RSC

REGENERATIVE STREAM CONVEYANCE

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RSC Construction Training
Maryland Department of Natural Resources

WHAT IS RSC?

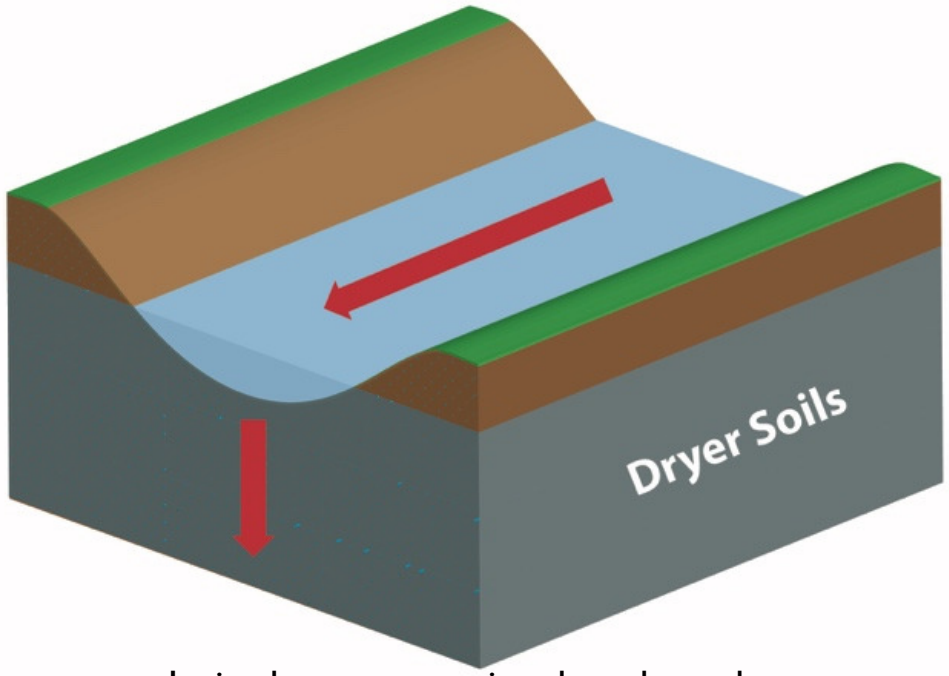
- Free streams from incised channels
- Reconnect stream to its floodplain
- Reset from degenerative to regenerative mode
- Re-establish dense native vegetation

SLOW IT DOWN

SOAK IT IN

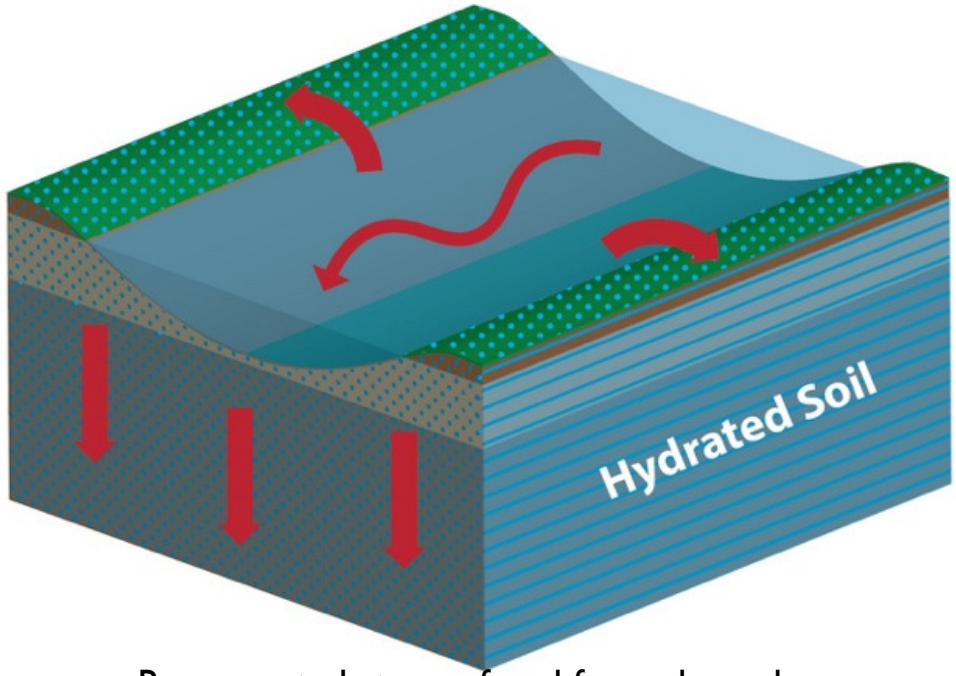
SPREAD IT OUT

2D Flow of Water



Incised stream restricted to channel

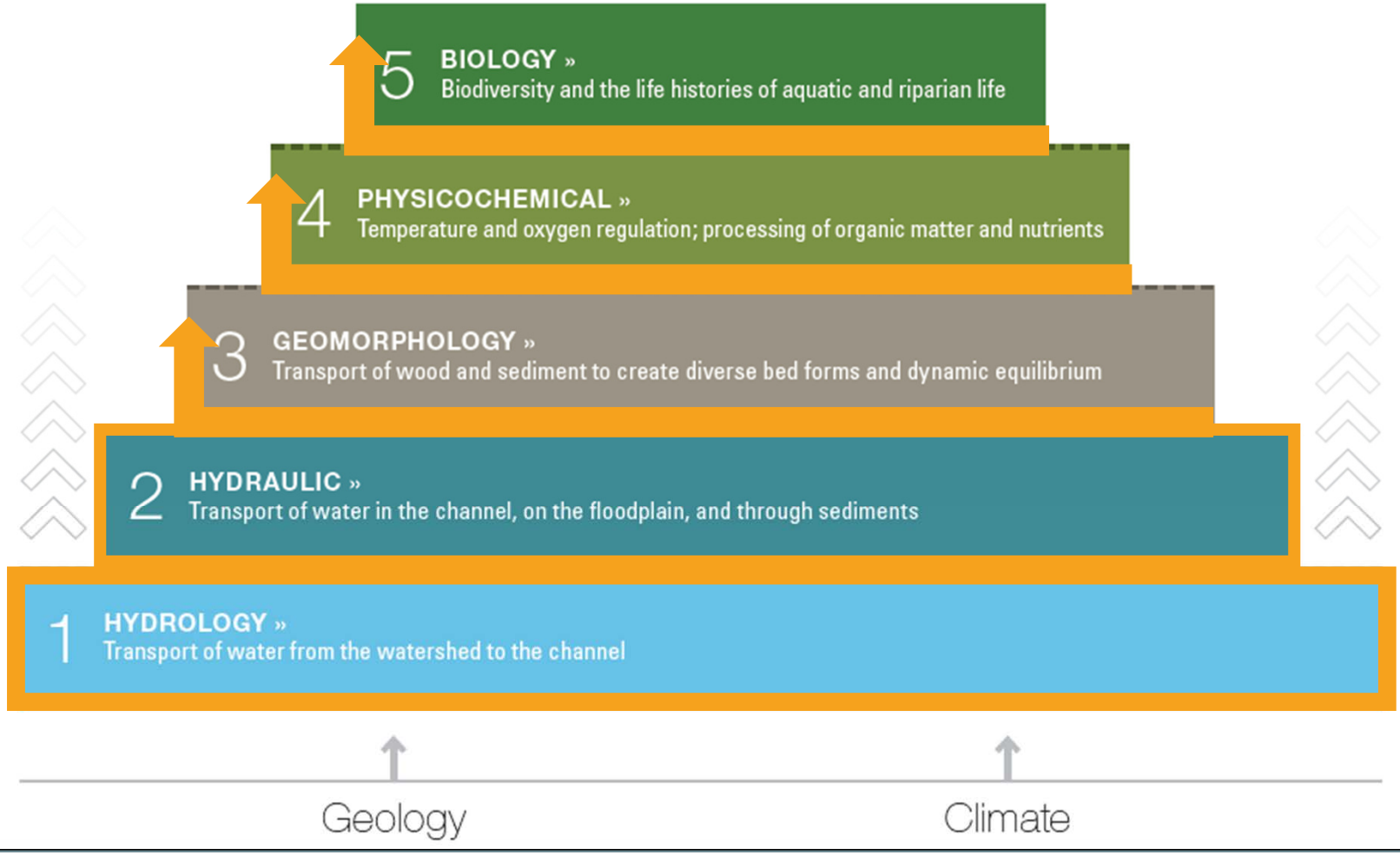
3D Movement of Water



Reconnected stream freed from channel

Stream Functions Pyramid

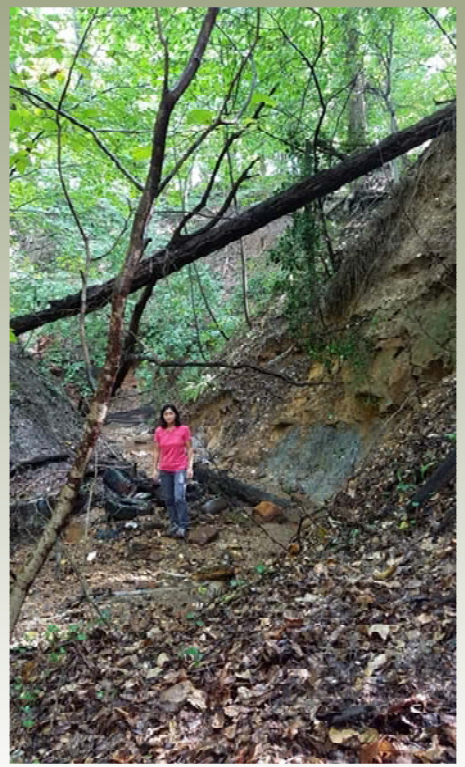
A Guide for Assessing & Restoring Stream Functions » OVERVIEW

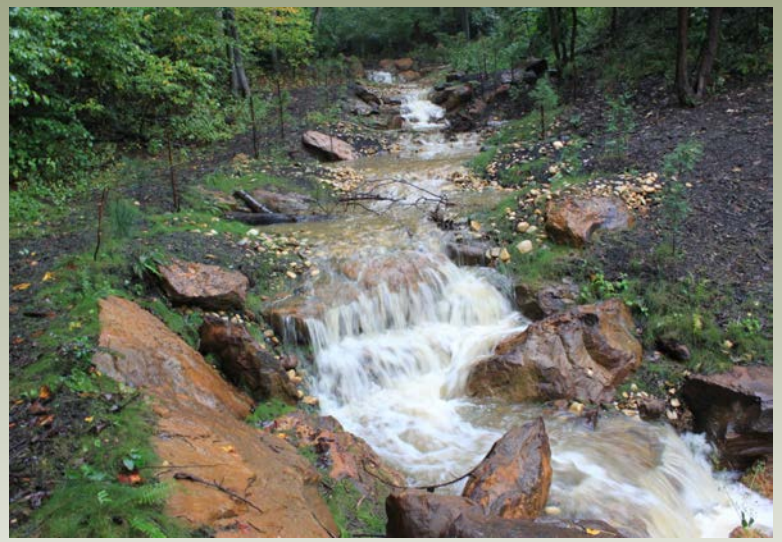


STREAM FUNCTIONS	HEALTHY STREAM	DEGRADED STREAM
Hydrology	• Healthy baseflow continuously fed by seeping groundwater from hydrated soils	• Low and/or intermittent baseflow due to dehydrated soils and lower groundwater levels
Hydraulic	• Flow tops banks and dissipates energy throughout the floodplain	• Flow restricted within channel picks up energy and erodes channel
Geomorphology	• Replenishes the system by sustainably transporting sediment and woody debris to establish dynamic equilibrium and create diverse in-stream features	• Flushes the system with excessive transport of sediment and woody debris and strips system of diversity resulting in a straight and denuded channel
Physicochemical	• Cooler temperature that support fisheries • Higher oxygen levels* • Abundant and diverse sources of organic matter that replenishes seasonally and supports biological processes • Maintains complex processes that breakdown and take up nutrients	• Warmer temperature that inhibit fisheries • Lower oxygen levels • Stripped of organic material which limits biological processes • Simply transports nutrients to downstream waterbodies
Biology	• Diverse flora and fauna including sensitive species • Supports native species	• Fewer flora and fauna dominated by tolerant species • Susceptible to non-native species

WHERE CAN RSCS BE APPLIED?

