The City of Calgary

# RIPARIAN MONITORING PROGRAM PHASE 2 FINAL PROGRAM REPORT

KERR WOOD LEIDAL
consulting engineers

**Final Report**
**December 14, 2023**
**KWL Project No. 810.090.300**

# Contents

## Figures

## Tables

## Photos

## Information Boxes



## Appendices

# Acknowledgements

The agencies and individuals listed below are acknowledged for their significant contribution and support for this project including the preparation of this report.

- The City of Calgary Sponsors:
  - Carolyn Bowen – Climate and Environment
  - Harpreet Sandhu – Climate and Environment
  - Pamela Duncan – Climate and Environment
  - Sandy Davis – Climate and Environment

- The City of Calgary Project Team and Subject Matter Experts:
  - Norma Posada – Climate and Environment
  - Narayan Pokhrel – Climate and Environment
  - Jonathan Slaney – Climate and Environment
  - Caitlyn Howe – Climate and Environment
  - Sarah Marshall – Climate and Environment
  - Maggie Nelson – Climate and Environment
  - Reed Froklage – Climate and Environment
  - George Roman – Climate and Environment
  - Rene Letourneau – Utilities Delivery
  - Tim Walls – Former City Parks
  - Jason Weiler – Public Spaces Delivery
  - James Papineau – Public Spaces Delivery

- City of Calgary Project Managers (City of Calgary Monitoring Sites):
  - Former Water Resources Business Unit
  - Former Parks Business Unit

- All external organizations that provided project information:
  - Shana Barbour and Dylan Barnes – Friends of Fish Creek
  - Lesley Peterson – Trout Unlimited Canada (TUC)
  - Rob Kobzar – Valley Ridge Golf Course
  - Clayton Weiss – Alberta Agriculture and Irrigation
  - Angelique Lavigne – Alberta Forestry, Parks and Tourism

- Prime Consultant Team / Subject Matter Experts
  - Craig Kipkie, Mike Gallant, Dave Murray, and Deighen Blakely – Kerr Wood Leidal Associates Ltd. (KWL)

- Sub-Consultant Team / Subject Matter Experts
  - Pierre Raymond – Terra Erosion Control Ltd. (TEC)
  - Kathryn Hull and other key contributors: Christy Sikina, Kristina Boehler, and Kathryn Romanchuk – Alberta Riparian Habitat Management Society (Cows and Fish)
  - Andre Evette, Delphine Jaymond, and Marie-Ann Dusz – National Research Institute for Agriculture, Food and Environment, Grenoble, France (INRAE)
  - Alan Dodd – Longview Ecological (LE)

# Executive Summary

The City of Calgary (The City) has committed to conserving and improving the ecological health of riparian areas in Calgary as outlined in the *Riparian Strategy* (City of Calgary, 2013) and the *Riparian Action Program* (City of Calgary, 2017). Riparian areas are critical habitats along Calgary's stream and river valleys, contributing to flood and drought resilience, water quality, biodiversity, and recreational amenities. The City's *Riparian Action Program* establishes actions to protect and manage riparian areas and sets a 2026 riparian health target of a city-wide average riparian health score of 72%.

To address key actions in the *Riparian Action Program*, The City initiated the Riparian Monitoring Program (RMP) in 2017. The main objectives of the program were to better understand long-term trends in riparian health in Calgary and the effectiveness of riparian restoration techniques in Calgary. Phase 1 was completed in 2018 and consisted of the development of the *Monitoring Plan* for this program. Phase 2 was undertaken from 2018 to 2022 as part of a five-year monitoring program to implement the RMP *Monitoring Plan*.

The purpose of this Final Program Report is to summarize the key results, successes, areas for improvement and recommendations that were documented during Phase 2 of the RMP. This report is not meant to be a specific guideline document for City project managers or practitioners. However, the results of the RMP will be accessible to City staff and external stakeholders including practitioners, contractors, and the public. This report provides information that can be used during the planning and design of riparian restoration projects, and the results may inform the development and/or review of City guidelines and procedures. Identified priority restoration areas may also inform future City restoration plans.

The RMP consists of five components, of which the key results from the following three components are summarized in this report: riparian health trend monitoring, bank effectiveness monitoring, and riparian effectiveness monitoring. Brief descriptions of these components are provided below.

- **Riparian health trend monitoring:** The Riparian Health Inventory (RHI) protocols were used to assess vegetation, soil, and hydrological parameters in riparian sites across major streams and rivers. The objectives were to track changes in riparian health, measure progress toward the city-wide riparian health target of 72%, and expand monitoring sites for a more representative cross-section of locations.
- **Bank effectiveness monitoring:** The success of riverbank bioengineering projects was evaluated by selecting representative monitoring sites, assessing structure and material performance, assessing vegetation establishment, and evaluating the projects' effectiveness after one, three, and five-or-more-years post-construction. The goal was to determine the effectiveness of different bioengineering techniques and provide recommendations for design improvements and long-term monitoring needs.
- **Riparian effectiveness monitoring:** The success of riparian restoration projects was evaluated by selecting representative monitoring sites, assessing vegetation establishment, and evaluating the projects' effectiveness after one, three, and five-or-more-years post-construction. The goal was to determine the effectiveness of different planting techniques and provide recommendations for design improvements and long-term monitoring needs.

Table 1 below summarizes key facts and highlights contained in this report.

**Table 1: Quick Facts and Key Highlights**

| Quick Facts | Trend Monitoring | Bank Effectiveness | Riparian Effectiveness |
|---|---|---|---|
| **Data Collection Years** | 2007-2022 (16 years) | 2018-2022 (5 years) | 2018-2022 (5-years) |
| **Number of Individual Sites/Projects Assessed for Riparian Health / Project Effectiveness** | 122<br>(104 permanent waterbodies[1];<br>18 unnamed minor tributaries) | 69<br>(52 City-delivered projects;<br>17 external projects) | 42<br>(25 City-delivered projects;<br>17 external projects) |
| **Total Number of Assessments (i.e., including revisit assessments)** | 780<br>(since 2007) | Detailed: 99 | Reconnaissance: 42<br>Detailed: 59 |
| **Site Locations** | Primarily along major rivers and streams (i.e., Bow River, Elbow River, Nose Creek and West Nose Creek) | Bow River - 41 sites<br>Elbow River - 17 sites<br>Nose Creek - 4 sites<br>West Nose Creek - 3 sites<br>Shaganappi Creek - 2 sites<br>Confederation Creek - 1 site<br>Forest Lawn Creek - 1 site | Bow River - 19 sites<br>Elbow River - 8 sites<br>Fish Creek - 6 sites<br>Nose Creek – 1 site<br>West Nose Creek - 8 sites |
| **Monitoring Extent Highlights** | Total of 591 ha of riparian area and 84 km of bank assessed since 2007 | Total 7.6 km of bank assessed<br>10,912 trees and shrubs sampled | Total 16.5 km and 228 ha of bank area assessed<br>5,457 trees and shrubs sampled |
| **Number of Failure Sites [2]** | n/a | 7 of 69 sites<br>(5 City-delivered and 2 external projects) | 12 of 42 sites<br>(3 City-delivered and 9 external projects) |
| **Current Average City-Wide Riparian Health Score** | 69%<br>(compared to Baseline 61%) | n/a | n/a |
| **Number of Assessed Techniques** | n/a | 9 | 2 |
| **Highest to Lowest Rated Technique [3]** | n/a | Brush mattress; Vegetated crib wall; Vegetated retaining wall; Brush layers; Wattle fence; Fascine; Plantings; Vegetated Riprap; Live staking. | Planting; Live Staking |

Notes:
1. Note that only 101 sites were included in the current health score due to overlap with other sites, and access constraints during relevant timing window leading to deferred assessments. See Section 2.14 in the main report for additional details.
2. Per the definition in the *Monitoring Plan* (KWL, 2018), a Year 1 site is determined to be a failure if: 1) the works are found to be missing, degraded or ineffective; and/or, 2) if the woody vegetation survival is < 25%. A Year 3 or 5+ site is a failure if the works are found to be missing, degraded or ineffective. 'Works' refers to the bioengineering approach (e.g., technique) used at a site.
3. Bioengineering technique rankings are based on a ranking of five woody vegetation growth parameters (leader growth, shoot length, diameter, Year 1 survival, and canopy cover). The preferred riparian effectiveness technique was determined based on Year 1 survivorship. Design / construction costs, construction complexity, or regulatory approval requirements/ timelines were not factored in the ranking.

# RMP Key Results

Below is a summary of key results. More detailed results can be found in the Technical Executive Summary and Sections 3.3 and 4.3 of this report.

## Riparian Health Trend Monitoring Key Results

### Long-Term Trend Analysis (Original 58 Sites)

The original trend analysis to support the preparation of the city-wide riparian health target in the *Riparian Action Program* report (City of Calgary, 2017) consisted of long-term data from **58** sites along major streams and rivers. These data were collected from 2007-2010, 2014-2015, and 2019-2020, with an approximate five-year revisit frequency. Based on that data, riparian health scores city-wide have increased from **61% to approximately 65%**, remaining in the *healthy, with problems* category[1] (the current City-wide riparian health score is provided on page 5). Factors contributing to this improvement include beneficial impacts from the 2013 flood along the Bow and Elbow Rivers such as the regeneration of poplar and other native trees where deposits from the flood provided ideal habitat for growth. In addition, there has been improved management and restoration efforts in some sites allowing for natural recovery of vegetation.

Riparian health trends by management zone show the largest score increase since baseline conditions for the **Restoration Management Zone**, a focal area for ongoing restoration projects city-wide. The highest average riparian health rating for riparian habitat is the **Conservation Management Zone** (i.e., natural environment parks such as Weaselhead Flats, the Inglewood Bird Sanctuary, and Bowmont Park).

By sub-basin, the Bow River's riparian health scores increased by approximately 3% from 2008-2010 to 2014/2015 but then slightly declined in 2019/2020,mainly due to post-flood landscaping and bank stabilization projects. Many of these projects included a bioengineering component that, although beneficial in the long term, can also negatively impact health in the short term while plants establish and mature. For example, these impacts can include increases in bare ground during construction or soil compaction from equipment which lessen over time as the area naturalizes and plants grow and mature. The Elbow River had different health scores for its upper and lower reaches (above and below the Glenmore Reservoir), with overall healthier scores for the upper reach and slight improvements in the lower reach. Nose Creek sites mostly rated as *unhealthy* due to historic impacts from channelization while West Nose Creek sites were generally *healthy, with problems*.

Table 2 below shows the long-term trends for key RHI parameters since 2007.

[1] RMP trend monitoring component objective 1 and 2

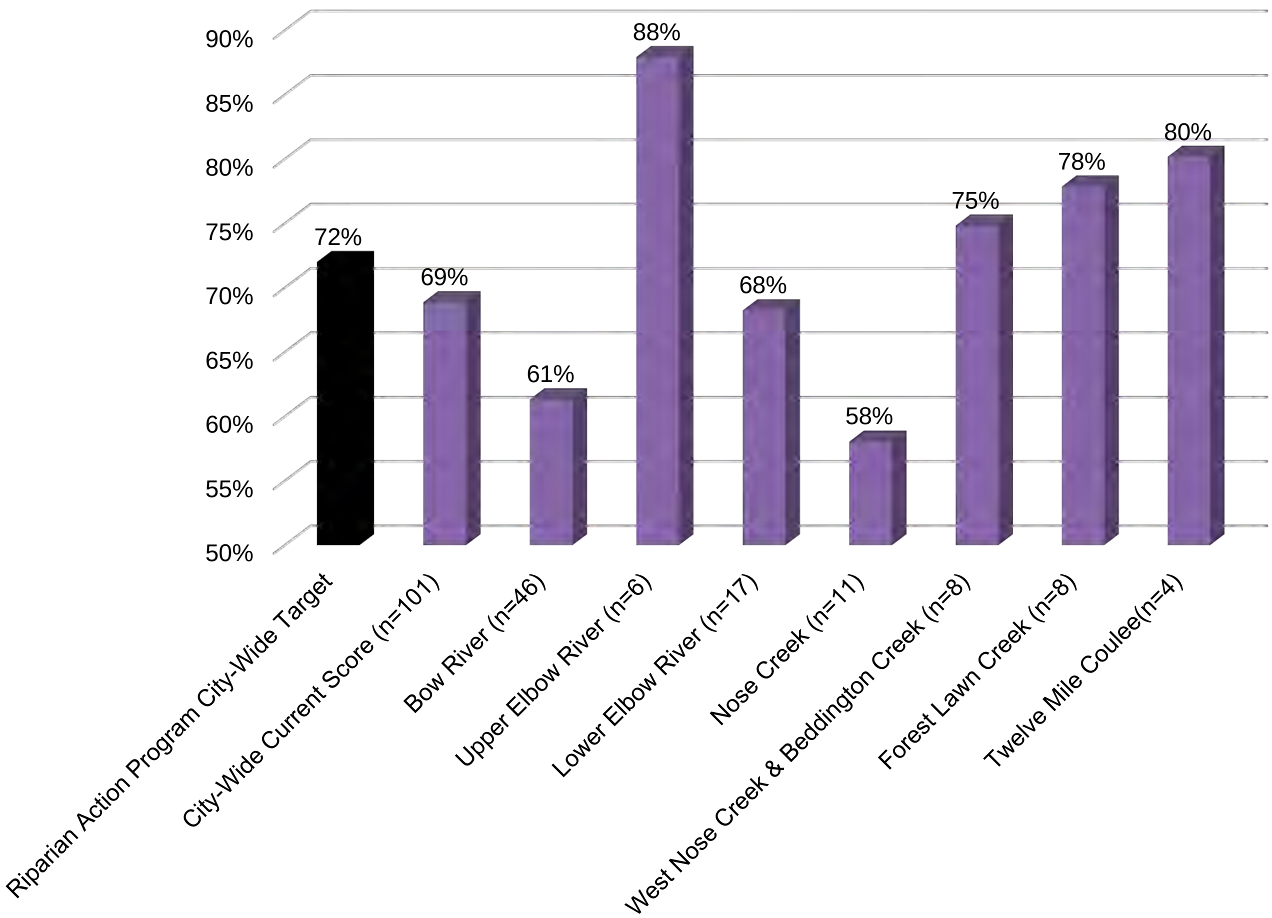
**Table 2: General Long-Term Trends in Key Riparian Health Parameters Since 2007 (58 sites)**

| *Improving or Declining Parameters:* | *Waterbody:* | *Contributing Factors:* |
|---|---|---|
| Improved cottonwood and balsam poplar regeneration<br>Improved regeneration of other native trees | Bow River | – Post-2013 flood poplar and willow recruitment<br>– Natural recovery following management improvements to fence-out riverbank habitats |
| Improved regeneration of preferred shrubs | Upper Elbow River | – Post-2013 flood poplar and willow recruitment |
| Improved vegetative cover<br>Reduced human-caused bare ground | Lower Elbow River | – Riparian planting and bioengineering projects<br>– Natural recovery following management improvements to fence-out riverbank habitats |
| Reduced root mass protection | Lower Elbow River,<br>Nose Creek | – Lower Elbow: increasing riprap armouring at base of bank<br>– Nose Creek: stormwater inputs and channelization increase bank slumping and erosion |
| Increased human-caused bare ground | Bow River | – Recreational trails reinstated post-flood and increasing use occurring in many river parks |
| Increased invasive plants (canopy cover) | Bow River,<br>Lower Elbow River,<br>Nose Creek | – Increased expansion of pre-existing populations of weeds<br>– New invasive species incursions and threats<br>– Disturbance/bank repair related infestations |
| ***Watershed Limiting Factors:*** | | |
| Control of flood peak and timing by upstream dams | Bow River | – All Bow River sites have score deductions due to stabilization of flows by operation of upstream dams (i.e., the Kananaskis Falls, Horseshoe Falls, Ghost and Bearspaw dams and an additional five hydroelectric facilities/dams located along tributaries of the Bow River). |
| Channelization | Nose Creek | – The majority of Nose Creek south of Airport Trail NE was historically straightened, resulting in loss of natural meanders and historic floodplain riparian habitat. |

### Expanded City-Wide Riparian Health Results (major streams and rivers only) and Current City-Wide Score

From 2014 onward and during Phase 2 of the RMP, the trend monitoring program expanded from 58 sites to 101 sites city-wide[2], resulting in a **current city-wide riparian health score of approximately 69%** (*healthy, with problems*)[3]. Figure 1 below shows the results for the expanded project area in comparison to baseline. The highest rated riparian sites were located along the southeast fringe for the Bow River and in Weaselhead Flats and Clearwater Legacy Parks for the Elbow River.

**Figure 1: City-Wide Current Score Summary by Waterbody (n=101 sites, 84 km of bank length; 590.5 ha of habitat)**




[2] RMP trend monitoring component objective 3

[3] RMP trend monitoring component objectives 1 and 2

## Bank Effectiveness Monitoring Key Results

For the bank effectiveness component of the RMP, each site was classified by typology and age class[4]. Data collection included observations of physical stability and material condition, and measurements of vegetation survival and growth. A rating system was used to evaluate project effectiveness, combining five individual ratings to create an overall score out of 100. Statistical analysis was conducted to determine statistically significant results regarding age class, typology, bioengineering technique, vegetation survival and growth, beneficial practices, and limiting factors. Key results are provided below and split into general findings and statistical results.

### General Findings

#### Monitoring Data Filling Key Knowledge Gap

The data that was collected for the bank effectiveness component is helping to fill a key technical, practical, and scientific knowledge gap for bioengineering projects. Until now there have been few monitoring studies conducted for bioengineering projects in Calgary or elsewhere in the province, across North America, or worldwide and none as thorough as the RMP.

#### Project Documentation[5]

Key project documentation such as design drawings, maintenance records, and as-built reports was not always available to the RMP team for review for the monitoring sites. As-built/record drawings and maintenance records were available for less than 50% of assessed sites.

#### Physical Stability and Material Condition[6]

Results showed that most sites were stable with little erosion, but there were some erosion issues due to unsuitable materials or design – particularly in the backfill material in vegetated crib walls. Permanent bioengineering construction materials such as rock, timber, concrete, and steel were generally in good condition, but the condition of temporary materials varied with some issues with installation and material selection. Synthetic erosion and sediment control materials were observed at 21 of the 69 bank effectiveness monitoring sites (30%) and will persist in the environment, and where exposed may cause risks for wildlife, fish, and the public over the lifespan of the product.

#### Habitat Enhancements [6]

Habitat enhancements such as instream boulders, woody debris, and overhanging vegetation that were incorporated into bioengineering structures are performing well. For example, overhanging cover was observed to be 2 m to 3 m at some locations and providing good overhead shade, cover, and organic debris input for fish habitat.

#### Vegetation Design, Installation, and Establishment [6]

Most often, vegetation species and stock were selected appropriately. A relatively new stock referred to as tall rooted stakes were found to provide a good option for summer construction when the use of dormant live cuttings is no longer recommended. Poor vegetation growth and high mortality was observed at sites where best

[4] RMP effectiveness monitoring component objective 2
[5] RMP effectiveness monitoring component objective 8
[6] RMP effectiveness monitoring component objective 3, 4, 5, and 7

practices for scheduling the installation of live cuttings was not followed. It was visually estimated that overall an average of 85% of the streambank for all monitoring sites had deep, binding root mass with 23 sites with 100%. It was observed for several sites that full canopy closure from higher density planting was limiting invasive weed growth, root growth from planted vegetation was binding soil, and that natural stabilization and ecological development is occurring over time.

### Site-Specific Limiting Factors[7]

The dry climate governs bioengineering design in Calgary overall due to low soil moisture conditions. Because of this, irrigation is needed to support vegetation establishment until an adequate root system is established. For failure sites, the next most often documented site-specific limiting factors for site stability and vegetation establishment were “erosion”, “existing vegetation competition”, and “maintenance issues” (six of seven sites). Over all sites, the most often noted limiting factors for site stability and vegetation establishment were “maintenance issues” (93 of 99 assessments), “existing vegetation competition” (92 of 99 assessments), and “compacted soils” (76 of 99 assessments). Additionally, soil compaction was found to have a negative impact on vegetation growth.

### Maintenance Practices[8]

Maintenance documentation needs to be improved, and practices such as weed whacking should be discontinued in favor of hand practices due to the damage to planted vegetation that was observed. While limited irrigation data was available, better irrigation appears to be needed for container plants that are installed above the bank on the terrace. Temporary browsing protection fencing needs to be repaired immediately, otherwise severe browsing has been observed to occur.

### Failure Sites[9]

Seven failure sites were identified, mainly due to Year 1 age class vegetation survival of less than 25% or structural issues.

### Performance Targets[10]

Results for woody vegetation survival, cover, and density of living shoots for several bioengineering techniques were compared to the literature values to validate site performance and confirm if literature targets are applicable to projects in Calgary. Several published targets were met or exceeded, confirmed that the literature values can be used for Calgary bioengineering projects.

### Highest Rated Bank Effectiveness Site [9]

Many sites were observed with outstanding vegetation establishment and growth across the city that will serve as benchmarks for future bioengineering and riparian planting projects. **The highest-rated site was the Riverdale Avenue Retaining Wall Replacement Phase 2 – Downstream on the Elbow River** (see Photo 3 Photo 2 below).

[7] RMP effectiveness monitoring component objectives 3, 4 and 5

[8] RMP effectiveness monitoring component objective 8

[9] RMP effectiveness monitoring component objective 1

[10] RMP effectiveness monitoring component objective 6

**Photo 1: Bank Effectiveness Highest Rated Site: Riverdale Avenue Retaining Wall Replacement Phase 2 – Downstream (July 21, 2020)**

**Photo 2: Bank Effectiveness Highest Rated Site: Riverdale Avenue Retaining Wall Replacement Phase 2 – Downstream (July 25, 2022)**

## Statistical Results

Details on the statistical approach are included in the Technical Summary and the main report Section 3.2.

### Woody Vegetation Survival and Growth[11]

Survival rates for Year 1 live cuttings and container plants combined were **76%**, which was significantly weighted towards the much higher Year 1 survival for container plants over live cuttings. Based on data from a total of 3,872 container plants and 5,298 live cuttings**, sandbar willow (*Salix interior*) was the highest performing species** as both a container plant and live cutting. Unique growth data for species used in Calgary were collected and are presented in the report. Tall rooted stakes were found to be a suitable plant material that can be used outside of the dormancy period for traditional live cuttings[12].

### Seeding Germination Success [11]

Seeding germination success analysis showed that many species are not present; however, five native species were identified to have the best success rates, including slender wheat grass (*Elymus trachycaulus* ssp. *trachycaulus*), fowl bluegrass (*Poa palustris*) Canada wild rye (*Elymus canadensis*), wild blue flax (*Linum lewisii*), and northern wheat grass (*Elymus lanceolatus*).

### Matching Vegetation Elevation, Soil Amendment, and Fencing [11]

Beneficial practices that were identified as statistically significant included matching the lowest elevation of planted woody vegetation with native woody vegetation, using soil amendment, and installing fencing around sites until vegetation establishes.

[11] RMP effectiveness monitoring component objective 3, 4, 5, and 6

#### Bioengineering Technique Success[13]

Based on data from five woody vegetation growth parameters (leader growth, shoot length, diameter, Year 1 survival, and woody vegetation canopy cover), each bioengineering technique was ranked from highest to lowest performance. **The highest rated technique was brush mattress, followed by the vegetated crib wall, vegetated retaining wall, and brush layers**. The lowest performing technique based on the above listed parameters was **live staking.**

#### Invasive Plant Species [14]

*Noxious* weeds were identified at most sites and two *Prohibited noxious* weeds (nodding thistle [*Carduus nutans*] and common buckthorn [*Rhamnus cathartica*]) were identified on the Elbow River at Sandy Beach and at the Riverdale pedestrian bridge.

## Riparian Effectiveness Monitoring Key Results

For the riparian effectiveness component of the RMP, each site was classified by typology and age class[15]. Data collection involved desktop reviews and field assessments of functional performance, vegetation growth, and health parameters. Ratings were calculated similarly to the bank effectiveness component, using five categories to determine the overall score.

### General Findings

#### Record Keeping [14]

Improved record keeping of project-specific documents was noted as a potential improvement area for future riparian effectiveness projects.

#### Site-Specific Limiting Factors [16]

In the same way as the bank effectiveness component, the dry climate is the overall governing limiting factor for riparian restoration design, but other, site-specific limiting factors were assessed as well. Herbaceous species competition, wildlife, and human disturbance were found to be the main limiting factors to restoration success, affecting 83%, 31%, and 26% of sites, respectively.

#### Failure Sites [17]

Twelve total failures and 3 partial failures were observed, with the Native Tree and Shrub Cuttings typology having the most failures due to Year 1 age class vegetation survival of less than 25%.

#### Highest Riparian Effectiveness Rated Site [17]

The overall scores for the sites ranged from Poor to Good, with maintenance, implementation, and BRQI ratings often scoring lower. **Griffiths Woods – RBC and Other Plantings** site (see Photo 3 and Photo 4 below)

[13] RMP effectiveness monitoring component objective 6
[14] RMP effectiveness monitoring component objective 8
[15] RMP effectiveness monitoring component objective 2
[16] RMP effectiveness monitoring component objectives 3, 4 and 5
[17] RMP effectiveness monitoring component objective 1

**received the highest overall rating** among all riparian monitoring sites, with success factors including good planting design and appropriate native species selection.

**Photo 3: Riparian Effectiveness Highest Rated Site: Griffiths Woods – RBC and Other Plantings site (2018)**

**Photo 4: Riparian Effectiveness Highest Rated Site: Griffiths Woods – RBC and Other Plantings site (2018)**

## Statistical Results

Details on the statistical approach are included in the Technical Summary and the main report Section 4.2.

### Vegetation Survival and Growth [18]

A large amount of data was collected on the growth performance of individual live cutting and container shrub species, data which will be useful to practitioners when selecting woody species for future restoration projects. In general, container plants had higher survival rates one year after installation than live cuttings. Species like **balsam poplar** (*Populus balsamifera*), **red-osier dogwood** (*Cornus sericea*), and **sandbar willow** had significantly higher survivorship rates as container plants compared to live cuttings. Survivorship and growth of Year 1 cuttings was higher on southerly aspects, but the results for plantings were not significant. When live cuttings did establish, their growth rate outperformed container plants. Stem diameters and shoot lengths of woody species as a whole were generally higher for older age class sites, indicating successful establishment over time. Leader growth tended to be higher for Year 1 and 3 age class sites compared to Year 5+ sites, a trend which is reflects natural slowing of growth as vegetation ages.

### Herbaceous Seed Mixes [18]

Grass species that established best when used in herbaceous seed mixes included: slender wheat grass (*Elymus trachycaulus* ssp. *trachycaulus*), northern wheat grass (*E. lanceolatus*), Canda wild rye (*E. canadensis*), fowl bluegrass (*Poa palustris*), and western wheat grass (*Pascopyrum smithii*). Forb species that established best included: tall goldenrod (*Solidago altissimus*), Canada milk vetch (*Astragalus canadensis*), purple prairie clover (*Dalea purpurea*), wild blue flax (*Linum lewisii*), and wild vetch (*Vicia americana*).

[18] RMP effectiveness monitoring component objectives 3, 4, and 5

### Invasive Plant Species [19]

Invasive plant species were common at riparian restoration sites, with an average of five species present. *Prohibited Noxious* weeds observed included nodding thistle and common buckthorn, both of which were found at two sites each, the former along the Bow River and the latter along the Elbow River.

### Soil Compaction [19]

Compacted soil was generally not a concern at most riparian effectiveness sites except where large construction equipment was used at three Large-Scale Riparian Retrofit typology projects.

## General Conclusions and Potential Program Opportunities

The RMP is an important component of the implementation of the *Riparian Action Program*. City-wide data is being collected regarding riparian health, and trends are being analyzed that provide key information to understand the condition and trajectory of the health of riparian areas in the city. Annual reporting on the riparian health indicator is being submitted to Council to inform on the progress toward meeting the riparian health target of 72% average city-wide riparian health score by 2026.

The results of Phase 2 of the RMP indicate that great strides have been made and riparian health is improving. However, the expanded city-wide results show that **accelerated efforts such as riparian restoration and the conservation of existing undeveloped riparian areas are needed to improve the 2022 riparian health scores from 69% to 72% by 2026**. Proactive conservation of existing undeveloped riparian areas is essential to achieving The City's *Riparian Action Program* goals including the Land Use Planning target of “No Net Loss” of riparian open spaces along major perennial creeks and rivers at a city-wide scale. Monitoring riparian health trends is integral to assessing success/failure and for informing and directing ongoing riparian restoration, stewardship and management efforts in Calgary.

The results of the effectiveness monitoring components show that the **overall average rating for all sites was in the ‘Fair’ category** with a relatively small number of failure sites. Most of the effectiveness projects were found to be successful, but there is room for improvement in the way that bioengineering and riparian restoration projects in Calgary are delivered. The data and analysis for the effectiveness components are helping to fill a key technical and scientific knowledge gap for bioengineering and riparian restoration projects and place the city in a unique position worldwide regarding these practices. Until now there have been few if any monitoring studies done for bioengineering and planting projects in Calgary or elsewhere in the province, across North America, or worldwide.

Detailed RMP conclusions are included in the Technical Summary and Section 6.0 of this report. Trend monitoring and effectiveness recommendations can also be found in the Technical Summary and Section 7.0 of this report including recommendations for improved design, construction, and maintenance practices.

[19] RMP effectiveness monitoring component objective 8

# Technical Summary

This Technical Summary includes detailed descriptions of the methods, data collection and analysis, results, success, and lessons learned for the riparian health trend monitoring, bank effectiveness monitoring, and riparian effectiveness monitoring components of the five-year (2018-2022) City of Calgary Phase 2 Riparian Monitoring Program (RMP). The three components of the RMP are described as follows:

- **Riparian health trend monitoring**: consists of ongoing monitoring of riparian sites in the city using the Riparian Health Inventory (RHI) protocols (Hansen, et al., 2000; Fitch, Adams, & Hale, 2014; Cows and Fish, 2016). Riparian health monitoring has been conducted since 2007 across Calgary's major streams and rivers. Riparian health trend monitoring was incorporated as one of the main objectives for the RMP as a means to inform progress toward achieving the riparian health targets identified in The City of Calgary's *Riparian Action Program* (City of Calgary, 2017). Health targets were established for a city-wide scale and for various riparian management zones corresponding to land use priorities (i.e., conservation, recreation, restoration). Riparian health scores are determined from an evaluation of vegetation, soil and hydrological parameters that are primarily assessed in the field. Riparian health scores fall into one of three broad categories – *unhealthy* (0-59% score), *healthy, with problems* (60-79% score) and *healthy* (80-100% score). RHI sites are monitored on a five-year revisit schedule and are typically large-scale polygons that can encompass one or more bank and/or riparian effectiveness sites.
- **Bank effectiveness monitoring**: consists of monitoring projects where the primary purpose is riverbank stabilization, protection, or erosion mitigation with bioengineering structural- and vegetation-based components. Bank effectiveness sites encompass the riverbank and often a strip as wide as 15 m along the top of bank. The bank effectiveness monitoring component consists of detailed assessments of individual project sites. Some of these projects are located in the trend monitoring areas.
- **Riparian effectiveness monitoring**: consists of monitoring projects where the main purpose is enhancing riparian habitat away from the bank, with little to no structural components. Riparian restoration sites are mostly focused on the top of bank (riparian) areas, and general riparian/floodplain areas but may extend down onto the bank of smaller streams and creeks. The riparian effectiveness monitoring component consists of detailed assessments of individual project sites. Some of these projects are located in the trend monitoring areas.

## Program Objectives

### Objectives for Riparian Health Trend Monitoring

Riparian health monitoring is important for tracking progress toward The City of Calgary's (The City) commitment to conserving and improving the ecological health of riparian areas in Calgary and for prioritizing future restoration and conservation efforts as part of an adaptive management approach.

The objectives for trend monitoring for this project are listed below.

1. Assess changes in city-wide riparian health primarily for major rivers and streams, excluding private residential land.
2. Measure and inform The City of progress toward meeting the city-wide riparian health target identified in the *Riparian Action Program* (City of Calgary, 2017) of 72% by 2026
3. Expand monitoring sites to be more representative of city-wide conditions for a larger cross section of sites including tributaries and priority source-water protection areas.

### Objectives for Bank and Riparian Project Effectiveness Monitoring

The objectives for the bank and riparian effectiveness components of the RMP are listed below.

1. **Project Effectiveness Monitoring**: Determine the effectiveness of riverbank bioengineering and riparian restoration sites against the desired goals and objectives of each project.
2. **Site Selection and Typology**: Select a representative number of riverbank bioengineering and riparian restoration monitoring sites from The City's *Master List – Riparian Restoration Projects* bases on age class (described in the following 3 bullets) and typology (i.e., technique).
3. **Evaluate Success Year 1**: Evaluate vegetation establishment success (i.e., after the first growing season post construction) to determine early plant material establishment, survival rates, plant material quality, potential work structure deficiencies, performance ratings for each typology and bioengineering/planting technique, and adequacy of implementation and maintenance practices.
4. **Evaluate Success Year 3**: For sites that are three years post-construction, evaluate the effectiveness of each project relative to their intended restoration objectives (e.g., improved bank stability, erosion control, and establishment and improvement of native plant cover) and develop performance ratings for each typology and bioengineering/planting technique.
5. **Evaluate Success Year 5**: For sites that are five years or more post-construction, evaluate the effectiveness of each project relative to improvement of key ecological function/riparian health indicators, biodiversity indicators or progress toward a desired reference plant community or habitat type and develop performance ratings for each typology and bioengineering/planting technique.
6. **Techniques**: Identify advantages and limitations of riverbank bioengineering and streambank/riparian restoration techniques and if required, identify preferred techniques and plant species including plant material type (i.e., pot sizes, plugs, bare roots and/ or live cuttings) considered best suited to the site.
7. **Material Supply**: Identify advantages and limitations in plant material supply and make recommendations for involvement of local nurseries in the development of specific plant materials (i.e., species and stock type) to accommodate soil bioengineering design and local climate.
8. **Maintenance**: Evaluate the effectiveness of maintenance procedures.
9. **Citizen Science**: Integrate citizen science opportunities, where possible, into project effectiveness monitoring to support the *Riparian Action Program*'s education and outreach goals for improving community engagement and riparian awareness (City of Calgary, 2017).
10. **Design Improvements**: Provide recommendations for design improvement to develop more adapted techniques/approaches for the Calgary local conditions and watercourses for future applications that can be considered as part of an update to *the Design Guidelines for Erosion and Flood Control Projects for Streambank and Riparian Stability Restoration* (AMEC, 2012).
11. **Monitoring Recommendations**: Provide recommendations for future long-term monitoring needs (e.g., climate change resiliency monitoring).

## Riparian Health Trend Monitoring Key Results

Long-term riparian health information is available for a subset of 58 sites along the Bow River, Elbow River, Nose Creek, West Nose Creek, and Beddington Creek in Calgary. These sites were used to support the preparation of the riparian health targets in the *Riparian Action Program* report (City of Calgary, 2017). For these sites, riparian health information was collected between 2007-2010, 2014-2015 and again between 2019-2020. Since 2014 and as part of Phase 2 of the RMP, riparian health monitoring has been expanded across the city to encompass 101 sites along these and three other major tributaries (Forest Lawn Creek, Twelve Mile Coulee and Pine Creek). Some sampling of unnamed ephemeral and intermittent streams in the Bow and Elbow River watersheds have also been done mainly in priority source-water protection areas (in 2016 and in 2021)and are discussed in section 2.1 of this report.

Below is a summary of key results for major creeks and rivers. Results presented here focus on long-term trend results for the 58 site sub-set and the expanded area that includes 101 sites.

## Long Term Trend Highlights (subset of 58 sites):

- Compared to baseline conditions[1] for 58 sites with long-term data, **city-wide riparian health scores have increased from 61% to approximately 65% (2019/2020)** (remaining in the *healthy, with problems* category). This is based on an "*area-weighted average*"[2] of riparian health scores, consistent with how The City's *Riparian Action Program* riparian health targets were calculated (City of Calgary, 2017).
- Riparian health gains since baseline[3] were attributed to a combination of factors including beneficial impacts along the Bow and Elbow Rivers from the 2013 flood and improved management or restoration in some sites allowing for natural recovery. Of note, Balsam poplar (*Populus balsamifera*) recruitment (new growth) increased in 10 of 30 Bow River sites following the 2013 flood. This is significant given the importance of poplars as a keystone species that is vital to the foundation of healthy riverine ecosystems. The flow from the June 2013 flood event exceeded 1,700 $m^3/s$ and provided sufficiently high flows to promote conditions suitable for promoting poplar regeneration such as sediment deposition, flood scour and high soil moisture levels co-incident with peaks in poplar seed release.
- By sub-basin, between 2007 and 2015, Bow River riparian health scores increased by approximately 3% from baseline conditions but declined slightly between 2014/15 and 2019/20. These minor score declines were mainly attributed to post-flood landscaping, bank stabilization and repair works and increased recreational use impacts. Bank stabilization projects since 2013 have resulted in a substantial net increase in riprap armouring along both the Bow and lower Elbow Rivers (below the Glenmore Reservoir). However, significant uptake in the use of soil bioengineering partially offsets negative impacts from rock armouring.
- The average Bow River riparian health score is 59% and in the *unhealthy* category, comparatively much lower than for the Elbow River, since the scores on the Bow account for upstream damming, flood berms, and water diversions (i.e., the Western Irrigation District diversion). The Elbow River was assessed as a 'small river' in Calgary, and thus excludes these parameters. The Elbow River riparian health scores are much different for the Upper and Lower reaches (i.e., above and below the Glenmore Reservoir). *Healthy* conditions in Weaselhead Flats and Griffith Woods parks in the Upper Reach have been maintained since 2007. Lower Elbow River health scores are lower but have shown slight improvements since 2007 linked

[1] Baseline assessments were completed between 2007 and 2010.

[2] Area-weighted averages account for the variance in RHI polygon (site) sizes, where larger riparian polygons have a stronger proportional influence on the average compared to smaller sites.

[3] Baseline assessments were completed between 2007 and 2010.

with ongoing restoration and improved management efforts. Most Nose Creek sites continue to rate as *unhealthy* whereas the West Nose Creek sites continue to rate as *healthy, with problems* on average. Historic impacts from channelization negatively affect Nose Creek riparian health scores, limiting potential for improvement.

- Riparian health trends by management zone show the largest score increase since baseline conditions for the “Restoration Management Zone”. The highest average riparian health rating for riparian habitat is the “Conservation Management Zone” (i.e., natural environment parks such as Weaselhead Flats, the Inglewood Bird Sanctuary and Bowmont Park).

## Expanded City-Wide Project Area Key Highlights (101 sites)

- Current riparian health scores reported on in Section 2 of this report are for an expanded project area of 101 sites encompassing 591 ha of riparian habitat and 84 km of bank length for eight major streams and rivers. This represents an addition of 44 sites encompassing 237 ha of assessed riparian habitat (a 43% expansion) and 31.8 km of bank length compared to the 58 site long-term sub-set. The expanded project area includes sampling key gaps geographically in the city along the Bow River, Elbow River, Nose Creek, Twelve Mile Coulee, Pine Creek and Forest Lawn Creek. The RMP target was to achieve a 30% minimum target (by length) of representative major stream/river reaches within city limits.
- **The current city-wide area-weighted riparian health score for the expanded area is approximately 69%** (*healthy, with problems*). Four large sites were added from Weaselhead Flats and Clearwater Legacy Park in the Upper Elbow which contributed significantly to the higher city-wide average due to overall healthy conditions in these important natural environment parks. Other sites along Twelve Mile Coulee and Nose Creek also contributed positively to the city-wide score.
- Common limiting factors across all systems are extensive bank and floodplain structural alterations due to recreation use and city infrastructure (pathways, bridges, stormwater outfalls and other park facilities). Permanent impacts have also resulted from channelization and consequent channel incisement along the lower half of Nose Creek (south of Airport Trail NE). Control of flood peak and timing due to upstream damming affects all Bow River riparian health scores in Calgary (an 11% score deduction).
- Widespread incursion of non-native grasses and invasive weeds is another common limitation. Invasive weeds are increasing in cover and distribution city-wide.

## The 2013 Floods- How Did it Influence Riparian Health?

- Balsam poplar regeneration increased in 10 of 30 Bow River sites after the 2013 flood and remains at healthy levels at 10 sites. Poplar recruitment is largely linked to periodic flooding (Mahoney & Rood, 1998) and they require specific conditions for seedling germination and growth. The June 2013 flood event provided sufficiently high flows to promote the establishment and growth of these poplars in co-incident with peaks in poplar seed release.
- While the scour and deposition from the 2013 flood encouraged poplar regeneration it created hazards and risks to infrastructure necessitating the need for repairs and bank stabilization works. Bank alterations have increased along both the Bow and Elbow Rivers since the flood and riprap now accounts for 61% of the alterations along the Bow River compared with 40% in 2008/2010. However, recent bioengineering efforts have helped to partially mitigate adverse fish and wildlife impacts from bank hardening.

# Bank Effectiveness Monitoring

## Data Collection and Organization, and Methods

A total of 69 sites were assessed either once (42 sites), twice (24 sites), or three times (3 sites) for a total of 99 assessments over the five-year bank effectiveness program. Each site was classified according to five typology categories as shown in Figure 1 and three age classes (Year 1, Year 3, and Year 5+ post-construction). Data was collected for each site based on desktop review of background information and field reviews of functional performance, physical stability and material condition, and vegetation growth and health parameters. Failure site assessments were also completed when required. The data was collected in Microsoft® Excel® forms developed specifically for the RMP. A detailed description of these methods is included in Sections 3.1 and 3.2 of the report.

| **Vegetated Riprap** | **Vegetated Retaining Wall** | **Vegetated Crib Wall** | **Primarily Vegetative** | **Planting** |
|---|---|---|---|---|
| Riprap bank protection with live cuttings inserted within the rock/joint planting | Mechanically stabilized earth (MSE) walls, or vertical earth/concrete walls with live cuttings inserted | Vegetated Crib Wall with live cuttings | Brush Mattresses/fascines /brush layers/wattle fences /live staking/vegetated soil wraps | Seeding, live staking and/or rooted stock planted along shoreline of river and creek banks |

**Figure 1: Bank Effectiveness Monitoring Typology**

## Ratings

A rating system was developed for the effectiveness components of the RMP to help identify individual sites that are successful in meeting project objectives and where there are opportunities to establish learnings and recommendations for better project design, implementation, maintenance, and vegetation success. Ratings for design, implementation, maintenance, success, and Bank and Riparian Quality Index were developed for the bank effectiveness monitoring sites as part of the Monitoring Plan (KWL, 2018). An overall score was developed for each site by combining the five individual ratings and applying a multiplier to achieve a total weighted score out of 100). Projects were subjectively classified into one of three ratings categories: Good (75-100), Fair (50-74), and Poor (0-49). The ratings allowed an understanding of which sites were performing well and which sites could be improved.

## Failure Sites

Some monitoring sites are labelled 'failure sites' in this report. The definition of a failure site is based on the RMP project-specific definition in the *Monitoring Plan* (KWL, 2018) where a Year 1 age class site is determined to be a failure if: **1) the works are found to be missing, degraded or ineffective, and/or 2) if the woody vegetation survival is < 25%.** For Year 3 and 5+ age class sites, a site is determined to be a failure only if the works are found to be missing, degraded or ineffective. The vegetation survival failure criteria of < 25% does not apply to Year 3 and Year 5+ age class sites since it is not always possible to accurately assess the survival of planted woody vegetation for Year 3 and older age class sites due to either the growth of other vegetation obscuring dead cuttings/plantings and/or state of decay of the dead cuttings/plantings.

## Bioengineering Techniques

Statistical analysis was also conducted on the bioengineering techniques that were identified for each transect at each site as part of the vegetation assessment. The nine techniques that were assessed are listed below.

- **Brush layers**: Row(s) of live cuttings placed in a criss-cross or overlapping manner between layers of soil, with tips protruding beyond the face of the fill (Gray & Sotir, 1996).
- **Brush mattress**: A layer of interlaced/adjacent live cuttings placed on the face of the riverbank (AMEC, 2012).
- **Fascine**: Fascines are live cuttings that are tied together in long cylindrical bundles. Contour fascines are installed in shallow trenches constructed on contour, and anchored in the trench using stakes (AMEC, 2012).
- **Live staking**: Insertion of live cuttings into the ground in such a manner as to promote root growth and leaf-out (Gray & Sotir, 1996).
- **Plantings**: Planting of container stock seedling species that are selected for beneficial attributes such as fast-growing, natural colonizer, deep rooting, nitrogen fixing, and food production (AMEC, 2012).
- **Vegetated crib wall**: Consists of a hollow, box-like interlocking arrangement of structural timber, filled with suitable backfill material and layers of live cuttings (Gray & Sotir, 1996).
- **Vegetated retaining wall**: A vegetated structure used to resist unbalance lateral earth forces, retain earthen masses, and protect against scour and undermining (McCullah & Gray, 2005).
- **Vegetated riprap**: A layer of stone and/or boulder armoring that is vegetated, optimally during construction, using pole planting, brush layering and live staking techniques. (McCullah & Gray, 2005).
- **Wattle fencing**: Short retaining walls built by weaving living cuttings between upright stakes to form a lattice (Polster D. , 2020).

