THE CITY OF CALGARY
WATER RESOURCES

June 20, 2014

Re: Design Guidelines for Erosion and Flood Control: Streambanks and Riparian

This document, prepared by AMEC Environment & Infrastructure, on behalf of The City of Calgary Water Resources, provides guidance for the planning, analysis, and construction of new streambank and riparian restoration projects. The guidelines include soil bioengineering techniques for the restoration of streambanks and riparian areas. To date, these guidelines are not regulatory requirements, and have not yet been fully reviewed by all stakeholders.

The guidelines are intended to be part of a living document, with the flexibility to evolve over time as new regulations or techniques are developed. Discussions of regulatory requirements contained in this document are general in nature, due to the evolving nature of regulatory requirements and site-specific modifications and requirements. It is recommended to obtain more up to date information directly from regulatory agencies when interpreting the document for specific sites.

If you have any additional questions on these guidelines, please contact Norma Posada, Watershed Engineer, via email at Norma.Posada@calgary.ca, or by phone at 403-268-4779.

February 2012

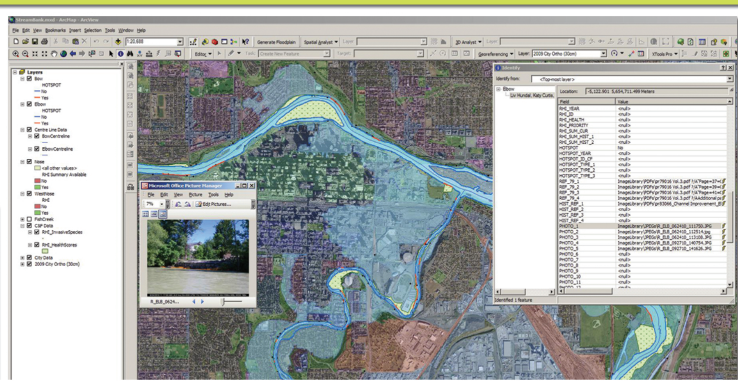
Design Guidelines for Erosion and Flood Control Projects for Streambank and Riparian Stability Restoration

Project No. CW2098

Submitted by:
AMEC Environment & Infrastructure

Submitted to:
The City of Calgary, Water Resources





DESIGN GUIDELINES FOR EROSION AND FLOOD CONTROL PROJECTS FOR STREAMBANK AND RIPARIAN STABILITY RESTORATION

Submitted to:

The City of Calgary
Calgary, Alberta

Submitted by:

AMEC Environment & Infrastructure
Calgary, Alberta

February 2012

CW2098

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EXECUTIVE SUMMARY

Study Objectives and Scope

Within The City of Calgary, there are approximately 115 km of stream channel on the Bow River, Elbow River, Nose Creek and West Nose Creek. The Streambank and Riparian Stability Restoration project included evaluation of the left and right streambanks for the majority of this channel length and adjacent riparian areas.

The overall objective of the study was to develop an integrated Bank Stability and Flood Control Structure Development and Maintenance Program which includes an overall Riparian Assessment and Evaluation. The scope included development of a geo-referenced catalogue for existing and anticipated future erosion, flood protection and riparian restoration works compatible with The City's Geographic Information Systems (GIS), including past and current condition assessments, references/links to relevant reports, photos, drawings, field inspections, estimated capital value, design information, retrofits, maintenance history and related data.

Project Deliverables

A complete list of project deliverables is contained below with this report highlighted in bold. The documentation noted below provides a full understanding of the project.

AMEC Reports and Project Documentation

1. Project Summary For Streambank and Riparian Stability
2. **Design Guidelines for Erosion and Flood Control Projects For Streambank and Riparian Stability Restoration**
3. TBL Prioritization Manual For Streambank and Riparian Stability Restoration
4. GIS Manual For Streambank and Riparian Stability GeoDataset
5. 2010 Site Characterization Summary Reports For Streambank and Riparian Stability Assessment
    - Volume 1: Elbow River
    - Volume 2: Bow River
    - Volume 3: Nose Creek and West Nose Creek
    - Volume 4: RHI Polygons **(This is a Cows and Fish Report)
6. 2010 Geotechnical Summary Report For Streambank Stability Assessment
7. 2010 Conceptual Restoration Design Summary Reports For Streambank and Riparian Stability Restoration
    - Volume 1: Elbow River
    - Volume 2: Bow River
    - Volume 3: Nose Creek and West Nose Creek
    - Volume 4: RHI Polygons

8. 2010 TBL Prioritization Summary Reports For Streambank and Riparian Stability Restoration
   - Volume 1: Elbow River
   - Volume 2: Bow River
   - Volume 3: Nose Creek and West Nose Creek
   - Volume 4: RHI Polygons
9. 2010 Stakeholder Engagement Summary For Streambank and Riparian Stability
10. 2010 Streambank and Riparian Stability Assessment Map sheets
    - Volume 1: Elbow River
    - Volume 2: Bow River
    - Volume 3: Nose Creek and West Nose Creek

Cows and Fish Reports

11. 2007-2010 Riparian Evaluation Synthesis and Riparian Restoration Recommendations
12. 2007-2010 Riparian Health Inventory Summary Reports (**This is Volume 4 of *2010 Site Characterization Summary Reports for Streambank and Riparian Stability Assessment*).

Non-hardcopy Deliverables

13. Streambank and Riparian Stability GeoDataset (GIS GeoDataset)

DESIGN GUIDELINES OVERVIEW

The design guidelines contained herein provide guidance for the planning, analysis, configuration, specification and construction of new or rehabilitation erosion and flood control and riparian restoration projects. These design guidelines are intended to be part of a 'living document' that has the flexibility to evolve as new regulations and techniques are developed and as more knowledge is gained about successful erosion and flood control projects in Calgary. Innovative and emerging restoration techniques not described in this document should be considered on a project specific basis.

Due to the continually changing regulatory framework, the discussion contained herein on regulatory requirements is of a general nature and individual projects should be discussed with the appropriate regulatory agencies and the latest reference material consulted.

ACKNOWLEDGEMENTS

AMEC acknowledges the assistance of the following agencies and individuals for their contribution in the preparation of these guidelines:

- The City of Calgary, Water Resources – Frank Frigo, Lily Ma, Norma Posada, Twyla Hutchinson
- The City of Calgary, Parks – Jenna Cross
- Alberta Riparian Habitat Management Society (Cows and Fish) – Kathryn Hull, Norine Ambrose and Amanda Halawell
- Terra Erosion Control Ltd. - Pierre Raymond, Jason McDiarmid

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1.0 INTRODUCTION

One of the objectives of The City of Calgary's (The City) Streambank and Riparian Stability Restoration project was the development of a set of design guidelines for the analysis, configuration, specification and construction of new or repair of existing streambank/riparian rehabilitation projects. The design guidelines scope of work included the following:

Design Guidelines for Streambank Stability and Flood Control

1. Development of guidelines for the planning, analysis, design, tendering and construction of erosion control and slope stability works along rivers. Including:
   a) Analysis methodology;
      - Acceptable means to appropriately account for design event frequencies.
      - Guidelines regarding preferable practices for hydraulic modeling, scour/bed shear estimation, morphologic interpretation, stability assessment, factors of safety.
      - Geotechnical factors, considerations and data requirements.
   b) Soil bioengineering techniques and discussion on local suitability;
   c) Identification of limiting conditions and appropriate uses of engineered and soil bioengineering erosion control techniques;
   d) Review of erosion control products and their appropriateness in different scenarios;
   e) Plan, section or profile drawings showing typical configuration of erosion protection measures, illustrating key dimensions, ratios and layout elements. Including typical lineal, volumetric or unit area costs;
   f) Inspection, operation and maintenance considerations for the techniques;
   g) Environmental/habitat and biophysical merits of various erosion protection measures;
   h) Guidelines for tendering specifications, care of water measures consistent with other related federal, provincial and The City of Calgary standards and design guidelines;
   i) Summary of regulatory submissions requirements, processes and constraints;
   j) Environmental and biophysical assessment guidelines;
   k) Summary of proposed products and the corresponding maximum slope of embankment, acceptable river velocities and resulting shear stresses; and
   l) Summary of proposed vegetation and the corresponding maximum slope of embankment, acceptable river velocities and resulting shear stresses.

Design Guidelines for Riparian Assessment, Evaluation and Restoration

2. Design guidelines for the assessment, evaluation, design, tendering and construction of restoration projects along riparian zones. Including:
   a) Above noted items a) through l), with respect to riparian restoration; and
   b) Recommendations for management and control of invasive species.

1.1 Background on the Streambank and Riparian Stability Restoration Project

Within The City of Calgary, there are approximately 115 km of stream channel on the Bow River, Elbow River, Nose Creek and West Nose Creek. The Streambank and Riparian Stability Restoration project included evaluation of the left and right streambanks for much of this channel length and adjacent riparian areas.

The objective of the study was to develop an integrated Bank Stability and Flood Control Structure Development and Maintenance Program which includes an overall Riparian Assessment and Evaluation. The scope included development of a geo-referenced catalogue for existing and anticipated future erosion, flood protection and riparian restoration works compatible with The City's Geographic Information Systems (GIS), including past and current condition assessments, references/links to relevant reports, photos, drawings, field inspections, estimated capital value, design information, retrofits, maintenance history and related data.

1.2 Project Team

The Client team consisted of The City of Calgary, Water Resources and The City of Calgary, Parks.

The consultant project team consisted of AMEC and the following two firms: (1) Alberta Riparian Habitat Management Society (Cows and Fish) who undertook the riparian health inventory; and (2) Terra Erosion Control Ltd (Terra) who provided specialist input on the use and construction of bioengineering techniques for restoration. The design guidelines contained in **Appendix C** of this document were developed in large-part by Terra with input from AMEC and Cows and Fish. The riparian sections of these design guidelines (**Sections 6, 7, 8.3**, and **10.1** to **10.4** as well as Design Guideline L in **Appendix C**) were written by Cows and Fish. **Table 8.4**, which is a tool to assist selection of remedial techniques, was developed by Terra.

2.0 REGULATORY REQUIREMENTS, CITY POLICIES AND WATERSHED MANAGEMENT PLANS

A comprehensive review of applicable environmental federal, provincial and municipal regulatory requirements applicable to Streambank and Riparian Stability Restoration projects is contained in The City of Calgary documents listed below.

1. *Environmental Regulatory Review and Responsibilities: Calgary Construction Sites*, 2009, The City of Calgary, http://www.calgary.ca/UEP/Water/Documents/Water-Documents/esc_regulatory_review_responsibilities.pdf
2. *Guidelines for Erosion and Sediment Control, October, 2011, The Ci*ty of Calgary. http://www.calgary.ca/PDA/DBA/Documents/urban_development/publications/ESC-guidelines-2011.pdf

Another detailed review of *the regulatory framework for watercourse pr*ojects is contained in the document "*Alberta Transportation Environmental Management System Manual Transportation and Civil Engineering*", January 2011, Alberta Transportation, http://www.transportation.alberta.ca/2643.htm

The intent of this section of these guidelines is not to duplicate the information contained in the above noted documents, which the reader should refer to for detailed information. The intent is to provide some key information, mostly from the above noted documents, specific to Streambank and Riparian Stability Restoration projects.

2.1 The City of Calgary Policies and Bylaws

A good summary of The City's policies related to Calgary's river system is contained in the document for the *Calgary Plan (pp 22 to 29) (The City Plan – Municipal Development Plan – Part 2 Life in the City of Calgary, 2008)*, which is attached in **Appendix A** of these guidelines. **Appendix A** summarizes The City's policies, relative to the river system for the following categories: (1) Water Quality; (2) Land Stewardship and Protection; and (3) Natural Areas. Additionally, **Appendix A** contains the guiding principles from the *Urban Park Master Plan*, relative to Calgary's river system.

The City of Calgary's 2010 State of the Environment Report 4th edition, January 2011 (http://www.calgary.ca/UEP/ESM/Documents/ESM-Documents/2010-state-of-the-environment-report.PDF) contains the following policy references:

- Council Priorities 2009-2011: Protect the quality of water in our rivers and streams.
  - Conduct ongoing water quality testing.
  - Reduce the amount of runoff and sediment that enters our rivers and streams.
- The City's Total Loading Management Plan 2008 recommends general principles for managing total loadings of pollutant releases from Calgary to the Bow River.

- The *Environmental Reserve Setback Guidelines Discussion Draft (August 2006)* require a minimum setback for development of 50 metres from Nose Creek, the Elbow River and the Bow River. Setbacks for new developments adjacent to wetlands have been increased from 6 metres to 30 metres, allowing for better protection of these waterbodies. http://www.calgary.ca/UEP/Water/Documents/Water-Documents/environmental_reserve_setback_guidelines.pdf

Both The City's documents *Environmental Regulatory Review and Responsibilities: Calgary Construction Sites* and *Guidelines for Erosion and Sediment Control* contain descriptions of the following four bylaws that may be applicable to streambank and riparian stability restoration projects: (1) Drainage Bylaw (37M2005); (2) Street Bylaw (20M88); (3) Sewer Service Bylaw (2M96); and (4) Community Standards Bylaw (5M2004). **Appendix B** of these Design Guidelines contains Table 3 from the document *Environmental Regulatory Review and Responsibilities: Calgary Construction Sites*, which is a summary of applicable Municipal Legislation.

2.2 Federal Regulatory Requirements

The City's document *Environmental Regulatory Review and Responsibilities: Calgary Construction Sites* contains description of the three main applicable pieces of federal legislation for which permits/approvals are required, which are the *Fisheries Act*, the *Navigable Waters Protection Act (NWPA)*, and *Canadian Environmental Assessment Act (CEAA)*. These three acts along with the *Migratory Birds Convention Act* are discussed in greater detail below.

Alberta Transportation (January 2011) contains a detailed discussion of all potentially applicable Federal Regulatory Requirements including the following list (current to 01 November 2011):

- *Canada Water Act,* R.S.C. 1985, c. C-11
- *Canada National Parks Act*, S.C. 2000, c. 32
- *Canada Wildlife Act*, R.S.C. 1985, c. W-9
- *Canadian Environmental Assessment Act*, S.C. 1992, c. 37
- *Canadian Environmental Protection Act, 1999*, S.C. 1999, c. 33
- *Environmental Enforcement Act* (received Royal Assent on June 18, 2009; not yet in force)
- *Fisheries Act*, R.S.C. 1985, c. F-14
- *Forestry Act*, R.S.C. 1985, c. F-30
- *Hazardous Materials Information Review Act,* R.S.C. 1985, c. 24 (3rd Supp.)
- *Migratory Birds Convention Act, 1994,* S.C. 1994, c. 22
- *Navigable Waters Protection Act*, R.S.C. 1985, c. N-22
- *Species At Risk Act, 2002, c. 29*
- *Transportation of Dangerous Goods Act, 1992*, S.C. 1992, c. 34

2.2.1 Navigable Waters Protection Act

The *Navigable Waters Protection Act* (*NWPA*), administered by Transport Canada, applies to all navigable waters and coastal areas across Canada. The *NWPA* prohibits the building or placing of a work in, on, over, under, through or across navigable waters unless the work, the site and the plans have been approved by Transport Canada prior to commencement of construction (s. 5(1)(a)). "Work" is defined in s. 3 and includes bridges, booms, dams, wharves, docks, piers, tunnels, pipes, telegraph or power cables or wire, dumping of fill or excavation of materials from the bed of a navigable water, and any other structure, device or thing that may interfere with navigation.

The *NWPA* was amended in June 2009 by the Minor Works and Waters (Navigable Waters Protection Act) Order. The Amendments focus on establishing clearly defined classes of waters. Some classes, such as small irrigation and drainage ditches, are now considered not suitable for navigation, and other classes of works are defined as posing no concern to ongoing navigational safety (certain buried pipelines, aerial cables and small docks, for example) and thus considered to be minor works not requiring an approval. The *NWPA* also includes the concept of temporary work to further simplify the approval process.

The streams reviewed for the Calgary Streambank and Riparian Restoration project included the Elbow River, Bow River, Nose Creek, West Nose Creek and Fish Creek. None of these streams are understood to be exempt from the *NWPA* based on the above noted Minor Works and Waters Order. Projects should be discussed with Transport Canada on a site specific basis. The following definition of a minor work may exempt many streambank and riparian restoration projects from the *NWPA* approval process (http://www.tc.gc.ca/eng/marinesafety/tp-tp14594-menu-2977.htm):

> *An erosion protection project meeting all of the following criteria and standards is considered a minor work and does not require the submission of an application for review and approval under the NWPA if:*

1. *the works are integrated with and parallel to the existing or natural shoreline or bank;*
2. *the base of the works is 5 metres (m) or less from the high-water mark;*
3. *the vertical to horizontal slope of the works from the navigable waters is greater than 33 percent (i.e. 1:1, 1:2 and 1:3 vertical to horizontal ratios are acceptable);*
4. *the works are not associated with an existing or proposed structure, including a bridge, a boom, a dam or a road, across the navigable waters; and*
5. *the works do not include groynes or spurs or other devices to deflect the current.*

2.2.2 Fisheries Act

The *Fisheries Act* deals with the protection of fish habitat and is regulated by Fisheries and Oceans Canada (DFO). The *Fisheries Act* applies to work or improvements that cause the alteration, disruption, or destruction of fish habitat; this includes the impacts of urban development and sediment control. Section 35 of the *Fisheries Act* states that "*no person shall carry on any work or undertaking that results in the harmful alteration, disruption or destruction of fish habitat*." Section 36 of the *Fisheries Act* regulates deposition of any substance (which would include sediment) which is deemed "deleterious" in waters frequented by fish.

Section 35 of the *Fisheries Act* prohibits the carrying on of any work or undertaking that results in the harmful alteration, disruption or destruction (HADD) of fish habitat without an authorization. DFO's guiding principle is "no net loss", whereby habitat losses must be mitigated with habitat replacement on a project-by-project basis.

The use of soil bioengineering methods could be more beneficial to aquatic habitat, in comparison to traditional bank stabilization techniques. Hence, the use of bioengineering may reduce or provide an offset to the HADD. The Aquatic Environment Assessments (discussed in **Section 8** of these guidelines) will assist in determining the extent of the project related impacts to habitat.

2.2.3 Canadian Environmental Assessment Act

The *Fisheries Act* and the NWPA are both "triggers" for a more detailed federal environmental review under the *Canadian Environmental Assessment Act* (*CEAA*). If an approval is required pursuant to either Act, this will trigger CEAA.

Section 14 of the *CEAA* details several levels of review exist under CEAA:

- **Screening** – a systematic approach to reviewing, assessing and suggesting mitigation measures for the environmental impacts of a project (approximately 99% of assessments are at a Screening level);
- **Comprehensive Study** – required for large projects with significant potential to adversely affect the environment or cause public concern;
- **Mediation** – a mediator appointed by the Minister of Environment helps parties involved negotiate and resolve their issues; and
- **Review Panel** – a group of experts selected by the Minister of Environment impartially and objectively reviews and assesses the project.

If an activity triggers a *CEAA* review, project documents sent by a proponent to DFO or Transport Canada will be posted on the CEAA website for a 15-day public review. The public review must be completed, and there must be a conclusion of no significant impacts prior to issuing an authorization under the *Fisheries Act* or an approval under the *NWPA*. The CEAA website has a hotlink called *A Primer for Industry* (http://www.ceaa.gc.ca/default.asp?lang=En&n=26AA9EFB-1), which provides additional information.

2.2.4 Migratory Birds Convention Act

The *Migratory Birds Convention Act*, 1994 and the Migratory Birds Regulations are the result of a Convention signed between the United States and Canada directed at the protection and preservation of migratory birds and migratory bird habitats. Under the Act no disturbance to migratory bird nests or nesting birds is allowed during breeding and nesting periods (generally early April to late August). Section 6 of the Act states that ". . .no person shall disturb, destroy or take a nest, egg, nest shelter. . .of a migratory bird. . . .". The Act applies to all lands and bodies of water in Canada and to the activities of all organizations, industries and individuals. For more information see: http://www.capp.ca/getdoc.aspx?DocId=162165&DT=NTV.

2.3 Provincial Regulatory Requirements

The two main applicable pieces of provincial legislation for which permits/approvals are required are the *Water Act* and the *Public Lands Act* and these are discussed in greater detail in **Sections 2.3.1** and **2.3.2** of these design guidelines.

Alberta Transportation (January 2011) contains a detailed discussion of all potentially applicable Provincial Regulatory Requirements including the following list (current to 01 November 2011):

- *Alberta Land Stewardship Act*, S.A. 2009, c. A-26.8
- *Climate Change and Emissions Management Act,* S.A. 2003, c. C-16.7
- *Dangerous Goods Transportation and Handling Act*, R.S.A. 2000, c. D-4
- *Environmental Protection and Enhancement Act*, R.S.A. 2000, c. E-12
- *Forest and Prairie Protection Act*, R.S.A. 2000, c. F-19
- *Government Organization Act*, R.S.A. 2000, c. G-10
- *Historical Resources Act*, R.S.A. 2000, c. H-9
- *Natural Resources Conservation Board Act,* R.S.A. 2000, c. N-3
- *Provincial Parks Act*, R.S.A. 2000, c. P-35
- *Public Highways Development Act*, R.S.A. 2000, c. P-38
- *Public Lands Act*, R.S.A. 2000, c. P-40
- *Soil Conservation Act*, R.S.A. 2000, c. S-15
- *Special Areas Act*, R.S.A. 2000, c. S-16
- *Water Act*, R.S.A. 2000, c. W-3
- *Weed Control Act*, S.A. 2008, c. W-5.1
- *Wilderness Areas, Ecological Reserves, Natural Areas and Heritage Rangelands Act*, R.S.A. 2000, c. W-9
- *Wildlife Act*, R.S.A. 2000, c. W-10

2.3.1 Water Act

The *Water Act* regulates the allocation, protection and conservation of water in the Province of Alberta and is administered by Environment and Water (AEW).

Section 36(1) of the *Water Act* prohibits anyone from commencing or continuing an activity unless that person holds the required approval. "Activity" is broadly defined in s. 1(1)(b) and can be summarized as:

- Placing, constructing, operating, maintaining, removing or disturbing works
- Maintaining, removing or disturbing ground, vegetation or other material
- Carrying out any undertaking in or on any land, water or water body that:
  - alters or may alter the flow or level of water,
  - changes or may change the location of water or direction or flow of water,
  - causes or may cause siltation of water or erosion of the bed or shore, or
  - causes or may cause an effect on the aquatic environment
- Altering the flow, direction of flow, level of water or changing the location of water for removing an ice jam, drainage, flood control, erosion control or channel realignment
- Drilling or reclaiming a water well or borehole
- Anything defined as an activity in the regulations.

2.3.2 Public Lands Act

The *Public Lands Act* (*PLA*) only applies to Public Land under the administration of the Minister of Alberta Sustainable Resource Development (s. 2(1)).

With a few exceptions, title to the beds and shores of (a) all permanent and naturally occurring bodies of water, and (b) all naturally occurring rivers, streams, watercourses and lakes, is vested in the Crown in right of Alberta (s. 3). Water and the use of water is also under provincial jurisdiction through the *Water Act*. The extent of the Province's ownership of the bed and shore is limited by the bank of the water body (defined in s. 17(2) of the *Surveys Act*). This is the line along the upper limit of the bed and shore. It is formed by the normal, continuous action or presence of surface water on the land, that forms a natural boundary between the Crown owned bed and shore, and privately owned land. The location of the bank is not affected by occasional periods of drought or flooding. The ‘bed’ is the land on which the water sits, and the ‘shore’ is that part of the bed that is exposed when water levels are not at their normal fullest level.

Under the *PLA*, a permit is required to divert water, or prior to developing the following structures or modifications on lake or stream beds, shores and floodplains:

- Any project (temporary or permanent) that impacts the aquatic environment or involves the disturbance, modification, placement or removal of material on the lake’s bed, shore or floodplain (includes removal of pressure ridges caused by ice thrusts and the placement of sand for beaches

- Any commercial development (temporary or permanent)
- Cutting or removal of aquatic vegetation
- Erosion protection, retaining walls, groynes, breakwaters and causeways
- Permanent piers, boat launches, boathouses, etc., and other associated improvements
- Permanent waterline installations into or beneath the lake
- Other permanent structures on the bed, shore or floodplain of the lake.

Applications are reviewed for potential impacts to the water body's bed shore, floodplain, water quality, fish and wildlife habitat, and public access.

2.4 Watershed Management Plans

The Watershed Management Plans listed below have been developed for the Calgary region under the Government of Alberta's *Water for Life* Strategy. These plans help define guidelines, targets and recommendations for watershed protection (*2010 State of the Environment Report*). Watershed Planning and Advisory Councils like the Bow River Basin Council and Watershed Stewardship Groups like the Nose Creek and Elbow River Watershed Partnerships are key partners in the implementation of Alberta's *Water for Life* Strategy. It may be appropriate to consult these groups and the Watershed Management Plans listed below as part of the planning process for Streambank and Riparian Stability Restoration projects in Calgary.

- Bow Basin Watershed Management Plan, 2010, Phase I and Phase II, Bow River Basin Council: http://www.brbc.ab.ca/index.php?option=com_content&view=article&id=96&Itemid=210
- Elbow River Basin Water Management Plan, January 2009, Elbow River Watershed Partnership: http://www.erwp.org/index.php/water-management-plan/plan
- Nose Creek Water Management Plan, January 2007, The Nose Creek Watershed Partnership: http://www.calgary.ca/UEP/Water/Documents/Water-Documents/nose_creek_water_mgmt_plan.pdf

In 2007, Calgary City Council approved the *Nose Creek Watershed Water Management Plan* to achieve specific water quality objectives. The *Bow Basin Watershed Management Plan*, *Phase I (Water Quality)* and the *Elbow River Watershed Management Plan* were approved in 2008 (2010 State of the Environment Report). The *Bow Basin Watershed Management Plan Phase II: Focus: Land Use, Headwaters, Wetlands and Riparian Lands*, is expected to receive approval in 2012.

3.0 MANAGEMENT STRATEGY FOR EROSION AND FLOOD CONTROL AND RIPARIAN RESTORATION PROJECTS

3.1 The City of Calgary Requirements

The City of Calgary's requirements for erosion and flood control and riparian restoration are project dependent and may vary. Select requirements are discussed below.

3.1.1 Triple Bottom Line (TBL) Approach

The *Triple Bottom Line (TBL) Prioritization Manual for Streambank and Riparian Stability Restoration* (AMEC, February 2012a), contains the TBL methodology used for this project. The TBL approach considers Economic, Environmental and Social Factors to assess the costs and benefits associated with the restoration of streambank and riparian area sites.

There were a total of 155 sites (134 streambank and 21 riparian) that were identified as a high priority and a TBL prioritization was conducted for most of these sites. The actual results of the TBL exercise are presented in a separate document, *Project Summary for Streambank and Riparian Stability* (AMEC, February 2012b). The TBL is discussed further in **Section 8.6**.

3.1.2 Stakeholder Engagement

In addition to required consultation with municipal, provincial and federal regulatory agencies, it may also be appropriate to solicit input from other stakeholders during the development of strategies and implementation of restoration projects. The City is a member of the Bow River Basin Council, the Elbow River Watershed Partnership, Ghost Stewardship Monitoring Group and the Nose Creek Watershed Partnership (City of Calgary 2010 State of the Environment Report, January 2011). Other stakeholders could include federal and provincial ministries, The City of Calgary Business Units, non-government organizations (e.g., Calgary River Valleys – www.calgaryrivervalleys.org), the public or other community or watershed stewardship groups.

3.1.3 Public Access

As contained in **Appendix A** (Item 2-1.4.1F), a guiding principle from Calgary's *Urban Park Master Plan* is:

> *The River Valley Park System will be accessible, usable and safe for all persons where practical and environmentally appropriate, bearing in mind the needs of persons with disabilities*.

Incorporating public access for a particular project should be discussed with the appropriate Business Units at The City of Calgary.

3.1.4 Public Education and Signage

As contained in **Appendix A** (Item 2-1.4H), a City of Calgary Natural Areas policy is:

> *Encourage stewardship and informed public, corporate and/or community participation. Also encourage partnerships in acquisition, management, research and protection of appropriate natural environments.*

Incorporating public education and signage for a particular project should be discussed with the appropriate Business Units at The City of Calgary. Public Education and Signage was one of the Social factors considered in the TBL prioritization undertaken for the Streambank and Riparian Stability project (AMEC, February 2012a). **Section 6.6** of these guidelines contains additional information regarding volunteer and community group participation in riparian restoration projects.

3.2 Contractor ECO Plan Responsibilities

An Environmental Construction Operations (ECO) Plan consists of written procedures and drawings for contractors to identify and mitigate the potential environmental issues that may occur as a direct or indirect result of construction activities being performed on a specific project site. The objective of an ECO Plan is to prevent and/or minimize environmental impacts and to enhance the environmental value of the air, land and water affected by projects. The contractor is responsible for preparing or updating the ECO Plan in accordance with the "*Environmental Construction Operations (ECO) Plan Framework Instructions for Preparing ECO Plans for Alberta Transportation, The City of Calgary and City of Edmonton Construction Projects*", 01 January 2012, prepared by Alberta Transportation, The City of Calgary and The City of Edmonton.

An ECO Plan would typically be required for erosion and flood control and riparian restoration projects. The ECO Plan is discussed in greater detail in **Section 9.2.1** of these Design Guidelines.

4.0 OVERVIEW OF EROSION AND FLOOD PROCESSES

This section contains an overview discussion of erosion and flood processes for streams within The City of Calgary. Reference is made to existing reports and information, which should be consulted for more detailed information.

4.1 Hydraulic, Hydrologic and Morphologic Considerations

The reports noted below contain detailed discussions of the Bow River and Elbow River hydrology, hydraulics and morphology.

- *Calgary Floodplain Study*, April 1983, Alberta Environment.
  - The City of Calgary and Alberta Environment and Water are currently updating the 1983 Calgary Floodplain Study with the *Bow and Elbow River Updated Hydraulic Model Project*, 2012, Golder and Associates.
- *Bow and Elbow Rivers at Calgary, Alberta – River Regime Study*, October 1986, Northwest Hydraulic Consultants Ltd (NHC), prepared for Alberta Environment.

The NHC report states *"…the Bow River and Elbow River within the City of Calgary have both been influenced in the last 100 years by the presence of man. The construction of dams, weirs, dikes, landfills and bank armouring has affected the natural regimes of these rivers. As well, there has been an absence of large floods in both rivers since 1932*."

The objective of the NHC report was to analyze existing river regimes and assess how these regimes might change with a return to more frequent high flood flows, given the absence of large floods in both rivers since 1932. The NHC report concludes the reduced discharges in the recent past combined with a closing of the bed material transport past the Bearspaw Dam has "*resulted in the Bow River attempting to take on the appearance of a smaller river*". The NHC report states that with a return to the higher, pre-1933 flood peak regime "*considerable amounts of bank erosion would occur, particularly downstream of the W.I.D. (Western Irrigation District) weir; and the local bed aggradation accompanying bank erosion would result in the formation of new mid-channel bars and islands*".

For the Elbow River, the NHC (1986) report states the following:

- *The present-day Elbow River regime downstream of Glenmore dam is quite different from what it was prior to 1933.*
- *Minor bed degradation has likely occurred since 1933 (i.e., post Glenmore Dam) but bed material at the surface is currently in the cobble to boulder range, so the bed is effectively armoured.*
- *A return to the 1911-1932 flood peak regime might produce important changes in plan form. If as expected, much of the existing bank protection fails during a large flood, significant quantities of eroded material would be deposited in the channel. Therefore, eroded coarse*

bank material would be deposited locally in gravel bars. To continue (no repair or extension of bank protection works) this process would cause the flow pattern to shift around gravel bars, creating bank erosion opportunities along previously stable banks.

A detailed description of hydrology and floods on the Elbow River, Bow River and Nose Creek is contained in the above noted *Calgary Floodplain Study* (AENV, 1983), which as noted previously is currently being updated.

The reports noted below contain detailed discussions of Nose Creek and West Nose Creek hydrology, hydraulics and morphology.

- *West Nose Creek Stream Corridor Assessment Phase 2*, June 2003, Westhoff Engineering Resources Inc., prepared for The City of Calgary, Wastewater.
- *Nose Creek Flood Risk Mapping Study*, October 2004, Golder Associates Ltd. prepared for Alberta Environment.
- *Towards Restoration of the Nose Creek Corridor, Alberta, An Overview of Historical Versus Existing Conditions and Identification of Priority Sites for Rehabilitation*, January 2003, M.K., Van Wyk, Masters Degree Project, University of Calgary.

Westhoff (2003) states the following regarding the development and channel changes on West Nose Creek:

> *Rural and urban communities have introduced pressures that have caused the creek system to shift in time and to establish its equilibrium. Some of these pressures have caused conditions such as degraded riparian areas from intensive grazing, alteration and disruption of the channel from works such as bridge and cattle crossings, encroachment of urban areas and amenities, and increased flow from development. The equilibrium shift, in addition to perpetuating further disturbance, has resulted in an inability for the creek to carry out its functions along the study area (e.g., sediment transport and bank building).*

Van Wyk (2003) states the following regarding the sections of Nose and West Nose Creek within The City of Calgary, which he refers to as Reach E.

> *Numerous diversions and channelizations have affected both the Nose Creek branch and the West Nose Creek branch in Reach E – largely the result of continued urban expansion in the region. Since 1926, it is estimated that between 15 000 m and 20 000 m of the Nose Creek channel in Reach E has been lost because of the number and size of diversions and channelizations in the area.*

To put the above noted distances in perspective, the existing length of Nose Creek and West Nose Creek within The City of Calgary are 26.6 km and 16.5 km, respectively. The reintroduction of meander bends or meandering channel form to Nose Creek and West Nose Creek should be a consideration for future restoration works.

4.1.1 Ice Processes

The following discussion of ice processes within The City of Calgary is specific to the Bow River, where the majority of the ice problems occur. The term frazil is used in the discussion below and the following definition is modified from Sui et al. (2006) "*in turbulent river flow, frazil ice is the dominant ice phenomenon. Frazil is formed in super-cooled water and thus is only generated in open reaches. In rivers with fast flowing sections where an ice cover cannot form, tremendous quantities of frazil ice can be generated throughout the winter. This frazil ice is carried in suspension, moving with the flow to be deposited on the underside of a continuous ice-cover at some point downstream*".

Good descriptions of historic ice jam flooding are contained in the following documents:

- *Report on Ice Forming & Ice Jamming Conditions on Bow River In The Vicinity Of Calgary from October, 1945 to January, 1946*, 25 January 1946, E.P. Collier, Dominion Water & Power Bureau.
- *Freeze-Up Observations and Aspects of the Ice Anchor on The Bow River at Calgary,* Andres, D.D., and Fonstad, G.D., 1982, Alberta Research Council.
- *An Assessment of the Operation of the Bow River Ice Pack Anchorage Bow River at Calgary*, 1990, Alberta Environment.

Andres and Fonstad (1982) contains the following description of ice jam floods in Calgary

- *Under natural, non-regulated conditions, the discharges during freeze-up and break-up were often relatively low; the former resulting mainly from groundwater entering the Bow River upstream of Calgary and the latter due to the melt of a generally very low snow pack in the plains area. For example, the mean December non-regulated flow was about 32 m^3/s and the average spring snowmelt peak discharge under natural conditions was about 60 m^3/s. Flows of such relatively low magnitudes seldom resulted in any significant ice related problems.*
- *The first major regulation of the Bow River was due to the Ghost Dam which is located about 50 km upstream of Calgary. It came on stream in 1929 and was used primarily to meet peak load demands. This resulted in larger mean daily flows (40 to 80 m^3/s) and also considerable daily fluctuations in discharge. Almost immediately ice jams during freeze up became an annual problem and it was not uncommon for water levels to increase by 3 to 4 m during the period of ice cover formation. The relatively low banks within The City of Calgary resulted in serious flooding and following a proliferation of complaints in 1940 and 1941, the freeze-up process was studied in efforts to achieve flood reduction.*
- *Early freeze-up observations revealed that initially a lightly consolidated ice cover formed at various locations. These ice covers would subsequently consolidate and thicken, keying at favourable locations and producing extremely high water levels. In areas where gravel had*

been mined from the channel a very early ice cover was observed to form. Frazil accumulated in these low velocity sections and initiated the upstream progression of the ice cover. Even during large consolidations the ice was held upstream of the frazil accumulation and the areas downstream were spared the high water levels.

- *From these observations, the (Bow River Ice) Committee (1950) concluded that a similar excavation of sufficient length and depth placed at a strategic location could isolate downstream river reaches from ice consolidations and thereby provide some measure of flood control. The Committee also recognized that if the large daily fluctuations in flow releases could be moderated, the ice problem could be more easily managed. The problem of large daily fluctuations was solved by the 1954 construction of the Bearspaw Dam located on Calgary's west City limit. Despite this, high mean daily discharges due to releases from the Ghost Reservoir still created difficulties within The City. Therefore, in 1959, an ice anchor was constructed just downstream of the Louise Bridge at the head of Prince's Island (Figure I in the Andres and Fonstad report). The ice anchor consisted of a large excavation across the entire width of the main channel at the upstream end of Prince's Island. Initially, approximately 71,000 m^3 of material was excavated, with an additional 38,000 m^3 removed in 1963. The final configuration of the channel, which has not been significantly altered by sedimentation, is an excavation approximately 200 m in length, with a top width of 100 m, a maximum depth of 6.5 m and an average depth of about 3.4 m.*
- *In 1962 the Brazeau Dam was constructed on a tributary of the North Saskatchewan River to provide for peak power demands previously made up on the Bow system. The Ghost Dam has since been used to meet intermediate power demands, resulting in lower outflows and narrower daily fluctuations. Subsequently, fewer freeze-up problems have occurred in Calgary. Notable exceptions were in 1965, 1975 and 1980 when extremely cold conditions and/or large releases from the Ghost Reservoir led to a thickened ice cover and stage increases of 3, 3.2 and 3 m, respectively.*

The report *Bow River Ice Pack Anchorage Rehabilitation Proposal Level I Design Report*, May 1997, Alberta Environmental Protection, contains the following description of infilling with sediments of the Ice Pack Anchor (IPA).

> *Generally the IPA has filled in with sediments particularly in the upstream portion. From 1961 through 1989 an estimated 37,000 m^3 of sediments have been deposited in the upstream end of the IPA. This deposition has reduced the physical length of the anchorage in 1989 to about 50% of the original 1959/63 limits. From 1989 through 1996 an additional 1,100 m^3 of sediments were deposited in the IPA, making a total deposition of 38,100 m^3 since 1961.*

There are numerous locations other than the IPA that are subject to ice jams. The report *Design Ice Conditions at Western Headworks Weir*, 29 May 2007, Northwest Hydraulic Consultants, states:

> *An ice cover forms initially as a result of the lodgement of surface ice at hydraulically conducive locations. The ice cover then advances upstream from that point as long as an ice supply is available. It appears that there are multiple lodgement points in the vicinity of Calgary – certainly at the Weir, downstream of the Weir, and perhaps upstream as well. Anecdotal evidence suggests that in some years an ice cover forms first at the "Ice Anchor" near Prince's Island Park, or at the Calgary Zoo*

Another area that has historically been subject to ice jams is the Bow River at the very downstream end of the study area, where the outfall for the Shepard Ditch is located at NE 7-TWP 22-R. 28-W4M. This is believed to be the upstream extent of the ice front that forms at the Carseland Weir, which is approximately 38 km downstream.

4.2 Riparian Considerations

The evaluation of riparian areas, which was undertaken by Cows and Fish between 2007 and 2010 was a significant component of the *Streambank and Riparian Stability Study*. The results of this riparian evaluation are contained in the following documents:

a) *2007-2010 Riparian Evaluation Synthesis and Riparian Restoration Recommendations*, January 2012a, Cows and Fish.
b) *2007-2010 Riparian Health Inventory Summary Reports*, January 2012b, Cows and Fish

Cows and Fish (January 2012a) contains the following description below on the importance of riparian areas.

> *When in a properly functioning condition or healthy state, riparian areas help reduce loss of land during floods, provide habitat for fish and wildlife, and enhance the overall quality of stream/river water.*
>
> *Healthy riparian areas trap and store sediment to maintain and build banks; recharge groundwater supplies, providing stable flows and flood protection; and improve water quality by filtering runoff and reducing the amount of contaminants and nutrients reaching the water.*

Hence, it is important that riparian areas be considered integral with bank stability in the design of erosion and flood projects and the information contained in the above noted Cows and Fish documents should be incorporated into the project. Further discussion of the importance of riparian areas is contained in **Section 6** of this design guideline manual.

4.3 Geotechnical Considerations

Geotechnical factors should be considered in the design of erosion and flood control projects if: (1) slope stability is an issue, for example if the stream channel is located adjacent to the valley wall; and (2) if dikes are present.

The Streambank and Riparian Stability Study included a geotechnical assessment to review valley wall, dikes and flood works stability, which is contained in *2010 Geotechnical Summary Report for Streambank Stability Assessment*, AMEC, February 2012c.

AMEC's review of background information for the Streambank and Riparian Stability Study indicated that many of the slope instabilities in The City have been documented in previous reports. These historical reports should be reviewed, if slope instability is an issue. However, there is very little historical information regarding the geotechnical considerations in the design of existing dikes. For example, AMEC (February 2012c) included a review of the Sunnyside Dikes and no historical geotechnical information on the dike structure was found. Geotechnical assessments are discussed in **Section 8.4** of these guidelines.

5.0 EROSION AND FLOOD CONTROL TECHNIQUES

The guidelines discussed below and contained in **Appendix C** are intended to be part of a 'living document' that has the flexibility to evolve as new techniques are developed and as more knowledge is gained about successful soil bioengineering strategies in Calgary. It is not intended to limit the techniques, but rather it is meant to provide a foundation for Calgary projects. Innovative and emerging restoration techniques not described in these guidelines should be considered on a project specific basis. The selection of appropriate design techniques should be based on the engineering and environmental assessments described in **Section 8**.

5.1 Overview

The design guideline techniques developed for the Streambank and Riparian Stability Project are listed with a brief description in **Table 5.1**. The detailed design guidelines techniques themselves are contained in **Appendix C** and can be characterized as follows:

- Guidelines A to I4 describe specific streambank erosion control and riparian area restoration techniques. Each of these guidelines includes information such as description of technique; suitability; limitations; design considerations; implementation; and references.
- Guidelines J to Q provide general guidance related to design and best management practices.
- Guideline R (Stabilized Access) and Guideline S (Fencing) are important components of restoration projects but are standard techniques and no detailed documentation was required to describe these techniques.

There are numerous references that were consulted in the development of Guidelines A to Q in **Appendix C**. Authorization for the use of the reference material was obtained from the various authors and select sources are noted below. The information contained herein is not all-encompassing and the reader is encouraged to consult the references noted below and in the references section of the individual Guidelines contained in **Appendix C**.

- Schiechtl, H.M. and R. Stern. 1997, *Water Bioengineering Techniques for Watercourse Bank and Shoreline Protection. Cambridge: Wiley-Blackwell*.
- Alberta Transportation, June 2011, *Erosion and Sediment Control Manual*, http://www.transportation.alberta.ca/4626.htm
- McCullah, J.A., 2010, *Bio Draw 3.0 Compendium of Biotechnical Soil Stabilization Solutions, Salix Applied Earthcare*.

5.1.1 Limiting Conditions and Applicability of Techniques to Local Context

The success of bioengineering techniques will depend largely on the use of the appropriate techniques and plants for the site specific conditions such as moisture, aspect, climate, soils, ice conditions, etc. Caution must be applied in the use of bioengineering techniques developed in moister regions such as coastal British Columbia. Most of the Guidelines in **Appendix C** contain a discussion on limitations and applicability for local conditions.

Guideline K (Live Cuttings/Stock Handling) and Guideline L (Native Seeds, Seedlings and Nursery Stock) contain detailed guidance on the use of suitable native material and local plant nurseries and suppliers. It is recommended that the production of live plant material required for the application of soil bioengineering techniques (such as live cuttings of suitable species) be encouraged on a large scale basis with local nurseries within The City of Calgary region.

5.1.2 Environmental/Habitat and Biophysical Merits of Various Erosion Protection Measures

The use of bioengineering techniques contained herein will enhance fish and wildlife habitat and aesthetics. Ecological advantages (Donat, 1995) include:

- Regulation of temperature and humidity close to the surface, thus promoting growth;
- Improvement of the soil water regime via interception, evapotranspiration and storage;
- Soil improvement and top soil formation;
- Improvement of and provision of riparian habitat.

Polster (2002) states soil bioengineering "*can provide a finished product that treats the problem as well as providing appropriate riparian vegetation. The natural successional process associated with development of a healthy, functioning riparian vegetation cover is the model that is used to design repair systems that encourage restoration of riparian values. By providing a living, growing system for repair of damaged sites, possibly with wood and rock, the repair can contribute to a living riparian area*". The value and benefits of a healthy riparian area are also discussed in **Sections 4.2** and **6** of these guidelines.

In addition to the general habitat and biophysical merits of bioengineering described above, Guideline Q (Low Undermined Shoreline Protection of High Value Fish Habitat), is intended to further enhance shoreline protection and fish sheltering habitat.

5.2 Review of Erosion Control Products and Their Appropriateness in Different Scenarios

Guideline J (Erosion and Sedimentation Control Products) provide general information on common erosion and sedimentation control products that might be used for erosion and sedimentation control on streambank restoration projects. These products were divided into the following general categories:

- Instream Sediment Control
- Rolled Erosion Control Products

- Blown On or Hand Applied Erosion Control Products
- Hydraulically Applied Erosion Control Products
- Silt Fences
- Sediment Retention Fibre Rolls (Wattles)
- Gabion Baskets

Guideline J should be used in conjunction with The City of Calgary's existing *Erosion and Sediment Control Guidelines* (October 2011) and The City's Contractor ECO Plan Responsibilities discussed in **Section 3.2** and **Section 9.2.1** of these guidelines.

Table 5.1 contains a summary of the design guidelines, which are described in detail in **Appendix C**.

TABLE 5.1
Design Guideline Techniques

Guideline	Description
'A' Fascines With Double Poles	Fascines with double willow (or balsam poplar) poles are used to protect the toe of an eroding streambank. Fascines are live cuttings from branches and stems of suitable native shrubs and trees which have properties of vegetative propagation (e.g., willow, balsam poplar and/or red osier dogwood). Live fascines are further described in 'I2'.
'A1' Aquatic Species Rolls and Single Poles	Similar to 'A' but rolls or clumps of aquatic species with single poles are used to protect the toe of an eroding streambank. The aquatic rolls / clumps may consist of native sedges (*Carex* spp.), bulrushes (*Scirpus* SPP.), cattail (*Typha latifolia*) or other suitable native aquatic species. Can be used as an alternative to 'A' when attack is less severe and aquatic species are available.
'A2' Fascines With Double Poles and Brush Layers	Similar to 'A' but rows of brush layers can be added above the fascines to provide additional slope stabilization on higher banks. A brush layer consists of a row of live cuttings (willow, balsam poplar and / or red osier dogwood) placed in a criss-cross or overlapping manner in between layers of soil, with tips protruding beyond the face of the fill (see'I1').
'B' Longitudinal Peak Stone Toe Protection (LPSTP)	LPSTP is a free-standing structure (i.e., not keyed into the bed or bank) that has a triangular shape (the apex of the triangle is the peaked top). The triangular shape of the LPSTP allows plantings (e.g., brush layering see 'I1') to be more easily incorporated behind the structure. The LPSTP is designed to launch with scour, hence it does not require a key-in to the streambed or an apron.
'B1' LPSTP with Brush Layers	Similar to 'B' but brush layering (see 'I1') is incorporated behind the structure.
'C1' Rock Toe With One Brush Layer Row	A rock toe is placed along shorelines to provide erosion protection and a brush layer is installed above the rock toe. The brush layer (see 'I1') consists of a row of live cuttings (native willow, balsam poplar and red osier dogwood) placed in a criss-cross or overlapping manner in between layers of soil, with tips protruding beyond the face of the fill.
'C2' Rock Toe With Multiple Brush Layer Rows	Similar to 'C1' but multiple brush layers are placed if the bank is high or slope requires stabilization.
'D1' Vegetated Riprap with One Vegetated Row	Vegetated riprap with one row of vegetation. Provides bank stability and prevents erosion of streambank by combining both rock and live root systems protection. Can be used in location where the streambank is relatively low and subject to severe attack.
'D2' Vegetated Riprap with Multiple Vegetated Rows	Similar to 'D1' but provides additional rows of vegetation for higher banks. Can be used in locations where the streambank is higher and subject to severe attack.
'E1' Vegetated Gabion and Optional Rows of Brush Layer	Gabions are rectangular shaped containers made from twisted wire mesh or welded wire mesh that are filled with stone. When live materials are combined with the gabion baskets they are called vegetated or green gabions. Potential use in narrow sections of the Elbow River, West Nose Creek and Nose Creek that are subject to severe attack.
'E2' Log Crib Wall and Optional Brush Layers	Vegetated log crib walls consist of multiple courses of logs, drainage material, geotextiles, backfill and live vegetation. Potential use in narrow sections of the Elbow River, West Nose Creek and Nose Creek that are subject to severe attack.
'F1' Vegetating Existing Rock Riprap with Stinger Technique	Live staking of existing riprap improves riparian, aquatic, and terrestrial habitat while softening rock appearance. Suitable for enhancement or retrofit of existing riprap of shallow to moderate thickness. Stinger technique utilizes an excavator with stinger attachment or long narrow bucket that is used to remove or reposition riprap and make a hole for the planting.
'F2' Vegetating Existing Rock Riprap with Bucket Technique	Similar to 'F1' except a conventional excavator bucket is used to force open ground to allow placement of live stakes
'G1' Live Pole Drains	Slope and gully stabilizing technique drain system that consists of cylindrical bundles of live cuttings (see 'K') installed in a chevron fashion, where drain fascines are connecting to a main central live drain.
'G2' Live Pole Drains with Rock Drain	Similar to 'G1' but rock / drain stone is incorporated into the center drain in wetter conditions.
'H' Plantings of Live Stakes and Seedlings with mulch	Planting of live stakes or container stock seedlings, in combination with mulching, can be used to enhance the species diversity and riparian attributes of areas colonized by non-native grasses and invasive weeds.
'H1' Plantings of Live Stakes only with mulch	Similar to 'H' but only live stakes are used (i.e., no seedlings)
'H2' Plantings of Seedlings only with mulch	Similar to 'H' but only seedlings are used (i.e., no live stakes)
'I1' Brush Layers	A brush layer consists of a row of live cuttings (willow, balsam poplar and/or red osier dogwood) placed in a criss-cross or overlapping manner in between layers of soil with tips protruding beyond the face of the fill. Can be used in conjunction with many other techniques.
'I2' Live Fascines	Fascines are cylindrical bundles of live cuttings from branches and stems of shrubs and trees, which have properties of vegetative propagation (i.e., *Salix* spp. / *Populus balsamifera* spp.). The bundles are tied together using twine or strapping. They are installed in shallow trenches and anchored in the trench using wooden stakes. These are used on slopes, along the contours, to provide a physical barrier that slows run off and traps sediment. They can also be angled to provide drainage. Can be used in conjunction with many other techniques.
'I3' Straw Wattles	Straw wattles are an erosion control product used to provide a physical barrier on slopes to reduce the rilling resulting from sheet erosion. The straw wattles will collect sediment, seed and organic material, thereby providing an environment for plant establishment.
'I4' Branchpacking	Used to repair small eroded gullies and / or slumps. It consists of branches placed in a herringbone fashion, within a gully or small slump, with the tip ends at the bottom of the gully. Each layer of branches is placed horizontally starting at the bottom of the gully, covered with soil and secured with wooden poles and stakes.
'I5' Brush Mattress	A brush mattress is a layer of interlaced/adjacent live stems placed on a streambank face. Live material is normally willows, but can be combined with balsam poplar and red osier dogwood. Used primarily for watercourse bank erosion protection. Appropriate for narrow channels since there is minimum encroachment. Can be used with a rock toe or crib wall toe. Can replace rock riprap armouring. Provides added watercourse bank roughness to slow down the water and can accumulate sediment.
'J' Erosion Control Products	General information on common erosion and sedimentation control products that might be used for erosion and sedimentation control on streambank restoration projects. These products were divided into the following general categories: Instream Sediment Control: Rolled Erosion Control Products; Blown On or Hand Applied Erosion Control Products; Hydraulically Applied Erosion Control Projects; Silt Fences: Sediment Retention Fibre Rolls (Wattles); and Gabion Baskets.
'K' Live Cuttings/Stock Handling	Harvested plants for live cuttings should be from native tree and shrub species, capable of vegetative propagation that will roots and shoots from cuttings when placed in contact with soil and moisture. They should be harvested during the plant dormancy period. Additional native willow species that may be used for live cuttings are listed in 'L'.
'L' Native Seeds/ Seedlings/Nursery Stock	Contains suitable stock and sources for native seeds, seedlings and nursery stock.
'M' Soil Amendments	Application of soil amendments within soil bioengineering techniques (i.e., live cuttings, seedlings and seeding) will address deficiencies in soil chemistry (e.g., soil salinity, available nitrogen, phosphorus, potassium, pH, soil toxins) and will enhance the soil moisture retaining capacity.
'N' Construction and Environmental practices	Provides general construction and environmental practices for streambank erosion remedial projects to reduce environmental impact and to avoid the spread of invasive species.
'O' Rock Riprap	Rock riprap reduces erosion in areas where softer engineering techniques are not adequate.
'P' Critical Shear Stress & Resistance of Materials	Provides examples for both maximum permissible velocities or a design based on critical shear stress (or tractive force) for soils, gravels, cobbles, rocks, vegetation and soil bioengineering structures.
'Q' Low Undermined Shoreline Protection of High Value Fish habitat	Applicable if ongoing shoreline erosion does not pose a threat to nearby infrastructure and / or fish habitat improvement is desirable. This technique is intended to provide improved shoreline protection while maintaining and enhancing the fish sheltering habitat.
'R' Stabilized Access	Simple technique so no specific guideline produced. Stabilized Access would be used in an area that has been degraded due to heavy use by the public. An example would be a 10 m x 3 m area that would consist of: (1) 16 m of wooden fencing to restrict access to adjacent areas; (2) a stable surface consisting of 0.25 m thick layer of cobble overlying 0.3 m thick gravel filter layer; and (3) one cubic metre of rock riprap that can be used to stabilize the shoreline or used to create steps.
'S' Fencing	Simple technique so no specific guideline produced. Wooden fencing used to restrict on a long-term basis public access to areas that are being restored.

