River Restoration Toolbox
Practice Guide 7

Streambank Toe Protection/Stabilization

Iowa Department of Natural Resources

April, 2018

Table of Contents

LIST OF TABLES

LIST OF DRAWINGS

LIST OF PHOTOGRAPHS

Executive Summary

Streambank toe protection/stabilization techniques protect streambanks from high velocity flows and provide near bank stress reduction. Streambank toe protection/stabilization techniques include a variety of structures. The following techniques are detailed in this chapter:

1. Toe Wood Protection
2. Stone Toe Protection
3. Fabric Encapsulated Soil Lifts
4. Log Vane with Boulder Hook
5. Single and Double Wing Deflectors

The *River Restoration Toolbox Practice Guide 7: Streambank Toe Protection/Stabilization* has been developed to assist with the presentation of design and construction information for stream restoration in Iowa. It is intended to provide guidance to:

- Those responsible for reviewing and implementing stream restoration,
- Engineers responsible for the design of stream restoration projects, and
- Others involved in stream restoration at various levels who may find the information useful as a technical reference to define and illustrate streambank protection and stabilization techniques.

This Practice Guide includes a written assessment of the streambank toe protection/stabilization practice and describes a variety of streambank toe protection/stabilization techniques. Each technique includes design guidelines, a specifications list, photographs, and, when applicable, drawings.

The information in the Practice Guide is intended to inform practitioners and others, and define typical information required by the State of Iowa to be included with the use of streambank toe protection/ stabilization techniques. The information and drawings are not meant to represent a standard design method for any type of technique and shall not be used as such. The Practice Guide neither replaces the need for site-specific engineering and/or landscape designs, nor precludes the use of information not included herein.

The Practice Guide may be updated and revised to reflect up-to-date engineering, science, and other information applicable to Iowa streams and rivers.

1.0 INTRODUCTION

Streambank toe protection and stabilization is key to preventing erosion and mass wasting of banks. Streambank erosion is a natural process; however, changes in land use and alteration of channel pattern, profile, and dimension can exacerbate bank erosion and subject infrastructure to potential damage. The toe of the slope is the interface where the bank meets the streambed and is important to the structural integrity of the bank. Streambank erosion can be caused by multiple variables often acting collectively; hydraulic forces, climate, land use, vegetation, ice impacts, freeze/thaw and geology can all affect bank erosion processes.

Determination of the cause of bank instability is important in choosing the correct technique. The techniques outlined in this chapter will work best when used in conjunction with the techniques outlined in River Restoration Toolbox Practice Guide 2: Vegetative Restoration.

2.0 STREAMBANK TOE PROTECTION/STABILIZATION TECHNIQUES

2.1 TOE WOOD PROTECTION

2.1.1 Narrative Description

Toe wood is a streambank protection technique used to protect streambanks from erosion while providing instream cover for fish using natural materials. Toe wood is designed to look natural and provide bank stabilization while vegetation is establishing, and eventually the wood will deteriorate leaving a vegetated, stabilized bank. Toe wood dissipates flow energy and helps maintain deep lateral scour pools (Rosgen 2015) by creating turbulence and shifting the thalweg off the bank toe. A bankfull bench is preferred when using toe wood to stabilize an existing bank. The bankfull bench reduces sheer stress on the existing bank and provides a flat surface to minimize runoff erosion and slumps, keeping additional soil from entering the stream.

Toe wood is an economical choice for streambank protection when it can be harvested nearby or onsite.

2.1.2 Technique Information

- **Use:** Stabilize toe of bank and dissipate flow energy.
- **Other uses:** Toe wood creates exceptional aquatic habitat due to the flow complexity generated by the root wads and pool depth created.
- **Best applications:** Toe wood protection is best used to stabilize laterally unstable B, C, DA, and E channels.

- **Variations:** Toe wood is sometimes combined with sod mats, live brush layering, or fabric encapsulated soil lifts that strengthen and vegetate the bank above the wood. Toe wood is used in conjunction with bank vegetation establishment, which may include live staking, planting, seeding, etc.

- **Computations/Considerations:**

    - Hydrologic and hydraulic computations aid in verifying that the appropriate conditions exist for use of toe wood protection. Hydraulic analysis is required to determine required material size, and to verify that the velocities and shear stresses generated by streamflow do not exceed the strength of the structure. When used in stream restoration projects, wood toe protection requires design by a professional.

    - Material size calculations are required. Minimum log dimensions and woody material size will vary depending on the size of the stream system. Footer logs should be below low flow and at 20-30° angles to streambank. Face logs should be at similar angles to the footer logs.

    - Buoyancy calculations should also be performed to ensure the toe wood does not become buoyant and float away during the expected stream flows.

- **Key Feature:** Elevation of toe wood protection may vary, but keeping the wood submerged is important in avoiding wood deterioration.

2.1.3 Detail Drawings and Data Table

The following drawings and data table depict information that should be included in construction plans for toe wood protection. The data table includes design guidelines and sources, where applicable.

Table 1. Required Design Data for Toe Wood Protection

Dimension[1]	Name	Typical Unit[3]	Guidelines[2]	Description
A	Bankfull Width	Feet	Medium to large streams	The channel width at bankfull stage, often where discharge has filled the channel to the top of its banks and water begins to overflow onto a floodplain.
B	Pool D_{max}	Feet	Varies based on designed cross-section	The channel maximum depth of pool at bankfull stage.
C	Depth of Sod Mat or Soil Lifts	Feet	Varies based on bank height	Vertical depth of soil lifts or sod mats from above toe wood material to top of bank.
D	Depth of Wood Toe	Feet	Varies based on low flow depth	Total vertical depth of toe wood material from bottom of footer log to highest elevation of face log.
E	Length of wood buried in bank	Feet	Varies	Lateral distance from exposed surface of toe wood material to end of wood material buried in the bank.
F	Protrusion	Feet	Varies	Lateral distance from face of bank to end of exposed wood in the stream.

Table 1. Required Design Data for Toe Wood Protection

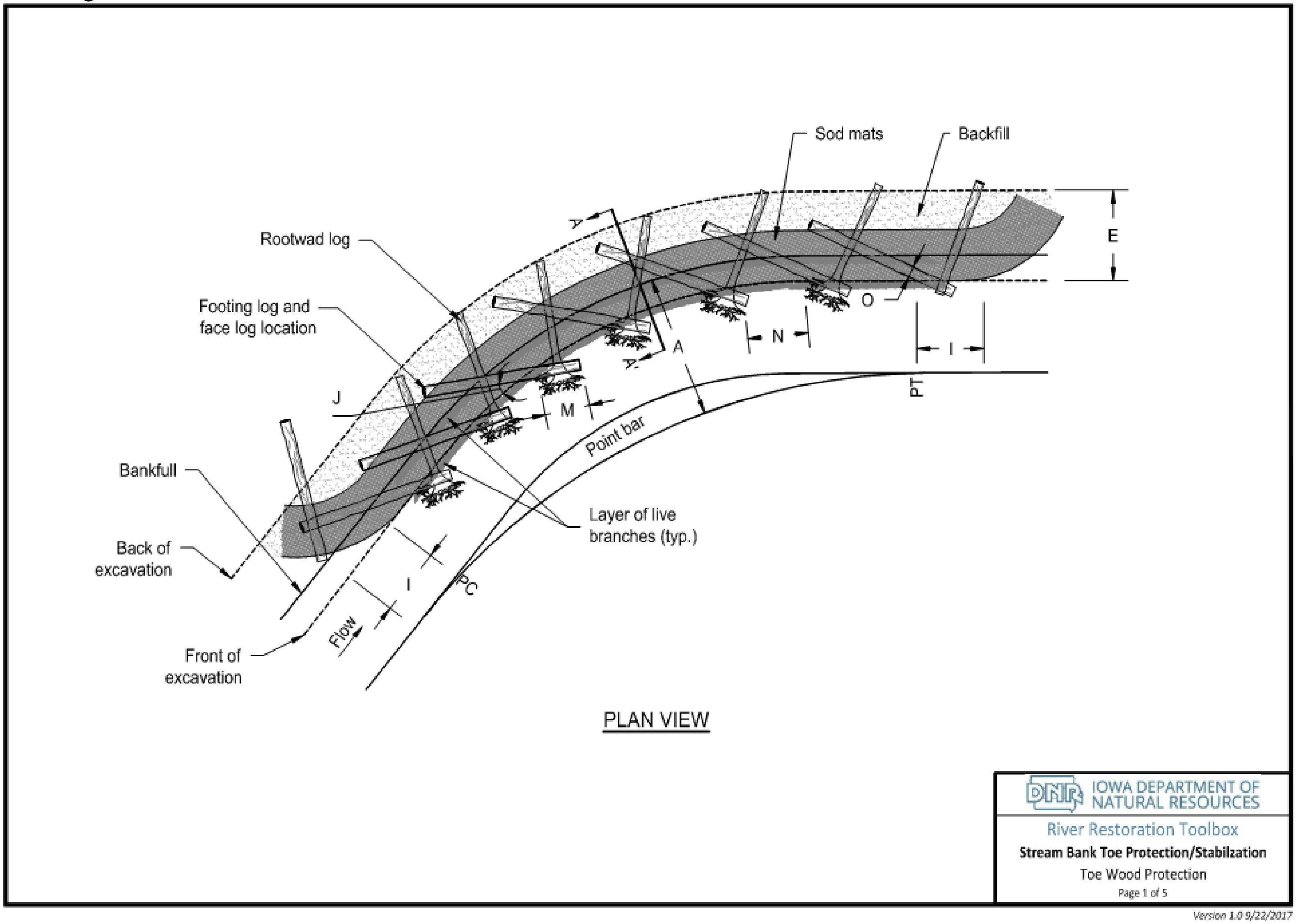
Dimension[1]	Name	Typical Unit[3]	Guidelines[2]	Description
G	Height above Bankfull	Feet	Varies	Additional height above bankfull elevation on outside bend of pool to account for superelevation of water surface
H	Bank Slope	Foot:Foot, %	Varies based on designed cross-section	Ratio of elevation rise to horizontal run of face of bank above the wood toe.
I	Offset Distance	Feet	Varies	Distance upstream/downstream of PC/PT[4] of stream bend.
J	Footer/Face Log Angle	Degrees	20-30°	Measured upstream from the tangent line where the footer/face log intercepts the bank.
K	Depth of sod mat or soil lift	Feet	Maximum of one foot	Vertical depth of each individual lift or mat forming the bank. Multiple lifts or mats can be benched to form the face of the bank.
L	Length of exposed live brush	Feet	0.5 to 1 foot	Lateral distance from face of bank (or sod mat) to end of exposed live brush material.
M	Root wad Diameter	Feet	Varies based on stream and log sizes and buoyancy calculations	Diameter of the root portion of the root wad log.
N	Root wad Spacing	Feet	Typically, equal to one root wad diameter	Distance between root wads