- Top to bottom of watershed
- Steep to flat
- Perennial and ephemeral
- To replace or repair outfalls
- As a stormwater conveyance
- Small to large drainage areas





RSC CONSTRUCTION

Knowledge, Skills and Abilities

Design and Permit Team

- Set the stage for success

Construction Team

- Ecological Specialist
- Restoration Manager
- Restoration Crew

RSC CONSTRUCTION

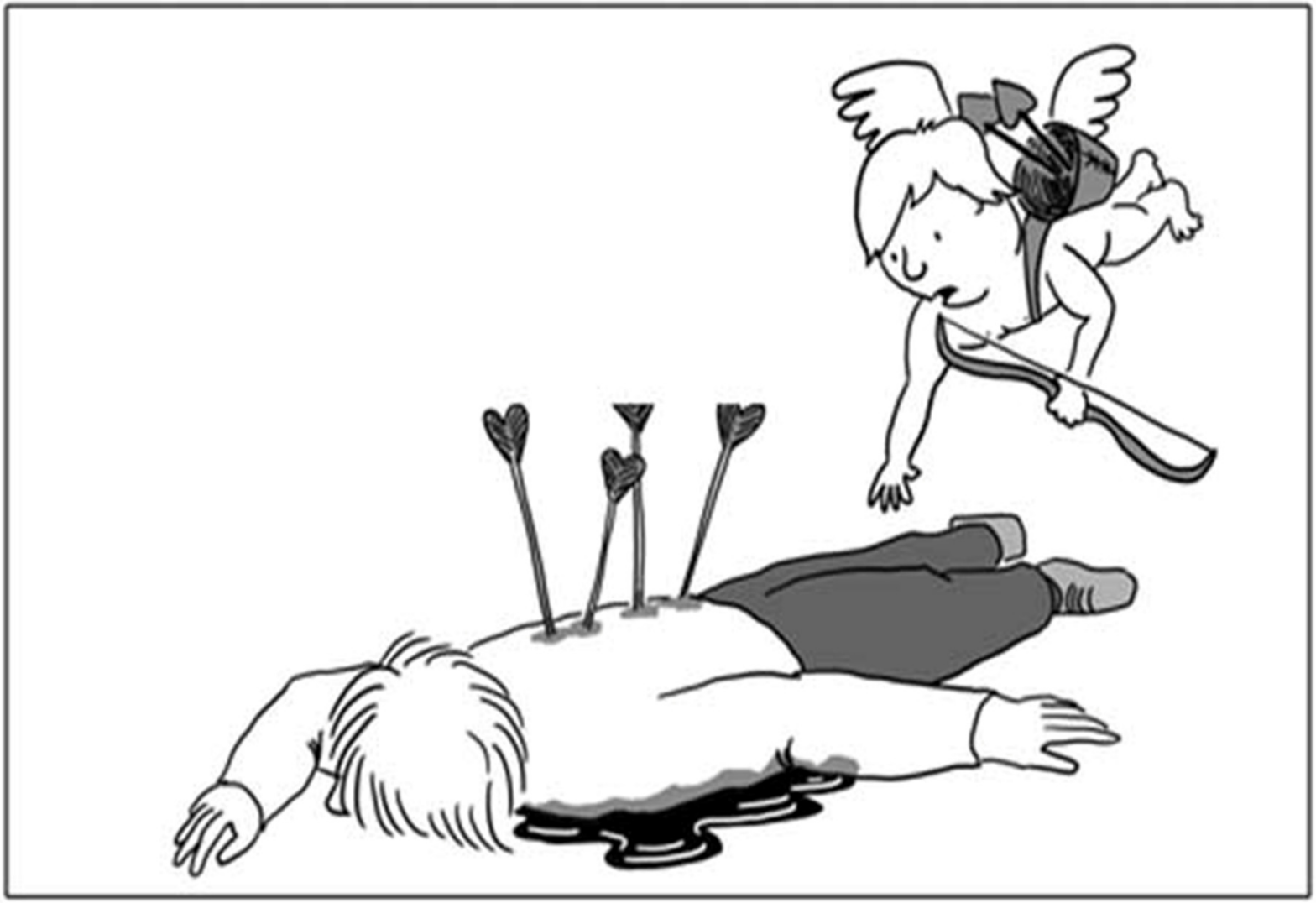
Team Commitments

Construction Practices

- Impact minimization
- Adaptive management

Code of Regenerative Construction

- Avoid Tree Removal
- Minimize land/soil disturbance
- Preserve Microtopography
- Maintain and enhance gw interactions
- Adopt an iterative approach



...Hello? Gary?

B.2 Adaptive Management

- Deliberate and **iterative** process implemented sequentially over time
- Estimate and construct at the **microscale** recognizing the mesoscale of design
- Secure reasonable **flexibility**, time collaboration and resources to further fine tune the project through responsive decisions:
  - Access to site for repairs, replanting, invasive species control
  - Modifications to structures post storm observations during construction, e.g. shift to manage actual, not modeled, flow patterns
- Include adaptive management efforts in SOW
  - Design Engineer's close collaboration with contractor and permitting agency during construction
  - Maintenance access post construction
  - Additional material to supplement site during settling phase

RSC CONSTRUCTION

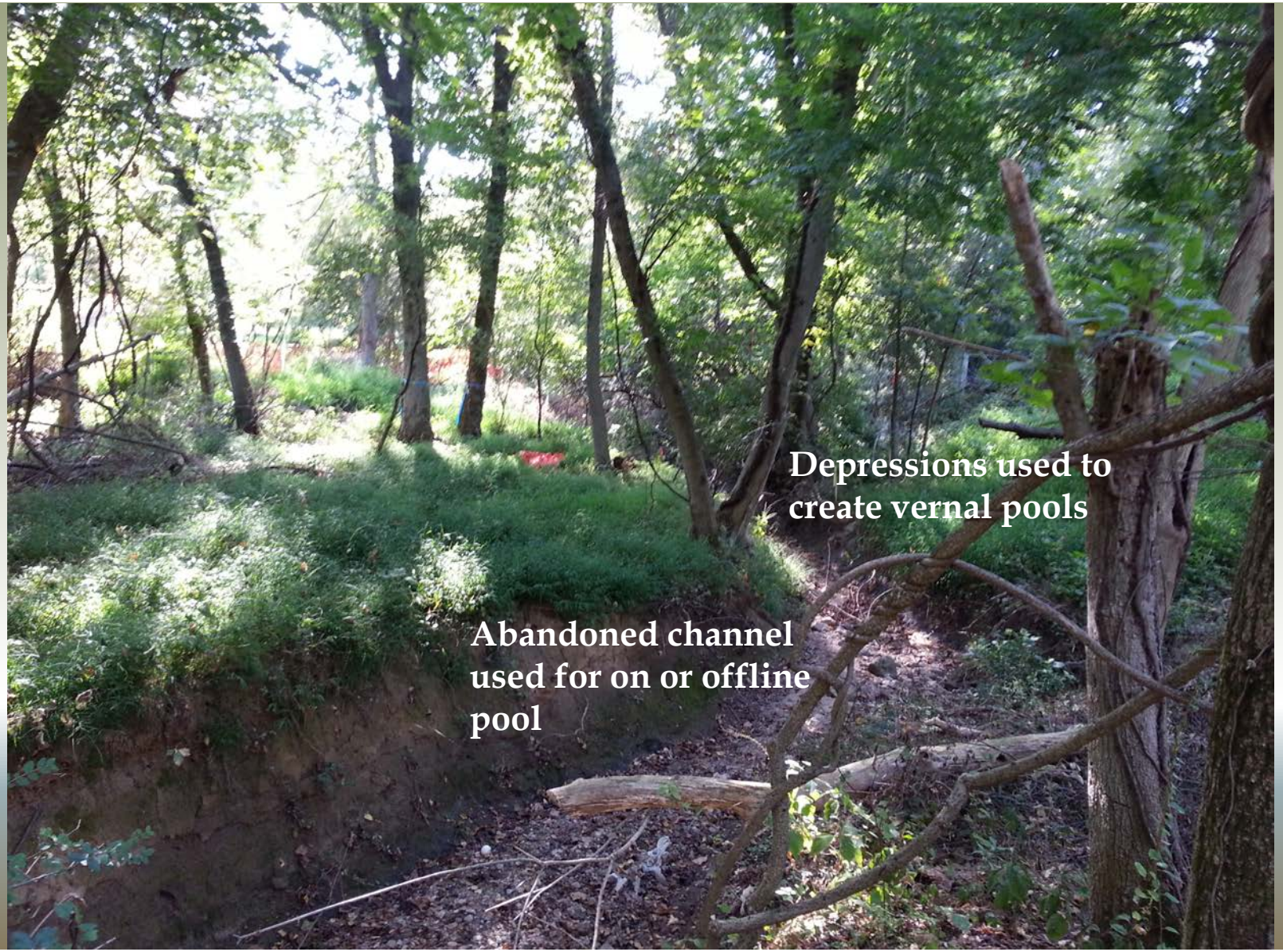
D. Site Preparation

- D.1 Preserve Microtopography
- D.2 Minimize Tree Removal
- D.3 Minimize Riparian Footprint

D.1 Preserve Microtopography

- Fence off natural features within LOD
- Three phases of grading
  - Rough
  - Final
  - Fine
- Limit excavation
  - In fill projects – limit to subgrade
  - In cut projects – keep native soil layers intact


Boulder outcrop at steep slope instead of grading back


Depressions used to create vernal pools
Abandoned channel used for on or offline pool

TECHNIQUES AND PRACTICES

1. Fenced off depression parallel to stream captures uphill seepage
2. Minimized haul road width to preserve existing depression
3. No unnecessary excavating in the area

