



Case Studies of Floodplain and Stream Restoration (FSR) Projects and their Potential Use for Flood Hazard Mitigation and Community Resiliency

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Stantec Consulting Services Inc.

November 8, 2018



Goals & Objectives

- FSR for Hazard Mitigation and Community Resiliency
- Review of Basic Geomorphic Principles
- Natural Channel Design Overview
- Design of Vane Structures
- Design of Floodplain and Habitat Features
- Case Studies of Floodplain and Stream Restoration (FSR) Projects



FSR for Hazard Mitigation

- Hazard Mitigation is any action taken to reduce or eliminate long-term risk to life and property from a hazard event.
- FEMA encourages communities to incorporate methods to mitigate impacts of climate change into eligible Hazard Mitigation Assistance (HMA) funded risk reduction activities.
- FSR projects are designed to be self-sustaining and are eligible for HMA funding to mitigate for:
 - Erosion
 - Flood Risk
 - Flood Reduction
 - Drought Mitigation

FSR for Community Resilience

- Community Resiliency is defined as the ability of a community to:
 - Adapt to Changing Conditions including Climate Change
 - Withstand Disruption
 - Recover from Emergencies
- FSR projects have the capacity to provide resilience to threats and hazards to multiple Ecosystem and Natural Resource issues:
 - Water/Hydrological Systems
 - Fisheries
 - Agriculture (Production & Livestock)
 - Wildlife Ecosystems
- FSR projects also address threats and hazards caused by or exacerbated by Climate Change including:
 - Climate Change Adaptation & Mitigation
 - Changing Weather Patterns & Severe Weather
 - Droughts and Floods

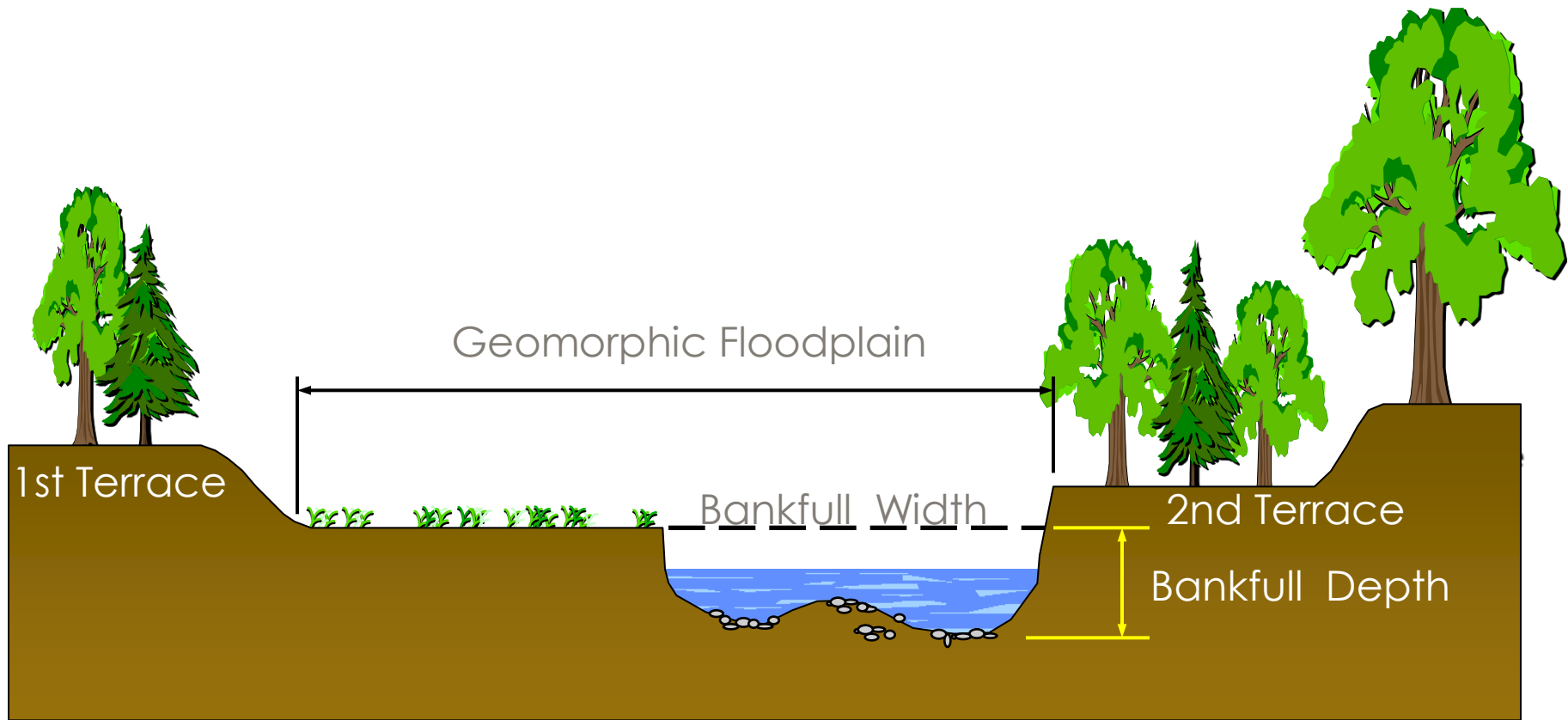
Fluvial Geomorphology

Branch of science concerned with influence of rivers and streams on the formation of the earth's surface

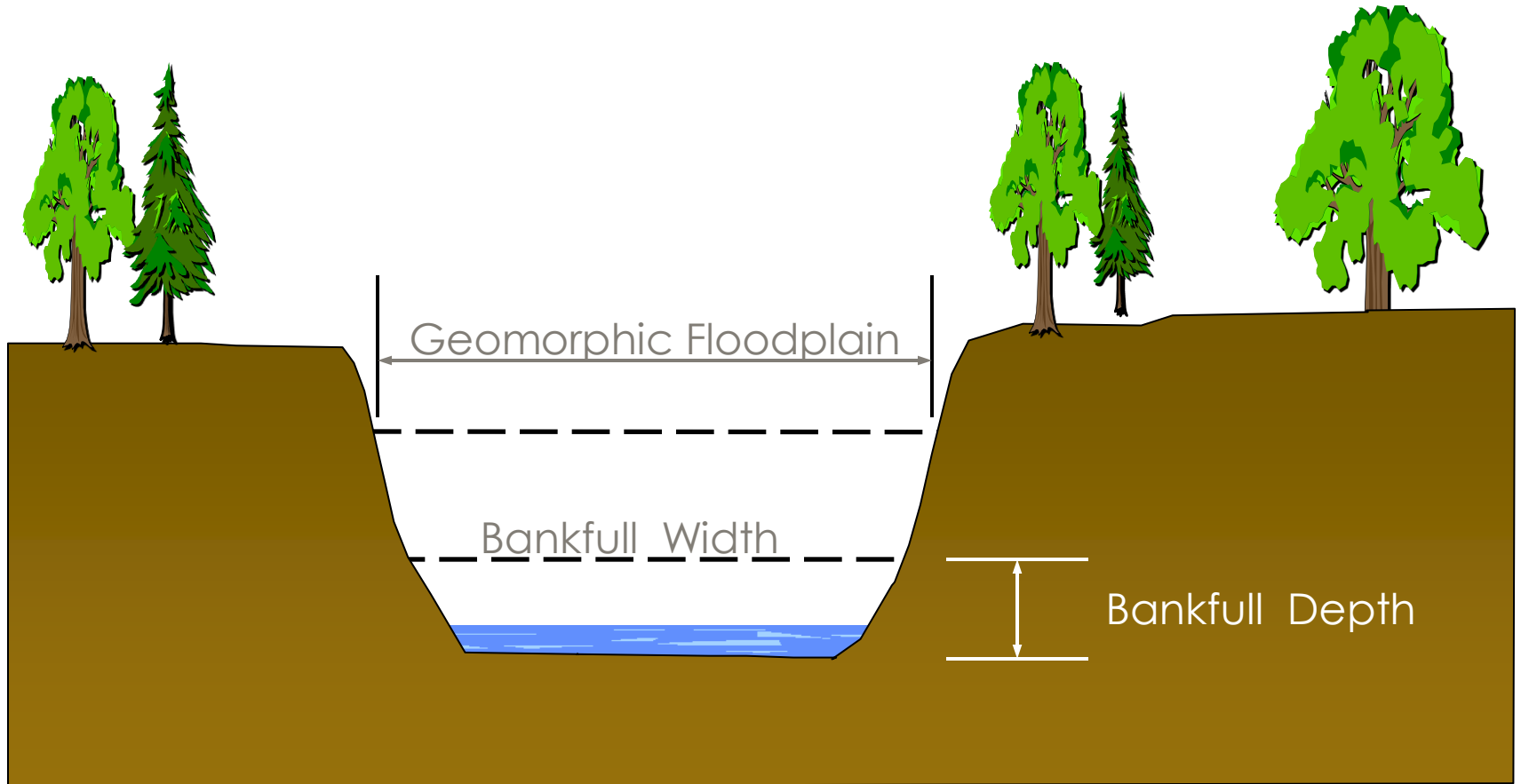
Governing Processes:

- Erosion
- Sediment Transport
- Sediment Deposition

Natural Stream Systems



Entrenched Channel



Bankfull Discharge

- Controls Channel Form
- Corresponds to the Discharge at Which Channel Maintenance is Most Effective
- Recurrence Interval on Order of 1.2 to 1.6 Years
- Higher Recurrence Interval in Urban Watersheds



Bankfull Indicators

- Flat, Depositional Surface Adjacent to Active Channel
- Height of Depositional Features (Point Bars)
- Change in Vegetation
- Slope or Topographic Breaks or Changes Along the Bank



Past Attempts at Designing Streams to Prevent Flooding



Past Attempts at Designing Streams to Prevent Flooding



Past Attempts at Designing Streams to Prevent Flooding



Designing Channels to be Natural and Resilient



Designing Channels to be Natural and Resilient



Differences

CONCEPT	TRADITIONAL	GEOMORPHOLOGICAL
Time	Short-term	Long-term
Model	Theoretical	Field Measurement
Water	Clear	Sediment Laden
Spatial Scale	Reach	Watershed
Boundary	Rigid	Mobile
Maintenance	High	Sustainable
Design Flow	100 yr.	Bankfull Flow
Factor of Safety	Conservative	Balance of Forces

River Stability Definition

River stability (equilibrium or quasi-equilibrium) is defined as “the ability of a river, over time, in the present climate to transport the flows and sediment produced by it’s watershed in such a manner that the stream maintains its dimension, pattern and profile without either aggrading or degrading” (Rosgen, 1994, 1996, 2001)



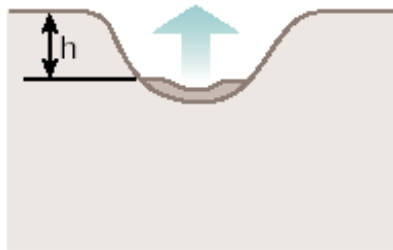
Indicators of Instability

- Incision/Bed-cutting
- Channel Filling
- Entrenchment/High Streambanks
- Lateral Migration
- Over Widening
- Lack of Habitat
- Eroded Banks
- Slope Instability

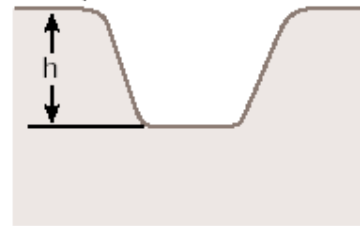


Simon's Modification of Schumm's Model

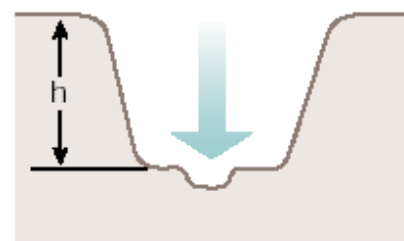
Class I. Sinuous, Premodified
 $h < h_c$



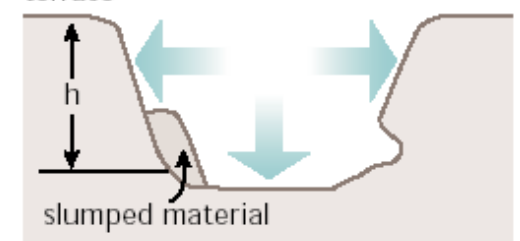
Class II. Channelized
 $h < h_c$
floodplain



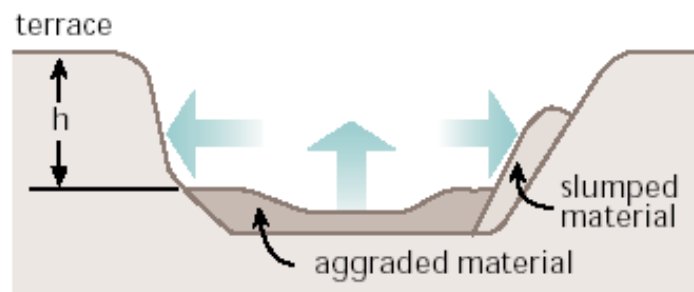
Class III. Degradation
 $h < h_c$



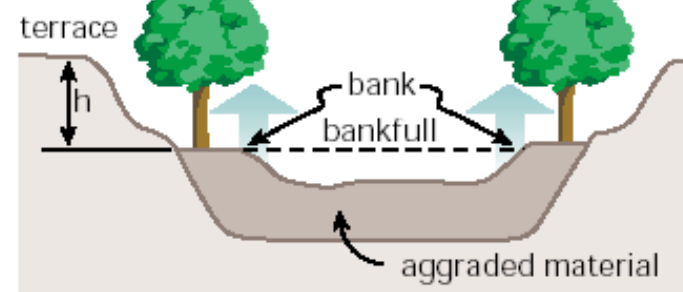
Class IV. Degradation and Widening
 $h > h_c$
terrace



Class V. Aggradation and Widening
 $h > h_c$



Class VI. Quasi Equilibrium
 $h < h_c$



Natural Channel Design

Process by which new or re-constructed stream channels and their associated floodplain riparian systems are designed to be naturally functional, stable, healthy, productive, resilient to changing conditions, and sustainable.

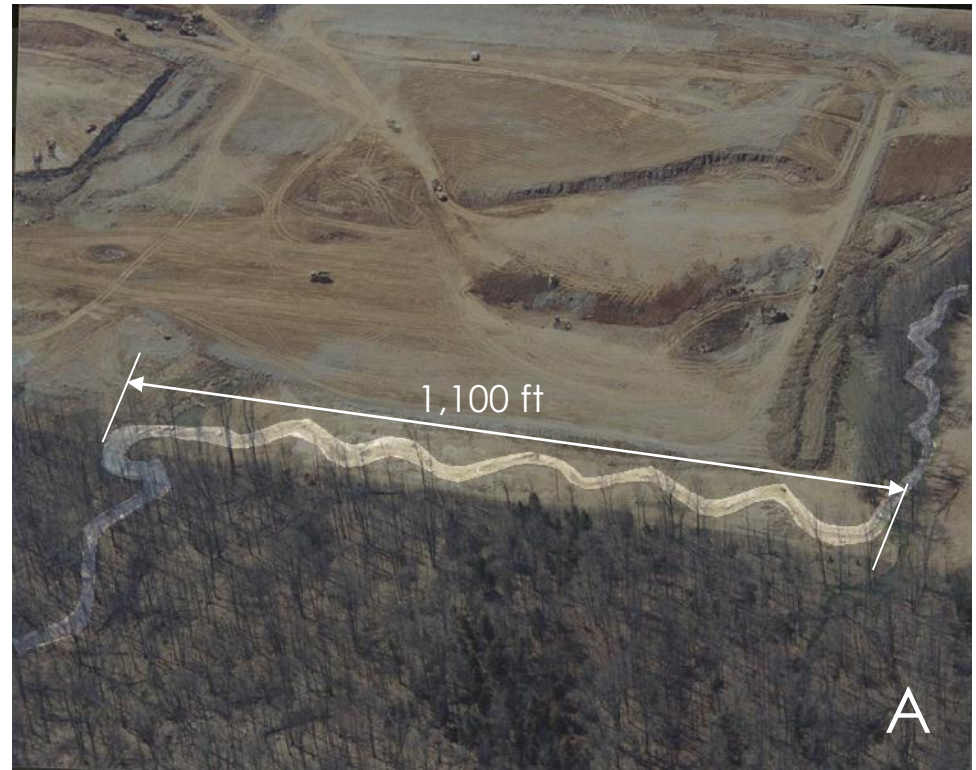


Phases of Natural Channel Design Using a Geomorphic Approach

1. Define Restoration Objectives
2. Develop Regional & Localized Specific Geomorphic and Hydraulic Data
3. Conduct Watershed/River Assessment
4. Assess Potential for Passive Restoration (i.e. Land Use Changes)
5. Initiate Natural Channel Design w/ Analytical Testing of Hydraulics & Sediment Transport
6. Design Stabilization/Enhancement Measures to be Resilient
7. Implement Proposed Design
8. Design & Implement Monitoring & Maintenance Plan