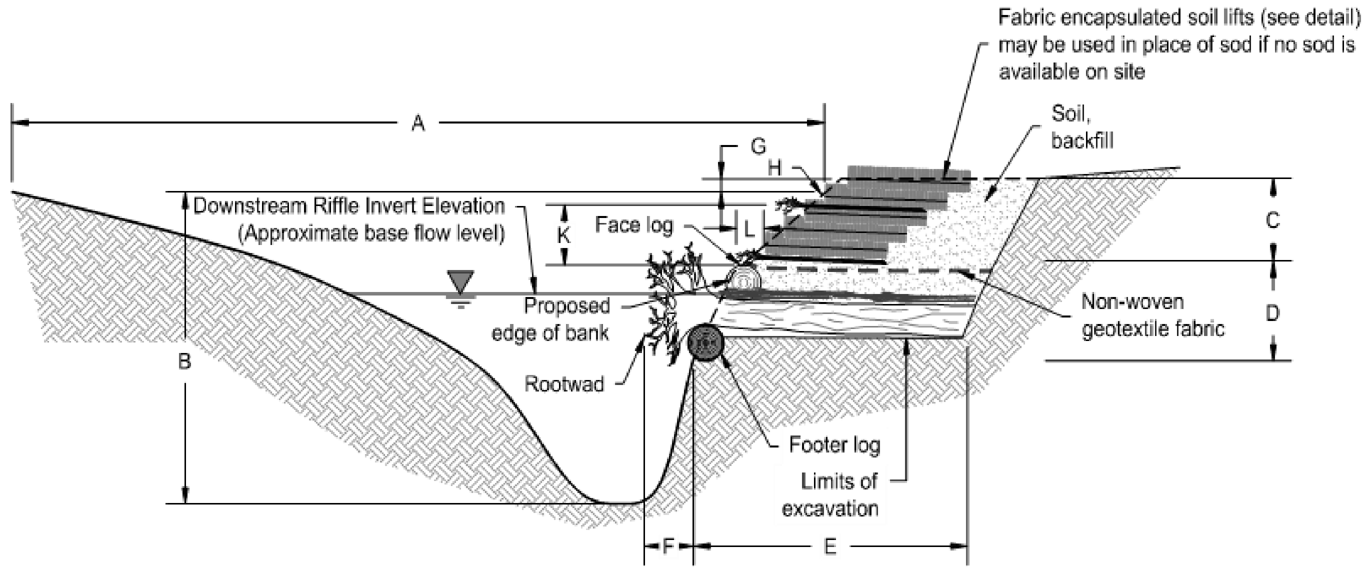
Table 1. Required Design Data for Toe Wood Protection

Dimension[1]	Name	Typical Unit[3]	Guidelines[2]	Description
O	Log Diameter	Feet	Varies based on stream size and buoyancy calculations	Diameter of footing and face logs

1. Some labels are referenced in the detail drawings.
2. Common guidance, values, or ranges are given unless they require computation using site-specific input.
3. NAVD-North American Vertical Datum or other, as appropriate.
4. PC/PT – Point of Curvature/Point of Tangency.

Drawing 1. Toe Wood Protection



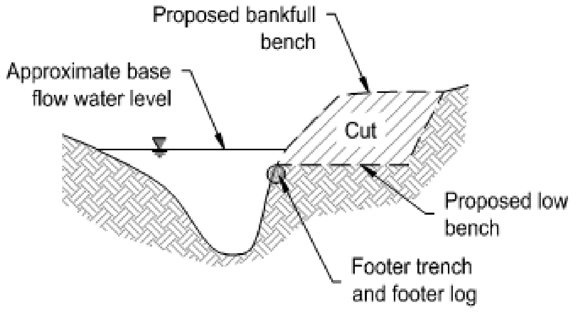


CROSS SECTION A-A'

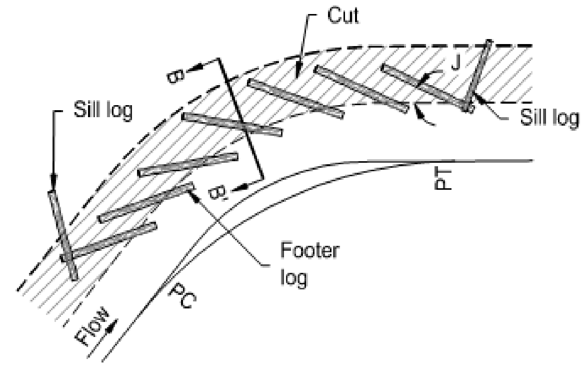
IOWA DEPARTMENT OF NATURAL RESOURCES
River Restoration Toolbox
Stream Bank Toe Protection/Stabilization
Toe Wood Protection
Page 2 of 5

Version 1.0 9/22/2017

1. Excavate low bench for wood toe material. Excavate footer trench in lower bench and place footer logs.

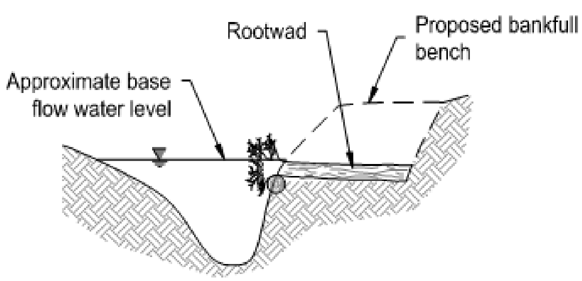


CROSS SECTION B-B'

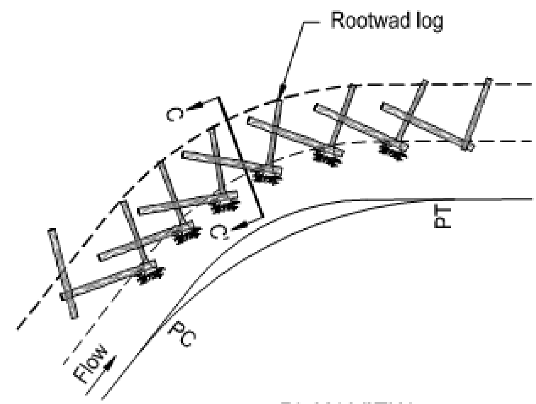


PLAN VIEW

2. Place Root wad logs cantilevered over footer logs.



CROSS SECTION C-C'



PLAN VIEW

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River Restoration Toolbox

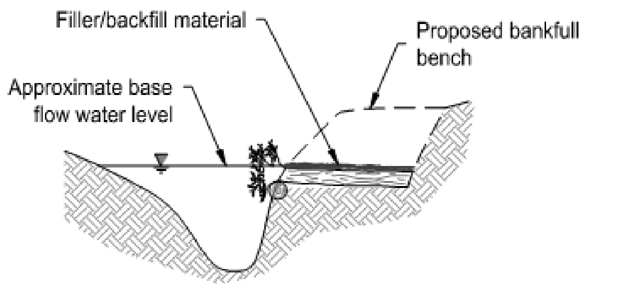
Stream Bank Toe Protection/Stabilzation

Toe Wood Protection

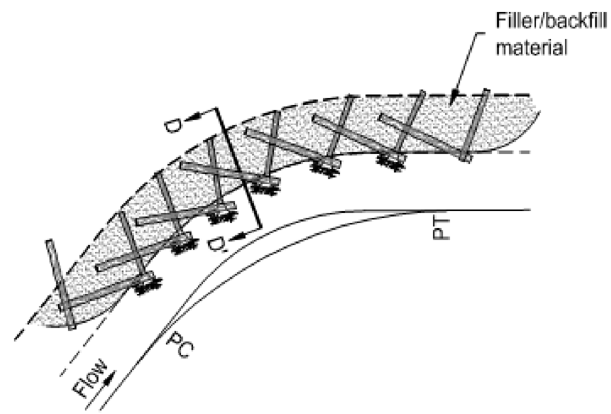
Page 3 of 5

Version 1.0 9/22/2017

3. Place filler material (woody debris) between and on top of the rootwads. Place backfill between filler material and rootwads.