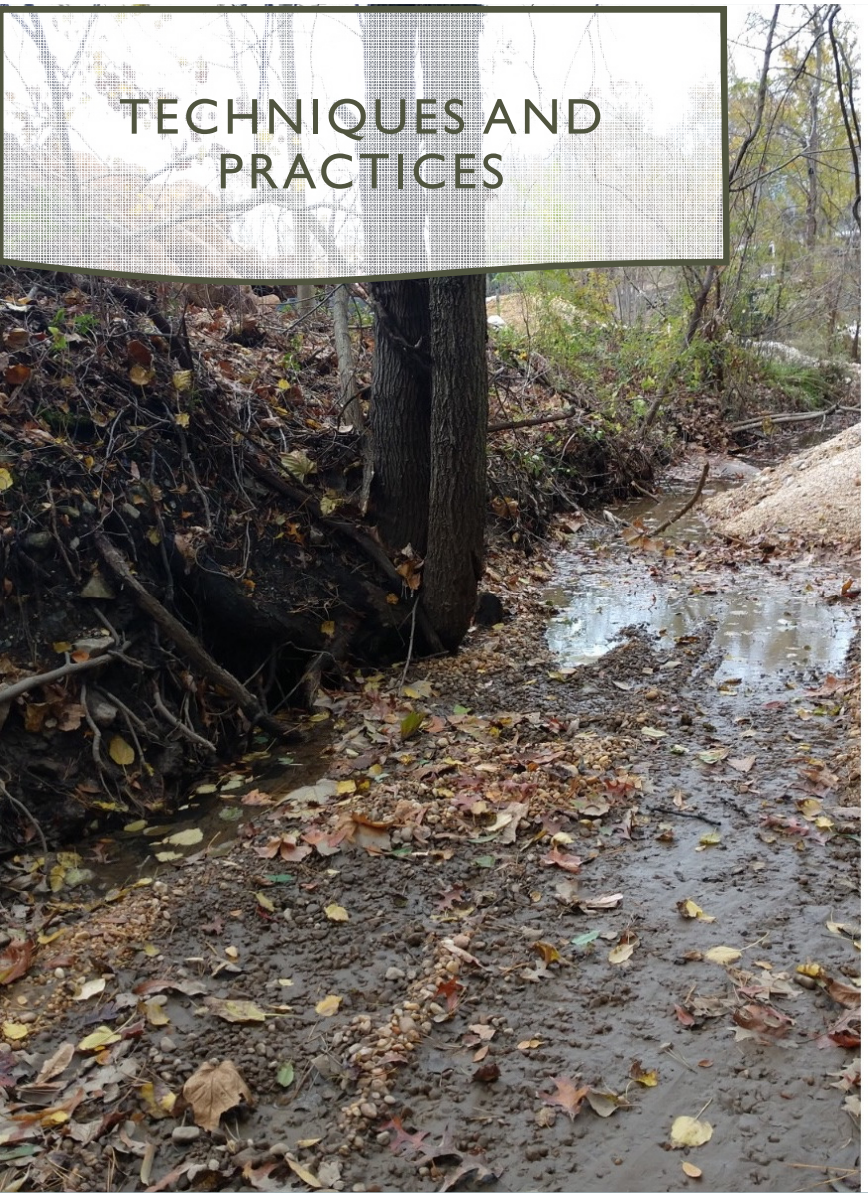
D.2 Minimize Tree Removal

- Conservative and Iterative Decision Making
  - Prevents soil compaction, erosion
  - Creates habitat
  - Maintains canopy
- Compensation for Saved Trees
  - Level of effort for avoiding
  - Advocate for approval and compensation

TECHNIQUES AND PRACTICES

1. Filling channel to raise streambed often saves trees

TECHNIQUES AND PRACTICES



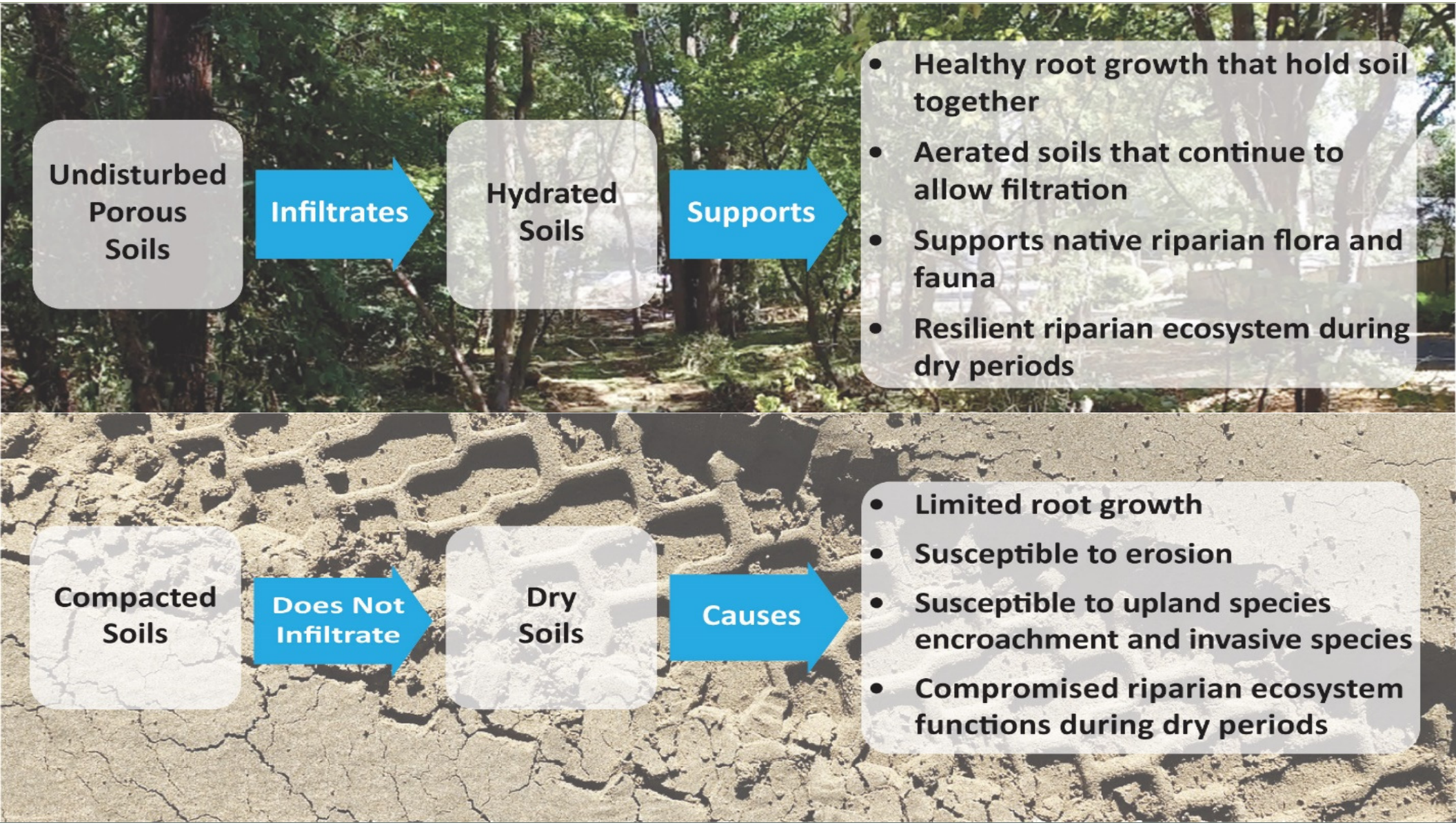
TECHNIQUES AND PRACTICES

2. Tree wells and boulder walls protect trees

D.3 Minimize Riparian Footprint

- Utilize in-stream haul road
  - Key RSC feature
    - Enables in-stream construction and reduces need to utilize the riparian area
    - Critical to re-establishing active gw and sw interaction
- Keep heavy equipment off riparian area

Keep Machines Out of the Riparian Area


Undisturbed Porous Soils
Infiltrates
Hydrated Soils
Supports
Healthy root growth that hold soil together
Aerated soils that continue to allow filtration
Supports native riparian flora and fauna
Resilient riparian ecosystem during dry periods
Compacted Soils
Does Not Infiltrate
Dry Soils
Causes
Limited root growth
Susceptible to erosion
Susceptible to upland species encroachment and invasive species
Compromised riparian ecosystem functions during dry periods

RSC CONSTRUCTION

E. Construction Methods and Techniques

- E.1 Slotted Pipe and Gravel Underdrain
- E.2 Construction Entrance and Haul Road
- E.3 Stratified Lenses
- E.4 Riffle Weir
- E.5 Berms
- E.6 Cascades
- E.7 Pools
- E.8 Coarse Woody Debris

E.1 Slotted Pipe and Gravel Underdrain

- Function
  - Dewater haul road and carry base flow
  - Used in conjunction with CWD
  - French drain https://www.youtube.com/watch?v=qgFSMCRhwco
- Materials and Supplies
  - Slotted or perf pipe
  - Sandbags, wooden stakes and wire ties
  - Sand and gravel

INSTALLATION

1. Lay pipes along flow path
2. Cap upstream end
3. Secure slotted pipe using stakes and sandbags
4. Install gravel seam
5. Install sand and woodchip haul road
6. Modifications for outfall vs. mid-stream
7. Pull pipe sections out during pool and riffle weir construction

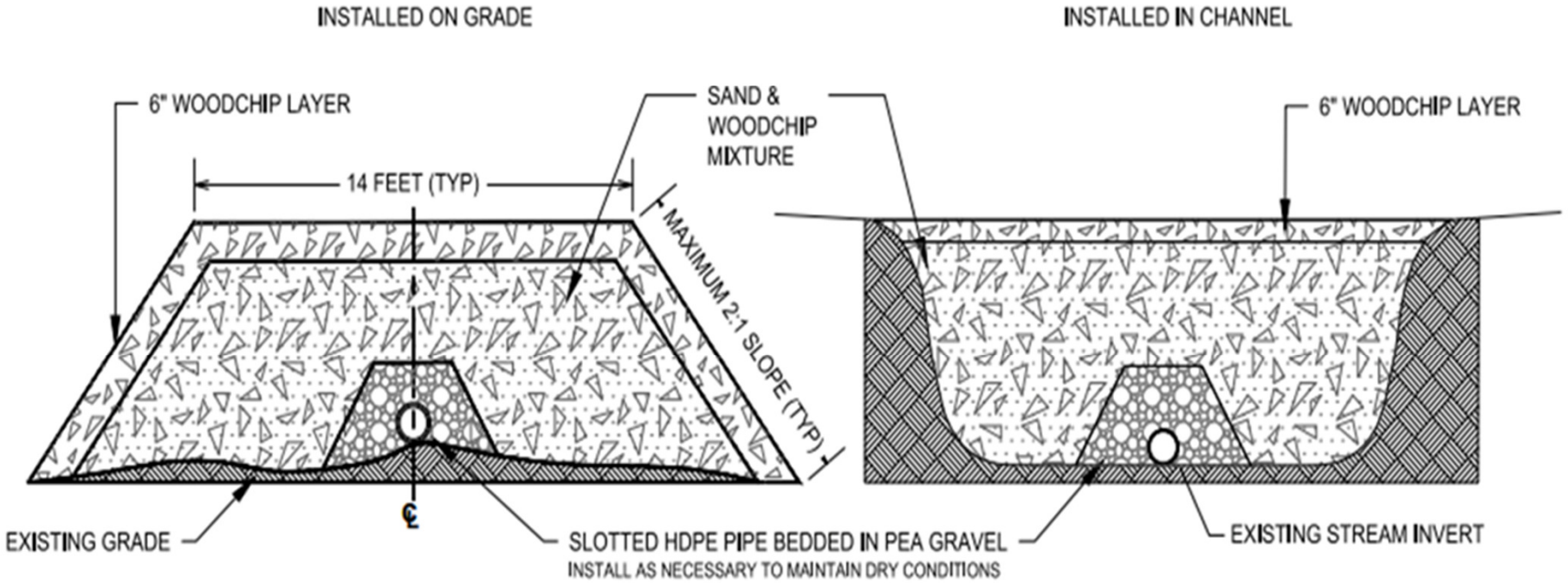
INSTALLATION

1. Lay pipes along flow path (lowest elevation)
2. Cap upstream end
3. Secure slotted pipe using stakes and sandbags
4. Install gravel seam
5. Install sand and woodchip haul road
6. Modify for at outfall vs. mid-stream
7. Pull pipe sections out during pool and riffle weir construction