Natural Channel Design Process

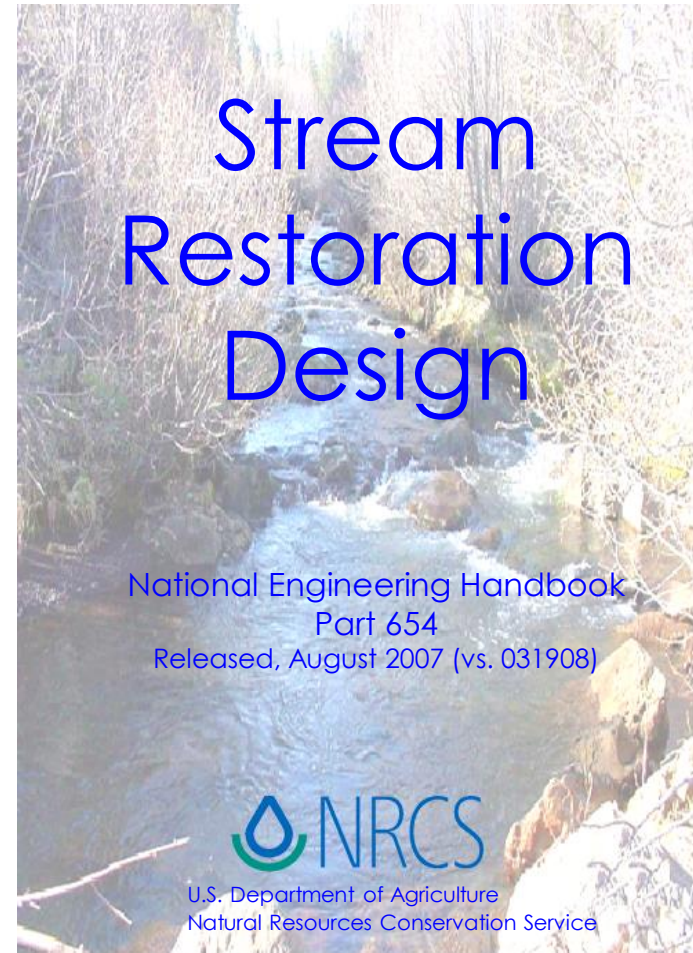
- Determine Site Constraints & Design Parameters
- Determine/Design Impact of Flood Flows on Potential Design
- Predict Stable Geometry Based on Reference Reach
- Check Sediment Transport Competency and Capacity
- Iterative Design Until Geometry and Calculated Depths Converge



Primary Reference

Chapter 11: Geomorphic Approach for Natural Channel Design

USDA NRCS, *Stream Restoration Design Handbook*, 2007.



Types of Restoration

- Priority I – Raise the Stream up to the Floodplain
- Priority II – Bring the Floodplain Down to the Channel
- Priority III – Do Not Alter Planform but Change Stream Type Along Existing Pattern
- Priority IV – Armour in Place using Soil Bioengineering or More Structural Approaches

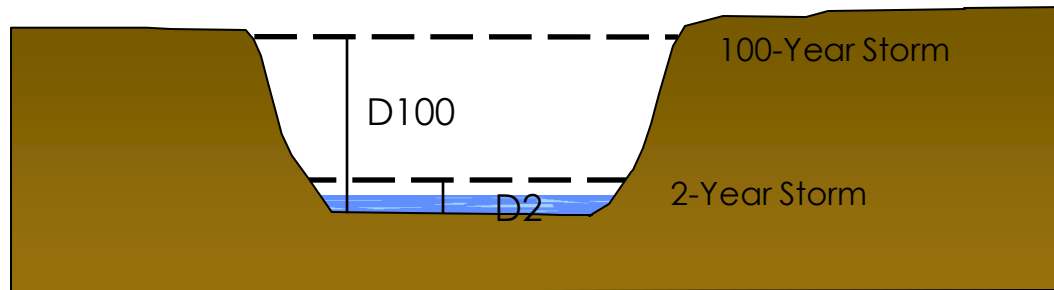


Reduction of Flood Elevation

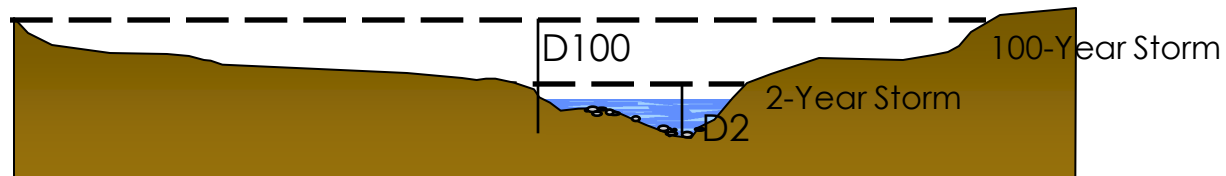
- Priority II or III - Potential to Reduce Flood Elevation
- Priority II – Excavate Floodplain, Creating Storage
- Priority III – Do not Alter Planform but Alter Cross Section, which Often Lowers Flood Elevation
- Comparing Flood Elevations of Same Precipitation Event