## Statistical Analysis and Sample Size

Statistical analysis was completed on the collected data from the 69 individual sites mentioned above (99 assessments) including collected vegetation data where a total of 10,912 individual live cuttings and plantings were sampled via 227 transects and 669 quadrats. Statistical analysis was completed by typology, age class, bioengineering technique, monitoring site (for some data sets), and for various growth characteristics such as survivorship, vigour, condition, leader growth, shoot length, and stem diameter. For statistical analysis that was completed by typology and age class, the target population for each typology and age class was eight (8) sites with a minimum of five (5) sites so that there were enough samples to determine statistical significance.

Groupings of sites by typology and age class met the minimum target sample sizes except for two categories: Vegetated Retaining Wall Year 1 and Year 3 age class. Sample sizes for the nine bioengineering techniques ranged from a total of 55 transects for the plantings technique down to one transect for the wattle fence technique.

### Limitations of Data and Assumptions.

Simple, correlative statistical approaches were used in the RMP to disentangle the factors driving project performance and to identify trends, with results that are significant as summarized in Section 3.3.2 of this report. However, there are some limitations regarding the RMP data and analysis that are listed below.

- The lack of documentation provided to the monitoring team limited complete understanding of monitoring sites – particularly maintenance aspects.
- The five-year monitoring timeframe for the program may have limited the ability to capture all relevant learnings, and the observations of the long-term (10 years or greater) effectiveness of the bioengineering approaches is limited.
- A truly independent site sampling approach was not possible because of the requirement to monitor some sites over the monitoring period to meet other project reporting obligations.
- There was limited site availability for some typologies and age classes which reduced the ability to conduct statistical analysis for those populations.
- Not all design, construction, and maintenance activities were able to be assessed by the RMP monitoring team during documentation or field reviews since activities could have been completed.
- Effectiveness analysis did not factor cost, construction complexity, and regulatory approval requirements/timelines in the analysis or recommendations.

These limitations did not significantly reduce the overall ability of the RMP to produce valuable results for bioengineering project effectiveness. Many results from the overall analysis remain statistically significant and those that were not valid were not included in this Final Program Report.

## Bank Effectiveness Monitoring Key Results

Key activities, observations, and results from the five-year bank effectiveness monitoring component are listed below. More detailed results are contained in Section 3.3 of this report. The results are divided in General Findings and Statistical Results.

### General Findings

#### Data Filling Key Knowledge Gap

The data that was collected for the bank effectiveness component is helping to fill a key technical, practical, and scientific knowledge gap for bioengineering projects. Until now there have been few monitoring studies conducted for bioengineering projects in Calgary or elsewhere in the province, across North America, or worldwide and none as thorough as the RMP (Stokes, et al., 2014; Zaimes, et al., 2019; Evette, et al., 2021).

#### Site Stability and Condition of Structural Materials

In general, most monitoring sites were observed to be stable with little to no erosion occurring within, upstream or downstream of the site. For the revisit sites, there was little to no change since the first assessments. However, there were a minority of sites (~10%) that were observed to have specific instances of erosion, undermining, slope raveling, and backfill material washout. Often, the key reasons for the observed issues were that the materials selected prematurely degraded or the design approach were not suitable to resist the erosive forces.

All permanent or extended life-cycle materials used in the bioengineering sites were in good to very good condition. Temporary structural material such as matting, and wattles were in variable condition and did not always meet their intended function due to premature degradation or poor installation. Additionally, 21 of the 69 monitoring sites (30%) included a synthetic erosion control matting, geogrid, or wattle product where it appeared to not be necessary due to successful vegetation establishment and available alternate biodegradable products. These materials will now persist in a sensitive location in the environment (riverbank and/or riparian area) and will likely pose a hazard for human activities, fish, and wildlife.

### Habitat Enhancements

Habitat enhancements such as instream boulders, woody debris, and overhanging vegetation that were incorporated into bioengineering structures are performing well. For example, overhanging cover was observed to be 2 m to 3 m at some locations and providing good overhead shade, cover, and organic debris input for fish habitat.

### Vegetation Design, Installation, and Establishment

Most often, vegetation species and stock were selected appropriately. But where best practices for scheduling the installation of live cuttings was not followed, poor vegetation growth and high mortality was observed. A relatively new stock referred to as tall rooted stakes was found to provide a good option for summer construction when the use of dormant live cuttings is no longer recommended.

It was observed over several sites with full canopy closure because of higher density planting that invasive weed growth was limited, root growth from planted vegetation was binding soil, and that natural stabilization and ecological development is occurring over time.

### Site-Specific Limiting Factors

The dry climate governs bioengineering design in Calgary overall due to low soil moisture conditions. Because of this, irrigation is needed to support vegetation establishment until an adequate root system is established. For failure sites, the next most often documented site-specific limiting factors for site stability and vegetation establishment were “erosion”, “existing vegetation competition”, and “maintenance issues” (six of seven sites). Over all assessments, the most often noted limiting factors for site stability and vegetation establishment were “maintenance issues” (93 of 99 assessments), “existing vegetation competition” (92 of 99 assessments), and “compacted soils” (76 of 99 assessments). Additionally, soil compaction was found to have a negative impact on vegetation growth.

### Construction and Maintenance Practices

Contractors devised several innovative methods to allow successful construction outside of the dormancy period for live cuttings such as wooden pallets in riprap (not recommended) and creating planting holes using several forks on an excavator bucket. Remote operated solar irrigation and placing material using a telebelt were also observed.

Maintenance documentation needs to be improved, and practices such as weed whacking should be discontinued in favor of hand practices due to the damage to planted vegetation that was observed. While limited irrigation data was available, better irrigation appears to be needed for container plants that are installed above the bank on the terrace. Temporary browsing protection fencing needs to be repaired immediately, otherwise severe browsing has been observed to occur. Browsing during the earlier period of plant establishment was found to reduce plant survival.

Documentation for the watering regime used for irrigating sites was only available for seven of 69 sites and specific data on irrigation method (drip or spray), volume and during were not available. However, observations of moisture stress and irrigation systems during the field inspection resulted in noting that irrigation for container plants on the top of bank needs improvement. It was also noted that impact sprinkler heads installed higher from the ground (i.e., 1.3 m) thoroughly cover larger areas through the plants establishment period and avoid potential erosion created by water spray interfering with vegetation when sprinkler heads are installed closer to the ground.

### Deep Binding Root Mass

It was visually estimated that overall, an average of 85% of the streambank for all monitoring sites had deep, binding root mass. A total of 23 sites were observed with 100% of the bank with deep, binding root mass.

### Failure Sites

Seven failure (7) sites were identified out of the 99 assessments completed over 2018-2022. The most common reason for failure was due to vegetation survival of less than 25% (5 sites). Other failures are due to the structures no longer being present (one Planting typology site) or failing structurally (one Primarily Vegetated typology site).

### Ratings

The average ratings are summarized in Table 1 for all 99 bank effectiveness assessments. The average overall rating for all sites assessed was 67/100 which falls in the **'Fair'** category. The average design rating was highest, with maintenance and BRQI ratings as the lowest.

Many sites were observed with outstanding vegetation establishment and growth across the city that will serve as benchmarks for future bioengineering and riparian planting projects. **The highest-rated site was the Riverdale Avenue Retaining Wall Replacement Phase 2 – Downstream on the Elbow River** (see Photo 1 and Photo 2 below).

**Table 1: Mean Ratings**

| Age Class | Design rating (/18) | Implementation rating (/18) | Maintenance rating (/18) | Success rating (/24) | BRQI (/22) | Overall score (/100) | Number of samples |
|---|---|---|---|---|---|---|---|
| 1 | 14 | 12 | 12 | 18 | 13 | 67 | 37 |
| 3 | 14 | 13 | 11 | 16 | 13 | 65 | 33 |
| 5+ | 14 | 12 | 10 | 18 | 14 | 69 | 29 |
| Mean | 14 | 12 | 11 | 17 | 12 | 67 | -- |
| **Total (/100)** | **78** | **67** | **61** | **71** | **55** | **67** | |

**Photo 1: Bank Effectiveness Highest Rated Site: Riverdale Avenue Retaining Wall Replacement Phase 2 – Downstream (July 21, 2020)**

**Photo 2: Bank Effectiveness Highest Rated Site: Riverdale Avenue Retaining Wall Replacement Phase 2 – Downstream (July 25, 2022)**

### Performance Targets

Results for woody vegetation survival, cover, and density of living shoots for several bioengineering techniques were compared to the literature values to validate site performance and confirm if literature targets are applicable to projects in Calgary. Several published targets were met or exceeded, confirmed that the literature values can be used for Calgary bioengineering projects.

## Statistical Results

### Vegetation Survival and Growth

The 2018-2022 bank effectiveness results for survival of Year 1 age class live cuttings and container plants combined was **76%** (n = 7,280). Analyzed separately, survival success was as follows: Year 1 age class container plants was **94%** (n = 1,982), and Year 1 age class live cuttings was **69%** (n = 5,298).

Year 1 age class survival and vegetation growth data were collected for both live cuttings and container species, as presented in Section 3.3.2 of the report. The species that performed best as both live cutting and container plant was **sandbar willow (*Salix interior*).**

For 10% of monitored sites, woody vegetation canopy cover was **over 70%.** Woody vegetation canopy cover was generally 6% to 10% greater for Year 3 versus Year 1 projects; and by Year 5+, woody vegetation canopy cover was highest for the **brush mattress technique**. The density of living shoots target was achieved for brush layers, fascines, and brush mattress bioengineering techniques.

Year 1 survival and vegetation growth data **by bioengineering technique** is presented in Section 3.3.2 of the report. The highest performing

### Seeding Germination Success

Seeding germination success was found to vary widely among the seeded graminoid and forb species. Among the 54 assessed species, three species has a 100% germination success rate in the Year 3 age class sites, and seven species had a 100% germination success rate in the Year 5+ age class sites, most of which were non-native that are not preferred for bioengineering applications. Six native species had germination rates less than

100% but more than 50% for at least one age class, including slender wheat grass (*Elymus trachycaulus* ssp. *trachycaulus*), fowl bluegrass (*Poa palustris*), Canada wild rye (*Elymus canadensis*), wild blue flax (*Linum lewisii*), and northern wheat grass (*Elymus lanceolatus*). More than half (n=28) of the species seeded were not observed, meaning they likely did not establish. In particular, 11 species were seeded 5 or more times and were not found in the surveys.

The seeding method with the highest germination success rate was **drill seeding** at 42%. Broadcast seeding was second at 36%, and hydroseeding was lowest at 31%. The differences were not statistically significant but do possibly point to drill seeding as a best practice, where it is feasible and broadcast seeding under erosion control matting as an efficient and low-cost method.

### Herbaceous Species Cover

The mean percent herbaceous cover for Year 1 age class is 33%, for Year 3 age class is 17%, and Year 5+ age class is 14%. A possible explanation for the decrease in herbaceous cover over the three age classes could be that woody vegetation cover is increasing, shading out the herbaceous vegetation, and limiting its growth.

The results for percent herbaceous cover by bioengineering technique show that the seeding technique has the highest mean percent cover for Year 3 and Year 5+ age class sites. This is an intuitive result since this technique targets herbaceous plant growth. The lowest mean percent cover for Year 1 age class sites is the riprap technique at 0%, for Year 3 age class sites is the brush mattress technique at 0%, and for the Year 5+ age class sites are the riprap, vegetated crib wall, and vegetated riprap techniques that are all at 1%.

### Matching Native Vegetation Elevation, Soil Amendment, and Fencing

Beneficial practices identified and verified based on statistically significant results include: 1) design the lowest elevation of planted vegetation (woody, herbaceous and emergent) to match the observed lowest elevation of native vegetation at a site; 2) soil amendment use during planting of vegetation; and 3) fencing use to protect against browsing and disturbance.

### Soil Compaction

Of the total number of sites that were assessed, 51 of 65 sites (78%) were classified as having significant compaction issues. Soil compaction impedes the growth of planting/cutting roots and shoots, impacts survival rates and vigour, and contributes to increased runoff due to decreased water percolation within the soil.

### Invasive Weed Species Monitoring

In total, 19 invasive weed species were observed across all sites, based on transect and quadrat data, consisting of 12 *Noxious* weeds, two *Prohibited noxious* weeds, and five other weeds. The most common invasive weed species observed were creeping thistle (*Cirsium arvense*), observed at 89% of sites (82 of 92 assessments), followed by smooth perennial sow-thistle (*Sonchus arvensis* ssp. *Uliginosus*), observed at 84% of sites (77 of 92 assessments).

### Bioengineering Technique Performance

Based on data from five woody vegetation growth parameters (leader growth, shoot length, diameter, Year 1 age class survival, and woody vegetation canopy cover), each bioengineering technique was ranked from highest to lowest performance as shown in Table 2. **The highest rated technique was brush mattress, followed by the vegetated crib wall, vegetated retaining wall, and brush layers**. The lowest performing technique based on the above listed parameters was **live staking.**

Note that this method only includes the five parameters listed above and does not include considerations such as cost, construction complexity, or regulatory approval requirements/timelines. While results show that certain bioengineering techniques may be performing better than others based on the data that was collected, a full evaluation of growing performance, cost, construction, and regulatory complexity should be undertaken when evaluating a particular bioengineering approach or technique. Some techniques can still be effective and preferred because of relatively low cost, simple design, and less complex construction. To mitigate low survivorship or growth parameters for a certain technique, the density of installed live cuttings and container plants can be increased so that survivorship, density, or cover targets can still be met. Additionally, it is recommended that projects using lower performing techniques should closely follow best practices described in the main report.

**Table 2: Bioengineering Technique Performance Ranking**

| Bioengineering Technique | Average Rankings[1] | | | Average Ranking[4] | Overall Ranking[5,6] |
|---|---|---|---|---|---|
| | Year 1[2] | Year 3[3] | Year 5+[3] | | |
| Brush layers | 5 | 2 | 4 | 3.7 | 4 |
| Brush mattress | 3 | 3 | 1 | 2.3 | 1 |
| Fascine | 6 | 4 | -- | 5.0 | 5 |
| Live staking | 8 | 8 | 6 | 7.3 | 8 |
| Plantings | 4 | 7 | 6 | 5.7 | 7 |
| Vegetated crib wall | 2 | 1 | 5 | 2.7 | 2 |
| Vegetated retaining wall | -- | 5 | 2 | 3.5 | 3 |
| Vegetated riprap | 7 | 6 | 3 | 5.3 | 6 |
| Wattle fencing [6] | 1 | -- | -- | -- | -- |

Notes:
1. Rankings are 1 for the highest-and 9 for the lowest.
2. Year 1 age class ranking calculation is the average ranking by bioengineering technique for five Year 1 parameters: mean leader growth, mean shoot length, mean stem diameter, mean woody vegetation canopy cover, and mean survival rate.
3. Year 3 and Year 5+ age class rankings are the average ranking by bioengineering technique for four Year 3 and Year 5+ parameters: mean leader growth, mean shoot length, mean stem diameter, and mean woody vegetation canopy cover.
4. The average ranking was calculated by averaging Year 1, Year 3, and Year 5+ age class rankings for each bioengineering technique.
5. This ranking method only includes the five parameters listed above and does not include considerations such as cost, construction complexity, or regulatory approval requirements/timelines.
6. Wattle fencing was not included in the overall average ranking due to the small sample size for measurements (n = 30) for only one age class.

# Riparian Effectiveness Monitoring

## Data Collection and Organization, and Methods

In total, 42 reconnaissance and 59 detailed assessments were completed over the course of the five-year program. Of the 31 sites that underwent detailed assessments, 14 were monitored twice and 6 were monitored three times. Each site was classified according to typology (Table 3) and age class (i.e., Year 1, 3, and 5+).

Data was collected for each site based on a desktop review of background information and detailed site assessments. Detailed site assessments included various data collections methods, including pin-point transects, quadrats, and vegetation growth and survivorship assessments. Failure site assessments were also completed when required. Data was collected in analogue form using data sheets developed specifically for the RMP.

**Table 3: Riparian Effectiveness Typologies**

| Typology | Description | Photo |
|---|---|---|
| Native Tree and Shrub Cuttings | Projects involving primarily the use of live Native Tree and Shrub Cuttings. |  |
| Native Tree and Shrub Plantings | Projects involving primarily the use of native tree and shrub rooted plugs and/or potted plants. |  |
| Mixed Techniques | Projects involving a mix of techniques, including live cuttings and rooted stock, in addition to either a native seed mix or herbaceous plantings, site preparation such as weed removal, or in combination with one or more unique features such as Waterboxx® planters. |  |
| Large-Scale Riparian Retrofit | Large-scale construction projects, often involving multiple techniques. Includes the following three projects:<br>• **Site #48B** (Harvie Passage – South Side Channel);<br>• **Site #68** (Quarry Park Fish Compensation Project); and<br>• **Site #92** (Bowmont Natural Area East – A). |  |

## Ratings

Similar to the bank effectiveness component of the project, each riparian effectiveness project was rated using the five different rating systems developed specifically for the RMP project: design, implementation, maintenance, success, and BRQI. The individual ratings were also summarized to give projects an overall score out of 100. Projects were subjectively classified into one of three ratings categories: Good (75-100), Fair (50-74), and Poor (0-49).

## Failure Sites

As discussed above for the bank effectiveness component of the project, the term ‘failure’ was applied to some projects, including some riparian effectiveness projects. For the RMP, a site was considered a failure if it had less than 25% survival of installed woody material. The term ‘total failure’ was used for riparian effectiveness sites where the entre site did not meet the minimum threshold of 25% survivorship. The term ‘partial failure’ was used for sites where a portion of the site (e.g., one technique) failed but another portion of the site was successful (i.e., it had greater than 25% survival). All sites deemed to be failures underwent a detailed failure analysis to determine potential causes of the poor outcomes.

## Statistical Analysis and Sample Size

Statistical analyses were completed on the collected data from 57 assessments spanning 2018 to 2022 (Table 4). Analyses were completed by typology, age class, and monitoring site (for some data sets) for various growth characteristics such as survivorship, vigour, condition, leader growth, shoot length, and stem diameter. A minimum of five sites per typology and age class was required to achieve a statistically significant sample size. Of the 12 possible age class / typology combinations, 50% met this minimum size threshold.

In total, 5,457 individual live cuttings and plantings from 81 transects and 243 quadrats were analyzed. Analyses were also completed on the failure sites, including the proportion of failures by age class and typology as well as the limiting factors to restoration success and the main causal factors for restoration failure.

**Table 4: Final Number of Detailed Assessments by Age Class and Typology for Statistical Analysis**

| Age Class | Typology | | | | |
|---|---|---|---|---|---|
| | Cuttings | Mixed | Plantings | Riparian Retrofit | Total |
| 1 | 2 | 6 | 9 | 3 | 20 |
| 3 | 5 | 5 | 9 | 3 | 22 |
| 5+ | 4 | 3 | 5 | 3 | 15 |
| **Total** | **11** | **14** | **23** | **9** | **57** |

## Data Limitations

The data included in the riparian effectiveness analysis does have some limitations, including small sample sizes in some cases that were not always sufficient to make robust statistical conclusions. Additionally, several riparian effectiveness sites were visited several times, including sites from different age classes. As a result, the same re-visit sites can be found in several age classes for the same analyses. The results of these analyses, presented by age class, should be interpreted temporally with caution, as the presence of repeated data does not allow for statistical comparisons. However, these limitations did not significantly reduce the overall ability of the RMP to produce valuable results for riparian project effectiveness. A number of the results from the overall analysis remain statistically significant. Data limitations were discussed in detail above for the bank effectiveness component of the project.

## Riparian Effectiveness Monitoring Key Results

Key activities, observations, and results from the five-year riparian effectiveness monitoring component are listed below. More details on key results are contained in Section 4.3 of this report. The results are divided in General Findings and Statistical Results.

## General Findings

### Record Keeping

Improved record keeping of project-specific documents was noted as a potential improvement area for future riparian effectiveness projects.

### Random Plantings

Random planting as a restoration technique was assessed for evidence of success. Unfortunately, strong evidence is lacking at this time, partly due to the low sample size of projects available for monitoring and partly due to the mixed results of those sites that were monitored.

### Site-Specific Failure Factors

The main cause of failure for the riparian effectiveness sites monitored was vegetation competition, which was a contributory factor at 100% of failure sites. Other important factors were poor planting installation (67% of failure sites affected) and damage by wildlife (e.g., beaver cutting) (58% of failure sites affected).

### Site-Specific Limiting Factors

Herbaceous species competition, wildlife, and human disturbance were found to be the main limiting factors to restoration success, affecting 83%, 31%, and 26% of sites, respectively.

### Failure Sites

Of the 42 unique riparian effectiveness projects assessed over the course of the program, 12 were total failures and 3 were partial failures. Refer to the section above (page vi) for a description of the terms ‘failure’ and ‘partial failure’ as they pertain to this project. The native tree and shrub cuttings typology had the greatest number of failures.

### Ratings

Average overall rating of the 57 assessments completed over the course of the program was 55 out of 100 (Fair), indicating moderate overall success. Generally speaking, riparian effectiveness sites scored well for design ratings, but suffered with low implementation and maintenance ratings. The highest rated site was **Griffiths Woods – RBC and Other Plantings** site (see Photo 3 and Photo 4 below).

**Photo 3: Riparian Effectiveness Highest Rated Site: Griffiths Woods – RBC and Other Plantings site (2018)**

**Photo 4: Riparian Effectiveness Highest Rated Site: Griffiths Woods – RBC and Other Plantings site (2018)**

### BRQI

Similar to the overall rating, BRQI scores rated moderately overall (53 out of 100). In general, riparian effectiveness sites tended to have high vegetation cover and low amounts of riprap and concrete. BRQI scores often scored below optimally for factors such as high invasive species cover and poor regeneration of preferred woody plant species.

## Statistical Results

### Performance of Individual Woody Species

A large amount of data was collected on the growth performance of individual live cutting and container shrub species, data which will be useful to practitioners when selecting woody species for future restoration projects. In general, most native species tended to perform well when installed as container shrubs. Sample sizes are limited for some species.

### Year 1 Survivorship of Live Cuttings and Container Plants

Year 1 survivorship was found to be much higher for container plants (93%, n=1,701) compared to live cuttings (47%, n=621). Commonly used species such as balsam poplar, red-osier dogwood (*Cornus sericea*), and sandbar willow had low Year 1 survivorship values (range = 25% to 51%) when installed as live cuttings. All three species had greater than 80% survival when installed as container shrubs. As well, a number of native shrub and tree species monitored had estimated Year 1 survivorship values of 100% (e.g., northern gooseberry [*Ribes oxyacanthoides*]), although sample sizes were small for some species.

### Woody Species Survivorship Based on Aspect and Shade

Although there were some significant findings, Year 1 survivorship of cuttings and plantings showed a clear results with respect aspect. While survivorship of plantings was significantly higher in sunny versus shady locations, the same relationship was not true for cuttings.

### Woody Species Growth Measurements

Stem diameters and shoot lengths of woody species as a whole were generally higher for older age class sites, indicating successful establishment over time. Leader growth tended to be higher for Year 1 and Year 3 age class sites compared to Year 5+ age class sites, a trend which reflects natural slowing of growth as vegetation ages. However, these relationships could not be tested statistically due to the presence of the same sites in multiple age classes (sample dependence).

### Woody Species Performance by Site

Sites monitored were highly variable both in terms of Year 1 age class woody species survivorship and total woody canopy cover over time. Year 1 survivorship ranged from 30% to 100%. Woody canopy cover is improving at a number of sites, which is the goal of all riparian restoration projects; however, some sites have actually seen declining canopy cover over time.

### Woody Species Performance Over Time

For sites assessed multiple times during the course of the program, there was a wide variability in growth performance of woody species over time. Average shoot growth of container shrubs was 10 cm per year, whereas live cuttings showed growth of 13 cm per year. A few sites had negative growth over time.

### Herbaceous Seed Mixes

Grass species that established best when used in herbaceous seed mixes included: slender wheat grass (*Elymus trachycaulus* ssp. *trachycaulus*), northern wheat grass (*E. lanceolatus*), Canda wild rye (*E. canadensis*), fowl bluegrass (*Poa palustris*), and western wheat grass (*Pascopyrum smithii*). Forb species that established best included: tall goldenrod (*Solidago altissimus*), Canada milk vetch (*Astragalus canadensis*), purple prairie clover (*Dalea purpurea*), wild blue flax (*Linum lewisii*), and wild vetch (*Vicia americana*).

### Invasive Plant Species

Invasive plant species were observed at every riparian effectiveness site. The mean number of invasive species was five (range: 1 to 13). Creeping (Canada) thistle (*Cirsium arvense*) and smooth perennial sow-thistle (*Sonchus arvensis* ssp. *uliginosus*) were the most commonly observed species.

### Soil Compaction

Compacted soil was generally not a concern at most riparian effectiveness sites. Most projects involved plantings and cuttings being installed into existing vegetation with no major construction works. The exceptions were the three Large-Scale Riparian Retrofit. Not coincidentally, these retrofit sites had significantly higher soil compaction compared to the other three typologies.

## Key RMP Conclusions

The following section includes the key conclusions from the trend monitoring and effectiveness monitoring components of the RMP. The conclusions are organized according to the RMP objectives as listed in Section 1.1.

### Trend Monitoring Key Conclusions

**Trend Monitoring Objective 1 and 2**: The first objective of the trend monitoring component was to assess changes in city-wide riparian health primarily for major rivers and streams, excluding private residential land. The second objective of the trend monitoring component was to measure and inform The City of progress toward the city-wide riparian health target identified in the *Riparian Action Program* (City of Calgary, 2017): an average city-wide riparian health score of 72% by 2026. Key conclusions related to this objective are listed below.

**The average city-wide riparian health score has improved compared to baseline and has increased from 61% to approximately 65%** for the 58 sites with long-term data (remaining in the *healthy, with problems* category). Riparian health gains since 2007 were attributed to a combination of factors including beneficial impacts along the Bow and Elbow Rivers from the 2013 flood and improved management or restoration in some sites allowing for natural recovery.

**The current city-wide riparian health score is approximately 69%** (*healthy, with problems*) for the total expanded area representing 101 sites. This score does not represent entirely a long-term monitoring result, but it is a representation of the current city-wide score based on the expanded area. The addition of four large natural environment park sites influenced the increase of the score due to the overall healthy condition of these sites. Common limiting factors are extensive bank and floodplain structural alterations due to recreation use and city infrastructure (pathways, bridges, stormwater outfalls and other park facilities) as well as widespread incursion of non-native grasses and invasive weeds.

These trend analysis results are currently informing the progress to meet the 2026 target and the results show that great strides have been made to improve riparian health in the city. However, the current city-wide riparian health score is 69% and the 2026 target has not yet been achieved. This indicates that **enhanced efforts such as riparian restoration and the conservation of existing undeveloped riparian areas are needed to accelerate the improvement trend to meet the 2026 target**. Proactive conservation of existing undeveloped riparian areas is essential to achieving The City's Riparian Action Program goals including the Land Use Planning target of “No Net Loss” of riparian open spaces along major perennial creeks and rivers at a city-wide scale. Monitoring riparian health trends is integral to assessing success/failure and for informing and directing ongoing riparian restoration, stewardship and management efforts in Calgary.

**Trend Monitoring Objective 3**: The third objective of the trend monitoring component was to expand monitoring sites to be more representative of city-wide conditions for a larger cross section of sites including tributaries and priority source-water protection areas. Key conclusions related to this objective are listed below.

In addition to the expanded area encompassing 101 sites, there were an additional 21 sites assessed which including 18 sites on ephemeral and intermittent streams in priority source-water areas for a total of 122 sites city wide. Gap analyses identified areas where additional sites were needed in order to meet a target of a city-wide representative sample for riparian health (30% coverage by length of named permanent streams/rivers). Sites identified in this analysis were completed as part of the 2018-2022 project achieving this 30% target.

# Effectiveness Monitoring Key Conclusions

## Key Conclusions by RMP Objectives

Conclusions for bank and riparian effectiveness monitoring have been summarized below with respect to project objectives. Key conclusions are listed below.

**Effectiveness Monitoring Objective 1 – Project Effectiveness Monitoring**: The first objective of the RMP was to determine the effectiveness of bank and riparian sites against the desired goals and objectives of each project. Key conclusions are summarized below.

- Based on the ratings system developed for the RMP, the overall average ratings for all bank and riparian effectiveness sites were in the 'Fair' category (67 / 100 and 60 / 100 respectively) which means that there is room for improvement in the way that bioengineering and riparian restoration projects in Calgary are delivered. Based on the ratings, projects were designed better than they were implemented and maintained. Improving best practices for plant installation and schedule or appropriate stock selection would improve long-term survival. Improving maintenance practices such as weeding, irrigation, and documentation will also improve BRQI ratings, which points to improved maintenance as the focus for overall bioengineering and riparian restoration project improvement.
- Mean design, implementation, maintenance, success, and BRQI ratings were relatively consistent between Year 1, Year 3 and Year 5+ age classes for both bank and riparian effectiveness. So the age of the site did not have a strong influence on the ratings.
- Many sites were observed to have outstanding vegetation establishment and growth across the City that will serve as benchmarks for future bioengineering and riparian planting projects. The Riverdale Avenue Retaining Wall Replacement Phase 2 – Downstream (Age Class: Year 1, Typology: Vegetated Crib Wall) on the Elbow River was identified as the highest rated bank effectiveness site and is featured in Box 11 in the main report. The Griffiths Woods – RBC and Other Plantings site (Age Class: Year 1, Typology: Native Tree and Shrub Plantings) on the Elbow River was the highest rated riparian effectiveness site and is shown in Box 12 in the main report.

**Effectiveness Monitoring Objective 2 – Site Selection and Typology**: The second objective of the RMP was to select a representative number of bank and riparian effectiveness monitoring sites from The City's *Master List – Riparian Restoration Projects* based on age class and typology. Key conclusions related to this objective are listed below.

- There were adequate monitoring sites available to develop protocols and categorize bank effectiveness sites into five typologies (Vegetated Riprap, Vegetated Retaining Wall, Vegetated Crib Wall, Primarily Vegetative, and Planting) and three age classes (Year 1, Year 3 and Year 5+) and riparian effectiveness sites into four typologies (Native Tree and Shrub Cuttings, Native Tree and Shrub Plantings, Mixed Techniques, and Large-scale Riparian Retrofit) and three age classes (Year 1, Year 3 and Year 5+).
- There were adequate sample sizes for most combinations of typology and age class for bank effectiveness statistical analysis.
- Only half of the age class / typology combinations had adequate sample sizes for the riparian effectiveness component.

**Effectiveness Monitoring Objectives 3, 4 and 5 – Evaluate Success of Year 1, Year 3 and Year 5+ Age Class Sites**: The third, fourth and fifth objective are combined due to data similarities. The third objective of the RMP was to evaluate vegetation establishment success after the first growing season post construction. The fourth objective of the RMP was to evaluate the effectiveness of each Year 3 age class project relative to their intended restoration objectives (e.g., improved bank stability, erosion control, and establishment and improvement of native plant cover). The fifth objective of the RMP was to evaluate the effectiveness of each Year 5 and older age class project relative to improvement of key ecological function/riparian health indicators, biodiversity indicators or progress toward a desired reference plant community or habitat type. Key conclusions related to these objectives are listed below.

*Bank Effectiveness Key Conclusions*

- Year 1, Year 3 and Year 5+ age class bank effectiveness projects have mostly been successful in relation to vegetation establishment and structure effectiveness with no major erosion or scour issues observed at most sites (exceptions have been classified as failure sites).
- The design, construction and maintenance of permanent materials appears to be satisfactory as almost all of the permanent materials used at the bank sites remain in good to very good condition, with the exception of decaying timber at the older timber crib wall sites prior to woody vegetation establishment. The implementation of temporary erosion and sediment control materials could be improved since they were observed to be in variable condition and did not always meet their intended function due to premature degradation, not using the material for its intended purpose, or poor installation. Additionally, synthetic materials were observed to have been used when biodegradable products would have been suitable and would have less impact on the environment.
- Live cutting survival rates were found to be typically lower than container plants. The brush mattresses technique and plantings technique were the highest Year 1 age class survivorship out of all the techniques with a large number of samples. Woody vegetation canopy cover was measured to increase over the Year 1, Year 3, and Year 5+ age classes; however, the overall mean canopy cover was not measured to be as high as expected in comparison to the literature values.
- Based on leader growth, shoot length, stem diameter, and condition data, **sandbar willow** was the best performing species for both container plants and live cuttings.
- Higher soil moisture conditions are typically found at locations with lower sun exposure which can lead to higher growth, which was observed in the results for measured growth parameters for the “North, North-East, East” aspect category.
- Top herbaceous species performers with good germination success that are native species were slender wheat grass, fowl bluegrass, Canada wild rye, wild blue flax, and northern wheat grass. Many native seed species did not germinate which confirms the general understanding that native herbaceous species are difficult to establish.
- Poor vegetation growth and high mortality was observed at sites where best practices for plant installation schedule or appropriate stock selection were not followed. High vegetation mortality was also the most often reason for failure sites. Site stability and vegetation success were also limited by erosion, existing vegetation competition, and maintenance issues.

*Riparian Effectiveness Key Conclusions*

- Container plants were found to have high survival rates that were much higher than live cuttings survival rates. However, when live cuttings successfully established, they were measured to have higher growth performance than container plants.
- **Sandbar willow** was the best performing species for container plants as it consistently measured in the top two or three for all measured parameters. For live cuttings species, hungry willow and beaked willow performed well for the Year 1 age class, shining willow and false mountain willow performed well for the Year 3 age class, and shining willow performed well for the Year 5+ age class.

- The majority of sites that were assessed multiple times had increasing shoot lengths over the monitoring period. This data provides a quantitative indication of the shoot growth that might be expected for riparian restoration projects.
- Top herbaceous species performers with good germination success that are native species included slender wheat grass, tall goldenrod, northern wheat grass, Canada wild rye, and fowl bluegrass. Otherwise, many native seed species were not recorded on sites.
- The most common reason for failure was low survival of live cuttings that was often a result of existing vegetation competition in the form of non-native perennial grasses such as reed canary grass. Failure was also observed when best practices for plant installation were not followed.

**Effectiveness Monitoring Objective 6 – Techniques**: The sixth objective of the RMP was to identify advantages and limitations of riverbank bioengineering and streambank/riparian restoration techniques and if required, identify preferred techniques and plant species including plant material type (i.e., pot sizes, plugs, bare roots and/ or live cuttings) considered best suited to the site. Key conclusions related to this objective are listed below.

*Bank Effectiveness Key Conclusions*

- Based on the data, the highest rated technique was **brush mattress**, followed by the vegetated crib wall, vegetated retaining wall, and brush layers. The lowest performing technique was **live staking**. Note that this analysis does not include cost, construction complexity, and regulatory approval requirements/timelines which may affect the technique selected for a project.
- Observation of installation of container plants in exposed, high velocity locations were that they were easily eroded and displaced. This wasn't the case for cuttings as they resisted high velocity flows.
- There was limited site data for tall rooted stakes (TRS) but where they were installed properly they were observed to be establishing well. The use of TRS as substitution for live cuttings during summer construction appears to be confirmed.

*Riparian Effectiveness Key Conclusions*

- Based on Year 1 survivorship data, plantings are the preferred restoration technique over live staking.
- Based on the data collected, the effectiveness of the new planting technique where small plugs of native tree and shrub species are randomly planted on a site in large quantities with minimal follow-up maintenance or monitoring cannot be confirmed. More research on the effectiveness of this technique is needed.

**Effectiveness Monitoring Objective 7 – Material Supply**: The seventh objective of the RMP was to identify advantages and limitations in plant material supply and make recommendations for involvement of local nurseries in the development of specific plant materials (i.e., species and stock type) to accommodate soil bioengineering design and local climate. Key conclusions related to this objective are listed below.

- TRS were observed to successfully support construction of bioengineering projects outside of the typical dormancy period for live cuttings. Note that TRS must have adequate root mass development prior to installation.

**Effectiveness Monitoring Objective 8 – Maintenance**: The eighth objective of the RMP was to evaluate the effectiveness of maintenance procedures. In general, improvements to maintenance practices were noted for many of the assessed sites with irrigation, existing vegetation competition, herbaceous species competition, weeding, and site repairs were often noted. Key conclusions related to this objective are listed below.

- The lack of documentation was a common reason for low maintenance ratings that contributed to lower overall ratings. Improvements to contractor requirements for documentation and more stringent maintenance requirements would have quickly increased overall maintenance ratings.
- Specific data on irrigation method (drip or spray), volume, and duration were not available so specific conclusions were not possible. However, it was observed that moisture stress was occurring on some vegetation, particularly container plants on the top of bank. It was also noted that impact sprinkler heads installed higher from the ground (i.e., 1.3 m) cover larger areas than other methods and avoid potential erosion created by water spray interfering with vegetation when sprinkler heads are installed closer to the ground.
- Competition from herbaceous plant species was the most common site-specific limiting factor for vegetation establishment success cited at both the bank effectiveness and riparian effectiveness monitored sites. In many cases, high seeding application rates appear to be the main source of herbaceous competition with woody vegetation.
- Mechanical weeding using a weed whacker resulted in damage to the planted vegetation. Manual weed removal provided better results. The mowing of native grasses did not allow for proper establishment and reseeding.
- *Noxious* weeds are prevalent on bank effectiveness sites, but *Prohibited Noxious* weeds are currently not.
- Temporary browsing protection fencing has an important influence on vegetation establishment. Browsing by beavers was observed when the fencing was in disrepair. Depending on the site, damaged fencing was causing a safety risk to the public.

**Effectiveness Monitoring Objective 9 – Citizen Science**: The ninth objective of the RMP was to integrate citizen science opportunities, where possible, into project effectiveness monitoring to support the *Riparian Action Program*'s education and outreach goals for improving community engagement and riparian awareness (City of Calgary, 2017).

Due to changes in the work program, this objective was no longer completed under the effectiveness monitoring component.

**Effectiveness Monitoring Objective 10 – Design Improvements**: The tenth objective of the RMP was to provide recommendations for design improvement to develop more adapted techniques/approaches for the Calgary local conditions and watercourses for future applications that can be considered as part of an update to *the Design Guidelines for Erosion and Flood Control Projects for Streambank and Riparian Stability Restoration* (Bioengineering Design Guidelines) (AMEC, 2012).

The results of Phase 2 of the RMP provided valuable information for updating the Bioengineering Design Guidelines including significant data and results to improve design, implementation, and maintenance practices. Recommendations are discussed in the Key Effectiveness Monitoring Recommendations section of this Technical Summary and in Section 7.2.3 of the main report.

**Effectiveness Monitoring Objective 11 – Monitoring Recommendations**: The eleventh objective of the RMP was to provide recommendations for future long-term monitoring needs.

Recommendations for future long-term monitoring needs were developed based on the results of the program and are discussed below and in Section 7 of this report.

# Key RMP Recommendations

## Key Trend Monitoring Recommendations

In general, RHI monitoring is recommended to continue on a five-year revisit interval. This allows for tracking the progression of riparian health over time in response to ongoing management efforts and land use pressures. As a field-based monitoring tool, RHIs can provide comprehensive, site-specific information coupled with on the ground photography monitoring. However, like all ground-based monitoring methods, these can be costly and as such generally cannot be applied at a geographic scale to capture comprehensive riparian conditions with full coverage across the city. Moreover, to date, RHI polygon boundaries conform to discrete management units primarily within the inner riparian zone (O2, 2014). Riparian habitat in the mid to outer floodplain zones is generally not well represented by RHI polygons. Consequently, net loss or change to riparian habitat at a city-wide scale is not readily captured by RHI data. Another limitation of continuing forward with the RHI metric on its own is that it is premised on comparison to an undisturbed, natural reference condition. This can limit the ability to detect smaller project specific changes in an urban context where some watershed parameters are unable to be influenced at a smaller scale (i.e. damming & dewatering on large rivers).

To address the limitations of the RHI method described above and fully capture the required data to track the *Riparian Action Program* riparian health targets, a hybrid approach may be warranted moving forward that better accounts for the urban context (Ehrenfeld, 2000). To allow more flexibility and judicious use of funding resources, a combination of monitoring approaches at various spatial scales is recommended for the long-term.

In determining a long-term riparian health monitoring framework, it is recommended that there is consistency and alignment among the monitoring approaches being applied by various City Business Units responsible for jointly managing natural assets (e.g. riparian city parks). *Riparian Action Program* targets linked to riparian health should be reviewed to reflect a more comprehensive monitoring approach.

## Key Effectiveness Monitoring Recommendations

Based on the results of 2018 to 2022 bank and riparian effectiveness monitoring activities, recommendations have been developed to improve project implementation.

The top recommendations are shown below. These recommendations were prioritized according to their perceived priority based on the RMP team's site observations, understanding of the results, and professional judgement. Additional recommendations for each of the categories are provided in Section 7 of this report.

Recommendations are provided for the following:

- Improvements to structural design practices (Table 5);
- Improvements to vegetation design, installation, and maintenance practices (Table 6);
- General program recommendations (Table 7); and,
- Improvements to City of Calgary project management practices (Table 8).

Recommendation for updates to The City's Bioengineering Design Guidelines include updates to existing sections, tables, figures, appendices, and bioengineering technique design guidelines; recommended new sections; and additional recommendations to include specific results and observations from the RMP. These recommendations are provided in Section 7.2.3 of the main report.

**Table 5: Top Recommendations for Improved Structural Design Practices**

| No. | Item | Report Section |
|---|---|---|
| S1 | Provide Irrigation for Two to Three Years Post-Construction | 3.3.1, p. 3-44 |
| S2 | Install Fencing Around Planted Vegetation to Protect from Browsing and Disturbance until Vegetation is Established | 3.3.1, p.3-46<br>3.3.2, p. 3-63 |
| S3 | Reduce Soil Compaction due to Construction Activities | 3.3.2, p. 3-84<br>4.3.27, p. 4-33 |
| S4 | Use Biodegradable Erosion Control Matting Products | 3.3.15, p. 3-22 |

**Table 6: Top Recommendations for Improvements to Vegetation Design, Installation, & Maintenance Practices**

| No. | Item | Report Section |
|---|---|---|
| V1 | Use Recommended Bioengineering Techniques and Species | 3.3.1, p. 3-20<br>3.3.2, p. 3-55<br>4.3.1, p. 4-8<br>4.3.2, p. 4-29 |
| V2 | Increase the Use of Container Plants in Combination with Live Cuttings Where Possible | 3.5, p. 3-55<br>4.6, p. 4-29 |
| V3 | Use Best Practices for Live Cuttings, Potted Plants, and Seed Mix Installation | 3.3.1, p. 3-38<br>3.3.1, p. 3-39 |
| V4 | Use Tall Rooted Stakes when Construction is Outside of the Live Cutting Dormancy Period | 3.3.1, p. 3-30 |
| V5 | Better Invasive Weed Control Needed | 3.3.2, p. 3-72 |
| V6 | Use Soil Amendment on Live Cuttings and Container Plants | 3.3.2, p. 3-60 |

**Table 7: Top General Program Recommendations**

| No. | Item | Report Section |
|---|---|---|
| G1 | Continue BDEP Monitoring | Refer to bank effectiveness annual summary reports |
| G2 | Share RMP Results via Field Days/Workshops | Refer to bank effectiveness annual summary reports |
| G3 | Update Bioengineering Design Guidelines | 7.2.3, p. 7-11 |

**Table 8: Top Recommendations for Improved City of Calgary Project Management Practices**

| No. | Item | Report Section |
|---|---|---|
| PM1 | Improve Document Control and Record Keeping | 3.3.1, p. 3-21<br>4.3.1, p. 4-28 |
| PM2 | Address Failure Sites and Implement Remedial Measures | Appendix D |
| PM3 | Incorporate Survival and Woody Vegetation Canopy Cover Targets | 3.3.1, p. 3-49 |

# 1. Introduction

## 1.1 Riparian Monitoring Program Background

The City of Calgary (The City) initiated a five-year Riparian Monitoring Program (RMP) in 2017 to better understand long term trends in riparian health in Calgary and the effectiveness of riparian restoration practices in Calgary. Riparian areas are described in Box 1 and Figure 1-1. The RMP was developed as part of the implementation of the following key strategy and planning initiatives, both of which can be retrieved from www.calgary.ca:

- Riparian Strategy – The City's Riparian Strategy was developed in 2013 and provides general approaches and decision-making criteria to guide a coordinated protection and enhancement program for riparian areas in Calgary (City of Calgary, 2013).
- Riparian Action Program (RAP) – The RAP was developed in 2016 to implement the Riparian Strategy and summarizes priority actions for riparian protection. The RAP recognizes the need to implement an adaptive management process that uses monitoring to adjust planning, design, and implementation of restoration projects (City of Calgary, 2017). The RAP contains three program areas including: (i) Riparian Health Restoration and Monitoring, (ii) Riparian Land Use Planning, and (iii) Outreach and Education. The RMP was developed to address the following key actions of RAP Program area two: riparian health restoration and monitoring:
    a. Integrate bioengineering techniques into bank restoration;
    b. Monitor riparian health and evaluated performance; and,
    c. Build capacity for riparian restoration.

In 2017 The City selected a consulting Project Team consisting of Kerr Wood Leidal Associates Ltd. (KWL) as prime consultant to develop and implement the RMP. KWL partnered with Terra Erosion Control Ltd. (TEC), the Alberta Riparian Habitat Management Society (Cows and Fish), National Research Institute of Science and Technology for Environment and Agriculture, Grenoble, France (INRAE), Longview Ecological (LE), and Hemmera Envirochem Inc. (Hemmera) as sub-consultants to complete the RMP.

