel form and structure to meet habitat objectives, including habitat unit frequency and diversity

Geomorphic Considerations

- Create channel through cut and fill earthwork where geomorphic processes will not naturally restore conditions within a reasonable period of time
- Integrate process-based restoration where feasible by identifying dominant processes and enabling a response around them (e.g., where deposition is a likely response, add strategic structure to capture sediment forming new bars, islands, and floodplain areas; where erosion is a likely response, excavate a narrow "pilot channel" with strategic structure enabling the river to cut new channels where directed).

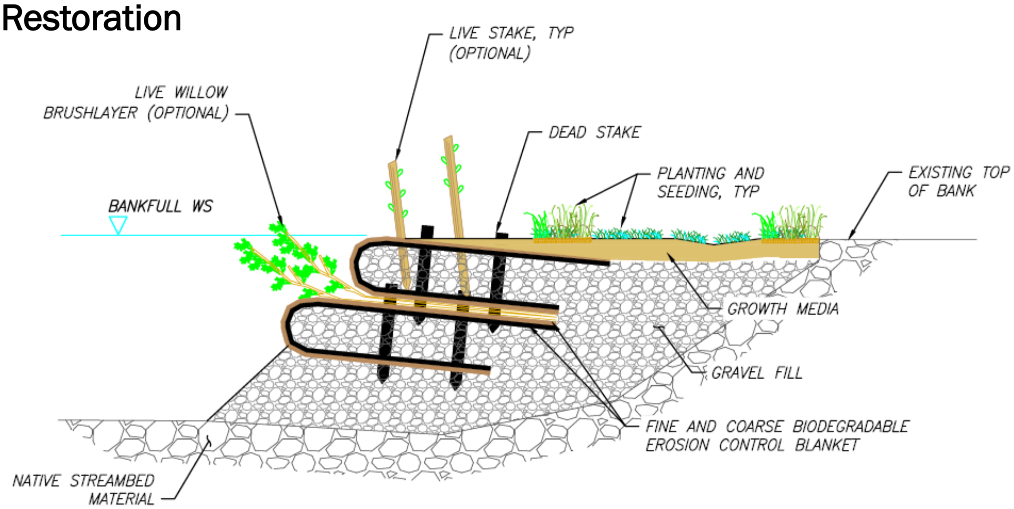
Design Considerations

- Determine target planform, side-channel character, and channel geometry conceptually based on reach geomorphic and biological targets/objectives
- Multiple iterations of design and 2-dimensional hydraulic modeling recommended to evaluate likely response and make appropriate adjustments
- Target bank treatments and instream structure where appropriate based on potential stream energy and habitat needs
- Need sufficient area to execute successfully
- Potential to increase floodwater and groundwater elevations

Newly constructed channel with LWM bank structure 1 year after construction; Catherine Creek, OR

New channels with FESL bank treatments and increased floodplain activation 6 months after construction during spring runoff; Lemhi River, ID

Treatment: Bank Fill – Fabric Encapsulated Soil Lift (FESL)
Type: Restoration



Application

- Temporarily stabilize banks (typically outside bends) until riparian vegetation is established
- Used to retain soil to fill over-widened channel

Biological Considerations

- Integrate brush, willow clumps, and/or LWM to increase cover and interstitial spaces for juvenile salmonids
- Integrate live vegetation to improve riparian conditions and enhance root mat development

Geomorphic Considerations

- Can create stable, near vertical banks

Design Considerations

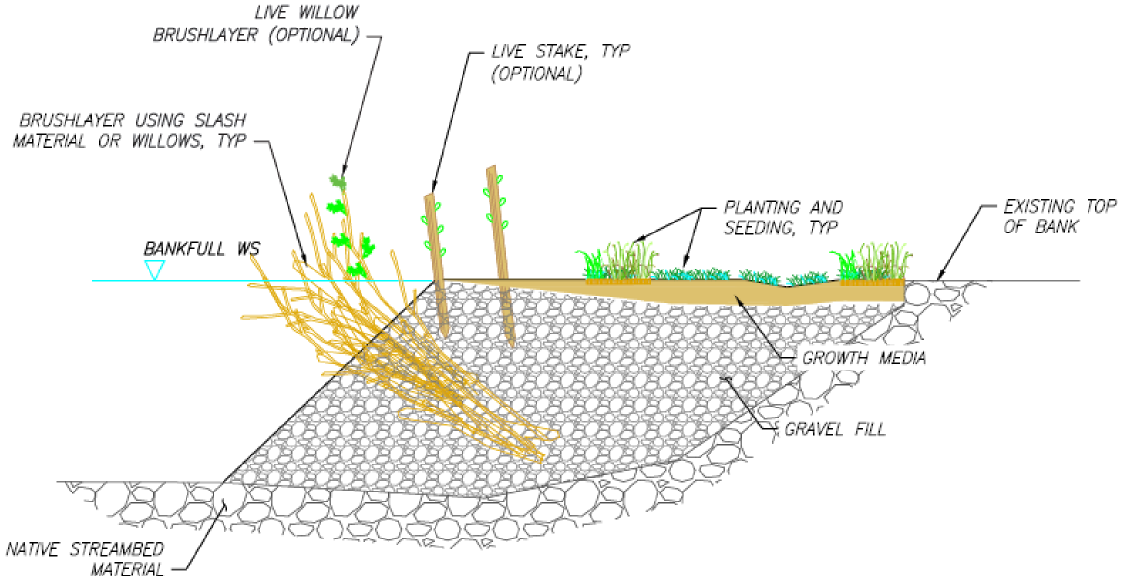
- Select appropriate geotextile fabric to withstand anticipated hydraulic forces
- Useful with otherwise unstable fill material (silt/sand)
- Use narrow sheets of fabric to reduce the overall width of the FESL treatment
- Install top lift several inches below final design elevation to allow space for sod mat if proposed
- Consider planting container plants directly into FESL
- Install with an irregular final surface elevation to provide topographic complexity
- Do not fill fabric with soil or leave gaps where LWM will be placed to provide space for the LWM

Over-widened channel; Big Springs Creek, ID

Big Springs Creek 1 year after construction; Width-to-depth ratio reduced by over 50% using FESL on both banks

Big Springs Creek during construction; Fill placed behind the FESL with potted plants; Sod mat and potted plants within FESL not yet installed

Treatment: Bank Fill – Brush Layer
Type: Restoration



Application

- Temporarily stabilize banks (typically outside bends) until riparian vegetation is established
- Used to dissipate energy in high-energy areas
- Can be used with or without other treatments to retain soil to fill over-widened channels