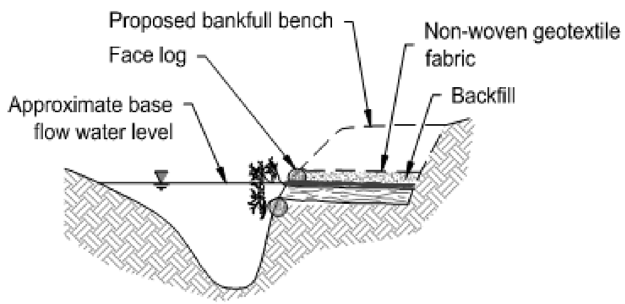


CROSS SECTION D-D'

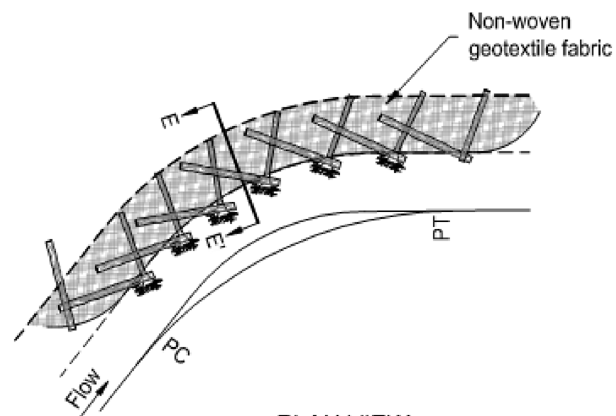


PLAN VIEW

4. Place face logs against the rootwads at similar angles to the footer logs. Backfill in between face logs. Place non-woven geotextile fabric over backfill.



CROSS SECTION E-E'



PLAN VIEW

IOWA DEPARTMENT OF NATURAL RESOURCES

River Restoration Toolbox

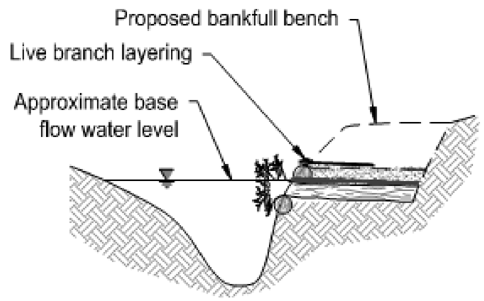
Stream Bank Toe Protection/Stabilzation

Toe Wood Protection

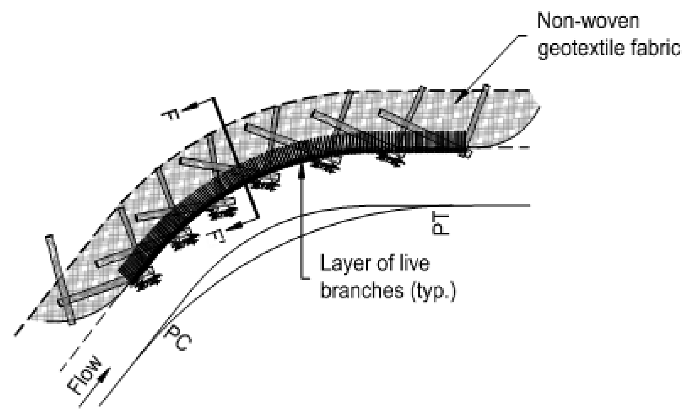
Page 4 of 5

Version 1.0 9/22/2017

5. Place a layer of live cuttings over the non-woven geotextile fabric.

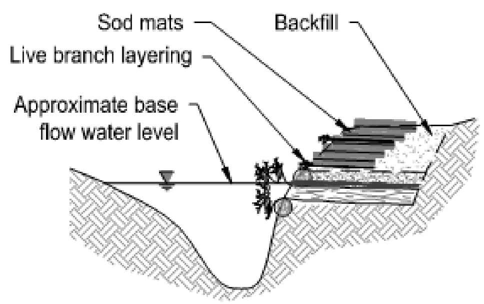


CROSS SECTION F-F'

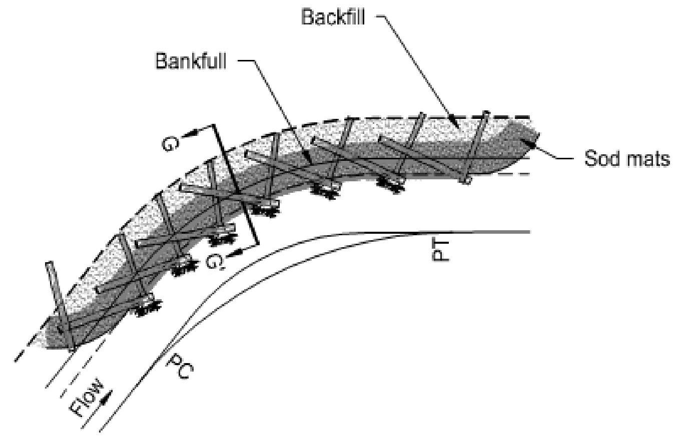


PLAN VIEW

6. Install sod mats and layers of cuttings between sod mats up to bankfull stage.



CROSS SECTION G-G'



PLAN VIEW

IOWA DEPARTMENT OF NATURAL RESOURCES
River Restoration Toolbox
Stream Bank Toe Protection/Stabilization
Toe Wood Protection
Page 5 of 5

Version 1.0 9/22/2017

2.1.4 Specifications

The following information should be developed into specifications to accompany the use of toe wood protection:

- Materials:
    - Woody material of appropriate size consisting of root wads, logs, tree trunks, and smaller woody debris.
    - Live brush or other bank vegetation may be incorporated.
    - Fabric encapsulated soil lifts or sod mat may be incorporated.
    - Backfill material. Backfill material should be topsoil suitable for vegetation and harvested on-site. If native topsoil material is predominantly sand, more cohesive material may be recommended, according to design.
- Equipment/Tools: excavator with a thumb attachment.
- Sequence:
    - Reshape channel including pools and placement of substrate as specified.
    - Excavate bank down to the bottom elevation of the root wad.
    - Dig trench for footing log.
    - Place footing log in trench.
    - Place root wad on top of footing log as shown.
    - Construct backfill matrix between logs, placing large woody material on the bottom and smaller material on top to fill voids.
    - Place geotextile fabric then place sod mat layers, soil lifts, and/or live brush layering with soil wraps above the wood toe to construct bank to appropriate grade.
    - Install live stakes and plantings as specified.
- Workmanship:
    - The finished surface of the banks should be generally in accordance with the lines, grades, cross sections, and elevations of the design.

- Maintenance: During and immediately after construction, bank slopes above the wood toe are vulnerable to erosion. Establishing vegetation or other cover material as soon as possible will help reduce erosion. Additional maintenance is not expected once vegetation establishes. Inspection after large flow events may be advisable to determine if any material movement or unexpected scour has occurred.

2.1.5 Photographs

Photo 1. Toe wood with sod mats. Source: Wildland Hydrology.

Photo 2. Installation of toe wood protection. Source: Stantec.

Photo 3. Newly constructed toe wood protection. Source: Stantec.

Photo 4. Toe wood installation during construction. Source: Wildland Hydrology.

2.2 STONE TOE PROTECTION

2.2.1 Narrative Description

Stone toe protection is a technique used to stabilize the toe of a slope when the upper bank is fairly stable due to vegetation and cohesion. Stone toe protection is used to keep high velocity currents from undercutting the bank and causing bank failure. This technique is best used in combination with bio-engineering techniques on the bank. If not designed correctly accelerated bank erosion can occur at edges of treatment. It is critical that stone toe protection is placed below the scour depth of the pool.

2.2.2 Technique Information

- **Use:** Stabilize toe of bank while preserving existing vegetation and discouraging currents from undercutting the bank.

- **Other uses:** Add bank cover and rock substrate to available stream habitat.

- **Best applications:** Stone toe protection is best used in laterally unstable channels where the upper bank is relatively stable.

- **Variations:** Stone toe is sometimes combined with fabric encapsulated soil lifts or sod mats, and can make use of a variety of different media, depending on locally available materials or ease of site access by construction equipment. Stone toe is used in conjunction with bank vegetation.

- **Computations:**

    - Computations are necessary to properly size rock material and should accompany any design using stone toe protection. Stone toe protection requires design by a professional.

    - Hydrologic and hydraulic computations aid in verifying that the appropriate conditions exist for use of stone toe protection. Geometric calculations are required to properly size and situate the structure within the context of the meander bend location. Proper location and transition can help prevent erosion around the edges of the toe treatment. Hydraulic analysis is required to determine size, thickness, and/or depth of rock materials that will resist becoming dislodged or undermined.

- **Key Feature:** The stone toe should extend below the deepest estimated scour depth. Boulders and/or rock should be property embedded into the channel bottom and/or the channel bank to reduce the risk of unintended localized scour and mobilization.

2.2.3 Detail Drawings and Data Table

The following drawings and data table depict information that should be included in construction plans for stone toe protection. The data table includes design guidelines and sources, where applicable.

