Stream Restoration Planning and Design

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Fluvial System Stabilization and Restoration

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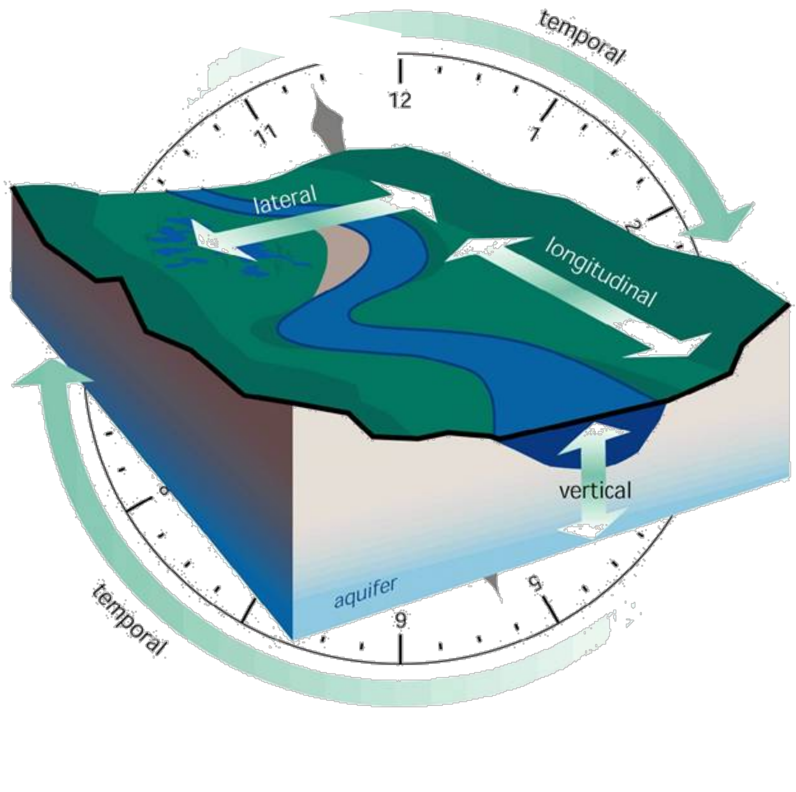
-Field Guide-



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NRCS

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Advisory Note
Techniques and approaches contained in this handbook are not all-inclusive, nor universally applicable. Designing stream restorations requires appropriate training and experience, especially to identify conditions where various approaches, tools, and techniques are most applicable, as well as their limitations for design. Note also that product names are included only to show type and availability and do not constitute endorsement for their specific use.

Stream Restoration Planning and Design
Field Guide

This document is intended as a pocket field guide for use in the Natural Resources Conservation Service (NRCS) design training workshops in support of the **NEH 653 Stream Corridor Restoration** and **NEH 654 Stream Restoration Design Handbook**. Much of the text for this guide is excerpted from both NEH 653 and NEH 654.

Material for use in assessment and planning is provided in this field guide training document. This field guide contains a collection of sample conceptual design details for a variety of fluvial system stabilization and restoration approaches. These details are provided for discussion purposes. In addition some information that may be useful in assessment and classification of stream sites is included.

This field guide is neither inclusive nor exhaustive. Advantages and disadvantages of the different techniques and approaches are not addressed. While design tables and equations are provided, this document is intended as a general field reference and training tool. Many publications, including NEH 653 and NEH 654, are available which provide more detail on these as well as other treatments. The practitioner is encouraged to review these publications as well as available local knowledge of the project area.

This field guide is small enough to fit in a field pack. The user is encouraged to take notes on the pages during the field exercise portions of the workshop. The information in the field book is meant to provide a quick reference and not intended to be a complete assessment or design tool.

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The Nine-Step Conservation Planning Process

The Natural Resources Conservation Service uses a nine step planning process whenever it begins a project. The purpose of the steps is to develop and implement plans that protect, conserve, and enhance natural resources within a social and economic perspective.

<u>1 - Identify Problems and Opportunities:</u> Everyone needs a reason to plan. Planning can start with a problem, an opportunity, shared concerns, or a perceived threat. Initial opportunities and problems are first identified based on readily available information provided by the client(s). There may be information available through the County Conservation Districts or through a larger-scale conservation plan.

<u>2 - Determine Objectives:</u> During this step, the stakeholders identify their objectives. A conservationist guides the process so that it includes both the stakeholder needs and values and the resource uses and on-site and off-site ecological protection. Objectives may need to be revised and modified as new information is learned later in the inventory and analysis stages. Objectives may not be finalized until Step 4 of the planning process.

<u>3 - Inventory Resources:</u> In this step, appropriate natural resource, economic and social information for the planning area is collected. The information will be used to further define the problems and opportunities. It will also be used throughout the entire process to define alternatives and to evaluate the plan. It is important that as much information as possible can be collected so that the plan will fit both the needs of the landowner and the natural resources. Inventories can range from a farmstead or small watershed all the way up to a complete inventory of resources for a state or the entire nation, such as with the NRCS National Resources Inventory or the Soil Survey Program.

<u>4 - Analyze Resource Data:</u> Study the resource data and clearly define existing conditions for all of the natural resources, including limitations and potential for the desired use. This step is crucial to developing plans that will work for a landowner and their land. It also provides a clear understanding of the baseline conditions will help to judge how effective a project is after it has been put into place.

5 - Formulate Alternatives: The purpose of this step is to achieve the goals for the land, by solving all identified problems, taking advantage of opportunities, and meeting the social, economic, and environmental needs of the planning project. With NRCS conservation planning, we often can help landowners formulate alternatives based on cost-sharing programs that help offset the financial expense of implementing conservation practices.

6 - Evaluate Alternatives: Evaluate the alternatives to determine their effectiveness in addressing the client's problems, opportunities and objectives. Attention must be given to those ecological values protected by law or executive order.

7 - Make Decisions: At this point the landowner chooses which project or plan will work best for their situation. The planner prepares the documentation. In the case of an area wide plan, public review and comment are obtained before a decision is reached.

8 - Implement the Plan: Technical assistance is provided to help with the installation of adequate and properly-designed conservation practices. At this point in NRCS conservation planning, our conservation engineers step in and make designs based on our technical standards. Also, assistance is given in obtaining permits, land rights, surveys, final designs, and inspections for structural practices.

9 - Evaluate the Plan: Conservation planning is an ongoing process that continues long after the implementation of a conservation practice. By evaluating the effectiveness of a conservation plan or a practice within a plan, stakeholders can decide whether to continue with other aspects of an overall area wide plan.

Pre Field Work
(Preliminary Inventory)

The following is a list of information that might be collected before going to the field. This information will help the team understand the catchment and stream to help focus field collection and evaluation efforts. Not all items will be used in every investigation and not all items will be collected at the same level of detail.

- Geology
- Climate - Water and Climate Center
- Maps
  - Topographic Maps
  - USGS quad sheets
  - State Division of Lands
  - State Lands Map
- Aerial Photos

- Soils - USDA Soil Survey
- Land Use – current and historical
- Ownership
- Gage data
- Watershed development patterns and history
- Prior Investigations
  FEMA floodplain maps and studies
  Federal PFC
  BURP
  USFS Watershed Analysis
  Water Resources Investigation
  Large Private Land Owners (timber, power, agricultural)
  Fish and Game fish surveys,
- Key Reach Identification, project and reference reach

Look at some of the data, and estimate which data types contain the most relevant information for your effort. Try and combine some of the data for clarity (e.g. dry cropland on steep slopes, streams on north slopes, streams near mass wasting areas).

Stream Assessment Procedure

1. Prior to conducting fieldwork, it may be advisable to conduct a team meeting and discuss the following:
   - Develop goals, objectives of assessment
   - Identify and discuss inventory procedures (SVAP, PFC, etc)
   - Discuss reaches, how they were identified and delineated.
   - Discuss constraints that may impact the type of project that can be implemented (both physical and ecological)
   - Discuss dominant processes in watershed
   - Identify and discuss recent extreme events (flood, drought, fire, etc) and their effects on the project site
   - Discuss the plan of movement, logistics, and safety requirements
   - Identify relevant field equipment (clothes, water, lunch, sun block, bug juice, graduated wading staff, clip board, tape (25 to 100 foot), waders, camera, chalk board or white board for photo caption, binoculars, radios, GPS, digital range finder, hand level, plant keys, field packet, topo of area, site diagram, inventory worksheets, stream bug id sheets)
2. Once on the site the team should assess the site as a group.
   - Discuss the dominant processes acting on the site (both physical and ecological)
   - Discuss what might have occurred to result in the current condition of the site

- Discuss how the site might respond to future conditions (flood, fire, development, etc)
- Discuss what conditions may limit change in the site
- Measure the entire channel depth and width for the various points identified in the riparian zones.
- Estimate the side slopes of the channel.
- Measure entire stream cross section including some of the overbank
- Measure the bed gradient
- Assess and quantify the bed and bank material
- Assess the condition and type of riparian vegetation
- Discuss possible treatment alternatives
- Assess the impact of the "do nothing" alternative
- Discuss the access to the site, construction and staging areas
- Take photographs at the start of reach, at each active erosion site, and at end of reach looking upstream

3. At the end of the day, the entire team should meet.
    - Discuss problems
    - Discuss possible treatment solutions
    - Discuss possible impacts of solutions (physical and ecological)

Hydrology

Rarely does the behavior of a channel under a single discharge adequately reflect the range of design conditions required of a stream restoration project. Stream restoration design should consider a variety of flow conditions. These flows should be considered from both an ecological as well as a physical perspective. A discussion of some of the various types of design discharges is provided in this section. Although a project may not require the use of all of these flows for design, the hydraulic engineer/designer should still consider how the project will perform during a range of flow conditions.

Low flows

Design of a low flow channel may be required as part of a channel modification. Normally, the design of the project for low flows is performed to meet biological goals. For instance, summer low flows are often a critical period for fish, and project goals may include narrowing the low flow channel to provide increased depths during low flow. Low flows may also be necessary to evaluate depths and velocities for fish spawning or fish passage during critical times of the year. Coordination with the biologist on the study team and familiarity with regulatory requirements are essential to make sure an appropriate flow (or range of flows) is selected.

Channel forming discharge

The channel-forming discharge concept is based on the idea that, for a given alluvial channel, there exists a single steady discharge that, given enough time, would produce channel dimensions equivalent to those produced by the natural hydrograph. This discharge is thought to dominate channel form and process. Estimates of channel-forming discharges are used to classify stream types, estimate channel dimensions, assess stability, and express hydraulic geometry relationships. Depending on the application, channel-forming discharge can be estimated analytically by drainage area, effective discharge calculation or a specified annual peak frequency discharge.

Channel-forming discharge can also be estimated with the use of "bankfull" indices. These are determined in the field by visually inspecting the reach in question or surveys of this reach to locate morphological evidence of the "bankfull" stage. The discharge associated with this stage is then computed or estimated.

Identifying relevant features that define the "bankfull" stage is not easy. It can be especially problematic in dynamic, unstable channels. The following two tables list information about the identification of bankfull indicators. The first provides a list of bankfull indicators that may be observed in the field. The second table lists some of the effects that different stream conditions may have on the identification of bankfull indicators.

Bankfull Indicator
Minimum width/depth ratio
Highest elevation of channel bars
Elevation of middle bench in rivers with several overflow sections
Minimum width/depth ratio plus a discontinuity (vegetative and or physical) in the channel boundary
Elevation of active flood plain
Lower limit of perennial vegetation
Change in Vegetation (herbs, grass, shrubs)
A combination of • Elevation associated with the highest depositional features • Break in bank slope • Change in bank material • Small benches and other inundation features • Staining on rocks • Exposed root hairs

Reach Condition	Process	Effect on bankfull indices
Threshold	Sediment transport capacity of the reach exceeds the sediment supply, but the channel grade is stable.	Bankfull indices may be relics of extreme flood events, and may indicate a bankfull flow that is too high.
Degrading	The sediment transport capacity of the reach exceeds the sediment supply to the reach, and the channel grade is lowering.	The former flood plain is in the process of becoming a terrace. As a result, bankfull indices may indicate a flow that is too high.
Aggrading	The sediment transport capacity of the reach is less than the sediment supply.	The existing flood plain or in channel deposits may indicate a flow that is too low.
Recently experienced a large flow event	Erosion and/or deposition may have occurred on the bed and banks.	Bankfull indices may be missing or may reflect the large flow event.
Channelized	Sediment transport capacity may not be in balance with sediment supply. The channel may be aggrading or degrading. The reach may be functioning as a threshold channel.	Bankfull indices may be relics of previous channel, artifacts of the construction effort, embryonic, or missing altogether.

High discharge

The reaction of a channel to a high discharge can be the impetus for a channel project. An identified high flow event is often used in the specification of a design feature or purpose of a channel project as the reaction of the stream to a recent high event may be the impetus for a project. In addition, the impact of the project on flooding must be evaluated. The choice of a maximum design flow for stability analysis should be based on project objectives and consequences of failure. For example, the 100-year discharge might be used to design bank protection in a densely populated area while a 10-year discharge might be appropriate in a rural stream.

Flow Duration

A flow duration curve represents the percentage of time that a flow level is equaled or exceeded in a stream. This analysis is done in sediment transport assessments, ecological assessments, as well as in assessments of the duration of stress on soil bioengineering banks stabilization techniques.

Seasonal flows

It is often important to determine how the proposed restoration project will perform with low or normal flows. In addition, seasonal flow variations can have critical habitat importance. For example, a project goal may include a minimum flow depth during a critical spawning period for salmonoid species and a lower minimum depth for resident fish species. The same techniques used to develop flow duration curves for sediment analysis can also be used to assess and design for habitat conditions. In many states, the U.S. Geological Survey (USGS) has developed regional regression curves for the critical flow periods. This might be the 10 year-7day low flow. The USGS has also developed this type of flow duration curve for many gaged sites.

Future Flows

Estimates of future flow conditions are often required to properly assess future project performance. In some cases the USGS has developed regional peak flow frequency curves that include a variable that can be used to estimate the impact of future changes in land use. This might be an increase in the percent of impervious area or urban development. For example, typically 10-20% of the average rainfall event is runoff for an undeveloped watershed while 60-70% of the average rainfall event is runoff for a developed watershed. However in many cases there is not a variable in the regional equations and a hydrologic model must to use to determine the change in the peak flow.

Regulatory

Various state and federal agencies may have established minimum flow requirements for the stream for fish habitat. For example; FEMA has established flood lines for the 100 year and 500 years events and has the flow associated with these events. Consultation with the appropriate authorities is needed if there is a possibility of a project impacting this flood level. Also, in many areas, EPA may have established minimum flow requirements. These should be considered when determined the required design flows. While the determination and maintenance of these established flows may be based more on administrative decisions than current hydrologic data and analysis, they can be a critical component of a stream analysis or project design.

Fluvial Geomorphology and Stream Classification

Fluvial geomorphology techniques provide insight relative to general responses of a river system to a variety of conditions. These techniques may be useful in analyzing the stability of the existing stream system and in identifying the source of instabilities. Fluvial geomorphology techniques also provide generalized guidance related to appropriate cross-section geometry, slope and channel planform. Some of the techniques are expressed with classification schemes that can aid in communication as well as stratifying data. It is important to recognize that the science of fluvial geomorphology is primarily based on observation. As a result, predicted trends and changes tend to represent average conditions. Assessment and design for a specific project area requires use of physically based calculations.

Three different stream classifications systems are presented in this document. The Channel Evolution Model is a system based on non-stable processes. The basis is channel response. The Montgomery and Buffington system is based on defining channel processes, The Rosgen system is a classification of the current status of the channel. Each of these classification systems was designed to address a specific set of practical requirements by its developers and as a result, each has specific application areas in which it is strongest and weakest. Keep in mind that no one system works for all situations, and professionals working in the field of stream restoration are well advised to match the appropriate classification system to the problem at hand.

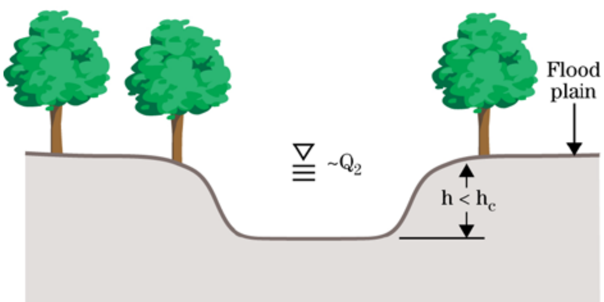
Schumm, Harvey, Watson Classification–Channel Evolution Model(CEM)

The Channel Evolution Model (CEM) was developed to help predict the changes a channel encounters going through the process of headcutting. The CEM is based on geomorphic measurements of a reach of the channel system both upstream and downstream of a headcut. As a result, it is most accurate in its descriptions of what the next stage will be for the disturbed channel. Also, the CEM is most valuable when verified for the watershed of interest. This method provides an indication of reaches that can be worked on with good probability of success.

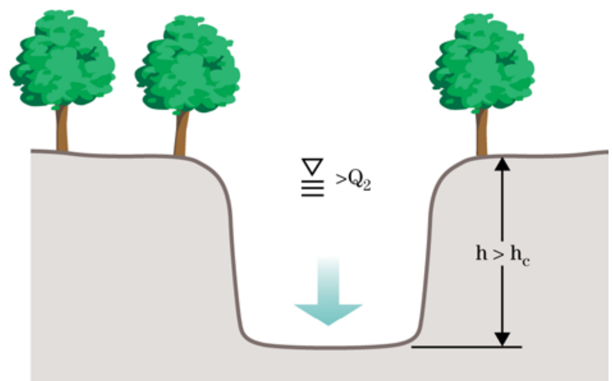
Types in a downstream direction	Sediment Storage	Shape	Location and Stability	Width Depth Ratio (F)
Type I	very little or none	AU≅ shaped	Upstream of active nickpoints, have oversteepened slopes	highly variable (F) 4.0 - 7.0
Type II	variable	Steep vertical channel banks and increased depth	immediately downstream of active nickpoints, degrading	(F) 3.0 - 4.0
Type III	1.5-2.0 ft.	Banks failing	active channel widening and degrading	(F) ˜ 5.0
Type IV	2.5-3.5 ft.	low water sinuous thalweg	reduced rate of active channel widening, aggrading, beginning of	(F) ˜ 6.0

The channel evolution model (CEM) describes a predictable sequence of change in a disturbed channel system. Stage I channels are generally stable and have frequent interaction with their floodplains. Land-use activities that increase runoff, or channelization that reduces the tailwater can result in channel incision processes characteristic of stage II in channel evolution. The height of the banks increases due to down cutting of the channel and the stream and floodplain have less frequent interaction. Bank vegetation becomes stressed and banks are prone to failure. Once failures begin, the channel widening of stage III begins. Channel widening continues until the stream bed is wide enough to disperse stream flows, and slow the water, beginning stage IV in channel evolution. During stage IV, sediments begin to build up in the channel instead of moving downstream, aggrading the bed. Eventually, vegetation begins to establish in the sediment deposited along the edge of the stream, creating channel roughness and further slowing the flow. Stage V begins when the sediments from the slumped banks begin to form new, vegetated flood plains at a lower elevation.

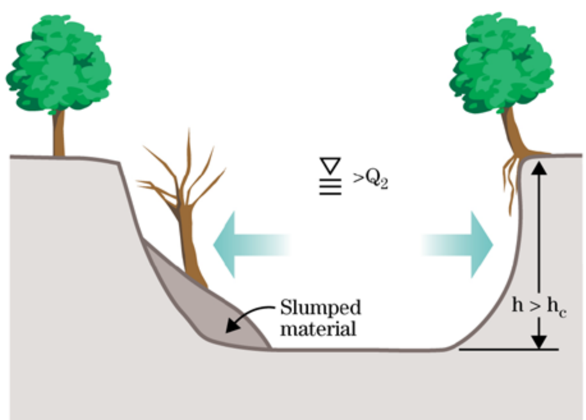
Type I–Stable



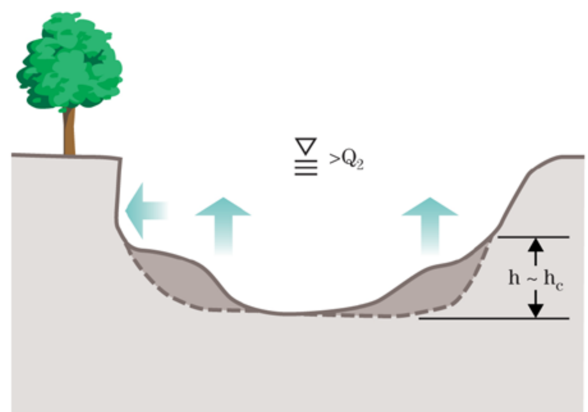
Type II–Incision



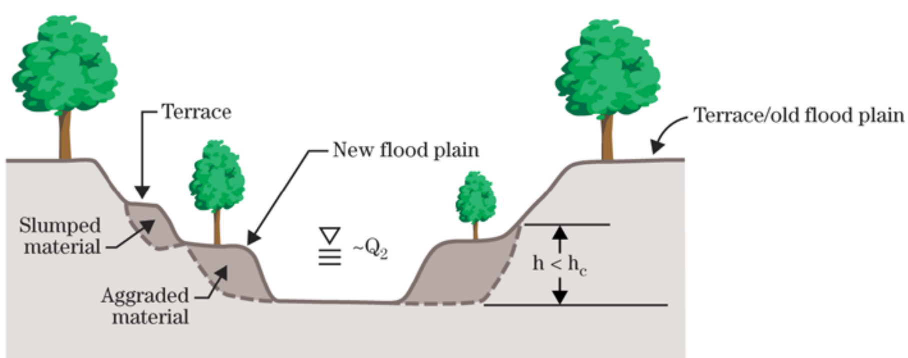
Type III–Widening



Type IV–Depostion/stabilizing

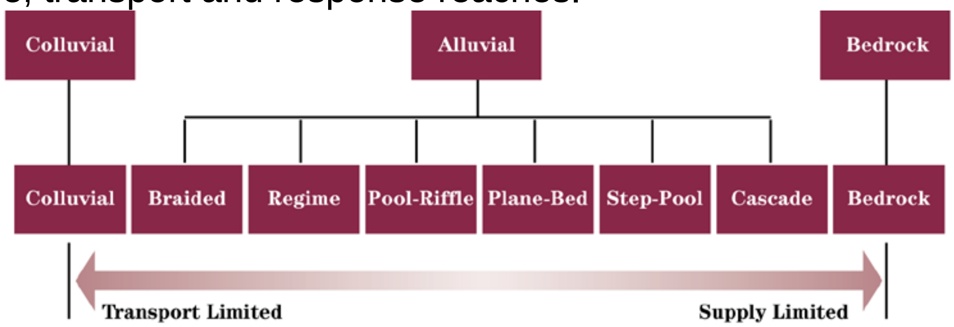


Type V–Quasi-equilibrium stable



Montgomery and Buffington Classification

The Montgomery and Buffington system classifies channel reach morphology for forested mountainous streams. The authors emphasize that there are very distinct differences between mountain channels and their lowland counterparts. Mountainous streams can be categorized into erosion (sediment supply source), transport, and depositional reaches. The classification system aids the user in identifying source, transport and response reaches.

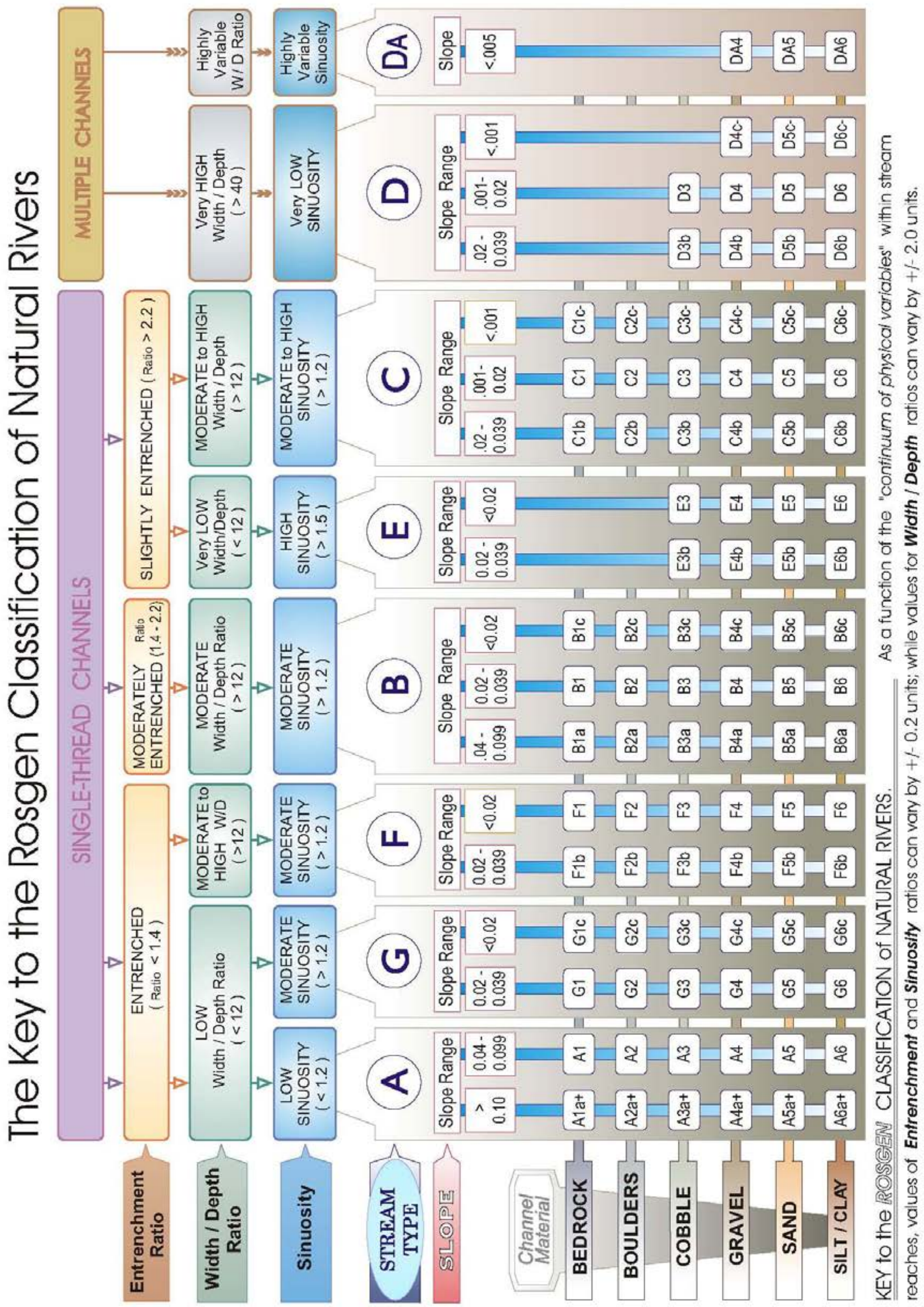


	Braided	Regime	Pool-Riffle	Plane-Bed	Step-Pool	Cascade	Bedrock	Colluvial
Typical Bed Material	Variable	Sand	Gravel	Gravel, cobble	Cobble, boulder	Boulder	N/A	Variable
Bedform Pattern	Laterally oscillary	Multi-layered	Laterally oscillary	None	Vertically oscillary	None	•	Variable
Reach Type	Response	Response	Response	Response	Transport	Transport	Transport	Source
Dominant Roughness Elements	Bedforms (bars, pools)	Sinuosity, bedforms (dunes, ripples, bars) banks	Bedforms (bars, pools), grains, LWD, sinuosity, banks	Grains, banks	Bedforms (steps, pools), grains, LWD, banks	Grains, banks	Boundaries (bed & banks)	Grains, LWD
Dominant Sediment Sources	Fluvial, bank failure, debris flow	Fluvial, bank failure, inactive channel	Fluvial, bank failure, inactive channel, debris flows	Fluvial, bank failure, debris flow	Fluvial, hillslope, debris flow	Fluvial, hillslope, debris flow	Fluvial, hillslope, debris flow	Hillslope, debris flow
Sediment Storage Elements	Overbank, bedforms	Overbank, bedforms, inactive channel	Overbank, bedforms, inactive channel	Overbank, inactive channel	Bedforms	Lee & stoss sides of flow obstructions	•	Bed
Typical Slope (m/m)	$S < 0.03$	$S < 0.001$	$0.001 < S$ and $S < 0.02$	$0.01 < S$ and $S < 0.03$	$0.03 < S$ and $S < 0.08$	$0.08 < S$ and $S < 0.30$	Variable	$S > 0.20$
Typical Confinement	Unconfined	Unconfined	Unconfined	Variable	Confined	Confined	Confined	Confined
Pool Spacing (Channel Widths)	Variable	5 to 7	5 to 7	none	1 to 4	< 1	Variable	Variable

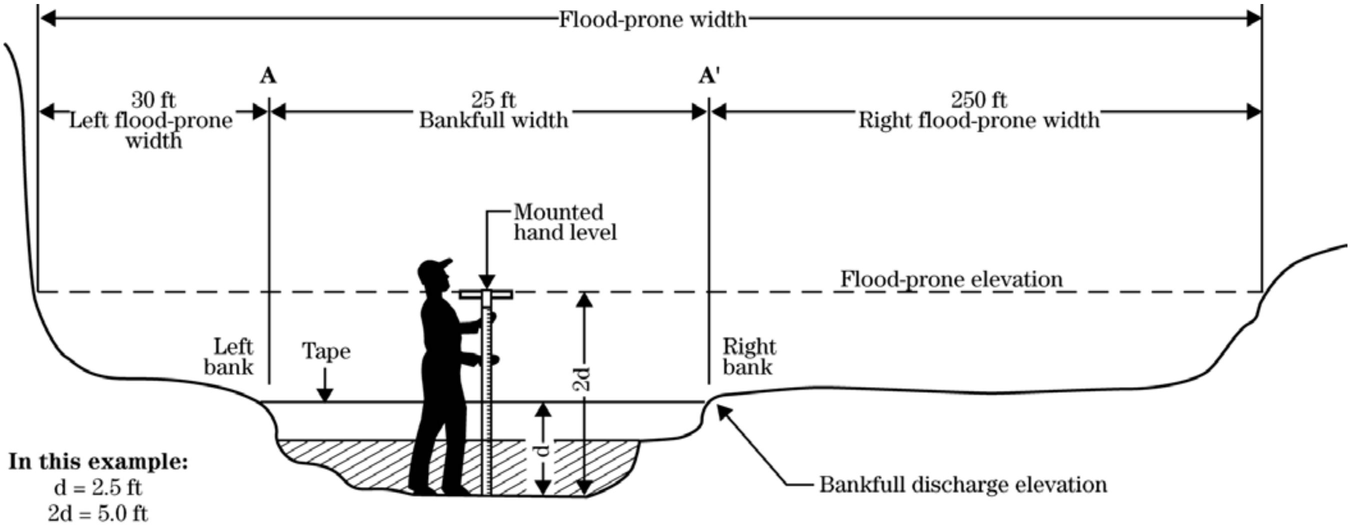
Source: Montgomery and Buffington, 1993.

Rosgen Classification

The Rosgen system relies on field measurements. A restoration practitioner or stream assessment specialist without extensive knowledge of stream hydraulics and fluvial geomorphology can use the field information in a hierarchal format to determine Rosgen classification of the current status of a stream reach.

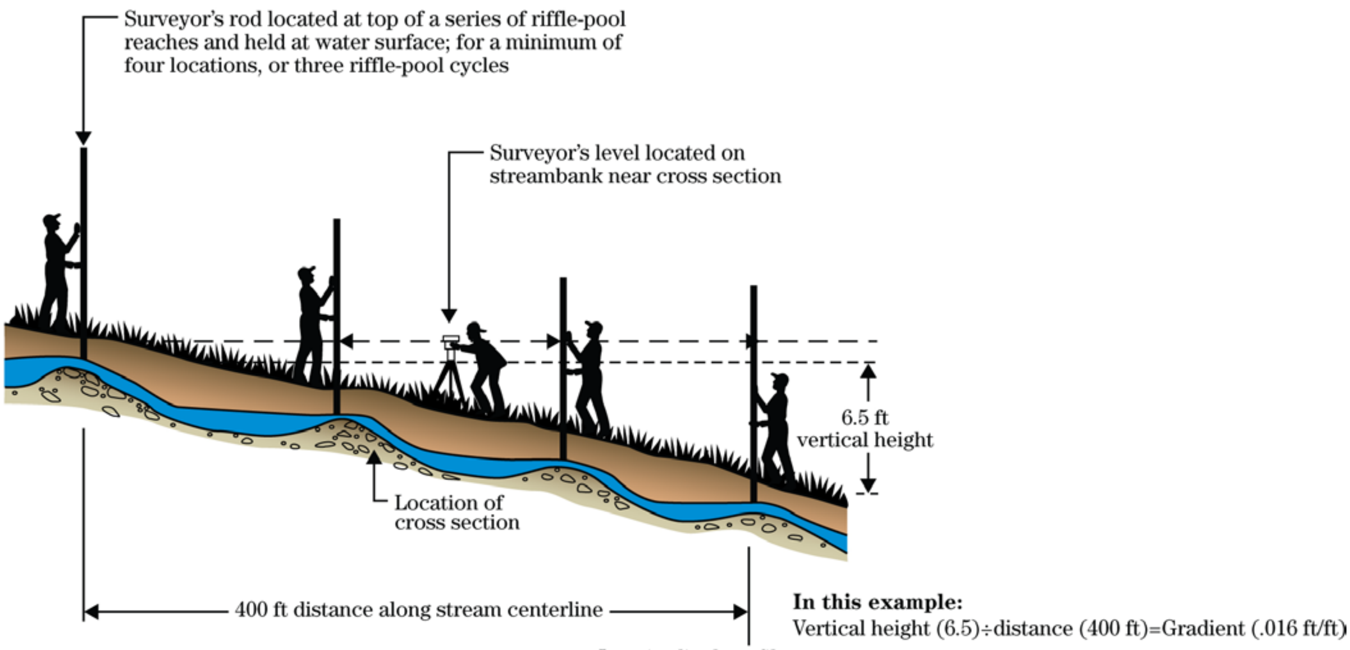


Field measurements used in the Rosgen stream classification system are illustrated in the figures below.



Cross sections

Figures are not to scale



Longitudinal profile

Note: Riffle to riffle gradient approximates the average water surface slope

Field Indicators of River Stability/Instability

Practitioners are often asked to assess the general stability of a stream reach. There are many possible field indicators of stability. A partial list is provided in the table below. Users are cautioned to note that these indicators are not absolutes and that items listed as indicators of instability may occur in stable channels and natural streams. Also, no single indicator should be relied on to define the equilibrium state of a stream.

Evidence of Degradation	• Terraces (abandoned floodplains) • Perched channels or tributaries • Headcuts and knickpoints • Exposed pipe crossings • Suspended culvert outfalls and ditches • Undercut bridge piers • Exposed or "air" tree roots • Leaning trees • Narrow/deep channel • Banks undercut, both sides • Armored bed • Hydrophytic vegetation located high on bank
Evidence of Aggradation	• Buried structures such as culverts and outfalls • Reduced bridge clearance • Presence of midchannel bars • Outlet of tributaries buried in sediment • Sediment deposition in floodplain • Buried vegetation • Perched main channel • Significant backwater in tributaries • Uniform sediment deposition across the channel • Hydrophobic vegetation located low on bank or dead in floodplain • Vegetated bars and banks
Evidence of Stability	• Vegetated bars and banks • Limited bank erosion • Older bridges, culverts and outfalls with bottom elevations at or near grade • Mouth of tributaries at or near existing main stem stream grade • No exposed pipeline crossings

Stream Reach Condition Assessment

Information collected during field reconnaissance may be used to divide stream reaches into sections of similar stability. This may be used to prioritize work or to identify possible reference reach sites. This can involve a great deal of work and care must be taken to assure that observations are consistent between observers.

Observer bias can be reduced with the consistent use of a trained team that agrees on definitions. An example table is provided below.

Condition	Bed	Bank
Stable	The channel bed is as close to a stable condition as can be expected in a natural stream. If the reach exhibits signs of local bed scour or deposition with a low rate of change, it would fall into this category.	The channel banks are as close to a stable condition as can be expected in a natural stream and appear to have a low potential to erode. Banks are predominantly covered with extensive vegetation, boulders, or bedrock formations. If the reach exhibits signs of local bank erosion within an allowable rate of change, it would fall into this category.
Moderately stable	The channel bed in the reach is in a moderately stable condition. However, the reach may be in transition. Reaches where the bed is experiencing bed aggradation or degradation at a low rate of change would fall into this category. In addition, moderate to high local bed scour or deposition would fall into this category. For example, rapid aggradation immediately above and scour immediately below a minor debris blockage (such as a single tree blocking the channel).	The channel banks in the reach are in a moderately stable condition and exhibit medium erodibility. Banks are partially vegetated with moderately erodible soils. Typically, parallel flows would not result in bank erosion. The reach may be in transition. Reaches with banks that exhibit moderate local bank erosion that does not appear to be spreading would fall into this category. For example, in an otherwise stable reach, a single section of the bank could fall into the stream and result in local, moderate bank erosion.
Unstable	The channel bed in the reach is in an unstable condition. Reaches where the bed is undergoing widespread bed aggradation or degradation at a moderate rate would fall into this category. Moderately scoured reaches or reaches where many of the pools are filled with loose sediment would fall into this category.	The channel banks in the reach are predominantly unstable. Reaches where the banks are experiencing widespread erosion at a moderate rate would fall into this category. Reaches where the channel banks are undergoing local bank erosion at a high rate of change and where the erosion is not likely to be self healing would also fall into this category.
Very Unstable	The channel bed in the reach is in a very unstable condition. Typically the channel shows no signs of approaching equilibrium with the current shape and planform. Reaches where the bed is undergoing widespread aggradation or degradation at a high rate would fall into this category. Severely scoured reaches would fall into this category. Reaches where all of the pools are filled with loose sediment would also fall into this category.	The channel banks in the reach exhibit high erodibility and do not have any controls that would restrict extensive changes in planform or shape. Riparian root masses are not present to slow rapid bank retreat. Any parallel or impinging flows would cause extensive bank erosion. Reaches with near vertical to overhanging banks.

Project Selection Guidance

The following tables provide some generalized guidance in the selection of Streambank stabilization and restoration project. These are only generalities and exceptions are certainly to be expected.

Site Description	Tolerance for movement	Type of project
Eroding streambank threatening a home or municipal sewage treatment plant	None – streambank must be made static	Relies primarily on hard or inert structures but may include a vegetative component for adjunctive support, environmental and aesthetic benefits.
Eroding streambank adjacent to a secondary road	Slight – road must be protected for moderate storms, but some movement is allowed	Rely on streambank soil bioengineering measures that incorporate hard or inert components.
Eroding streambank threatening hiking trails in a park	Moderate – a natural system is desired, but movement should be slowed	May rely entirely on vegetative protection, but more likely on streambank soil bioengineering measures that incorporate some hard or inert components.
Eroding streambank in rangeland	Relatively High – but erosion should be reduced	Rely on fencing, plantings or streambank soil bioengineering measures--perhaps ones that incorporate some hard or inert components in areas which have suffered significant damage.
Erosion on a wild and scenic stream system	High – but erosion should be reduced	Do nothing or rely on plantings and vegetative streambank soil bioengineering measures.

Treatment Strategies Based on Stream Classification* for Low Banks (< 8 ft) on Low Gradient Streams in Valley Floor Landscapes			
Schumm CEM	**Rosgen Classification**	**Treatment Strategies**	**Typical Practices**
I Stable	C, E	Maintain existing watershed runoff volumes and patterns and sediment loads. Maintain or improve existing riparian corridor vegetation. May need to implement bank protection/restoration in isolated spots.	Spot treatments with rock, fascines, live stakes, seedlings, rooted stock, or grasses.

II Down- cutting	Gc, F?	Reduce watershed runoff and sediment loads. May need to raise channel bottom to reconnect stream to floodplain and reestablish sinuosity, or may need to establish grade control structurally. May need to reestablish or improve riparian corridor vegetation. .	May need to either fill the down cut channel and create a new one in a different alignment or install grade control; then whatever small scale bank treatments are required.
Early III Widening following down- cutting	F	May need to reduce watershed runoff and sediment loads. May need to create more floodplain (excavation) and shape banks enough to place toe protection. May need to reestablish or improve riparian corridor vegetation.	May require minor grading with permanent toe protection; then whatever soil bioengineering is required.
III Widening w/o down- cutting	C, E[1]	Maintain existing watershed runoff volumes and patterns and sediment loads. Reestablish or improve existing riparian corridor vegetation. Consider physically modifying channel width. May need to shape banks enough to place temporary toe protection. Implement soil bioengineering where needed.	May require minor grading with temporary toe protection; then whatever bank protection/restoration (soil bioengineering) is required.
Late III Widening	F, Bc	Maintain existing watershed runoff and sediment loads. May need to create more floodplain (excavation) and shape banks enough to place toe protection. May need to reestablish or improve riparian corridor vegetation.	Minor grading with permanent toe protection; then whatever bank protection/restoration (soil bioengineering) is required.
Early IV Deposition	F, Bc	Maintain existing watershed runoff and sediment loads. May need to create more floodplain (excavation) and shape banks enough to place toe protection. Improve riparian corridor vegetation. Implement soil bioengineering where needed.	Minor grading with permanent toe protection; then whatever bank protection/restoration (soil bioengineering) is required.
Late IV Deposition	Bc, C, E	Maintain existing watershed runoff and sediment loads. May need to shape some banks enough to place toe protection. Improve riparian corridor vegetation. Implement soil bioengineering where needed.	Minor grading with permanent toe protection; then whatever bank protection/restoration (soil bioengineering) is required.

V Stable	C, E	Maintain existing watershed runoff volumes and patterns and sediment loads. Maintain or improve existing riparian corridor vegetation. May need to implement soil bioengineering in isolated spots.	Spot treatments with rock, fascines, live stakes, seedlings, rooted stock, or grasses.

Treatment Strategies Based on Stream Classification* for High Banks (> or = to 8 ft) on Low Gradient Streams in Valley Floor Landscapes			
Schumm CEM Type	**Rosgen Classification**	**Treatment Strategies**	**Typical Practices**
I Stable	C, E	Maintain existing watershed runoff volumes and patterns and sediment loads. Maintain or improve existing riparian corridor vegetation. May need to implement soil bioengineering in isolated spots.	Spot treatments with rock, fascines, live stakes, seedlings, rooted stock, or grasses.
II Down-cutting	Gc, F?	Reduce watershed runoff and sediment loads. Raise channel bottom to reconnect stream to floodplain and reestablish sinuosity, or establish grade control structurally. May need to reestablish or improve riparian corridor vegetation.	Either fill channel and realign or install grade control; then whatever bank protection/restoration (soil bioengineering) is required.
Early III Widening following down-cutting	F	Reduce watershed runoff and sediment loads. Create more floodplain (excavation) and shape banks to reduce slope failure hazard and place toe protection. May need to reestablish or improve riparian corridor vegetation.	Major grading with permanent toe protection; then whatever bank protection/restoration (soil bioengineering) is required.
III Widening w/o down-cutting	C, E[1]	Maintain existing watershed runoff volumes and patterns and sediment loads. Reestablish or improve existing riparian corridor vegetation. Consider physically modifying channel width. May need to shape banks enough to reduce slope failure hazard and to place temporary toe protection. Implement bank protection/restoration where needed.	May require grading with temporary toe protection; then whatever bank protection/restoration (soil bioengineering) is required.

* Modified from guidance developed by Lyle J. Steffen, Geologist, USDA-NRCS, Lincoln, NE (retired)

Late III Widening	F, Bc	Maintain existing watershed runoff and sediment loads. Create more floodplain (excavation) and shape banks to reduce slope failure hazard and place toe protection. May need to reestablish or improve riparian corridor vegetation.	Major grading with permanent toe protection; then whatever bank protection/restoration (soil bioengineering) is required.
Early IV Deposition	F, Bc	Maintain existing watershed runoff and sediment loads. May need to create more floodplain (excavation) and shape some banks to reduce slope failure hazard and to place toe protection. Improve riparian corridor vegetation. Implement bank protection/restoration where needed.	Minor grading with permanent toe protection; then whatever bank protection/restoration (soil bioengineering) is required.
Late IV Deposition	Bc, C, E	Maintain existing watershed runoff and sediment loads. May need to shape some banks to reduce slope failure hazard and to place toe protection. Improve riparian corridor vegetation. Implement bank protection/restoration where needed.	Minor grading with permanent toe protection; then whatever bank protection/restoration (soil bioengineering) is required.
V Stable	C, E	Maintain existing watershed runoff volumes and patterns and sediment loads. Maintain or improve existing riparian corridor vegetation. May need to implement bank protection/restoration in isolated spots.	Spot treatments with rock, fascines, live stakes, seedlings, rooted stock, or grasses.

[1]"C" or "E" stream types with higher width/depth ratios than the norm, and with accelerated streambank erosion rates, may be in Type II due to loss or deterioration of riparian corridor vegetation.

Hydraulics

The affects of the water current on the stability of any streambank treatment should be considered. This evaluation should include the full range of flow conditions that can be expected during the design life of the project. Two approaches that are commonly used to express the tolerances are allowable velocity and allowable shear stress.

Flow in a natural channel is governed in part by boundary roughness, gradient, channel shape, obstructions and downstream water level. If the project represents a sizable investment, it may be appropriate to use a computer model such as HEC-RAS to assess the hydraulic conditions. However, if a normal depth approximation is applicable, velocity can be estimated with Manning's equation as provided below. It is important to note that this estimate will be an average channel velocity. Velocity along the outer bank curves may be considerably larger.

$$Q = \frac{1.486}{n} AR^{2/3}S^{1/2}$$

$$V = \frac{1.486}{n} R^{2/3}S^{1/2}$$

Where

A = flow area (ft^2)
R = hydraulic radius (Area divided by wetted parameter) (ft)
S = friction slop (approximated as channel profile slope) (decimal value)
n = roughness coefficient

Type of Natural Stream	Manning's n estimates		
	Min	Normal	Max
Clean, straight, no deep pools	0.025	0.030	0.033
Clean, winding, some pools and shoals	0.033	0.040	0.045
Very weedy, deep pools, heavy brush/timber	0.075	0.100	0.150
Mountain Stream, no vegetation in channel, steep banks, stream bed of gravel and cobbles	0.030	0.040	0.050
Mountain Stream, no vegetation in channel, steep banks, stream bed of cobbles and large boulders	0.040	0.050	0.070

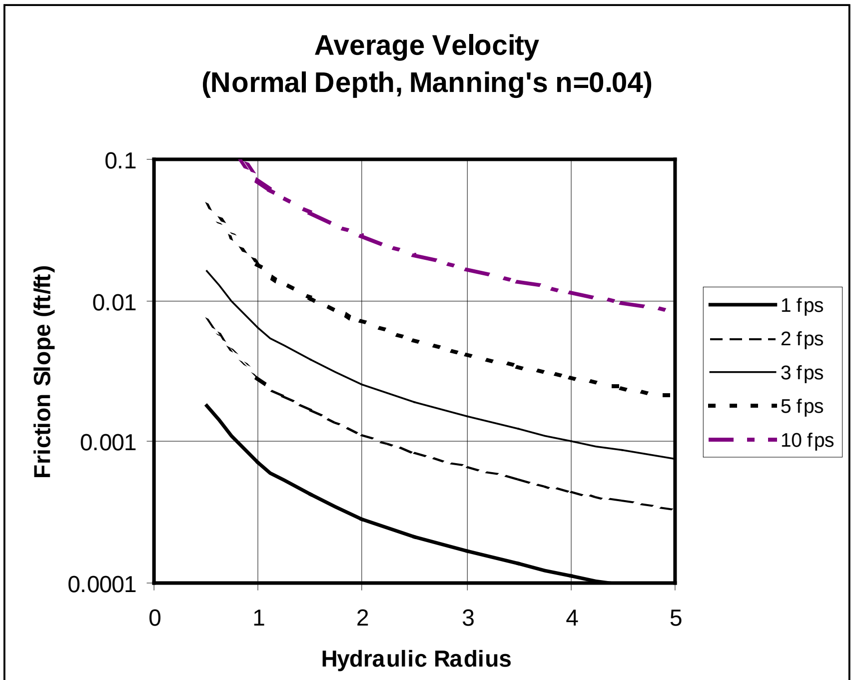
The average shear stress exerted on a channel boundary can be estimated with the equation provided below, assuming the flow is steady, uniform, and two-dimensional.

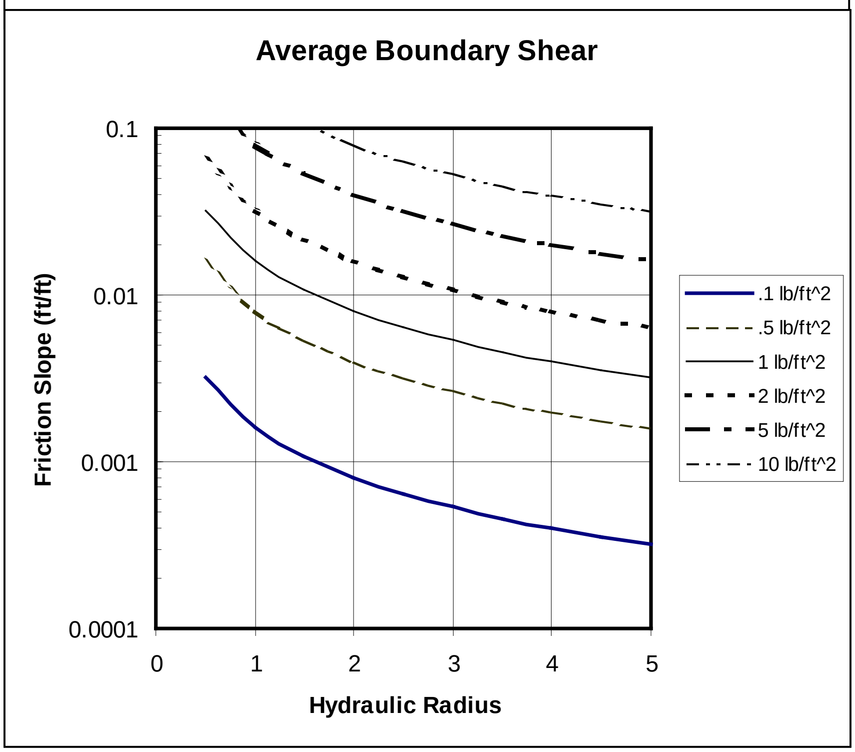
$$\tau_o = \gamma RS$$

Where

τ_0 = total bed shear stress, lbs/ft^2 or N/m^2
γ = specific weight of water, lbs/ft^3 or N/m^3

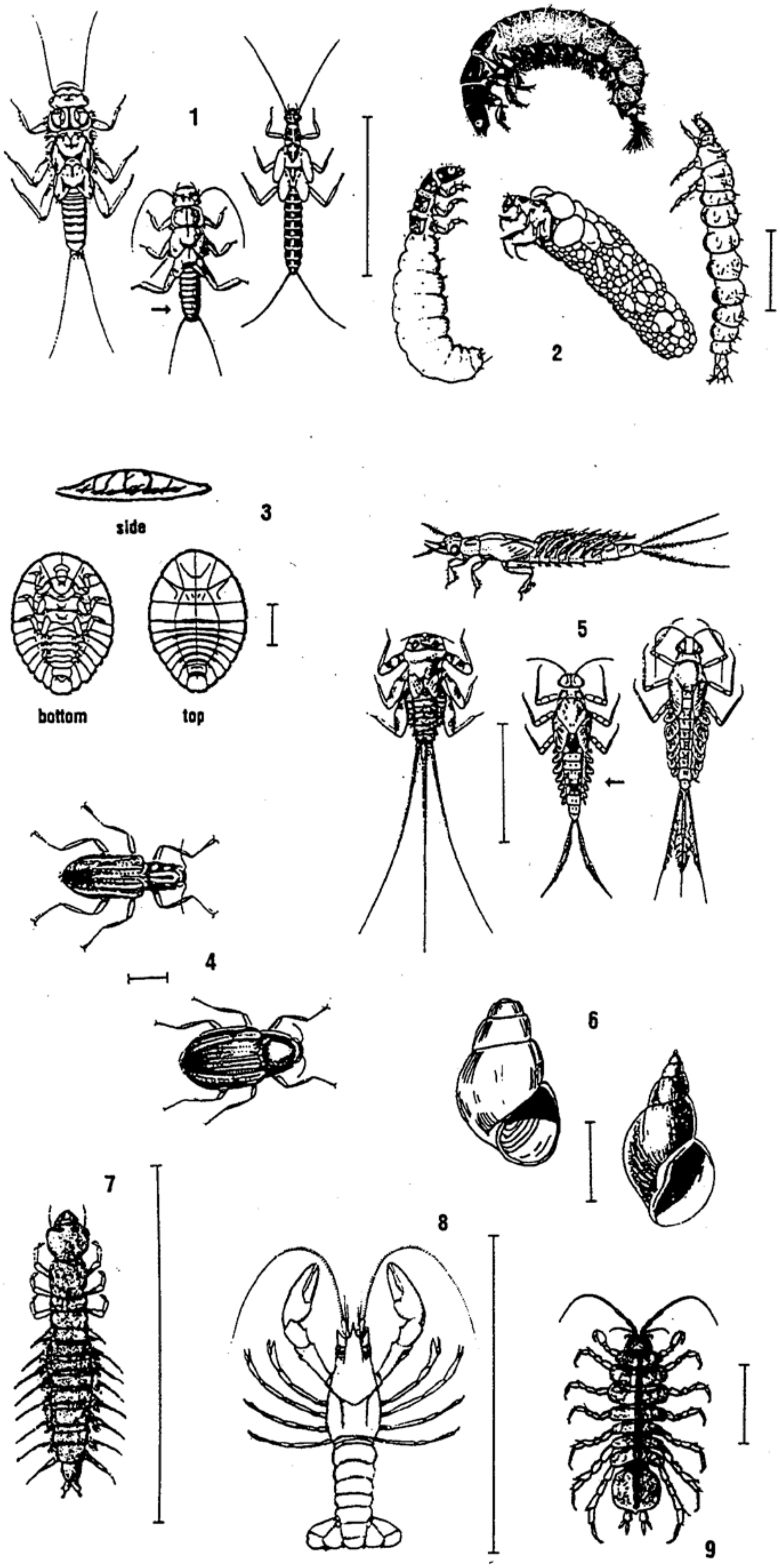
In wide channels, where the width is more than 10 times the depth, *R* is generally taken to be equal to the depth. It should be noted that this equation is an approximation and does not account for such things as flow non uniformity, form drag on banks, and bed forms. Spatial and temporal variation may also result in the final value being larger as well.





Stream Invertebrates

Aquatic invertebrates are important to aquatic food webs. The presence of pollution sensitive species indicates healthy, resilient stream conditions. The following figures illustrate each of the three groups of macroinvertebrates along with the listing of invertebrate taxonomic order. Group I is sensitive to pollution and do not tolerate polluted water. Group II macroinvertebrates are facultative, meaning they can tolerate limited pollution. The dominant presence of Group III macroinvertebrates without the presence of Group I, suggests the water is significantly polluted.



Bar lines indicate relative size

Stream Invertebrates

Group One Taxa: Pollution-sensitive organisms found in good quality water.

1. Stonefly Order Plecoptera. 1/2" to 1 1/2", 6 legs with hooked antenna, 2 hair-line tails. Smooth (no gills) on lower half of body (see arrow).

2 Caddisfly: Order Trichoptera. Up to 1", 6 hooked legs on upper third of body, 2 hooks at back end. May be in a stick, rock, or leaf case with its head sticking out. May have fluffy gill tufts on under- side.

3 Water Penny: Order Coleoptera. 1/4", flat saucer-shaped body with a raised bump on one side and 6 tiny legs and fluffy gills on the other side. Immature beetle.

4 Riffle Beetle: Order Coleoptera. 1/4", oval body covered with tiny hairs, 6 legs, antennae. Walks slowly underwater. Does not swim on surface.

5 Mayfly: Order Ephemeroptera. 1/4" to 1", brown, moving, plate-like or feathery gills on the sides of lower body (see arrow), 6 large hooked legs, antennae, 2 or 3 long hair-like tails. Tails may be webbed together.

6 Gilled Snail: Class Gastropoda. Shell opening covered by thin plate called operculum. When opening is facing you, shell usually opens on right.

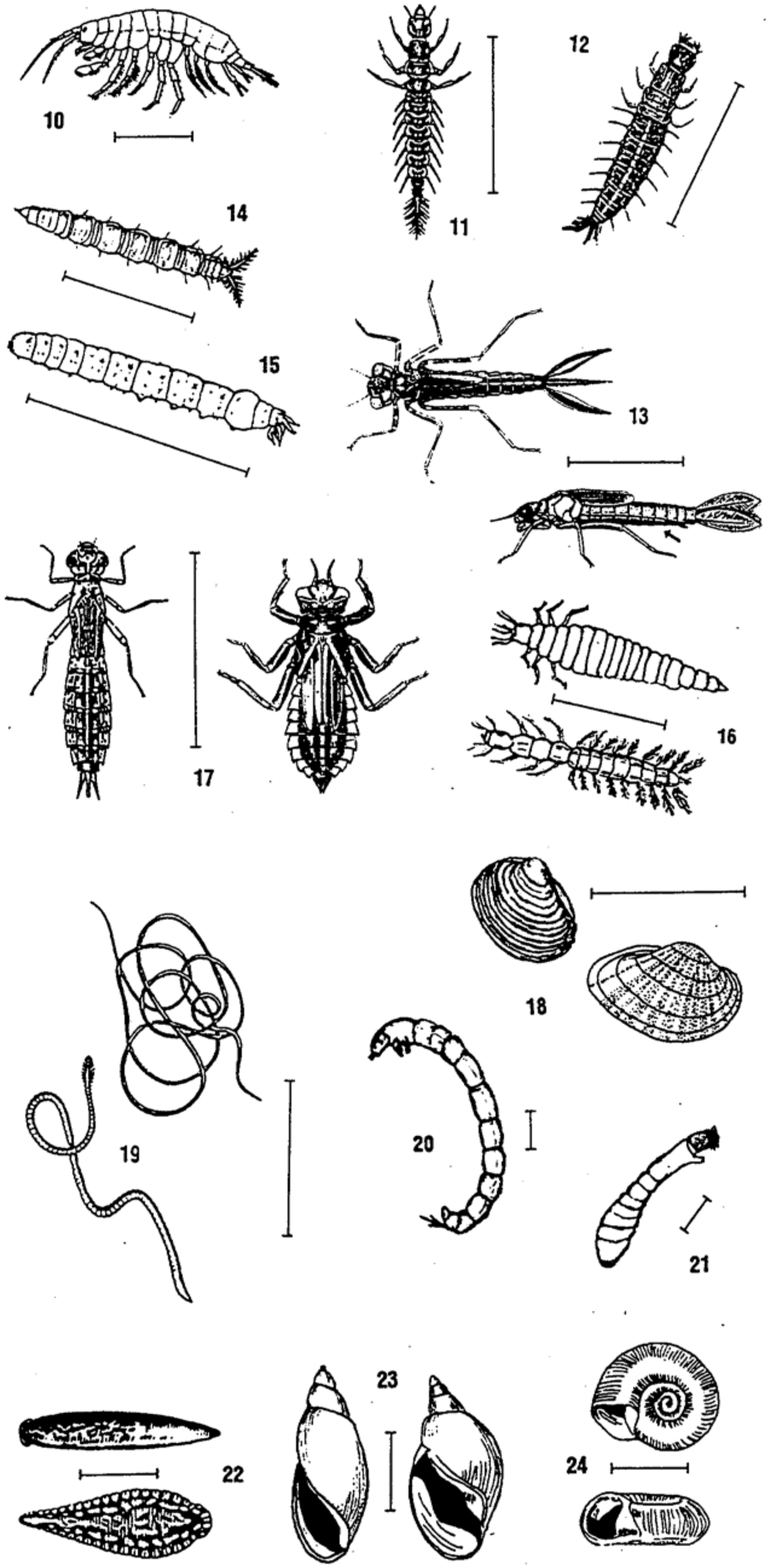
7 Dobsonfly (hellgrammite): Family Corydalidae. 3/4" to 4", dark-colored, 6 legs, large pinching jaws, eight pairs feelers on lower half of body with paired cotton-like gill tufts along underside, short antennae, 2 tails, and 2 pairs of hooks at back end.