Biological Considerations

- Provides increased cover and interstitial spaces for juvenile salmonids
- Integrate live vegetation to improve riparian establishment and enhance root mat development

Geomorphic Considerations

- Creates significant bank roughness that can accumulate fine sediment in low-energy areas

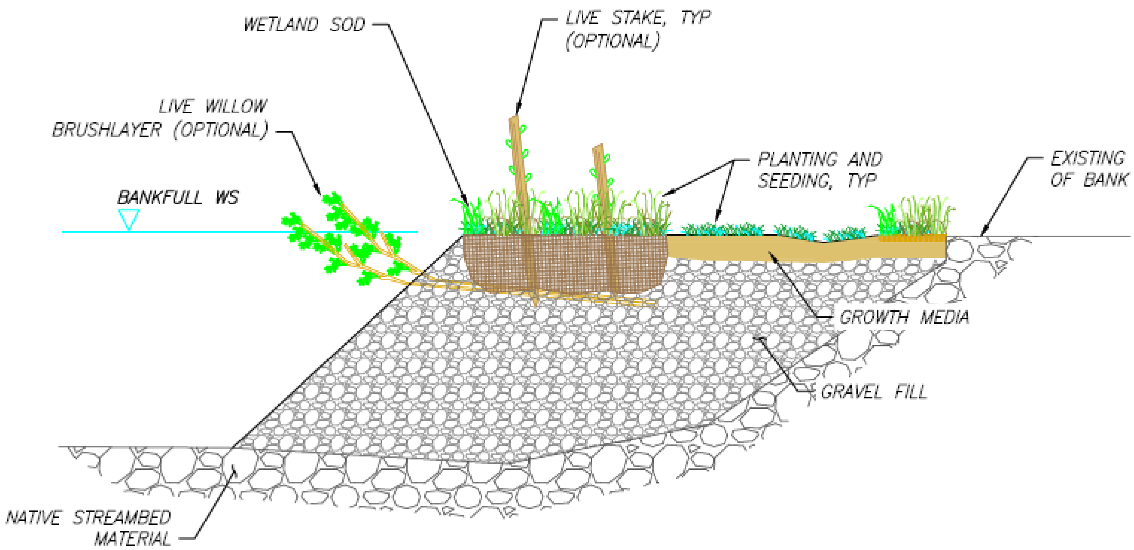
Design Considerations

- Specify min/max protrusion to match roughness conditions from hydraulic model

Willow brush layer during construction (Above) and immediately after construction (Below); Lemhi River, ID

Slash brush layer 1 year after construction; Catherine Creek, OR

Treatment: Bank Fill – Wetland Sod
Type: Restoration



Application
- Used with or without other treatments to retain soil to fill over-widened channels
- Used for short- and long-term bank stabilization

Biological Considerations
- Increases rates of vegetative establishment
- Integrate woody vegetation (potted plants and/or live stakes) to increase riparian diversity, structure, cover, and shade
- Provides high flow cover and refuge for juvenile fish

Geomorphic Considerations
- Creates bank roughness and promotes the formation of a root mat providing long-term bank structure

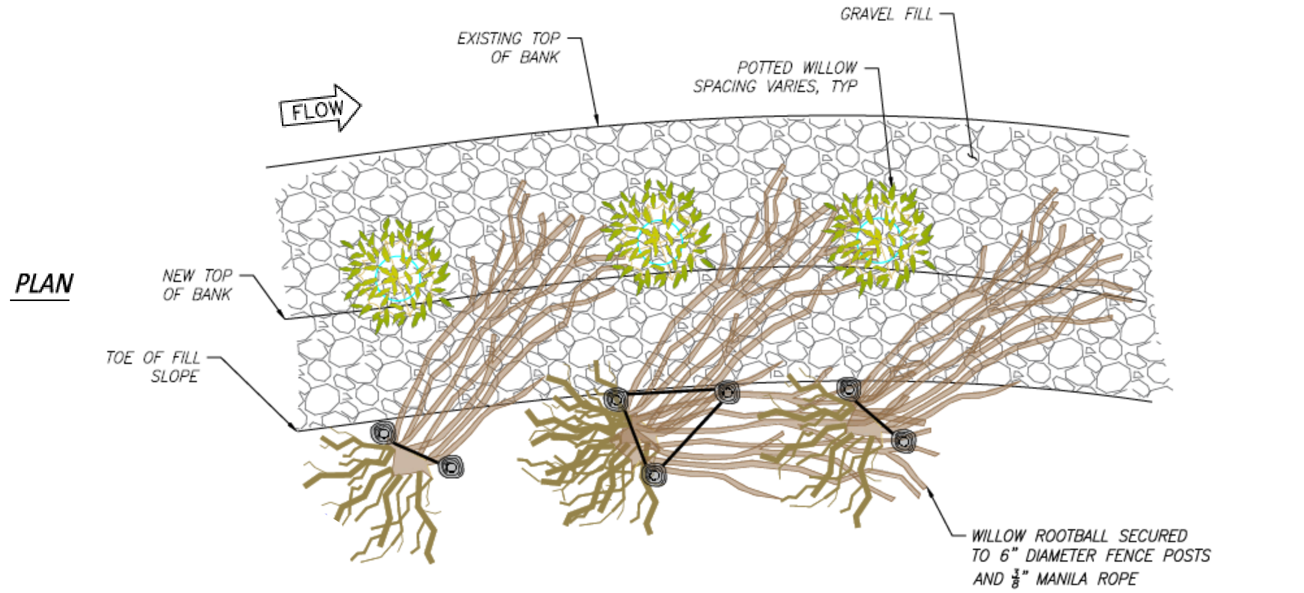
Design Considerations
- Can use nursery stock or harvest sod mats on-site
- Specify thickness and ensure final grade elevations are sufficiently low to accommodate the sod mats
- Prioritize directly adjacent the bank, but consider strips of sod with woody plantings in between