### 1.1.1 RMP Timelines

As shown in Figure 1-2, Phase 1 of the RMP was initiated in 2017 with the development of the underlying methods and tools for implementing the project as documented in a report titled *The City of Calgary Riparian Monitoring Program Monitoring Plan* (KWL, 2018). Phase 1 was completed in 2018. Phase 2 of the RMP consisted of the implementation of the five-year monitoring plan which began in 2018 and ended in 2022. This report is the final deliverable of Phase 2 of the RMP. Phase 3 of the RMP began in 2023 and will continue to 2026.

## Box 1: What are Riparian Areas?

According to the Alberta Water Council (AWC, 2013): *"Riparian lands are transitional areas between upland and aquatic ecosystems. They have variable width and extent above and below ground and perform various functions. These lands are influenced by and exert an influence on associated water bodies, including alluvial aquifers and floodplains. Riparian lands usually have soil, biological, and other physical characteristics that reflect the influence of water and hydrological processes."* Figure 1-1 illustrates the key concepts of riparian areas.

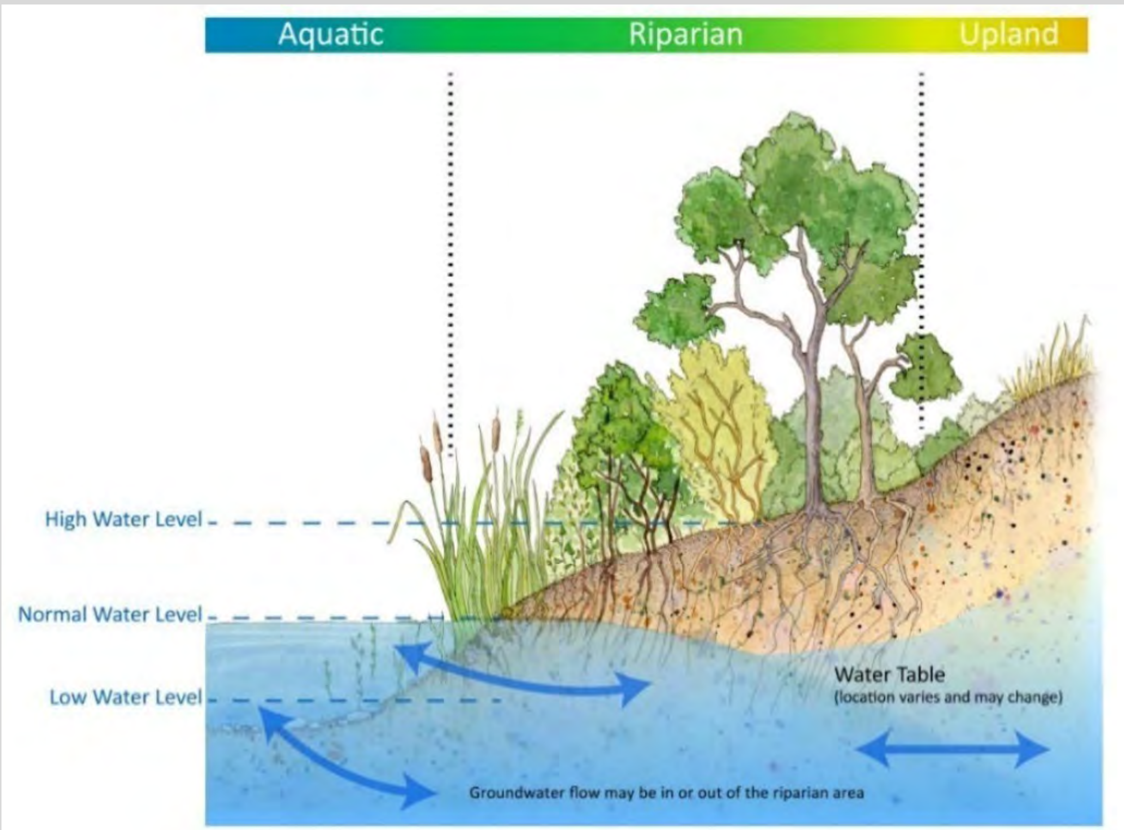



**Figure 1-1: Key concepts of riparian areas**

Figure source: Alberta Water Council *Riparian Land Conservation and Management Report and Recommendations* (AWC, 2013)

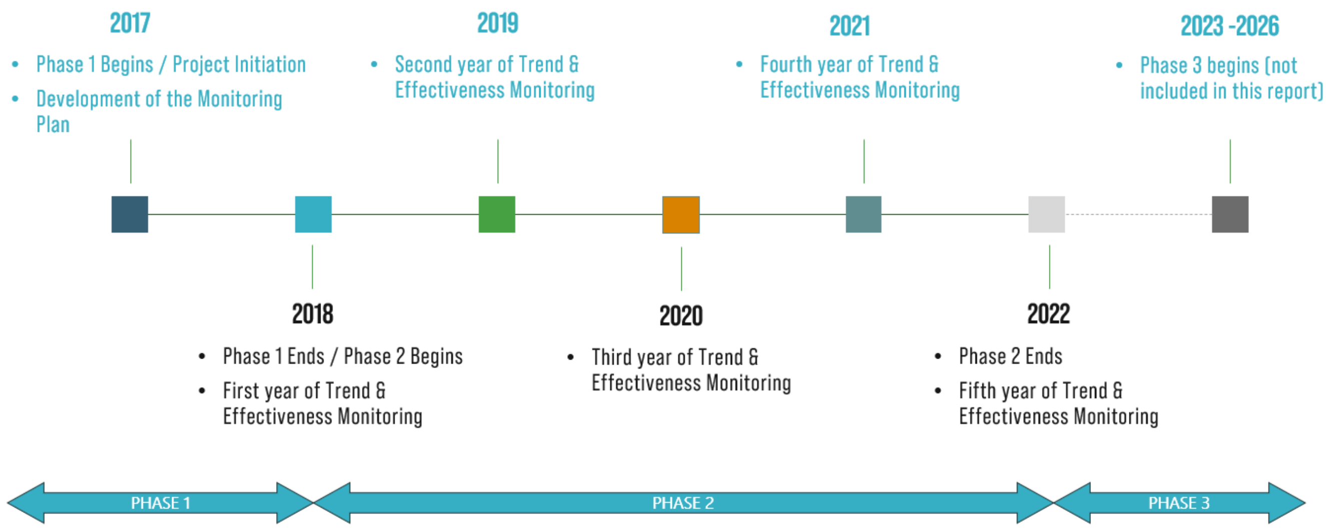



**Figure 1-2: RMP Timeline**

### 1.1.2 RMP Components

The RMP consists of the following five (5) components:

1. Riparian health trend monitoring;
2. Bank effectiveness monitoring;
3. Riparian effectiveness monitoring;
4. Special Project: Geomorphic monitoring of the Elbow River in Weaselhead Flats; and,
5. Special Project: post-construction monitoring of the Bioengineering Demonstration and Education Project (BDEP) (refer to Calgary.ca/BDEP for more information).

The focus of this Final Program Report is the first three components of the RMP, consisting of the riparian health trend and bank/riparian effectiveness monitoring components as further described below. The SWCRR and BDEP monitoring components are not included in this report as they are special projects with either their own specific plan or with special monitoring requirements not covered in the overall RMP.

- **Riparian health trend monitoring**: consists of ongoing monitoring of riparian sites in the City using the Riparian Health Inventory (RHI) protocols (Hansen, et al., 2000; Fitch, Adams, & Hale, 2014; Cows and Fish, 2016). Over 100 RHI benchmark sites have been monitored since 2007 across City watercourses and are being used to track against City-wide riparian health targets established in the *Riparian Action Program* (City of Calgary, 2017). RHI sites are monitored on a five-year revisit schedule and are typically large-scale polygons that can encompass one or more bank and/or riparian effectiveness sites.
- **Bank effectiveness monitoring**: consists of monitoring projects where the primary purpose is riverbank stabilization, protection, or erosion mitigation with bioengineering structural- and vegetation-based components. Bank effectiveness sites encompass the riverbank and often a strip

as wide as 15 m along the top of bank. The bank effectiveness monitoring component consists of more detailed assessment of an individual project site than RHI monitoring.

- **Riparian effectiveness monitoring**: consists of monitoring projects where the main purpose is enhancing riparian habitat away from the bank, with little to no structural components. Riparian restoration sites are mostly focused on the top of bank (riparian) areas, and general riparian/floodplain areas but may extend down onto the bank of smaller streams and creeks. The riparian effectiveness monitoring component consists of more detailed assessment of an individual project site than RHI monitoring.

### 1.1.3 RMP Objectives

**Objectives for Riparian Health Trend Monitoring**

Riparian health monitoring is important for tracking progress toward The City's commitment to conserving and improving the ecological health of riparian areas in Calgary and for prioritizing future restoration and conservation efforts as part of an adaptive management approach. Monitoring riparian health trends is integral to assessing success/failure and for informing and directing ongoing riparian restoration, stewardship, and management efforts in Calgary.

The objectives for trend monitoring for this project are listed below.

1. Assess changes in city-wide riparian health primarily for major rivers and streams, excluding private residential land.
2. Measure and inform The City of progress toward riparian health targets identified in the *Riparian Action Program* (City of Calgary, 2017).
3. Expand monitoring sites to be more representative of city-wide conditions for a larger cross section of sites including tributaries and priority source-water protection areas.

**Objectives for Bank and Riparian Effectiveness Monitoring**

The objectives for the bank and riparian effectiveness components of the RMP are listed below.

1. **Project Effectiveness Monitoring**: Determine the effectiveness of bank and riparian sites against the desired goals and objectives of each project.
2. **Site Selection and Typology**: Select a representative number of bank and riparian effectiveness monitoring sites from The City's *Master List – Riparian Restoration Projects* based on age class (described in the next three bullets immediately below) and typology (i.e., technique).
3. **Evaluate Success of Year 1 Age Class Sites**: Evaluate vegetation establishment success (i.e., after the first growing season post construction) to determine early plant material establishment, survival rates, plant material quality, potential work structure deficiencies, performance ratings for each typology and bioengineering/planting technique, and adequacy of implementation and maintenance practices.
4. **Evaluate Success of Year 3 Age Class Sites**: For sites that are three years post-construction, evaluate the effectiveness of each project relative to their intended restoration objectives (e.g., improved bank stability, erosion control, and establishment and improvement of native plant cover) and develop performance ratings for each typology and bioengineering/planting technique.

5. **Evaluate Success of Year 5+ Age Class Sites**: For sites that are five years or more post-construction, evaluate the effectiveness of each project relative to improvement of key ecological function/riparian health indicators, biodiversity indicators or progress toward a desired reference plant community or habitat type and develop performance ratings for each typology and bioengineering/planting technique.
6. **Techniques**: Identify advantages and limitations of riverbank bioengineering and streambank/riparian restoration techniques and if required, identify preferred techniques and plant species including plant material type (i.e., pot sizes, plugs, bare roots and/ or live cuttings) considered best suited to the site.
7. **Material Supply**: Identify advantages and limitations in plant material supply and make recommendations for involvement of local nurseries in the development of specific plant materials (i.e., species and stock type) to accommodate soil bioengineering design and local climate.
8. **Maintenance**: Evaluate the effectiveness of maintenance procedures.
9. **Citizen Science**: Integrate citizen science opportunities, where possible, into project effectiveness monitoring to support the *Riparian Action Program*'s education and outreach goals for improving community engagement and riparian awareness (City of Calgary, 2017).
10. **Design Improvements**: Provide recommendations for design improvement to develop more adapted techniques/approaches for the Calgary local conditions and watercourses for future applications that can be considered as part of an update to *the Design Guidelines for Erosion and Flood Control Projects for Streambank and Riparian Stability Restoration* (AMEC, 2012).
11. **Monitoring Recommendations**: Provide recommendations for future long-term monitoring needs (e.g., climate change resiliency monitoring).

## 1.2 Report Objectives

The purpose of this Final Program Report is to summarize the key results, successes and areas for improvement that were documented over the five-year RMP. The intent of the report is to highlight significant findings in a manner that is accessible to City of Calgary staff and external stakeholders including practitioners, contractors, and the public.

This report is not meant to be a specific guideline document for City project managers or practitioners. However, the results of the RMP will be accessible to City staff and external stakeholders including practitioners, contractors, and the public. This report provides information that can be used during the planning and design of riparian restoration projects, and the results may inform the development and/or review of City guidelines and procedures. Identified priority restoration areas may also inform future City restoration plans.

### 1.2.1 Detailed RMP Reports

More detailed methods, analysis, results, conclusions, and recommendations from each of the RMP components are provided under separate cover in annual technical reports/memorandums for 2018 to 2022 and are available only to internal City staff. This Final Program Report is derived from these detailed technical reports/memorandums for the trend and effectiveness monitoring components.

## 1.3 Report Organization

This report is organized into the sections listed below.

- **Section 1 – Introduction**: Covers the program background and timelines, components, objectives, report terminology/conventions, and acknowledgements.
- **Section 2 – Riparian Health Trend Monitoring**: In this section, a summary of the background, methods, analysis results, successes, and areas for improvement for the riparian health trend monitoring component of the RMP is provided.
- **Section 3 – Bank Effectiveness Monitoring**: In this section, a summary of the background, methods, analysis results, successes, and areas for improvement for the bank effectiveness monitoring component of the RMP is provided.
- **Section 4 – Riparian Effectiveness Monitoring**: In this section, a summary of the background, methods, analysis results, successes, and areas for improvement for the riparian effectiveness monitoring component of the RMP is provided.
- **Section 5 – Global and Climate Change Implications**: A summary impact of climate change on bioengineering and planting practices is provided.
- **Section 6 – Conclusions**: The conclusions stemming from the trend and effectiveness monitoring components are summarized.
- **Section 7 – Recommendations**: The recommendations stemming from the trend and effectiveness components are summarized.
- **Section 8 – Glossary**: Contains definitions of key terms used in the report.
- **Section 9 – References**: The references that are cited in the report are listed in this section.
- **Section 10 – Report Submission**: Signatories to the reports are provided in this section.

## 1.4 Report Conventions

The conventions listed below are used in this report.

- **Site Location Codes**: Bank and riparian effectiveness sites are referred to using a unique site location code (e.g., BE-ELB-4A) that includes the project type (i.e., 'BE' for bank effectiveness and 'RE' for riparian effectiveness), watercourse name (i.e., 'ELB' for Elbow River, 'BOW' for Bow River, 'WNO' for West Nose Creek, 'NOS' for Nose Creek, 'CON' for Confederation Creek, 'SHA' for Shaganappi Creek, and 'FIS' for Fish Creek), and Master List Site Number (e.g., 4A for Site #4A).
- **Vegetation Taxonomy**: All plant species common and scientific names used in this report follow the most recent nomenclature as listed by the Alberta Conservation Information Management System (ACIMS), the provincial agency that tracks the status of plant species in Alberta (ACIMS, 2022).
- **Invasive Plant Species**: For the purposes of this report, and to ensure consistency with the terminology used for the Riparian Health Inventory project, the term 'invasive species' as used here refers to species listed as *Noxious* and *Prohibited Noxious* on the Alberta Weed Control Regulation of the Weed Control Act as well as nine additional species that Cows and Fish considers invasive in riparian habitats.

- **Statistically Significant Results in Graphs**: Statistically significant results are indicated by the different letters above the bars in graphs. For example, if letters ‘a’ and ‘b’ are shown over bars in a graph, it indicates that the results are statistically different. On the other hand, if letters ‘a’ and ‘a’ are shown over bars in a graph, it indicates that the results are not statistically different.
- **Statistically Significant Results in the Text:** When the term “*statistically significant”* is used in the text of this report, it indicates that the results that are being described have been analyzed statistically and they meet the significance criteria of p-value less than 0.05.
- **Box Plots**: Box plots are a type of graph that are used later in the report to show results. Where data are presented in box plots, the following applies:
    - the bottom of the box is the 25th percentile (lower quartile);
    - the top of the box is the 75th percentile (upper quartile);
    - the band near the middle of the box is the 50th percentile (the median);
    - fifty per cent of the data are within the box;
    - the upper whisker is the ‘statistical maximum’ = (upper quartile + 1.5 * interquartile range);
    - the lower whisker is the ‘statistical minimum’ = (lower quartile – 1.5 * interquartile range); and,
    - outliers are shown above the upper whisker or below the lower whisker.
- **Failure**: The term failure as used in this report is based on the RMP project-specific definition in the *Monitoring Plan* (KWL, 2018) where a Year 1 site is determined to be a failure if: 1) the works are found to be missing, degraded or ineffective; and/or, 2) if the woody vegetation survival is < 25%. Year 3 and 5+ sites are considered to be a failure if the works are found to be missing, degraded or ineffective. The vegetation survival failure criteria of <25% does not apply to Year 3 and Year 5+ sites since it is not always possible to accurately assess the survival of planted woody vegetation for Year 3 and older sites due to the growth of other vegetation obscuring dead cuttings/plantings and/or state of decay of the dead cuttings/plantings. It is highly likely that survival for Year 3 and older sites gets exaggerated because of this.

A glossary is provided in Section 8 as a reference for many of the technical terms used in this report.

# 2. Riparian Health Trend Monitoring

Riparian areas include shoreline and floodplain habitats along Calgary's stream and river valleys as shown in Box 2. These important natural assets have direct relevance to flood and drought resilience, stormwater mitigation, water quality maintenance, and as critical ecological corridors for biodiversity and habitat connectivity. These areas are also at the heart of Calgary's park networks, providing conservation but also valuable recreational amenities. Calgary's river parks play a crucial role in enhancing quality of life opportunities for all Calgarians, greatly enriching the urban landscape.

The City of Calgary has set out strong policy directives for the conservation, management, and restoration of these vital riparian habitats. This includes commitments outlined in the 2013 *Riparian Strategy* (City of Calgary, 2013) and the 2017 *Riparian Action Program* (City of Calgary, 2017) which tie into the provincial *Water for Life strategy*, regional and watershed planning objectives, and Calgary's Municipal Development Plan's goal of "Greening the City". Targets established under the *Riparian Action Program* focus on i) tracking progress toward enhancing municipal protection of riparian lands and ii) achieving gains in riparian health.

**Box 2: Why Riparian Health Matters to The City of Calgary**

Healthy riparian areas provide:

1. Flood and drought resilience
2. Clean, Safe Water
3. Biodiversity
4. Economic Benefits
5. Quality of Life

Riparian health monitoring has been done since 2007 across Calgary's major streams and rivers. Riparian health trend monitoring was incorporated as one of the main objectives for the 2018-2022 RMP to inform progress toward achieving riparian health targets. Health targets were established for a city-wide scale and for various riparian management zones corresponding to land use priorities (e.g. conservation versus recreation use). Sites were focused on City of Calgary owned lands but also included other privately owned sites (n=22) such as golf courses and industrial sites. Riparian health scores are determined from an evaluation of vegetation, soil, and hydrological parameters that are primarily assessed in the field. Riparian health scores fall into one of three broad categories – ***unhealthy*** (0-59% score), ***healthy, with problems*** (60-79% score), and ***healthy*** (80-100% score) (Table 2-2).

**Table 2-1: Riparian Health Parameters Assessed for Streams and Small Rivers**

| Riparian Health Parameter | | Streams and Small Rivers (e.g., Nose Creek) | Large Rivers (e.g., Bow River) |
|---|---|---|---|
| **Vegetation Parameters** | vegetation cover | þ | |
| | cottonwood and poplar regeneration | | þ |
| | regeneration of other native tree species | | þ |
| | preferred shrub regeneration | | þ |
| | preferred tree/shrub regeneration | þ | |
| | preferred tree/shrub utilization and live woody vegetation removal by beaver/humans | þ | þ |
| | standing dead/decadent woody material | þ | þ |
| | total canopy cover of woody plants | | þ |
| | invasive plant canopy cover and density distribution | þ | þ |
| | disturbance plant canopy cover | þ | þ |
| **Soil/ Hydrology Parameters** | root mass protection | þ | þ |
| | human-caused alterations to banks | þ | þ |
| | human-caused bare ground | þ | þ |
| | human-caused alterations away from the bank | þ | þ |
| | floodplain accessibility | | þ |
| | channel incisement | þ | |
| | removal or addition of water from / to river system | | þ |
| | control of flood peak and timing by upstream dam(s) | | þ |

**Table 2-2: Riparian Health Scoring Categories**

| Health Category | Score Ranges | Description |
|---|---|---|
| *Healthy* | 80-100% | little to no impairment to any riparian functions |
| *Healthy, with problems* | 60-79% | some impairment to riparian functions due to human or natural causes |
| *Unhealthy* | <60% | severe impairment to riparian functions due to human or natural causes |

Riparian Health scores represent how effectively a riparian site can perform various ecological functions based on the severity of degradation of vegetation and soil/hydrology features compared to a natural, undisturbed ‘reference’ state. Healthy riparian areas have the following pieces intact and functioning properly:

- ✓ successful reproduction and establishment of seedling, sapling, and mature trees and shrubs,
- ✓ lightly browsed trees and shrubs (by livestock or wildlife),
- ✓ floodplains, and banks with abundant plant growth,
- ✓ banks with deep-rooted plant species (e.g. trees, shrubs, and sedges),
- ✓ very few, if any, invasive weeds (e.g. common tansy),
- ✓ not many disturbance-caused plant species (e.g. Kentucky bluegrass, dandelion),
- ✓ very little bare ground or altered banks,
- ✓ the ability for floodwaters to frequently (i.e. every few years) access a floodplain at least double the channel width or stream size, and,
- ✓ the ability to store water, sustain, and establish new plant communities even during natural climatic cycles (e.g. drought).

When riparian health degrades it usually means that one or more of the pieces has been impacted by natural or human-caused disturbances such as development, recreation, grazing, flooding, or fire. As the rate and intensity of disturbance increases, the severity of health degradation can reach a point when the riparian area fails to perform its functions properly and becomes ***unhealthy*****.** Riparian areas with moderate levels of impacts will typically fall within the ***healthy, with problems*** category, while those with very few or no impacts will normally be rated as ***healthy****.* Given the urban context and permanent limiting factors to riparian health improvement (e.g., transportation, stormwater outfalls, flood protection infrastructure, upstream damming), riparian health targets are based on percentage increases rather than categorical increases. Examples of sites in each riparian health category (*healthy*, *healthy, with problems*, and *unhealthy*) are provided in Figure 2-1.

**Figure 2-1: Examples of Calgary Sites in Each Riparian Health Category**

***Healthy*** | ***Healthy, with problems*** | ***Unhealthy***

**Weaselhead Flats Park (ELB30)**
Conservation Zone
*(Image no. RHIP30ELB072)*

**Lindsay Park (ELB26)**
Mixed Recreation/Conservation Zone
*(Image no. RHIP26ELB30)*

**Bow River, Sunnyside (BOW49)**
Flood and Erosion Control Zone
*(Image no. RHIP49BOW067)*

## 2.1 Riparian Health Trends

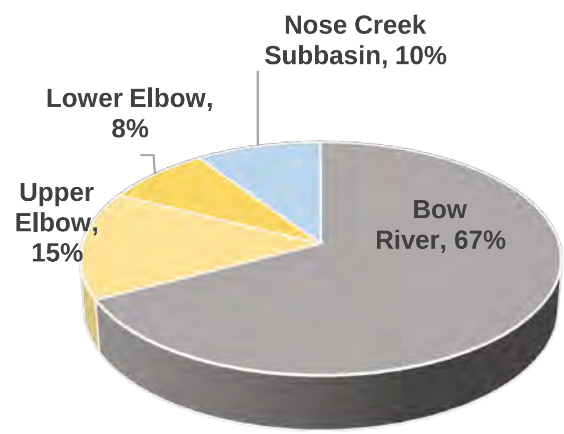
### 2.1.1 Long-Term Trend Analysis (Original 58 Sites)

Long-term riparian health data is available for a subset of **58** sites along the Bow River, Elbow River, Nose Creek, West Nose Creek, and Beddington Creek in Calgary. Table 2-3 shows the breakout of how sites were distributed across the various waterbodies. Baseline data collected for these sites in 2007-2010 and again in 2014-2015 informed riparian health targets incorporated in The City's 2017 *Riparian Action Program.* Results presented in this section focus on long-term trend results for these sites from 2007 to 2020.

A total of 122 sites have been assessed since 2007 including an additional 47 sites along the Bow, Elbow, Nose Creek and West Nose Creek. An additional 18 ephemeral sites have also been assessed. This expanded project area and ephemeral streams are discussed Section 2.1.4 A Riparian Health Inventory comprehensive site list including scoring, highlighted site case studies and success stories, as well as trend maps for all city-owned sites[1] are provided in Appendix A for reference.

**Table 2-3: Long-Term Monitoring RHI Project Area (58 Sites)**

| Waterbody Name | Number of Sites | Total Length Assessed (km) | Total Area Assessed (ha) | % of Total Project Area |
|---|---|---|---|---|
| **Bow River** | 30 | 28.5 | 238.1 | **67%** |
| **Elbow River** | | | | |
| Upper Elbow | 2 | 2.0 | 53.2 | 15% |
| Lower Elbow | 13 | 9.4 | 28.5 | 8% |
| *Elbow River* | ***15*** | ***11.3*** | ***81.7*** | ***23%*** |
| **Nose Creek Subbasin** | | | | |
| Nose Creek | 6 | 6.0 | 14.6 | 4% |
| West Nose Creek & Beddington Creek | 7 | 6.3 | 19.2 | 5% |
| *Nose Creek Subbasin* | ***13*** | ***12.4*** | ***33.7*** | **10%** |
| **Totals** | **58** | **52.2** | **353.5** | |




[1] Sites included in the riparian health analysis included both city-owned and privately owned lands. Due to confidentially only city-owned sites are shown visually on the maps.

### 2.1.2 Long-Term Trend Highlights (58 Sites)

For the 58 sites with long-term data, city-wide riparian health scores **have increased from 61% (2007-2010) to approximately 65%[2] (2019/2020),** remaining in the *healthy, with problems* category compared to baseline condition (2007-2010) as shown in Figure 2-2. Less than a 5% score change is considered a 'stable' (static) score trend. For more details, refer to individual waterbody report cards for the Bow River, Elbow River, and Nose Creek in Figure 2-4, Figure 2-5, and Figure 2-6 respectively.

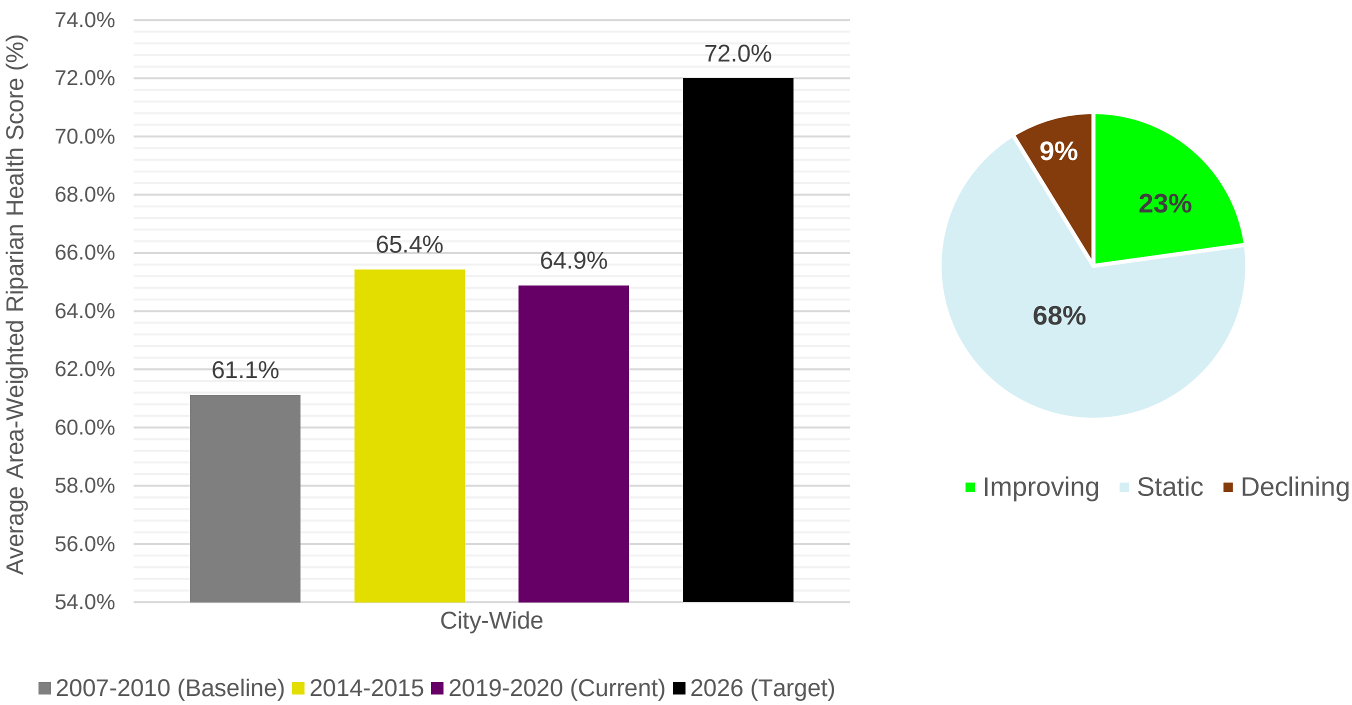



**Figure 2-2: Long-Term Riparian Health Trends for 58 Sites City-Wide**

Riparian health gains since 2007-2010 were attributed to a combination of factors including:

- Beneficial impacts along the Bow and Elbow Rivers from the 2013 flood and improved management or restoration in some sites allowing for natural recovery. Recreation access management and increases in the use of bioengineering techniques are some examples and are highlighted in more detail in the case studies section of Appendix A.
- Balsam poplar (*Populus balsamifera*) recruitment (new growth) increased in 10 of 30 Bow River sites following on from the 2013 flood. This is significant given the importance of poplars as a keystone species that is vital to the foundation of healthy riverine ecosystems. Although historically abundant, riparian poplar forests of the western prairies are now endangered as a result of widespread damming and diversion of rivers in this region. The June 2013 flood event with flows

[2] Riparian health scores were area weighted based on the size of the site. This means that larger sites contribute more to the overall average than smaller sites proportionally based on their size. By using area weighting the scores the average better represents the city as a whole since there is wide variation in the size of the sites.

exceeding 1,700 $m^3/s$ provided sufficiently high flows to promote conditions suitable for promoting poplar regeneration (sediment deposition, flood scour and high soil moisture levels co-incident with peaks in poplar seed release (refer to the next section). Figure 2-7 outlines some of the impacts of the 2013 flood in more detail.

Minor score declines from 2014/2015 to 2019/2020 were mainly attributed to:

- Post-flood landscaping;
- Bank stabilization and repair works, and
- Increased recreational use impacts.

Bank stabilization projects (including hard engineering and bioengineering) since 2013 have resulted in a substantial net increase in riprap armouring along both the Bow and lower Elbow Rivers (below the Glenmore Reservoir). However, significant uptake in the use of vegetated bioengineering techniques may partially offset negative impacts from rock armouring as vegetation establishes over time. Many bioengineering projects have a variable rock riprap component at the toe of the bank. Figure 2-8 summarizes the how the 2013 impacted riparian health in relation to post-flood repair works.

Riparian health trends by management zone show the largest score increase since baseline conditions for the "**Restoration Management Zone**", a focal area for ongoing restoration projects city-wide (Figure 2-3). The highest average riparian health rating for riparian habitat is the "Conservation Management Zone" (i.e., natural environment parks such as Weaselhead Flats, the Inglewood Bird Sanctuary, and Bowmont Park).

The Bow River area-weighted scores range in the ***unhealthy*** category (59% approximately; Figure 2-4), comparatively much lower than for the Elbow River. Bow River scores account for upstream damming, flood berms, and water diversions (i.e., the Western Irrigation District diversion) along the river. These large river health parameters require data inputs from Alberta Environment and Protected Areas that were not available at the time of baseline inventories (2007) for the Elbow River. Subsequent monitoring of the Elbow River, for consistency, has not included these metrics. Thus, Elbow River sites were assessed using "Small River" RHI scoring methodology.

The Elbow River riparian health scores, not surprisingly, are much different for the Upper and Lower reaches (i.e., above and below the Glenmore Reservoir) (Figure 2-5). ***Healthy*** conditions in the expansive Weaselhead Flats and Griffith Woods parks in the Upper Reach have been maintained since 2007. Conditions below the reservoir are much more heavily impacted, where only very narrow strips of riparian habitat remain. Nonetheless, Lower Elbow health scores have shown slight improvements since 2007 linked with ongoing restoration and improved management efforts (e.g., Sandy Beach and River Parks and in Mission).

Most Nose Creek sites continue to rate as ***unhealthy*** whereas the West Nose Creek sites continue to rate as *healthy, with problems* on average (Figure 2-6). Historic impacts from channelization negatively affect Nose Creek riparian health scores, limiting potential for improvement. West Nose Creek by comparison does have greater retention of natural channel meanders within larger conserved 1:100-year floodplain parks (e.g., Confluence Park). Continued efforts to improve stormwater management in the Nose Creek basin as a whole is a key factor influencing riparian health.

**Conservation Zone**

*Long-term trend: +3%*

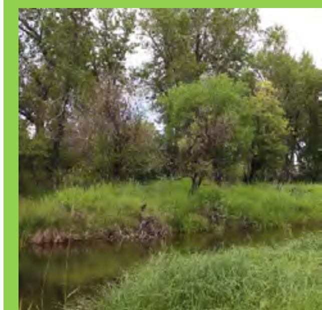


*Image #: RHIP74BOW074*

- Management priority is to conserve intact riparian habitat for ecosystem health, biodiversity, habitat connectivity and natural open space.
- *Examples:* Inglewood Bird Sanctuary, Bowmont Park, Weaselhead Flats Park
- Goal is to limit infrastructure development is limited.
- Goal is to prohibit 'Hard' engineering bank stabilization options.

**Restoration Zone**

*Long-term trend: +9%*

*Image #: RHIP35ELB022*

- Management priority is to restore degraded riparian health.
- *Examples:* Sandy Beach Park, Carburn Park, Confluence Park.
- 'Hard' engineering bank stabilization options highly discouraged.

**Recreation Zone**

*Long-term trend: +2%*

*Image #: RHIP44BOW060*

- These are areas of high recreational value and use. Management priority is to facilitate recreational use; includes manicured parks and golf courses.
- *Examples:* Prince's Island Park, Lindsay Park, Inglewood Golf Course
- 'Hard' engineering bank stabilization options highly discouraged (discretionary)

**Flood & Erosion**

*Long-term trend: +2%*

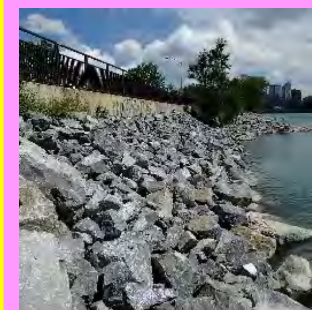


*Image #: RHIP33BOW037*

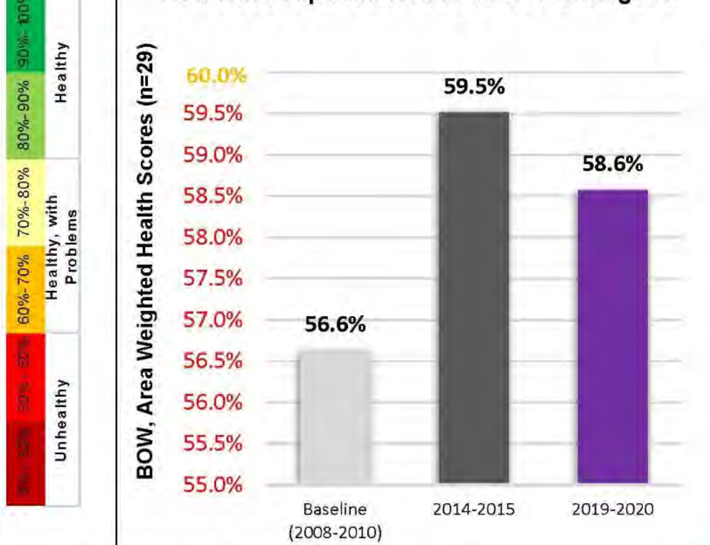
- These are areas subject to flood and erosion risk to adjacent infrastructure. The priority is to 'mitigate potential flood or erosion risk using the best options available' (City of Calgary 2017).
- *Examples:* Memorial Drive & 19th Street; Bridge crossings
- 'Hard' engineering bank stabilization options permitted as necessary

**Figure 2-3: Riparian Health Trends by Management Zone**

## Figure 2-4 Bow River Long-Term Trend Monitoring Report Card: 2008-2020

No. of sites assessed: 29 (Excludes BOW45*) | Total area assessed: 222.1 ha | Total length assessed: 27.4 km

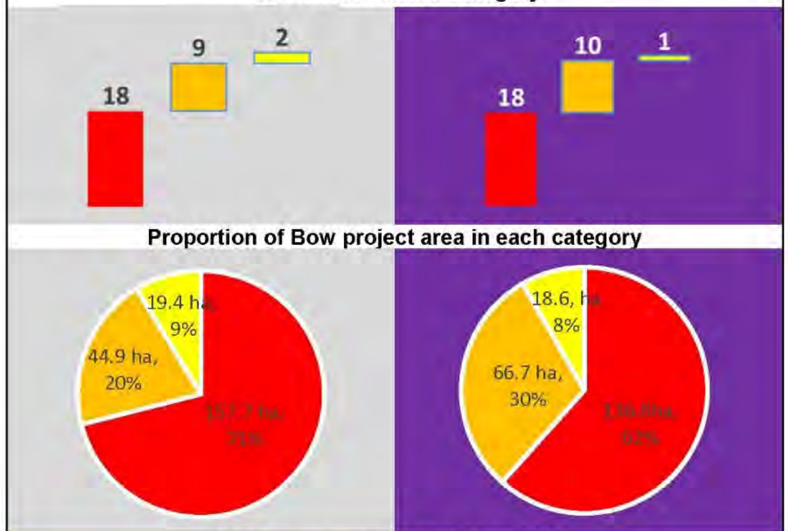
### How Have Riparian Health Scores Changed?




| 2008-2010 (n=29) | 2019-2020 (n=29) |
|---|---|

**No. of sites in each category**

**Proportion of Bow project area in each category**




### Trends since baseline (2008-2010):

| Number of Improving Sites (>5% score increase) | Number of static (stable) sites (<5% score change) | Number of declining sites (>5% score decline) |
|---|---|---|
| **6** | **22** | **1** |

### Key improvements since 2008:

-Post 2013 flood balsam poplar regeneration
-Other native tree and shrub regeneration
-Total woody cover

### Trend Discussion (excludes BOW45*):

- Average, area-weighted Bow River riparian health scores increased by approximately 3% from baseline conditions (2008-2010) compared to 2014/2015. This was mainly due to beneficial impacts from the 2013 flood and restoration or improved management in some sites. Beneficial flood impacts included improved balsam poplar regeneration; flood deposition covering areas of human-caused bare ground or soil compaction; and erosion of formerly trampled or altered banks with little root mass protection. Where the bank eroded back to the treeline, this resulted in improved root mass protection scores for some sites.
- Bow River riparian health scores declined slightly (by approximately 1%) from 2014/2015 to 2019/2020. Score declines were attributed to post-flood landscaping or repair works and bank stabilization; flood protection berm construction; and higher recreational use in some sites. Other than exclusively planting projects, other bioengineering projects with a structural component (e.g., vegetated crib-walls) are considered a bank structural alteration in the short term. If successful, in the long term, these types of projects will naturalize as the wood structures decompose and planted trees and shrubs take root. Thus, riprap projects typically have a much longer-term structural alteration impact versus softer bioengineering projects. Softer bioengineering projects, if successful, also contribute positively to root mass protection, woody cover and tree/shrub regeneration parameters.
- **Overall, compared to baseline, there have been positive trends for tree/shrub health parameters** (poplar, other native tree and shrub regeneration plus overall woody cover). **However, bank stabilization projects since 2013 have resulted in a substantial net increase in riprap armouring** within the Bow River study area. Riprap accounted for about 40% of the altered bank length in 2007-2010 compared to 61% in 2019/2020. Despite an increase in riprap armouring, the net length of altered bank (8.3 km) is similar to what was reported in the baseline period.
- **Invasive weed cover is increasing** along the Bow River in Calgary. A total of 27 invasive species were observed in the Bow River project area in 2019-2020 compared to 20 species in 2008-2010. There are currently 15 sites with more than 15% cover from invasive weeds compared to 9 in this category in 2014-2015.

### Limiting Factors

- Although successful restoration works are in progress in many Bow River sites, many of these are localized, small-scale projects. In addition, many sites (21 out of 29) are high-use recreation areas or represent narrow sites along a regional pathway corridor. Some are considered 'critical erosion protection' sites due to adjacent roadway or other infrastructure, requiring more intensive, 'hard' engineering bank stabilization approaches. Sites with numerous amenities and manicured landscape features have limited potential for substantial improvement under current land uses and riparian management zoning.
- Other limiting factors are impacts due to control of flood peak and timing by upstream dams. If flow-ramping criteria were introduced to benefit balsam poplar recruitment, this may be mitigated to some degree. All sites downstream from the Western Irrigation District Weir also have reduced scores for removal of water from the river system. As such, there are permanent watershed scale alterations which limit riparian health score improvements within this urbanized catchment. Like many urban catchments, historic land use disturbance has resulted in a prevalence of invasive weeds and disturbance-caused plants.

### Areas for Improvement:

- Continue efforts to control and manage invasive weeds
- Continue careful management of recreational use impacts
- Continue riparian planting projects and promote bioengineering retrofit (e.g. vegetated riprap) where possible
- Continue to prioritize habitat conservation and retain undisturbed habitat parcels

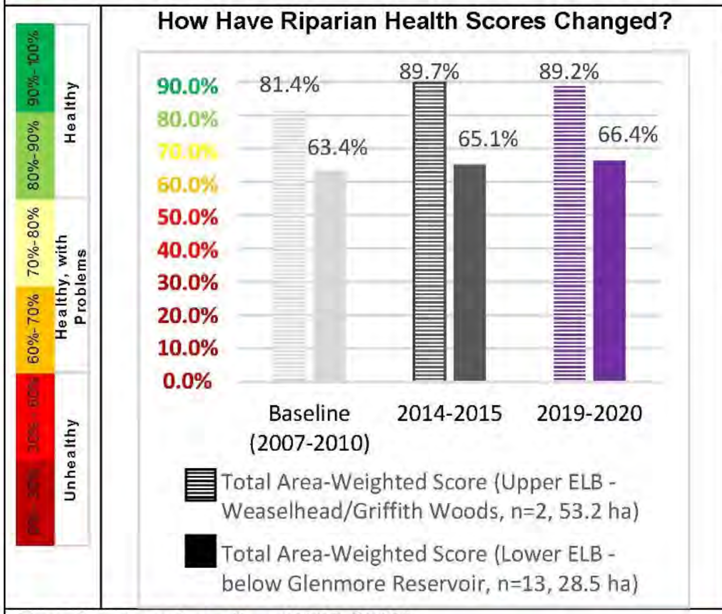
** BOW45 (South Highfield) – Active construction prevented RHI monitoring in 2019/2020. Trend results here exclude this site.*

## Figure 2-5 Elbow River Long-Term Monitoring Report Card: 2007-2020

No. of sites assessed: 15*

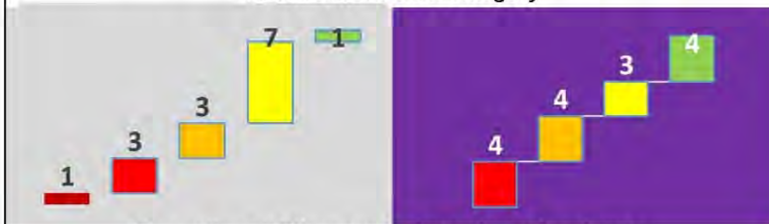
Total area assessed: 81.7 ha   Total length assessed: 11.3 km

### How Have Riparian Health Scores Changed?

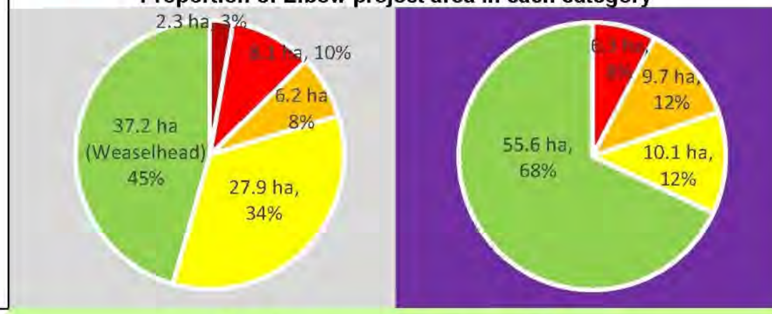



| 2007-2010 (n=15) | 2019-2020 (n=15) |
|---|---|

**No. of sites in each category**




**Proportion of Elbow project area in each category**




**Trends since baseline (2008-2010):**

| Number of Improving Sites (>5% score increase) | Number of static (stable) sites (<5% score change) | Number of declining sites (>5% score decline) |
|---|---|---|
| 6 | 7 | 2 |

**Key improvements since 2007:**

- Improved vegetation cover
- Reduced human-caused bare ground

**Trend Discussion:**

- Elbow River area-weighted scores are strongly influenced by *healthy*, natural conditions in the Weaselhead and Griffith Woods Natural Environment Parks upstream from the Glenmore Reservoir. These large intact Conservation Zone parks, by area, represent about 65% of the Elbow River project area. By comparison, the remainder of the project area is mostly comprised of highly altered, narrow sites downstream from the Glenmore dam. Most of the historic Elbow River riparian area in downtown Calgary is developed. Most sites downstream from the dam continue to rate as *Unhealthy* or *Healthy, with Problems*.
- Positive improvement was seen from baseline conditions (2007-2010) compared to 2014/2015 mainly due to beneficial flood impacts and restoration projects. Compared to 2014/2015 most sites show little to no change in riparian health scores, but some increase is occurring where restoration works coupled with improved management efforts are ongoing (e.g., Sandy Beach and River Parks and in Mission).
- Similar to the Bow River study area, riprap bank stabilization has increased notably since baseline along the Elbow River downstream from the Glenmore dam. In 2007/2008 riprap accounted for about 23% of bank alteration kinds, compared to 42% in 2019/2020. However, except for about 230 m of un-vegetated riprap adjacent to the Calgary Stampede, most other riprap installations do include a vegetated component.
- **Invasive weed cover is increasing** along the Elbow River A total of 24 invasive species were observed in the Elbow River project area in 2019/20 compared to 15 species in 2008/10. Compared to 2014/15 invasive weed cover has increased in five Elbow River sites by more than 7%. Invasive weed cover averages about 12% in 2019/20 compared to 9.8% in 2014/15.
- Bank stabilization projects and resulting ground disturbance and introduction of soil media or application of seed mix contamination may be a contributing factor to weed increases. Weed monitoring and maintenance is a requirement for all bank stabilization projects. In general, urbanized catchments have many other potential contributing sources for weed introductions. Ongoing weed monitoring and control is recommended in addition to minimizing new ground disturbance, where possible.
- Only one site, ELB51 (Saddledome) shows consistent declines since baseline, due in part to increased physical alterations, increased invasive weeds and reduced root mass protection. ELB51 continues to be a highly disturbed site overall. Although ELB50 (Sandy Beach Park south) has had increased recreational use pressures since 2008, restoration and management efforts since 2015 are having beneficial outcomes.