Group Two Taxa: Somewhat pollution tolerant organisms can be in good or fair quality water.

8 Crayfish: Order Decapoda. Up to 6", 1 large claws, 8 legs, resembles small lobster.

9 Sowbug: Order Isopoda. 1/4" to 3/4", gray oblong body wider than it is high, more than 6 legs, long antennae.

Source: Izaak Walton League of America, 707 Conservation Lane, Gaithersburg, MD 20878-2983. (800) BUG-



Bar lines indicate relative size

Group Two Taxa:Continued: Somewhat pollution-tolerant organisms can be in good or fair quality water.

10. Scud: Order Amphipoda. 1/4", white to gray, body higher than it is wide, swims sideways, more than 6 legs, resembles small shrimp.

11. Alderfly Larva: Family Sialedae. 1" long. Looks like small Hellgramite but has long, thin, branched tail at back end (no hooks). No gill tufts underneath.

12 Fishfly Larva: Family Cordalidae. Up to 1 1/2" long. Looks like small hellgramite, but often a lighter reddish- tan color, or with yellowish streaks. No gill tufts underneath.

13. Damselfly: Suborder Zygoptera. 1/2" to 1", large eyes, 6 thin hooked legs, 3 broad oar-shaped tails, positioned like a tripod. Smooth (no gills) on sides of lower half of body. (See arrow.)

14. Watersnipe Fly Larva: Family Athericidae (Atherix). 1/4" to 1", pale to green, tapered body, many caterpillar- like legs, conical head, feathery "horns" at back end.

15. Crane Fly: Suborder Nematocera. 1/3" to 2", milky, green, or light brown, plump caterpillar-like segmented body, 4 finger-like lobes at back end.

16. Beetle Larva: Order Coleoptera. 1/4" to 1", light-colored, 6 legs on upper half of body, feelers, antennae.

17. Dragon Fly: Suborder Anisoptera., 1/2" to 2", large eyes, 6 hooked legs. Wide oval to round abdomen.

18. Clam: Class Bivalvia.

Group Three Taxa: Pollution-tolerant organisms can be in any quality of water.

19. Aquatic Worm: Class Oligochaeta, 1/4" to 2", can be very tiny, thin worm-like body.

20. Midge Fly Larva: Suborder Nemato-cera. Up to 1/4", dark head, worm-like segmented body, 2 tiny legs on each side.

21. Blackfly Larva: Family Simulidae. Up to 1/4", one end of body wider. Black head, suction pad on other end.

22. Leech: Order Hirudinea. 1/4" to 2", brown, slimy body, ends with suction pads.

23. Pouch Snail and Pond Snails: Class Gastropoda. No operculum. Breath air. When opening is facing you, shell usually open to left.

24. Other Snails: Class Gastropoda. No operculum. Breaths air. Snail shell coils in one plane.

Soil Classification

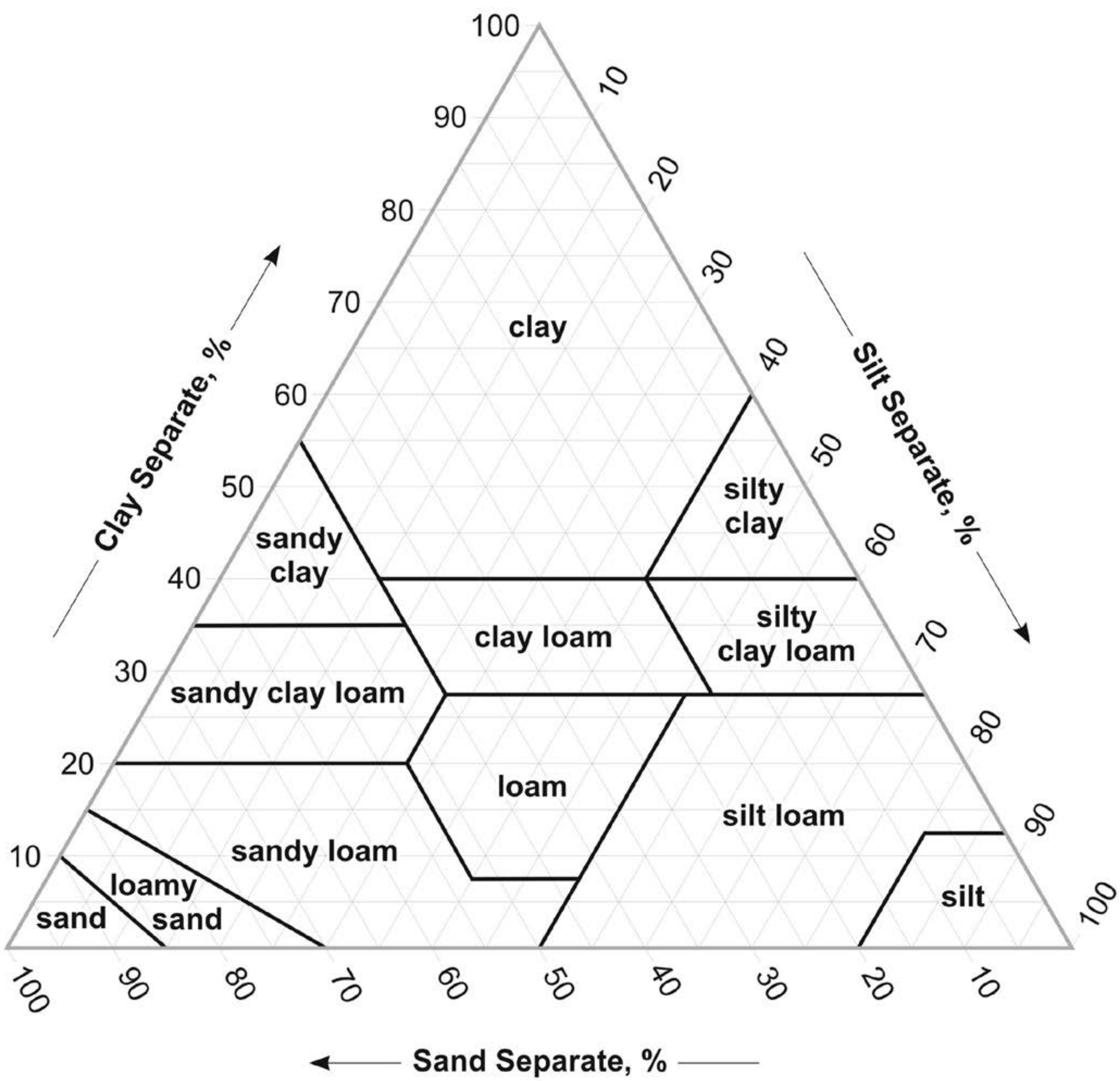
The consistent and accurate assessment of soil types is important for a variety of assessment and restoration projects. The charts and tables blow provide guidance for field personnel involved in projects.

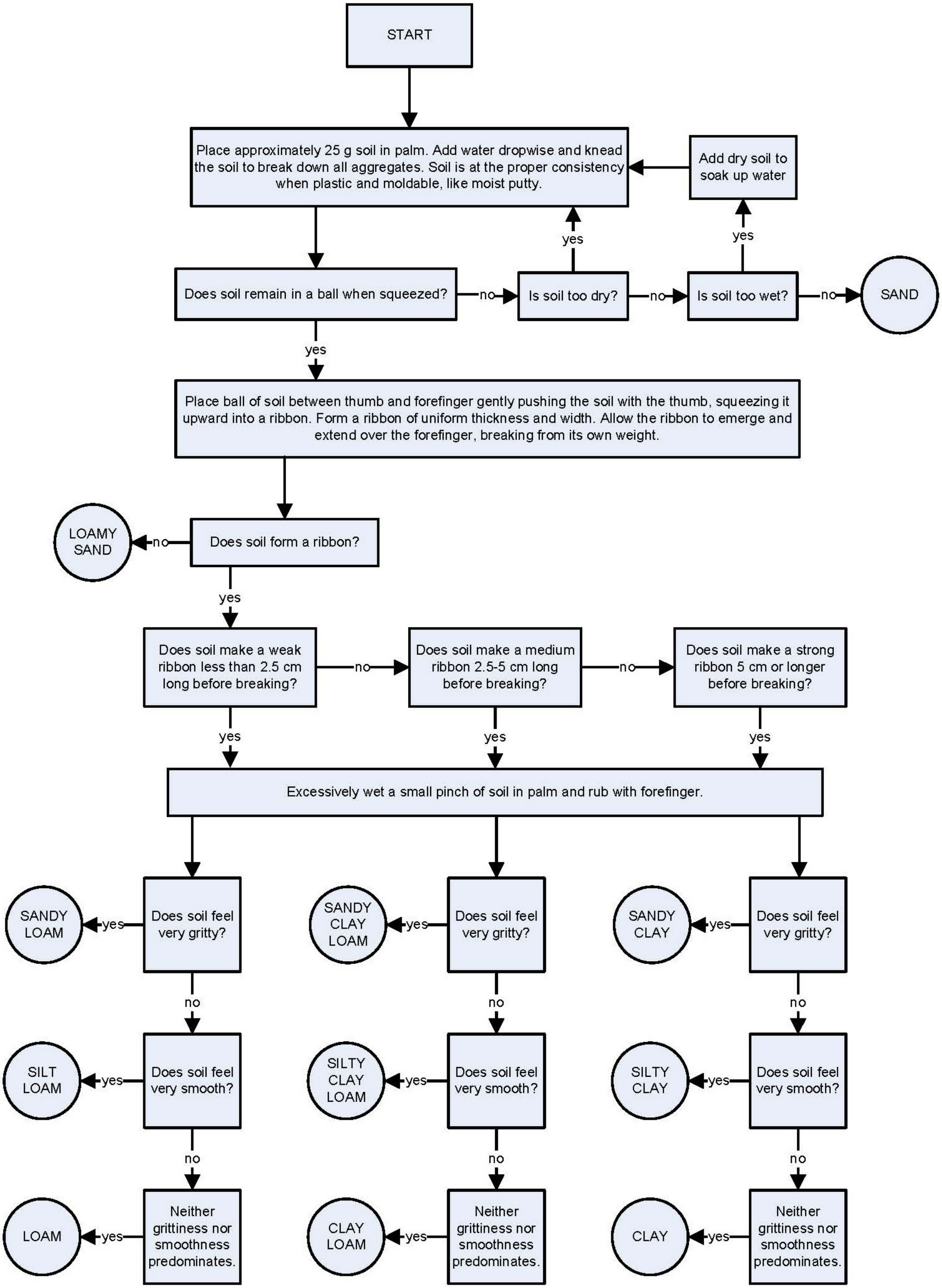
Soil Type	**Description**
CL, CH	Low to high plasticity, generally high clay content, high dry strength, shrink-swell may be a problem depending on clay type. These materials generally provide good to high resistance to erosion.
MH	High plasticity silts, moderate dry strength. These materials generally have fair to good erosion resistance
ML	Low plasticity to non plastic silts. Low dry strength. These materials generally have poor erosion resistance
SC, GC	Grain to grain contact as well as plastic fines add cohesion, which results in these materials having fair to good resistance to erosion.
SM, GM	Low plasticity to nonplastic fines in combination with sand and/or gravel. Low wet and dry strength. Since grain to grain contact is important in coarser soil materials for erosion resistance, these materials generally have poor to fair erosion resistance.
SP, SW	Non plastic poorly to well graded clean sands. May act as a single grain if cemented by a cementing agent (iron oxide, calcium carbonate, or silica). These materials generally have poor erosion resistance if uncemented.
GP, GW	Non plastic poorly to well graded clean gravels. May act as a single grain if cemented by a cementing agent (iron oxide, calcium carbonate, or silica). These materials generally have poor erosion resistance if rounded. Erosion resistance is better if angular.

Description of Coarse-Grain Soil Density	Evaluation/Description
Very Loose	A ½” rod can be pushed easily by hand into soil
Loose	Soil can be excavated with a spade. A 2” square wooden peg can easily be driven to a depth of 6”.
Medium Dense	Soil is easily penetrated with a ½” rod driven with a 5 pound hammer.
Dense	Soil requires a pick for excavation. A 2” square wooden peg is hard to drive to a depth of 6”.
Very Dense	Soil is penetrated only a few centimeters with a ½” rod driven with a 5 pound hammer.

Description of Fine-Grain Soil Consistency	Evaluation/Description
Very Soft	Thumb will penetrate greater than 1-inch. Soil is extruded between fingers.
Soft	Thumb will penetrate about 1-inch. Soil molded by light finger pressure.
Medium	Thumb will penetrate about ¼ -inch. Soil molded by strong finger pressure.
Stiff	Indented with thumb
Very Stiff	Indented by thumb nail.
Hard	Thumbnail will not indent.

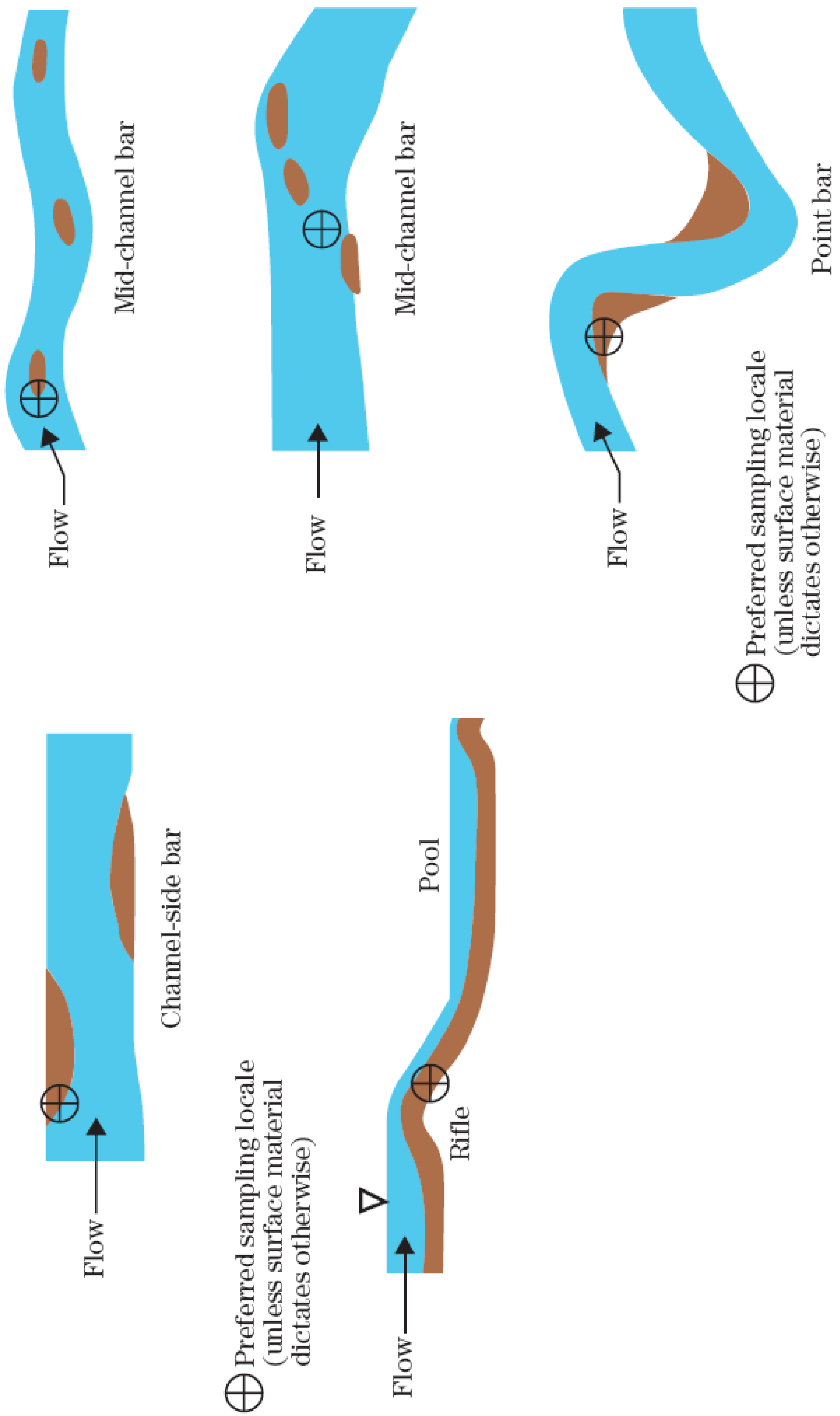
Soil Textural Triangle




START
Place approximately 25 g soil in palm. Add water dropwise and knead the soil to break down all aggregates. Soil is at the proper consistency when plastic and moldable, like moist putty.
Add dry soil to soak up water
yes
yes
Does soil remain in a ball when squeezed?
no
Is soil too dry?
no
Is soil too wet?
no
SAND
yes
Place ball of soil between thumb and forefinger gently pushing the soil with the thumb, squeezing it upward into a ribbon. Form a ribbon of uniform thickness and width. Allow the ribbon to emerge and extend over the forefinger, breaking from its own weight.
LOAMY SAND
no
Does soil form a ribbon?
yes
Does soil make a weak ribbon less than 2.5 cm long before breaking?
no
Does soil make a medium ribbon 2.5-5 cm long before breaking?
no
Does soil make a strong ribbon 5 cm or longer before breaking?
yes
yes
yes
Excessively wet a small pinch of soil in palm and rub with forefinger.
SANDY LOAM
yes
Does soil feel very gritty?
SANDY CLAY LOAM
yes
Does soil feel very gritty?
SANDY CLAY
yes
Does soil feel very gritty?
no
no
no
SILT LOAM
yes
Does soil feel very smooth?
SILTY CLAY LOAM
yes
Does soil feel very smooth?
SILTY CLAY
yes
Does soil feel very smooth?
no
no
no
LOAM
yes
Neither grittiness nor smoothness predominates.
CLAY LOAM
yes
Neither grittiness nor smoothness predominates.
CLAY
yes
Neither grittiness nor smoothness predominates.

Stream Bed Material Sampling

The characteristics of a given stream are linked to the composition of the material that comprises its channel bed, bank, and sediment flow. Knowledge of streambed material is necessary for a variety of engineering and environmental purposes. Sufficient sampling of the streambed should be conducted to determine the spatial variability, size, and gradation of the bed material. Sampling locations must be representative of the hydraulic and sedimentation processes that occur in that reach of the river.



The location of the bed sample should be chosen with the target analysis in mind. The table below provides guidance for where a bed-material sample might be taken as a function of the type of geomorphologic or engineering analysis to be conducted.

Purpose of Analysis	Sample location
To estimate the maximum permissible velocity in a threshold stream	Riffle
To estimate the minimum permissible velocity in a threshold stream	Areas of local deposition
To estimate sediment yield for an alluvial stream	Crossing or middle bar
To quantify general physical habitat substrate condition	Bars, riffles, and pools

It is often necessary to group sediments into different size classes or grades. Many such classifications are available in the engineering and geologic literature. One is provided below:

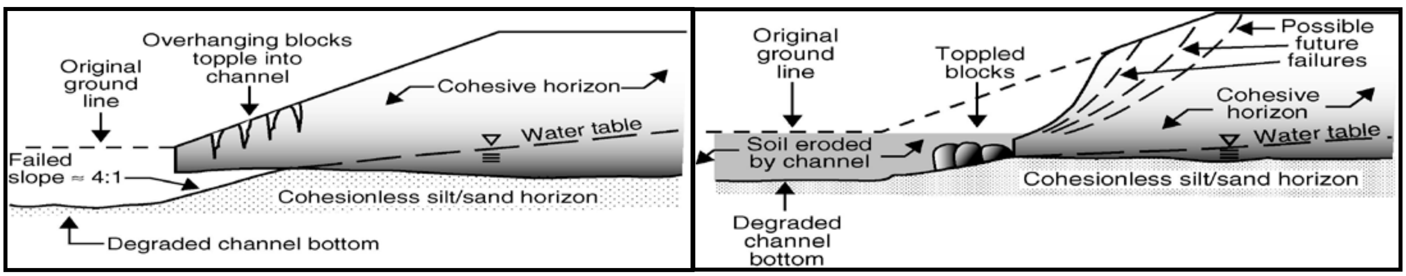
Class Name*	Size Range (mm)	Size Range (in)
Very large boulders	4096 – 2048	160 – 80
Large boulders	2048 – 1024	80 - 40
Medium boulders	1024 – 512	40 - 20
Small boulders	512 – 256	20 - 10
Large cobbles	256 – 128	10 – 5.0
Small cobbles	128 – 64	5.0 - 2.5
Very coarse gravel	64 – 32	2.5 – 1.3
Coarse gravel	32 – 16	1.3 - 0.6
Medium gravel	16 - 8.0	0.6 - 0.3
Fine gravel	8.0 - 4.0	0.3 - 0.16
Very fine gravel	4.0 – 2.0	0.16 - 0.08
Very coarse sand	2.0 – 1.0	
Coarse sand	1.0 – 0.5	
Medium sand	0.5 – 0.25	
Fine sand	0.25 – 0.125	
Very fine sand	0.125 – 0.062	
Coarse Silt	0.062 – 0.031	
Very fine to medium silt	0.031 – 0.004	
Very fine to coarse clay	0.004 – 0.00024	

Abbreviated from ASCE Engineering Practice No. 54

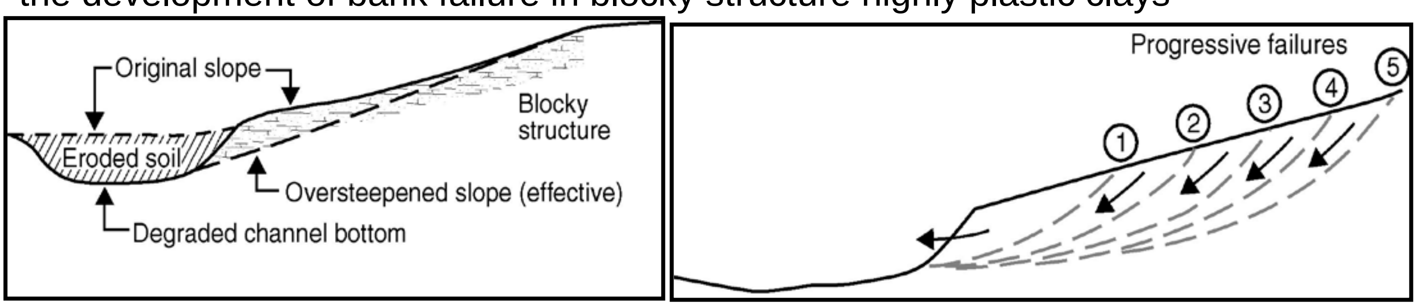
Soil Mechanics Considerations

The banks of stream channels can fail when conditions change that affect the stability of the slope. The toe of the slope may be eroded by stream flow. This removal of soil at the toe of the slope reduces the gravity forces resisting failure and may cause the safety factor of the slope to reduce to less than 1.0. Slope failures will occur at this point. This type of change in the geometry of the slope is probably responsible for more slope failures in stream banks than any other single cause. Many channel stability problems result from a combination and interaction of a number of different causes. These causes can include not only issues related to fluvial erosive forces, but also seepage problems as well as properties of the soil. Three common geotechnical stability problems are briefly outlined below.

Piping/Sapping of Channel Banks: May occur where silts and sands are layered between lower permeability clays. Water flowing from the bank can detach the cohesionless soil particles and carry them out of the channel bank leaving a void that may be pipe or shelf shaped. The overlying soils then fail by toppling into the channel. The slope failure that results is called an *infinite slope failure*. Streambank soil bioengineering measures alone are generally ineffective in preventing a piping/sapping failure from occurring. However, streambank soil bioengineering may be effective in stabilizing the upper and lower banks after a suitable filter layer or drain is installed and after the bank has been graded to a stable slope. The figure below shows the development of piping/sapping bank failure



Shallow Slope Failure in Block Structure and Highly Plastic Clays: The blocky structure in these types of materials generally results from alternating wetting and drying cycles. The soil structure is further weakened when water enters these cracks and lubricates them. Bank failures are generally arc shaped and occur in successive incidences of slope movement. The slides are generally no more than 3 to 4 feet deep. The ultimate stable slope can be in the range of 4H:1V to 7H:1V. Solutions to a stability problem of this nature may involve replacing the highly plastic soil, soil reinforcement, and shaping the bank. Streambank soil bioengineering alone is of limited benefit. The figure below shows the development of bank failure in blocky structure highly plastic clays



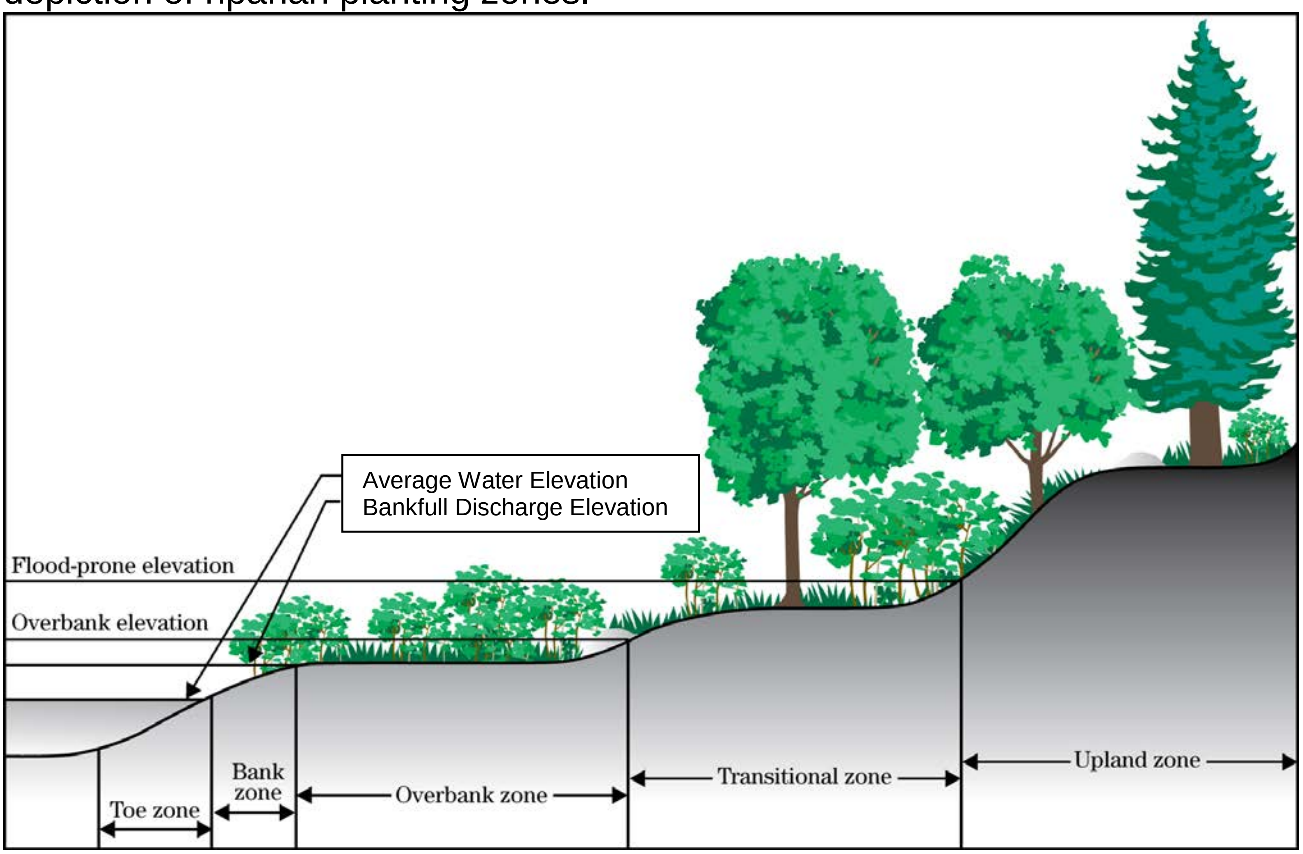
Dispersive Clays: These materials have a different chemical composition than typical clays, which causes them to break down in the presence of water. The erosion patterns are often described as jug shaped. A useful field test for identifying dispersive clays is the crumb test where a small clump of the soil is placed in a glass of distilled water and observed. A rapid formation of a cloud around the soil indicates that it is dispersive. Streambank soil bioengineering alone is generally not effective on sites that are experiencing failures due to dispersive clays. Solutions may involve covering the clays with a protective blanket or chemically altering the soils with lime, fly ash, and gypsum.

Streambank Soil Bioengineering

Streambank soil bioengineering is defined as the use of living and non-living plant materials in combination with natural and synthetic support materials for slope stabilization, erosion reduction, and vegetative establishment. The treatments that fall under this broad definition generally include the use of living, riparian plants as part of the design. These stream bank treatments that are generally viewed as being more ecologically beneficial than traditional stabilization approaches.

Riparian Planting Zones

The success of a stream bank soil bioengineering project is dependent upon the establishment of riparian plant species. The success of the plants is, in turn, dependent upon their location relative to the stream. Therefore, it is important to note the location and types of existing vegetation in and adjacent to the project area. The elevation and lateral relationships to the stream can be described in terms of *riparian planting zones*. Proposed streambank soil bioengineering techniques should be assessed and designed in terms of the location of the plants relative to the stream and water table. The figure below illustrates an idealized depiction of riparian planting zones.



Some of these zones identified in the above figure may be absent in some stream systems. Sections that have “missing” zones will be especially prevalent in streams in the American southwest, as well as areas that have been impacted by development. Before working on a streambank stabilization project, local experts should be consulted to determine which zones are present. A brief description of each zone is provided below:

Toe Zone: This zone is located below the average water elevation or baseflow. The cross-sectional area at this discharge often defines the limiting biologic condition for aquatic organisms. Typically, this is the zone of highest stress. It is vitally important to the success of any stabilization project that the toe is stabilized. Due to long inundation periods, this zone will rarely have any woody vegetation in it. Some small streams will have woody vegetation in this zone. Often riprap or another type of inert protection is required to stabilize this zone.

Bank Zone: The bank zone is located between the average water elevation and the bankfull discharge elevation. While it is generally in a less erosive environment than the toe zone, it is potentially exposed to wet and dry cycles, ice scour, debris deposition, and freeze–thaw cycles. The bank zone is generally vegetated with early colonizing herbaceous species and flexible stemmed woody willow, dogwood, elderberry and low shrubs. Sediment transport typically becomes an issue for flows in this zone, especially for alluvial channels.

Bankfull Channel Elevation*:* Bankfull stage is typically defined at a point where the width-to-depth ratio is at a minimum. Practitioners use other consistent morphological indices to aid in its identification. Often, the flow at the bankfull stage has a recurrence interval of 1.5 years. Due to the high velocities and frequent inundation, streambank soil bioengineering projects frequently incorporate hard structural elements, such as rock, below this elevation.

Bankfull flow is often considered to be synonymous with channel-forming discharge in stable channels, and is used in some channel classification systems, as well as for an initial determination of main channel dimensions, plan and profile. In many situations, the channel velocity begins to approach a maximum at bankfull stage. In some cases, on wide, flat floodplains, it has been observed that the channel velocity can drop as the stream overtops its bank, and the flow spills onto the floodplain. In this situation, it may be appropriate to use the bankfull hydraulic conditions to assess stability and to select and design streambank protection. However, when the floodplain is narrower or obstructed, channel velocities may continue to increase with rising stage. As a result, it may also be appropriate to use a discharge greater than bankfull discharge to select and design streambank protection treatments.

Overbank Zone: This zone is located above the bankfull discharge elevation. This typically flat zone may be formed from sediment deposition. It is sporadically flooded, usually about every 2 to 5 years. Vegetation found in this zone is generally flood-tolerant and may have a high percentage of hydrophytic plants. Shrubby willow with flexible stems, dogwoods, alder, birch and others may be found in this zone. Larger willows, cottonwoods and other trees may be found in the upper end of this zone.

Transitional Zone: The transitional zone is located between the overbank elevation and the flood-prone elevation. This zone may only be inundated every 50 years. Therefore, it is not exposed to high velocities except during high water events. Larger upland species predominate in this zone. Since it is infrequently flooded, the plants in this zone need not be especially flood-tolerant.

Upland Zone: This zone is found above the flood-prone elevation. Erosion in this zone is typically due to overland water flow, wind erosion, improper farming practices, logging, development, overgrazing and urbanization. Under natural conditions the upland zone is typically vegetated with upland species.

Stream Velocity and the Selection of Streambank Soil Bioengineering Treatments

The effects of the water current on the stability of any streambank protection treatment must be considered. This evaluation includes the full range of flow conditions that can be expected during the design life of the project. Recommendations for limiting velocity and shear vary widely but some are provided in the table below. Judgment and experience should be weighed with the use of this information. The recommendations must be scrutinized and modified according to site-specific conditions such as duration of flow, soils, temperature, debris and ice load in the stream, plant species, as well as channel shape, slope and planform.

Practice	**Permissible shear stress (lb/ft^2)***	**Permissible velocity (ft/s)***
Live poles (Depends on the length of the poles and nature of the soil)	Initial: 0.5 to 2 Established: 2 to 5+	Initial: 1 to 2.5 Established: 3 to 10
Live poles in woven coir TRM (Depends on installation and anchoring of coir)	Initial: 2 to 2.5 Established: 3 to 5+	Initial: 3 to 5 Established: 3 to 10
Live poles in riprap (joint planting) (Depends on riprap stability)	Initial: 3+ Established: 6 to 8+	Initial: 5 to 10+ Established: 12+
Live brush sills with rock (Depends on riprap stability)	Initial: 3+ Established: 6+	Initial: 5 to 10+ Established: 12+
Brush mattress (Depends on soil conditions and anchoring)	Initial: 0.4 to 4.2 Established: 2.8 to 8+	Initial: 3 to 4 Established: 10+
Live fascine (Very dependent on anchoring)	Initial: 1.2 to 3.1 Established: 1.4 to 3+	Initial: 5 to 8 Established: 8 to 10+
Brush layer/branch packing (Depends on soil conditions)	Initial: 0.2 to 1 Established: 2.9 to 6+	Initial: 2 to 4 Established: 10+
Live cribwall (Depends on nature of the fill (rock or earth), compaction and anchoring)	Initial: 2 to 4+ Established: 5 to 6+	Initial: 3 to 6 Established: 10 to 12
Vegetated reinforced soil slopes (VRSS) (Depends on soil conditions and anchoring)	Initial: 3 to 5 Established: 7+	Initial: 4 to 9 Established: 10+
Grass turf—bermudagrass, excellent stand (Depends on vegetation type and condition)	Established: 3.2	Established: 3 to 8
Live brush wattle fence (Depends on soil conditions and depth of stakes)	Initial: 0.2 to 2 Established: 1.0 to 5+	Initial: 1 to 2.5 Established: 3 to 10
Vertical bundles (Depends on bank conditions, anchoring, and vegetation)	Initial: 1.2 to 3 Established: 1.4 to 3+	Initial: 5 to 8 Established: 6 to 10+

Plant Species Used in Streambank Soil Bioengineering

Adventitiously rooting woody riparian plant species are typically used in streambank soil bioengineering treatments because they have root primordia or root buds along the entire stem. When the stems are placed in contact with soil, they sprout roots. When the stem is in contact with the air, they sprout stems and leaves. This ability to root, independent of the orientation of a stem, is a reproductive strategy of riparian plants that has developed over time in response to flooding, high stream velocities, and streambank erosion. The keystone species that meet these criteria are willows, shrub dogwoods, and cottonwoods. The traits of these species allow their use in treatments such as fascines, brush mattress, brush layer, and pole cuttings. Typically, the most consistently successful rooting plants are the willow. However, there are many others that are used as well.

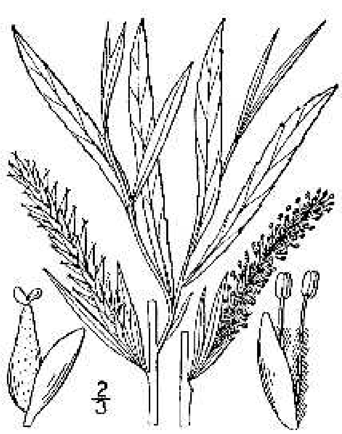

Coyote Willow

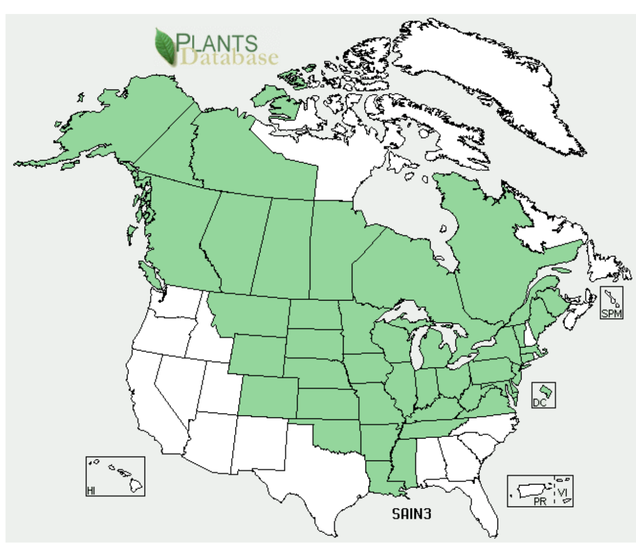

Peachtree Willow


Narrowleaf Cottonwood

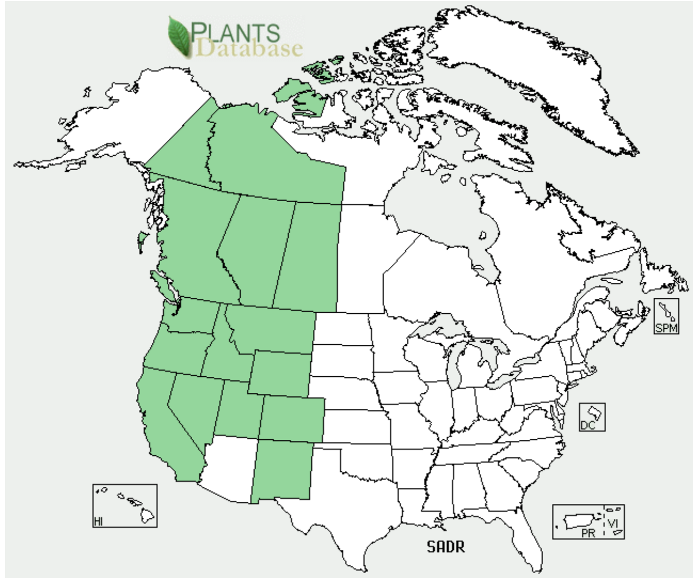

Redosier Dogwood

The figures below are from the USDA NRCS Plants Data base at http://plants.usda.gov/ and are in no order of preference. This list is neither inclusive nor exhaustive. This list is provided to show the breadth and variety of species that can be used for streambank soil bioengineering. The suitability of the species listed will vary considerably by location and treatment type. It is strongly recommended that practitioners consult local expertise and guidelines when selecting the appropriate plant material.



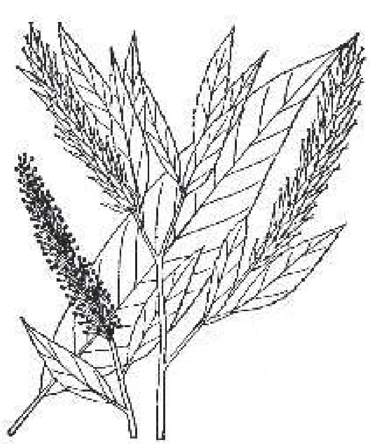


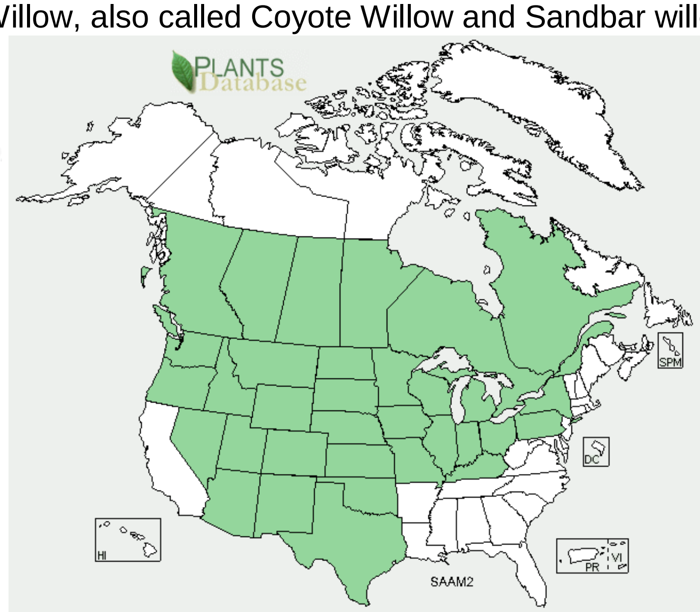
*Salix interior (*Sandbar willow): Tree/Shrub



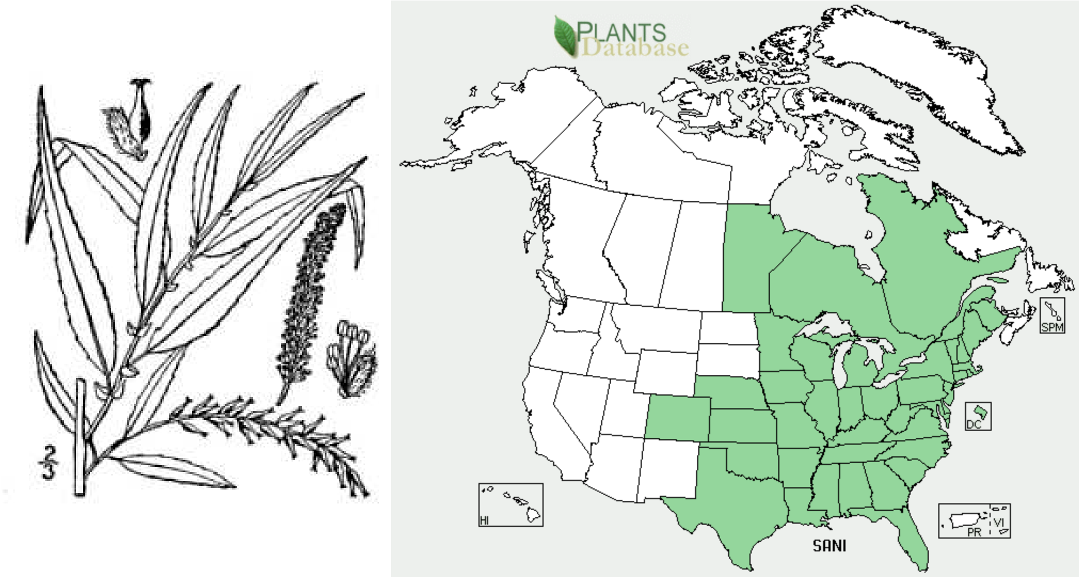
Salix drummondiana (Drummond's willow): Shrub

Salix exigua (Narrowleaf Willow, also called Coyote Willow and Sandbar willow): Tree/Shrub

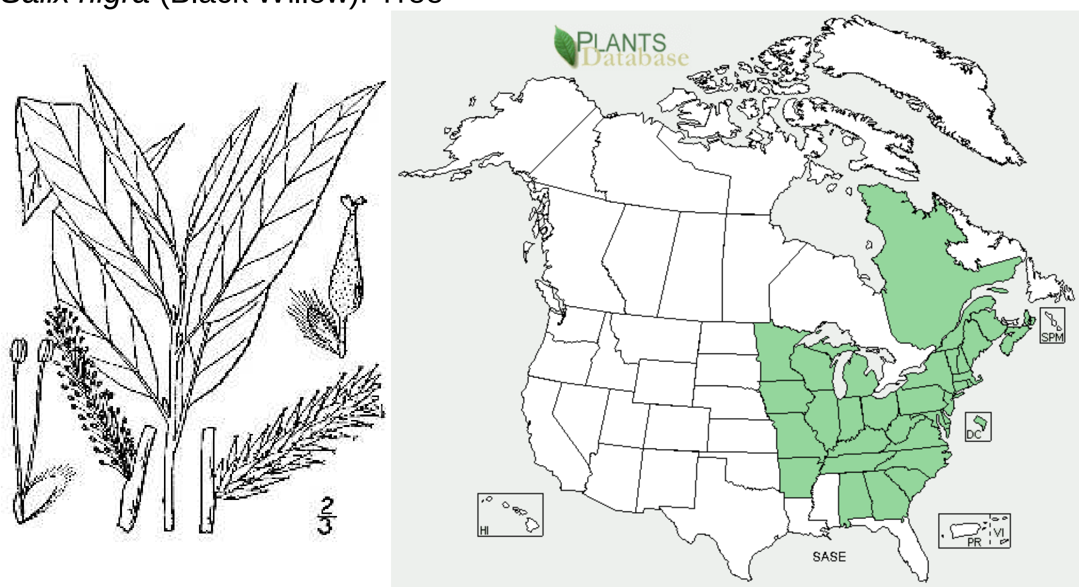




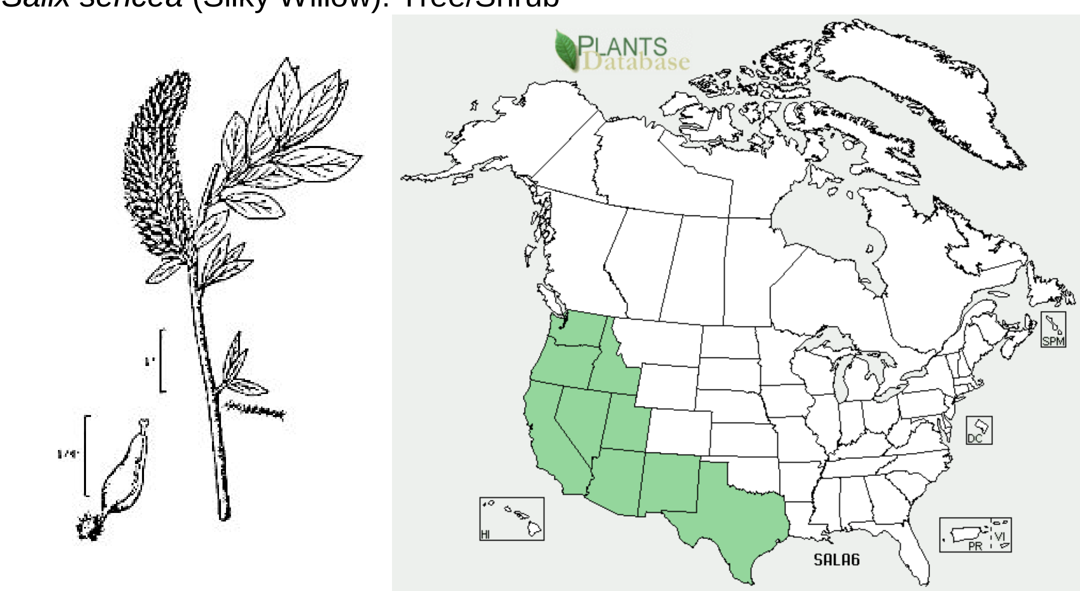
*Salix amygdaloides (*Peachleaf Willow) Tree/Shrub



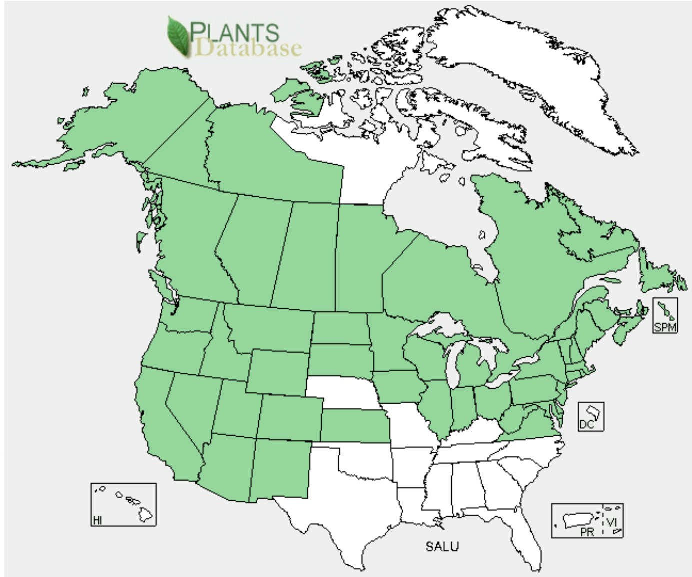
Salix nigra (Black Willow): Tree



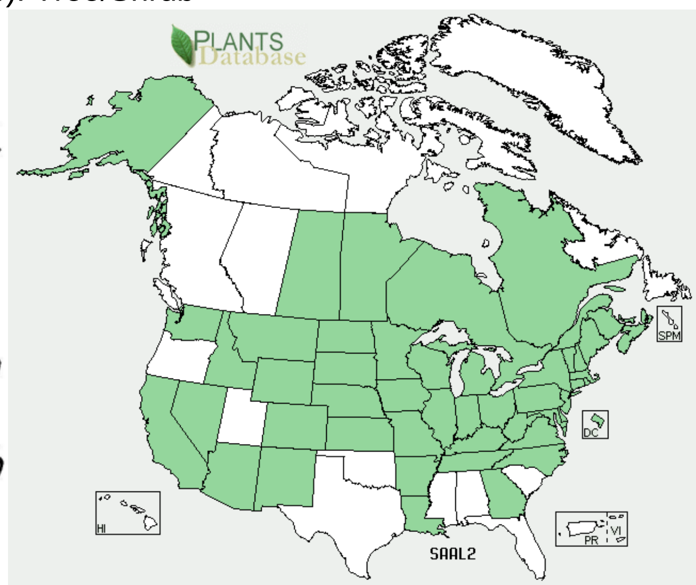
Salix sericea (Silky Willow): Tree/Shrub



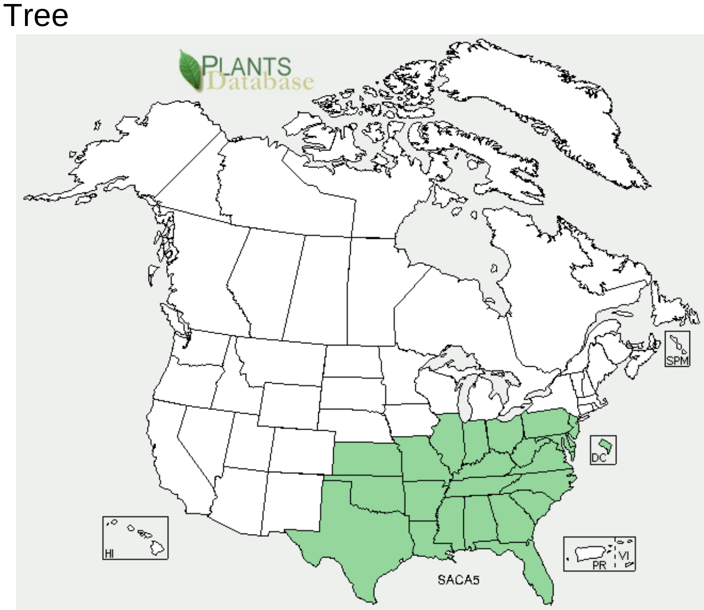
Salix lasiolepis (Arroyo Willow): Tree/Shrub



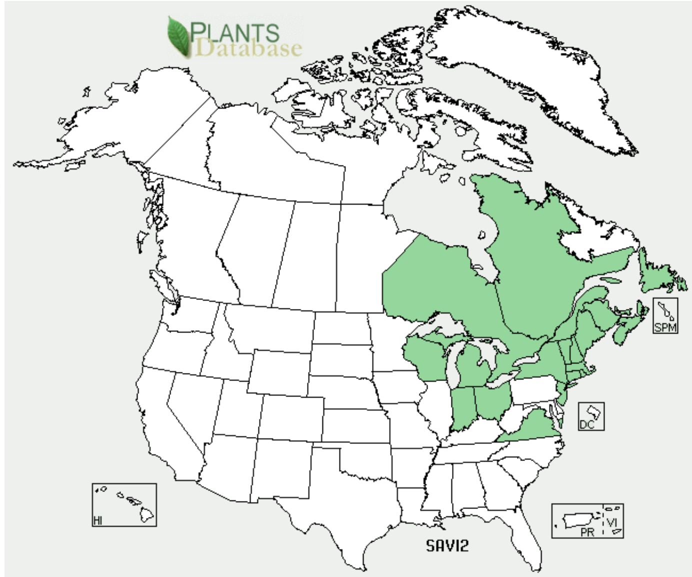
Salix lucida (Shining willow): Tree/Shrub



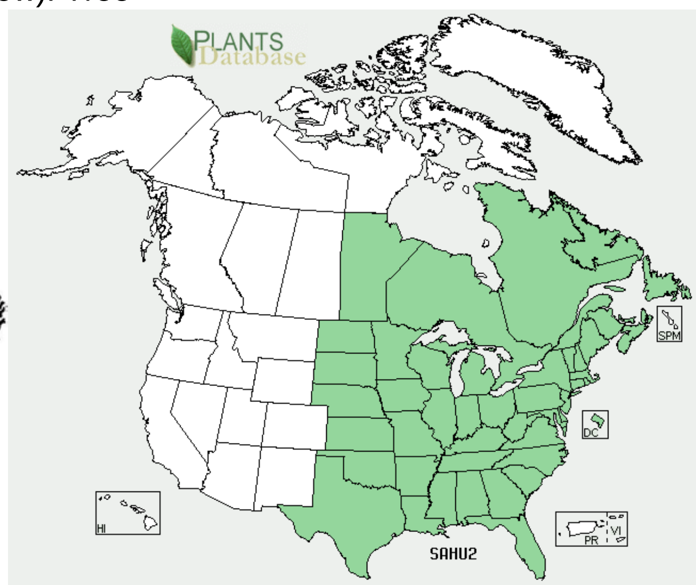
Salix alba (White willow): Tree



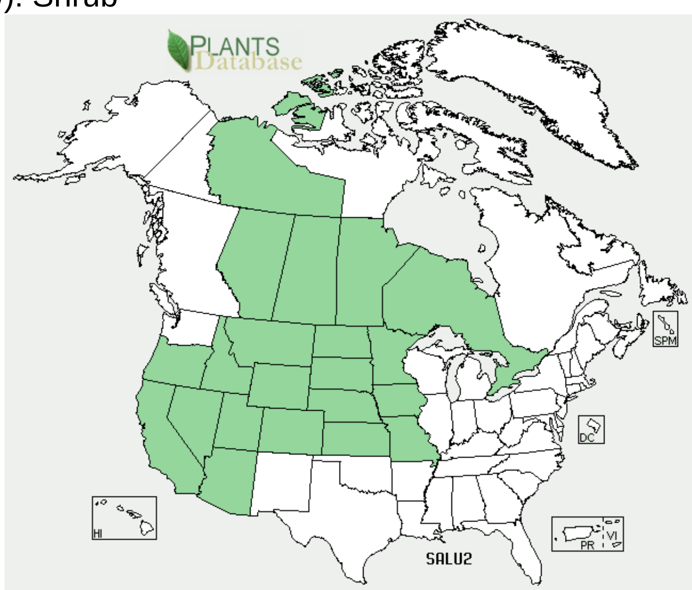
Salix caroliniana (Coastal plain willow): Tree



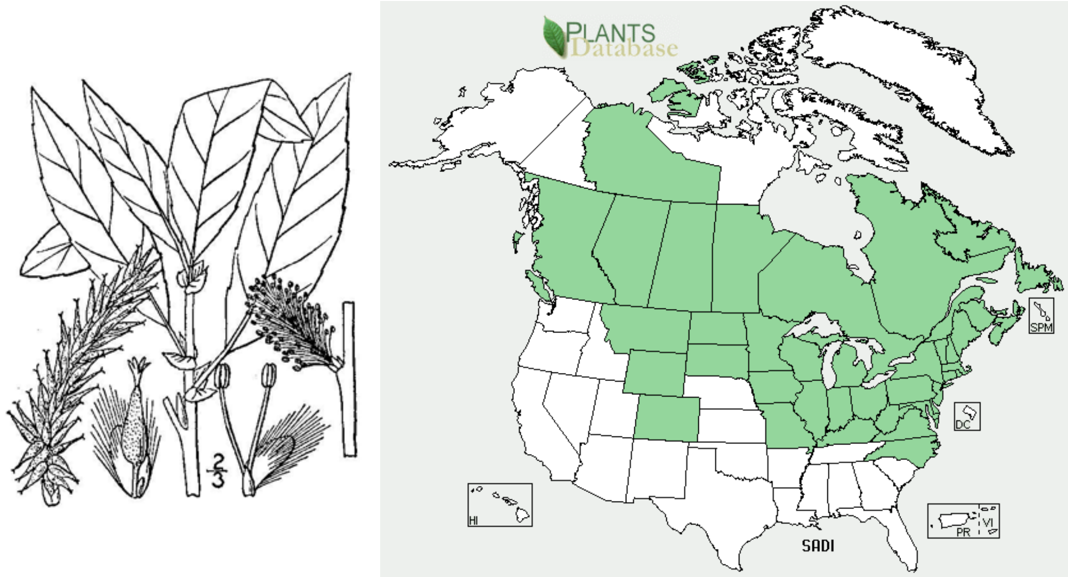
Salix viminalis (Basket willow): Tree



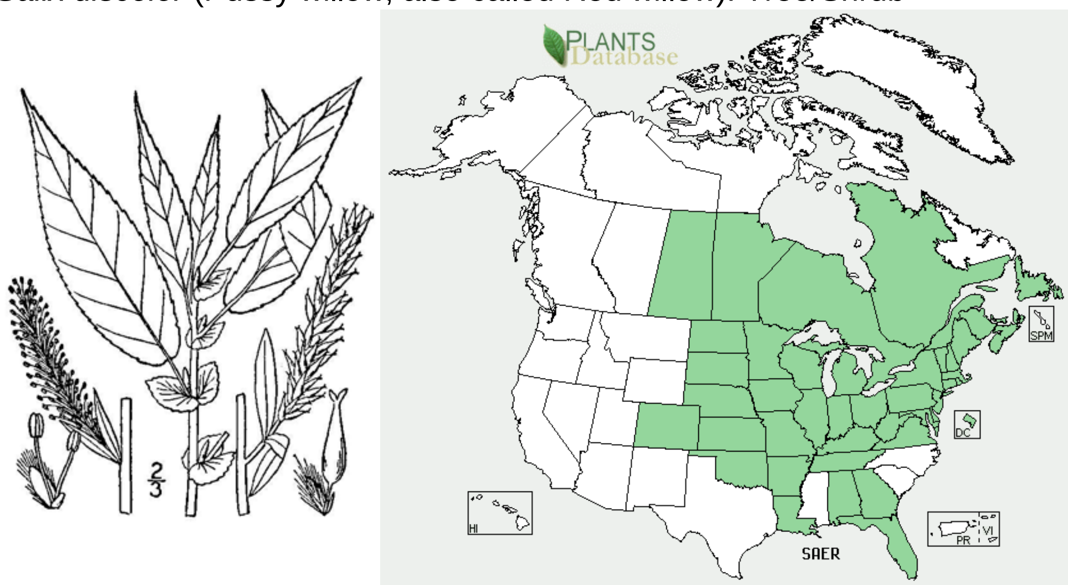
Salix humilis (Prairie willow): Shrub



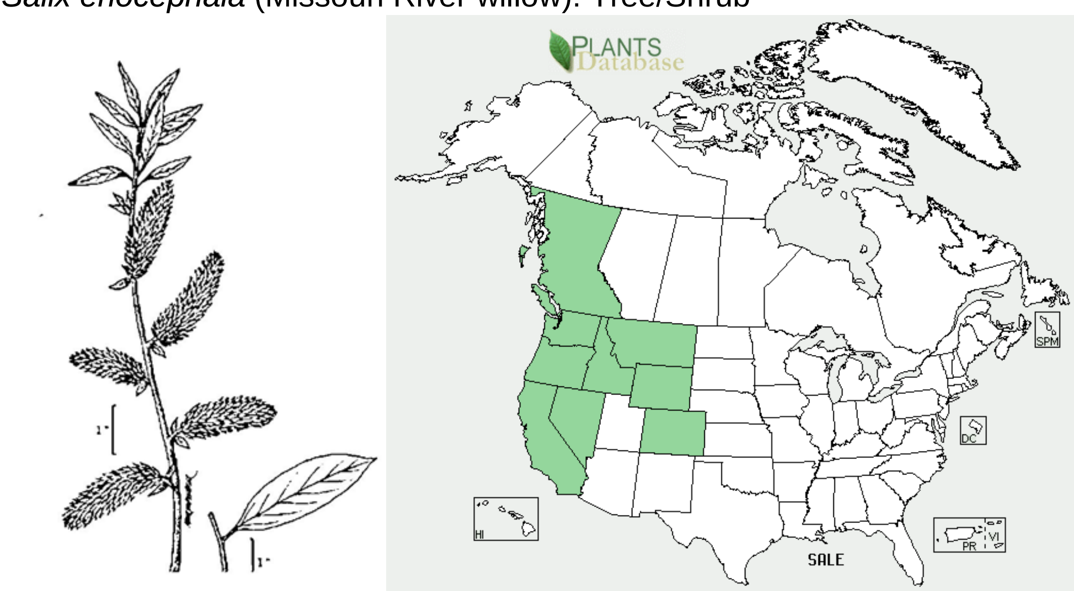
Salix lutea (Yellow willow): Tree/Shrub



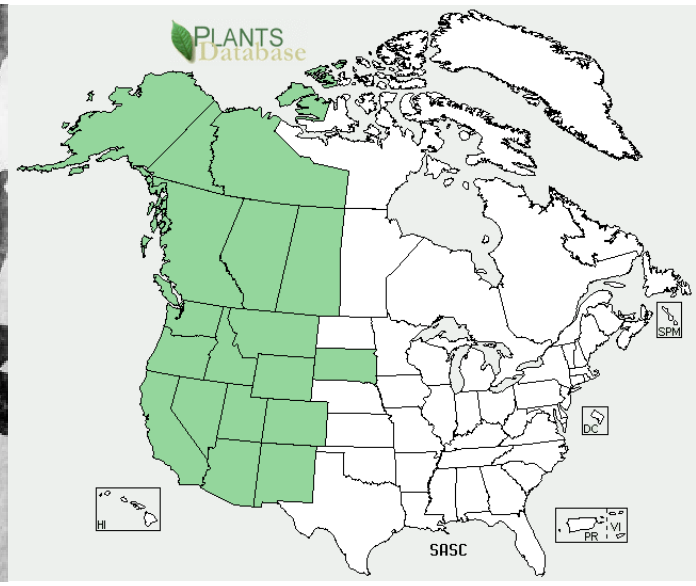
Salix discolor (Pussy willow, also called Red willow): Tree/Shrub