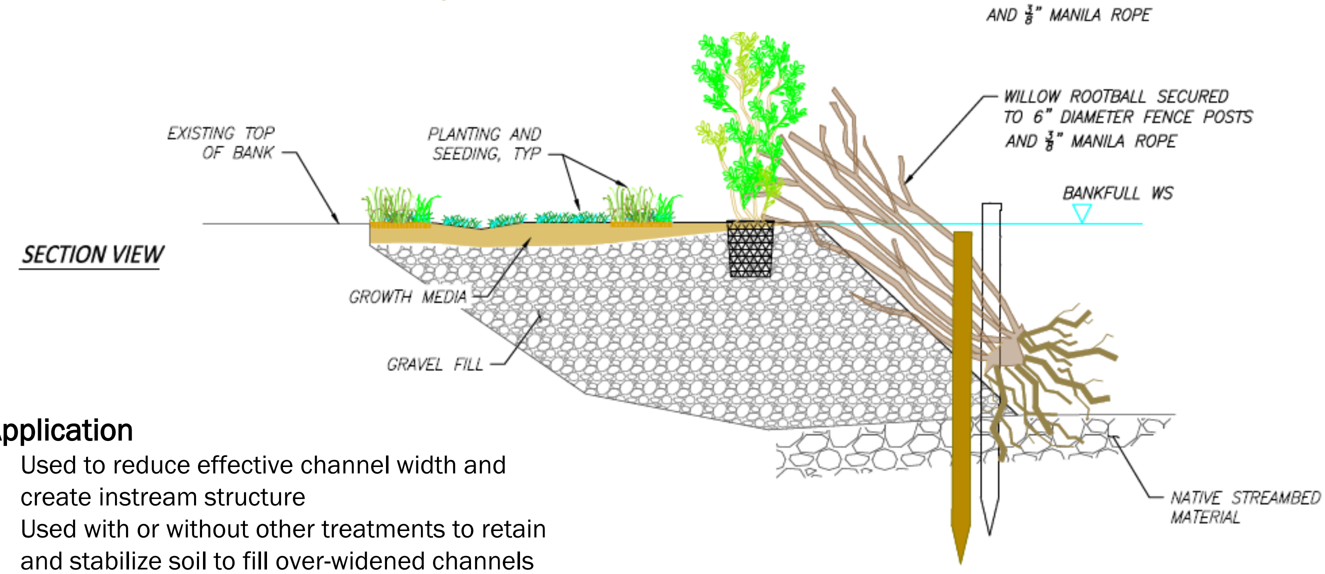
Thick strips of wetland sod harvested on-site used to retain unstable sandy bank fill immediately after construction; Big Springs Creek, ID

Bank fill stabilized with on-site harvested wetland sod immediately after construction; Big Springs Creek, ID

Strips of nursery-grown wetland sod placed over FESL bank treatment with potted willows between strips 1 year after construction; Big Springs Creek, ID

Treatment: Bank Fill – Willow Clumps
Type: Restoration





Application

- Used to reduce effective channel width and create instream structure
- Used with or without other treatments to retain and stabilize soil to fill over-widened channels
- Used for short- and long-term bank stabilization

Biological Considerations

- Provides cover, structure, and interstitial spaces for juvenile salmonids
- Creates instream velocity and habitat complexity across a range of flows

Geomorphic Considerations

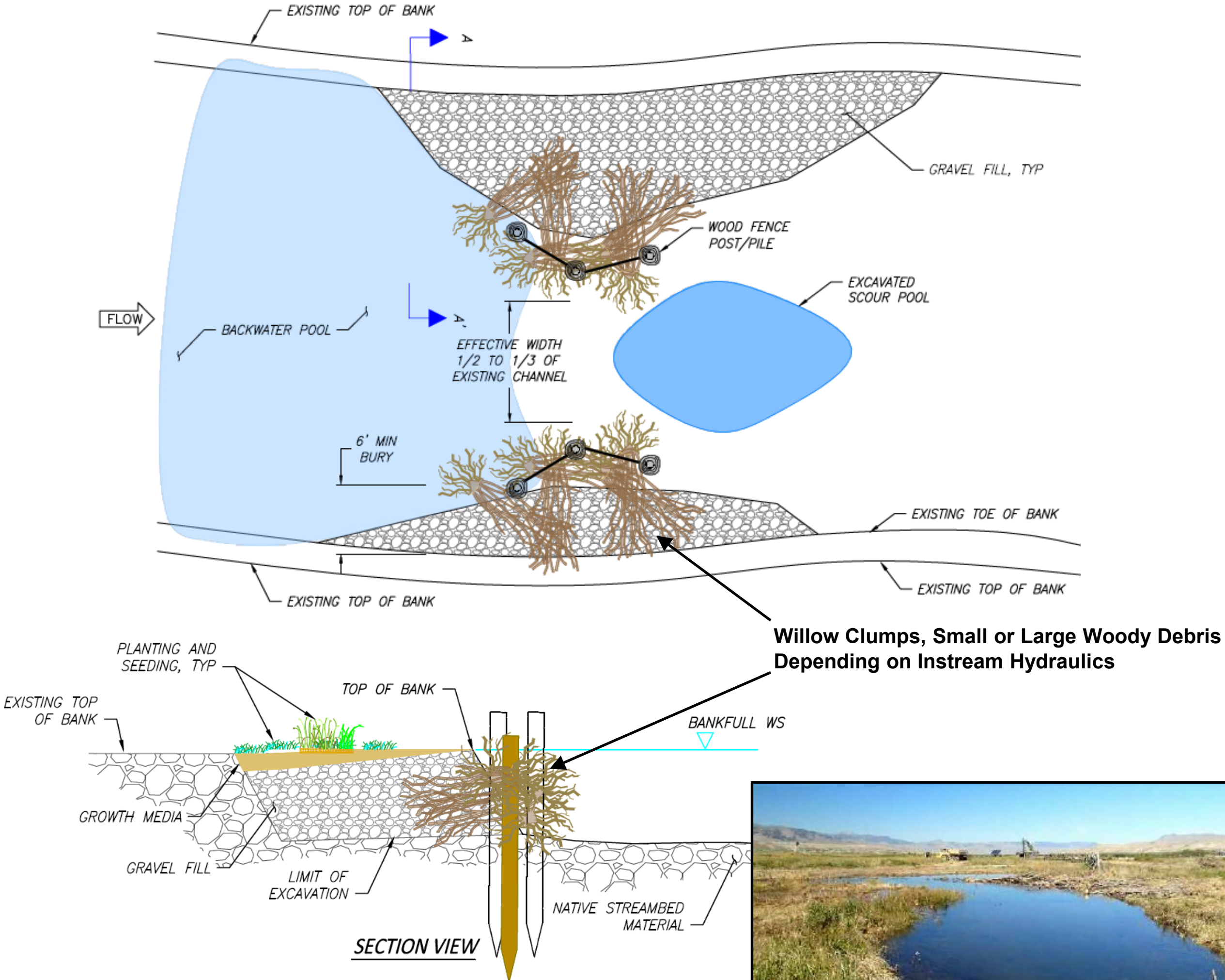
- Creates bank roughness and structure until riparian vegetation can be established
- Can be used to obstruct flow and provide sharp hydraulic gradients sorting bedload and directing flow