Table 2. Required Design Data for Stone Toe Protection

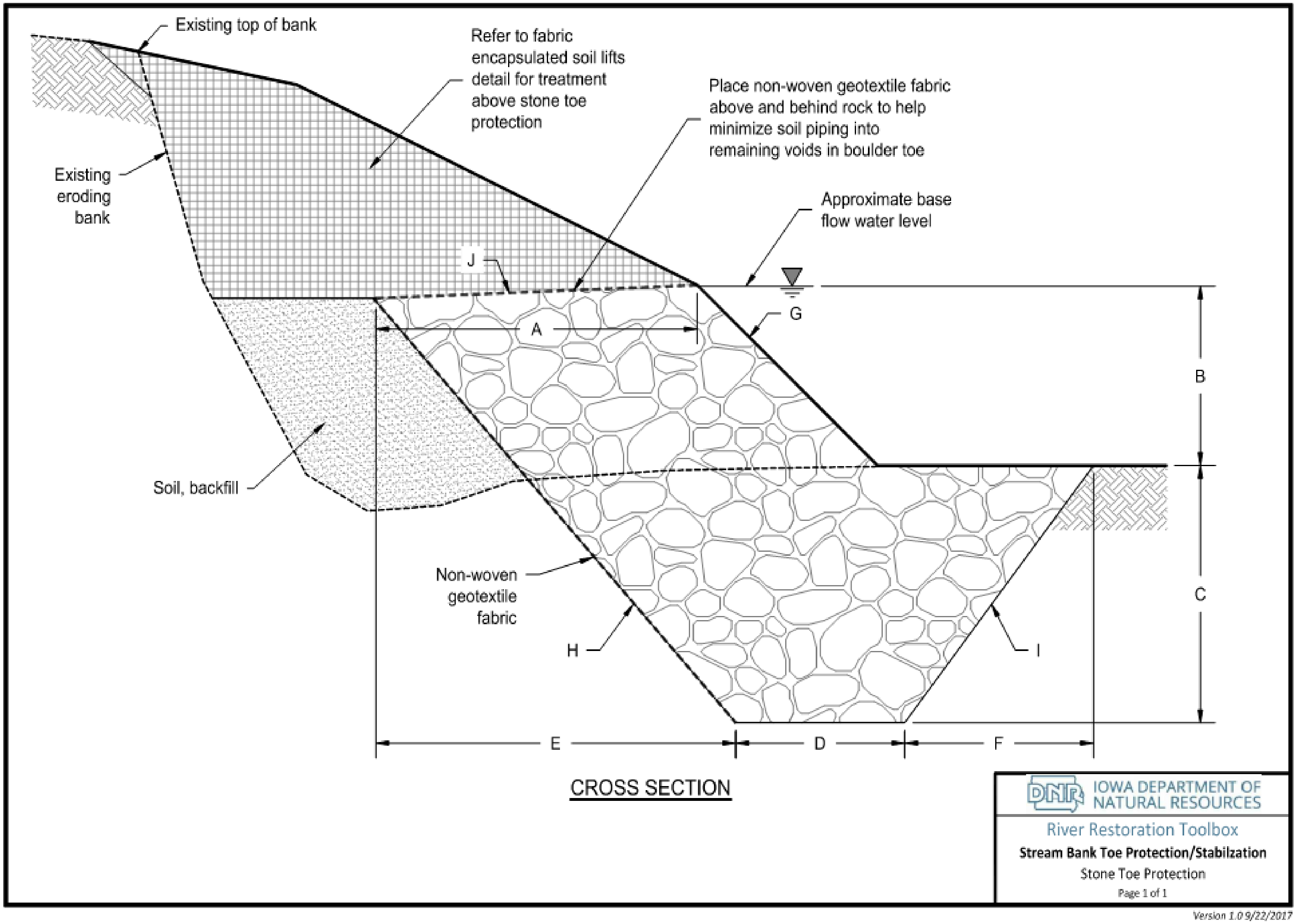
Dimension[1]	Name	Typical Unit[3]	Guidelines[2]	Description
A	Top Width of Stone Toe	Feet	Varies based on slope stability analysis	Lateral distance from exposed face of stone toe to soil backfill behind rock material.
B	Depth of Low Flow Channel	Feet	Varies	Maximum depth from channel bottom to approximate base flow water level.
C	Depth of Footing Stone	Feet	Varies based on slope stability analysis and potential scour depth.	Vertical depth from channel bottom to lowest buried rock material.
D	Bottom Width of Stone Toe	Feet	Varies based on slope stability analysis	Width of the buried stone toe material at the lowest depth.
E	Width of Back Slope of Stone Toe	Feet	Varies based on slope stability analysis	Lateral distance from back of stone toe material at the base (lowest elevation) to the back of stone toe material at the top (highest elevation) of the stone toe material.
F	Width of Front Slope of Stone Toe	Feet	Varies based on slope stability analysis	Lateral distance from toe of bank to end of stone material within channel buried under channel bed.

Table 2. Required Design Data for Stone Toe Protection

Dimension[1]	Name	Typical Unit[3]	Guidelines[2]	Description
G	Low Flow Channel Side Slope	Foot:Foot, %	Varies based on designed cross-section and slope stability analysis	Ratio of elevation rise to horizontal run of face of bank from the approximate base flow water level to the channel bottom.
H	Back Slope of Stone Toe	Foot:Foot, %	Varies based on slope stability analysis	Ratio of elevation rise to horizontal run of back of stone material (placed against the soil backfill) from the approximate base flow water level to the lowest elevation of stone material buried below the channel bottom.
I	Front Slope of Stone Toe	Foot:Foot, %	Varies based on slope stability analysis	
J	Slope of Stone Toe-Soil lift interface	Foot:Foot, %	5%-10%	Ratio of elevation rise to horizontal run of top of stone toe. Fabric encapsulated soil lifts above the stone toe will follow the same slope.

1. Some labels are referenced in the detail drawings.
2. Common guidance, values, or ranges are given unless they require computation using site-specific input.
3. NAVD-North American Vertical Datum or other, as appropriate.

Drawing 2. Stone Toe Protection



2.2.4 Specifications

The following information should be developed into specifications to accompany the use of stone toe protection:

- Materials:
    - Rock, including boulder, stone, or rip rap material as specified.
    - Non-woven geotextile fabric.
    - Fabric encapsulated soil lifts or sod mat above stone toe, as appropriate.
    - Live brush or other bank vegetation may be incorporated.
- Equipment/Tools: excavator with a thumb attachment.
- Sequence:
    - Excavate enough bank and bed material to place the rock material for the stone toe.
    - Construct stone toe and backfill matrix, placing coarse rock material with some smaller rock and fines on the bottom, followed by some smaller rock material on top of the coarse material to fill voids.
    - Place geotextile fabric on top of the stone toe, and install live brush or bank material to construct or repair bank as specified.
- Workmanship: The finished surface of the banks should be generally in accordance with the lines, grades, cross sections, and elevations of the design.
- Maintenance: While maintenance will vary based on the stream system, stone toe protection generally requires little maintenance. Inspection following large flow events may be advisable to determine if any movement of material or unexpected scour has occurred.

2.2.5 Photographs

Photo 5. Bank of Lancassange Creek before reshaping and installation of stone toe.

Photo 6. Construction of bank with stone toe protection and soil wraps with live brush layering. Source: Stantec.

Photo 7. Finished bank with stone toe protection following revegetation. Source: Stantec.

2.3 FABRIC ENCAPSULATED SOIL LIFTS

2.3.1 Narrative Description

Fabric encapsulated soil lifts are a bioengineering technique used to rebuild eroded banks and create banks on top of newly installed toe protection technique. Soil is "encapsulated" in biodegradable fabric to shape a bank. Once vegetation is established and the fabric degrades, the roots hold the new slope in place. Fabric encapsulated soil lifts are also commonly referred to as "burrito" soil lifts or coir lifts.

2.3.2 Technique Information

- **Use:** Rebuild eroded banks or construct a new bank on top of a bank toe protection practice.
- **Other uses:** Fabric encapsulated soil lifts are also a successful and aesthetic option for eroding lake shorelines.
- **Best applications:** Using cohesive soil in the lifts works best and prevents the soil from leaking out of the fabric.
- **Variations:** Hay bales or coir fiber blocks can be used instead of soil.
- **Computations:**
    - Fabric encapsulated soil lifts should not be used at slopes that exceed appropriate bank slopes. Generally, for soils in Iowa, a 2:1 bank slope is considered appropriate; however, this may vary based on constrictions and location considerations. Appropriate cross section for the system should be determined by a professional.
    - Hydrologic and hydraulic computations aid in verifying that the appropriate conditions exist for use of fabric encapsulated soil lifts. Hydraulic analysis is required to verify that the velocities and shear stresses generated by streamflow do not exceed the strength of the structure.
- **Key Features:** Can be useful for establishing vegetation in areas with greater erosive forces.

2.3.3 Detail Drawings and Data Table

The following drawings and data table depict information that should be included in construction plans for fabric encapsulated soil lifts. The data table includes design guidelines and sources, where applicable.