**Limiting Factors:**

- Calgary's development footprint below the Glenmore Reservoir constrains natural fluvial processes. Bank armouring and stabilization is extensive along the lower reach of the Elbow, effectively 'straight jacketing' the river. Much of the historical Elbow River floodplain in this reach is fully developed.

**Areas for Improvement:**

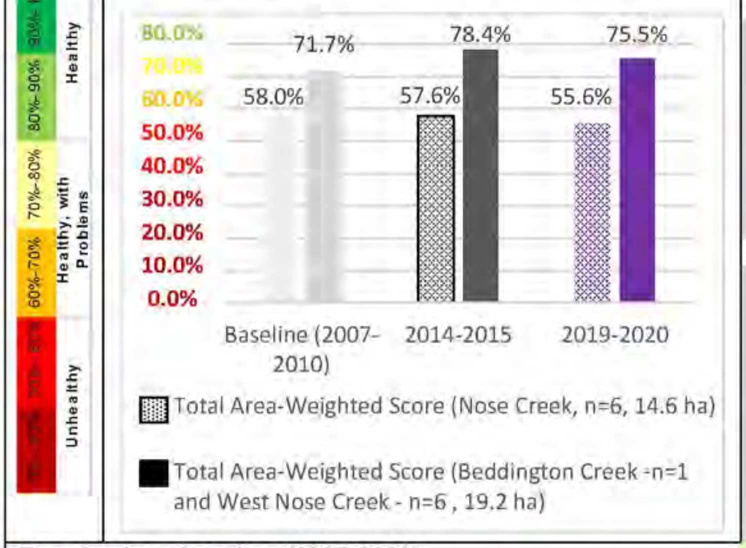
- Continued efforts to control and manage invasive weeds
- Continued careful management of recreational use impacts
- Continue riparian planting and habitat restoration efforts
- Continue to prioritize habitat conservation and retain undisturbed habitat parcels in the upper reaches of the Elbow River

- **Important note:** Unlike for the Bow River, ***Elbow River riparian health scores do not account for the effect of upstream dams and artificial additions and removal of water.*** Thus, Elbow River riparian health scores downstream from the Glenmore Dam do not account for the impacts of the dam itself on fluvial geomorphology, flow stabilization and other natural processes.

**Figure 2-6 Nose Creek Basin Long-Term Trend Monitoring Report Card: 2007-2020**

No. of sites assessed: 13 | Total area assessed: 33.7 ha | Total length assessed: 12.4 km

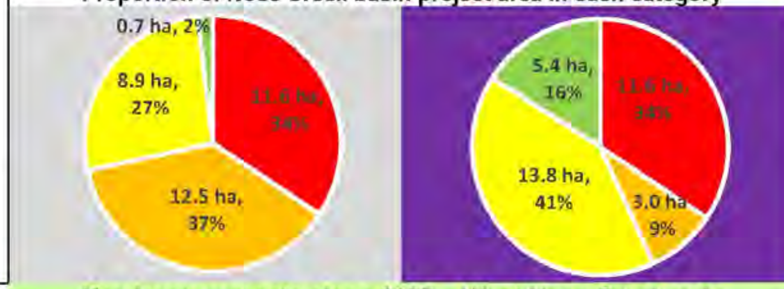
**How Have Riparian Health Scores Changed?**




| 2007-2010 (n=13) | 2019-2020 (n=13) |
|---|---|

**No. of sites in each category**


**Proportion of Nose Creek basin project area in each category**




**Trends since baseline (2007-2010):**

| Number of Improving Sites (>5% score increase) | Number of static (stable) sites (<5% score change) | Number of declining sites (>5% score decline) |
|---|---|---|
| 1 | 10 | 2 |

**Key improvements since 2007 – West Nose Creek only**

-Post 2013 flood poplar regeneration
-Other native tree regeneration
-Total woody cover

**Trend Discussion:**

- Most Nose Creek sites continue to rate as *unhealthy* whereas the West Nose Creek sites continue to rate as *healthy, with problems* on average. Historic impacts from channelization negatively affect Nose Creek riparian health scores, limiting potential for improvement due to permanent impacts to bank and floodplain alterations and channel incisement.
- Improved riparian health conditions have occurred since baseline along West Nose Creek in Confluence Park (WNO18) due to natural recovery of historic agricultural impacts, beneficial wetland habitat creation by beavers, and ongoing restoration efforts. Similarly, these factors have positively affected scores for all other West Nose Creek sites, with all having slight upward trending scores (1-5% increases)
- Riparian health has declined for two sites by more than 5% since baseline: NOS5, Greenview Industrial Park south of McKnight Blvd NE; and BED1, Panorama Urban Reserve. Invasive species increases and reduced root mass protection have mainly affected Nose Creek basin score declines.
- Except for the upper reach of West Nose Creek (i.e., upstream from Hidden Creek Drive NW), there has been a steadily increasing bank instability trend for most of the Nose Creek, West Nose Creek and Beddington Creek re-visit sites. Channelization coupled with urban-modified stormwater inputs far in exceedance of natural conditions, have likely contributed to accelerated rates of bank erosion and slumping. Development in the upper Nose Creek catchment has progressed steadily since 2007-2010.
- The majority of Beddington Creek (a small tributary to Nose Creek) has been entirely developed and piped below ground except where it was protected as Environmental Reserve, south of Panatella Blvd NW (BED1). BED1 does have some remnant native plant communities, but it has been heavily invaded by weeds and disturbance-caused plants. This reach is also being impacted by urban runoff and altered hydrology.

**Limiting Factors:**

- Limiting factors to riparian health improvement for Nose Creek are permanent impacts from channelization. The majority of Nose Creek south of Airport Trail NE was historically straightened, resulting in loss of natural meanders and historic floodplain riparian habitat. Most of the Nose Creek corridor has an abundance of non-native, agronomic grasses (mainly smooth brome) and weedy spe+cies. This corridor is also negatively impacted by urban-modified stormwater inputs far in exceedance of natural conditions, contributing to accelerated rates of bank erosion and slumping.
- West Nose Creek, by contrast, has retained natural stream channel meanders and a wider protected riparian corridor within Calgary City limits. Most of the sites assessed are now managed as urban parks where environmental reserves have been retained along West Nose Creek. Historically, West Nose Creek was actively grazed by livestock as part of ranching operations. Long-term livestock use likely contributed to suppression of preferred native shrubs. Historical conversion of native grassland in the valley to hayfields and tame pasture also contributed to shifts in native plant communities and an increase in non-native grasses like smooth brome.

**Areas for Improvement:**

- Retain natural channel meander bends within the 1:100-year floodplain along the north reach of Nose Creek and along West Nose Creek.
- Reintroduce channel meanders along the channelized reach of Nose Creek, where possible to promote natural recovery.
- Promote beaver co-existence and explore opportunities for beaver dam analogs where possible to alleviate channel incisement.
- Continue to set progressive stormwater management targets for runoff rates (L/s/ha), runoff volumes (mm/ha), and stormwater quality treatment.
- Continue efforts to strengthen and improve Calgary's stormwater management strategy.

Although riparian health trends varied by waterbody there were some common themes. Table 2-4 outlines some of the general trends in various health parameters and what were likely contributors to either their improvement or decline.

The 2013 flood was an important event which greatly affected riparian health across the city. There were both positives and negatives to riparian health as a result of the floods which are summarized in Figure 2-7 and Figure 2-8.

**Table 2-4: General Long-Term Trends in Key Riparian Health Parameters Since 2007 (58 Sites)**

| ***Improving or Declining Parameters:*** | ***Waterbody:*** | ***Contributing Factors:*** |
|---|---|---|
| Improved cottonwood and balsam poplar regeneration<br>Improved regeneration of other native trees | Bow River | – Post-2013 flood poplar and willow recruitment<br>– Natural recovery following management improvements to fence-out riverbank habitats |
| Improved regeneration of preferred shrubs | Upper Elbow River | – Post-2013 flood poplar and willow recruitment |
| Improved vegetative cover<br>Reduced human-caused bare ground | Lower Elbow River | – Riparian planting and bioengineering projects<br>– Natural recovery following management improvements to fence-out riverbank habitats |
| Reduced root mass protection | Lower Elbow River,<br>Nose Creek | – Lower Elbow: increasing riprap armouring at base of bank<br>– Nose Creek: stormwater inputs and channelization increase bank slumping and erosion |
| Increased human-caused bare ground | Bow River | – Recreational trails reinstated post-flood and increasing use occurring in many river parks |
| Increased invasive plants (canopy cover) | Bow River, Lower Elbow River, Nose Creek | – Increased expansion of pre-existing populations of weeds<br>– New invasive species incursions and threats<br>– Disturbance/bank repair related infestations |
| ***Watershed Limiting Factors:*** | | |
| Control of flood peak and timing by upstream dams | Bow River | – All Bow River sites have score deductions due to stabilization of flows by operation of upstream dams (i.e., the Kananaskis Falls, Horseshoe Falls, Ghost and Bearspaw dams and an additional five hydroelectric facilities/dams located along tributaries of the Bow River). |
| Channelization | Nose Creek | – The majority of Nose Creek south of Airport Trail NE was historically straightened, resulting in loss of natural meanders and historic floodplain riparian habitat. |

**Figure 2-7: The 2013 Flood: How did it influence Riparian Health Trends? Gains due to Poplar Regeneration**

## Balsam poplars are keystone species for:

- **water quality & river bank stability** (by slowing flow, trapping sediment, shading water)
- **woody habitat & microclimate** (essential to the whole community of plants and animals)
- **flood, drought and climate resilience** (poplars cool our urban environment, absorb and store floodwaters, buffering flood and drought impacts)

Riparian forests are the result of past flows. Future forests will result from present flows.

***"Collapse of Collapse of riparian poplar forests downstream from dams in western prairies: Probable causes and prospects for mitigation" – Rood & Mahoney 1990***

*- "Although historically abundant, the riparian poplar forests of the western prairies are now endangered as a result of the damming and diversion of rivers in this region. Recent reports have described substantial declines of riparian poplar forests downstream from dams in Alberta, Canada; Montana, North Dakota, Wyoming, Colorado, and Arizona, USA.*

*- Dams were found to contribute to forest failure by (1) **reducing downstream flows** and/or (2) **altering flow patterns to attenuate spring flooding and/or stabilize summer flows.** Reduced flows are reported to induce drought stress, which is particularly lethal to seedlings and very old poplars. The artificial moderation of spring flooding may inhibit the formation of seedbeds essential for seedling replenishment."*

**-Source:** Rood, S.B., Mahoney, J.M. Collapse of riparian poplar forests downstream from dams in western prairies: Probable causes and prospects for mitigation. Environmental Management 14, 451–464 (1990). https://doi.org/10.1007/BF02394134

### Why poplars matter?

**-The hot, dry future?** Without proper management of our poplar riparian woodlands, we risk loosing these vital ecosystems, the cornerstone of healthy rivers. Riparian woodlands provide unique forested areas in dry prairie areas, creating biodiversity hotspots.

The 2013 flood prompted a flush of poplar regeneration and formed new island habitats along the Bow River

Poplar recruitment nodes occur in areas of new gravel bars in deposition areas and flood scoured surfaces.

### Calgary's Dying Poplars – A legacy of damming, flow stabilization, and bank stabilization

- Balsam poplar recruitment is largely linked to periodic flooding (Mahoney and Rood 1998). Balsam poplars require specific conditions for seedling germination and growth including scoured bare soils, abundant soil moisture and a lack of flooding during the post establishment period. Earlier studies show that compared to reaches of the Bow River below the confluence with the non-dammed Highwood River, fluvial geomorphic processes along the Bow River through Calgary have been influenced by flow stabilization and upstream damming (Rood *et al.* 1999). These factors contributed to reduced channel movement, braiding and island occurrence by 1991. This in turns has reduced suitable nursery sites for recruitment of riparian poplars. Concurrent with findings of Rood and Bradley (1993), our riparian health results from 2008/2010 show poor poplar recruitment in many Bow River RHI sites in Calgary.
- Peaks of balsam poplar recruitment in Calgary have been linked with historic flood events that have exceeded 600 m3/s (*Rood et al.* 1999). Several high magnitude flood events occurred in the Bow River through Calgary in the late 1800s and early 1900s, including 1879, 1897, 1902, 1929, and 1932. The legacy of these floods on stimulating balsam poplar recruitment can be seen in the old, somewhat decrepit stands of native poplar through the city.

### The 2013 Flood: A Boon to our Watery Woodlands

- The June 2013 flood event with flows exceeding 1,700 m3/s provided sufficiently high flows to promote sediment deposition, flood scour and high soil moisture levels co-incident with peaks in poplar seed release.
- **Poplar regeneration appears to have increased in 10 of 30 Bow River sites and remains at healthy levels in 10 sites.** 2013 flood-induced natural recruitment is most evident in the Inglewood Bird Sanctuary (BOW74) and in gravel bars along the southern reaches of the river.

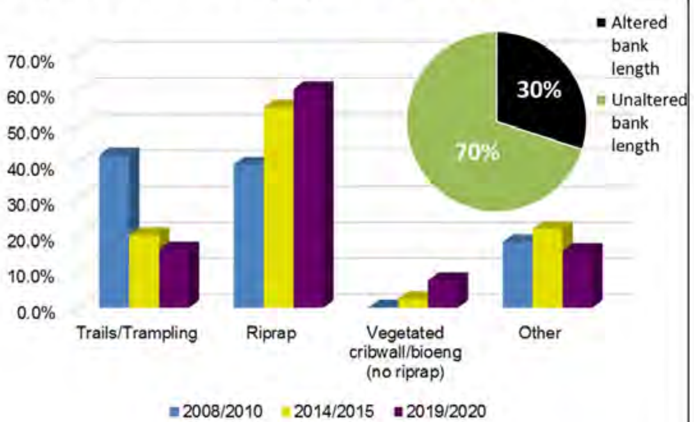
**Figure 2-8: The 2013 Flood: How did it influence Riparian Health Trends? Losses Following Flood Repairs**

**Historical development of Calgary's floodplains has put infrastructure at risk of flood and erosion impacts, necessitating ongoing and costly repairs and bank stabilization. This also comes at a cost to fish and wildlife habitat and Species At Risk.**

### Bow River

*"Major Infrastructure is the third most common land use category, occupying eight per cent of the Bow's riparian areas. This includes The City's three Wastewater Treatment Plants, as well as railways, railyards, and major highways (Deerfoot Trail, Stoney Trail)." (City of Calgary 2017)*

- About a third of the 30 km (approximate) of Bow River bank length assessed since 208 is structurally altered. Riprap accounted for about 40% of the altered bank length in 2008/2010. In 2019/2020, riprap accounted for 61% of bank alterations due to multiple bank stabilization projects since the 2013 flood.

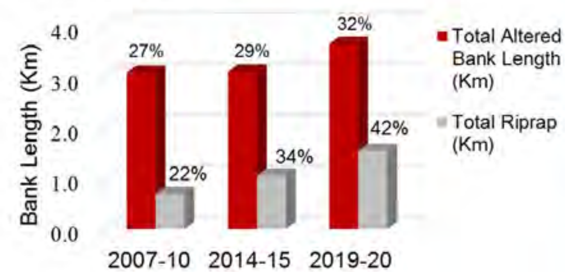



### Elbow River

Within City Limits, 38 per cent of the Elbow riparian area has been developed. This includes residential communities (Elbow Park, Roxboro, Erlton), commercial and mixed uses (Mission), and the Calgary Stampede grounds. *"These land-use legacies have created significant flood risk to people and businesses along the Lower Elbow, which requires careful ongoing management." (City of Calgary 2017).*

**Much of the Lower Elbow has been stabilized to protect adjacent infrastructure.**

- Bank alterations along the Elbow River have increased from about 27% in 2007-2010 to 32% in 2019/2020. Much of this is due to an increase in riprap bank armouring and other bank stabilization projects conducted since 2013. Since the 2013 flood, major riprap bank stabilization projects have been conducted. Except for about 230 m of un-vegetated riprap in ELB33, most other riprap installations include a vegetated component.




**Bank Swallows – A Species At Risk, Losing Ground**

Bank swallows are a federally listed *Threatened* species due to severe population declines (a loss of 98% of its Canadian population over the last 40 years) (COSEWIC 2013). Eroding, vertical banks comprised of unconsolidated substrates (e.g., silty fine sands) provide critical nesting habitat for this species (COSEWIC 2013). Widespread bank armouring and bank stabilization is attributed as one of the causal factors for population declines across its range in Canada (COSEWIC 2013).

Stanley Park (ELB27) – Example of loss of potentially suitable bank swallow nesting habitat:

**2014 (post flood)**

**2019 (vegetated riprap)**

### 2.1.3 Expanded City-Wide Project Area Key Highlights

Current riparian health scores reported on in this section are for an expanded total project area of **101** sites encompassing 591 ha of riparian habitat and 84 km of bank length for eight major permanent streams and rivers (Table 2-5). Compared to the 58 site long-term subset, this represents an addition of 44 sites, 237 ha of riparian habitat (a 43% expansion) and 31.8 km of bank length. The expanded project area includes sampling key gaps geographically in the city (e.g., the northwest and southeast extent of the Bow River; the north reach of Nose Creek; and the westerly extent of the Upper Elbow). Other sampling gaps included Twelve Mile Coulee, Pine Creek, and enhanced monitoring in Forest Lawn Creek. The RMP target was to achieve a 30% minimum target (by length) of representative major stream/river reaches within city limits. The expanded project area also includes baseline and/or pre- and post- monitoring for 14 existing or proposed restoration or demonstration sites.

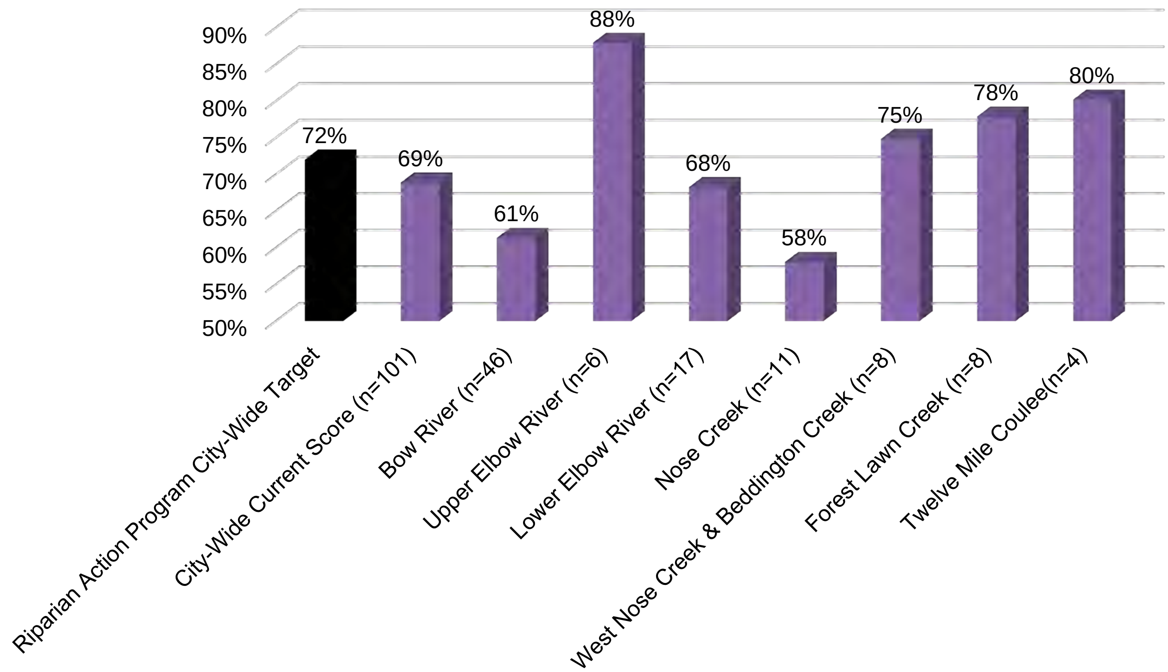
**Table 2-5: Expanded City-Wide Project Area Description**

| Expanded City-Wide Project Area (n=101) | | | | | Comparison to 2007-2022 Long-term Monitoring Project Area (excluding BOW45 | | | |
|---|---|---|---|---|---|---|---|---|
| **Waterbody** | **Total No. Sites** | **Total Length (km)** | **Total Area (ha)** | **Percent of Project Area** | **Number of Sites Added** | **Length Added (km)** | **Area Added (ha)** | **% Expansion of Assessed** |
| **Bow River (n=46)** | 46 | 41.3 | 351.0 | **59%** | 17 | 13.9 | 129.0 | **37%** |
| **Elbow River:** | | | | | | | | |
| Upper Elbow River (n=6) | 6 | 6.1 | 128.9 | 22% | 4 | 4.2 | 75.7 | 59% |
| Lower Elbow River (n=17) | 17 | 10.5 | 31.3 | 5% | 4 | 1.1 | 2.8 | 9% |
| ***Elbow River Subtotal*** | **23** | **16.6** | **160.2** | **27%** | **8** | **5.3** | **78.5** | **49%** |
| **Tributaries:** | | | | | | | | |
| Nose Creek (n=11) | 11 | 9.1 | 21.5 | 4% | 5 | 3.1 | 6.9 | 32% |
| West Nose Creek & Beddington Creek (BED1) (n=8) | 8 | 7.0 | 20.2 | 3% | 1 | 0.6 | 1.1 | 5% |
| Forest Lawn Creek (n=8)[3] | 8 | 5.8 | 31.8 | 5% | 8 | 5.8 | 31.8 | 100% |
| Twelve Mile Coulee(n=4) | 4 | 2.6 | 3.6 | 1% | 4 | 2.6 | 3.6 | 100% |
| Pine Creek (n=1) | 1 | 1.7 | 2.2 | 0.4% | 1 | 1.7 | 2.2 | 100% |
| ***Tributaries Subtotal*** | **32** | **26.1** | **79.3** | **13%** | **19** | **13.8** | **45.6** | **57%** |
| **Expanded City-Wide Project Area** | **101** | **84.0** | **590.5** | | **44** | **32.9** | **253.0** | **43%** |

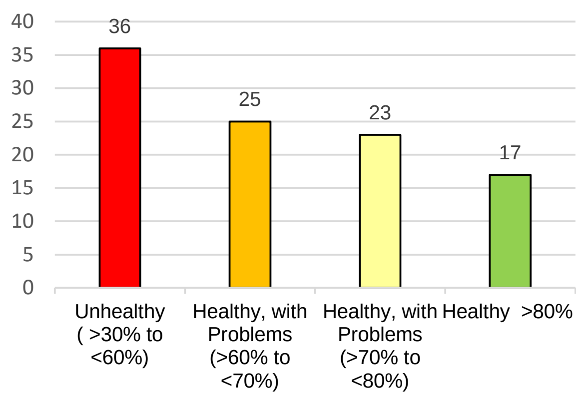
**The current city-wide area-weighted riparian health score for the expanded project area is approximately 69%** (*healthy, with problems*). This is not a trend comparison but a representation of the current health since new sites were added that do not have baseline data for comparison. Compared to the long-term dataset (58 sites), four large sites were added in Weaselhead Flats and Clearwater Legacy Park in the Upper Elbow. These sites alone bump up the city-wide average due to overall *healthy* conditions in these important natural environment parks (Figure 2-9). Twelve Mile Coulee also

[3] Note: baseline data has been collected in 2008-2013 for Forest Lawn Creek; however, these data were not included in the long-term subset due to inconsistent monitoring associated with land ownership changes and creek realignment.

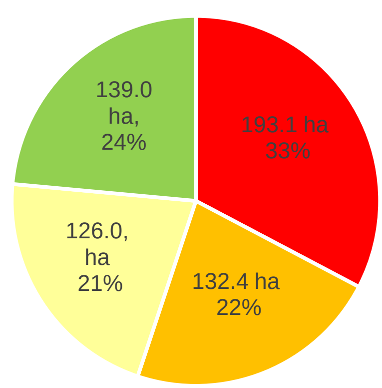
contributes positively to the city-wide score, since two of the four sites on this stream rate healthy (>80%). Sites added along the north reach of Nose Creek (north of Airport Trail NE) have natural stream meanders and are not channelized, as reflected by higher average ratings for these.




**Number of Sites in Each Riparian Health Category:**




**Proportion of Habitat in Each Health Category:**




| 0% - 30% | 30% - 60% | 60%-70% | 70%-80% | 80%-90% | 90%-100% |
|---|---|---|---|---|---|
| **Unhealthy** | | **Healthy, with Problems** | | **Healthy** | |

**Figure 2-9: City-Wide Current Score Summary by Waterbody**

(n=101; 84 km of bank length; 590.5 ha of habitat)

City-wide area-weighted RHI scores are highest for the Conservation (72.2%) and Restoration (65.9%) Management Zones, respectively (Figure 2-10). "Conservation" zones represent parks (and/or Environmental Reserves) where the management priority is conservation of natural riparian habitat and where recreation use is mainly limited to designated pathways. "Restoration" zones correspond closely with areas where recent bioengineering and/or riparian plantings have been done to enhance riparian health.

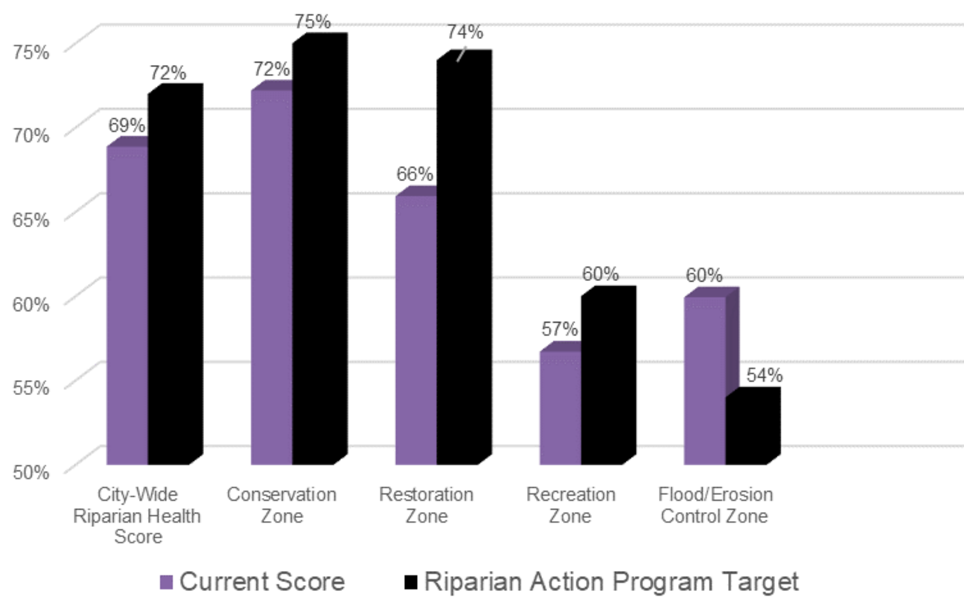



**Figure 2-10: Current Riparian Health Scores by Management Zone (n=101)**

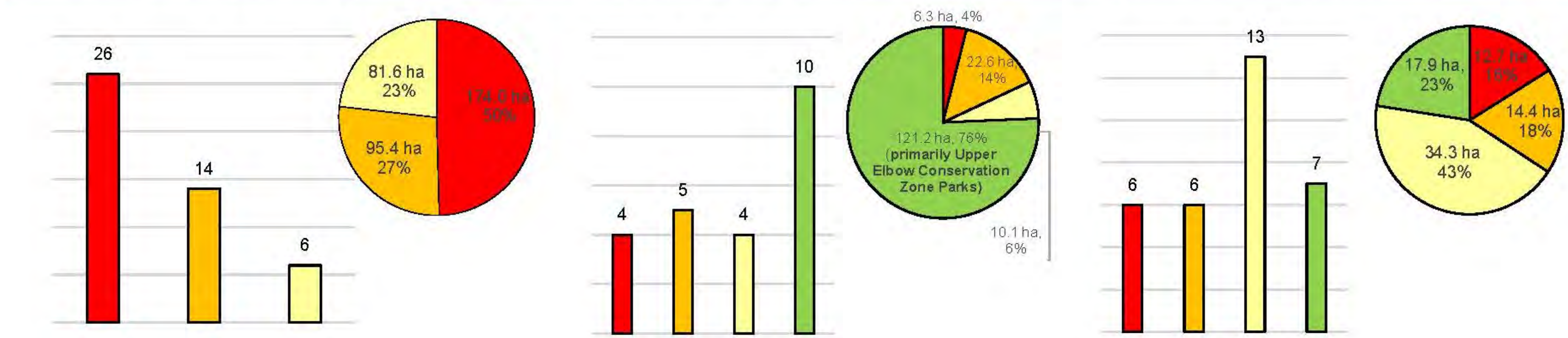
Riparian health area-weighted scores for the expanded city-wide project area (n=101) range from 84.1% for the Elbow River, 71.5% for all major tributaries, and 61.3% for the Bow River (Figure 2-11). Common limiting factors across all systems are extensive bank and floodplain structural alterations due to recreation use and city infrastructure (pathways, bridges, stormwater outfalls, and other park facilities). Permanent impacts have also resulted from channelization and consequent channel incisement along the lower half of Nose Creek. Control of flood peak and timing due to upstream damming affects all Bow River riparian health scores in Calgary (an 11% score deduction).

Widespread incursion of non-native grasses and invasive weeds is another common limitation. Invasive weeds are increasing in cover and distribution city-wide. New invasive weed introductions are also notable since 2014. Seven *Prohibited Noxious* weed species have been observed in 36 unique RHI sites across Calgary. One of the most abundant *Prohibited Noxious* weed threats in Calgary is nodding thistle (*Carduus nutans*) which is especially prolific in the upper reaches of Nose Creek. *Prohibited Noxious* weed eradication is a management priority, in keeping with more stringent regulatory requirements for this species.

**Figure 2-11: Current Riparian Health Results by Major Waterbody (Expanded City-Wide Project Area)**

| Bow River (n=46) | Elbow River (n=23) | Major Tributaries |
|---|---|---|

Charts below show the number of sites (bar graphs) and the proportion of habitat (pie charts) in each riparian health category based on 2019-2022 current overall scores.




**Bow River Avg Area-Weighted Score: 61.3%** | **Elbow River Avg Area-Weighted Score: 84.1%** | **Major Tributaries Avg Area-Weighted Score: 71.5%**


| Riparian Health Indicator Averages: | BOW | ELBOW | MAJOR TRIBUTARIES | CITY |
|---|---|---|---|---|
| Decadent and Dead Woody Material | 96.4% | 98.6% | 93.8% | 96.2% |
| Preferred Tree and Shrub Establishment and Regeneration* | 89.3% | 91.3% | 86.5% | 89.0% |
| Total Canopy Cover of Woody Species (BOW) OR Total Vegetation Cover | 86.2% | 82.6% | 97.9% | 88.9% |
| Wildlife Browse of Preferred Trees and Shrubs | 78.3% | 91.3% | 81.3% | 83.6% |
| Beaver or Human Clearing of Trees and Shrubs | 77.0% | 79.7% | 94.8% | 83.8% |
| Human-Caused Bare Ground | 71.0% | 82.6% | 96.9% | 83.5% |
| Bank Root Mass Protection | 51.9% | 72.5% | 63.5% | 62.6% |
| Bank Structurally Altered | 47.4% | 60.9% | 50.0% | 52.8% |
| Floodplain Structurally Altered | 42.8% | 60.9% | 58.3% | 54.0% |
| Invasive Plant Species (Cover) | 21.0% | 31.9% | 22.9% | 25.3% |
| Disturbance-Caused Undesirable Herbaceous | 6.1% | 37.7% | 14.6% | 19.4% |
| Invasive Plant Species (Density Distribution) | 0.0% | 1.4% | 1.0% | 0.8% |
| Control of Flood Peak/Timing by Upstream Dams | 0.0% | n/a | n/a | |

### 2.1.4 Riparian Health Trends (122 Sites, including Unnamed Minor Tributaries)

A total of 122 sites have been assessed to date including 18 sites on ephemeral and intermittent streams located in priority source-water protection areas. Riparian health trends are currently ‘stable’ for 65 sites (53%), declining for 11 (9%), and improving for 23 (19%). The remainder of the sites (23 sites,19%), have ‘unknown’ trends since these have only one year of RHI data. A 5% score change threshold is used to determine trends (i.e., <5% change = stable; >5% increase = improving; >5% decrease = declining).

Key factors that are affecting declining trends include new construction and/or development impacts (4 sites), increased recreational use impacts (3 sites), increased invasive weeds or disturbance plants (3 sites), and cumulative impacts from stormwater and/or channelization impacts (2 sites). In contrast, key factors that are affecting improving trends include riparian plantings (13 sites; 57%), bioengineering (7 sites; 30%), access management (6 sites; 26%), flood related natural recovery (4 sites; 17%) and other natural recovery (6 sites; 26%).

These additional sites (total 22) are not included in the calculation of the average riparian health score due to the several reasons listed below.

- The Current RAP target of 72% only applies to permanent waterbodies.
- Sites focusing on smaller project specific areas that overlap with sites already counted in the average.
- Based on the 5 year frequency, some sites were outside the 2019-2022 window and will be assessed in the future.
- Sites having access constraints and therefore could not be assessed in the relevant timeframe.

Riparian health trends for select ephemeral and intermittent stream examples sites are shown in Figure 2-12.

**Examples of downward trending sites**

**2016:** View north from the upstream end of an unnamed tributary in Aspen Woods showing natural wooded riparian habitat. (*Image no. RHIP01ELX001*)

**2021:** About 6% of the ELX1 site (at the upstream end) has been cleared and impacted by the Bow Trail westward extension project. (*Image no. RHIP01ELX022*)

**2016**: The south Elbow riverbank in Clearwater Legacy Park had few bank alterations in 2016. (*Image no. RHIP62ELB004*)

**2021:** Extensive riprap armouring and vegetation clearing was done here due to Hwy 8 works.

(*Image no. RHIP62ELB068*)

**Examples of improving sites (see Appendix A for more)**

**2018:** Quarry Park (BOW100), fish habitat compensation project, newly excavated side channel with riparian plantings above the riprap toe. (*Image no.RHIP100BOW025*)

**2022*:*** Excellent establishment of sandbar willow plantings is evident here.

(*Image no. RHIP100BOW081*)

**2015:** A large depositional area formed during the 2013 flood at the base of the BOW91 bank (Inglewood Northfield). *(Image no*. *RHIP91BOW024*).

**2020:** This is one of many examples of a flush of poplar regeneration stimulated by the 2013 flood. (*Image no. RHIP91BOW059*).

**Figure 2-12: Riparian Health Trends at Examples Sites**

## 2.1.5 Invasive Species Trends and Emerging Threats

Based on the re-visit dataset reported on in 2020, invasive species canopy cover has increased across all major waterbodies. This is illustrated by trend data shown below in Table 5 and Figures 8 and 9. The analysis below is for a subset of 63 sites with revisit data from 2014/2015.

**Table 2-6 Long-Term Invasive Species Canopy Cover Trends (Based on 63 sites with re-visit data since 2014/2015)**

| | Bow River (n=33) | Elbow River (n=17) | Nose Creek Basin (n=13) |
|---|---|---|---|
| Percent of sites with >15% invasive species cover (i.e., 0/3 rating) (2019/2020 data) | 45% (i.e., 15/33) | 29% (i.e., 5/17) | 46% (i.e., 6/13) |
| Percent of sites with increased invasive species cover since 2014/2015 | 36% (i.e., 12/33) | 35% (i.e.,6/17) | 46% (i.e.,6/13) |

Invasive weeds are increasing in cover across the major waterbodies assessed since 2007-2010 and since 2014/2015. The number of invasive weed species is also increasing since baseline (2007-2010) due to new introductions.

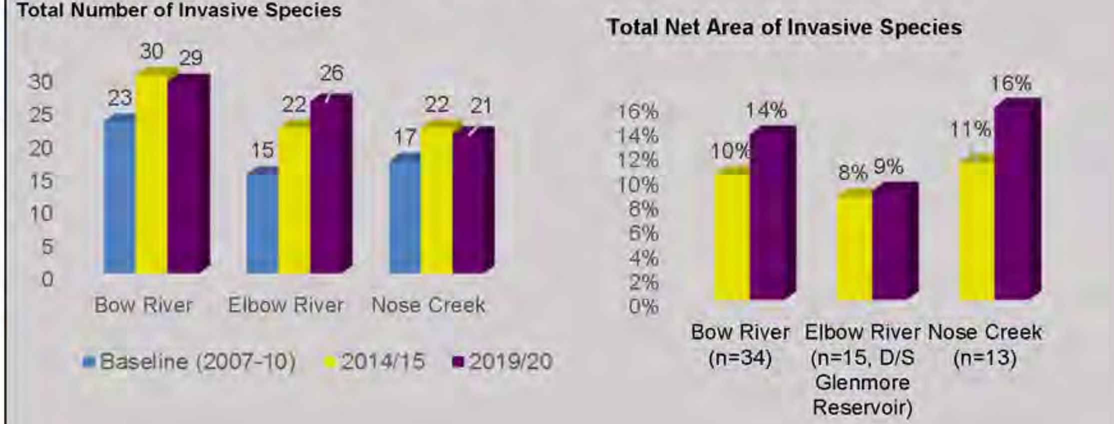
**Table 2-7 Top 10 Invasive Weeds in Calgary's Riparian Areas**

| | Bow River | Elbow River | Nose Creek Basin |
|---|---|---|---|
| **Tufted vetch** | **1** | **3** | **3** |
| **Common tansy** | **2** | 7 | 10 |
| **Canada thistle** | **3** | **2** | **1** |
| Caragana | 4 | 1 | 5 |
| Perennial sow-thistle | 5 | 4 | 2 |
| Leafy spurge | 6 | (13) | (n/a) |
| Yellow toadflax | 7 | 10 | 7 |
| Burdock (common & woolly) | 8 | 6 | 9 |
| Yellow clematis | 9 | (12) | 4 |
| Creeping bellflower | 10 | 5 | (11) |
| Ox-eye daisy | (13) | 8 | (19) |
| Scentless chamomile | (11) | 9 | 8 |
| ***Nodding thistle*** | (22) | (15) | 6 |

Numbers indicate dominance by sub-basin based on percent cover.

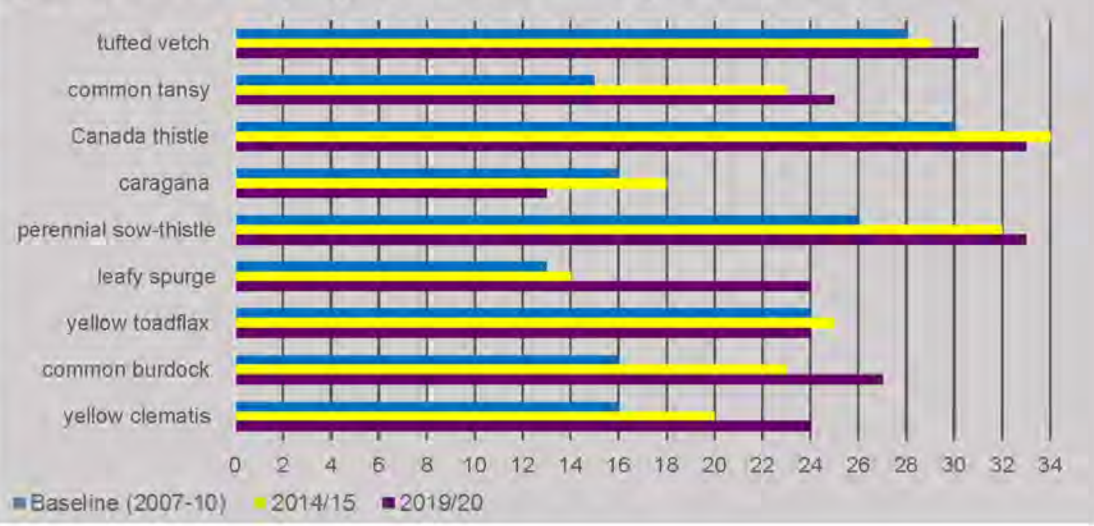
The majority of invasive species inventoried are *Noxious* weeds regulated by Alberta's *Weed Control Act*.

**Figure 2-13 Invasive Species Long-Term Trends (Bow River, Elbow River, Nose Creek Basin)**




Example of invasive species long-term trends for the Bow River (2008-2020) (note increasing frequency of occurrence for tufted vetch, leafy spurge, common burdock, and yellow clematis since baseline):

**Figure 2-14 Bow River Frequency of Occurrence of Invasive Species - Trends Since Baseline**



Examples of dominant invasive species in Calgary's riparian areas:

Tufted Vetch (*Vicia cracca*)* (not a regulated 'noxious weed' in Alberta, but highly invasive in riparian areas and increasing city-wide)

Common Tansy (*Tanacetum vulgare*)

(*Noxious* weed)

Canada (Creeping) Thistle (*Cirsium arvense*)

(*Noxious* weed)

Common Caragana (*Caragana arborescens*) (not a regulated 'noxious weed' in Alberta, but highly invasive in riparian areas and increasing city-wide)

Leafy Spurge (*Euphorbia esula*)

(*Noxious* weed)

### Why Invasive Species Are a Concern:

If left unchecked, dense infestations of invasive weeds can have cumulative negative impacts to riparian ecosystems due to factors listed below (not exhaustive):

- Aggressive displacement of preferred native plant species (i.e., reduced biodiversity);
- Loss of habitat structure;
- Often reduced root mass protection and bank stability functions;
- Degraded forage quality for wildlife;
- Altered plant succession trajectories; and;
- Competition for pollinators with native species.

One of the most abundant *Prohibited Noxious* weed threats in Calgary is nodding thistle – it is especially prolific in the upper reaches of Nose Creek (north of Airport Trail NE).

### *Prohibited Noxious* Weeds – Emerging Threats

As per Alberta's *Weed Control Act*, there are more stringent 'eradication' requirements for *Prohibited Noxious* weeds. These species are emergent threats that are not yet widely established in Alberta. If allowed to proliferate these species are particularly harmful to native ecosystems due to aggressive growth habits. Seven *Prohibited Noxious* weed species have been observed in 36 unique RHI sites across Calgary (including unnamed tributaries) (**see Appendix A** for more details):

| Prohibited Noxious Weed Species | Waterbodies | Year(s) Detected | No. of RHI Sites | Average Canopy Cover |
|---|---|---|---|---|
| Common barberry (*Berberis vulgaris*) | BOW | 2014 | 1 | 0.5% |
| Diffuse knapweed (*Centaurea diffusa*) | BOW | 2021 | 1 | 0.5% |
| European (common) buckthorn (*Rhamnus cathartica*) | ELB (9), BOW(1) | 2014-2022 | 10 | 1.1% |
| Himalayan balsam (*Impatiens glandulifera*) | PXB | 2021 | 1 | 0.5% |
| Nodding thistle (*Carduus nutans*) | BOW (4), ELB (3), NOS (5), WNO (2), BED (1), FOR (1) | 2008 (NOS only) - 2022 | 17 | 1.5% |
| Purple loosestrife (*Lythrum salicaria*) | ELB (2), BOW (2) | 2015 (3) – 2022 (1) | 4 | 0.5% |
| Spotted knapweed (*Centaurea maculosa acc. Centaurea stoebe*) | BOW (5), ELB (2), WNO (1) | 2014-2022 | 8 | 0.5% |

# 3. Bank Effectiveness Monitoring

The methods, data collection, key results, successes, and areas for improvement for the bank effectiveness monitoring component of the RMP are summarized in this section. Bank effectiveness sites are projects where the primary purpose is bank stabilization, protection, or erosion mitigation with bioengineering structural- and vegetation-based components. An example bank effectiveness site on the Elbow River referred to as Lindsay Park – A – Bioengineering Site is shown in Photo 3-1. Bioengineering techniques used in the projects are described in detail in Section 3.1.5 and include but are not limited to vegetated riprap, vegetated retaining wall, vegetated timber crib wall, vegetated soil wraps, brush layers, and live staking.