Design Considerations

- Place rootwad into channel for greater rigidity (i.e., outside of bend) and consider placing willow branches into channel where hydraulic forces are less severe (i.e., inside of bend)
- Consider use of live willow clumps to increase vegetative establishment

Series of willow clumps placed along the outside of a newly constructed meander bend to provide bank stability, instream structure, and cover immediately after construction; Big Springs Creek, ID

Treatment: Channel Constriction
Type: Reconnection, Restoration



Application

- Create channel constriction to force upstream backwater and/or downstream scour pool
- Reduce effective channel width locally

Biological Considerations

- Increases habitat unit frequency near suitable areas for spawning and rearing salmonids
- Can create backwater and scour pools
- Provides in-channel complexity, velocity and depth variability
- Incorporating LWM or similar structure may increase structural diversity and habitat value

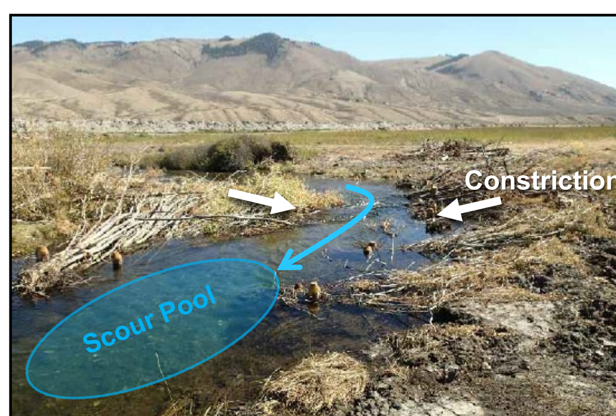
Geomorphic Considerations

- Hydraulic contraction and expansion creates velocity gradients that can sort sediment and create geomorphic complexity
- The greater the contraction the greater the hydraulic effect

Design Considerations

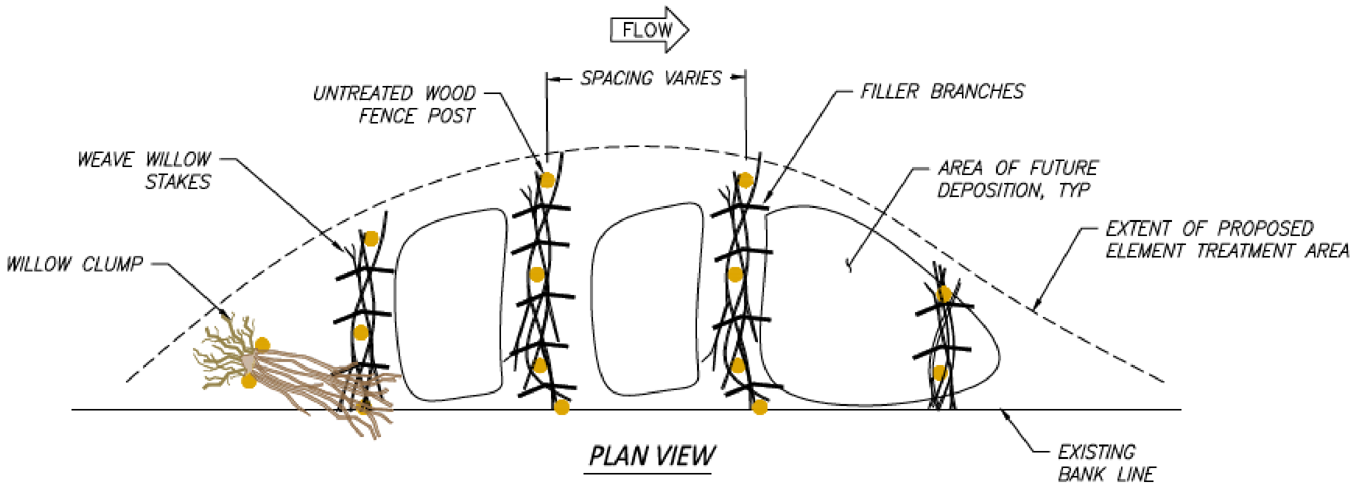
- Allow an appropriate width within the conservation easement (minimum of one channel width from existing banks).

Backwater pool above flow constriction; Big Springs Creek, ID



Flow acceleration and scour pool downstream of flow constriction; Big Springs Creek, ID

Treatment: Post-Line Willow-Weave
Type: Reconnection and Restoration



PLAN VIEW

Application

- Used to reduce effective channel width and capture sediment forming point bars
- Primarily used to form or enhance the inside of bends
- Can be used with or without other treatments to capture sediment to fill over-widened channel areas

Biological Considerations

- Provides short-term cover and low-velocity refuge for juvenile salmonids
- Creates long-term vegetated point bar increasing habitat diversity, cover, and shade

Geomorphic Considerations

- Narrows effective channel width forming areas of contraction and expansion creating hydraulic diversity
- Captures fine sediment forming point bars increasing sinuosity and reducing overall width-to-depth ratio
- To be used in streams with moderate to high sediment supply

Design Considerations

- Consider adding willow clumps, LWM, or other structure to the upstream and/or outer ends of the willow-weave to dissipate energy
- Using live willows in the weave may increase the rate of point bar vegetation establishment

Before

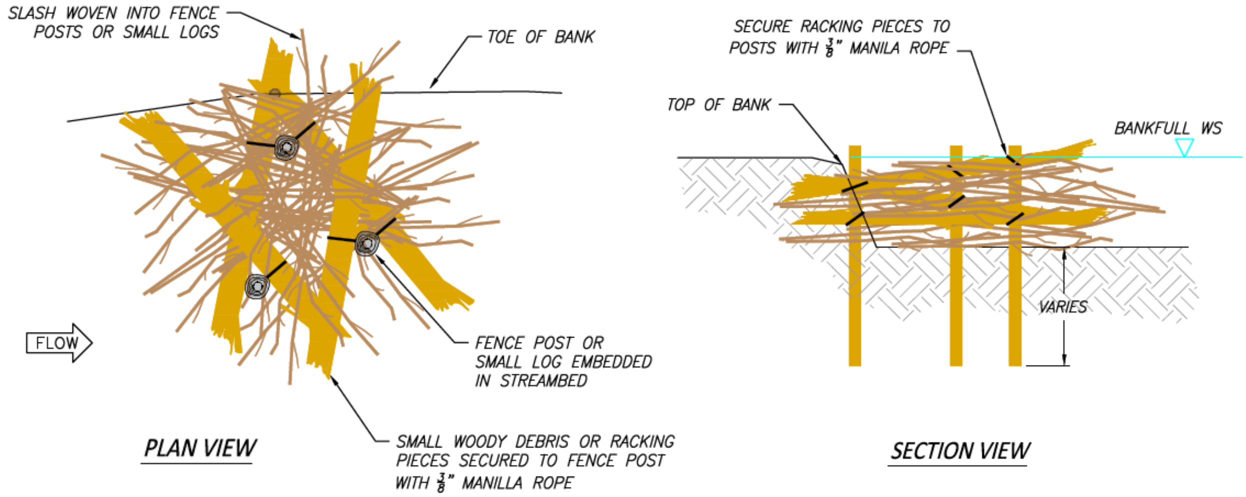
Over-widened channel before construction; Big Springs Creek, ID