Reduction of Flood Elevation



Degraded or Channelized Stream



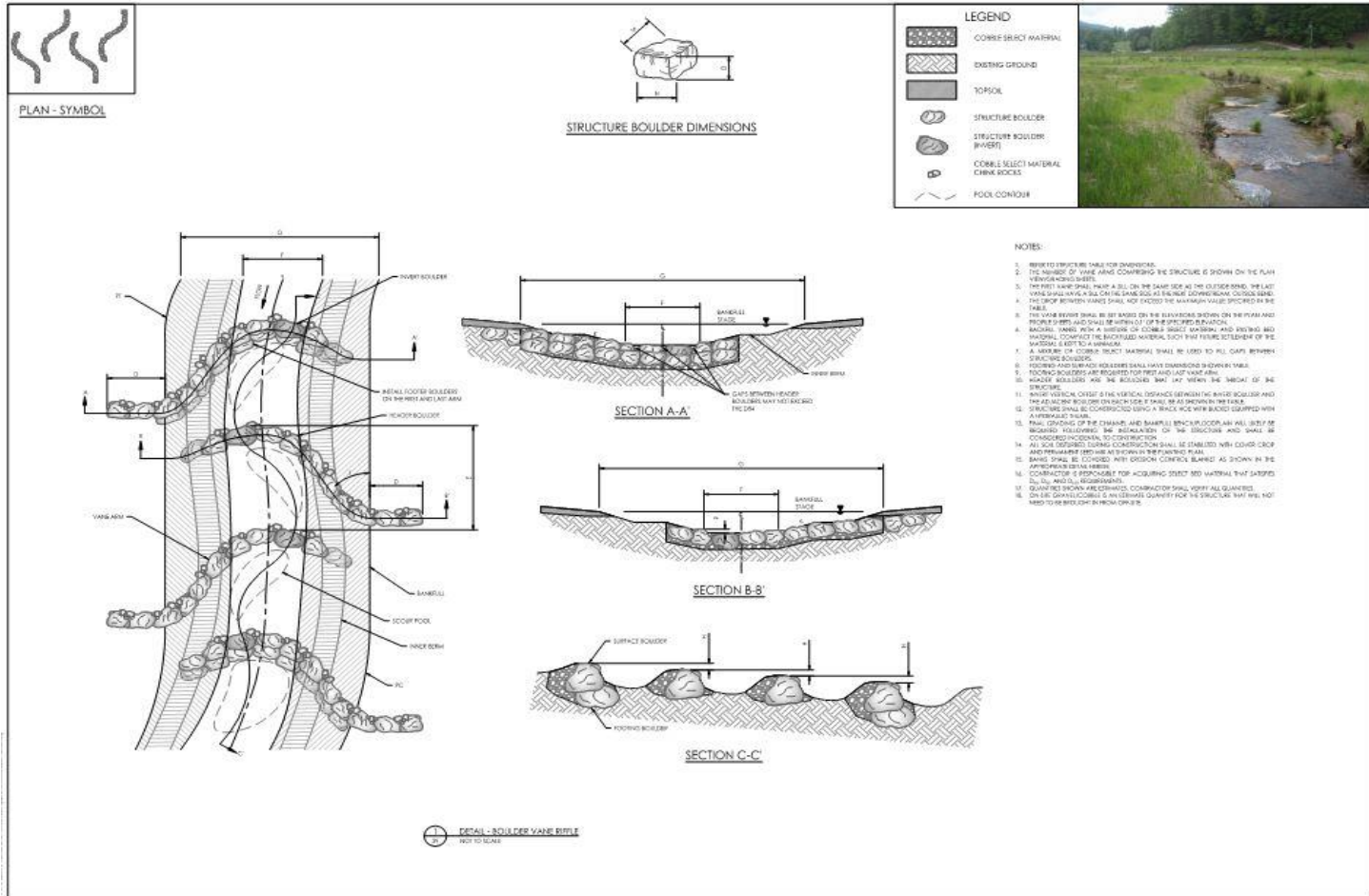
Restored Stream

Use of Structures in Natural Channel Design

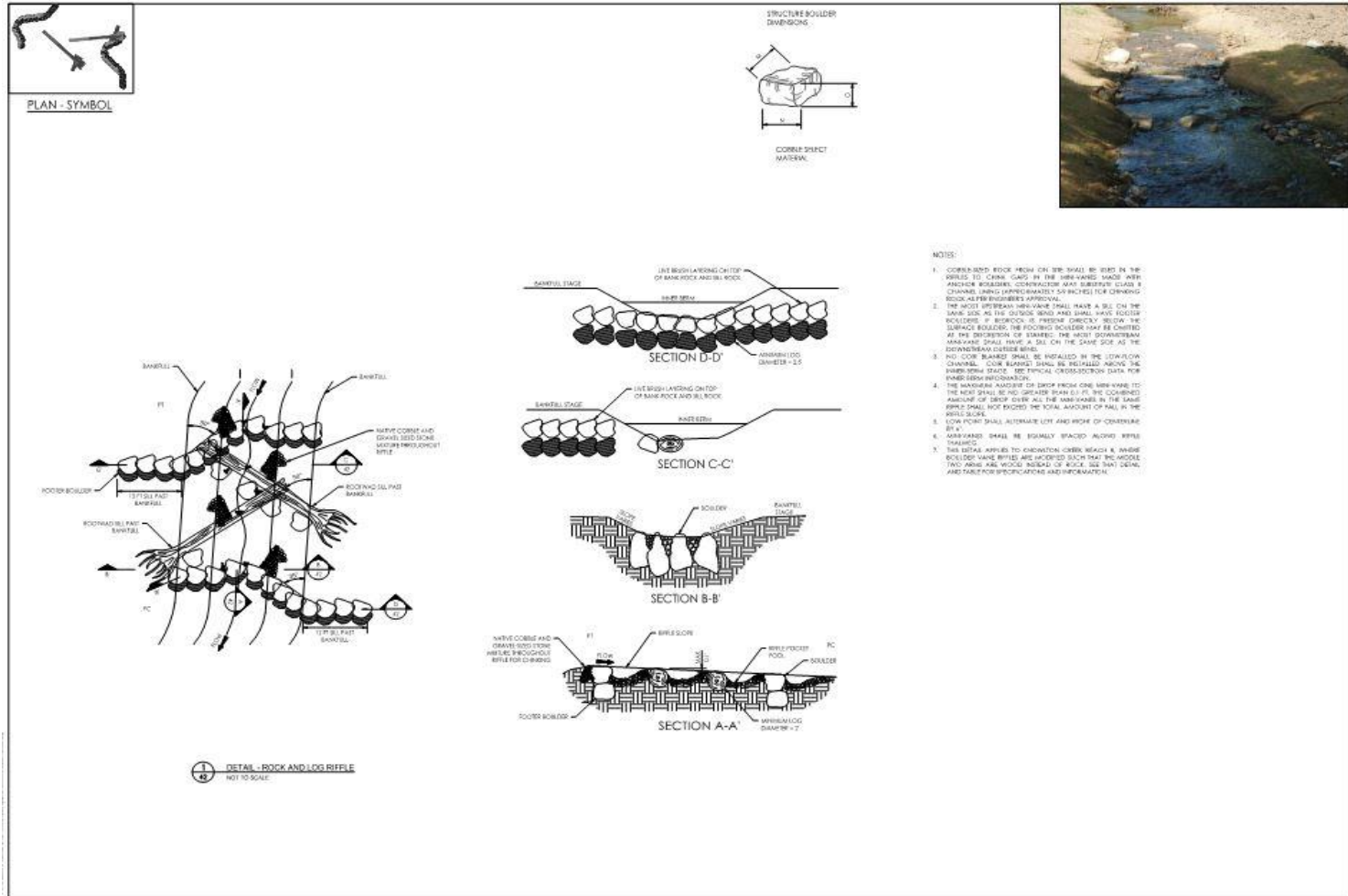
- Provide Grade Control
- Maintain Stable Aquatic Habitat
- Maintain Shear Stresses for Sediment Transport
- Decrease Bank Erosion
- Fish Passage at All Flows
- Control During Larger Flows
- Diversion Structures
- Bridge Openings



Boulder Vane Riffle



Rock and Roll Riffle

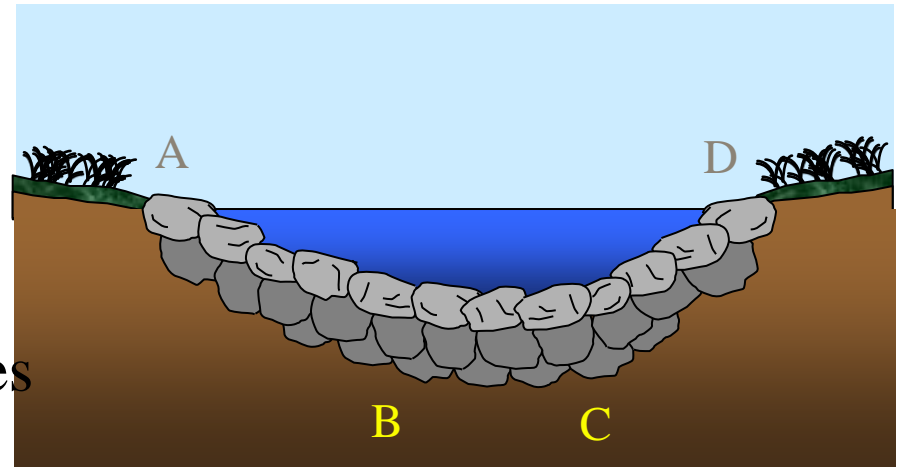
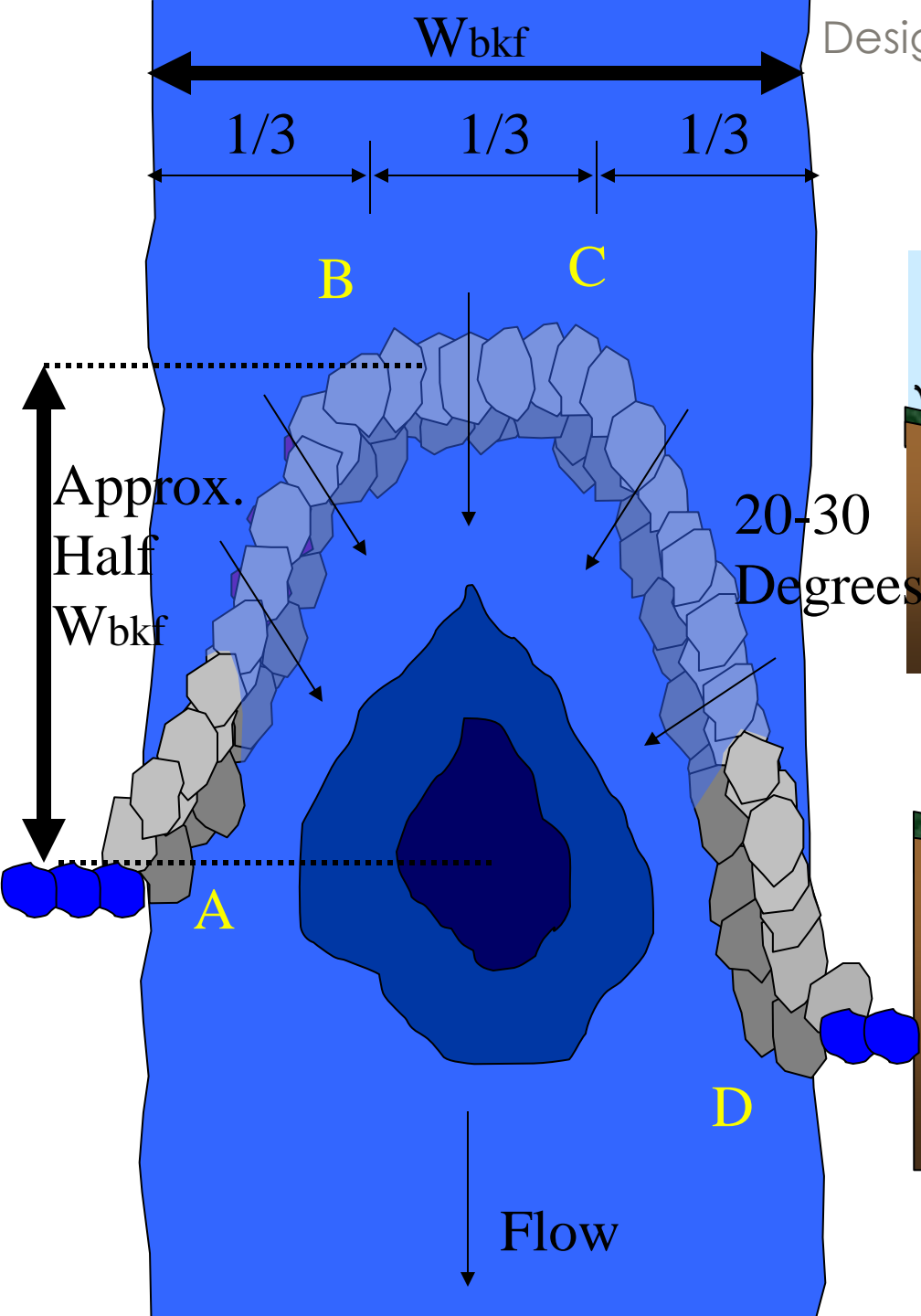