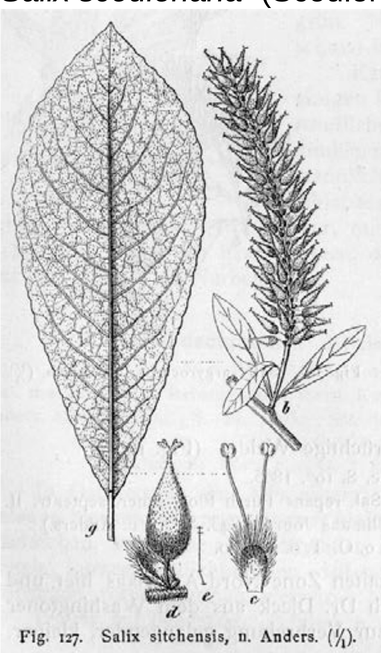
Salix eriocephala (Missouri River willow): Tree/Shrub

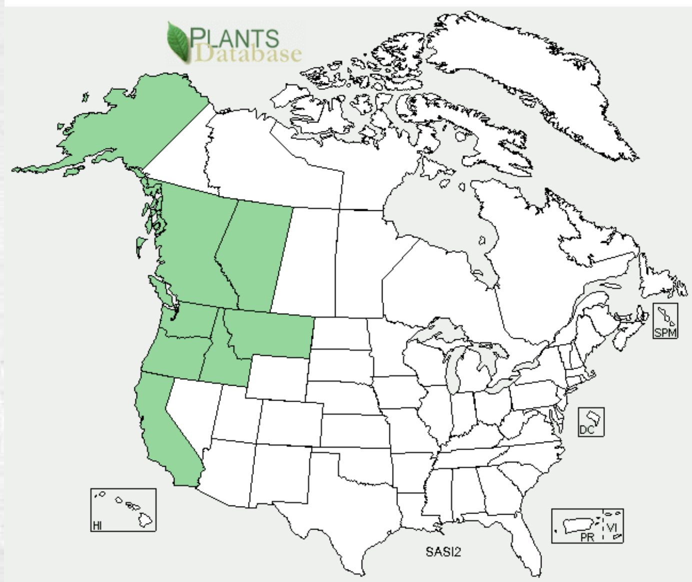


Salix lemmonii (Lemmon's willow): Shrub

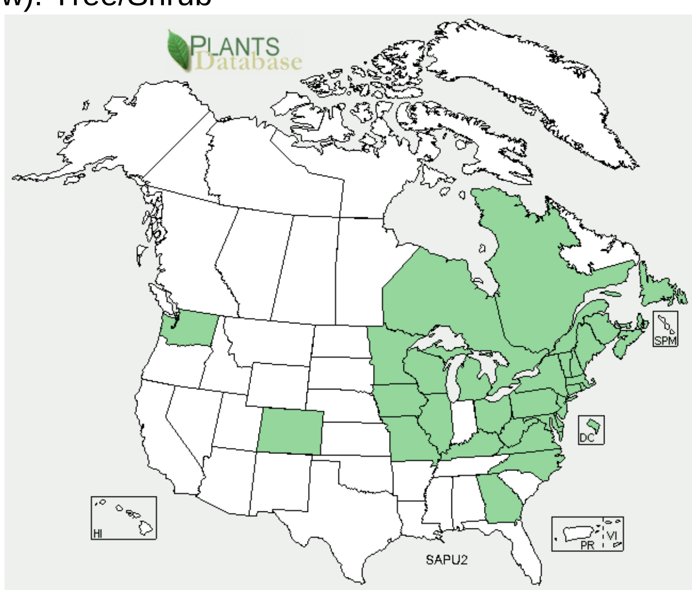


Salix scouleriana (Scouler's willow): Tree/Shrub

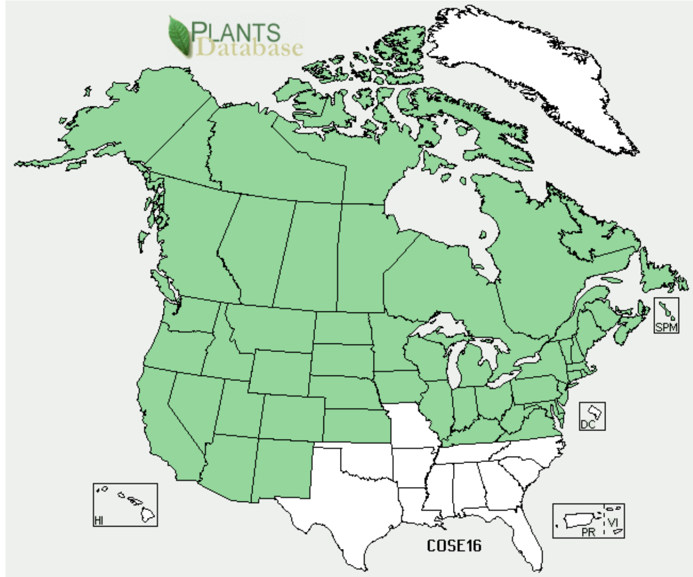




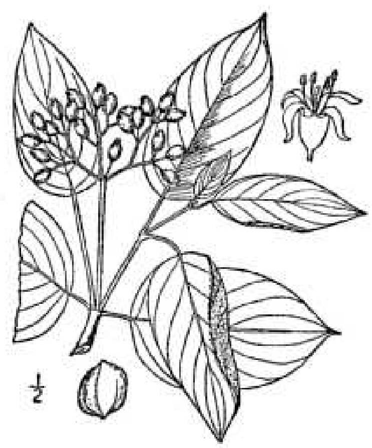
Salix sitchensis (Sitka willow): Tree/Shrub

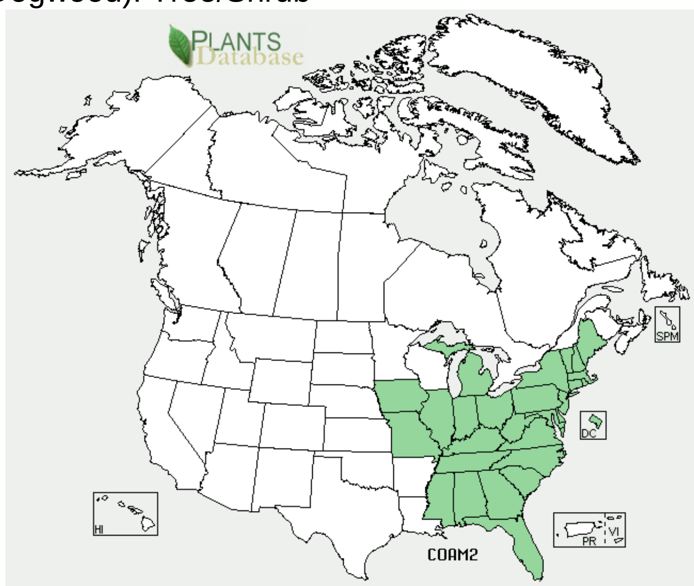


Salix purpurea (Purpleosier willow, also called streamco willow): Tree/Shrub

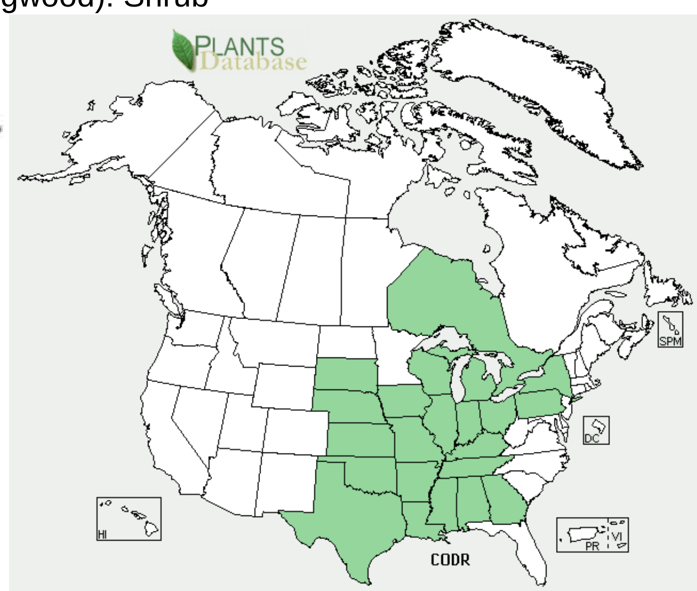


Cornus sericea (Redosier Dogwood): Tree/Shrub

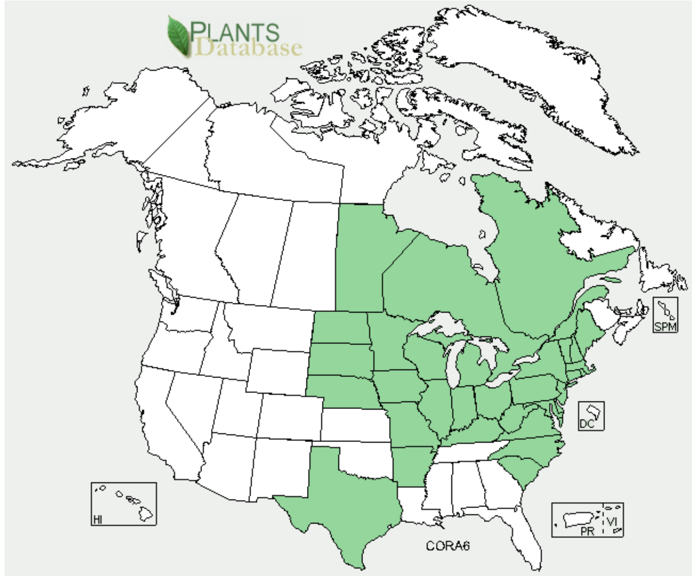




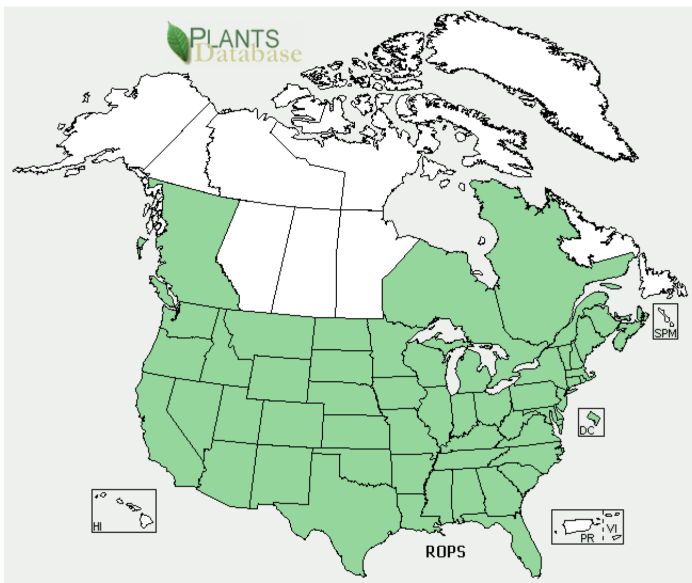
Cornus amomum (Silky Dogwood): Shrub



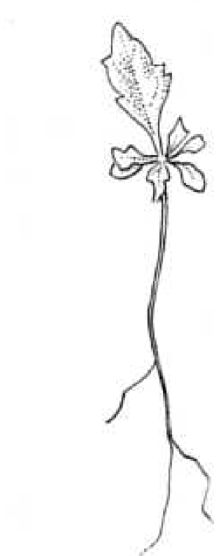
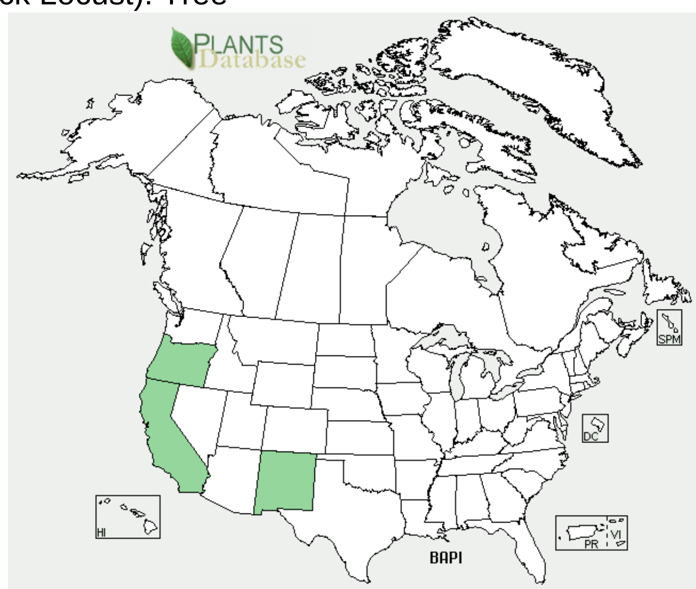
Cornus drummondii (Roughleaf Dogwood): Tree/Shrub

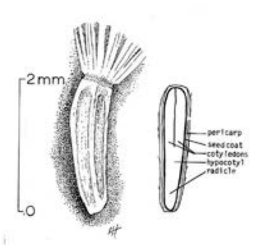
Cornus racemosa (Gray dogwood): Shrub

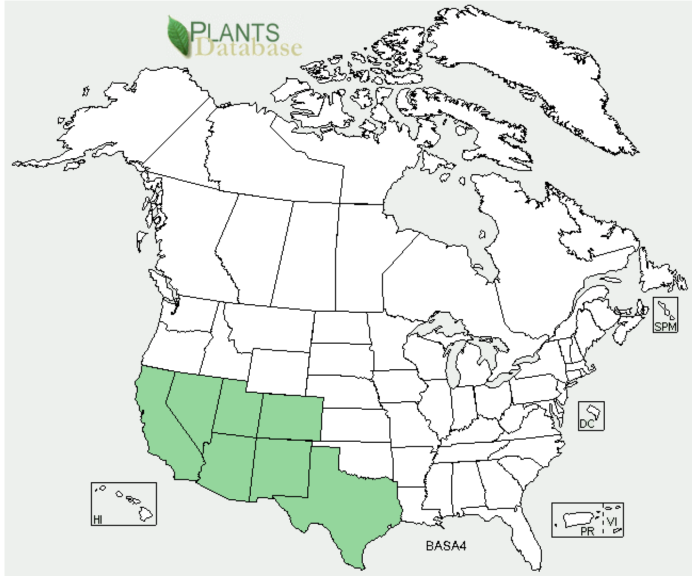



*Robinia pseudoacacia (*Black Locust): Tree

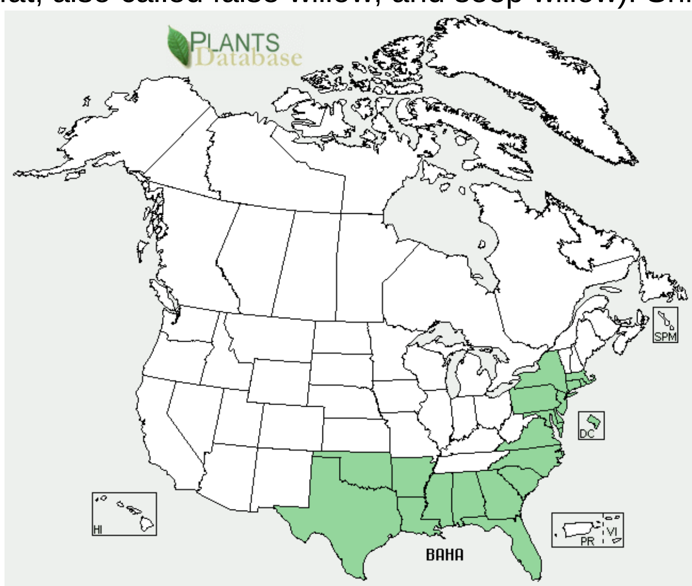



Baccharis pilularis (Coyote Brush): Shrub

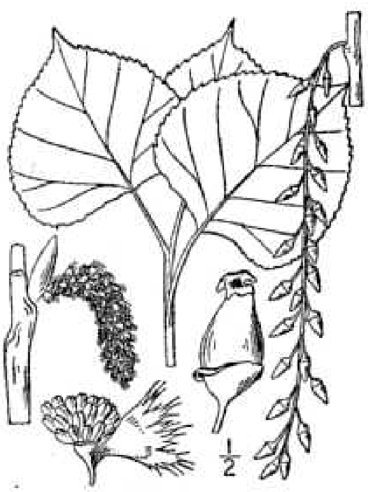


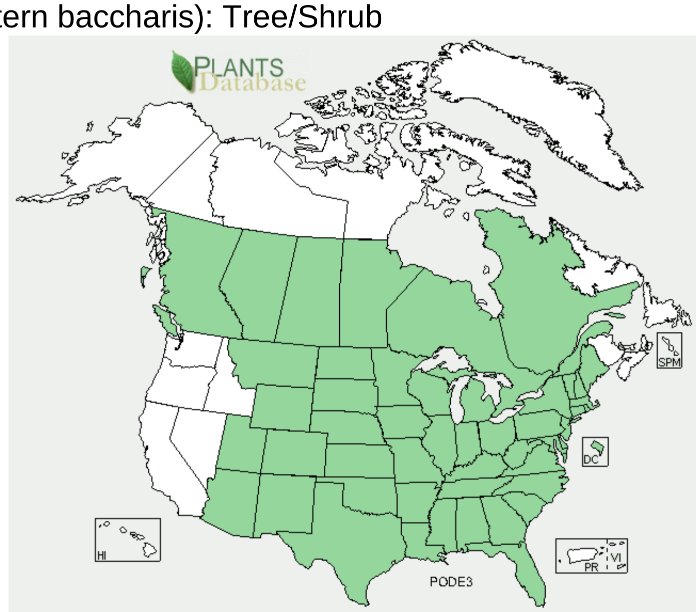


Baccharis salicifolia (Mule-fat, also called false willow, and seep willow): Shrub

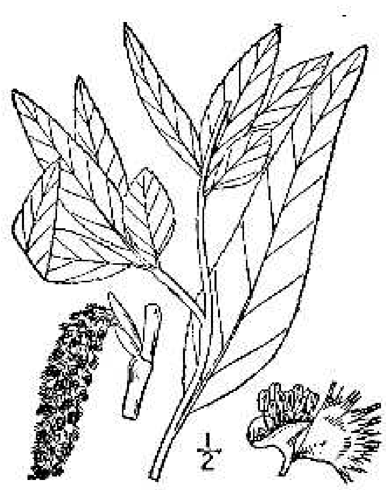


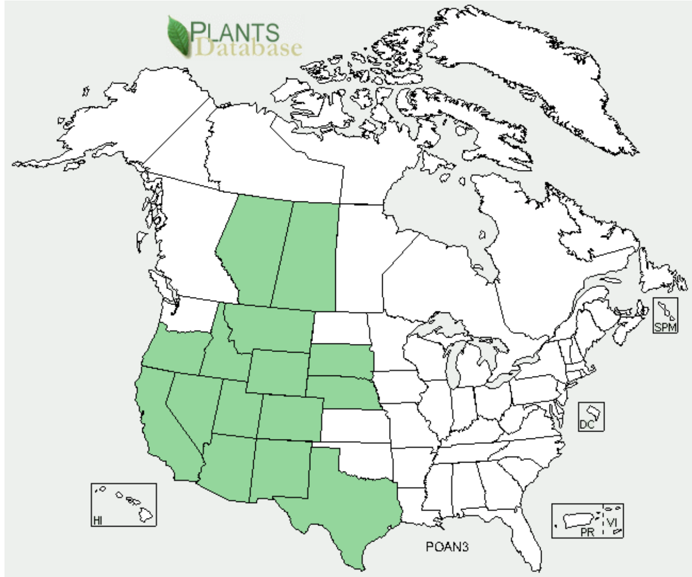
Baccharis halimifolia (Eastern baccharis): Tree/Shrub



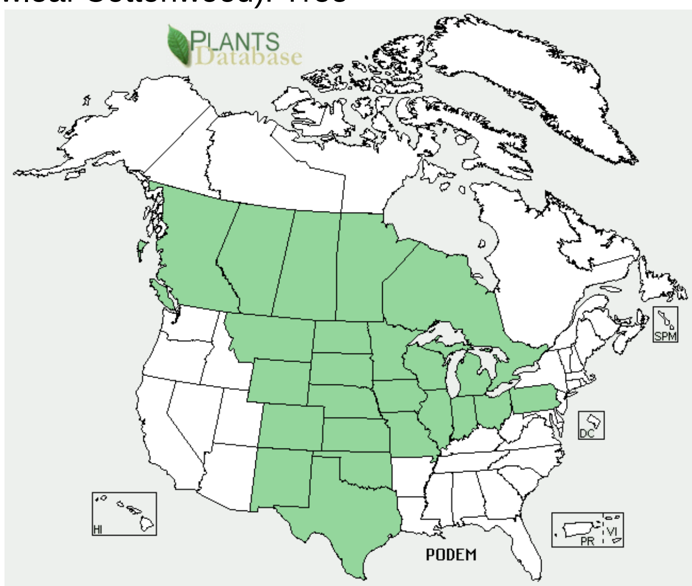


Populus deltoids (Eastern Cottonwood): Tree

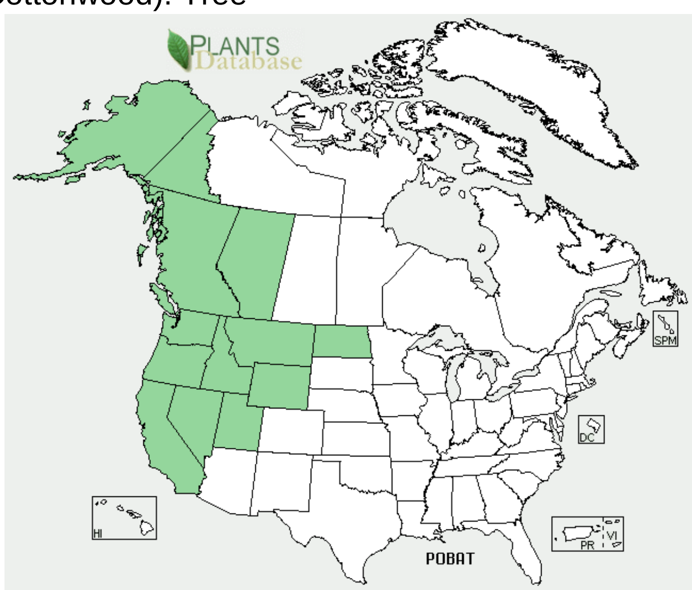




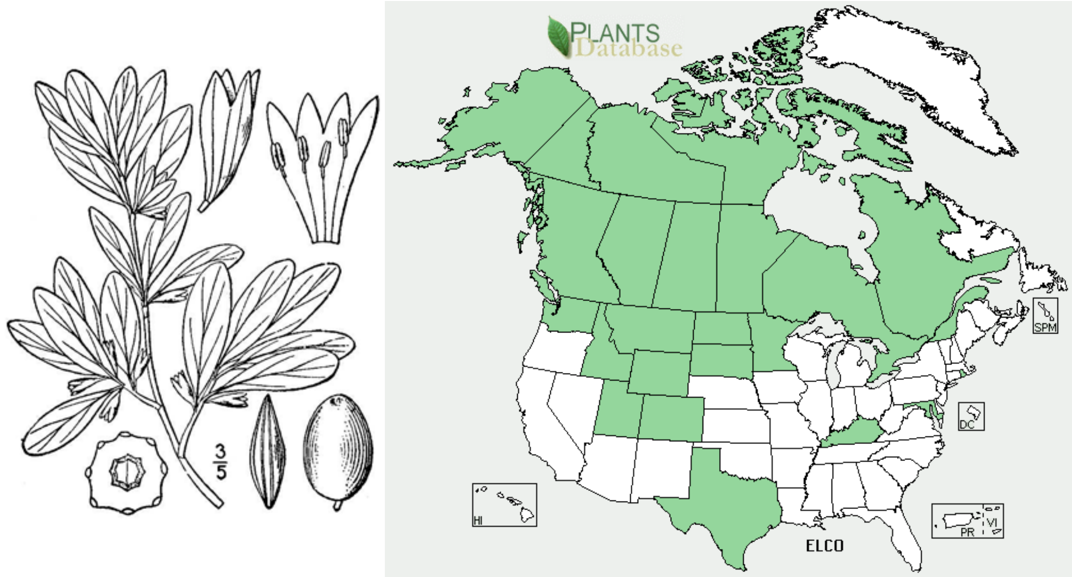
Populus angustifolia (Narrowleaf Cottonwood): Tree



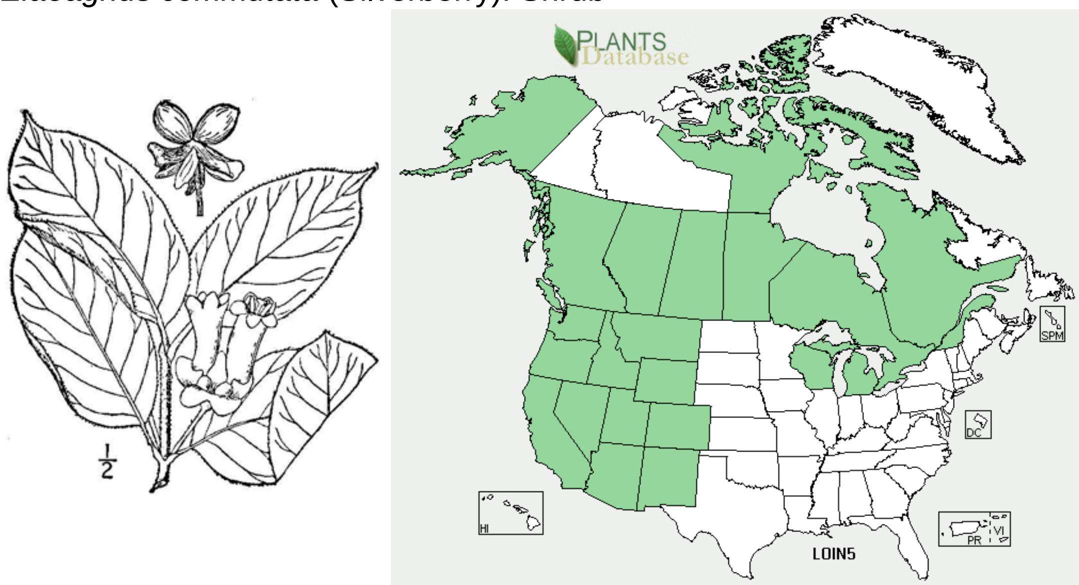
Populus deltoides (Plains Cottonwood): Tree



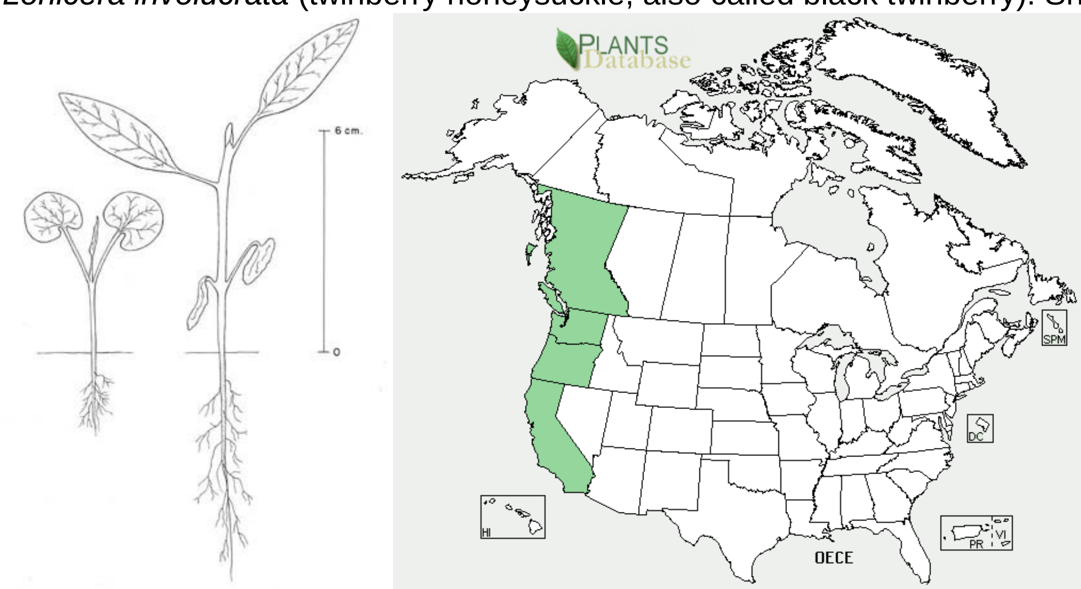
Populus balsamifera (Black cottonwood): Tree



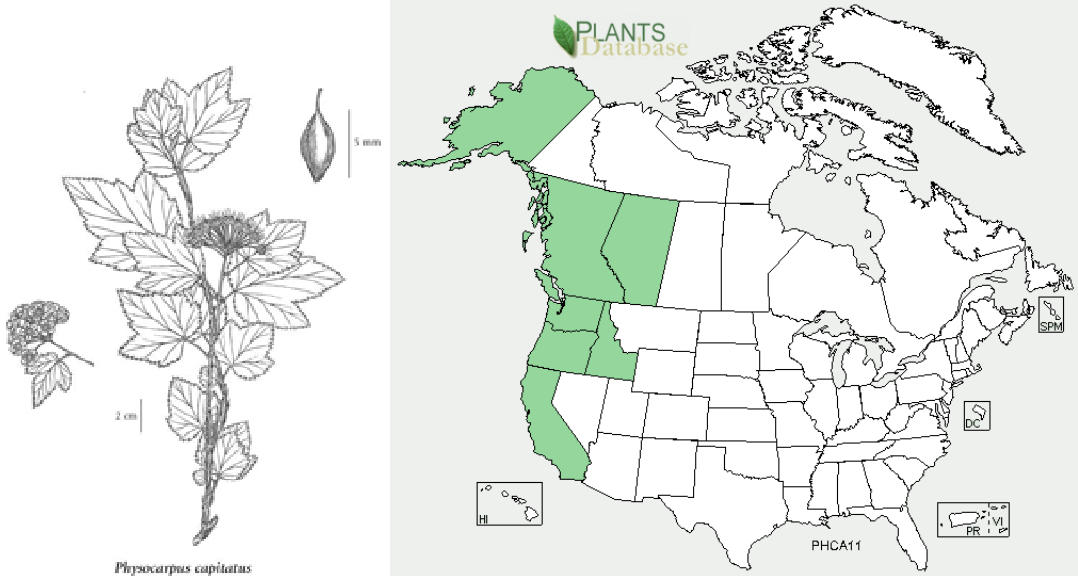
Elaeagnus commutata (Silverberry): Shrub



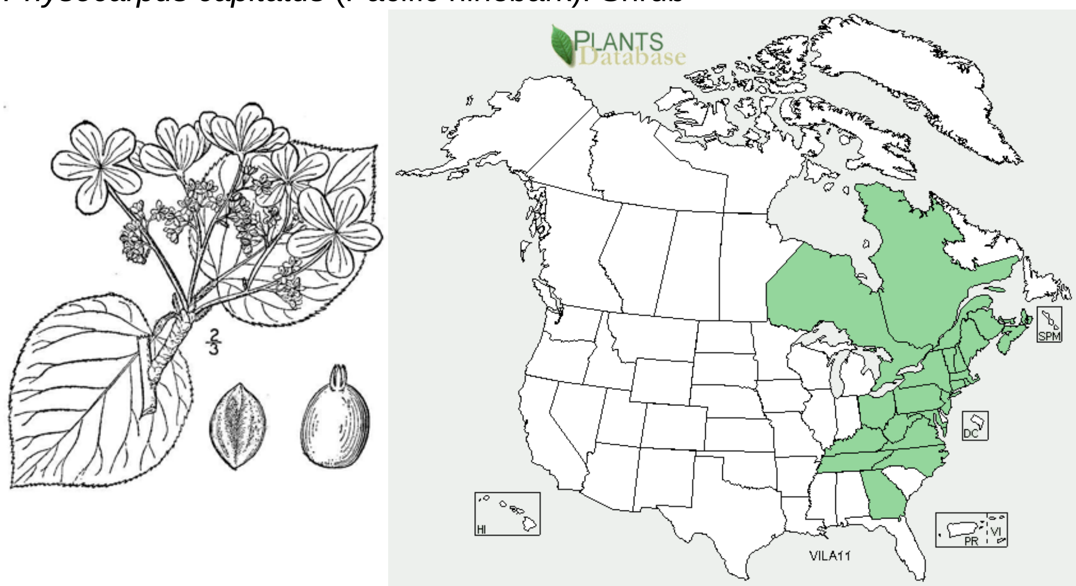
Lonicera involucrata (twinberry honeysuckle, also called black twinberry): Shrub



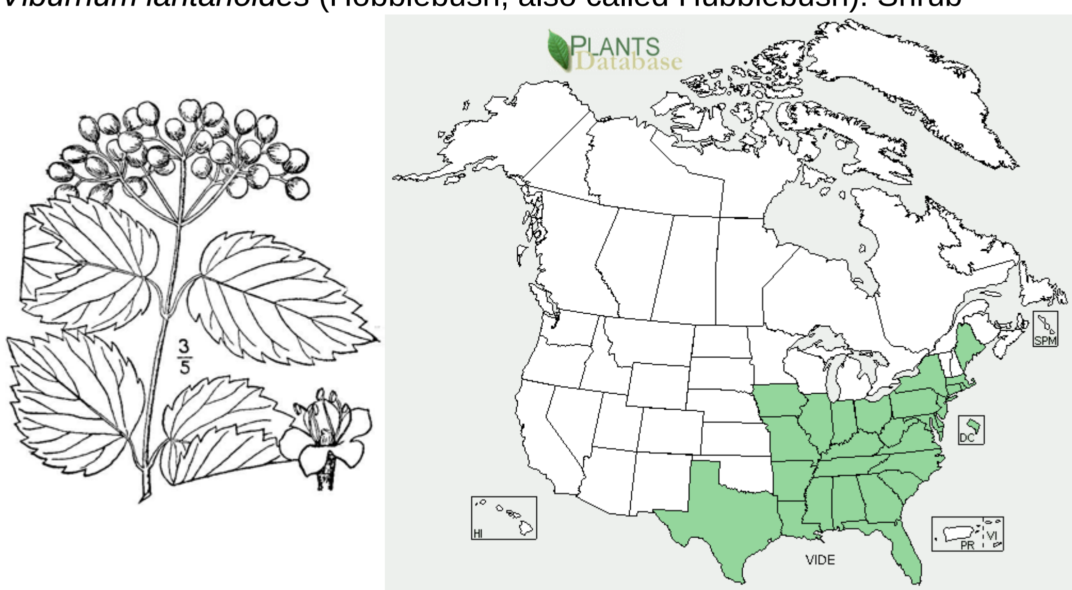
Oemleria cerasiformis (Indian plum): Tree/Shrub



Physocarpus capitatus (Pacific ninebark): Shrub

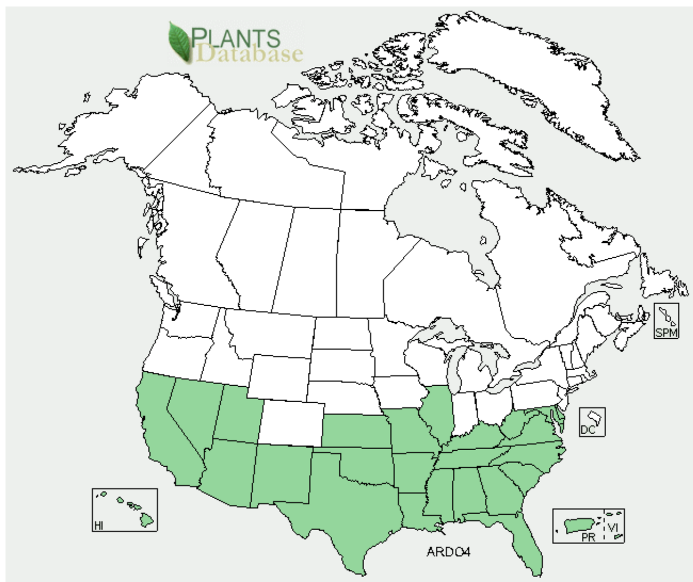


Viburnum lantanoides (Hobblebush, also called Hubbiebush): Shrub



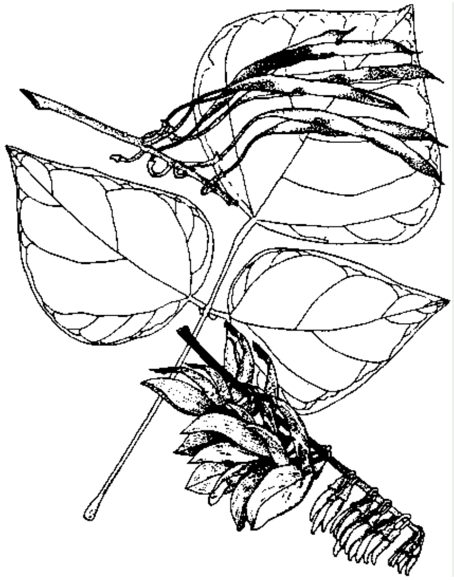
Viburnum dentatum (Southern arrowwood): Tree/Shrub

*Cordia sebestenea (*largeleaf geigertree, Vomitel): Tree/shrub

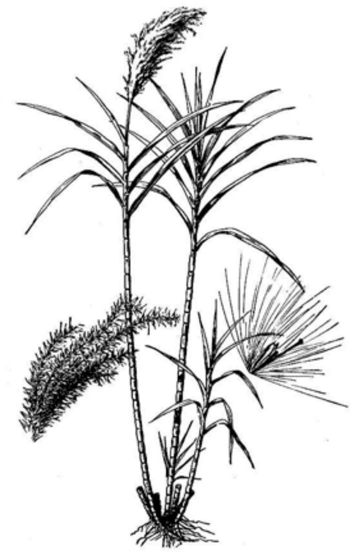


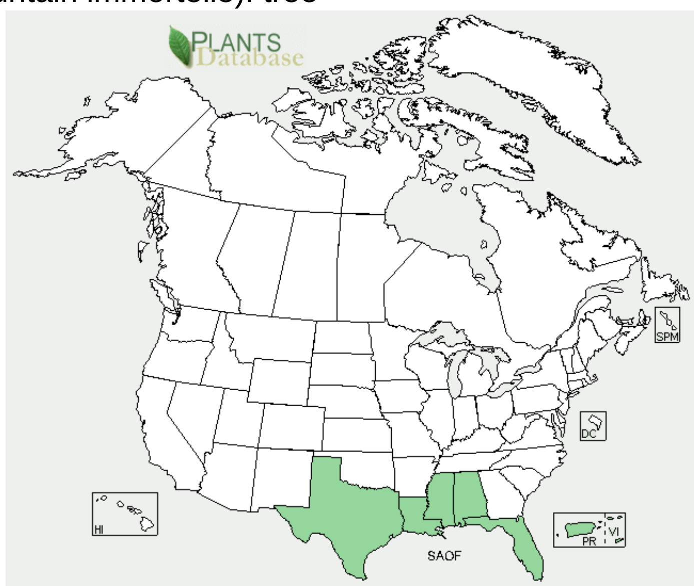
Arundo Donax (Giant Reed): Grass/Reed, use as cutting (considered noxious weed in areas)

*Vetiveria zizanioides (*vetivergrass): bunch grass



Erythrina poeppigiana (mountain immortelle): tree



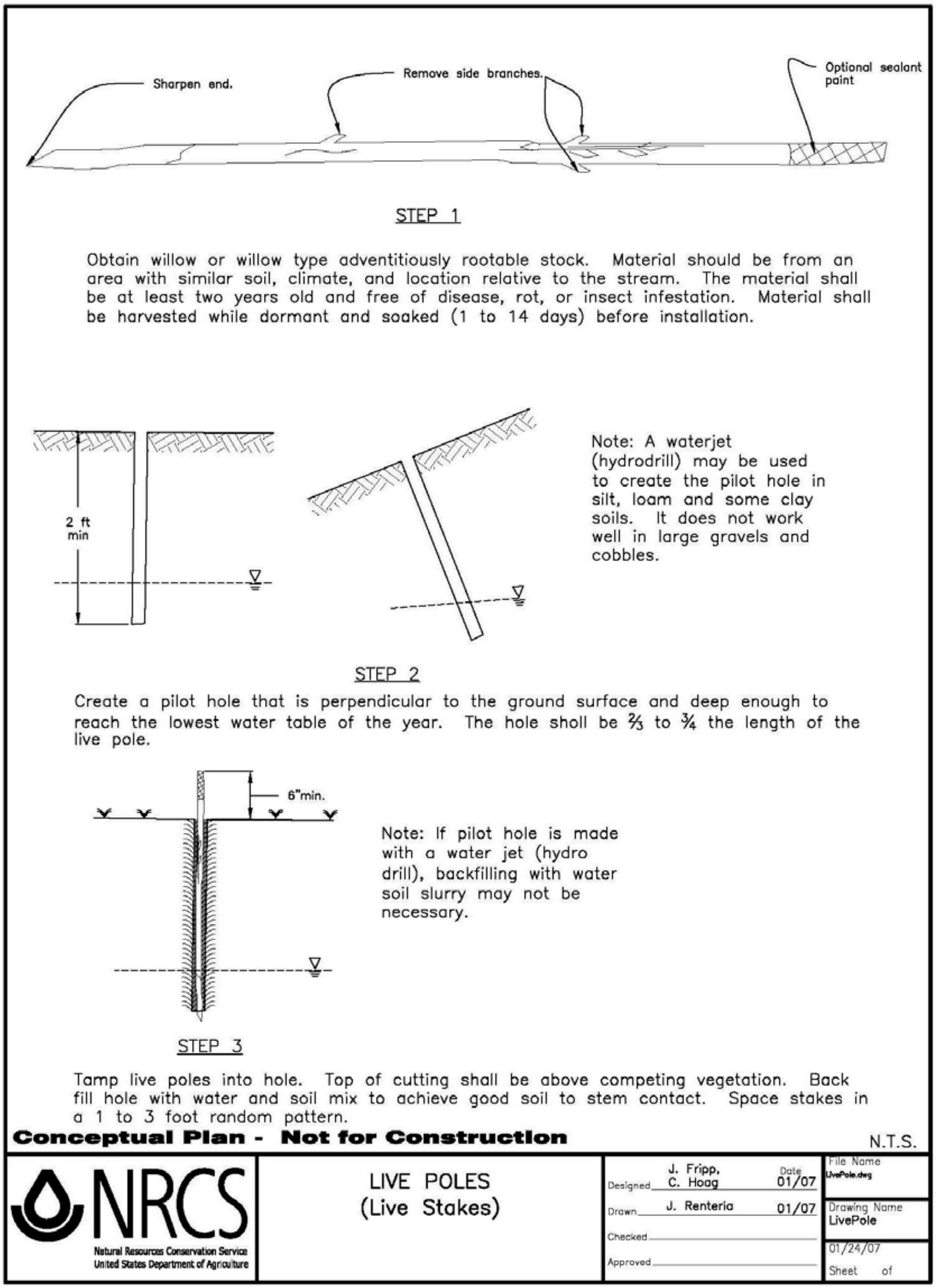


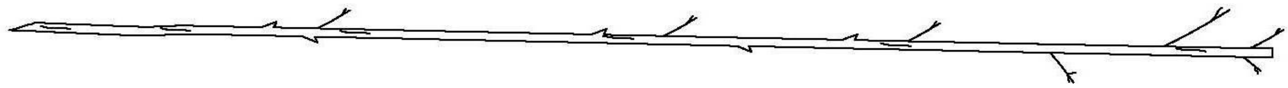
Saccharum officinarum (sugarcane): reed

*Bursera simaruba(*Turpentine tree or Amacigo): tree

Plant Based Streambank Soil Bioengineering

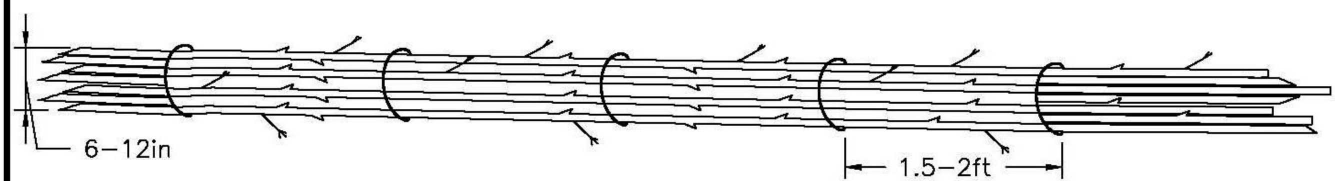
A Plant Based Streambank Soil Bioengineering approach does not intend to produce a static bank line. A successful project is a flexible project. The treatments may include inert components and even grading but they fundamentally rely on riparian plants to provide long-term strength to the bank. These treatments are applied to sites where the goal is to slow the dynamics of the system to a more natural rate. Additional bank movement after construction of the project is acceptable and expected during high flows. A plant based treatment is characterized by reliance on such treatments as live clumps, fascines, vertical bundles, brush barbs, brush revetments, and live cuttings.





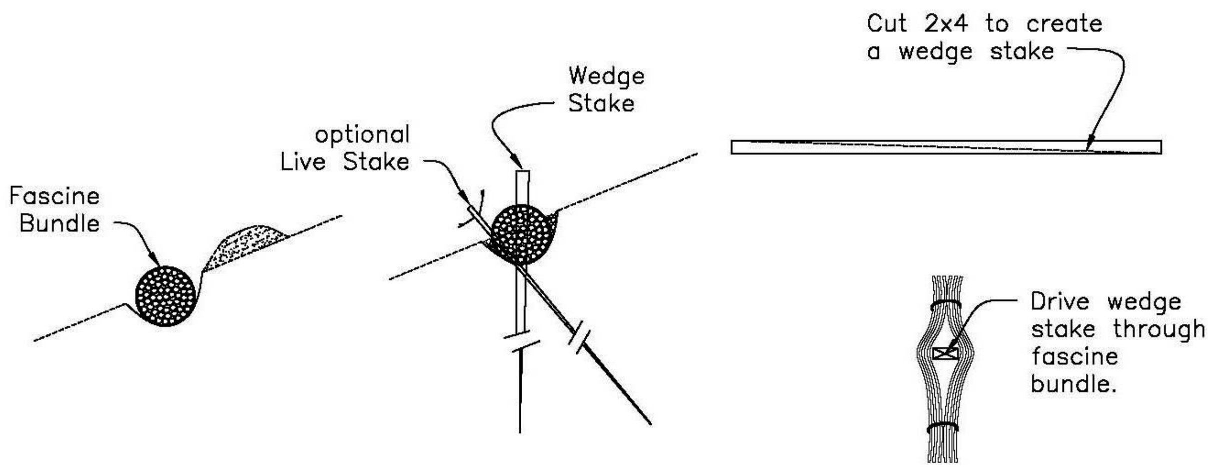
STEP 1

- Obtain willow or willow type adventitiously rootable stock. ½ to 2 inch diameter, 5 to 10 ft long.
- Material should be from an area with similar soil, climate,a nd location relative to the stream. The material shall be free of disease, rot, or insect infestation.
- Material shall be harvested while dormant and soaked (1 to 14 days) before installation.
- Side branches can be left intact.



STEP 2

- Stagger cuttings in a uniform bundle, 5 to 20 feet long depending on site conditions and handling capibilties. Vary orientation of cuttings.
- Tie bundle with string or non– galvanized wire.



STEP 3

- Excavate trench approximately ⅔rds bundle diameter.
- Place erosion control fabric if specified.
- Place and stake fascine bundle in trench.
- Wash loose soil into trench and around cuttings to get good soil to stem contact.

Conceptual Plan - Not for Construction

N.T.S.

NRCS
Natural Resources Conservation Service
United States Department of Agriculture

Fascine

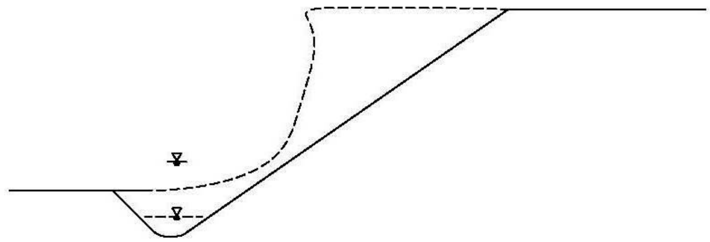
Designed	J. Fripp, C. Hoag	Date 03/07
Drawn	J. Renteria	03/07
Checked		
Approved		

File Name
Fascine.dwg

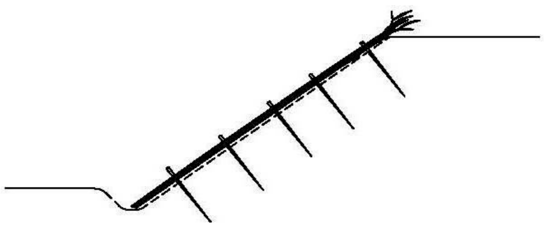
Drawing Name
Fascine

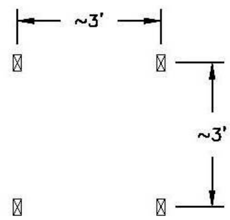
04/03/07

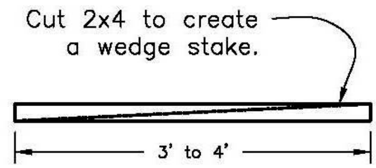
Sheet 1 of 1



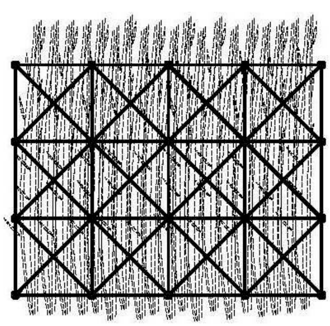
STEP 1
- Remove loose or failed material.
- Excavate to a stable slope.
- Excavate a trench at toe to lowest water table of the year.

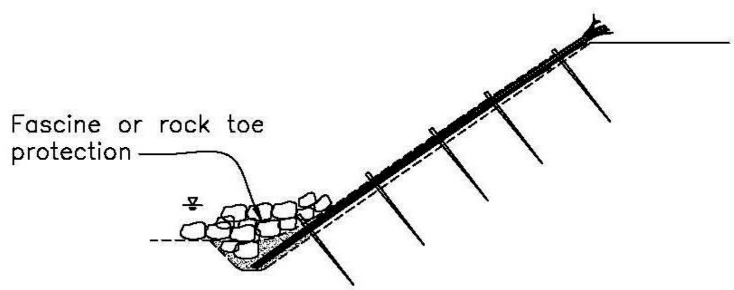






STEP 2
- Drive wedge stakes into slope on an approximate 3'x3' grid.
- Stakes should extend ~12" above surface.
- Place willow or willow type adventitiously rootable stock ½ to 1 inch diameter on slope. (12 to 24 branches per foot)
- Side branches can be left intact.
- Up to 50% dead material can be used.
- Basil(cut) end should be in trench and below lowest water table.
- Terminal bud should extend above top of slope.





STEP 3
- Secure cuttings by tieing with short lengths of string or non-galvanized wire to stakes. Use a diamond pattern.
- Hammer stakes to firmly pull cuttings against soil.
- Wash loose soil into cuttings. Approximately half of the depth of the mattress should be covered.
- Backfill trench and apply suitable toe protection (rock, fascine, revetment, etc.)
- Trim terminal bud.

Conceptual Plan - Not for Construction

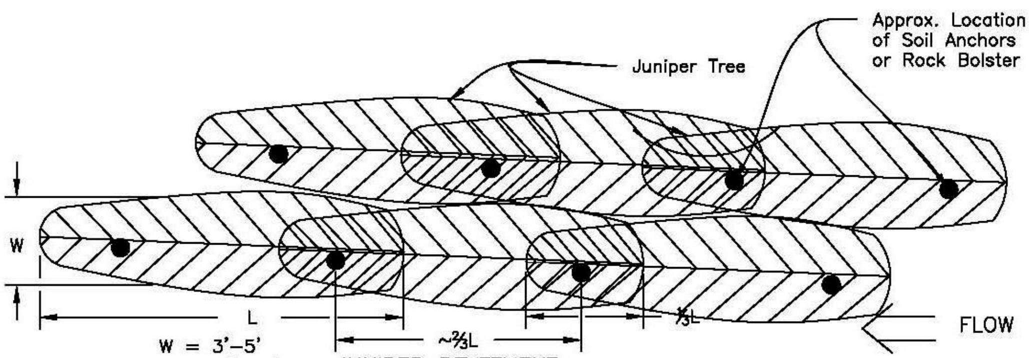
N.T.S.

NRCS
Natural Resources Conservation Service
United States Department of Agriculture

Brush Mattress

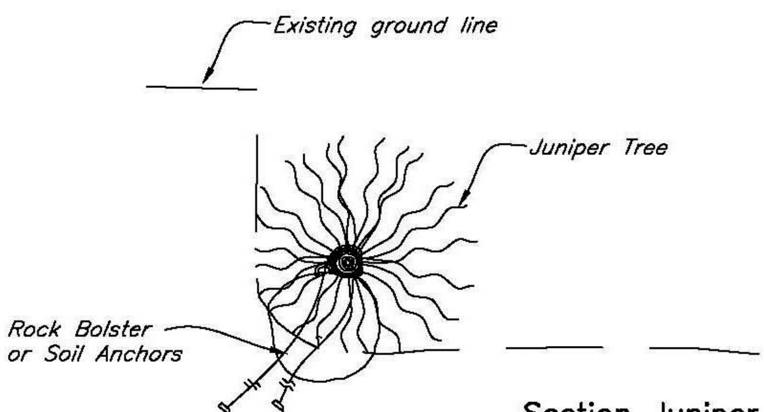
Designed J. Fripp, C. Hoag Date 04/07
Drawn J. Renteria 04/07
Checked
Approved

File Name BrushMattress2.dwg
Drawing Name BrushMattress2
04/06/07
Sheet 1 of 1

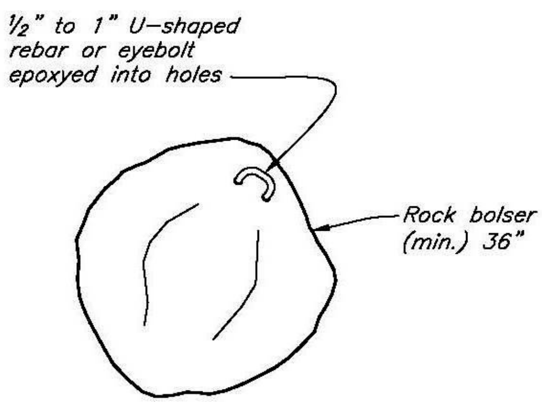


JUNIPER REVETMENT
(Plan)

Notes For Juniper Revetment
Overlap juniper by ¼ to ⅓ length in a shingle-like arrangement. Secure at overlap with three wraps of 12 gage wire or ⅛" cable and clamp securely. Anchor with a minumum of two sets of soil anchors or rock bolsters per trunk as per specifications. Start at toe of bank. If additional rows are required, offset by not more than tree width. Press rows tight together. Cable rows together with 12 gage wire or ⅛" cable and clamp.



Section Juniper
N.T.S



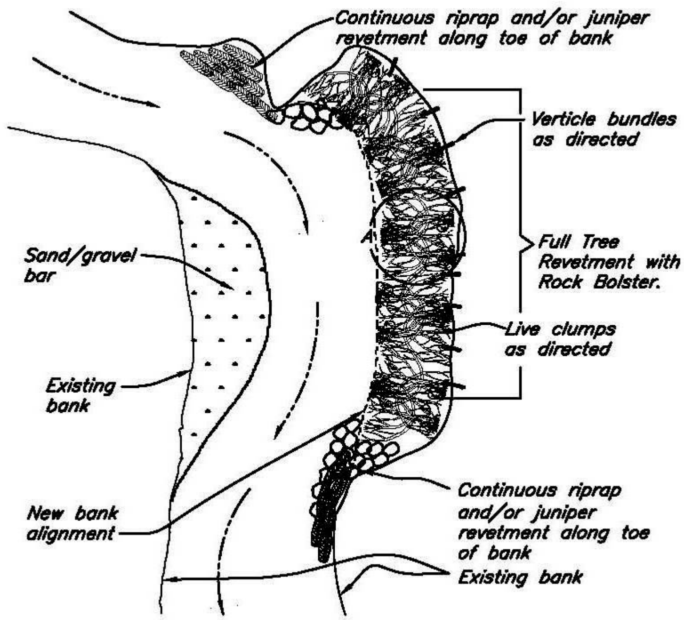
ROCK BOLSTER DETAIL
N.T.S.

Notes:

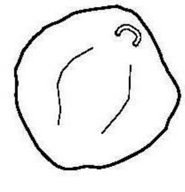
Secure logs to rock bolsters at overlap with a minumum of three wraps of ⅛-¼" diameter galvanized non-greased, wire rope. If constructing in or near water drill holes in rock bolsters with gas or pneumatic drill. The min. depth should be 6 inches. Holes must be clean of all dust, debris, oil, and soap following drilling. Insert a U-shaped rebar or eyebolt into holes several times to dispense and completely mix epoxy and eliminate air pockets. Epoxy resin systems shall meet the requirements of ASTM C881, Type IV
Grade 3. Test strength of bond after minumum cure time recommended by the epoxy manaufacturer.