After

6 months after construction; fine sediment deposition observed between willow weaves; effective channel width reduced by approximately 50%

During Construction

Treatment: Small Wood Material Structure
Type: Reconnection and Restoration



Application

- Used to create in-channel complexity, velocity, and depth variability
- Can be used to create channel constrictions promoting scour and gravel sorting
- Create cover for improved habitat

Biological Considerations

- Promotes velocity gradients and habitat diversity suitable for juvenile and adult salmonids
- Provides instream cover and interstitial spaces for juvenile salmonids

Geomorphic Considerations

- Increasing frequency and size of structures has a proportional affect on channel roughness
- Encourages sorting of bedload sediment

Design Considerations

- Incorporate LWD for increased stability and habitat diversity
- Consider excavating a scour pool to increase rate of channel response
- Anticipate channel response to determine size and frequency of structures

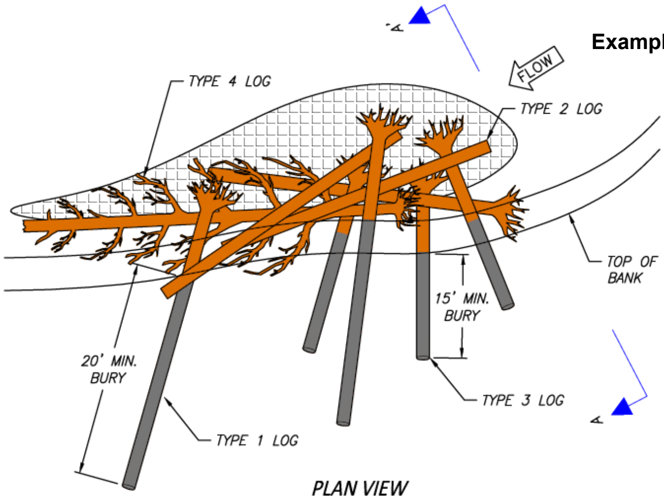
Small wood material structures 1 year after construction; Big Springs Creek, ID

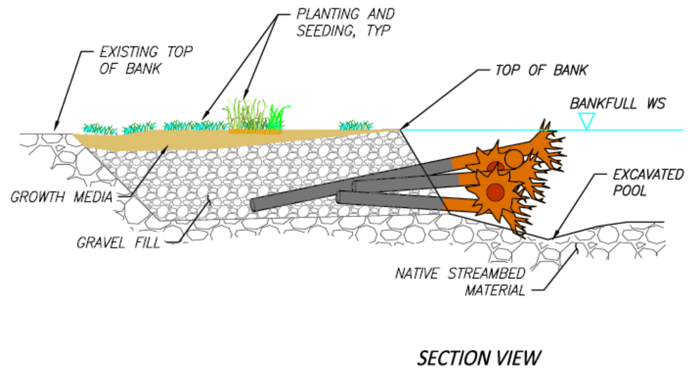
Small and large wood material bank structures immediately after construction; Big Springs Creek, ID

Small wood material bank structures with excavated scour pool immediately after construction; Big Springs Creek, ID

Treatment: Large Wood Material (LWM) Habitat Structure
Type: Reconnection and Restoration

Example Structure





Application

- Used to create in-channel complexity and velocity and depth variability
- Can be used in series for bank stabilization to buffer bank soils from erosive stream forces
- Can be used individually or on opposite banks to create channel constrictions
- Can be used to obstruct and/or block flows

Biological Considerations

- Create habitat diversity including scour pools with instream cover suitable for adult and juvenile salmonids

Geomorphic Considerations

- Can be used to obstruct flow to create backwater areas, sort gravel, and improve floodplain connection

Design Considerations

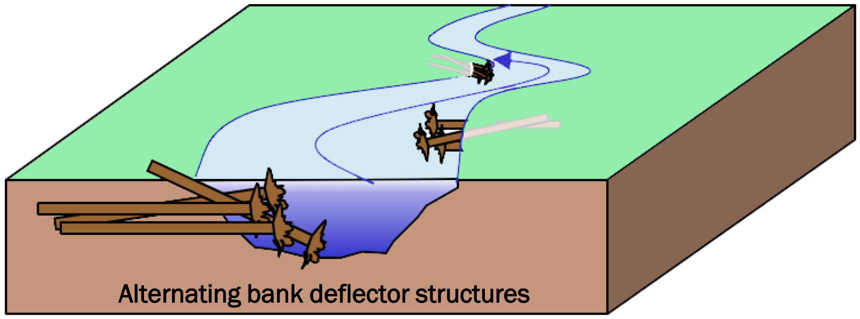
- Hydraulic modeling should be used to calculate the appropriate size and frequency of structure(s) to evaluate likely hydraulic response and change to habitat
- Incorporate small woody material and slash between key LWM members to provide interstitial cover
- Greater protrusion into stream can improve habitat and hydraulic response

LWM habitat structure immediately after restoration; Lemhi River, ID

Series of LWM habitat structures 1 year after construction; Lemhi River, ID

1 year after construction; Nason Creek, WA

Treatment: Bank Deflector Structures (Barbs)
Type: Reconnection and Restoration



Log bank deflector structure during installation; Lemhi River, ID

Application

- Structures that protrude from either streambank but do not span the channel
- Deflect flows away from the bank, form scour pools by creating channel constriction, and define channel thalweg