6.0 RIPARIAN RESTORATION TECHNIQUES

6.1 Riparian Restoration Design Considerations:

The desired end goal for a riparian restoration project is to create a low maintenance and self sustaining ecosystem that closely mirrors natural riparian ecosystems and allows for processes of natural succession to occur. A vital component of any riparian restoration plan is to first identify and develop strategies to address the root cause of riparian degradation in any given site. Riparian degradation may stem from on-site local land use activities or from urbanization impacts at a watershed scale that are contributing to issues such as accelerated erosion or channel incisement.

In some instances, restoration of healthy riparian areas will be slow, particularly for sites that have been substantially altered from their natural state. In cases such as permanently modified riparian sites along the Bow River and Elbow River through Calgary's downtown core, it may not be possible to achieve a return to a 'healthy' state. However, on these sites, some improvement may be recognised within a few years, depending on the commitment to monitor and maintain the site, riparian site potential and the riparian management strategy implemented. Sites with minimal disturbance and existing native riparian plant communities have a higher potential for natural recovery and a return to a healthier state. When rested from disturbance, willows, balsam poplar and sedges will naturally re-establish in degraded riparian areas if moisture and soil compaction are not limiting and there is minimal competition from non-native species. New sediment deposition from flood events can help re-build banks and alleviate soil compaction concerns.

Riparian restoration guiding principles and strategies:

- Promote natural recovery of riparian areas or use restoration practices that mimic or enhance natural recovery processes.
- Use appropriate native species complexes and design techniques to enhance or restore degraded riparian areas. Native species mixes and design techniques must be customised to the soil type, aspect, moisture regime and topography of the site. Native species complexes should include early successional (pioneer) species such as willows and balsam poplars that are adapted to the local site conditions. Planting later successional (climax) species such as white spruce can be expensive and may not be as successful at establishing initial vegetative cover.
- Aim to improve or enhance one or more riparian ecological functions (**Section 6.4**).
- Evaluate success and failure of restoration projects, and use the findings of follow-up monitoring to improve future riparian restoration projects.
- Involve local community and user groups, Watershed Stewardship Groups and other stakeholders in the design process, implementation, maintenance and/or monitoring of riparian restoration projects in publicly accessible, City managed sites.

Differential zoning (for high and low impact activities), effective educational signage, and temporary or permanent access restrictions (fencing) may be required for both natural recovery and more intensive riparian restoration projects.

6.2 Riparian Planting Guidelines

Riparian restoration designs should incorporate the use of native species that are suitably adapted to the environmental characteristics of the restoration site and to the desired end land use.

Recommendations are given in Guideline L (Native Seeds, Seedlings and Nursery Stock) for:

- sourcing native species in the Calgary region;
- harvesting live native plant material;
- custom native seed mixes;
- use of local genotypes;
- weed prevention; and
- site preparation prior to planting.

6.2.1 Harvesting Live Native Plant Material

Where feasible, native plants may be sourced or harvested from appropriate donor sites within the same Natural Subregion (Natural Regions Committee, 2006) as the project site. Donor sites should have a similar climate, elevation, soil type, moisture and nutrient regime as the project site. Prime donor sites may include proposed road or subdivision developments where native vegetation clearing is required. Careful project planning is required to select a suitable donor site in consultation with The City of Calgary (or other adjacent municipalities), obtain necessary approvals, and to ensure appropriate timing of live plant material harvest. Where possible, multiple harvest sites should be used to improve genetic diversity and lessen the potential to damage donor sites. Live native plant material harvest, handling and storage techniques and scheduling should follow Guideline K (Live Cuttings / Stock Handling) and the *"Plant Collection Guidelines for Horticultural Use of Native Plants".* (Alberta Native Plant Council, 2007) (see – www.anpc.ab.ca)

Considerations[1]:

- Ensure that all necessary approvals are obtained prior to harvesting wild native plants.
- Ensure that contractors are able to identify appropriate plant species if harvesting from the wild.

[1] Cows and Fish Fact Sheet: *Growing Restoration*.
http://www.cowsandfish.org/publications/fact_sheets.html

- For soil bioengineering structures, harvested plants for live cuttings should be from native tree and shrub species capable of vegetative propagation (i.e., that will grow roots and shoots from live cuttings when placed in contact with soil and moisture as they go out of dormancy). These include most willows, balsam poplars, and red osier dogwood.
- When harvesting native plant material from undisturbed donor sites, collect plant material scattered over as large an area as possible and collect only 5% of the seed (if propagating in a nursery first). Limit harvest of an individual plant to less than one third of the total live stems emerging from one root system to ensure that this plant survives.
- Most plant materials are best collected during the dormant period, which generally occurs when leaves are not present between September and March. The exception to the dormant harvest rule is where aquatic / emergent plants (e.g., cattails, bulrushes and sedges) will be planted immediately into an aquatic setting. In these cases active growth of the plants will help them re-establish in their new location.
- Only cuttings of adequate length and diameter should be used (refer to Guideline K for more details). Cuttings should be trimmed so that the smallest part of the cutting is a minimum of 2 cm on the apical (top) end and at least 80 cm to 3+ m long, depending on which soil bioengineering treatment is being used.
- Ensure cuttings are healthy and growing well (i.e., they should be green and soft if the bark is scraped away). Avoid dying or diseased wood.
- Live willow / poplar cuttings should be carefully harvested, handled, transported and stored to prevent damage from desiccation and sun/heat exposure prior to planting (refer to Guideline K for more details). Live cuttings should be kept moist and protected from hot sun, drying winds and drying frosts. To extend the viability of cuttings, store them in a dark area to slow metabolism. Wrap cuttings with wet burlap and soak with water every day or two. Cuttings may be stored in a cold storage facility (about 0˚C) or snow banks, as long as they are kept moist.

6.2.2 Native Plant Suppliers in the Calgary Region

Guideline L provides a listing of Native Plant and Seed Nurseries in the Calgary Region for sourcing native plant stock. The Alberta Native Plant Council (www.anpc.ab.ca) and The City of Calgary Parks should be contacted for an updated listing of native plant suppliers. Of note, availability of native plant species stocks (live cuttings / plugs / pots / rootballs etc.) will vary each year. Project contractors should contact native plant suppliers as far in advance as possible to assess stock availability. At least 1 to 2 years advance notice may be required for propagation of select native species that are not commercially available.

The preference is to use local native species (i.e., local genotypes) that have originated in the immediate Natural Subregion for your project area. Plants and seeds of local origin are best adapted to local climatic fluctuations, soil conditions, pollinators, and predator or disease stresses. If registered native cultivars or ecovars are used, ensure that the original plant material was collected and developed from the local Natural Subregion, where possible.

Registered native cultivars should be used sparingly since they have limited genetic variation making them less tolerant of climatic or environmental changes.

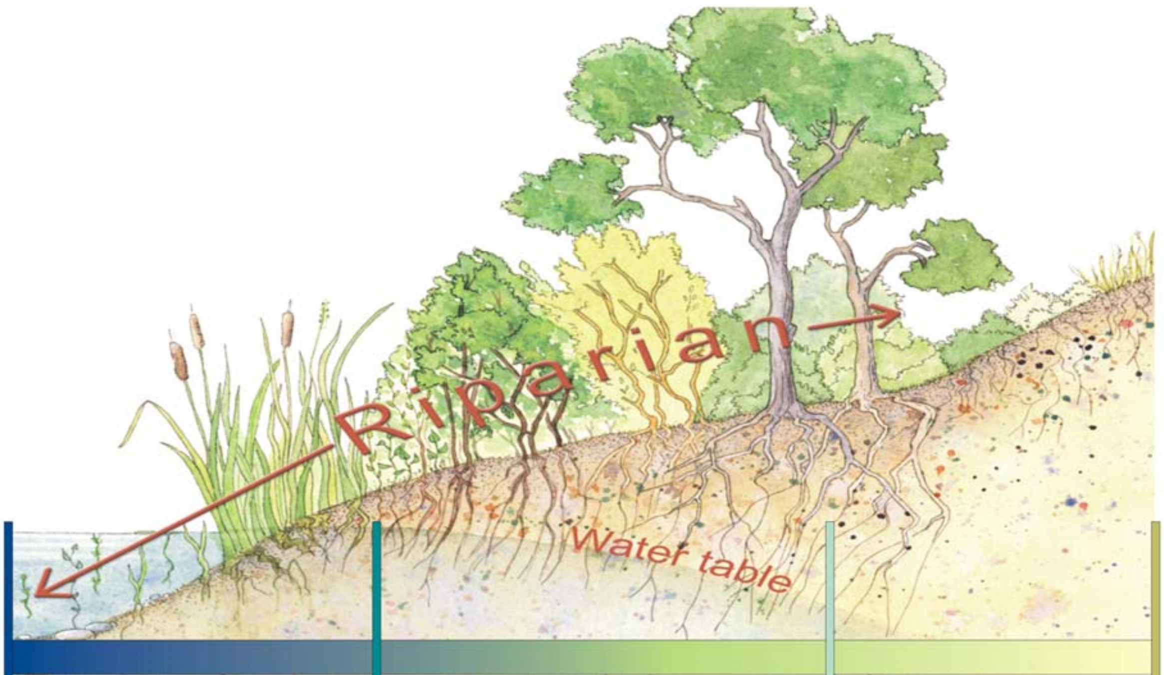
6.2.3 Native Species Selection

Refer to Guideline L for a detailed list of suggested native riparian plant species to be used for stream bank / riparian restoration projects in Calgary. Native species lists in Guideline L were developed by the Alberta Riparian Habitat Management Society (Cows and Fish) based on four years of riparian health inventory data in Calgary. These species lists include locally occurring native plants that have beneficial attributes for bank or slope stabilization (e.g., fast-growing, natural colonizer species); erosion control (e.g., deeply rooted species); soil improvement (e.g., native legumes capable of nitrogen fixation); and / or fish and wildlife habitat improvement (e.g., shade trees, berry producing shrubs etc.).

The final selection of suitable native plant species for riparian restoration projects will depend on local site conditions (topography / soils / aspect / moisture availability), the desired end land use, and management considerations. For restoration projects within Natural Areas (Natural Environment Parks), Calgary Parks - Natural Areas Management department must be consulted on appropriate riparian species mixes.

Considerations:

- Aim to restore native plant species diversity and natural community structure (i.e., low, medium and tall height layers and rooting depths). Healthy riparian forests have the following characteristics:
  - a native tree layer (e.g., balsam poplar) with seedling, sapling and mature aged trees;
  - tall (e.g., choke cherry, willows), medium (e.g., common wild rose) and short (e.g., buckbrush) native shrub layers; and
  - a herbaceous layer of native grasses or grass-like plants (i.e., sedges and rushes) and native wild flowers.
- Pay attention to moisture gradients, soil type and appropriate plant species selection.
  - **Figure 6.1** on the following page provides examples of common riparian species that can be planted in saturated to dry soil conditions along rivers and streams in Calgary. (Refer to Guideline L for more detailed native plant lists).
  - Soil type must be considered in plant species selection. For example certain species are well adapted to alkaline / saline conditions (e.g., salt grass, wire rush) while others are suited to sandy soils (e.g., choke cherry, silverberry, sand grass).
- Use appropriate planting techniques to reduce competition from aggressive non-native grasses and weeds.
  - Layers of cardboard and a minimum depth of 0.15 cm of mulch should be installed in conjunction with planting stakes or container stock seedlings to reduce competition from non-native grasses and weeds (refer to Guideline H - Plantings of Live Stakes or Seedlings with mulch for more details).



EMERGENT / AQUATIC SPECIES

Native sedges:

awned sedge (*Carex atherodes*)
small bottle sedge (*Carex utriculata*)
water sedge (*Carex aquatilis*)
woolly sedge (*Carex lanuginosa*)

Native rushes:

creeping spike-rush (*Eleocharis palustris*)
small-fruited bulrush (*Scirpus microcarpus*)
great bulrush (*Scirpus validus / S. Acutus*)
wire rush (*Juncus balticus*)

Native grasses:

common tall manna grass (*Glyceria grandis*)

Other:

common cattail (*Typha latifolia*)

MOIST SITE SPECIES
(High water table / flood prone zone)

Native trees:

balsam poplar (*Populus balsamifera*)

Native willows:

beaked willow (*Salix bebbiana*)
basket / meadow willow (*Salix petiolaris*)
false mountain willow (*Salix pseudomonticola*)
flat-leaved willow (*Salix planifolia*)
sandbar willow (*Salix exigua*)
shining willow (*Salix lucida*) **=** Pacific willow (*Salix lasiandra*)
yellow willow (*Salix lutea*)

Other native shrubs:

red-osier dogwood (*Cornus stolonifera*)
river alder (*Alnus tenuifolia*)
water birch (*Betula occidentalis*)

Native grasses

bluejoint (*Calamagrostis canadensis*)
fowl bluegrass (*Poa palustris*)
green needle grass (*Stipa viridula*)
northern reed grass (*Calamagrostis inexpansa*)
slough grass (*Beckmannia syzigachne*)
tufted hair grass (*Deschampsia cespitosa*)
western wheat grass (*Agropyron smithii*)

DRY SITE SPECIES
(South aspect / steep bank)

Native trees:

balsam poplar (*Populus balsamifera*)
aspen (*Populus tremuloides*)

Native shrubs:

Tall shrubs
choke cherry (*Prunus virginiana*)
pin cherry (*Prunus pensylvanica*)
saskatoon (*Amelanchier alnifolia*)
silverberry (*Elaeagnus commutata*)

Medium height shrubs
Canada buffaloberry
(*Shepherdia canadensis*)
common wild rose (*Rosa woodsii*)
northern gooseberry
(*Ribes oxyacanthoides*)
wild red raspberry (*Rubus idaeus*)

Short or creeping shrubs
buckbrush / snowberry
(*Symphoricarpos occidentalis*)
common bearberry (ground cover)
(*Arctostaphylos uva-ursi*)
creeping juniper (ground cover)
(*Juniperus horizontalis*)
shrubby cinquefoil
(*Potentilla fruticosa*)
twining honeysuckle (*Lonicera dioica*)

Native grasses:

Canada wild rye (*Elymus canadensis*)
green needle grass (*Stipa viridula*)
June grass (*Koeleria macrantha*)
needle-and-thread (*Stipa comata*)
northern wheat grass
(*Agropyron dasystachyum*)
sand grass (*Calamovilfa longifolia*)
Sandberg bluegrass (*Poa sandbergii*)
western porcupine grass (*Stipa curtiseta*)

Figure 6.1 Recommended Native Riparian Plant Species for Wet, Moist and Dry Site Conditions in Calgary

6.2.4 Monitoring and Maintenance of Riparian Plantings

Proper maintenance and monitoring of riparian plantings is key to the success of riparian restoration projects. Once a restoration project is complete, it will need ongoing monitoring and attention for 2 or 3 years at a minimum until plants become established.

Considerations:

- Frequent watering may be necessary in the short–term until riparian plants are established, particularly in drier south facing sites. Lack of summer moisture is a common cause of failure of many soil bioengineering projects. Although spring moisture can stimulate sprouting and periods of rapid growth, subsequent periods of dry weather during the summer can easily cause plants to die due to insufficient root growth to support those shoots. Watering newly planted areas may be necessary during this period to ensure survival.
- Temporary fencing may be necessary to protect riparian restoration sites from wildlife damage (e.g., beaver or deer use) or recreational use impacts
- Ongoing weed control is necessary to control aggressive non-native / weedy species such as smooth brome and Canada thistle (see **Section 7.3**). If these kinds of species become established early, they may prevent the successful growth of woody species. Disturbance caused by constructing a soil bioengineering treatment may in the short-term create ideal conditions for invasion by weeds and subsequently become a source of infestation along a water body.

6.3 Riparian Restoration Design Guidelines

In addition to Guideline L, riparian restoration projects should adhere to:

- General recommendations given in **Sections 2, 3** and **Section 8** of these guidelines for project planning, environmental surveys / assessments and regulatory approvals;
- Care of Water and Erosion Sediment Control considerations discussed in **Section 9.2** of these guidelines;
- Guideline N (Construction and Environmental practices) for general preventative measures to reduce the potential for transferral / introduction of weed species during site preparation and construction;
- Guideline M (Soil Amendments) for recommended soil amendment mixtures to address deficiencies in soil chemistry, enhance the soil moisture retaining capacity, and provide optimum growing conditions for riparian plantings or broadcast seed mixes;
- Guideline K (Live Cuttings/Stock Handling) for live cutting and aquatic plant harvesting guidelines, including harvesting schedule, harvest site selection, and live plant material handling and storage considerations;

- Guideline J (Erosion Control Products) for general information on common erosion and sedimentation control products that may be used for erosion and sedimentation control during riparian restoration projects;
- Guideline H, H1, H2 (Plantings of Live Stakes or Seedlings With Mulch) for recommended mulching techniques to be used in combination with planting of live stakes or container stock seedlings; and
- Guideline S (Fencing) for recommended fencing techniques to prevent access to riparian restoration / natural recovery sites during critical stages of establishment.

6.4 Restoration Strategies to Improve or Enhance Riparian Health

Riparian restoration plans should be designed to improve one or more key ecological functions of a riparian area (**Table 6.1**). The plan should be informed by baseline riparian health inventories to identify what types of improvements are necessary (Cows and Fish, January 2012a). To improve riparian function, restoration plans should incorporate the use of appropriate native plant species and native plant species assemblages, site preparation, weed control methods, and application of soil bioengineering techniques (where appropriate).

For example, to improve ecological functions, riparian restoration plans may be designed to:

- reduce bare ground cover;
- remediate compacted soil;
- improve native plant species biodiversity;
- improve tree and shrub structural habitat layers for breeding birds;
- improve fish habitat (e.g., through improved overhanging cover and shade along the streambank);
- filter upland pollutants; and/or
- provide soil binding root systems to reduce erosion and improve bank stability.

TABLE 6.1
Riparian Area Functions

Riparian Functions	Why Is This Function Important?
Trap Sediment	• Sediment adds to and builds soil in riparian areas • Sediment aids in soil's ability to hold and store moisture • Sediment can carry contaminants and nutrients - trapping it improves water quality • Excess sediment can harm the aquatic environment
Build and Maintain Banks	• Balances erosion with bank restoration - reduces effects of erosion by adding bank elsewhere • Increases stability and resilience • Maintains or restores profile of channel - extends width of riparian area through higher water table
Store Water and Energy	• Stream safety valve - stores high water on the floodplain during floods • Reduces flood damage • Slows flood water allowing absorption and storage in aquifer
Recharge Aquifer	• Stores, holds and slowly releases water • Maintains surface flows in rivers and streams • Maintains high water table and extends width of productive riparian area
Filter and Buffer Water	• Reduces amount of contaminants, nutrients and pathogens reaching the water • Uptake and absorption of nutrients by riparian plants • Traps sediment, improves water quality and enhances amount of vegetation to perform filtering and buffering function
Reduce and Dissipate Energy	• Reduces velocity which slows erosion and material transport • Provides erosion protection and slows meander rate • Aids in sediment capture
Maintain Biodiversity	• Creates and maintains habitats for fish, wildlife, invertebrates and plants • Connects other habitats to allow corridors for movement and dispersal • Maintains a high number of individuals and species
Create Primary Productivity	• Increases vegetation diversity and age-class structure - links to other riparian functions • Ensures high shelter and forage values • Enhances soil development • Assists nutrient capture and recycling

(Table 6.1 source – Fitch et al. 2001.)

6.5 Stormwater Harvest Considerations for Irrigation of Riparian Restoration Sites

In many instances, riparian degradation stems from altered hydrology due to flood control, channel incisement, dikes or berms which prevent natural flooding and irrigation of riparian sites. While these types of impacts in Calgary are likely permanent, there are mitigations that can be developed to locally harvest stormwater to irrigate desiccated riparian sites. Use of stormwater to irrigate riparian areas has the added benefit of reducing unfiltered runoff volumes into Calgary's streams and rivers, thereby improving water quality.

One of the first stages of riparian restoration planning should involve identification of point-sources of stormwater runoff within the local drainage area (e.g., paved parking lots, compacted sports fields, compacted picnic sites, roof-tops etc.). Where water quality considerations are met and appropriate approvals / licenses can be obtained under the *Water Act* (if applicable), mechanisms may be developed to capture and utilize this stormwater for the long-term irrigation of riparian restoration projects. This approach requires planning at a larger scale than the immediate restoration site and application of low-impact development, integrated stormwater management principles. The Alberta Low Impact Development Partnership (ALIDP) (www.alidp.org) should be consulted on a project specific basis to assist with designing appropriate stormwater capture and distribution mechanisms to irrigate riparian restoration sites.

Considerations:

- Alberta Environment and Water has established guidelines with respect to the use of stormwater.
- Alberta Environment and Water should be consulted during the project planning phase to discuss the feasibility and permitting / licensing requirements for stormwater diversion for the purpose of irrigating riparian restoration sites.

6.6 Volunteer and Community Group Participation in Riparian Restoration Projects

A key means of generating community support for riparian restoration projects is to involve community groups in the design, implementation, maintenance and monitoring of these projects wherever possible. All large scale riparian restoration projects in Calgary should include a public consultation phase and an opportunity, where feasible, for volunteer participation in the installation and long-term maintenance / monitoring of restoration works. Being actively involved in hands-on restoration projects helps to foster a sense of community, ownership and long-term responsibility for these projects. It also is a tremendous opportunity for promoting education and awareness about riparian health issues in Calgary.

The City of Calgary Parks has the opportunity to foster riparian stewardship in Calgary through its "Adopt-A-Park" program and initiatives such as the "Riverbank Rescue" program. Pilot restoration projects such as the 2008 Sandy Beach Riverbank Rescue Project along the Elbow River provide an opportunity to understand what can be achieved through demonstration sites and the amount of time it will take these sites to recover (Cows and Fish, 2009). Demonstration sites create a better understanding of the types of techniques that are successful in re-establishing native plant communities. These sites can also be used to experiment with unconventional techniques for weed control.

Another means of engaging community groups with riparian restoration projects is to coordinate these projects with local Watershed Stewardship Groups such as the Nose Creek Watershed Partnership (www.nosecreekpartnership.com) and the Elbow River Watershed Partnership (www.erwp.org). Watershed Stewardship Group coordinators should be contacted early on in the planning process to allow enough time to facilitate volunteer activities. Cows and Fish, Fisheries and Oceans Canada, and Trout Unlimited Canada offer riparian education programs that can be incorporated into community-based riparian restoration events.

7.0 INVASIVE SPECIES MANAGEMENT AND CONTROL

7.1 Invasive Species Contamination and Transfer Considerations

- Ensure that the source and supply of fill material, topsoil, mulch and compost is free of the seeds of potentially invasive, non-native species (e.g., "noxious" and "prohibited" noxious weeds listed on the *Alberta Weed Control Act*).
- Ensure all vehicles and equipment entering and leaving the work site are clean and free of mud and weed seeds.
- Require that contractors familiarize their employees with specific invasive, noxious and prohibited noxious weeds[2] common to the project area, during discussions at daily work-site meetings.

7.2 Plant Material Purchase Guidelines

- Use only suitably adapted native plants for riparian restoration projects that are sourced from appropriate donor sites (where feasible) or that are purchased from local suppliers of native plant materials. Refer to Guideline L and Guideline K for more details.
- For restoration projects within Natural Areas / Natural Environment Parks, Calgary Parks - Natural Areas Management department must be consulted on appropriate riparian species mixes.
- Avoid the use of generic 'wildflower seed mixes' since these have potential to contain non-native and potentially invasive species.
- A "Certificate of Seed Analysis" should be requested for all reclamation seed mixes to ensure that the seed is weed free. Certificates of Seed Analysis should be examined and approved by a qualified professional (such as RP Bio., P.Biol., or P.Ag.) prior to seed purchase.
- The following non-native species should be flagged and banned from riparian plantings due to their invasive growth habit and negative impact to native plant communities:
  - Noxious and Prohibited Noxious Weeds as designated by the Alberta Weed Control Act.
  - Invasive ornamental species as designated by the Alberta Invasive Plant Council (AIPC) including creeping bellflower (*Campanula rapunculoides*), baby's breath (Gypsophila *paniculata*), Dame's rocket (*Hesperis matronalis*), Himalayan balsam (*Impatiens glandulifera*), Maltese cross (*Lychnis chalcedonica*), Queen Anne's lace (*Daucus carota*), St. Johns wort (*Hypericum perforatum*), teasel (*Dipsacus fullonum*), tufted vetch (*Vicia cracca*) and wild caraway (*Carum carvi*). Refer to the AIPC website (www.invasiveplants.ab.ca) for updated invasive ornamental species lists and species descriptions (including photographs).
  - Invasive shrub species including caragana (*Caragana* spp.), Russian olive (*Elaeagnus angustifolia*), European / common buckthorn (*Rhamnus catharticus*), salt cedar (*Tamarix* spp.) and yellow clematis (*Clematis tangutica*).

[2] Alberta *Weed Control Act, Weed Control Regulation.* Alberta Regulation 19/2010

- Agronomic, rhizomatous grasses such as smooth brome (*Bromus inermis*), timothy (*Phleum pratense*) and meadow foxtail (*Alopecurus pratensis*).

7.3 Invasive Species Monitoring and Control

- Apply weed prevention techniques such as installation of cardboard and mulch layers around new plantings where necessary. Refer to Guideline H (Plantings of Live Stakes or Seedlings With Mulch) for more details
- Conduct weed monitoring and weed control at the restored site for up to 5 years post construction.
- Develop weed control plans in consultation with Calgary Parks (Natural Areas) and Calgary's Integrated Pest Management Department and the Alberta Invasive Plant Council (www.aipc.org).
- Weed control methods (e.g., herbicide / mechanical / biological control methods) should be carefully researched prior to their application. Environmental site conditions (topography, soil type, proximity to water etc.) and the biology of the target weed should be considered. For example, mechanical treatments (e.g., hand pulling / mowing) may stimulate undesirable tillering (i.e., development of new shoots from rootbuds) in rhizomatous weed species such as leafy spurge. A single control method is rarely effective and it may be necessary to use two or more methods at any given site.
- Avoid the use of herbicides within close proximity to rivers, streams or other water bodies (typically 30 horizontal meters) in keeping with Alberta Environment and Water's Code of Practice for Pesticides (Alberta Government, 2010). As stipulated in the Code of Practice, "herbicides must **not** be deposited on areas that have slumped, been washed out or are subject to soil erosion into the water body".
- Pilot studies and monitoring programs should be conducted where appropriate to assess emerging weed control techniques and the effectiveness of standard weed control practices.

Other considerations:

- When invasive plants are found in areas that are otherwise dominated by non-native species, such as smooth brome, herbicide application is possible with minimal risk of loss of important native species. However, legally designated herbicide application set-backs from water bodies must be adhered to, to ensure protection of water.
- In areas with a healthy component of native herbaceous species or shrubs and young trees, the utility of herbicide application is limited, with the possible exception of specialized, hand-held weed wiper applicators[3]. Approved biological or mechanical control options (e.g., mowing or hand-pulling) may be suitable in these areas, although mechanical options

[3] Weed wipers can be used to apply herbicide directly onto the target weed leaf surface by wiping a sponge or wick saturated with the herbicide mix directly onto weeds. For weed wiper techniques to be effective the target weed (e.g. Canada thistle) must be taller than or isolated from the non-target native vegetation.

are typically labour intensive and therefore costly. Community involvement may be an important aspect of applying mechanical weed control strategies.

- Mechanical control options such as mowing or hand-pulling may need to be applied multiple times over the growing season and usually have to be repeated over a period of years to be effective. Mechanical control should be carefully timed to occur before seed set during the early bolting / bud stage (i.e., when the plant is beginning to develop flowering parts). This will reduce the potential for seed spread and gradually deplete starch reserves in the root, stressing the plant. A number of years of repeated mowing may be needed to fully exhaust stored root reserves. Care should be taken to avoid disturbance to native vegetation and to wildlife (e.g., ground-nesting bird nests) during mowing.
- Cautions: Mechanical control methods (mowing and hand-pulling) are not suited to all weed species and can stimulate underground tillering by perennial rhizomatous species like leafy spurge and Canada thistle. Mechanical control methods can also result in undesirable seed dispersion if control occurs after seed set or if the weed stand has old seed heads from the previous growing season. Caution should be used when applying this strategy to prevent these types of undesirable affects. The suitability of mechanical control techniques for the target weed should be carefully researched before applying this strategy. In some instances, mechanical control followed by herbicide application of re-growth a few weeks later may provide more effective results. Mechanical control methods are usually best suited to small weed patches.
- Federally approved biological control options, such as the use of flea-beetle species of the genus *Aphthona* to control leafy spurge (Bourchier, 2009), may be a viable option to reduce the spread of some invasive plant infestations.
- Control of invasive shrub species such as caragana should be done with extreme caution so as not to create bank or slope instability issues. It may not be desirable or practical to remove invasive shrubs along steep slopes or cutbanks. Invasive shrub removal efforts should be focused in Natural Environment Parks within The City. Native shrub planting programs should be implemented in conjunction with invasive shrub removal efforts where there is limited potential for natural regeneration of native woody species.

8.0 ENGINEERING AND ENVIRONMENTAL ASSESSMENTS

The multi-disciplinary nature of streambank and riparian stability projects requires numerous assessments, including:

1. Hydrotechnical (including geomorphic, hydrological, hydraulics) – The hydrotechnical assessment is discussed in greater detail in **Sections 8.1** and **8.2**.
2. Aquatic Environment Assessments – The fisheries assessment is an important component of the environmental permitting. Although the requirements for an Aquatic Environmental Assessment will be project specific, an excellent reference document containing typical requirements is *Fish Habitat Manual – Guidelines and Procedures for Watercourse Crossings in Alberta*, August 2009, Alberta Transportation, Edmonton, Alberta. http://www.transportation.alberta.ca/Content/docType245/Production/Complete_Fish_Habitiat_Manual.pdf
3. Environmental Assessments – The requirements for a general Environmental Assessment (EA) will be project specific and dependant on federal regulatory requirements. An excellent reference document containing typical EA requirements is the *Alberta Transportation document Terms of Reference for Environmental Assessment to Meet CEAA Requirements*, June 2011. http://www.transportation.alberta.ca/Content/docType245/Production/EnvironmentalAssessmentTOR%20_June%202011.pdf
4. Riparian Health Assessment – Discussed in greater detail below in **Section 8.3**.
5. Geotechnical Assessment – Discussed in greater detail below in **Section 8.4**.

8.1 Hydrotechnical and General Site Characterization

The desktop review and site assessment components of the hydrotechnical site characterization are discussed below.

8.1.1 Aerial Photos

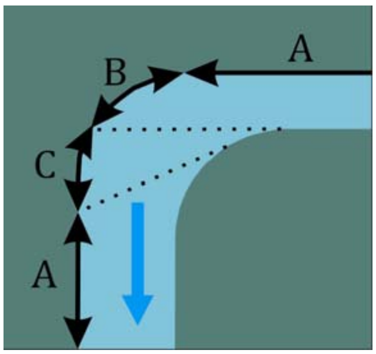
Aerial photographs are an essential tool for assessing channel conditions and stability. Historical aerial photographs are used to assess the lateral stability of streams and to assess rates of bank migration. Changes in vegetation along the channel are another important aspect, as these changes can indicate changes in the channel stability, occurrence of recent high stream flow events or land use. Sources of aerial photography include The City of Calgary and Alberta Sustainable Resource Development.

8.1.2 Surveys

The most up-to-date survey and Digital Elevation Model (DEM) information for the Bow River and Elbow River is contained in *Bow and Elbow River Updated Hydraulic Model Project Survey Data Collection and DEM Creation*, December 2011, Golder Associates, prepared for The City of Calgary and Alberta Environment.

8.1.3 Site Assessment

Table 8.1 contains a basic list of items that should be characterized during the site assessment. The 'Attribute' column corresponds to the Attribute labels that are contained in the GeoDataset detailed in the *GIS Manual for Streambank and Riparian Stability Dataset* (AMEC, February 2012d). The 'Attribute' listing is provided so the City can maintain a consistent approach to future assessments as taken herein for the Streambank and Riparian Stability Restoration project. **Figure 8.1** is a schematic for determining angle of attack on the bank, which is one of the attributes in **Table 8.1**. This schematic is also referred to in **Section 8.5** for selection of remedial techniques.



Angle of Attack on Bank (see schematic on left)
A: Parallel or Nearly Parallel to Flow (0° to 10°)
B: Moderate Angle to Flow (10° to 45°)
C: Directly Facing Flow (45° to 90°)

Figure 8.1 Schematic for Determining Angle of Attack on Bank

8.2 Guidelines for Hydraulic Stability Assessment

A hydraulic stability assessment is required to determine the nature, extent, magnitude, frequency and potential effect of all flood and erosion hazards that may affect a site. The assessment could potentially include a review of historical flood information including Water Survey of Canada (WSC) hydrometric data (discharges, flow depths, and velocities), Environment Canada climate data, City and Alberta Environment and Water reports, local newspapers archives and interviews with local residents. Additional steps in the hydraulic stability assessment are detailed in the sections below.

8.2.1 Geomorphological Assessment

Section 4.1 of these guidelines contains an overview of Hydraulic and Geomorphic Characteristics of Rivers in Calgary. As previously noted, all of the streams in Calgary are significantly influenced by human works and regulation. The documents referenced in that section should be reviewed for further details. The following documents contained detailed discussions of methodology for morphologic and channel stability assessments:

- *Channel Stability Assessments for Flood Control Projects*, 31 October 1994, U.S. Army Corps of Engineers (USACE), EM 1110-2-1418.
- *Applied River Morphology*, 1996, Rosgen, D, Printed Media Companies, Minneapolis.

TABLE 8.1
List of Basic Information to Collect During Site Assessment

Attribute	Description
SITE_ID	A unique Site ID is manually assigned to each site. The first letter refers to the name of the watercourse (i.e., "B" = Bow River, "E" = Elbow River), followed by an "L" or "R" to indicate the Left or Right side of the bank or Island, then a "B" or an "I" to indicate if the site is located on a Bank or Island. The five digits in the Site ID are the chainage at the downstream end of the site, measured along the channel centerline. For the Bow River, stationing commences at the confluence of the Highwood River. For the Elbow River, stationing commences at the confluence of the Bow River. (i.e., ERB10881 = Elbow River, Right Bank of main channel, 10881 m upstream of the confluence with the Bow River).
US_EAST; US_NORTH; DS_EAST; DS_NORTH	3TM (NAD83) Eastings and Northings of the start and end points of the site. Obtain either from GPS during site assessment or from ArcGIS.
OBS_NAMES	Names of observers conducting site assessment.
OBS_YEAR_MONTH	Date of assessment in the format YYYY_MM.
WATERCOURSE	Name of watercourse.
BANK_ISLAND	Description of location of bank looking downstream, right bank, left bank, right island bank, left island bank
MAP_SHEET_1; MAP_SHEET_2	Map sheet number on which the site is located. Up to two map sheets can be referenced if the site extends to more than one map sheet. Obtain from *2010 Streambank and Riparian Stability Assessment Mapsheets*.
ASPECT_1; ASPECT_2; ASPECT_3; ASPECT_4	The aspect (direction) the site is facing. Up to four aspects can be selected for each site.
PRIVATE_LAND	Is the site located adjacent to private land? Yes/No
LOCATION	Site location description, including major roads/parks or landmarks, and adjacent infrastructure such as outfalls bridges, roads, parks, paths etc.
BANK_HEIGHT	Bank height (m) from the top of the bank to the toe of the bank.
BANK_SLOPE	Slope of the bank in degrees, measured from horizontal.
SLOPE_HEIGHT	Height of the river valley wall (m) or embankment, above the top of the bank.
SLOPE_SLOPE	Angle of the river valley wall (m) in degrees, measured from horizontal.
LENGTH_PARALLEL_FLOW	Length of the site that is parallel to the flow (0 to 10 degrees), refer to **Figure 8.1.**
LENGTH_MOD_ANG_FLOW	Length of the site that is a moderate angle to the flow (10 to 45 degrees), refer to **Figure 8.1.**
LENGTH_FACE_FLOW	Length of the site that is directly facing flow (45 to 90 degrees), refer to **Figure 8.1.**
CHANNEL_GRADE	Channel gradient (m/m), which is equivalent to a straight-line fit drawn through plot of water surface elevation vs. thalweg distance. An accurate representation of channel gradient can be obtained from Bow and Elbow River Updated Hydraulic Model Project Survey Data Collection and DEM Creation, December 2011, Golder Associates.
BANKFULL_DEPTH	Bankfull depth (m) of watercourse, typically identified as the elevation where incipient flooding of the floodplain begins, based on site investigation or the *Bow and Elbow River Updated Hydraulic Model Project Survey Data Collection and DEM Creation*, December 2011, Golder Associates.
BANKFULL_CHANNEL_WDTH	Width of channel (m), based on air photos, maps or the *Bow and Elbow River Updated Hydraulic Model Project Survey Data Collection and DEM Creation*, December 2011, Golder Associates.
LARGEST_STONE	Largest stone moved by flowing water (mm) (Obtain from the *Bow and Elbow Rivers at Calgary, Alberta River Regime Study, October 1986, Northwest Hydraulic Consultants Ltd.)*
GEN_DESCR; GEN_DESCR_2	General site description, including site condition, infrastructure in jeopardy, etc. Note bank characteristics (vegetative protection, root density, Large Woody Debris), ice conditions. If applicable, note any slope instability/mass wasting and vegetation of valley slope. Description can extend into a second field, if required.
MORPH_DESCR; MORPH_DESCR_2	General morphological description of river type, plan form (straight reach or meander bend) relative channel width compared to adjacent reach, depositional features, etc. Description can extend into a second field, if required.
WORK_PLANNED	Description of known work planned by The City of Calgary or Private Landowner at the site.
EX_BANK_PROT_1 to EX_BANK_PROT_5	Existing bank protection type. Describe up to five fields, if required.
HOTSPOT	Is the site classified as a Hotspot? Yes/No
HOTSPOT_YEAR	Year this site was last classified as a hotspot (YYYY).
HOTSPOT_TYPE_1 to HOTSPOT_TYPE_3	If the site is a hotspot, what type? Bank/Slope/Riparian. Select up to three types, if required.
PHOTO_1 to PHOTO_20	Photo-documentation of up to 20 photos.

USACE (1994) contains the following definitions:

- *"Geomorphology here means the relationship of stream channels and floodplains to the geology and physiography of the region. Factors that have produced the present channel features and will affect the response of the channel to engineering works include sources and supply of sediments, basin materials and vegetation, catastrophic events, earth movements, landslides, eruptions and major floods, changes in land use and development, and past interferences including structures, dredging, and diking. The existing condition of the channel may depend on factors far removed in space and time, and instability response to flood control works may affect locations beyond the project length far into the future."*
- *"The concept of channel stability implies that the plan, cross-section, and longitudinal profile of the channel are economically maintainable within tolerable limits over the design life of the project."*

A general approach for the geomorphological assessment is presented below and is based on USACE (1994), which together with other documents should be referred to for a detailed discussion. The approach suggested below contains items that are typically considered but is not intended to limit alternate approaches. The nature of the individual project will determine the level of detail required for the geomorphic assessment. The evaluation of potential impacts on adjacent areas and opposite banks is an important component of the assessment.

- **Characterize existing channel:** This is based on the site assessment and review of existing information. A comparative air photo analysis can provide a historic perspective on channel shifting and instability.
- **Analyze using principles of channel equilibrium and response**. Utilize morphologic and channel regime concepts that state the cross section and slope of a sediment-transporting channel in erodible materials tends to a state of quasi-equilibrium. That is the average river channel-system tends to develop in a way to produce an approximate equilibrium between the channel and the water and sediment it must transport (Leopold and Maddock 1953). USACE (1994) contains the following discussion of the concept that the cross section and slope of a sediment-transporting channel in erodible materials tends to be in a state of equilibrium, which is referred to as a regime channel.

  "The equilibrium or regime concept has been tested against sets of river and canal data from various parts of the world. Channel widths, depths, and slopes are usually plotted independently against a characteristic discharge. Plots are sometimes stratified according to bed material size or other factors. Curves or equations are fitted and recommended for various analysis and design purposes."
- **Define and analyze using concepts of channel stability**. As detailed below, these concepts include hydraulic geometry relations, sediment transport, allowable velocity and shear stress, slope stability, and meander geometry. The following discussion is adapted from USACE (1994).
  - Allowable Velocity and Shear Stress: Numerous charts and tables are available in the literature, which provide allowable velocity and shear stress relations for various channel materials. These are discussed in more detail in Guideline P in **Appendix C**.

- Empirical Relationships for Channel Properties: Concepts of channel equilibrium (or regime) and hydraulic geometry include empirical relationships expressing the width, depth, and slope (or velocity) of alluvial channels as separate functions of a dominant or channel-forming discharge. USACE (1994) contains figures (figures 5.9, 5.10 and 5.11) that show relationships between channel width and discharge, channel depth and discharge, and channel slope and discharge.
- Analytical Relationships for Channel Properties: Researchers have proposed that stable channel dimensions can be calculated analytically by simultaneous solution of the governing equations. These methods consider discharge, sediment transport, and bed material composition as independent variables and width, depth, and slope as dependant variables. An example of this method is the minimum stream power concept.
- Sediment Transport and Sediment Budget: The streams reviewed in the Calgary Streambank and Riparian Stability project have substantial inflows of bed sediment from upstream and from tributaries. The Glenmore Dam traps most of the incoming sediment in the Elbow River. Stability of channel cross section and profile requires not only that the channel should resist erosion, but also that the bed sediment should be transported.
- Slope Stability and Mechanisms of Bank Failure: Bank erosion or failure often involves both hydraulic and geotechnical factors. Failure may be part of an overall process such as meander migration, it may be due to local hydraulic phenomena; or it may be due mainly to geotechnical factors like drawdown or seepage. Apparent geotechnical failure may be a delayed response to hydraulic scour at the toe. Other causes to consider include boat-generated waves and turbulence, jams of ice or debris, and traffic of animals or vehicles.
- Meander Geometry: Meander plan dimensions are more or less proportional to the width of the river and numerous meander geometry relationships have been developed are available in the literature. Meander wavelength and channel length between inflection points have both shown good correlations with channel width. The ratio of radius of curvature to channel width in well-developed meander bends is generally in the range 1.5 to 4.5, and commonly in the range 2 to 3. The amplitude of meander systems is quite variable, being controlled to some extent by the valley bottom width. However, the ratio of amplitude to wavelength is commonly in the range 0.5 to 1.5.

8.2.2 Design Event Frequencies

Flood frequency estimates for streams in Calgary are contained in the *Calgary Floodplain Study* (AENV, 1983) and are noted below in **Table 8.2**. The City of Calgary and Alberta Environment and Water are currently updating the previous floodplain study with the *Bow and Elbow River Updated Hydraulic Model Project, 2012,* Golder and Associates, Prepared for The City of Calgary and Alberta Environment and Water. This new flood study was not available for review when these guidelines were prepared, with the exception of the survey/DEM report, which is discussed in **Section 8.1.2**. The new flood study should be consulted when it is released and the flood frequencies contained therein should be used.

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TABLE 8.2
Flood Frequencies for Calgary Streams

Return Period (Years)	Annual Maximum Instantaneous Discharge (m^3/s)						
	Bow River above Elbow River	Elbow River above Glenmore Dam	Elbow River below Glenmore Dam	Bow River below Elbow River	Nose Creek at the Mouth	Bow River below Nose Creek	Bow River below Fish Creek
100	1970	883	758	2760	80.7	2750	3110
50	1630	657	597	2140	65.7	2210	2490
20	1190	439	340	1430	46.4	1480	1690
10	886	294	185	971	32.6	1010	1160
5	617	169	169	705	19.7	725	821
2	351	56.9	56.9	377	5.55	382	413

Based on City of Calgary Floodplain Study, April 1983, Alberta Environment.

The selection of the design event is based on the judgement of the professional undertaking the design. There is no City of Calgary regulation or Alberta provincial regulation stating that a specific recurrence interval must be used for the design of erosion and flood control projects. It is common practice in Alberta to use the 100-year flood as the design basis for these kinds of projects. Furthermore, the 100-year flood is used as the design flood in the Calgary Flood Study. Hence, it would be reasonable to use the 100-year flood as the design event flood frequency for streambank and riparian stability restoration projects. A qualified professional should select the appropriate design criteria based on the site specific requirements.

8.2.3 Hydraulic Analysis

The purpose of the hydraulic analysis could include some or all of the following:

- Estimate the hydraulic parameters required for the design of erosion and flood control including water levels, velocities, depths and shear stress.
- Determine whether the erosion and flood control works may have an impact on the existing hydraulic parameters or impact adjacent areas.
- Review the impacts on fish habitat the proposed works may have (e.g., creation of pools or providing backwater in areas that were previously dry, etc.).

The two zone flood concept for flood risk mapping is used in The City of Calgary. The flood risk area is defined as the area that would be inundated by the 100-year flood. Within a flood risk area, the following distinction is made between the floodway and flood fringe areas:

- The floodway is the stream channel and that portion of the flood risk area required to convey the 100-year design flood. Floodway waters are deepest, fastest and most destructive.
- The flood fringe is that portion of the flood risk area between the floodway and the outer boundary of the flood risk area.

The flood and erosion works should not adversely affect the existing hydraulic parameters or adjacent areas, to a significant degree. Flood protection structures such as dikes should not extend into the floodway zone to a significant degree.

A one-dimensional numerical computer model such as the US Army Corps of Engineers HEC-RAS model, is a commonly used tool for undertaking a hydraulic analysis for erosion and flood control projects. The *Calgary Floodplain Study* (AENV, 1983) was based on the HEC-2 model, which was a precursor to the HEC-RAS model. The new flood study (Golder, 2012) is based on the HEC-RAS model. Required input for the HEC-RAS model includes the design discharge, channel surveys and estimates of channel roughness. These input parameters can be obtained from AENV (1983) and Golder (2012), when the report is released.

The HEC-RAS model can be used in either steady state (the discharge does not change) or unsteady state (the inflow hydrograph changes). The use of two-dimensional hydraulic mathematical models is becoming more common and certainly should be considered for some applications. **Table 8.3** contains a comparison of the following three categories of hydraulic models: steady 1D; unsteady 1D; and 2D.

8.2.4 Hydraulic Design

Design Guideline O (Rock Riprap), contained in **Appendix C**, provides guidance on riprap design including; stone size selection; filters (geotextile and granular); and use of vanes. Design Guideline P (Critical Shear Stress Due to Water Flow and Resistance of Materials), contained in **Appendix C**, provides guidance on; selection of channel roughness coefficients (Manning's n); shear stress calculations; and permissible shear stress values and velocities for various materials. The publication *Engineering and Design Hydraulic Design of Flood Control Channels*, 30 June 1994, U.S. Army Corps of Engineers, EM 1110-2-1601, contains detailed information on, open channel hydraulic theory, riprap protection, toe scour estimation and protection, etc.

8.3 Riparian Health Assessment

Riparian Health Assessment methods should follow protocols developed by the Alberta Riparian Habitat Management Society (Cows and Fish) or other equivalent methods approved by Alberta Environment and Water or Alberta Sustainable Resource Development.

Current Riparian Health Assessment Forms and User Manuals developed by the Alberta Riparian Habitat Management Society (Cows and Fish) can be downloaded from this website: http://www.cowsandfish.org/riparian/health.html These Forms and User Manuals are updated on a regular basis. Use of these forms requires extensive ecological knowledge, specifically of native riparian plant communities and native plant identification, watershed hydrology, and related topics. Also, ensuring a reasonable level of consistency and appropriate use of these tools requires training and ongoing practice of the techniques with qualified practitioners.

8.4 Geotechnical Assessment

The Streambank and Riparian Stability Project included a geotechnical assessment to review valley wall, dike and flood works stability. This geotechnical assessment is presented in the document *2010 Geotechnical Summary Report for Streambank Stability Assessment*, February 2012c, AMEC, which contains the following items.

- A review of sites along the Bow and Elbow Rivers where slope instability could affect infrastructure or cause a significant alteration to the river course.
- The Sunnyside Dike Hydrogeological Assessment, which reviews: (1) likelihood of failure of the Sunnyside Dike due to piping under a 100-year flood condition in the Bow River; and (2) the extent of flooding in Sunnyside if a 100-year flood condition exists in the Bow River for a period of up to 24 hours.

TABLE 8.3
Comparison of 1D and 2D Hydraulic Models

Model Type & Examples	Description	Advantages	Disadvantages	Potential Applications
Steady 1D • HEC-RAS • WSPRO	Unchanging flow assumed to travel entirely in the downstream direction	• Easiest to set up and run • Geometry requirements are channel and floodplain cross section • Efficient mapping tool	• Simplifies flow processes to 1D unchanging in time • Does not capture complex overbank flow processes • Does not address overbank storage	Use for standard applications, except when conditions are too complex for 1D models to provide reasonable estimate of hydraulics
Unsteady 1D • HEC-RAS • MIKE II HD	Changing flow (e.g., inflow hydrograph) assumed to travel entirely in the downstream direction	• More accurate timing of peak, especially where multiple sources of water converge • Geometry requirements are channel and floodplain cross section • Overbank and structure flows can be simulated using approximations at locations entered by the user • Takes floodplain storage into account	• Simplified flow processes to 1D • Requires specific data input to represent significant water flux into and out of overbank storage areas • Less stable than steady models • Requires additional data development, hydrographs	More complex hydraulic analyses to support the identification of impacts and the determination of appropriate mitigation. Unsteady-state models account for floodplain storage. An unsteady 1D model will assist in: • The identification of upstream and downstream impacts (e.g., stage, velocity, duration) of floodplain alterations, and • The development of appropriate and effective mitigation measures.
2D • RIV 2D • MIKE Flood HD	Changing flow assumed to travel both downstream and laterally across the channel/floodplain	• More realistic simulation of complex flow patterns (e.g., strongly meandering streams, overbank flows, flow compression at bridge piers)	• More data intensive to • Build 3D Digital Elevation Model (DEM) • More prone to instability • Needs hydrograph for all major tributaries	• Locations with uncertain and potentially changeable flow paths • Bridges or other locations where flows experience significant lateral flow compression. For example, the use of a 2D model is common for scour analyses at bridge piers and for the design of fish habitat improvement projects. Flow surrounding bridge piers has a strong lateral component which cannot be captured with a 1D approach. Similarly, a 2D model will be the more appropriate choice to capture post-project conditions for habitat restoration projects that include the use of engineered log jams to create more complex flow processes

Note: *Modified from Regional Guidance for Hydrologic and Hydraulic Studies*, FEMA - Region 10, January 2010

The above mentioned geotechnical report also contain references to historic geotechnical reports for individual sites. These reports were obtained from The City's library and document database and should be reviewed if applicable.

A qualified geotechnical engineer should be consulted for the site specific requirements for a geotechnical assessment. Some general requirements for a geotechnical assessments related to dikes are listed below (British Columbia Ministry of Water, Land and Air Protection, July 2003).

- Foundation Conditions
- Dike stability with respect to embankment shear strength
- Settlement, Seepage and Erosion
- Materials used for Dike Construction

Although geared towards highway and bridge projects, detailed geotechnical investigation requirements are contained in the Alberta Transportation (AT) document *Engineering Consultant Guidelines for Highway and Bridge Projects Volume 1, Design and Tender* (AT, 2002). AT's *Erosion and Sediment Control Manual* (June 2011), contains the following guidance for geotechnical assessments:

- Geotechnical investigation for highway design usually includes aerial photo review, terrain assessment and soil survey investigation for both gradeline and borrow sources. An assessment of difficult/adverse site conditions (i.e., unstable slope, soft subgrade, high groundwater, highly erodible soils) may also be provided.
- For a typical earthwork grading project, the following soil testing information is provided on the design drawings:
  - Plasticity index (PI);
  - Soil classification according to USCS;
  - Moisture content (%);
  - Estimated optimum moisture content (%); and
  - Estimated maximum dry density from moisture density relationship testing (kg/m³).
- Depending on the scope of work, the geotechnical report may include the following additional information related to erosion and sediment control concerns:
  - A review of the gradeline design from a geotechnical as well as an erosion perspective;
  - Hydrometer (gradation) and Atterberg Limit testing results for fine-grained soils;
  - Soil permeability; and
  - Stability of large cuts and high fill areas.