Table 3. Required Design Data for Fabric Encapsulated Soil Lifts

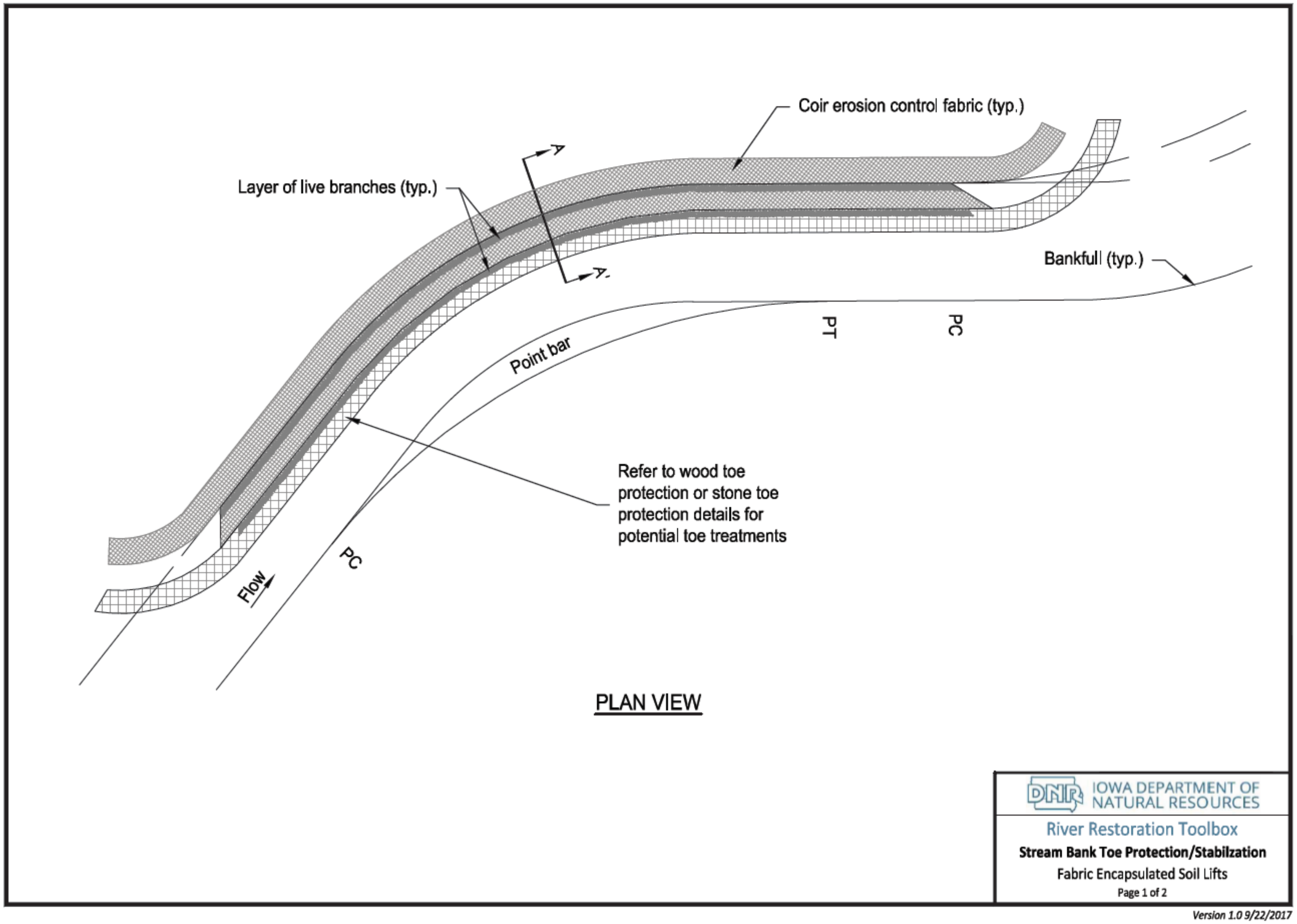
Dimension[1]	Name	Typical Unit[3]	Guidelines[2]	Description
A	Depth of Soil Lift	Feet	Maximum one foot	Vertical depth of each individual lift forming the bank. Multiple lifts can be benched to form the face of the bank.
B	Average Slope of Soil Lifts	Foot:Foot, %	Varies based on design bank slope	Ratio of elevation rise to horizontal run of face of soil lifts if a straight line is drawn from face of lowest lift to face of highest lift (top of bank).
C	Tie-in Slope	Foot:Foot, %	Typically, not steeper than 2:1	Ratio of elevation rise to horizontal run of face of transitional slope from face of highest soil lift to the existing ground.
D	Soil Lift Offset	Inches, feet	Varies based on design bank slope	Lateral distance from face of soil lift to the face of the soil lift below (bench).

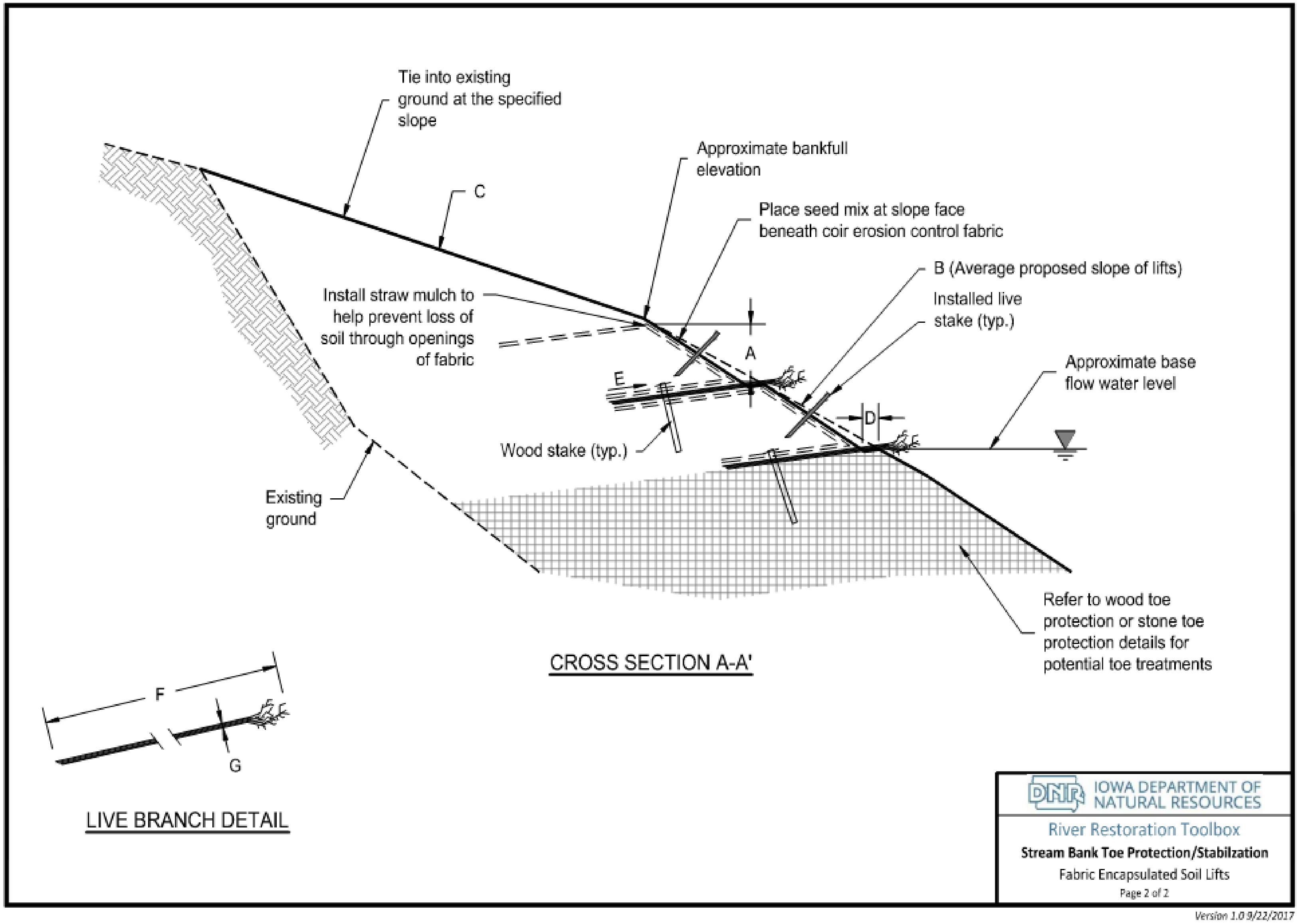
Table 3. Required Design Data for Fabric Encapsulated Soil Lifts

Dimension[1]	Name	Typical Unit[3]	Guidelines[2]	Description
E	Live Brush Slope	%	Slope away from stream 5-10%	Slope of brush material buried in the bank such that buried end is lower than exposed end of live brush in channel.
F	Live Branch Length	Feet	Typically 3' to 6'	Total length of live branch from buried end in bank to end of exposed branch in channel.
G	Live Branch Diameter	Inches	Typically ¼" to ½"	Diameter of individual live branches

1. Some labels are referenced in the detail drawings.
2. Common guidance, values, or ranges are given unless they require computation using site-specific input.
3. NAVD-North American Vertical Datum or other, as appropriate.

Drawing 3. Fabric Encapsulated Soil Lifts




Tie into existing ground at the specified slope
C
Approximate bankfull elevation
Place seed mix at slope face beneath coir erosion control fabric
B (Average proposed slope of lifts)
Installed live stake (typ.)
Install straw mulch to help prevent loss of soil through openings of fabric
A
E
D
Approximate base flow water level
Wood stake (typ.)
Existing ground
Refer to wood toe protection or stone toe protection details for potential toe treatments
CROSS SECTION A-A'
F
G
LIVE BRANCH DETAIL
IOWA DEPARTMENT OF NATURAL RESOURCES
River Restoration Toolbox
Stream Bank Toe Protection/Stabilzation
Fabric Encapsulated Soil Lifts
Page 2 of 2
Version 1.0 9/22/2017

2.3.4 Specifications

The following information should be developed into specifications to accompany the use of fabric encapsulated soil lifts:

- Materials:
  - Coir erosion control fabric.
  - Straw mulch.
  - Seed mix.
  - Excavated native bank soil or appropriate topsoil fill.
  - Live brush material and live stakes may be incorporated.
- Equipment/Tools:
  - Excavator may be required.
  - Shovel, rubber mallet/hammer, and stakes.
- Sequence:
  - Place fabric over topsoil, toe protection material, or live brush material as specified.
  - Place and gently compact soil layer over the fabric, slightly back from the face of the slope, creating a small bench.
  - Place topsoil, seed, mulch, and erosion control fabric on outer face of the soil lift, and wrap the erosion control fabric over the face of the slope, creating a new surface for the next layer of material.
  - Place live brush on a layer on top of soil lift, as specified.
  - Install live stakes at appropriate spacing specified in planting plan.
- Workmanship: The finished surface of the banks created by the fabric encapsulated soil lifts should be generally in accordance with the lines, grades, cross sections, and elevations of the design.
- Maintenance: Very little maintenance is generally required due to the protective fabric; however, soil lifts are more susceptible to erosion prior to vegetation establishment. Vegetation must be established so that lifts do not fail as the fabric deteriorates.