Biological Considerations

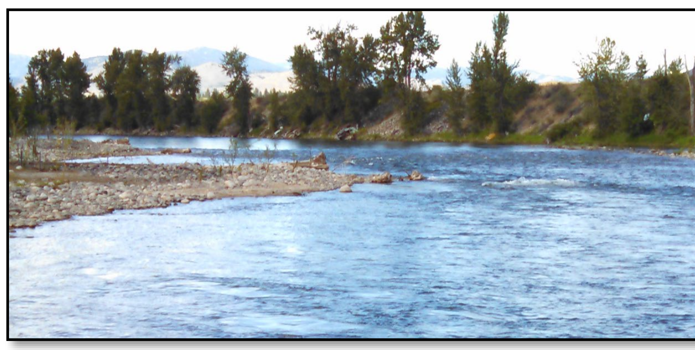
- Create velocity gradients and habitat complexity along the channel margin

Geomorphic Considerations

- Alternating bank deflector structures can be used to define and/or shape the thalweg

Design Considerations

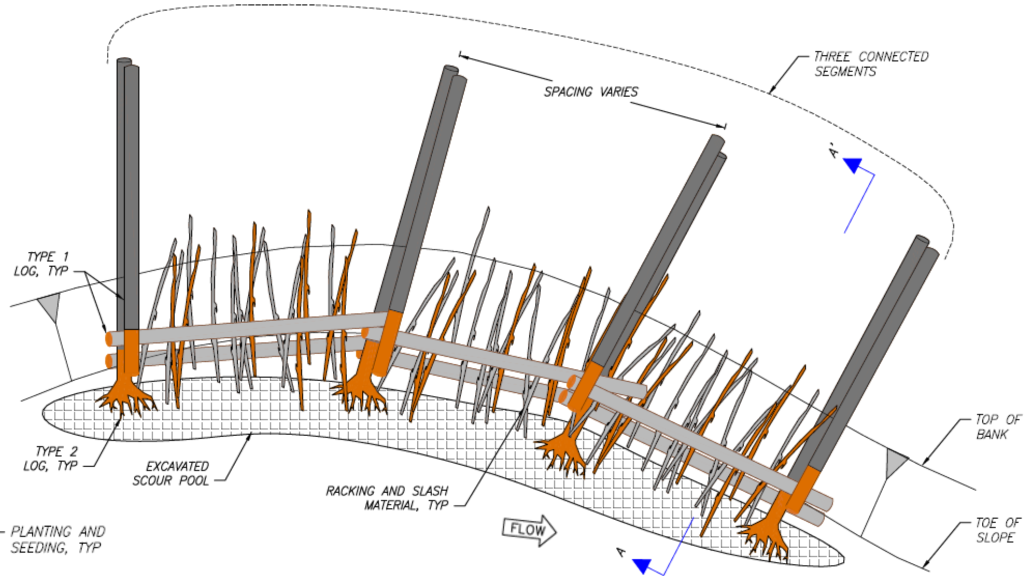
- Bank deflector structures can be constructed of LWM, small wood material, willow clumps, slash, post-line willow-weave, rock, or other suitable structure depending on local hydraulics and site conditions
- Material type, structure size, and spacing should be based on anticipated scour, stream energy, and anticipated hydraulic response
- Can be installed in series to redirect the thalweg away from an existing eroding bank (i.e., bank stabilization)
- Can be installed along alternating streambanks to encourage lateral migration, channel widening, and inset floodplain development and produce a meandering thalweg and associated structural diversity.
- Flow overtopping structures will be directed perpendicular to the axis of the structure; upstream angled structures will direct overtopping flows toward the middle of the stream while downstream angled structures will direct overtopping flows toward the adjacent bank
- Can stabilize one bank and destabilize the opposite bank if structure extends into the channel a significant distance

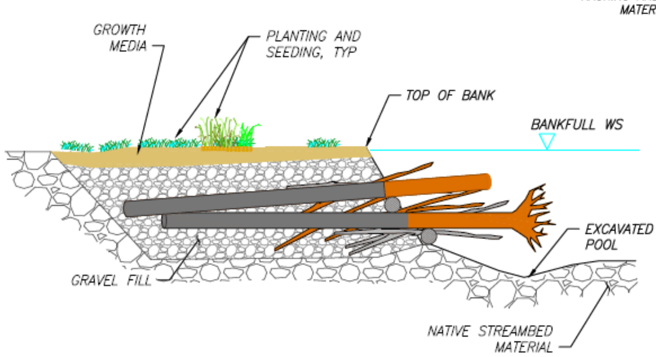


Series of low-profile wood and rock bank deflectors used to narrow the effective channel width and define the thalweg; Methow River, WA

Series of post-line willow-weave bank deflectors creating a point bar; Lemhi River, ID

Treatment: Bank Roughening Structure
Type: Reconnection and Restoration





Bank roughening structure during construction; Lemhi River, ID

Bank roughening structure on newly created side channel 1 year after construction; Lemhi River, ID

Application

- Used to create in-channel habitat complexity with velocity and depth variability
- Can be used for habitat and/or bank stabilization

Biological Considerations

- Creates contraction scour pools and provides cover with many interstitial spaces for rearing salmonids

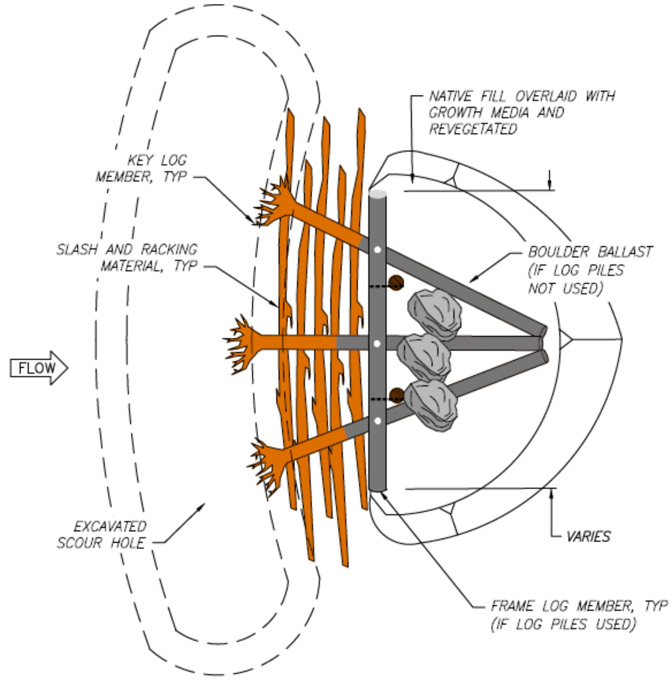
Geomorphic Considerations

- Can reduce local hydraulic energy and/or obstruct stream flow
- Creates instream roughness