Bank effectiveness sites encompass the bank and, where applicable, often a strip as wide as 15 m along the top of bank (sometimes referred to as the bench, floodplain, or terrace). Where there are bioengineering works within this strip that are directly tied to the adjacent bank project, they are considered part of the bank effectiveness site and are assessed according to the bank effectiveness protocols.

**Photo 3-1: Bank Effectiveness Monitoring Site Example: Lindsay Park – A – Bioengineering Site**

*Project constructed in 2014 and monitored under the bank effectiveness component in 2021*

## 3.1 Data Collection and Organization

The methods used to monitor the bioengineering sites include desktop assessments, field assessments, failure assessments, and ratings as summarized below. The data for each monitoring site were collected and recorded on Microsoft® Excel® data forms that were specifically developed for the RMP effectiveness monitoring component. The data record for each site includes desktop assessment forms (general context and planting), structure assessment forms, vegetation assessment forms, failure assessment forms (when required), and rating calculation forms.

### 3.1.1 Desktop Assessment

The desktop assessment includes the collection and review of information used to complete the general information and planting details forms as described in Table 3-1. It also covers site selection from The City's *Master List – Riparian Restoration Projects*, classification of each site into a typology and age class, and collection/review of information to gain a general understanding of the project. The information that was requested from The City Project Manager for City projects, or the project contact for external projects includes the following:

- Site location/map (shapefile, waypoint, or Google Earth formats);
- Design information: reports, drawings, specifications, regulatory approvals packages, and documentation related to lists of plant species/numbers and plant material types;
- Construction information: construction inspection reports, close-out reports, as-built drawings;
- Maintenance information: maintenance records;
- Permission to visit the sites;
- Permission to contact the contractors and/or the designers and their contact information; and,
- Any additional background information that might be of interest to the RMP team.

Desktop assessments were typically conducted in April, May, June each year prior to the field assessments.

### 3.1.2 Field Assessments

**Structure Assessment**

The purpose of the structural assessment was to assess the functional performance, physical condition, and overall bank stability of the installed works, and to identify the presence/absence and the condition of the work and the installed materials. Methods that were used include visual observations, probing, surveys, measurements, documentation review, and photos with more detail provided in Table 3-1. The structural assessment was generally conducted in July of each year after flood season.

**Vegetation Assessment**

The purpose of the vegetation assessment was to assess and document the living plant structure and general attributes and suitability of selected species for each bioengineering technique applied to the bank restoration sites based on age classes since project construction. Methods included vegetation inventory transects and quadrats, planting survival assessments, and growth parameter measurements (e.g., leader growth, shoot length, stem diameter, and vigour) with more detail provided in Table 3-1 and Box 3. The vegetation assessment was generally conducted in May and September of each year.

**Table 3-1: Bank Effectiveness Data Collection Methods**

| Desktop/ Field | Description | Method(s) | Data Form(s) |
|---|---|---|---|
| Desktop | Project Information | • Collect and review available project documentation (e.g., design/construction/ maintenance) and climate data<br>• Coordinate data collection and field activities | • General Context Information form<br>• Project Planting Details form |
| Field | Structure Assessment | • Site vegetation elevation surveys and general site dimension measurements<br>• Visual assessment of condition of structural materials and estimate of remaining useful life based on observed condition<br>• Visual assessment and probing for erosion and scour<br>• Assessment of factors that may be limiting successful project establishment including implementation practices<br>• Documentation of potential repair options, alternative design options, and success attributes | • Bank Protection/ Stabilization Structure Assessment form |
| Field | Vegetation Assessment | • Perpendicular transect through the width of the site and parallel transect(s) through the length of the site<br>• Visual estimates<br>• Plant health and survivorship measurements / observations for both live cuttings and container plants<br>o Bioengineering techniques at Year 1 sites: total of 50 trees and shrubs cuttings per species are tallied for survival and 10 measurements of leader growth, shoot length, stem diameter, and vigour per species<br>o Container plants on the top of bank at Year 1 age class sites: 20 of each species for survival and 10 for measurements (same as above) per species<br>o All live cuttings and container plants at Year 3 and older sites: total of 10 measurements (same as above) per species (shrubs & trees)<br>• 20 m long pin-point transects located on representative sections within each typology where 50 sampling points are collected<br>• 1 m by 1 m quadrat surveys at three locations on the pin-point transect (at 5 m, 10 m and 15 m points)<br>• Soil compaction measurements within each quadrat using a DICKEY-john soil compaction tester<br>• Deep binding root mass estimates by calculating the ratio of the measured length of vegetated bank to the total site length | • Technical and Living Plant Structure Assessment form<br>• Plant Health and Survivorship Data Sheet<br>• Transect Data Sheet<br>• Quadrat Data Sheet |
| Field | Failure Assessment | • Photo monitoring<br>• Detailed inventory of survival percentage for live cuttings and container plants combined<br>• Visual assessment of reasons for restoration failure<br>• Risk assessment for consequences and probability of failure | • Failure Analysis form |

## Box 3: Why Did We Measure These Woody Vegetation Parameters?

1. **Survivorship** is an important metric to measure vegetation establishment success for a bioengineering project. It is usually measured against survival targets for contractual warranty purposes and regulatory approvals to meet the requirements of the approval. Typical survivorship targets are 70% to 80% for the first year after implementation. Percent survivorship for a project is determined by dividing the number of alive cuttings and/or plantings by the total number of installed cuttings and/or plantings. Survivorship should normally be higher in the first two years and decrease over time as woody plants (trees and shrubs) establish and outcompete each other for nutrients, growing space, moisture, and light. In contrast, while survivorship decreases over time, woody vegetation canopy cover is expected to increase as vegetation establishes and matures as illustrated in **Figure 3-1**.
2. **Leader growth** is a quantitative measure for the growth of new tree/shrub shoots from the current growing season. Leader growth gives an indication of the relative health and vigour of the vegetation, quality of the growing substrate, available moisture, and aspect. It is also a proxy measure for the amount of root growth for the current growing season since root growth is closely linked to leader growth (Reich, 2002). Root growth is a key component when using vegetation to stabilize a riverbank.
3. **Shoot length** is a quantitative measure for the total growth of vegetation since it was planted. Shoot length also gives an indication of the relative health of the vegetation, and quality of the growing substrate, available moisture, and aspect. It is also a proxy measure for root growth since the vegetation was planted since root growth is closely linked to shoot length (Reich, 2002). Root growth is a key component when using vegetation to stabilize riverbanks. A higher root to shoot ratio is recommended to reduce mortality caused by desiccation in drier climates such as in the Calgary region.
4. **Vegetation Canopy Cover** is a quantitative overall measure of how well vegetation is protecting the soil surface. Higher canopy cover means better protection against the erosive force of rainfall, and prevention of invasive species establishment by shading/occupying growing space (if cover is composed of the targeted species).
5. **Vigour** is a qualitative measure of vegetation health that takes into consideration such factors as shoot length, leader growth, leaf colour, pest infestation, etc. It can be used to assess the health trajectory of planted vegetation and if interventions such as weeding, fertilization, pest management or pruning are required to improve vegetation health and growth.
6. **Leader growth, shoot length, and overall plant vigour** in combination are strongly related to soil conditions such as moisture, nutrients, and oxygen availability, but also to soil compaction. For example, soil can be very fertile, but if it is extremely compacted, the overall growth and vigour of plants will be poor and they will never develop properly, becoming stressed and targeted by insects and diseases as a result.
7. **Species diversity** can be measured in several different ways, the simplest way being species richness, or the total number of individual species present. Higher native species diversity is generally associated with increased ecosystem stability and resilience to pests, drought, climate change, and impacts from humans and wildlife.

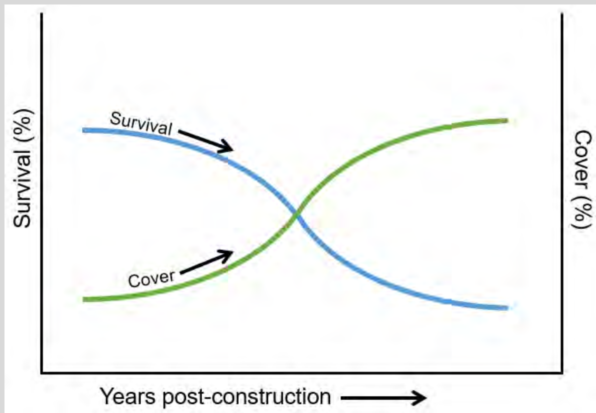



**Figure 3-1: Idealized Illustration of Relationship Over Time Between Live Cutting Survival & Woody Vegetation Canopy Cover on Successful Sites**

### 3.1.3 Ratings

A rating system was developed for the effectiveness components of the RMP to help identify individual sites that are successful in meeting project objectives and where there are opportunities to establish learnings and recommendations for better project design, implementation, maintenance, and vegetation success. The ratings were also established to identify if differences between overall typology or age class categories could be observed.

Five (5) types of ratings were developed for the bank effectiveness monitoring sites as part of the *Monitoring Plan* (KWL, 2018) and are described in Table 3-2. An overall score was developed for each site by combining the five individual ratings and applying a multiplier to achieve a total weighted score out of 100 (Table 3-3). For the purposes of this report, rating percentages were broken into the three categories shown in Table 3-4 based on range health assessment methodology developed by Alberta Environment and Parks (Adams, et al., 2016).

**Table 3-2: Bank Effectiveness Ratings**

| Type | Description |
|---|---|
| Design (/6) | Design ratings are made up of two components:<br>• Stabilization Structure Design Rating: technical documentation (reports, drawings, and specifications), and design suitability (structure type, hydraulic/geotechnical, plant growth).<br>• Living Vegetation Design Rating: technical documentation (reports, drawings, and specifications), and design suitability (appropriate species, appropriate design). |
| Implementation (/6) | Implementation ratings are made up of two components:<br>• Stabilization Structure Construction Rating: placement of techniques, correspondence between design and implementation, and as-built report.<br>• Implementation of Plant Materials Rating: as-built report, quality of source plant materials, handling, fencing, correspondence b/w design and implementation, and planting quality. |

| Type | Description |
|---|---|
| Maintenance (/6) | Maintenance ratings are made up of two components:<br>• Stabilization Structure Maintenance Rating: structure integrity, maintenance report, erosion and sediment control measures and fencing.<br>• Vegetation Maintenance Rating: maintenance report, irrigation, weed control, and plant replacement. |
| Success (/6) | Success ratings are made up of two components:<br>• Bank Protection/Stabilization Structure Success Rating.<br>• Vegetation Success:<br>  • Survivorship or density of installed cuttings or plantings.<br>  • Average vigour of installed cuttings or plantings.<br>  • Per cent cover of seeded herbaceous species. |
| Bank and Riparian Quality Index (BRQI) (/100) | Health rating of a site based on various vegetation and physical indicators. Eight weighted parameters assessed:<br>1. Vegetation cover (/12)<br>2. Invasive species cover (/12)<br>3. Disturbance-increaser plant species cover (/12)<br>4. Native tree and shrub species cover (/12)<br>5. Plant community structure (i.e., number of life form layers present) (/12)<br>6. Regeneration of preferred tree and shrub species (/12)<br>7. Cover of human-caused bare ground (/12)<br>8. Cover of riprap and concrete (/16) |

**Table 3-3: Overall Score**

| Rating | Max. Score | Multiplier | Weighted Score |
|---|---|---|---|
| Design | /6 | 3 | /18 |
| Implementation | /6 | 3 | /18 |
| Maintenance | /6 | 3 | /18 |
| Success | /6 | 4 | /24 |
| BRQI | /100 | 0.22 | /22 |
| | | **Total** | **/100** |

**Table 3-4: Rating Scores and Categories**

| Score | Categories |
|---|---|
| 75-100 | Good |
| 50-74 | Fair |
| 0-49 | Poor |

### 3.1.4 Typology and Age Class

At the beginning of the program, a detailed process was undertaken to classify each monitoring site according to typology and age class as defined in the *Monitoring Plan* (KWL, 2018) and was continued as new sites were added to the program over the years. The classification according to typology and age class was conducted so that detailed statistical analysis could be conducted on discrete sample populations. As shown in Figure 3-2, the five typologies are: Vegetated Riprap, Vegetated Retaining Wall, Vegetated Crib Wall, Primarily Vegetative, and Planting[4]. The three age class categories are: Year 1, Year 3, and Year 5+. While eight sites for each typology and age class category were targeted for the end of the program, there was an uneven distribution of projects that met these criteria. Based on availability of projects, the resulting populations that were used in the analyses varied (see Table 3-10, page 3-17). The purpose of classifying sites into typology and age class was so that fair comparisons could be made between sites of similar design and vegetation age. A minimum target sample size of 5 was attained for all age classes and techniques except for the Vegetated Retaining Wall typology, Year 1 and Year 3 age class projects. The Plantings typology and Year 5+ age class just met this minimum, whereas other typologies and age classes had sample sizes that exceeded the minimum.

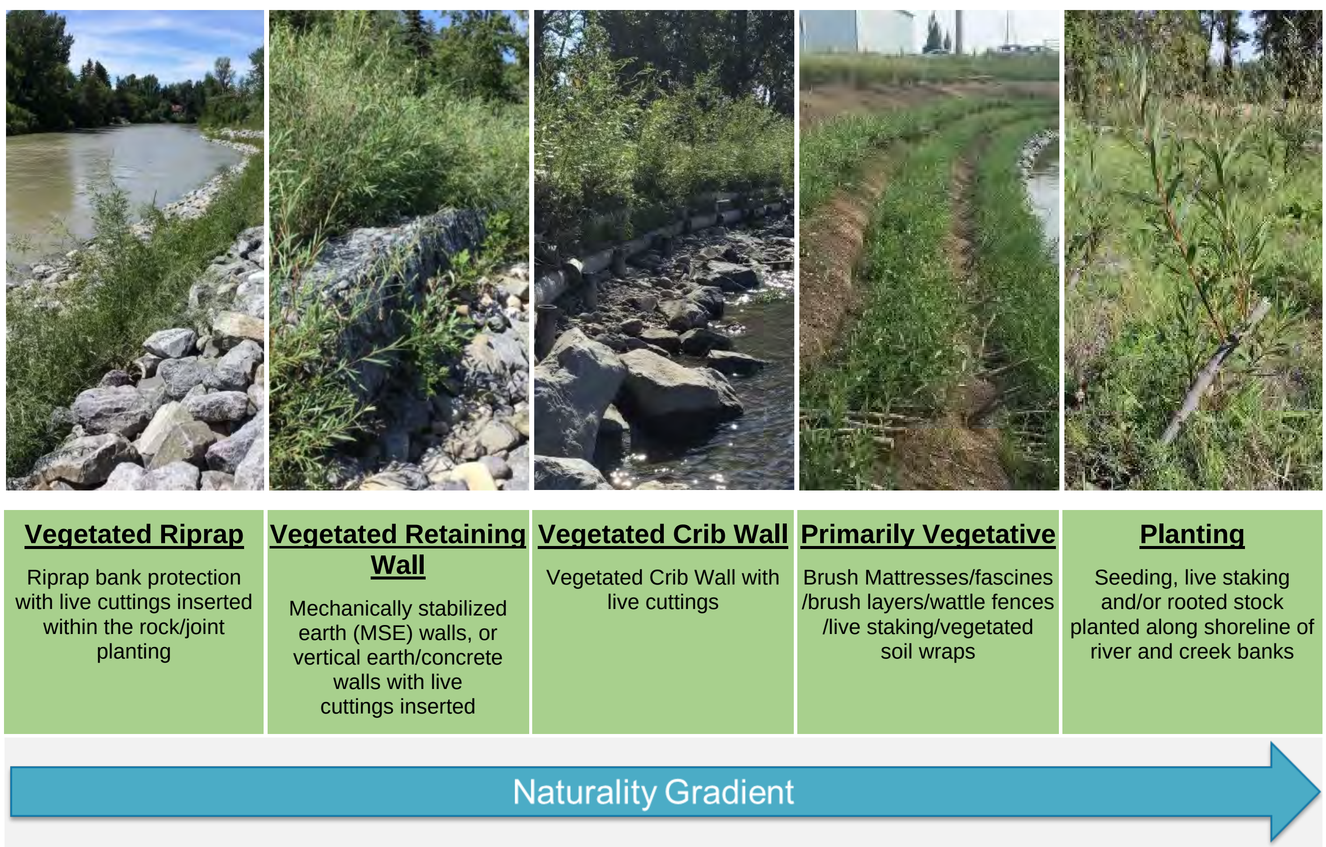


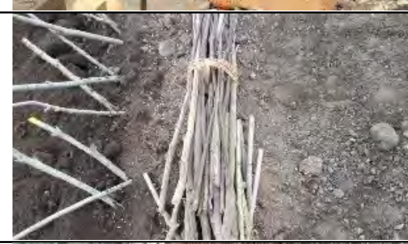

**Figure 3-2: Bank Effectiveness Monitoring Typology**

[4] To distinguish between Typology and bioengineering technique in the report, the former are capitalized and the latter are not capitalized.

### 3.1.5 Bioengineering Techniques

While the bank effectiveness sites were combined in typologies based on the dominant bioengineering technique used at each site per the above, specific bioengineering techniques were also identified during field data collection and analysed in detail via statistical analysis. Since several bioengineering techniques may have been used at each monitoring site (e.g., brush layers, fascines, etc.), the analysis was based on the techniques identified for each transect as part of the vegetation assessment. The nine techniques that were assessed are shown in Table 3-5.

**Table 3-5: Bioengineering Techniques**

| Bioengineering Technique | Description | Photo |
|---|---|---|
| Brush layers | Row(s) of live cuttings placed in a criss-cross or overlapping manner between layers of soil, with tips protruding beyond the face of the fill (Gray & Sotir, 1996) |  |
| Brush mattress | A layer of interlaced/adjacent live cuttings placed on the face of the riverbank (AMEC, 2012) |  |
| Fascine | Fascines are live cuttings that are tied together in long cylindrical bundles. Contour fascines are installed in shallow trenches constructed on contour, and anchored in the trench using stakes (AMEC, 2012) |  |
| Live staking | Insertion of live cuttings into the ground in such a manner as to promote root growth and leaf-out (Gray & Sotir, 1996) |  |
| Plantings | Planting of container stock seedling species that are selected for beneficial attributes such as fast-growing, natural colonizer, deep rooting, nitrogen fixing, and food production (AMEC, 2012) |  |

| Bioengineering Technique | Description | Photo |
|---|---|---|
| Vegetated crib wall | Consists of a hollow, box-like interlocking arrangement of structural timber, filled with suitable backfill material and layers of live cuttings (Gray & Sotir, 1996) |  |
| Vegetated retaining wall | A vegetated structure used to resist unbalance lateral earth forces, retain earthen masses, and protect against scour and undermining. (McCullah & Gray, 2005) |  |
| Vegetated riprap | A layer of stone and/or boulder armoring that is vegetated, optimally during construction, using pole planting, brush layering and live staking techniques. (McCullah & Gray, 2005) |  |
| Wattle fencing | Short retaining walls built by weaving living cuttings between upright stakes to form a lattice (Polster D. , 2020) |  |

### 3.1.6 Effectiveness Monitoring

The data that was collected for the bank effectiveness component is helping to fill a key technical and scientific knowledge gap for bioengineering projects. Until now there have been few monitoring studies conducted for bioengineering projects in Calgary or elsewhere in the province, across North America, or worldwide and none as thorough as the RMP (Stokes, et al., 2014; Zaimes, et al., 2019; Evette, et al., 2021). The RMP is unique because published data for long-term monitoring programs is scarce, and because of the list of factors below.

- Financial resources were committed over five-years, allowing a complete and detailed follow-up of numerous works including review of design documentation and fieldwork monitoring.
- The data was collected and analysed by a team of experienced professionals allowing for critical science-based feedback to inform bioengineering project design, implementation, maintenance, and monitoring.
- A large number of works were assessed (69 sites and 99 assessments) creating a statistically robust dataset.
- A large amount of high-quality quantitative data for vegetation survival, growth, and condition for 7,040 live cuttings from 14 species, and 3,872 container plants from 31 species was collected (Photo 3-2 and Photo 3-3).

**Photo 3-2: Measuring live cutting growth parameters during the pin-point transect**

**Photo 3-3: Recording presence of herbaceous species and percent cover within a quadrat**

Using the methods described in the sections above, the data that was collected for the bank effectiveness component of the RMP is summarized in Table 3-6. The data was collected in Microsoft® Excel® forms developed specifically for the RMP. Photos of data collection activities are shown in Photo 3-4, Photo 3-5, Photo 3-6, and Photo 3-7.

A total of 99 assessments (69 individual site assessments, 30 re-visit assessments, and 7 failure sites) were conducted as part of the bank effectiveness component of the RMP. The distribution of assessed sites per year from 2018-2022 is shown in Table 3-7. A complete list of all bank effectiveness sites assessed over the course of the RMP is provided in Appendix B. Appendix B also contains a figure showing the locations of all sites assessed[5]. A list of priority restoration sites is provided in Appendix C.

[5] Note that there are 18 sites that are considered external due to having been implemented by external organizations. Only the external sites that have been approved by the landowner are shown on maps and in appendices.

Lists of successful and failure sites are provided in Appendix D. Also listed in Appendix D are the lowest-scoring bank effectiveness sites.

**Table 3-6: Data Collected for the Bank Effectiveness Monitoring Component**

| Assessment Form | General Description | Data Collected |
|---|---|---|
| General Context Information | Used to record general environmental and vegetation attributes | • Site name, RMP site code, and UTM coordinates;<br>• Watercourse name and bank location;<br>• Management and land use zones;<br>• Available RHI information;<br>• Contact details for City PM, and implementation team<br>• Available project documentation for design/construction/ maintenance documentation, construction costs, and restoration goals;<br>• RMP Typology and Age Class;<br>• Site climate data, peak flow design data, and maximum flow, depth, velocity, and shear stress since construction;<br>• Geomorphology issues at the site identified in the Calgary Rivers Morphology Study; and<br>• Percent of the site composed of riprap, timber, steel, vegetation alone, erosion control blankets, etc. |
| Project Planting Details | Desktop assessment based on available project documentation | • Identification of the different bioengineering techniques used;<br>• Species, stock types, quantities, and dimensions of live cuttings described in the bioengineering techniques design documentation;<br>• Available live cuttings harvest, storage, and handling information;<br>• Species, stock types, and quantities of container plants described in the design documentation;<br>• Seed mix species and seeding method;<br>• Topsoil, soil amendment and fertilization use;<br>• Fencing type used; and<br>• Weed control methods. |
| Bank Protection / Stabilization Structure Assessment (First Assessment) | Field assessment of structural components of bioengineering techniques | • Site identification (name, RMP code, and watercourse) and photo-monitoring;<br>• River flow at time of survey;<br>• Site survey including aspect, river width and slope, site width, length, and height, site location on bend or parallel to flow, and site elevations for planted vegetation and existing native vegetation;<br>• Assessment of condition of materials used at the site (e.g., rock, timber, matting, etc.) and estimate of remaining useful life;<br>• Assessment for toe scour, upstream or downstream erosion, erosion within structure, ice abrasion, or sediment deposition within the site;<br>• Assessment of factors that may be limiting successful project establishment (e.g., erosion, compaction, anaerobic soils, insect damage, diseased vegetation, trampling, aspect, existing vegetation competition, maintenance issues, site access);<br>• Potential repair options for minor, moderate, or major issues<br>• Alternative design options; and<br>• Success attributes. |

| Assessment Form | General Description | Data Collected |
|---|---|---|
| Technical and Living Plant Structure Assessment (Second Assessment) | Field assessment of vegetation components of bioengineering techniques | • Perpendicular transects to delineate the technique(s) used within a site (e.g., riprap, MSE wall, live staking, brush mattress, brush layers, etc.);<br>• Invasive weed species names and visual estimate of percent cover; and<br>• Total length of vegetated bank and estimated root mass protection percentage over the total site length. |
| Transect Data Sheet | Detailed field assessment of vegetation | • Percent cover of individual plant species;<br>• Total vegetation cover;<br>• Percent cover of various ground cover types, including moss and lichen, litter/LFH, and large woody debris;<br>• Percent cover of various physical site attributes, including human-caused and non-human-caused bare soil, sediment, gravel, cobble, riprap, and concrete/asphalt;<br>• Vegetation structure (plant layers); and<br>• Forb and graminoid height and vigour. |
| Quadrat Data Sheet | Used to record detailed vegetation data | • Herbaceous species richness (i.e., total number of different forb and graminoid species present);<br>• Density of plantings/cuttings;<br>• Percent cover of native herbaceous species; and<br>• Soil compaction. |
| Plant Health and Survivorship Data Sheet | Used to record detailed data for installed woody material | • Survivorship (i.e., dead vs. alive);<br>• Condition (e.g., browsing, mechanical damage);<br>• Vigour (scale of 1 to 5);<br>• Pest damage (scale of 1 to 5);<br>• Shoot length;<br>• Diameter;<br>• Leader length; and<br>• Length of exposed cuttings (if applicable). |
| Failure Analysis | Used to record information on restoration failure | • Site identification (name, RMP code, and watercourse) and photo-monitoring;<br>• Possible causes of restoration failure, such as erosion, soil compaction, soil anoxia, wildlife damage, vegetation competition, poor planting/cutting installation, inappropriate plant material type, etc.; and<br>• Risk assessment for consequences and probability of failure |

**Photo 3-4: Existing vegetation elevation survey**

**Photo 3-5: Structure assessment**

**Photo 3-6: Pin-point transect**

**Photo 3-7: Quadrat**

**Table 3-7: Summary of Bank Effectiveness Monitoring Sites Per Year**

| Monitoring Year | Total Assessments Per Year | Failure Sites | Revisit Assessments |
|---|---|---|---|
| 2018 | 19 | 5 | 0 |
| 2019 | 18[2] | 1 | 0 |
| 2020 | 21 | 1 | 9 |
| 2021 | 21 | 0 | 12 |
| 2022 | 20 | 0 | 9 |
| **Total** | **99[1]** | **7** | **30[2]** |

Notes:
1. There are 69 sites carried forward into the analysis.
2. The total number of 30 revisit assessments includes 24 sites that have been visited twice and 3 sites that have been assessed 3 times.

### 3.1.7 Failure Sites Assessment

Some monitoring sites were assessed to be 'Failure Sites' as part of the effectiveness monitoring. The definition of a Failure Site is based on the RMP project-specific definition in the *Monitoring Plan* (KWL, 2018) as described below.

- A Year 1 site is determined to be a failure if 1) the works are found to be missing, degraded or ineffective, and/or 2) if the woody vegetation survival is < 25%.
- A Year 3 or Year 5+ site is determined to be a failure if the works are found to be missing, degraded or ineffective.

The vegetation survival failure criteria of < 25% was removed for Year 3 and Year 5+ sites mid-program (in 2020) since it was not always possible to accurately assess the survival of planted woody vegetation for Year 3 and older sites due to either the growth of other vegetation obscuring dead cuttings/plantings and/or state of decay of the dead cuttings/plantings.

In total, seven failure sites were identified out of the 99 assessments completed over 2018-2022 as shown in Table 3-8.

**Table 3-8: Summary of Failure Sites**

| Site Number | Site Name | Age Class | Typology[1] | Assess't Year | Failure Criteria[2] |
|---|---|---|---|---|---|
| BE-BOW-68A | Quarry Park – Fish Compensation | 1 | VR | 2018 | <25% survival |
| BE-NOS-59 | Palmer Bridge Nose Creek Riverbank | 1 | VRW | 2018 | <25% survival |
| BE-NOS-9 | Nose Creek – behind Telus Spark | 3 | P | 2018 | Not present |
| BE-SHA-106A | Shaganappi Creek (SHG920) – TU bioengineering and plantings | 1 | PV | 2018 | <25% survival |
| BE-WNO-57 | Confluence Park – West Nose Creek | 1 | PV | 2018 | <25% survival |
| BE-BOW-6 | Centre Street Bridge | 1 | PV | 2019 | <25% survival |
| BE-CON-2 | Confederation Park | 3 | PV | 2020 | Structural |

Notes:
1. Typology abbreviations: VR = Vegetated Riprap; VRW = Vegetated Retaining Wall; VC = Vegetated Crib Wall; PV = Primarily Vegetative; and P = Planting.
2. The site met the failure criteria listed. More information on the failure criteria is provided in Section 3.1.

### 3.1.8 Data Collection Quick Facts Summary

Bank effectiveness monitoring quick facts of note are listed in Table 3-9.

**Table 3-9: Bank Effectiveness Monitoring Quick Facts**

| | |
|---|---|
| Number of years of data collection | 5 (2018-2022) |
| Number of unique bioengineering projects visited | 69 |
| Number of bioengineering sites that have been assessed once | 42 |
| Number of bioengineering sites that have been assessed twice | 24 |
| Number of bioengineering sites that have been assessed three times | 3 |
| Total number of revisit assessments | 30 |
| Number of detailed assessments completed | 99 |
| Number of City of Calgary-delivered projects visited | 51 |
| Number of external organization-delivered projects visited | 18 |
| Watercourse with the greatest number of projects | Bow River (41) |
| Number of sampled transects | 227 |
| Number of sampled quadrats | 669 |
| Number of individual trees and shrubs sampled for survivorship and growth characteristics | 10,912 |
| Average Year 1 survivorship of container plants versus live cuttings | 94% vs. 69% |
| Average overall rating for all projects assessed by age class | Year 1: 67 (Fair);<br>Year 3: 65 (Fair);<br>Year 5+: 69 (Fair) |
| Most common condition of for restoration success | Dead stems, leaves, and/or branches |
| Number of *Noxious* weeds / *Prohibited Noxious* weeds / Other invasive plant species encountered* | 12 / 2 / 5 |
| Percentage of sites at which Canada thistle (the most common invasive species) was found | 89% |

* Invasive species for this project refer to Prohibited Noxious and Noxious weeds as well as several other species considered invasive by Cows and Fish.

## 3.2 Analysis Methodology

The statistical methods and sample sizes are summarized below.

### 3.2.1 Statistical Methods

A main consideration in the development of the methods used for RMP data analysis was to meet the City's objective of generating statistically valid results that would support recommendations for improvements to bioengineering and riparian planting projects. Statistical tests (e.g., Student t-test, Wilcoxon-Mann-Whitney, Kruskal-Wallis, Analysis of Variance, Tukey's honestly significant difference, chi-squared) were used to test for statistical significance of the median and/or mean values for various growth characteristics such as survivorship, vigour, condition, leader growth, shoot length, and stem diameter compared by typology, age class, bioengineering technique, and monitoring site (for some data sets). If the statistical tests resulted in a p-value < 5%, the result was considered statistically significant.

The R statistical software package (R Core Team, 2019) was selected as the computational engine for the statistical analysis. RMP desktop and field data were processed into a suitable format for the R software then RMP project-specific coding in R was developed to analyze the data.

Multi-variate statistical analysis was also conducted on the large data set that was collected for the RMP. Non-metric Multidimensional Scaling (NMDS) was used to analyse the vegetation data collected along the pin-point transects at each of the bank effectiveness detailed assessment sites. Principal component analysis (PCA) was used to analyze the different rating scores for the monitoring sites to understand how the different sites and typologies are structured depending on their scores for design, implementation, maintenance, success and BRQI. The results of these analyses are not included herein but are summarized in separate technical memorandums for each monitoring year.

### 3.2.2 Sample Size

For statistical analysis that was completed by typology and age class, the target population for each typology and age class was eight (8) sites with a minimum of five (5) sites so that there were enough samples to determine statistical significance. The resulting sample size by age class and typology at the end of the five-year RMP is shown in Table 3-10. The sample population size requirements were met for all but Vegetated Retaining Wall Year 1 and Year 3 age classes due to a lack of available monitoring sites. In total, 92 assessments (99 total assessments minus the seven failure sites as described in Section 3.1.7) were completed (Table 3-10).

The vegetation data sample size was a total of 10,912 individual live cuttings and container plants that were sampled via 227 transects and 669 quadrats.

The sample size for the 9 bioengineering techniques that were assessed is shown in Table 3-11 by age class. While not bioengineering techniques, unplanted riprap and seeding are also shown in Table 3-11 for reference. The total number of transects by age class are also shown in Table 3-11 as 83 Year 1 transects, 76 Year 3 transects, and 68 Year 5+ transects.

**Table 3-10: Total RMP Bank Effectiveness Monitoring Statistical Sample Sizes by Typology & Age Class**

| Typology [1] | Age Class [1] | | | |
|---|---|---|---|---|
| | Year 1 | Year 3 | Year 5+ | Total |
| Vegetated Riprap | 7 | 8 | 6 | **21** |
| Vegetated Retaining Wall | 1 | 2 | 6 | **9** |
| Vegetated Crib Wall | 8 | 8 | 6 | **22** |
| Primarily Vegetative | 11 | 8 | 6 | **25** |
| Planting | 5 | 5 | 5 | **15** |
| **Total** | **32** | **31** | **29[2]** | **92** |

Notes:
1. Green highlighting indicates that the optimal sample size has been met. Blue highlighting indicates that the minimum target sample size has been met.
2. 18 of the 29 Year 5+ age class assessments were on sites that were 6 years or older post-construction, with the oldest site being 14 years post-construction.

**Table 3-11: Bioengineering Techniques Sample Size by Age Class**

| Bioengineering Technique | Number of Samples (Transects) Per Age Class | | | Total |
|---|---|---|---|---|
| | Year 1 | Year 3 | Year 5+ | |
| Brush layers | 16 | 16 | 5 | 37 |
| Brush mattress | 3 | 2 | 2 | 7 |
| Fascine | 6 | 5 | 0 | 11 |
| Live staking | 9 | 7 | 5 | 21 |
| Plantings | 20 | 20 | 15 | 55 |
| Riprap (unplanted)[1] | 11 | 10 | 15 | 36 |
| Seeding[1] | 6 | 5 | 7 | 18 |
| Vegetated crib wall | 2 | 2 | 6 | 10 |
| Vegetated retaining wall | 0 | 1 | 6 | 7 |
| Vegetated riprap | 9 | 8 | 7 | 24 |
| Wattle fencing | 1 | 0 | 0 | 1 |
| **Total** | 83 | 76 | 68 | 227 |

**Note:**
Riprap (unplanted) and Seeding are not considered bioengineering techniques but are included for reference as transect data was also collected for these techniques.

### 3.2.3 Monitoring Site Project Documentation

Relevant project information on design, implementation, and maintenance, combined with site observations, formed key data that was used to assess each site. A summary of the percent of sites where the requested information was provided is shown in Table 3-12. As can be observed, the full list of background documentation requested by the RMP monitoring team was not usually available to review. In general, for the 99 assessments over the five-year RMP (including failure sites), design documentation was available for a higher percentage of sites than construction and maintenance documentation as shown in Table 3-12.

**Table 3-12: Available Project Documentation – Combined 2018-2022 Data**

| Project Phase | Project Documentation | Sites with Documentation (%) |
|---|---|---|
| Design | Design Report | 62* |
| | Design Drawings | 92* |
| | Technical Specifications | 75* |
| | Cost Estimate | 44 |
| | Regulatory Approvals Documentation | 68 |
| | Live Cuttings Harvest and Handling Plan (or specifications) | 68* |
| Construction | Construction contract/tender | 49 |
| | Construction cost (actual) | 48 |
| | Construction Inspection Records | 51 |
| | Construction Environmental Monitoring Records | 39 |
| | As-built/record drawings | 37* |
| | Construction close-out/as-built report | 17* |
| Maintenance | Maintenance records | 43* |
| | Watering regime duration | 7 |

*Indicates documentation that is directly used to develop project ratings

### 3.2.4 Variables Identified from Data Collection

Independent variables that were identified based on the data that was collected are listed below. The results of the analysis for these variables are described in Section 3.3.

- Age Class: Year 1 age class, Year 3 age class, and Year 5+ age class.
- Typology: Vegetated Riprap, Vegetated Retaining Wall, Vegetated Timber Crib Wall, Primarily Vegetative, and Planting (see Figure 3-2).
- Vegetation stock type: live cuttings and container plants
- Vegetation species: a complete list of woody species can be found in Table 3-19 and Table 3-20 and a list of herbaceous species in Table 3-33.
- Bioengineering techniques: a list of techniques is provided in Table 3-5.
- Aspect: “North, North-East, East”, “North-West”, “Flat”, “South-East”, and “South, South-West, West”.
- Seeding method: broadcast seeding, hydroseeding, and drill seeding.
- Soil amendment: used or not used on the planted vegetation.
- Fencing: human control fencing or ungulate/rodent herbivory control fencing (used or not used).
- Lowest elevation of planted vegetation.

Dependent variables that were identified based on the data that was collected are listed below. The results of these variables in relation to each of the dependent variables is provided in Section 3.3.

- Woody vegetation survival and growth parameters: Year 1 age class survival, leader growth, shoot length, and stem diameter.
- Woody vegetation percent canopy cover.
- Density of living shoots for live cuttings and container plants.
- Invasive weeds species monitoring.
- Herbaceous seeding germination success.
- Herbaceous vegetation percent cover.
- Herbaceous species diversity.
- Soil compaction: depth to uncompacted soil, and maximum depth.

### 3.2.5 Limitations and Statistical Validity of the Effectiveness Monitoring Data

Bank effectiveness sites are inherently challenging to study as they are a living ecosystem with some element of human intervention (e.g., planting, bioengineering structure). The success of a site depends on many historical and present-day factors, from engineering components such as design, implementation, and maintenance, to ecological factors such as drought, flooding, and browsing. Disentangling the hundreds of factors involved to build a definitive explanation for a certain condition is extremely challenging and often impossible.

As described in Section 3.2.1, simple, correlative statistical approaches were used in the RMP to disentangle the complex interactions and identify trends, with results that are significant as summarized in Section 3.3.2. However, there are some limitations regarding the RMP data and analysis that are listed below.

- The lack of documentation provided to the monitoring team as discussed in Section 3.2.3 affects the ability to conduct detailed analysis on several important variables such as irrigation and maintenance issues.
- The five-year monitoring timeframe for the program may have limited the ability to capture all the relevant learnings, and since most of the assessments were on sites that were five years or less since construction (81 of 99 assessments), the observations of the long-term (10 years or greater) effectiveness of the bioengineering approaches is limited.
- Because of the requirement to assess some sites year after year (e.g., the Bioengineering Demonstration and Education Project), a truly independent site sampling approach was not possible, meaning that dependent samples were collected, and statistical significance of the results were limited. Stronger statistical results would have been available if independent sampling was permitted.
- There was limited site availability for the Vegetated Retaining Wall typology in the effectiveness monitoring component that led to smaller sample sizes than anticipated for statistical analysis for Year 1 and Year 3 age classes. Important general findings for these age classes were still made and there was adequate site sampling for the Year 5+ age class.

- Not all design, construction, and maintenance activities were able to be assessed by the RMP monitoring team as monitoring occurred after construction was completed (e.g., soil amendment application, irrigation, weeding) and assumptions were made that the activities either occurred or did not occur depending on available documentation.
- Effectiveness analysis did not factor cost, construction complexity, and regulatory approval requirements/timelines in the analysis or recommendations. While results show that certain bioengineering techniques may be performing better than others based on the data that was collected, a full evaluation of growing performance, cost, construction, and regulatory complexity should be undertaken when evaluating a particular bioengineering approach or technique.

While the above did affect statistical independence and sample size, this represents a slight limitation on the overall ability of the RMP to produce valuable results for bioengineering project effectiveness. Many results from the overall analysis remain statistically significant including those described in Section 3.3.2 and are a significant contribution (i.e., publishable in scientific journals) to the practice of bioengineering and riparian planting projects. The entire dataset is unique, both in terms of the quantity of data collected (number of cuttings, plants, techniques or works) and their quality (detailed data on vegetation, structure of works, success analyses), it allows an improvement of knowledge about riparian engineering, useful at the City scale and abroad. **Unless related to the key issues identified in sections below, results of the statistical analysis that were not statistically valid are not included in this Final Program Report but are provided in the annual summary reports.**

## 3.3 Results and Discussion

Key results from the bank effectiveness monitoring component of the RMP are presented in this section. Results are provided for general findings (e.g., project documentation, site stability and condition of structure materials; habitat enhancements, vegetation succession; structure design, vegetation design and installation, construction and maintenance practices, post-construction monitoring, limiting factors, failure sites; and ratings), and statistical analysis (e.g., Year 1 age class woody vegetation survivorship and growth, woody vegetation canopy cover and density of living shoots, invasive weed species monitoring, seeding germination success; herbaceous vegetation cover and species diversity; and limiting factors for success) and are based on site and bioengineering practice level. These results provide background information to support the recommendations for future bank effectiveness projects and are divided into General Findings and Statistical Results.

### 3.3.1 General Findings

#### Lack of Project Documentation

Project documentation that is a requirement of most construction contracts (e.g., design drawings, maintenance records, as-built reports) was not always available to the RMP team for review. Background documentation is an important component of a construction project and was very important to the RMP to track the effectiveness of the monitoring sites (based on actual or adjusted design implemented) against the project objectives. Additionally, as noted in Section 3.2.3, as-built/record drawings and maintenance records were available for less than 50% of assessed sites (Table 3-12). This documentation provides a record of what was constructed and how it was maintained to support future follow-up or new initiatives at the site.

#### Site Stability and Material Condition Observations

**General Site Stability**

In general, most monitoring sites were observed to be stable with little to no erosion occurring within, upstream or downstream of the site, an example of which is shown in Photo 3-8. For the revisit sites, there was little to no change since the first assessments. However, there were a minority of sites that were observed to have specific instances of erosion, undermining, slope raveling, and backfill material washout per the example shown in Photo 3-9. Often, the key reasons for the observed issues were that the materials selected prematurely degraded or the design approach were not suitable to resist the erosive forces.

That said, erosion at the monitoring sites would not typically be expected given the flood record in the City's watercourses over the five-year monitoring period from 2018-2022. Most of the sites were five years old or less during the RMP assessments (81 of 99 assessments were on sites that were five-years old or less) and did not experience flood conditions beyond an approximate five-year return period flood event in 2021. So, the monitoring sites were most often not tested against a design flood event – which is typically the 100-year return period flood event for Calgary.

Additional information on the physical characteristics and limiting factors for each site is provided in Table E-1 and Table E-2 in Appendix E.

**Photo 3-8: Example of stable site with a vegetated timber crib wall installed on Nose Creek in 2021 and assessed in 2022**

**Photo 3-9: Example of backfill material washout in a timber crib wall installed on the Bow River in 2015 and assessed in 2021**

**Condition of Structure Materials**

In general, the permanent materials selected for the structural components of the monitoring sites are fit-for-purpose and in good to very good condition. Rock, timber, steel, and concrete materials were found to be present according to the design of the sites and in good to excellent condition. An example of the permanent materials assessed is shown in Photo 3-10. The condition of gabion baskets and mattresses was variable, with those installed in areas with consistent exposure to stream flow in worse condition than those exposed infrequently.

Temporary structural materials are intended to provide short- to medium-term stability at a site so that vegetation can establish and take over the long-term stability function. Common examples of temporary structural materials are erosion control matting, coir geogrid, hydromulch, and wattles. The condition and application of temporary structural materials was variable. When installed correctly, these products appeared to be functioning as intended per the example of the biodegradable coir geogrid shown in Photo 3-11. However, in some cases, they were not used for the appropriate application (e.g., erosion control matting used as material containment in timber crib walls alone instead combining with a coir geogrid) or were not installed properly (e.g., wattles installed vertically instead of on contour) and were not effective as implemented as they were not providing site stability for vegetation establishment.

**Photo 3-10: Example of site with riprap, timber and steel components installed on the Elbow River in 2015 and assessed in 2022**

**Photo 3-11: Example of biodegradable coir geogrid installed at a site on Bow River in 2017 and assessed in 2019 and 2021**

**Biodegradable Erosion Control Products**

A fully biodegradable erosion control matting was observed at many sites and relied upon for temporary erosion control until vegetation was established. An example is shown in Photo 3-12 where the brush layers have established well, and the matting may no longer be required. A biodegradable wattle product (Curlex® Sediment Logs®) was observed in an advanced form of decomposition after having served its purpose to facilitate herbaceous vegetation growth (Photo 3-13). Biodegradable erosion control matting or wattles typically provide the same level of temporary erosion protection as their synthetic counterparts, but they are fully biodegradable and can be left to decompose at the site while vegetation establishes.