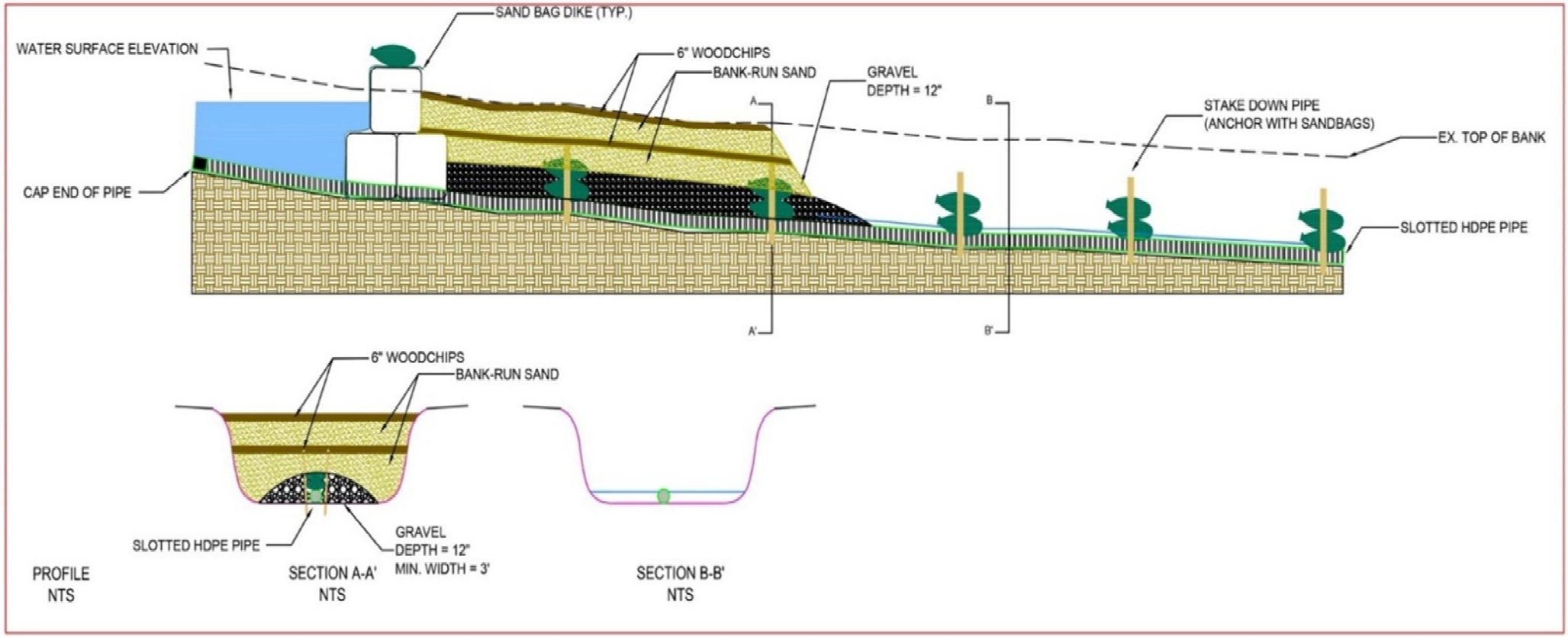
DETAILS

HAUL ROAD CROSS-SECTION DETAIL

N.T.S.



DETAILS


SAND BAG DIKE (TYP.)
WATER SURFACE ELEVATION
6" WOODCHIPS
BANK-RUN SAND
GRAVEL
DEPTH = 12"
A
B
STAKE DOWN PIPE
(ANCHOR WITH SANDBAGS)
EX. TOP OF BANK
CAP END OF PIPE
SLOTTED HDPE PIPE
A'
B'
6" WOODCHIPS
BANK-RUN SAND
SLOTTED HDPE PIPE
GRAVEL
DEPTH = 12"
MIN. WIDTH = 3'
PROFILE
NTS
SECTION A-A'
NTS
SECTION B-B'
NTS

E.2 Construction Entrance and Haul Road

- Function
  - Access for trucks and equipment
  - Erosion and sediment control
  - Sand/Woodchip filter
  - Replenishes organic carbon, an energy source for microbes
- Materials and Supplies
  - Clean sand/sandy fill
  - Woodchip
  - Temporary stabilization seed

INSTALLATION

1. Cover gravel underdrain with sand
2. Continuously add and track woodchip into sand
    a. Thoroughly incorporate wc into sand
    b. Track to create stable medium
3. Repeatedly seed site
    a. Establish a seed bank
    b. Enable site to revegetate and stabilize on its own

E.3 Stratified Lenses

- Function
  - Mimic form and function of stratified lenses inherent in intact soils
  - Enables storage and movement of gw
  - Supports complex processes
- Materials and Supplies
  - Sand
  - Range of gravel sizes
  - Woodchip

INSTALLATION

1. Identify sand and/or gravel seams along length of stream
2. Install sand and/or gravel layers to fully connect to existing substrate
3. Avoid introducing silt into seam
4. Avoid excavating into these lenses
5. Place pea gravel in pools to create opportunities for lenses/seeps to daylight

BREAK

E.4 Riffle-Weir

- Function
  - Weirs hold water (control grade)
  - Riffles deflect water
  - Allows fish passage
- Materials and Supplies
  - Sand and sandy fill
  - Range of gravel sizes
  - Specified stone, e.g., river rock
  - Specified boulder
  - Geotextile

INSTALLATION

Footer Boulder

- ***Anchors*** the weir
- Keeps parabolic shape intact

3. Place footer boulders sufficiently into soil, tilt downstream, press and pound

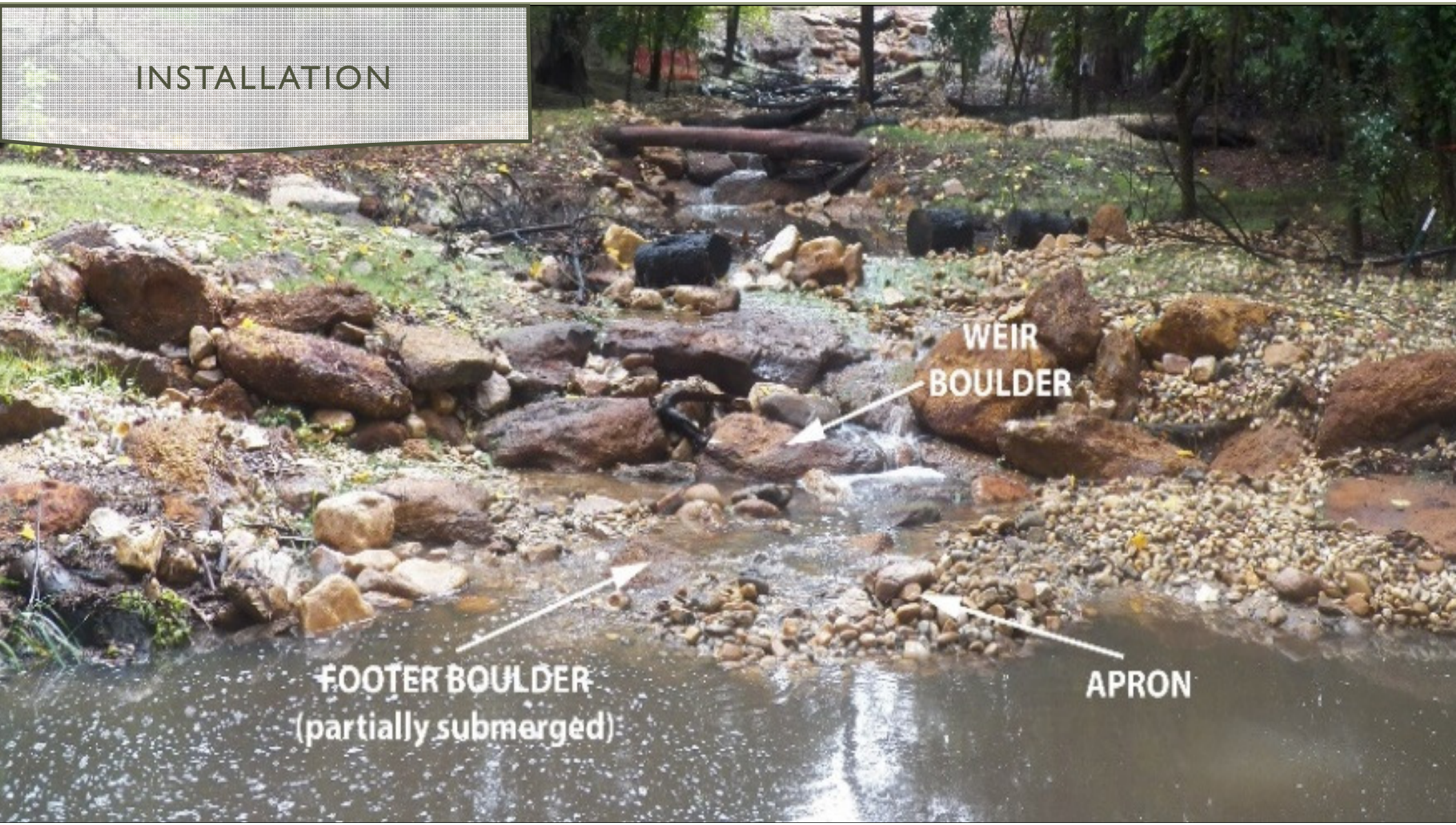
INSTALLATION

3.1 Elevation of footer boulder

- Most of footer boulder should be submerged during storm events.
- Upper 3”-6” of footer boulder should break water surface
  - Fail safe feature
  - Particularly important in cobble weirs