Conceptual Plan - Not for Construction

NRCS Natural Resources Conservation Service United States Department of Agriculture	JUNIPER REVETMENT	Designed J. Fripp, C. Haag, K. Worster — Date 08/05	File Name Juniper-Revet.dwg
		Drawn K. Miller, J. Renteria 08/05	Drawing Name Juniper-Revet
		Checked	02/02/06
		Approved	Sheet 1 of 1



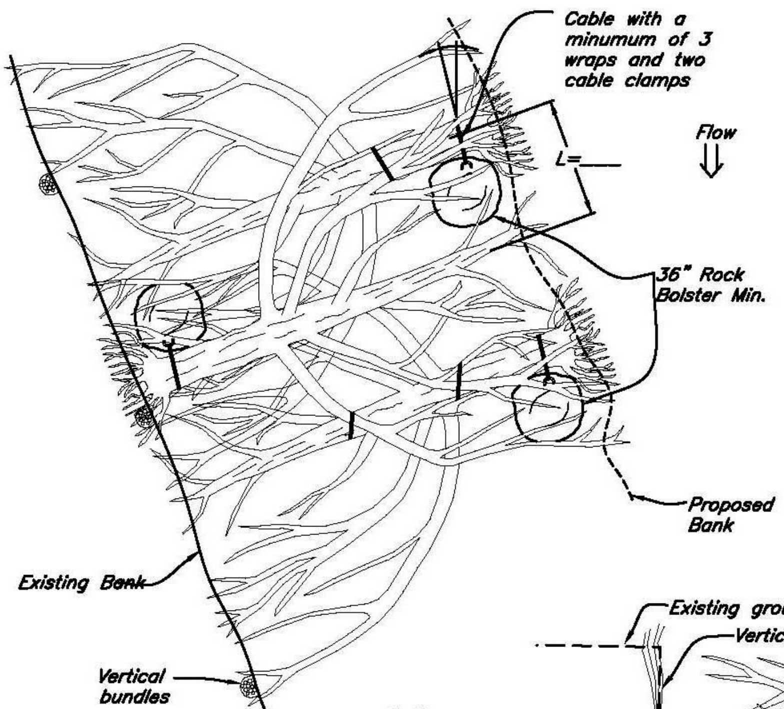
FULL TREE REVETMENT WITH ROCK BOLSTERS
(PLAN)
N.T.S.



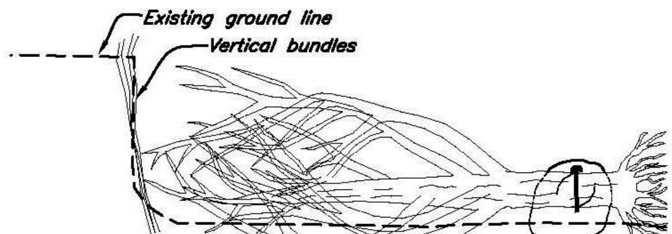
ROCK BOLSTER DETAIL
N.T.S.

Notes for Rock Bolster:

Secure to rock bolsters at overlap with a minumum of three wraps of 1/8 – 1/4" diameter galvanized non-greased, wire rope. If constructing in or near water drill holes in rock bolsters with gas or pneumatic drill. Holes must be clean of all dust, debris, oil, and soap following drilling. Insert a U-shaped 1" rebar into holes several times to dispense and completely mix epoxy and eliminate air pockets. Epoxy resin systems shall meet the requirements of ASTM C881, Type IV Grade 3. Test strength of bond after minumum cure time recommended by the epoxy manaufacturer.



Detail "A"



Section

Conceptual Plan - Not for Construction

Drawings not to scale

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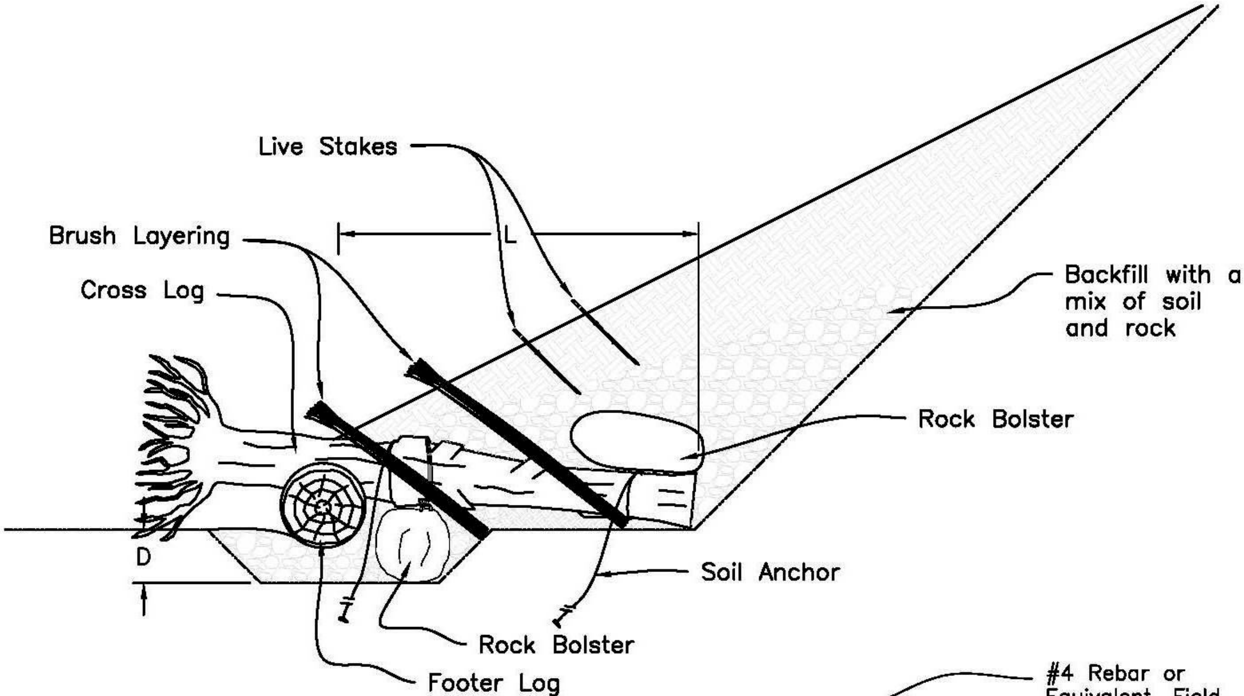
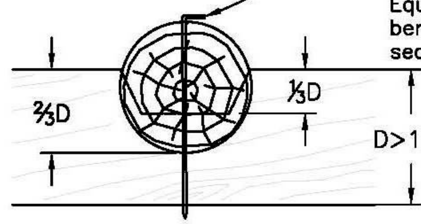
FULL TREE REVETMENT WITH ROCK BOLSTERS

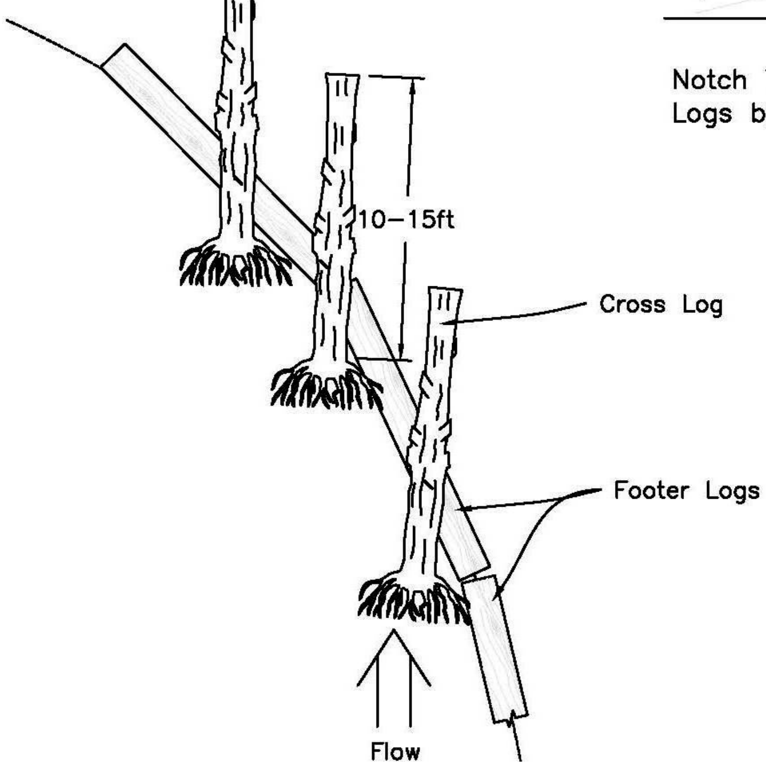
Designed	J. Fripp, C. Haag	Date 07/07
Drawn	J Renteria	07/07
Checked		
Approved		

File Name: Tree-Revet-RB1.dwg
Drawing Name: rvTree-Revet-RB1-Plan
07/27/07
Sheet of





Notch Top and Bottom Logs by ⅓D

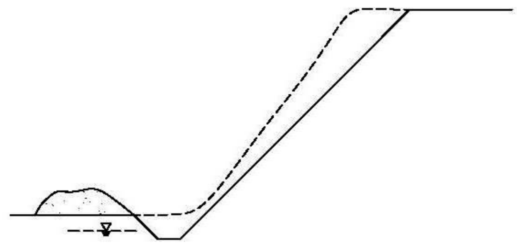


Notes:
A minium of two cross logs per Footer log is required to anchor Footer log. Secure Cross logs using soil anchors and/or rock bolsters. Size anchoring based on the bouyancy force on the logs when completely submerged then subtract the downward force from the backfill.

Conceptual Plan Not for Construction

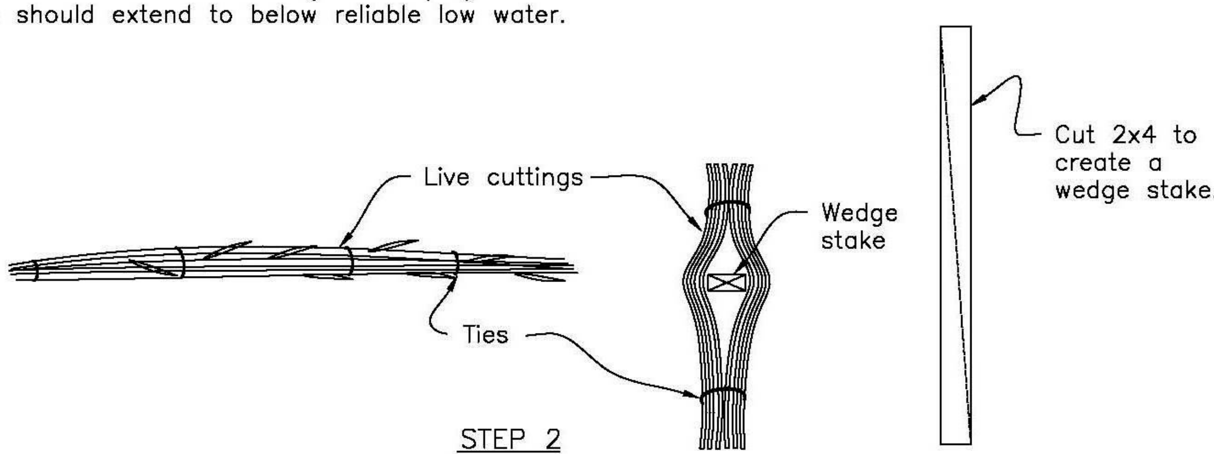
Drawings not to scale

NRCS Natural Resources Conservation Service United States Department of Agriculture	LOG TOE PROTECTION – LOW BANK	Designed K. Worster, J. Fripp Date 03/08	File Name LogRevetment-lowbk.dwg
		Drawn J. Renteria 03/08	Drawing Name LogRevetment-lowbk
		Checked	03/26/08
		Approved	Sheet of



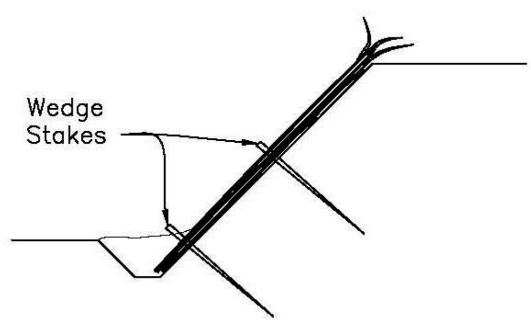
STEP 1

- Remove loose or failing bank material.
- Excavate a trench into bank (4–9" depth).
- Trench should extend to below reliable low water.



STEP 2

- Assemble bundles of live cuttings. Use a minimum of 4 cuttings per bundle.
- Orient all cuttings in one direction.
- Tie cuttings at 2 to 3 ft intervals.
- Place a bundle in trench and stake with 2 to 3 wedge stakes between ties.

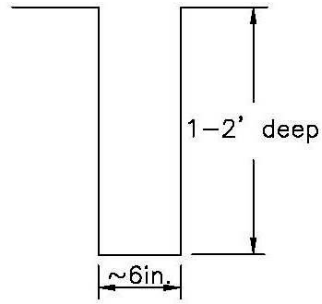


- Refill bottom of trench.
- Wash loose soil into cuttings. Approximately ½ to ¾ of bundle should be covered.
- Trim terminal buds of cuttings.
- Irrigate as necessary.

Conceptual Plan - Not for Construction

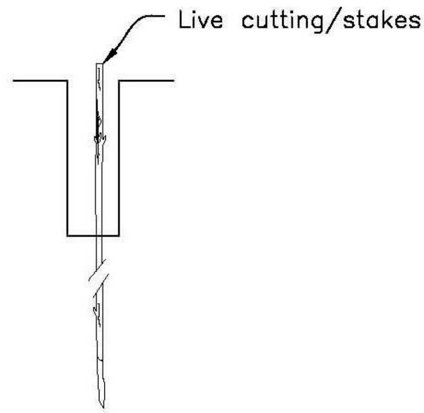
N.T.S.

NRCS Natural Resources Conservation Service United States Department of Agriculture	Vertical Bundles	Designed J. Fripp, K. Worster — Date 01/06 Drawn J. Renteria — 01/06 Checked Approved	File Name: Vertical Bundles.dwg Drawing Name: Bundles 01/24/07 Sheet 1 of 1



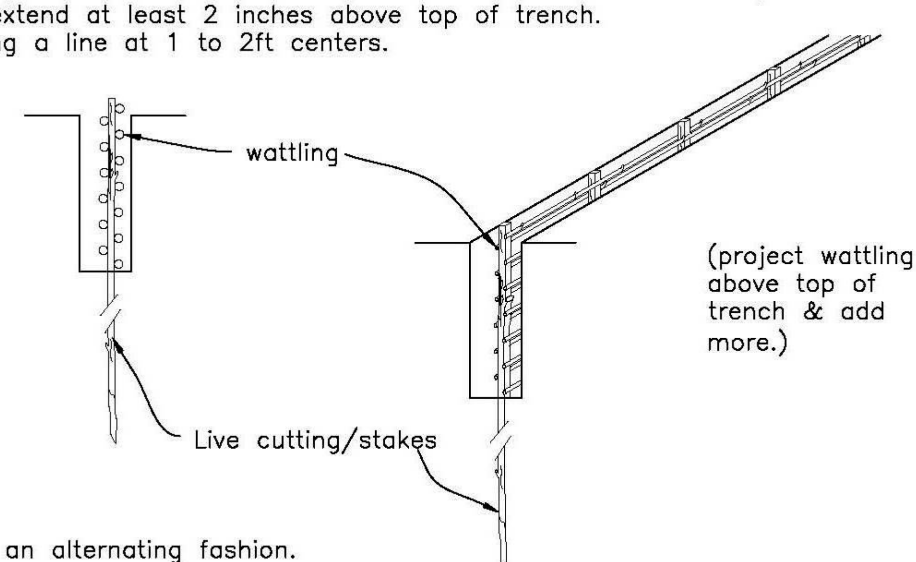
STEP 1

- Collect and soak wattling. Leave side branches. Wattling should be ¼ to 1in diameter, flexible, and 4 to 20 feet long.
- Collect and soak live cuttings. The cuttings should be 2 to 4 inch diameter and 3 to 5ft long.
- Excavate a trench 1 to 2 feet deep as shown on the plans.



STEP 2

- Install live cuttings/stakes into the invert of the trench. The minimum depth should be 1ft. The tops should extend at least 2 inches above top of trench.
- Space stakes along a line at 1 to 2ft centers.



STEP 3

- Weave wattling in an alternating fashion.
- Press dow on each strand.
- Backfill trench and wash in soil.
- Trim as specified.

Conceptual Plan - Not for Construction

N.T.S.

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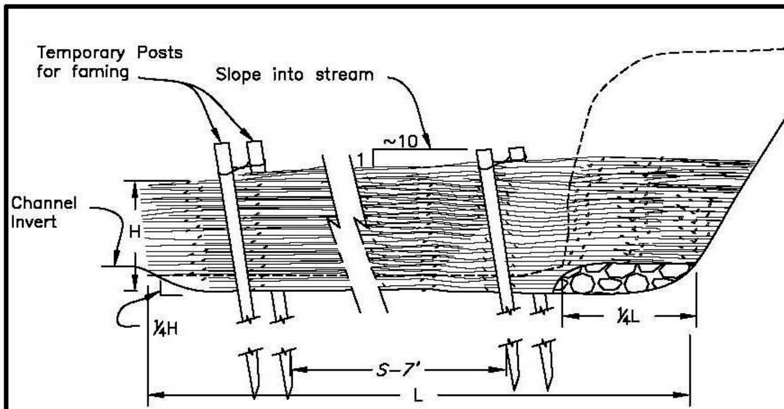
Natural Resources Conservation Service
United States Department of Agriculture

Wattle

		Date
Designed	J. Fripp, C. Hoag	03/07
Drawn	J. Renteria	03/07
Checked		
Approved		

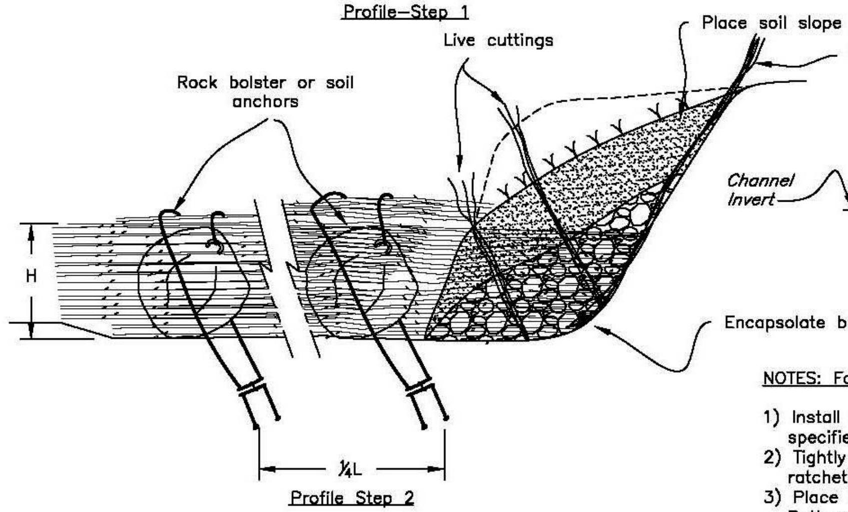
File Name: Wattle.dwg
Drawing Name: Wattle
03/26/07
Sheet of



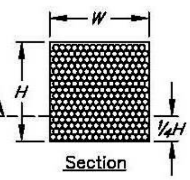
Profile–Step 1

NOTES: For Vegetated Spur Step 1

1) Remove loose and failing bank material, excavate key into bank as shown. Place rock into key trench
2) Excavate trench along alignment of spur at depth as shown. Trench should be a minimum of ¼ thickness of vegetated spur at section A.
3) Install two pairs of framing posts at width of spur.
4) Place live material tightly between anchor posts. Butt ends shall be firmly into bank as length of material permits. Material shall overlap by ⅓–½L.



Profile Step 2



Section

L=__________

℄=__________

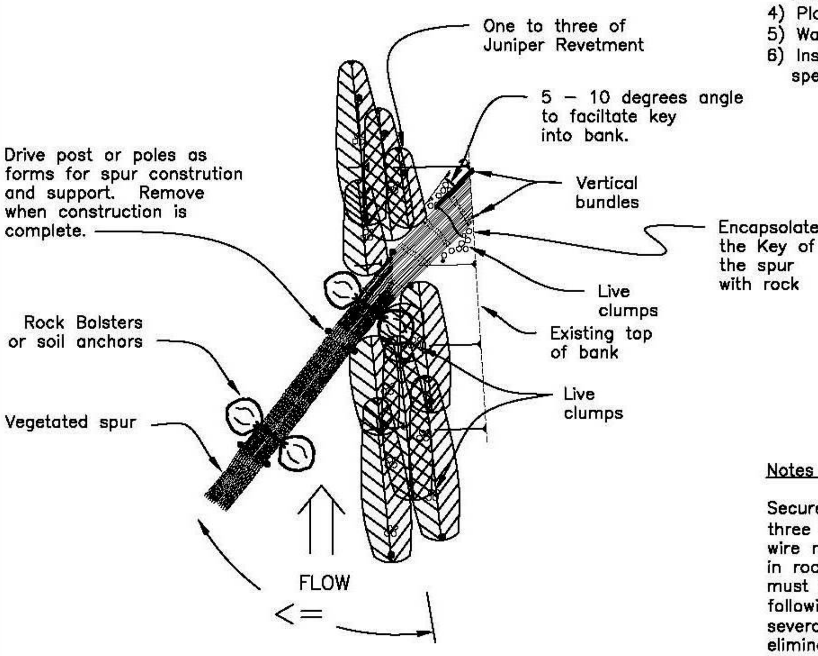
H=__________

W=__________ *

* spacing between anchors should be <4w

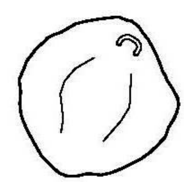
NOTES: For Vegetated Spur Step 2

1) Install soil anchors in pairs or Rock Bolster as specified.
2) Tightly secure live material to soil anchors with ratcheting cable clamps.
3) Place vertical bundles into key area as shown. Butt ends of live material must extend firmly to soil.
4) Place Rock over key and backfill.
5) Wash in soil to achieve good soil to stem contact
6) Install juniper revetment over spur at bank if specified.



VEGETATIVE SPUR WITH JUNIPER REVETMENT

(Plan)



ROCK BOLSTER DETAIL

N.T.S.

Notes for Rock Bolster:

Secure to rock bolsters at overlap with a minumum of three wraps of ⅛–¼" diameter alvanized non–greased, wire rope. If constructing in or near water drill holes in rock bolsters with gas or pneumatic drill. Holes must be clean of all dust, debris, oil, and soap following drilling. Insert a U–shaped 1" rebar into holes several times to dispense and completely mix epoxy and eliminate air pockets.
Epoxy resin systems shall meet the requirements of ASTM C881, Type IV Grade 3. Test strength of bond after minumum cure time recommended by the epoxy manaufacturer.

Conceptual Plan - Not for Construction

Drawings not to scale

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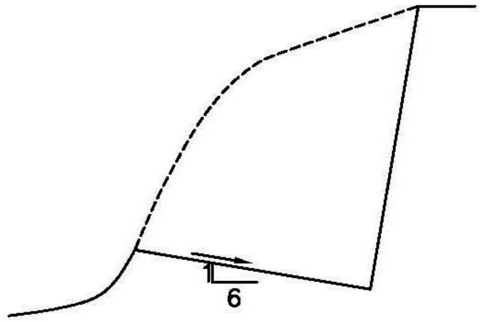
Vegetated Spur* with Rock Key

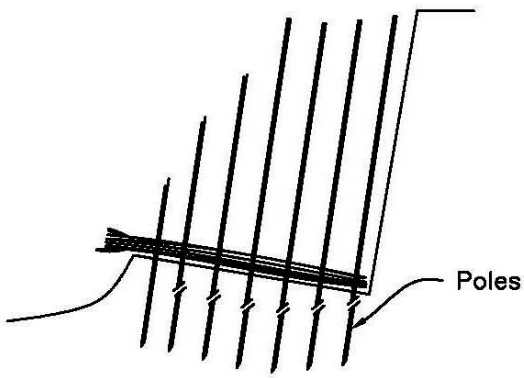
*also called vegetated stream barb, piper spur, or brush box barb

Designed	J. Fripp, C. Hoag	Date 07/07	File Name VEG–SPUR.dwg
Drawn	Juan Renteria	07/07	Drawing Name Veg–Spur
Checked			07/27/07
Approved			Sheet of



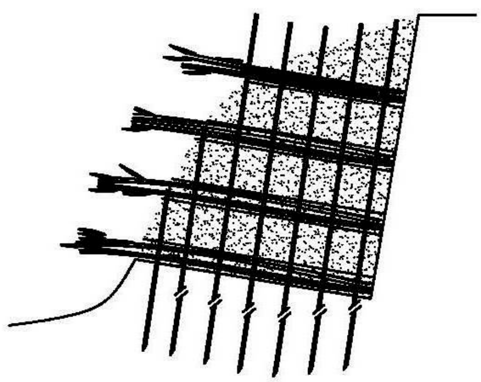
STEP 1

- Collect and soak cuttings. Leave side branches. Cuttings should be ½ to 3in diameter and long enough to extend from undisturbed soil to >12in beyond face of slope.
- Remove loose or failing material.
- Construct a bench on contour. Slope bench ~1V:6H towards bank.



STEP 2

- Drive poles 3 to 5 feet into ground. The tops should extend above final grade. Live poles can be used. Space 1 to 2ft apart.
- Place a 3 to 6 inch layer of live cuttings on bench. Cut end should be in contact with undisturbed soil.



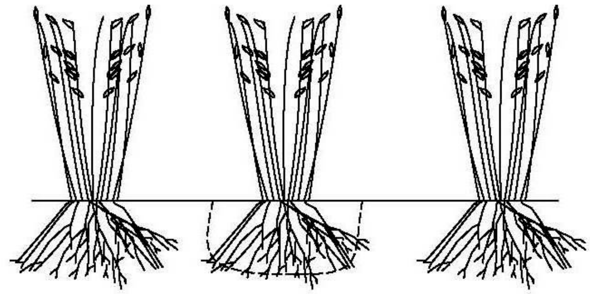
STEP 3

- Wash in soil over and into cuttings.
- Add additional soil in 3 inch lifts to 6–8 inch total.
- Tamp to remove air pockets.
- Place additional cuttings and soil until complete.
- Trim terminal buds.

Conceptual Plan - Not for Construction

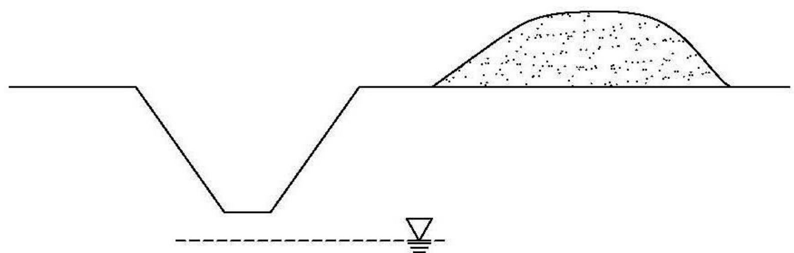
N.T.S.

NRCS Natural Resources Conservation Service United States Department of Agriculture	Brush Packing	Designed J. Fripp, C. Hoag Date 03/07 Drawn J. Renteria 03/07 Checked Approved	File Name Brush Packing.dwg Drawing Name Brush Packing 04/04/07 Sheet of



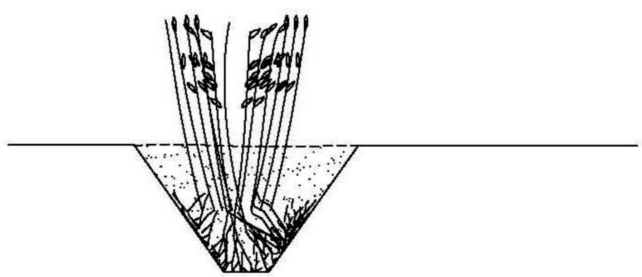
STEP 1

- Locate vigorous clumps, 8–20 ft. tall
- Remove clump with back hoe bucket. Obtain approximately 70% of root mass.



STEP 2

- Dig a hole that is of approximate area of the clump.
- The depth of the hole should be just above the water table (approx. 6–10 inches).



STEP 3

- Place clump in hole. Root mass can be 3 to 6 ft below soil surface depending upon depth to water table..
- Fill hole with soil and wash soil in around roots to get good soil to stem contact.
- Cut the willow clump off 3–4 ft above ground. Leave more if significant deposition is expected.

Conceptual Plan - Not for Construction

N.T.S.

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Natural Resources Conservation Service
United States Department of Agriculture

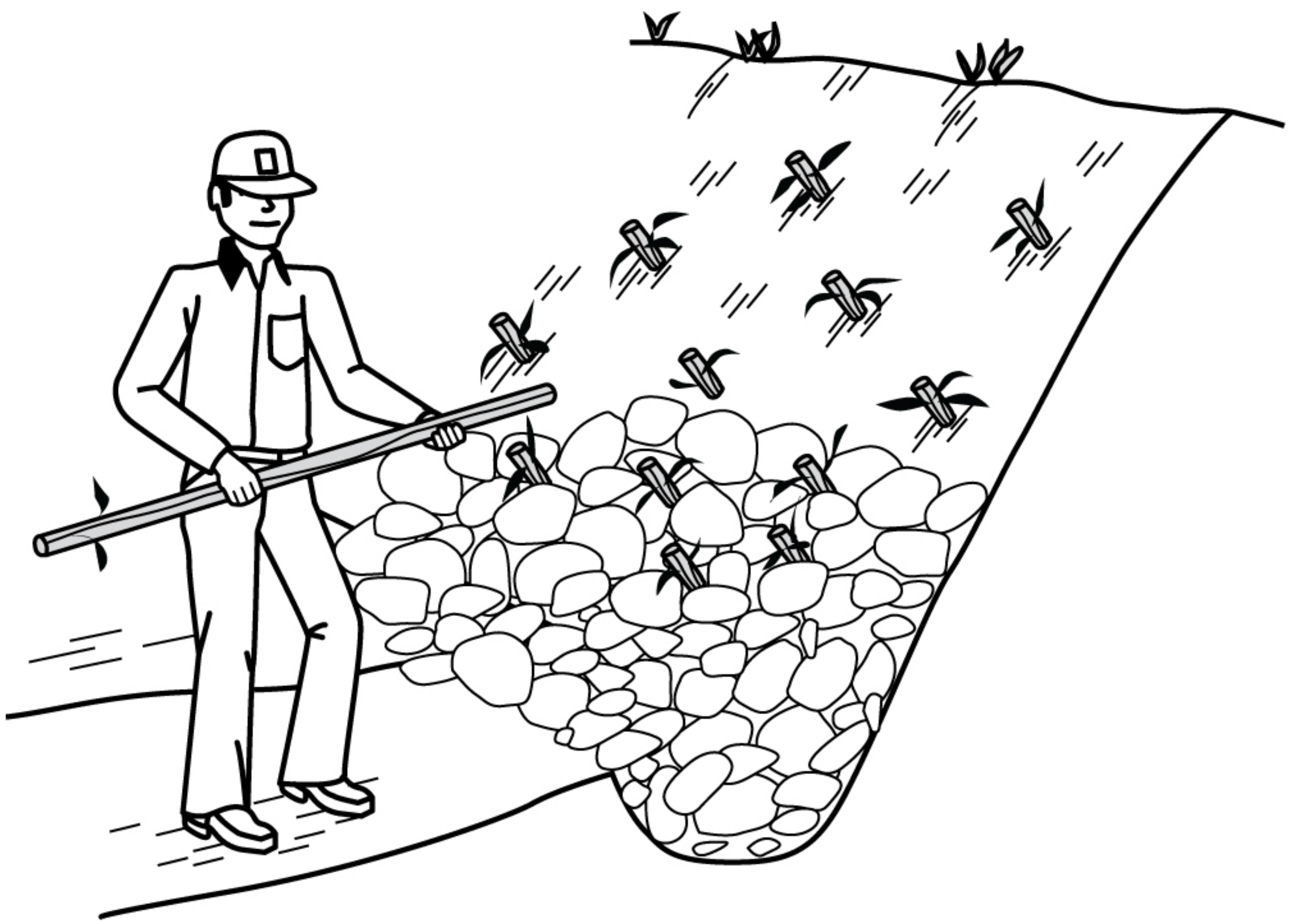
Willow Clump Plantings

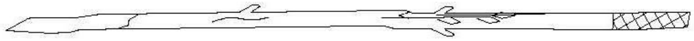
Designed J. Fripp, C. Haag — Date 01/06
Drawn J. Renteria — 01/06
Checked
Approved

File Name: Willow Clump Planting.dwg
Drawing Name: willows
03/02/06
Sheet 1 of 1

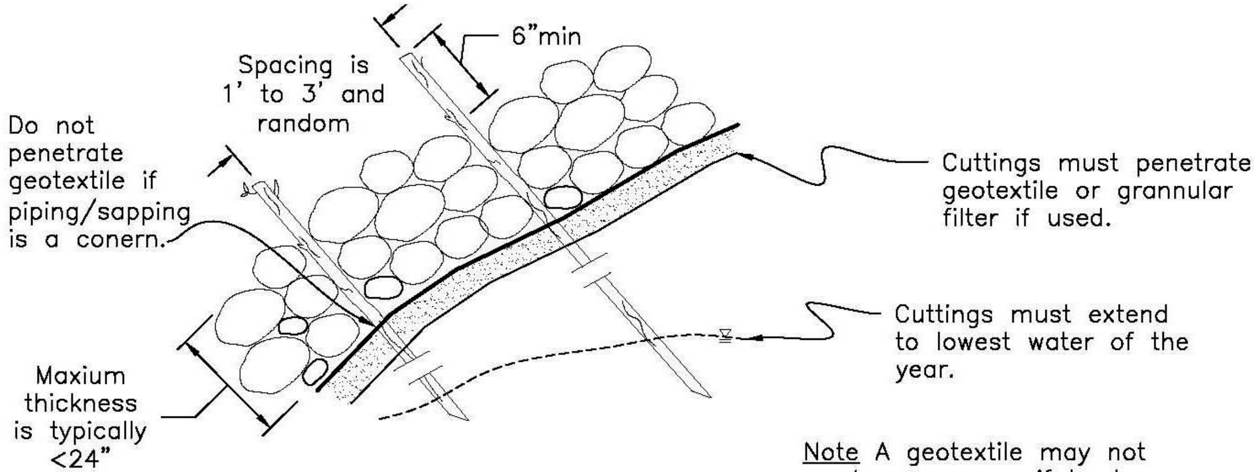
Structural Based Streambank Soil Bioengineering

A Structural Based Streambank Soil Bioengineering approach is successful when it results in a fairly static bank. The treatments that would fall in this category rely on rock, manufactured products, or other inert material to result in a fixed condition. Treatments involving stone toes, vegetated gabions, and stone deflectors generally fall in this category. Treatments such as these are generally applied at high risk sites and areas where additional bank movement is unacceptable. Installed plant material certainly provides aesthetic and habitat benefits to such projects. Plants may also increase strength and shielding to the structure but, fundamentally, the bank line limits are defined by the installed structural material. A successful project is a static project. The bank line for these projects should remain in a defined location over the life of the project. If the structural material fails, the project fails. Self healing is not really an option with these sorts of treatments.



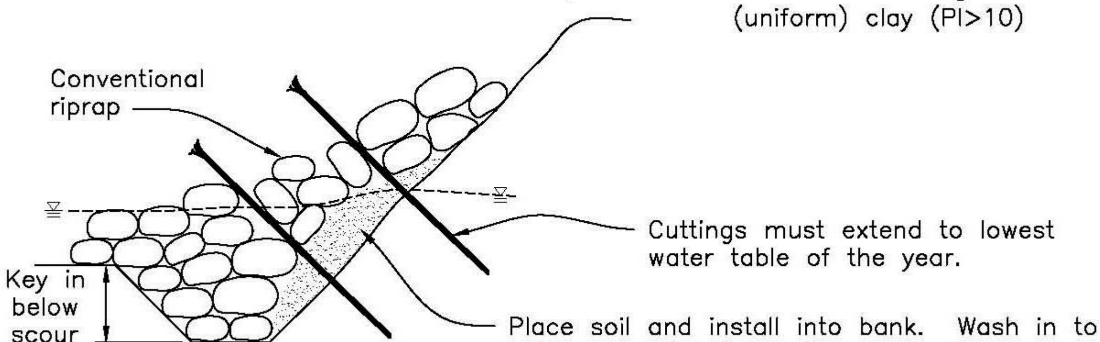


Use willow or willow type adventitiously rootable stock. Material should be from an area with similar soil, climate, and location relative to the stream. The material shall be at least two years old and free of disease, rot, or insect infestation. Material shall be harvested while dormant and soaked (1 to 14 days) before installation.

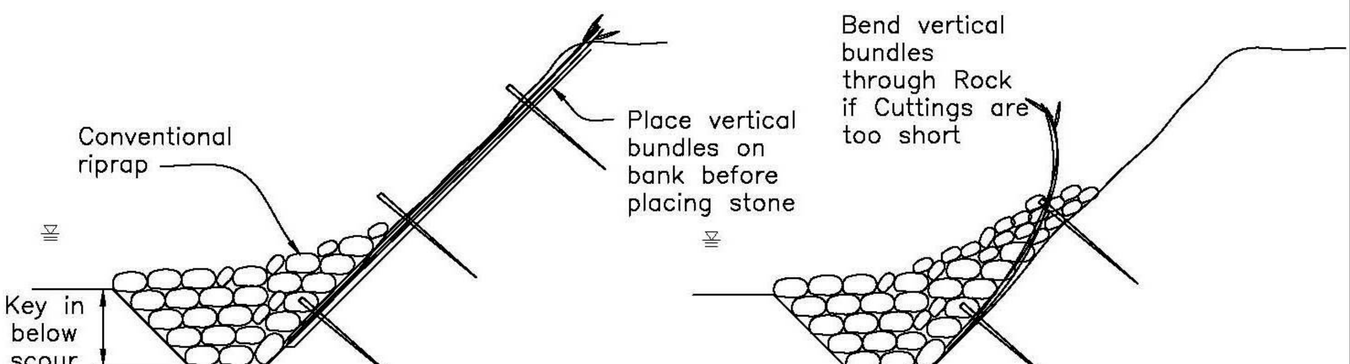


Joint Planting

Note A geotextile may not be necessary if bank material is homogenous (uniform) clay (PI>10)



Rock Toe Brush Layer

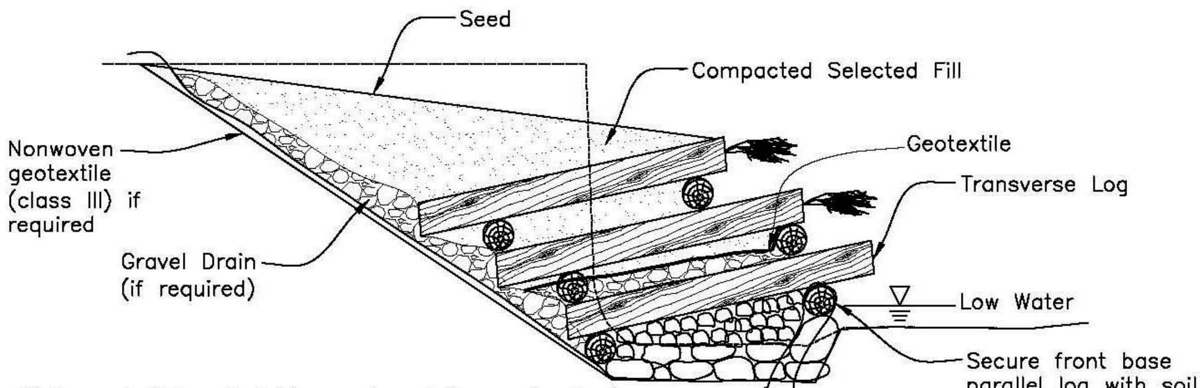


Vertical Bundles and Rock

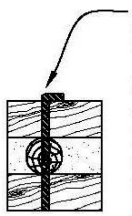
Conceptual Plan - Not for Construction

N.T.S.

NRCS Natural Resources Conservation Service United States Department of Agriculture	Cuttings and Rock – Various Options	Designed C. Hoag, J. Fripp Date 04/07 Drawn J. Renteria 04/07 Checked Approved	File Name Cuttings–N–Rock.dwg Drawing Name Cuttings Options 04/17/07 Sheet of

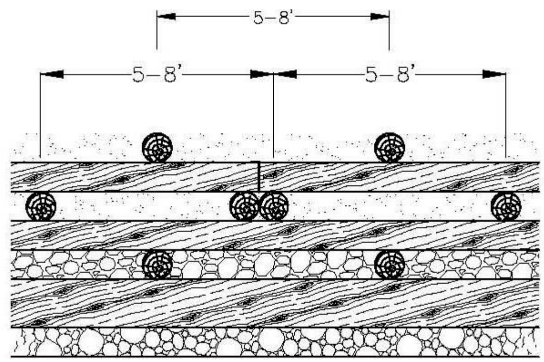


All logs shall be straight sound and freee of rot, decay or insect infestation. Salvaged timber is recommended. Diameter should be 6 to 8 inches except where otherwise approved by the engineer. The two base parallel logs maybe up to 16" in diameter.



#4 Rebar or Equivalent
Field bend 90°, both ends.

Secure longitudinal and transfer use logs as shown. Length of rebar shall penetrate a minimum of 3 members. Bend exposed ends of rebar 90 degrees to secure logs.



- Place front base parallel log.
- Place rear base paralled log. The top of the rear base parallel log should be a minimum of 4 inches below the top of the front.
- Place transverse logs perpindicular to the parallel logs at 5 to 8ft. centers. The end of the transverse logs should overlap the parallel logs by 6" to 1foot.
- Pin parallel logs to transverse logs with #4 steel rebar or equivalent.Fill open crib with rock over first set of transverse logs.
- Place non woven geotextile (Class III) on top of the rock.
- Lay sucessive parallel and transverse logs.
- Stagger parallel log butt joints such that joints on adjacent courses do not fall in the same vertical plane.
- Place a transverse log on each side of butt joint.
- Place soil and live branch cuttings in each course of the crib wall as indicated on the drawing. Soil can be any mixture of organic or non-organic soils salvaged from construction activities or from sources approved by the engineer. Always cover the rock in the first course with soil poured deep enough so as to be level with the top of the horizontal log that is parallel to the flow before placing the cuttings. Once the cuttings are placed, water and pack the soil around the cuttings to get good soil to stem contact. Compact soils with at least 1 pass over the entire surface area with a manually directed powered tamper. Live branch cuttings shall be ½ inch to 2 inch dormant stock plant material of sufficient length to reach the back side of the crib structure and out the front by 1 foot. Cuttings shall be placed at a density averaging not less than 20–30 stems per foot of width.
-

Conceptual Plan - Not for Construction

N.T.S.

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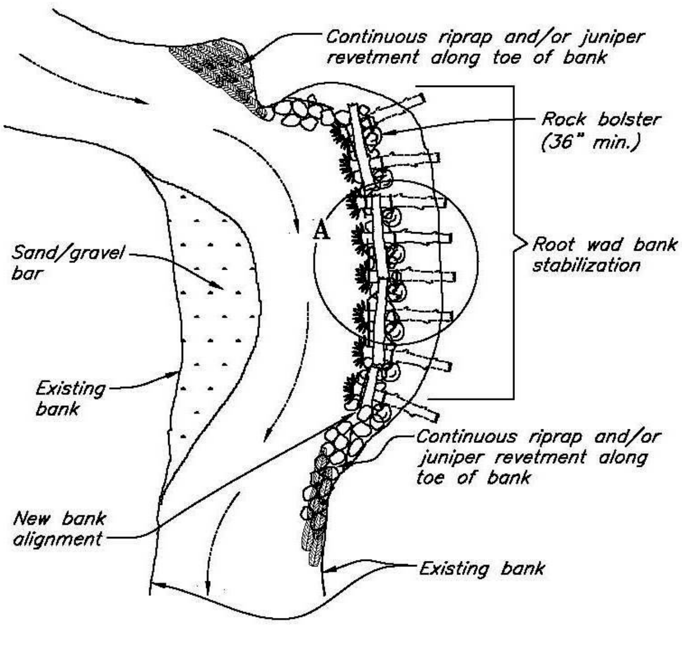
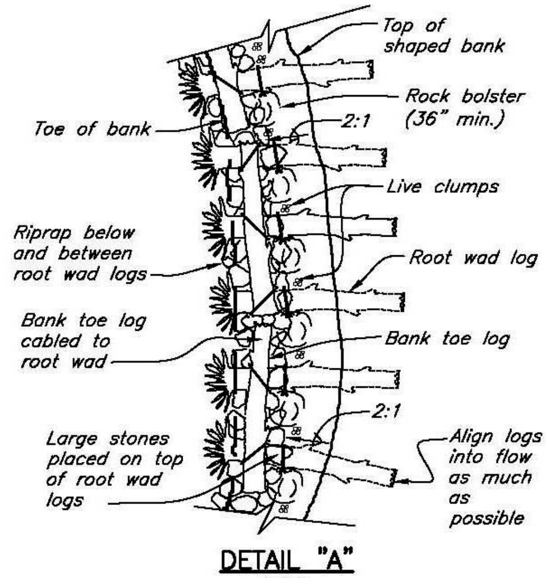
Natural Resources Conservation Service
United States Department of Agriculture

LOG CRIB STRUCTURE

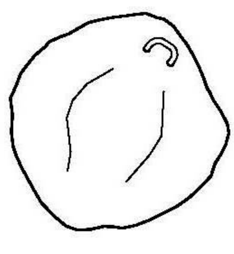
Designed	J. Fripp C. Haag, L. Saele	Date	File Name: Log Crib.dwg
Drawn	J. Renteria		Drawing Name: Log Crib Str Step5
Checked			08/14/07
Approved			Sheet of





DETAIL "A"
N.T.S.

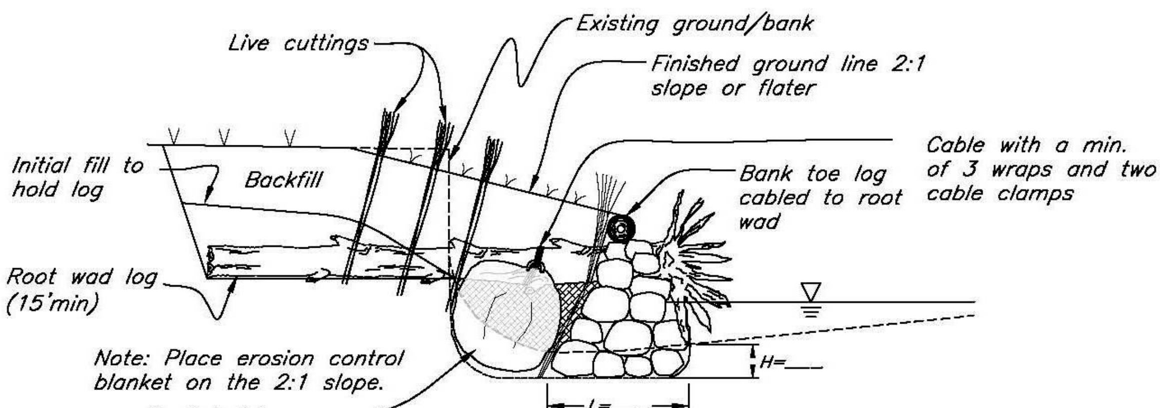
ROOT WAD REVETMENT OVER STONE
(PLAN)
N.T.S.



ROCK BOLSTER DETAIL
N.T.S.

Notes for Rock Bolster:

Secure to rock bolsters at overlap with a minumum of three wraps of 1/8 – 1/4" diameter galvanized non–greased, wire rope. If constructing in or near water drill holes in rock bolsters
with gas or pneumatic drill. Holes must be clean of all dust, debris, oil, and soap following drilling. Insert a U–shaped 1" rebar into holes several times to dispense and completely mix epoxy and eliminate air pockets.
Epoxy resin systems shall meet the requirements of ASTM C881, Type IV Grade 3. Test strength of bond after minumum cure time recommended by the epoxy manaufacturer.



Section
N.T.S.

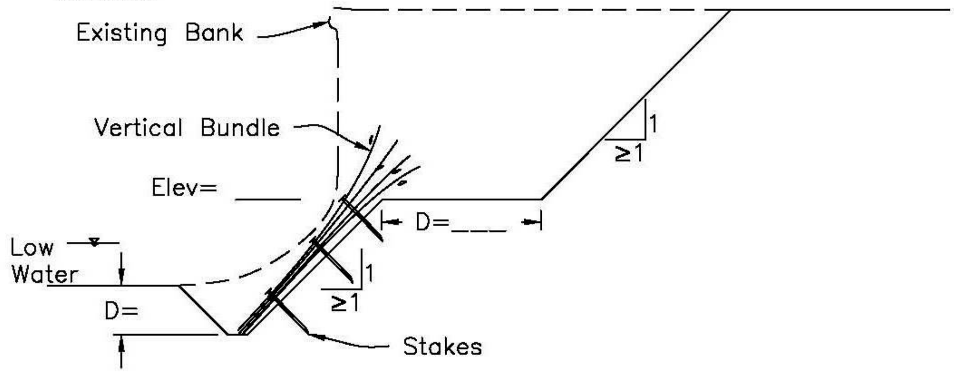
Conceptual Plan - Not for Construction

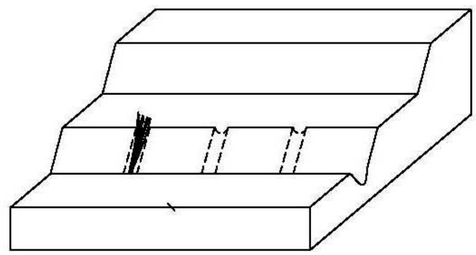
Drawings not to scale

NRCS Natural Resources Conservation Service United States Department of Agriculture	ROOT WAD REVETMENT OVER STONE *(Modified from NRCS, Alabama Root Wad Stabilization Details)*	Designed J. Fripp, C. Hoag — Date 07/07 Drawn Juan Renteria 07/07 Checked Approved	File Name Rw–Revet–Stone1.dwg Drawing Name rvRw–Revet–Stone1–Plan 07/27/07 Sheet of

STEP 1

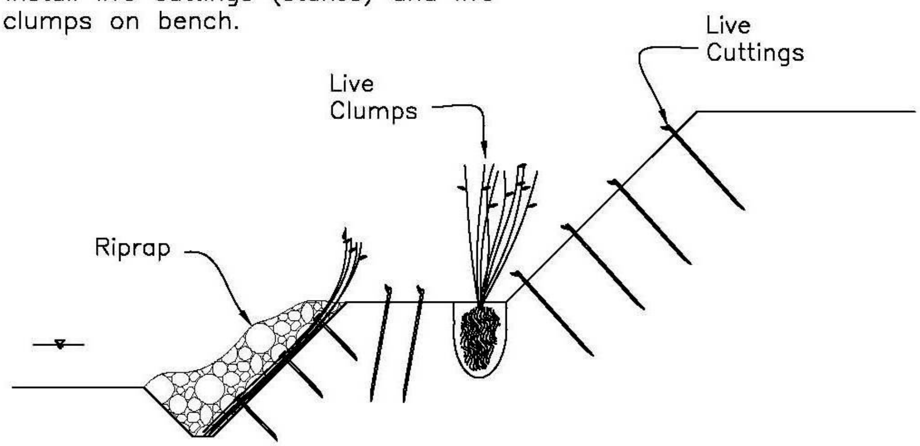
1. Clear bank of loose and failing material.
2. Excavate bench
3. Excavate lower toe and slope bank.
4. Excavate trenches down lower toe to below water (approximately every 10ft. along the bank).
5. Place and stake bundles of live cuttings into trench.
6. Backfill and wash in soil for good soil to stem contact.





STEP 2

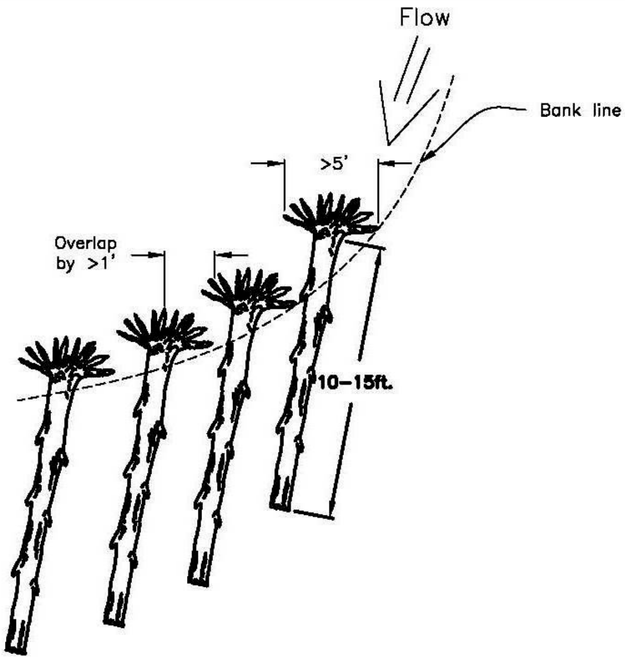
1. Place riprap on face of lower slope.
2. Install live cuttings (stakes) and live clumps on bench.

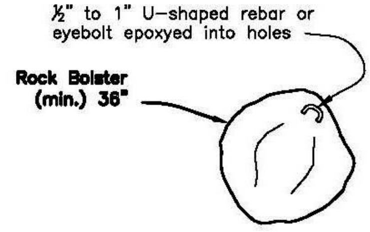


Conceptual Plan - Not for Construction

Drawings not to scale

NRCS Natural Resources Conservation Service United States Department of Agriculture	VEGETATED EXCAVATED BENCH	Designed J. Fripp, K. Worster C. Hoag — Date 08/06 Drawn Juan Renteria 08/06 Checked Approved	File Name veg-ex-bench.dwg Drawing Name Veg-excavated 08/25/06 Sheet 1 of 1

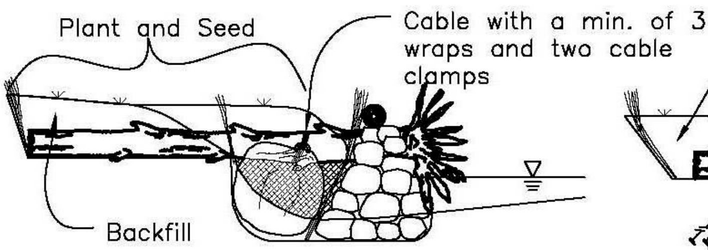




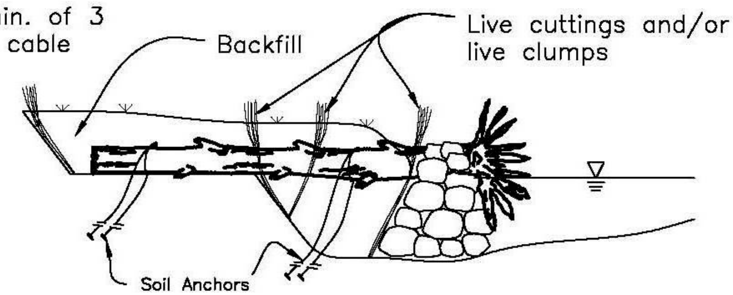
ROCK BOLSTER DETAIL
N.T.S.

Notes:

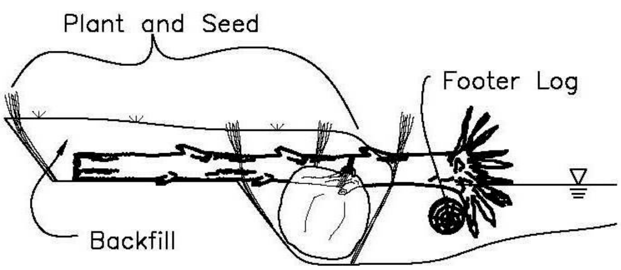
Secure logs to rock bolsters at overlap with a minumum of three wraps of ⅜" diameter galvanized non–greased, wire rope. Drill holes in rock bolsters with gas or pneumatic drill. The min. depth should be 6". Holes must be clean of all dust, debris, oil, and soap following drilling. Insert a U–shaped or eyebolt rebar into holes several times to dispense and completely mix epoxy and eliminate air pockets.
Epoxy resin systems shall meet the requirements of ASTM C881, Type IV Grade 3. Test strength of bond after minumum cure time recommended by the epoxy manufacturer.



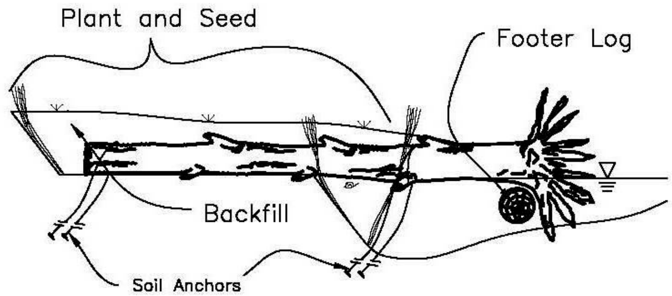
Option A
Anchor with Rock Bolster and Stone toe.



Option B
Anchor with Soil Anchors and Stone toe.



Option C
Anchor with Rock Bolster and Log toe.



Option D
Anchor with Soil Anchors and Log toe.

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N.T.S.

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ROOTWAD IN LOW BANK

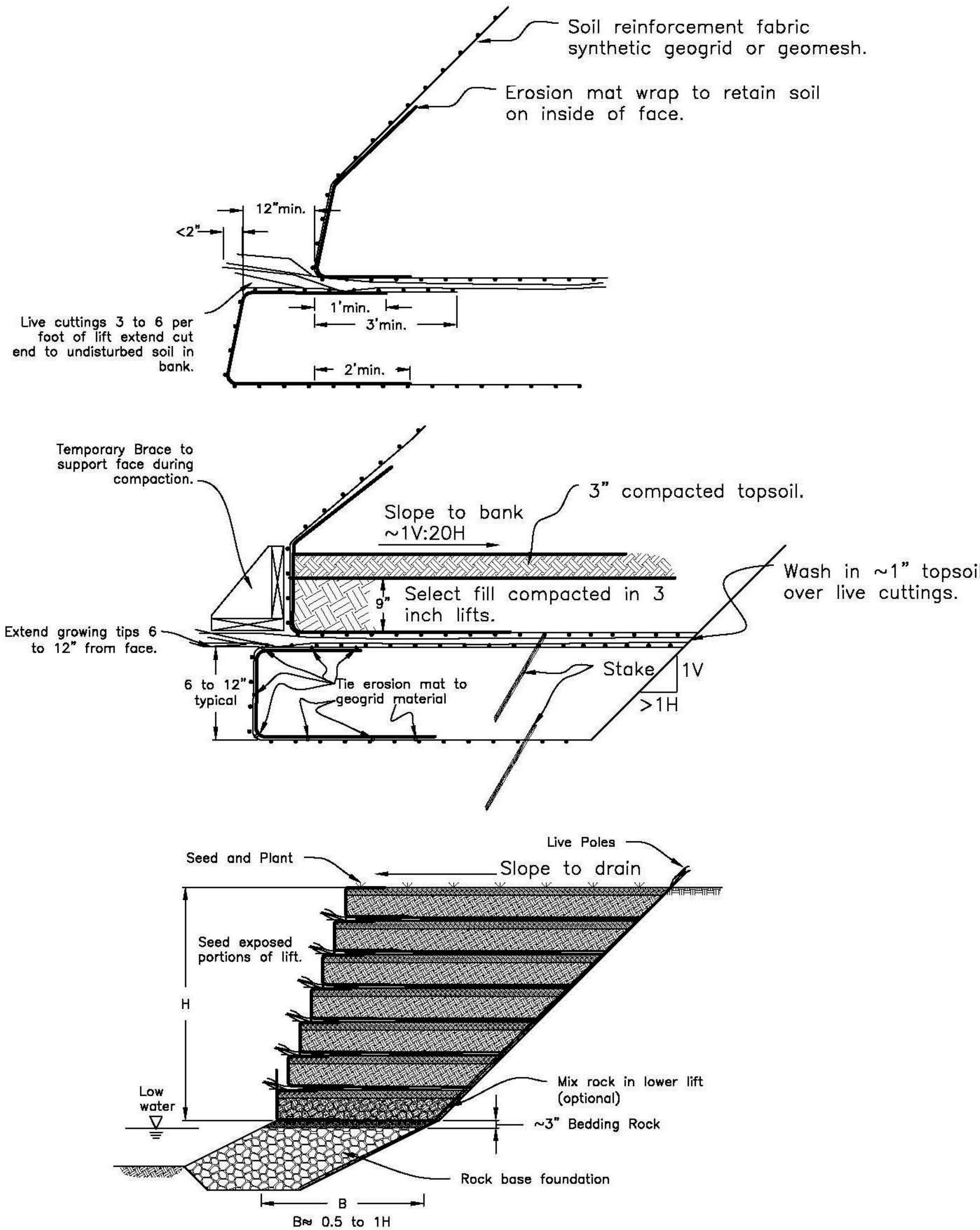
Designed	J. Fripp, K. Worster, C. Hoag	Date 01/07
Drawn	J. Renteria	01/07
Checked		
Approved		

File Name
Rootwad.dwg

Drawing Name
Rootwad

01/24/07

Sheet of



Conceptual Plan - Not for Construction

N.T.S.