Design of Vane Structures

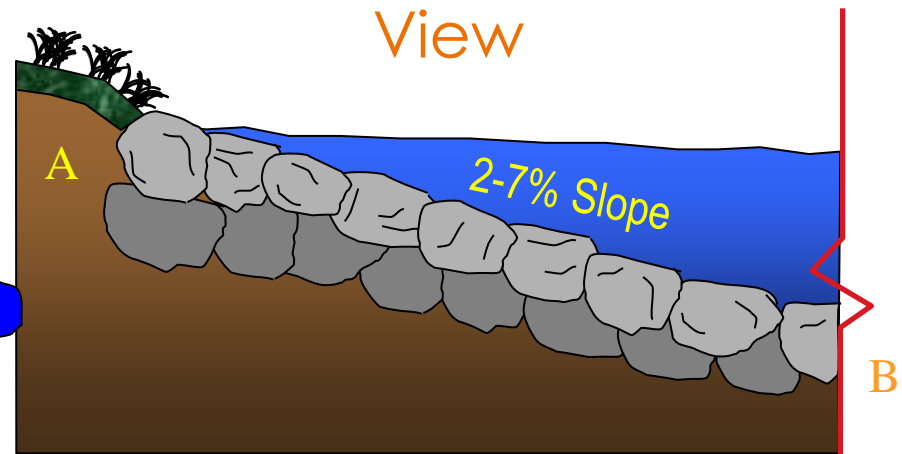
Constructed Riffle



Cross-Vane



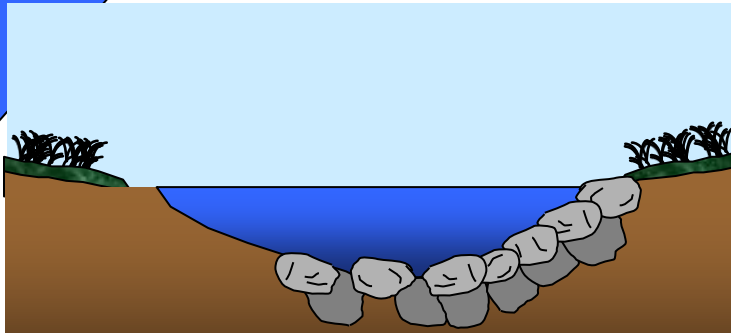
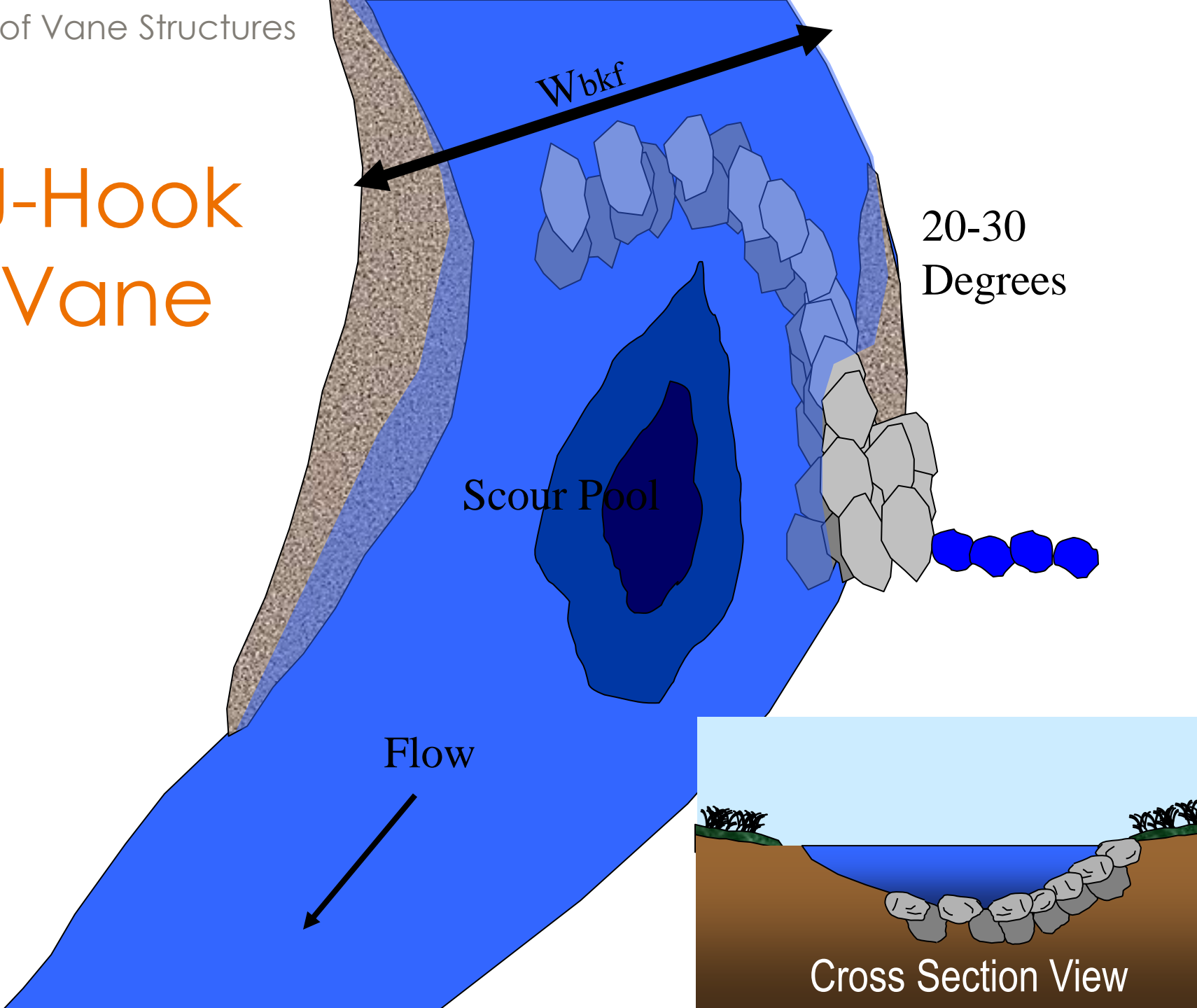
Cross Section View