**Photo 3-12: Example of biodegradable coir geogrid at a vegetated soil wrap site installed on the Bow River in 2018 and assessed in 2022**

**Photo 3-13: Example of biodegradable wattle (Curlex® Sediment Log®) at an advanced state of decomposition installed on the Elbow River in 2015 and assessed in 2018**

**Use of Synthetic Erosion Control Materials**

Synthetic erosion and sediment control materials were observed at 21 of the 69 bank effectiveness monitoring sites (30%). Synthetic erosion control matting, wattles, and silt fences were observed at these sites in various condition and in some cases, were observed in the Bow River (Photo 3-14). At most of the sites with synthetic materials, vegetation had established and was providing effective erosion control (Photo 3-15). It appeared that the initial application of synthetic matting was not necessary, and a medium-term fully biodegradable matting or geogrid would have been a suitable alternative. These materials will now persist in a sensitive location in the environment (riverbank and/or riparian area). Where synthetic erosion control matting is exposed, it poses immediate risks to wildlife – for example, songbirds have been observed entangled in the matting. It also poses a lethal risk to terrestrial garter snakes (*Thamnophis elegans*, a *Sensitive* species in Alberta) if entrapment and strangulation occurs. A list of the sites with synthetic products and the products used is provided in Table E-3 in Appendix E.

Additionally, synthetic products ideally should be removed from site at the end of the project – even those synthetic products that are promoted as photo-degradable as they typical persist for many years after installation in Calgary's arid climate versus the climates where they were designed and tested (USDA NRCS, 2013). However, many synthetic products have been incorporated into structures and cannot be removed. These products can be released into the river environment or will stay within the soil at the end of the structure's life cycle since they will very likely outlast the structure. This represents a residual environmental risk due to the project.

Synthetic geotextiles used to prevent backfill materials from washing out of bank protection structures also create root barriers to the installed vegetation and can cause a slip plane. This is contrary to the purpose of bioengineering projects which is to strengthen the bank and increase soil cohesion through extensive development of root system into the natural bank. Synthetic geotextiles used as a filter should be substituted with a granular filter.

**Photo 3-14: Example of synthetic erosion control matting that was installed in 2008 and observed in the Bow River in 2020**

**Photo 3-15: Example of the remains of synthetic erosion control matting that was installed in 2008 and observed in 2020**

## Habitat Enhancements

### Fish Structures, Woody Debris, and Overhanging Vegetation

Fish structures such as instream boulders have been included in several sites and appeared to be providing good quality habitat by way of hydraulic diversity and in-stream cover for fish (Photo 3-16). Woody debris was also observed to be incorporated into and naturally recruited onto structures (Photo 3-17). When located on the bank, this woody debris supports moisture retention at the site, contributes organic material to the soil as it degrades, and promotes habitat for wildlife. When it is located in-stream along the toe of the structure, it provides fish and wildlife habitat. Overhanging vegetation was observed at several sites and is providing good overhead shade, cover, and organic debris input for fish habitat, and assisting the reduction of water temperatures. The overhanging cover was measured to be in the range of 2 to 3 m at several sites (Photo 3-17).

**Photo 3-16: Example of fish habitat enhancement boulders and woody debris at a timber crib wall site on the Elbow River assessed in 2019 and 2021**

**Photo 3-17: Example of overhanging vegetation at a timber crib wall site on the Bow River that was assessed in 2018 and 2022**

## Structure Design

### Vegetated Timber Crib Wall Design

There are several improvements to timber crib wall design that could be made based on detailed observations of 14 different timber crib walls in the City as part of the RMP monitoring efforts. These design improvements are listed below.

- **Do not overlap crib joints**. Wash-out of backfill material was observed in several timber crib walls with the most wash-out typically near the joints of the cribs. In some cases, the overlapping joints in the timber cribs were oriented such that the downstream crib overlapped the upstream crib and projected out into the flow, which likely entrains turbulent flow into the open rows in the cribbing, leading to soil loss inside the structure.
- **Use double layered biodegradable coir geogrid for backfill material containment**. Light duty erosion control matting was used for backfill containment in the cribbing at several sites. The manufacturer's specifications for this type of matting typically state that it has a functional longevity of 24 months. It has been observed by the RMP team that the matting degrades prior to full

vegetation establishment and the fill in the timber crib is at risk of or has already washed out in some places. The double layered biodegradable coir geogrid material has been observed in place during site assessments to have a functional durability of five years or more and is providing good material containment while vegetation establishes.

- **Specify a high-quality grade untreated cedar for the timber**. Most often the timber used to construct timber crib walls appeared to be in good to very good condition. However, the grade of timber used to construct these timber crib walls was not available in the background design information or specifications that were reviewed by the RMP team. At one site, the grade of timber used was standard grade and was observed to contain dry rot and insect damage that likely pre-dated timber installation at the site as shown in Photo 3-18. There is a concern with this timber that it might degrade prior to full vegetation establishment.

  Given the uncertainty in the long-term durability of timber used in the timber crib walls in Calgary, it is recommended that high-quality grade cedar timber such as Select Structural, No.1/ No.2, or Construction grade be specified in construction specifications. Alternatively, in Europe the approach to vegetated timber crib wall is to use peeled logs from species with decay-resistant properties. It is believed that an entire log would take a longer time to decay than processed dimensional lumber (pers. comm. with Dr. Massimiliano Schwarz, Bern University of Applied Sciences Switzerland).

- **Use transverse connections at joints**: Different methods for timber connections were observed over during monitoring assessments, with the main techniques being notched and transverse connections (Photo 3-19). Based on the RMP team's observations of these two different types on connections, transverse connections are expected to be more durable over the long-term than notched connections due to their ability to more effectively drain water (Roman, 2009). Timber that was notched at connection points appeared to be decaying faster than elsewhere.

- **Use appropriate backfill materials and compaction levels**: Conditions in vegetated crib walls are known to be challenging for vegetation growth due to conflicting demands for providing engineered soils for ballast and drainage (typically well draining and compacted soils), versus soils capable of sustaining vegetation (soils that contain organic matter and fines, and retain moisture). Special considerations for the design of the soils used for backfill in a timber crib wall should be considered so that both ballasting and plant requirements can be met. For example, a soil with greater than 10% fines could be included in otherwise granular backfill soils with compaction limited to 80%-85% SPMDD (Goldsmith, Silva, & Fischenich, 2001).

**Photo 3-18: Standard grade cedar timber with dry rot used in the timber crib wall**

**Photo 3-19: Transverse connections between timbers used in the timber crib wall (inset: notched connection for comparison)**

### Void Filled / Covered Riprap

At several sites, river gravels were used to cover and/or infill riprap as shown in Photo 3-20 and Photo 3-21. This was observed to allow for better wildlife passage, accelerated ecological succession through colonization by herbaceous and emergent vegetation, and results in a more aesthetically pleasing bank. Further research is needed to confirm if void filling would result in an increase in erosive resistance and potentially result in a reduction in riprap size and avoid the need for a granular filter. Best practices for void fill construction are also needed.

**Photo 3-20: Example of riprap covered with river gravels on the Bow River**

**Photo 3-21: Example of void-filled riprap using river gravels and vegetated with live staking on the Bow River**

### Vegetating Existing Riprap

Vegetating existing riprap was trialed at sites on the Bow River as part of the BDEP. The intent of the trials was to cover or fill void spaces in the existing riprap with growing medium and then establish vegetation in the growing medium. One site featured topsoil placed over the existing riprap in a 600 mm layer that was referred to as soil-covered riprap. After Year 1 post-construction, the soil-covered riprap was meeting the intent of establishing container plants and herbaceous vegetation over the riprap based on measurements of vegetation growth, but high mortality was observed by Year 3 post-construction.

At the other two sites, growing medium (topsoil or pitrun) was used to void-fill the existing riprap and live staking or plugs were installed as vegetation. Topsoil installation is shown in Photo 3-51 and pitrun installation is shown in Photo 3-22. Despite the void-fill in the riprap, it remained challenging to establish woody vegetation, with high temperature fluctuations and low soil moisture as measured with in-situ soil moisture and temperature probes. Plugs were found to establish relatively well in the topsoil void-fill material, but there was high mortality in the live staking. It was thought that the void-fill may not have achieved the anticipated depth or have adequately filled in all the void spaces. This would have left some air voids in the fill that would result in air pruning of any roots that were growing from the live cuttings. Because of this, establishing live cuttings in the riprap has been very challenging, and shrub plugs have been planted to supplement the high mortality of the live cuttings. However, the herbaceous vegetation is establishing nicely at the site (Photo 3-23).

While there is still room for improvement in developing an effective technique to vegetate existing riprap, filling voids as best as possible then focusing on establishing woody vegetation using plugs and seeding herbaceous vegetation appears to be a more appropriate approach given the observed challenging environment for establishing woody vegetation using container plants or live cuttings.

Note that if the woody vegetation does not establish, herbaceous vegetation remains an improvement over bare riprap, particularly if native species are established, and may over time create the conditions necessary for native woody species to establish.

**Photo 3-22: Placing planting material in the riprap voids in May 2018**

**Photo 3-23: High mortality of live cuttings but good herbaceous establishment in void-filled existing riprap installed on the Bow River in 2018 and assessed in 2019 and 2021**

### Erosion and Sediment Control Wattles

Possible improvements in the installation of wattles for erosion and sediment control were noted at several assessed sites. In general, the wattles were not properly secured or keyed-in and were observed to be floating in the river (Photo 3-24), allowing progressive erosion to continue, and were prematurely degrading prior to vegetation establishment (Photo 3-25). The lack of proper design and implementation could be improved by following the design guidance for wattles in Guideline I3 in the *Design Guidelines* (AMEC, 2012) so that surficial erosion might be reduced, and vegetation established.

**Photo 3-24: Floating wattles at site on the Bow River**

**Photo 3-25: Wattle installed improperly and in poor condition on slope with surface erosion**

### Signage

Signage was installed at several sites to inform the public of the activities occurring at the sites and to educate the public on the importance of riparian health, examples of which are shown in **Photo 3-26** and **Photo 3-27**. Signage is a beneficial practice as it promotes a greater general awareness of the importance of riparian areas in Calgary and emphasizes the ongoing, site-specific riparian restoration works and the need for the public to respect the area.

**Photo 3-26: Example of signage installed at a bioengineering site on Shaganappi Creek**


**Photo 3-27: Example of signage installed at a bioengineering site on the Bow River**

## Vegetation Design and Installation

### Planting Installation Schedule

Poor vegetation growth and high mortality was observed at sites where special considerations were not made for bioengineering project construction schedule or appropriate stock selection. For example, live cuttings were installed at the site shown in Figure 3-3 during two different periods: 1) April 2017, and 2) August 2017. The spring installed cuttings have established quite well but there was high mortality in the August-installed cuttings. Live cuttings (and willow whips) should be installed when dormant – an appropriate schedule for the Calgary area is installation from October to the third week of June as shown in Figure 3-4.

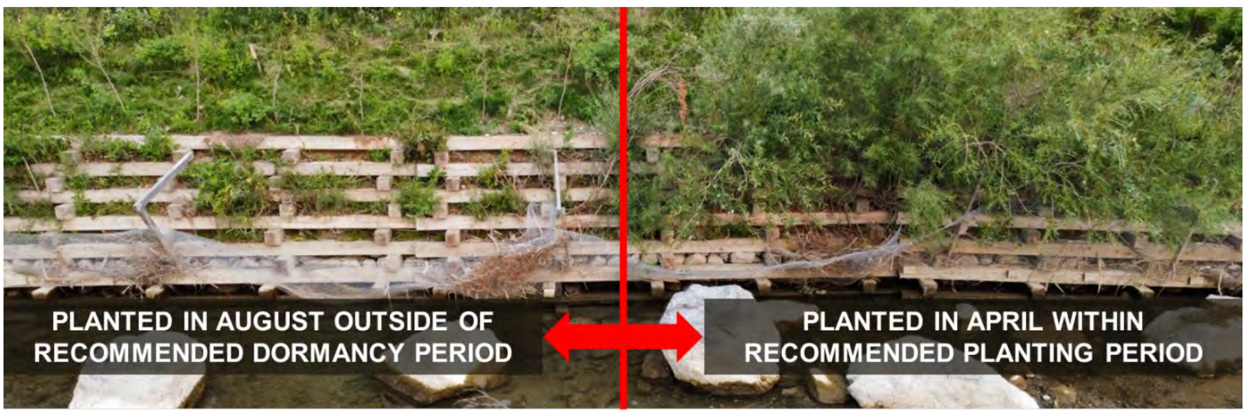



**Figure 3-3: Result of Installing Live Cuttings Inside and Outside of Recommended Periods**

| Vegetation Type[1] | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Native Plant Seeding[2] | | | | * * * * | | | | | | | + + + + | |
| Container Plants[3] | | | | | | | | | | | + + + + | |
| Live Cuttings - Harvest[4] | | | | | | | | | | | | |
| Live Cuttings - Installation[5] | | | | | | | | | | | | |

Notes:
1. Legend: * after ground thaw; + before ground freeze
2. Recommended schedule is subject to change as new information is collected.
3. Spring native seeding period: after ground thaw to mid June at the latest (May is preferred). Fall native seeding period: October to ground freeze. Source: The City of Calgary. 2018. The City of Calgary Seed Mixes.
4. Source: Smreciu,A., Sinton,H., Walker,D., and Bietz,J. 2003. Establishing Native Plant Communities; NRCAN. 2017. A Guide to Planting: Timing, Microsites, Techniques, and Monitoring.
5. All live cuttings to be harvested during the dormancy period - typically October to March. Source: AMEC. 2012. Design Guidelines for Erosion and Flood Control Projects for Streambank and Riparian Stability Restoration.
6. Live cuttings harvested in October to March to be installed either immediately or no later than the third week of June. Live cuttings harvested over the previous October-March period shall not be stored over the summer and planted in the following installation period. Source: Smreciu,A., Sinton,H., Walker,D., and Bietz,J. 2003. Establishing Native Plant Communities

**Figure 3-4: Recommended Planting Schedule**

### Vegetation Stock Selection and Design

Various vegetation stock including live cuttings, container plants, tall rooted stakes (TRS), and plugs were observed in use on sites across the city. Live cuttings and container plants were the two key stock types that were assessed statistically as part of the bank effectiveness analysis. Most often, live cuttings and container plants were used in appropriate locations, with some exceptions such as live cuttings struggling in areas where container plants would typically thrive and container plants in high-velocity areas where live cuttings should have been used (Photo 3-28). Generally, however, the design of appropriate locations and arrangements for live cuttings and container plants appears to be understood. A further discussion on the use of live cuttings and container plants is provided in Box 4.

TRS are a special vegetation stock that was originally developed to provide immediate shade in riparian areas to shade out invasive species. It was then used to support construction of bioengineering projects outside of the typical dormancy period for live cuttings. They are live cuttings that have been rooted out at the base for around 40 cm and have top growth (canopy) as well (Photo 3-30). Because they have a well-developed root system, they can be installed following the same general scheduling as container plants.

TRS have been used at three monitoring sites and have shown good establishment potential when installed properly (Photo 3-29). However, as shown in Photo 3-30, TRS at one site was observed to be installed incorrectly with only the root mass buried, leaving the bare stem and top growth exposed. This resulted in the TRS being unstable, easily eroded and toppled. An additional issue is that willow stems are not usually exposed to direct sunlight and there will likely be high mortality from sunburn and drying out because of the TRS installation method. An option to increase the use of container plants is to more regularly use hedge brush layers which is a combination of rooted stock and live cuttings within a brush layer (Photo 3-31).

As TRS become more popular, better guidance needs to be provided for appropriate design and installation. TRS when used for bioengineering applications, typically have a long, bare section of stem between the roots and top growth that is intended to allow for deep burial of the root mass and promote adventitious rooting along the stem. The top growth is then meant to be the only portion of the TRS that is left exposed. The entire stem would normally be buried approximately two-thirds of its length in a similar manner to the hedge brush layer technique. Where this is not achieved, failure of the technique is a risk.

Plugs were observed infrequently but offer a good option for dead vegetation replacement, for planting in void-filled riprap, and for planting at high density in top of bank areas. Emergent vegetation was only observed at two monitoring sites with mixed results due to growing material wash-out. Their use requires further study and is recommended in low velocity locations that are inundated during mean annual flows or higher.

**Photo 3-28: Example of container plant in an eroded section of side channel on the Bow River in 2018 and assessed in 2019**

**Photo 3-29: Example of sandbar willow Tall Rooted Stakes (August 2018)**

**Photo 3-30: Example of TRS installed too shallow on West Nose Creek in 2021 and assessed in 2022**

**Photo 3-31: Example of a hedge brush layer on a site on the Bow River (July 2021)**

## Box 4: Why Use Live Cuttings?

A live cutting is a cut stem or branch from a woody shrub or tree species that has adventitious growth properties and will root when embedded or inserted into the ground (USDA SCS, 1992; Eubanks & Meadows, 2002). Some key reasons why live cuttings are the main live materials used in bioengineering projects are listed below:

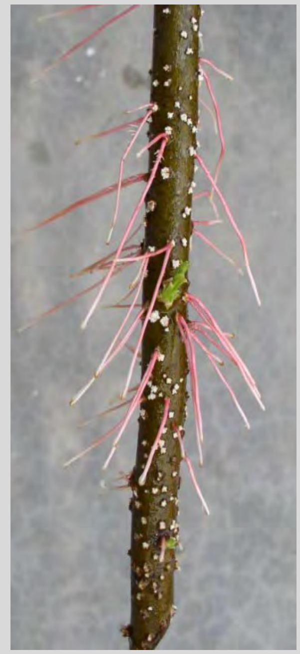


**Photo 3-32: Roots sprouting from adventitious buds after 13 days of soaking** (Source: USDA-NRCS, Aberdeen Plant Materials Center)

1. Willows and some species of trees (e.g., balsam poplar) are pioneer species and have properties that are highly adapted to survival in disturbed environments: they are resistant to high-velocity flood waters, burial by sediments, long-periods of water inundation, high winds, and heavy browsing by wildlife (Lezberg & Giordanengo, 2008). They also provide deep rooting which contribute to soil reinforcement as they increase soil cohesion.
2. Willows and some species of trees have a high concentration of adventitious roots and buds located throughout the length of the stem that can sprout new roots and shoots when planted in the proper conditions (Haissig, 1973; Hoag, 2007; Lezberg & Giordanengo, 2008).
3. Live cuttings harvested during the dormancy period possess the highest level of carbohydrates in their annual cycle and can provide fresh growth in the growing season without the benefit of further photosynthesis (Polster, Restoration of Landslides and Unstable Slopes: Considerations for Bioengineering in Interior Locations, 1997). Using cuttings harvested and installed during dormancy allows the highest amount of stored energy from the plant to be expended in the growth of new roots and shoots during the growing season and has been shown to be on average more growth than a container plant (see Section 3.3).
4. Live cuttings are typically cheaper than container plants (except for large size plugs that are usually the cheapest stock type) – about 5 to 10 times cheaper based on experience in Calgary – and are relatively easy to harvest and store. They are also easy to plant (Hoag, 2007).
5. While high mortality can occur as shown by the data collected for the RMP, this is somewhat offset by lower cost, ability to rapidly plant large numbers, and ease of replanting the following year (Hoag, 2007).
6. Live cuttings can be embedded and arranged in the ground in special patterns and configurations to support engineering functions such as 1) soil reinforcements, 2) barriers to earth movement, 3) moisture wicks, and 4) hydraulic drains (Gray & Sotir, 1996). Live cuttings planted along riverbanks also provide immediate surface roughness to reduce velocity and erosive forces on the bank.
7. While survivorship of container plants is higher than live cuttings, they cannot be used in the same arrangements and for the same functions as live cuttings due to shallow roots systems that can easily wash out (Hoag, 2007). Also, several live cuttings can be planted for the same cost as a container plant to accommodate the lower survivorship, depending on the size (length and diameter) of the live cuttings and size and cost of the container plants.

**Deep Cuttings and Root Establishment**

Some vegetated riprap sites have very good vegetation establishment despite the large amount of riprap placed at the site (Photo 3-33). For these sites, live cuttings were designed and installed at an angle and of a sufficient depth to access the water table, a practice sometimes referred to as installing live cuttings with 'wet toes' (Photo 3-34). Access to adequate soil moisture or groundwater is important for vegetation planted in thick riprap installations, since the riprap is known to retain heat and cause desiccation and high mortality of planted vegetation. Additionally, evidence of browsing and regrowth were also observed during the re-visits at these sites, indicating that the vegetation has developed significant root mass to withstand this type of disturbance.

**Photo 3-33: Example of good vegetation establishment at a vegetated riprap site installed on the Elbow River in 2015 and assessed in 2021**

**Photo 3-34: Example of long live cuttings placed with 'wet toes' at a vegetated riprap site installed on the Elbow River in 2014 and assessed in 2021**

At one site on the Elbow River, the rodent fencing was in disrepair in the spring of 2020 when water levels on the Elbow River rose higher than average. The local beaver population took advantage of the damaged fence and browsed a ±27 m section of the site (Photo 3-35). The fencing was repaired promptly and by mid-July browsing resulted in generally three to six (average of four) shoots growing (coppicing) from the cut stems (Photo 3-36). By September, the shoots had grown to an average height of 1.5 m creating a very dense vegetation cover (Photo 3-37). This vigorous growth is due to deeply planted cuttings and a well-established root system.

**Photo 3-35: Recently browsed site on May 25, 2020**

**Photo 3-36: 3 to 6 shoots growing from each browsed stem on May 25, 2020**

**Photo 3-37: Vegetation regrowth with average height of 1.5 m on July 21, 2020**

### Shallow Burial Impacts on Live Cutting Survival

Several sites were observed to have challenging conditions for woody vegetation growth due to aspect, lack of shade, and presence of large rock revetments or other structural components that retain heat (e.g., gabion baskets). An example of these conditions is shown in Photo 3-38 where the intent was to grow live cuttings in a cigar-shaped roll of soil on the riprap toe. Conditions such as these were sometimes mitigated through good design and installation practices such as live cuttings that were planted deep enough to access groundwater (see section above). However, considering Calgary's dry climate, planting depth for both live cuttings and container plants continues to be an issue (Photo 3-39).

For live cuttings, shallow burial restricts access to soil moisture, and results in a higher root to shoot ratio, creating a progressive desiccation of the plant. This is caused by a high moisture requirement on the root system from evapotranspiration resulting in the drying out of the cutting, death of any leaders and overall mortality of the cutting. For container plants, shallow burial can result in exposed roots and drying out of the root mass and mortality of the plant.

**Photo 3-38: Example of a site with challenging growing conditions due to sun exposure on a large riprap toe**

**Photo 3-39: Example of shallow burial and mortality of a live cutting**

### Live Cutting Survival Despite Submergence

Bow River flows remained seasonally high for most of June, July, and August in 2020. This led to some live cuttings that were planted at low elevations being submerged for extended periods of time. Some TRS at the BDEP site were submerged for an estimated 16 days during high flows and intermittently for another ±10 days over summer. A brush layer below a box fascine was estimated to be submerged for a period of 18 days during high flows and intermittently for another ±15 days over summer. Site observations were that sandbar willow and hungry willow (only used in the box fascine) survived despite the submergence while other species such as balsam poplar and red-osier dogwood did not survive as well or at all. Where inundation is anticipated at a site, it appears that better choices for species are sandbar and hungry willow.

### Lowest Elevation of Planted Vegetation

Survey data was collected at each monitoring site to measure the lowest elevation of planted and existing vegetation. Matching the lowest elevation of planted vegetation (woody, herbaceous or emergent) with the observed lowest elevation of native vegetation adjacent to the site represents good practice for riverbank bioengineering sites since it maximizes the riverbank protection provided by roots and canopy growth, the habitat value of the vegetative techniques, improves species survival when they are planted in suitable habitats (e.g., not too low, not too high), and provides additional bank protection against erosion.

The results of comparing the surveyed difference in elevation between planted and existing woody vegetation by age class are shown in Figure 3-5. Median lowest elevation of planted vegetation for Year 1 age class sites more closely match the observed lowest elevation of native vegetation in comparison to the Year 3 and Year 5+ age class sites. These results appear to indicate that designers are changing their practice to lower the planted vegetation to meet the elevation of the existing vegetation. This suggests an improvement in the use of vegetation in bioengineering projects.

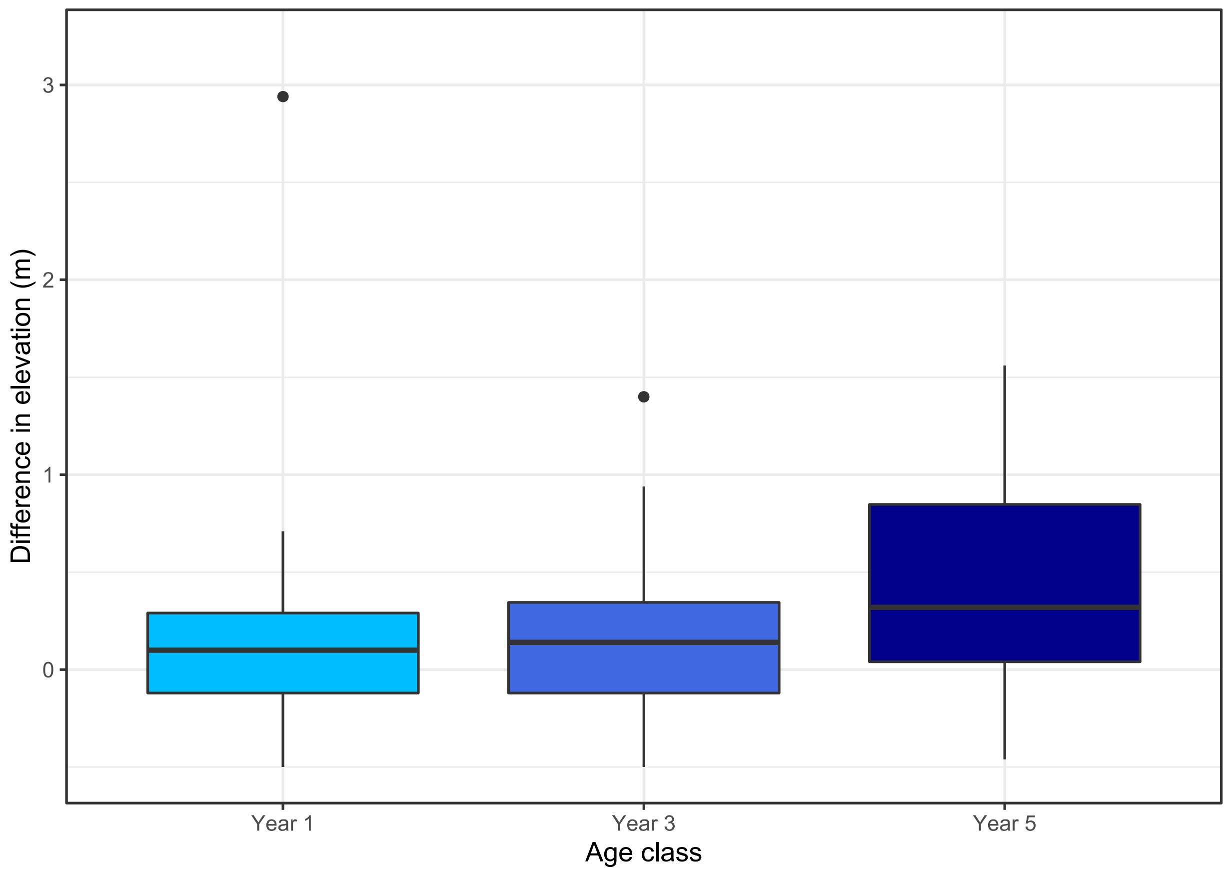



**Figure 3-5: Difference in Elevation Between Planted & Existing Woody Vegetation[2]**

### Hydrological Connectivity

The Forest Lawn Creek Realignment was the oldest site assessed as part of the bank effectiveness component of the RMP and is a rare example in Calgary of a full channel relocation (Photo 3-40). About 2 km of Forest Lawn Creek was completely rebuilt in 2007. It is considered a successful example of earthwork and hydrologic conditions working together to support plant growth where the 'U' shaped valley and sinuous channel were specifically designed to maintain a hydrological connection between the channel and the riparian soils. This was done to achieve a capillary feed of water to the riparian plants with very successful results for vegetation establishment (Photo 3-41). This focus on creating a hydrological connection between the creek and the riparian area to support plant growth would be useful for smaller systems in the City (e.g., Nose Creek) where this connection is currently broken due to historic channel straightening and resulting downcutting.

**Photo 3-40: Hydrologic connectivity in valley bottom of the relocated Forest Lawn Creek channel constructed in 2007 and assessed in 2021**

**Photo 3-41: Dense riparian vegetation at planting site installed on Forest Lawn Creek in 2007 and assessed in 2021**

### Deep, Binding Root Mass

It was estimated based on visual estimates for all monitoring sites that an average of 85% of the streambank had deep, binding root mass (Appendix E, Table E-5). Of the 69 individual bank effectiveness monitoring sites, there were 23 sites with 100% of the streambank with deep, binding root mass and seven with 50% or less.

When looking at patterns across sites that had been assessed more than once (i.e., revisit sites), the deep, binding root mass estimate was equal or greater than the original assessment for 27 revisit sites, which indicates a general trend towards improved erosion protection and bank stabilization. Three sites were observed to have reductions in the range of 7% to 11% from the original assessment. Note that failure sites were not included in this analysis.

To confirm the visual results above and gain better understanding of the root system growth in the bank effectiveness sites in Calgary, several sites could be selected to perform excavations of the root system. The intent would be to assess root mass growth (e.g., root area ratio over soil mass and added soil cohesion) and effectiveness in strengthening soil (e.g., for vegetated riprap, assess the displacement force and tensile strength required to remove rocks enveloped by roots). Methods could be trench excavation and hydraulic pressure excavation (Tron & Raymond, 2014), high pressure air excavation (e.g., www.airspade.com/pages/arbor), or high pressure water excavation (not recommended due to sedimentation concerns). Performing such an experiment would provide valuable data to The City with regard to root mass development, soil cohesion values, root depth, and root interaction with various soil type compaction for structures such as dikes and vegetated riprap.

**Soil Moisture**

Soil moisture was measured for several sites in 2022 due to its importance for vegetation success and also its importance in assessing whether irrigation is effective. This data was not collected in a systematic manner so was not analysed statistically.

Soil moisture was measured using Volumetric Water Content (VWC), which is the ratio in percent of the amount of water held in the soil. Soil moisture would ideally stay between the field capacity and wilting point for the type of soil at a site. Typical riverbank soils in Calgary should have VWC between 7% to 16% for sandy loams or 11% to 29% for silty loams (Saxton & Rawls, 2006).

The measured results for VWC ranged between 0% to 24%. When paired with the Vegetation Success Rating, which are based on measurements of woody vegetation density and vigour, and seeding percent cover, it appeared that sites with higher VMC also have better Vegetation Success Ratings. This is an intuitive result in that vegetation should have better success with more available soil moisture.

**Vegetation Design Best Practices**

As described in Section 3.3.2 the bank effectiveness data revealed low to moderate survival (between 62% to 78% as shown in Table 3-20 below) for balsam poplar, hungry willow, and sandbar willow live cuttings. These species are the most commonly used species for bioengineering in Calgary and are known to have a very good ability to root from cuttings (AMEC, 2012; USDA NRCS, 1996; Gray & Sotir, 1996). Based on the RMP results, live cutting survivorship could be improved, particularly considering the overall Year 1 age class survivorship was 69% for all live cuttings assessed during the program and that the Year 1 age class survivorship would likely have been lower if vegetation survival data from failure sites was included in the analysis[6]. Photo 3-42 and Photo 3-43 show representative photographs of failure sites where survival was less than 25% for all species.

The reasons for this low to moderate survival need to be better understood to improve the design and implementation practices and overall bank project outcomes. However, following the best practices identified in Box 5 for live cutting installation and Box 6 for container plant installation and avoiding the common planting issues shown in Figure 3-6 will lead to some level of change in survival and long-term establishment. There may be other factors beyond those identified – particularly for balsam poplar where the appropriate best practices were used at some sites, but overall survival was still low. Overall, **it is important to keep in mind that key plant growth limiting factors within the Calgary region are primarily climate-related, including low precipitation and occurrence of Chinooks, or desiccating warm winter conditions. Vegetation design should be tailored appropriately by using best practices such as deeply buried techniques**.

[6] The failure sites were not included in the analysis because vegetation data was not collected per the failure monitoring protocols as described in (KWL, 2018).

**Photo 3-42: Example of dead live cuttings installed on the Bow River in 2016 and assessed in 2019**

**Photo 3-43: Example of dead live cuttings installed on the Bow River in 2018 and assessed in 2019**

## Box 5: Live Cutting Installation Best Practices

Best practices for live cutting installation are listed below.

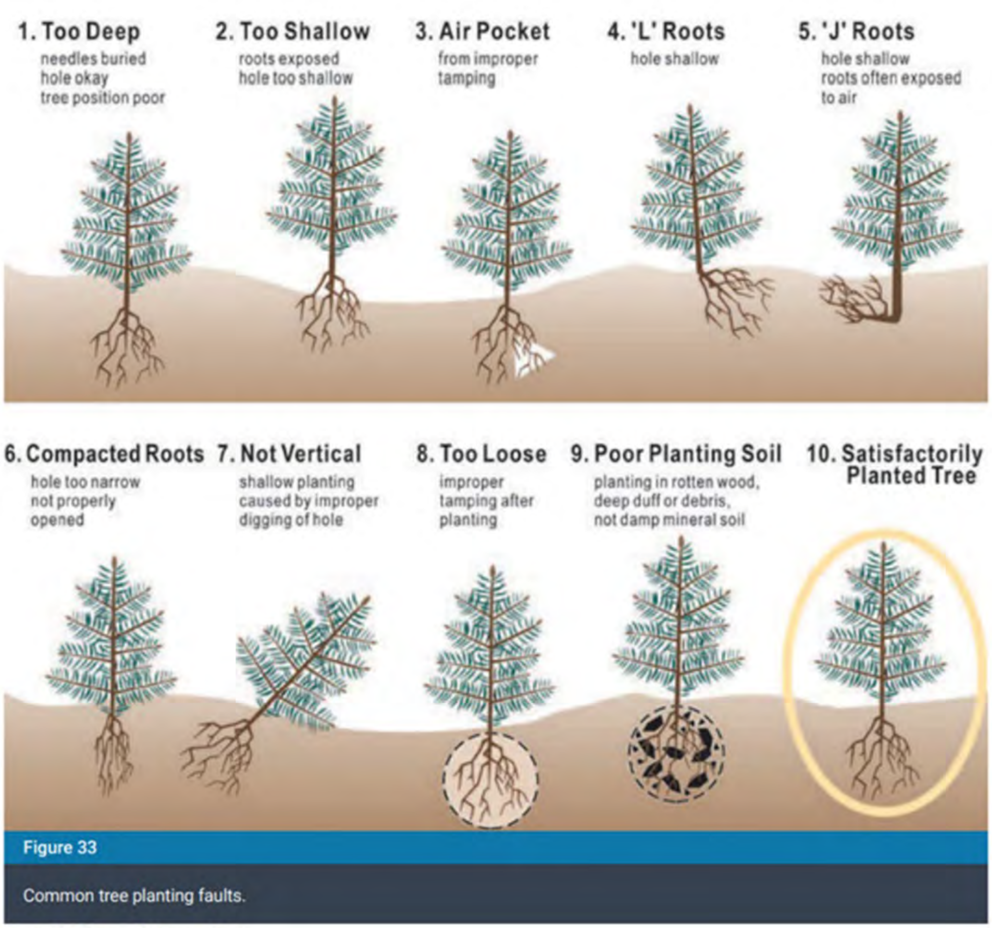
- Ensure cuttings are dormant when harvested and installed. The dormancy period in the Calgary area is typically from approximately the beginning of October until the end of March. Cuttings that are no longer dormant when harvested are unlikely to establish and persist. It is preferred to install cuttings in the spring, however, not always possible.
- If cuttings are not installed immediately after harvest, they should be placed in cold storage to help maintain dormancy. Cold storage should be at an average temperature of -2˚C and/or under a snow pack (~0.6 m to 1.0 m in depth) insulated by either peat moss/muskeg and/or arborist mulch (also ~0.6 m to 1.0 m in depth) placed in a shady area if possible.
- Minimize the length of storage time if possible. Live cuttings harvested over winter / spring should not be planted past the third week of the following June.
- Ensure cuttings are of sufficient length and diameter. Cuttings that are longer and thicker have a better chance of establishing due to the larger amount of nutrient reserves present. Cuttings should be a minimum of 60 cm in length with a diameter of 2 cm to 5 cm at the tip. Cuttings should be installed such that approximately 80% of their lengths are below ground.
- Cuttings should be kept shaded and soaked in clean, fresh water for approximately five to seven days prior to installation.
- Cuttings that are stored on site for any length of time should be covered with appropriate tarps (e.g., 'Silvicool', not plastic) and watered to prevent desiccation from sun and wind exposure.
- Fence off installed cuttings to prevent disturbance from humans and wildlife, especially beavers.
- Cuttings installed higher up along the bank need to be longer in length than those placed closer to edge of the watercourse. Cuttings need to be of adequate length such that the buried portion reaches the water table and/or the humid/moist soil zone.
- Avoid installing cuttings in areas of existing dense grasses (e.g., smooth brome, reed canary grass) unless the area has been properly pre-treated for dense grass removal.
- Avoid installing cuttings in anaerobic soil. If possible, test soil conditions prior to installation by drilling a pilot hole. Anaerobic soils have an identifiable 'rotten egg' smell and generally have a black/blueish organic colour.

## Box 6: Container Plant Installation Best Practices

Best practices for container plant installation are listed below.

- Ensure all plant material selected for use in restoration projects is in a healthy state. Plant material delivered by a supplier that has low vigour (e.g., numerous dead leaves) or appears to be infested with pests or is diseased should be rejected.
- Where possible, ensure the genetics of the plant material selected for restoration projects is from the same or a similar natural subregion as that of the planting location. If given sufficient lead time (i.e., approximately two years), nurseries may be able to contract-grow the requested plant material from locally-sourced stock.
- Source plant materials as soon as possible during the course of a project to ensure that the desired species and sizes are available from the supplier. If contacted immediately prior to when the plants need to be installed on site, suppliers may not have the requested species and/or numbers. It should also be noted that suppliers may be able to contract-grow material if given sufficient lead time.
- Ensure potted plant material is not left on site to dry out in the sun. Plants should be watered regularly prior to installation and protected from direct sunlight either by using a shade cloth and/or by placing them in a shady location under mature trees if not being installed immediately while on site.
- Ensure thorough watering of all installed plant material immediately after planting. Plants should also be watered regularly throughout the first growing season at a minimum (see irrigation frequency discussion below). Placing a small amount of mulch around planted shrubs will help with moisture retention as well as weed suppression.
- Ensure potted material is planted properly per Figure 3-6. Holes in the ground should be excavated such that the entire root ball is planted below ground with no exposed roots. The hole should be deep enough such that the plant crown is right at soil level. Additional topsoil (if needed) and soil amendment should be mixed with the native topsoil and placed in the hole around the roots. The soil around the stem should then be pressed firmly by hand or lightly by foot to remove air pockets and ensure good soil to root contact. When planting on sloped ground, a small compacted berm built in a half-circle shape should be constructed on the downhill side of the plant on the outside perimeters of the rooting zone in order to retain moisture and allow percolation into the root system.
- Avoid planting in compacted soil. Compacted soil could restrict root development of planted material and lead to poor growth and survivorship. Soil can be de-compacted over a larger area if needed to plant shrubs or trees and allow proper root development. For larger projects such as the large-scale riparian retrofit sites where vehicle and large equipment use may be necessary, limiting access to specially designated travel corridors can help to minimize soil compaction. Strategically-placed fencing can be used to limit vehicle and equipment access to designated areas. Soil compaction along travel corridors can be minimized through the use of temporary thick geotextile material covered with road gravel.
- When installing shrubs and trees in areas with established perennial vegetation, particularly if aggressive, rhizomatous plant species are present, using a brush mat or mulch placed around the plant will help suppress competition from surrounding vegetation and improve the likelihood of establishment success. Larger pot sizes, although more expensive, may also be appropriate in these circumstances due to their already well-developed root systems.

- If small rodent damage to installed trees and shrubs is observed, such as girdling or chewing along the lower stems (which is common on sites with dense herbaceous cover and/or where mulch is used), apply fertilizer around the base of the shrubs/trees in late fall. The odour from the Milorganite fertilizer will deter small rodents such as voles and mice from chewing on the stems.
- Where possible, use a clustered planting design for potted shrubs and trees. Clustered plantings have an increased likelihood of survival versus random plantings (Pinno, Schoonmaker, Yucel, & Albricht, 2017). Shrub and tree clusters are also easier to fence-off (from human trampling/wildlife herbivory), weed, and water than random plantings. Individual random plantings are less visible and may be easily obscured by herbaceous vegetation. This makes them more susceptible to damage during weeding activities if hand-held mowers are used for weed control.
- Ensure species are planted at elevations and aspects as per their soil moisture and shade requirements, mimicking their occurrence in their natural ecosystem. For example, moisture-loving plants such as willows should be placed on moist sites and at lower elevations closer to waterbodies, whereas drought-resistant plants such as prickly rose should be installed at higher elevations and on south and west aspects.




*Created by Rose and Morgan, 1992.*

**Figure 3-6: Common Planting Issues**

## Vegetation Establishment

### Full Canopy Closure

Several sites were observed to have established complete or nearly complete woody vegetation canopy cover at all or portion of each site footprint (examples are shown in Photo 3-44 and Photo 3-45). Full woody vegetation canopy cover is a key goal for bioengineering projects as this condition provides the highest erosion protection, habitat, and most closely resembles a natural condition. High woody vegetation canopy cover also limits the ability for invasive weeds to establish with some of the sites with full or nearly complete canopy cover and shade having the lowest number of invasive weed species.

**Photo 3-44: Example of full canopy cover at a site installed on the Elbow River in 2015 and assessed in 2022**

**Photo 3-45: Example of full canopy cover at a site installed on the Bow River in 2016 and assessed in 2019 and 2022**

### Stems, Roots, Suckering, and Succession

Stems from shrub species were observed growing through openings in timber, rock, and concrete structures (Photo 3-46). The shrubs growing in the openings did not appear to be impacted by the restricted opening size or the vertical opening orientation and were establishing well. This demonstrates how shrubs and trees grow around and incorporate objects without displacement or deformation of the object, including riprap, and without harm to the plant (Gray & Sotir, 1996).

Roots were observed at several sites growing down below structures and growing within native substrate (Photo 3-47). The roots growing within the native soils will help to bind the soil together and increase soil cohesion and overall bank stability. Root suckering was also observed into riprap and into unplanted areas at several sites (Photo 3-48). This beneficial property of certain species such as sandbar willow and balsam poplar allow woody vegetation to establish in areas where planting had not previously occurred and contribute to overall increases in woody canopy cover and project success.

Spruce (*Picea* spp.) saplings were observed at some sites to be establishing within the bioengineering techniques (Photo 3-49). This is evidence that vegetation succession processes are occurring and demonstrates that these sites have been stable since construction and are providing the appropriate conditions for natural stabilization and ecological development over time. Also, these sites demonstrate a bioengineering tenet that recruitment from the surrounding natural communities brings the full necessary outcome for a successful project.

**Photo 3-46: Example of stem growth through a structure on the Elbow River**

**Photo 3-47: Example of root growth through a structure on the Bow River**

**Photo 3-48: Example of root suckering into toe riprap on a site on the Bow River**

**Photo 3-49: Example of a spruce tree establishing at a site on the Elbow River**

## Construction and Maintenance Practices

### Contractor Innovations

Contractors devised several innovative methods to allow successful construction outside of the dormancy period for live cuttings as described below.

- Wooden pallets were embedded into the riprap and filled with topsoil that was placed in the summer. Live cuttings were then installed in the pallets and topsoil later in the fall. Mixed vegetation survival results were observed during assessment of this technique.
- TRS were re-designed and adapted for use in Calgary in 2018 and were installed during summer construction when dormant live cuttings should not be used.
- A timber crib wall was constructed in the summer, but live cuttings were not installed until the fall dormancy period. The contractor created planting holes in the timber crib wall backfill using forks on an excavator bucket (Photo 3-50). Dormant live cuttings were then installed in the planting holes.

Contractors also developed innovative approaches to place materials, including to infill void spaces in the riprap by using a telebelt to effectively shoot the planting material deep into the riprap matrix as shown in Photo 3-51. Several innovative temporary browsing protection fences were observed during the bank effectiveness monitoring – particularly on timber crib walls.


**Photo 3-50: Forks welded to a bucket to create planting holes in timber crib wall backfill for a site on the Elbow River**

**Photo 3-51: Telebelt used to 'shoot' planting material into the void space in existing riprap on a site on the Bow River**

Another innovation that was observed was a temporary, remote, autonomous solar irrigation system that provides consistent watering to container plants via drip or spray irrigation (Photo 3-52 and Photo 3-53). The idea behind this irrigation set up is to be more cost-efficient, improve reliability and reduce risk of a fuel spill over the conventional gas-powered pumps or water trucks that also require personnel on site to maintain and operate the system. Site observations of the in-situ system were that proper coverage was not always achieved due to displacement of the drip irrigation lines. Additionally, there is some discussion whether drip irrigation provides enough volume and depth of irrigation water for live cuttings. Using the spray irrigation option can potentially resolve these issues. With Calgary being an urban environment, there are also issues with vandalism and theft of these autonomous solar watering units.