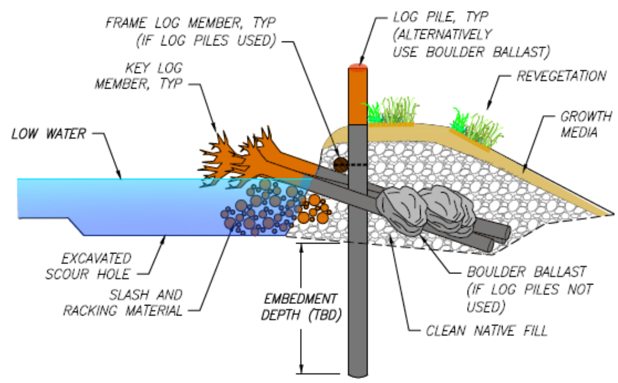
Design Considerations

- For bank stabilization – overlap wood material structure and/or place in series along an eroding bank to buffer the bank soils from erosive stream forces; obstruct flow with the wood material creating the appropriate overall width-to-depth ratio; create an inset floodplain (if necessary) along the bank to establish riparian vegetation for long-term stability and shade
- For in-channel habitat – place an individual structure or structures on opposite banks to interact with and obstruct flow creating areas of contraction (scour) and expansion (sediment deposition and gravel sorting) with cover
- Incorporate slash and retain appropriate interstitial space for habitat cover
- Consider incorporating an excavated scour pool to expedite habitat response

Treatment: Apex Log Jam
Type: Reconnection and Restoration



PLAN VIEW



SECTION VIEW

Application

- Used to split flow, obstruct flow and create in-channel complexity with velocity and depth variability

Biological Considerations

- Split flow into multiple channels, doubling margin habitat
- Incorporate excavated scour pool and cover
- Creates diverse habitat suitable for adult and juvenile salmonids

Geomorphic Considerations

- Evaluate bed and banks to determine if a large mid-channel obstruction is likely to erode the banks or scour the bed; design accordingly
- Use obstruction to activate new or relic side channels
- Evaluate reach-scale sediment transport and deposition to inform bar formation expectations

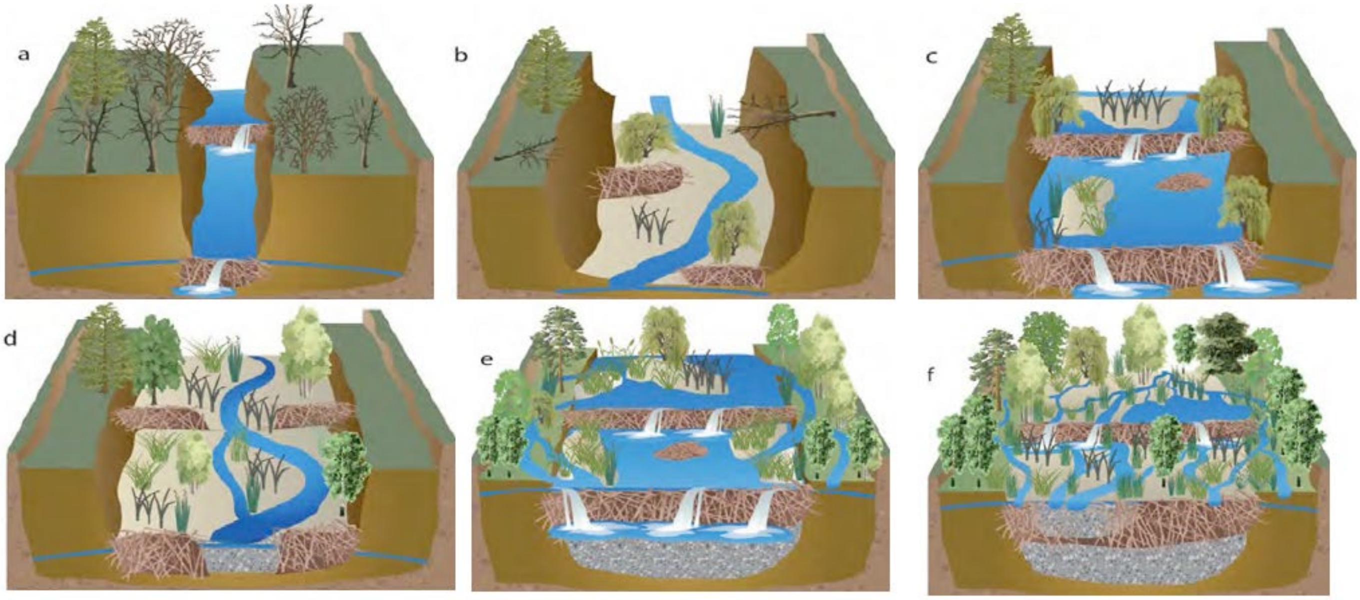
Design Considerations

- Consider use of piles where depth of alluvium is sufficient to enable adequate embedment
- Use ballast where piles are not feasible
- Design key structures assuming additional racking material will be retained over time
- Provide adequate protrusion of logs into the channel for cover
- Willow clumps may be a suitable replacement for LWD in certain environments where stream size and power allow

Apex log jam 1 year after construction; Yankee Fork of the Salmon River, ID

Apex jam constructed of willow clumps; Lemhi River, ID

Treatment: Beaver Dam Analogues (BDAs)
Type: Reconnection and Restoration



Conceptual model of how beaver dams help a stream to progress from an incised trench to an aggraded channel. Beaver attempting to build dams within narrow incision trenches resulting in blowouts (a), which help to widen the incised channel allowing an inset floodplain to form, as illustrated in (b). The widened channel more readily dissipates energy, enabling beaver to build wider, more stable dams (c). Beaver ponds fill with sediment, facilitating the growth of riparian vegetation (d). The process repeats itself until the beaver dams raise the water table sufficiently to reconnect the stream to its former floodplain (e). Eventually the stream ecosystem develops a high level of complexity (f). Figure from Pollock et al. 2015.