8.5 Selection of Remedial Techniques

Designs for streambank and riparian stability restoration should be undertaken by qualified personnel working in a multidisciplinary team. The guidelines contained in **Appendix C**, and discussed in this section, contain guidance on conditions and limitations for the selection of individual techniques. Some further guidance is presented in **Table 8.4**, which can be used as a tool in the conceptual and preliminary design stage for the selection of appropriate restoration techniques.

8.6 Triple Bottom Line (TBL) Site Prioritization

The City of Calgary's TBL statement is shown below:

> *The Triple Bottom Line is an approach to decision making that considers economic, social and environmental issues in a comprehensive, systematic and integrated way.*
>
> *The Triple Bottom Line has been adopted by many organizations in both the public and private sector. It is a departure from making decisions based solely on the financial bottom-line. It also reflects a greater awareness of the impacts of our decisions on the environment, society and the external economy - and how those impacts are related.*
>
> *The Triple Bottom Line must be applied to Projects on a case-by-case basis, using a contextual analysis. What this means is that an equal weighting of the three bottom lines is not necessary; in some cases the three might be roughly equal, but in others, one might clearly outweigh the others or not be a factor.*
>
> *The value of TBL thinking is that when it comes time to make a decision, all three aspects have been considered thoughtfully and critically. It is not meant to enhance or improve performance in one area at the expense of the others. Rather, the intention of TBL thinking is to identify ways to add value across all three bottom lines.*

For the Streambank and Riparian Stability Project, a Triple Bottom Line (TBL) prioritization was undertaken that considers Economic, Environmental and Social factors to assess the costs and benefits associated with the restoration of streambank and riparian area sites

A detailed discussion of TBL methodology is contained in the document *Triple Bottom Line (TBL) Prioritization Manual for Streambank and Riparian Stability Restoration* (AMEC, February 2012a). The document *Project Summary for Streambank and Riparian Stability for Streambank and Riparian Stability* (AMEC, February 2012b) contains a discussion and summary of the prioritization results. The document *2010 TBL Prioritization Summary Reports for Streambank and Riparian Stability Restoration* (AMEC, 2012e) contains the individual TBL prioritization reports for each of the high priority sites. The above noted documents should be read in conjunction with each other to gain a more complete understanding of the prioritization approach and results.

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TABLE 8.4
Design Guideline Selection Matrix

Site Conditions		Yes	No	Potential Restoration Design Guideline
1.1	**Toe Erosion Present, Eroded Bank < 1 m High**			
1.1a	Bank is Parallel or Nearly Parallel to Flow (0° to 10°), refer to **Figure 8.1**.			**A** - Fascines with Double Poles **A1** – Aquatic Species Rolls with Single Poles can be used when the attack is less severe and aquatic species are available.
1.1a1	Bank is Parallel or Nearly Parallel to Flow (0° to 10°) refer to **Figure 8.1** with undermined bank and high value fish habitat • Where erosion **is not** a concern to nearby infrastructure. • Where erosion **is a** concern to nearby infrastructure.			**Q** – Low Undermined Shoreline Protection of High Value Fish Habitat • When undermined at water level with or without dense woody vegetation (shrubs & trees) located directly on shoreline leave as is to provide fish habitat (cover & hiding) if erosion is not a concern to nearby infrastructure. • If erosion is a concern and habitat is desirable , combine with another more robust technique.
1.1b	Bank is at Moderate Angle to Flow (10° to 45°), refer to **Figure 8.1**.			**C1** - Rock Toe with One Brush Layer
1.1c	Bank is Directly Facing Flow (45° to 90°), refer to **Figure 8.1**.			**D**1- Vegetated Riprap with One Vegetated Row **B** and **B1** – Longitudinal Peak Stone Toe Protection (LPSTP) with and without Brush Layers.
1.1c1	Bank facing stream flow on narrow section of Elbow River			**E1** - Vegetated
1.2	**Toe Erosion Present, Eroded Bank > 1 m High**			
1.2a	Bank is Parallel or Nearly Parallel to Flow (0° to 10°), refer to **Figure 8.1**.			**A2** – Fascines with Double Poles and Brush Layers
1.2b	Bank is at Moderate Angle to Flow (10° to 45°), refer to **Figure 8.1**.			**C2** - Rock Toe with Multiple Brush Layer Rows
1.2c	Bank is Directly Facing Flow (45° to 90°), refer to **Figure 8.1**.			**D2** - Vegetated Riprap with Multiple Vegetated Rows
1.2c1	Bank is Facing Flow on narrow section of Elbow River			**E1** - Vegetated Gabion and Optional Rows of Brush Layers or **E2** – Log Crib Wall and Optional Brush Layers **I5** – Brush Mattresses with Crib Wall Toe
1.3	**Seepage Present**			
1.3.1	Minor Seepage			**G1** - Live Pole Drains
1.3.2	Significant Seepage			**G2** – Live Pole Drains with Rock Drain
1.4	**Random Patch Erosion** (areas of bank and riparian areas that have localized erosion primarily due to pedestrian and dog access).			**I** – **I1)** Brush Layers **I2)** Live Fascines (north & east aspects) **I3)** Straw wattles (south & west aspects) **I4)** Branch Packing **J** – Erosion and Sediment Control Products
1.5	**Eroded Bank Present (without toe erosion)**			**I** – **I1)** Brush Layers **I2)** Live Fascines (north & east aspects) **I3)** Straw wattles (south & west aspects) **I4)** Branch Packing **J** – Erosion and Sediment Control Products
1.6	**Grassy Invasive Species Present**			**H – H)** Plantings of Live Stakes and Seedlings with mulch **H1)** Plantings of Live Stakes only with mulch **H2)** Plantings of Seedlings only with mulch
1.7	**Existing Riprap with no Vegetation**			**F1** and **F2** Vegetating Existing Riprap
Design Guidelines Considerations				
2.1	**Maximum Design Flow Velocities and Shear Stress**			**O**– Rock Riprap **P** – Critical Shear Stress and Resistance of Materials
	Note: It may be appropriate to use different riprap gradations at different elevations, depending on the velocities and shear stress.			Riprap Class to elevation m Riprap Class to elevation m Riprap Class to elevation m
2.2	**Seeding Mixes**			**L** - Native Seeds/Seedlings/Nursery Stock
				Broadcast Seed: Y / N Hydroseeding: Y / N Seed Mix: Application Rate:
2.3	**Shrub & Tree Species Selection**			**L** - Native Seeds/Seedlings/Nursery Stock
2.3.1	Shrubs			Species: Container Size: ______________________________ _______________ ______________________________ _______________ ______________________________ _______________
2.3.2	Trees			Species: Container Size: ______________________________ _______________ ______________________________ _______________ ______________________________ _______________
2.3.3	Live Cuttings / Stock Handling			**K** - Live Cuttings/Stock Handling
2.3.4	Soil Amendment			**M** – Soil Amendments
2.4	**High Recreation Site**			**R** – Stabilized Access **S** - Fencing

Note: Combination of restoration techniques should be considered based on erosion problem type.

9.0 CONSTRUCTION OF EROSION AND FLOOD CONTROL PROJECTS

Guideline N (Construction and Environmental Practices), in **Appendix C**, contains guidelines for Environmental Protection and Low Impact Construction, including:

- Protection of existing vegetation
- Protection of significant features
- Specialized equipment for working in watercourses and sensitive areas
- Specialized techniques for working in watercourses and sensitive areas
- Import of topsoil and fill material to reduce environmental impact and avoid the spread of invasive species
- Live cuttings and seed stock to reduce environmental impact and avoid the spread of invasive species
- Monitoring
- Cleaning of Equipment

9.1 Construction Specifications

The design guidelines contain general guidance and specifications that, when used in conjunction with the detailed design drawings, site specific specifications, landscape plans, and manufacturer's installation instructions, can be used to provide the specifications for Erosion and Flood Control Projects.

Additionally, the following specifications from The City of Calgary should be reviewed with regards to certain aspects of the works that may not be detailed in the guidelines in **Appendix C**:

- *Standard Specifications*, Roads Construction, 2012; http://www.calgary.ca/Transportation/Roads/Documents/Contractors-and-Consultants/Roads-Construction-2012-Standard-Specifications.pdf and,
- *Development Guidelines and Standard Specifications*, Landscape Construction, 2012, http://www.calgary.ca/PDA/DBA/Documents/urban_development/publications/Landscape2012.pdf.

9.2 Care of Water and Erosion and Sediment Control Considerations

Guideline J (Erosion and Sedimentation Control Products), in **Appendix C**, contains information on products that may be used on streambank and riparian restoration products, including:

- Instream Sediment Control
- Rolled Erosion Control Products
- Blown On or Hand Applied Erosion Control Products

- Hydraulically Applied Erosion Control Projects
- Silt Fences
- Sediment Retention Fibre Rolls (Wattles)
- Gabion Baskets

Additional key erosion and sedimentation control references, include:

- *Guidelines for Erosion and Sediment Control,* The City of Calgary, 2009 (http://www.calgary.ca/docgallery/bu/water_services/erosion_sediment_control/ESCGuidelines2001-02-12.pdf)
- *Field Manual for Effective Erosion and Sediment Control,* The City of Calgary. 2011 (http://www.calgary.ca/docgallery/bu/water_services/erosion_sediment_control/escfieldmanual2001-02-12.pdf)
- *Erosion and Sediment Control* Guidelines, City of Edmonton 2005, http://www.edmonton.ca/city_government/documents/ControlGuide.pdf;)
- *Erosion and Sediment Control Manual*, Alberta Transportation, June 2011, http://www.transportation.alberta.ca/4626.htm

9.2.1 ECO Plan

An ECO Plan is compiled by the contractor undertaking construction and consists of written procedures and drawings to identify and mitigate the potential environmental issues that may occur as a direct or indirect result of construction activities being performed on a specific project site. The objective of an ECO Plan is to prevent and/or minimize environmental impacts and to enhance the environmental value of the air, land and water affected by projects. The ECO Plan may also be undertaken on behalf of City if they directly hire a consultant to prepare an ECO Plan to include in the Tender.

The City's ECO Plan requirements are contained in the document *Environmental Construction Operations (ECO) Plan Framework Instructions for Preparing ECO Plans for Alberta Transportation, The City of Calgary and The City of Edmonton Construction Projects*.
01 January 2012, Prepared by Alberta Transportation, The City of Calgary and The City of Edmonton.

10.0 POST CONSTRUCTION: MONITORING, OPERATIONS, MAINTENANCE

Post-construction monitoring, operations and maintenance schedule for the various techniques contained in **Appendix C** are contained in the individual guidelines.

For the conceptual level cost estimates that were generated for the TBL prioritization that are contained in *TBL Prioritization Manual*, February 2012a, AMEC, the monitoring, operations and maintenance schedule listed in **Table 10.1** was assumed: The success of these bioengineering treatments depends significantly on maintenance including weeding, watering, mulching, mowing and monitoring.

TABLE 10.1
Typical Maintenance Regime for Bioengineering Projects

	Watering	Weeding/Mowing	Monitoring
Initial Year	Bi-weekly	Bi-weekly	Annually
Short-term (approximately first 5 Years)	Annually	Annually	Annually
Longer-term	Every 5th year	Every 5th year	Every 5th year

The following inspection and operation and maintenance schedule is recommended for existing works.

- An annual inspection during the low water period in the spring or fall.
- A high water inspection during large flow events.
- A winter inspection during ice jam events.
- Undertake maintenance if there are problems or damage (erosion, scour, loss of material, rodent borrows, sinkholes, loss of vegetation, debris, etc.).

10.1 Soil Bioengineering Projects and Riparian Restoration Monitoring Guidelines

For all soil bioengineering and riparian restoration projects, comprehensive records should be kept to document restoration progress (e.g., native planting survival rates) and on-going site maintenance treatments (e.g., watering or weeding frequency) and associated manpower and equipment costs. The detailed soil bioengineering / riparian restoration design plan, plant species mixes and sources (native plant supplier or donor plant location), and monitoring records / photographs should be linked to The City's GIS database. This will enable improved tracking of successful restoration techniques, preferred plant species composition or plant source stocks, and maintenance costs.

Riparian Health Monitoring

For riparian sites where restoration activities are planned, riparian health monitoring should be done one year prior to restoration implementation, immediately following restoration (from July to September), and at three to five year successive intervals to track restoration progress. As discussed in **Section 8.3,** riparian health assessments should follow protocols developed by Cows and Fish or other approved equivalent methods (http://www.cowsandfish.org/riparian/health.html).

Riparian health monitoring allows The City to track whether the restoration project is successful in improving key indicators such as native vegetation composition. Examples of restoration success indicators and monitoring questions that can be assessed using the Cows and Fish riparian health inventory protocol are described in the **Table 10.2** below.

TABLE 10.2
Monitoring Indicators for Assessing the Success of Riparian Restoration Projects

Restoration Success Indicator	Monitoring Question	Riparian Health Inventory Parameter
Overall riparian health	• Did the restoration practice improve the overall health and function of the riparian area?	• Riparian health inventory overall rating
Invasive and disturbance-caused plant abundance and distribution	• Did the restoration practice reduce the abundance of invasive species and non-native disturbance-caused species in the riparian community?	• Canopy cover and distribution of invasive species and disturbance-caused species targeted for control
Restoration of human-caused alterations (e.g., non-designated trails)	• Did the restoration practice decrease human-caused bare ground and reduce soil compaction in the floodplain?	• Percentage of human-caused bare ground; and • percentage of bank and floodplain alterations resulting from soil compaction
Native riparian vegetation cover	• Did the restoration practice improve riparian habitat structure and increase the cover of native riparian vegetation?	• Overall canopy cover of native vegetation and canopy cover by life form (e.g., trees / shrubs / graminoids / forbs) and height class
Streambank root mass protection	• Did the restoration practice increase cover of deeply rooted woody plants along the streambank?	• Percent of the streambank with deep-rooted native trees and shrubs
Streambank stability	• Did the restoration practice decrease the length of unstable streambank?	• Percent unstable streambank

Monitoring objectives and key indicators should be customized to fit the goals of each restoration project (Harris *et al*. 2005). Line-intercept transects can be used for monitoring vegetation changes at a finer level of detail (**Section 10.3**, below). Other types of monitoring protocols (e.g., fish habitat and wildlife assessments) should be considered where warranted to compare and contrast pre- and post- restoration conditions. For example, breeding birds are considered a good indicator of habitat changes associated with improved riparian health (Bryce *et al*. 2002). Bird species richness (i.e., the number of different species relying on a given area for all or part of their lifecycle) has been linked with increased shrub density and vegetation strata diversity, (i.e., vegetation height layers).

10.2 Record Keeping

Keeping a comprehensive record of restoration activities applied on a site will assist with interpreting long-term monitoring results. For example records should be kept to document:

- timeline of restoration activities;
- age, source (geographic origin / greenhouse supplier) and species used for restoration plantings;
- survival rates of plantings (as determined by annual survival counts following one growth season);
- lessons learned and natural or human-caused factors affecting survival of plantings; and
- watering and maintenance requirements (e.g., frequency and quantity of water needed to maintain plantings).

It is also important to keep a record of public / community group feedback to gauge public interest and positive or negative responses to restoration activities. This will help in future planning of restoration projects to improve their implementation success.

10.3 Line-Intercept Transects

Line-intercept transects can be used to assess the recovery of small restoration sites, where this level of detail is warranted. Line intercept transects can be established along the bank line or extending out to at least 15 m in a perpendicular direction from the channel at upstream, mid and downstream portions of the floodplain (Harris *et al*. 2005). Line intercept transects may also be strategically placed in disturbed and undisturbed riparian habitat to compare recovery of disturbances in the long-term in relation to an undisturbed reference natural area.

Using this method, the observer walks along the channel bank or line transect and records interception of the line (in metres to the nearest 0.5 m) by:

- tree and shrub species in three height categories (less than 1 m, 1 m to 5 m, and over 5 m);
- herbaceous cover (if more than 10% cover); and

- other ground cover types (e.g., litter, rock, bare ground or restoration structures where vegetation is not present).

Dividing the total length of a recorded plant species or ground cover type along the transect line by the total length of the line yields accurate canopy cover measures for various ground cover types, individual plant species or vegetation types within three height layers.

- Greenline (bankline) intercept transects are an effective means of assessing changes in bank cover, bank stability, vegetation structure and species composition at or near the bankfull boundaries of the channel. Erosion, flooding or ice scour may alter the morphology of the bank making it impossible to reassess exactly the same line. This is to be expected, but it does not prevent comparisons of total vegetation cover, species composition and bank stability since these measures are relevant to the active bank.
- Floodplain line intercept transects provide a means to quantitatively assess and compare changes in total woody vegetation cover in each of three height layers and proportional changes in the cover of individual tree and shrub species, and total herbaceous and bare ground cover.

Refer to Harris *et al.* (2005) for data forms and a detailed review of the line intercept methodology for monitoring riparian vegetation restoration. Greenline transects, floodplain line-intercept transects and disturbance monitoring transects should be repeated after five years and subsequently at five year intervals if desired. To facilitate exact replication of these transects, permanent metal pegs can be installed at the start, end and mid points of these transects. Metal pegs can be relocated using metal detectors.

10.4 Photography Monitoring

Photography monitoring is an effective and cost-efficient method for documenting visible changes to soil bioengineering and riparian restoration sites. Metal pegs or GPS coordinates can be used to mark benchmark photograph locations. Re-taking benchmark photographs should be done on an annual basis at the same time of year for at least the first five years. Changes are likely to be most apparent during the first five years of the restoration program. Once the site has stabilized, visible changes may be less apparent and monitoring may only need to be done on a biannual basis or once every three years thereafter, if desired. Although photographs do not provide quantitative data, time series photographs do provide an excellent visual tool to assess restoration success. Photographs that clearly show visible changes in riparian health over time following implementation of a restoration program are an effective public education and awareness tool.

Photography monitoring should be done following the basic principles and methods described by Rasmussen and Voth (2001):

- Benchmark photographs should contain a skyline or permanent landscape feature (e.g., buildings, telephone poles, bridges, rock outcrops, valley slope etc.) in the background of the photograph for easy relocation.
- A tripod should be used to provide a consistent height at which photographs are taken.
- A reference pole should be used to provide a sense of scale in the photograph to monitor changes in vegetation height and structure over time. The reference pole should be marked at 25 cm intervals and should be at least 1.5 m long. The pole should be placed at a consistent distance (usually 10 m to 15 m) and orientation from the camera tripod. In some instances where re-growth of willows or other riparian vegetation makes it difficult to see the pole, it may have to be moved forward over time. The distance of the pole from the tripod should be recorded each time as part of the site observations.
- A photo board with the date and location written on it should be placed in the foreground of the photograph to contain a permanent record of where and when the photograph was taken for record keeping purposes.
- Observation records should be digitally stored with each set of monitoring photographs from a particular year. These records should contain details about the distance setback of the reference pole, the type of camera and the lens focal length, lens diameter and lens filter used (if applicable). In addition detailed notes should be taken concerning the type of soil bioengineering / riparian restoration treatment applied at each site and observed signs of vegetation recovery or management concerns (e.g., wildlife browse or human damage to the restoration site).

11.0 CLOSURE

These guidelines have been prepared for the exclusive use of The City of Calgary. These guidelines are based on, and limited by, the interpretation of data, circumstances, and conditions available at the time of completion of the work as referenced throughout the report. They have been prepared in accordance with generally accepted engineering practices. No other warranty, express or implied, is made.

Yours truly,

AMEC Environment & Infrastructure

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Permit to Practice No. P-4546

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Appendix A

The City of Calgary Policies and Bylaws

2-1.2 Water Quality

A vision of the future... *"Calgary's river system is an ecological model; the water is cleaner every year due to concerted efforts by all users and our high technology water treatment facilities. We have worked hard over the decades to ensure the Bow River retains its reputation as a world-class trout stream." (Calgary 2020, 1989)*

Clean water is not only a basic necessity of human life but is also required for sustaining healthy ecosystems. Water sources, such as rivers, creeks, sloughs, lakes and ground-water, support a complex array of life and ecological processes within the region.

In the urban context, a reliable supply of clean, potable water is a necessity. Calgary's drinking water comes from the Bow and Elbow Rivers. Just as we draw our drinking water from these two sources, so do we discharge our wastewater and stormwater into them. Water supplies transcend municipal boundaries and Calgarians have a right to receive water treated by our upstream neighbours that satisfies all provincial water quality requirements. We are also responsible for ensuring that the water which flows past our municipal boundaries satisfies all provincial requirements.

The management of stormwater in an urban context is also important for a number of reasons:

- flooding and erosion
- risk to life
- potential contamination of stormwater runoff.

The City supports innovation in stormwater management as a means of addressing these issues.

Lands adjacent to rivers and creeks are subject to periodic flooding. Development on these lands is restricted through the *Land Use Bylaw* in order to reduce risk of property damage and possible loss of life. The *Bylaw* identifies floodways that have major restrictions on any form of development. Special provisions for floodplains are also included in the *Bylaw* to reduce damage to development in these areas in the event of a flood.

River crossings and associated roadways may affect water quality. Therefore, they should be designed and operated in a manner sensitive to environmental impacts. In particular, it is important that water quality not be degraded.

Policies

Water Quality

2-1.2A Recognize the importance of ground and surface water in supporting life and the prosperity of Calgarians and downstream municipalities.

2-1.2B Commit to the protection of ground and surface water, public health, property and the environment through the use of water management programs that :

- maintain healthy ecosystems
- provide safe and reliable drinking water
- provide advanced waste water treatment and stormwater management, to the greatest extent possible within The City's resources. (Also see 2-1.4.1B)

2-1.2C Encourage water conservation through public education and metering programs.

2-1.2D Reduce risk to life and damage to property through the use of appropriate floodplain management processes and techniques as set out in the *Land Use Bylaw* and the *Calgary River Valleys Plan.*

2-1.2E Design and operate river crossings and associated roadways in a manner that will reduce degradation of water quality. (Also see 2-1H, 2-1.4.1B)

Key References

- Calgary Transportation Plan
- Environmental Policy, Principles & Goals

2-1.3 Land Stewardship and Protection

Human activity has a tremendous impact on the natural state of land and the ecosystems it supports, whether it be through agricultural activity, resource extraction and harvesting or urban development. This is an unavoidable consequence of human existence. However, there are ways in which the impact can be lessened. Within the urban context, responsible stewardship of the land base includes measures such as:

- efficient use of the land base (i.e., reduce and/or contain total land absorption)
- protection of environmentally significant areas
- reduction of the amount of land needed for landfill sites
- remediation and reuse of contaminated sites.

The policies in this section address solid waste management and reclamation. Later in this chapter, there are a number of policies regarding the protection of environmentally significant areas and efficient use of the land base.

In 1997, Calgarians recycled 10,700 tonnes of newspaper and magazines, 2,100 tonnes of mixed paper, 840 tonnes of glass and 487 tonnes of metal through the City's recycling depots.

Key References

- Environmental Policy, Principles & Goals

Calgarians can choose from over 100 natural areas covering a total of 2,700 hectares.

Policies

Land Stewardship and Protection

2-1.3A Reduce the solid waste stream by implementing an integrated waste management program designed around the 4 Rs (reduce, reuse, recycle and recover).

2-1.3B Recognize that the most effective way to reduce waste is to address waste generation at the source.

2-1.4 Natural Areas

In major public planning processes in the 1990s, Calgarians clearly expressed their love and concern for the many natural areas that are found throughout the city. The protection of environmentally significant areas can serve numerous purposes including maintenance of ecosystem integrity, accessibility, recreation and aesthetics.

One of the priorities of this plan is to protect environmentally significant areas by reducing the need for new river crossings. This can be pursued by integrating the location of future residential and employment growth with the design of the transportation network. Secondly, escarpments will be protected through a number of means including dedication of undevelopable lands as environmental reserve and the use of development setbacks. The following policies will guide the preparation of more specific plans and processes.

Natural areas include the river/creek valleys and their ecosystems. The importance of these particular natural areas to Calgarians is such that they warrant a separate discussion and set of policies. These are found in the next section. However, as river/creek valleys are a subset of all natural areas, the policies in this section also apply to them.

Policies

Natural Areas

2-1.4A Give highest priority to the protection of environmentally significant areas in the allocation of land uses. (Also see 2-1A)

2-1.4B Protect and maintain representative and viable natural habitat types as an integral component of the parks and open space system.

2-1.4C Protection of significant habitats located within The City's parks and open space system will take precedence over recreational use where it may conflict with the long-term survival of the resource.

2-1.4D Design and manage recreation facilities to minimize negative impact on natural areas.

2-1.4E Preserve undeveloped major escarpments as natural open space features that enhance the environment. (Also see 2-1.4.1L)

2-1.4F Establish setback zones of 18 m (60 feet) from the top of an escarpment in any new development or redevelopment area. (Also see 2-1.4.1L)

2-1.4G Acquire major open space and natural areas, as part of the development of a total park and recreation network, in association with other governments and agencies.

2-1.4H Encourage stewardship and informed public, corporate and/or community participation. Also encourage partnerships in acquisition, management, research and protection of appropriate natural environments.

2-1.4I Work with adjacent municipalities to protect contiguous natural habitat.

Key References

- Calgary Transportation Plan
- Natural Area Management Plan

2-1.4.1 River and Creek Valleys

A vision for Calgary's River Valley Park System... "The people of Calgary envision a continuous integrated river valley park system that reflects the city's unique prairie and foothills setting. The River Valley Park System will express citizens' commitment to its preservation, use and enjoyment, and will promote understanding of our natural and historic heritage. We envision a river valley park system in which we all take pride, and in which every citizen will assume responsibility for its protection." (Urban Park Master Plan, 1994)

The following excerpt from the *Urban Park Master Plan* expresses why the river and creek valleys are so important to Calgarians.

> "River valleys are dynamic, living systems. They are comprised of flowing waters, springs, wetlands, islands, riverbanks, ravines, escarpments, terraces and forested slopes. They change yearly with the seasons and over decades and centuries as bank erosion, flooding and channel realignment alter their courses.
>
> ...As cities like Calgary have matured, the river valleys around which they have grown have increasingly become sanctuaries from the stresses of daily life, aesthetic resources and areas for recreation." (*Urban Park Master Plan*, 1994)

The following principles, from the *Urban Park Master Plan*, are to guide the use, protection, development and rehabilitation of the river and creek valleys.

Key References
- Urban Park Master Plan

Guiding Principles

Guiding Principles from the *Urban Park Master Plan*

2-1.4.1A The overall structure of the River Valley Park System will be based upon protection, rehabilitation and/or re-establishment of naturally sustainable landscapes, waterways and ecosystems.

2-1.4.1B All significant sources of contamination or degradation of river and related waters will be eliminated, recognizing that watershed management coordination with upstream and downstream municipalities and governing agencies will be essential. (Also see 2-1.2B)

2-1.4.1C The primary use of the River Valley Park System will be passive, low intensity, informal, unstructured activities.

2-1.4.1D Intensively used facilities will be designated to appropriate sites which are not environmentally sensitive and which are carefully designed as "special use areas".

2-1.4.1E The River Valley Park System will include a continuous river valley pathway, not always adjacent to the river's edge.

2-1.4.1F The River Valley Park System will be accessible, usable and safe for all persons where practical and environmentally appropriate, bearing in mind the needs of persons with disabilities.

2-1.4.1G Year-round enjoyment of the River Valley Park System will be encouraged, but with regard to environmental impact.

2-1.4.1H Appropriately designed park linkages will extend into adjacent communities, connecting school sites, community centres, recreational facilities and urban open spaces.

2-1.4.1I Adjacent development will respect and reflect the character of the River Valley Park System, and provide for reasonable public access to the park system.

2-1.4.1J The River Valley Park System will complement and reflect the unique character and the qualities of the individual park areas and adjacent communities.

2-1.4.1K The River Valley Park System will be designed to accommodate the planned intensity of use in each specific area to ensure the integrity of the landscape and waterways, and overuse may be accommodated by creative alternatives outside of the river valley.

2-1.4.1L Landscape features contributing to the visual continuity and aesthetic quality of the River Valley Park System will be protected, maintained and enhanced where appropriate.

2-1.4.1M Through protection, sensitive planning and design, education and interpretation, the River Valleys Park System will promote a sense of stewardship in all Calgarians.

2-1.4.1N Calgarians will be urged to accept responsibility and liability for their use of the River Valley Park System.

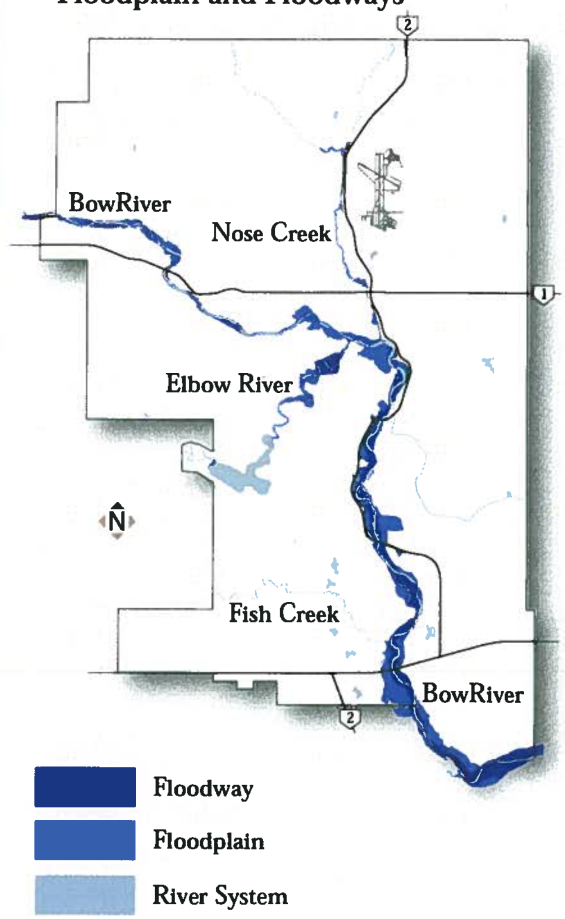
2-1.4.1O To assure long term benefits for all Calgarians, the success of the plan will depend on fiscal responsibility in planning, management and maintenance.

2-1.4.1P When human use versus wildlife use comes into serious conflict in those areas designated as major natural areas in the 1984 *Calgary River Valleys Plan* and the *Urban Park Master Plan*, wildlife and habitat will take priority.

2-1.4.1Q The River Valley Park System will be a park resource for all Calgarians and will be in addition to the neighbourhood parkland entitlement within adjacent communities.

2-1.4.1R All bridges will accommodate pedestrian and bicycle use and all new road and bridge construction required will comply with the Vision Statement. (See page 26)

Floodplain and Floodways



2-1.5 Natural Resource Extraction

The Calgary region has an abundance of natural extractive resources such as oil and gas and gravel deposits. The presence of these resources, along with agricultural activities, provides the base for a significant component of the region's economic development. However, the development and use of such resources is sometimes incompatible with urban growth and development. It is, therefore, necessary to strike an appropriate balance between resource-based activities (e.g., natural gas extraction, gravel operations) and urban growth. It is important that the resource base is protected from inappropriate urban intrusion (e.g., residential development infringing unduly on gravel extraction activity). Conversely, the city needs room to grow and residential areas should be protected from unacceptable impacts of industrial activity such as excessive noise, dust and truck traffic.

Areas where the primary use will be the extraction of mineral resources or surface materials, such as sand and gravel, should be identified early in the land use planning process. This will allow for the development of appropriate mitigative measures to facilitate resource extraction without undue constraint. Existing sand and gravel extraction operations should continue to operate in accordance with the conditions of the necessary permits.

The need to balance the economic benefits of sour gas extraction with the surface rights of landowners has led to the establishment of provincial minimum development setback zones which are regulated through the subdivision and development application processes. It is also recognized that there may be local circumstances and conditions that make it desirable to establish minimum setback distances greater than provincial minimums. Such is the case in a number of northeast Calgary communities. Through the local planning process (area structure plans), The City has established:

- more restrictive setback zones for urban residential development (nuisance setback)
- notification zones in which prospective homeowners are advised of sour gas well and pipeline locations and the potential nuisance associated with well workovers (e.g., noise, odour and flaring).

Policies regarding protection of residential areas from the negative impacts of industrial activity, in a general sense, are included in 2-2.2.6 Industrial. The following policies address the need to protect the ability of operators to extract valuable non-renewable resources and the need to mitigate negative impacts of resource extraction activities.

Policies

Natural Resource Extraction

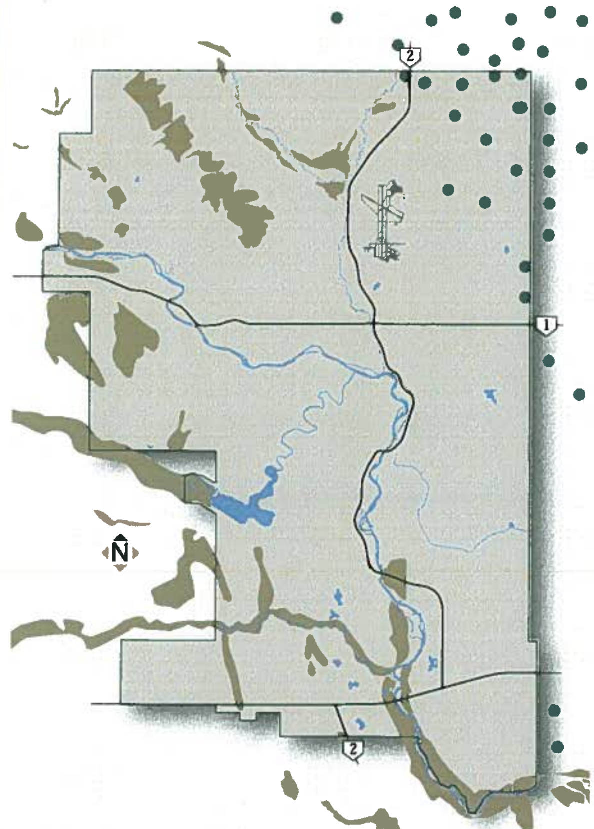
2-1.5A Encourage the relocation of sour gas extraction facilities in and near the city in a timely fashion.

2-1.5B Address the potential impacts of sour gas extraction facilities on urban development in local planning processes.

2-1.5C Establish minimum development setbacks on lands impacted by sour gas extraction in order to address nuisance factors such as noise, odour and flaring. Where local conditions warrant, these setbacks may be greater than those required in accordance with the provisions of the Subdivision and Development Regulations.

2-1.5D Encourage the protection of resource extraction through the early identification of areas where extraction should be the primary land use and through the development of appropriate measures to mitigate any safety or nuisance factors associated with retrieval of the resource.

Natural Extractive Resources



Sand and Gravel Deposits

Sour Gas Wells

Appendix B

Environmental Regulatory Review and Responsibilities: Calgary Construction Sites

Table 3 – Municipal Legislation

Note: Legislation is subject to change. For legislative certainty, you should consult the applicable bylaw, regulation, act, or enactment. The City of Calgary is not responsible for the accuracy of this information.

REGULATORY AUTHORITY	*LEGISLATION*	*RELEVANT SECTIONS*	*KEY POINTS*	*FINES*
CITY OF CALGARY **Tel: 3-1-1** **www.calgary.ca**	**Drainage Bylaw 37M2005**	*Section 4(1) – Discharges to Storm Drainage System, Prohibition*	*No person shall release or allow to be released any prohibited material into the Storm Drainage System unless permitted by the bylaw.*	➢ *$3000* ➢ *Summary Conviction: up to $10,000 and/or not more than 1 year in jail.*
		Section 4(2)- Release Impounded Water	*No person shall release impounded water either passively or actively into the storm drainage system.*	➢ *$1500* ➢ *Summary Conviction: up to $10,000 and/or not more than 1 year in jail.*
		Section 4(3) – Discharges to Storm Drainage System, Permitted	*Water may be discharged in accordance with a permit or written approval from the Director, Water Resources. A failure to obtain a permit is an offence.*	➢ *$1500* ➢ *Summary Conviction: up to $10,000 and/or not more than 1 year in jail.*
		Section 5(4) – Unauthorized Discharges	*Any person who releases, or causes or allows any prohibited materials to be released into the Storm Drainage System, shall immediately take all reasonable measures to notify the appropriate authorities and mitigate the discharge.*	➢ *$500 (failure to notify)* ➢ *$3000 (failure to mitigate discharge)* ➢ *Summary Conviction: up to $10,000 and/or not more than 1 year in jail.*
		Section 7 – Directing Storm Drainage	*Except in an emergency, no person shall direct impounded water from a parcel to the Storm Drainage System without the consent of the Director, Water Resources. A Drainage or Dewatering Permit is required from The City.*	➢ *$1500* ➢ *Summary Conviction: up to $10,000 and/or not more than 1 year in jail.*
		Section 11 – Restricting access or flow or altering the storm drainage system	*No person shall restrict access or flow to or within the storm drainage system or alter, remove or change the storm drainage system without prior approval*	➢ *$1500* ➢ *Summary Conviction: up to $10,000 and/or not more than 1 year in jail*
		Section 15 – Authority of Director	*The Director, Water Resources has the authority to require testing, monitoring, reporting and water treatment of water released to the Storm Drainage System.*	➢ *N/A*
	Street Bylaw 20M88	*Section 17 – Unauthorized Material on the Street*	*Do not store any material on any portion of a street. Material stored on private property must be stored so as not to enter the street.*	➢ *$500 (first offence)* ➢ *Summary Conviction: up to $10,000 or in the event of non-payment not more than 90 days in jail.*
		Section 18 & 18.1 Material entering Street	*Material entering the street by natural forces from a person or a landowner.*	➢ *$250 (first offence)* ➢ *Summary Conviction: up to $10,000 or not more than 90 days in jail.*

		Section 19 – Tracking Mud onto Street	*Mud and other construction debris may not be tracked by vehicles onto the street.*	➢ *$250 (first offence)* ➢ *Summary Conviction: up to $10,000 or not more than 90 days in jail.*
		Section 20(1) No Permit	*Use of Street without permit*	➢ *$300 (first offence) Summary Conviction: up to $10,000 or in the event of non-payment not more than 90 days in jail.*
		Section 20(2) Permit Conditions	*Failure to comply with permit conditions*	➢ *$500 (first offence) Summary Conviction: up to $10,000 or in the event of non-payment not more than 90 days in jail.*
		Section 37 Excavation	*Excavation of street surface*	➢ *Mandatory court appearance Summary Conviction: up to $10,000 or in the event of non-payment not more than 90 days in jail.*
	Sewer Service Bylaw 24M96	*Section 6(1) – Storm Drainage*	*Do not allow any storm drainage to be placed in the wastewater collection system, except as authorized by a permit.*	➢ *$350* ➢ *Summary Conviction: up to $10,000 or not more than 1 year in jail.*
		Section 8(1) – Prohibited Material	*No person shall release or discharge, or permit the release or the discharge of any waste described in Schedule "A" into the wastewater collection system.*	➢ *$600* ➢ *Summary Conviction: up to $10,000 or not more than 1 year in jail.*
	Community Standards Bylaw 5M2004	*Section 42 – Nuisances Escaping Property, Smoke and Dust*	*No owner or occupier of premises shall engage in an activity likely to allow smoke, dust or other airborne matter likely to disturb another Person, to escape the Premises without taking precautions to ensure that the smoke, dust or other airborne matter does not escape the premises.*	➢ *$300* ➢ *Summary Conviction: up to $10,000 or not more than 6 months in jail.*
		Section 51(1) – Hazardous Excavation, Drain, Ditch or Depression	*No owner shall allow a excavation, drain, ditch or other depression in the ground to become or remain a danger to public safety. This includes ponded water.*	➢ *$300* ➢ *Summary Conviction: up to $10,000 or not more than 6 months in jail.*

4.0 OFFENCES AND DUE DILIGENCE

Under the law, there two categories of offences: (1) common law offences; and (2) regulatory offences. Common law offences are based on previous court decisions rather than on codified written laws. Regulatory offences are those offences that are created by statutes, such as the *Fisheries Act* or the *Alberta Environmental Protection and Enhancement Act (EPEA)*. Statutes are passed by federal and provincial legislatures. The *Fisheries Act* is a federal statute while the *EPEA* is a provincial statute. Federal statutes apply cross country while statutes passed by the Alberta Legislature apply only within the jurisdiction of the Province of Alberta. Most statutes contain provisions for inspection and investigation, as well as penalties that may be levied against individuals or companies.

Appendix C

Design Guidelines

FASCINES WITH DOUBLE POLES

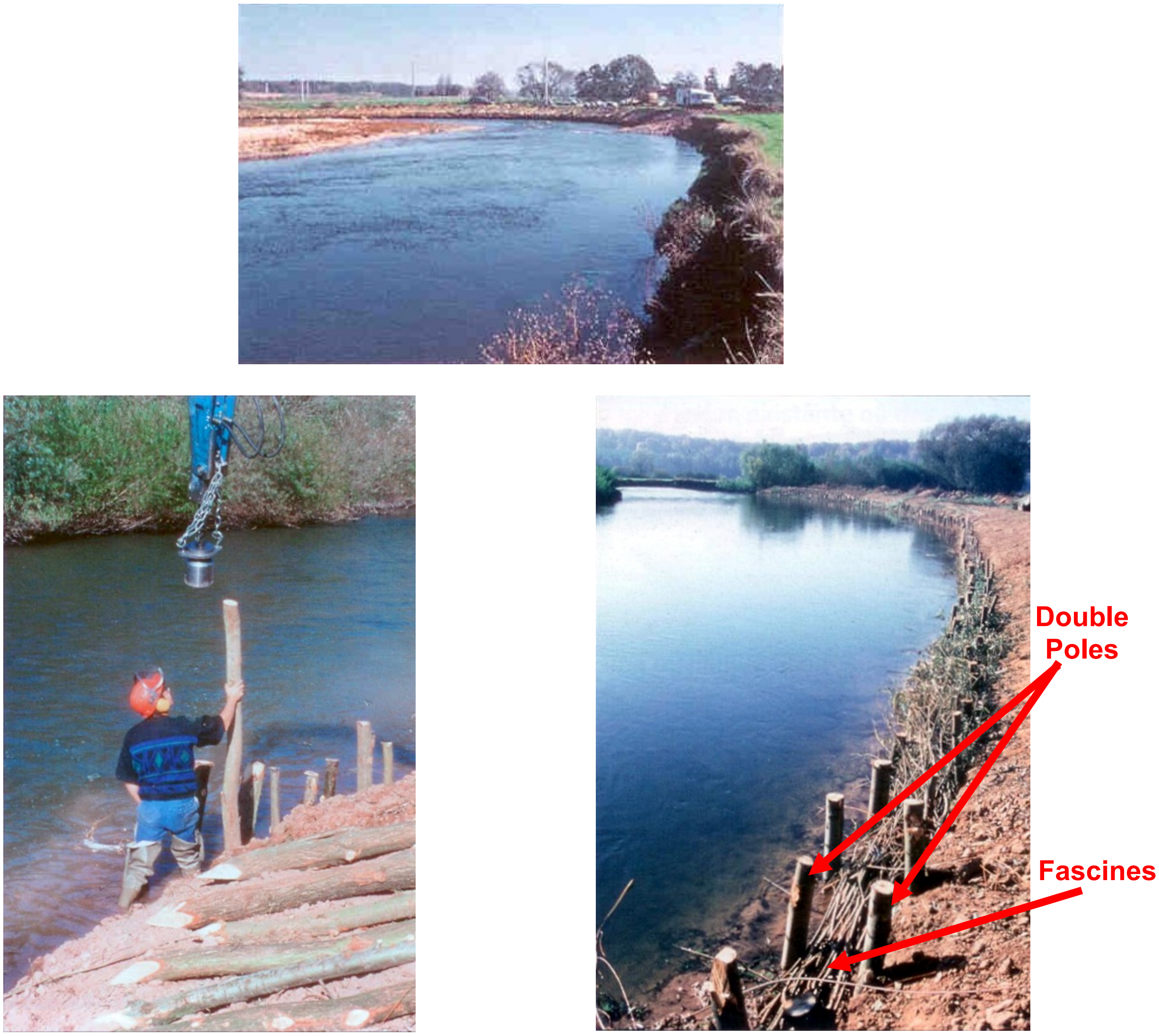


Figure A.1: Fascine with Double Poles – Before and After Installation[1]

Description

Fascines with double willow (or balsam poplar) poles are used to protect the toe of an eroding streambank. . Fascines are live cuttings from branches and stems of suitable native shrubs and trees which have properties of vegetative propagation (e.g. willow, balsam poplar and/or red-osier dogwood). Live fascines are further described in Design Guideline I2.

[1] Reproduced from: Bernard Lachat, "30 Années d'Expérience de Génie Biologique dans les Cours d'Eau en Suisse et en France", Ingenieurbiologie Genie Biologique, Bulletin No. 4 (December 2009), 67.

FASCINES WITH DOUBLE POLES

Suitability

Efficient method to stabilize an eroding streambank toe, where:

- the eroded bank is less than 1 m high; and
- the streambank is parallel to stream flow.

Advantages

- Quick and simple construction.
- Structure follows the bank contours.
- Immediate protection against wave attack and fast flowing water.
- The growing elastic branches bend easily and the rising water level or wave action causes them to form a protective cover on the bank.
- Root system consolidates the bank by binding the soil.
- Provides habitat for fish and wildlife by creating shade, cover and small organic debris input to the watercourse.

Limitations

- Construction must occur during the dormancy period of the live cuttings.
- Requires a large quantity of live cuttings.
- Limited protection of bank height (up to 1 m). Should be combined with other slope protection techniques such as seeding and live staking (see Figure A.2).
- Specialized equipment may be required if there are access restrictions.

Design Considerations

- The top of the fascines should be at or slightly above the average depth of the early summer water level.
- The level of the existing vegetation adjacent to the proposed project site should be used as a guideline for the elevation of the proposed works.
- Additional vegetation above the fascine should be placed higher than typical ice levels.
- See Figure A.2.

FASCINES WITH DOUBLE POLES

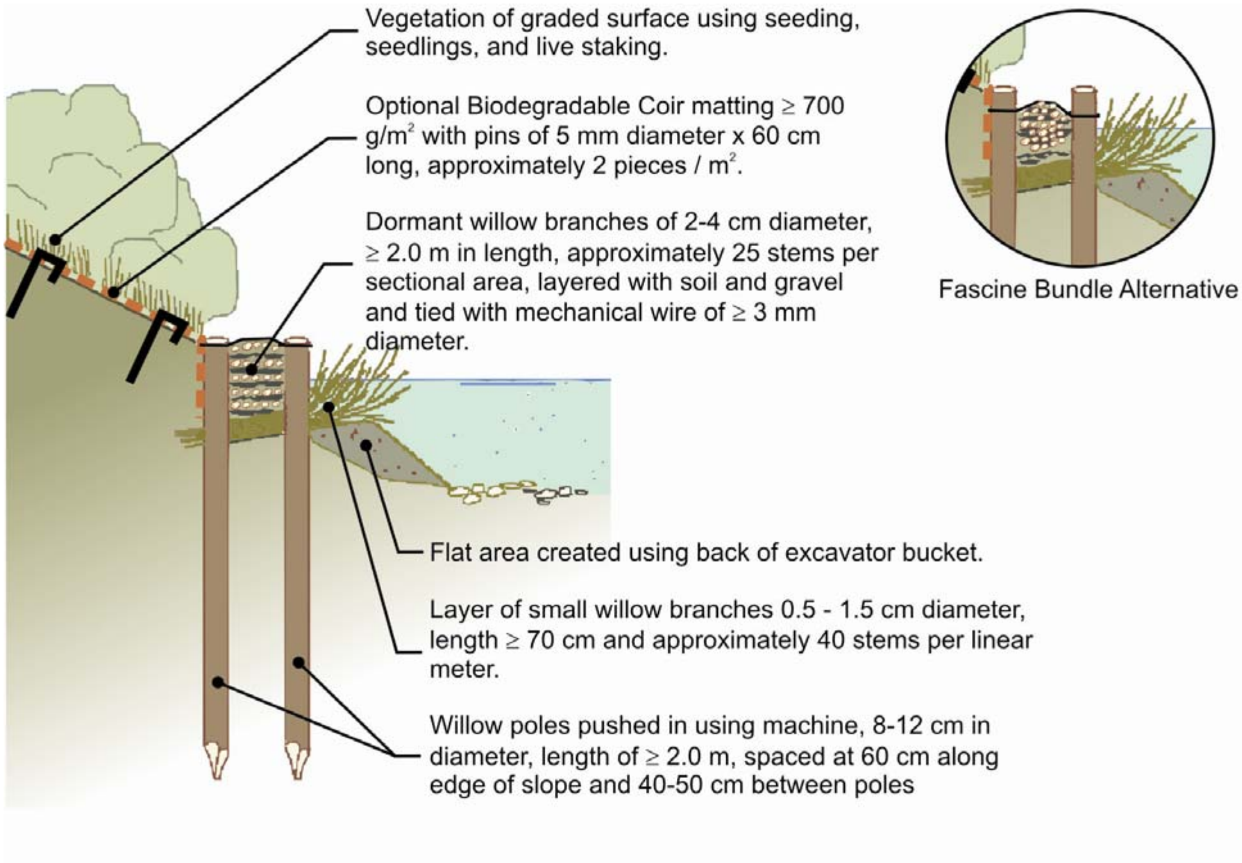


Figure A.2: Fascines with Double Willow (or Balsam Poplar) Poles Detail [2]

Implementation

- Install adequate protection to prevent / reduce sediment delivery to the watercourses in accordance with regulations.
- Grade streambank to a 2:1 slope where possible.
- Remove rocks and other materials prohibiting installation of the structure and create a flat bench area below the structure as required.
- See Design Guideline K for further information on the harvesting of live cuttings and stock handling.

[2] Adapted from: Bernard Lachat. *Génie Biologique, March 20, 2009* (PowerPoint slides). BIOTEC, http://www.clubsconseils.org/database/Image_usager/2/Les%20clubsconseils/Lachat_Bernard_cours_formation_v1.pdf (Oct. 26, 2010).

- The fascines can be prepared (on site or off site) and then placed between the poles, or else built in place (i.e., between the poles). See Design Guideline I2 for further information on preparing fascines. If fascines are built in place, the center of the fascine can be layered with soil, cobbles and / or gravel. This technique allows for better compaction of the live material layered with soil in the bank.
- Poles should preferably be made of live willow or balsam poplar, but could be made of other species of dead wood and / or metal.
- Voids between the fascines and banks should be backfilled with soil. Compacted slightly.
- Optional – install a layer of small diameter willow branches (see Figure A.1) on the flat bench below the structure. Recommended for fine textured river beds (i.e., sand or silt / clay).
- Optional – place coir matting[3] (see Figure A.2) between the fascines and streambank.

OPTION A1: AQUATIC SPECIES ROLLS AND SINGLE POLES

Description

Rolls or clumps of aquatic species with single poles are used to protect the toe of an eroding streambank. The aquatic rolls / clumps may consist of native sedges (Carex spp.), bulrushes (Scirpus spp.), cattail (*Typha latifolia*) or other suitable native aquatic species[4] . Willow branches / fascine bundles can also be substituted. Figure A.3 shows construction of rolls with cylindrical rock gabion and Figure A.4 shows an alternative in which the roll is constructed using coir mesh. Figure A.5 shows an alternative where a brush mattress is used above the cylindrical rock gabion. Brush mattresses are described in Design Guideline I5.

Suitability

Efficient method to stabilize an eroding streambank toe, where:

- the streambank is parallel to stream flow.
- Can be used as an alternative to fascines with double willow poles when attack is less severe and aquatic species are available.