Longitudinal Profile



J-Hook Vane



Cross Section View



Design of Vane Structures

Log Vane with Sill



Wood Toe

PLAN - SYMBOL

SECTION A-A

LIVE BRANCH

STEP 1

SECTION **PLANVIEW**

SECTION **PLANVIEW**

SECTION **PLANVIEW**

SECTION **PLANVIEW**

SECTION **PLANVIEW**

SECTION **PLANVIEW**

NOTES

1. REFER TO STRUCTURE TABLE FOR DIMENSIONS.
2. COVER WOODY DEBRIS SHALL CONSIST OF LIVE, NON-LIVING, AND LIVE BRANCHES NOT SUITABLE FOR CONSTRUCTION OF WOOD STRUCTURES. ALL MATERIALS ARE TO BE APPROVED BY ENGINEER.
3. COVER WOODY DEBRIS SHALL BE CONNECTED WITH THE LARGEST AVAILABLE DAPLES AND LOGS SHALL BE PLACED PARALLEL TO THE TOE OF WOOD. BRANCHES SHOULD BE PLACED IN A CROSSING PATTERN OR WEAVER SUCH THAT EACH LOG IS PROTECTED BY WOODWORK LOG.
4. SMALL PILE WOODY DEBRIS SHALL CONSIST OF MEDIUM TO SMALL LIMBS AND CAN BE BRANCHES, BUNDS, AND/OR LOGS. INACTIVE SPECIES SHALL NOT BE USED.
5. ALL WOODY DEBRIS SHALL BE COMPACTED WITH THE ROCKY/HEAVY BEDS IN ORDER TO REDUCE THE PROBABILITY OF UPROOTING AND TO MAINTAIN WOODY DEBRIS IN PLACE.
6. THE HORIZONTAL LOCATIONS OF ALL WOODY DEBRIS ARE LOCATED ON THE SPREADSHEET AND STRUCTURE TABLE AND WILL BE PROVIDED TO THE CONTRACTOR. SPACING TABLES FOR WOODY DEBRIS SHALL VARY FROM THE PLAN LOCATIONS UNLESS OTHERWISE NOTED FROM THE STAMPING ENGINEER.
7. NON-WOODY DEBRIS SHALL BE INSTALLED ABOVE THE WOODY DEBRIS. THE WOODY DEBRIS SHOULD BE THE SOIL LIFT AND INSTALLED OVER THE FABRIC. A PROVISIONAL TO CONSTRUCTION.
8. THE SOIL BACKFILL LOGS FOR SOIL AND COVER LOGS SHOULD BE PLACED WITH THE LIVE BRANCHES ABOVE THE SOIL LIFT AND WOODY DEBRIS AND SHALL GENERALLY BE FREE FROM ANY CORROSION MATERIAL.
9. SOIL BACKFILL SHALL BE COMPACTED SUCH THAT IT RISES 20" AND WILL BE SET TO AN APPROXIMATE 1% AND SUCH THAT THE WOODY DEBRIS IS DISPLACED OR DAMAGED.
10. TOP OF WOOD SHALL BE NO MORE THAN 1' ABOVE THE ELEVATION OF THE WOOD CONTROL BURNET.
11. THE TOP OF THE BACKFILL FOR THE SOIL LIFT SHALL BE SLOPED AS APPROVED BY THE ENGINEER FROM THE STREAM.
12. PLACE A LAYER OF TOPSOIL AND LIVE BRANCHES ON TOP OF EACH SOIL LIFT SUCH THAT APPROXIMATELY 6 INCHES TO 1 FOOT OF EACH LIVE BRANCH WILL BE EXPOSED AND THE REMAINDER IS TO BE COVERED BY LIVE BRANCHES ON THE NEXT SOIL LIFT.
13. LIVE BRANCHES SHALL BE THE SPECIES SPECIFIED FOR LIVE STAKES OR APPROVED BY ENGINEER FOR REPLACEMENT.
14. LIVE BRANCHES SHALL BE PLACED WITH THE WOODY DEBRIS TO WHICH BRANCHES SHALL BE COVERED BY LIVE BRANCHES ON THE NEXT SOIL LIFT AND LIVE BRANCHES SHALL BE 1/2" HBT OF THE BACKFILL OR BURIED BELOW THE NEXT SOIL LIFT. ALLOW THE BRANCHING 4" REST OF BRANES TO REST OVER THE WOODWORK OR MARKED OVER THE CROSS CONTROL BURNET TO THE SAME LIMITS.
15. SOIL CAN BE COMPACTED BY STAKING A PILE OF 2" OR 3" X 1/2" SAWN LAMBER EDGWAYS UP TO THE HEIGHT SPECIFIED IN THE STRUCTURE TABLE AND SOIL BACKFILL WITH WOODEN STAKES TO PROVIDE A PROTECTIVE COVER FOR COMPACTING THE SOIL.
16. PLACE SOIL BACKFILL UP TO THE HEIGHT SPECIFIED IN NO GREATER THAN 10" TO BEING CAREFUL NOT TO PILE UP OR TEAR THE FABRIC PREVIOUSLY PLACED.
17. THE TOP OF THE SOIL BACKFILL SHALL BE FLAT WITHIN THE LEFT STRAKE DISTANCE SPECIFIED IN THE STRUCTURE TABLE. BEYOND THE LEFT STRAKE DISTANCE THE SOIL BACKFILL SHALL BE SLOPED AS APPROVED BY THE ENGINEER AND FROM THE STREAM.
18. REMOVE THE SOIL LIFT WITH TOPSOIL FROM THE FACE OF THE SOIL LIFT AND FROM THE FACE AND TOP OF THE SOIL LIFT USING THE WOODEN AND NON-WOODY COVER MARKING OVER THE PREVIOUS LEFT COVER LOGS.
19. THE PROTECTIVE COVER FABRIC SHALL BE PILED AS RIGHT ABOVE WITH NO BRANES OR DEBRIS ON TOP OF THE FABRIC.
20. SECURE THE EROSION CONTROL AND NON-WOODY DEBRIS IN PLACE BY STAKING THE END OF THE EROSION CONTROL FABRIC WITH WOODEN LIMBS ON A 10' TO 15' CENTERLINE.
21. MEDIA CONSTRUCTION OF THE NEXT SOIL LIFT BY REPEATING THE PREVIOUS STEPS STARTING FROM NOTE 11.
22. THE COVER BRANES USED FOR THE FIRST SOIL LIFT WILL BE SECURED WITHIN A WOODY DEBRIS OR WOODY DEBRIS AS SHOWN IN THE PLAN. THE SURFACE OF THE STRUCTURE SHALL BE FINISHED TO A SMOOTH AND COMPACT SURFACE IN ACCORDANCE WITH THE LABELS, DIMENSIONS AND CROSS-SECTIONS OR EVALUATING DOWN ON THE DRAWINGS. THE DEPTH OF FINISH FOR DEBRIS SHALL BE WITHIN 1 FT OF THE STREAM AND BE NON-WOODY DEBRIS.
23. PREPARATION OF CHANNEL AND BANKS SHALL BE COMPLETED BEFORE INSTALLATION OF WOODEN BRANES AND SHALL BE COMPLETED INCLUDING TO CONSTRUCTION.
24. SOIL MAY BE USED INSTEAD OF THE TOP SOIL ABOVE THE WOOD TO IF IT IS AVAILABLE AND APPROVED BY ENGINEER.
25. SINGLE BRANCH AND DOUBLE BRANCH LOGS OF TOP WOOD ALONG THE BANK NOT THE CHANNEL.
26. LIVE STAKES SHALL BE PLACED AT THE CHANNEL EDGE AS DESCRIBED IN THE PLAN AND PLAN.
27. LIVE STAKES ARE INSTALLED ONCE LIVE AND LOG SOIL HAS BEEN CONSTRUCTED.