3.2 Avoid stacking

INSTALLATION



INSTALLATION

Apron

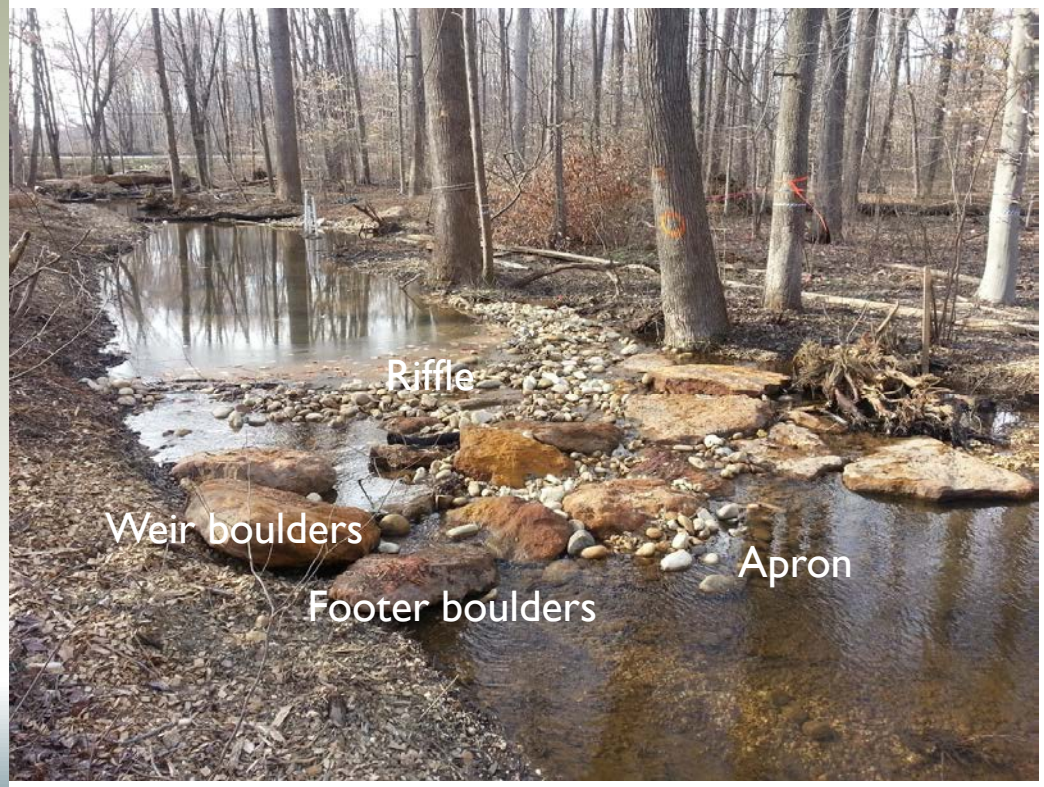
- Carries flow from weir to pool in a non-erosive manner

4. Place small boulders and rock along downstream edge of footer boulders and down the pol slope

   4.1 Place larger rock in the center third of the width of the weir where flow is most concentrated

   4.2 Scatter few larger rocks in apron to disrupt flow

   4.3 Expect movement of gravel and river rock as stream dynamically adjusts



INSTALLATION

Weir Boulders/River Rock

5. Moving upstream, set boulders/rock **behind** footer boulder to finished elevation

   5.2 Create one-foot drop by creating a sloped plane (minimize falls, unlike cascades)

   5.3 For cobble weirs, set river rock over half of footer boulder and continue upstream

   5.3.2 Tilt boulders 10% downstream)

INSTALLATION

Weir Boulders/River Rock (cont'd)

- 5.4 Form gently curved rack
  - Broad crescent shape facing downstream
  - Encourages broader flow
- 5.5 Create a parabolic shape
  - Crescent shape facing skyward
  - Deflects flow to center of pool
- 5.8 Avoid tree removal

6. Add sand and gravel to fill voids
   - 6.1 Observe flow during/post storms
   - 6.2 Supplement post storms

INSTALLATION

10. Randomly cast mixed size gravel into riffle and edges and leave excess

    Bedload material to naturally create diverse bed morphology

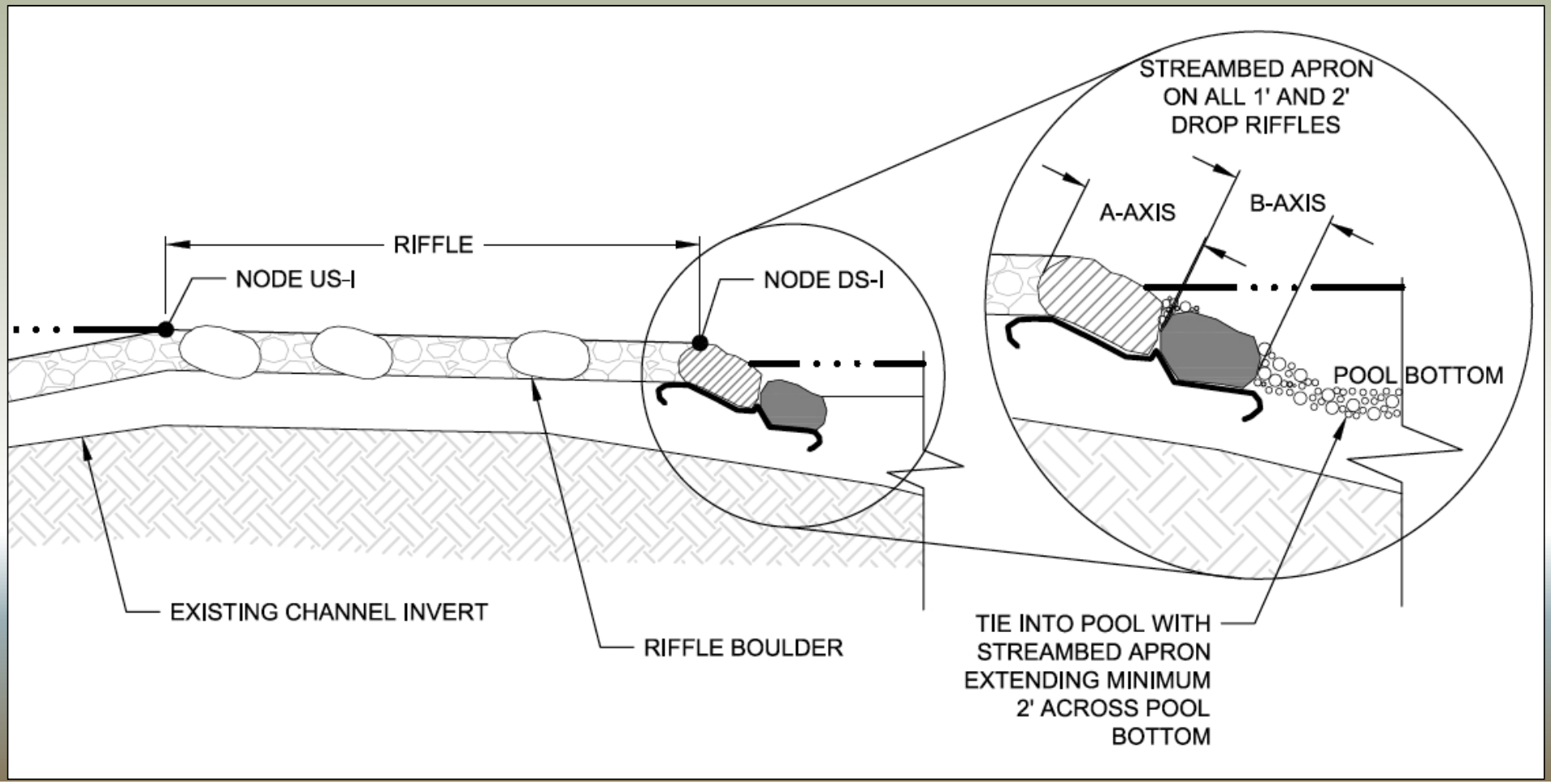
12. Touch ups over time

INSTALLATION

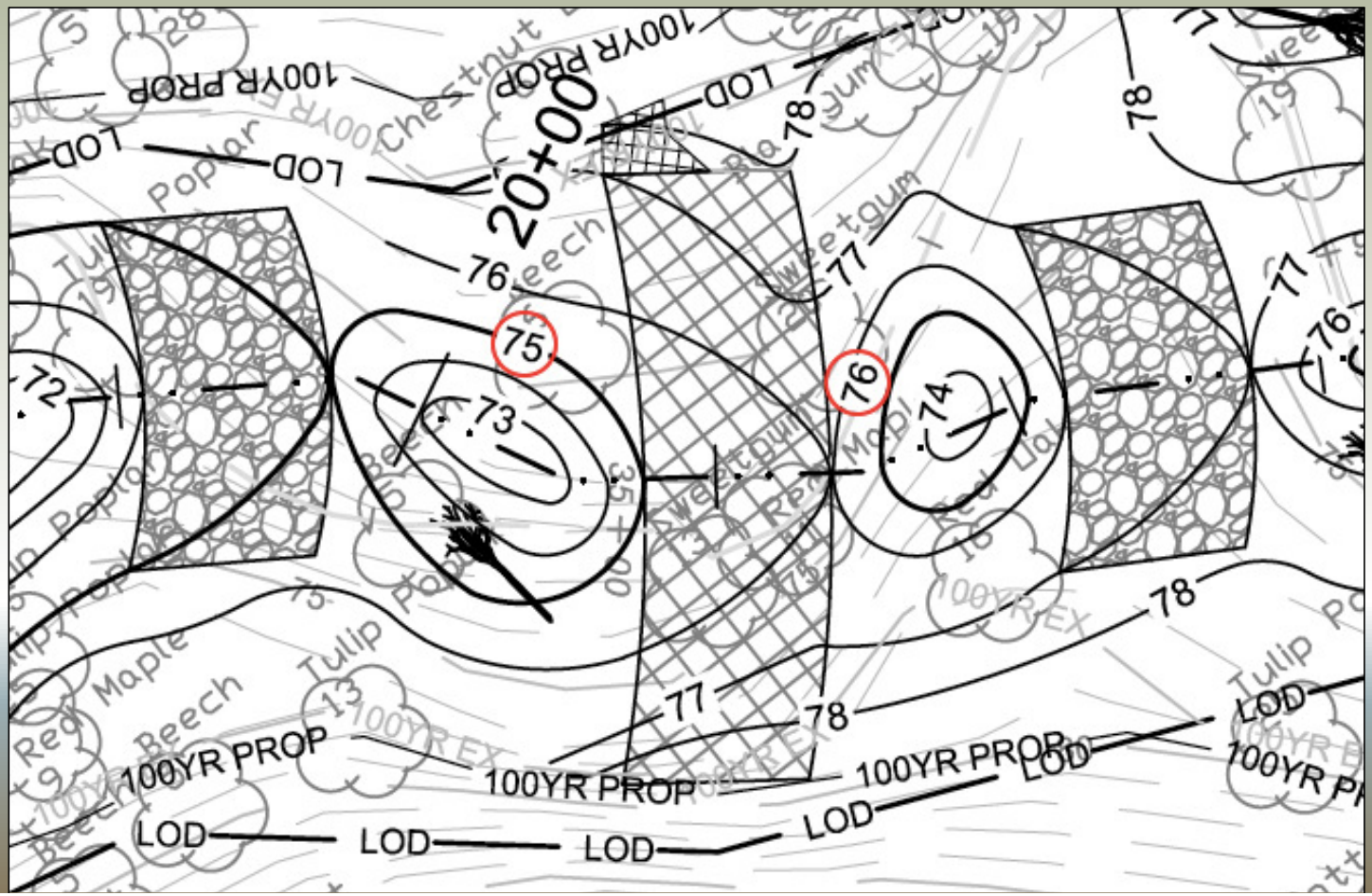
Chink and Wash-In

13. Place small boulders and rock in cracks and openings between weir boulders
14. Use dewatering pump to wash structures to create movement of smaller particles into and over riffle-weirs
    - 14.1 Start at top most weir
    - 14.2 Place sufficient wash in material
    - 14.4 Observe flows over weirs and adjust adding materials
    - 14.5 Repeat multiple times