NRCS Natural Resources Conservation Service United States Department of Agriculture	ENCAPSULATED SOIL LIFT	Designed J. Fripp, K. Worster Date 01/07	File Name Rootwad-n-low-bank.dwg
		Drawn J. Renteria 01/07	Drawing Name Soil Lifts
		Checked	01/24/07
		Approved	Sheet of

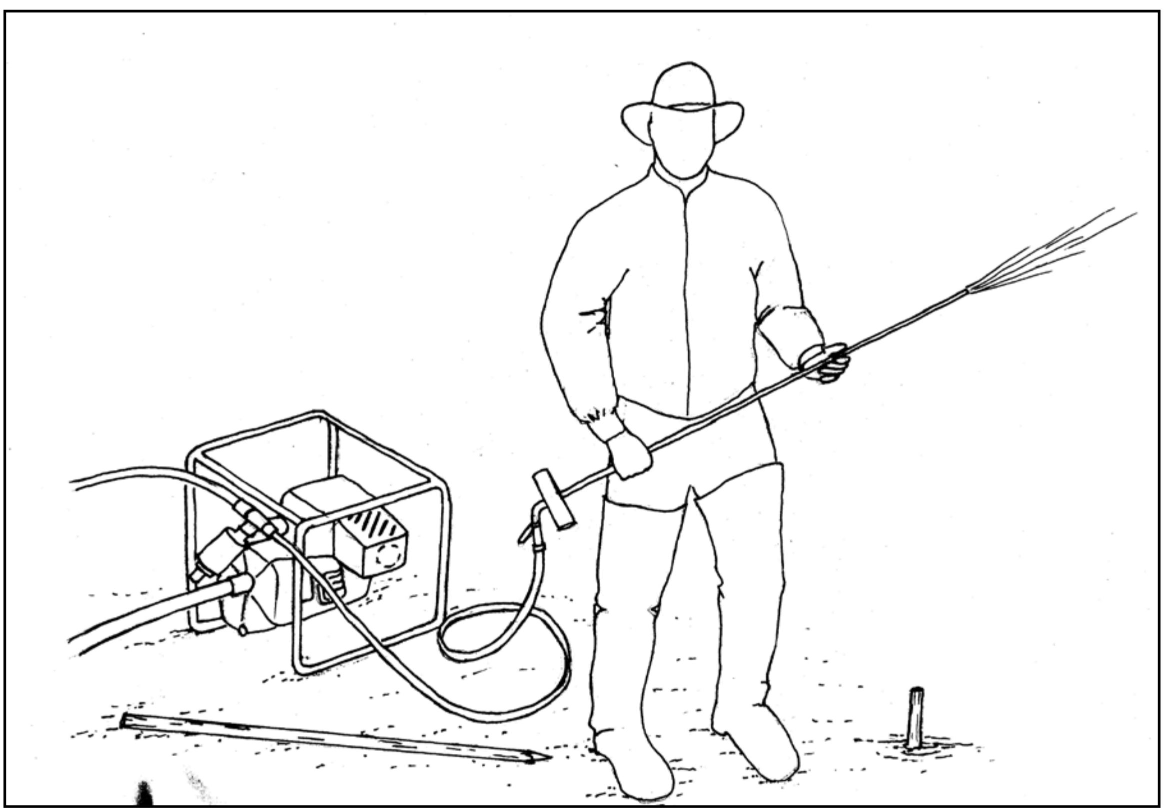
Waterjet Stinger

Adequate hydrology is critical for the success of projects involving live posts and poles. Typically, live posts and poles are installed so that the bottom of the cutting is about a foot below the lowest water table. This can be difficult in many areas since the watertable may be 3 to 6 feet below the surface. A waterjet stinger is a tool used to plant dormant, unrooted cuttings of willows, cottonwoods, dogwoods and other species as part of riparian bioengineering projects. This piece of equipment uses high pressure water to hydrodrill a hole.

The simple device consists of a nozzle of stainless steel welded to the end of a ½ inch pipe. A T-handle is located at the top to aid in the planting operations. A valve is fixed to the top to control flow. The probe is connected by a garden hose to a pump. A pressure relief valve is included on the pump for safety. The requirements for the pump include:

- gasoline powered
- small enough to be transported
- minimum 80 psi output
- 120 gpm output
- minimum vertical lift of 18 feet

The waterjet is operated by placing the nozzle against the ground and turning on the valve. As the water starts to jet out, the waterjet will slowly sink into the ground. If the probe hits a hard layer, it may slow or stop but the jet should eventually work through it. If medium sized rocks are encountered, the user will need to wiggle the jet back and forth until the water can find a way around it. Once the desired depth is reached, the user should pull the waterjet out of the hole, while continuously rocking it back and forth to create a larger hole. The

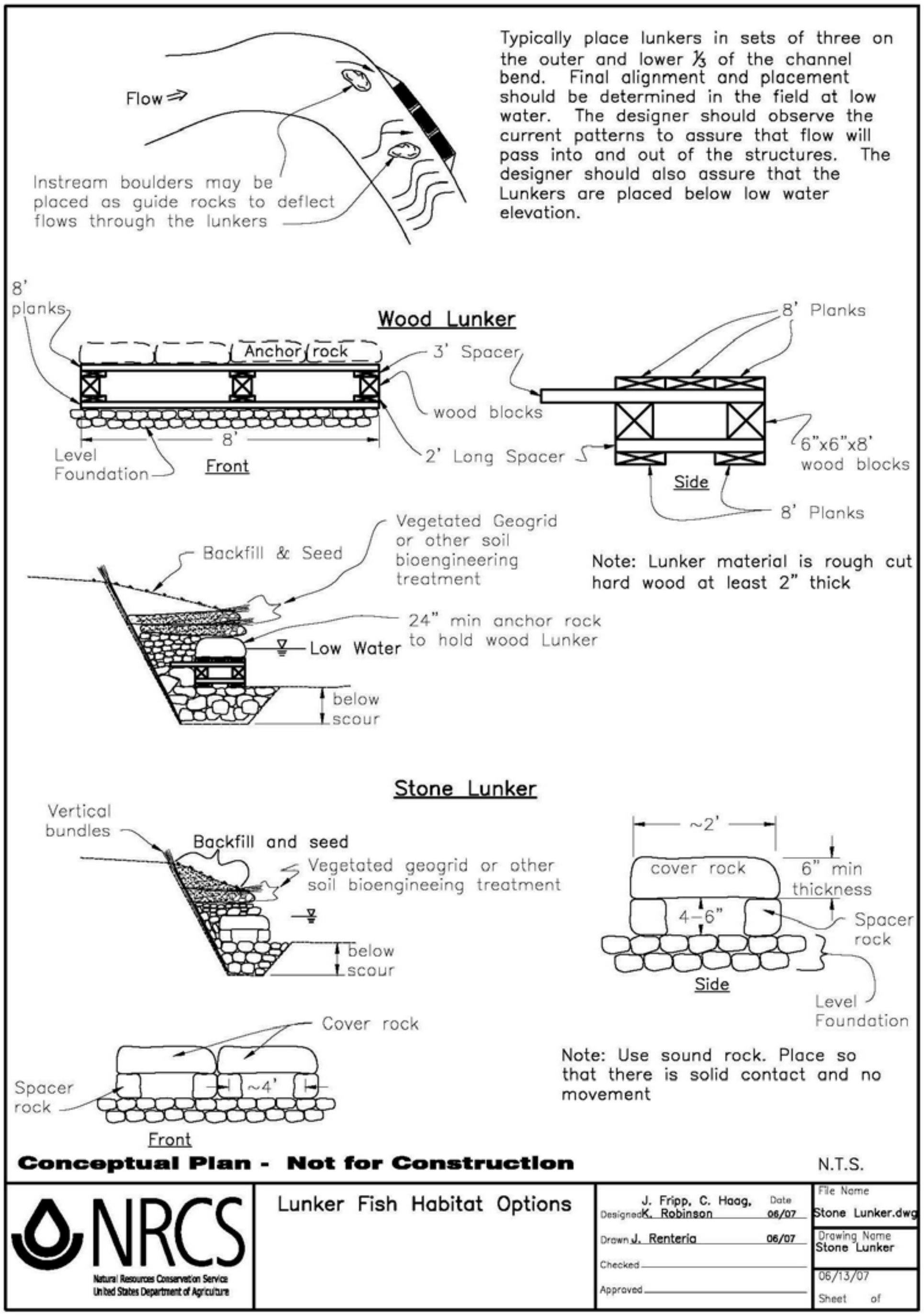


cuttings should be pushed into the hole immediately after it has been created, to avoid having it collapse or fill with silt.

The waterjet stinger works best in silt and loam soils. It can also work in some clays and sands. It does not work well in stream banks were the predominat material is boulders, cobbles, large gravels or bedrock.

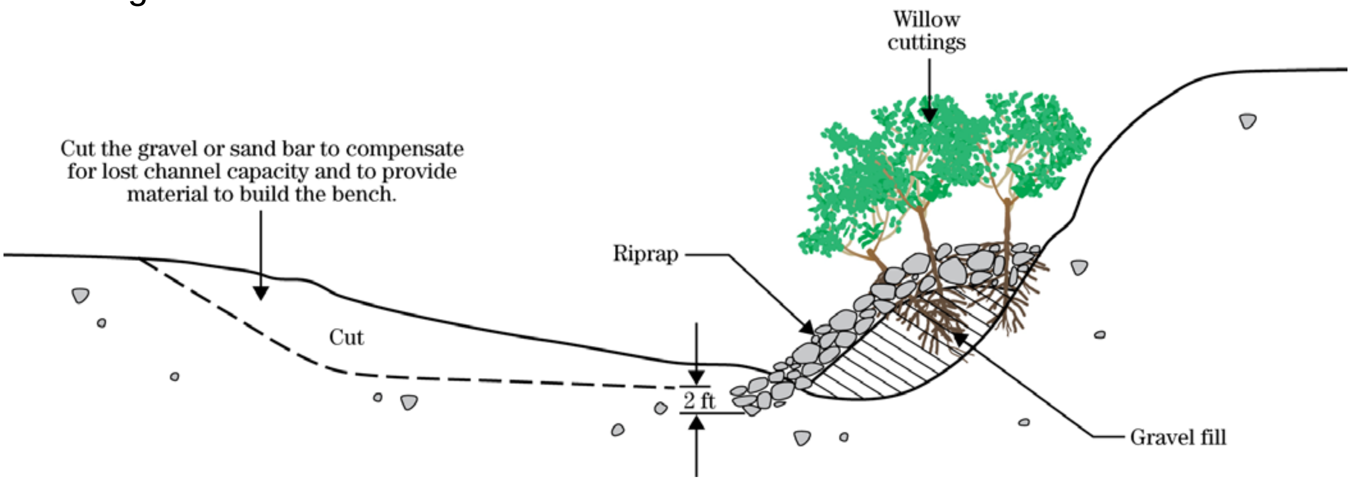
Stream Habitat Enhancement using LUNKERS

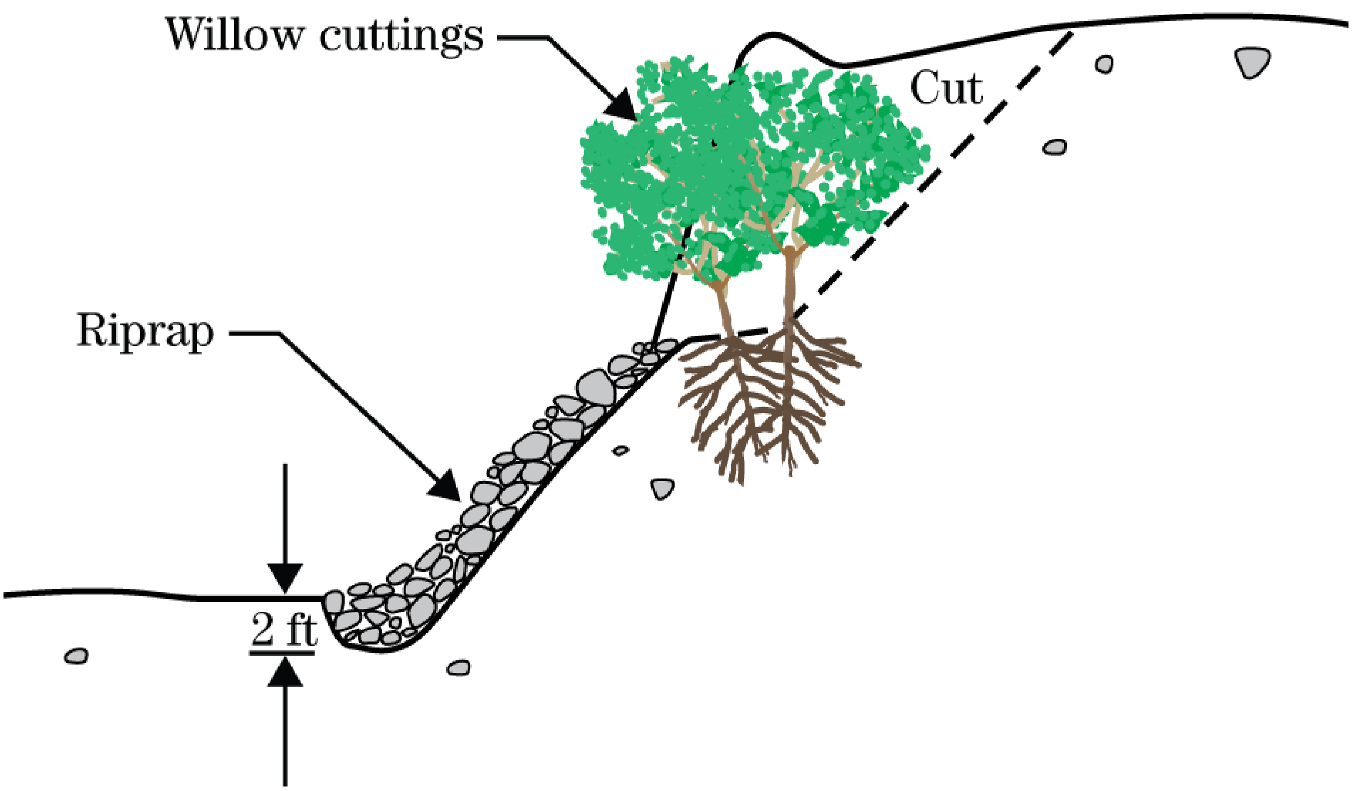
LUNKERS (Little Underwater Neighborhood Keepers Encompassing Rheotactic Salmonids) are a technique to provide both streambank stability and edge cover aquatic habitat. While their use has primarily focused on providing trout habitat, they are applicable to other species as well.



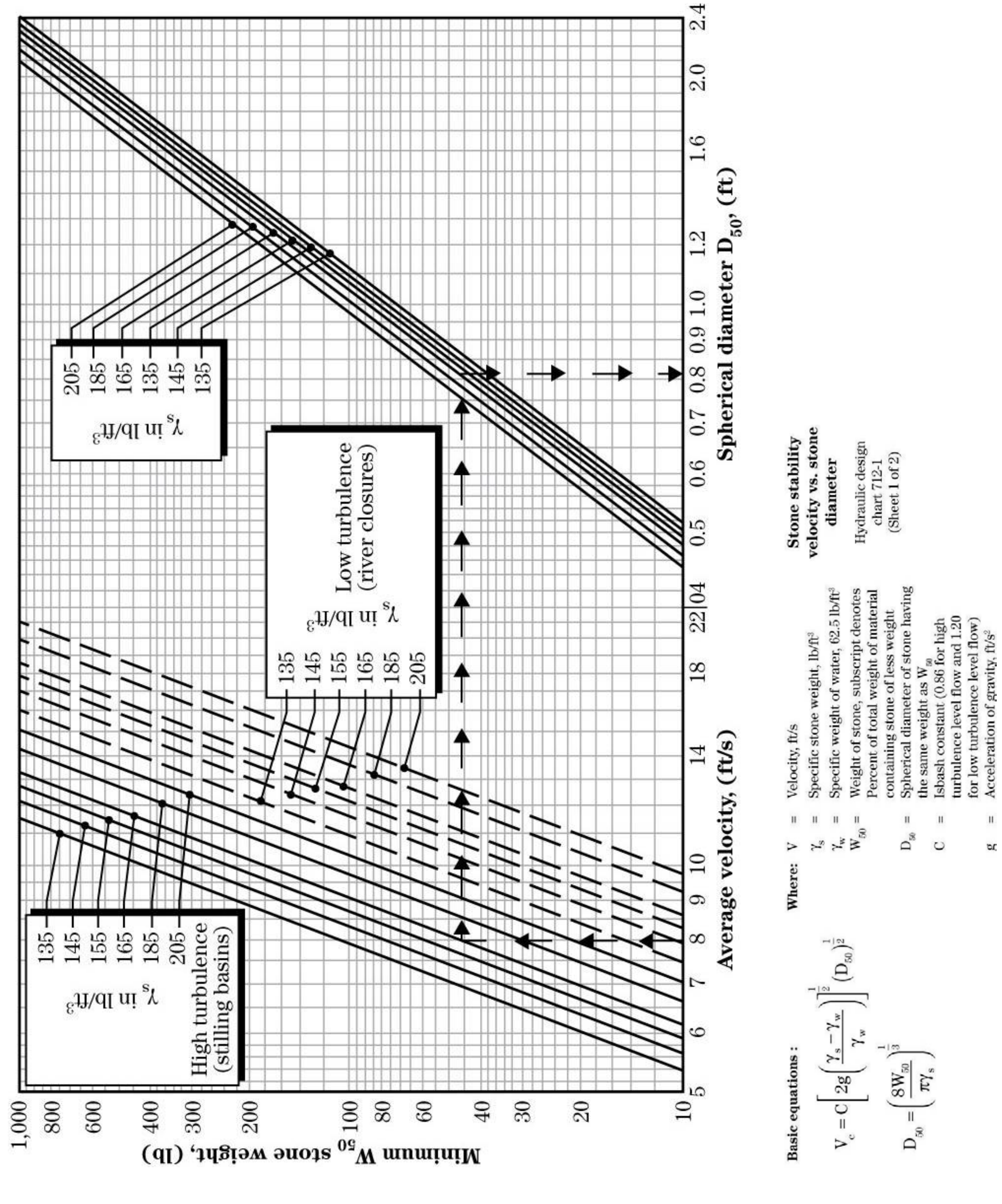
Rock Size Determination

Stone has long been used to provide immediate and permanent stream and river protection. It continues to be a major component in many of the newer and more ecologically friendly projects as well. Many State and Federal agencies have developed methods and approaches for sizing riprap, and two of those techniques are briefly described in this document. Stone sizing methods are normally developed for a specific application, so care should be exercised in matching the selected method with the intended use. While many of these were developed for application with stone riprap revetments, they are also applicable for other designs involving rock as well.





Rock Size Based on Isbash Method



Rock Size Based on Far West States – Lane Method

$$D_{75} = \frac{3.5}{C \times K} \times \gamma_w \times d \times S$$

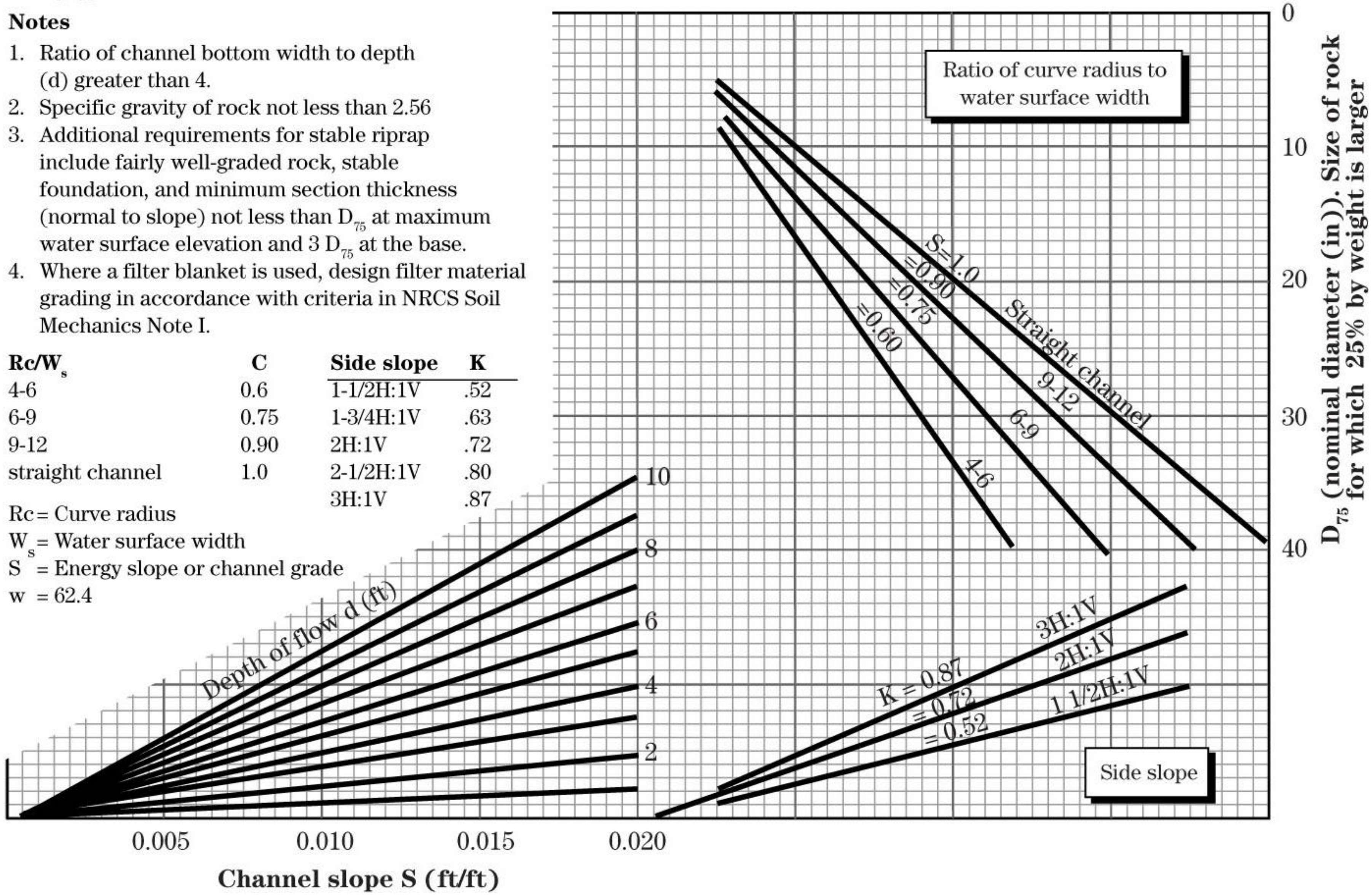
Notes

1. Ratio of channel bottom width to depth (d) greater than 4.
2. Specific gravity of rock not less than 2.56
3. Additional requirements for stable riprap include fairly well-graded rock, stable foundation, and minimum section thickness (normal to slope) not less than D_{75} at maximum water surface elevation and 3 D_{75} at the base.
4. Where a filter blanket is used, design filter material grading in accordance with criteria in NRCS Soil Mechanics Note I.

Rc/W_s	C
4-6	0.6
6-9	0.75
9-12	0.90
straight channel	1.0

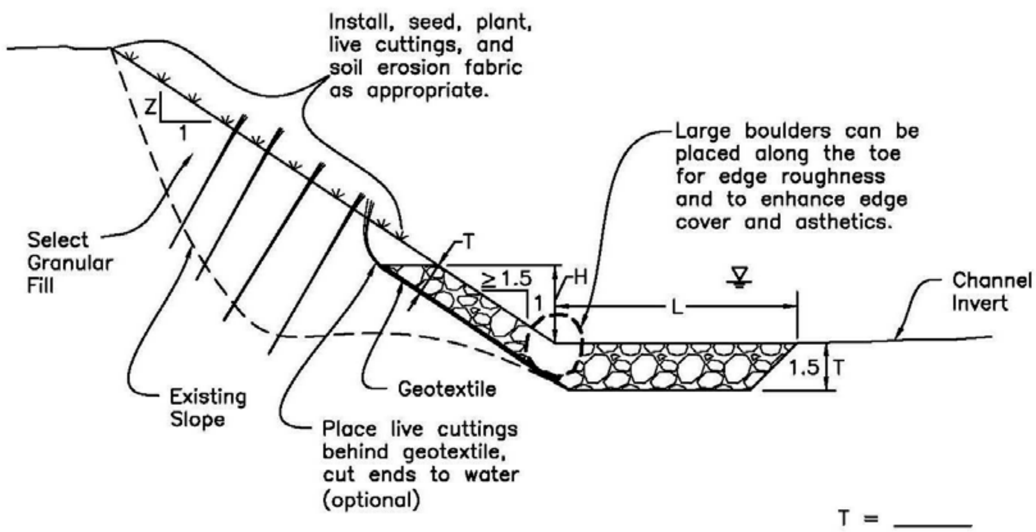
Side slope	K
1-1/2H:1V	.52
1-3/4H:1V	.63
2H:1V	.72
2-1/2H:1V	.80
3H:1V	.87

Rc = Curve radius
W_s = Water surface width
S = Energy slope or channel grade
w = 62.4

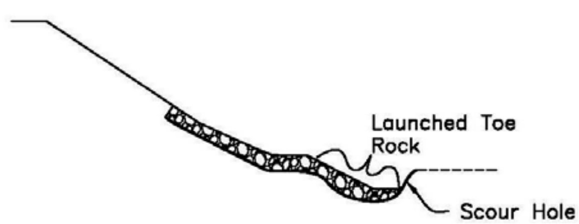


Stream Bank Stabilization with Rock

Structural measures for streambank protection, particularly rock riprap, have been used extensively in support of stream restoration designs. Stone continues to be an important component of many stream restoration and stabilization projects, where stone or rock provides the needed weight or erosion protection, as well as providing a needed foundation for other design elements.



Direction of Bank Seepage	Z
No Seepage	1.6
Parallel to Slope	3
Horizontal Flow	3.3



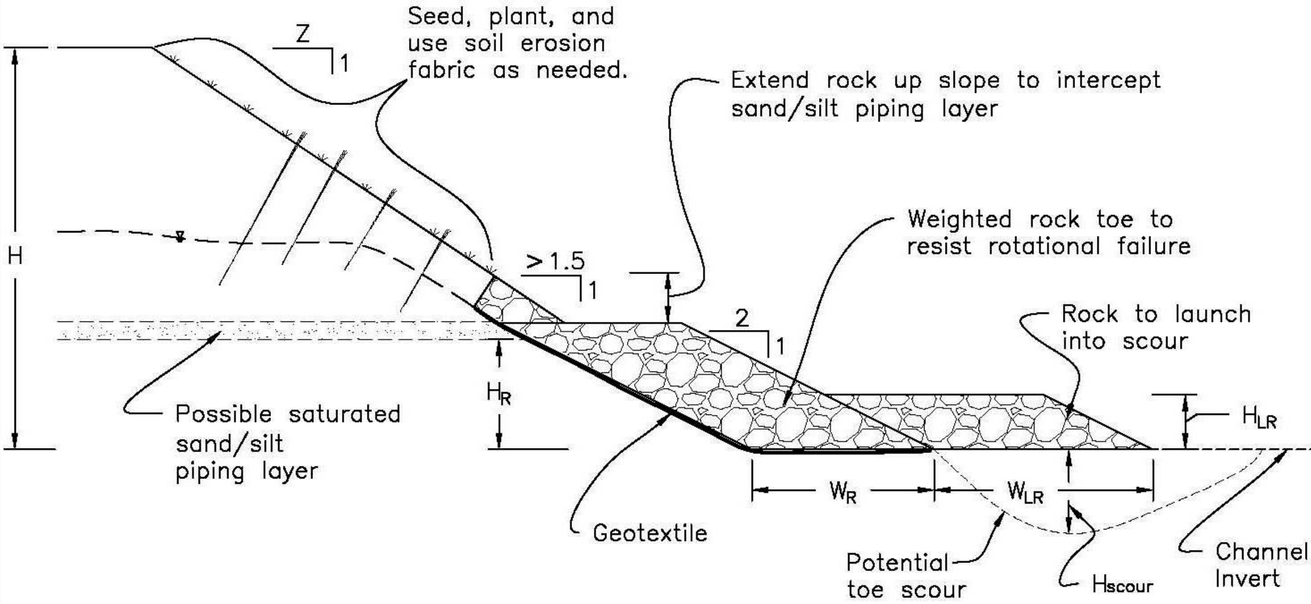
Rock launches into toe scour to prevent undermining of rock bank protection.

Notes:

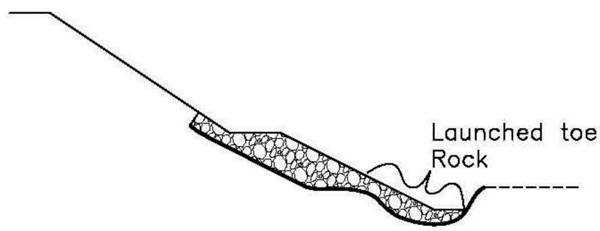
- Launchable toe is not applicable if channel invert is to be lined.
- Slope(Z) is based on an infinite slope stability analysis of an angular gravel fill material with $\Phi'=35$, FS=1.1, $\gamma_b=68.5$, $\gamma_{sat}=130.9$.
- A site specific geotechnical analysis is recommended.
- Live cuttings should extend into undisturbed soil and the lowest water table. Cuttings shall be washed in during installation to ensure good soil to stem contact.
- Seeding, live cuttings, and soil erosion fabric is not applicable for railroad embankment due to RR O&M practice.

Conceptual Plan - Not for Construction N.T.S.

NRCS — Natural Resources Conservation Service, United States Department of Agriculture	Stone Toe Bank Protection – Granular Soils – Launchable Toe Scour Protection	Designed: Fripp, Doerge, Robinson — Date 06/08 Drawn: K. Miller — 06/08 Checked: Approved:	File Name: Granular Soils.dwg Drawing Name: Granular Soils 06/16/08 Sheet of



H=20
H_{scour}=5'
H_R=6'
W_R=6'
Z=3
H_{LR}=3'
W_{LR}=12'



Rock launches into toe scour to prevent undermining of weighted rock toe.

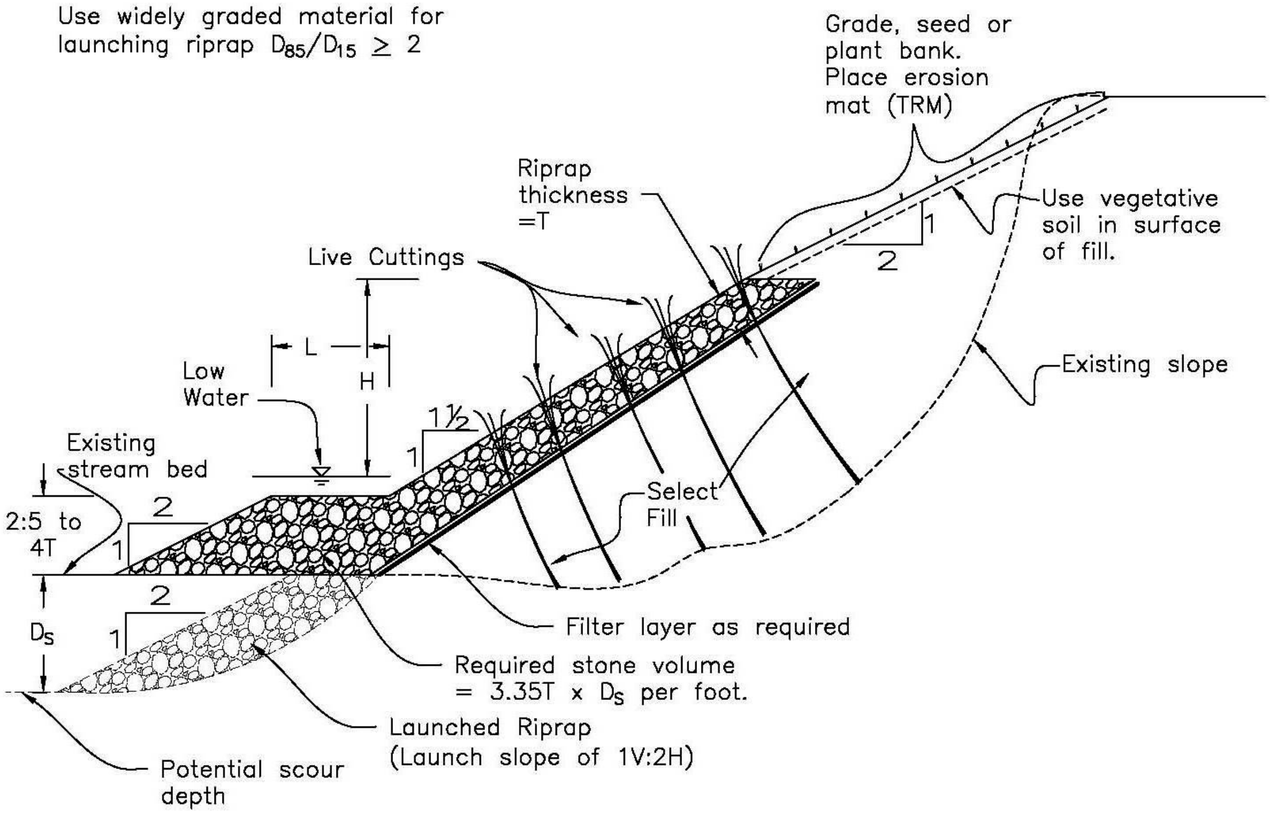
Notes:

- Slope(Z) is based on the stability analysis of a clay slope with Φ= 25°, C= 75psf, and γ=115pcf. F.S.=1.3. A site specific geotechnical analysis may result in determining that the soil parameters would allow for a steeper slope or require a flatter slope.
- Use a minimum slope of Z=4 if upper bank is predominantly sand.
- Geotextile may not be necessary if bank material is homogenous (uniform) clay (PI>10).
- Extend live cuttings through riprap and graded bank to water table.
- Do not install live cuttings through geotextile if piping/sapping is a concern.

Conceptual Plan - Not for Construction

N.T.S.

NRCS Natural Resources Conservation Service United States Department of Agriculture	Stone Toe Bank Protection — Cohesive Soils, Launchable Scour Protection	Designed W. Anderson, J. Fripp Date 04/07 Drawn J. Renteria 04/07 Checked Approved	File Name Cohesive–Soils.dwg Drawing Name LaunchableScour 04/11/07 Sheet of



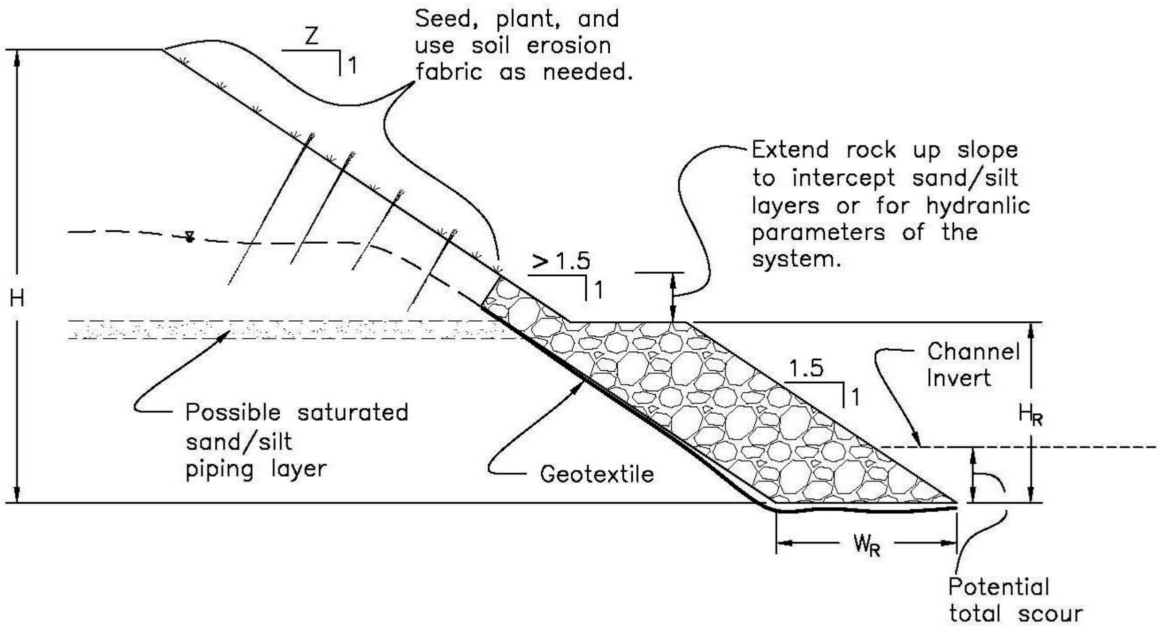
Notes:

- Live cuttings should extend to undisturbed soil and should be washed in during installation to ensure good soil to stem contact.
- Further analysis required for final design.

Conceptual Plan Not for Construction

N.T.S.

NRCS Natural Resources Conservation Service United States Department of Agriculture	Riprap Toe Protection with Launch Toe Scour Protection	Designed W. Anderson, J. Fripp, K. Worster Date 10/06	File Name Riprap–Toe.dwg
		Drawn J. Renteria 10/06	Drawing Name Riprap–Toe
		Checked	10/24/06
		Approved	Sheet of



H	H_R	W_R	Z
20	2	2	2.5
	5	5	2
25	5	5	2.5
	8	8	2

Notes:

- Slope(Z) is based on the stability analysis of a clay slope with $\Phi = 25^{\circ}$, C= 75psf, and γ=115pcf. F.S.=1.3 A site specific geotechnical analysis may result in determining that the soil parameters would allow for a steeper slope or require a flatter slope.
- Use a minimum slope of Z=4 if upper bank is predominantly sand.
- Geotextile may not be necessary if bank material is homorgenous (uniform) clay (PI>10).
- Extend live cuttings through riprap and graded bank to water table.
- Do not install live cuttings through geotextile if piping/sapping is a concern.

Conceptual Plan - Not for Construction

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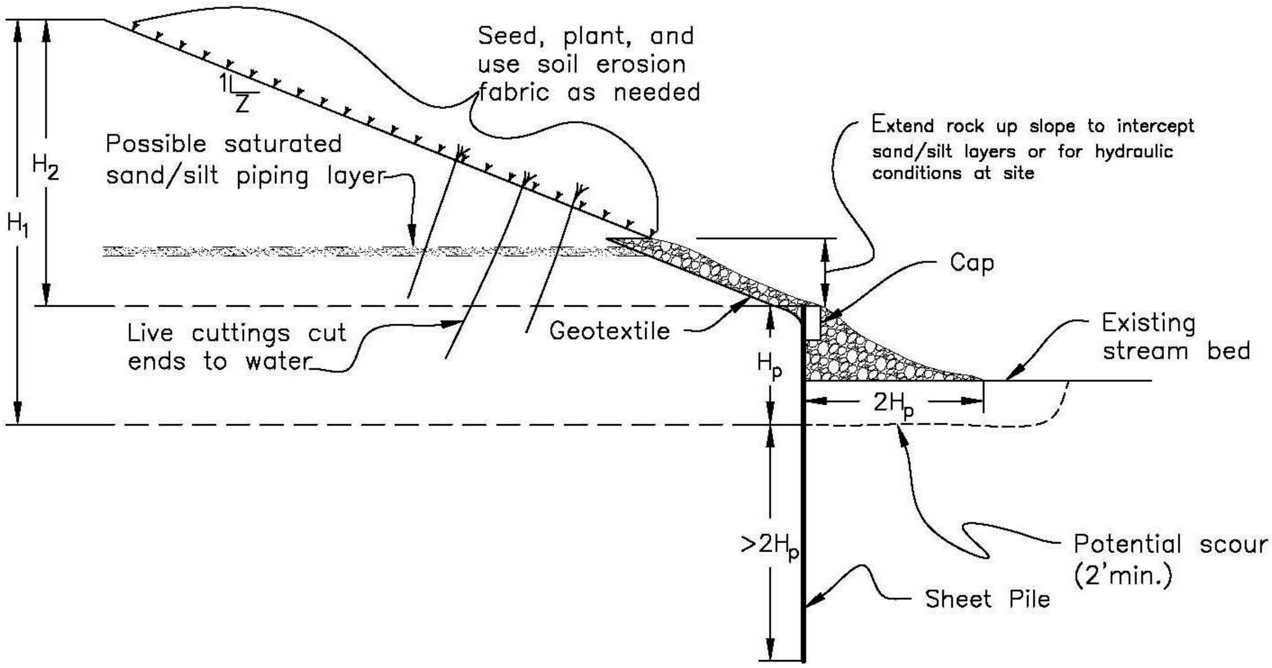
Natural Resources Conservation Service
United States Department of Agriculture

Stone Toe Bank Protection — Cohesive Soils

Designed	W. Anderson, J. Fripp	Date 04/07
Drawn	J. Renteria	04/07
Checked		
Approved		

File Name: Cohesive–Soils.dwg
Drawing Name: Cohesive Soils
04/10/07
Sheet of



H_2 = 18'
H_1 = 25'
Z = 2.5
H_p = 8'

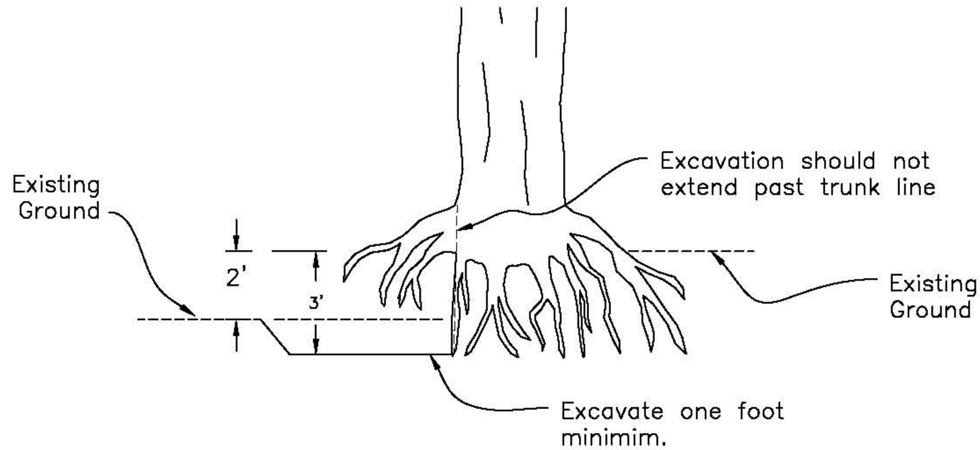
Note:

- Slope (Z) is based on the stability analysis of weathered, blocky clay with ø=18, c=100 psf, and γ=122pcf. F.S.=1.4.
- A site specific geotechnical analysis may allow for a steeper slope.
- Live cuttings shall extend into undisturbed soil and the lowest water table. They should be washed in during installation to ensure good soil to stem contact.
- H_p no greater than 15'

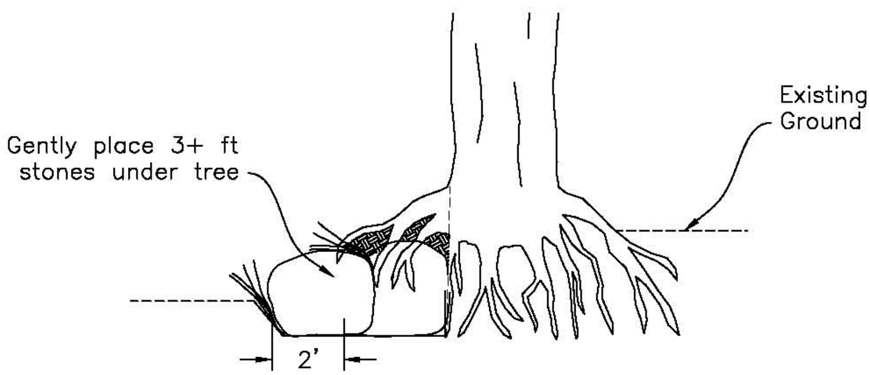
Conceptual Plan - Not for Construction

N.T.S.

NRCS Natural Resources Conservation Service United States Department of Agriculture	Sheet Pile Toe Weathered Blocky Clay	Designed J. Fripp, D. McCook, L. Fragameli — Date 04/08	File Name ShtPile_Toe_WBC.dwg
		Drawn J. Renteria 04/08	Drawing Name ShtPile_Toe_WBC
		Checked	04/16/08
		Approved	Sheet of



Step 1
- Remove loose and failing soil.
- Avoid damage to roots.
- Excavate at least one foot into bed.
- If excavation extends past trunk line, consider coppicing.



Step 2
- Place live cuttings into hole and around roots.
- Place 3 to 5 36"+ stones into trench and under roots to support tree. It may be necessary to lift the roots.
- Avoid damage to roots.

Conceptual Plan - Not for Construction

N.T.S.

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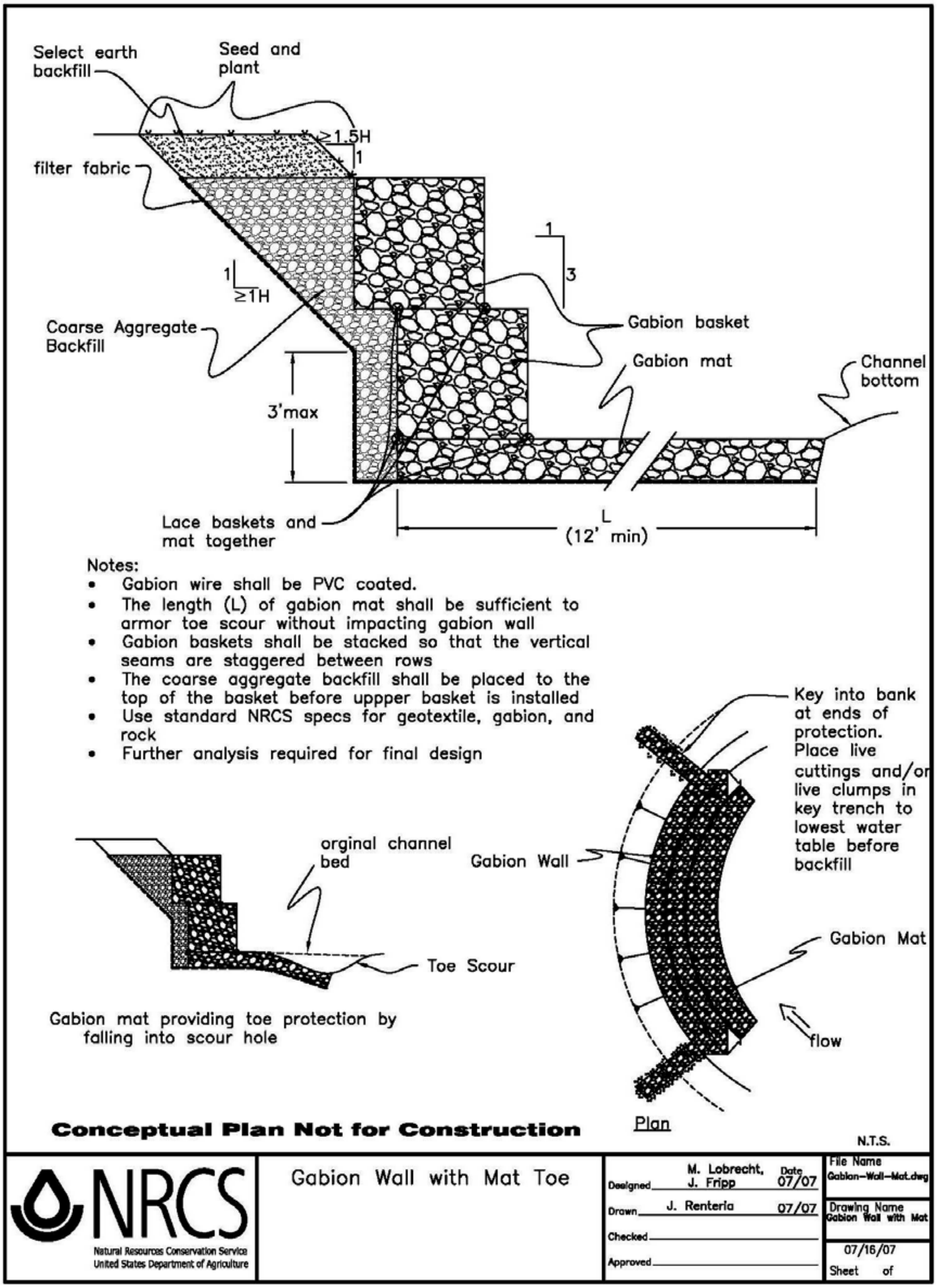
Natural Resources Conservation Service
United States Department of Agriculture

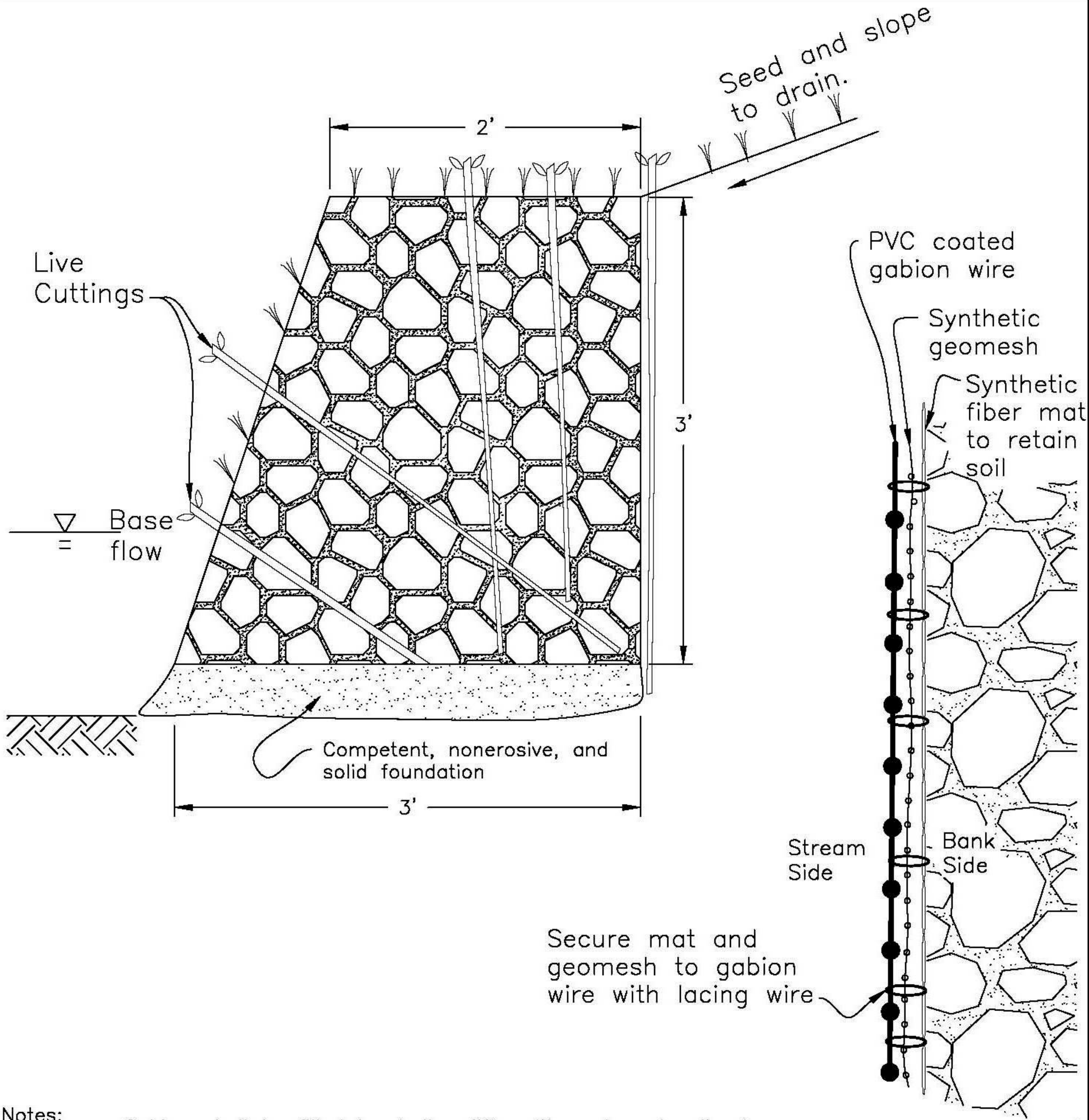
Placed boulders to support trees at edge of bank

Designed	J. Fripp C. Haag	Date 11/05	File Name Rock-udr-Tree.dwg
Drawn	J. Renteria	11/05	Drawing Name tree
Checked			02/02/06
Approved			Sheet 1 of 1

Gabion and Gabion Type Bank Stabilization

Gabions offer important advantages for bank protection. They can provide vertical protection in high-energy environments where construction area is restricted. Gabions can also be a more affordable alternative, especially where rock of the needed size for riprap is unavailable. Gabion wire mesh baskets can be used to stabilize streambank toes and entire slopes. Gabion and gabion type treatments can also be compatible with many soil bioengineering practices.





Detail

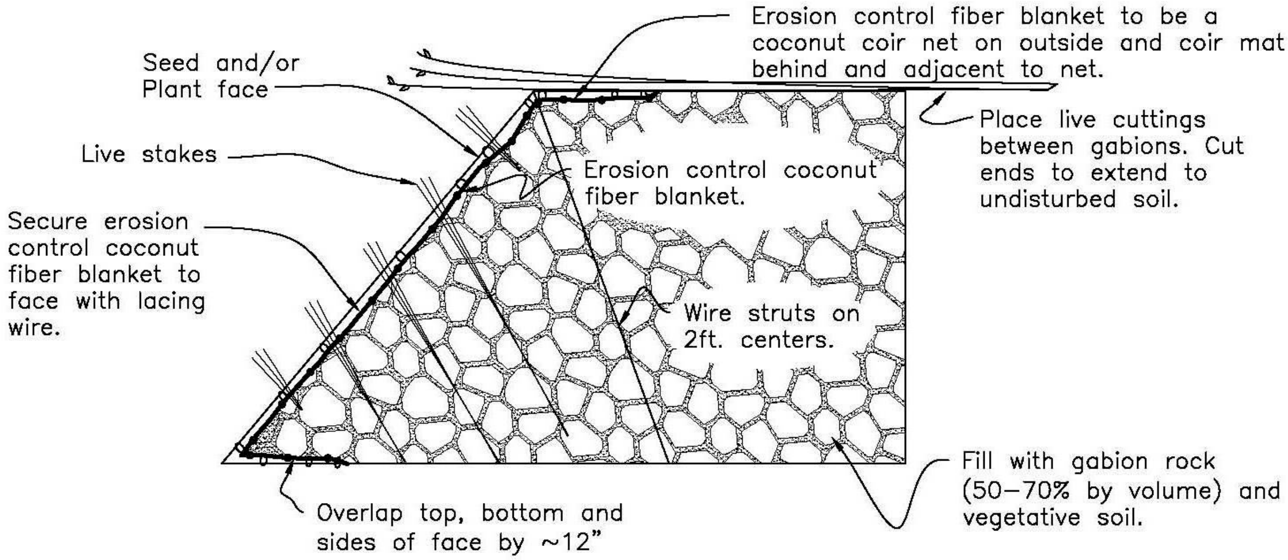
Notes:

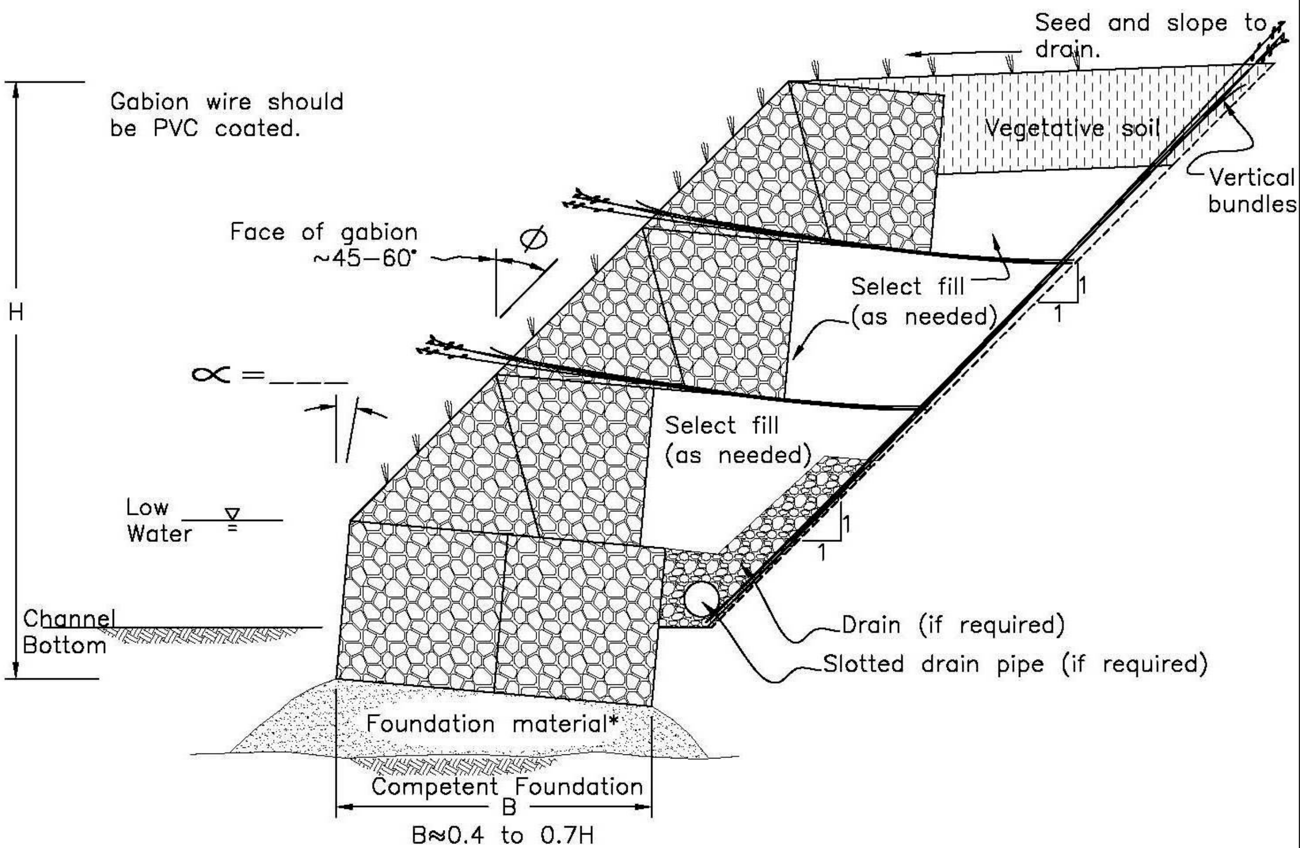
- Gabion shall be filled in shallow lifts with rock and soil mix.
- Fill gabion with rock (60–70% by volume) and vegetative soil.
- Place stone first in lift followed by soil
- Maintain rock to rock contact with in gabion.
- Place live cuttings as gabion is being filled. Cuttings must extend to lowest water of the year
- Wash in soil to achieve good soil to stem contact
- Seed soil along face as basket is filled

Conceptual Plan Not for Construction

N.T.S.

NRCS Natural Resources Conservation Service United States Department of Agriculture	Vegetated Green Gabion – Low Bank ***based on a modification of Maccaferi Green Gabion**	Designed: Fripp, Robinson, Gullet — Date 04/07 Drawn: J. Renteria — 04/07 Checked: Approved:	File Name: Green–Gabion–Low.dwg Drawing Name: Green–Gabion–Low–Bank 05/03/07 Sheet of





*Foundation of gabion wall should be competent and non–erosive. For example: extend to competent insitu material or establish a base with grouted rock or concrete mud slab (shown). Foundation should be below frost line and have adequate bearing capacity.

Conceptual Plan Not for Construction

N.T.S.