Application

- Intended to mimic beaver dams obstructing flow, capturing sediment, raising the water table, more frequently inundating the floodplain, attenuating high flows, and creating habitat diversity

Biological Considerations

- Backwater pools and interstitial spaces within the beaver dam provide juvenile salmonid rearing habitat
- May create partial passage barriers to certain species and life stages of fish depending on conditions

Geomorphic Considerations

- Channel-spanning structures capture sediment and raise the water elevation
- Partial spanning structures capture sediment forming point bars enhancing sinuosity (see post-line willow-weave treatment)

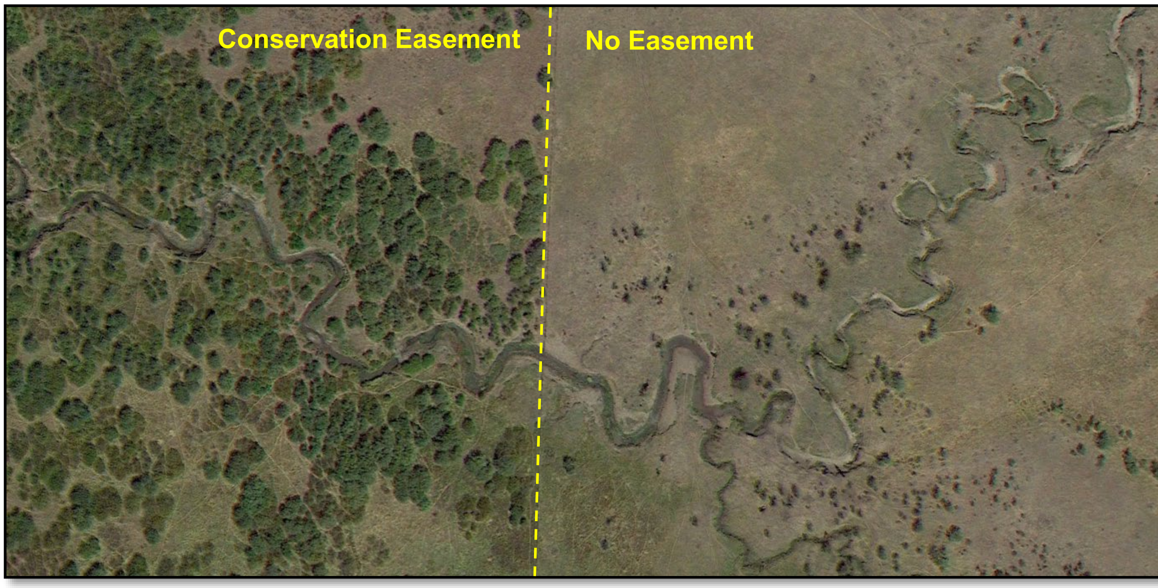
Design Considerations

- Construction requires minimal machinery and disturbance
- Can be used to initiate complex stage-0 habitat conditions (Cluer and Thorne 2014)
- Typically requires annual monitoring, maintenance, and additional structures to achieve goals, especially if there are no live beavers supporting the structures over time
- Generally only suitable in smaller streams and/or side channels of large rivers

BDA series capturing sediment and raising the water surface immediately after construction; Hawley Creek, ID

Recently installed BDA; Hulls Gulch, ID

Treatment: Conservation Easements
Type: Reconnection and Restoration



Application

- Management tool used to protect, preserve, and/or enable the enhancement of river, floodplain, and upland habitat in critical locations
- Can be used in conjunction with more active restoration strategies where rates of natural habitat recovery are slow or trending negatively

Biological Considerations

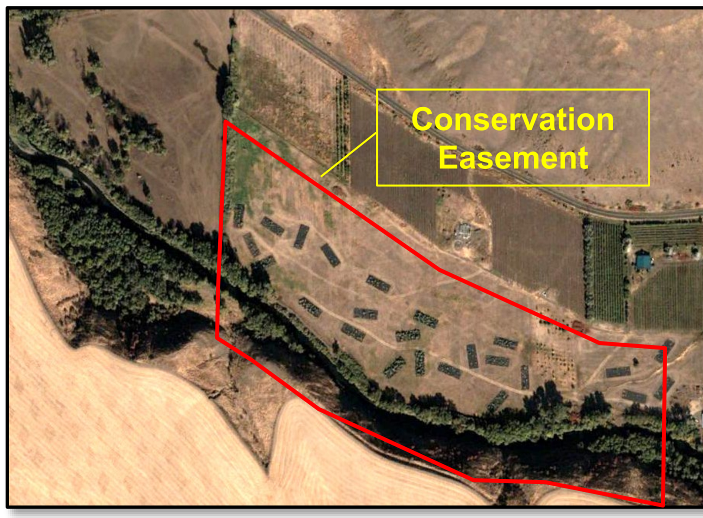
- Broad range of biological applications and benefits ranging from conservation of pristine habitat, to habitat protection enabling natural recovery, to habitat management allowing active restoration to expedite recovery

Geomorphic Considerations

- Management strategy is dependent on trend and rate of natural recovery
- May require active restoration to reverse impact trends and offset unmitigated watershed impacts

Design Considerations

- Fencing is needed to protect, maintain, or improve riparian flora and fauna and water quality
- Applicable on stable areas adjacent to permanent or intermittent streams, wetlands, and areas with groundwater recharge
- Supplemental planting may be desired based on overall goals of conservation easement
- Tolerant plant species and supplemental watering may be needed in some areas
- Can reduce grazing and human impacts to allow riparian vegetation to respond naturally or with assisted planting efforts



Conservation easement recently established illustrating multiple planting strips (dark rectangles); Walla Walla River, OR

Conservation easement 12 years after establishment and riparian planting; Walla Walla River, OR

Treatment: Riparian Planting
Type: Reconnection and Restoration


Riparian vegetation 5 years after restoration (left photo) and 14 years after restoration (right photo); Meadow Creek, ID

Application

- Create appropriate, long-term streambank conditions, bank stability, and shade through root structure and overhead canopy
- Increase rate of colonization of native species and reduce non-native species

Biological Considerations

- Provides instream structure and cover for multiple life stages of salmonids
- Channel erosion into dense riparian vegetation provides undercut banks, instream structure, and cover

Geomorphic Considerations

- Promotes woody debris recruitment
- Enables appropriate rates of channel migration
- Dense riparian vegetation provides floodplain structure promoting side-channel formation and maintenance versus channel avulsion during periods of floodplain activation

Design Considerations

- Requires many years to achieve desired outcomes
- May require temporary short-term bank stabilization to facilitate vegetative establishment
- Can be used to promote long-term bank stabilization
- Surface and groundwater elevations must be appropriately near the bank and floodplain surface to promote riparian establishment
- Species selection, spacing, and density depend on site conditions, riparian management strategy, and land use; temporary irrigation may improve establishment

Prior to riparian revegetation; Big Springs Creek, ID

1 year after riparian revegetation; Big Springs Creek, ID