Advantages

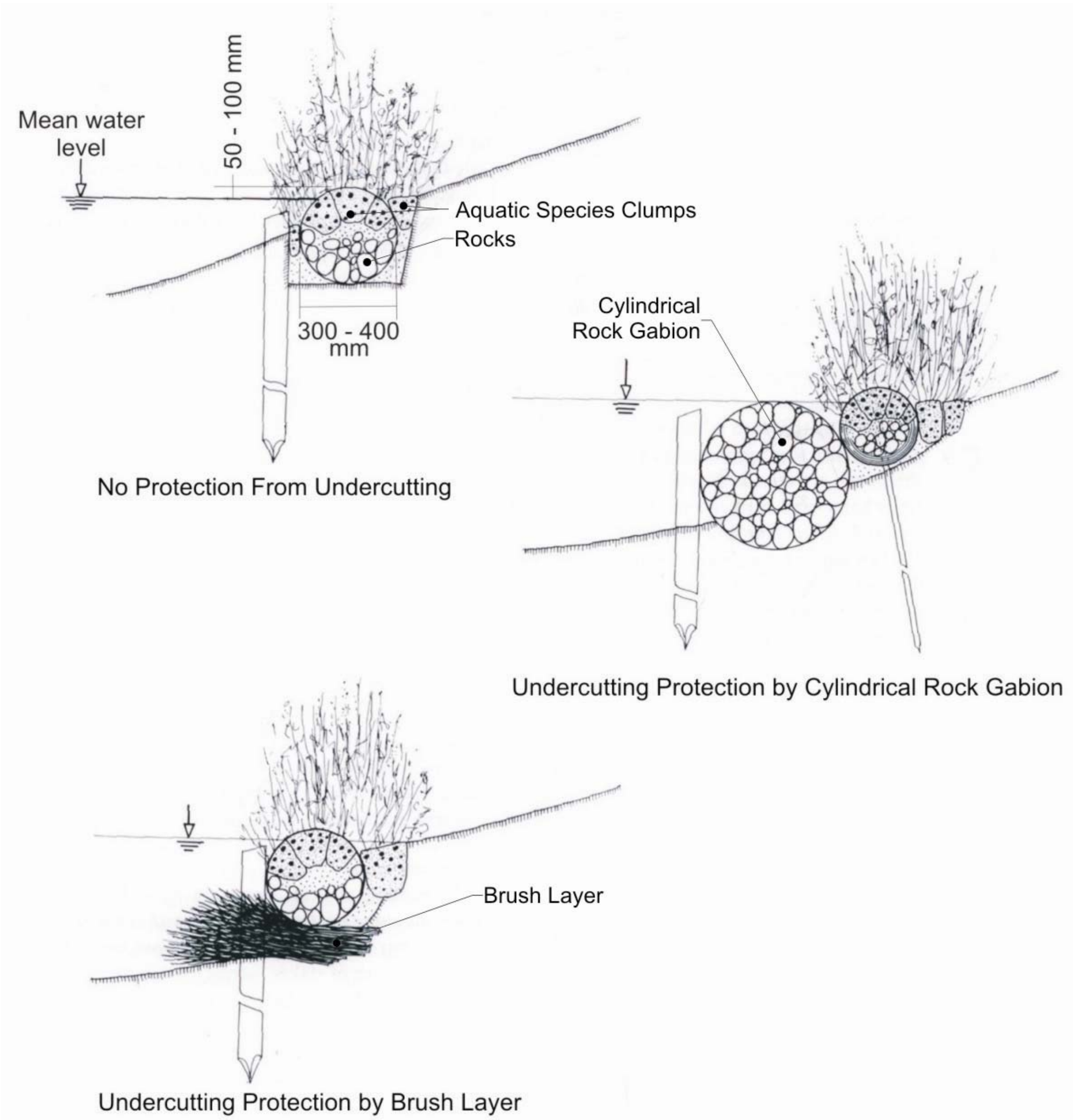
- Protects shorelines against erosion by absorbing wave energy.
- Provides a stable structure made of aquatic species.

[3] Coir matting description (see Design Guideline J)
[4] Species selection (see Design Guideline L)

- Provides habitat for fish and wildlife by creating shade, cover and small organic debris input to the watercourse.

Limitations

- Labour intensive and requires a large variety of materials, such as plants, rock, soil, coir matting and wooden stakes.



FASCINES WITH DOUBLE POLES

Figure A.3: Aquatic Species Roll Constructed of Cylindrical Rock Gabions[5]

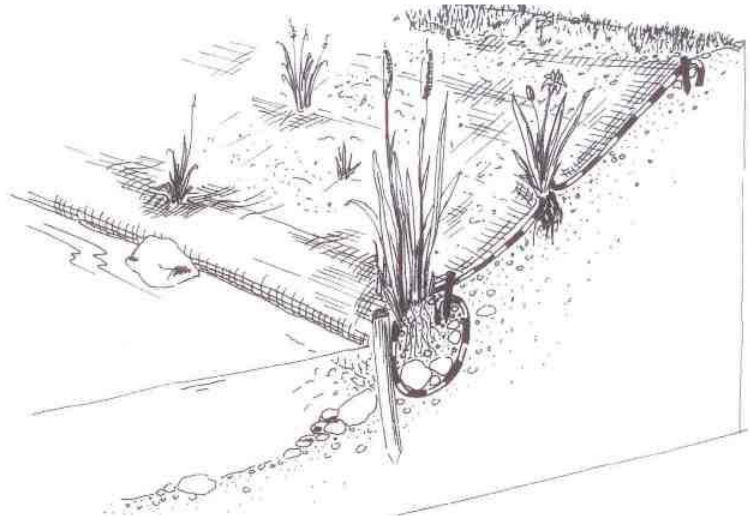


Figure A.4: Aquatic Species Rolls Constructed of Coir Mesh[6]

[5] Reproduced from: H.M. Schiechtl and Stern, *Water Bioengineering Techniques for Watercourse Bank and Shoreline Protection*, (Cambridge: Wiley-Blackwell, 1997), 114.
[6] Reproduced from: Helgard Zeh, *Soil Bioengineering Construction Type Manual*, (Zurich: European Federation for Soil Bioengineering, 2007), 322.

FASCINES WITH DOUBLE POLES

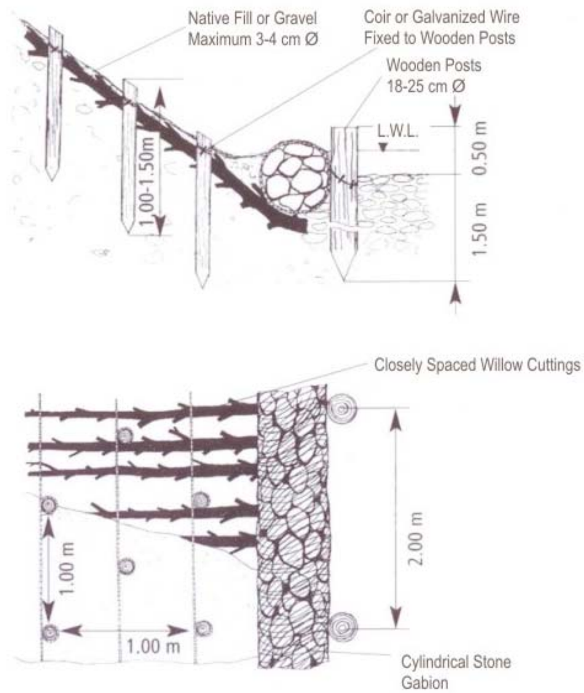


Figure A.5: Cylindrical Rock Gabions with Brush Mattress

Implementation

- As shown in Figures A.3 to A.5, install 1 – 1.5 m long vertical wooden poles at 1 – 1.5 m intervals parallel to the stream. The poles are temporarily left exposed 300 mm above the early summer water level.
- Excavate a 0.4 – 0.5 m deep by 0.4 – 0.5 m wide trench behind the wooden poles.
- Wooden planks may be used for trench support as required.
- Place wire mesh in trench to secure the 300 – 400 mm diameter cylindrical aquatic species roll.
- Or place 700 g/m² coir matting within trench, starting on the upslope side and unfold matting in front of trench towards the body of water.
- Voids below mesh and / or matting can be filled with soil through the mesh and / or matting.
- Fill the bottom 2/3 of the wire mesh and / or matting with coarse gravel (20 – 60 mm), crushed rock (60 - 120 mm) and soil and vegetative pieces from aquatic species clump trimmings harvested as a clump of live rhizomatous material (see Design Guideline K).

- Fill the top 1/3 of the wire mesh and / or placed matting with aquatic species clumps to form a roll of approximately 300 – 800 mm and fasten the mesh together with wire to form a cylindrical shape. The top of the aquatic species roll cylinder should be 50 – 100 mm above the water level.
- For the matting option, the coir geotextile should be raised up onto the adjacent slope (previously broadcast seeded) and fastened there and planted with seedlings and or live cuttings.
- Any planks used to support the trench can then be removed and the void filled with soil.
- Drive vertical poles further into ground to just below the top of the aquatic species roll.

OPTION A2: FASCINES WITH DOUBLE POLES AND BRUSH LAYERS

Description

Rows of brush layers can be added above the fascines to provide additional slope stabilization on higher banks. A brush layer consists of a row of live cuttings (willow, balsam poplar and / or red osier dogwood) placed in a criss-cross or overlapping manner in between layers of soil, with tips protruding beyond the face of the fill (see Design Guideline I1).

FASCINES WITH DOUBLE POLES

Suitability

Efficient method to stabilize an eroding streambank toe, where:

- the streambank is parallel to stream flow;
- Protection of infrastructure such as buildings, roads, water intakes, storm outfalls and utility crossings of watercourses.

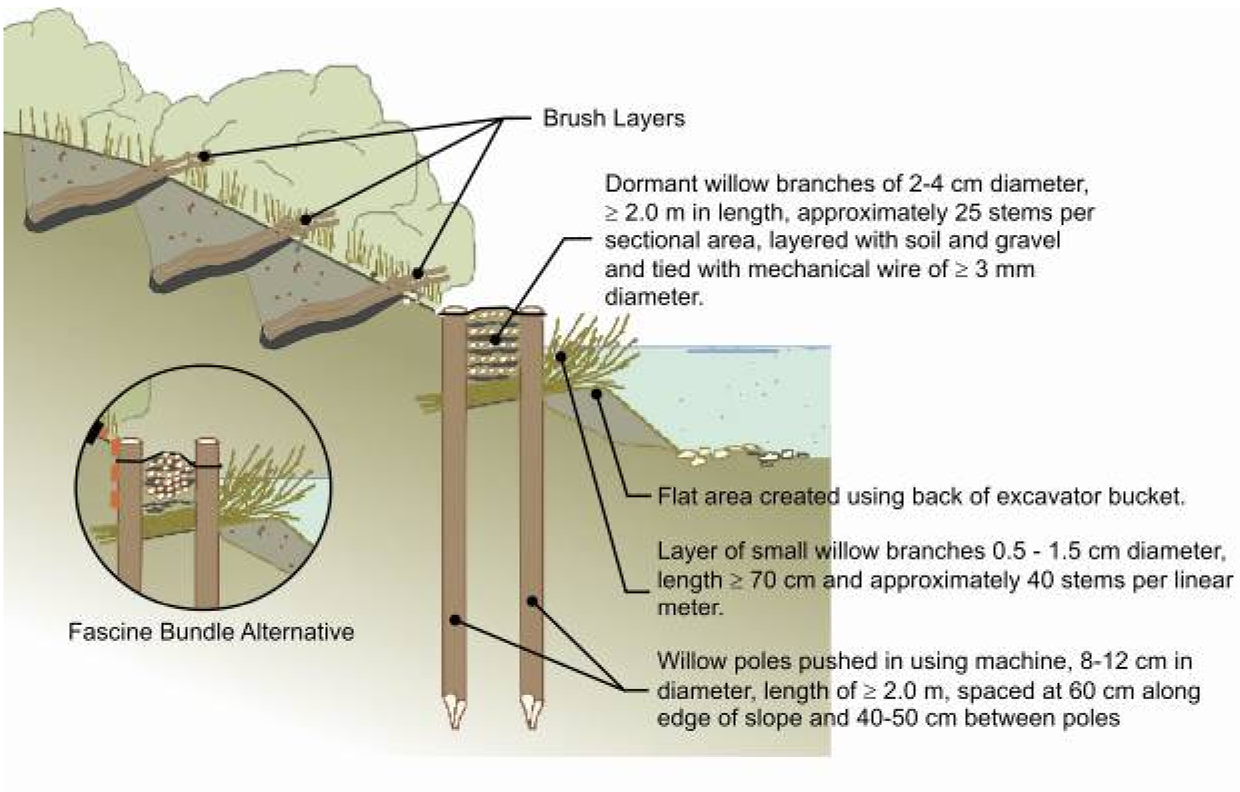


Figure A.5: Fascines with Double Willow Poles and Brush Layer Detail [7]

Maintenance

- Monitor site for growth and erosion for the first three growing seasons and repair minor failures if necessary. Water the upper slope portions, based on weather, twice a week. Remove weeds competing with the establishing vegetation (see Design Guideline N).

[7] Adapted from: Bernard Lachat. "Génie Biologique" (PowerPoint slides). BIOTEC, March 20, 2009: Retrieved from: http://www.clubsconseils.org/database/Image_usager/2/Les%20clubsconseils/Lachat_Bernard_cours_formation_v1.pdf

References and Further Reading

- Lachat, Bernard. Guide de Protection des Berges de Cours d'Eau en Techniques Végétales. Diren: Ministere de L'Amenagement du Territoire et de L'Environnement, 1999.
- Lachat, Bernard. "30 Années d'Expérience de Génie Biologique dans les Cours d'Eau en Suisse et en France", Ingenieurbiologie Genie Biologique Bulletin No. 4. December 2009. 59-69.
- Schiechtl, H.M. and R. Stern. Water Bioengineering Techniques for Watercourse Bank and Shoreline Protection. Cambridge: Wiley-Blackwell, 1997.
- Zeh, Helgard. Soil Bioengineering Construction Type Manual. Zurich: European Federation for Soil Bioengineering, 2007.

LONGITUDINAL PEAK STONE TOE PROTECTION (LPSTP)

Figure B.1: LPSTP – Construction and After Installation[1]

Description

As shown in Figures B.1 and B.2, Longitudinal Peak Stone Toe Protection (LPSTP) is a free-standing structure (i.e., not keyed into the bed or bank) that has a triangular shape (the apex of the triangle is the peaked top). The triangular shape of the LPSTP allows plantings (e.g., brush layering, see Design Guideline I1) to be more easily incorporated behind the structure. The LPSTP is designed to launch with scour, hence it does not require a key-in to the streambed or an apron.

Advantages

- As compared to conventional riprap armouring, LPSTP reduces channel encroachment since it can be constructed at a 1H:1V side-slope and it does not require an apron or key-in to the streambed at the toe. Conventional riprap requires a 2H:1V side-slope and an apron or key-in at the toe.
- LPSTP can be constructed in the 'wet' in an environmentally sensitive manner. Because the LPSTP structure is free-standing, the large riprap sized material (that is relatively free of fines) can be placed in the 'wet' prior to the placement of the finer-grained material that constitutes the fill between the LPSTP and the bank. Conventional riprap treatments require the finer-grained material to be placed first, which may require a more elaborate isolation technique to prevent silt from entering the watercourse.
- Typically an LPSTP structure does not require a submission to Transport Canada (TC), Navigable Waters Protection Branch since it complies with TC's definition of minor work.
- LPSTP should perform well under ice conditions as long as the rock is adequately sized to resist ice forces. The top of LPSTP corresponds to bankfull level. Bankfull corresponds to the discharge that has a flood frequency corresponding to a 1:2-year return period or slightly greater flood.

1AMEC .

LONGITUDINAL PEAK STONE TOE PROTECTION (LPSTP)

Suitability

Efficient method to stabilize an eroding streambank toe, where:

- The streambank is subject to severe attack (e.g., where the bank is angled towards the stream flow).
- Does not need to follow the bank toe exactly, but should be designed and placed to form an improved or "smoothed" alignment through the stream bend. The "smoothed" longitudinal alignment results in improved flow (less turbulence) near the toe of the eroding bank.
- It is especially effective in streams where most erosion is due to relatively small but frequent events.
- It protects the toe so that slope failure of a steep bank landward of the stone toe will produce a stable angle.
- Such a bank is often rapidly colonized by natural vegetation.

Limitations

- Only provides toe protection and does not protect mid- and upper bank areas.
- Some erosion of these areas should be anticipated during long-duration, high energy flows, or until the areas become otherwise protected.
- Stone toe is not suitable for reaches where rapid bed degradation (lowering) is likely, or where scour depths adjacent to the toe will be greater than the height of the toe.

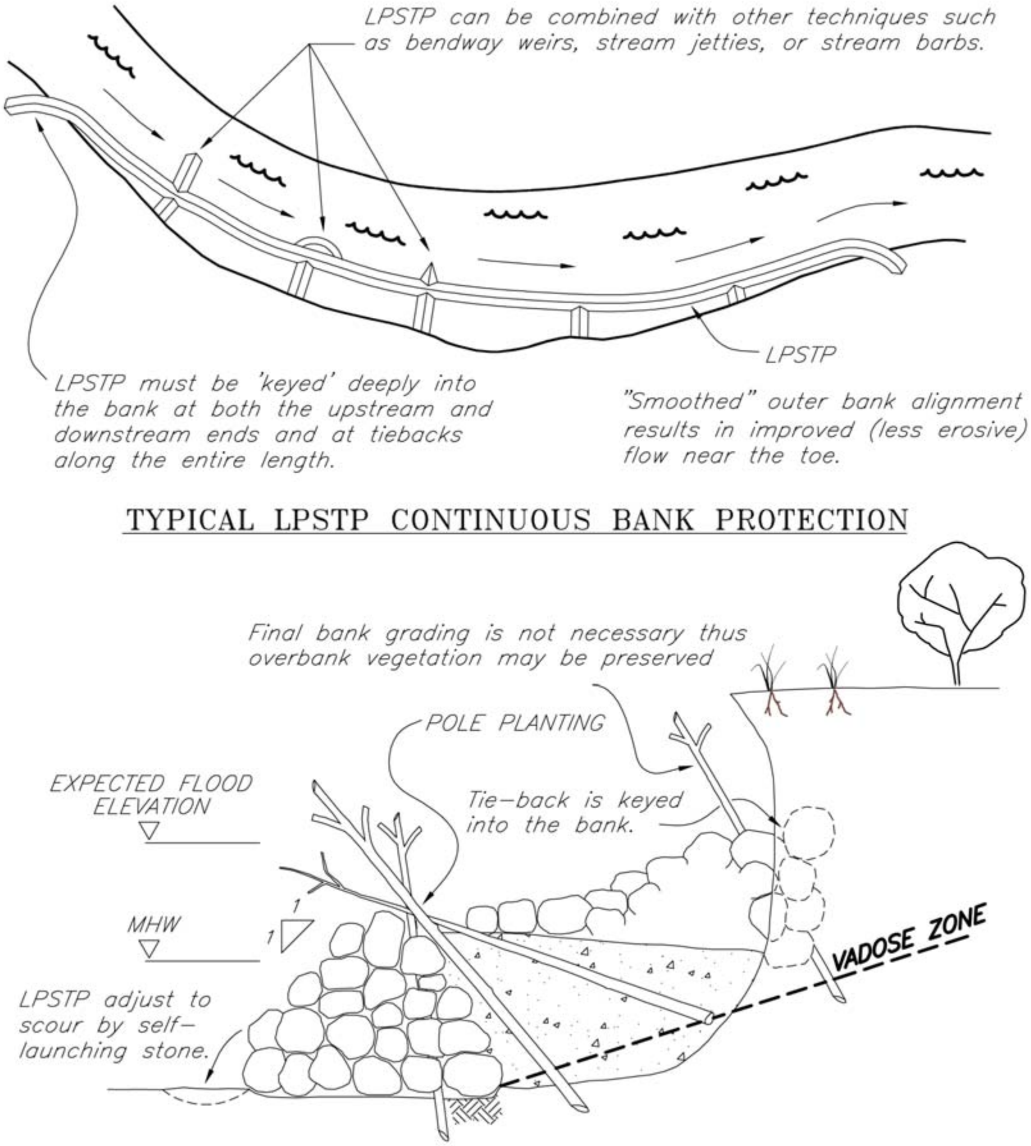
Design Considerations

- Often used in conjunction with Brush Layering' (see Design Guideline I1), which is a thick layer of live willow cuttings that is placed behind the back face of the sloped rock riprap. The above-ground portion of the brush layer should be at or above bankfull / normal ice level. LPSTP with brush layering is referred to herein as Option B1.
- Stone for the structure should be well graded and properly sized.
- An upstream and downstream key-trench into the streambanks is required (see Figure B2).

Implementation

- Requires heavy equipment for excavation of the keys (tie-backs) and efficient hauling and placement of stone.
- Can be constructed from within the stream, from roadways constructed along the lower section of the streambank itself, or from the top.

LONGITUDINAL PEAK STONE TOE PROTECTION (LPSTP)



NOTES:
1. LPSTP is well suited when continuous bank protection is needed for the toe but the mid and upper banks are relatively stable and/or biotechnical practices are suitable.
2. The success of LPSTP depends on the ability of the well-graded stone to self adjust or "launch", into any scour holes formed on the stream side of LPSTP.

Figure B2: LPSTP Typical Plan and Cross Section[2]

[2] Reproduced from Bio Draw ©2000 John McCullah

ROCK TOE WITH ONE OR MULTIPLE BRUSH LAYER ROWS

OPTION C1 – ROCK TOE WITH ONE BRUSH LAYER ROW

Figure C.1: Rock Toe with One Brush Layer Row, Contour Fascine and Aquatic Species[1]

Description

A rock toe is placed along shorelines to provide erosion protection and a brush layer is installed above the rock toe. The brush layer consists of a row of live cuttings (native willow, balsam poplar and red osier dogwood) placed in a criss-cross or overlapping manner in between layers of soil, with tips protruding beyond the face of the fill. See Design Guideline I1 for description of brush layers.

Suitability

Low shorelines with toe erosion, where:

- the eroded bank is less than 1 m high; and
- the streambank is angled towards the stream flow.

Advantages

- More natural and aesthetically pleasing than rock riprap alone.
- Provides habitat for fish and wildlife by creating shade, cover and small organic debris input to the watercourse.
- Can negate or reduce the amount of habitat alteration compensation required by regulators.

[1] Terra Erosion Control Ltd. photo.

ROCK TOE WITH ONE OR MULTIPLE BRUSH LAYER ROWS

- Provides deep rooting, which will contribute to surface bank stability and prevent erosion of the streambank by combining both rock and live root systems protection.

Limitations

- Requires local supply of rock riprap.
- Requires local supply of suitable native live materials.
- Must ensure that navigability of the channel is not impeded.
- Specialized equipment may be required if there are access restrictions.

Design Considerations

- Selection of appropriate riprap class based on stream velocity (see Design Guideline P).
- Machine requirement (in most cases) to excavate and place rock toe.
- Trenched installation or backfilled installation of brush layer (manual or machine).
- Live cuttings harvesting and stock handling (see Design Guideline K).
- Live cutting length (1.0 m minimum in soil, plus 0.2 m exposed).
- Live planting density (20 to 50 stems per linear meter).
- Live planting angle (45˚).
- Live planting density of additional rows of brush layers above first row: 8 to 10 stems per linear meter (see Design Guideline I1).
- Live planting angle (additional rows): 10˚ (see Design Guideline C – Option C2).
- Live planting above natural ice scour elevation.
- Rodent predation and fencing.
- Soil amendment (see Design Guideline M).
- Backfill material.

ROCK TOE WITH ONE OR MULTIPLE BRUSH LAYER ROWS

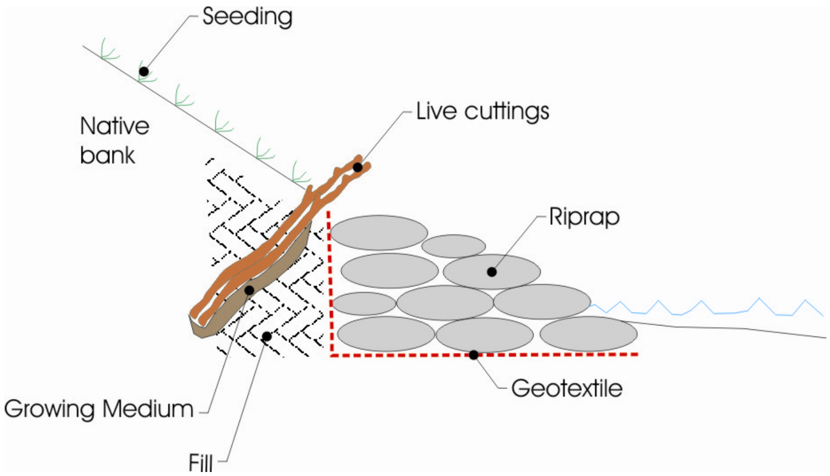


Figure C.2. Rock Toe with One Brush Layer Row[2]

Implementation

- Install adequate protection to prevent / reduce sediment delivery to the watercourses in accordance with regulations.
- Excavate toe for placement of rock.
- Place geotextile within excavated area.
- Place rocks and slightly compact with back of bucket
- Start at either the upstream or downstream end of the treatment area.
- Force excavator bucket into soil to desired depth and open ground to allow placement of live cuttings.

Figure C.3: Machine assisted brush layer planting [3]

[2] Terra Erosion Control Ltd. drawing.
[3] Terra Erosion Control Ltd. photo.

- Place live cuttings and soil amendments.
- Water thoroughly to saturate soil amendments.
- Release soil over placed cuttings by retrieving excavator bucket.
- Compact slightly using back of bucket.
- Repeat similar action adjacent to planted brush layer.
- Once the first row is complete, continue with additional rows as required (see Option C2).

Alternatively, a complete trench can be excavated first (manually or using a machine), then live cuttings and soil amendments can be placed and watered and the trench can then be back filled.

Alternatives

Rock toe with one brush layer[4] row and contour fascine[5] placed above the brush layer and clumps of aquatic species[6] planted in front of the rock toe to provide additional habitat and improve slope stability.

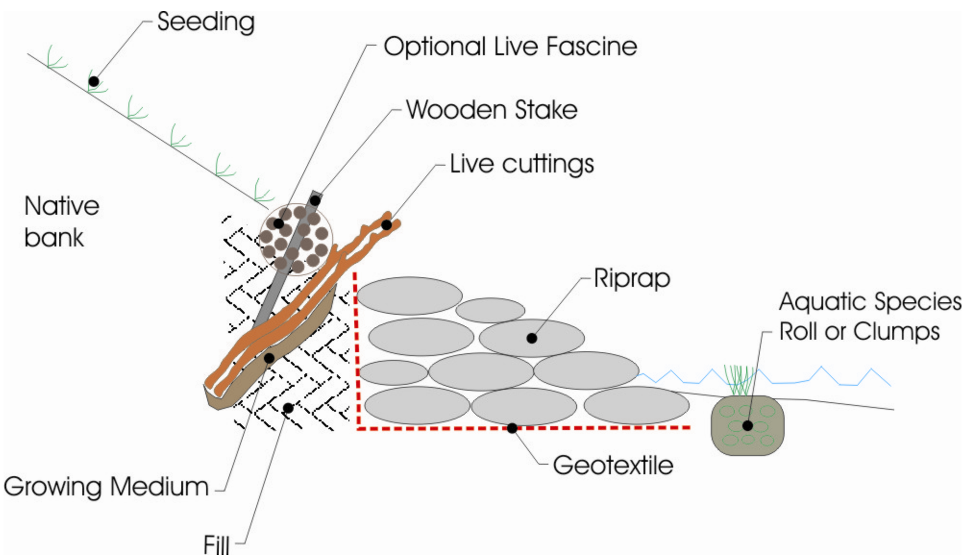


Figure C.4: Rock Toe with One Brush Layer Row – Contour Fascine & Aquatic Species Roll Alternatives[7]

[4] See Guideline I1
[5] See Guideline 12
[6] Species selection (see Design Guideline L)
[7] Terra Erosion Control Ltd. drawing.

OPTION C2 – ROCK TOE WITH MULTIPLE BRUSH LAYER ROWS

Figure C.5: Rock Toe with Multiple Brush Layer Rows and Contour Fascines[8]

Description

A rock toe is placed along shorelines to provide erosion protection and brush layers are installed above the rock toe (see Design Guideline C1). A brush layer consists of a row of live cuttings (native willow spp., balsam poplar and red osier dogwood) placed in a criss-cross or overlapping manner in between layers of soil, with tips protruding beyond the face of the fill (see Design Guideline I1).

Suitability

High shorelines with toe erosion, where:

- the eroded bank is greater than 1 m high; and
- the streambank is angled towards the stream flow

[8] Terra Erosion Control Ltd. photos (Alternative option shown – rock toe with brush layers and contour fascines).

ROCK TOE WITH ONE OR MULTIPLE BRUSH LAYER ROWS

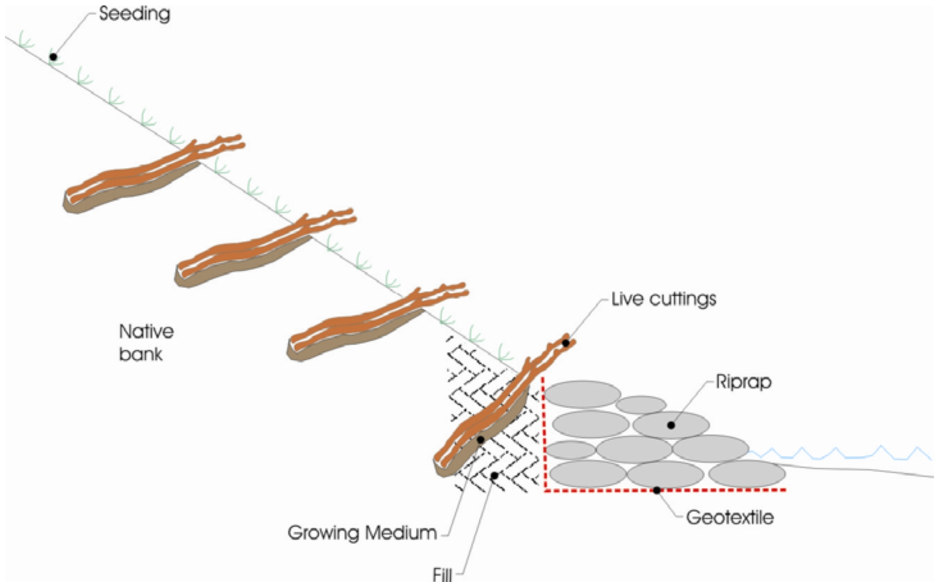


Figure C.6: Rock Toe with Multiple Brush Layer Rows[9]

Alternatives

- Contour fascines (see Design Guideline I2) can be installed above every second brush layer to act as a physical barrier to reduce rilling, trap sediment and slow runoff. Contour fascines should be installed on wetter or moist slope aspects (see Figure C7).
- Straw wattles (see Design Guideline I3) can be installed above every second brush layer to act as physical barriers reducing rilling, trapping sediment and slowing runoff and should be utilized on dry slope aspects. See Figure C8.
- "Hedge brush layers" are a variation on standard brush layers. They utilize rooted stock, possessing layering (adventitious) rooting properties, as the vegetative component within the brush layers (i.e., alder Alnus spp.). The advantage of hedge brush layers are that they utilize species that don't root from cuttings but have high slope stabilization properties because of their root systems and in some cases (i.e. Alnus spp) will be nitrogen fixing.
- Clumps of aquatic species can also be planted in front of the rock toe to provide additional habitat and bank protection (see Design Guideline K for aquatic species harvest techniques and Design Guideline A for additional information on the installation of aquatic species rolls).
- Coir matting or geogrid can be incorporated in between brush layer on steeper slope gradient (see Figure C9)

[9] Terra Erosion Control Ltd. drawing.

- A brush mattress (see Design Guideline I5) can be incorporated from the rock toe and onto the slope, as shown in Figure C.10

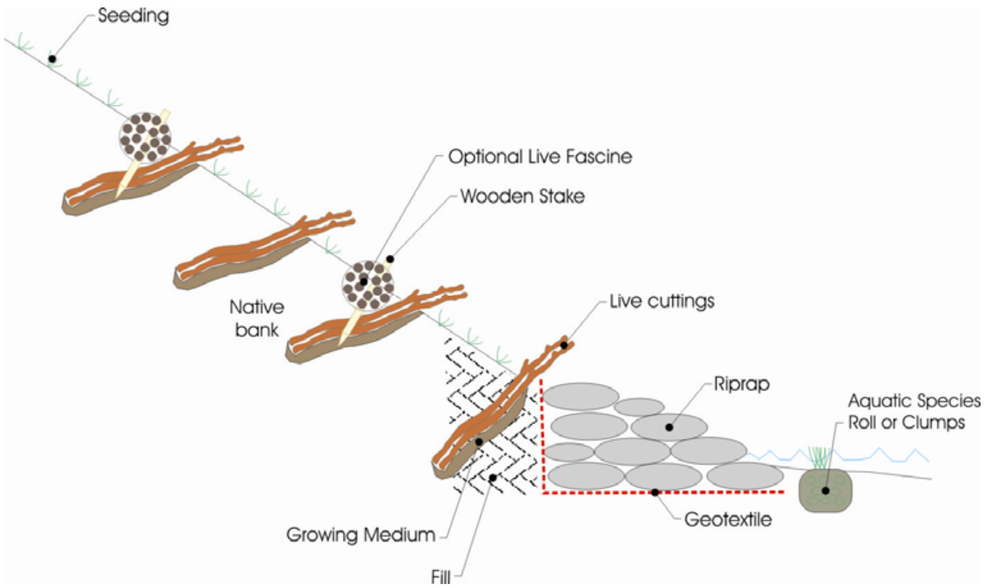
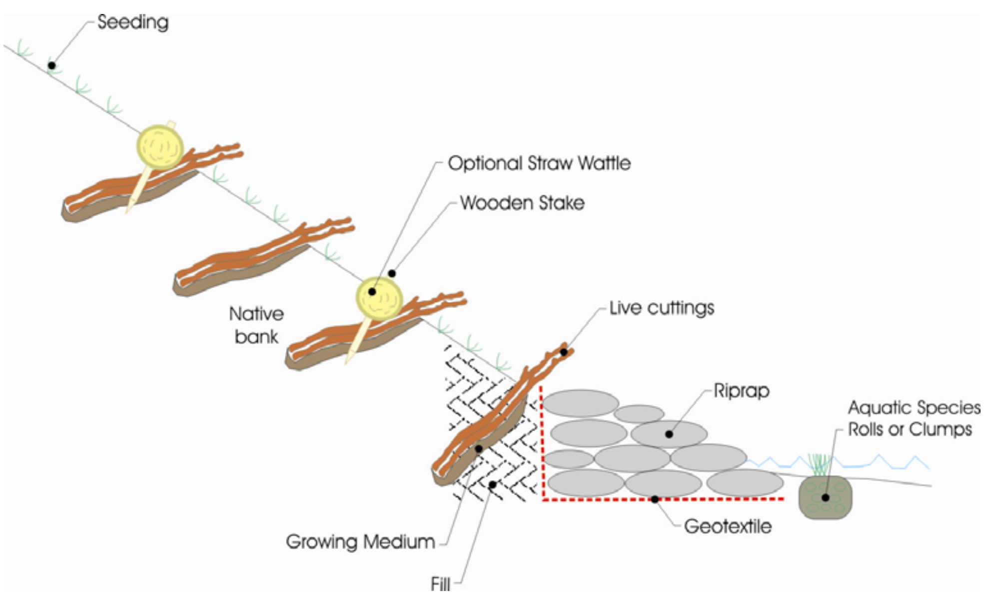


Figure C.7: Rock Toe with Multiple Brush Layer Rows, Contour Fascines and Aquatic Species Roll Alternatives (Moist Site)[10]



[10] Terra Erosion Control Ltd. drawing.

Figure C.8: Rock Toe with Multiple Brush Layer Rows, Straw Wattles and Aquatic Species Roll Alternatives (Dry Site)[11]

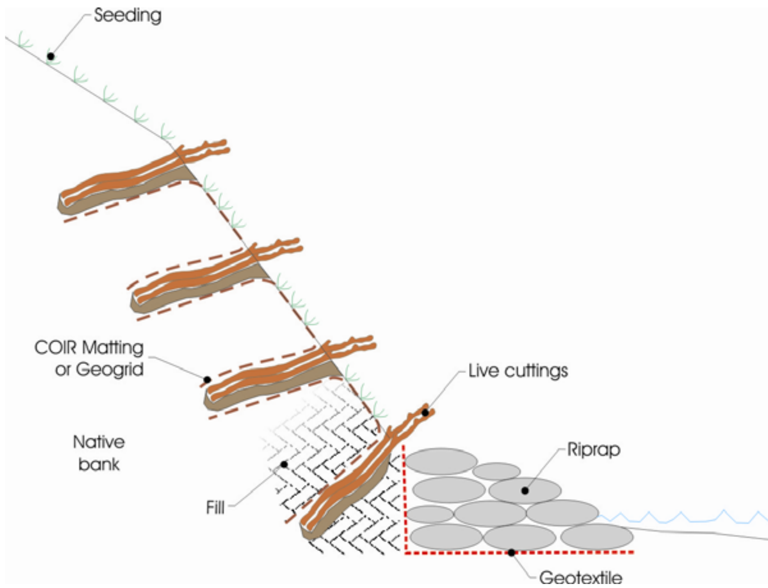


Figure C.9: Rock Toe with Multiple Brush Layer Rows, Coir Matting and / or Geogrid (Steeper Slopes)[12]

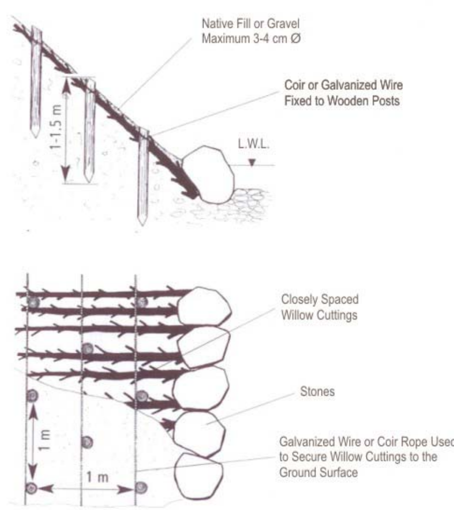


Figure C.10: Brush Mattress with Rock Toe[13]

[11] Terra Erosion Control Ltd. drawing.
[12] Terra Erosion Control Ltd. drawing.

Maintenance

- Monitor site for growth and erosion for the first three growing seasons and repair minor failures if necessary.

References and Further Reading

- Gray, D.H. and R. B. Sotir. Biotechnical and Soil Bioengineering Slope Stabilization. A Practical Guide for Erosion Control. New York: John Wiley & Sons, Inc., 1996.
- Schiechtl, H.M. and R. Stern. Ground Bioengineering Techniques for Slope Protection and Erosion Control. Cambridge: Wiley-Blackwell, 1996.
- Zeh, Helgard. Soil Bioengineering Construction Type Manual. Zurich: European Federation for Soil Bioengineering, 2007.

[13] Adapted from: Florin Florineth, *Piante Al Posto Del Cemento Manuale di Ingegneria Naturalistica e Verde Tecnico*, (Milano, Italy: Il Verde Editoriale S.r.l., 2007)

VEGETATED RIPRAP WITH ONE OR MORE VEGETATED ROWS

OPTION D1 – VEGETATED RIPRAP WITH ONE VEGETATED ROW

Figure D.1: Vegetated Riprap with Toe Apron and One Vegetated Row [1]

Description

- Vegetated riprap with one row of vegetation.
- Provides bank stability and prevents erosion of streambank by combining both rock and live root systems protection.

Suitability

- Streambank toe erosion stabilization with low bank (less than 1 m high).
- Streambanks facing the stream flow.
- Protection of infrastructure such as buildings, roads, water intakes, storm outfalls and utility crossings of watercourses.

Advantages

- More natural and aesthetically pleasing than traditional rock riprap.
- Provides habitat for fish and wildlife by creating shade, cover and small organic debris input to watercourse.
- Flexible and not affected by slight movements from ground settlement, shifting, frost heave or toe erosion.
- Cost effective in comparison to other hard erosion control techniques.

[1] Terra Erosion Control Ltd. photos.

- Can negate or reduce the amount of habitat alteration compensation required by regulators.
- Minimal maintenance requirements.

Limitations

- Requires local supply of rock riprap.
- Requires local supply of suitable native live materials.
- Need to ensure that navigability of the channel is not impeded.
- Specialized equipment might be required if there are access restrictions.

Design Considerations

BANK SLOPE AND GRADING

The minimum bank grade is dependant upon available equipment and access.

ROCK RIPRAP DESIGN GUIDELINES CONSIDERATIONS

See Design Guideline O – Rock Riprap

VEGETATED RIPRAP DESIGN CONSIDERATION

- Trenched installation.
- Oriented Strand Board (OSB) or wooden board protection.
- Coir protection (900gr/m^2).
- Live cuttings harvesting and stock handling (see Design Guideline K).
- Live cutting length (1.0 m minimum in soil, plus thickness of riprap, plus 0.2 m exposed).
- Live planting density (20 to 50 stems per linear meter).
- Live planting angle (45˚).
- Live planting depth (1.0 m minimum into native or topsoil).
- Live planting top exposure (approximately 0.3 m).
- Live planting above natural ice scour elevation.
- Rodent predation and fencing.
- Soil amendments (see Design Guideline M).
- Backfill material.

VEGETATED RIPRAP WITH ONE OR MORE VEGETATED ROWS

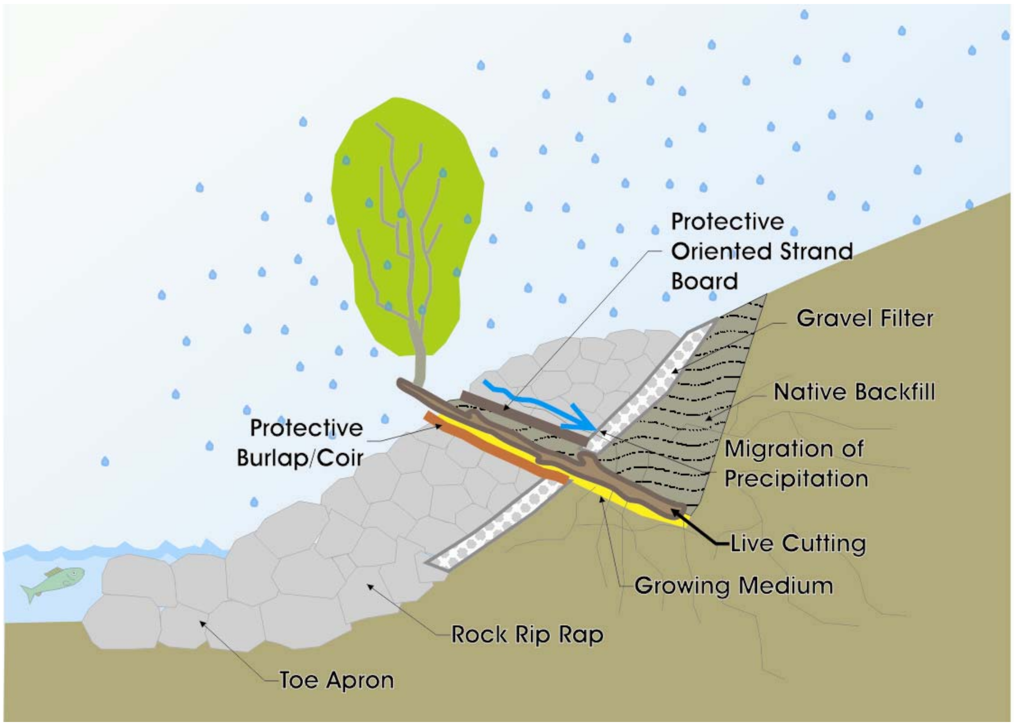


Figure D.2: Vegetated Riprap with Toe Apron and One Brush Layer Row[2]

Other Potential Features That Can Be Incorporated

- Rock vanes.
- Brush layers, contour fascines / straw wattles above riprap – see Design Guidelines I1, I2, I3.
- Live pole drains above riprap – see Design Guideline G.
- Native seeds, seedlings and nursery stock above riprap – see Design Guideline L.

TEMPORARY IRRIGATION SYSTEM

Precipitation or regular watering is critical to the survival and establishment of the live plantings. In areas subject to short-term drought, consideration for a temporary irrigation system should be made when possible (i.e., where access is available).

Standard landscape irrigation equipment can be economically implemented. Where irrigation or municipal water is not readily available the irrigation system can be connected to a portable gas driven pump when watering is required[3].

[2] Terra Erosion Control Ltd. drawing.
[3] A permit for pumping water out of the river will be required from Alberta Environment.

Implementation

INSTALLATION

- Install adequate protection to prevent / reduce sediment delivery to the watercourses in accordance with regulations.
- Prepare the slope to desired gradient.
- Install geotextile or gravel filter and riprap toe apron below the first row of live plantings.
- Working in short sections, excavate a live planting trench horizontally along slope at an equal elevation.
- Place excavation spoil upslope in order to not contaminate any previously placed riprap.
- Place coir matting over riprap.
- Place live cuttings in trench with basal (bottom) end down and protruding approximately 300 mm above riprap.
- Place soil amendments in trench over live cuttings.
- Place native soil over live cuttings / burlap.
- Species shall be randomly mixed.
- Water the soil amendments (see Design Guideline M), pumping water out of the river or water tank.
- Backfill the trench with native soil and lightly bucket pack only.
- Place gravel filter on slope.
- Place protective O.S.B. sheathing over cuttings while overlapping sheathing edges.
- Install additional riprap live planting row.

Figure D.3: Installation of Vegetated Row[4]

IRRIGATION

- Thoroughly water the live plantings after completion of installation.
- Water slowly and do not allow irrigation water to flow down slope.
- Water live plantings periodically throughout the course of construction, to ensure that the cuttings do not dry out.

[4] Terra Erosion Control Ltd. photo.

OPTION D2 – VEGETATED RIPRAP WITH MULTIPLE VEGETATED ROWS


Figure D.4: Vegetated Riprap Before and After[5]

Description

- Construction of rock riprap and live cuttings.
- Provides bank stability and prevents erosion of streambank by combining both rock and live root systems.
- Provides additional vegetation for higher banks than vegetated riprap application with only one row. See Design Guideline D1 for additional vegetated riprap information.

Suitability

- Streambank toe erosion stabilization with over 1.0 meter high bank.
- Streambanks facing the stream flow.
- Protection of infrastructure such as buildings, roads, water intakes, storm outfalls and utility crossings of watercourses.

[5] Terra Erosion Control Ltd. photos.

Alternatives

A) Brush layer rows and contour fascines (see Design Guidelines I1 and I2) installed above the vegetated riprap to provided additional slope stability on steep eroded moist slopes.

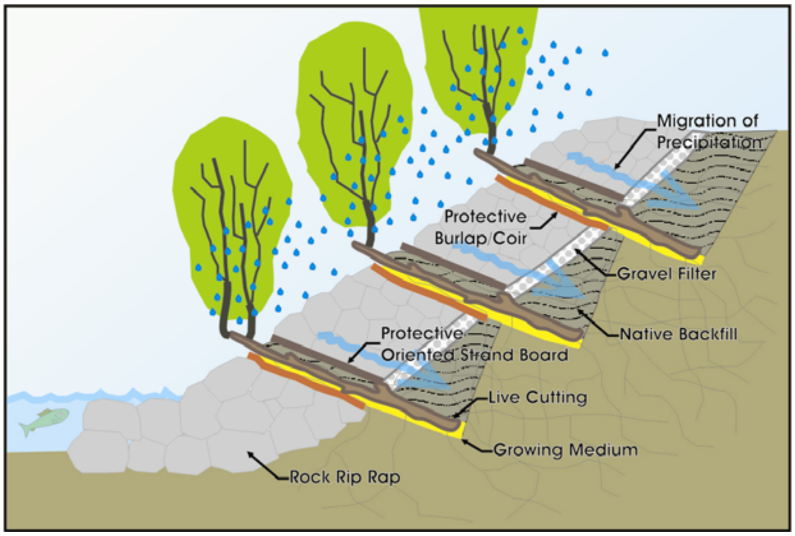


Figure D.5: Vegetated Riprap with Toe Apron and Multiple Vegetated Rows[6]

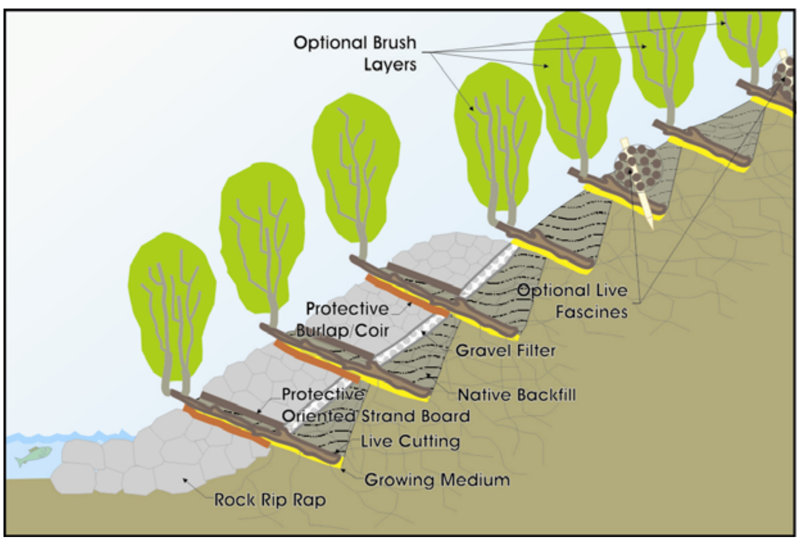


Figure D.6: Vegetated Riprap with Multiple Vegetated Rows and Brush Layer / Fascine Rows Installed Above[7]

[6] Terra Erosion Control Ltd. drawing.
[7] Terra Erosion Control Ltd. drawing.

VEGETATED RIPRAP WITH ONE OR MORE VEGETATED ROWS

B) Brush layer rows and straw wattles (see Design Guidelines I1 and I3) installed above the vegetated riprap to provided additional slope stability on steep eroded dry slopes.

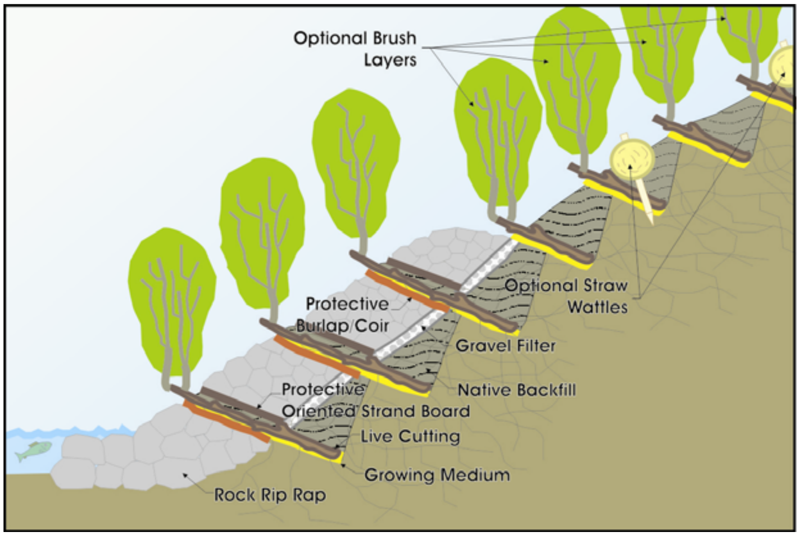


Figure D.7: Vegetated Riprap with Multiple Vegetated Rows and Brush Layer / Straw Wattle Rows Installed Above[8]

C) Branch packing (see Design Guidelines I4) installed above vegetated riprap applications will provide additional slope stability on steep eroded gullied slopes.

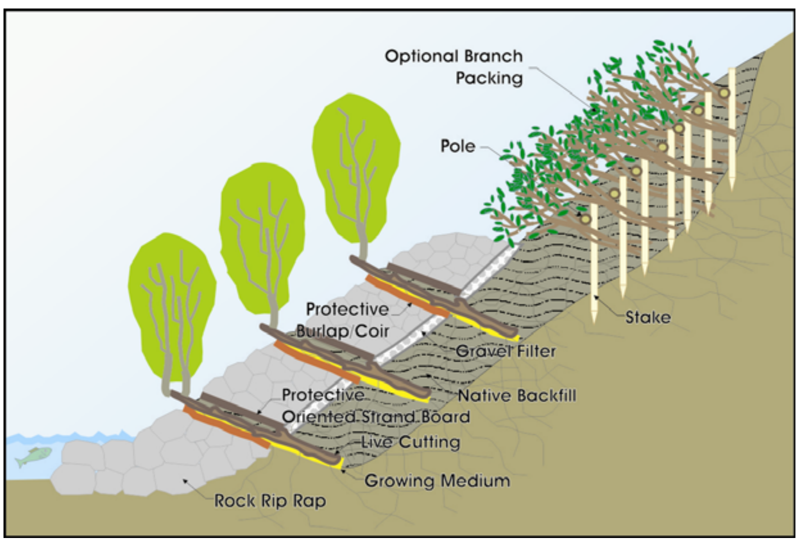


Figure D.8: Vegetated Riprap Application, with Branch Packing Installed Above, on a Steep Eroded Gullied Slope.[9]

[8] Terra Erosion Control Ltd. drawing.

D) Swallow nests located above eroded streambanks can be protected by installing vegetated riprap below the nesting area. This can be done by accessing the lower bank using specialized equipment, such as a walking excavator, and building a temporary ramp made of imported cobbles over geotextile. These cobbles can be retrieved after completion of the work. Rocks can be transported using a tracked dump truck with similar access. Construction activities should occur outside of the nesting season, with appropriate in-stream works regulatory approvals.