**Photo 3-52: Example of a solar powered irrigation system on a bioengineering site on the Bow River**

**Photo 3-53: Example of a solar powered irrigation system on a bioengineering site on the Bow River**

**Irrigation**

It is generally understood that the most important design consideration for bioengineering in Calgary is the arid climate due to its impact on vegetation establishment. The combination of low mean annual rainfall (419 mm) and the occurrence warm winter conditions referred to as Chinooks can cause vegetation dry-out and mortality.

General design and maintenance records were requested for the effectiveness monitoring sites including documentation for watering regime duration. However, the assessment of this limiting factor on vegetation establishment was limited in the RMP by the availability of data – particularly the lack of irrigation timing and volume records from contractors at the sites that were assessed. Key results are listed below.

- Documentation for watering regime duration was available for only **seven of the 69 sites (10%)** that were assessed (Table 3-12). The documentation that was reviewed during the desktop assessment for information on watering regime included design drawings, specifications, and maintenance records which were not always available for each project as described in Section 3.3.1.
- Irrigation practices were also evaluated as part of the field assessment of site maintenance practices that are documented by the RMP team under the Maintenance Ratings component. The average rating for irrigation integrity / efficiency / coverage under the Maintenance Rating was 0.5 / 1 with "1" being the maximum score for acceptable irrigation. Acceptable irrigation was defined as irrigation that provided full coverage of the site, was in working order (i.e., was not observed to be in disrepair with broken components) and was observed to be providing adequate water to the planted vegetation as indicated by the health of the plants and the moisture in the soil. Based on the Maintenance Rating results, 25 sites of the 69 sites **(36%)** received a full score of 1 / 1, and 26 sites **(38%)** received a zero score. A zero-score meant either no irrigation was observed at the site or no documentation was provided to the RMP team to indicate that irrigation was implemented at the site. The remaining sites received a reduced score mainly due to irrigation missing in parts of the site and the top of bank missing irrigation.
- Moisture stress was documented during the condition assessment for each of the live cuttings and container plants. Of the total 10,912 live cuttings and container plants, 511 (5%) were noted with moisture stress. The planting technique was observed to have two-thirds of the documented moisture stressed vegetation (n = 339), with brush layers and live staking with 12% (n = 62) and 9% (n = 45), respectively. **This result points to the need for improved irrigation for container plants that are installed on the top of bank.**

In addition, 12 different sites were observed to have one transect with 25% or more of the assessed vegetation with moisture stress. The 12 sites included three brush layer and vegetated riprap technique transects, two planting and live staking technique transects, and one box fascine and vegetated retaining wall technique transects. Given the diversity of techniques, **there is not a strong conclusion regarding a particular bioengineering technique that needs improvement in irrigation implementation, with the exception of the planting technique noted above.**

- Using deeply buried structures such as brush layers or hedge brush layers on their own or in other structures such as timber crib walls or vegetated riprap can reduce the required irrigation volume since the live cuttings have better access to soil moisture. Additionally, irrigation volume may be reduced by deeply installing container plants (i.e., root mass 2 cm below the soil surface).

Specific data on irrigation method (drip or spray), volume, and duration were not available from the bank effectiveness data that was provided. There is considerable debate on the whether drip or spray irrigation is the best technique, as both have their pros and cons. For example, drip irrigation wastes less water and provides water at a specific plant location when targeting specific plants but may not be suitable for high density planting such as brush layers. Also, spray irrigation provides better coverage of an area, but may also irrigate unwanted plants (e.g., weeds) due to overspray (should be mitigated by weed control), and will likely use a larger volume of water than drip irrigation.

When spray irrigation is used, a good practice is to initially install the system at a height of ±1.3 m to avoid interference by growing vegetation and provide consistent coverage of the site. This will also reduce soil erosion created by the interference of the spray from the vegetation stems and canopy and avoid additional work to raise the sprinkler heads above the height of the growing vegetation at a later date.

For volume and duration, examples of specifications that have been used in past projects are provided in Box 7. Note that these specifications are prescriptive and may not work for all sites. Additional considerations for irrigation design that should be considered include vegetation type, soil type, site location (e.g., bank, top of bank, riparian area, etc.), and irrigation water source (e.g., municipal source, river water, pond, etc.). Irrigation volume should be measured using a water meter to facilitate billing for use of municipal water and tracking against Temporary Diversion Licence requirements when river water is used. A designer should work with The City to determine a site-specific approach with adequate justification for the chosen system.

### Box 7: Example Irrigation Specifications

Two example irrigation specifications for watering duration regime are provided below. Note that the irrigation system design should be approved by The City based on a site-specific approach with adequate justification for the chosen system.

**Example Irrigation Specification 1**

1. Water the live cuttings and container plants in the bioengineering structures for the first three (3) growing seasons for a period of 6 months (May to October) in accordance with the following schedule:
    a. Once (1) per week in May / September / October;
    b. Two (2) times per week in June / July / August; and,
    c. Additional watering may be required up to a maximum of three (3) times per week if daily high temperatures are above 30°C or as specified by The City Representative or their designate.
2. Water the live cuttings and the container plants per the schedule above unless 25 mm of precipitation (rain) or more was recorded near over the project site area during the previous 7 days.
3. Water between the hours of 6am to 9am and/or 7pm to 11pm, unless otherwise directed by the Consultant
4. Water container trees no less than 80 L per watering application.

**Example Irrigation Specification 2**

1. The “growing season” referred to below is defined as May to October (inclusive) and “summer” is defined as July and August. Watering shall be done prior to 9am or after 7pm for conservation and plant health.
2. Minimum Vegetation Watering Schedule:
    a. First week to ten days after installation: water daily 1-2 hours.
    b. First growing season: water 3 hours, 2x per week.
    c. First summer: water 4 hours, 3x per week, unless looking dry (temperatures above 30°C), then add additional watering cycle as necessary.
    d. Second growing season: 3 hours, 2x per week.
    e. Second summer: water 3 hours, 3x per week, unless looking dry (temperatures >30°C), then add additional watering as necessary.

   f. Third growing season: 2 hours, 1x per week.
   g. Third summer: 2 hours, 2x per week, unless looking dry (temperatures >30°C), then add additional watering as necessary.
3. Additional watering requirements are as follows:
   a. An additional watering may be required in April each year, dependent on dry and warm temperatures. Check with The City Representative for direction and approval in late March and throughout April.
   b. Deep soaking of trees is required prior to winter shutdown (1st week of November).
4. Watering date, time, and approximate volume is to be recorded in the maintenance log.
5. Natural precipitation (moderate rate) for >45min may substitute as one watering application.

**Temporary Browsing Protection Fencing Repair/Removals**

As observed in each monitoring year, temporary fencing was documented at several sites to be in a state of disrepair and/or left behind after construction activities were complete, examples of which are shown in Photo 3-54 and Photo 3-55. This fencing is intended to protect the planting areas from browsing and human/animal impacts during the construction warranty period and should be maintained in working condition and then removed at the end of the construction contract when the vegetation has established. Note that in many cases fencing and metal posts that have not been removed from site are also causing a public hazard to boaters, pedestrians, and wildlife.

**Photo 3-54: Temporary browsing protection fencing to be removed due to hazard to wildlife and the public**

**Photo 3-55: Submerged temporary browsing protection fencing in need of repair**

**Weeding Methods**

In 2020, mechanical damage was observed on 8 out of 21 (38%) sites visited as shown in Photo 3-56 and Photo 3-57. A manual tool should be used to remove invasive weeds and seeded graminoids that are competing with the plantings instead of mechanical tools such as a weed wacker. The spacing between plants can make it challenging to operate a weed wacker without damaging neighbouring plants.

It should be noted and enforced that native grasses <u>should not be mowed</u> throughout the growing season to allow them to establish properly and reseed themselves. Mowing was observed on many of the monitoring sites and in some cases mowing damage extended to planted woody shrubs.

Photo 3-56: Weed wacker damage to Year 1 age class prickly rose in summer 2019


Photo 3-57: Weed whacker damage to Year 1 age class saskatoon in Fall 2020

## Post-Construction Performance Monitoring

### Post-Construction Monitoring Methods

A key success for the bank effectiveness component of the RMP is the methods and protocols that have been developed and used to collect the data. The methods are replicable on any bioengineering site, and while collecting the full data-set for a site can be time intensive, they can be adjusted if only a particular component of the data is of interest (e.g., Year 1 survival, density, or canopy cover). The result of using the RMP data collection methods at a previously unmonitored bioengineering site is that the data can be compared against the RMP bank effectiveness data to assess post-construction performance and the vegetation growth trajectory over time.

An example of how the bank effectiveness data can be used for post-construction monitoring is illustrated by the following. In this example, two species of live cuttings (balsam poplar and sandbar willow) and three species of container plant (Common wild rose, red-osier dogwood, and saskatoon) were individually measured for shoot length in Year 1 post-construction (Table 3-13) and Year 3 post-construction (Table 3-14). By comparing the measured shoot length to the bank effectiveness data, the following observations can be made:

- Balsam poplar live cutting were establishing well in Year 1 (above the 75$^{th}$ percentile) but have begun to lag in their growth in Year 3 (well below the mean) and mitigation measures (e.g., weeding, irrigation, soil decompaction, etc.) may be needed.
- Sandbar willow are establishing very well as both Year 1 and Year 3 values are above the 75$^{th}$ percentile for shoot length.
- Common wild rose may be struggling to establish at the site (both Year 1 and Year 3 values are below the 25$^{th}$ percentile) and mitigation measures may be needed.
- Red-osier dogwood were struggling to establish in Year 1 (below 25$^{th}$ percentile) and has all died by Year 3. Replanting is required – possibly of another species.
- Saskatoon was of concern in Year 1 (between 25$^{th}$ percentile and mean) but in Year 3 seems to be growing as expected where shoot length was measured slightly above the mean.

**Table 3-13: Comparison of Leader Growth by Species for Year 1 Post Construction**

| Species | Cutting (C) / Rooted (R) | RMP Year 1 Shoot Length Data | | | Measured Shoot Length (cm) | Measured Sample Size |
|---|---|---|---|---|---|---|
| | | 25th PCTL (cm) | Mean (cm) | 75th PCTL (cm) | | |
| Balsam poplar (*Populus balsamifera*) | C | 26 | 44 | 56 | 70 | 10 |
| Sandbar willow (*Salix interior*) | C | 64 | 110 | 150 | 153 | 10 |
| Common wild rose (*Rosa woodsii*) | R | 46 | 63 | 72 | 52 | 10 |
| Red-osier dogwood (*Cornus sericea*) | R | 50 | 74 | 89 | 45 | 10 |
| Saskatoon (*Amelanchier alnifolia*) | R | 30 | 51 | 66 | 40 | 10 |

**Table 3-14: Comparison of Leader Growth by Species for Year 3 Post Construction**

| Species | Cutting (C) / Rooted (R) | RMP Year 3 Shoot Length Data | | | Measured Shoot Length (cm) | Measured Sample Size |
|---|---|---|---|---|---|---|
| | | 25th PCTL (cm) | Mean (cm) | 75th PCTL (cm) | | |
| Balsam poplar (*Populus balsamifera*) | C | 67 | 99 | 129 | 75 | 10 |
| Sandbar willow (*Salix interior*) | C | 117 | 170 | 228 | 232 | 10 |
| Common wild rose (*Rosa woodsii*) | R | 63 | 91 | 116 | 62 | 10 |
| Red-osier dogwood (*Cornus sericea*) | R | 66 | 98 | 123 | n/a | 0 |
| Saskatoon (*Amelanchier alnifolia*) | R | 69 | 48 | 83 | 55 | 10 |

**Bioengineering Site Performance Targets**

The data collected for the effectiveness component of the RMP allow the validation of bioengineering site performance targets that have been established in the literature but not confirmed for Calgary. The results for woody vegetation survival, cover, and density of living shoots for several bioengineering techniques are provided in Section 3.3.2 in Table 3-21, Table 3-31, and Table 3-32 respectively and for herbaceous canopy cover are provided in Table 3-35. When these results are compared to the published cover, density and survival targets as recommended by Schiechtl and Stern (1997) the published targets are met or exceeded as listed in Table 3-15. Because the bank effectiveness results either meet or are close to meeting the Schiechtl and Stern (1997) targets (Table 3-15), they are recommended for consideration as contract warranty and regulatory targets for bioengineering projects in Calgary.

**Table 3-15: Bioengineering Technique Performance Targets**

| Target Application | Target Description[1,2] | Target Achieved Based on RMP Results (Y/N) |
|---|---|---|
| Herbaceous Vegetation | Seeding and seed mats must have an even stand of the specified graminoids with no less than 50% effective ground cover. Volunteer vegetation suitable for the habitat and of equal value may be accepted as part of the ground cover. | N – Seeding technique at 39% for Year 1, 35% for Year 3, and 37% for Year 5+ age class sites (Table 3-35) |
| Woody vegetation survival | Shrubs and tree plantings maximum failure rate for the individual shrubs or tree must not exceed 30% (from initially planted) and the objectives must be achieved. | Y – all except for the below<br>N – brush layers (67%), vegetated crib wall (57%), and vegetated riprap (65%)<br>(Table 3-21) |
| Woody vegetation density of living shoots by bioengineering technique | Live plants material: fascines, brush layers, hedge brush layer and wattle fences must show an average of five and a minimum of two live shoots per linear meter. | Y – Brush layers and fascines results range from 3 to 5.9 stems/m and 30 to 37 stems/m respectively depending on age class (Table 3-32) |
| | Brush mattress must show an average of ten and a minimum of five shoots per $m^2$ approximately evenly spaced. | Y – Brush mattress results range from 19 to 43 stems/m² depending on age class (Table 3-32) |
| Woody vegetation canopy cover | Two thirds of all live staking/poles must have thrown shoots maintaining an even distribution pattern over the whole area. | N – Live staking canopy cover ranges from 45% to 55% depending on age class (Table 3-31) |

Notes:
1. Source: *Schiechtl & Stern (1997) Water Bioengineering Techniques for Watercourse Bank and Shoreline Protection*
2. From Schiechtl & Stern (1997): “This requires on average from two to five growing seasons, and provision should be made in the tender specifications. At the end of this period, all vegetative components should be at a stage that ensures their continuing progress, and all works should be fully functional.”

## Site-Specific Limiting Factors for Success

As mentioned above in the discussion on irrigation in the Construction and Maintenance Practices section, a limiting factor for all sites in Calgary is the dry climate. Additional, site-specific limiting factors for site stability and vegetation establishment success were documented as part of the Structural Assessment. The limiting factors that were documented do not necessarily indicate a cause of failure, but rather conditions that limit the ability of the site to reach its full potential – either from sites not stabilizing as intended or vegetation growth not meeting expectations.

Based on the results shown in Table 3-16, the limiting factors that were most often documented for failure sites were “erosion”, “existing vegetation competition”, and “maintenance issues”, which were all identified at six of seven failure sites. The most often documented limiting factor for successful sites was “maintenance issues” for Year 1 age class sites (29 of 32 sites), “existing vegetation competition” and “maintenance issues” for Year 3 age class sites (30 of 31 sites), and “insect disease”, “existing vegetation competition”, and “maintenance issues” for Year 5+ age class sites (28 of 29 sites). The most often noted limiting factors over all sites were “maintenance issues” (93 of 99 sites), “existing vegetation competition” (92 of 99 sites), and “compacted soils” (76 of 99 sites).

Planting into anaerobic soils was considered a direct cause of failure for three (3) sites: one on Nose Creek, one on the Bow River at Quarry Park, and one at Shaganappi Creek (KWL, 2019b). Anaerobic soils are identifiable by the 'rotten egg' smell and a general bluish/black colour (**Photo 3-58** and **Photo 3-59**) and were not observed everywhere. They were, however, often observed at the toe of bank for both Nose Creek and West Nose Creek. To avoid planting in anaerobic soils, it is recommended to test the soil prior to live cutting installation with a small soil test pit or pilot hole. An option to manage anaerobic soil zones is to use rock as erosion protection up to the limit of anaerobic soils and bioengineering techniques above.

Site-specific physical characteristics and limiting factors for each bank effectiveness site are provided in Table E-1 and Table E-2 in Appendix E.

**Table 3-16: Limiting Factors by Failure or Successful Assessments and Age Class**

| Limiting Factors | No. of Failure Assessments (n = 7) | No. of Successful Assessments | | | Total No. of Assessments (n = 99) |
|---|---|---|---|---|---|
| | | Year 1 age class (n = 32) | Year 3 age class (n = 31) | Year 5+ age class (n =29) | |
| Slope instability | 5 | 8 | 9 | 6 | 28 |
| Slope gradient | 5 | 15 | 15 | 23 | 58 |
| Erosion | 6 | 23 | 20 | 14 | 63 |
| Compacted soils | 5 | 19 | 26 | 26 | 76 |
| Anaerobic soils | 5 | 4 | 1 | 3 | 13 |
| Insect damage and disease | 2 | 19 | 24 | 28 | 73 |
| Trampling by people or dogs | 4 | 16 | 12 | 16 | 48 |
| Motorized vehicles | 1 | 1 | 0 | 0 | 2 |
| Non motorized vehicles | 3 | 3 | 2 | 0 | 8 |
| Aspect | 3 | 16 | 15 | 17 | 51 |
| Bank profile | 4 | 18 | 17 | 23 | 62 |
| Existing vegetation competition | 6 | 28 | 30 | 28 | 92 |
| Shade | 3 | 14 | 12 | 14 | 43 |
| Maintenance issues | 6 | 29 | 30 | 28 | 93 |
| Wildlife impact | 3 | 13 | 15 | 20 | 51 |
| Access | 5 | 16 | 12 | 23 | 56 |

**Photo 3-58: Live cutting planted in anaerobic soil at a site on West Nose Creek**

**Photo 3-59: Live cutting planted in anaerobic soil at a site on Shaganappi Creek**

## Failure Sites

The RMP failure site protocol is described in Section 3.1.7. The most common reason for failure was due to vegetation survival of less than 25%. Other failures were due to the structures not being present or failing structurally. When site failures are assessed based on typology as shown in Figure 3-7, the highest failure rate and number of failure sites is Primarily Vegetative at 14% with four failure sites. The lowest failure rate is 0% for Vegetated Crib Wall; however, there was a Vegetative Crib Wall site that was assessed as a failure but was removed from the program due to a data collection issue.

The top seven failure factors from the detailed failure analysis that was conducted are presented in Table 3-17. As shown, the main reason sites failed was noted to be “other” where the issues that were noted were structure type (wattle fence), late installation of spring harvested cuttings (installed in July/August), and live staking not installed according to design (spaced too far apart, too shallow, and too far down the bank into anaerobic soil at the toe). Other common failure factors were planting into anaerobic soils, bank or slope instability/erosion, structure failure, wildlife damage, vegetation competition, and poor planting installation (e.g., too shallow with root system exposed). Future restoration projects will need to ensure these issues are dealt with as best as possible to avoid failure.

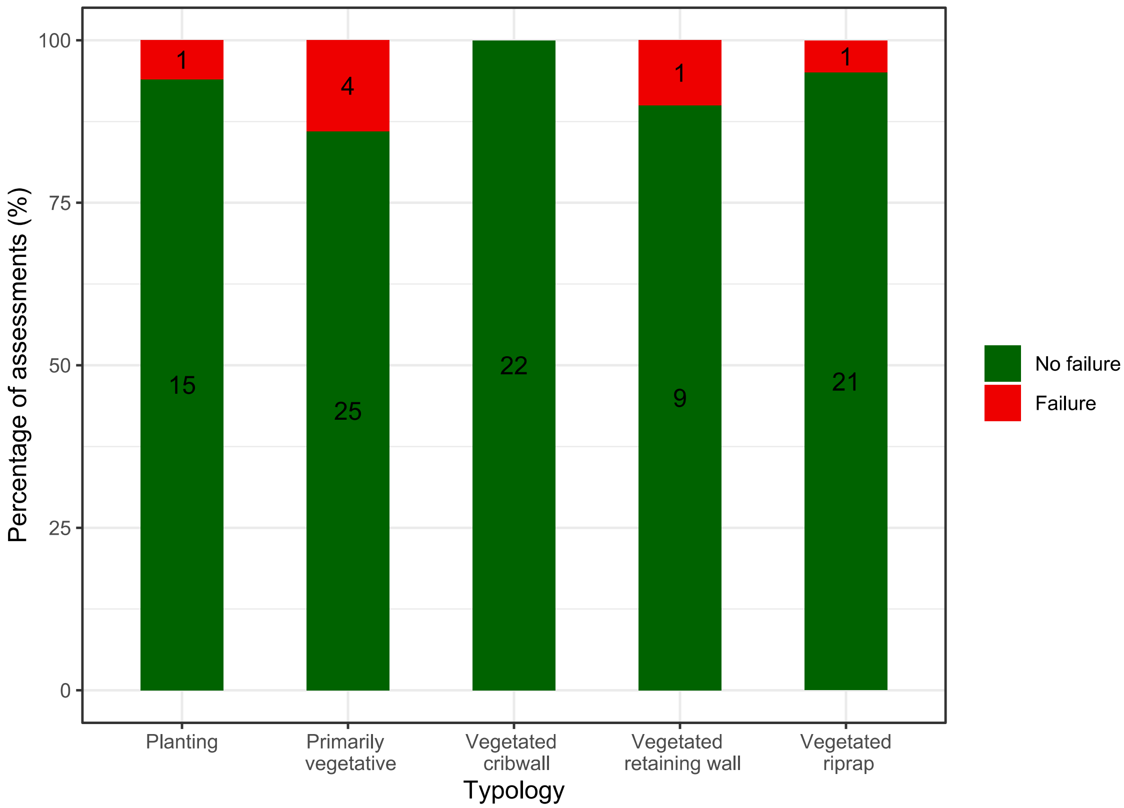



**Figure 3-7: Failure Sites by Typology** [7]

**Table 3-17: Failure Factors for Failure Sites**

| Failure Factors | No. Sites | Proportion of Sites (%) |
|---|---|---|
| Other | 7 | 100 |
| Anaerobic soil | 6 | 86 |
| Bank or slope instability/erosion | 5 | 71 |
| Structure failure | 5 | 71 |
| Wildlife damage/browsing/girdling | 5 | 71 |
| Vegetation competition | 5 | 71 |
| Poor planting installation | 5 | 71 |

[7] The numbers shown on the bars in the chart indicate the number of sites.

## Ratings

The average ratings are summarized below for all 99 bank effectiveness assessments. The average overall rating for all assessments was 67/100 which falls in the 'Fair' category. There were 34 assessments in the 'Good' category (ratings between 75-100), 55 assessments in the 'Fair' category (ratings between 50-74) and 10 assessments in the 'Poor' category (ratings between 0-49) which indicates that there is still room for improvement in bioengineering projects in Calgary for all sites to achieve a 'Good' rating.

- **Design Rating**: The overall average design rating was 14/18. Examples of reasons for reductions in design ratings were limited design information provided to the RMP team; design approach not fully suited to site conditions (e.g., erosion was observed, missing toe protection, synthetic matting used when not necessary); and contract specifications that do not follow the City of Calgary design guidelines (AMEC, 2012) (e.g., scheduling, stock handling, soil amendment, rodent fencing).
- **Implementation Rating**: The overall average implementation rating was 12/18. In general, the non-living components of the constructed works were found to be installed well; however, the implementation of the living, or plant, component of the projects could be improved.
- **Maintenance Ratings**: The overall average maintenance rating was 11/18. There continues to be room for improvement for maintenance scores. Maintenance records were unavailable to the project team for many of the assessed sites (see Section 3.3.1). Therefore, it was difficult to confirm what, if any, maintenance activities were occurring, which led to low ratings. Low maintenance scores were one of the main reasons for low overall scores for the bank effectiveness sites.
- **Success Ratings**: The overall average success rating was 17/24. Good stability and vegetation establishment led to high success ratings.
- **BRQI Ratings**: The overall average BRQI score was 12/22. Total vegetation cover was generally high at all sites outside of riprap areas. The most common reasons for reduced BRQI ratings were low cover of regenerating preferred trees and shrubs, low diversity in plant community structure, and high cover of invasive species and disturbance-increaser species.

**Table 3-18: Mean Ratings**

| Age Class | Design rating (/18) | Implementation rating (/18) | Maintenance rating (/18) | Success rating (/24) | BRQI (/22) | Overall score (/100) | Number of samples |
|---|---|---|---|---|---|---|---|
| 1 | 14 | 12 | 12 | 18 | 13 | 67 | 37 |
| 3 | 14 | 13 | 11 | 16 | 13 | 65 | 33 |
| 5+ | 14 | 12 | 10 | 18 | 14 | 69 | 29 |
| Mean | 14 | 12 | 11 | 17 | 12 | 67 | -- |
| **Total (/100)** | **78** | **67** | **61** | **71** | **55** | **67** | **--** |

### Low Maintenance and BRQI Ratings

The most common reasons for low overall ratings were low maintenance and BRQI ratings. Low maintenance ratings were often attributable to lack of documentation that maintenance was occurring. Improvements in contractor requirements for record keeping and/or more stringent maintenance requirements would quickly improve maintenance ratings.

BRQI ratings are more challenging to improve as they are based on eight vegetation and physical parameters that are generated from transect data. In general, while all components of the BRQI rating could be improved, a reduction in disturbance increaser plant species canopy cover, reduction in invasive species canopy cover, and improvements in plant community structure through maintenance activities (e.g., weeding) would be relatively simple ways to help improve overall BRQI scores. BRQI scores should improve naturally over time as, for example, vegetation cover increases, bare soil cover decreases, and structural diversity improves, provided sites are set on the proper trajectory early on through good design, implementation, and maintenance practices.

### 3.3.2 Statistical Results

Key statistical results are summarized in the section below. Given the volume of data that was collected during the five years of monitoring, only the results that were statistically significant and that were important to justify a recommendation are provided in the section below. A large number of results are not included due to limited statistical validity and applicability but are available in the annual summary reports.

#### Woody Vegetation Year 1 Age Class Survivorship

As described in Box 3, woody vegetation survivorship is an important metric to measure vegetation establishment success for a bioengineering project and is typically a contractual target for warranty and regulatory purposes. The results for Year 1 age class woody vegetation survivorship are provided below for live cuttings and container plants, woody vegetation species, and bioengineering technique for the 92 successful assessments. Note that survivorship results were only collected for Year 1 age class woody vegetation because it is the most accurate data for survivorship since a full count of both living and dead planted material is possible. Year 3 and Year 5+ age class results were not collected due to the difficulty in counting dead container plant or live cuttings as they would be in an advanced state of decay or missing completely and likely obscured by the established vegetation.

**Survivorship for Live Cuttings and Container Plants**

Over the five years of pooled data, survival of Year 1 age class live cuttings and container plants combined was 76% (n = 7,280) as shown in Figure 3-8 a). The overall survivorship for Year 1 age class container plants alone was (94%, n = 1,982) as shown in Figure 3-8 b). The overall survivorship for Year 1 age class live cuttings was 69% (n = 5,298) as shown in Figure 3-8 c).

It was a consistent finding for each monitoring year that container plant survivorship was statistically higher than live cuttings survivorship. This was attributed in part to nurseries' acclimatizing container plants to the plant growth limiting factors within the Calgary region which are primarily climate-related, including low precipitation and occurrence of Chinooks (i.e., desiccating warm winter conditions) prior to installation.

Note that while survivorship of container plants was higher than live cuttings, they cannot be used in the same arrangements and for the same functions as live cuttings due to shallow roots systems that can easily wash out (Hoag, 2007). Also, several live cuttings can be planted for the same cost as a container plant to accommodate the lower survivorship, depending on the size (length and diameter) of the live cuttings and size and cost of the container plants. Thus, it is still recommended to use live cuttings as the key component to bioengineering projects as discussed in Box 4. However, it may be prudent to use container plants instead of live cuttings for bank and riparian restoration projects where the site conditions and project objectives warrant. For example, if the primary objective of a project is to improve cover of riparian vegetation and not soil stabilization on the riverbank, then container plants likely should be used instead of live cuttings.

The overall survivorship data for 2018-2022 are in the range of the typical Year 1 age class survival thresholds for regulatory approvals (often in the 70% to 80% range); however, the results encompass a large variability across sites and species, and this analysis only includes the successful sites. If failure sites were included, the overall survivorship across the projects in the city would have been lower.

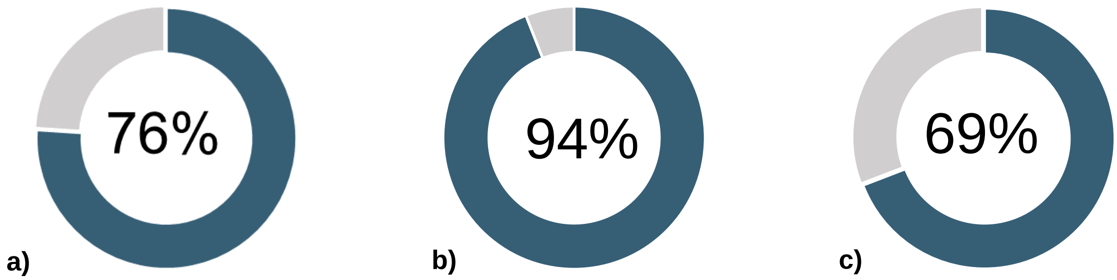



**Figure 3-8: Survivorship for Year 1 Woody Vegetation: a) Combined Live Cuttings and Container Plants; b) Container Plants; and c) Live Cuttings**

**Survivorship by Species**

A key result from the data collected for the RMP over 2018-2022 was the species-specific survivorship data for both container plant and live cuttings species.

The survivorship of container plant species is shown in Table 3-19 for a total of 3,872 container plants sampled over 2018-2022. The survival rate for Year 1 age class plants for most species was found to be quite high, often over 90%. The exceptions are green alder (*Alnus viridis*) and Canada buffaloberry (*Shepherdia canadensis*) with survivorships of 25% (n = 25) and 70% (n = 33) respectively for Year 1 age class – likely due to poor nursery stock.

The survivorship of live cuttings species is shown in Table 3-20 for a total of 5,298 live cuttings sampled over 2018-2022. The Year 1 age class survivorship of balsam poplar (*Populus balsamifera*), hungry willow (*Salix famelica*), and sandbar willow (*Salix interior*), the most commonly used species for bioengineering in Calgary, were found to be moderate (between 62% to 78%) even though these species are known to have a very good ability to root from cuttings (AMEC, 2012; USDA NRCS, 1996; Gray & Sotir, 1996). Low Year 1 age class survivorship of red-osier dogwood (*Cornus sericea*) (49%) was observed in the results but was anticipated due to the observed lower success rate for live cuttings of this species in Calgary over the last decade.

Based on the RMP team's understanding of the available literature for vegetation survivorship, there is very limited or no data available to compare live cutting and container plant species survivorship in bioengineering sites to the results from the RMP. Thus, this data is a benchmark for further research into species survival.

**Table 3-19: Survival Rates & Mean Values of Growth Measurements of Container Plant Species by Age Class**

| Species | Year 1 Age Class[1] | | | | | Year 3 Age Class[1] | | | | Year 5+ Age Class[1] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. Plants | Survival Rate (%) | Leader Growth (cm) | Shoot Length (cm) | Stem Dia. (cm) | No. Plants | Leader Growth (cm) | Shoot Length (cm) | Stem Dia. (cm) | No. Plants | Leader Growth (cm) | Shoot Length (cm) | Stem Dia. (cm) |
| Alder (*Alnus incana*) | 57 | 86 | 35 | 91 | 1.4 | 12 | 23 | 90 | 1.8 | 1 | 29 | 114 | 1.7 |
| Aspen (*Populus tremuloides*) | 31 | 100 | 14 | 394 | 6.1 | 38 | 26 | 455 | 6.0 | 1 | 83 | 103 | 1.0 |
| Balsam poplar (*Populus balsamifera*) | 204 | 96 | 73 | 248 | 3.5 | 101 | 28 | 301 | 4.8 | 42 | 35 | 353 | 7.9 |
| Basket willow (*Salix petiolaris*) | 0 | n/a | n/a | n/a | n/a | 0 | n/a | n/a | n/a | 14 | 35 | 81 | 1.5 |
| Beaked willow (*Salix bebbiana*) | 20 | 100 | 6 | 12 | 0.4 | 0 | n/a | n/a | n/a | 32 | 33 | 177 | 3.7 |
| Buckbrush (*Symphoricarpos occidentalis*) | 94 | 100 | 28 | 51 | 0.7 | 108 | 20 | 73 | 0.9 | 81 | 18 | 74 | 1.0 |
| Canada buffaloberry (*Shepherdia canadensis*) | 33 | 70 | 13 | 49 | 1.1 | 1 | 22 | 62 | 2.1 | 7 | 8 | 73 | 1.4 |
| Choke cherry (*Prunus virginiana*) | 108 | 94 | 22 | 77 | 1.3 | 80 | 26 | 93 | 1.5 | 10 | 45 | 94 | 1.7 |
| Common wild rose (*Rosa woodsii*) | 230 | 98 | 29 | 62 | 0.7 | 135 | 35 | 91 | 1.0 | 65 | 32 | 133 | 1.3 |
| Dwarf birch (*Betula pumila*) | 0 | n/a | n/a | n/a | n/a | 1 | 12 | 154 | 2.4 | 0 | n/a | n/a | n/a |
| Golden current (*Ribes aureum*) | 25 | 100 | 42 | 82 | 1.0 | 23 | 30 | 110 | 1.2 | 5 | 27 | 158 | 2.5 |
| Green alder (*Alnus viridis*) | 36 | 25 | 30 | 50 | 0.7 | 0 | n/a | n/a | n/a | 0 | n/a | n/a | n/a |
| High-bush Cranberry (*Viburnum opulus*) | 57 | 98 | 18 | 34 | 0.8 | 12 | 16 | 52 | 0.7 | 0 | n/a | n/a | n/a |
| Hungry willow (*Salix famelica*)[2] | 50 | 86 | 26 | 109 | 1.4 | 36 | 53 | 124 | 1.6 | 24 | 30 | 292 | 4.1 |
| Northern gooseberry (*Ribes oxyacanthoides*) | 214 | 97 | 20 | 50 | 0.6 | 82 | 21 | 67 | 0.8 | 13 | 17 | 68 | 1.0 |
| Oval-leaved milkweed (*Asclepias ovalifolia*) | 0 | n/a | n/a | n/a | n/a | 9 | n/a | 47 | n/a | 0 | n/a | n/a | n/a |
| Prickly rose (*Rosa acicularis*) | 37 | 81 | 20 | 47 | 0.7 | 95 | 19 | 78 | 0.8 | 35 | 26 | 107 | 1.1 |
| Pussy willow (*Salix discolor*) | 0 | n/a | n/a | n/a | n/a | 0 | n/a | n/a | n/a | 1 | 26 | 125 | 1.4 |
| Red elderberry (*Sambucus racemosa*) | 4 | 100 | 43 | 69 | 4.5 | 4 | 27 | 75 | 1.4 | 4 | 9 | 123 | 2.3 |

| Species | Year 1 Age Class[1] | | | | | Year 3 Age Class[1] | | | | Year 5+ Age Class[1] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. Plants | Survival Rate (%) | Leader Growth (cm) | Shoot Length (cm) | Stem Dia. (cm) | No. Plants | Leader Growth (cm) | Shoot Length (cm) | Stem Dia. (cm) | No. Plants | Leader Growth (cm) | Shoot Length (cm) | Stem Dia. (cm) |
| Red-osier dogwood (*Cornus sericea*) [3] | 264 | 95 | 31 | 74 | 1.0 | 141 | 28 | 98 | 1.5 | 70 | 26 | 139 | 1.9 |
| Sandbar willow (*Salix interior*) [4] | 74 | 96 | 73 | 119 | 1.0 | 35 | 57 | 160 | 1.7 | 99 | 60 | 201 | 2.5 |
| Saskatoon (*Amelanchier alnifolia*) | 156 | 92 | 15 | 51 | 1.0 | 66 | 25 | 69 | 1.2 | 45 | 30 | 132 | 1.7 |
| Shinning willow (*Salix lasiandra*) | 22 | 96 | 20 | 64 | 2.0 | 24 | 18 | 70 | 1.6 | 10 | 16 | 419 | 6.2 |
| Showy milkweed (Asclepias speciosa) | 0 | n/a | n/a | n/a | n/a | 5 | n/a | 70 | n/a | 0 | n/a | n/a | n/a |
| Showy mountain ash (*Sorbus decora*) | 2 | 100 | 12 | 169 | 2.2 | 2 | 25 | 179 | 3.0 | 0 | n/a | n/a | n/a |
| Shrubby cinquefoil (*Dasiphora fruticosa*) | 43 | 100 | 25 | 50 | 1.0 | 64 | 14 | 75 | 0.9 | 30 | 20 | 97 | 1.3 |
| Silverberry (*Elaeagnus commutata*) | 152 | 99 | 27 | 64 | 1.2 | 82 | 27 | 87 | 1.4 | 66 | 21 | 126 | 1.8 |
| Thorny buffaloberry (*Shepherdia argentea*) | 4 | 100 | 15 | 75 | 1.2 | 18 | 25 | 60 | 1.2 | 2 | 15 | 82 | 2.4 |
| Twinberry honeysuckle (*Lonicera involucrata*) | 0 | n/a | n/a | n/a | n/a | 2 | 31 | 71 | 1.6 | 0 | n/a | n/a | n/a |
| Water birch (*Betula occidentalis*) | 65 | 92 | 28 | 146 | 1.8 | 27 | 26 | 162 | 2.5 | 20 | 39 | 134 | 2.2 |
| Wild red raspberry (*Rubus idaeus*) | 0 | n/a | n/a | n/a | n/a | 0 | n/a | n/a | n/a | 10 | 49 | 64 | 0.8 |

Notes:
1. Mean values for leader growth, shoot length, and diameter are provided in the table. Mean, 25th and 75th percentile data is provided in Appendix E, Table E-7.
2. Synonym: Yellow Willow (*Salix lutea*)
3. Synonym: *Cornus stolonifera*
4. Commonly referred to as *Salix exigua* in the background documentation.

**Table 3-20: Survival Rates & Growth Measurements of Live Cutting Species by Age Class**

| Species | Year 1 Age Class[1] | | | | | Year 3 Age Class[1] | | | | Year 5+ Age Class[1] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. plants | Survival rate (%) | Leader growth (cm) | Shoot length (cm) | Dia. (cm) | No. plants | Leader growth (cm) | Shoot length (cm) | Dia. (cm) | No. plants | Leader growth (cm) | Shoot length (cm) | Dia. (cm) |
| Balsam poplar (*Populus balsamifera*) | 642 | 62 | 33 | 44 | 0.8 | 158 | 32 | 99 | 1.5 | 61 | 38 | 161 | 2.3 |
| Basket willow (*Salix petiolaris*) | 53 | 98 | 22 | 27 | 0.4 | 26 | 51 | 104 | 1.4 | 23 | 25 | 121 | 1.5 |
| Beaked willow (*Salix bebbiana*) | 393 | 79 | 48 | 53 | 0.5 | 52 | 33 | 97 | 1.0 | 66 | 33 | 141 | 2.0 |
| False mountain willow (*Salix pseudomonticola*) | 12 | 100 | 30 | 73 | 0.6 | 0 | n/a | n/a | n/a | 2 | 125 | 151 | 1.6 |
| Flat-leaved willow (*Salix planifolia*) | 3 | 100 | 33 | 33 | 0.4 | 0 | n/a | n/a | n/a | 15 | 30 | 120 | 1.8 |
| Hoary willow (*Salix candida*) | 0 | n/a | n/a | n/a | n/a | 1 | 20 | 38 | 0.7 | 0 | n/a | n/a | n/a |
| Hungry willow (*Salix famelica*) [2] | 1,403 | 74 | 57 | 77 | 0.7 | 305 | 55 | 152 | 1.5 | 206 | 49 | 180 | 2.2 |
| Narrow-leaf cottonwood (*Populus angustifolia*) | 0 | n/a | n/a | n/a | n/a | 0 | n/a | n/a | n/a | 2 | 26 | 239 | 4.5 |
| Plains cottonwood (*Populus deltoides*) | 0 | n/a | n/a | n/a | n/a | 0 | n/a | n/a | n/a | 18 | 48 | 207 | 3.4 |
| Pussy willow (*Salix discolor*) | 0 | n/a | n/a | n/a | n/a | 10 | 19 | 21 | 0.4 | 10 | 61 | 138 | 1.7 |
| Red-osier dogwood (*Cornus sericea*) | 559 | 49 | 23 | 29 | 0.4 | 89 | 23 | 65 | 0.8 | 34 | 18 | 121 | 1.5 |
| Salix spp. [3] | 190 | 0 | n/a | n/a | n/a | 0 | n/a | n/a | n/a | 0 | n/a | n/a | n/a |
| Sandbar willow (*Salix interior*) [4] | 2,041 | 78 | 68 | 110 | 0.7 | 398 | 61 | 170 | 1.4 | 252 | 60 | 232 | 2.4 |
| Shining willow (*Salix lasiandra* var. *lasiandra*) | 2 | 100 | 25 | 25 | 0.3 | 0 | n/a | n/a | n/a | 11 | 32 | 155 | 1.9 |
| Shining willow (*Salix lasiandra* var. *caudata*) | 0 | n/a | n/a | n/a | n/a | 3 | 17 | 23 | 0.5 | 0 | n/a | n/a | n/a |

Notes:
1. Mean values for leader growth, shoot length, and diameter are provided in the table. Mean, 25th and 75th percentile data is provided in Appendix E, Table E-7.
2. Synonym: Yellow Willow (*Salix lutea*)
3. These cuttings were all dead and not identifiable as a particular species.
4. Commonly referred to as *Salix exigua* in the background documentation.

### Survivorship by Bioengineering Technique

Survival of live cuttings and container plants according to eight bioengineering techniques assessed during the five-year RMP is shown in Table 3-19. The largest number of assessed plants was from the brush layer technique (n = 2,292), followed by the plantings technique (n = 1,554) and vegetated riprap technique (n = 1,056). Year 1 age class survivorship for the brush mattresses technique at 96% (n = 343) and plantings technique at 94% were the highest of all the techniques with a large number of samples.

The brush layers and vegetated riprap techniques had a Year 1 age class survivorship of 67% and 65% respectively. The lowest survivorship of the techniques assessed using 2018-2022 data was vegetated crib wall at 57% (n = 254). Live staking survivorship was 70% (n = 980).

The wattle fence technique is shown with the highest Year 1 age class survivorship (100%, n = 30) in Table 3-19 but there was only one site assessed so it has the fewest samples of all the techniques. When the wattle fence site was assessed as a re-visit site two years later, it was observed to be a structural failure. Thus, the wattle fence technique is likely misrepresented due to the small sample size and due to observations of high mortality at other wattle fence structures in the city not assessed as part of the RMP.

**Table 3-21: Mean Year 1 Age Class Survival According to Bioengineering Technique**

| Bioengineering Technique | Year 1 Age Class Survival (%) | Number of Samples |
|---|---|---|
| Brush layers | 67 | 2,292 |
| Brush mattress | 96 | 343 |
| Fascine | 85 | 781 |
| Live staking | 70 | 980 |
| Plantings | 94 | 1,554 |
| Vegetated crib wall | 57 | 254 |
| Vegetated retaining wall[1] | n/a[1] | 0[1] |
| Vegetated riprap | 65 | 1,056 |
| Wattle fencing[2] | 100[2] | 30[2] |

Notes:
1. The vegetated crib wall technique was assessed at 14 sites; however, the technique used to vegetate the crib wall was often either brush layers or live staking and so the data is captured under the other techniques.
2. There was only one wattle fence site that was assessed during the five-year program. While the wattle fence technique had the highest survivorship (100%, n = 30), it also had the fewest samples and so is likely misrepresented based on observations of other wattle fence structures in Calgary with high mortality.

### Survivorship by Soil Amendment

Soil amendments were recommended in the *Design Guidelines for Erosion and Flood Control Projects Streambank and Riparian Stability Restoration* (AMEC, 2012) to address deficiencies in soil chemistry, enhance the soil moisture retention capacity, and provide optimum growing conditions for riparian plantings. The use of a soil amendment on live cuttings and container plants was identified during the desktop assessment based on the technical documentation that was provided. The use of a soil amendment could not be confirmed during field assessments since it is applied to the soils during vegetation installation.

The results of the comparison between survivorship of Year 1 age class live cuttings and container plants with documented soil amendment use is shown in Figure 3-9 and Table 3-22. The survivorship of Year 1 age class live cuttings with soil amendment (71%, n = 2,853) was found to be statistically higher than the survivorship of Year 1 age class live cuttings without soil amendment (54%, n = 409) as indicated by the different letters above the bars in the figure [8]. No statistical difference was found between survivorship of Year 1 age class container plants with soil amendment (94%, n = 1,351) and Year 1 age class container plants without soil amendment (94%, n = 229).