WOOD TOE WITH COR WRAPPED SOIL LIFTS
NOT TO SCALE



Design of Floodplain & Habitat Features

Woody Toe Sod Mats

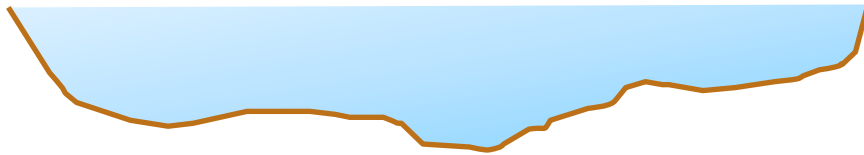


Design of Floodplain & Habitat Features

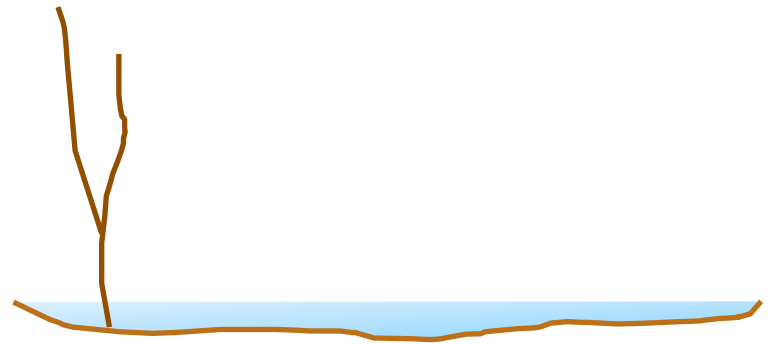
Woody Toe Sod Mats



Oxbows



Vernal or Ephemeral Pools



Design Considerations

Hydrology

Depth

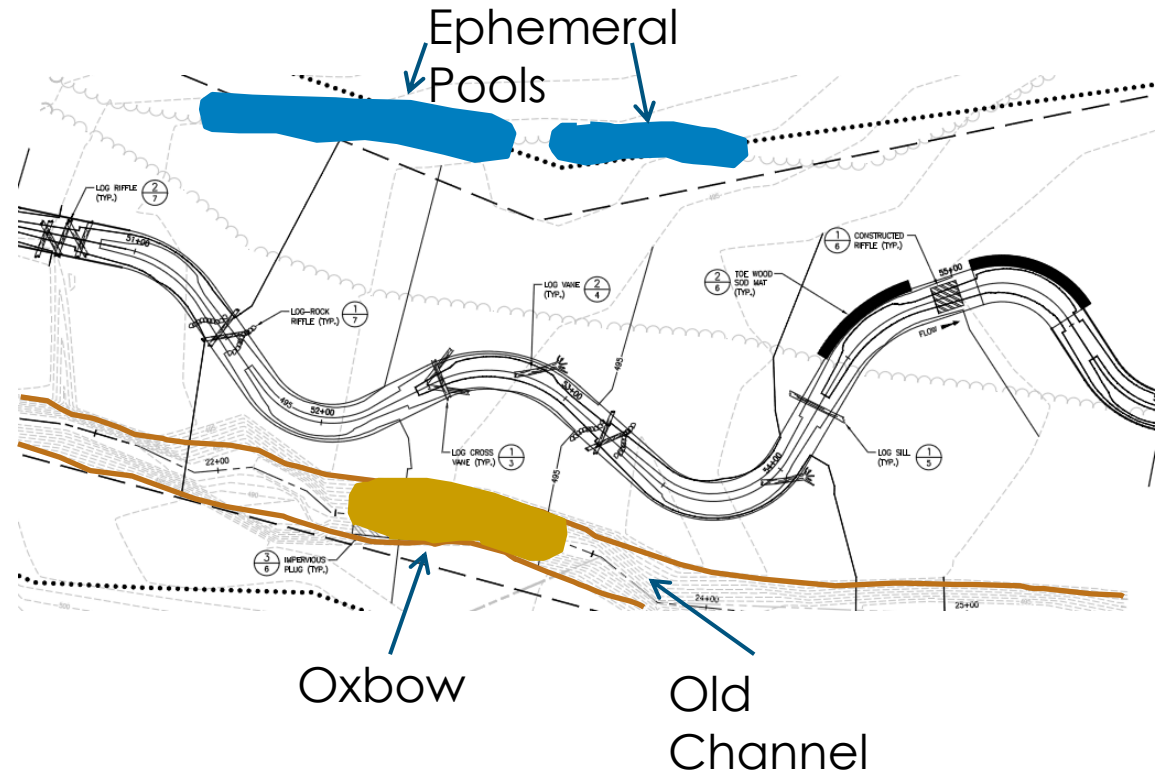
- Deep
- Shallow

Vegetation

- In-pool
- Shading

Outlet

Cut/Fill Balance



Functions and Linkages

Habitat

- Amphibians
- Invertebrates
- Breeding
- Rearing
- Refuge



Nutrient Processing

- Organic Inputs
- Hydric Soils



Ecosystem Functions

Flood Storage (Oxbows)

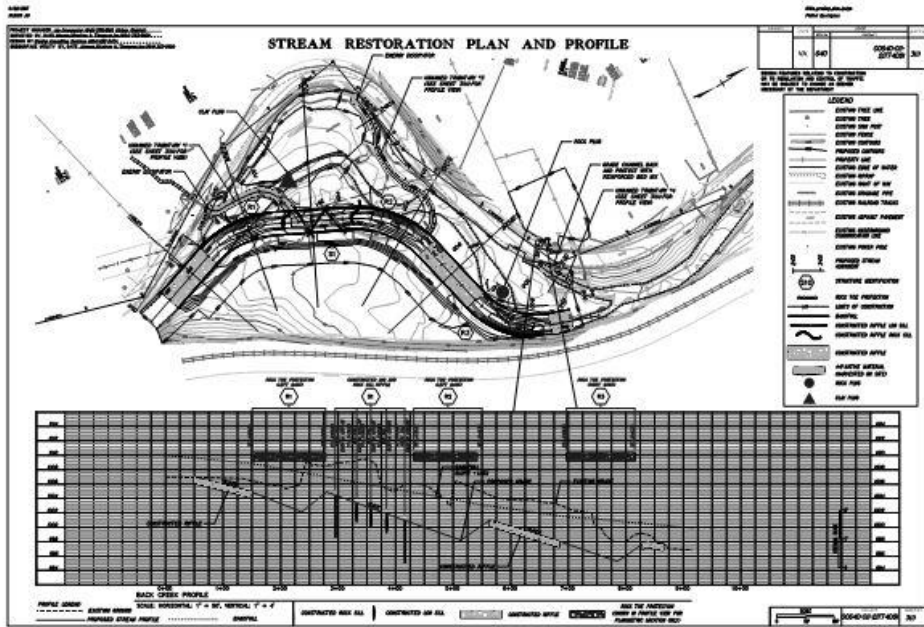
Back Creek Stream Restoration at Lithia Road, Troutville, VA (VDOT)



Pre-Restoration Conditions

- Aggrading Channel as a Result of:
 - Upstream Watershed Conditions
 - Poor Restoration Attempt
- Serious Flooding During Most Rain Events
- Major Road for Area
- Impassable 5X Per Year

Back Creek Stream Restoration at Lithia Road, Troutville, VA (VDOT)



Restoration Design & Construction

- Proper Assessment of Geomorphic Conditions
- Natural Channel Design Approach
- Fish Habitat Improvement
- Improved Flood Conveyance



Dare Elementary School Stream Restoration, York County, VA



Pre-Restoration Conditions

- Collapsing Concrete-Lined Channel – 20' Headcut
- 800 Linear Feet of Channel
- Safety Issue to Adjacent Properties



Pre-Restoration Conditions

- Large Source of Erosion to Downstream Watershed
- Water Quality Problems

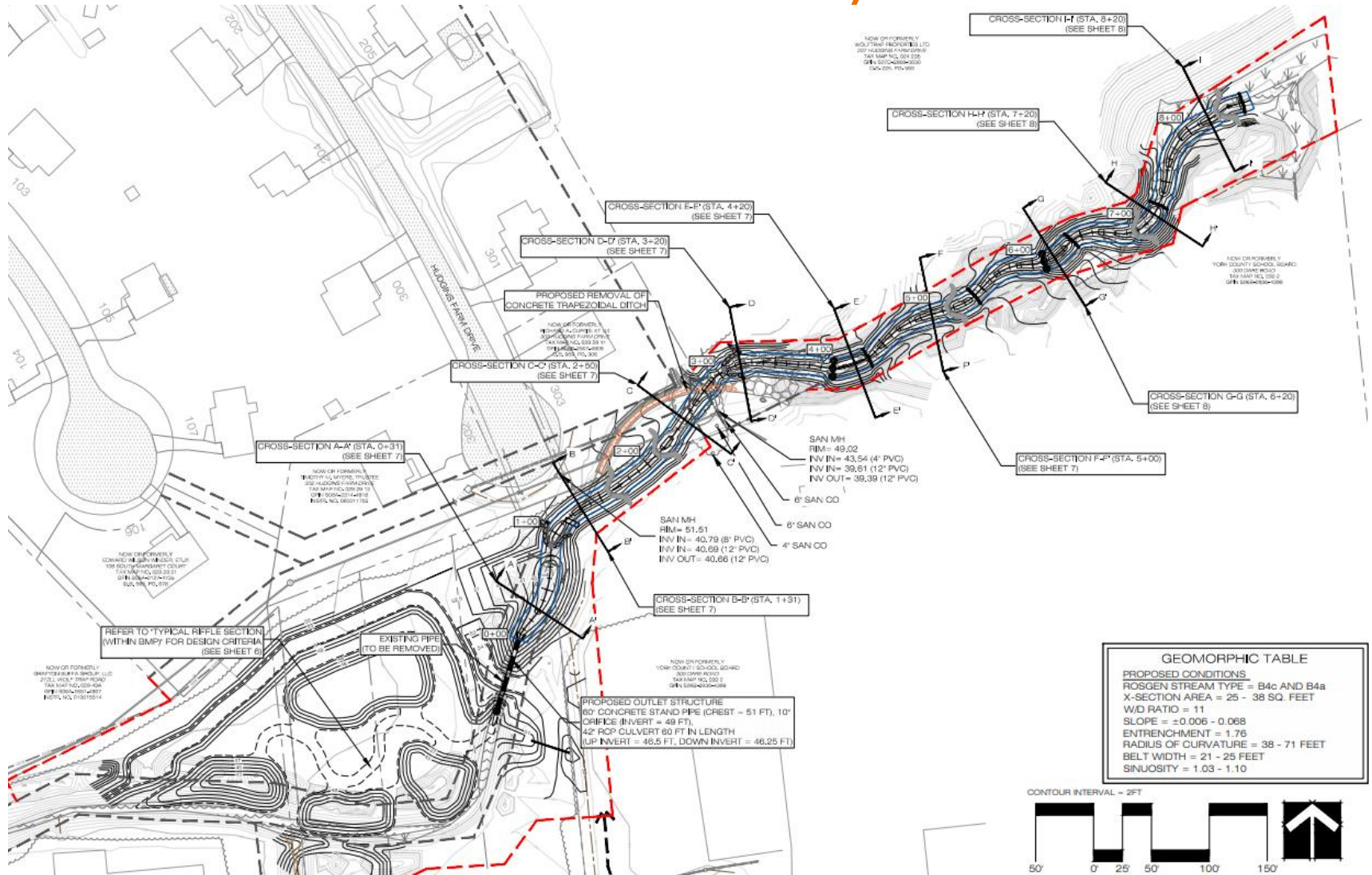
Dare Elementary School Stream Restoration, York County, VA