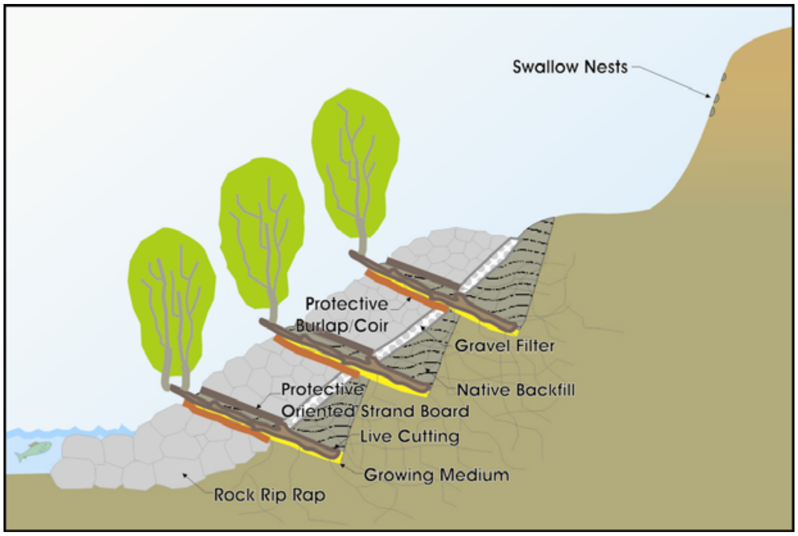


Figure D.9: Protection of Eroded Streambank, Located Below Swallow Nests, Using a Vegetated Riprap Application.[10]

Maintenance

- Water during dry periods until vegetation has been re-established.
- Maintenance of temporary rodent and construction fencing will be required until vegetation is established.
- Establish monitoring schedule.
- Only limited long term maintenance will be required if designed and installed correctly.
- Periodic inspections for undermining or rock displacement.

[9] Terra Erosion Control Ltd. drawing.
[10] Terra Erosion Control Ltd. drawing.

References and Further Reading

- Schiechtl, H.M. and R. Stern. Water Bioengineering Techniques for Watercourse Bank and Shoreline Protection. Cambridge: Wiley-Blackwell, 1997.
- United States Department of Agriculture. Natural Resources Conservation Services, 1996, Engineering Field Handbook – Chapter 16, Streambank and Shoreline Protection. Washington: USDA, 1996.

VEGETATED GABION (OPTION E1) OR LOG CRIB WALL OPTION E2)

Figure E.1: Overview Vegetation Establishment at Log Crib Wall

A) Construction of vegetated crib wall, live cuttings, fill, logs and drainage rocks at the back.
B) Completed work.
C) First season of growth.

Figure E.2: Detail Vegetation Establishment at Log Crib Wall

A) Vegetated crib wall, log structure sloped back and exposed live cuttings.
B) Log joints and coir matting in between layers above water.
C) Vegetated crib wall after approximately 10 years of growth.

Photos above show installation of vegetated crib walls and growth using both synthetic and biodegradable geotextile[1].

[1] Philippe Adam, et al., Biotec Biologie appliquée. *Le génie végétal*. (Paris : Ministère de l'Écologie, de l'Énergie, du Développement durable et de l'Aménagement du territoire, 2008), 129-130.

VEGETATED GABION OR LOG CRIB WALL AND OPTIONAL ROWS OF BRUSH LAYER

Description

Vegetated log crib walls consist of multiple courses of logs, drainage material, geotextiles, backfill and live vegetation.

Gabions are rectangular shaped containers made from twisted wire mesh or welded wire mesh that are filled with stone. When live materials are combined with the gabion baskets they are called vegetated or green gabions.

Suitability

Streambanks facing the stream flow on narrow sections of the Elbow River, West Nose Creek and Nose Creek.

- Gabions and crib walls can be used at the base of slopes to construct a low wall to reduce the steepness of the bank slope above.
- Gabions and crib walls can be used to protect the toe of a slope from stream erosion.
- Gabions can be used as an alternative to large riprap where large riprap is not cost effective, or where vertical structure is required to minimize encroachment of the structure into the stream.

Advantages

- Vegetation can provide a more natural appearance than gabion alone.
- Vegetated gabions and vegetated log crib walls provide overhanging shrub cover for fish and may provide nesting habitat for songbirds.
- Established root system provides additional slope stability by binding the rocks within the gabion and / or logs to the backfill and slope material.
- Roots, stems and leaves of vegetation will improve overall drainage of the structure, providing additional slope stability.
- Rooting within crib wall structures will eventually fill in and reach native soil surrounding the structure and bind into a coherent mass.
- Gabions and crib walls can be constructed around existing mature trees on streambanks (depending on extension of existing root system).
- Fast and simple construction.
- Can negate or reduce the amount of habitat alteration compensation required by regulators.

VEGETATED GABION OR LOG CRIB WALL AND OPTIONAL ROWS OF BRUSH LAYER

Limitations

- Construction only during the dormancy period.
- Requires availability of stones or small rocks.
- Limited height.
- If a retaining wall is higher than 1.0 m and is accessible by the public the Canadian Building Code requires:
- The retaining wall be designed by an Engineer.
- A guard rail at the top.

Design Considerations

- Crib wall or gabion design has to be reviewed by a hydraulic specialist to determine if it will provide adequate erosion protection for the proposed usage.
- Live cuttings harvest and stock handling (see Design Guideline K)
- A portion of the live cuttings should extend into the backfill and / or native bank where possible so that the baskets / crib wall, backfill and original ground can eventually be tied together by the established root system.
- Live cutting length includes the width of the gabions / crib wall, plus fill behind the structure, plus penetration into the original ground if possible, plus 0.2 to 0.3 m exposed.
- Live planting density: 8 to 10 stems per linear meter.
- Live planting angle: 10˚ to 20˚, closer to 10˚ where possible is preferred.
- Live planting top exposure: approximately 0.2 to 0.3 m.
- Live planting above natural vegetation scour elevation.
- Rodent predation and fencing.
- Soil amendments (see Design Guideline M).
- Backfill material.

Implementation

INSTALLATION VEGETATED GABIONS

Install adequate protection to prevent / reduce sediment delivery to the watercourses.

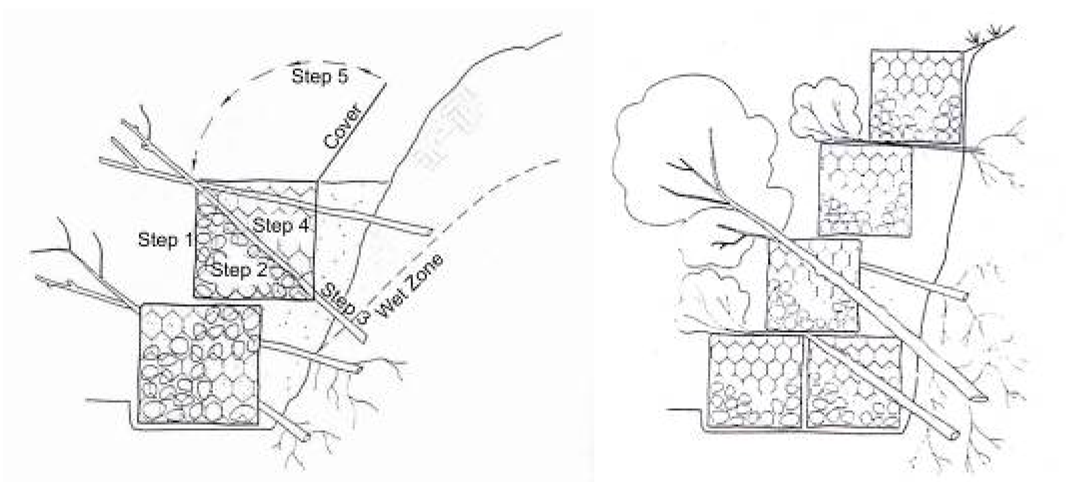


Figure E.3: Vegetated Gabions with Live Stakes Placed Through the Gabion Baskets[2]

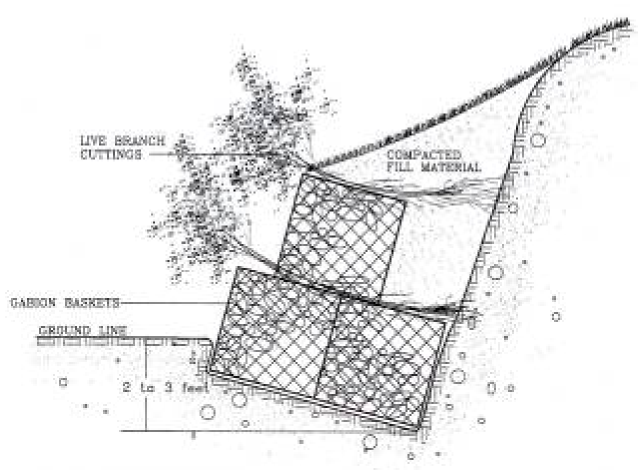


Figure E.4: Live Branches Placed Between Gabion Baskets[3]

[2] Adapted from: Jaime Suáres Días, *Control De Erosión en Zonas Tropicales*, (Colombia: Librería UIS, 2001), 331.
[3] Reproduced from: D.H. Gray and R. B. Sotir, *Biotechnical and Soil Bioengineering Slope Stabilization. A Practical Guide for Erosion Control* (New York: John Wiley & Sons, Inc., 1996), 290.

VEGETATED GABION OR LOG CRIB WALL AND OPTIONAL ROWS OF BRUSH LAYER

Vegetated Gabions

- Starting at the lowest point, excavate a footing base 60 to 90 cm deep within native soil and inclined into the slope at approximately 1:6 (H : V).
- Place excavation spoil upslope and use as backfill material as structure is erected.
- Width to height ratio should be approximately 0.5 for external stability. Wall construction should follow design approved by geotechnical engineer.
- Place the first row of gabion baskets on the prepared footing base and fill with rocks and coarse gravel. A second row of gabion baskets filled with only rocks and coarse gravel may be required depending on natural scour elevation, required height of wall and gabion basket dimensions.
- Place first row of live planting above the natural scour elevation by inserting live cuttings through the gabion basket insuring that 0.5 to 1.0 m of the basal end of the cutting is in the backfill and / or native ground behind the wall and 0.2 to 0.3 m is protruding in front of the basket wire mesh.
- Incorporate soil amendments (see Design Guideline M) within the soil / backfill material over live cuttings.
- A mix of coarse gravel and soil should be spread around the cuttings within the gabion basket.
- Fill remainder of basket with rock and coarse gravel and close wire basket.
- A thin layer of soil can also be placed above each layer of the gabion basket and cuttings can be laid as mentioned above. A second layer of soil is then placed and lightly compacted above the live cuttings.
- Fill material is placed and lightly compacted behind the gabion basket wall as the structure is erected.
- Additional rows of gabion baskets are installed to the required height of the wall.
- If there is any risk of movement, long steel pegs can be hammered into the ground.
- Grade the slope above the gabion wall to desired gradient.
- Seed and plant upper slope with native seed, legumes, shrubs and trees as required (see Design Guideline L).

VEGETATED GABION OR LOG CRIB WALL AND OPTIONAL ROWS OF BRUSH LAYER

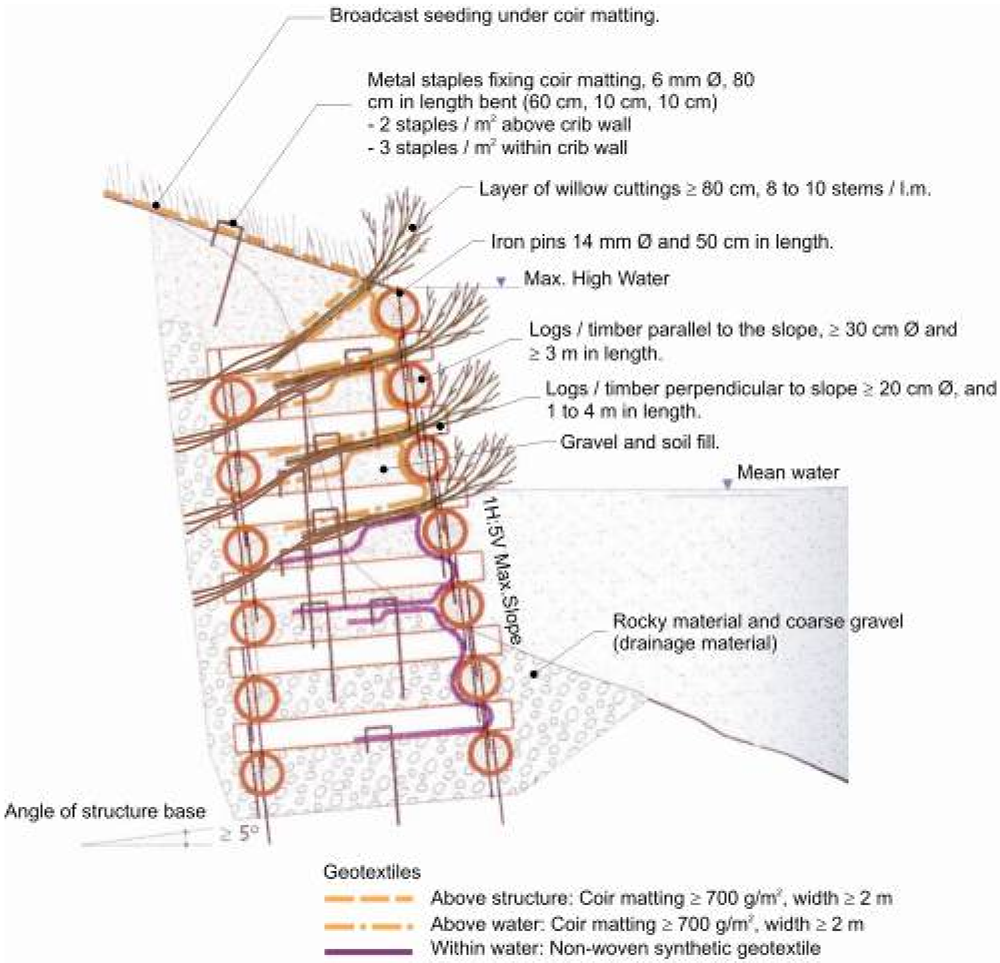


Figure E.5: Vegetated Crib Wall[4]

[4] Adam, 128.

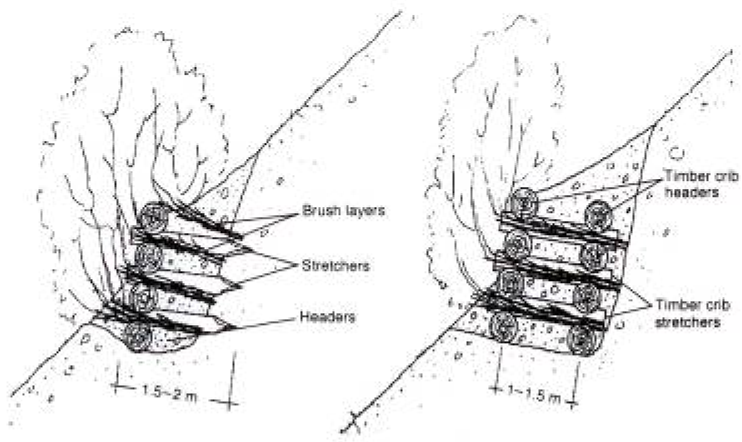


Figure E.6: Live Crib Wall[5]

Vegetated Crib Wall

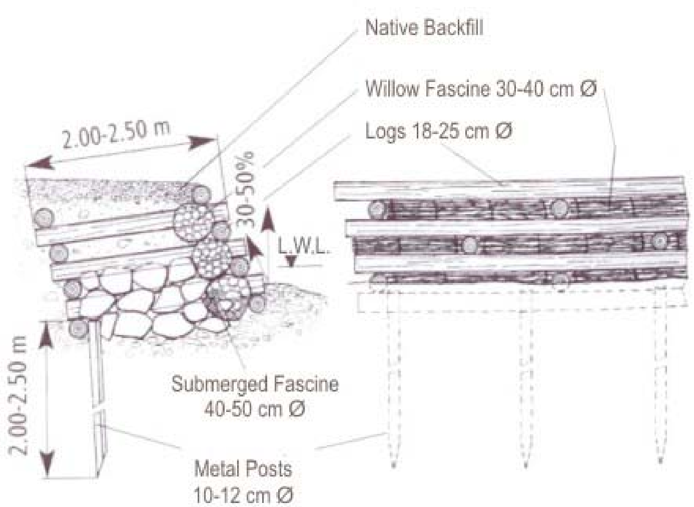
- Starting at the lowest point, excavate a footing base 60 to 90 cm deep within native soil and inclined into the slope at approximately 1:6 (H : V).
- Place excavation spoil upslope and use as backfill material as structure is erected.
- Vegetated crib walls can be constructed using a single or double header structure (See Live Crib Wall sketch, reference 5).
- Place first row of logs or timbers at the front and back (if constructing a double header wall), approximately 2.0 m apart.
- Place the second row of logs or timbers perpendicularly to the slope above the first row, overhanging approximately 15 cm in the front and back, and secure using long spikes or small diameter re-bar hammered through the log joints.
- Follow adjacent slope gradient in-sloping structure as it is erected.
- Fill in lower section of crib wall with riprap rocks and coarse gravel, place synthetic geotextile above placed rock and fill with additional rocks and coarse gravel wrapping fabric behind front header logs (see Vegetated Crib Wall drawing, reference 4) up to the natural scour line.
- Secure geotextile with metals pins.
- Place coarse gravel and top soil over synthetic geotextile (~ 15 to 20 cm).

[5] Reproduced from: H.M. Schiechtl and R. Stern, *Ground Bioengineering Techniques for Slope Protection and Erosion Control* (Cambridge: Wiley-Blackwell, 1996), 96.

- Place first row of vegetation above the natural scour elevation, by placing layers of live cuttings at approximately 10º, in-sloped above the coarse gravel / soil layer, insuring that the basal end of the cutting is placed within the backfill and drain gravel reaching towards the back of the wall and protruding 0.2 to 0.3 m in front.
- Incorporate soil amendments (see Design Guideline M) within the soil / backfill material over live cuttings.
- Place coir matting over the covered layers of live cuttings and unfold in front of the cuttings.
- Place lift of soil to the height of crib / log thickness, broadcast native seed mix over front portion of soil lift and unfold layer of coir over soil and secure with metal pins.
- Place additional layer of soil and live cuttings and repeat soil lift layer with fabric to desired height of wall.
- Construct wall height as required.
- Grade the slope above the vegetated crib wall to desired gradient.
- Seed and plant upper slope with native seed, legumes, shrubs and trees as required (see Design Guideline L).

Optional Rows of Brush Layers

- A brush layer consists of a row of live cuttings (willow spp., balsam poplar and red osier dogwood) placed in a criss-cross or overlapping manner in between layers of soil, with tips protruding beyond the face of the fill (see Design Guideline I1).
- Live fascines (see Design Guidelines I2) can be incorporated into the crib wall as shown in Figure E.7 and photos below.



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- **Figure E.7: Crib Wall Fascines**

Vegetated crib wall construction using fascines bundles placed on the face of the structures.[6]

[6] Photos, Dr. Hans Peter Rauch Universität für Bodenkultur

VEGETATED GABION OR LOG CRIB WALL AND OPTIONAL ROWS OF BRUSH LAYER

Vegetated crib wall using fascines bundles placed on face of structures.[7]

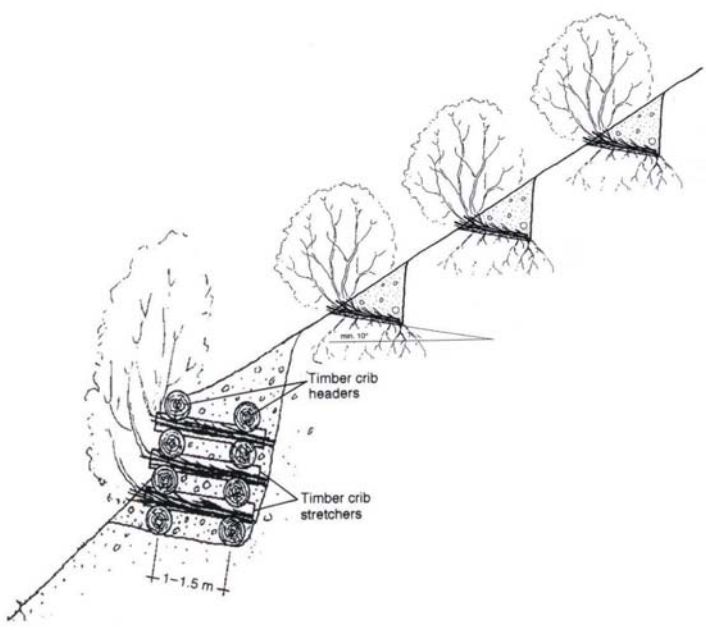


Figure E.9: Vegetated Crib Wall with Brush Layers[8]

[7] Photos Terra Erosion Control Ltd.
[8] Adapted from: H.M. Schiechtl and R. Stern. *Ground Bioengineering Techniques for Slope Protection and Erosion Control* (Cambridge: Wiley-Blackwell, 1996), 81, 96.

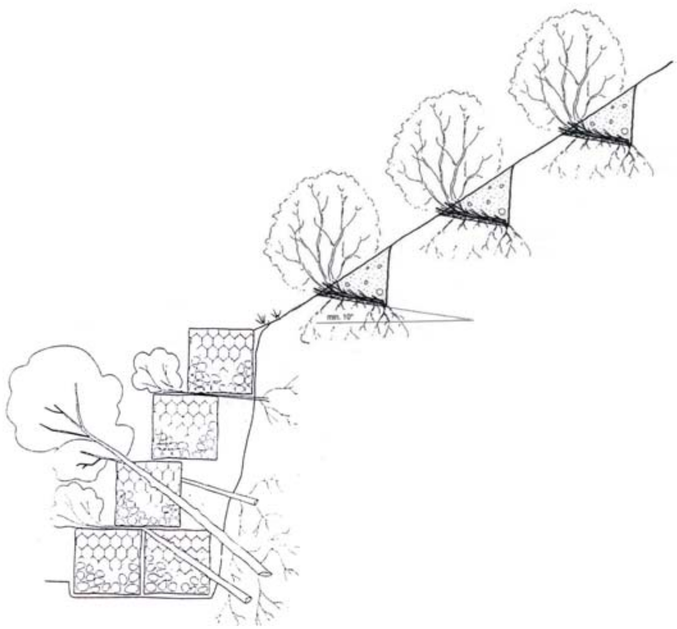


Figure E.10: Vegetated Gabions with Brush Layers[9]

[9] Adapted from: Jaime Suáres Días. *Control De Erosión en Zonas Tropicales* (Colombia: Librería UIS, 2001), 331. and Schiechtl, 81.

Maintenance

- Water during dry periods until vegetation has been re-established.
- Maintenance of temporary rodent and construction fencing will be required until vegetation is established.
- Establish monitoring schedule.
- Only limited long term maintenance will be required if designed and installed correctly.

References and Further Reading

- Adam, Philippe, et al. Le génie végétal. Paris: Ministère de l'Écologie, de l'Énergie, du Développement durable et de l'Aménagement du territoire, 2008.
- Días, Jaime Suáres. Control De Erosión en Zonas Tropicales. Colombia: Librería UIS, 2001.
- Gray, D.H. and R. B. Sotir. Biotechnical and Soil Bioengineering Slope Stabilization. A Practical Guide for Erosion Control. New York: John Wiley & Sons, Inc., 1996.
- Schiechtl, H.M. and R. Stern. Ground Bioengineering Techniques for Slope Protection and Erosion Control. Cambridge: Wiley-Blackwell, 1996.

VEGETATING EXISTING ROCK RIPRAP

Description

- Live staking of existing riprap improves riparian, aquatic, and terrestrial habitat while softening rock appearance.

Suitability

- Existing riprap of shallow to moderate thickness.

Advantages

- Enhances riparian habitat by establishing woody shrubs and trees.
- Enhances aquatic habitat by creating shade and contributing small organic debris to the stream.
- Enhances terrestrial habitat by creating cover, shelter, and food.
- Provides a more natural appearance.

Limitations

- Working around existing riprap can be difficult, especially if it is thick and/or lined with geotextile.
- Lower density of plantings compared to vegetated riprap. See Design Guideline D.
- Specialized equipment, such as a walking excavator and / or a large excavator with a long reach might be required to access riprap on high banks.
- Might be difficult to install in loose native material.

Design Considerations

- Calculate riprap area and determine appropriate planting density per hectare. i.e., 700 to 1000 stems/ha or 3.4 to 4.0 m triangular spacing.
- Harvesting of live cuttings and handling of stock. Stronger, larger diameter stakes should be used for this application. See Design Guideline K.
- Soil amendments may be applied as slurry in conjunction with the planting of live cuttings or live poles. See Design Guideline M.

VEGETATING EXISTING ROCK RIPRAP

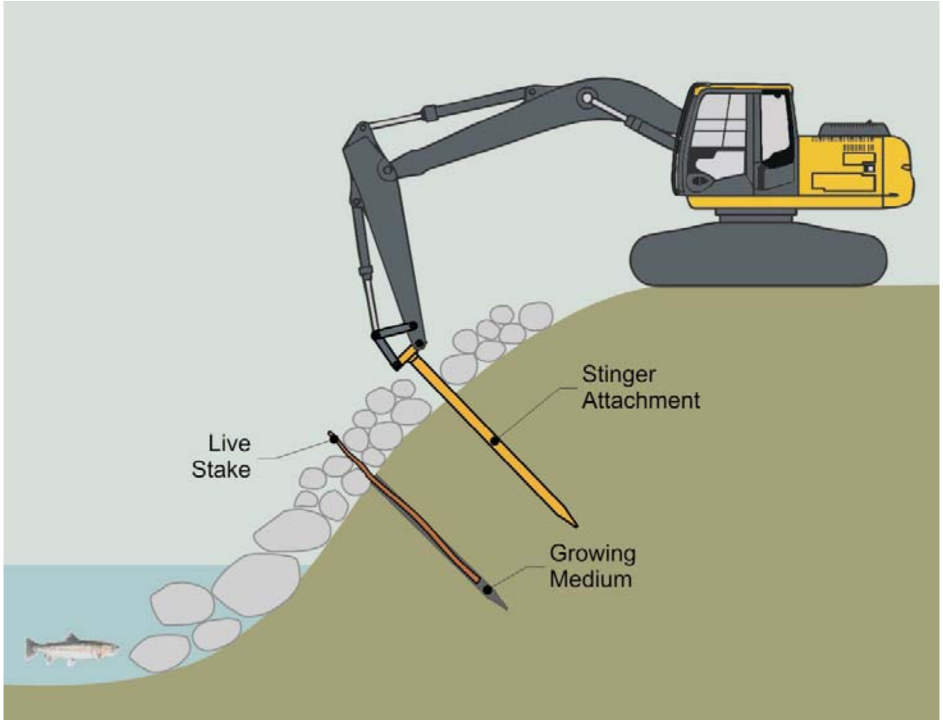


Figure F.1: Live Staking with Excavator Stinger Attachment[1]

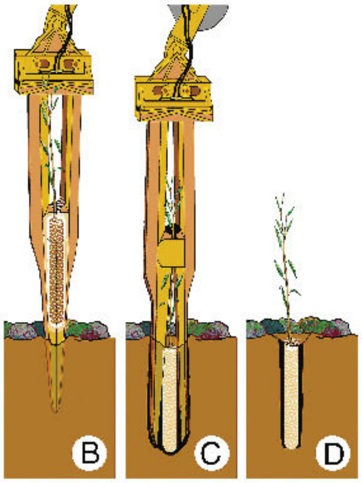
Implementation

- Excavator with stinger attachment or long narrow bucket.

STINGER TECHNIQUE

- Remove or reposition riprap as required using stinger attachment.
- Insert stinger attachment into soil and enlarge hole as required by wiggling the stinger.
- Remove stinger and insert live stake in the void.
- Use hammer or excavator pushing attachment to push live stake in the void. If using a hammer, cut the top of the live stake to remove any splitting or cracking.
- Place soil amendments in void around live cutting as slurry or by watering.
- Paint top ends of cutting tips after installation.

[1] Terra Erosion Control Ltd. drawing



Expandable Stinger Used to Plant Nursery Stock could be adapted for live cuttings or small poles[2]

Figure F.2: Expandable Stinger[3]

BUCKET TECHNIQUE

- Remove or reposition riprap as required using bucket.
- Force excavator bucket into soil to desired depth and open ground to allow placement of live stakes.
- Hold bucket in place while ground is opened.
- Place 5 to 10 live cuttings with additional soil and soil amendments.
- Water thoroughly to saturate soil amendments.
- Insert a piece of oriented strand board (width of bucket) above the cutting to protect it from upper riprap.
- Release soil over placed cuttings by retrieving excavator bucket.
- Replace any displaced riprap and compact lightly using back of bucket.
- Repeat similar actions at the desired spacing.

[2] WildLands, Inc., *Mechanical Planting,* http://www.wildlands-inc.com/mechanical.html, (October 28, 2010).
[3] WildLands, Inc., *Mechanical Planting,* http://www.wildlands-inc.com/mechanical.html, (October 28, 2010).

Figure F.3: Planting of existing riprap using excavator bucket[4]

Maintenance

- Monitor site for growth for the first three growing seasons, water if necessary;
- Add mulch if required.

[4] Terra Erosion Control Ltd. photo

LIVE POLE DRAINS WITH OPTIONAL ROCK DRAIN

Figure G.1: Installed Live Pole Drains and Same Site with Two Years of Growth[1]

Description

Option G1 is a Live pole drain system that consists of cylindrical bundles of live cuttings (see Design Guideline K). Live pole drains are normally installed in a chevron fashion, where drain fascines are connecting to a main central live drain. Rock / drain stone (Option G2), non-live poles or drainage pipe can also be incorporated into the center drain in wetter conditions.

[1] Terra Erosion Control Ltd. photos.

LIVE POLE DRAINS WITH OPTIONAL ROCK DRAIN

Suitability

- Wet slopes where there is evidence of moderate to high ground seepage contributing to slope instability.
- Steep slopes with seepage, where water can be drained within lower toe protection structures.

Advantages

- Immediately effective after installation.
- Provides a live drain system for moderate to high ground seepage.
- Suitable for area drainage.
- Drained water can be directed into various locations such as: vegetation, ditch line and / or French drain.
- Provides vegetation cover and shallow slope stabilization.
- After vegetation is established, drainage function is increased by water use of the vegetative cover.

Limitations

- Large quantity of live material required.
- Only provides shallow slope stabilization until roots are well established.
- Can be labour intensive to install if equipment is not used.
- Might not be suited for heavy water seepage.

Design Considerations

- Layout of live pole drain systems should follow the general slope fall line, starting where seepage occurs on the slope. Outlet is to be located where drainage of water is required.
- Center drain generally consists of two to three cylindrical bundles.
- Gravel filter material and / or perforated pipe should be calculated based on drainage requirements.
- Side drains generally consists of drain fascine bundles (Design Guideline I1) connected to central drain.
- Side drains can be constructed with or without brush layers.
- Live cuttings harvesting and stock handling: (see Design Guideline K). Preferred species for live cuttings include native willow, balsam poplar and red osier dogwood.
- Non rooting live cuttings (i.e., trembling aspen or alder) can be used in the center of the bundles or buried bundles as fill material within the central drain.

- Live cutting length: up to manageable fascine bundle length and shorter pieces can be used when overlapped in the bundles.
- Bundle diameter size: central drain approximately 300 mm, drain fascines approximately 200 mm. Diameter can be adjusted to volume of water flow.
- Ends of cylindrical bundles should be thinner in order to accommodate required diameter for intertwining overlap of ends when installed.

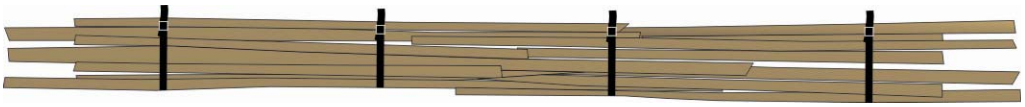


Figure G.2: Fascine Bundle[2]

- Bundles secured with twine or strapping during construction.
- Bundles secured within each other during installation.
- Wooden stakes and / or "T" re-bars (see photo below) are used to secure bundles within the trenches on the slope.

Figure G.3: Fascine Bundle with "T" Rebar[3]

- Back fill on either side of central drains and contour fascines, leaving approximately 1/3 of bundle exposed with fill placed in between stems.
- Rodent predation and fencing.
- Soil Amendments: See Design Guideline M.
- For Option G2 rock drain portion, backfill with clean, coarse drainage gravel and / or non-woven geotextile fabric to provide filtration separation with adjacent soils.

[2] Terra Erosion Control Ltd. drawing.
[3] Terra Erosion Control Ltd. photo.

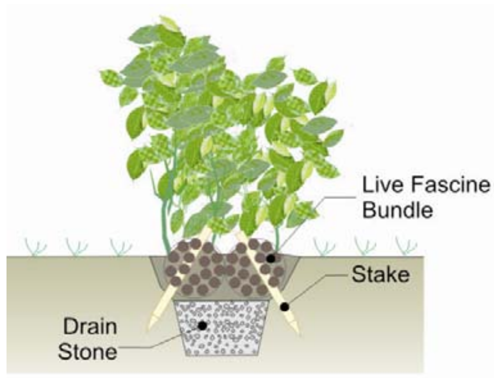


Figure G.4: Option G2 – Live Pole Drains Center Rock Drain Section[4]

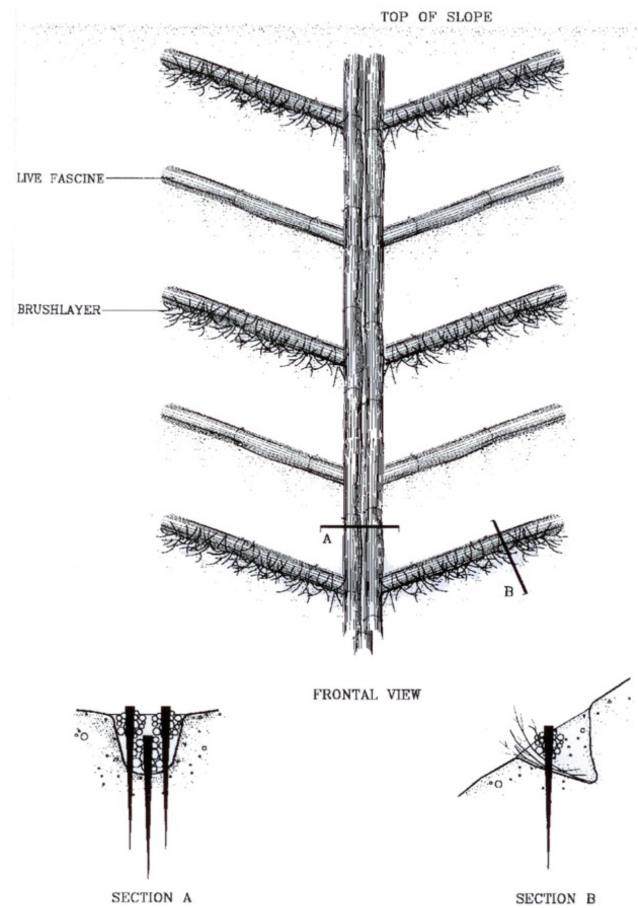


Figure G.5: Option G1 – Live Pole Drains Frontal View and Sections[5]

[4] Terra Erosion Control Ltd. drawing.

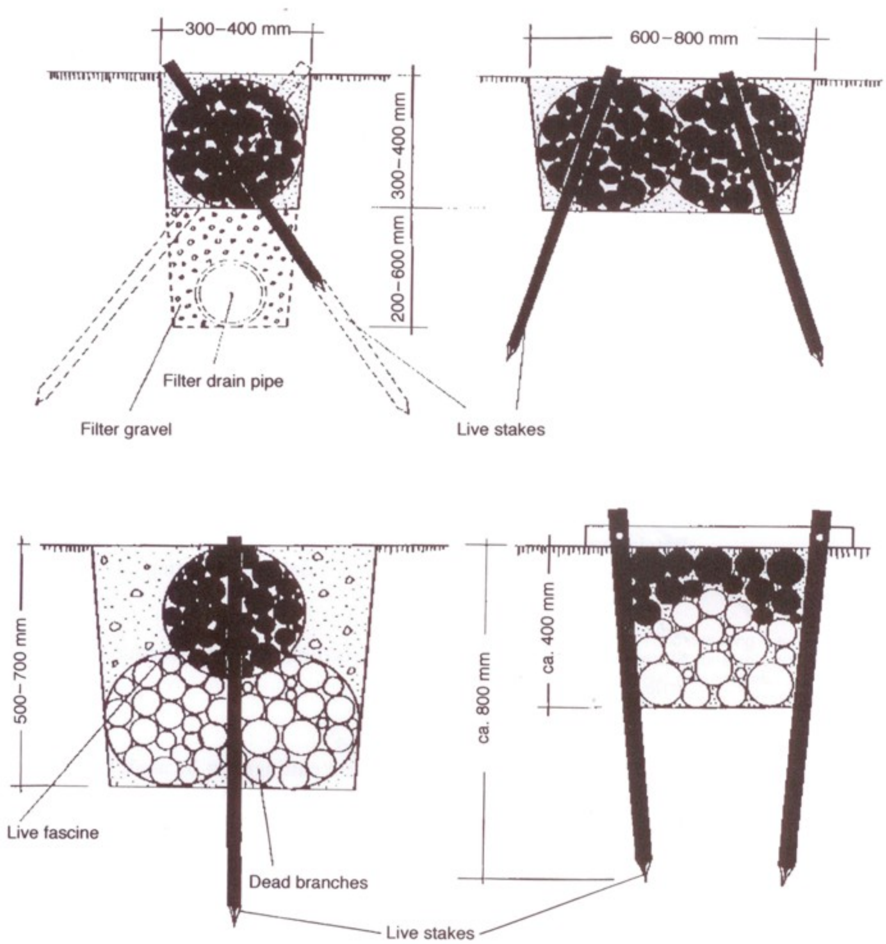


Figure G.6: Live Pole Drains Center Drain Alternative Sections[6]

Implementation

- Grading of slope to required gradient.
- Layout live pole drain system using spray paint and / or wooden stakes.
- Manual or machine assisted trenching for installation of central drain and drain fascines on slope.
- Place gravel filter and / or perforated drainage pipe within gravel, leaving enough room for the central drain to lie flush with the soil surface.

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[5] Reproduced from: D.H. Gray and R. B. Sotir, Biotechnical and Soil Bioengineering Slope Stabilization. A Practical Guide for Erosion Control (New York: John Wiley & Sons, Inc., 1996), 227.
[6] Reproduced from: H.M. Schiechtl and R. Stern, *Ground Bioengineering Techniques for Slope Protection and Erosion Control* (Cambridge: Wiley-Blackwell, 1996), 72.

- Apply soil amendments within excavated trench (see Design Guideline M).
- Placement of central drains starting at bottom of slope where upper bundles are intertwined with lower bundles, progressively working up slope.
- Intertwine drain fascines into main drain.
- Intertwine additional drain fascines into each other, progressively working up slope to desired length.
- Place "T" re-bars and / or wooden stakes in the middle of the drain and below twine or strapping, at approximately a 1.5 m slope distance interval.
- Use electric demolition hammer with ground rod pounding attachment or sledge hammer to insert re-bar in ground.
- Back fill on either side of central drains and contour fascines leaving approximately 1/3 of bundle exposed with fill placed in between stems.
- Clean up any excess soil over central drain and contour fascines after back filling.
- Connect lower portion (outlet) of central drain with toe protection structures.
- Seed and plant exposed soil in between central drain, drain fascines and remainder of disturbed slope with native seed, legumes, shrubs and trees as required (see Design Guideline L).

Maintenance

- Monitor site for growth and erosion for the first three growing seasons and repair minor failures if necessary.

References and Further Reading

- Gray, D.H. and R. B. Sotir. Biotechnical and Soil Bioengineering Slope Stabilization. A Practical Guide for Erosion Control. New York: John Wiley & Sons, Inc., 1996.
- Schiechtl, H.M. and R. Stern. Ground Bioengineering Techniques for Slope Protection and Erosion Control. Cambridge: Wiley-Blackwell, 1996.

PLANTING OF LIVE STAKES OR SEEDLINGS WITH MULCH

Description

- Planting of live stakes or container stock seedlings, in combination with mulching, can be used to enhance the species diversity and riparian attributes of areas colonized by non-native grasses and invasive weeds.

Suitability

- Streambank and riparian areas colonized by fast spreading, non-native and invasive herbaceous[1] species. This includes rhizomatous, non-native grasses such as smooth brome [Bromus inermis] and invasive weeds designated as "noxious" and "prohibited noxious" under Alberta's Weed Control Act and Regulation and the City of Calgary's Community Standards Bylaw Number 5M2004.
- Streambank and riparian areas with human-caused bare ground.
- Streambank and riparian areas with a lack of native tree and shrub species and / or with only mature-aged woody plants.

Advantages

- Removes and inhibits encroachment of disturbance vegetation (weeds and non-native grasses) and allows live native tree and shrub cuttings or seedlings to establish.
- Enhances riparian habitat structure and diversity by establishing native shrubs and trees.
- Creates age class diversity in the understory of mature / decadent tree stands, improving the longevity potential of riparian forests.
- Augments fish and wildlife food sources, habitat availability and habitat connectivity.
- Improves riparian stability, water infiltration, runoff filtration and sediment capture functions.
- Creates improved wildlife viewing and outdoor education opportunities.
- Augments aesthetic appeal of streambanks and riparian zones.
- Supervised manual plantings can be done as part of volunteer stewardship activities. Activities of this kind promote community and stewardship building.

Limitations

- Straw mulch may attract rodents and cause problems with girdling and / or the chewed bark of planted seedlings, use of woody mulch is preferable.

[1] Non-woody plants

- Access (limited road access to bring in material and tools required) and slope gradient over 40% will require specialized machinery (see Design Guideline N).
- Regular watering may be necessary until new plantings establish.
- Long-term, ongoing monitoring and control is needed to control weeds and non-native grasses.
- Access restrictions may be needed to prevent damage to new plantings from public recreation or dog use.

Design Considerations

- Calculate area and determine appropriate planting density per hectare. A density of 1200 to 1400 stems / ha is recommended for balsam poplar and conifers.
- Shrubs density should be planted at 10000 stems / ha using grid spacing of 1.0 m (not shown on diagram).
- Place one layer of cardboard and 0.15 cm layer of mulch around planted live stakes or large stock seedlings to control non-native grasses and weeds. See diagrams below for various planting and mulching techniques and specifications.
- Mulch (from trees and shrubs) might be obtained free from arborists or municipal transfer stations.
- Where possible and applicable (size and budget limitation) cut down herbaceous cover and apply 0.15 cm layer of mulch over treatment area in between planted live cuttings and / or seedlings.
- Cardboard might be obtained free from recycling depots or municipal transfer stations.
- Live cuttings harvesting and stock handling - see Design Guideline K.
- Nursery stock selection – see Design Guideline L.
- Soil amendments may be added in conjunction with the planting of live cuttings or seedlings – see Design Guideline M.
- Recommended timing of plantings, seedlings March to June, live cuttings March to June and October to November.
- Recommended watering twice per week, weather dependant.

PLANTING OF LIVE STAKES OR SEEDLINGS WITH MULCH

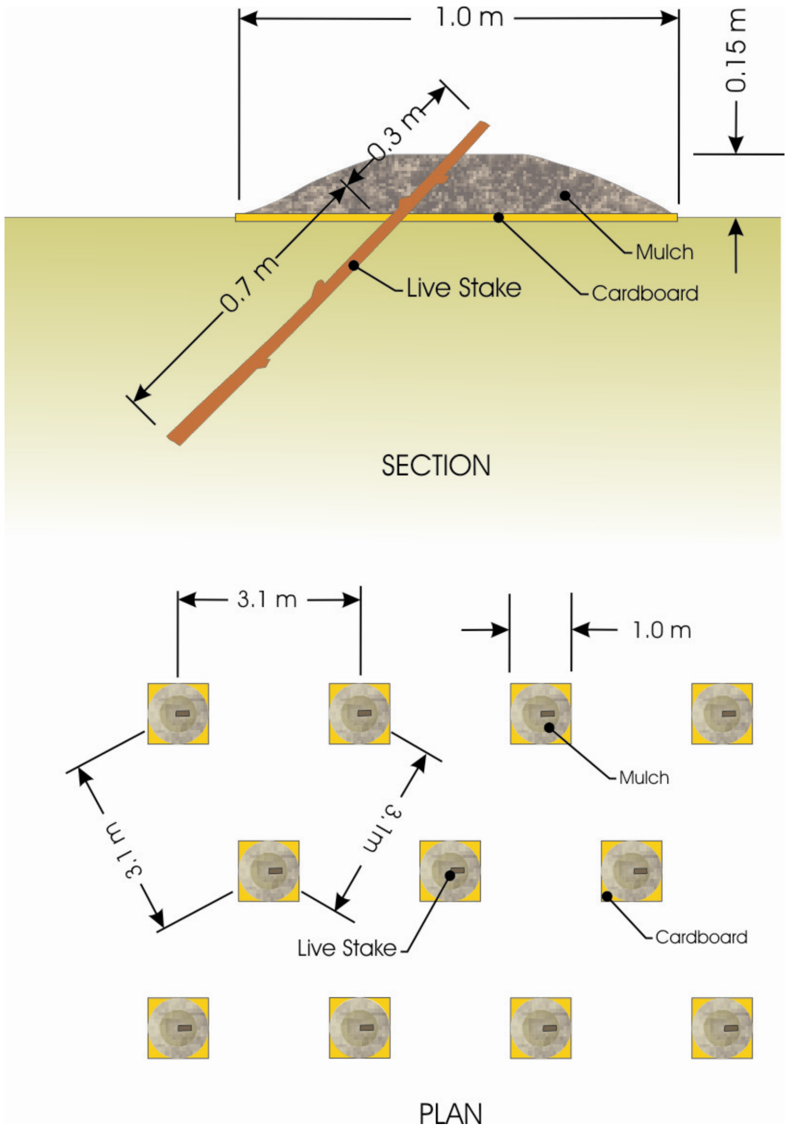


Figure H.1: Live Staking Plan View and Cross Section Using 3.1 m Triangular Spacing (~ 1200 stems / ha)[2]

[2] Terra Erosion Control Ltd. drawing

PLANTING OF LIVE STAKES OR SEEDLINGS WITH MULCH

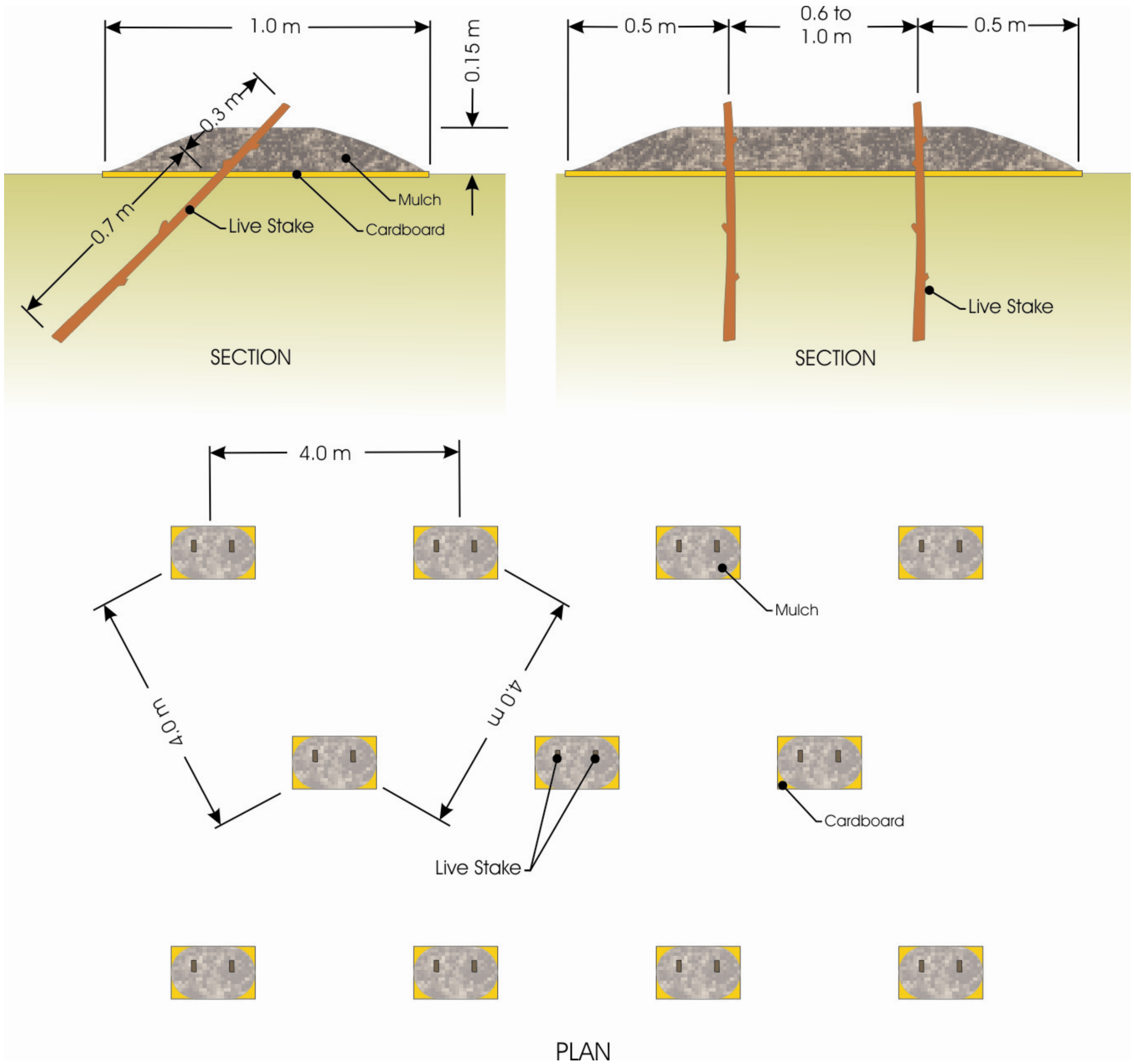


Figure H.2: Double Pole Live Staking with Equipment, Plan View and Cross Section Using 4.0 m Triangular Spacing (~ 1400 stems / ha)[3]

[3] Terra Erosion Control Ltd. drawing

PLANTING OF LIVE STAKES OR SEEDLINGS WITH MULCH

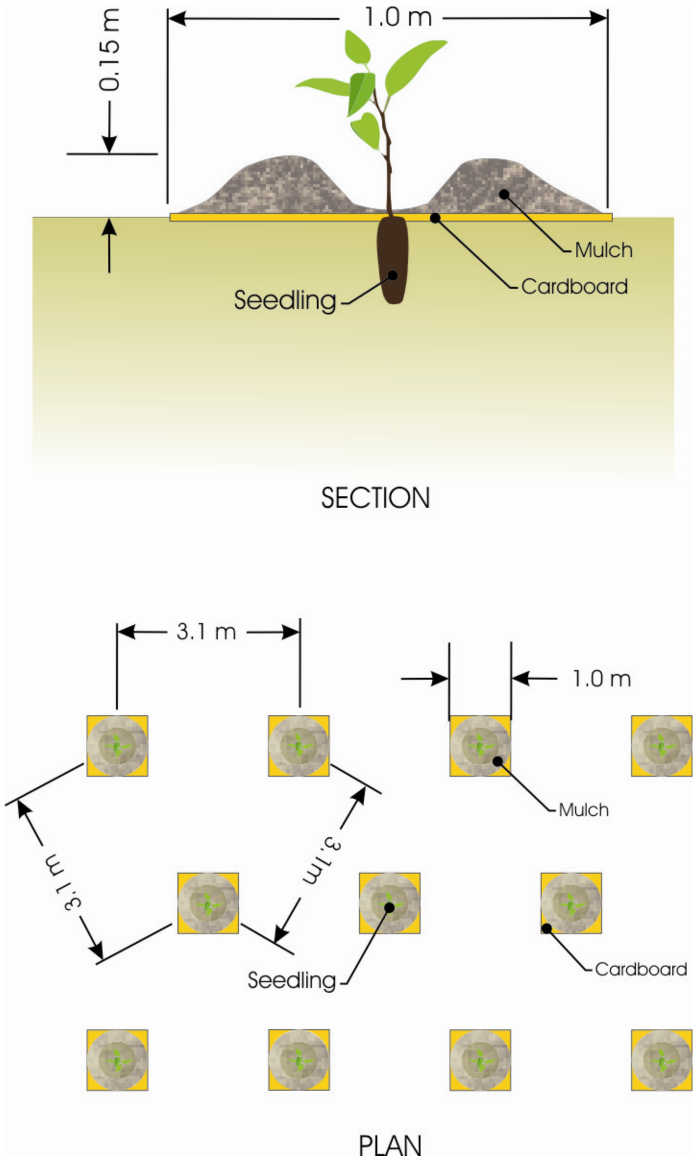


Figure H.3: Seedling Planting Plan View and Cross Section Using 3.1 m Triangular Spacing (~ 1200 stems / ha)[4]

Implementation

Machine assisted planting of live cuttings, at the required triangular spacing:

[4] Terra Erosion Control Ltd. drawing

- Force excavator bucket into soil to desired depth and open ground to allow placement of live cuttings (see photo below).

Figure H.4: Machine Assisted Planting[5]

- Place one or two live cuttings and soil amendments.
- Water thoroughly to saturate soil amendments.
- Release soil over placed cuttings by retrieving excavator bucket.
- Compact slightly using back of bucket.
- Repeat similar actions at the desired spacing.
- Alternatively, a skid steer with a narrow bucket, auger or stinger can be used.