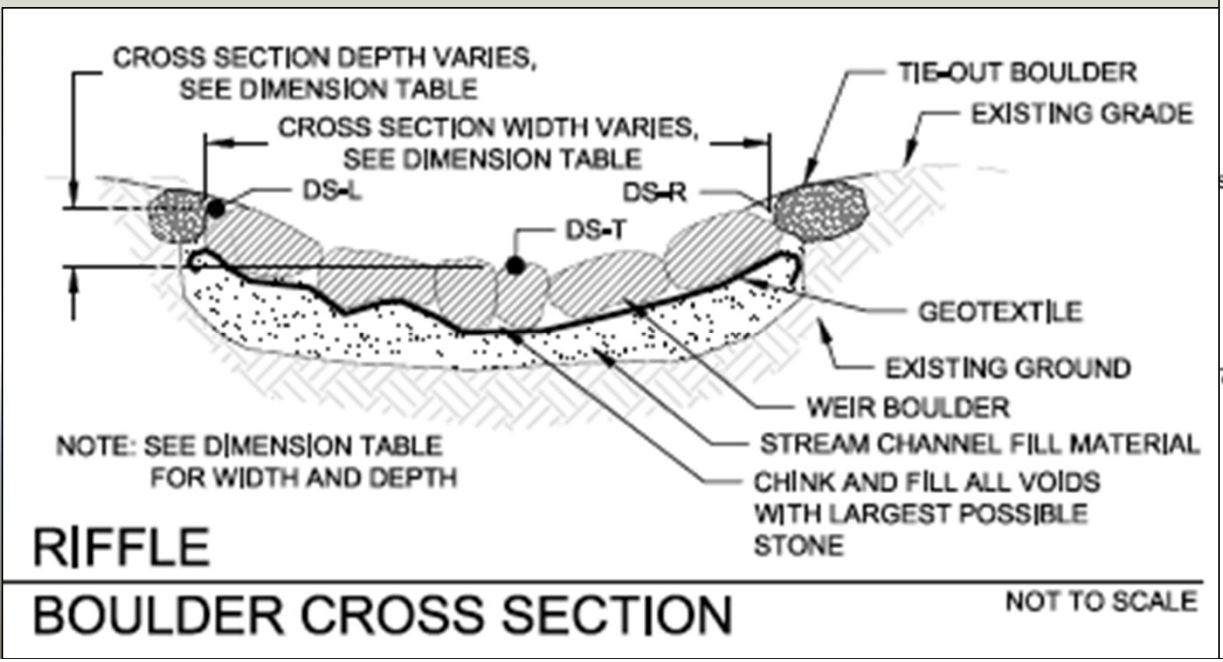
DETAILS

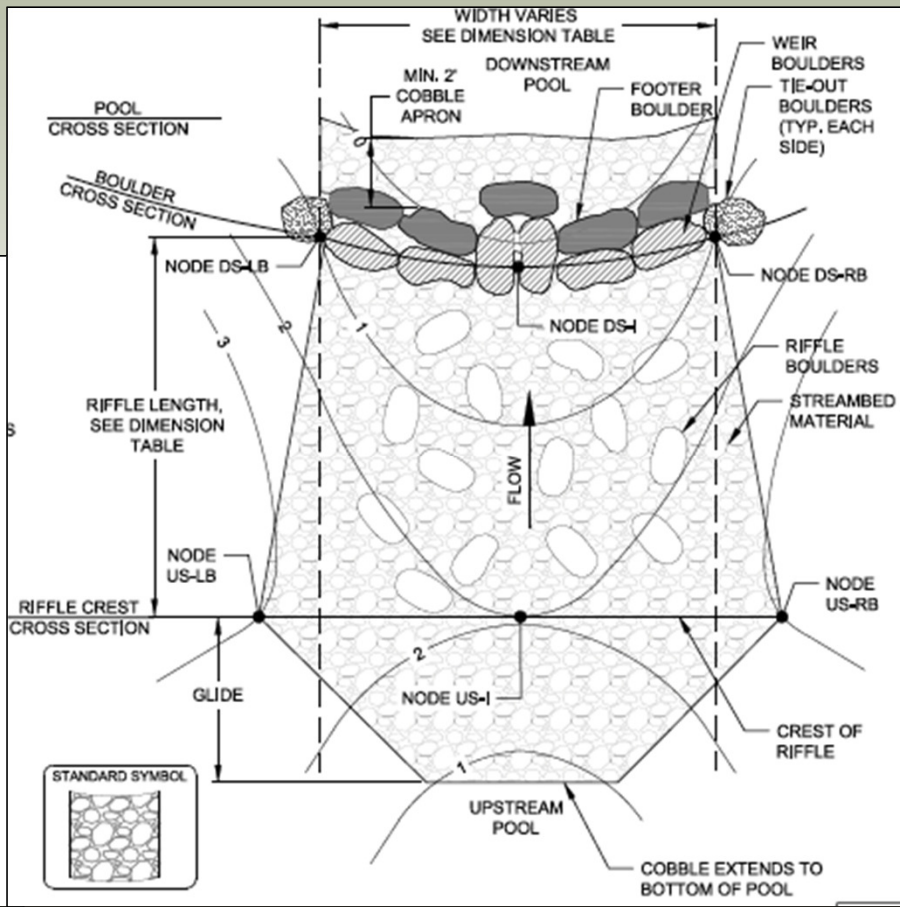

STREAMBED APRON
ON ALL 1' AND 2'
DROP RIFFLES
A-AXIS
B-AXIS
RIFFLE
NODE US-I
NODE DS-I
POOL BOTTOM
EXISTING CHANNEL INVERT
RIFFLE BOULDER
TIE INTO POOL WITH
STREAMBED APRON
EXTENDING MINIMUM
2' ACROSS POOL
BOTTOM

DETAILS


100YR PROP
LOD
20+00
75
76
77
78
72
73
74
Chestnut
Poplar
Beech
Sweetgum
Maple
Tulip

DETAILS


CROSS SECTION DEPTH VARIES, SEE DIMENSION TABLE
CROSS SECTION WIDTH VARIES, SEE DIMENSION TABLE
DS-L
DS-R
DS-T
TIE-OUT BOULDER
EXISTING GRADE
GEOTEXTILE
EXISTING GROUND
WEIR BOULDER
STREAM CHANNEL FILL MATERIAL
CHINK AND FILL ALL VOIDS WITH LARGEST POSSIBLE STONE
NOTE: SEE DIMENSION TABLE FOR WIDTH AND DEPTH
RIFFLE
BOULDER CROSS SECTION
NOT TO SCALE


WIDTH VARIES SEE DIMENSION TABLE
DOWNSTREAM POOL
MIN. 2' COBBLE APRON
FOOTER BOULDER
WEIR BOULDERS
TIE-OUT BOULDERS (TYP. EACH SIDE)
POOL CROSS SECTION
BOULDER CROSS SECTION
NODE DS-LB
NODE DS-RB
NODE DS-I
RIFFLE BOULDERS
STREAMBED MATERIAL
RIFFLE LENGTH, SEE DIMENSION TABLE
FLOW
NODE US-LB
NODE US-RB
RIFFLE CREST CROSS SECTION
GLIDE
NODE US-I
CREST OF RIFFLE
STANDARD SYMBOL
UPSTREAM POOL
COBBLE EXTENDS TO BOTTOM OF POOL

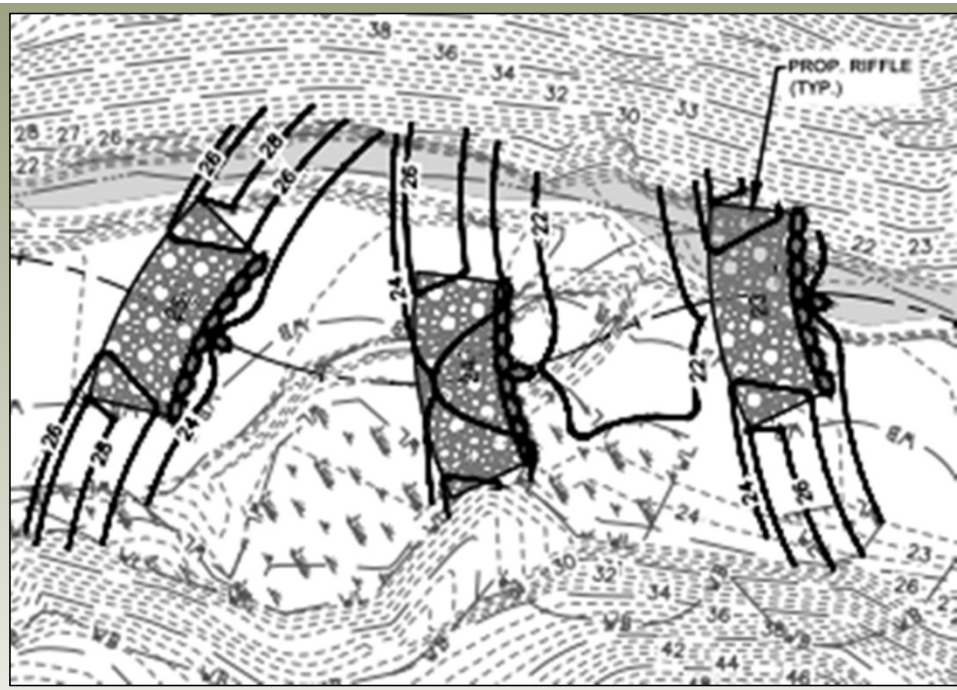
E.5 Berms

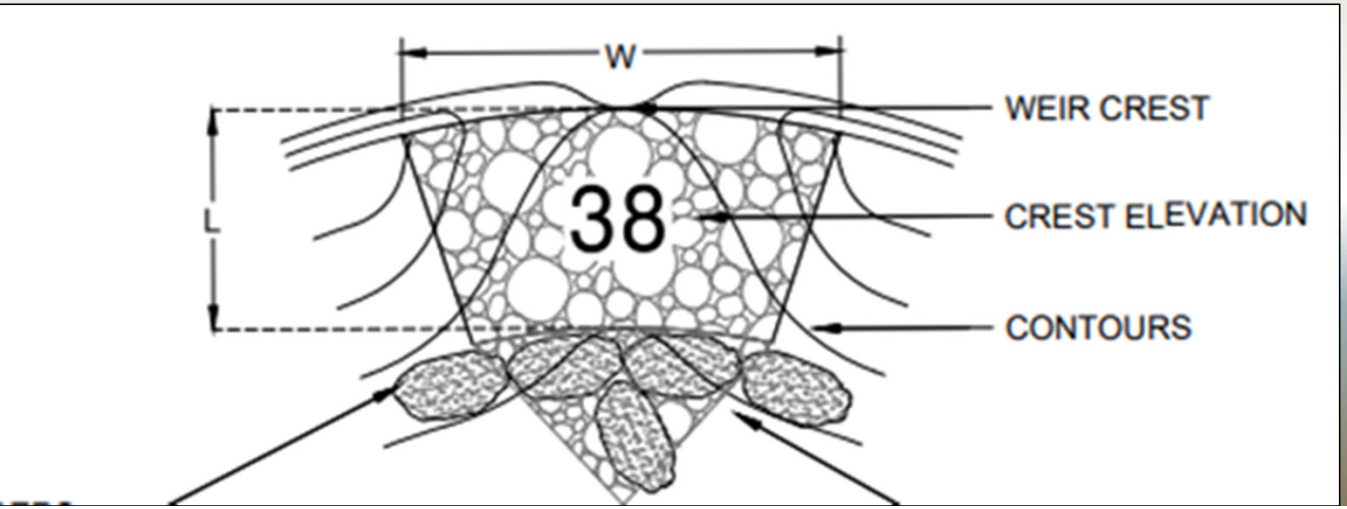
- Function
  - Connect weir to landscape
  - Hold and spread water laterally onto floodplain
  - Keep flow from cutting around weir during large storm events
  - Increase saturated periods
  - Filter water
- Materials and Supplies
  - Sand and sandy fill
  - Woodchip