Restoration Design & Construction

- Priority III Restoration Approach
- Designed In-Line BMP Upstream to Provide Peak Flow Attenuation & WQ Treatment
- Stabilized Severe Headcut
- Protected Adjacent Properties
- Maintained Low Flow Channel Connected to Floodplain
- Phosphorus Removed – 141 LB/YR
- Savings Per LB of TP - \$8,511
- Value to Watershed - \$2.4M
- Total Project Cost - \$1.2M

Dare Elementary School Stream Restoration, York County, VA



Dare Elementary School Stream Restoration, York County, VA



Post-Construction Conditions

- Project Stable and Functioning as Designed for 5 Years



Case Studies of Floodplain and Stream Restoration Projects

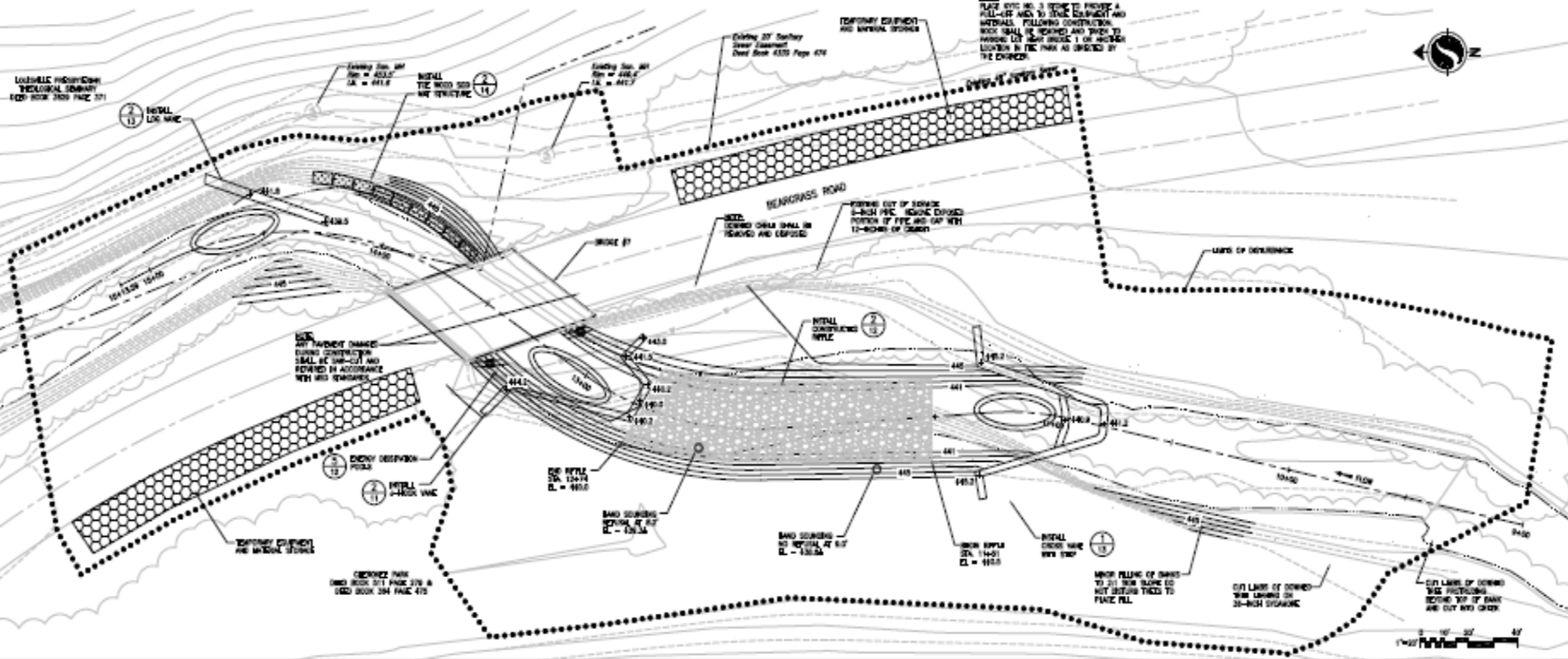
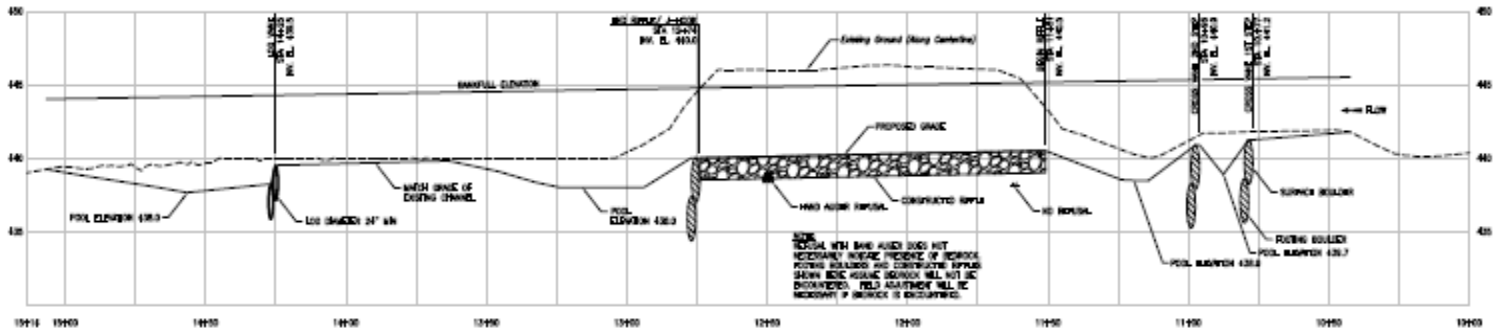


Middle Fork of Beargrass Creek at Cherokee Park Stream Restoration, Louisville, KY









NO.	DATE	REVISION	BY	APPROVED	DATE

Last Designer's Seal
Professional Engineer's Seal

PLANS PREPARED AND SUBMITTED BY:
Starbuck Consulting Services Inc.
 1801 Nelsonville Pike
 Louisville, Kentucky
 40223-2177
 Tel: 502.212.3000
 Fax: 502.212.3005
 www.starbuck.com



CONSTRUCTED BY:
 Company Name _____ Date _____

RNAL RECORD DRAWING BY:
 Company Name _____ Date _____

LOUISVILLE AND JEFFERSON COUNTY
 METROPOLITAN SEWER DISTRICT

DESIGN APPROVED BY: _____ Date _____

APPROVED FOR CONSTRUCTION BY: _____ Date _____

ALL ELEVATIONS IN THIS SET OF PLANS ARE BASED ON MGD AS DATUM. ELEVATIONS WILL NOT AGREE WITH ELEVATIONS ON EXISTING PLANS FROM PREVIOUS PLANT CONSTRUCTION.

MSD MIDDLE FORK BEARGRASS CREEK
 STREAM ENHANCEMENT PROJECT

CHEROKEE PARK BRIDGE #7
 PLAN AND PROFILE
 STATION 104-00 TO STATION 15+14

SCALE: 1" = 20'H
 1" = 2'V

Date: 05/26/10 Drawing No.: CT-101















20
M.P.H.

REMEMBER
WEATHER
CONDITIONS
AFFECT
TRAVEL









QUESTIONS?

November 8, 2018

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Rich Pfingsten, PWS

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