Manual planting techniques:

- Manually plant live cuttings using a large pry bar and hammer or a hand auger.
- If a hammer is used to complete live stake installation, insure the top is cut to remove any splitting and / or cracking of stems.
- Paint protruding ends of cutting tips after installation.
- Seedlings can be planted by hand using a tree planting shovel.

Maintenance

- Monitor site for growth for the first three growing seasons and manually remove grasses and weeds competing with planted live cuttings and / or seedlings.
- Add mulch if required.
- Recommended watering twice per week, weather dependant.

[5] Terra Erosion Control Ltd. photo

Streambank Erosion and Potential Remedial Measures

Guideline I1

I1) BRUSH LAYERS
I2) LIVE FASCINES
I3) STRAW WATTLES
I4) BRANCH PACKING
I5)BRUSH MATTRESS

Figure I.1: Brush Layer Installation[1]

I1) Brush Layers

Description

A brush layer consists of a row of live cuttings (willow spp., balsam poplar and red osier dogwood) placed in a criss-cross or overlapping manner in between layers of soil with tips protruding beyond the face of the fill.

[1] Terra Erosion Control Ltd. photos.

Streambank Erosion and Potential Remedial Measures

Guideline I1

I1) BRUSH LAYERS
I2) LIVE FASCINES
I3) STRAW WATTLES
I4) BRANCH PACKING
I5)BRUSH MATTRESS

Suitability

Suitable for bank stabilization and erosion control of steep eroded banks in conjunction with / or above constructed toe protection structures.

Advantages

- Easy to construct.
- Fast establishment of stabilizing root system.
- Immediate impact, protective and stabilizing effect provides deep rooting.

Limitations

- Not suitable on its own for stabilization of deep seated slope failures.
- Willows and red osier dogwood shrubs are suitable for moist soils (e.g. natural seeps) or shaded (north-facing) aspects in Calgary. On dry slopes consult a plant ecologist for alternative native shrubs suitable for these conditions. Hedge brush layers which utilize rooted stock may be an option for these types of dry conditions. See discussion in Alternatives section of this guideline.

Design Considerations

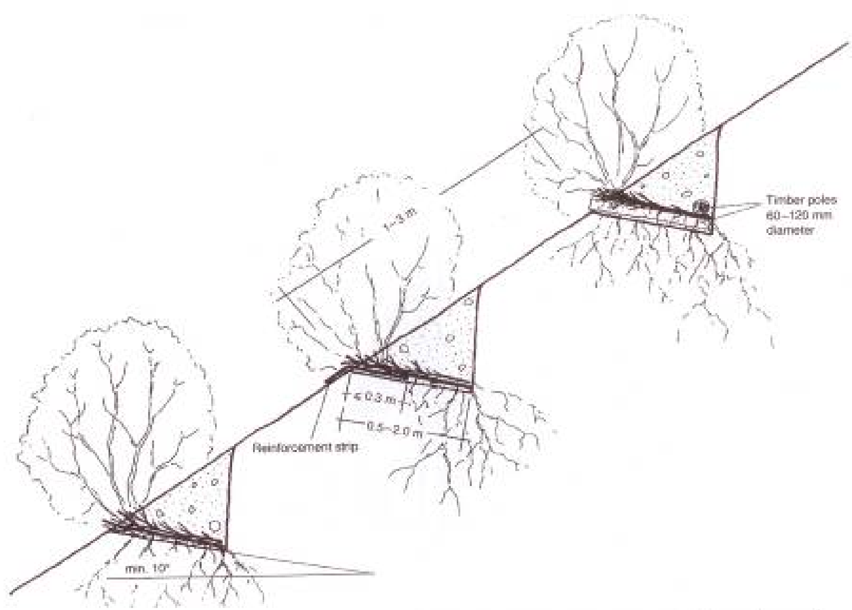


Figure I.2: Standard Brush Layer (Bottom), Brush Layer with Geotextile or Geogrid (Middle) and Brush Layer Reinforced with Poles (Top)[2]

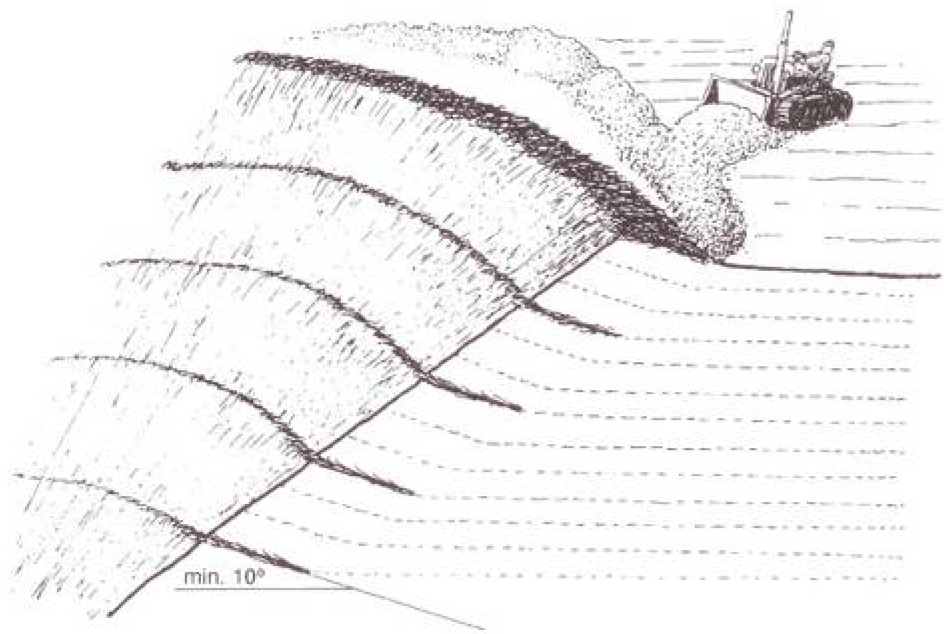


Figure I.3: Brush Layer Construction[3]

- Trenched installation or backfilled installation of brush layer (manually or machine).
- Live cuttings harvesting and stock handling: See Design Guideline K.
- Live cutting length: 1.0 m minimum in soil, plus 0.2 m exposed (length can be adjusted to depth of fill).
- Live brush layers planting density: 8 to 10 stems per linear meter.
- Live planting angle: 10˚.
- Rodent predation and fencing.
- Soil Amendments: See Design Guideline M.
- Backfill material.
- Brush layer spacing: See table below.

[2] Reproduced from: H.M. Schiechtl and R. Stern. *Ground Bioengineering Techniques for Slope Protection and Erosion Control* (Cambridge: Wiley-Blackwell, 1996), 81.
[3] Reproduced from: Schiechtl, 80.

Table I1
Recommended Spacing of Brush Layer Rows on Slopes[4]

Slope Steepness	Approximate Slope Distance Between Brush Layer Rows	
	On Angle Wet Sloped	On Contour Dry Slopes
(H:V)	(m)	(m)
1.5:1 to 2:1	0.9 to 1.2	1.2 to 1.5
2:1 to 2.5:1	0.9 to 1.2	1.5 to 1.8
2.5:1 to 3:1	1.2 to 1.5	1.8 to 2.4
3:1 to 4:1	1.5 to 1.8	2.1 to 3.0

Implementation

- Install adequate protection to prevent / reduce sediment delivery to water bodies.
- Install site specific and adequate toe protection.
- At required vertical spacing above installed toe protection, force excavator bucket into soil to desired depth and open ground to allow placement of live cuttings (see photo below).

Figure I.4: Machine assisted brush layer planting[5]

- Place live cuttings and soil amendments.
- Water thoroughly to saturate soil amendments.

[4] Adapted from: D.H. Gray and R. B. Sotir, *Biotechnical and Soil Bioengineering Slope Stabilization. A Practical Guide for Erosion Control* (New York: John Wiley & Sons, Inc., 1996), 237.
[5] Terra Erosion Control Ltd. photo

- Release soil over placed cuttings by retrieving excavator bucket.
- Compact slightly using back of bucket.
- Repeat similar actions adjacent to planted brush layer.
- Once the first row is complete, continue with additional rows as required.
- Alternatively, a complete trench can be excavated at first (manually or using a machine), live cuttings and soil amendments can be placed and watered and the trench can then be back filled.

Alternatives

- Contour fascines (see Design Guideline I2) can be installed above every second brush layer to act as physical barriers reducing rilling, trapping sediment and slowing runoff. Contour fascines should be installed on wetter or moist slope aspects.
- Straw wattles (see Design Guideline I3) can be installed above every second brush layer to act as physical barriers reducing rilling, trapping sediment and slowing runoff and should be utilized on dry slope aspects.
- “Hedge brush layers” are a variation on standard brush layers. They utilize rooted stock, possessing layering (adventitious) rooting properties, as the vegetative component within the brush layers (i.e., alder [*Alnus* spp.]). The advantage of hedge brush layers are that they utilize species that do not root from cuttings but have high slope stabilization properties because of their root systems and for some species such as alder, the plant will provide nitrogen fixing into the soil. Caution should be used to ensure only native shrubs are used for this application.

Maintenance

- Monitor site for growth and erosion for the first three growing seasons and repair minor failures if necessary.
- Water the site, based on weather and whether the site has ‘wet’ or ‘dry’ conditions. Water up to twice a week during the first growing season.

References and Further Reading

- Gray, D.H. and R. B. Sotir. Biotechnical and Soil Bioengineering Slope Stabilization. A Practical Guide for Erosion Control. New York: John Wiley & Sons, Inc., 1996.
- Schiechtl, H.M. and R. Stern. Ground Bioengineering Techniques for Slope Protection and Erosion Control. Cambridge: Wiley-Blackwell, 1996.

I1) BRUSH LAYERS
I2) LIVE FASCINES
I3) STRAW WATTLES
I4) BRANCH PACKING
I5) BRUSH MATTRESS

Installation of Fascines Rows on Steep Slope[1]

Brush Layers and Live Fascine Rows[2]

Backfilled Live Fascine[3]

Figure I.5: Installation of Fascines and Brush Layers

I2) Live Fascines

Description

Fascines are cylindrical bundles of live cuttings from branches and stems of shrubs and trees, which have properties of vegetative propagation (i.e., Salix spp. / Populus balsamifera spp.). The bundles are tied together using twine or strapping. They are installed in shallow trenches and anchored in

[1] Terra Erosion Control Ltd. photo.
[2] Terra Erosion Control Ltd. photo.
[3] Terra Erosion Control Ltd. photo.

the trench using wooden stakes. These are used on slopes, along the contours, to provide a physical barrier that slows run off and traps sediment. They can also be angled to provide drainage.

Suitability

- Wet or moist aspect slopes.
- Steep gradient slopes.
- Used as drainage structures in combination with central live pole drains (see Design Guideline G).

Advantages

- Reduces rilling erosion potential by forming short benches, dispersing run off and trapping sediment.
- Provides protection against surface erosion.
- Simple and effective structures that require minimal excavation.
- Normally installed manually.

Limitations

- Not suitable for dry aspect slopes due to shallow depth of installation and desiccation problems.
- Only provides shallow slope stabilization until roots are well established.
- Construction only during the dormancy period.
- May require fall protection equipment for workers on steep gradient slopes.

Design Considerations

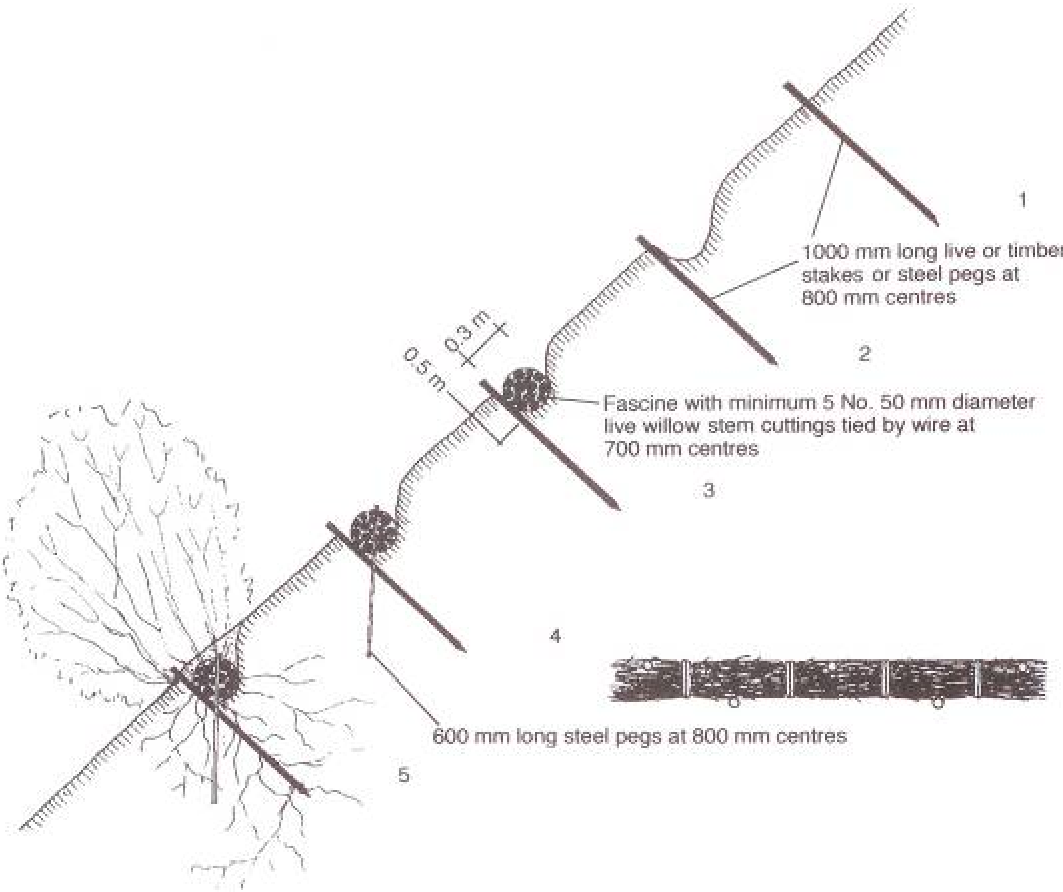


Figure I.6: Fascine Construction[4]

- Live cuttings harvesting and stock handling: See Design Guideline K.
- Live cutting length: up to manageable fascine bundle length (3.0 to 4.0 m), shorter pieces can be used when overlapped in the bundles.
- Bundle size: Approximately 200 mm diameter.
- Ends of fascines to be thinned in order to accommodate minimum 300 mm intertwining overlap of ends when installed.

[4] Reproduced from: H.M. Schiechtl and R. Stern, *Ground Bioengineering Techniques for Slope Protection and Erosion Control* (Cambridge: Wiley-Blackwell, 1996), 70.

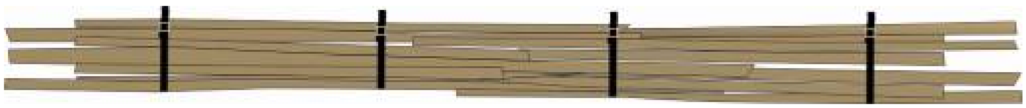


Figure I.7: Fascine Bundle[5]

- Bundles secured with twine or strapping during construction.

Implementation

- Layout the location of contour or drain fascines on slope using spray paint and laser or hand level.
- Trench installation of live fascines to a depth slightly shallower than the fascine bundle diameter.
- Install contour fascines in trenches at required vertical spacing based on slope gradient (see table below).
- Apply soil amendments: See Design Guideline M
- Bundles to be secured in place using wooden stakes.
- Backfilled on either side leaving approximately 1/3 of the bundle exposed, insuring that fill is placed in between the exposed stems.
- Rodent predation and fencing.
- Backfill material.

Table I2
Recommended Spacing for Live Fascine Rows on Slopes[6]

Slope Steepness	**Slope Distance Between Trenches**	
(H:V)	**On Contour** (m)	**On Angle** (m)
1:1 to 1.5:1	0.9 to 1.2	0.3 to 0.9
1.5:1 to 2:1	1.2 to 1.5	0.9 to 1.5
2:1 to 2.5:1	1.5 to 1.8	0.9 to 1.5
2.5:1 to 3:1	1.8 to 2.4	1.2 to 1.5
3.5:1 to 4:1	2.4 to 2.7	1.5 to 2.1
4.5:1 to 5.:1	2.7 to 3.0	1.8 to 2.4

[5] Terra Erosion Control Ltd. drawing
[6] Adapted from: D.H. Gray and R. B. Sotir, *Biotechnical and Soil Bioengineering Slope Stabilization. A Practical Guide for Erosion Control* (New York: John Wiley & Sons, Inc., 1996), 224.

Maintenance

- Monitor site for growth and erosion for the first three growing seasons and repair minor failures if necessary.

References and Further Reading

- Gray, D.H. and R. B. Sotir. Biotechnical and Soil Bioengineering Slope Stabilization. A Practical Guide for Erosion Control. New York: John Wiley & Sons, Inc., 1996.
- Schiechtl, H.M. and R. Stern. Ground Bioengineering Techniques for Slope Protection and Erosion Control. Cambridge: Wiley-Blackwell, 1996.

Streambank Erosion and Potential Remedial Measures

Guideline I3

I1) BRUSH LAYERS
I2) LIVE FASCINES
I3) STRAW WATTLES
I4) BRANCH PACKING
I5) BRUSH MATTRESS

Figure I.8: Installed Straw Wattles, Streambank and Riparian Applications[1]

I3) Straw Wattles

Description

Straw wattles are an erosion control product used to provide a physical barrier on slopes to reduce the rilling resulting from sheet erosion. The straw wattles will collect sediment, seed and organic material, thereby providing an environment for plant establishment.

Straw wattles are used in conjunction with brush layers, erosion control matting (such as coir and coconut products) or on their own, combined with hydro or broadcast seeding. They are made out of rice straw and black, UV degradable plastic net (or an equivalent product). They also come wrapped in jute fabric and can be 9" in diameter and 25' long or 12" in diameter and 12' long. They normally will last 3 to 5 years in the Alberta climate and can be left in place.

Suitability

- Slopes that are difficult to vegetate due to surface soil movement, with rilling and erosion.
- Slopes with dry raveling conditions.
- 12" diameter straw wattles can be used as a substitution for silt fences on rocky shorelines to prevent sediment from entering the water course (see photo below).

1 Terra Erosion Control Ltd. photo

I1) BRUSH LAYERS
I2) LIVE FASCINES
I3) STRAW WATTLES
I4) BRANCH PACKING
I5) BRUSH MATTRESS

Figure I.9: 12" Straw Wattles Used as Sediment Delivery Prevention along Rocky Shoreline[2]

Advantages

- Allows vegetation establishment by reducing rill and gully erosion, providing protection against surface erosion.
- Acts as a sediment trap and retains moisture to assist with germination and growth of vegetation.
- Relatively low cost application.
- Straw will become a source of organic material.
- Simple and effective structures, require minimal excavation.
- Normally installed manually.

Limitations

- Not to be used in concentrated water flow conditions.
- In a Canadian climate, photo degradation of the plastic mesh will take over 5 years.
- Can be undermined if not installed properly.
- Insure product weed free certified.

[2]Terra Erosion Control Ltd. photo

Design Considerations

- Insure wattles are level when installed, i.e., contour to the slope in order not to conduct water.
- Install straw wattles in trenches at the required vertical spacing, based on slope gradient and soil type, i.e., use tighter vertical spacing on steeper slope gradients and with higher erodable soil types. Vertical spacing ranges from 1 to 4 m.

Implementation

- Layout location of straw wattles on slope using spray paint and laser or hand level.
- Install straw wattles in a trench with a depth of approximately 1/3 to 1/2 of the wattle's diameter.
- Install straw wattles in trenches at the required vertical spacing.
- Bundles to be secured in place using wooden stakes and / or 10 mm "T" re-bars on harder compacted ground.
- Stretch wattles as stakes are placed.
- Allow for 300 mm overlap between each wattle (see drawing below).

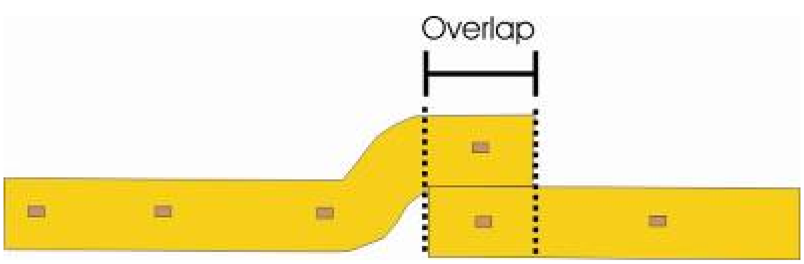


Figure I.10: Overlap on Straw Wattles Installation[3]

- Use a hand dry wall saw to incise wattles at wooden stake locations and use a sledge hammer to pound wooden stakes in.
- Electric hammer, with a ground rod attachment, can be used for pounding re-bar into compacted soil.
- Backfill on either side and create a depression on the upslope side to provide sediment storage capacity (see drawing below).

[3] Terra Erosion Control Ltd. drawing

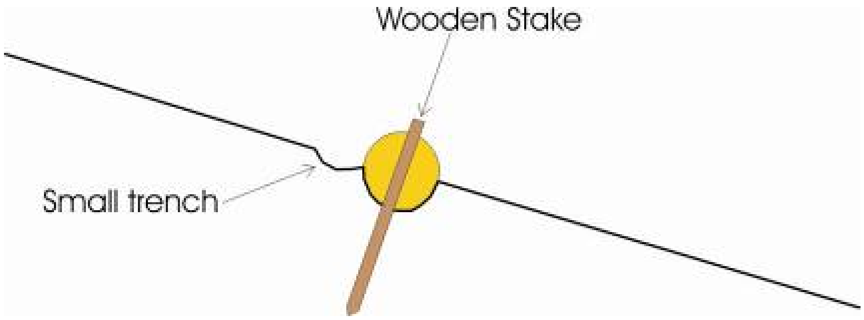


Figure I.11: Straw Wattle Installation[4]

- Keep straw wattles stored in a dry location or under plastic tarps (will get very heavy if wet).
- On steep slope gradients with access to upper slope, connected sono tubes (12" to 14" diam) can be used to transport the wattles down slope to the desired location. The connected sono tubes are secured to the slope using long re-bars pound into the ground and strapped to the various sections of tubes, the wattles are than inserted inside the tubes at the upper location and with sufficient slope gradient the wattles will slide to end of tubes. Snow fences secured with re-bars are placed below the outlet to stop wattles as it exit the tubes (see Figure I.12).

Figure I.12: Transport of straw wattles on steep slope with access on top of slope[5]

[4] Terra Erosion Control Ltd. drawing
[5] Terra Erosion Control Ltd. photos

Maintenance

- Monitor site for erosion and undermining of the structure for the first three growing seasons and repair minor failures if necessary.
- Monitor and control weeds as necessary.
- Straw wattles can be emptied of accumulated sediment manually using shovels.

I1) BRUSH LAYERS
I2) LIVE FASCINES
I3) STRAW WATTLES
I4) BRANCH PACKING
I5) BRUSH MATTRESS

Figure I.13: Branch Packing Installation during Construction [1]

I4) Branch Packing

Description

Branch packing is designed to repair small eroded gullies and / or slumps. It consists of branches placed in a herringbone fashion, within a gully or small slump, with the tip ends at the bottom of the gully. Each layer of branches is placed horizontally starting at the bottom of the gully, covered with soil and secured with wooden poles and stakes.

Suitability

- For repair of small localized slumps and eroded gullies.
- To provide surface protection on slopes and streambanks.
- Can be used alone or combined with rock toe (see Design Guideline C), vegetated riprap (see Design Guideline D) and cribwall (see Design Guideline E).

Advantages

- Very effective.
- Inexpensive, can be done manually.

1Reproduced from: D.H. Gray and R. B. Sotir, Biotechnical and Soil Bioengineering Slope Stabilization. A Practical Guide for Erosion Control (New York: John Wiley & Sons, Inc., 1996), 224.

- Rapidly achieve dense vegetative cover and intensive rooting in placed fill and adjacent earth of stream bank.
- Provides immediate soil reinforcement.
- Assists in trapping sediment.
- Produces a filter barrier preventing erosion.

Limitations

- For gullies with a maximum depth and width of 1.0 to 1.5 m.
- Requires large amounts of live material and labour.

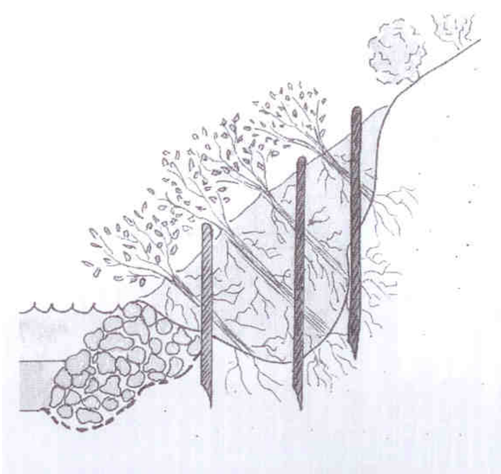


Figure I.14: Branch Packing Cross Section[3]

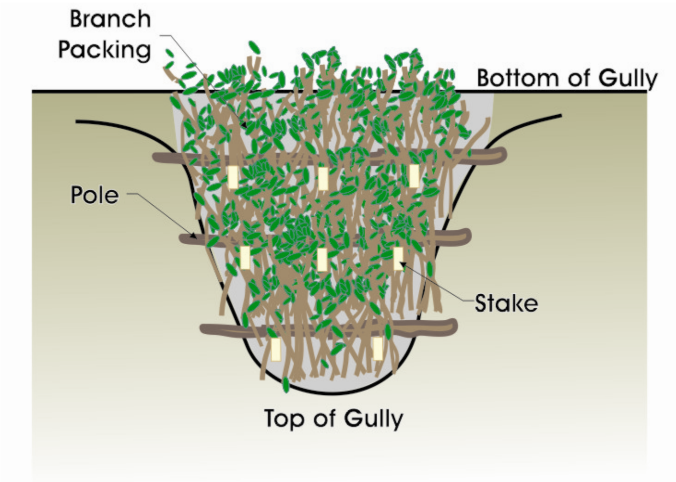


Figure I.15: Branch Packing Plan View[2]

Design Considerations

- Gully dimensions (width and depth).
- Used alone or combined with other techniques.
- Live cuttings harvesting and stock handling (see Design Guideline K).
- Live cutting length (depth of gully, plus 0.2 m exposed).

[2] Terra Erosion Control Ltd. drawing
[3] Joanne E. Norris, Alexia Stokes, Slobodan B. Mickovski, Erick Cammeraat, Rens van Beek, Bruce C. Nicoll, Alexis Achim (eds), *Slope Stability and Erosion Control: Ecotechnological Solutions* (Dordrecht, The Netherlands: Springer), 2008.

- Live planting density (depends on gully depth, layer of 10 to 15 cm thick).
- Soil amendments (see Design Guideline M.)
- Back fill material.
- Rodent predation and fencing.

Implementation

- Install adequate protection to prevent / reduce sediment delivery to water bodies.
- Starting at the lowest point of the gully and / or above placed rock toe protection.
- Drive wooden stakes approximately 1.0 m into the ground at approximately 60 cm spacing.
- Place a branch layer approximately 10 to 15 cm thick, with the growing tips pointing down in between the wooden stakes at the bottom of the gully, in a crisscross pattern with some of the basal ends reaching up to the disturbed slope at the back of the hole.
- Cover branch layer with up to 0.5 m of compacted soil and soil amendments (see Design Guideline M), watering in between each layer to insure soil is moist.
- Subsequent layers of branches are placed with the basal ends lower than the growing tips.
- Place a cross pole, embedded on the gully sides and attached to wooden stakes, to secure branches at approximately 2.0 m intervals.
- Installation of structures should conform to the existing slope on either side of the eroded gully or slump, with branch tips protruding slightly out of the fill.

Maintenance

- Monitor site for growth and erosion for the first three growing seasons and repair minor failures if necessary.

References and Further Reading

- Gray, D.H. and R. B. Sotir. Biotechnical and Soil Bioengineering Slope Stabilization. A Practical Guide for Erosion Control. New York: John Wiley & Sons, Inc., 1996.
- Norris, Joanne, et al. (eds), Slope Stability and Erosion Control: Ecotechnological Solutions. Dordrecht, The Netherlands: Springer, 2008.
- United States Department of Agriculture. Natural Resources Conservation services Engineering Field Handbook – Chapter 16 Streambank and Shoreline Protection. Washington: USDS, 1996.

- Schiechtl, H.M. and R. Stern. Ground Bioengineering Techniques for Slope Protection and Erosion Control. Cambridge: Wiley-Blackwell, 1996.

Streambank Erosion and Potential Remedial Measures

Guideline I5

I1) BRUSH LAYERS
I2) LIVE FASCINES
I3) STRAW WATTLES
I4) BRANCH PACKING
I5) BRUSH MATTRESS

Brush Mattress Installation[1]

Brush Mattress Stem Growth After 7 years

Brush Mattress Stem Growth After 7 years

Brush Mattress After 7 Years

Description

A brush mattress is a layer of interlaced/adjacent live stems placed on a streambank face. Live material is normally willow ssp., but can be combined with balsam poplar and red osier dogwood.

[1] Photo, Dr. Hans Peter Rauch Universität für Bodenkultur

I1) BRUSH LAYERS
I2) LIVE FASCINES
I3) STRAW WATTLES
I4) BRANCH PACKING
I5) BRUSH MATTRESS

Suitability

Streambanks angled or parallel to stream flow on narrow sections of the Elbow River, West Nose Creek and Nose Creek.

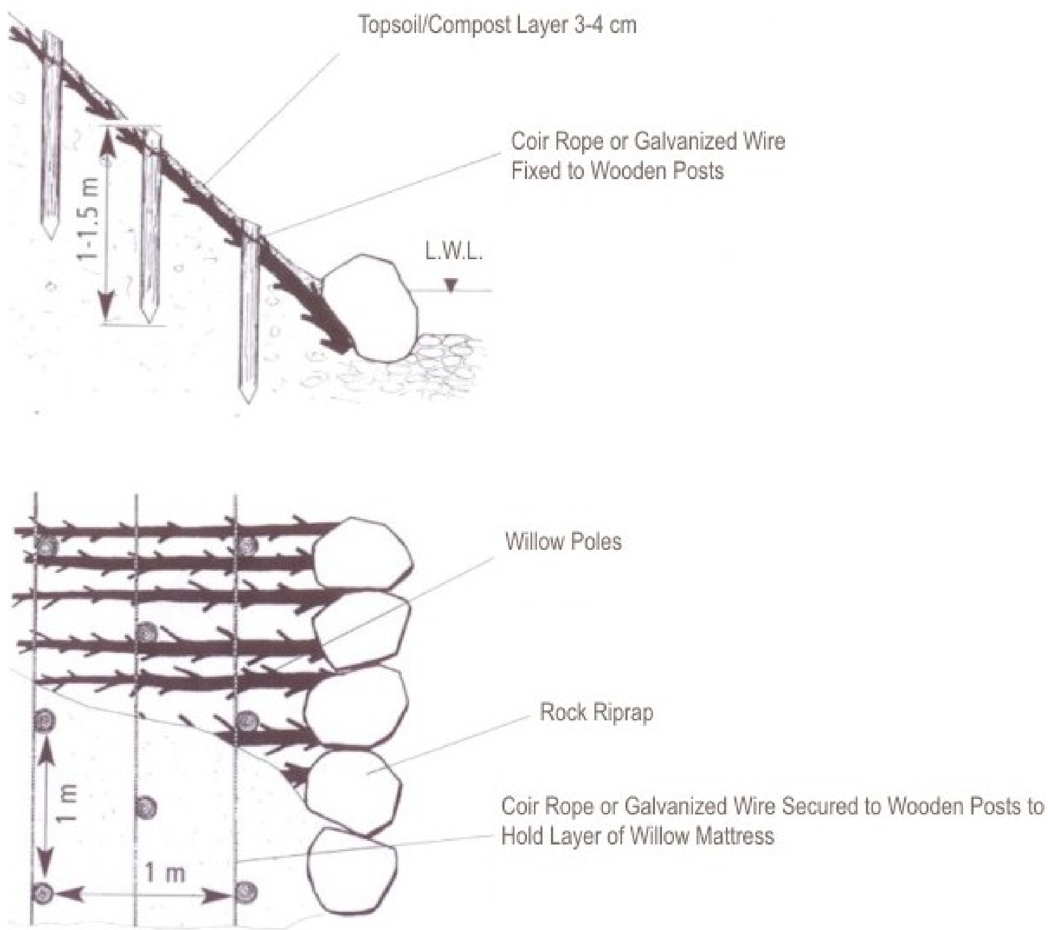
- Used primarily for watercourse bank erosion protection.
- Used on narrow channel (minimum protruding into channel)
- Can be used with a rock toe or crib wall toe.

Advantages

- Very effective.
- Can replace rock riprap.
- Provides added watercourse bank roughness to slow down the water and can accumulate sediment.
- Rapidly achieve dense vegetative cover and intensive rooting in stream bank.
- Provides immediate soil reinforcement.
- Traps overbank sediment.
- Produces a filter barrier preventing erosion.

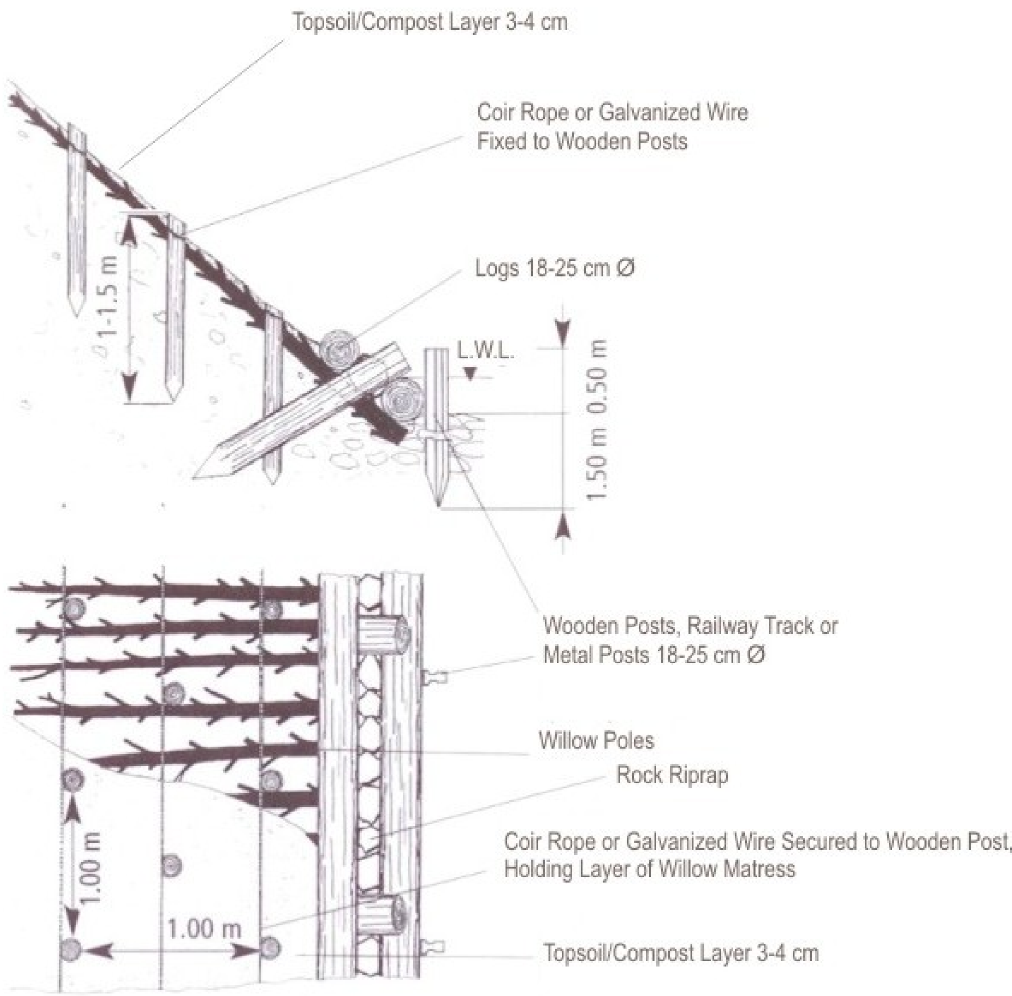
Limitations

- Requires large amounts of live material and labour.



Option 1: Brush Mattress with Rock Riprap Toe[2]

[2] Adapted from: Florin Florineth, *Piante Al Posto Del Cemento Manuale di Ingegneria Naturalistica e Verde Tecnico*, (Milano, Italy: Il Verde Editoriale S.r.l., 2007)



Option 3: Brush Mattress with Crib Wall Toe[1]

Design Considerations

- Used alone or combined with other techniques.
- Short-term and long-term resistance to water flow shear forces if being used to replace riprap (See design guideline P)
- Live cuttings harvesting and stock handling (See design guideline K).
- Use full length live stems.
- Live planting density of 20 to 50 poles per linear meter.
- Soil amendments (See design guideline M.)

- Back fill material.
- Rodent predation and fencing.

Brush Mattress Log Toe Construction

Brush Mattress During Construction

Brush Mattress After Backfilling

Brush Mattress After 1 Year

Photos, Dr. Hans Peter Rauch, Universität für Bodenkultur

Implementation

- Install adequate protection to prevent / reduce sediment delivery to water bodies.
- Constructed log crib wall or excavate trench for rock toe protection.
- Drive wooden stakes approximately 1.0 to 1.5 m into the ground at approximately 1.0 m spacing.

- If treatment area is taller than poles, start at the top of the slope and work downward, randomly placing a brush mattress poles at a rate of 20 to 50 poles per linear meter.
- If treatment area is shorter than poles, place brush mattress poles at a rate of 20 to 50 poles per linear meter with base of poles below low water level as much as possible. Trim any tops of poles that extend above the edge of the treatment area.
- Place rock toe protection over cuttings within excavated trench
- Install Coir rope or galvanized wire to wooden posts to secure brush mattress.
- Water brush mattress and cover with 3 to 4 cm of lightly compacted topsoil or compost.
- Seed as required and water topsoil or compost when complete.

Maintenance

- Monitor site for growth and erosion for the first three growing seasons and repair minor failures if necessary.

References and Further Reading

- Florin Florineth. Piante Al Posto Del Cemento Manuale di Ingegneria Naturalistica e Verde Tecnico. Milano, Italy: Il Verde Editoriale S.r.l., 2007.
- Zeh, Helgard. Soil Bioengineering Construction Type Manual. Zurich, Switzerland: vdf Hochschulverlag AG an der ETH, 2007.
- Schiechtl, H.M. and R. Stern. Water Bioengineering Techniques for Watercourse Bank and Shoreline Protection. United Kingdom: Blackwell Science, 1997.

EROSION AND SEDIMENTATION CONTROL PRODUCTS

Description

The following guidelines provide general information on common erosion and sedimentation control products that might be used for erosion and sedimentation control on streambank restoration projects.

These products have been divided into the following general categories:

- Instream Sediment Control
- Rolled Erosion Control Products
- Blown On or Hand Applied Erosion Control Products
- Hydraulically Applied Erosion Control Projects
- Silt Fences
- Sediment Retention Fiber Rolls (Wattles)
- Gabion Baskets

This guideline should be used in conjunction with the City of Calgary's existing Erosion and Sediment Control Guidelines (February 2001) and the City's erosion and sediment control contractor responsibilities.

Use of Erosion and Sediment Control techniques should also comply with municipal, federal and provincial regulatory requirements as detailed in the City of Calgary's publication Environmental Regulatory Review and Responsibilities: Calgary Construction Sites (November 2009).

Instream Sediment Control

Instream sediment control can be achieved by temporary isolation dams or just turbidity isolation of the work area.

TEMPORARY ISOLATION DAMS

Sheet pile coffer dams, sandbag / earth filled dams, portable dams or water inflated dams can be used to achieve complete water isolation and have an advantage over turbidity isolation when working in the dry is required.

Sheet pile coffer dams provide the higher protection, in terms of resistance to flood failure, but are generally more expensive to implement than sandbag / earth filled dams, portable dams or inflated dams.

EROSION AND SEDIMENTATION CONTROL PRODUCTS

Figure J.1: Earth / Sandbag Coffer Dam, Intake and Outlet Willow Creek Ravine Outfall 13, City of Edmonton[1]

Figure J.2: Sandbag Coffer Dam, Using Sand Bags and Big-O-Pipes, Willow Creek Ravine, Outfall 13, City of Edmonton[2]

[1] Terra Erosion Control Ltd. photos
[2] Terra Erosion Control Ltd. photo

Figure J.3: Portadam[3]

Figure J.4: Water Inflated Dam[4]

TURBIDITY ISOLATION

Turbidly isolation can be a more economical and practical option than temporary isolation dams. Turbidity isolation can be achieved with staked or floating turbidity curtains. Staked turbidity curtains can be used in shallow, slow moving water and are similar to a heavy duty silt fence but are made from an impervious fabric.

Figure J.5: Heavy Duty Silt Fence Installed in Shallow Water, Salmon River, New Brunswick[5]

[3] Portadam Inc., *Channelization,* http://www.portadam.com/PortadamNetscape.htm (October 26, 2010).
[4] Aqua Barrier, *Sediment Control and Shoreline Restoration*, http://www.hydrologicalsolutions.com/aqua-barrier/sediment-control-shoreline-restoration#shoreline (Oct. 25, 2010).
[5] Terra Erosion Control Ltd. photos.

Figure J.6: Floating Turbidity Curtain, Outfall 56, City of Edmonton[6]

Floating turbidity curtains are made from either impervious or pervious materials with floatation constructed into the top of the curtain and weight constructed into the bottom of the curtain. The most commonly used specifications for floating turbidly curtains are the US Army Corps of Engineers / Department of Transportation specification as follows:

Table J.1
Floating Turbidity Curtain Properties[7]

Curtain Parameters	Type 1 EcoPlan	Type 1 DOT	Type 2 EcoPlan	Type 2 DOT	Type 3 DOT
Flow Rates	Standing or slow moving water	up to 1 ft/sec (0.3 m/s) velocity	up to 2 ft/sec (0.6 m/s) velocity	up to 3 ft/sec (0.91 m/s) velocity	up to 5 ft/sec (1.5 m/s) velocity
Body Fabric	10 oz yellow	18 oz yellow	Monofilament geotextile	18 oz yellow	Monofilament geotextile
- Grab Tensile	105 lb	410 lb	370 x 250 lb	410 lb	370 x 250 lb
- Tear Strength	23 lb	100 lb	100 x 60 lb	100 lb	100 x 60 lb
- Hydrostatic	Not tested	600 psi	450 psi	600 psi	450 psi
- AOS (Sieve)	Impermeable	Impermeable	70 Sieve	Impermeable	70 Sieve
Standard Sizes	5' x 50'	3' x 50'	5' x 50'	5' x 50'	5' x 50'
	10' x 50'	5' x 50'	10' x 50'	10' x 50'	10' x 50'
	-	10' x 50'	-	15' x 50"	15' x 50'

[6] Terra Erosion Control Ltd. photos.
[7] Layfield Construction Materials, *Turbidity Barriers and Curtains*, http://www.layfieldenvironmental.com/pages/EGI/Cutsheets.aspx?id=5436 (Oct. 26, 2010).

Floating turbidity curtains come in standards sizes but can also be customized. Table J1 lists permeable fabrics, which would be capable of passing 70 micron sizedparticles. Caution should be used in the use of permeable fabrics to ensure compliance with appropriate regulatory requirements.

If the current is faster than the floating turbidity curtain rating, it may be appropriate to consider the installation of rock vanes, also sometimes referred to as spurs, barbs or groynes, upstream of the curtain to break the current. The rock vane can also be used to anchor the upstream end of the curtain (see Figure J. 6). Vanes can be permanent structures incorporated into the works or temporary structures used as a component of the construction erosion and sediment control plan.

Rolled Erosion Control Products

Rolled erosion control products are used to reduce soil erosion, help retain moisture and to protect seed and seedlings during heavy rainfall or strong winds. For applications where natural vegetation alone will ultimately provide sufficient permanent erosion protection, a temporary rolled erosion control product may be used.

As there are many types of rolled erosion control products available, product selection is usually based on strength of the materials, the functional longevity required (short term, long term or permanent usage), and cost of the materials. Erosion control blankets should generally not be used as a permanent erosion control product for streambank remediation projects as natural vegetation is preferred for habitat and aesthetic reasons.

Temporary erosion control blankets can consist of either non-woven natural fibers enclosed between biodegradable or photodegradable mesh or of an open weave natural fiber textile.

The non-woven erosion control blankets are generally more affordable than the open weave biodegradable geotextiles; however, the open weave geotextiles such as coir matting provide better tensile strengths for longer slopes and can withstand higher flow velocities. In addition, the more durable coir products are better suited to areas that might be subject to pedestrian disturbances. The open weave geotextiles are also more suitable for the planting of seedlings, live staking and for seeding before placement of the erosion control blanket.

The following table provides typical erosion control blanket specifications:

Table J.2
Typical Erosion Control Blanket and Matt Specifications[8]

Product Type	Typical Roll Size (m)	Functional Longevity (months)	Maximum Slope	Typical Max Longitudinal x Cross Tensile Strength (kN/m)	Max Flow Velocity (m/s)
100% Straw matrix with degradable netting	2.0 x 32.9	2 to 12	4:1 to 2:1	4.7 x 3.5	1.8
70% Straw & 30% coconut fiber matrix with degradable netting	2.0 x 32.9	18 to 24	2:1 to 1:1	4.1 x 3.0	2.4
100% coconut fiber matrix with degradable netting	2.0 x 32.9	24 to 36	1:1 & steeper	5.0 x 3.1	3.1
Coir (woven twisted coconut fiber) mats – 460g/m2	2.0 x 50 3.0 x 50 4.0 x 50	48 to 72	2:1	9.8 x 9.5	2.4
Coir (woven twisted coconut fiber) mats – 780g/m2	2.0 x 50 3.0 x 50 4.0 x 25	48 to 72	1:1 & steeper	21.7 x 15.1	3.7
Coir (woven twisted coconut fiber) mats – 980g/m2	2.0 x 50 3.0 x 50 4.0 x 25	48 to 72	1:1 & steeper	26.0 x 13.7	4.9

The data provided in the table above is based on typical supplier information and can vary by manufacturer and actual product specifications should be checked.

[8] Nilex Civil Environmental Group, *Designer's Guide: Temporary Erosion Control Blankets (ECBs)*, http://www.nilex.com/sites/default/files/Nilex_ECB_Designers_Guide.pdf (Oct. 26, 2010). and RoLanka International Inc, *Erosion Control Blankets Mats and TRMs,* 2005 product pamphlet.

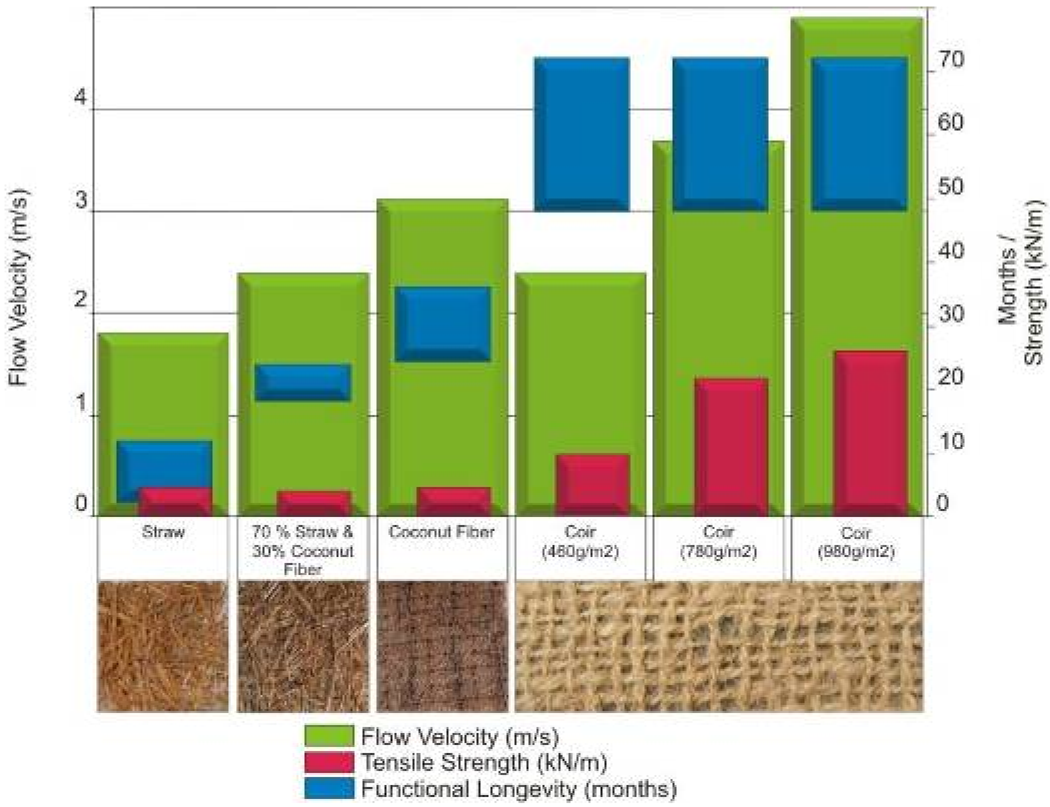


Figure J.7: Erosion Control Blanket and Mat Typical Performance[9]

The figure above provides typical water flow velocity ranges, expected longevity and tensile strengths for a straw erosion control blanket, a 70% straw / 30% coconut fiber erosion control blanket, a 100% coconut erosion control blanket and coir matting (460/780/980g/m2).

9 Terra Erosion Control Ltd. drawing.

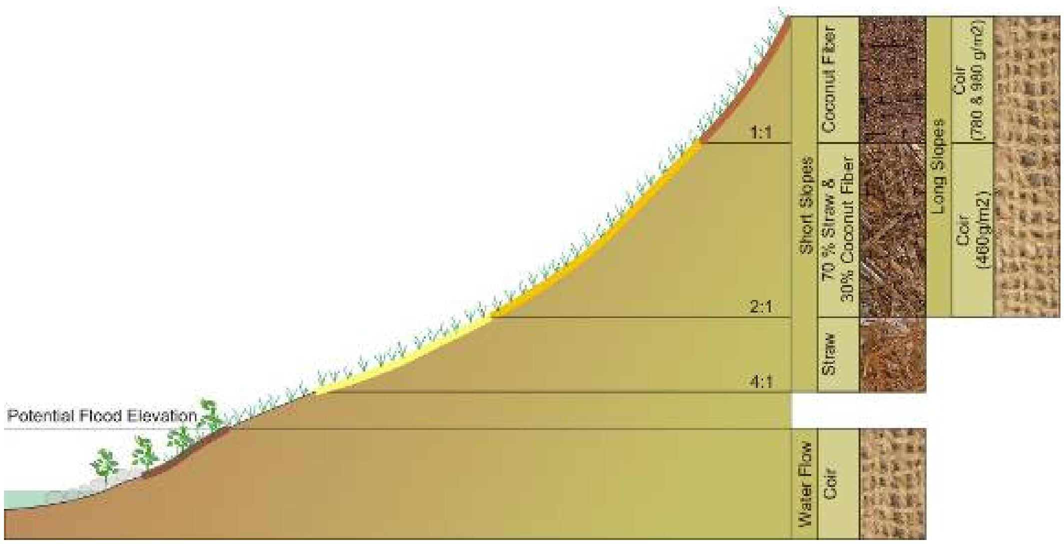


Figure J.8: Erosion Control Blanket Usage Guide[10]

The figure above provides a typical slope gradient installation range for a straw erosion control blanket, a 70% straw / 30% coconut fiber erosion control blanket, a 100% coconut erosion control blanket and coir matting.

Blown On or Hand Applied Erosion Control Products

Blown on or hand applied erosion control products include straw mulch and wood fiber. In comparison to rolled erosion control blankets, blown on straw or wood fiber can be more cost effective but generally have a lower effective longevity and durability.

Blown on products are not expected to do well on areas subject to water flow or on steep slopes. Blown on or hand applied products might, however, be a cost effective technique for temporary erosion control during construction or in areas with moderate grades where vegetation is expected to be quickly re-established.

Hydraulically Applied Erosion Control Products

There are a large number of hydraulically applied erosion control products available with varied properties. They can be classified as Fiber Reinforced Matrix (FRM), Bonded Fiber Matrix (BFM), Stabilized Mulch Matrix (SMM) and Hydraulic Mulch (HM). Hydraulically applied mixes can have various fiber matrices, tackifiers, super-absorbents, flocculating agents, man-made fibers, plant biostimulants and other performance enhancing additives.[11]

[10] Terra Erosion Control Ltd. drawing.
11 Erosion Control Technology Council, What Are The Various Types of Erosion Control Products?, http://www.ectc.org/Product_Types.asp (Oct. 26, 2010)

As there are a large variety of products available, specific performance and usage data would best be provided by the suppliers. The ultimate goal of each hydraulically applied erosion control product is to provide immediate erosion protection while creating an environment that promotes accelerated vegetation establishment.