Establishing vegetation or other cover material as soon as possible will help prevent erosion.

2.3.5 Photographs

Photo 8. Construction of bank with fabric encapsulated soil lifts over stone toe protection. Source: Michigan State University Extension.

Photo 9. Soil lifts with live brush layering at Middle Fork Beargrass Creek. Source: Stantec.

Photo 10. Soil lifts with live brush layering. Source: Stantec.

Photo 11. Construction of soil lifts with live brush layering at Cherokee Park. Source: Stantec.

2.4 LOG VANE WITH BOULDER HOOK

2.4.1 Narrative Description

A log vane with a boulder hook is designed to re-direct high velocity flows away from the near-bank region and reduce the need for bank armoring. These structures are placed on the outside of meander bends. The use of logs and rocks together creates a natural and aesthetically pleasing structure. The boulder hook is placed perpendicular to the log vane portion, creating a scour pool that dissipates energy and creates cover for fish (Rosgen 2001).

2.4.2 Technique Information

- **Use:** Intended to reduce near bank stress to reduce the need for bank armoring. Log vane structures are also used to promote deep pools and provide habitat. Log vanes can be used in conjunction with toe protection for additional bank protection in bends.

- **Other uses:** This technique can also be used on long straight reaches to create scour pools, reduce lateral erosion, protect bridge infrastructure (Johnson et al., 2001,2002), and create cover for fish.

- **Best applications:** Log vanes with boulder hooks are best used in E, C, and B channels.

- **Computations:**

  - Log vanes with boulder hooks require design by a professional. Computations are necessary to properly size logs and rock material and should accompany any design using in-stream rocks and logs.

  - Hydrologic and hydraulic computations aid in verifying that the appropriate conditions exist for use of log vanes with boulder hooks. Hydraulic analysis is required to determine required material size, and to verify that the velocities and shear stresses generated by streamflow do not exceed the strength of the structure.

  - Material size calculations are required. Minimum log dimensions and boulder size will vary depending on the size of the stream system.

- **Key Features:** Location of the log vane structure is important for proper function. The end of the of the vane arm must be positioned at the point of tangency. If not placed correctly pools can fill in with sediment and banks can become susceptible to erosion.

2.4.3 Detail Drawings and Data Table

The following drawings and data table depict information that should be included in construction plans for log vane with boulder hook. The data table includes design guidelines and sources, where applicable.

Table 4. Required Design Data for Log Vane with Boulder Hook

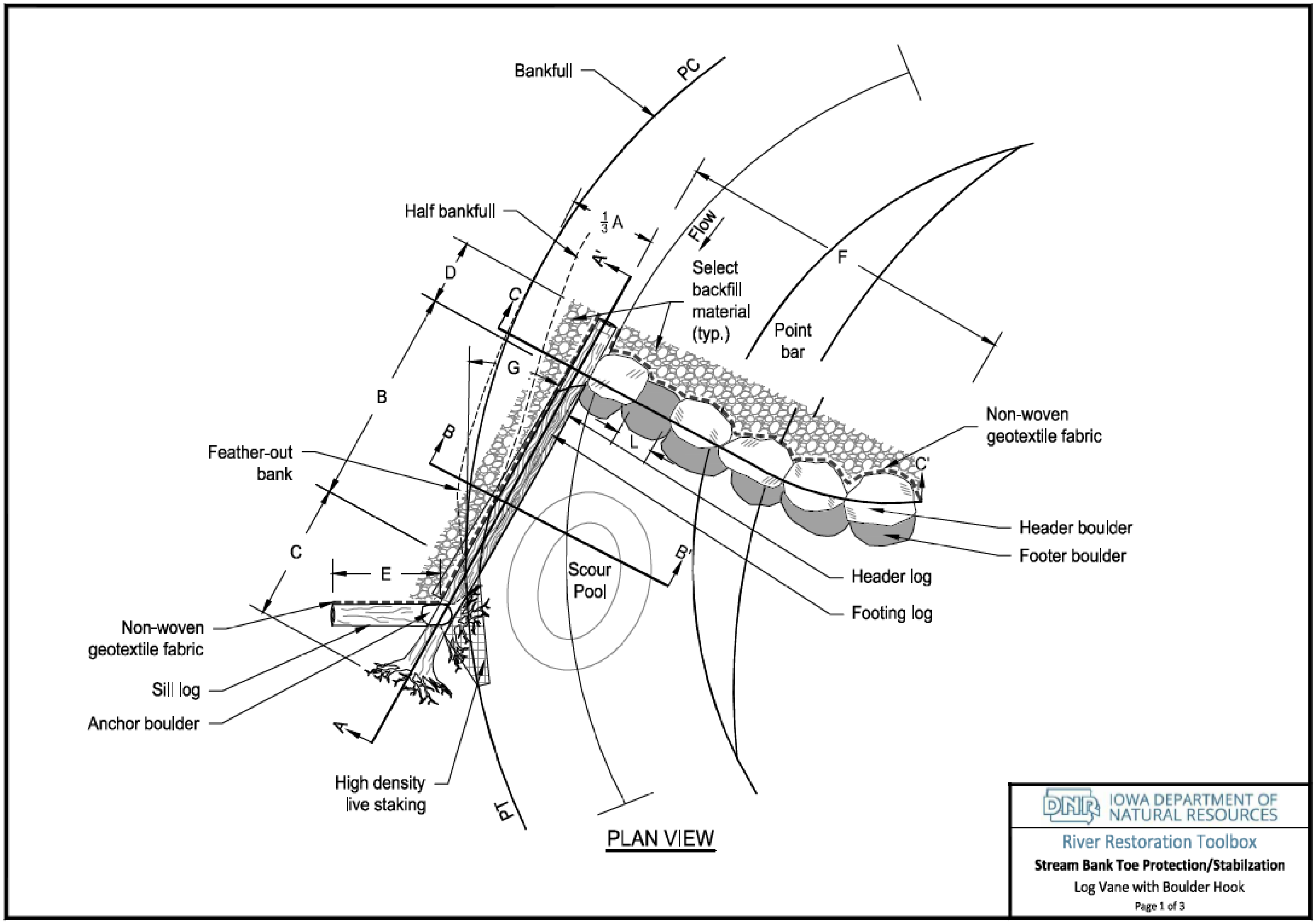
Dimension[1]	Name	Typical Unit[3]	Guidelines[2]	Description
A	Bankfull Width	Feet	Small to medium streams	The channel width at bankfull stage, often where discharge has filled the channel to the top of its banks and water begins to overflow onto a floodplain.
B	Vane Length	Feet	--	Length of exposed surface of log vane in channel.
C	Length of Log Buried in Bank	Feet	--	Length of portion of log vane buried in bank from face of bank to end of buried log in the bank.
D	Length of Log Buried in Streambed	Feet	--	Length of buried portion of log vane from the point where it enters channel bed (invert) to the end of buried log under channel bed.
E	Sill Length	Feet	Minimum ½ W_{bkf}	Length of floodplain cutoff sills connecting each vane arm at the point where it intercepts the stream bank. Sills are required to prevent out-of-bank flows from washing around the structure.