NRCS
Natural Resources Conservation Service
United States Department of Agriculture

Green Gabion

Designed: W. Anderson, C. Hoag, J. Fripp, K. Worster — Date: 10/06
Drawn: J. Renteria — 10/06
Checked:
Approved:

File Name: Green–Gabion.dwg
Drawing Name: Green–Gabion
01/24/07
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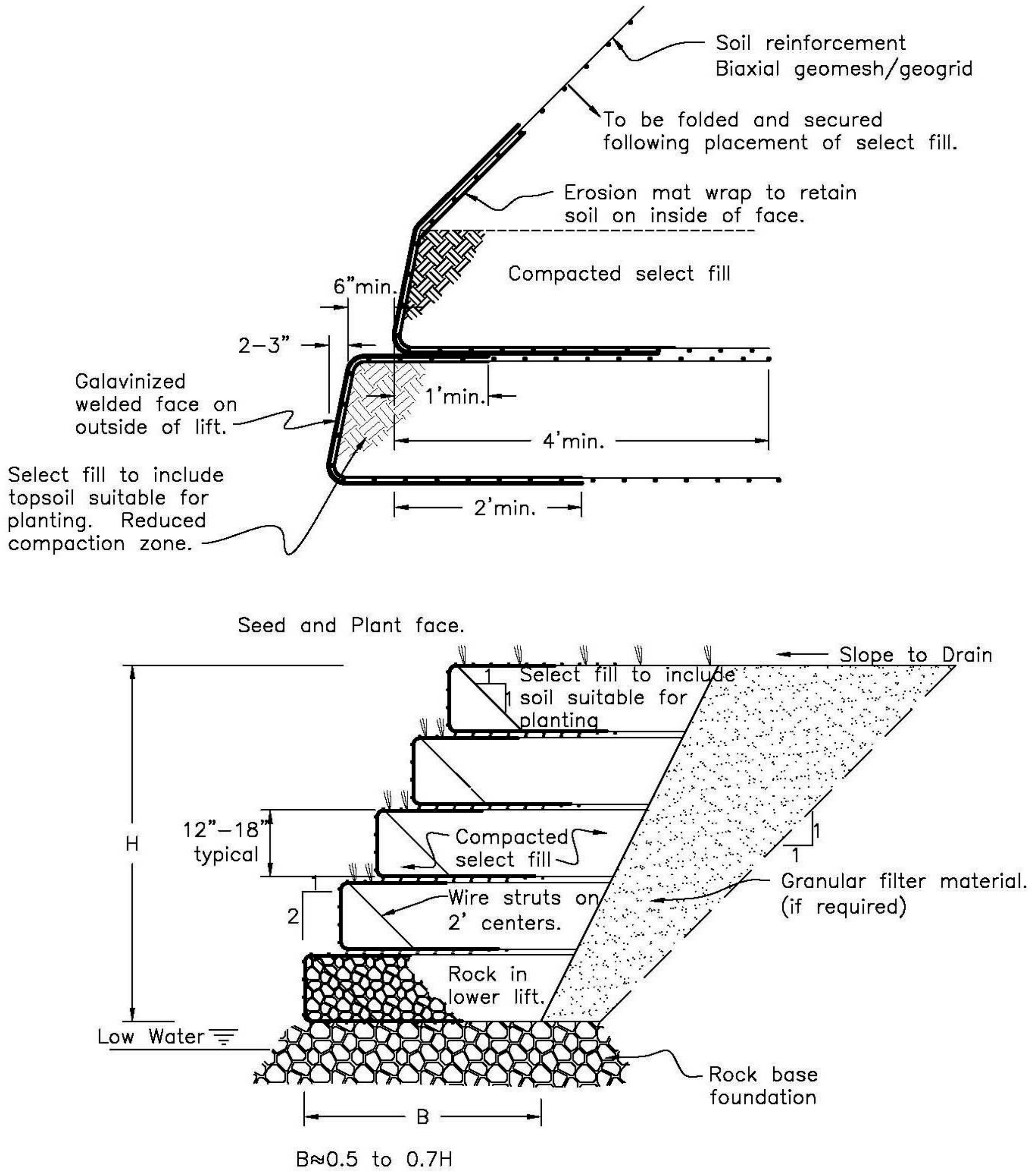


Notes:

- Wire face shall be PVC coated.
- Foundation shall be competent and non-erosive.
- Further analysis required for final design.

Conceptual Plan Not for Construction

N.T.S.

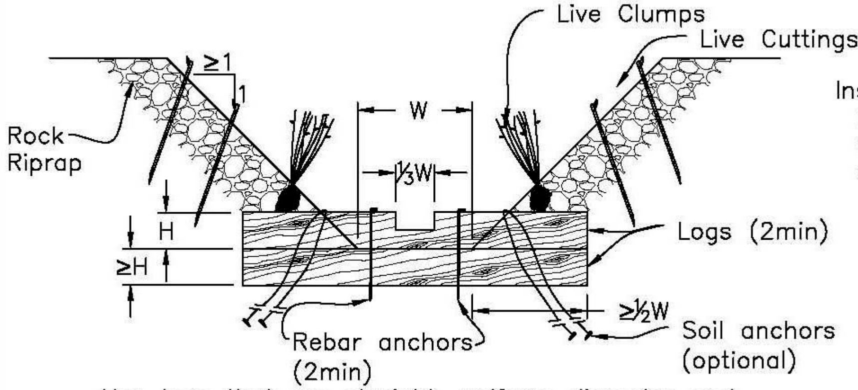
Natural Resources Conservation Service United States Department of Agriculture	Vegetated Wireface MSE Wall	Designed W. Anderson, J. Fripp, K. Worster Date 10/06 Drawn J. Renteria 10/06 Checked Approved	File Name Wireface.dwg Drawing Name Wireface 10/24/06 Sheet of

Grade Stabilization

Grade stabilization or grade control structures typically used to stop head cutting, reduce upstream energy, and to prevent bed scour. The establishment of a stable grade in an eroding stream is a critical first step in any stream bank stabilization or restoration effort. Grade control is an essential component to establishing stability in a degrading stream, or in one that is subject of forces that may cause degradation. Bank protection of any sort, is generally ineffective over the long term if the channel continues to degrade.

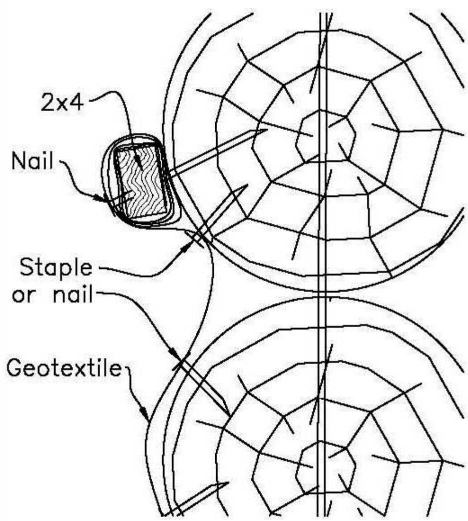
There are certain features that are common to most grade control structures. These features include a control section for accomplishing the grade change, an energy dissipation section, and protection of the upstream and downstream approaches. The structures act in an upstream direction so they must be appropriately spaced. There is considerable variation in the design of these features. Several types are illustrated in the concept plans provided. The applicability of a particular type of structure to any given situation depends on a number of factors such as: hydrologic conditions, sediment size and loading, channel morphology, floodplain and valley characteristics, availability of materials, and project objectives, as well as, the inevitable time and funding constraints. The successful use of a particular type of structure in one situation does not necessarily ensure that it will be effective in another. Some advantages and disadvantages of different structure types are outlined in the table below.

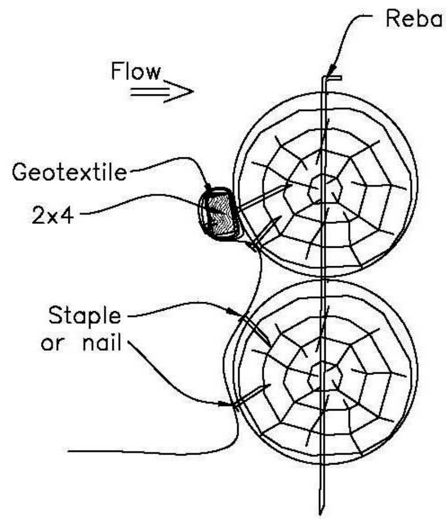
Structure Type	Advantages	Disadvantages
Loose-rock Structures	Economical to design and build, limited environmental impacts, ease of construction	Generally limited to less than about 3 ft drop heights, potential for displacement of rock due to seepage flows
Channel Linings	Provides for energy dissipation through the structure, can be designed to accommodate fish passage	Significant design effort, relatively high cost, larger construction footprint due to length of structure
Loose-rock Structures with Water Cutoff	Provides positive water cutoff that eliminates seepage problems and potential for rock displacement, higher drops heights up to about 6 ft	More complex design required, higher construction cost than simple loose-rock structures, more potential for fish obstruction at higher drop heights
Structures with Pre-formed Scour Holes and Water Cutoffs	Improved energy dissipation, scour holes provide stable reproductive habitat, higher drops heights up to about 6 ft	Larger construction footprint, more complex design effort required, increased construction cost, more potential for fish obstruction at higher drop height
Rigid-drop Structures	Can accommodate drops heights greater than 6 ft, provides for energy dissipation, single structure can influence long reach of stream	High construction cost, large construction footprint, significant potential for obstruction to fish, and potential for downstream channel degradation due to tapping of sediment
Alternative Construction Materials	Economically feasible where stone is costly, and local labor force is cheap and available	Often lack detailed design guidance, increased monitoring and maintenance often required



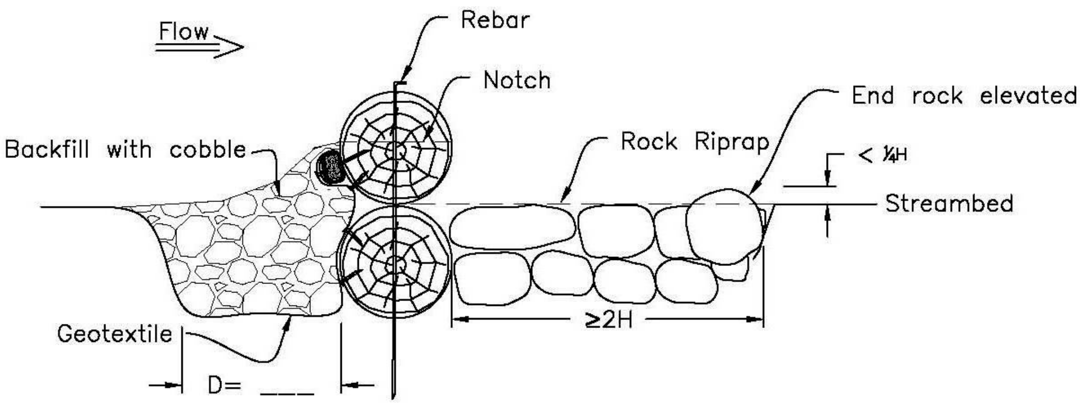
Install live clumps and live cuttings into adjacent protection during construction. Extend to below stream bed.

Use logs that are straight, uniform diameter and free of rot, disease or insect infestation.





Drill 1⅛" dia. hole and drive #8 rebar through. Bend end at top.



Conceptual Plan - Not for Construction

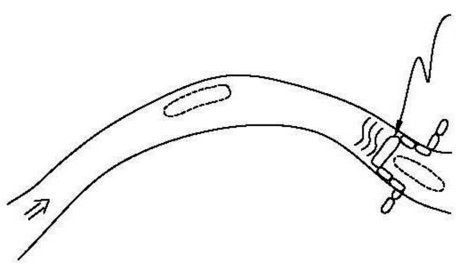
Drawings not to scale

Natural Resources Conservation Service
United States Department of Agriculture

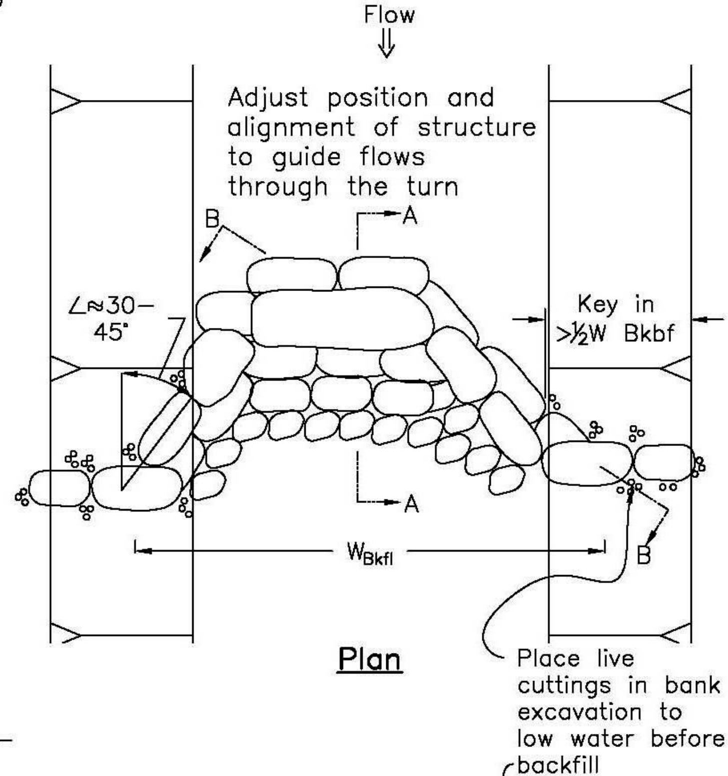
LOG CHECK DAM
–SMALL STREAM
(Less Than 12ft.)

Designed	J. Fripp, K. Worster C. Hoag	Date 08/06
Drawn	Juan Renteria	08/06
Checked		
Approved		

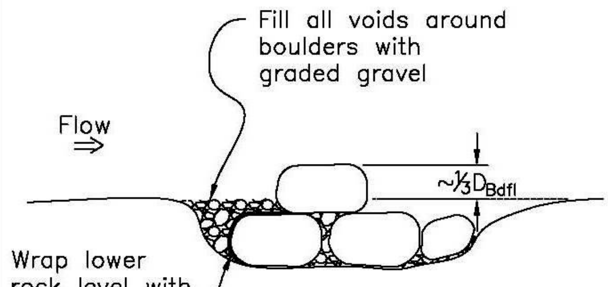
File Name: Small–Stream.dwg
Drawing Name: Small Stream
08/25/06
Sheet 1 of 1



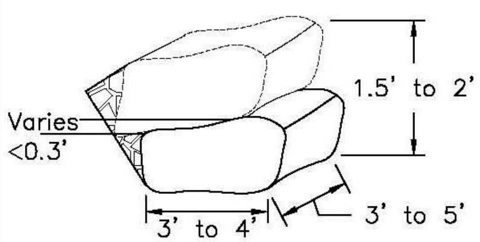
Layout



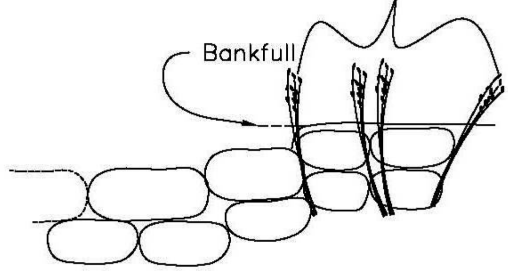
Plan



Section A–A



Typical Rock Dimensions and Placement
(stone size to be stable at highest
design discharge)



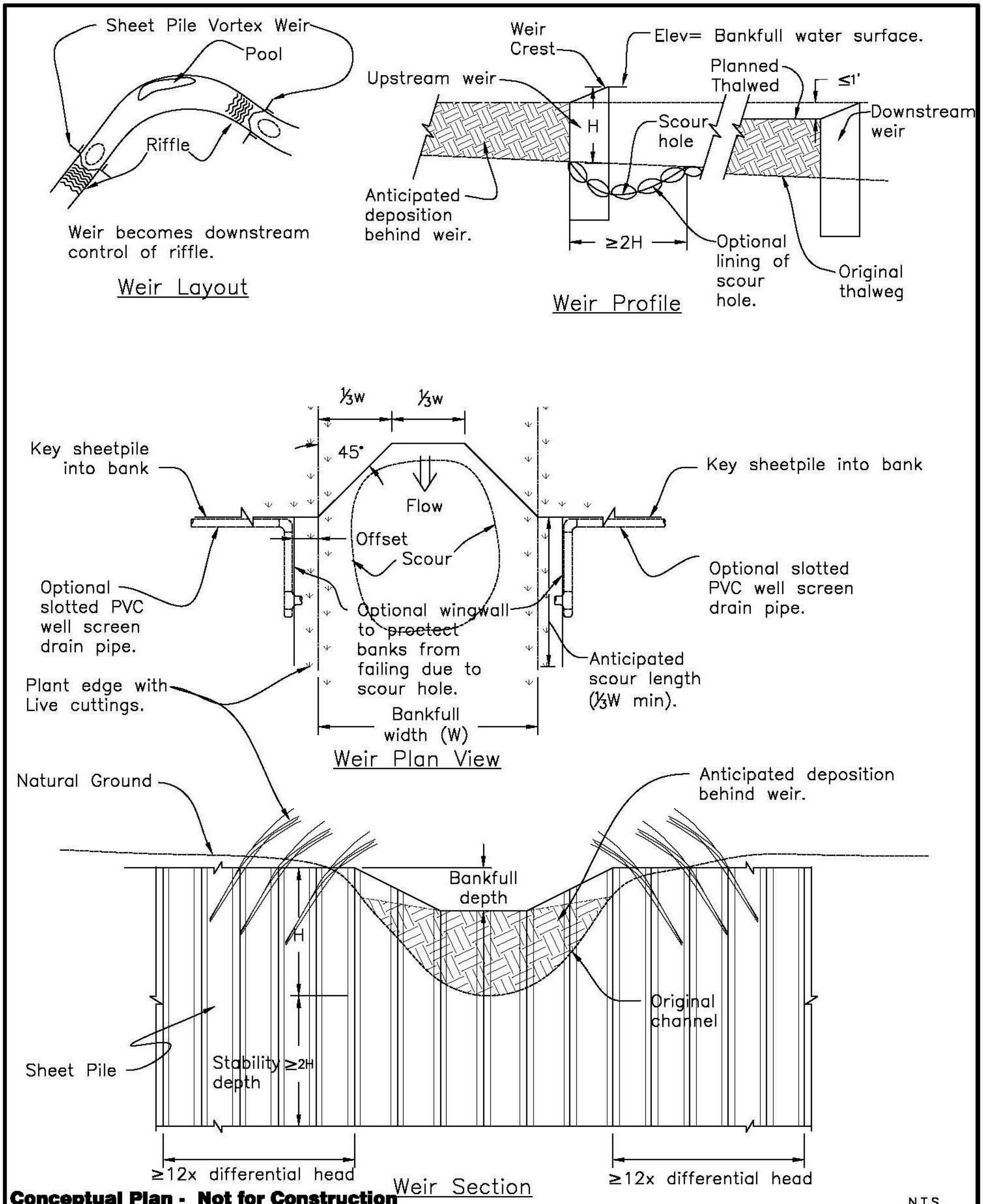
Section B–B

Notes: The rocks should be rectangluar or nearly so at the rock to rock contact. The rock to rock cantact should be solid. If rocks are not perfectly flat, the thicker end should be placed downstream. Fill gaps with smaller stones.

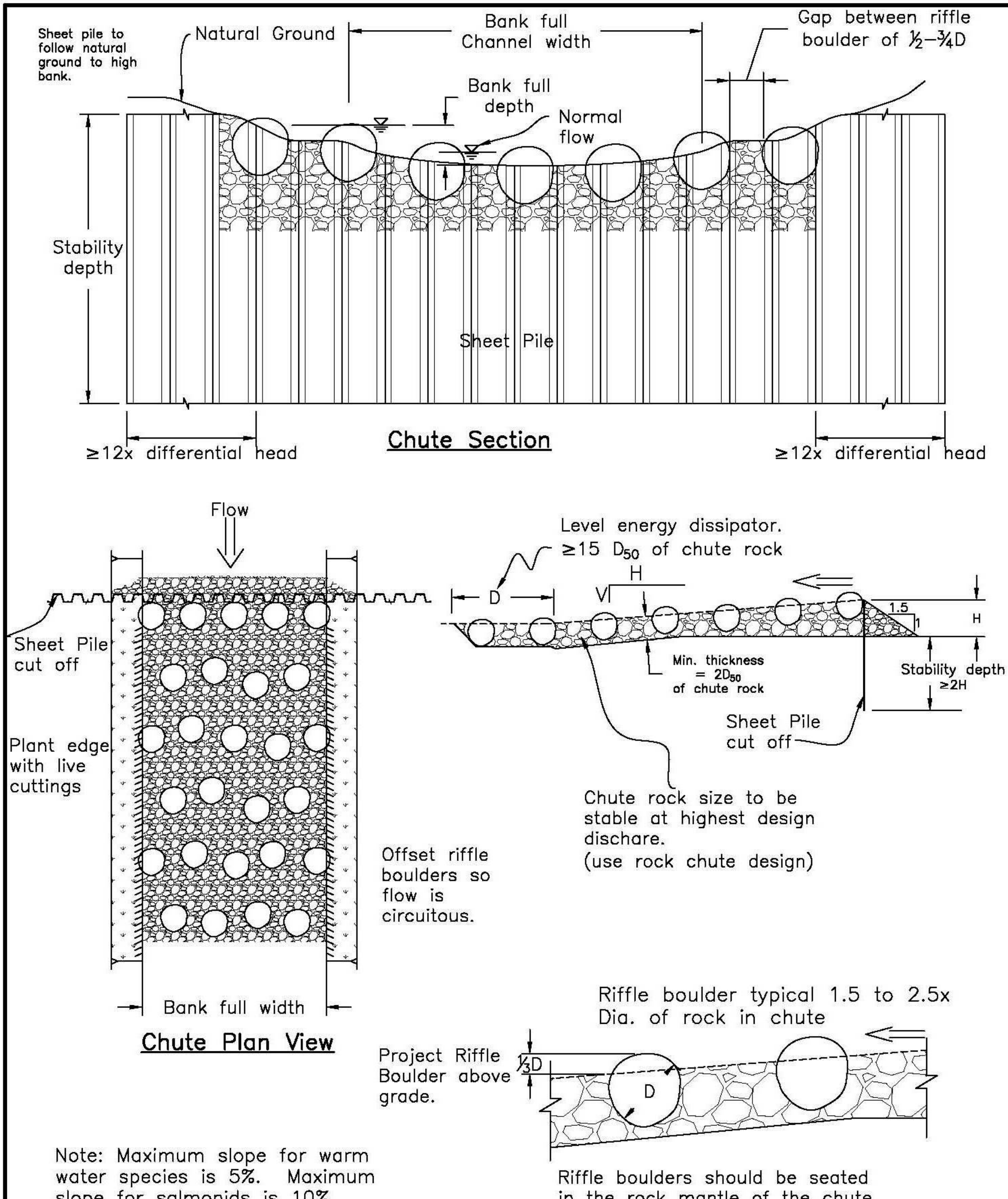
Conceptual Plan Not for Construction

N.T.S.

NRCS Natural Resources Conservation Service United States Department of Agriculture	Stone Drop – Small Stream	Designed Fripp, Weber — Date 06/07 Drawn J. Renteria — 06/07 Checked Approved	File Name: Small Stream.dwg Drawing Name: Small Stream 06/12/07 Sheet of



NRCS Natural Resources Conservation Service United States Department of Agriculture	Sheet Pile Vortex Weir	Designed R. Weber, J. Fripp Date 01/07 Drawn J. Renteria 01/07 Checked Approved	File Name ShtPile-Weir.dwg Drawing Name Weir 01/26/07 Sheet of



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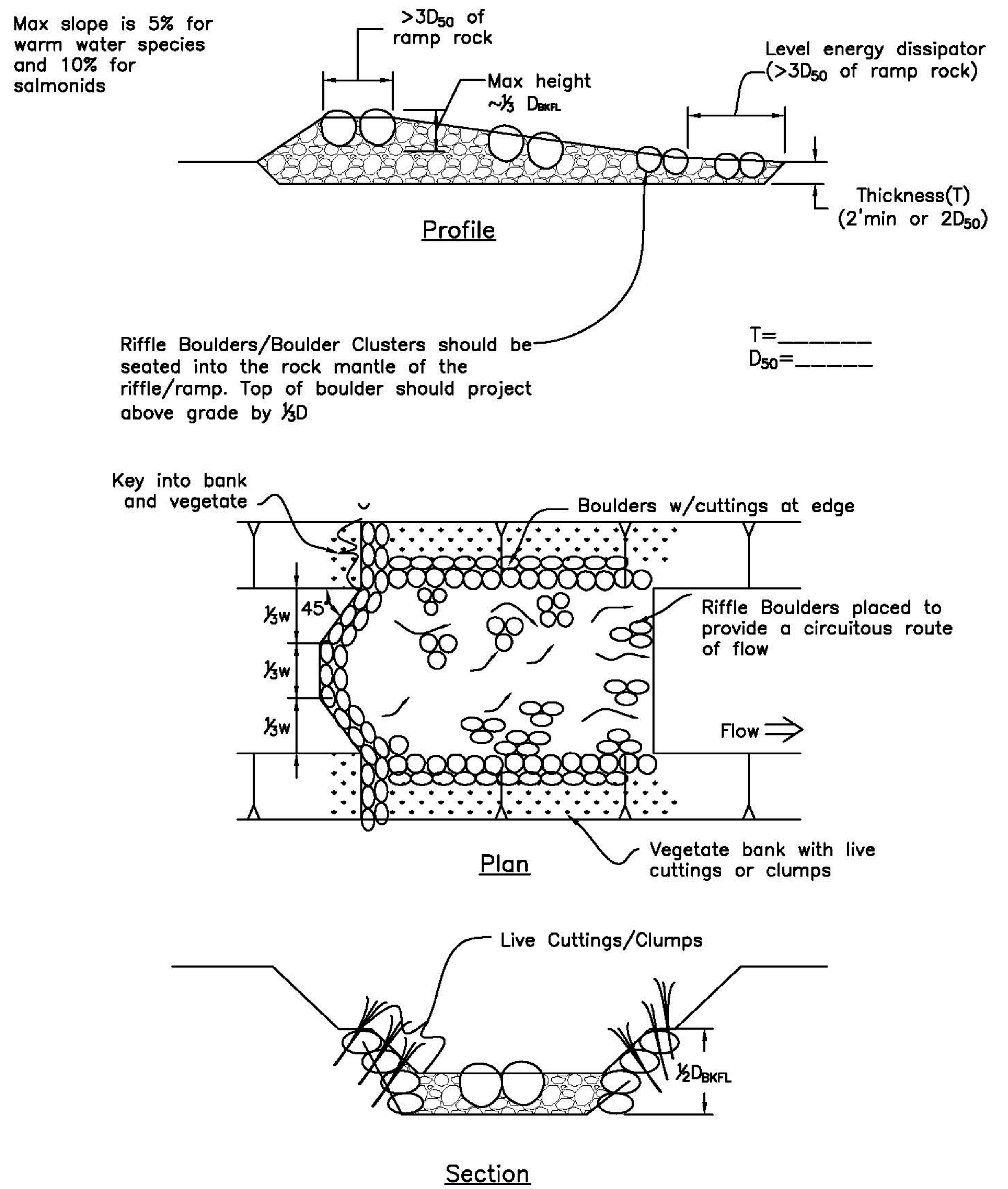
N.T.S.

NRCS
Natural Resources Conservation Service
United States Department of Agriculture

ROCK CHUTE – SHEET PILE CUT OFF

Designed	K. Robbinson, J. Fripp, K. Gullett	Date 01/07
Drawn	J. Renteria	01/07
Checked		
Approved		

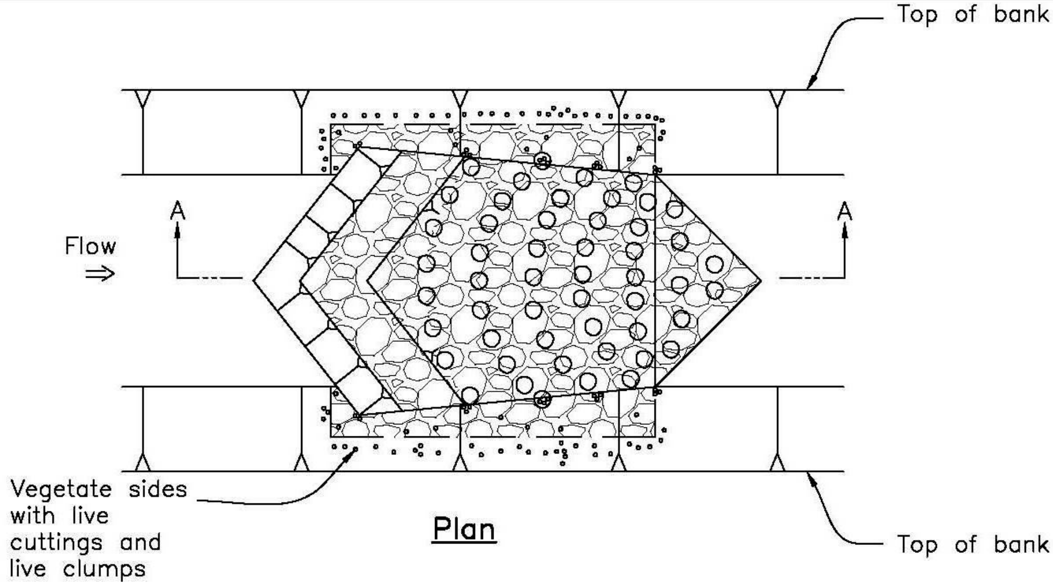
File Name: RockChute–SP.dwg
Drawing Name: RockChute–SP
01/26/07
Sheet 1 of 1



Conceptual Plan Not for Construction

N.T.S.

NRCS Natural Resources Conservation Service United States Department of Agriculture	Riffle Ramp With Bouler Clusters	Designed J. Fripp, K.Robinson — Date 01/12 Drawn J. Renteria — 01/12 Checked Approved	File Name Riffle-Ramp.dwg Drawing Name Riffle Ramp 01/17/12 Sheet 1 of 1



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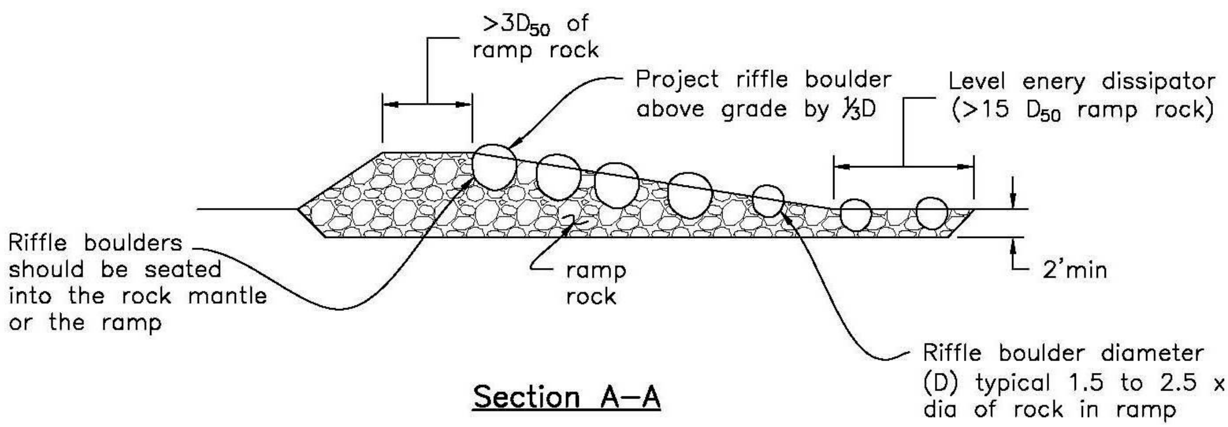


Section A–A

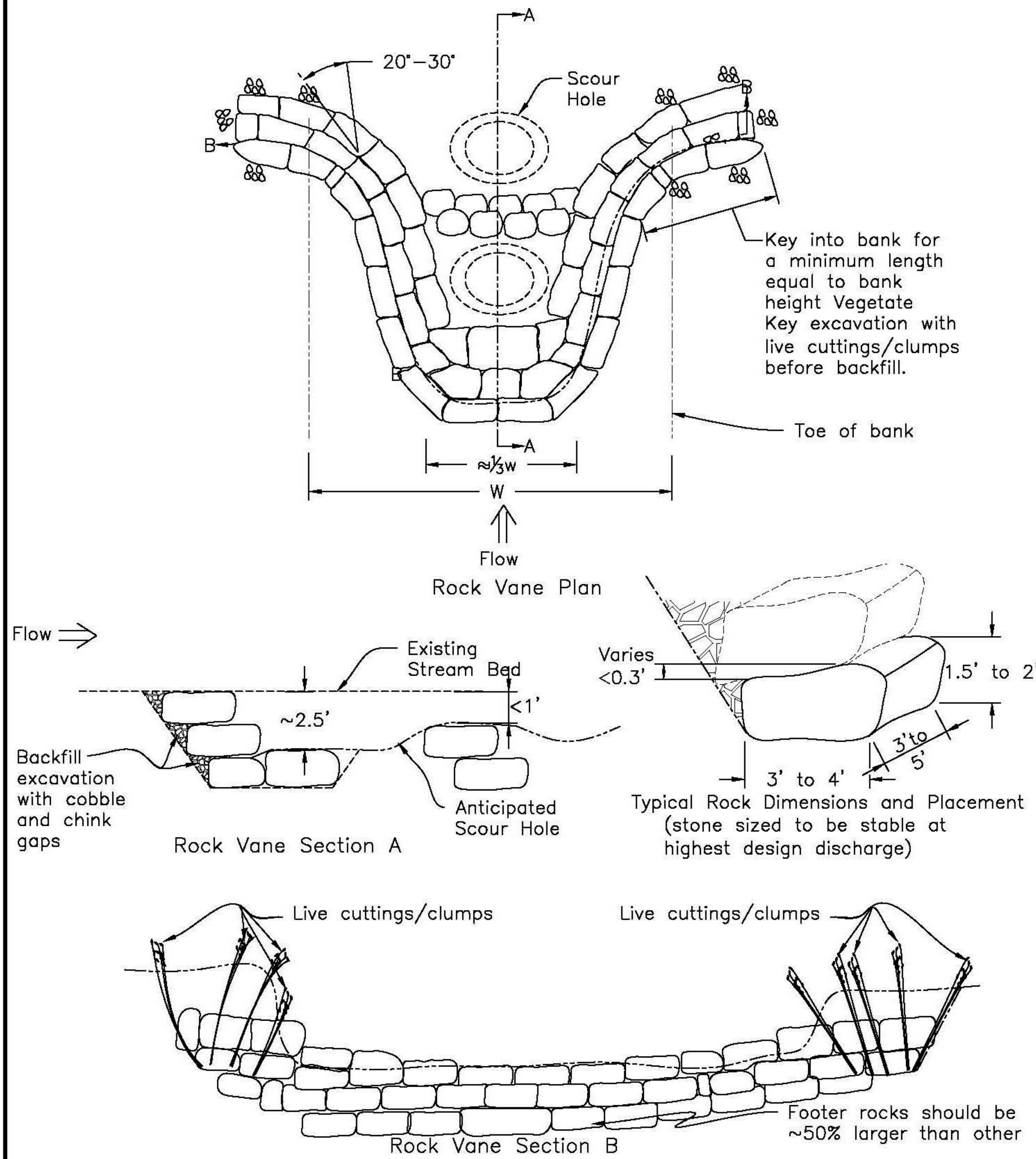
Note:

- Size rock in ramp to be stable at highest design discharge (use rock chute design)
- Maximum slope for warm water species is 5%. Maximum slope for salmonids is 10%.
- Off set the riffle boulders in teh ramp so that the flow is circuitous

Conceptual Plan Not for Construction

N.T.S.

NRCS Natural Resources Conservation Service United States Department of Agriculture	CHEVRON WEIR	Designed K. Boyer, R. Weber, J. Fripp Date 06/07	File Name Chevron Weir.dwg
		Drawn J. Renteria 06/07	Drawing Name Chevron Weir
		Checked	06/12/07
		Approved	Sheet 1 of 1



Notes: The rocks should be rectangluar or nearly so at the rock to rock contact. The rock to rock contact should be solid. If rock are not perfectly flat, the thicker end should be placed downstream. Fill gaps with smaller stone.

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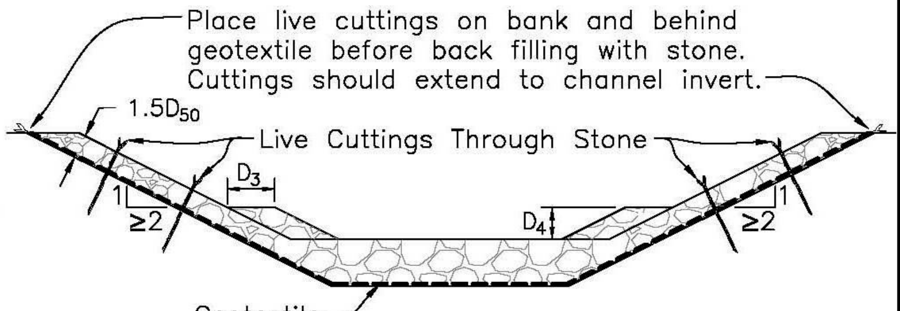
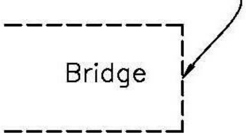
STEP POOL ROCK CROSS VANE

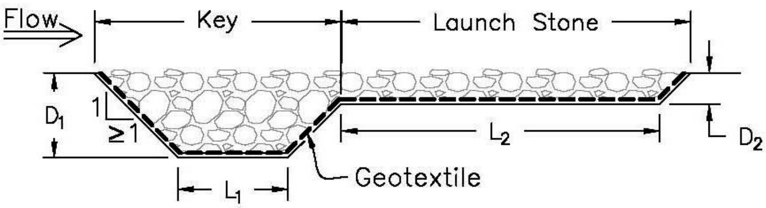
Designed J. Fripp, K Gullet, K. Robinson	Date 10/06	File Name Step Pool Rocking Crossing.dwg
Drawn J. Renteria	10/06	Drawing Name StepPool
Checked		01/18/07
Approved		Sheet of



Section

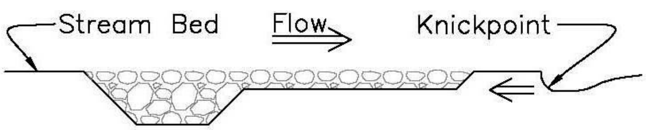
Note: If applicable, locate launch stone downstream of bridge.



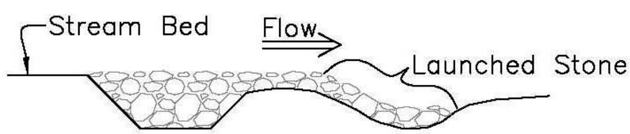


Profile

Note: Excavate bank and bed of stream to place stone.



Profile: Rock sill grade control as constructed. Knickpoint approaching structure.



Profile: Rock sill acting as grade control. Structure stops knickpoint from proceeding upstream. Launch stone must be sufficient to resist the bed degradation (knickpoint) and local scour (scour hole).

H = ____(maxium expected head cut to be stopped by structure)

D_{50}= ____(2xD_{50} as determined for streambank riprap)

D_2 = ____($\geq 3D_{50}$)

D_1 = ____($\geq 1.5D_2$, 2'min)

L_1 = ____(D_1, 4'min)

L_2 = ____ ($\geq$10H, gravel bed channel; $\geq$12H, sand bed channel)

D_3 = ____($\geq 2D_{50}$)

D_4 = ____($\geq$H)

Notes:

- For small stream or drainage canal applications.(<20 wide)
- Not for use where possible bed degradation(H) is greater than 3 feet.
- An impervious cut off of sheetpile or clay may be required in upstream end of key if structure is constructed on highly erodible fine sands or similar mobile, permeable bed material.
- Do not use cuttings through geotextile if piping/sapping is a concern.

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N.T.S.

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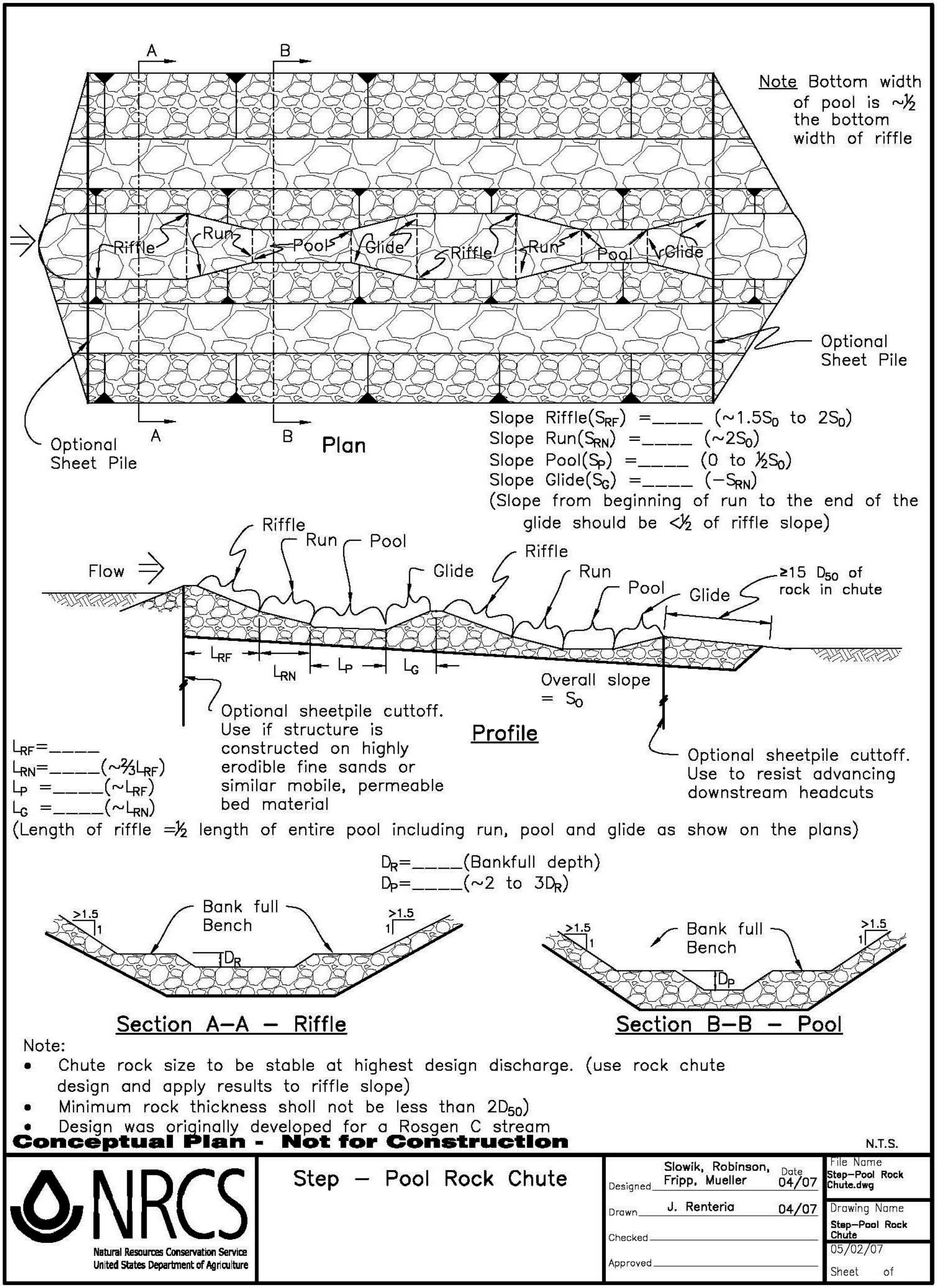
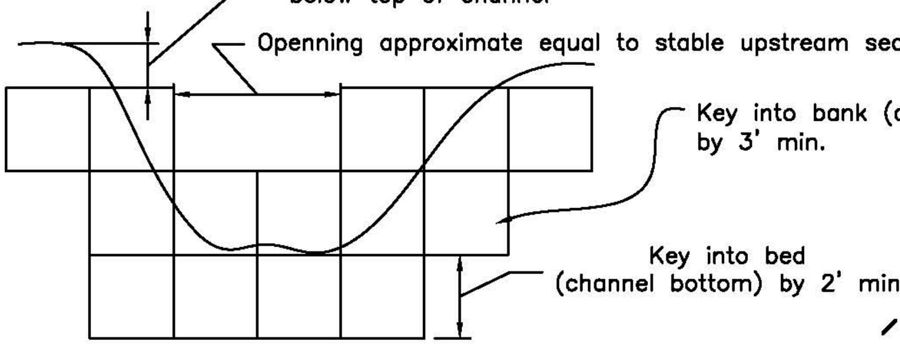
Natural Resources Conservation Service
United States Department of Agriculture

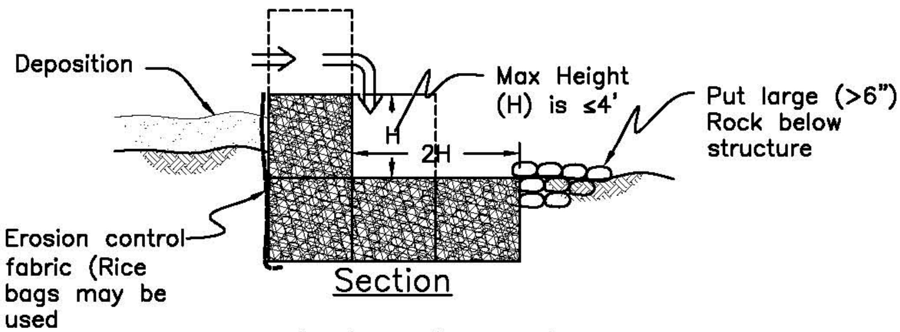
Rock Sill Grade Control

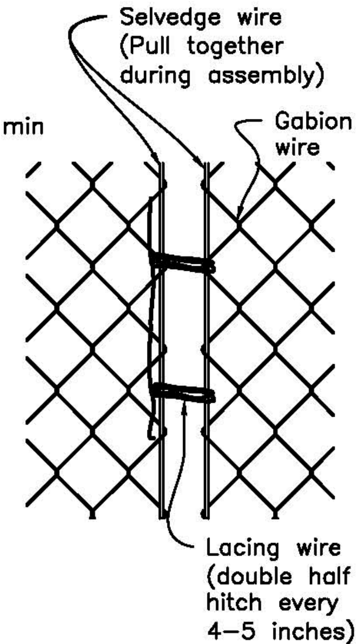
Designed	Fripp, Worster, Anderson, Robinson	Date 04/07
Drawn	K. Miller, J. Renteria	04/07
Checked		
Approved		

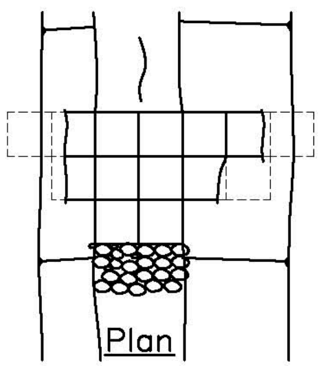
File Name: Rock Sill Grade Control.dwg
Drawing Name: Rock Sill Grade Control
04/11/07
Sheet of


Note Bottom width of pool is ~½ the bottom width of riffle
A
B
Riffle
Run
Pool
Glide
Riffle
Run
Pool
Glide
Optional Sheet Pile
Optional Sheet Pile
A
B
Plan
Slope Riffle(S_RF) =_____ (~1.5S0 to 2S0)
Slope Run(S_RN) =_____ (~2S0)
Slope Pool(S_P) =_____ (0 to ½S0)
Slope Glide(S_G) =_____ (−S_RN)
(Slope from beginning of run to the end of the glide should be <½ of riffle slope)
Flow
Riffle
Run
Pool
Glide
Riffle
Run
Pool
Glide
≥15 D50 of rock in chute
L_RF
L_RN
L_P
L_G
Overall slope = S0
Optional sheetpile cuttoff. Use if structure is constructed on highly erodible fine sands or similar mobile, permeable bed material
Profile
Optional sheetpile cuttoff. Use to resist advancing downstream headcuts
L_RF=_____
L_RN=_____(~⅔L_RF)
L_P =_____(~L_RF)
L_G =_____(~L_RN)
(Length of riffle =½ length of entire pool including run, pool and glide as show on the plans)
D_R=_____(Bankfull depth)
D_P=_____(~2 to 3D_R)
>1.5
1
Bank full Bench
D_R
>1.5
1
Section A–A – Riffle
>1.5
1
Bank full Bench
D_P
>1.5
1
Section B–B – Pool
Note:
• Chute rock size to be stable at highest design discharge. (use rock chute design and apply results to riffle slope)
• Minimum rock thickness sholl not be less than 2D50)
• Design was originally developed for a Rosgen C stream
Conceptual Plan - Not for Construction
N.T.S.
NRCS
Natural Resources Conservation Service
United States Department of Agriculture
Step – Pool Rock Chute
Designed Slowik, Robinson, Fripp, Mueller
Date 04/07
Drawn J. Renteria 04/07
Checked
Approved
File Name Step–Pool Rock Chute.dwg
Drawing Name Step–Pool Rock Chute
05/02/07
Sheet of



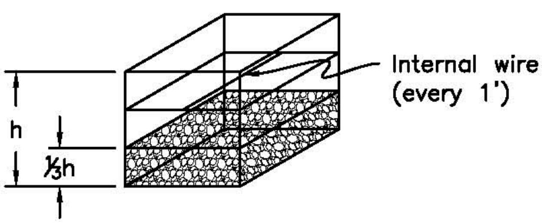


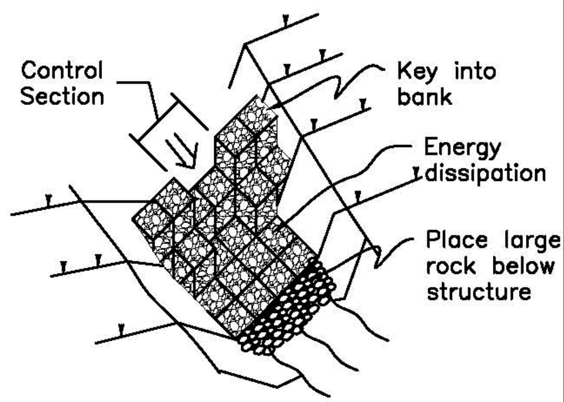




Component Properties

Gabion wire: 12 gage
Gabion opening: 3.25x4.5 in or approximate
Selvedge wire: 10 gage
Lacing wire: 13.5 gage
Internal reinforcement: 13.5 gage





Notes:

- Rock size shall be between 4 and 8 inches
- Fill gabion only with rock in layers.
- Place rock firmly but do not overfill.
- Install internal reinforcing wire every foot.
- Secure with lacing wire or clutes every 4–5".

Gabion check dams used to stop erosion on small gullies. Not for flowing streams or terrace foundation

Conceptual Plan Not for Construction

N.T.S.

NRCS
Natural Resources Conservation Service
United States Department of Agriculture

Gabion Check Dam
Upper Watershed
Stabilizaton

Designed	J. Fripp, L. Christenson	Date 12/10
Drawn	J. Renteria	12/10
Checked		
Approved		

File Name
Gabion–Check_Dam.dwg

Drawing Name
Gabion–Check_Dam.dwg

12/14/10

Sheet of

Introduction to Redirective Techniques

Stream redirective techniques are a broad category of treatments that can be used to divert flows away from eroding banks or to define and hold a given channel alignment. These techniques redirect stream flows with a low weir and disrupt the velocity gradient in the near bank region. Stream redirective techniques can be contrasted with structures such as riprap, gabion walls, and concrete lining which armor the bank making it more resistant to the existing flows. Stream redirective structures tend to be less massive and are submerged at higher stages of flow. These redirective structures are usually discontinuous, independent structures.

Stream redirective treatments have been used in projects involving stream restoration, stream bank protection, instream habitat improvements, navigation improvements, and irrigation diversions. They have been applied on large and small stream and river systems. The structures are typically made out of large boulders and stone but timber and brush have also been successfully used as part of many stream design and restoration projects. While a variety of techniques are described, the primary focus of this section is on stream barbs. This field guide also provides current NRCS design recommendations for stream barb design.

Types of Redirective Techniques

There are a variety of different types of stream redirective techniques used in stream design projects. These include devices known as deflectors, bendway weirs, vanes, spurs, kickers, and barbs. While there are variants in their design and behavior, they are all basically structures that:

- Project from a stream bank
- Are oriented upstream
- Redirect stream flow away from an eroding bank
- Alter secondary currents
- Promote deposition at the toe of the bank

Some of the most commonly used techniques are briefly described below:

Bendway Weirs

Bendway weirs were developed by the U.S. Army Corps of Engineers to reduce erosion along the Mississippi River and then adapted for smaller streams. The premise behind the function of bendway weirs is that flow over the weir is directed perpendicular to the angle of the weir. Bendway weirs are oriented upstream at an angle that is between 50° - 80° to bank tangent. The length of a bendway weir is typically less than ¼ bankfull width. Often the design is based on base flow widths. In this case, their length is typically between 1/4 to 1/2 of the base flow width. In all cases, both the length and the angle may vary through the bend of the river to better capture, control and direct the flows.

Bendway weirs are typically wide structures with a flat to slight weir slope up toward bank. They should be keyed into the bank at a length equal to the bank height plus anticipated scour depth. More information on the design and application of bendway weirs is provided in The WES Stream Investigation and Streambank Stabilization Handbook (USACE 1997).

Stream Barbs

Stream barbs are low dikes or sill like structures that extend from the bank towards the stream in an upstream direction. Stream barbs are similar in structure to bendway weirs, perform a similar function, and were developed about the same time by NRCS for smaller streams. As flow passes over the sill of the stream barb, it accelerates, similar to flow over the weir of a drop structure, and discharges normal to the face of the weir. Thus a portion of the stream flow is redirected in a direction perpendicular to the angled downstream edge of the weir. If the weir is too high, flow is deflected instead of being hydraulically redirected; and if too low, the redirected flow is insignificant relative to the mass of the stream.

Performance varies as the stream flow stage varies. At low flows, a stream barb may first deflect flow and then, as the stage increases, flow passes over the weir and is redirected. At high flow stage, the weir effect becomes insignificant. The height of the stream barb weir is important since it will generally function most efficiently during “bankfull” or channel forming flow events. Stream barbs are typically constructed with rock; however brush may be used for some applications.

Stream barbs are used for bank protection measures, to increase scour of point and lateral bars, to direct stream flow towards instream diversions, and to change bedload transport and deposition patterns. Other benefits of stream barbs include encouraging deposition at the toe of a bank, reducing the width to depth ratio of a stream channel and providing pool habitat for fish.

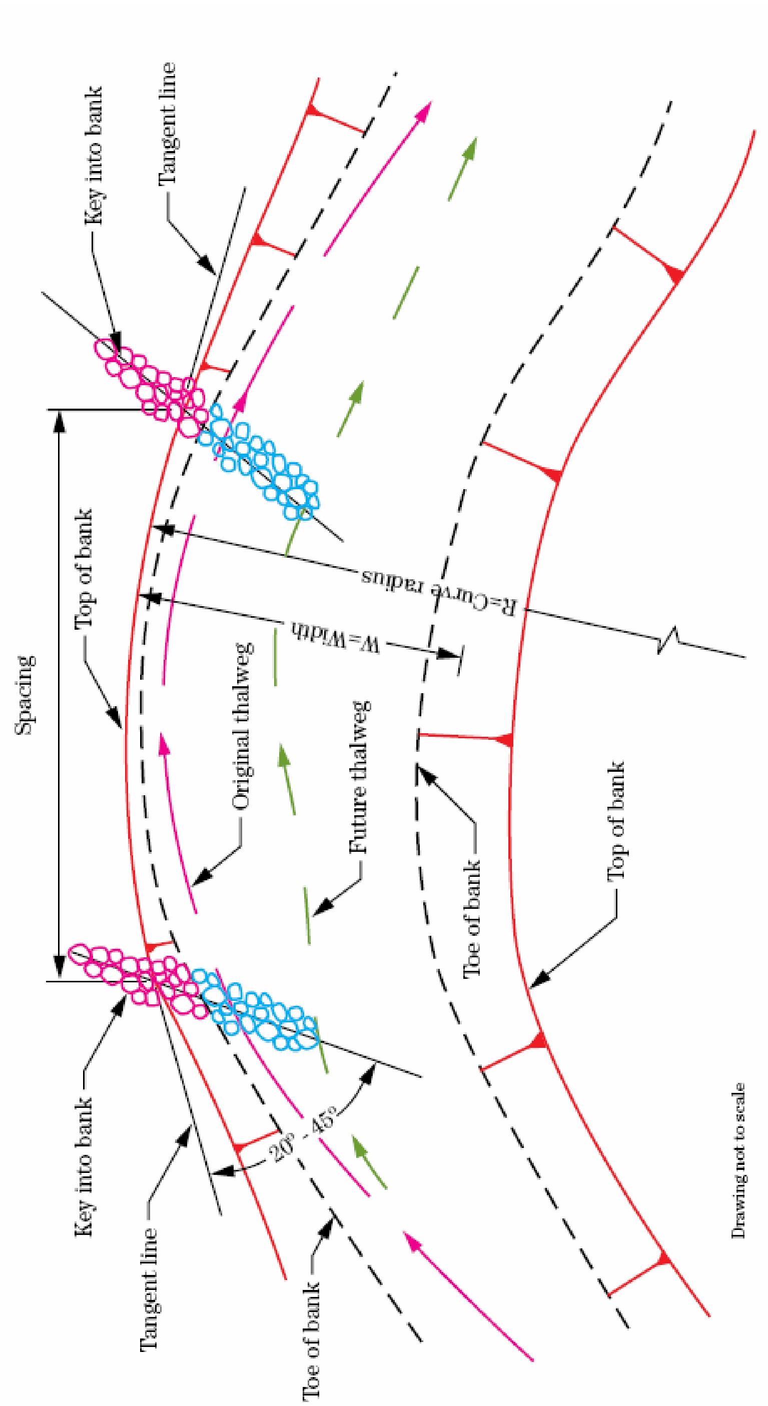
Vanes

Vanes are structures constructed in the stream designed to redirect flow by changing the rotational eddies normally associated with stream flow. They are used extensively as part of natural stream restoration efforts to improve instream habitat. There are quite a few variants on rock vane design.

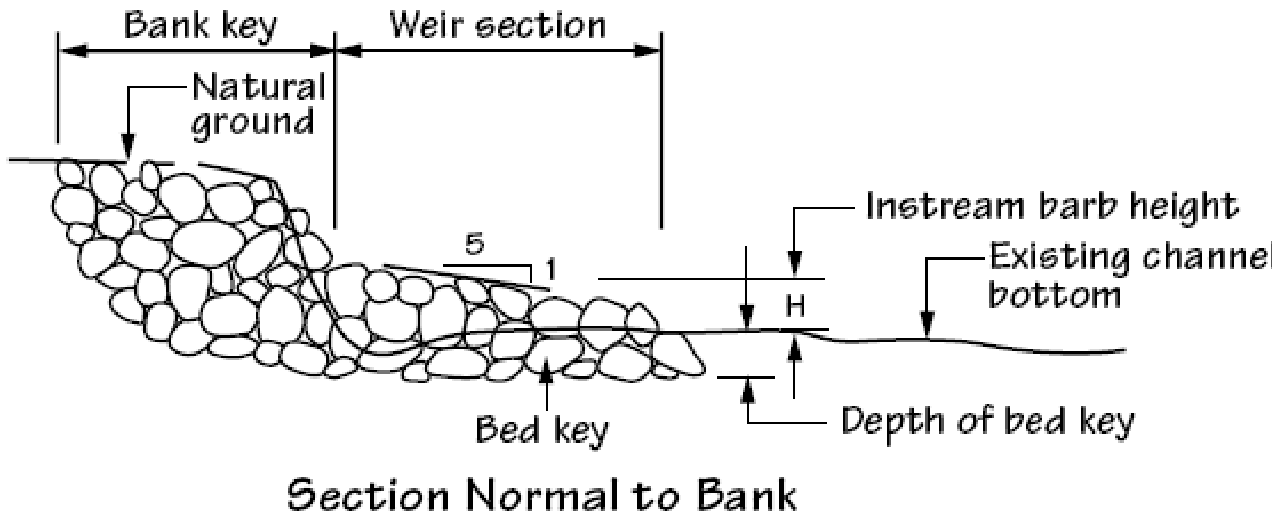
Vanes are typically oriented upstream 20° to 30° to the bank tangent. However, the angle may vary as they work around the curve. Design of vanes is based on bankfull depth. The length is typically 1/3 of the bankfull width and the height at the bank is 1/3rd of the bankfull depth. The weir slope is 2° - 7° up towards bank. The required stone size for vanes is often very large.