Silt Fences

Silt or sediment control fences are barriers constructed from geosynthetic material that are used to reduce erosion by intercepting and dissipating minor storm water flow. Silt fences also provide containment for the deposition of larger particles but are not designed to filter small sediment particles. Silt fences are available in many woven or non woven fabric options with varying permeability and fabric strengths.

Figure J.9: Installed Silt Fence[12]

For additional information on the usage and proper installation see The City of Calgary, Wastewater & Drainage, Urban Development, Guidelines for Erosion & Sediment Control, February 2001, and The City of Calgary Wastewater & Drainage, Urban Development, Field Manual for Effective Erosion & Sediment Control, February 2001.[13]

Sediment Retention Fiber Rolls (Wattles)

Sediment retention fiber rolls are manufactured rolls designed to retain larger sediment particles and reduce erosion by dissipating minor storm water flow. The usage of sediment retention fiber rolls is similar to silt fence but sediment retention fiber rolls will ultimately biodegrade after vegetation is established and will not potentially retain as much water as a silt fence.

12 Terra Erosion Control Ltd. photo
13 City of Calgary, Bylaws and Construction Specifications, http://www.calgary.ca/portal/server.pt/gateway/PTARGS_0_0_784_203_0_43/http;/content.calgary.ca/CCA/City+Hall/Business+Units/Water+Services/Specifications/Specifications.htm (Oct. 26, 2010).

Sediment retention fiber rolls consist of filler material encapsulated within a flexible containment material, most commonly rice straw, wheat straw, barley straw or coconut fiber contained within netting. Straw filled rolls are commonly called straw wattles and coconut fiber contained with coir rolls are commonly called coir wattles or coir logs. Straw wattles may also be referred to as straw worms, bio-logs, straw noodles, straw socks or straw tubes.

Straw wattles are commonly installed on slopes, in shallow trenches along equal elevation contours, to break up the effective slope rilling length and to dissipate storm water. Coir wattles are more durable and longer lasting than straw based wattles and can be used along shorelines for erosion protection or planting of aquatic species.

Straw wattle are commonly available in 9" (230 mm) x 7.6 m or 12" (300 mm) x 3.6 m long rolls. Straw wattles can be expected to last 3 to 5 years. Coir wattles are available in 150 mm x 4.6 m, 230 mm x 4.6 m or 6.0 m, and 300 mm x 3 m long. Coir wattles can be expected to last longer than straw wattles.

Wattles should be supplied noxious weed free. See also Design Guideline I3 – Straw Wattles.

Gabion Baskets

Gabion baskets are wire baskets that are filled with rock and stone. Gabions can be used as erosion control and retaining walls. Gabion baskets are supplied in many sizes including the following nominal dimensions.

Table J.3
Standard Gabion Basket Sizes

Length (m)	**Width** (m)	**Depth** (m)
2	1	0.3
2	1	0.5
2	1	1
3	1	0.3
3	1	0.5
3	1	1
4	1	0.3
4	1	0.5
4	1	1
6	2	1
2	0.5	0.5
3	0.5	0.5

Gabion baskets are normally made from either galvanized steel wire or PVC coated galvanized steel wire. The PVC coated wire can be expected to last longer than just galvanized wire and is usually supplied in a green colour.

The wire mesh can either be woven, using a double twist pattern forming approximately 80 mm x 100 mm hexagonal openings, or can be welded wire mesh forming 80 mm x 80 mm square openings.

Welded wire panel gabions are rigid and not as flexible as woven wire gabions and are, therefore, less likely to deform under light loads which results in a neater appearance. However, under larger loads the potential for failure of the welded wire gabions is greater than woven wire gabions, as woven wire mesh will elongate before failing.

See also Design Guideline E - Vegetated Gabion or Log Crib Wall.

References and Further Reading

- The City of Calgary, Wastewater & Drainage, Urban Development, Guidelines for Erosion & Sediment Control, February 2001.
- The City of Calgary Wastewater & Drainage, Urban Development, Field Manual for Effective Erosion & Sediment Control, February 2001.
- Land Development Guidelines for the Protection of Aquatic Habitat http://www.dfo-mpo.gc.ca/Library/165353.pdf
- Alberta Transportation Erosion and Sediment Control Manual, June 2011
- The City of Calgary website has links to an “Erosion and sediment control products supplier and installer list” (http://www.calgary.ca/UEP/Water/Pages/Watersheds-and-rivers/Erosion-and-sediment-control/Products-Supplier-and-Installer-List.aspx)

LIVE CUTTINGS / STOCK HANDLING

Selection of Live Materials

HARVESTED LIVE CUTTINGS

Harvested species may consist of, but are not limited to the following:

Common Name	Scientific Name[1]
Beaked willow	*Salix bebbiana*
Yellow willow	*Salix lutea*
False mountain willow	*Salix pseudomonticola*
Sandbar willow (also called Narrowleaf willow)	*Salix exigua*
Shining willow (also called Pacific willow)	*Salix lucida (=Salix lasiandra)*
Balsam poplar	*Populus balsamifera*
Red-osier dogwood	*Cornus stolonifera*

Harvested plants for live cuttings should be from native tree and shrub species, capable of vegetative propagation that will grow roots and shoots from cuttings when placed in contact with soil and moisture. They should be harvested during the plant dormancy period. Additional native willow species that may be used for live cuttings are listed in Design Guideline L.

AQUATIC SPECIES

- Bulrushes (*Schoenoplectus* spp. / *Scirpus* spp.), sedges (*Carex* spp.) and cattails (*Typha latifolia*) are suitable for the protection of shorelines of slower moving water bodies against wave action.
- .
- Aquatic species can be ordered in nurseries as plugs (see Design Guideline L).
- Aquatic species can be planted as a single stem, rhizome or in clumps or rolls (see Design Guideline A). See below for details on how to harvest aquatic species clumps.

ROOTED AND LIVE CUTTINGS NURSERY STOCK

- Native trees, shrubs and grass plugs (see Design Guideline L).
- Live cuttings from native tree and shrub species may become available from nursery suppliers in the future. The supply source should be considered when planning a project in order to evaluate the most economical option for live cuttings procurement.

[1] Primary resource for plant species naming is E.H. Moss, Flora of Alberta (Toronto: University of Toronto Press, 1994).

LIVE CUTTINGS / STOCK HANDLING

Harvest & Preparation of Live Cuttings

All potential harvest sites for live tree and shrub cuttings and aquatic species should be identified in consultation with the City of Calgary. Harvesting of native plant material from City Parks is not permitted without prior approval.

HARVEST SCHEDULING AND SELECTION OF HARVESTING SITES

- All live cuttings should be harvested during the dormancy period (typically October to March).
- When possible, it is best and more cost effective to harvest and implement the project during autumn, where live material can be utilized without cold storage requirements.
- Live material should be harvested from a similar elevation, soil type, and moisture regime as the project site.
-
- Harvest sites should be within a regulator (City of Calgary or the Alberta Ministry of Environment) approved maximum distance from the project site or within the same natural sub region, to prevent regional genetic mixing.
- Multiple harvest sites should be used to improve genetic diversity.

HARVEST LIVE CUTTINGS

- Live cuttings should be harvested by hand using chains saws or loppers, as close to the ground as possible.
- Live cutting ends should be cut square and with a clean cut (no bark peeling).
- All limbs should be hand pruned close to the stock using pruners or loppers.
- Diseased material should be removed (pruned off) and / or not harvested.
- The minimum diameter of live cuttings should be 20 mm on the apical (top) end.
- The minimum length should be based on end use objectives, as rule of thumb > 80 cm.
- Live cuttings for brush layers or vegetated riprap should be cut to required length.

LIVE CUTTINGS / STOCK HANDLING


Figure K.1: Bench for Fascine Construction

- Live cuttings for brush layers or vegetated riprap should be temporarily bundled for handling, in similar lengths and the same number of stems per bundle, with all basal ends on the same side.
- Live cuttings for fascines or live pole drains should be bundled:
  - On a bench (see Figure K.1 above[2]).
  - To the required diameter and length.
  - With strapping that does not damage the bark.
  - With an adequate number of straps to secure the bundle (i.e., approximately 1 per 60 cm length of stem).
  - With thinned out (feathered) ends of adequate length to accommodate fascine bundle overlapping during installation (see Figure K.2 below[3]).

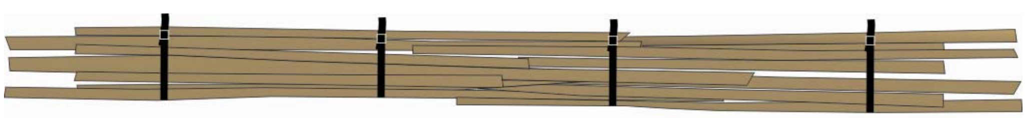


Figure K.2: Fascine Bundle

HARVEST OF AQUATIC SPECIES

- Schiechtl and Stern (Water Bioengineering Techniques and Shore Stabilisation) advise that the preferred time for harvesting of aquatic species is during the dormancy period in the spring prior to the reeds growing roots. Harvesting should be as close to construction period as possible. It may be possible to harvest in the late-spring (Figure K.3) with appropriate handling and storage measures as discussed in the next section.

[2] Terra Erosion Control Ltd. photos
[3] Terra Erosion Control Ltd. drawing

- Aquatic species should be harvested in clumps of 20 to 30 cm square and approximately 20 cm in thickness.
- Clumps should be harvested at a ratio of one clump per 3 – 4 m² in order to minimize the impact on natural stands and allow filling in of species.
- Clumps should be bundled and wrapped in burlap bags or fabric for transport to prevent accidental damage to the plant root system (see Figure K.3 below[4]).
- Clumps should be stored in the shade if possible and watered regularly until planting.


Figure K.3: Clump Harvesting, Bundling and Wrapping in Burlap Bags

Live Materials Handling and Storage

HARVESTED LIVE CUTTINGS HANDLING AND STORAGE

- Live cuttings should be handled and transported carefully such that the bark does not become excessively damaged.
- Live cuttings should not be exposed to direct sun and heat.
- Live cuttings should be covered with silva cool tarps[5] or wet burlap (not plastic tarps) at all times during harvesting and construction to keep the cuttings cool.
- Live cuttings should be watered, as required, to prevent the cuttings from drying.
- Storage time before soaking should be kept to a minimum if the project is taking place directly after soaking.

[4] Terra Erosion Control Ltd. photos

[5] Silva cool tarps" are clean, good quality reflective tarps that are designed to avoid heat buildup; they should be used with the, white side out and silver side in. The white surface is reflective, absorbing little radiation when clean, as well as being highly emissive, allowing for quick release of heat buildup.

See: Ministry of Forests, Planting Project Management, http://www.for.gov.bc.ca/hfp/publications/00099/Planting/3-PrjMng-05.htm#P290_22976 (Nov. 1, 2010).

- For indoor cold storage, temperatures should be a minimum of - 2 Celsius and cutting bundles should be wrapped in plastic and / or covered with wet burlap and watered regularly to avoid freezer burn.
- Cold storage of live cuttings outdoors should be carried out in high elevation areas or in areas with large snow accumulation. Allow cuttings to be covered with at least 60 cm of snow, cover with silva cool tarps and allow additional snow to fall on top. Retrieve cuttings in the spring and process with soaking prior to planting. **Stored live cuttings should not be planted after the third week of June.**

ROOTED NURSERY STOCK & AQUATIC SPECIES

Rooted nursery stock and aquatic species should be handled in such a way that they are kept cool and shaded.

- For temporary storage, leave rooted nursery stock inside cardboard box and open up box and plastic bags in order to avoid over heating of seedlings and increase of plant metabolism.
- For longer storage periods, locate a shaded area and place seedlings within the soil (i.e., excavate small trench, place the rooted containerized portion of the bundled seedlings within the trench and cover with soil.
- Water if necessary to keep seedlings moist and do not leave exposed to direct sunlight.

Prior to planting larger potted plants (i.e., #1 pot size or larger), plant should be removed from pot and roots should be loosened upwards from bottom of root ball if plant is root bound.

Appropriate mix of soil amendments should be applied within the planting hole in conjunction with planting (see Design Guideline M).

Soaking of Harvested Live Cuttings

Live cuttings should be soaked prior to installation for a minimum of: approximately 10 days for summer application, 5 days for spring application and 3 days for fall application.

- Live cuttings should be soaked as follows:
  - in a large water tight container and covered with silva cool tarps, or
  - in an approved watercourse or pond and covered with silva cool tarps and protected from rodent damage as required.
  - cuttings should be covered with silva cool tarps to prevent sprouting during the soaking period.
- Soaking water should not be allowed to become stagnated (water should flow in and out or be changed daily as required).
- Prevention of Disease Entry and Desiccation.

- The exposed portions (top 30 cm) of the brush layer should be painted with a mix of 50% latex primer paint and 50% water prior to installation to help reduce desiccation and disease entry. It is easier to paint the exposed ends of cuttings directly after stems have been bundled by dipping the tip ends of the bundle in a large pail, all at once.

References and Further Reading

- Muhlberg, Gary and Nancy Moore. Streambank Revegetation and Protection. A Guide for Alaska, Technical Report No. 98-3. Juneau: Alaska Department of Fish and Game, 1998.
- Schiechtl, H.M. and R. Stern. Water Bioengineering Techniques for Watercourse Bank and Shoreline Protection. Cambridge: Wiley-Blackwell, 1997.
- Zeh, Helgard. Soil Bioengineering Construction Type Manual. Zurich: European Federation for Soil Bioengineering, 2007.

NATIVE SEEDS, SEEDLINGS AND NURSERY STOCK

Sourcing Native Species in the Calgary Region

HARVESTING LIVE NATIVE PLANT MATERIAL

- Sourcing suitable native plant donor sites for harvest of live aquatic plants and / or willow / balsam poplar / red-osier dogwood cuttings should be discussed during the project planning phase in consultation with Calgary Parks and other relevant City departments (e.g. roads). Prime donor sites may include proposed road or subdivision developments where native vegetation clearing is required.
- Refer to **Design Guideline K** for live cutting and aquatic plant harvesting guidelines, including harvesting schedule, harvest site selection, and live plant material handling and storage considerations.
- Wherever possible, live cuttings and aquatic plants should be sourced from a site located at a similar elevation and with a similar soil type, alkalinity / salinity, slope, aspect, and moisture regime (i.e. ecosite) as the project site. Donor sites should be within a similar plant community and within the same Natural Subregion[1] as the project site. Multiple harvest sites should be used, where possible, to improve genetic diversity.
- Careful project planning is needed to ensure live plant material is harvested during the dormancy period (typically October to March) and stored appropriately (see Design Guideline K) until it is planted.
- For other recommendations concerning the harvesting of native plant materials, refer to the "*Alberta Native Plant Council's Plant Collection Guidelines for Horticultural Use of Native Plants*"[2].

LOCAL NATIVE PLANT NURSERIES / SUPPLIERS

- A listing of Native Plant and Seed Nurseries in the Calgary Region is given on pages 13-14 of this guideline. Note: This listing is current as of October 15, 2010. The Alberta Native Plant Council (www.anpc.ab.ca) should be contacted for an updated Native Plant Source List. Calgary Parks may also be contacted for additional native plant supplier suggestions.

CUSTOM NATIVE SEED MIXES

- Where appropriate, custom native forb and grass seed mixes may be used during bank / slope / riparian restoration projects. Custom native seed mix composition (i.e. percentage species composition by dry weight) and recommended application rates should be developed by a qualified Reclamation Specialist or Professional

[1] Natural Regions Committee 2006. Natural Regions and Subregions of Alberta. Compiled by D.J. Downing and W.W. Pettapiece. Government of Alberta. Pub. No. T/852.

[2] Alberta Native Plant Council. 2007. Plant Collection Guidelines for Horticultural Use of Native Plants. Published by the Alberta Native Plant Council on line at http://www.anpc.ab.ca/

Agrologist. Native seed mixes must be customized based on site specific soil, aspect and moisture conditions. Native seed mixes should mimic naturally occurring plant communities in the Calgary region.

- Refer to the *Native Plant Revegetation Guidelines for Alberta*[3] and *Establishing Native Plant Communities*[4] for more information about how to develop appropriate native grass and forb seed mix compositions and suitable seed application rates. These references have information about seed size, dormancy, germination rates and seeding performance for native species commonly used in restoration projects in Alberta.
- **A "Certificate of Seed Analysis" must be requested for each native seed lot ordered to ensure that the seed is free of "noxious"[5] and "prohibited noxious weeds**"[4] and other undesirable and potentially invasive non-native species. Certificates of Seed Analysis must be examined and approved by a qualified Reclamation Specialist or Professional Agrologist prior to seed purchase.
- Generic, commercially available "Wildflower Seed Mixes" should **not** be used due to their potential to contain non-native and potentially invasive species[6].

Recommended Native Plant Species for Bioengineering Projects in Calgary

NATIVE PLANT SPECIES RECOMMENDATIONS

Tables L1 and L2 provide lists of suggested native plant species to be used for stream bank / riparian restoration projects in Calgary in moist[7] and dry[6] sites, respectively. These lists represent common, naturally occurring native plants found in riparian habitats and valley slopes in Calgary.[8] Native plants listed in Tables L1 and L2 have beneficial attributes for bank or slope stabilization (e.g., fast-growing, natural colonizer species), erosion control (e.g., deeply rooted species), soil improvement (e.g., native legumes capable of nitrogen fixation), and / or fish and

[3] Native Plant Working Group. 2000. Native Plant Revegetation Guidelines for Alberta. H. Sinton-Gerling (ed.), Alberta Agriculture, Food and Rural Development and Alberta. Environment. Edmonton, Alberta. http://www.srd.alberta.ca/MapsFormsPublications/Publications/documents/NativePlantRevegetationGuidelinesForAlberta-Feb2001.pdf
[4] Smreciu, A., H. Sinton-Gerling and J. Beitz. 2001. Establishing Native Plant Communities. Alberta Agriculture, Food & Rural Development, Edmonton, Alberta
[5] As designated by Alberta's Weed Control Act and regulation and the City of Calgary's Community Standards Bylaw Number 5M2004.
[6] Alberta Native Plant Council. 2006. Guidelines for the Purchase and Use of Wildflower Seed Mixes. Published by the Alberta Native Plant Council. http://www.anpc.ab.ca/
[7] Moist sites include north and east facing aspects and sites located in the floodway or that have normally saturated soil conditions. Dry sites include south and west facing slope aspects above the normal flood prone zone (i.e. located above the floodway).
[8] Information obtained from the Riparian Health Inventories conducted in Calgary along the Bow and Elbow Rivers and Nose and West Nose Creeks by the Alberta Riparian Habitat Management Society (Cows and Fish) was used in the development of plant species listings in Tables 1 and 2.

NATIVE SEEDS, SEEDLINGS AND NURSERY STOCK

wildlife habitat improvement (e.g., berry producing shrubs). The naming convention for species listed in Tables 1 and 2 follows The Flora of Alberta by E.H. Moss (1994). When checking species availability, it is important to first check with native plant suppliers which scientific plant naming system they use. The Integrated Taxonomic Information System (http://www.itis.gov/) can be used to check for scientific (Latin) synonyms, naming updates, nomenclature changes and recent taxonomic revisions.

Of note, availability of native plant species stocks (live cuttings / plugs / pots / rootballs etc.) will vary each year. ***Stock availability shown in Tables 1 and 2 is not comprehensive and is subject to change. Project contractors should contact native plant suppliers as far in advance as possible to assess stock availability***. At least 1 to 2 years advance notice may be required for propagation of select species that are not commercially available. Native species substitutions may be considered for species that are not available for purchase provided substituted species have similar growth habits, environmental tolerances, and wildlife habitat value and are naturally occurring (native) in the Calgary region.

Random plantings of native plants will not by itself be effective for erosion control or bank stabilization. Native species combinations used for restoration projects should be strategically selected and customized based on site-specific biophysical conditions and used in combination with appropriate soil bioengineering and erosion control techniques. A few important species selection and site preparation considerations are listed below.

CONSIDERATIONS:

- ***Use of Local Genotypes***
  - Where possible, use only local native species (i.e., local genotypes) that have originated in the immediate Natural Subregion for your project area. Plants and seeds of local origin are best adapted to local climatic fluctuations, soil conditions, pollinators, and predator or disease stresses[9].
  - If registered native *cultivars* or *ecovars* are used, ensure that the original plant material was collected and developed from the local Natural Subregion, where possible. Registered native cultivars should be used sparingly since they have limited genetic variation making them less tolerant of climatic or environmental changes.

- ***Biodiversity and Native Plant Community Structure***
  - Native species mixes used for riparian restoration projects should incorporate a diversity of species with short, medium and tall growth habits. Multiple height layers and rooting depths benefit fish and wildlife habitat diversity, soil stabilization and stormwater runoff filtration capability.

[9] Alberta Native Plant Council. 2007. Plant Collection Guidelines for Horticultural Use of Native Plants. Published by the Alberta Native Plant Council on line at http://www.anpc.ab.ca/

- ***Weed Prevention***
  - As mentioned above, a “Certificate of Seed Analysis” must be obtained and examined by a qualified professional prior to application to ensure native seed mixes are weed free.
  - In addition to “noxious” and “prohibitive noxious” weeds[10], **other non-native weedy species to avoid planting, include**:

    - **Invasive ornamental species** as designated by the Alberta Invasive Plant Council including creeping bellflower (*Campanula rapunculoides*), baby's breath (*Gypsophila paniculata*), Dame's rocket (*Hesperis matronalis*), Himalayan Balsam (*Impatiens glandulifera*), Maltese Cross (*Lychnis chalcedonica*), Queen Anne's Lace (*Daucus carota*), St. Johns Wort (*Hypericum perforatum*), Teasel (*Dipsacus fullonum*), and wild caraway (*Carum carvi*). Refer to the AIPC website[11] for updated invasive ornamental species lists and species descriptions (including photographs).

    - **Invasive shrub species** including caragana (*Caragana* spp.), Russian olive (*Elaeagnus angustifolia*), European / common buckthorn (*Rhamnus catharticus*), salt cedar (*Tamarix* spp.) and yellow clematis (*Clematis tangutica*).

    - **Fast-spreading, rhizomatous grasses** including smooth brome (*Bromus inermis*), timothy (*Phleum pratense*) and Kentucky bluegrass (*Poa pratensis*).

  - Refer to **Design Guideline N** for general preventative measures to reduce the potential for transferring or introducing weed species during site preparation and construction. **Design Guideline N** describes best practices to avoid weed introduction for example from unclean equipment or unclean fill material.

- ***Site Preparation Prior to Planting***
  - The use of cereal cover crops is not recommended as a general practice. But where appropriate, short- lived (i.e., annual), <u>non-persistent</u> cover crops of non-native grains (e.g. oats) may be seeded on steep slopes or erosion prone sites. Annual cover crops with quick germination and emergence help provide vegetation cover for the first growing season while native plantings become established. To minimize competition for water and nutrients, annual cover crop seeding rates should be kept low (i.e., less than half the normally suggested agricultural rate).

[10] As designated by Alberta’s Weed Control Act and regulation and the City of Calgary’s Community Standards Bylaw Number 5M2004
[11] www.invasiveplants.ab.ca

Selection of suitable cover crop species and seeding rates should be determined by a qualified Professional Agrologist or Reclamation Specialist.

- Refer to **Design Guideline H** for recommended mulching techniques to be used in combination with planting of live stakes or container stock seedlings. Application of cardboard and mulch helps limit competition from non-native grasses and weedy species.
- Appropriate methods of weed control (e.g., hand pulling or persistent mowing prior to seed-set) should be applied prior to native revegetation projects. Several years of active control may be needed in some cases.
- The use of chemical fertilizers is not recommended as a general practice in riparian areas given runoff and water quality concerns. Locally adapted native plants do require less fertilizing and are more resistant to drought. The use of organic based fertilizers, along with site specific customized soil amendments, are recommended (see **Design Guideline M for** more information).

NATIVE SEEDS, SEEDLINGS AND NURSERY STOCK

Table L.1
Recommended Native Plant Species For Streambank / Riparian Restoration Projects in Calgary for MOIST SITES

Moist Site Species

	Live Cuttings	Spencer Lamier Plug			Pot Size Round (#2 is 2 gallon etc.)	Pot Size Square	Caliper, root ball and burlap, large trees >2m high	Could be grown with 1 to 2 yrs advance notice
		100mL	115mL	170mL				
TREES[1]								
balsam poplar *(Populus balsamifera)*						**50 mm+ F**		
SHRUBS[1]								
beaked willow (*Salix bebbiana*)				**B**	**#2 F**			
false mountain willow (*Salix pseudomonticola*)					**#2 F**			
basket / meadow willow (*Salix petiolaris*)[2]				**B**				
flat-leaved willow (*Salix planifolia)*					**#2 F**			**B**
red-osier dogwood (*Cornus stolonifera*)	**B**			**B**	**#2 F**			
river alder *(Alnus tenuifolia*)			**A**	**B**	**#2 F**			
sandbar willow *(Salix exigua)*	**B**			**B**	**#2 F**			
shining willow *(Salix lucida*) **=** Pacific willow (Salix lasiandra)				**B**	**#2 F**			
water birch *(Betula occidentalis*)				**B**	**#2 F**			
yellow willow *(Salix lutea*)				**B**	**#2 F**			
GRASSES[1]								
bluejoint *(Calamagrostis canadensis*)	**K**							**P**
fowl bluegrass *(Poa palustris)*	**K**							**P S**
green needle grass *(Stipa viridula)*			**A**					**K P S**
hair grass (*Agrostis scabra*)								
northern wheat grass (*Agropyron dasystachyum*)								
salt grass (*Distichlis stricta*)								
slender wheat grass (*Agropyron trachycaulum* and *Agropyron trachycaulum* var. *unilaterale*)								
slough grass *(Beckmannia syzigachne)*	**K**							**P**
sweet grass (*Hierochloe odorata*)			**A**					
tufted hair grass *(Deschampsia cespitosa)*		**K**						**P S W**

Moist Site Species

	Live Cuttings	Spencer Lamier Plug			Pot Size Round (#2 is 2 gallon etc.)	Pot Size Square	Caliper, root ball and burlap, large trees >2m high	Could be grown with 1 to 2 yrs advance notice
		100mL	115mL	170mL				
western wheat grass *(Agropyron smithii)*								
FORBS[1]								
alpine bistort *(Polygonum viviparum)*								**K**
alpine hedysarum (*Hedysarum alpinum*)			**A**					
arrow-leaved coltsfoot (*Petasites sagittatus*)								
Canada anemone (*Anemone canadensis*)								
Canada goldenrod *(Solidago canadensis)*			**A**					
common fireweed (*Epilobium angustifolium*)			**A**					**W**
common yarrow (*Achillea millefolium*)			**A**					
cream-colored vetchling *(Lathyrus ochroleucus)*								**K**
creeping white prairie aster *(Aster falcatus)*								**K**
cut-leaved anemone (*Anemone multifida*)			**A**					
golden bean *(Thermopsis rhombifolia)*			**A**					**K**
graceful cinquefoil *(Potentilla gracilis)*								**K W**
heart-leaved Alexanders *(Zizia aptera)*								**K**
northern hedysarum *(Hedysarum boreale)*								**K**
northern willowherb *(Epilobium ciliatum)*								**K**
prairie goldenrod (*Solidago missouriensis*)			**A**					
purple milk vetch *(Astragalus dasyglottis)*								**K**
smooth aster (*Aster laevis*)			**A**					
three flowered avens (*Geum triflorum*)			**A**					
wild licorice *(Glycyrrhiza lepidota)*								**K**
wild mint (*Mentha arvensis*)								
wild strawberry (*Fragaria virginiana*)			**A**					

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NATIVE SEEDS, SEEDLINGS AND NURSERY STOCK

Moist Site Species

	Live Cuttings	Spencer Lamier Plug			Pot Size Round (#2 is 2 gallon etc.)	Pot Size Square	Caliper, root ball and burlap, large trees >2m high	Could be grown with 1 to 2 yrs advance notice
		100mL	115mL	170mL				
wild vetch *(Vicia americana)*								**K S**
yellow hedysarum *(Hedysarum sulphurescens)*								**K**
EMERGENT / AQUATIC SPECIES[1]								
awned sedge (*Carex atherodes*)	**K**							
cattail *(Typha latifolia)*			**A**		#1 **BB**	6 cm **BB**		**BB**
common tall manna grass *(Glyceria grandis)*	**K**							**P**
creeping spike-rush *(Eleocharis palustris)*	**K**							
great bulrush *(Scirpus validus / S. acutus)*					#1 **BB**	6 cm **BB**		**BB**
small bottle sedge *(Carex utriculata)*	**K**							
small-fruited bulrush *(Scirpus microcarpus)*	**K**							
water sedge *(Carex aquatilis)*	**K**							
wire rush *(Juncus balticus)*	**K**							
woolly sedge *(Carex lanuginosa)*								

Legend

ALCLA: **A**
Bow Point Nursery: **B**
Bearberry Water Gardens: **BB**
Eagle Lake Nurseries: **E**
Foothills Nursery: **F**
Knutson and Shaw: **K**
Pickseed: **P**
Seaborn Seeds: **S** (seed only)
Wild About Flowers: **W**

Notes:

1) Primary resource for plant species naming is *Flora of Alberta* by E.H. Moss (1994). **Contractors should refer to the Integrated Taxonomic Information System (ITIS) (http://www.itis.gov/) for species naming synonyms / nomenclature updates prior to checking plant species availability with native plant suppliers.**
2) **Table L1 is not all inclusive and is subject to change based on stock availability. Contractors should contact native plant suppliers directly for updated native plant stock availability during the project planning phase.** In some cases up to 2 years advanced notice may be needed for propagation of select native species. **Refer to pages 13-14 for contact information and a listing of native plant suppliers in the Calgary region.**
3) Native seed stock availability is not included on Table L1. Contractors should contact native seed suppliers directly for a current listing of available native seeds. Native grass and forb seed mix composition by weight and seeding application ratings should be determined by a qualified Professional Agrologist or Reclamation Specialist. Certificates of Seed Analysis must be checked for all seed lots ordered to ensure seed mixes are free of invasive species (including Noxious and Prohibited Noxious Weeds as designated by Alberta's *Weed Control Act* and regulation and the City of Calgary's *Community Standards Bylaw Number 5M2004*).

Table L.2
Recommended Native Plant Species For Streambank / Riparian Restoration Projects in Calgary for DRY SITES

Dry Site Species

	Live Cuttings	Spencer Lamier Plug			Pot Size Round (#2 is 2 gallon etc.)	Pot Size Square	Caliper, root ball and burlap, large trees >2m high	Could be grown with 1 to 2 yrs advance notice
		100mL	115mL	170mL				
TREES								
aspen *(Populus tremuloides)*				**B**	#15 **F**, #1+ **E**		50mm **F**	
balsam poplar *(Populus balsamifera)*				**B**	#5+ **E**		50mm+ **F**	
lodgepole pine *(Pinus contorta)*				**B**	#1 **E**		2m+ **F**, **E**	
SHRUBS								
buckbrush/snowberry *(Symphoricarpos occidentalis)*				**B**	#1 **E**, #2 **E F**			
Canada buffaloberry *(Shepherdia canadensis)*				**B**	#2 **E F**			
choke cherry *(Prunus virginiana)*					#2 **F**, **#**7+ **E**	11cm **E**		**B**
common bearberry *(Arctostaphylos uva-ursi)*					#2 **F**			**B**
common wild rose *(Rosa woodsii)*			**A**	**B**	#1 **E**, #2 **E F**, #5 **E**			
creeping juniper *(Juniperus horizontalis)*					#1 **E**, #2 **E F**, #5 **E**			**B**
northern gooseberry *(Ribes oxyacanthoides)*				**B**	#2 **E F**			
pin cherry *(Prunus pensylvanica)*					#2 **E F**, #5 **E**			**B**
prickly rose *(Rosa acicularis)*			**A B**		#1 **E**, #2 **E F**, **#5 E**			
saskatoon *(Amelanchier alnifolia)*			**A**		#2 **E F**			**B**
shrubby cinquefoil *(Potentilla fruticosa)*				**B**	#2 **F**			
shrubby cinquefoil *(Potentilla fruticosa)* cultivars					#2 **E**, #5 **E**			
silverberry *(Elaeagnus commutata)*			**A**	**B**	#2 **E F**			
twining honeysuckle (*Lonicera dioica*)								
white meadowsweet (*Spiraea betulifolia*)			**A**					

Dry Site Species

	Live Cuttings	Spencer Lamier Plug			Pot Size Round (#2 is 2 gallon etc.)	Pot Size Square	Caliper, root ball and burlap, large trees >2m high	Could be grown with 1 to 2 yrs advance notice
		100mL	115mL	170mL				
SHRUBS continued								
wild red raspberry (*Rubus idaeus*)								
GRASSES [1]								
blue grama (*Bouteloua gracilis*)			**A**			15cm **E**		**K P S W**
bluebunch fescue *(Festuca idahoensis)*								**P**
Canada wild rye *(Elymus canadensis)*								**K P S**
giant wild rye *(Elymus piperi)*								
green needle grass *(Stipa viridula)*			**A**					**K P S**
june grass *(Koeleria macrantha)*			**A**			11cm **E**		**K P S W**
needle-and-thread *(Stipa comata)*								**P**
northern wheat grass *(Agropyron dasystachyum)*								**K P S**
Parry's oatgrass (*Danthonia parryi*)								
salt grass (*Distichlis stricta*)								
sand grass (*Calamovilfa longifolia*)								
Sandberg bluegrass *(Poa sandbergii)*								**P**
slender wheat grass *(Agropyron trachycaulum var. unilaterale)*								
slender wheat grass *(Agropyron trachycaulum)*								**K P S**
western porcupine grass (*Stipa curtiseta*)								
western wheat grass *(Agropyron smithii)*								
FORBS								
ascending purple milk vetch (*Astragalus striatus*)			**A**					
Canada goldenrod *(Solidago canadensis)*			**A**					
common yarrow (*Achillea millefolium*)			**A**					
cut-leaved anemone *(Anemone multifida)*			**A**					**K W**
early yellow locoweed (*Oxytropis sericea*)			**A**					**K W**
gaillardia (*Gaillardia aristata*)			**A**					
golden aster (*Heterotheca villosa*)			**A**					

NATIVE SEEDS, SEEDLINGS AND NURSERY STOCK

Dry Site Species

	Live Cuttings	Spencer Lamier Plug			Pot Size Round (#2 is 2 gallon etc.)	Pot Size Square	Caliper, root ball and burlap, large trees >2m high	Could be grown with 1 to 2 yrs advance notice
		100mL	115mL	170mL				
golden bean *(Thermopsis rhombifolia)*			A					K
FORBS continued								
late yellow locoweed *(Oxytropis monticola)*			A					K W
pasture sagewort *(Artemisia frigida)*			A					K W
prairie coneflower (*Ratibida columnifera*)			A					
prairie crocus (*Anemone patens*), 2 years from seed			A					K W
prairie onion *(Allium textile)*								K W
prairie sage *(Artemisia ludoviciana)*			A					K W
purple milk vetch *(Astragalus dasyglottis)*								K
purple prairie clover (*Petalostemon purpureum*)			A					
reflexed locoweed (*Oxytropis deflexa*)			A					
showy locoweed (*Oxytropis splendens*)			A					K W
small-leaved everlasting (*Antennaria parvifolia*)			A					
smooth aster (*Aster laevis*)			A					
smooth blue beardtongue (*Penstemon nitidus*)			A					
star-flowered Solomon's-seal *(Smilacina stellata)*			A					K W
three-flowered avens (*Geum triflorum*)			A					
tufted fleabane (*Erigeron caespitosus*)			A					
tufted white prairie aster (*Aster ericoides*)								
viscid locoweed *(Oxytropis viscida)*								K
wild bergamot *(Monarda fistulosa)*			A					K W
wild blue flax *(Linum lewisii)*			A					K W
wild licorice *(Glycyrrhiza lepidota)*								K
wild strawberry (*Fragaria virginiana*)			A					
wild vetch *(Vicia americana)*								K S W

NATIVE SEEDS, SEEDLINGS AND NURSERY STOCK

Legend

ALCLA: **A**	Eagle Lake Nurseries: **E**	Pickseed: **P**
Bow Point Nursery: **B**	Foothills Nursery: **F**	Seaborn Seeds: **S** (seed only)
Bearberry Water Gardens: **BB**	Knutson and Shaw: **K**	Wild About Flowers: **W**

Notes:

1) Primary resource for plant species naming is *Flora of Alberta* by E.H. Moss (1994). **Contractors should refer to the Integrated Taxonomic Information System (ITIS) (http://www.itis.gov/) for species naming synonyms / nomenclature updates prior to checking plant species availability with native plant suppliers.**

2) **Table L2 is not all inclusive and is subject to change based on stock availability. Contractors should contact native plant suppliers directly for updated native plant stock availability during the project planning phase.** In some cases up to 2 years advanced notice may be needed for propagation of select native species. **Refer to pages 13-14 for contact information and a listing of native plant suppliers in the Calgary region.**

3) Native seed stock availability is not included on Table L1. Contractors should contact native seed suppliers directly for a current listing of available native seeds. Native grass and forb seed mix composition by weight and seeding application ratings should be determined by a qualified Professional Agrologist or Reclamation Specialist. Certificates of Seed Analysis must be checked for all seed lots ordered to ensure seed mixes are free of invasive species (including Noxious and Prohibited Noxious Weeds as designated by Alberta's *Weed Control Act* and regulation and the City of Calgary's *Community Standards Bylaw Number 5M2004*).

Native Plant and Seed Nurseries, Calgary Region

1) **ALCLA Native Plant Restoration Inc.**
3208 Bearspaw Dr. NW,
Calgary, AB, T2L 1T2
Phone: 403-282-6516
Fax: 403-282-7090
Email: ALCLA@telus.net
www.alclanativeplants.com

2) **Foothills Nurseries (wholesale)**
2626-48 St. SE
Calgary, AB, T2B 1M4
Phone: 403-203-3338
Fax: 403-236-4433
Email: fhnurser@telusplanet.com
www.foothillsnurseries.ca

3) **Bearberry Creek Water Gardens**
RR2,
Sundre, AB, TOM 1X0
Phone: 403-638-4231
Fax: 403-638-4793
Email: bbcreek@telus.net
www.bbcreek.ca

4) **Prairie Waves**
Box 1633
Cochrane, AB, T4C 1B5
Phone: 403-815-8596
Email: info@prairiewaves.com
www.prairiewaves.com

5) **Boreal Horticultural Services Ltd.**
Box 5021
Bonnyville, AB, T9N 2G3
Phone: 780-826-1709
Fax: 780-826-1709
Email: boreal@mcsnet.ca
www.borealhort.com

6) **Greenview Nurseries**
Box 12, Site 16, RR7
Calgary, AB, T2P 2G7
Phone: 403-936-5431
Fax: 403-936-5981
Email: info@greenviewnurseries.ca
www.greenviewnurseries.ca

7) **Bow Point Nursery Ltd.**
244034 Range Rd. 32
Calgary, AB, T3Z 2E3
Phone: 403-686-4434
Fax: 403-242-8018
Email: info@bowpointnursery.com
www.bowpointnursery.com

8) **Cobblestone Home and Garden**
10300 17 Ave SE
Calgary, AB, T2P 2G7
Phone: 403-273-4760
Fax: 403-273-4770
Email: cobblestone@ourshop.ca
www.cobblestonegarden.ca

9) **Eagle Lake Nurseries Ltd.**
Box 2340
Strathmore, AB, T1P 1K3
Phone: 403-934-3622
Fax: 403-934-3626
Email: gardencenter@eaglelakenurseries.com
www.eaglelakenurseries.com

10) **Seaborn Seeds Inc.**
Box 8, Site 11, RR3
Rocky Mountain House, AB, T4T 2A3
Phone: 403-729-2267
Fax: 403-729-3428
Email: shorthorn@telusplanet.net
www.crookedpost.ca

11) **Knutson and Shaw Growers**
Box 295
Vulcan, AB, T0L 2B0
Phone: 403-485-6321
Fax: 403-485-6323
Email: knshaw@wildroseinternet.ca

12) **Pickseed**
Box 3230, 21 Streambank Ave.
Sherwood Park, AB, T8H 1N1
Phone: 800-265-3925
Fax: 780-464-0305
Email: tscott@pickseed.com
www.pickseed.com

Native Plant and Seed Nurseries, Calgary Region

13) Wild About Flowers
Box 1257
Turner Valley, AB, T0L 2A0
Phone: 403-933-3903
Email: contactus@wildaboutflowers.ca
www.wildaboutflowers.ca

15) The Professional Gardener Company
915-23 Ave. SE
Calgary, AB, T2G 1P1
Phone: 403-263-4200
Fax: 403-273-0029
Email: progar@telusplanet.net

14) Eastern Slopes Rangeland Seed Ltd.
Box 273
Cremona, AB, T0M 0R0
Phone: 403-637-2473
Fax: 403-637-2724
Email: Greenhouse@easternslopesrangelandseeds.com
www.nativeplantproducer-esrs.com

For more suppliers please see the
Alberta Native Plant Council's website at:
www.anpc.ab.ca/assets/ANPC_2010_Native_Plant_Source_List.pdf

SOIL AMENDMENTS

Description

The importance of a healthy soil, along with a microbial community, is well recognized for proper ecosystem functioning. Application of soil amendments within proposed soil bioengineering structures (i.e., live cuttings, seedlings and seeding) will address deficiencies in soil chemistry (e.g., soil salinity, available nitrogen, phosphorus, potassium, pH, soil toxins) and will enhance the soil moisture retaining capacity. This will provide optimum growing conditions for the establishment of live cuttings, seedlings, grasses and legumes and also facilitate the infiltration of surface water.

The mixture proposed for application consists of peat moss/compost, organic fertilizer, humate complexes and mycorrhiza fungii (ecto and endo types). A powdered form of endo mycorrhiza is suggested for seeding applications (broadcast and hydro seeding).

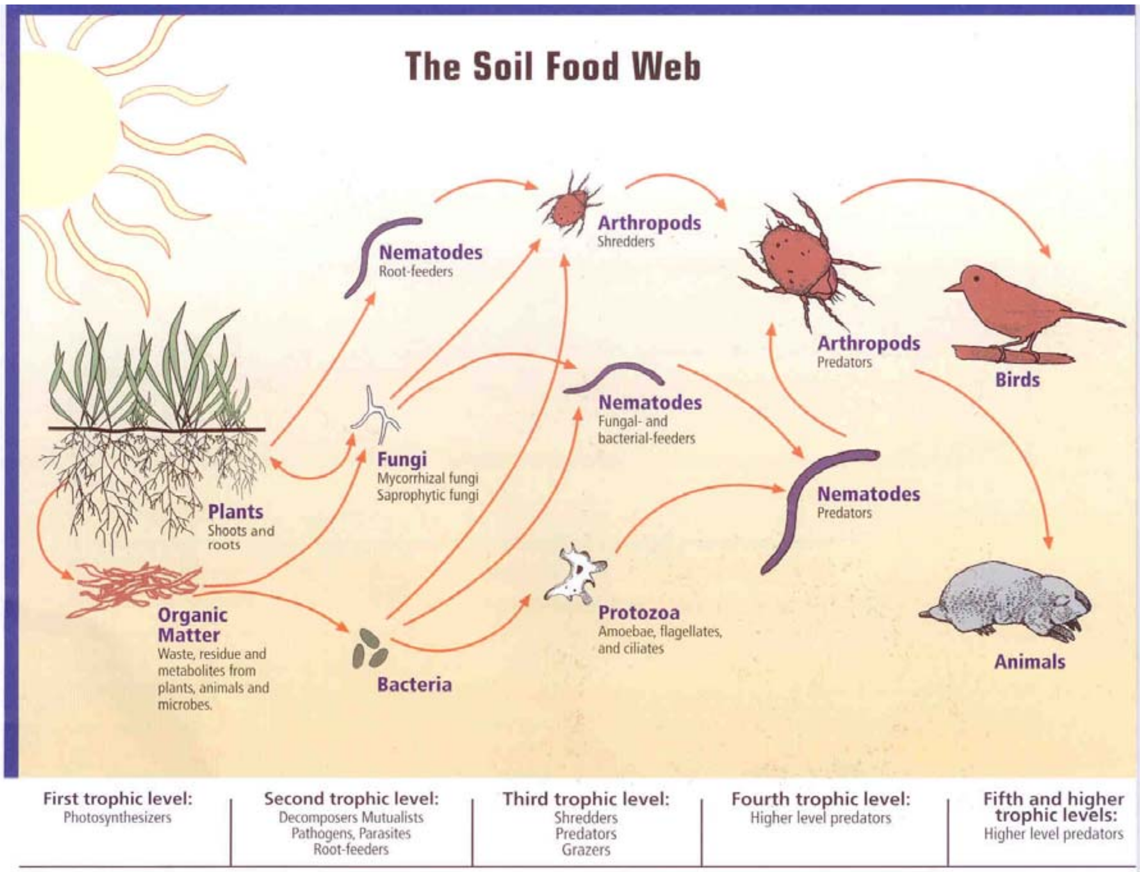

Figure M.1: The Soil Food Web[1]

[1] Soil and Conservation Society, "The Soil Foodweb", *Soil Biology Primer* (Ankeny, IA: Soil and Water Conservation Society, 2000), p.5.

SOIL AMENDMENTS

Suitability

- Disturbed landscape slopes and streambank failures.
- Poor growing substrate.

Advantages

- Peat moss / compost will enhance the moisture retaining capacity during summer drought conditions and provide a suitable growing medium.
- A balanced organic fertilizer (4-4-4), safe to use within the riparian zone, will supply required available nutrients to plant and soil micro-organisms.
- Humate complexes will increase biological activity in the soil and are a good source of energy for the micro-organisms. They absorb water, increasing the drought tolerance of plants, and are effective in converting iron into available forms which protect the plants from chlorosis (i.e., chlorosis is a condition in which leaves produce insufficient chlorophyll)[2].
- Mycorrhizal fungi can considerably improve plant growth and survival. They colonize a plant's root system by creating a network that increases the absorption of water and nutrients such as phosphorus, copper, and zinc[3]. This gives the plants enhanced rooting efficiency and greater resistance to water stress and diseases.

Limitations

- Not required on areas with a substantial A horizon and surface organic layer (LFH).
- Can be adjusted or customized to site specific conditions, based on soil testing for nutrients, contaminants and pH (consult with a professional agronomist or soil scientist).

Soil Amendments

LIVE CUTTINGS AND SEEDLINGS

- Soil Amendment should consist of the following mix:
  - 1 bale (200 L) of peat component mix with: 55%-65% Canadian Sphagnum Peat Moss, Perolite, Dolomitic Limestone, Gypsum, Wetting Agent or equivalent (compost).
  - 6 kg of organic fertilizer, 4-4-4 with: alfalfa meal, bone meal, blood meal, glacial rock dust, sulphate of potash, humate, rock phosphate, greensand, kelp meal, gypsum, or equivalent.
  - 3.5 L of Mycorrhizae fungii (granular form of endo and ecto types).

[2] Tecologic Products Ltd.
[3] Premier Tech Biotechnologies Ltd.

   - 0.8 Kg of humate complexes (humic acid).
- Each mix of the soil amendment will cover an area of 28 m^2.

BROADCAST AND HYDRO SEEDING

- Soil Amendments should consist of the following mix:
   - 3 kg/ha of endo mycorrhizae fungus (powder form).
   - 330 kg/ha of organic fertilizer, 6-2-3 with: feather meal, steamed bone meal, glacial rock dust, natural humate complex, gypsum.

References and Further Reading

- Gaia Green Products Ltd / Cobblestone Garden Centre, 10300-17th Ave, SE, Calgary, Alberta, T1x 0l4 (fertilizer).
- Premier Tech Biotechnologies, 1, avenue Premier, Rivière-du-Loup (Québec) G5R 6C1 CANADA (mycorrhizae).
- Soil and Conservation Society, Soil Biology Primer. Ankeny, IA: Soil and Water Conservation Society, 2000.
- Tecologic Products Ltd, Technologies & Products for the Betterment of Ecology, 11,6125-12Street SE, Calgary, Alberta, CANADA T2H 2K1 (humic acid).

Streambank Erosion and Potential Remedial Measures

Guideline N

CONSTRUCTION AND ENVIRONMENTAL PRACTICES

Figure N.1: Tree protection and Sedimentation Control, Outfall 101 Edmonton Alberta[1]

Description

The purpose of this guideline is to provide general construction and environmental practices for streambank erosion remedial projects to reduce environmental impact and to avoid the spread of invasive species.

Environmental Protection and Low Impact Construction

PROTECTION OF EXISTING VEGETATION

It is very important to minimize disturbance to any existing vegetation in order not to contribute to an erosion problem and to limit the disruption or disturbance to fish and wildlife habitat or parks.

Within the construction area, existing trees and shrubs should be protected, by fencing and / or other means, prior to the start of construction.

PROTECTION OF SIGNIFICANT FEATURES

Pre-site assessments and government consultation should be conducted in advance by qualified professionals to identify significant environmental or archaeological features (e.g., nests, dens, significant fish habitat, unique geological formations, historical artifacts, rare plants, etc.). These significant features should be appropriately protected by fencing, flagging and / or other means, prior to the start of construction. Construction activities should be postponed if these will interfere or disturb active nests or dens in accordance with Alberta's *Wildlife Act*.

[1] Terra Erosion Control Ltd. photos

Figure N.2: Tracked Dump Truck and Walking Excavator Working within Riparian/Instream Areas using Biodegradable Hydraulic Fluid. Outfalls 13 & 101, Edmonton Alberta[2]

SPECIALIZED EQUIPMENT FOR WORKING IN WATERCOURSES AND SENSITIVE AREAS

Working adjacent to or within watercourses can require specialized equipment to reduce the environmental impact. Equipment such as walking excavators and tracked dump trucks, equipped with biodegradable hydraulic fluid, can be used in riparian areas with difficult access to minimize disturbances.

Figure N.3: Turbidity Curtain, Outfall 56, Edmonton Alberta.[2]

[2] Terra Erosion Control Ltd. Photos

SPECIALIZED TECHNIQUES FOR WORKING IN WATERCOURSES AND SENSITIVE AREAS

Control of instream sediment delivery can be achieved by using various techniques, depending on the site specific requirements, such as:

- Isolation dams (sheet pile coffer dams, sandbag / earth filled dams, portable dams or water inflated dams).
- Turbidity isolation (staked or floating turbidity curtains).
- Erosion control blankets.
- Straw and wood fiber mulch.
- Silt fences.
- Sediment retention fiber rolls.

Refer to Design Guideline J for technical details and specifications for common erosion and sedimentation control products.

IMPORT OF TOPSOIL AND FILL MATERIAL

- Ensure that the source and supply of fill material, top soil and compost is free of the seeds of agronomic, invasive, "noxious" and "prohibited noxious" weed species[3], as well as chemical contaminants.
- If unsure about the soil or fill material source, soil testing should be performed to detect any metals or contaminants, as well as nutrient levels and pH.

LIVE CUTTINGS AND SEED STOCK

Refer to Guideline K and Guideline L for native species selection, sourcing, harvest and handling considerations for live cuttings, seedlings and / or seed stock. Use appropriately adapted native species for the soil type, moisture conditions, aspect and slope of the site. Plant species selection (including cuttings, seedlings and seed mixes) must be done in consultation with Calgary Parks for all City managed Parks and Natural Areas. Native plant suppliers in the Calgary region are listed in Guideline L. A "Certificate of Seed Analysis" must be requested for each native seed lot ordered to ensure that the seed is free of "noxious" and "prohibited noxious weeds" and other undesirable and potentially invasive non-native species. Certificates of Seed Analysis must be examined and approved by a qualified Reclamation Specialist or Professional Agrologist prior to seed purchase.

[3] As designated by Alberta's *Weed Control Act* and regulation and the City of Calgary's *Community Standards Bylaw Number 5M2004.*

MONITORING

- Require that contractors familiarize their employees with specific invasive, noxious and prohibited noxious weeds common to the project area, during discussions at the daily tool box meetings.
- Conduct weeds monitoring and hand removal of weeds at the restored site for up to 5 years post construction.

CLEANING OF EQUIPMENT

- All vehicles and machinery should be cleaned before and after leaving the site at an appropriate car / equipment wash facility.

References and Further Reading

- Environmental Protection Agency. "National Pollutant Discharge Elimination System. Construction Entrances." http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=35, October 29, 2010.
- The City of Calgary, Wastewater & Drainage, Urban Development, Guidelines for Erosion & Sediment Control, February 2001.
- The City of Calgary Wastewater & Drainage, Urban Development, Field Manual for Effective Erosion & Sediment Control, February 2001.

ROCK RIPRAP

Description

- Rock riprap reduces erosion in areas where softer engineering techniques are not adequate.

Suitability

- Suitable for flow velocities up to 4.7 m/s when using the design methods presented. Higher velocities are possible with additional design consideration.

Advantages

- Well proven method of erosion protection;
- Protects against higher flow velocities and forces;

Limitations

- Availability of rock.
- Placement of rock can be difficult depending on site characteristics.
- Not aesthetically pleasing when large areas are covered in rock riprap alone.
- Large areas of rock riprap alone can negatively impact riparian, aquatic, and terrestrial habitat.
- Rock riprap can contribute to accelerated water velocities and an increased potential for higher erosive force downstream if flow has been channelized or redirected.
- Rock riprap can result in increased stormwater runoff rates and reduced filtration when compared to vegetated riparian areas.