Table 4. Required Design Data for Log Vane with Boulder Hook

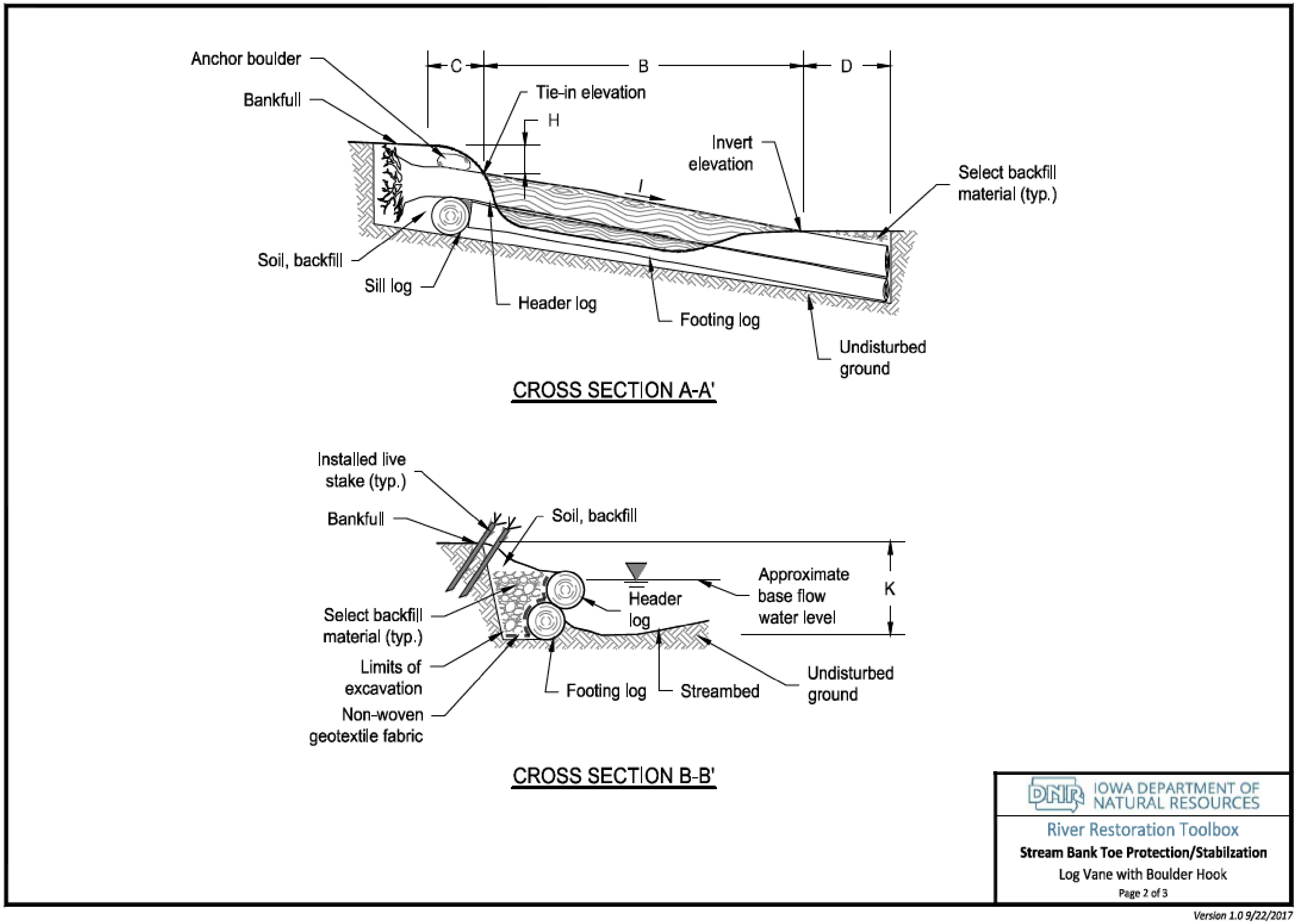
Dimension[1]	Name	Typical Unit[3]	Guidelines[2]	Description
F	Boulder Hook Length	Feet	--	Length of boulder structure from invert in channel to back of boulder buried in bank.
G	Vane Angle	degrees	Typically, 20-30 degrees from bank	The angle between the log vane and the stream bank.
H	Tie-in Depth	Feet	Typically, less than or equal to half maximum riffle depth	Depth from bankfull elevation to the point where log meets face of bank.
I	Vane Slope	%	Typically, 2% - 7%	Slope of log vane arm.
J	Maximum Riffle Depth	Feet	--	Depth from bankfull elevation to the invert. Log vane inverts are the low point of the structure, situated in the streambed, and oriented perpendicular to flow.
K	Pool D_{max}	Feet	--	The channel maximum depth of pool at bankfull stage.
L	Gap Width	Feet	0.5 - 2 feet	Width of gap left between hook boulders, if specified in design.

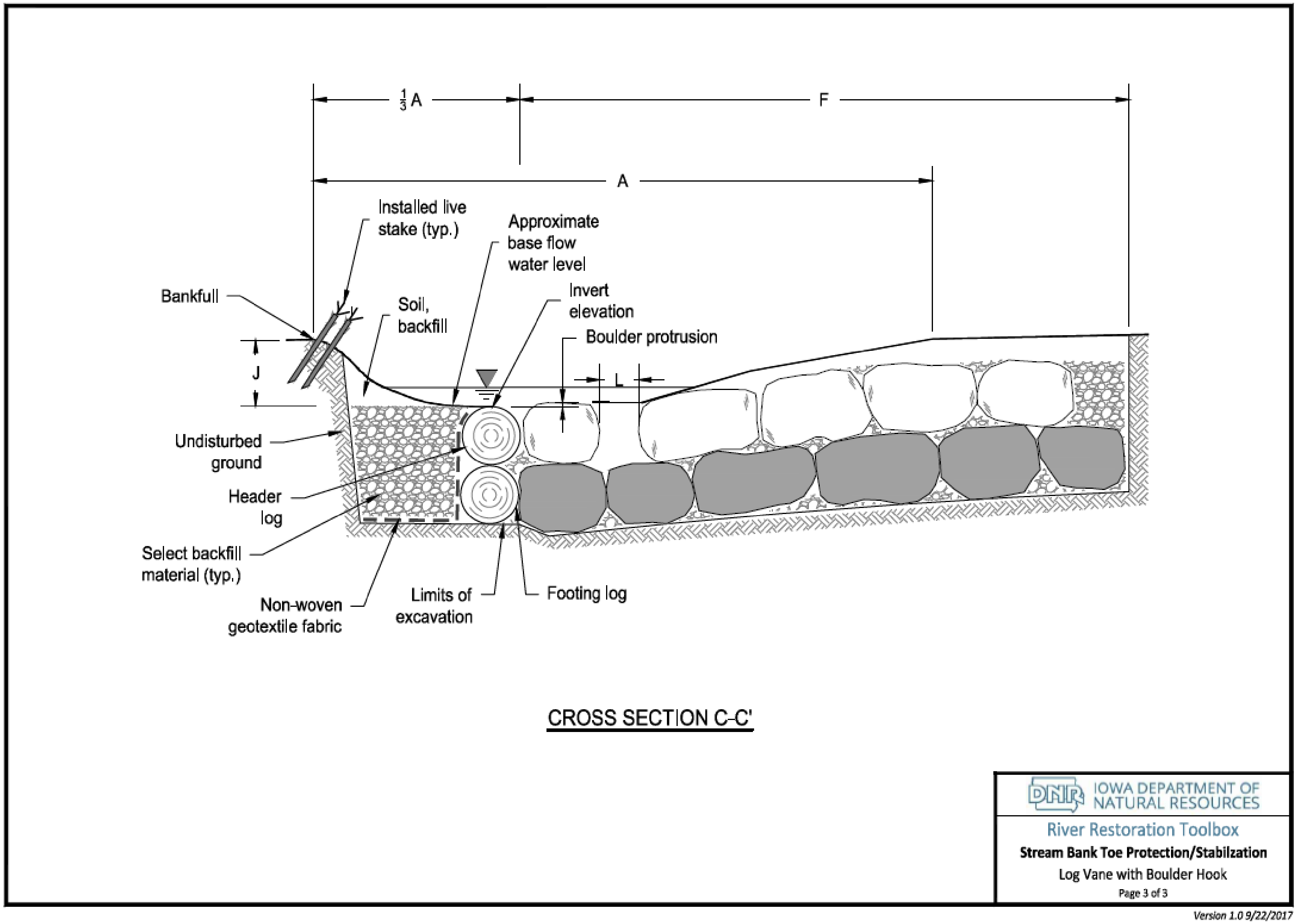
1. Some labels are referenced in the detail drawings.
2. Common guidance, values, or ranges are given unless they require computation using site-specific input.
3. NAVD-North American Vertical Datum or other, as appropriate.

Drawing 4. Log Vane with Boulder Hook



Version 1.0 9/22/2017


Anchor boulder
Bankfull
C
B
D
Tie-in elevation
H
Invert elevation
I
Select backfill material (typ.)
Soil, backfill
Sill log
Header log
Footing log
Undisturbed ground
CROSS SECTION A-A'
Installed live stake (typ.)
Bankfull
Soil, backfill
Header log
Approximate base flow water level
K
Select backfill material (typ.)
Limits of excavation
Non-woven geotextile fabric
Footing log
Streambed
Undisturbed ground
CROSS SECTION B-B'
IOWA DEPARTMENT OF NATURAL RESOURCES
River Restoration Toolbox
Stream Bank Toe Protection/Stabilzation
Log Vane with Boulder Hook
Page 2 of 3
Version 1.0 9/22/2017


1/3 A
F
A
Installed live stake (typ.)
Approximate base flow water level
Bankfull
Soil, backfill
Invert elevation
Boulder protrusion
J
L
Undisturbed ground
Header log
Select backfill material (typ.)
Non-woven geotextile fabric
Limits of excavation
Footing log
CROSS SECTION C-C'
IOWA DEPARTMENT OF NATURAL RESOURCES
River Restoration Toolbox
Stream Bank Toe Protection/Stabilzation
Log Vane with Boulder Hook
Page 3 of 3
Version 1.0 9/22/2017

2.4.4 Specifications

The following information should be developed into specifications to accompany the use of log vane with boulder hook:

- Materials:
  - Rock material, including gravel, cobble, and/or boulders. Boulders will be used for the hook portion of the structure, while smaller sized material will be used for backfill and substrate dependent on the stream system.
  - Logs and root wads with appropriate minimum dimensions for the size of the stream.
  - Geotextile fabric.
  - Live Stakes.
- Equipment/Tools: excavator with a thumb attachment.
- Sequence:
  - Shape bankfull channel to grades specified.
  - Excavate enough bed material to place the root wad (sill log), footer log vane, header log vane, and backfill material.
  - Place the sill log and log vane at appropriate angles and slopes. Bury specified length into steam bed.
  - Excavate enough bed material for the placement of the hook portion.
  - Place footer and surface stones as specified with no gaps and fill voids with backfill material.
  - Place and secure geotextile fabric on the upstream side of the structure as shown in drawings to prevent washout of sediment.
  - Place and compact backfill material as specified in the design against the upstream side of the structure, completely covering geotextile, and backfill area between the streambank and the vane on the upstream side of the structure.
  - Plant live stakes at locations specified.

- Workmanship:
  - The structure elevations, angles, and slopes should match the design to avoid undercutting of the structure or bank erosion. Check the elevations of the invert in accordance with the plans.
- Maintenance:
  - Log vanes with boulder hooks generally require minimal maintenance; however, they should be inspected annually for movement that may indicate stability issues.