INSTALLATION

1. Place sand to extend edge of weir
   a. Maintain same elevation until it connects with same elevation on existing landscape
   b. Flagt, 3-ft width top
   c. Gentle side slopes
   d. Avoid shaping like A dikes
   e. Avoid using silty material
   f. Track berms to uniformly compact, avoid low spots and depression
2. Cover with woodchip

DETAILS





Apron

E.6 Cascades

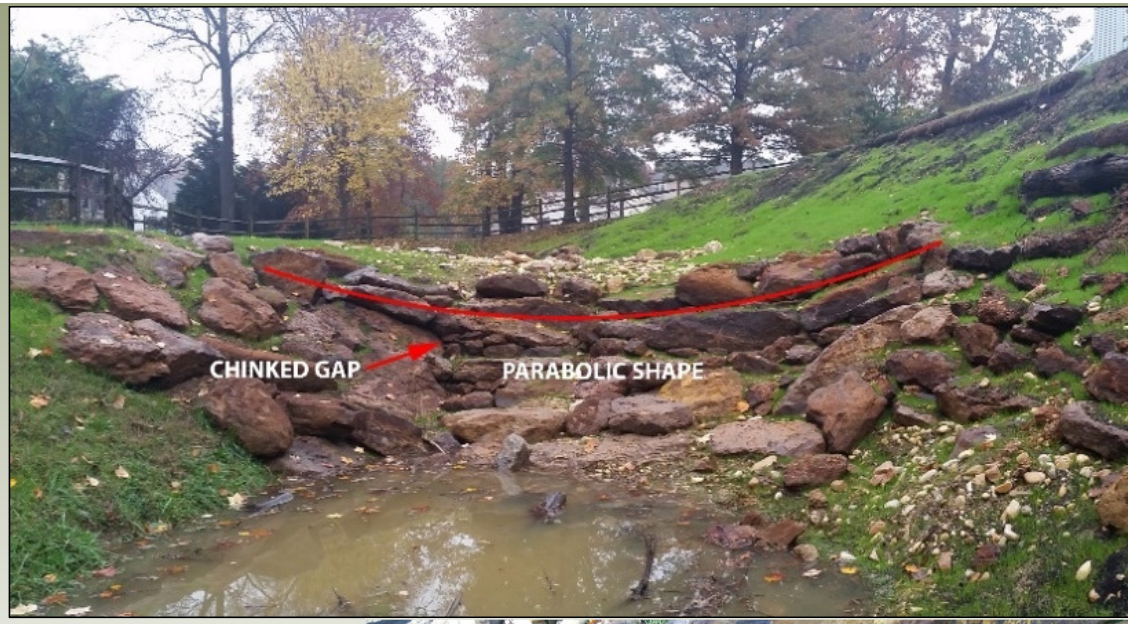
- Function
  - Safely transport flow over greater drop (> 2 ft) than weirs
- Materials and Supplies
  - Sandy fill
  - Range of gravel sizes
  - Range of river rock sizes
  - Boulders
  - Geotextile
  - Woodchip

INSTALLATION

1. Excavate subgrade
2. Place geotextile, including side slopes
   - 2.1 Overlap to convey water over fabric
   - 2.3 Reduce overlaps
3. Secure footer boulders (min 3 ft deep)
   - 3.1 Flat, not tilted like weir footers
   - 3.2 Press and pound
4. Crved rack to spread water laterally
5. Parabolic shape to keep flow within the thalweg and shoulders

INSTALLATION

6. Continue stacking boulders to designed elevation with slight overlap of layers
   - 6.1 FLAT
   - 6.2 Do not create a chute
   - 6.3 Minimum 3 boulders deep into upstream slope, rather than a stacked wall that is one row thick
7. Cast sand, gravel and rock to fill voids
8. Wash in
9. Chink



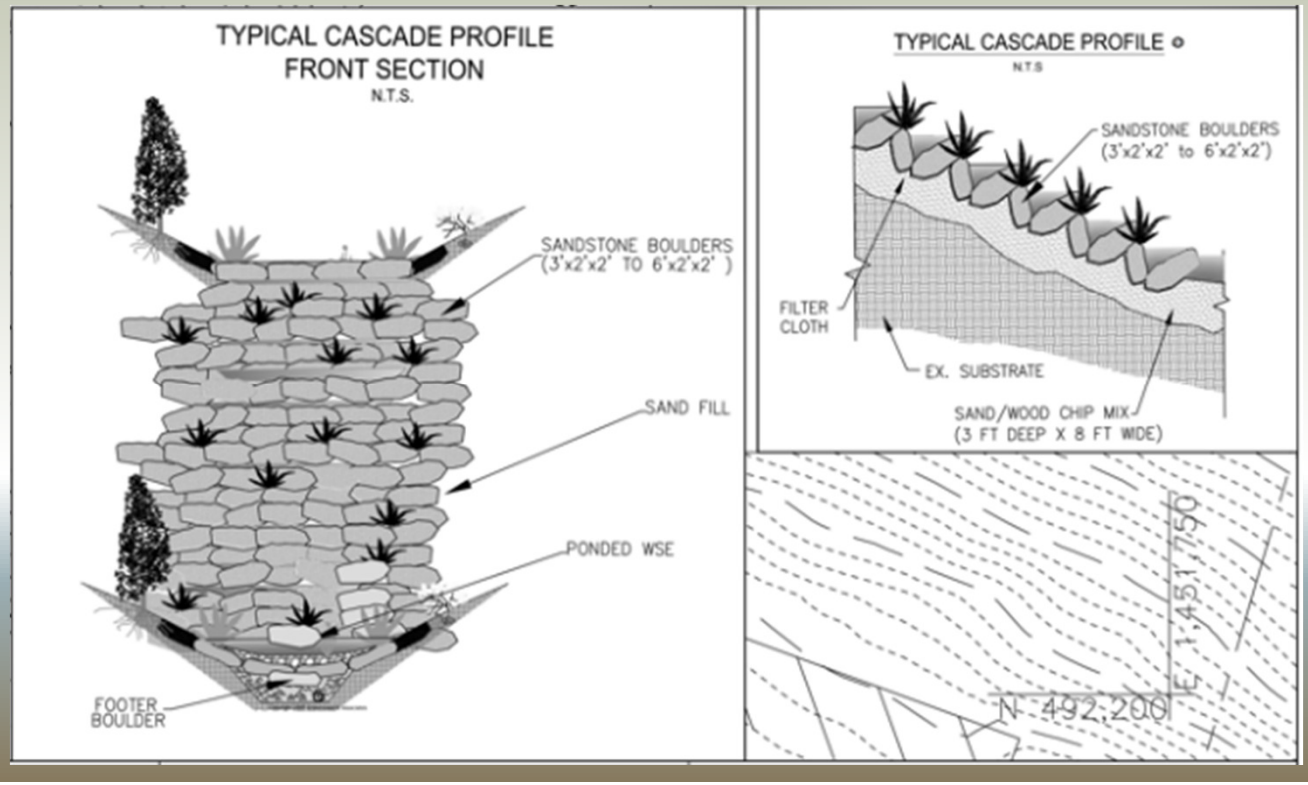
INSTALLATION

Preventing Common Failures and Issues

1. Water erodes a path adjacent and/or around boulders
   1.1 Do not spare sub-surface "key-in" boulders beyond the visible footprint.
   1.2 Carry the parabolic shape into the bank as boulders are "keyed in."
   1.3 During construction, observe drainage patterns carefully to characterize surface flow from sheet drainage arriving at the structure.
2. Excessive velocity and scour downstream.
   2.1 Do not tilt boulders downstream (smooth chute)! MUST BREAK FLOW with flat steps.
   2.2 Create roughness and turbulence in the structure by using flat and irregular surfaces to break flow.
3. Cascades unravel.
   3.1 Boulders must be three boulders deep into the upstream slope.

DETAILS

1. Carefully interpret details, keeping in mind that engineering software is limited in representing natural, 3D features.
2. Details are REPRESENTATIONS that need to be interpreted to:
   a. ensure stability
   b. functionality and
   c. naturalization into landscape.



E.7 Pool

- Function
  - Dissipate energy
  - Provide deep water habitat
- Materials and Supplies
  - Concrete sand
  - Masonry sand (if necessary)
  - Clay (if necessary)
  - Pea gravel
  - Coarse woody debris

INSTALLATION

1. Excavate within the footprint of the pool to remove underdrain pipe sections
2. Grade to designed pool depth
3. Shape pool working with surrounding grade:
   - minimize tree removal
   - create organic shapes
   - Widen wherever possible

INSTALLATION

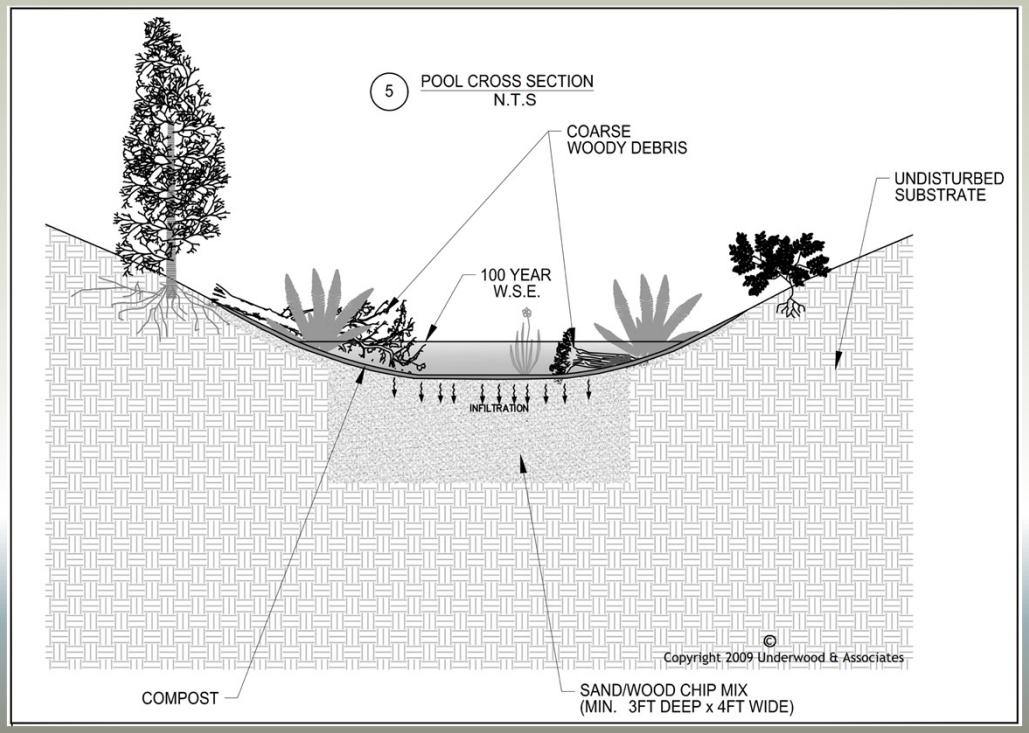
4. Adaptively manage during and post construction