Design Considerations

WATERCOURSE HYDRAULICS & HYDROLOGY

The watercourse hydraulics, hydrology and morphology should be reviewed by a specialist to predict design flow velocities, scour potential and any potential hydraulic impact to the watercourse and nearby structures.

BANK SLOPE AND GRADING

The bank slope should be graded prior to placement of riprap and the underlying filter fabric.

The minimum bank grade is dependant upon available equipment and installation techniques. A minimum slope of 2H:1V should be considered, however, steeper minimum slopes of around 1.5H:1V are possible but specialized equipment and installation techniques might be required. In addition, consideration of riprap stability should be made in terms of potential riprap failure and public safety. Extra care in rock placement is required at steeper slopes to ensure the rock interlocks.

ROCK RIPRAP

Rock riprap should be durable and angular in shape. Interlocking of angular rocks provides better resistance to movement than rounded rock.

ROCK SIZE AND DESIGN VELOCITY

There are many methods available to size rock riprap. One of the most common simplified methods of sizing riprap is based on flow velocity, however, this simplified method should not be used for the following conditions when:

- rock is subject to overtopping flow,
- there are aerated water splashes and cascades,
- there are hydraulic jumps,
- there are significant flow restrictions, or
- the flow super elevates around bends.

The table below provides maximum flow velocities for Class I modified, Class I, Class II, and Class III riprap by the simplified method.

Table O.1
Riprap Classification and Maximum Design Flow Velocities[1]

Riprap Class	**Class I Modified (Class I M)**		**Class I**		**Class II**		**Class III**	
Gradation	Size	Percent Passing	Size	Percent Passing	Size	Percent Passing	Size	Percent Passing
	300 mm	0	450 mm	0	800 mm	0	1100 mm	0
	200 mm	20	350 mm	20	600 mm	20	900 mm	20
	175 mm	50	300 mm	50	500 mm	50	800 mm	50
	125 mm	80	200 mm	80	300 mm	80	500 mm	80
Maximum Flow Velocity	2 m/s		3 m/s		4 m/s		4.7 m/s	

[1] Adapted from: S. Lowe, Fish Habitat Enhancement Structures - Typical Designs, (Edmonton, AB: Alberta Environmental Protection, Water Resources Management Services, 1996), 44.

When designing riprap, the bank flow velocity at various flood elevations needs to be considered. Depending on the channel shape and location, bank velocities can be significantly lower than the mean river channel velocity. Larger riprap is usually required at lower elevations where flood level bank velocities are higher.

RIPRAP THICKNESS

Riprap thickness ranging between DMAX and 1.5 DMAX is generally acceptable for high velocity flow areas[2], where DMAX is the maximum riprap diameter.

ICE ACTION ON RIPRAP

In addition to maximum flow velocities presented in the above table, ice action needs to be considered. Ice can damage or dislodge riprap by impact, ice pile up or by concentrating water flow. To account for this ice action, the Cold Regions Research Engineering Laboratory (CRREL) suggests that the maximum riprap diameter should be at least twice the ice thickness for slopes shallower than 3H:1V and about three times the ice thickness for steeper slopes.[3]

The CRREL suggestion could result in the requirement for very large riprap in cold regions with thick ice cover. It is likely that many other factors specific to any river, and in addition to ice thickness, can contribute to the potential level of ice action. Potentially the best way to design riprap for ice is to base the design on past experience within a particular river, however, specific site conditions such as location within the river and flow velocities need to be considered.

TOE SCOUR PROTECTION

When the bed of the watercourse is not on or near bedrock, consideration should be made for a riprap apron on the watercourse bed at the base of the slope to protect against undermining scour.

[2] Mike Slake & Associates Inc., *Water Control Structures - Selected Design Guidelines* (Edmonton, AB: Alberta Transportation & Civil Engineering Division, Civil Projects Branch and Alberta Environment Regional Services Water Management Operations, 2004), 11-22.
[3] P.F. Lagassee, P.E. Clopper, et al., *Riprap Design Criteria Recommended Specifications and Quality Control - NCHRP Report 568* (Washington: National Cooperative Highway Research Program, Transportation Research Board of the National Academies, 2006), 127.

ROCK RIPRAP DESIGN EXAMPLE

The following table is provided as an example only.

Table O.2
Example Flood Levels and River Velocities

Flood Event	**Mean Channel Velocity** (m/s)	**Bank Velocity** (m/s)	**Flow Elevation** (m)	**Riprap Class Required**
1:2 Year	1.3	1.2	1120.4	Class II **(for Ice Action)**
1:5 Year	2.1	1.8	1121.5	Class I (M)
1:10 Year	1.7	0.9	1122.6	Vegetation
1:25 Year	1.4	0.5	1123.0	Vegetation
1:50 Year	1.2	0.2	1123.6	Vegetation
1:100 Year	1.1	0.0	1124.0	Vegetation

In the preceding example table and following figure, Class II riprap was selected for toe erosion protection due to ice action and not bank flow velocity. The actual size of riprap used to protect against ice action can be based on past experience within a watercourse. The Class II riprap should be installed to at least the natural scour line elevation, below which vegetation is not established, as the natural scour line is likely caused by ice when design flow velocities are low.

Class 1 (M) riprap was chosen above the natural scour line based on flow velocity. Since natural vegetation is present on this bank, established vegetation alone should be adequate erosion protection at some point above the natural scour line. For this example the 1:10 year flood elevation was chosen, as this level is naturally vegetated and set back from the steep slope.

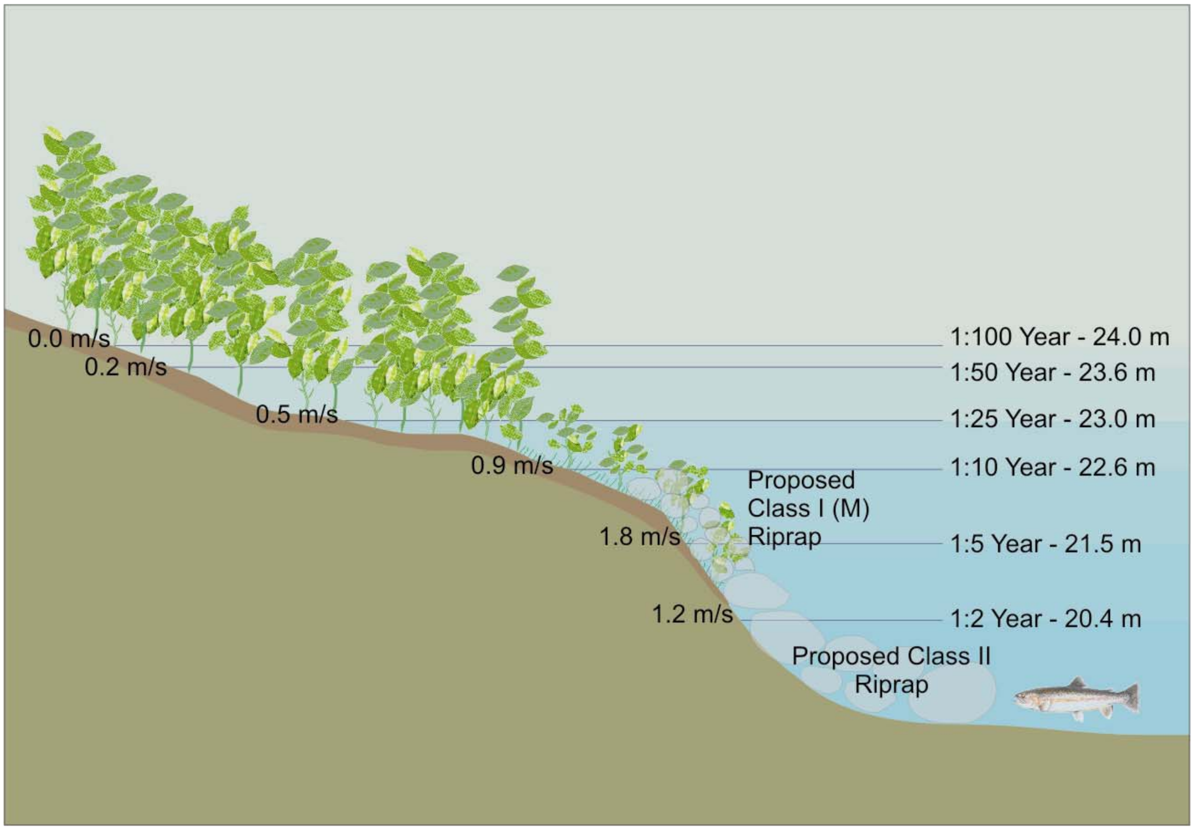

Figure O.1: Example of Riverbank Velocities and Riprap Selection[4]

FILTER MATERIAL

A filter is normally required between native soils and rock riprap to prevent piping of fine native materials into the rock riprap which could ultimately lead to slope or erosion failure. A geotextile filter is commonly used between rock riprap and native material, however, the use of geotextile as a filter under the rock riprap can make it difficult to install live plantings and a granular filter should be considered.

GRANULAR FILTER DESIGN CONSIDERATIONS

Any granular filter needs to be designed or approved by a geotechnical engineer for each specific application. Generally the gradation of the filter material should be parallel to the base soil[5.] This is to prevent piping of material through the filter. A common method of filter design is provided by Brown and Clyde for the U.S. Department of Transportation Federal Administration (1967, revised 1989), Hydraulic Engineering Circular No. 11, Design of Riprap Revetment, page 38. The filter requirements can be stated as follows:

[4] Terra Erosion Control Ltd. drawing.
[5] *RDCRSQC*, 62.

$$\frac{D_{15}(courserlayer)}{D_{85}(finerlayer)} < 5 < \frac{D_{15}(courserlayer)}{D_{15}(finerlayer)} < 40$$

Where the $finerlayer$ *is the native material and* $courserlayer$ *is the filter material. This condition must also be met when the* $finerlayer$ *is the filter and the* $courserlayer$ *is the riprap. The subscript values represent the 15%, 50% and 85% percent partial sizes. In some cases, multiple layers of filter and riprap might be required to meet the above conditions. Other publications, based on Brown and Clyde, also suggest that the following condition be met:*

$$\frac{D_{50}(courserlayer)}{D_{50}(finerlayer)} < 40$$

The gradation of the native material and potential filter materials need to be known in order to properly design a granular filter. This is particularly important if the native material is predominantly silt or clay.

The minimum granular filter thickness is generally stated as 150 mm where the gradation curves of adjacent layers are approximately parallel. Filter thickness should be increased as the gradations depart from parallel or when the filter is installed under water.

Geotextile Filter

A geotextile filter needs to be designed or approved by a geotechnical engineer for each specific application. Considerations for geotextile filter design might include the following steps[6]:

- Obtain base soil information.
- Determine particle retention criterion.
- Determine geotextile permeability criterion.
- Select a geotextile that meets the required strength criteria.
- Minimize long-term clogging potential.

[6] *RDCRSQC*, 62.

Optional Rock Vanes

Figure O.2: Constructed Rock Vane and Temporary Rock Vane Used to Anchor Floating Turbidity Curtain[7]

Vanes, also sometimes referred to as spurs, vanes or groynes, are low rock sills that project at an upstream angle from the stream bank. The potential benefits of vanes are as follows:

- Improved habitat by creating eddies, scour pools, sediment basins and areas of slowed water.
- Reduced erosion potential by deflecting flow away from the stream bank.
- Can reduce the amount or size of rock riprap required to protect the stream bank.
- Can be vegetated.
- Can be used to anchor and reduce current forces on temporary floating turbidity control curtains.

The suggested potential upstream angle of the vane varies in the available literature, with a range of 20˚ from the bank to nearly perpendicular to the bank. The actual angle implemented is dependent upon the desired affect to stream flow.

The size of rock used in the vane is depended on stream flow velocity but consideration needs to be made for potential increased flow velocities around the tip of the vane. If multiple vanes are used, the spacing between vanes is dependent upon the acceptable amount of water current on the bank.

[7] Terra Erosion Control Ltd. photos

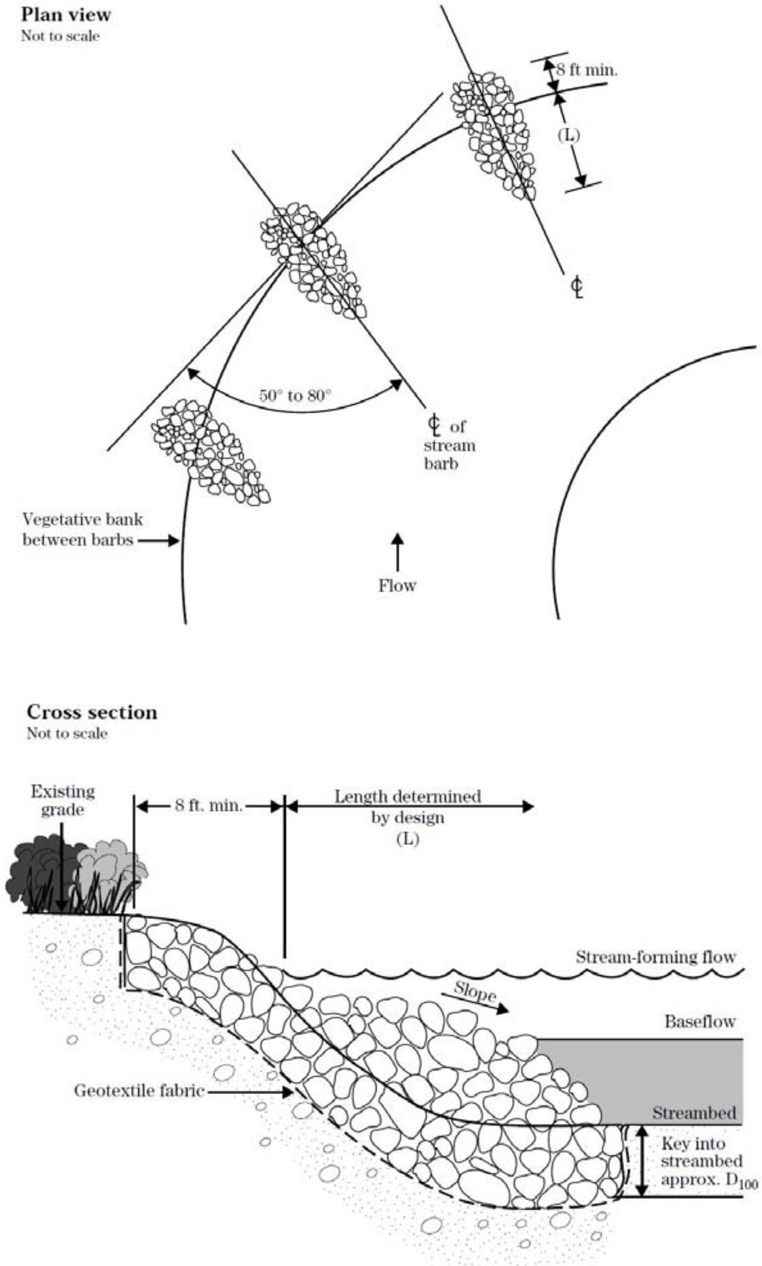

Figure O.3: Rock Vane Plan and Section[8]

[8] Reproduced from: United States Department of Agriculture, Natural Resources Conservation Services Engineering Field Handbook – Chapter 16 Streambank and Shoreline Protection (Washington: USDA, 1996), 16.58.

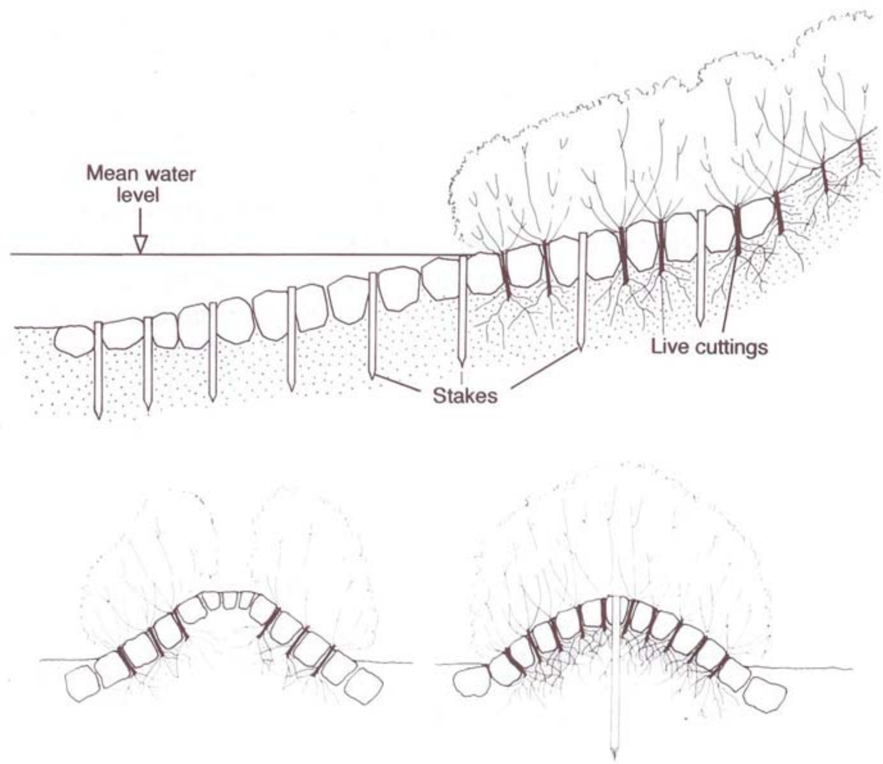

Figure O.4: Vegetated Vane Profile and Section[9]

Although rock vanes are viewed as beneficial to fish habitat and provide streambank protection, they can be viewed as a hazard to navigation by Transport Canada – Navigable Waters. Also, installation of any obstruction to stream flow can have negative impacts to stream morphology and erosion potential at areas not immediately adjacent to the obstruction. The watercourse hydraulics, hydrology and morphology should be reviewed by a specialist to predict design flow velocities, scour potential and any potential hydraulic impact to the watercourse and nearby structures.

[9] H.M Schiechtl and R. Stern. Water Bioengineering Techniques for Watercourse Bank and Shoreline Protection (Cambridge: Wiley-Blackwell, 1997), 96.

Maintenance

- Only limited long term maintenance will be required if designed and installed correctly.
- Periodic inspections for undermining or rock displacement.

References and Further Reading

- Lagasse, P.F., P.E. Clopper, et al. Riprap Design Criteria Recommended Specifications and Quality Control -NCHRP Report 568. Washington: National Cooperative Highway Research Program, Transportation Research Board of the National Academies, 2006.
- Lowe, S. Fish Habitat Enhancement Structures - Typical Designs. Edmonton, AB: Alberta Environmental Protection, Water Resources Management Services, 1996.
- Public Safety Section Water Management Branch. Riprap Design and Construction Guide. Victoria: Public Safety Section Water Management Branch, Ministry of Environment, Lands and Parks, Province of British Columbia, 2000.

CRITICAL SHEAR STRESS DUE TO WATER FLOW AND RESISTANCE OF MATERIALS

Description

There are a number of methods for designing stream flow erosion protection, however, the various methods generally fit into two categories of either a design based on maximum permissible velocities or a design based on critical shear stress (or tractive force).

This guideline provides examples for both methods and can be used for soils, gravels, cobbles, rocks, vegetation and soil bioengineering structures.

Suitability

- Suitable as a design aid for soils, gravels, cobbles, rocks, vegetation and soil bioengineering structures erodibility.

Advantages

- Provides a more detailed approach and can be used for more material types than that provided by Design Guideline O – Rock Riprap.

Limitations

There are number of methods for calculating maximum permissible velocities, critical shear stress and resistance of materials. This guideline only provides references to a few methods.

A good understanding of the site conditions, and the design equations and tools are required, as consideration needs to be made for such factors as:

- submergence of materials over time;
- materials on slopes;
- flow turbulence effects; and
- average stream velocities verses bank velocities or other peak velocities.

The watercourse hydraulics, hydrology and morphology should be reviewed by a specialist to predict design flow velocities, scour potential and any potential hydraulic impact to the watercourse and nearby structures. The following is provided only as a guideline.

Design Considerations

BACKGROUND

The following sections provide examples of how to design erosion control materials or bioengineering techniques based on either maximum permissible velocities or critical shear stress. These velocities or critical shear stresses can then be compared to material's resistance to velocity or shear stress. The materials resistance can either be calculated with the equations provided or looked up in one of the tables provided.

VELOCITY AND FLOW CALCULATION

The most detailed velocity and flow data for a watercourse can usually be obtained from a hydraulic modeling. The benefit of using a model is that watercourse velocities and flows can be evaluated under various flood conditions and usually at various points along a watercourse cross-section or profile.

If modeling data is not feasible or available, one of the most common methods of calculating open channel flow velocity is the Manning formula. It should be noted however that the velocity method should be used with caution as Manning formula results in the mean velocity for a channel. Considerations should be made for increases velocity at the center of a straight channel or outside bends of a curved channel. Manning formula as follows:

Manning Formula for Open Channel Velocity

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

Where V = Velocity (m/s)
n = Manning roughness coefficient (see below for values)
R = Hydraulic Radius (m^2/m)
S = Channel Slope (m/m)

The hydraulic radius can be calculated as follows:

$$R = \frac{A}{W_p}$$

Where R = Hydraulic Radius (m^2/m)
A = Water cross-sectional area (m^2)
W_p = Wetted perimeter or portion of the channel that is wet (m)

Manning formula can also be expressed in terms of flow rate as follows:

Manning Formula for Open Channel Flow

If the flow rate of an open channel is needed, Manning formula can be substituted into the standard flow equation $Q = VA$ to calculate flow (m^3/s) as follows:

$$Q = \frac{1}{n} A R^{2/3} S^{1/2}$$

Manning Roughness Coefficient (n)

There are a number of sources for determining Manning roughness coefficient (n). One good source is provided in Appendix F of the Alberta Transportation's Design Guidelines for Erosion and Sediment Control for Highways. An excerpt is provided as follows:

Table P.1
Manning Roughness Coefficients (n).[1]

	Stream Condition	Manning n
VI	**Natural stream channels**	
A.	**Minor streams (surface width at flood stage less than 100 ft)**	
1.	Fairly regular section	
	a. Some grass and weeds, little or no brush	0.030-0.035
	b. Dense growth of weeds, depth of flow materially greater than weed height	0.035-0.05
	c. Some weeds, light brush on banks	0.04-0.05
	d. Some weeds, heavy brush on banks	0.05-0.07
	e. Some weeds, dense willows on banks	0.06-0.08
	f. For trees within channel, with branches submerged at high stage, increase all above values by	0.01-0.10
2.	Irregular sections, with pools, slight channel meander; increase values in 1 a-3 about	0.01-0.002
3.	Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stage	
	a. Bottom of gravel, cobbles, and few boulders	0.04-0.05
	b. Bottom of cobbles, with large boulders	0.05-0.07
B.	**Flood plains (adjacent to natural streams)**	
1.	Pasture, no brush	
	a. Short grass	0.030-0.035
	b. High grass	0.035-0.05

[1] March, 2003 (Revised May 2003). Design Guidelines for Erosion and Sediment Control for Highways – Appendix F. Government of Alberta Transportation. Page F22.

	Stream Condition	Manning n
2.	Cultivated areas	
	a. No crop	0.03-0.04
	b. Mature row crops	0.035-0.045
	c. Mature field crops	0.04-0.05
3.	Heavy weeds, scattered brush	0.05-0.07
4.	Light brush and trees	
	a. Winter	0.05-0.06
	b. Summer	0.06-0.08
5.	Medium to dense brush	
	a. Winter	0.07-0.11
	b. Summer	0.10-0.16
6.	Dense willows, summer, not bent over by current	0.15-0.20
7.	Cleared land with tree stumps, 100-150 per acre	
	a. No sprouts	0.04-0.05
	b. With heavy growth of sprouts	0.06-0.08
8.	Heavy stand of timber, a few down trees, little undergrowth	
	a. Flood depth below branches	0.10-0.12
	b. Flood depth reaches branches	0.12-0.16
	c. Major streams (surface width at flood stage more than 100 ft): Roughness coefficient is usually less than for minor streams or on account of less effective resistance offered by irregular banks or vegetation on banks. The value of n for larger streams of most regular sections, with no boulders or brush, may be in the range of from	0.028-0.033

SHEAR STRESS OF WATER CALCULATION

There are number of methods to calculated shear stress induced by water. One of the simpler methods provided by Lachat 1999[2] is as follows:

Simplified Shear Stress Calculation

$$\tau = \rho R S$$

Where
τ = Fluid shear stress (N/m2)
ρ = Specific weight of water (10,000 N/m2)
R = Hydraulic Radius (m2/m)
S = Channel Slope (m/m)

[2] Translated from: Lachat, Bernard. Guide de Protection des Berges de Cours d'Eau en Techniques Végétales. Ministere de L'Amenagement du Territoire et de L'Environnement, 1999, page 34.

The hydraulic radius can be calculated as follows:

$$R = \frac{A}{W_p}$$

Where R = Hydraulic Radius or (m^2/m)
A = Water cross-sectional area (m^2)
W_p = Wetted perimeter or portion of the channel that is wet (m)

For large, wide channels $R \approx h$ (height of water in m) so the equation can be simplified as follows large, wide channels:

$$\tau \approx \rho h S$$

Shear Stress Correction for Flows on Outside Bends

The shear stress of water is generally greater on outside bends of watercourses and should be adjusted with the following multiplication factors:

1.10 – Slight meanders
1.35 – Moderate meanders
1.70 – High degree of meanders

CRITICAL SHEAR STRESS OF MATERIALS CALCULATION

The critical shear stress of materials is the pressure or force per unit area at which a material begins to move or fail due to an applied shear stress. Critical shear stress can also be thought of as a materials resistance to shear stress. The following calculations can be used as an alternative to figures and tables provided in this design guideline for material resistance to shear stress.

Critical Shear Stress Formula

There are a number of methods of calculating critical shear stress. Lachat 1999[3] provides the following method:

$$\tau_{cr} = 8d_{75}$$

Where τ_{cr} = Critical shear stress (N/m^2)
d_{75} = Is the diameter in cm where 75% of the material is smaller

[3] Translated from: Lachat, Bernard. Guide de Protection des Berges de Cours d'Eau en Techniques Végétales. Ministere de L'Amenagement du Territoire et de L'Environnement, 1999, page 34.

This formula is applicable to only cohesionless materials. For example, sand (d≈0.1 mm) erodes before silt (d≈0.01 mm) because silt has particle cohesion. The formula presented above by Lachat appears to have been simplified from Shields 1936[4]. Other derivations to improve predictions for various types of materials are also presented by Fischenich 2001[5].

Another alternate method is provided by Alberta Transportation[6] for particles larger than 100mm as follows:

$$\tau_p = 6.25x10^{-4} D_{50}$$

Where τ_p = Permissible shear stress in kPa (1 kPa = 1000 N/m^2)

d_{50} = Is the mean particle size in mm

Turbulence Effects on Critical Shear Stress

Critical shear stress can be lower in fast winding streams as flow turbulence can result in shear stress spikes. Lachat 1999 indicated that critical shear stress should be adjusted for turbulence with the following multiplication factors:

0.90 – Slight meanders
0.75 – Moderate meanders
0.60 – High degree of meanders

Slope Effects on Critical Shear Stress

Critical shear stress can also be lower for materials on a slope such as a bank toe. There are various equations to adjust critical shear stress such as those provided by Threshold Channel Design 2007[7] or Tools in Fluvial Geomorphology 2003[8]. This adjustment is however generally not required by the approach provide by these design guidelines as these guidelines recommend some sort of vegetative or hard surface toe protection and a simplified approach for riprap design is provided in Design Guideline O.

[4] Shields, A. 1936. Anwendung der Aehnlichkeitsmechanik und der Turbulenz Forschung auf die Geschiebebewegung. Mitt. der Preussische Versuchanstalt für Wasserbau und Schiffbau, Berlin, Germany, No. 26.
[5] Fischenich. 2001. Stability Thresholds for Stream Restoration Materials. EMRRP Technical Notes Collection (ERDC TN-EMRRP-SR-29), U.S. Army Engineering Research and Development Center, Vicksburg, Mississippi, Page 2.
[6] March, 2003 (Revised May 2003). Design Guidelines for Erosion and Sediment Control for Highways – Appendix F. Page F39.
[7] August 2007. Part 654 Stream Restoration Design National Engineering Handbook Chapter 8 Threshold Channel Design (210–VI–NEH), U.S. Department of Agriculture, Natural Resource Conservation Services.
[8] Editors: G. Mathias Kondolf and Herve Piegay. 2003. Tools in Fluvial Geomorphology, John Wiley & Sons Ltd., West Sussex, England, Page 315.

CRITICAL SHEAR STRESS OF MATERIALS (RESISTANCE OF MATERIALS TO SHEAR STRESS) TABLES AND FIGURES

The resistance of materials to erosion can be provided based on either critical shear stress of the material or maximum permissible velocity as presented in the following figures and tables.

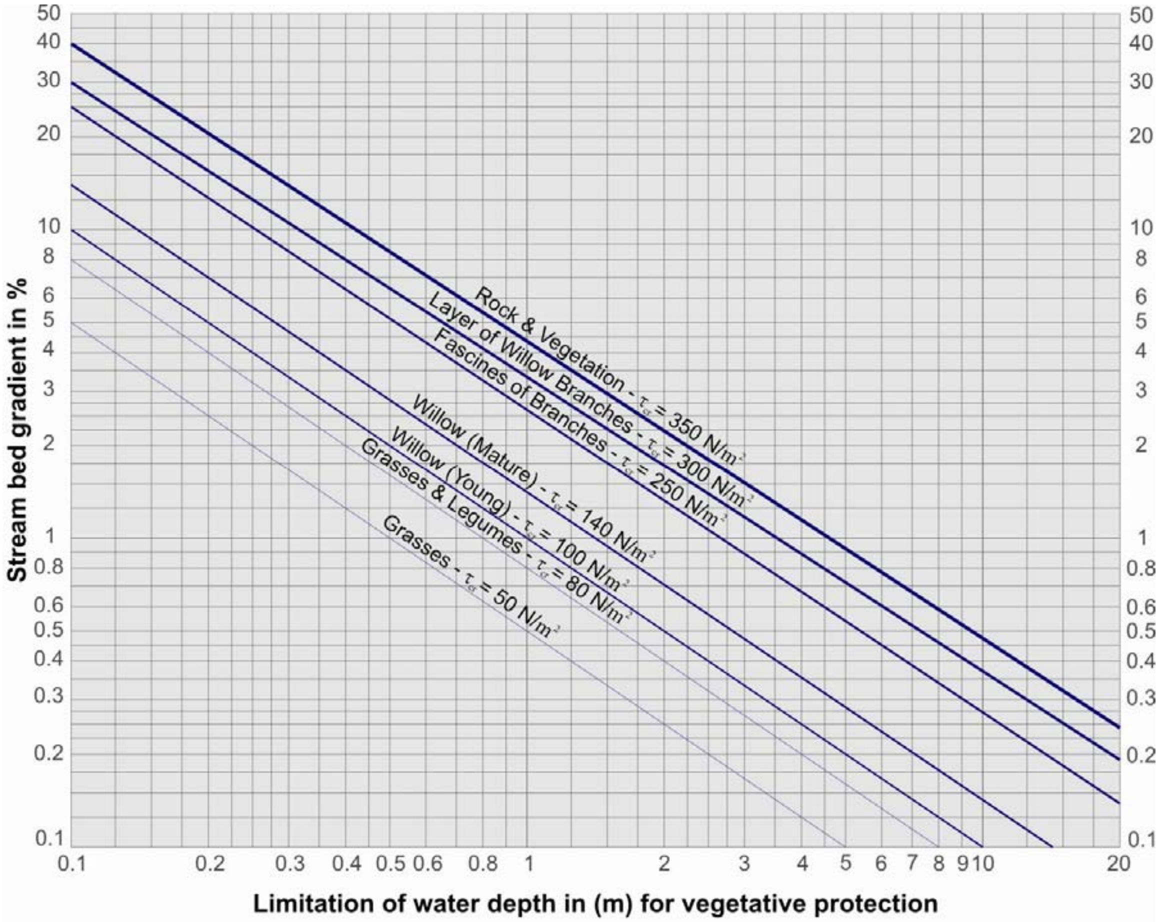

Figure P.1: Plant Protection on Scour Banks – Resistance to Shear Stress[9]

Figure P.1 above can be used to determine the critical shear stress of various bioengineering treatments on large, wide watercourses where the hydraulic radius ≈ the flow height. This method should however be used with caution or only as a check as the method is much simplified.

[9] Translated from: Lachat, Bernard. Guide de Protection des Berges de Cours d'Eau en Techniques Végétales. Ministere de L'Amenagement du Territoire et de L'Environnement, 1999, page 122.

Figure 2 provides Permissible Shear Stress in Pascals (1 Pascal = 1 N/m^2) for Cohesionless Soils.

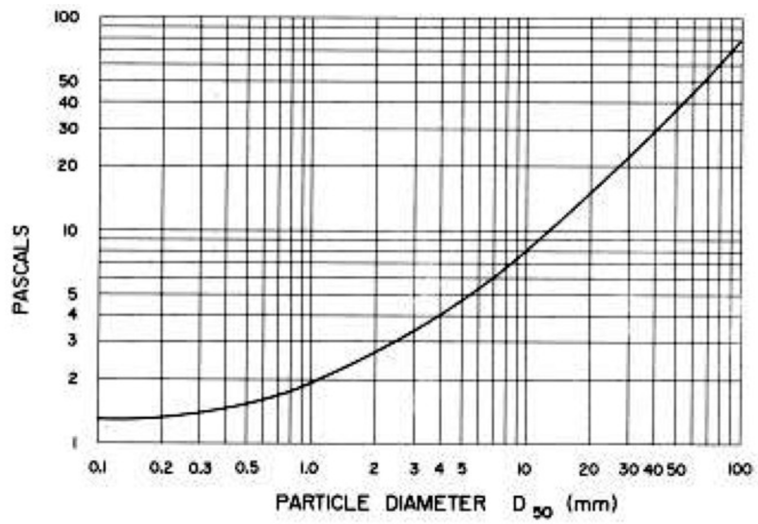

Figure P.2: Permissible Shear Stress for Cohesionless Soils[10]

Table P.2
Maximum Permissible Shear – Stress Values and Velocities for Various Materials[11]

Materials	**Test Time** (hr.)	**Performance Properties**	
		Maximum Permissible Shear Stress (N/m²)	**Maximum Permissible Velocity** (m/s)
Bare soil			
Noncohesive (Dia. = 0.1 – 25 mm)	-	1.5 – 20	0.46-0.76
Cohesive (P.I. = 4 – 50)	-	0.5 – 38	0.52-1.13 to 1.8 (hard pan)
Gravel riprap			
D_{50} = 25 mm (thickness t=2 D_{50})	-	15.8	0.76-1.13
D_{50} = 50 mm (thickness t=2 D_{50})	-	31.6	1.13-1.22
Rock riprap			
D_{50} = 150 mm (thickness t=1.5 D_{50})	-	95.8	2.2
D_{50} = 300 mm (thickness t=2 D_{50})	-	191.5	3.0
Gabion Mattress			
thickness = 0.25 m D_{50} = 120 mm	-	200	4.5 – 6.1
thickness = 0.30 m D_{50} = 150 mm	-	230	5.0 – 6.4
thickness = 0.50 m D_{50} = 190 mm	-	250	6.4 – 8.0

[10] March, 2003 (Revised May 2003). Design Guidelines for Erosion and Sediment Control for Highways – Appendix F. Government of Alberta Transportation. Page F39.
[11] March, 2003 (Revised May 2003). Design Guidelines for Erosion and Sediment Control for Highways – Appendix F. Government of Alberta Transportation. Page F16.

Materials	Test Time (hr.)	Performance Properties	
		Maximum Permissible Shear Stress (N/m²)	**Maximum Permissible Velocity** (m/s)
Grass (established)		16.8 – 177.2	0.8-2.4
Vegetative			
Class A Retardance	-	177.2	-
Class B Retardance	-	100.6	-
Class C Retardance	-	47.9	-
Class D Retardance	-	28.7	-
Class E Retardance	-	16.8	-
Fiberglass roving (SOP)			
Single	-	28.7	-
Double	-	40.7	-
Straw (loose) covered with net	-	69.4	-
Erosion Control mat (ECM)			
Coconut material	0.5	143	3.0-4.6
Wood excelsior material	-	74.2	-
Jute net	-	21.5	-
Straw blanket with sewn net	0.5	95.7 - 105	1.8 – 3.0
Straw/coconut blanket			
Straw/coconut blanket	0.5	120	3.0
Turf Reinforcement Mat (TRM)			
Bare ground conditions	0.5	239 – 287	5.5 – 8.2
	50	95.6	2.4
Vegetation established	0.5	100-380	5.5
growth period ≥ 36 mos. & growth density dependent	50	100-239	3.0
Composite Turf Renforcement Mat (C-TRM)			
Bare ground conditions	0.5	239	3.7
Vegetation established	0.5	382	6.1
	50	239	4.3

Table P.3
Permissible Shear Stress for Some Lining Materials[12]

Lining Type	Permissible Shear Stress (Pa)
Temporary	
Woven paper mat	7.19
Jute	21.56
Straw with net	69.46
Excelsior mat	74.25
Synthetic mat	95.80
Permanent	
Vegetation Class A	177.23
Vegetation Class B	100.59
Vegetation Class C	47.90
Vegetation Class D	28.74
Vegetation Class E	16.77
Gravel (25 mm)	15.81
Gravel (50 mm)	32.09
Rock riprap (150 mm dia.)	95.8
Rock riprap (300 mm dia.)	191.6

Table P.4
Material and Stream Restoration Techniques Resistance to Shear Stress[13]

Materials and Techniques	τ_{cr} (N/m^2)
Sand (<= 0.2mm)	2
Fine Gravel (< 2 cm)	12
Any grass, long immersed in water	15-18
Sod	25-30
Any Grass, just immersed in water	25-30
Small cobbles	40-60
Reeds roll	50
Willows, 1-2 years	50-70
Young grass, good quality	60-80
Willow, > 2 years	100-140
Herbaceous in Geotextile (Coir)	120

[12] March, 2003 (Revised May 2003). Design Guidelines for Erosion and Sediment Control for Highways – Appendix F. Government of Alberta Transportation. Page F42.
[13] Translated from: Lachat, Bernard. Guide de Protection des Berges de Cours d'Eau en Techniques Végétales. Ministere de L'Amenagement du Territoire et de L'Environnement, 1999, page 27.

Materials and Techniques	τ_{cr} (N/m^2)
Grassed precast concrete cellular blocks	160
Weaved willow & posts or piles	180
Riprap	200
Willow staking in loose riprap	250
Double willow posts with fascines	250
Brush Mattress	300
Willow staking in placed riprap	350
Willow, 20 years	800

Table P.5
Material and Stream Restoration Techniques Resistance to Shear Stress Over Time[14]

Plantation	Construction Completion (N/m2)	1st Growing Season (N/m2)	2nd Growing Season (N/m2)	3rd Growing Season (N/m2)
Plantation	0	10	30	>30
Sod	10	30	30	30
Brush mattress	50	150	300	>300
Shrubs carpet	32	40	100	300
Consolidated plantations	15	-	75	120
Willow staking in loose riprap	50	-	100	250
Fascine bundle mattress	100	200	-	>350
Willow staking in placed riprap	75	100	300	>350

Table P.6
Limiting Shear Stress and Velocity for Uniform Non-cohesive Sediments[15]

	Greater Than Diameter		□(deg)	τ_c	τ_{cr}		V_c	
Class Name	(inch)	(mm)			(lb/sf)	(N/m^2)	(ft/s)	(m/s)
Boulder	80	2030	42	0.054	37.4	1790	4.36	1.33
Very large	40	1020	42	0.054	18.7	900	3.08	0.94
Medium	20	510	42	0.054	9.3	450	2.2	0.67
Small	10	250	42	0.054	4.7	230	1.54	0.47
Cobble								
Large	5	130	42	0.054	2.3	110	1.08	0.33
Small	2.5	60	41	0.052	1.1	53	0.75	0.23

[14] Translated from: Lachat, Bernard. Guide de Protection des Berges de Cours d'Eau en Techniques Végétales. Ministere de L'Amenagement du Territoire et de L'Environnement, 1999, page 28.
[15] Fischenich. 2001. Stability Thresholds for Stream Restoration Materials. EMRRP Technical Notes Collection (ERDC TN-EMRRP-SR-29), U.S. Army Engineering Research and Development Center, Vicksburg, Mississippi, Page 3.

	Greater Than Diameter		□(deg)	τ_c	τ_{cr}		V_c	
Class Name	(inch)	(mm)			(lb/sf)	(N/m^2)	(ft/s)	(m/s)
Gravel								
Very course	1.3	33	40	0.05	0.54	26	0.52	0.16
Course	0.6	15	38	0.047	0.25	12	0.36	0.11
Medium	0.3	8	36	0.044	0.12	5.7	0.24	0.07
Fine	0.16	4	35	0.042	0.06	2.9	0.17	0.05
Very Fine	0.08	2	33	0.039	0.03	1.4	0.12	0.04
Sands								
Very Course	0.04	1.0	32	0.029	0.01	0.48	0.070	0.021
Course	0.02	0.51	31	0.033	0.006	0.29	0.055	0.017
Medium	0.01	0.25	30	0.048	0.004	0.19	0.045	0.014
Fine	0.005	0.13	30	0.072	0.003	0.14	0.040	0.012
Very Fine	0.003	0.08	30	0.109	0.002	0.10	0.035	0.011
Silts								
Course	0.002	0.05	30	0.165	0.001	0.05	0.030	0.009
Medium	0.001	0.03	30	0.25	0.001	0.05	0.025	0.008

Table P.7
Permissible Shear and Velocity for Selected Lining Materials[16]

	Permissible Shear Stress		Permissible Velocity	
Boundary Type	(lb/sq ft)	(N/m2)	(ft/sec)	(m/s)
Soils				
Fine colloidal sand	0.02 - 0.03	0.96 - 1.44	1.5	0.46
Sandy loam (non-colloidal)	0.03 - 0.04	1.43 - 1.92	1.8	0.53
Alluvial silt (non-colloidal)	0.045 - 0.050	2.15 - 2.39	2.0	0.61
Silty loam (non-colloidal)	0.045 - 0.051	2.15 - 2.39	1.75 - 2.25	0.53 - 0.69
Firm loam	0.075	3.59	2.5	0.76
Fine gravels	0.075	3.59	2.5	0.76
Stiff clay	0.26	12.45	3 - 4.5	0.91 - 1.37
Alluvial silt (colloidal)	0.26	12.45	3.75	1.14
Graded loam to cobbles	0.38	18.19	3.75	1.14
Graded silt to cobbles	0.43	20.59	4.0	1.22
Shales and hardpan	0.67	32.08	6.0	1.83
Gravel/Cobble				
1 inch (25mm)	0.33	15.8	2.5 - 5.0	0.76 - 1.52
2 inch (50mm)	0.67	32.08	3.0 - 6.0	0.91 - 1.83

[16] Fischenich. 2001. Stability Thresholds for Stream Restoration Materials. EMRRP Technical Notes Collection (ERDC TN-EMRRP-SR-29), U.S. Army Engineering Research and Development Center, Vicksburg, Mississippi, Page 5.

CRITICAL SHEAR STRESS DUE TO WATER FLOW AND RESISTANCE OF MATERIALS

	Permissible Shear Stress		Permissible Velocity	
Boundary Type	(lb/sq ft)	(N/m2)	(ft/sec)	(m/s)
6 inch (150mm)	2	95.8	4.0 - 7.5	1.22 - 2.29
12 inch (300mm)	4	191.5	5.5 - 12	1.68 - 3.66
Vegetation				
Class A turf	3.7	177.2	6.0 - 8.0	1.83 - 2.44
Class B turf	2.1	100.5	4.0 - 7.0	1.22 - 2.13
Class C turf	1	47.8	3.5	1.07
Long native grasses	1.2 - 1.7	57.5 - 81.4	4.0 - 6.0	1.22 - 1.83
Short native and bunch grasses	0.7 - 0.95	33.5 - 45.5	3.0 - 4.0	0.91 - 1.22
Reed plantings	0.1 - 0.6	4.79 - 28.7	-	-
Hardwood tree plantings	0.41 - 2.5	19.63 - 119.7	-	-
Temporary Degradable Rolled Erosion Control Products				
Jute net	0.45	21.5	1.0 - 2.5	0.30 - 0.76
Straw with net	1.5 - 1.65	71.8 - 79.0	1.0 - 3.0	0.30 - 0.91
Coconut fiber with net	2.25	107.7	3.0 - 4.0	0.91 - 1.22
Fiberglass roving	2	95.8	2.5 - 7.0	0.76 - 2.13
Non-Degradabel Rolled Erosion Control Products				
Unvegetated	3	143.6	5.0 - 7.0	1.52 - 2.13
Partially established	4.0 - 6.0	191.5 - 287.3	7.5 - 15	2.29 - 4.57
Fully vegetated	8	383	8.0 - 21	2.44 - 6.40
Riprap				
6 inch (150mm) d_{50}	2.5	119.7	5.0 - 10	1.52 - 3.05
9 inch (225mm) d_{50}	3.8	181.9	7.0 -11	2.13 - 3.35
12 inch (300mm) d_{50}	5.1	244.2	10 - 13	3.05 - 3.96
18 inch (450mm) d_{50}	7.6	363.9	12 - 16	3.66 - 4.88
24 inch (600mm) d_{50}	10.1	483.6	14 - 18	4.27 - 5.49
Soil Bioengineering				
Wattles	0.2 - 1.0	9.58 - 47.9	3.0	0.91
Reed fascine	0.6 - 1.25	28.7 - 59.9	5.0	1.52
Coir roll	3.0 - 5.0	143.6 - 239.4	8	2.44
Vegetated coir mat	4.0 - 8.0	191.5 - 383.0	9.5	2.90
Live brush mattress (initial)	0.4 - 4.1	19.2 - 196.3	4.0	1.22
Live brush mattress (grown)	3.9 - 8.2	186.7 - 392.6	12.0	3.66
Brush layering (initial/grown)	0.4 - 6.25	19.2 - 299.3	12.0	3.66
Live fascine	1.25 - 3.1	59.9 - 148.4	6.0 - 8.0	1.83 - 2.44
Live willow stakes	2.1 – 3.1	100.5 – 148.4	3.0 - 10	0.91 - 3.05
Hard Surfacing				
Gabions	10	479	14 - 19	4.27 - 5.79

Boundary Type	Permissible Shear Stress		Permissible Velocity	
	(lb/sq ft)	(N/m2)	(ft/sec)	(m/s)
Concrete	12.5	599	>18	>5.4

References and Further Reading

- Design Guidelines for Erosion and Sediment Control for Highways – Appendix F. Government of Alberta Transportation. March, 2003 (Revised May 2003)
- Lachat, Bernard. Guide de Protection des Berges de Cours d'Eau en Techniques Végétales. Ministere de L'Amenagement du Territoire et de L'Environnement. 1999
- Shields, A. Anwendung der Aehnlichkeitsmechanik und der Turbulenz Forschung auf die Geschiebebewegung. Mitt. der Preussische Versuchanstalt für Wasserbau und Schiffbau, Berlin, Germany, No. 26. 1936.
- Fischenich. Stability Thresholds for Stream Restoration Materials . EMRRP Technical Notes Collection (ERDC TN-EMRRP-SR-29). U.S. Army Engineering Research and Development Center, Vicksburg, Mississippi. 2001.
- Part 654 Stream Restoration Design National Engineering Handbook Chapter 8 Threshold Channel Design (210–VI–NEH). U.S. Department of Agriculture, Natural Resource Conservation Services. August 2007.
- Editors: G. Mathias Kondolf and Herve Piegay. Tools in Fluvial Geomorphology. John Wiley & Sons Ltd., West Sussex, England. 2003.

Streambank Erosion and Potential Remedial Measures

Guideline Q

LOW UNDERMINED SHORELINE - PROTECTION OF HIGH VALUE FISH HABITAT

Figure Q.1: Example of Undermined Bank with Excellent Overhanging Native Woody Vegetation[1]

Figure Q.2: Example of Undermined Bank with Lack of Overhanging Woody Vegetation where Fish Habitat Could Be Improved [2]

Description

When the shoreline is undermined at the normal water level, it may be left alone to provide fish habitat (cover & hiding) if erosion is not a concern to nearby infrastructure (see Figure Q.1). If ongoing shoreline erosion does pose a threat to nearby infrastructure and / or fish habitat improvement is desirable (Figure Q.2), mitigations described below could be applied. These mitigations are intended to provide improved shoreline protection while maintaining and enhancing the fish sheltering habitat.

Suitability

- Low (less than 1 m tall) undermined shorelines with high fish habitat value.

Advantages

- Creates or maintains hiding places and cover for fish to evade predators and improves shoreline protection.

Limitations

- Access to site and transport of materials.
- Potential fragility of site, i.e., working on the site without causing it to slump.

[1] AMEC Photo
[2] Cows and Fish Photo

Design Considerations

- Fish increase their chances of survival by seeking out hiding places where they evade predators. Hiding places are often found in the shallows where logs, boulders and aquatic vegetation can be found. Other potential hideouts can be found in deep water and in the shadows of undercut stream banks[3].

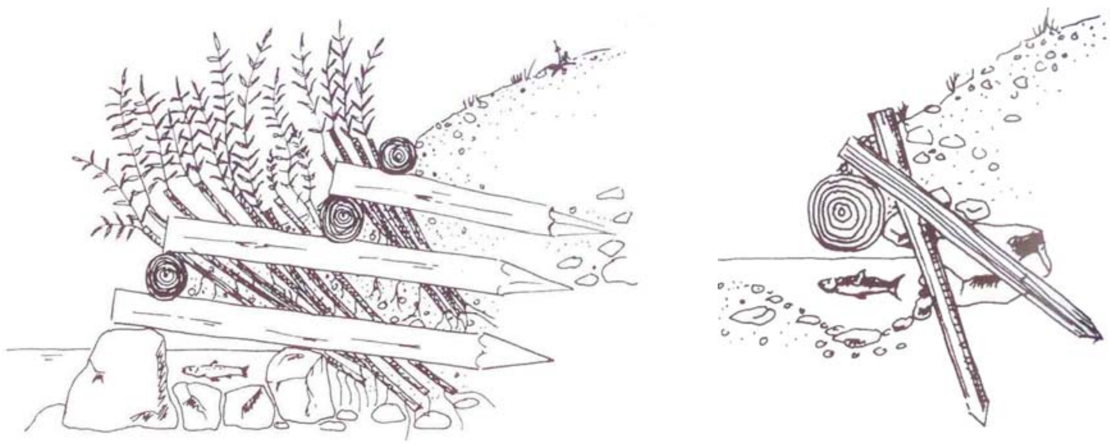

Figure Q.3: Constructed or Stabilized Fish Shelter Habitat and Bank Protection[4]

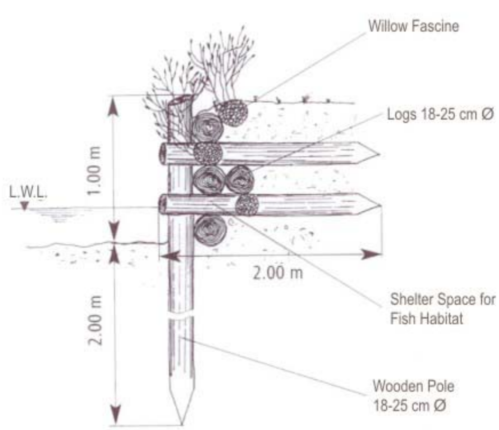

Figure Q.4: Shoreline Shelter Platform for Fish Habitat[5]

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[3] Fisheries and Oceans Canada, *The Fish Habitat Primer - A Guide to Understanding Freshwater Fish Habitat in the Prairies*, (Calgary: DFO, 2008), p6.
[4] Reproduced from: Helgard Zeh, *Soil Bioengineering Construction Type Manual* (Zurich: European Federation for Soil Bioengineering, 2007), 150.

Implementation

- Install adequate protection to prevent / reduce sediment delivery to water bodies in accordance with regulations.
- Fish shelters are built in the form of niches in wood, rocks, root stocks or fascines below the mean water level.
- For live material use see Design Guideline K.
- Customize protected bank structures / fish shelters to specific sites and dimensions of sites using local or imported material and site specific construction.

Maintenance

- Monitor site for growth and erosion for the first three growing seasons and repair minor failures if necessary.

References and Further Reading

- Fisheries and Oceans Canada. The Fish Habitat Primer - A Guide to Understanding Freshwater Fish Habitat in the Prairies. Calgary: DFO, 2008.
- Zeh, Helgard. Soil Bioengineering Construction Type Manual. Zurich: European Federation for Soil Bioengineering, 2007.
- Florin Florineth, Piante Al Posto Del Cemento Manuale di Ingegneria Naturalistica e Verde Tecnico, (Milano, Italy: Il Verde Editoriale S.r.l., 2007)

[5] Adapted from: Florin Florineth, Piante Al Posto Del Cemento Manuale di Ingegneria Naturalistica e Verde Tecnico, (Milano, Italy: Il Verde Editoriale S.r.l., 2007)