2.4.5 Photographs

Photo 12. Log vane with boulder hook. Source: Stantec.

Photo 13. Newly constructed log vane with boulder hook on Minors Creek. Source: Stantec.

Photo 14. Log vane with boulder hook. Source: Stantec.

Photo 15. Log vane with boulder hook on Ohio Creek. Source: NRCS.

2.5 SINGLE AND DOUBLE WING DEFLECTORS

2.5.1 Narrative Description

Wing deflectors are spurs of rocks, logs, or a combination of both. They were originally designed to improve fish habitat in trout streams. Wing deflectors are used to direct stream flows away from the bank, deepening the baseflow channel and forming small pools. Double wing deflectors are also used to narrow the channel and create larger pools than single deflectors. Wing deflectors enhance natural stream meanders, scour fine sediment, and provide cover and bank protection. These structures are best used in low gradient streams.

2.5.2 Technique Information

- **Use:** Direct flows away from a bank and create pool habitat.

- **Other uses:** Creates or improves habitat for aquatic life and creates meanders and defined base flow in straight channels.

- **Best applications:** Best used in channels with overly wide base flow to increase flow velocity and depth. Typically used in channels with slopes less than 3%.

- **Variations:**

    - Deflectors are constructed with rock material but may be rock-framed or log-framed, depending on availability of materials on site.

- **Computations:**

    - Computations are necessary to properly size rock material and should accompany any design using wing deflectors. Wing deflector structures require design by a professional.

    - Hydrologic and hydraulic computations aid in verifying that the appropriate conditions exist for use of wing deflectors. Geometric calculations are required to properly size and situate the structure within the context of the stream flow. Hydraulic analysis is required to determine size, thickness, and/or depth of rock and log materials that will resist becoming dislodged or undermined.

- **Key Feature:**

    - Wing deflectors enhance natural scour to deepen the baseflow channel and create pool habitat. They are not recommended for use in bedrock channels with no scour pool potential or streams with large sediment and debris loads.

2.5.3 Detail Drawings and Data Table

The following drawings and data table depict information that should be included in construction plans for single and double wing deflectors. The data table includes design guidelines and sources, where applicable.

Table 5. Required Design Data for Single and Double Wing Deflectors

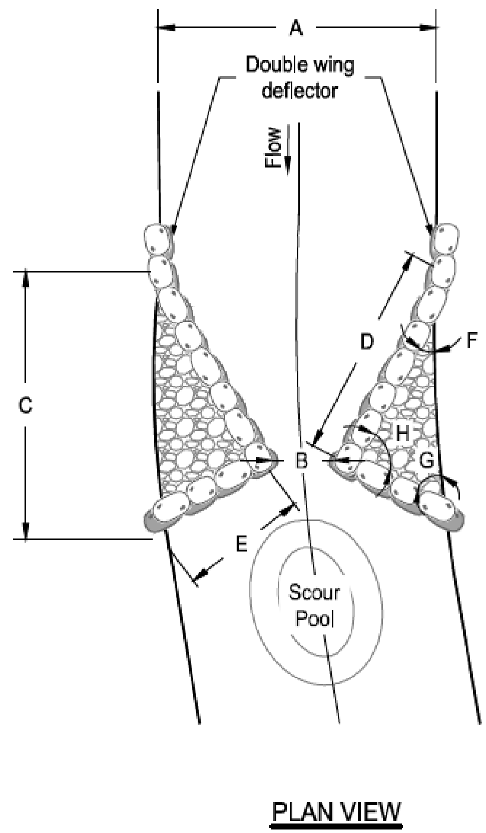
Dimension[1]	Name	Typical Unit[3]	Guidelines[2]	Description
A	Bankfull Width	Feet	--	The channel width at bankfull stage, often where discharge has filled the channel to the top of its banks and water begins to overflow onto a floodplain.
B	Low Flow Width	Feet	--	The width of channel designed to be wetted during baseflow.
C	Deflector Length	Feet	--	Length measured along the bank from the upstream intercept with the bank to the downstream intercept with the bank.
D	Length of Upstream Arm	Feet	--	Length measured along deflector arm from the upstream intercept with the stream bank to the point located furthest into the channel.

Table 5. Required Design Data for Single and Double Wing Deflectors

Dimension[1]	Name	Typical Unit[3]	Guidelines[2]	Description
E	Length of Downstream Arm	Feet	--	Length measured along deflector arm from the downstream intercept with the stream bank to the point located furthest into the channel.
F	Departure Angle	Degrees	Typically 30°	Measured between the bank tangent line and the upstream deflector arm.
G	Convergence Angle	Degrees	Typically 60°	Measured between the bank tangent line and the downstream deflector arm.
H	Deflector Angle	Degrees	Typically 90°	Measured between the upstream and downstream deflector arms.

1. Some labels are referenced in the detail drawings.
2. Common guidance, values, or ranges are given unless they require computation using site-specific input.
3. NAVD-North American Vertical Datum or other, as appropriate.

Drawing 5. Single and Double Wing Deflectors



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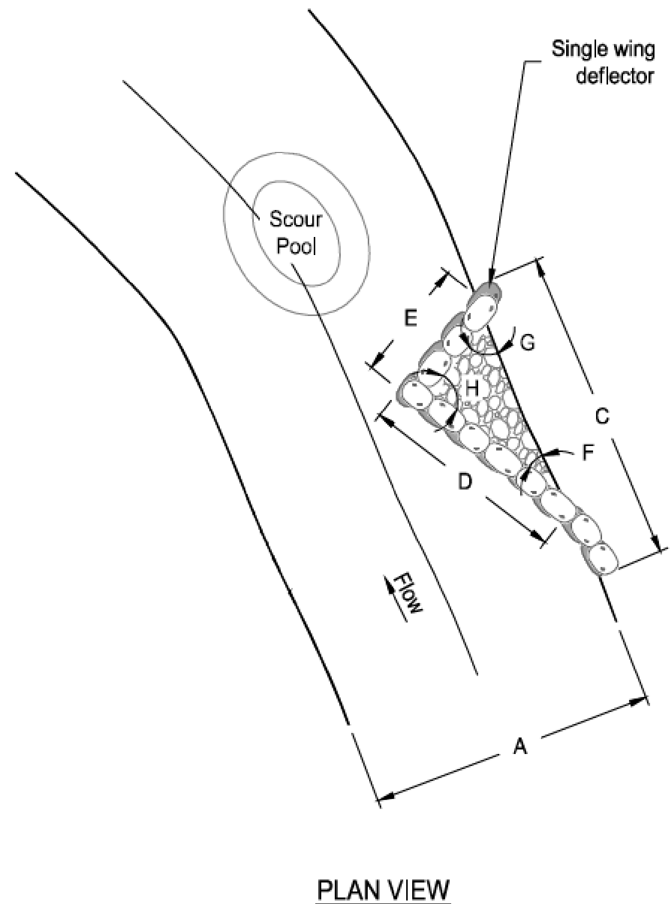
River Restoration Toolbox

Stream Bank Toe Protection/Stabilzation

Single and Double Wing Deflectors

Page 1 of 3

Version 1.0 9/22/2017



IOWA DEPARTMENT OF NATURAL RESOURCES

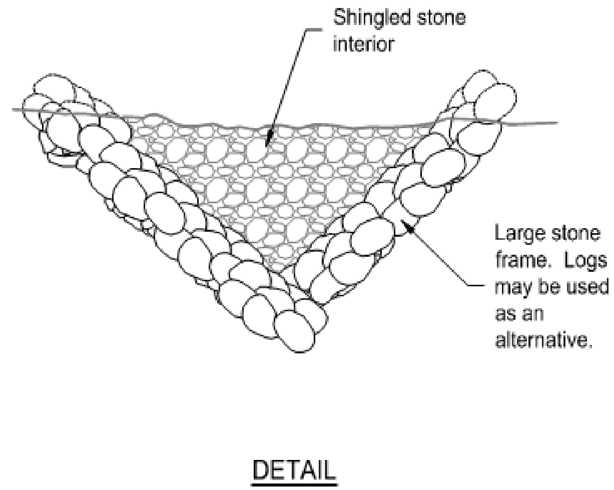
River Restoration Toolbox

Stream Bank Toe Protection/Stabilzation

Single and Double Wing Deflectors

Page 2 of 3

Version 1.0 9/22/2017



IOWA DEPARTMENT OF NATURAL RESOURCES
River Restoration Toolbox
Stream Bank Toe Protection/Stabilzation
Single and Double Wing Deflectors
Page 3 of 3

Version 1.0 9/22/2017

2.5.4 Specifications

The following information should be developed into specifications to accompany the use of single and double wing deflectors:

- Materials:
  - Rock material, including gravel, cobble, riprap, and/or boulders. Boulders will be used for the frame portion of the structure, while smaller sized material will be used for structure fill.
  - Logs with appropriate minimum dimensions for the size of the stream may also be used to frame the structure.
  - Geotextile fabric.
  - Rebar for log framed deflectors.
- Equipment:
  - Excavator with a thumb attachment.
- Sequence:
  - Install deflector frame with header & footer boulders or logs to the specified elevations and angles. If using logs, anchor into the streambed with rebar.
  - Install large stone near the bank at head of structure.
  - Backfill within frame with appropriately sized gravel or riprap.
- Workmanship:
  - The structure elevations, angles, and slopes should match the design to avoid undercutting, unexpected overtopping of the structure, or bank erosion. Check the structure elevations in accordance with the plans.

2.5.5 Photographs

Photo 16. Double wing deflector. Source: corduroybrook.org.

3.0 REFERENCES

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