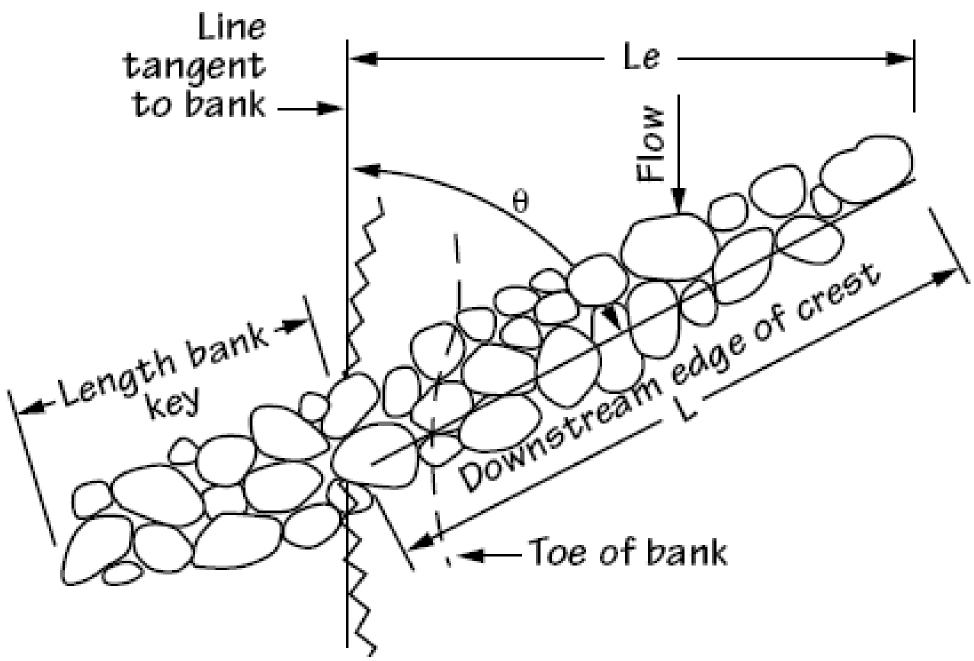
Design Criteria – Stream Barbs

The following is a generalized discussion of design criteria specific to stream barb design. The figures below provide an illustration of some of the terms used in this field guide. The designer should be generally familiar with the limitations and applications described in the following text. Since all designs in a riverine environment are site specific, the user is cautioned that there are certainly variants in many of the recommendations that are provided herein.



Typical stream Barb Design Layout





Typical Stream Barb

Bank Erosion

The cause of bank instability must be carefully assessed by the designer. Stream barbs are appropriate for sites where the mechanism of failure is toe and lower bank erosion. They decrease near-bank velocities and create low flow eddying adjacent to the toe of the bank which promotes sediment deposition. They are often used in combination with soil bioengineering methods since the sediment deposition and accumulation between the barbs promotes riparian establishment and development. Soil bioengineering techniques may also enhance further deposition between the barbs.

Stream barbs will not protect banks that are eroding due to rapid drawdown or mass slope failure. Problems have been observed where stream barbs have been applied to repair problems that are geotechnical rather than fluvial in nature.

Channel Stability
Stream barbs are not appropriate where the grade of the channel is unstable. In degrading streams, the foundation of the stream barb may be undermined while in aggrading streams; the stream barb may be buried. In addition, problems have been observed where these techniques have been applied in braided streams or stream systems that are prone to avulsions.

Channel Approach
The placement, length and alignment of barbs are dependent on the approach that the channel makes into the project area. Using stream barbs to make abrupt channel alignment changes should be avoided. The designer should consider the full range of flow behavior at the site as the alignment may change at high flows. For all significant design flow levels, the stream barb should serve to redirect rather than deflect or split the flow.

Location
Stream barbs are typically placed along the outside of a bend where the thalweg is near the stream bank. Generally these structures are not used when the thalweg is away from the bank except in situations where the channel is excessively wide or where they are used to induce sediment deposition at the toe of an eroding bank. The stream barb should then be located to capture the flow with a longer weir section, control it through the curve, and direct it downstream towards the center of the channel.

The furthest upstream stream barb should be located in the area that is first impacted by active bank erosion. Research by Matsuura (2004) indicates that stream barbs upstream of the active erosion were less effective than those placed at the point that bank erosion starts. Designers should note that since most of the stress is in the lower two-thirds of a bend, protection should extend to the point where the bank is stable and vegetated.

Field assessments documented by Sean Welch and Scott Wright in NRCS-OR Tech Note 23(2) indicate that the placement should be restricted to the outer portions of the current meander belts. This will reduce the possibility of flanking.

Bend Radius
While stream barbs are primarily used to control erosion in bends, their performance may not be satisfactory in sharp bends. When the meander bend radius divided by stream width is much less than three ($R/W<3$), there are often problems with erosion below the stream barb as a result of flow separation. This restriction may be relaxed by protecting the banks between the barbs, increasing the number of barbs, and decreasing the angle between the barb and the bank. However, in appearance, this may result in nearly a fully riprapped bank.

Determining a radius is not necessarily a simple exercise. Many bends are, in fact, more of a spiral. In addition, the bend radius and approach angle may change at high flow. The designer must assess affects at low, moderate and high flows. As with all aspects of stream barb design, experience and judgment play an important role.

Angle
The structure weir section must be oriented in an upstream direction. The angle (θ) generally varies, from 20 to 45 degrees off a tangent to the bank, depending upon the curvature of the bend and the intended realignment of the thalweg. The tighter the stream bend, the smaller the angle, and for situations where $R/W < 3$, it should be less than 20 degrees if a barb is to be used at all. If the purpose is to maintain a deep thalweg near the stream bank, then a tight angle (20 degrees) is desirable. A vector analysis, assuming a perpendicular flow direction from the weir alignment, can be used to estimate the angle required to turn the flow.

Length
There are two important length terms associated with stream barbs, "Weir Length" (L_w) and "Effective Length" (L_e). Weir length defines the length of the weir section of the stream barb and is relative to how much flow can be redirected and energy dissipated. The longer the weir, the more stream flow affected and energy dissipated. "Effective Length" is a function of the "Stream Width" (W) and defines the perpendicular projection of the stream barb from the bank into the stream. Experience has shown that an "Effective Length" greater than one third the stream "bankfull" flow width has been observed to result in unsatisfactory results by causing erosion on the opposite bank.

Maximum effective length: $L_e = W/4$

$$L_w = L_e/\sin\theta$$

Suitable range of L_e for effective bank protection: $W/10 < L_e < W/3$

For stream barbs to affect the dominant flow pattern, they must cross the thalweg. Shorter stream barbs will affect only secondary, near-bank currents. If the calculated effective length results in barbs that do not influence the dominant flow path, then adjustments should be made to the barb length. If this is not feasible, other techniques should be considered. Stream barbs that extend much beyond the effective length tend to alter the meander pattern of the stream and could adversely impact the opposite bank.

Number and Spacing
The number of stream barbs required at any given site will be determined by the following:

(1) Spacing

(2) The length of the eroding meander bend
(3) Channel geometry, and
(4) Desired effect for treatment of reach.

Proper spacing of stream barbs is necessary to prevent the stream flow from cutting between two barbs and eroding the bank. A vector analysis consists of plotting the proposed layout with vectors projecting at right angles to the downstream side of the stream barb. This can provide the designer with an indication of flow lines and flow interception by subsequent stream barbs. Given that the flow will leave the stream barb in a direction perpendicular to the downstream weir face, the subsequent structure should be placed so that the flow will be captured in the center portion of the weir section before the stream flow intersects the bank. Since the flow direction is controlled by the alignment of the stream barb, the downstream side of the stream barb is typically straight, so that this direction can be better estimated. Another method that can be used is shown illustrated later in this guide.

Although there is much local variation, typically stream barbs influence the flow patterns for a distance downstream from 5 to 10 times L_e. A limited stream barb spacing of 4 to 5 times L_e provides more consistent results.

Height

The height of the stream barb weir section (H_w) is related to the channel-forming or “bankfull” flow depth. The main portion of the weir should be below the bankfull flow depth, such that significant flow is over the weir. In some situations, a stream barb may be used to protect banks from flows that are considerably larger than bankfull. In these situations, the height may be larger, but generally should not exceed the bankfull flow level, as this results in a jetty rather than a barb.

The height of the stream barb weir is generally limited as follows:

H_w = 1/3 D_a to 1/2 D_a
D_a = average bankfull flow depth

Once flows are more than five times the height of the stream barb, the relative effectiveness of the barb in re directing flow is significantly reduced. If the height of the design storm is significantly higher than the height of the barb, it may be advisable to increase the height, augment the stream barbs with more bank protection between the barbs, or select another treatment technique.

The relative height between successive stream barbs is important. The difference in height between stream barbs should approximate the energy grade line of the stream regardless of local variations in bed topography.

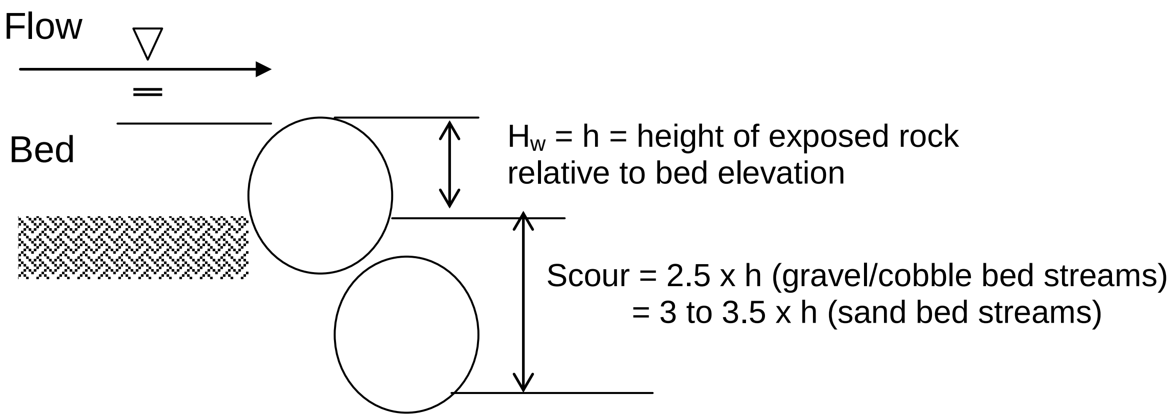
Profile
A stream barb is intended to function as a weir and therefore the profile is nearly flat with a positive slope towards the bank (slope of 1V:5H is common). Stream barbs constructed with a negative slope or where rocks have been displaced resulting in a negative slope may force water closer to the bank and thereby increase rather than decrease erosion. The profile should transition from the weir section to a steeper slope at the bank (1V:1.5H to 1V:2H is common). A typical configuration would be a profile starting at 1/3 H at the outer end and increasing to 1/2 to 2/3 H at the bank end of weir section. The top of the key must be high enough to prevent water from flowing around and eroding behind the structure. Banks that are frequently overtopped will require a more extensive key that extends further back into the bank. Bank condition, angle, height and material will also need to be considered when designing the dimensions of the key.

Width
The width of a stream barb generally ranges from one to three-times the design D_{100} rock size. The width does not need to be more than two rock diameters and can even be the width of a single large rock at the tip of the barb. However, stream barbs with a top width of a single stone have been shown to be more susceptible to damage than structures which are multiple stones in width. The stream barb width may also need to be increased (10 to 15 feet total width) to accommodate construction equipment in large rivers or where necessary. Wider structures will result in a more uniform, stronger hydraulic jump. Wider structures should be used if a deep scour hole downstream of the barb is expected.

Length of Bank Key
The purpose of the bank key is to protect the structure from flanking due to erosion in the near bank region. The bank key length should be at least eight feet and not be less than 1.5 times the bank height. Buried logs with rock ballast can be used in conjunction with the bank key. An inadequate key into the bank has been frequently observed to cause the structure being flanked. Rilling from overbank return flows down the backfilled bank key has also been observed to be a problem. It is also suggested that the key be planted with live poles and/or live clumps. The design can take advantage of the required excavation into the bank to assure adequate moisture is provided to these soil-bioengineering practices. This planting will not only enhance stability but will also provide important habitat benefits.

Depth of the Bed Key
The depth of the bed key is determined by calculating the expected scour depth around the tip of the structure. This scour depth will likely exceed the depth of the thalweg. If a bed key is not incorporated, or if the bed key is too shallow, scour may erode the bed material downstream, causing the rock to fall into the scour hole. Higher barbs cause greater flow convergence, and thus greater scour depths. To reduce scour depths, decrease the barb height. The bed key is

typically placed at a minimum depth of D_{100}. Scour depth can be estimated using the information provided in the figure below:



<u>Depth of bed key</u>

If it is not feasible to excavate below the anticipated scour depth, the designer can increase the width of the weir section so that sufficient stone is available to launch into and armor the scour hole.

Rock Size
Rock for stream barbs shall be durable and of suitable quality to assure permanence in the climate in which it is to be used. Because stream barbs are positioned to redirect fluvial forces at locations where these forces are greatest within stream channels, the rock used to construct them must be larger than the rock that would be required in a riprap revetment along the stream bank at the same location. Numerous failures have been attributed to using undersized rock.

Material sizing should follow standard riprap sizing criteria for turbulent flow. Several techniques are available in the literature for this calculation (USDA-NRCS, NEH 654). A simplified approach which has been used it to employ the NRCS Far West States-Lane method. This equation is as follows:

$$D_{75} = \frac{3.5}{C \times K} \times \gamma_w \times d \times S_f$$

Where:
D_m= Stone size (inches); *m* percent finer by weight
C = correction for channel curvature
K = correction for side slope
S = the channel friction slope in ft/ft
d = depth of flow in feet

The rock should be sized for the design flow conditions and then modified in accordance with the following:

D_{50}, stream barb = 2 x D_{50}, as determined for stream bank riprap

D_{100}, stream barb = 2 x D_{50}, stream barb

$D_{minimum}$= 0.75 x D_{50}, as determined for stream bank riprap

Note that the Far West States-Lane method gives the riprap D_{75} and not the D_{50}. A designed gradation is required to obtain the riprap D_{50}. A conservative approach which is often used in practice is to use D_{75} indicated by the Far West States-Lane method as D_{50}. When the ratio of curve radius to channel width is less than six, rock sizes become extremely large and may result in a conservative design.

Rock in the barb should be well graded in the D_{50} to D_{100} range for the weir section; the smaller material may be incorporated into the bank key. The largest rocks should be used in the exposed weir section, at the tip, and for the bed key (footer rocks) of the barb

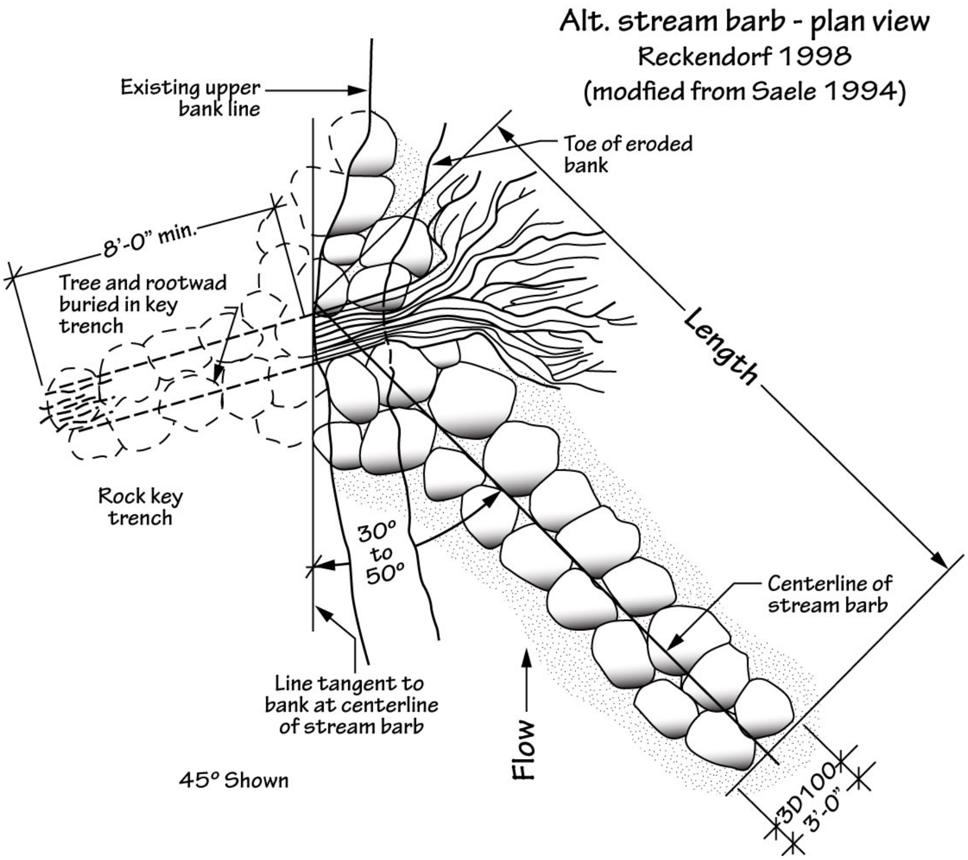
In general, structures that are constructed with graded material perform better than ones built out of a few large boulders. This may be due to the fact that a structure built with a larger number of smaller stones can be more easily constructed to a specified grade and can adjust better than one made out of a few larger boulders. However, it should be noted that, depending on availability, large rock (generally greater than 3-feet in diameter) can be less expensive by weight and can take less time to install.

Woody Material

Rootwads and other woody material have been incorporated into stream barbs to enhance aesthetics and the habitat benefits of the structure. The example concept detail shown in the figure below illustrates a rootwad being used in the key of a stream barb. Large wood elements have also been incorporated into the weir as well. Root wad sections have been incorporated both perpendicular to the weir, as well as longitudinally. In either case, the anchoring requirements of the wood elements must be considered.

If the wood element is not anchored sufficiently, it may break loose, damage the structure and possibly result in adverse downstream impacts. Anchoring could be accomplished by cabling to rock bolsters, soil anchors, or with the weight of the rocks that make up the barb. Forces of the flows during design conditions as well as buoyancy should be considered. In addition, the consequences of the woody material catching floating debris should be considered in the design and evaluation of its anchoring requirements. Finally, the designer should also consider how the placement of woody debris within the structure might also affect its hydraulics. Woody material should not be placed and aligned where it might direct flows into the bank.

Construction Considerations
Instream devices like stream barbs are best constructed during low flow. Achieving a design key in depth may require dewatering which may be accomplished with a cofferdam. If the designs include soil bioengineering or planting, either as part of the project or to stabilize the root or bank key, then appropriate planting designs also need to be considered. All stream or river design techniques should consider critical spawning and migration periods, as well as other regulatory concerns.



<u>Rootwad used in key of a stream barb</u>

Design Work Sheet – Stream Barbs

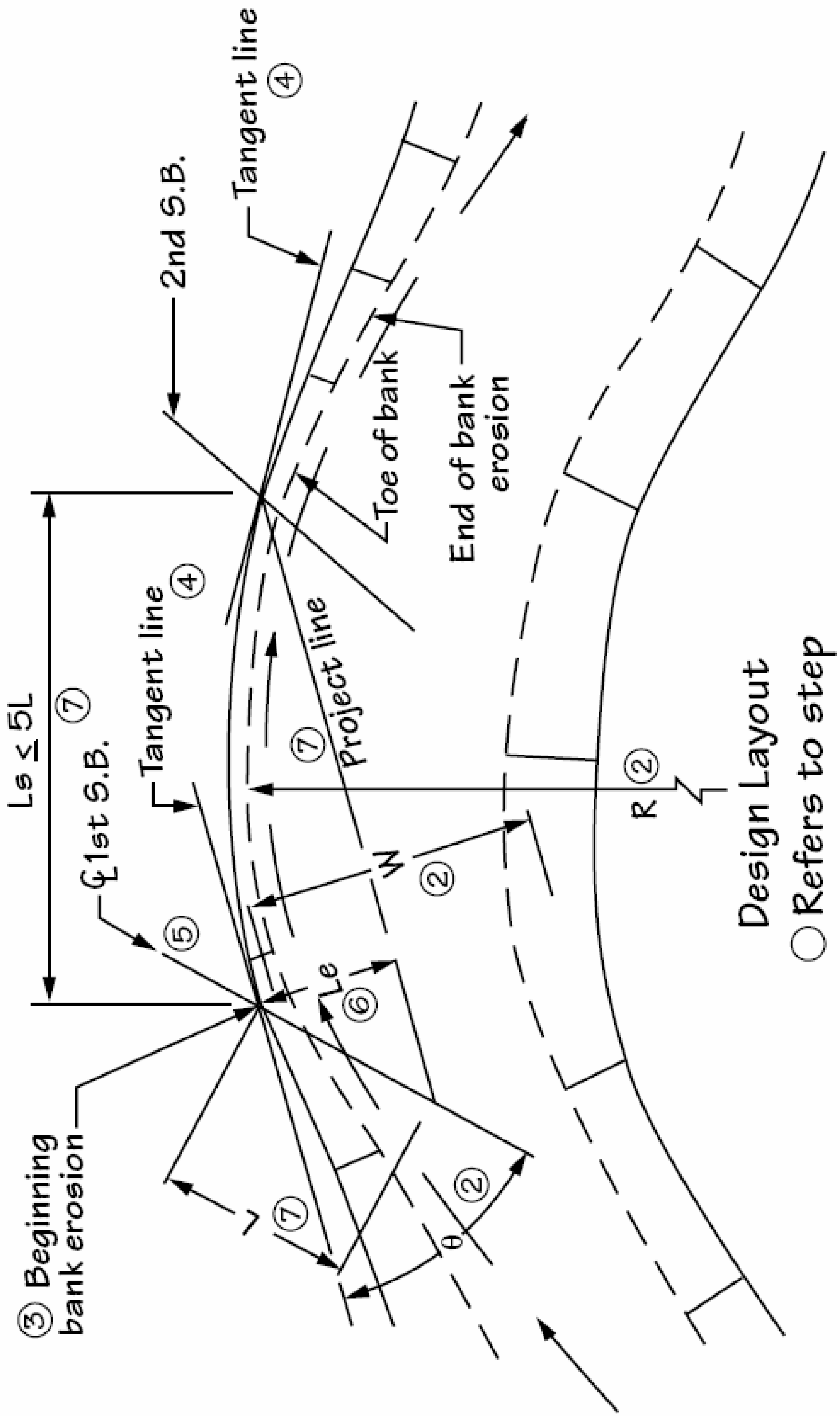
This section provides a generalized worksheet for designing a stream barb. The user is cautioned that, as with all stream projects, the design and placement of stream barbs are site specific. These listed steps will likely need to be modified and adjusted for specific projects.

Step 1. Investigate site and obtain physical and geomorphic based parameters. The designer should determine if site is suitable for stream barbs. The user should examine the site with the following questions in mind:

1. Is erosion occurring on the outside of a bend?
2. Is the channel bed stable or quasi stable?

3. Is the stream thalweg close to the eroding bank toe?
4. Is this a natural channel (uncontrolled)?

If the answer is *yes* to all of the above questions, proceed.



Design Layout

Step 2. Determine “bankfull” elevation, radius of outer bank, typical section, and hydraulic gradient. Develop a plan drawing of site from aerial photo or from survey information showing outer bank, “bankfull” line on opposite bank, on the eroding bank if it is significantly different than top of bank, and the thalweg. Locate beginning and ending points of the eroding bank. Using CAD or other methods, approximate the outer bank radius and “bankfull” width. If the radius varies significantly through eroded section of bend, determine the radius, width, and area at the beginning of erosion and at one or two other points that typify the stream curve.

From field survey and cross section data determine widths, radius, and area of “bankfull” discharge.

Radius of bend (R) R_1 = _________

R_2 = _________

“Bankfull” Width (W) W_1 = _________

W_2 = _________

“Bankfull” Area (A) A_1 = _________

A_2 = _________

Determine the average depth (Da) $= \dfrac{\frac{A_1}{W_1} + \frac{A_2}{W_2} + \cdots \frac{A_i}{W_i}}{i}$ = _________

Note: The value of A / W for each section should be somewhat similar. Calculate the ratio of radius of bend to width (R/W) for each section of the bend and determine the most favorable angle “θ” for stream barb alignment.

- If < 3, consider other treatment
- If < 6, consider reduced angle, “θ” $\leq$ 30°
- If > 6, “θ” = 30° to 45° generally satisfactory
- If > 9, consider larger angle, “θ” > 45°

Step 3. Mark the beginning point of bank erosion on the outer bank curve. This determines the location of the first stream barb and marks the point where the downstream face of the weir will intercept the bank line.

Step 4. Draw a tangent to bank curve passing through the point where the weir line intercepts the bank. Refer to the design layout in the figure below. Note that the circled numbers refer to the step numbers listed herein.

Step 5. Beginning at the tangent point above, draw a line angled upstream, "θ" (determined in step 2) degrees, from the tangent line and extending streamward. This line forms the downstream face of the stream barb. Extend this line out a sufficient distance to cross the thalweg and measure the length from the bank. This length (L) determines the stream barb weir length.

Step 6. Determine the effective length (L_e) of stream barb:

$$L_e = L * \sin\theta = \_\_\_\_\_\_\_\_$$

Check length: $\frac{W}{4} = \_\_\_\_\_\_$

Is $Le \leq \frac{W}{4}$?

If the answer is <u>*yes*</u>, proceed. If no, consider a reduced weir length or re-evaluate the use of stream barbs at this site. Toe erosion may be caused by processes other than direct stream flow.

Step 7. Determine the location of the subsequent stream barbs. From a point on the outer end of the first stream barb, draw a line extending downstream to the point where it intercepts the bank. This projected line (7), should be parallel to the tangent line (4). Determine "L_s", the distance from this point back to the point where previous stream barb intercepts the bank. If, L_s is $\leq 5 * L_e$, then this point is a suitable location for the next stream barb. If this point is > $5 * L_e$, consider limiting the distance to $5 * L_e$. It is important to note that anecdotal evidence indicates that close spacing may be required in fast, high energy streams.

Step 8. Repeat steps 4 through 6 for subsequent stream barbs. Typically the last stream barb ends near the end of the eroding section of bank or end of bend.

Step 9. Determine stream barb section properties.

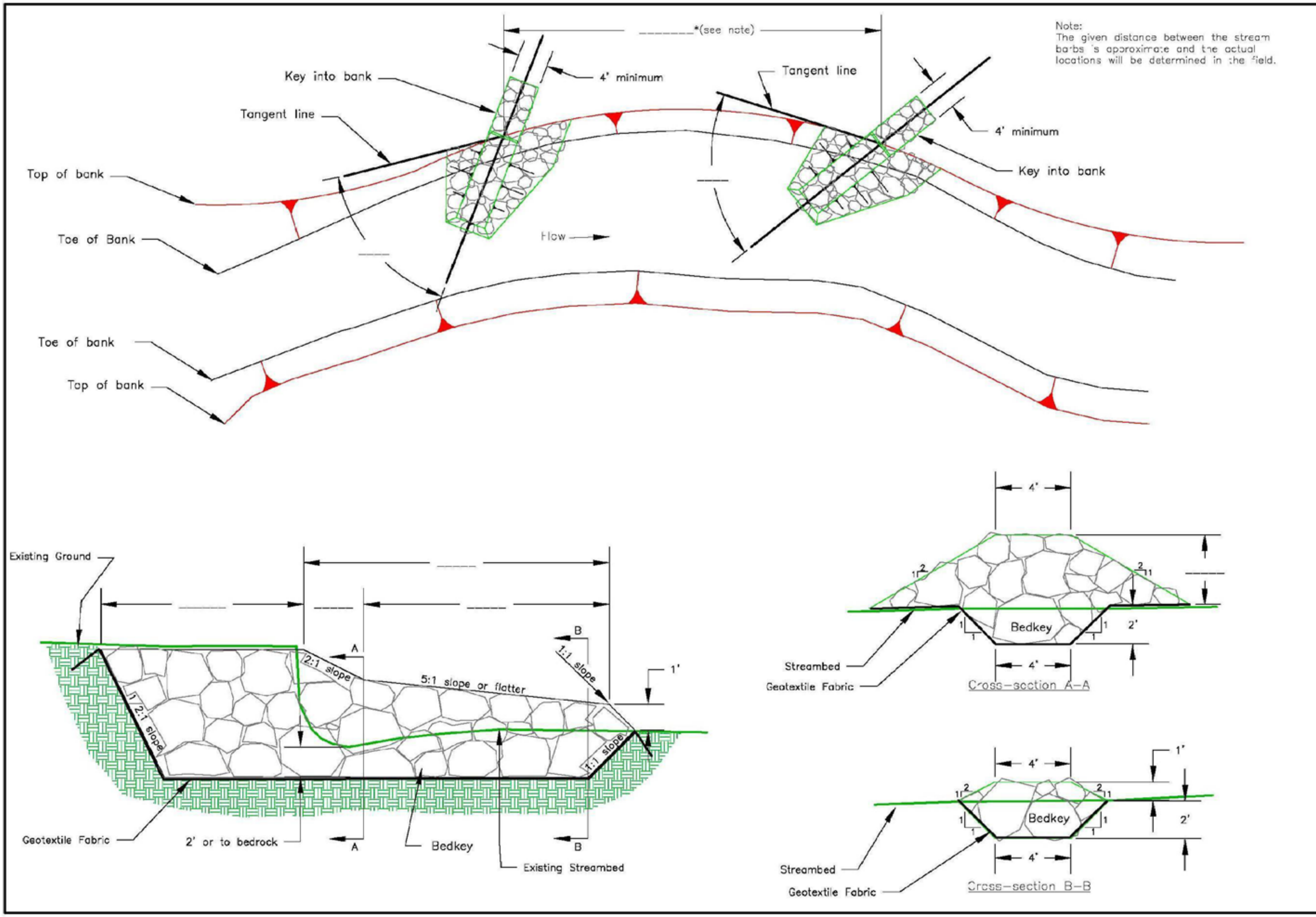
$H = \frac{1}{3}\, Da = \_\_\_\_\_$ Height of weir section, outer end

$H = \frac{1}{2}\, Da = \_\_\_\_\_$ Height of weir section, bank end

$S = (\frac{1}{3} \text{ to } \frac{1}{2}) * 2.5 * Da = \_\_\_\_\_\_\_\_$ depth of bed key

Step 10. Determine rock size per discussion above (Rock Size).

Step 11. Prepare Construction Drawings. Example concept design details are provided in the in the figures below.



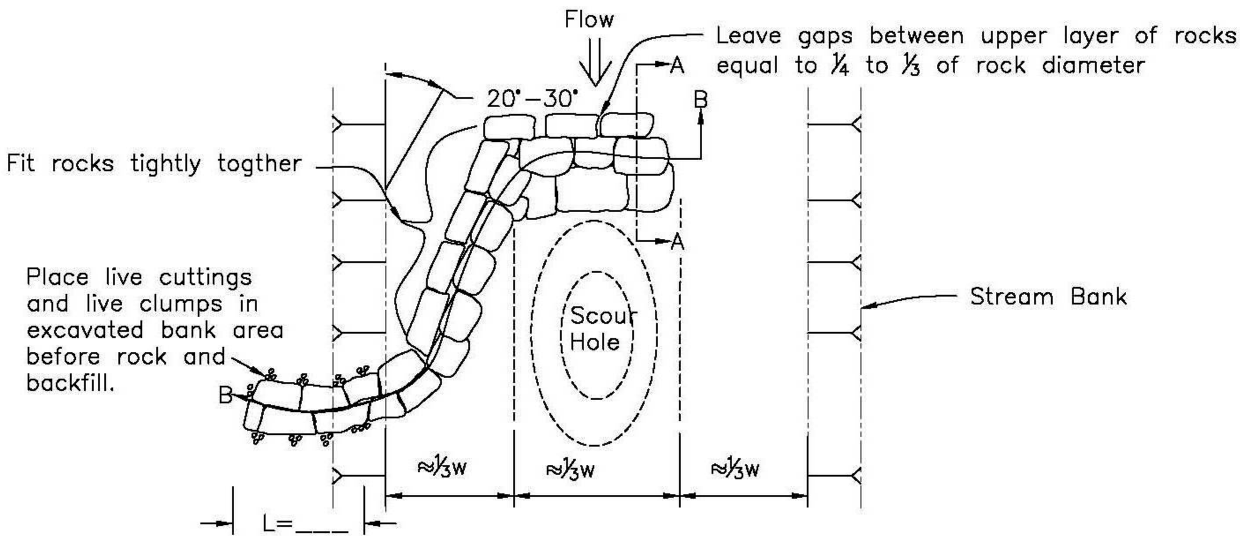
EWP Stream Barb Design Sheet

Date	7/05
Designed	
Drawn	Josh Edwards/John Cooke
Checked	
Approved	

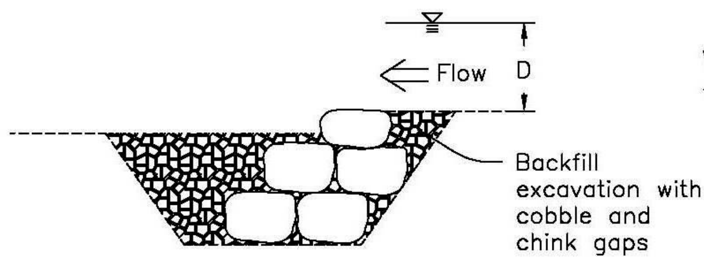
Site Name:
Site Location:
Sponsor:

NRCS
Natural Resources Conservation Service
United States Department of Agriculture

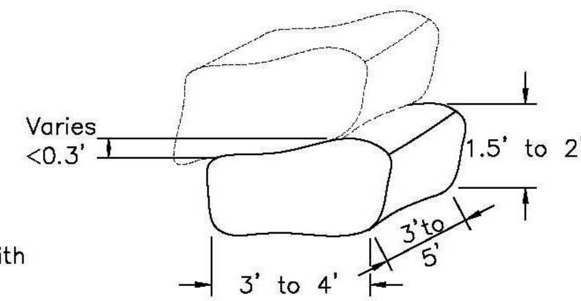
File Name VA-SO-1009-EWP9.dwg
Drawing Name StreamBarb Design Sheet
Sheet of



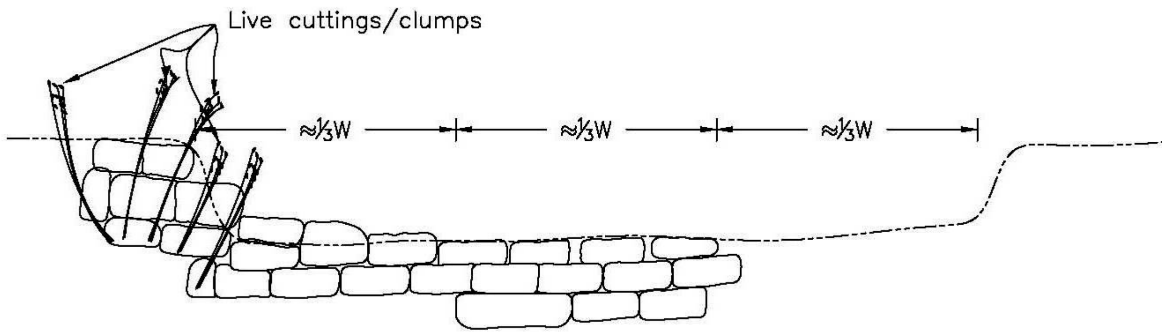
Hook Vane Plan



Rock Vane Section A



Typical Rock Dimensions and Placement (stone sized to be stable highest design discharge)



Section B

Notes: The rocks should be rectangular or nearly so at the rock to rock contact. The rock to rock contact should be solid. If rocks are not perfectly flat, the thicker end should be placed downstream.

Conceptual Plan - Not for Construction

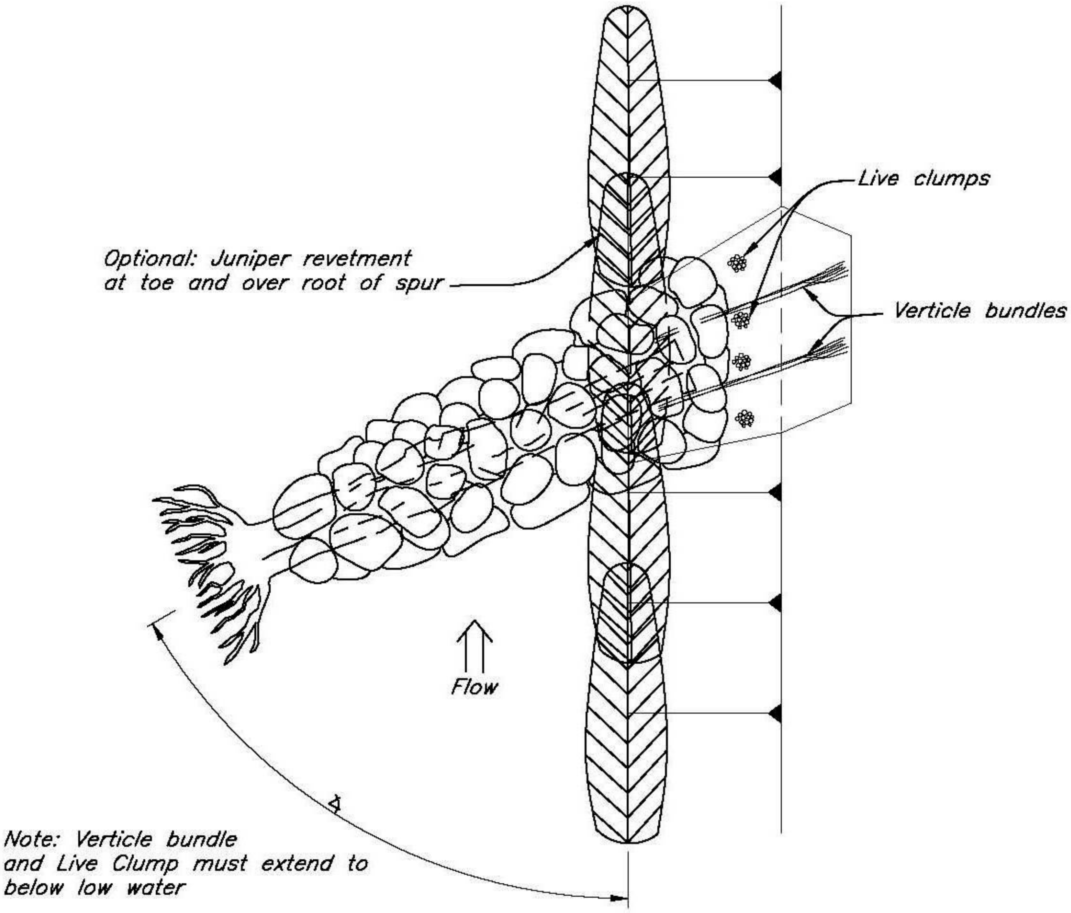
N.T.S.

NRCS
Natural Resources Conservation Service
United States Department of Agriculture

Hook Vane
(option 2)

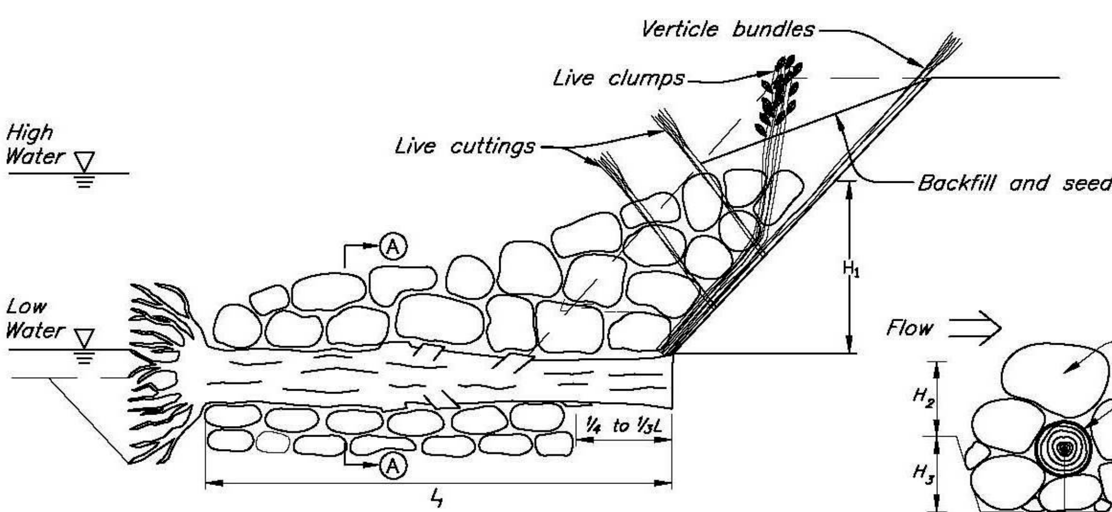
Designed	J. Fripp, K. Robinson	Date 08/07
Drawn	J. Renteria	08/07
Checked		
Approved		

File Name: Hook_Vane_opt2.dwg
Drawing Name: HookVaneOpt2
08/16/07
Sheet of

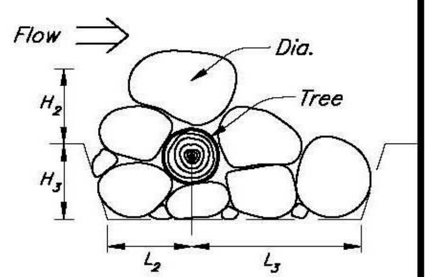


L1=___
L2=___
L3=___
H1=___
H2=___
H3=___
∢=___
Dia=___

ROCK BARB WITH ROOT WAD
(PLAN)
N.T.S.



ROCK BARB WITH ROOT WAD
(PROFILE)
N.T.S.



SECTION A–A
N.T.S.

Conceptual Plan Not for Construction

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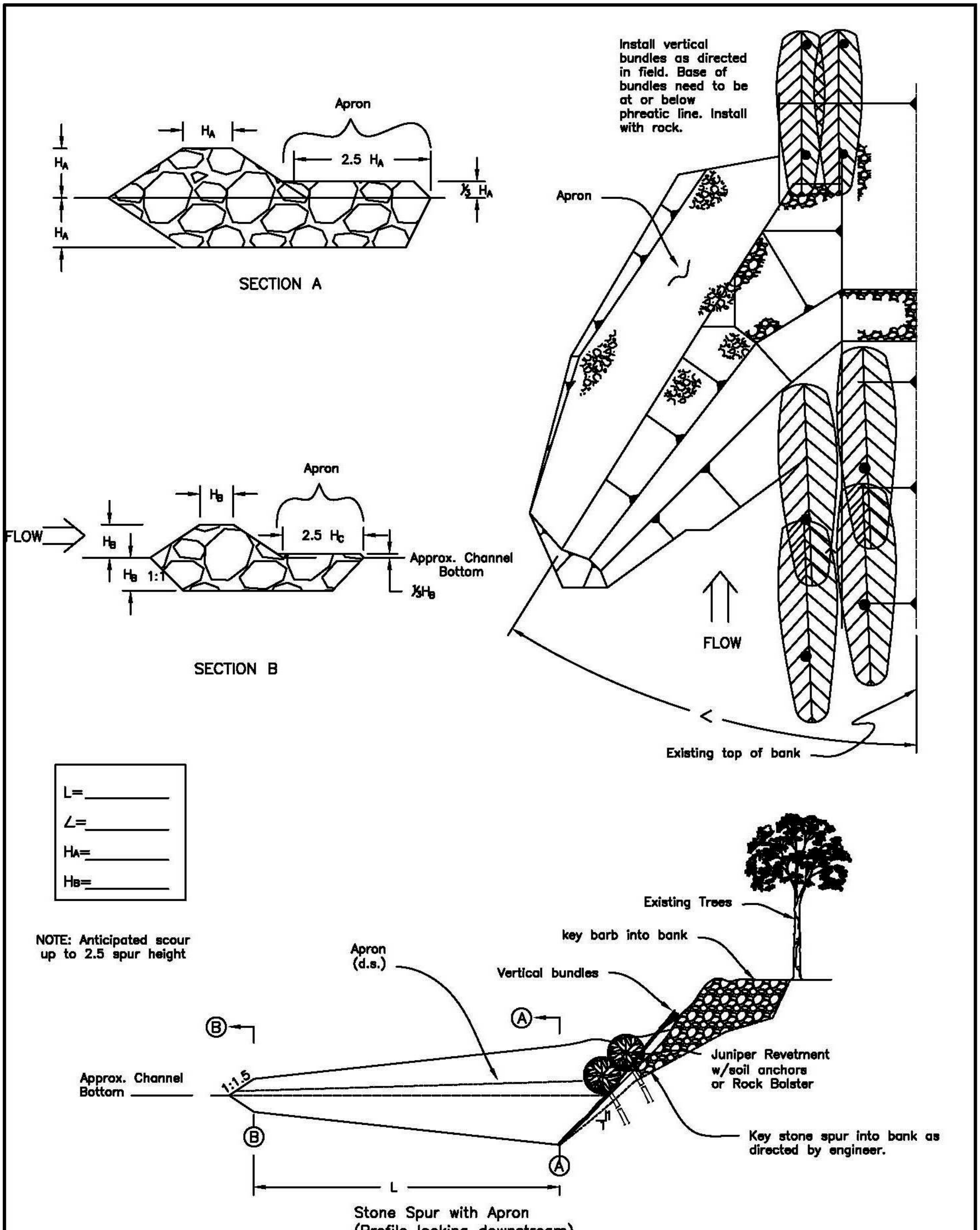
Natural Resources Conservation Service
United States Department of Agriculture

ROCK BARB WITH ROOT WAD

Designed	J. Fripp C. Haag, L. Saele	Date 08/05
Drawn	K. Miller, J Renteria	08/05
Checked		
Approved		

File Name: RBarb–Rw1.dwg
Drawing Name: RBarb–Rw1
02/02/06
Sheet 1 of 1



Conceptual Plan Not for Construction

Drawings not to scale

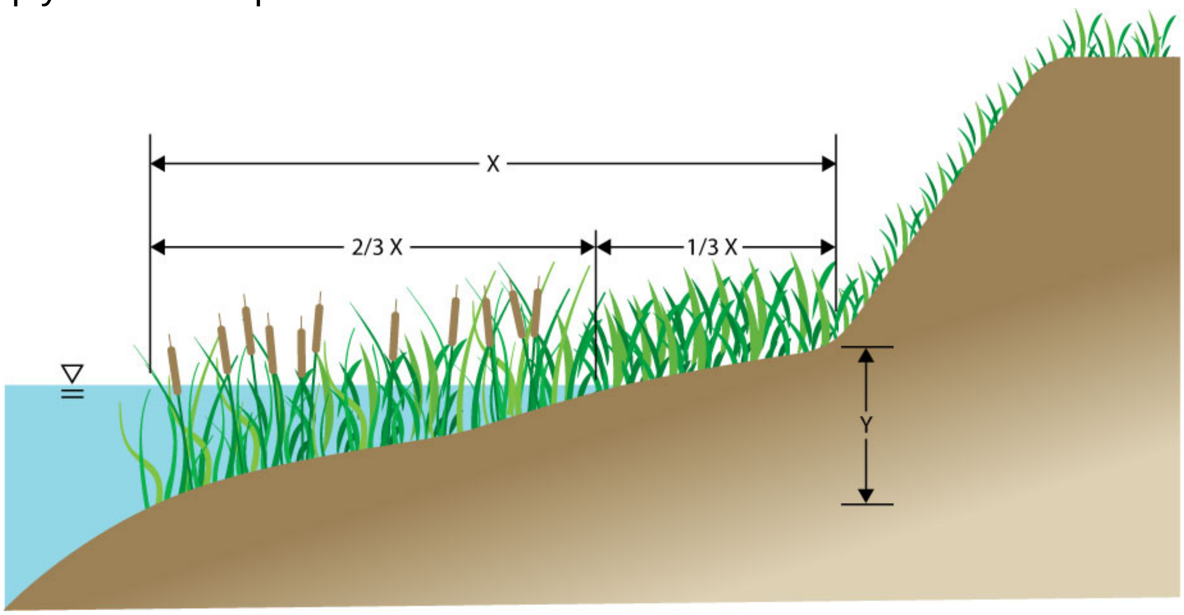
NRCS Natural Resources Conservation Service United States Department of Agriculture	STREAM BARB WITH LAUNCHABLE INTO STONE TOE	Date Designed J. Fripp, L. Saele 09/05 Drawn Juan Renteria 09/05 Checked Approved	File Name Stone-Barb.dwg Drawing Name StoneBarb 07/26/07 Sheet of

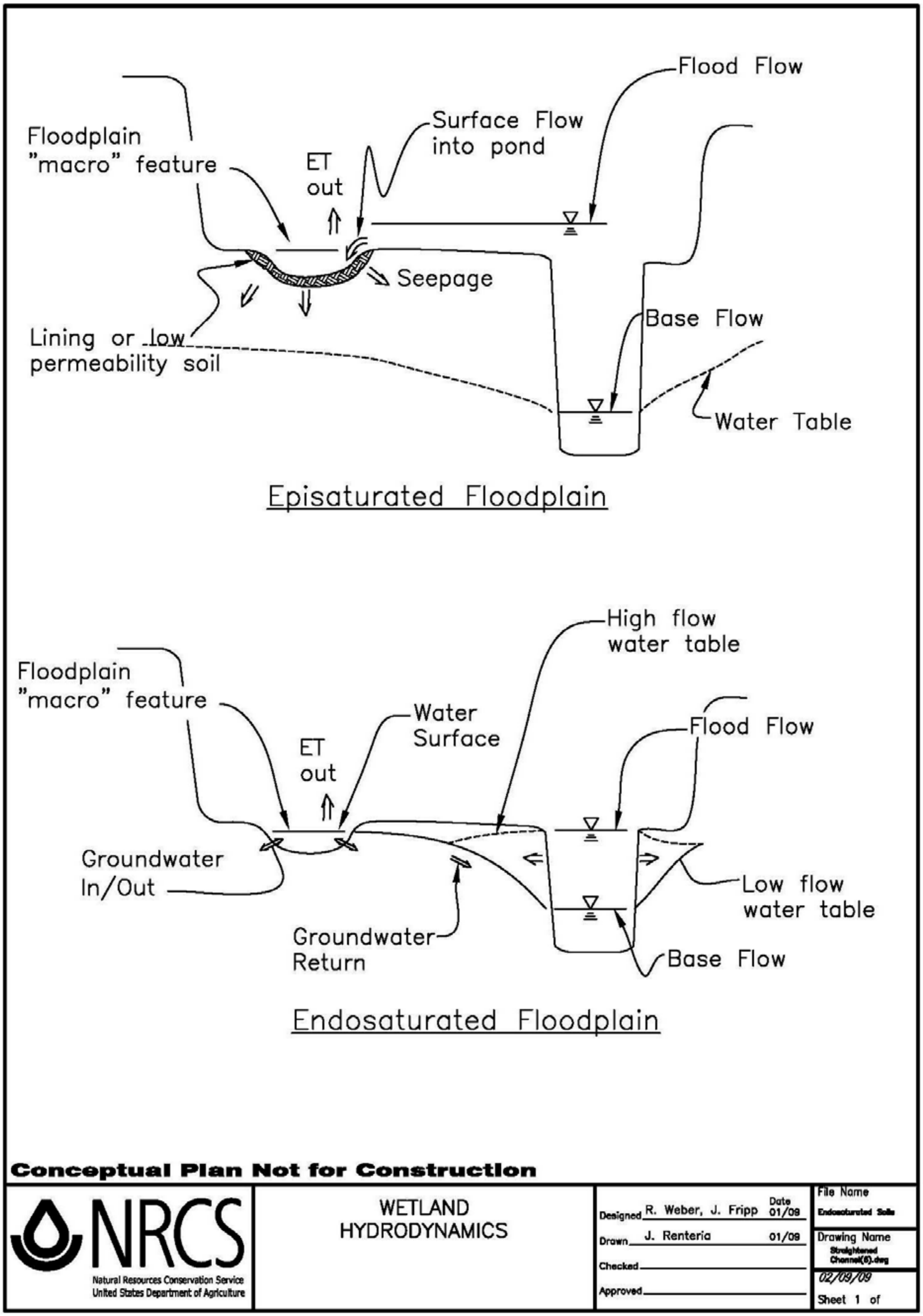
Wetland Creation/Restoration

Wetlands are defined as areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support a prevalence of vegetation typically adapted for life in saturated soil conditions. They occupy the transition zone between deep water and terrestrial landscapes. Wetlands types vary widely throughout the United States. Wetlands are typically classified according to factors such as geographic location, biological function, hydrologic function, and species composition. The following concept designs are intended to be used for discussion purposes by field personnel involved in restoring, enhancing, or creating wetlands. In all situation, planting wetland species will have a significant impact.

Wetland Hydrodynamics

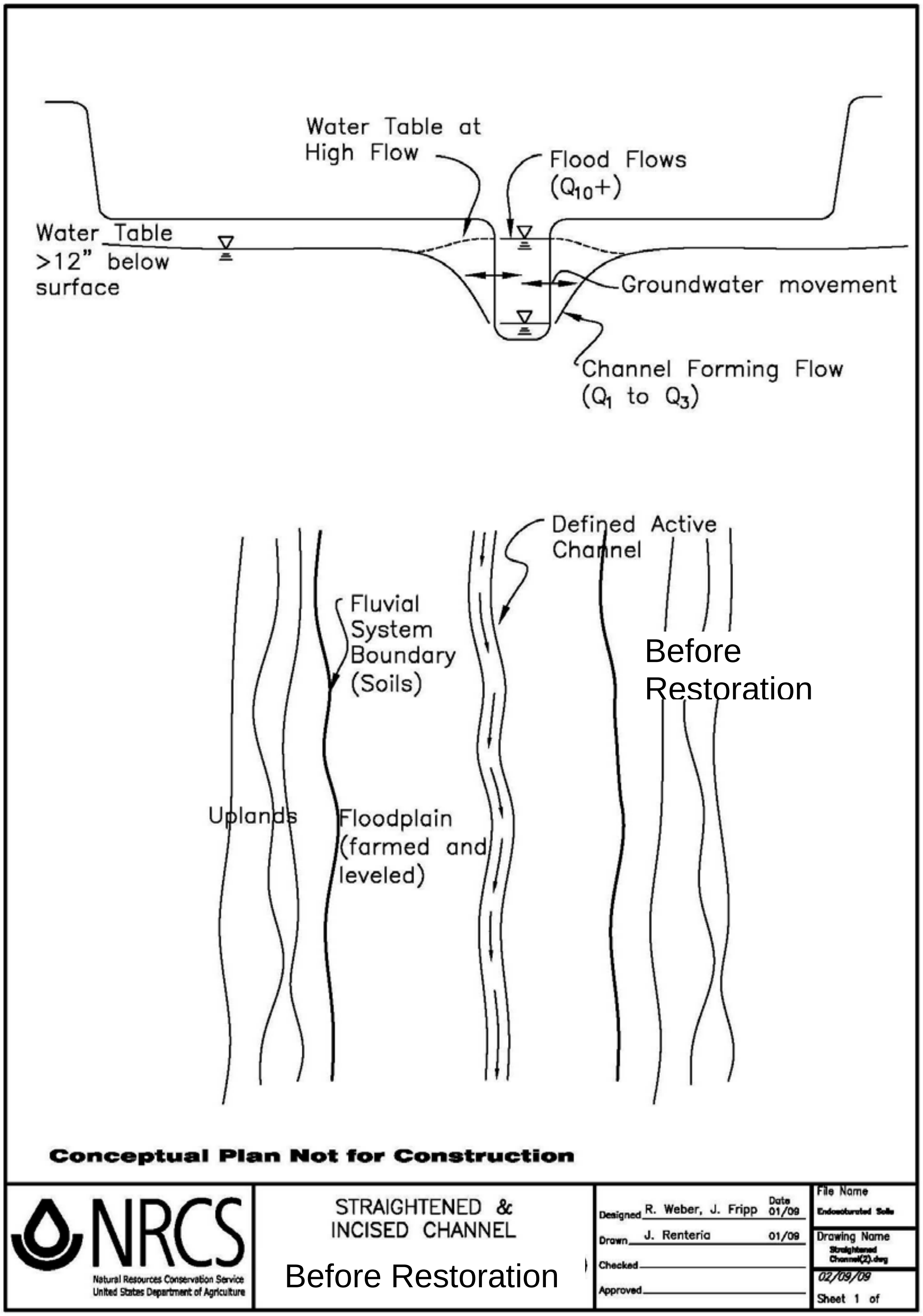
Fluvial system wetlands can be divided into two separate categories, based on the soil hydrodynamics. Episaturated systems depend on surface flooding to supply floodplain depressions with water. This water is perched on low-permeability soils. Endosaturated systems have high permeability soils that transmit water under the head provided by the stream water surface into the floodplain. Endosaturated systems do not require surface flooding, but do need long durations of high flow to support a shallow floodplain water table. Episaturated systems need high frequency surface flooding, but the durations need not be long to supply water to depressions.

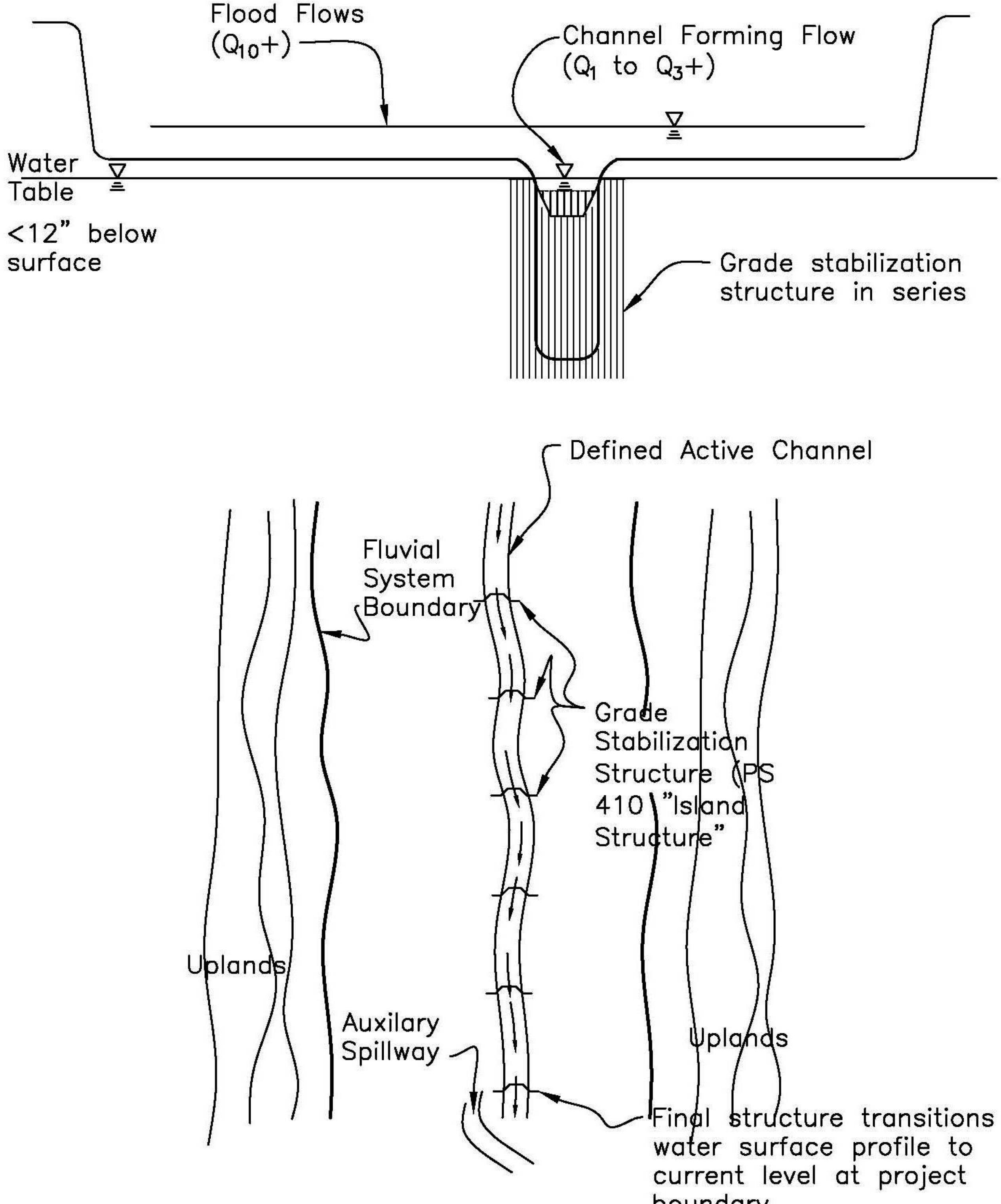




Restoration of Wetlands with Grade Stabilization

A common case is a fluvial system where the active channel has been straightened, has incised, and has a higher capacity than before. The floodplain wetlands no longer get high frequency flooding, or have a groundwater table that is near the surface. Grade stabilization structures in series can be installed to raise the water surface profile. The structures must be carefully sited so that flow around each structure encounters a high water surface provided by the downstream structure, and little or no overfall at the stream bank occurs. This is the Practice Standard 410 "Island Structure" criteria. The vertical and lateral extent of the structure must be adequate to defend against scour and piping. The scenario shown is one where the floodplain is endosaturated. After restoration, high frequency flows are contained within the channel, but still support a high groundwater table.