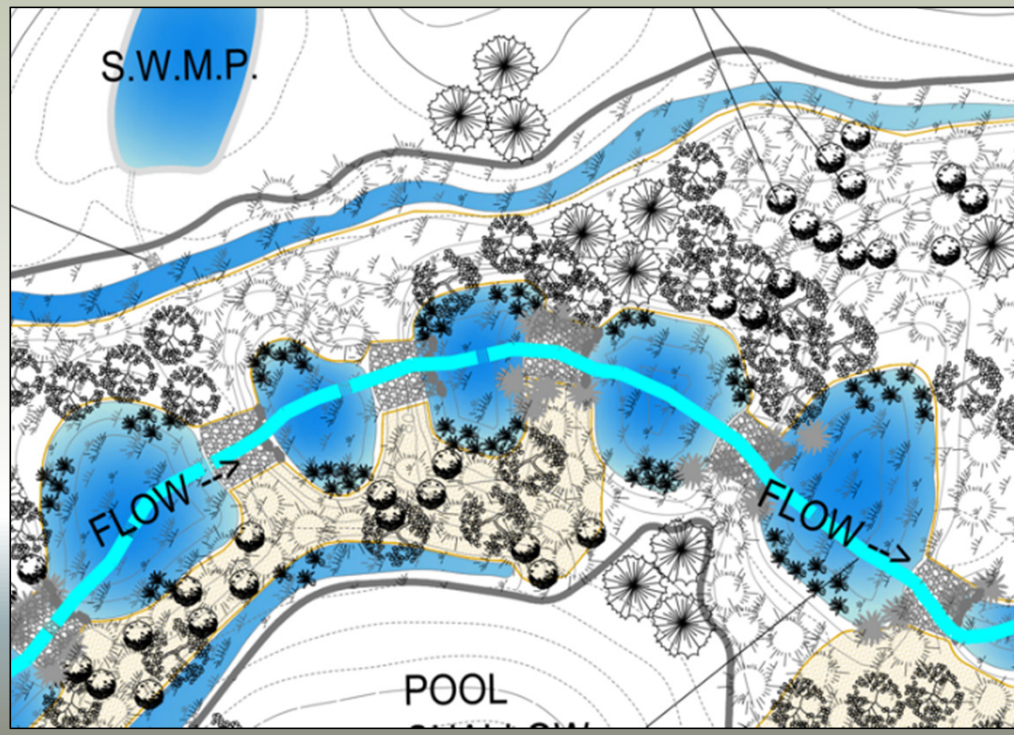
   4.1 Place layers of concrete sand to encourage infiltration

   4.2 If pool is infiltrating too fast, spread masonry sand

   4.3 If weir is draining pool too fast, first supplement masonry sand then install clay if necessary

DETAILS


5
POOL CROSS SECTION
N.T.S
COARSE
WOODY DEBRIS
UNDISTURBED
SUBSTRATE
100 YEAR
W.S.E.
INFILTRATION
COMPOST
SAND/WOOD CHIP MIX
(MIN. 3FT DEEP x 4FT WIDE)
© Copyright 2009 Underwood & Associates


S.W.M.P.
FLOW -->
FLOW -->
POOL

E.8 Coarse Woody Debris

- Function
  - Microbial processes that depend on organic carbon as source of energy
  - Chemical processes that build soil over time through decomposition
  - Hydraulic conditions that transport woody debris to redistribute throughout the system
  - Morphological processes that move debris to break flow and stabilize channels and banks; and
  - Habitat and food (biological) to support robust native flora and fauna.

- Materials and Supplies
  - Woodchip
  - Leaves
  - Brush and branches
  - Logs and tree stumps with roots intact (root wad)
  - Tree tops with branches intact

INSTALLATION

1. Place brush and secure logs in the riparian area, along pool edges and in pool
2. Place tree tops with branches along the pool edge to break up flow and provide habitat.
3. Turn root side up and pile the trunk securely into the bottom of the pool. Seed roots with permanent seed.
4. Leave leaf litter on site and if possible, supplement with leaf litter during first year after construction.
5. In RSC inspired projects that create limited (not full) connection to its floodplain and in projects that are close to roads and culverts, scale and modify CWD installation accordingly.

RSC CONSTRUCTION

F. Responsive Stabilization and Maintenance

F.1 Seed Bank

F.2 Material Movement and Rills

F.1 Seed Bank

- Function
  - Enables site to self-stabilize after disturbances and establish native vegetation

- Materials and Supplies
  - Temporary seed for multiple applications
  - Permanent seed for two applications (minimum)

INSTALLATION

1. Repeatedly and thoroughly seed the entire site with temporary seed, including weirs, cascades, haul roads and any disturbed area throughout duration of construction

2. Toward end of construction, thoroughly seed the site with permanent seed multiple times.

F.2 Material Movement and Rills

- Function of Rills
  - Miniature tributaries that hydrologically connect surrounding uplands to project area

- Materials and Supplies
  - Temporary and permanent seed
  - Concrete sand
  - Pea gravel
  - River rock

INSTALLATION

1. For deep rills on steeper slopes
   1.1 Fill part of rill with concrete sand
   1.2 Fill with river rock sized for flow almost flush to surrounding grade
   1.3 Add pea gravel to fill voids without raising grade
2. For shallow rills on entle slopes, fill with layer of sand capped by a layer of gravel
3. Seed with temporary or permanent seed
4. If possible, plant sphagnum moss along edges in shady areas to further stabilize and improve regenerative conditions

RSC
CONSTRUCTION

G. Planting

G. Planting

G. Planting

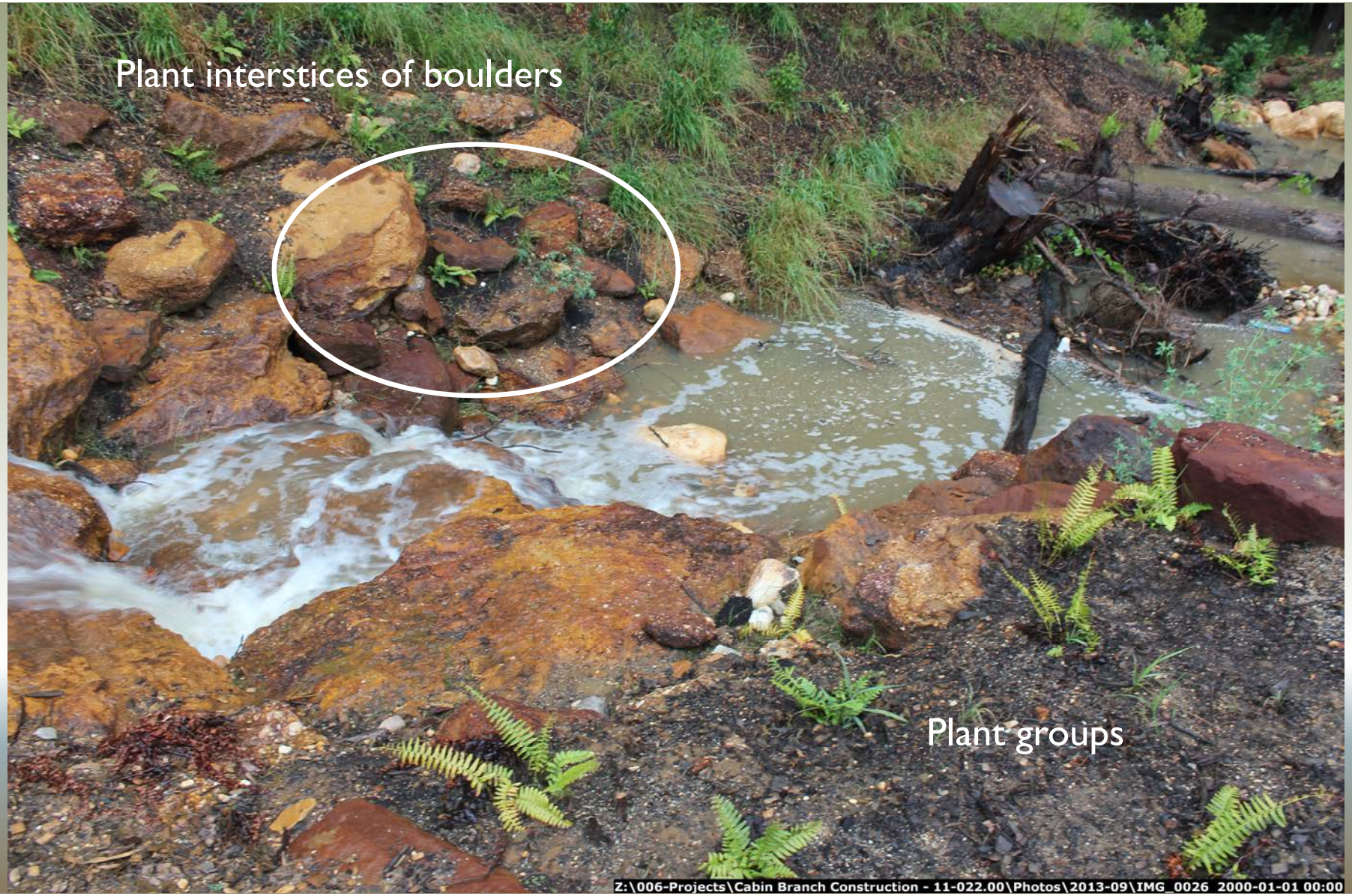
- Function
  - Support all five functions
  - Integral part of hydrologic cycle
- Materials and Supplies
  - Hand tools, e.g., auger, trowel, shovel, rakes, pitch forks, etc.
  - Compost
  - Concrete sand
  - Organic fertilizer
  - Native seeds and plants
  - Stakes
  - Wire ties
  - Hardware cloth or fence material

INSTALLATION

1. Continuously and overseed to quickly establish site and preclude invasive species
2. Observe stream flow during last stages of construction to ID microzones
3. List and separate plants for the micrzones: pool areas (saturated), edge of pool (wet), slope of pool (mesic), riparian areas (mesic), depressions in lowlands (hydric), uplands and ridges (dry)
4. Mix compost, sand and fertilizer to spec. If no specs, then use a 2:1 ratio of compost to sand with 5% of the mixed planting soil volume of fertilizer.

INSTALLATION

5. Trees and shrubs
   5.3 Place randomly, not in rows.
6. Herbaceous species
   6.1 Plant in clusters of 3-5
   6.2 Plant larger crevices in boulders with ferns
   6.3 Fill smaller crevices of boulders with planting soil and seed
   6.4 Densely plant aquatics to help hold soil, trap sediment and introduce roughness
6. Do not plant in the haul road but along.
7. Plant in stages and iteratively to allow the system to settle and to observe microzones to appropriately place plants.


Plant interstices of boulders
Plant groups
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INSTALLATION

9. Adaptive management should include invasive species management, especially in the first few years following construction. Herbicides should be used sparingly and sprays should be timed and targeted.
   9.1 Spray the underside of the leaves where the stomata (pores) are present.
   9.2 Time sprays to treat emerging plants before they fully leaf out, which reduces the amount of herbicide needed.
   9.3 If applications were not made in the spring, herbicide should be applied before the plants go to seed.