Conceptual Plan Not for Construction

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Natural Resources Conservation Service
United States Department of Agriculture

STRAIGHTENED & INCISED CHANNEL

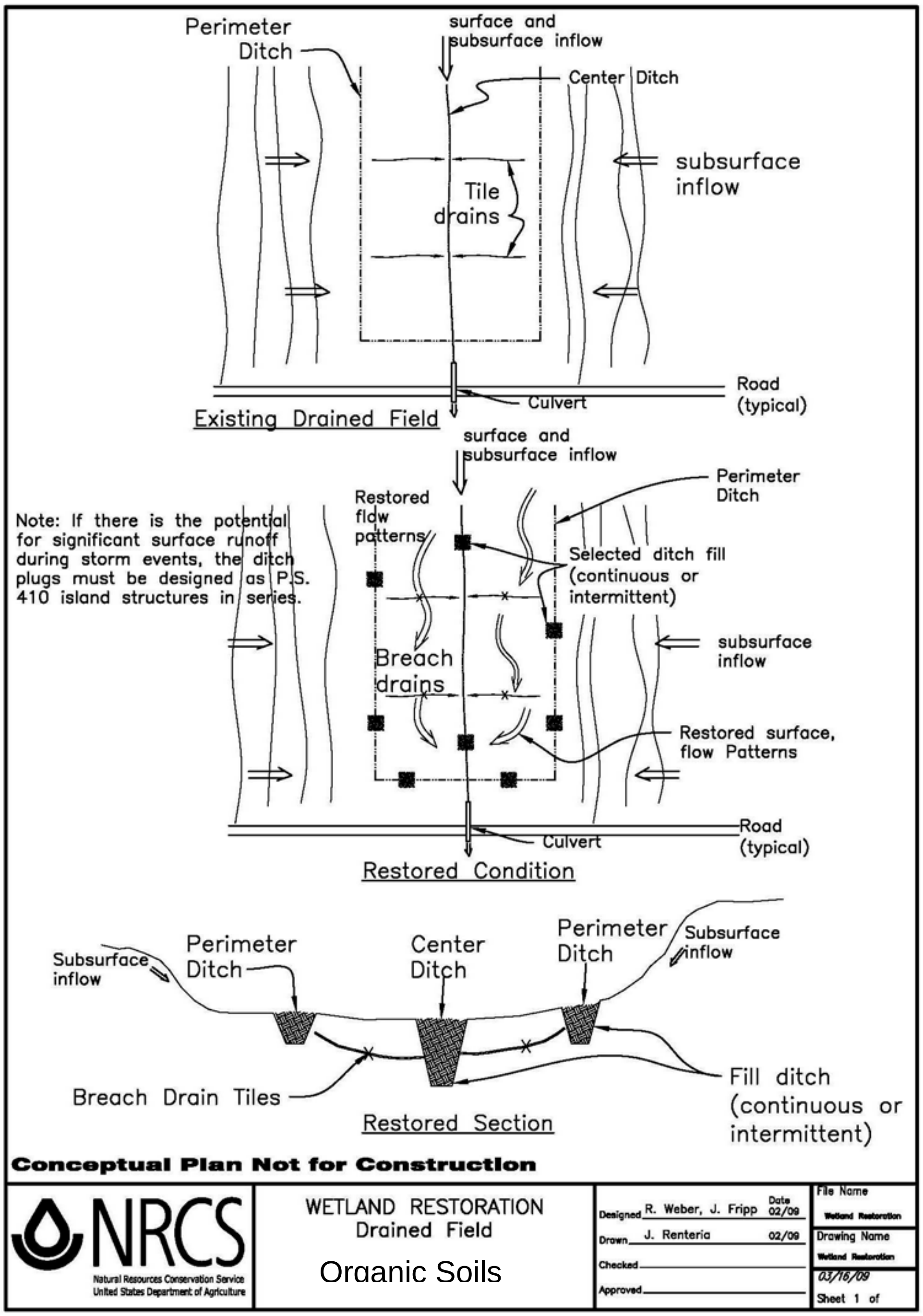
After Restoration

Designed	R. Weber, J. Fripp	Date 01/09
Drawn	J. Renteria	01/09
Checked		
Approved		

File Name: Endosaturated Soils
Drawing Name: Straightened Channel
02/09/09
Sheet 1 of

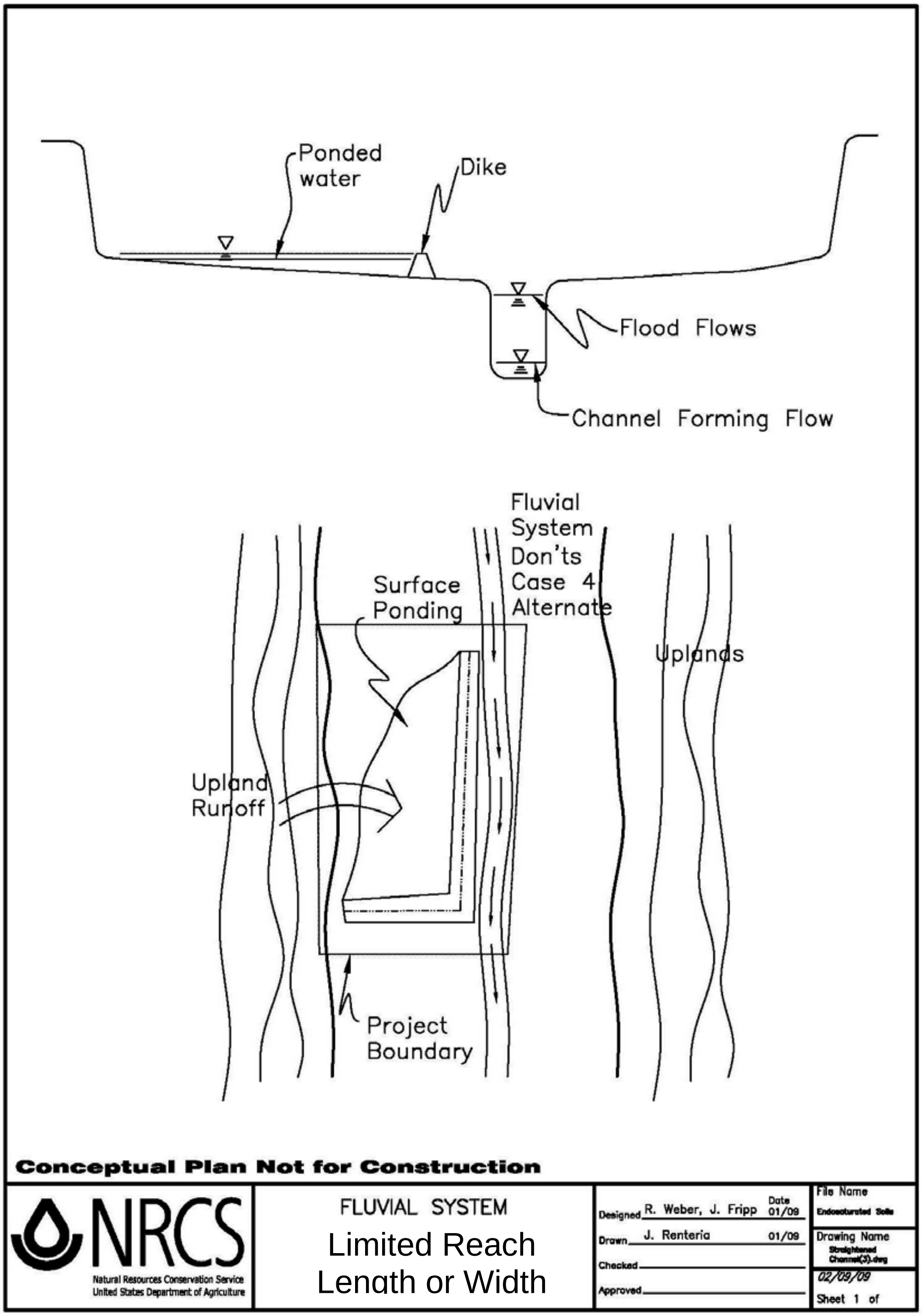
Restoration of Wetlands with Organic Soils

This special case is one in which the fluvial system features organic soils. The original hydrologic condition is one of near continuous surface saturation. The systems do not typically feature a defined active stream channel, even though they frequently carry large flow rates. The dominant water source is strong groundwater inflow, which was intercepted by perimeter drainage along the valley margins. Center ditches may have also been installed to carry away surface water falling on the system as precipitation, and these may currently have the appearance of a stream channel. Restoration consists of periodically plugging the channels, cutting any interior drain tiles, and restoring a regime of shallow sheet flow.



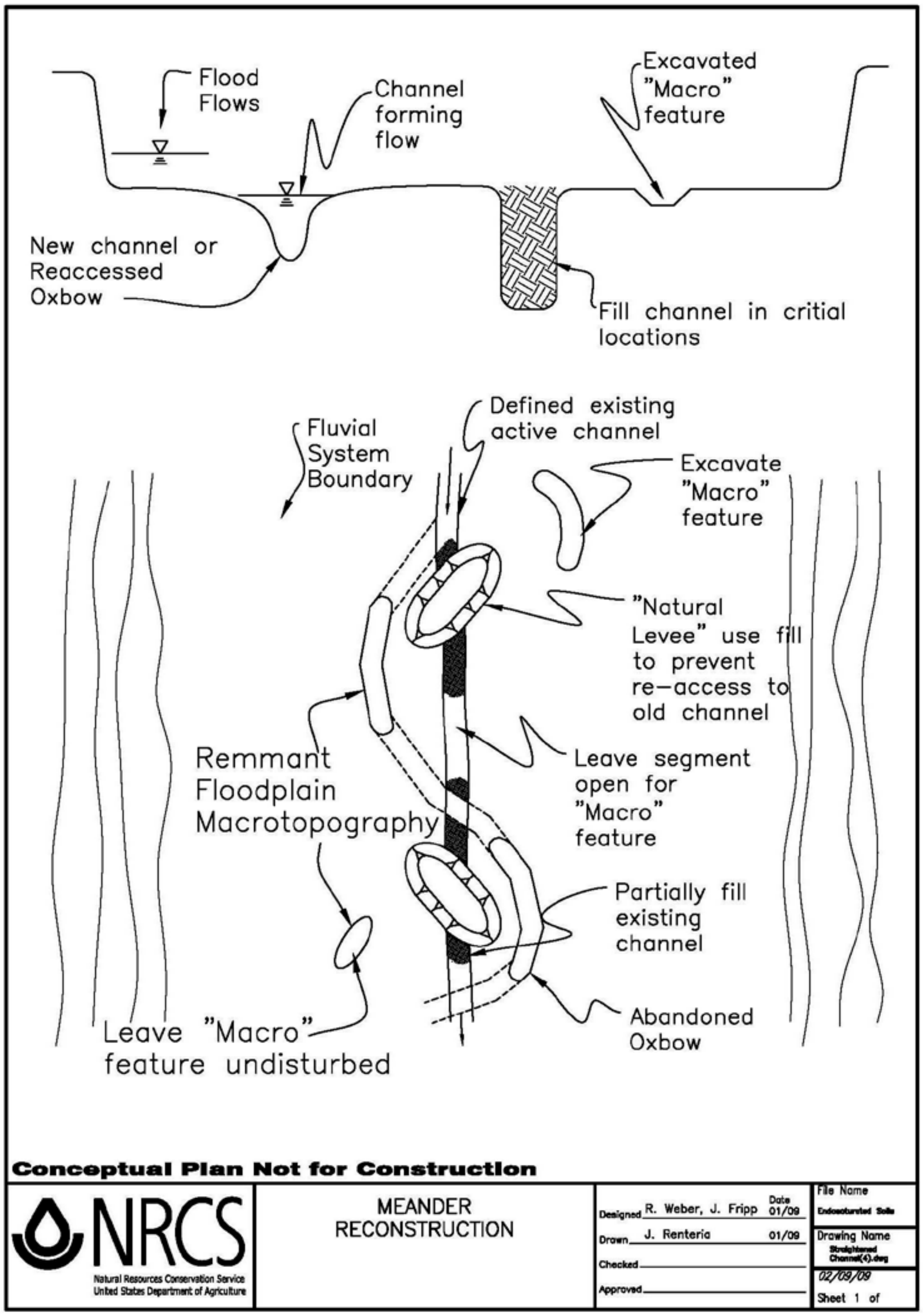
Restoration of Wetlands within Limited Reach Length/Width

In many cases, only a small portion of a fluvial system is available for restoration. In cases where the entire reach length and width cannot be modified, other means are appropriate to artificially provide floodplain wetland hydrology. In this case, a low dike captures surface runoff from upland sources to provide water for the wetland. Care must be taken so that such a structure will survive flooding events, and that it will not increase the flood elevation.



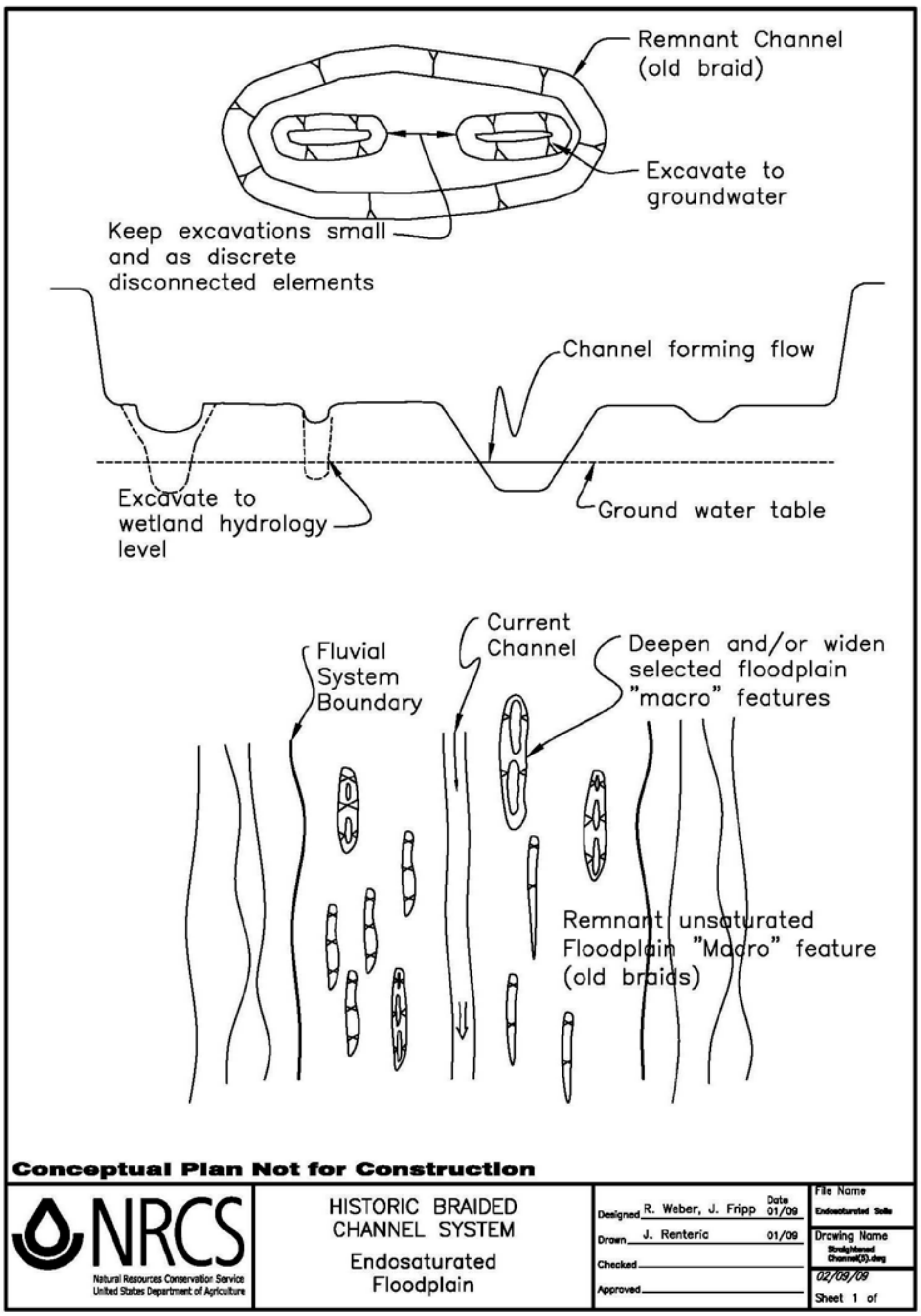
Restoration of Wetlands with Meander Reconstruction

A common case is a fluvial system where the active channel has been straightened, has incised, and has a higher capacity than before. The floodplain wetlands no longer get high frequency flooding, or have a groundwater table that is near the surface. A new, low capacity channel is excavated, with a channel grade and cross section that provides for long term equilibrium with the stream's hydrograph and sediment supply. If remnant abandoned channel features exist, they can be incorporated into the new channel alignment. The excavation is used to backfill the old channel and construct "natural levee" features that prevent flows from reaccessing the old channel, and provide floodplain macrotopography (macro). Additional floodplain macro is provided where possible to increase the diversity of hydroperiod and regime, create varied vegetative plant communities, and provide diverse habitats for aquatic and terrestrial organisms.



Restoration of Wetlands in Braided Streams

There are situations where the fluvial system is a naturally stable braided stream channel. In many cases in the western U.S. these systems have a much lower stream water surface because of water diversions. The groundwater table in the floodplain may be low enough that shallow groundwater no longer provides wetland hydrology. In addition, the remnant floodplain macro features are long, linearly shaped, and parallel with the active stream channel. The bottom of these are the lowest points in the system, and excavation can lower the bottoms to a point of contact with the groundwater table, and create wetland conditions. However, if these excavations are longitudinally extensive, groundwater will move to the lower end of the excavation under the energy of the valley gradient, and the feature will act as a drainage ditch. These excavations should be short and disconnected to prevent this occurrence.



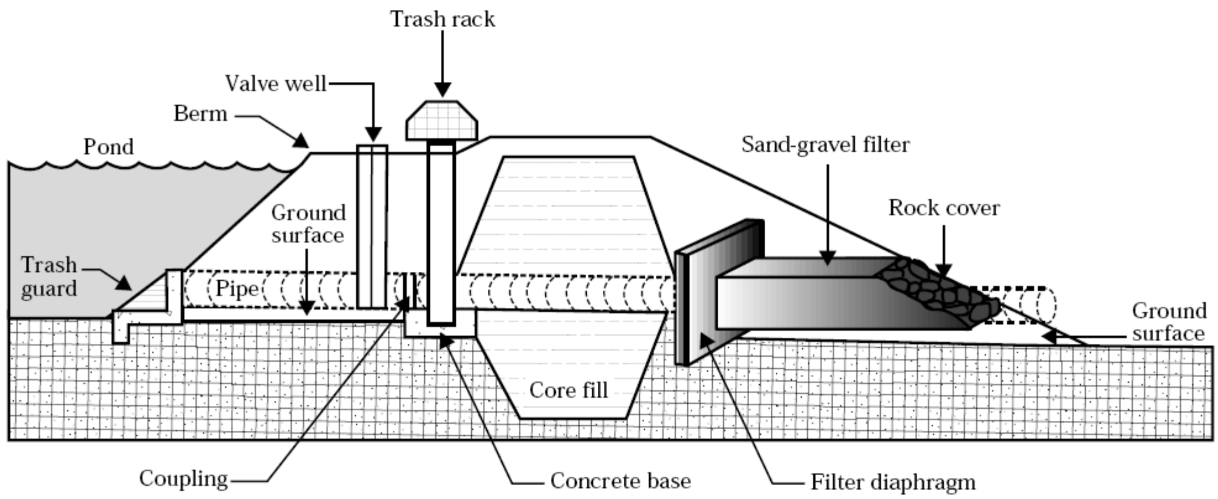
Stormwater Management

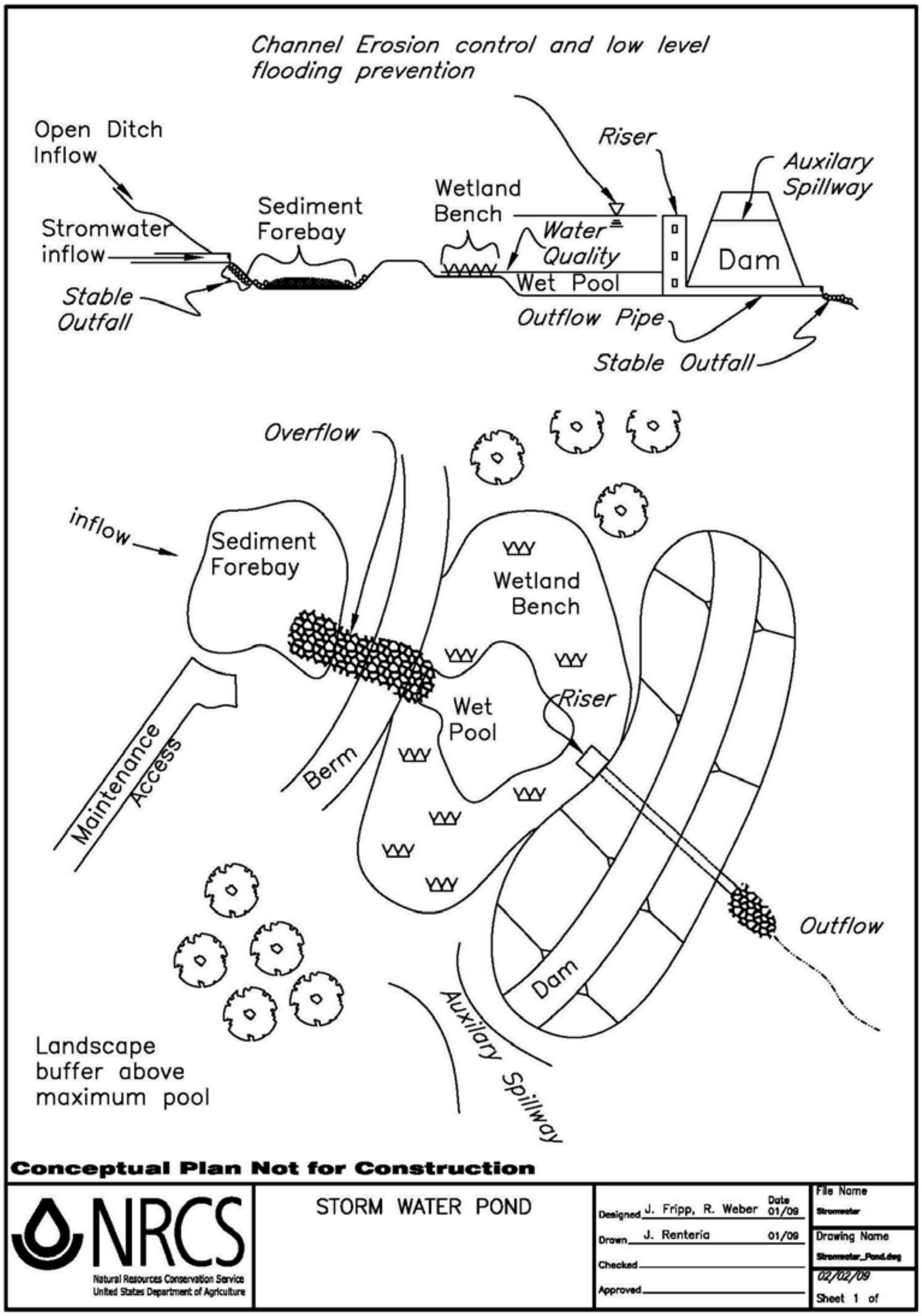
Stormwater management can be an important component of a broad restoration program in urban and suburban watersheds. There are a variety of stormwater management techniques that can provide for channel stability as well as habitat benefits. Stormwater ponds have traditionally been designed only to reduce the effects of development on nuisance level flooding. The ponds are directed towards maintaining the post development peak discharge of the 2-year and 10-year storm events and have been very effective for this design goal. However they do little to affect the overall quality and quantity of runoff.

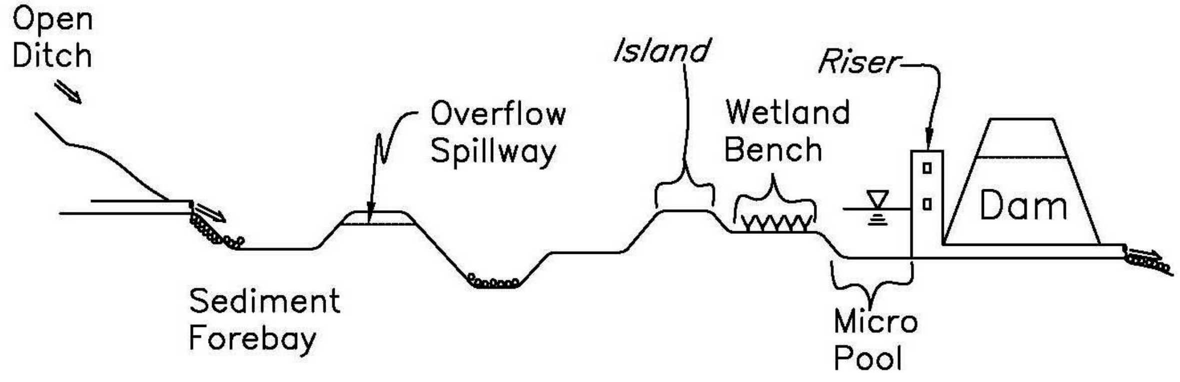
Extended detention ponds can provide both water quality benefits and reduce erosive flows. The most common design storms are the 1-year rainfall event or the event that generates 0.5 in. of runoff. The first 0.5 in. of runoff is considered to provide a first flush of the watershed and contains a significant concentration of pollutants. The 1-year event is also considered for erosion control. The design storms are detained for 12 to 24 hr as measured between the centroid of the inflow to the centroid of the outflow hydrograph. This results in a longer detention time and a decrease in the peak discharge over what would have occurred without the pond. The water quality benefits are provided by detaining water for enough time to allow sediments (and their attached pollutants) to settle to the bottom of the pond. The stream stability benefits are based on the premise that the increased volume of runoff from the developed watershed is offset by a reduced peak discharge.

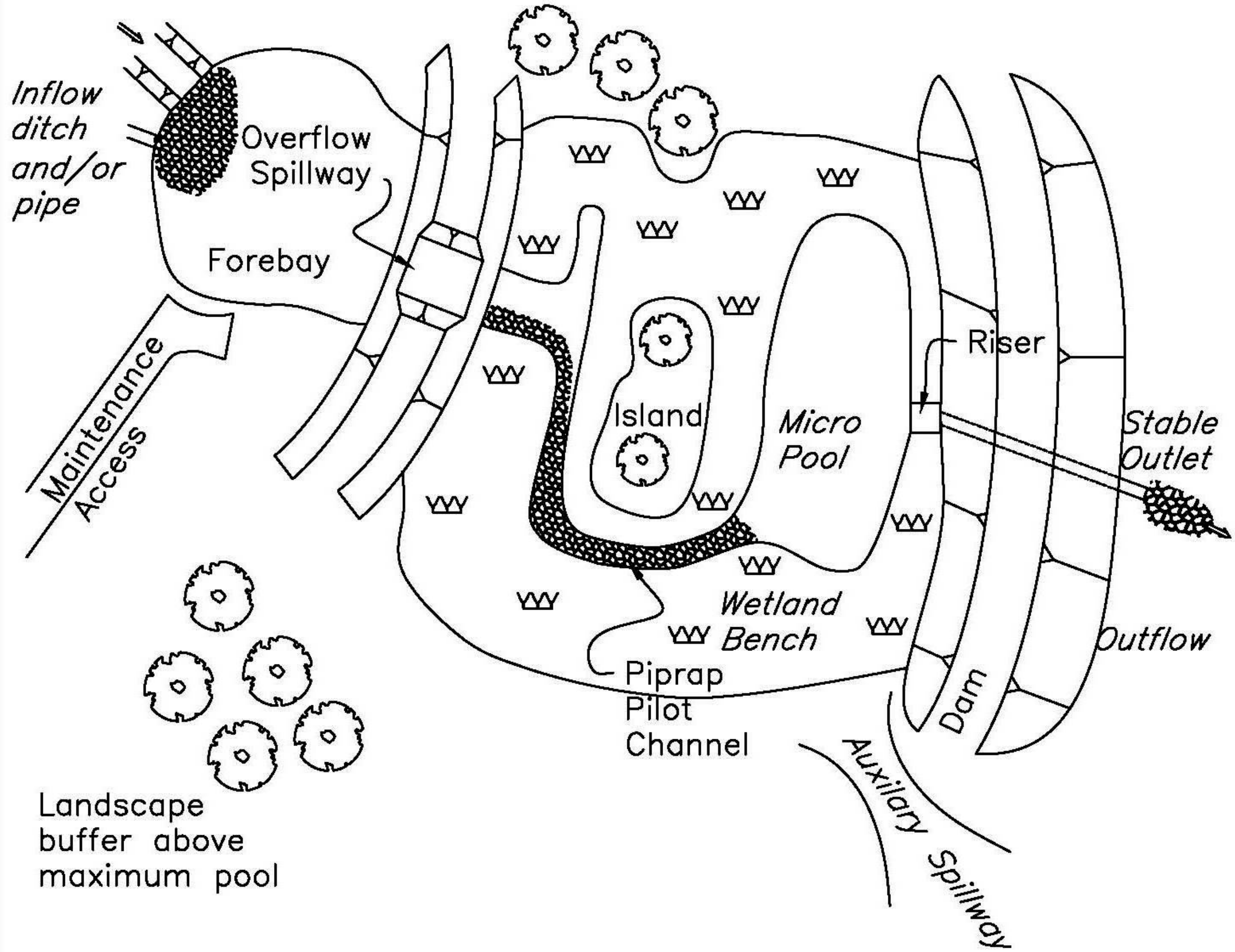
Wetland-pond systems are used to provide aesthetic, habitat, and water quality benefits. Often, large systems include nature and fitness trails. Habitat benefits can be provided with high and low marshes, nesting islands, and planting diversity. Water quality enhancement is a result primarily of the settlement of pollutant-laden sediment, and physical filtration of particulate matter as well as nutrient uptake. As with any shallow impoundment, a drawback for the use of wetland-pond systems is primarily thermal loading to downstream reaches. Effects of the structure on fish passage as well as public safety should also be considered.

Infiltration designs mimic predevelopment hydrology. They provide quasi habitat benefits through increased base flow and water quality benefits though filtration. Bioretention projects typically involve the use of shallow ponding areas and infiltration. The use of mulching and vegetation reduces the possibility of clogging and failure of the infiltration components of the bioretention systems. Because they are relatively small, they can be incorporated into the landscaping plans of almost any site. The primary benefit of this type of project is improved water quality and the maintenance of base flow. Bioretention and infiltration designs typically do not affect runoff during larger events runoff.


Trash rack
Valve well
Berm
Pond
Sand-gravel filter
Rock cover
Ground surface
Trash guard
Pipe
Ground surface
Core fill
Coupling
Concrete base
Filter diaphragm


Channel Erosion control and low level flooding prevention
Open Ditch Inflow
Riser
Auxilary Spillway
Sediment Forebay
Wetland Bench
Stromwater inflow
Water Quality
Dam
Wet Pool
Stable Outfall
Outflow Pipe
Stable Outfall
Overflow
inflow
Sediment Forebay
Wetland Bench
Wet Pool
Riser
Maintenance Access
Berm
Outflow
Dam
Auxilary Spillway
Landscape buffer above maximum pool
Conceptual Plan Not for Construction
NRCS
Natural Resources Conservation Service
United States Department of Agriculture
STORM WATER POND
Designed J. Fripp, R. Weber Date 01/09
Drawn J. Renteria 01/09
Checked
Approved
File Name
Drawing Name
Sheet 1 of



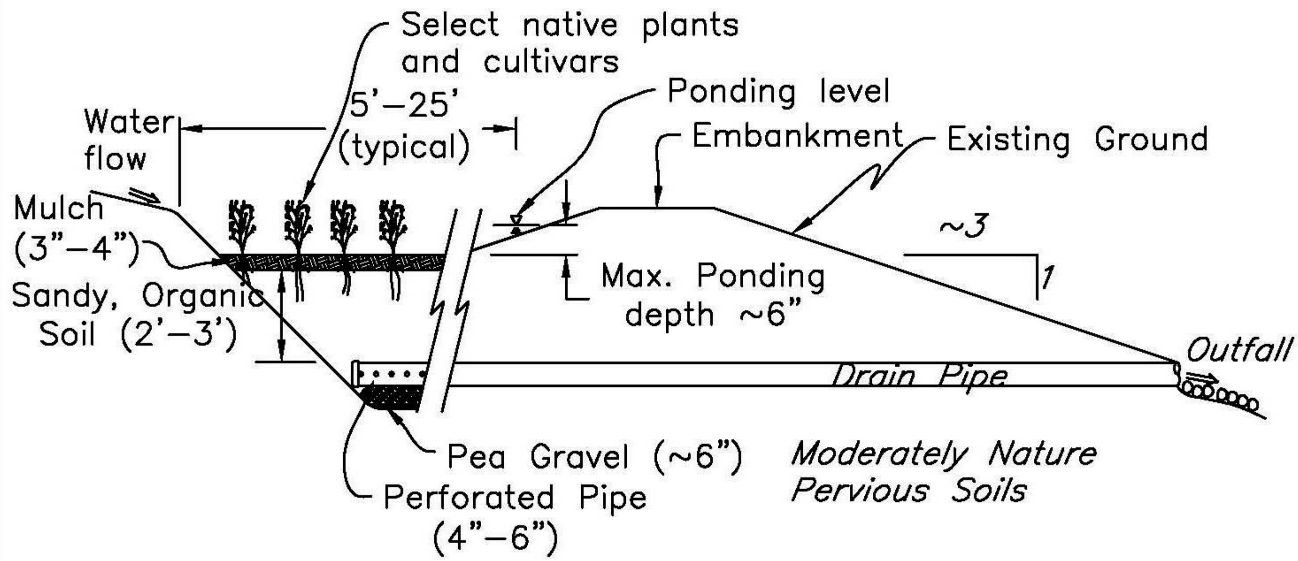


Conceptual Plan Not for Construction

NRCS
Natural Resources Conservation Service
United States Department of Agriculture

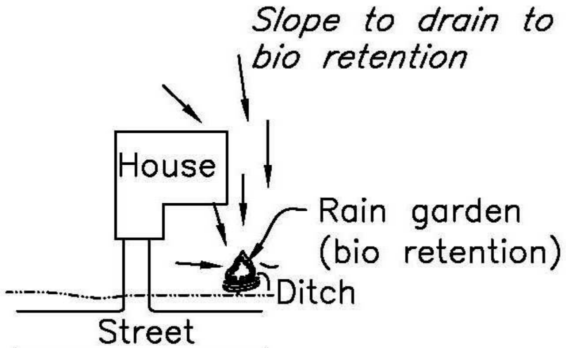
STORM WATER POND
SHALLOW MARSH

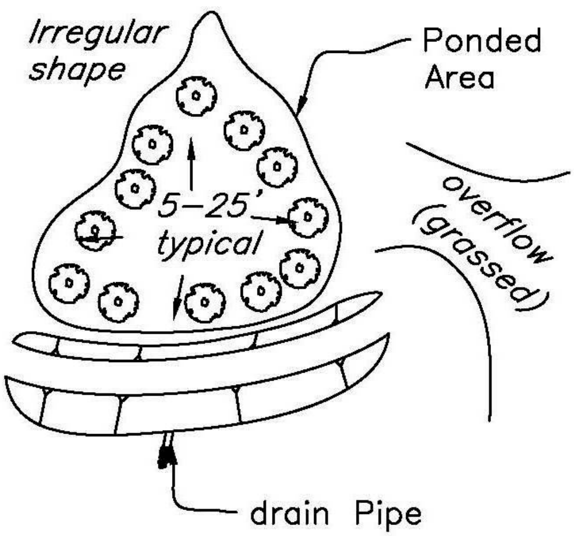
Designed J. Fripp, R. Weber	Date 01/09	File Name Stromwater
Drawn J. Renteria	01/09	Drawing Name Stromwater_Pond(2)
Checked		02/06/09
Approved		Sheet 1 of



Sandy Organic Soil
~50–60% sand
~20–30% topsoil (loam)
~20–30% compost

Provides a combination of filtration and infiltration for small drainage areas. Infilration rate is approximately 0.5"/hr.
In high pervious native soils, a drain pipe is not necessary.
Size garden bustd on drainage area (~.2 to 2 acres) permeability of soils, runoff.





Conceptual Plan Not for Construction

NRCS Natural Resources Conservation Service United States Department of Agriculture	RAIN GARDEN/BIO RETENTION	Designed J. Fripp, R. Weber Date 01/09	File Name Stromwater
		Drawn J. Renteria 01/09	Drawing Name Stromwater_Pond(3)
		Checked	02/09/09
		Approved	Sheet 1 of

Stream Visual Assessment Protocol 2

This section presents excerpts from the NRCS Stream Visual Assessment Protocol Version 2 (SVAP 2) for use by conservation planners, field office personnel and private landowners. The SVAP2 is a preliminary qualitative assessment tool to evaluate features that affect overall stream conditions at the property level. The focus of this assessment procedure is on the overall condition of wadeable streams, their riparian zones, and their instream habitats. The tool assesses visually apparent physical, chemical, and biological features within a specified reach of a stream corridor.

Stream Visual Assessment Protocol - Summary Sheet

Owner's name ____________________________ Evaluator's name_____________________________

Stream name ____________________________ Tributary to: _________________________HUC: ____

1. Preliminary Assessment

A. Watershed Description:

Ecoregion or MLRA_________________ Watershed Drainage area (acres or sq miles)_____________

Watershed management structures: (no.): dams___ water controls _____ irrigation diversions___

No. of miles of contiguous riparian cover/mile of entire stream in watershed (estimated)__________

Land use within watershed (%): cropland _____ hayland _____ grazing/pasture _____ forest ____

urban _____ industrial ______ other (specify) _____

Agronomic practices in uplands include: ____

Confined animal feeding operations (no.) ______ Conservation (acres) ______industrial(acres) _______

Number of stream miles on property________________ Number of total stream miles____________

Stream hydrology: _____intermittent; months of year wetted : _________________

____ perennial; months of year at base flow:_________________

B. Stream/Reach Description:

Stream Gage Location/Discharge: _________________________/____________cfs

Applicable Reference Stream: ___________________ Reference Stream Location: ____/_____

Information Sources:

2. Field Assessment:

A. Preliminary Field Data:

Date of Field Assessment_______________ Weather conditions today_________________________
(ambient temp.\cloud cover

Weather Conditions over past 2-5 days: ____).
(No. of days precip/average daytime temp.)

Reach Location (UTM or Lat./Long.) _______/_______ Channel Type/classification scheme_______/_______

Reach Length (12X bankfull width) _________

Riparian Cover Type(s): Forest___ Herbaceous___ Shrub ____Mixed____ None____

Bank Profile: Stratified___ Homogeneous____ Cohesive Soil___ Non-Cohesive Soil ____

Gradient (√ one): Low (0-2%)___ Moderate (>2<4%)___ High (>4%) ___

Bankfull channel width ______ Floodplain width________ Floodplain wetlands, if present acres)________

Dominant substrate (%): boulder ____ (> 250 mm) cobble ____ (60-250mm) gravel ____ (2-60 mm) sand____ (2-.06 mm) fine sediments ____ (< .06 mm)

Photo Point Locations and Descriptions:

Photo Pt. #	GPS Coordinates/Waypoints	Description
1		
2		
3		

SVAP Start Time/Water Temp: ________/________SVAP End Time/Water Temp: _____/________

B. SVAP2 Scores

Element	**Score**
1. Channel Condition	
2. Hydrologic Alteration	
3. Bank Condition	
4. Riparian Area Quantity	
5. Riparian Area Quality	
6. Canopy Cover	
7. Water Appearance	
8. Nutrient Enrichment	
9. Manure or Human Waste	
10. Pools	
11. Barriers to Movement	
12. Fish Habitat Complexity	
13. Aquatic Invertebrate Habitat	
14. Aquatic Invertebrate Community	
15. Riffle Embeddedness	
16. Salinity	

A. Sum of all elements scored _____

B. Number of elements scored ________

Overall score: A/B __________

1 to 2.9 Severely Degraded
3 to 4.9 Poor
5 to 6.9 Fair
7 to 8.9 Good
9 to 10 Excellent

Suspected causes of SVAP scores less than 5 (5.0 and greater meets Quality Criteria)

____

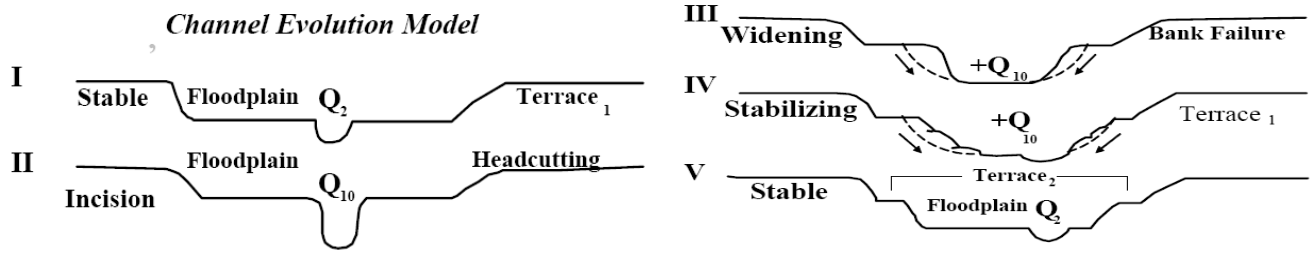
Recommendations for further assessment or actions: ______________________________

Projected improvement in stream condition with implemented conservation practice/land use change:

____

Element 1. Channel Condition Scoring Matrix

Natural, stable channel with established bank vegetation.	**If channel is incising (appears to be downcutting or degrading), score this element based on the descriptions in the upper section of the matrix:**		
No discernible signs of incision (such as vertical banks) or aggradation (such as very shallow multiple channels); Active channel and floodplain are connected throughout reach, and flooded at natural intervals; Streambanks low with few or no bank failures; Stage I : Score 10 Stage V: Score 9 (if terrace is visible)	Evidence of past incision and some recovery; some bank erosion possible; Active channel and floodplain are connected in ***most*** areas, inundated seasonally; Streambanks may be low or appear to be steepening; Top of point bars are below active floodplain. Stage I: Score 8 Stage V: Score 7-8 Stage IV: Score 6	Active incision evident; plants are stressed , dying or falling in channel; Active channel appears to be disconnected from the floodplain, with infrequent or no inundation; Steep banks, bank failures evident or imminent ; Point bars located adjacent to steep banks. Stage IV: Score 5 Stage III: Score 4 Stage II: Score 3	Headcuts or surface cracks on banks; active incision; vegetation very sparse; Little or no connection between floodplain and stream channel, and no inundation; Steep streambanks and failures prominent; Point bars, if present, located adjacent to steep banks. Stage II or III, scores ranging from 2 to 0, depending on severity.
	8 7 6	**5 4 3**	**2 1 0**
	If channel is aggrading (appears to be filling in and is relatively wide and shallow), score this element based on the descriptions in the lower section of the matrix:		
No more than 1 bar forming in channel	Minimal lateral migration and bank erosion; A few shallow places in reach, due to sediment deposits; Minimal bar formation (less than 3).	Moderate lateral migration and bank erosion; Deposition of sediments causing channel to be very shallow in places; 3-4 bars in channel	Severe lateral channel migration, and bank erosion; Deposition of sediments causing channel to be very shallow in reach; Braided channels (5 or more bars in channel.
10 9	**8 7 6**	**5 4 3**	**2 1 0**



Element 2. Hydrologic Alteration Scoring Matrix

Bankfull or higher flows occur according to the flow regime that is characteristic of the site, generally every 1 to 2 years, and no dams, dikes, or development in the floodplain‡, or water control structures are present ; and natural flow regime† prevails**.**	Bankfull or higher flows occur only once every 3 to 5 years, or less often than the local natural flow regime. Developments in the floodplain, stream water withdrawals, flow augmentation, or water control structures may be present *but* do not significantly alter the natural flow regime†.	Bankfull or higher flows occur only once every 6 to 10 years, or less often than the local natural flow regime. Developments in the floodplain, stream water withdrawals, flow augmentation, or water control structures alter the natural flow regime†.	Bankfull or higher flows rarely occur. Stream water withdrawals completely de-water channel; and/or flow augmentation, stormwater, or urban runoff discharges directly into stream and severely alters the natural flow regime†.
10 9	**8 7 6**	**5 4 3**	**2 1 0**

‡ "Development in the floodplain" refers to transportation infrastructure (i.e., roads, railways, etc.), commercial or residential development, land conversion for agriculture or other uses, and similar activities that alter the timing, concentration, and delivery of precipitation as surface runoff or subsurface drainage.

† As used here, "natural flow regime" refers to streamflow patterns unaffected by water withdrawals, floodplain development, agricultural or wastewater effluents, and practices that change surface runoff (e.g., dikes and levees) or subsurface drainage (e.g., tile drainage systems).

Element 3. Bank Condition Scoring Matrix

Banks are stable; protected by roots of natural vegetation, wood, and rock†; No man-made structures present on bank; No excessive erosion or bank failures‡; No recreational or livestock access.		Banks are moderately stable, protected by roots of natural vegetation, wood, or rock or a combination of materials; Limited number of structures present on bank; Evidence of erosion or bank failures, some with re-establishment of vegetation; Recreational use and, or grazing do not negatively impact bank condition.	Banks are moderately unstable; very little protection of banks by roots of natural wood, vegetation, or rock; Man-made structures cover more than half of reach or entire bank; Excessive bank erosion or active bank failures; Recreational and/or livestock use are contributing to bank instability.	Banks are unstable; no bank protection with roots, wood, rock or vegetation; Riprap, and/or other structures dominate banks; Numerous active bank failures; Recreational and/or livestock use are contributing to bank instability.
Right Bank	10 9	8 7 6	5 4 3	2 1 0
Left Bank	10 9	8 7 6	5 4 3	2 1 0

† Natural wood and rock does not mean riprap, gabions, log cribs, or other man-made revetments.

‡ "Bank failure" refers to a section of streambank that collapses and falls into the stream, usually because of slope instability.

Element 4. Riparian Area Quantity Scoring Matrix

Natural plant community extends at least two bankfull widths or over the entire active floodplain and	Natural plant community extends at least one bankfull width or over 1/2 to 2/3 of active floodplain and is generally contiguous throughout property.	Natural plant community extends at least one-half of the bankfull width or over at least 1/2 of active floodplain. Vegetation gaps do	Natural plant community extends at least 1/3 of the bankfull width or over ¼ of active floodplain. Vegetation gaps	Natural plant community extends less than 1/3 of the bankfull width or less than ¼ of active floodplain. Vegetation gaps

is generally contiguous throughout property.		Vegetation gaps do not exceed 10% of the estimated length of the stream on the property.	not exceed 30% of the estimated length of the stream on the property.	exceed 30% of the estimated length of the stream on the property.	exceed 30% of the estimated length of the stream on the property.
Left	**10 9**	**8 7**	**6 5**	**4 3 2**	**1 0**
Right	**10 9**	**8 7**	**6 5**	**4 3 2**	**1 0**

Score each bank separately. Scores should represent the entire stream riparian area within the property. Score for this element = left bank score + right bank score /2. If the score of one bank is 7 or greater and the score of the other bank is 4 or less, subtract 2 points from final score.

Element 5. Riparian Area Quality Scoring Matrix

Natural and diverse riparian vegetation with composition, density and age structure appropriate for the site. No invasive species or concentrated flows through area.		Natural and diverse riparian vegetation with composition, density and age structure appropriate for the site. Invasive species present in small numbers (20% cover or less).	Natural vegetation compromised. Evidence of concentrated flows running through the riparian area. Invasive species common (>20%<50% cover).	Little or no natural vegetation. Evidence of concentrated flows running through the riparian area. Invasive species widespread (>50% cover).
Left	**10 9**	**8 7 6**	**5 4 3**	**2 1 0**
Right	**10 9**	**8 7 6**	**5 4 3**	**2 1 0**

Score should represent the entire stream riparian area within the property.
Score for this element = left bank score + right bank score /2.

Only one canopy cover score (coldwater OR warmwater) should be used per assessment reach.

Element 6. Canopy Cover: Coldwater Streams Scoring Matrix

>75% of water surface shaded within the length of the stream in landowner's property.	75% to 50% of water surface shaded within the length of the stream in landowner's property.	49% to 20% of water surface shaded within the length of the stream in landowner's property.	<20% of water surface shaded within the length of the stream in landowner's property.
10 9	8 7 6	5 4 3	2 1 0

Element 6. Canopy Cover: Warmwater Streams Scoring Matrix

50 to 75% of water surface shaded within the length of the stream in landowner's property.	>75% of water surface shaded within the length of the stream in landowner's property.	49% to 20% of water surface shaded within the length of the stream in landowner's property.	<20% of water surface shaded within the length of the stream in landowner's property.
10 9	**8 7 6**	**5 4 3**	**2 1 0**

Element 7. Water Appearance Scoring Matrix

Very clear, or clarity appropriate to site (3-6'). No motor oil sheen on surface; no evidence of metal precipitates in streams.	Slightly turbid, especially after storm event, but water clears rapidly (>1.5-3'); no motor oil sheen on surface; no evidence of metal precipitates in stream.	Turbid most of the time (0.5-1.5') and/or presence of metal precipitates and/or motor oil sheen present in slackwater areas.	High turbidity most of the time (<0.5') and/or considerable amount of metal precipitates and/or motor oil sheen present throughout reach.
10 9 8	**7 6 5**	**4 3 2**	**1 0**

The **water appearance** assessment element compares turbidity, color, and other visual characteristics of the water with those of a reference stream. The assessment of turbidity is the depth to which an object can be clearly seen. Clear water indicates low turbidity. Cloudy or opaque water indicates high turbidity. Turbidity is caused mostly by particles of soil and organic and inorganic matter suspended in the water column.

Element 8. Nutrient Enrichment Scoring Matrix

Clear water along entire reach; little algal growth present.	Fairly clear or slightly greenish water; moderate algal growth on substrates.	Greenish water particularly in slow sections; abundant algal growth, especially during warmer months; and/or slight odor of ammonia or rotten eggs; and/or sporadic growth of aquatic plants within slack water areas.	Pea green color present; thick algal mats dominating stream; and/or strong odor of ammonia or rotten eggs, and/or dense stands of aquatic plants widely dispersed.
10 9	**8 7 6**	**5 4 3**	**2 1 0**

Nutrients are necessary for stream food webs by promoting algal and aquatic plant growth, which provide habitat and food for aquatic organisms. However, an excessive amount of algal and plant growth is detrimental to stream ecosystems. High levels of nutrients (especially phosphorus and nitrogen) lead to increased growth of algae and aquatic plants. Subsequently, respiration and decomposition of plant organic matter consume dissolved oxygen in the water, lowering the concentration of oxygen available to aquatic organisms, and possibly contributing to significant die-offs.

Element 9. Manure or Human Waste Scoring Matrix

Livestock do not have access to stream; no pipes or concentrated flows discharging animal waste or sewage directly into stream.	Livestock access to stream is controlled and/or limited to small watering or crossing areas; no pipes or concentrated flows discharging animal waste or sewage directly into stream.	Livestock have unlimited access to stream during some portion of the year; manure is noticeable in stream; and/or pipes or concentrated flows discharge treated animal waste or sewage directly into stream	Livestock have unlimited access to stream during entire year; manure is noticeable in stream; and/or pipes or concentrated flows discharge untreated animal waste or sewage directly into stream .
10 9	**8 7 6**	**5 4 3**	**2 1 0**

Only one pool morphology type (low gradient OR high gradient) should be used per assessment reach.

Element 10. Pools: Low-Gradient Streams Scoring Matrix (<2%)

More than 2 deep pools separated by riffles, each with greater than 30% of the pool bottom obscured by depth, wood, or other cover. Shallow pools also present.	One or 2 deep pools separated by riffles, each with greater than 30% of the pool bottom obscured by depth wood, or other cover; at least one shallow pool present.	Pools present but shallow (< 2 times maximum depth of the upstream riffle). Only 10 – 30% of pool bottoms are obscured due to depth or wood cover.	Pools absent, but some slow water habitat is available; no cover discernible. or Reach is dominated by shallow continuous pools or slow water.
10 9	**8 7 6**	**5 4 3**	**2 1 0**

Element 10. Pools: High-Gradient Streams (>2%) Scoring Matrix

More than 3 deep pools separated by boulders or wood, each with greater than 30% of the pool bottom obscured by depth, wood, or other cover. For small streams, pool bottoms may not be completely obscured by depth, but pools are deep enough to provide adequate cover for resident fish. Shallow pools also present.	Two to 3 deep pools, each with greater than 30% of the pool bottom obscured by depth wood, or other cover; at least one shallow pool present. For small streams, pool bottoms may not be completely obscured by depth, but pools are deep enough to provide *some* cover for resident fish. At least one shallow pool also present.	Pools present but relatively shallow, with only 10 – 30% of pool bottoms obscured by depth or wood cover. For small streams, pool bottoms may not be completely obscured by depth, but pools are deep enough to provide *minimal* cover for resident fish. No shallow pools present.	Pools absent.
10 9	**8 7 6**	**5 4 3**	**2 1 0**

Element 11. Barriers to Aquatic Species Movement Scoring Matrix

No artificial barriers that prohibit movement of aquatic	Physical structures, water withdrawals and/or water quality *seasonally* restrict	Physical structures, water withdrawals and/or water quality restrict movement	Physical structures, water withdrawals and/or water quality

organisms during any time of the year.	movement of aquatic species.	of aquatic species *throughout the year*.	*prohibi*t movement of aquatic species.
10	**9 8 7**	**6 5 4 3**	**2 1 0**

Element 12. Fish Habitat Complexity Scoring Matrix

10 or more habitat features available, at least one of which is considered optimal in reference sites (e.g., large wood in forested streams.)	8 to 9 habitat features available.	6 to 7 habitat features available.	4 to 5 habitat features available.	<4 habitat features available.
10 9	**8 7**	**6 5**	**4 3**	**2 1 0**

Fish habitat features: Logs/Large wood, deep pools, other pools (i.e. scour, plunge, shallow, pocket) overhanging vegetation, boulders, cobble, riffles, undercut banks, thick root mats, dense macrophyte beds, backwater pools, and other off-channel habitats

Element 13. Aquatic Invertebrate Habitat Scoring Matrix

At least 9 types of habitat present; a combination of wood with riffles should be present and suitable in addition to other types of habitat. (If non-forested stream, consider reference site's optimal habitat type needed for this high score.)	8 to 6 types of habitat; site may be in need of more wood or reference habitat features, and stable wood-riffle sections.	5 to 4 types of habitat present	3 to 2 types habitat present	None to 1 type of habitat present
10 9	**8 7 6**	**5 4**	**3 2**	**1 0**

Aquatic invertebrate habitat types, in order of importance: Logs/large wood, cobble within riffles, boulders within riffles. Additional habitat features should include: leaf packs, fine woody debris, overhanging vegetation, aquatic vegetation, undercut banks, pools, and root mats

Element 14. Aquatic Invertebrate Community Scoring Matrix

Invertebrate community is diverse and well represented by Group I or intolerant species; One or two species do not dominate.	Invertebrate community is well represented by Group II or facultative species, and Group I species are also present; one or two species do not dominate.	Invertebrate community is composed mainly of Groups II and III, and/or 1 or 2 species of any group may dominate.	Invertebrate community composition is predominantly Group III species and/or only 1 or 2 species of any group is present and abundance is low.
10 9 8	**7 6 5**	**4 3 2**	**1 0**

Aquatic invertebrates include crustaceans (such as crayfish), mollusks (such as snails), spiders, and aquatic insects. These organisms are important to aquatic food webs.

Element 15. Riffle Embeddedness Scoring Matrix

Gravel or cobble substrates are <10% embedded.	Gravel or cobble substrates are 10-20% embedded.	Gravel or cobble substrates are 21-30% embedded.	Gravel or cobble substrates are 31-40% embedded.	Gravel or cobble substrates are >40% embedded.
10 9	**8 7**	**6 5**	**4 3**	**2 1 0**

Embeddedness measures the degree to which gravel and cobble substrates are surrounded by fine sediment. It relates directly to the suitability of the stream substrate as habitat for macroinvertebrates, fish spawning, and egg incubation.

Element 16. Salinity Scoring Matrix

No wilting, bleaching, leaf burn or stunting of aquatic vegetation, no streamside salt- tolerant vegetation present.	Minimal wilting, bleaching, leaf burn, or stunting of aquatic vegetation; some salt-tolerant stream side vegetation.	Aquatic vegetation may show significant wilting, bleaching, leaf burn, or stunting; dominance of salt-tolerant streamside vegetation.	Severe wilting, bleaching, leaf burn, or stunting; presence of only salt tolerant aquatic vegetation; most streamside vegetation is salt tolerant.
10 9 8	**7 6 5**	**4 3**	**2 1 0**

Do not assess this element unless *elevated* salinity levels caused by people are suspected.

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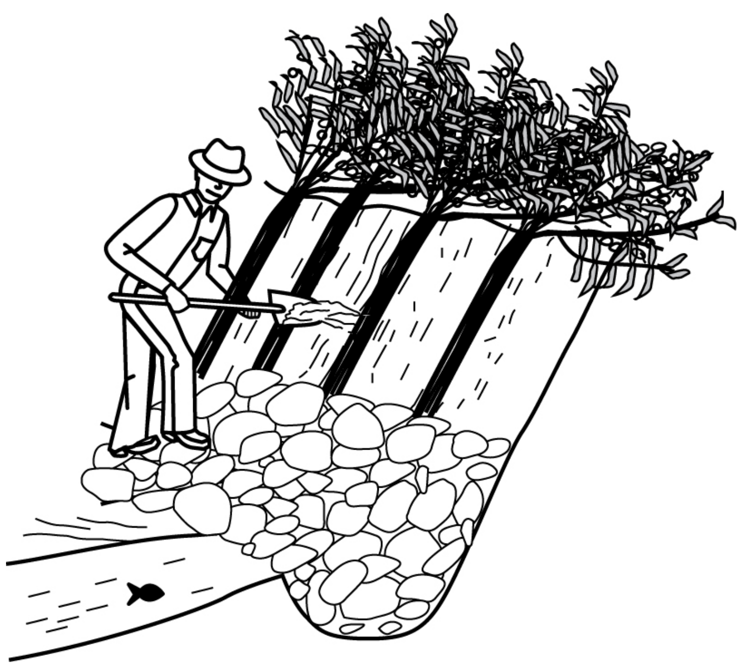

Further information can be obtained from the following website: http://www.ndcsmc.nrcs.usda.gov/technical/Stream/index.html
NEH 654 NRCS Stream Restoration Design Handbook can be ordered from the LANDCARE web page at http://landcare.nrcs.usda.gov/, e-mailing landcare@usda.gov, or by calling 1-888-LANDCARE.