The results of the comparison between mean leader growth, mean shoot length, mean stem diameter, and woody vegetation canopy cover by age class against the documented use of soil amendment are not provided herein but can be accessed in the bank effectiveness annual reports. In most cases, the use of soil amendment resulted in higher growth with some of the results being statistically significant (i.e., leader growth for Year 1 age class, shoot length for the Year 5+ age class, and stem diameter for the Year 5+ age class). Woody vegetation canopy cover was found to be higher for Year 1, Year 3 and Year 5+ age classes when soil amendment was used versus when it was not used (Table 3-22), although the results were not statistically significant. When considered in aggregate, these results point to long term benefits of the soil amendment for growth and establishment of the planted vegetation.

Based on the above, a soil amendment should be considered a beneficial practice given the significant influence on Year 1 age class live cuttings/container plants, leader growth for Year 1 age class plants, and shoot length for Year 5+ age class plants. Thus, it is recommended to include the soil amendment described in the *Design Guidelines for Erosion and Flood Control Projects Streambank and Riparian Stability Restoration* (AMEC, 2012) around live cuttings and container plants. Note that recent construction procurement for this soil amendment has identified that ingredients are no longer available or improvements on the original products are available. An updated ingredients list is provided in Box 8.

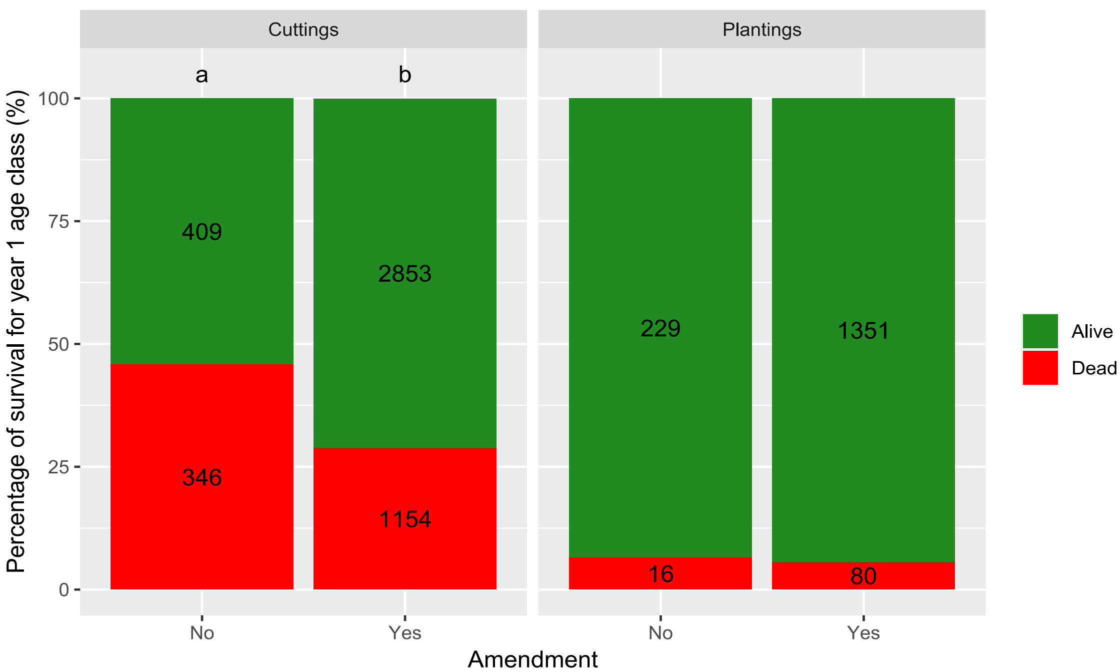



**Figure 3-9: Survival of Year 1 Age Class Cuttings and Container Plants by Soil Amendment Use**

[8] Per Section 1.3, different letters above the bars in the charts or boxes in the boxplots indicate a statistically significant difference between the data shown. For example, for Figure 6-3, there is an ‘a’ above the bar showing the data for when soil amendment was not used and a ‘b’ above the bar showing the data for when soil amendment was used. This indicates that the results are statistically significant according to the tests described in Section 5.1.

**Table 3-22: Mean Growth Parameters by Soil Amendment Use by Age Class**

| Soil Amendment | Year 1 | | Year 3 | | Year 5+ | |
|---|---|---|---|---|---|---|
| | With | Without | With | Without | With | Without |
| Year 1 Age Class Survival (%) | 77 | 64 | -- | -- | -- | -- |
| Leader Growth (cm) | 45 | 41 | 37 | 43 | 39 | 37 |
| Shoot Length (cm) | 91 | 80 | 132 | 124 | 194 | 152 |
| Stem Diameter (cm) | 1.1 | 1.0 | 1.6 | 1.5 | 2.4 | 2.3 |
| Woody Canopy Cover (%) | 53 | 29 | 47 | 38 | 67 | 44 |

### Box 8: Updated Soil Amendment Specification

Lack of product availability and industry improvements in products has necessitated an update to the soil amendment originally described in the *Design Guidelines for Erosion and Flood Control Projects Streambank and Riparian Stability Restoration* (AMEC, 2012). The updated specification for the soil amendment is provided below.

The soil amendment consists of the following:

- 1 bale (200 L) of peat component mix w/ mycorrhizae fungi. Includes sphagnum peat moss, endomycorrhiza, perlite and vermiculite, dolomitic and calcitic limestone, macronutrients and micronutrients, and wetting agent (e.g., brand name: Premier Tech Pro-Mix HP).

  OR
- 1 litre of granular form of endo + ecto mycorrhizae fungi (e.g., brand name: Premier Tech) mixed with 1 bale (200 L) of peat (e.g., brand name: Sunshine mix #4). One bale contains 55%-65% Canadian sphagnum peat moss, perlite, dolomitic limestone, gypsum, and wetting agent.
- 6 kg of organic fertilizer, 4-4-4 that contains alfalfa meal, bone meal, blood meal, glacial rock dust, sulphate of potash, humate, rock phosphate, greensand, kelp meal, gypsum (e.g., brand name: Gaia Green All Purpose 4-4-4).
- 0.8 kg of humate complexes (e.g., brand name: Black Earth HumiZen Magna Plus).

When placed on the ground surface, each soil amendment mixed dry will cover 28 m² and should be applied over live cuttings within each structure and watered thoroughly. Place the amendment in a thin, uniform layer. It is recommended that that the soil amendment mix be placed in 11 x five (5) gallon buckets (filled at ~ 80%) for ease of application. Each bucket should cover about 2.5 m², for a total coverage of approximately 28 m² per mix.

When placed in live staking or rooted stock planting holes, place 250 mL to 500 mL (1 to 2 cups) of soil amendment into the planting hole then wash it into the planting hole with a slurry of water and topsoil. The slurry should have a consistency of thick syrup. One batch of soil amendment should be satisfactorily applied to approximately 900 container shrubs.

Based on product costs in 2023, the additional cost to apply soil amendment is in the range of $0.15 per live cutting/container plant (applied at 250 mL per planting hole), and about $2 to $3 per square meter.

### Survivorship by Fencing

During the desktop assessment, the use of site fencing for protection from humans and/or wildlife was identified for each monitoring site based on the documentation provided. The presence of fencing was then confirmed while on site when possible.

Two types of fencing were specifically looked for in the background documentation and at site as listed below. Most sites (76%) have some type of fencing installed. The data was analyzed based on the presence or absence of either type of fencing.

- Human control fencing – often referred to as construction or public/project fencing.
- Ungulate/rodent browsing control fencing – often referred to as rodent fencing.

The influence of fencing (presence or absence of either type) was then assessed against live cuttings and/or planting Year 1 age class survival, and other parameters such as leader growth, shoot length, diameter, and woody vegetation canopy cover based on the data collected from the vegetation assessments. While Year 1 age class results are summarized below, the remainder of the results are not included herein but can be accessed via the bank effectiveness annual reports.

The results show that fencing has a statistically significant positive effect on measured Year 1 age class live cutting and container plant survivorship as shown in Figure 3-10. Mean survivorship of Year 1 age class live cuttings with fencing is 69% (n = 4,817) and without fencing is 62% (n = 312). Mean survivorship of Year 1 age class container plants with fencing is 95% (n = 1,719) and without fencing is 88% (n = 263).

These results indicate fencing is a beneficial practice that should be considered for all riverbank bioengineering and riparian restoration projects when possible. An example of temporary browsing protection fencing is shown in Photo 3-60. Permanent, wooden fencing (Photo 3-61) is also a beneficial practice in that it provides a physical barrier for the public that allows for improved safety, improved natural regeneration of trees and shrubs, and reduced disturbance to the planted vegetation from compaction and trampling.

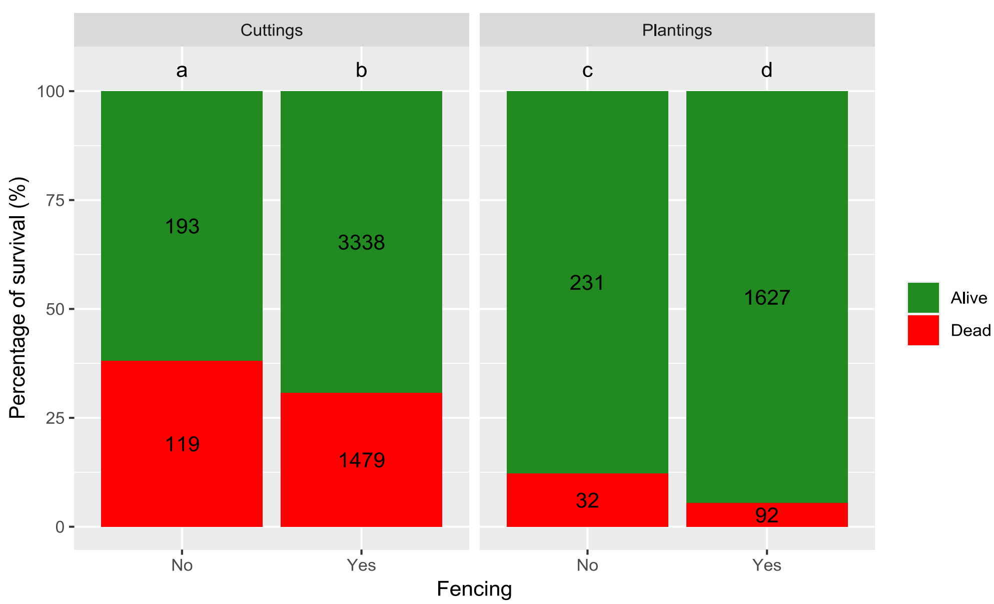



**Figure 3-10: Survival of Year 1 Age Class Cuttings & Container Plants by Fencing Use**

**Photo 3-60: Example of a temporary rodent fence installed around a bioengineering site on the Elbow River**

**Photo 3-61: Example of a permanent fence around a bioengineering site on the Elbow River**

## Woody Vegetation Growth Data

Woody vegetation growth data was collected for leader growth, shoot length, and stem diameter for a total of 3,872 container plants for the species shown in Table 3-19 and a total of 5,298 live cuttings for the species shown in Table 3-20. As indicated in Box 3, leader growth is a measure of the amount of growth in the current season, shoot length is a measure of the total size of the plant from ground to maximum height , and stem diameter is a measure of growth performance.

Based on the data collected, the best performing shrub species was the sandbar willow as it had the highest Year 1, Year 3 and Year 5+ age classes leader growth and highest Year 1 and Year 3 age classes shoot length for both container plant (Table 3-19) and live cutting (Table 3-20) stock types. Sandbar willow is clearly a key species for bank effectiveness projects in Calgary with further discussion in Box 9 below.

Similarly to the woody vegetation Year 1 age class survivorship data, there are no other currently known sources of data for growth parameters by species for bioengineering projects. Thus, this data is a benchmark for further research into species growth and establishment over time. Additionally, detailed establishment performance data collected for all native tree and shrub species and container plant species allows for the selection of the species that perform well in Calgary, and which species perhaps should be avoided in future bioengineering projects.

### Box 9: Spotlight on Sandbar Willow (*Salix interior*)

Sandbar willow (*Salix interior*) is a shrub that is native to the watercourses in Calgary and is commonly used in bioengineering projects. It is emerging as the key species for riverbank bioengineering projects in Calgary and should be considered for all bioengineering and riparian health projects in Calgary for the reasons listed below.

**Photo 3-62 Sandbar willow (*Salix interior*)**

- Its growth habit is a slender shrub that is 0.5-4 m tall (Gerling, Willoughby, Schoepf, Tannas, & Tannas, 1996). It has excellent ability to root from cuttings and a fast growth rate (USDA NRCS, 1996).
- It is found in wet to moist places on alluvial soils along streams and rivers, on floodplains, shorelines, around sloughs; however, the species is restricted in habitat due to high moisture requirements (Tannas, 2003).
- It can produce deep roots that are capable of penetrating soil substrates in search of the water table. Once deep roots are established, the plant can be sustained during periods of seasonal drought (Mosseler, Major, & Labrecque, 2014).
- It can also withstand flooding and high velocity flow by bending when shoots have developed as demonstrated at BE-ELB-4B (Riverdale U/S Phase II) where it was flooded for approximately 5 weeks during the first growing season.
- When browsed, it is an increaser and can send 2 to 9 or more shoots from a coppiced stem (Mosseler, Major, & Labrecque, 2014).
- It is Calgary's only rhizomatous willow and is capable of spreading quickly through root suckering and forming extensive colonies that develop from an extensive lateral root system (Tannas, 2003; Mosseler, Major, & Labrecque, 2014). Stem colonies can produce hundreds of stems arising from a single plant and spreading can be in the range of 1 m per year (Mosseler, Major, & Labrecque, 2014).
- It is of particular importance as a reclamation species, often as a natural pioneer on disturbances on waterways, having the ability to spread rapidly by vegetative means and form dense colonies (Tannas, 2003). It exhibited the most consistent and rapid root development from dormant live cuttings than six other species investigated for mine reclamation (Mosseler, Major, & Labrecque, 2014). It functions as an early successional species, showing a decline once climax trees and shrubs become established. Unlike other willows native to the Calgary region, propagation methods can include rhizome as well as live cuttings (Tannas, 2003).
- First Nations used the long, flexible branches since they were especially well suited for use in basketry, weaving and in the construction of back rests and sweat lodges (Tannas, 2003).

#### Growth Data by Bioengineering Technique

As shown in Table 3-23, the largest mean leader growth by bioengineering technique for Year 1 and Year 3 age class sites is the vegetated crib wall technique at 95 cm (n = 55) and 70 cm (n = 61) respectively, and for Year 5+ age class sites is the vegetated retaining wall technique at 57 cm (n = 126). The lowest mean leader growth by bioengineering technique for Year 1 and Year 3 age class sites is the plantings' technique at 29 cm (n = 911) and 26 cm (n = 780) respectively, which could be related to the species of plants used in this technique versus the other techniques. The lowest mean leader growth for Year 5+ age class sites is the brush mattress technique at 25 cm (n = 103).

As shown in Table 3-24 the largest mean shoot length by bioengineering technique for Year 1 age class sites is the wattle fence technique at 125 cm (n = 30), for Year 3 age class sites is the vegetated crib wall technique at 163 cm (n = 61), and for the Year 5+ age class sites is the brush mattress technique at 212 cm (n = 103). The lowest mean shoot length by bioengineering technique for Year 1, Year 3 and Year 5+ age class sites is the live staking technique at 66 cm (n = 245), 82 cm (n = 224) and 123 cm (n = 138).

As shown in Table 3-25, the largest mean diameter by bioengineering technique for the Year 1 age class sites is the plantings technique at 1.5 cm (n = 911), and for Year 3 and Year 5+ age class sites is the vegetated retaining wall technique at 1.9 cm (n = 61) and 2.5 cm (n = 126) respectively. The smallest mean diameters by bioengineering technique for Year 1 age class sites is the brush mattress technique at 0.5 cm (n = 102), and for the Year 3 and Year 5+ age class are the live staking technique at 0.9 cm (n = 224) and 1.4 cm (n = 138) respectively.

Additionally, there are several leaders measured in the brush layer data set that are in the ±1.5 m to ±3 m range, and many of the techniques were observed to have shoot lengths in the 3 m to 4 m range with plantings and vegetated riprap extending past 6 m in length.

**Table 3-23: Mean Leader Growth According to Bioengineering Technique and Age Class**

| Technique | Mean Leader Growth (cm) | | | Number of Samples | | |
|---|---|---|---|---|---|---|
| | Year 1 | Year 3 | Year 5+ | Year 1 | Year 2 | Year 3 |
| Brush layers | 53 | 50 | 49 | 632 | 507 | 119 |
| Brush mattress | 55 | 38 | 25 | 102 | 58 | 103 |
| Fascine | 47 | 40 | n/a | 157 | 114 | 0 |
| Live staking | 38 | 35 | 49 | 245-246[1] | 224 | 138 |
| Plantings | 29 | 26 | 30 | 911-912[1] | 780-794[1] | 608 |
| Vegetated crib wall | 95 | 70 | 44 | 55 | 61 | 162 |
| Vegetated retaining wall | n/a | n/a | 57 | 0 | 0 | 126 |
| Vegetated riprap | 54 | 42 | 56 | 259 | 233 | 121 |
| Wattle fencing[2] | 66[2] | n/a | n/a | 30[2] | 0 | 0 |

Notes:
1. The number of samples varies slightly according to the growth parameter measured.
2. Small sample size from one site that was assessed to be a structural failure during a re-visit assessment.

**Table 3-24: Mean Shoot Length According to Bioengineering Technique and Age Class**

| Technique | Mean Shoot Length (cm) | | | Number of Samples | | |
|---|---|---|---|---|---|---|
| | Year 1 | Year 3 | Year 5+ | Year 1 | Year 2 | Year 3 |
| Brush layers | 90 | 158 | 199 | 632 | 507 | 119 |
| Brush mattress | 69 | 157 | 212 | 102 | 58 | 103 |
| Fascine | 76 | 134 | n/a | 157 | 114 | 0 |
| Live staking | 66 | 82 | 123 | 245-246[1] | 224 | 138 |
| Plantings | 97 | 124 | 153 | 911-912[1] | 780-794[1] | 608 |
| Vegetated crib wall | 95 | 163 | 187 | 55 | 61 | 162 |
| Vegetated retaining wall | n/a | n/a | 183 | 0 | 0 | 126 |
| Vegetated riprap | 70 | 102 | 209 | 259 | 233 | 121 |
| Wattle fencing[2] | 125[2] | n/a | n/a | 30[2] | 0 | 0 |

Notes:
1. The number of samples varies slightly according to the growth parameter measured.
2. Small sample size from one site that was assessed to be a structural failure during a re-visit assessment.

**Table 3-25: Mean Stem Diameter According to Bioengineering Technique and Age Class**

| Technique | Mean Stem Diameter (cm) | | | Number of Samples | | |
|---|---|---|---|---|---|---|
| | Year 1 | Year 3 | Year 5+ | Year 1 | Year 2 | Year 3 |
| Brush layers | 0.8 | 1.6 | 2.0 | 632 | 507 | 119 |
| Brush mattress | 0.5 | 1.4 | 2.8 | 102 | 58 | 103 |
| Fascine | 0.7 | 1.2 | n/a | 157 | 114 | 0 |
| Live staking | 0.6 | 0.9 | 1.4 | 245-246[1] | 224 | 138 |
| Plantings | 1.5 | 1.8 | 2.3 | 911-912[1] | 780-794[1] | 608 |
| Vegetated crib wall | 0.9 | 1.9 | 2.3 | 55 | 61 | 162 |
| Vegetated retaining wall | n/a | n/a | 2.5 | 0 | 0 | 126 |
| Vegetated riprap | 0.8 | 1.3 | 2.3 | 259 | 233 | 121 |
| Wattle fencing[2] | 0.9[2] | n/a | n/a | 30[2] | 0 | 0 |

Notes:
1. The number of samples varies slightly according to the growth parameter measured.
2. Small sample size from one site that was assessed to be a structural failure during a re-visit assessment.

### Growth Data by Aspect

As shown in Table 3-18, the largest mean leader growth by aspect for Year 1 age class sites is the "North, North-East, East" aspect at 47 cm (n = 1445), for Year 3 age class sites is the "North-West" aspect at 43 cm (n = 292), and for Year 5+ age class sites is the "South-East" aspect at 64 cm (n = 25). The lowest mean leader growth by aspect for all age class sites is the "South, South-West, West" aspect.

As shown in Table 3-27, the largest mean shoot length by aspect for Year 1 and Year 3 age class sites is the "North-West" aspect at 100 cm (n = 286) and 152 cm (n = 292) respectively, and for the Year 5+ age class sites is the "South-East" aspect at 259 cm (n = 25). The lowest mean leader growth by aspect for all age class sites is the "South, South-West, West" aspect, which is again likely due to the higher sun exposure and lower soil moisture conditions.

As shown in Table 3-28, the largest mean stem diameter by aspect for Year 1 age class sites is the "North, North-East, East" aspect at 1.1 cm (n = 1445), for Year 3 age class sites is the "North-West" aspect at 1.8 cm (n = 292) , and for Year 5+ age class sites is the "South-East" aspect at 2.7 cm (n = 25). The lowest mean stem diameter by aspect for all age class sites is the "South, South-West, West" aspect, which is likely due to the higher sun exposure and lower soil moisture conditions.

The results show that the growth parameters for woody vegetation planted on north-facing aspects are mostly higher than the southern-facing aspects, which is likely due to the higher sun exposure and corresponding lower available soil moisture on south-facing aspects.

**Table 3-26: Mean Leader Growth According to Aspect and Age Class**

| Aspect | Leader Growth (cm) | | | Number of Samples | | |
|---|---|---|---|---|---|---|
| | Year 1 | Year 3 | Year 5+ | Year 1 | Year 3 | Year 5+ |
| North, North-East, East | 47 | 37 | 43 | 1445-1450[1] | 1129 | 570 |
| North-West | 42 | 43 | n/a | 286 | 292 | 193 |
| Flat | n/a | n/a | n/a | 0 | 0 | 0 |
| South-East | n/a | n/a | 64 | 0 | 0 | 25 |
| South, South-West, West | 36 | 36 | 37 | 656-657[1] | 556-570[1] | 589 |

Notes:
1. The number of samples varies slightly according to the growth parameter measured.

**Table 3-27: Mean Shoot Length According to Aspect and Age Class**

| Aspect | Mean Shoot Length (cm) | | | Number of Samples | | |
|---|---|---|---|---|---|---|
| | Year 1 | Year 3 | Year 5+ | Year 1 | Year 3 | Year 5+ |
| North, North-East, East | 93 | 135 | 151 | 1445-1450[1] | 1129 | 570 |
| North-West | 100 | 152 | 218 | 286 | 292 | 193 |
| Flat | n/a | n/a | n/a | 0 | 0 | 0 |
| South-East | n/a | n/a | 259 | 0 | 0 | 25 |
| South, South-West, West | 68 | 101 | 169 | 656-657[1] | 556-570[1] | 589 |

Notes:
1. The number of samples varies slightly according to the growth parameter measured.

**Table 3-28: Mean Stem Diameter According to Aspect and Age Class**

| Aspect | Mean Stem Diameter (cm) | | | Number of Samples | | |
|---|---|---|---|---|---|---|
| | Year 1 | Year 3 | Year 5+ | Year 1 | Year 3 | Year 5+ |
| North, North-East, East | 1.1 | 1.7 | 2.1 | 1445-1450[1] | 1129 | 570 |
| North-West | 0.9 | 1.8 | 3.2 | 286 | 292 | 193 |
| Flat | n/a | n/a | n/a | 0 | 0 | 0 |
| South-East | n/a | n/a | 2.7 | 0 | 0 | 25 |
| South, South-West, West | 0.9 | 1.2 | 2.0 | 656-657[1] | 556-570[1] | 589 |

Notes:
1. The number of samples varies slightly according to the growth parameter measured.

**Quick Facts for Bioengineering Projects Based on Performance Data**

Quick facts regarding the native tree and shrub data that was collected is provided in Table 3-29.

**Table 3-29: Bank Effectiveness Woody Vegetation Analysis Quick Facts**

| | |
|---|---|
| **Number of different tree and shrub species sampled for survivorship, health, and growth variables (cuttings and plantings)** | 45 |
| **Number of different container shrub species sampled** | 31 |
| **Number of different live cutting species sampled** | 14 |
| **Number of individual container shrub plantings sampled** | 7,040 |
| **Number of individual live cuttings sampled** | 3,872 |
| **Most commonly used container tree/shrub species** | Red-osier dogwood (*Cornus sericea*) (n = 345) |
| **Most commonly used live staking tree/shrub species** | Sandbar willow (*Salix interior*) (n = 2,336) |
| **Estimated Year 1 age class survival rate of sandbar willow cuttings** | 78% |

## Woody Vegetation Canopy Cover and Density of Living Shoots

Woody vegetation canopy cover and density of living shoots are methods to measure vegetation establishment success at a site. In combination with Year 1 age class survivorship, these three methods are recommended by the literature (e.g., Gray & Sotir, 1996; Schiechtl & Stern, 1997) for bioengineering-technique based targets that will allow for more realistic contract warranty and regulatory targets two to five years post-construction. Note that while woody vegetation canopy cover is expected to increase over time with a goal of 100% cover for the site, both Year 1 age class survival and density of living shoots are expected to decrease over time as vegetation naturally self-thins due to competition for sunlight, nutrients, and soil moisture as the vegetation grows.

#### Woody Vegetation Canopy Cover by Age Class

Measured woody vegetation canopy cover by age class for various statistical parameters are shown in Table 3-30. As expected, the values increase from the Year 1 age class to the Year 5+ age class (except for the Year 3 age class 25th percentile). However, the mean/median values are lower than expected for all age classes as the key goal of most riverbank bioengineering projects is full woody vegetation canopy cover. This condition provides the highest erosion protection and most closely resembles a natural condition. It appears that some improvement is necessary towards meeting this goal and that the results for the 75th percentile may be more suited as a target for contract warranty and regulatory approvals.

**Table 3-30: Woody Canopy Cover by Age Class**

| Woody Vegetation Canopy Cover | Year 1 Age Class | Year 3 Age Class | Year 5+ Age Class |
|---|---|---|---|
| 25th Percentile | 12.5% | 10% | 17.5% |
| Median | 42% | 42% | 59% |
| Mean | 46% | 48% | 55% |
| 75th Percentile | 80% | 82.5% | 84% |
| Sample Size | 83 | 76 | 68 |

#### Woody Vegetation Canopy Cover by Bioengineering Technique

Results for measured woody vegetation canopy cover by bioengineering technique are shown in Table 3-31. Woody canopy cover was found to be highest for the brush mattress technique for all age classes (Table 3-31). Woody canopy cover is lowest for the seeding technique which is expected since colonization from neighboring stands of woody vegetation would be required for this technique to register any amount of woody vegetation cover. The planting technique was second lowest which is likely due to the low density of plantings that are often spaced at 1 m or more.

**Table 3-31: Mean Woody Vegetation Canopy Cover by Bioengineering Technique and Age Class**

| Bioengineering Technique | Year 1 | | Year 3 | | Year 5+ | |
|---|---|---|---|---|---|---|
| | Mean Canopy Cover (%) | No. of Samples | Mean Canopy Cover (%) | No. of Samples | Mean Canopy Cover (%) | No. of Samples |
| Brush layers | 80 | 16 | 74 | 16 | 86 | 5 |
| Brush mattress | 90 | 3 | 96 | 2 | 97 | 2 |
| Fascine | 88 | 6 | 88 | 5 | n/a | 0 |
| Live staking | 45 | 9 | 55 | 7 | 50 | 5 |
| Plantings | 19 | 20 | 23 | 20 | 40 | 15 |
| Riprap | 28 | 11 | 40 | 10 | 49 | 15 |
| Seeding | 17 | 6 | 7 | 5 | 24 | 7 |
| Vegetated crib wall | 89 | 2 | 79 | 2 | 71 | 6 |
| Vegetated retaining wall | n/a | n/a | 72 | 1 | 78 | 6 |
| Vegetated riprap | 36 | 9 | 27 | 8 | 71 | 7 |
| Wattle fencing | 42 | 1 | n/a | 0 | n/a | 0 |

### Density of Living Shoots by Age Class and Technique

Results for measured density of living shoots for live cuttings, container plants, fascines, brush layers, and brush mattresses are provided by age class in Table 3-32. These results provide some understanding on the potential values for density of living shoots that could be expected in the city. These results could then be used in combination with survival and/or woody vegetation canopy targets to support contract warranty and regulatory approval targets for vegetation establishment. A selection of published targets for survival, cover and density as recommended by Schiechtl and Stern (1997) are provided in Table 3-15.

**Table 3-32: Mean Density of Living Shoots by Age Class and Technique by Age Class**

| Technique | Year 1 | | | Year 3 | | | Year 5+ | | |
|---|---|---|---|---|---|---|---|---|---|
| | Stems/m² | Stems/m | No. | Stems/m² | Stems/m | No. | Stems/m² | Stems/m | No. |
| Brush Layers[1] | n/a | 5.9 | 33 | n/a | 5.1 | 54 | n/a | 3 | 52 |
| Brush Mattresses[2] | 43 | n/a | 9 | 31 | n/a | 6 | 19 | n/a | 6 |
| Container Plants[3] | 0.7 | n/a | 30 | 1.7 | n/a | 72 | 5.6 | n/a | 48 |
| Fascines[1] | n/a | 30 | 18 | n/a | 37 | 15 | n/a | n/a | n/a |
| Live Cuttings[4] | 1.7 | n/a | 36 | 3.5 | n/a | 39 | 2.5 | n/a | 39 |

Note: Schiechtl and Stern (1997) targets for survival, cover and density are listed below.
1. Live plants material: fascines, brush layers, hedge brush layer and wattle fences must show an average of five and a minimum of two live shoots per linear meter.
2. Brush mattress must show an average of ten and a minimum of five shoots per m2 approximately evenly spaced.
3. Shrubs and Tree plantings maximum failure rate for the individual shrubs or tree must not exceed 30% (from initially planted) and the objectives must be achieved.
4. Two thirds of all live staking, poles must have thrown shoots maintaining an even distribution pattern over the whole area.
5. This requires on average from two to five growing seasons, and provision should be made in the tender specifications. At the end of this period, all vegetative components should be at a stage that ensures their continuing progress, and all works should be fully functional

## Seeding Germination Success

Germination success monitoring was conducted on 85 transects in areas where herbaceous seed mixes were applied. A total of 54 different graminoid (grass, sedge, and rush) and forb species were seeded over the 92 monitoring sites. Additionally, seeding method success for each seed species was analysed.

### Seeding Germination Success

Year 1, Year 3, and Year 5+ age class results for seeding germination success and cover rate are presented in Table 3-33. It is important to assess the germination based on age class, as some seeded species may not germinate the first year, or they may increase or decrease in cover over time in response to competition or environmental variables such as compaction, soil moisture, etc.

The results for seeding germination success are based on presence versus absence, or the number of times the species was observed in the vegetation quadrat or transect surveys (in any amount) compared to the number of times it was documented in a seed mix in the design information, expressed as a percentage.

Success varied widely among the seeded graminoid and forb species. Among the 54 assessed species, three species have a 100% germination success rate in the Year 3 age class sites, and seven species had a 100% germination success rate in the Year 5+ age class sites. However, two of the three Year 3 age class species and six of the seven Year 5+ age class species are non-native, which are not preferred for bioengineering applications.[9] Six native species had germination rates less than 100% but more than 50% for at least one age class, including slender wheat grass (*Elymus trachycaulus* ssp. *trachycaulus*), fowl bluegrass (*Poa palustris*), Canada wild rye (*Elymus canadensis*), wild blue flax (*Linum lewisii*), and northern wheat grass (*Elymus lanceolatus*)However, more than half (n=28) of the species seeded were not observed, meaning they likely did not establish. In particular, 11 species were seeded 5 or more times and were not found in the surveys.

**Seeding Cover Rate**

The seeding mean cover rate analysis shown in Table 3-33 focused on how abundant the seeded species were on the sites where they were seeded, with abundance measured as percent cover, or the number of times it was observed along a transect compared to the total number of sample points (e.g., 20 hits out of 50 transect sample points = 40% cover). Abundance is a factor of both how successful the species were as well as their relative amounts or proportions in the seed mixes.

The cover rate results for species that germinated ranged from a minimum of 2% to a maximum of 100% at each transect. The native species with the highest overall mean cover rate was bluebunch fescue (*Festuca idahoensis*) at 70% for the Year 3 age class. It is interesting to note that the Year 3 seeding germination success rate for bluebunch fescue was only 11%.

These results provide data on which grass and forb species should be included in future seed mixes. For example, top performers with good germination success that are native species included slender wheat grass, fowl bluegrass, Canada wild rye, wild blue flax, and northern wheat grass. As a general note, even many of the top performing seeded species only established on half of the sites where they were seeded, which is not uncommon for native species (Small, Degenhardt, & McDonald, 2019).

[9] Note that reed canary grass and red fescue both have native and non-native varieties present in Alberta. However, if the species were from a seed mix and not wild harvested, it seems likely that they are non-native in origin.

**Table 3-33: Seeding Germination Success and Mean Cover Rate**

| Species | Plant Habit | Native (Y/N) | Number of Seeded Transects | Seeding Germination Success Rate on Quadrats & Transects (%) | | | | | | Mean Cover Rate on Transects (%) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Year 1 | No. of samples | Year 3 | No. of samples | Year 5+ | No. of samples | Min | Max | Year 1 | Year 3 | Year 5+ |
| Red fescue (*Festuca rubra*) | Graminoid | Y/N | 8 | 80 | 5 | 100 | 3 | 100 | 5 | 4 | 88 | 19 | 61 | 39 |
| Hard fescue (*Festuca trachyphylla*) | Graminoid | N | 1 | n/a | 0 | n/a | 0 | 100 | 1 | 60 | 60 | n/a | n/a | 60 |
| Perennial ryegrass (*Lolium perenne*) | Graminoid | N | 1 | n/a | 0 | n/a | 0 | 100 | 1 | 2 | 2 | n/a | n/a | 2 |
| Reed canary grass (*Phalaris arundinacea*) | Graminoid | Y/N | 1 | n/a | 0 | n/a | 0 | 100 | 1 | 2 | 2 | n/a | n/a | 2 |
| Timothy (*Phleum pratense*) | Graminoid | N | 1 | n/a | 0 | n/a | 0 | 100 | 1 | 2 | 2 | n/a | n/a | 2 |
| Kentucky bluegrass (*Poa pratensis*) | Graminoid | N | 4 | 33 | 3 | 100 | 3 | 100 | 3 | 2 | 62 | 2 | 45 | 33 |
| Slender wheat grass (*Elymus trachycaulus* ssp. *trachycaulus*) | Graminoid | Y | 34 | 88 | 24 | 100 | 15 | 100 | 6 | 2 | 100 | 45 | 35 | 16 |
| Fowl bluegrass (*Poa palustris*) | Graminoid | Y | 40 | 58 | 24 | 47 | 19 | 80 | 15 | 2 | 88 | 15 | 25 | 25 |
| Canada wild rye (*Elymus canadensis*) | Graminoid | Y | 20 | 70 | 10 | 70 | 10 | 54 | 13 | 2 | 78 | 12 | 13 | 21 |
| Wild blue flax (*Linum lewisii*) | Forb | Y | 26 | 67 | 24 | 36 | 14 | 0 | 2 | 2 | 30 | 8 | 7 | |
| Northern wheat grass (*Elymus lanceolatus*) | Graminoid | Y | 47 | 73 | 30 | 56 | 25 | 25 | 16 | 2 | 60 | 16 | 12 | 3 |
| Western wheat grass (*Pascopyrum smithii*) | Graminoid | Y | 69 | 50 | 46 | 43 | 40 | 32 | 22 | 2 | 34 | 10 | 9 | 16 |
| Green needle grass (*Nassella viridula*) | Graminoid | Y | 51 | 44 | 41 | 43 | 28 | 25 | 8 | 2 | 40 | 9 | 11 | 11 |
| Sheep fescue (*Festuca ovina*) | Graminoid | N | 5 | 40 | 5 | 0 | 3 | 0 | 2 | 18 | 36 | 27 | n/a | n/a |

| Species | Plant Habit | Native (Y/N) | Number of Seeded Transects | Seeding Germination Success Rate on Quadrats & Transects (%) | | | | | | Mean Cover Rate on Transects (%) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Year 1 | No. of samples | Year 3 | No. of samples | Year 5+ | No. of samples | Min | Max | Year 1 | Year 3 | Year 5+ |
| Tufted hair grass (*Deschampsia cespitosa*) | Graminoid | Y | 47 | 45 | 29 | 33 | 24 | 25 | 20 | 2 | 86 | 22 | 8 | 25 |
| Wild vetch (*Vicia americana*) | Forb | Y | 7 | 0 | 5 | 50 | 4 | 0 | 3 | -- | -- | n/a | n/a | n/a |
| Rough hair grass (*Agrostis scabra*) | Graminoid | Y | 29 | 23 | 22 | 26 | 19 | 0 | 8 | 4 | 88 | 42 | 9 | n/a |
| Slender wheat grass (*Elymus trachycaulus* ssp. *subsecundus*) | Graminoid | Y | 37 | 19 | 21 | 15 | 26 | 23 | 13 | 2 | 32 | 11 | n/a | 4 |
| Italian ryegrass (*Lolium multiflorum*) | Graminoid | N | 9 | 29 | 7 | 0 | 3 | 0 | 4 | 44 | 44 | 44 | n/a | n/a |
| Rocky Mountain fescue (*Festuca saximontana*) | Graminoid | Y | 31 | 8 | 25 | 214 | 14 | 14 | 7 | 10 | 58 | 10 | 37 | 10 |
| Canada milk vetch (*Astragalus canadensis*) | Forb | Y | 8 | 17 | 6 | 0 | 4 | 0 | 3 | -- | -- | n/a | n/a | n/a |
| Blue grama (*Bouteloua gracilis*) | Graminoid | Y | 10 | 0 | 2 | 25 | 4 | 0 | 6 | 2 | 2 | n/a | 2 | n/a |
| Slough grass (*Beckmannia syzigachne*) | Graminoid | Y | 11 | 0 | 3 | 0 | 3 | 13 | 8 | 2 | 2 | n/a | n/a | 2 |
| June grass (*Koeleria macrantha*) | Graminoid | Y | 45 | 3 | 32 | 4 | 25 | 17 | 12 | 2 | 6 | n/a | n/a | 4 |
| Bluebunch fescue (*Festuca idahoensis*) | Graminoid | Y | 14 | 0 | 13 | 11 | 9 | 0 | 3 | 70 | 70 | n/a | 70 | n/a |
| Purple prairie-clover (*Dalea purpurea*) | Forb | Y | 16 | 0 | 15 | 7 | 15 | 0 | 1 | -- | -- | n/a | n/a | n/a |

| Species | Plant Habit | Native (Y/N) | Number of Seeded Transects | Seeding Germination Success Rate on Quadrats & Transects (%) | | | | | | Mean Cover Rate on Transects (%) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Year 1 | No. of samples | Year 3 | No. of samples | Year 5+ | No. of samples | Min | Max | Year 1 | Year 3 | Year 5+ |
| Indian rice grass (*Eriocoma hymenoides*) | Graminoid | Y | 1 | n/a | 0 | n/a | 0 | 0 | 1 | -- | -- | n/a | n/a | n/a |
| Crested wheatgrass (*Agropyron cristatum*) | Graminoid | N | 1 | n/a | 0 | n/a | 0 | 0 | 1 | -- | -- | n/a | n/a | n/a |
| Cicer milk vetch (*Astragalus cicer*) | Forb | N | 1 | n/a | 0 | n/a | 0 | 0 | 1 | -- | -- | n/a | n/a | n/a |
| Meadow brome (*Bromus biebersteinii*) | Graminoid | N | 4 | n/a | 0 | n/a | 0 | 0 | 4 | -- | -- | n/a | n/a | n/a |
| Fringed brome (*Bromus ciliatus*) | Graminoid | Y | 6 | 0 | 1 | | 0 | 0 | 5 | -- | -- | n/a | n/a | n/a |
| Keeled brome (*Bromus sitchensis* var. *carinatus*) | Graminoid | Y | 12 | 0 | 8 | 0 | 9 | 0 | 4 | -- | -- | n/a | n/a | n/a |
| Bluejoint reedgrass (*Calamagrostis canadensis*) | Graminoid | Y | 5 | 0 | 2 | 0 | 1 | 0 | 2 | -- | -- | n/a | n/a | n/a |
| Northern reed grass (*Calamagrostis stricta* ssp. *inexpansa*) | Graminoid | Y | 1 | 0 | 1 | 0 | 1 | n/a | 0 | -- | -- | n/a | n/a | n/a |
| Water sedge (*Carex aquatilis*) | Graminoid | Y | 1 | 0 | 1 | 0 | 1 | n/a | 0 | -- | -- | n/a | n/a | n/a |
| Small bottle sedge (*Carex utriculata*) | Graminoid | Y | 2 | 0 | 1 | 0 | 2 | n/a | 0 | -- | -- | n/a | n/a | n/a |
| Creeping spike-rush (*Eleocharis palustris*) | Graminoid | Y | 8 | 0 | 4 | 0 | 4 | 0 | 4 | -- | -- | n/a | n/a | n/a |
| Mountain rough fescue (*Festuca campestris*) | Graminoid | Y | 11 | 0 | 10 | 0 | 11 | n/a | 0 | -- | -- | n/a | n/a | n/a |
| Plains rough fescue (*Festuca hallii*) | Graminoid | Y | 10 | n/a | 9 | n/a | 9 | 0 | 1 | -- | -- | n/a | n/a | n/a |

| Species | Plant Habit | Native (Y/N) | Number of Seeded Transects | Seeding Germination Success Rate on Quadrats & Transects (%) | | | | | | Mean Cover Rate on Transects (%) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Year 1 | No. of samples | Year 3 | No. of samples | Year 5+ | No. of samples | Min | Max | Year 1 | Year 3 | Year 5+ |
| Gaillardia (*Gaillardia aristida*) | Forb | Y | 9 | 0 | 9 | 0 | 9 | n/a | 0 | -- | -- | n/a | n/a | n/a |
| Common tall manna grass (*Glyceria grandis*) | Graminoid | Y | 2 | n/a | 0 | n/a | 0 | 0 | 2 | -- | -- | n/a | n/a | n/a |
| Fowl manna grass (*Glyceria striata*) | Graminoid | Y | 15 | 0 | 12 | 0 | 11 | 0 | 2 | -- | -- | n/a | n/a | n/a |
| Needle-and-thread grass (*Hesperostipa comata*) | Graminoid | Y | 2 | n/a | 0 | 0 | 1 | 0 | 1 | -- | -- | n/a | n/a | n/a |
| Western porcupine grass (*Hesperostipa curtiseta*) | Graminoid | Y | 1 | 0 | 1 | 0 | 1 | n/a | 0 | -- | -- | n/a | n/a | n/a |
| Wire rush (*Juncus balticus*) | Graminoid | Y | 13 | 0 | 10 | 0 | 11 | 0 | 2 | -- | -- | n/a | n/a | n/a |
| Hairy wild rye (*Leymus innovatus*) | Graminoid | Y | 1 | 0 | 1 | 0 | 1 | n/a | 0 | -- | -- | n/a | n/a | n/a |
| Common flax (*Linum usitatissimum*) | Forb | N | 1 | n/a | 0 | n/a | 0 | 0 | 1 | -- | -- | n/a | n/a | n/a |
| Timberline bluegrass (*Poa glauca*) | Graminoid | Y | 4 | n/a | 0 | n/a | 0 | 0 | 4 | -- | -- | n/a | n/a | n/a |
| Sandberg bluegrass (*Poa secunda*) | Graminoid | Y | 7 | n/a | 0 | 0 | 1 | 0 | 7 | -- | -- | n/a | n/a | n/a |
| Narrow-leaf cottonwood (*Populus angustifolia*) | Tree | Y | 2 | n/a | 0 | n/a | 0 | 0 | 2 | -- | -- | n/a | n/a | n/a |
| Slender salt-meadow grass (*Puccinellia distans*) | Graminoid | N | 1 | n/a | 0 | n/a | 0 | 0 | 1 | -- | -- | n/a | n/a | n/a |

| Species | Plant Habit | Native (Y/N) | Number of Seeded Transects | Seeding Germination Success Rate on Quadrats & Transects (%) | | | | | | Mean Cover Rate on Transects (%) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Year 1 | No. of samples | Year 3 | No. of samples | Year 5+ | No. of samples | Min | Max | Year 1 | Year 3 | Year 5+ |
| Cusick's salt-meadow grass (*Puccinellia nuttalliana*) | Graminoid | Y | 1 | n/a | 0 | n/a | 0 | 0 | 1 | -- | -- | n/a | n/a | n/a |
| *Salix* spp. | Shrub | Y | 2 | n/a | 0 | n/a | 0 | 0 | 2 | -- | -- | n/a | n/a | n/a |
| Alkali cord grass (*Sporobolus hookerianus*) | Graminoid | Y | 3 | n/a | 0 | 0 | 1 | 0 | 2 | -- | -- | n/a | n/a | n/a |

### Seeding Method Germination Success Rate

The seeding methods that were observed at the monitoring sites fell into three categories: broadcast seeding, hydroseeding, or drill seeding. The results for seeding method germination success are based on presence versus absence, or the number of times the species was observed in the vegetation quadrat or transect surveys (in any amount) compared to the number of times it was documented in a seed mix for each seeding method in the design information, expressed as a percentage for each age class.

The overall results in Table 3-34 show that drill seeding for Year 1 and Year 3 age class sites had the highest and second highest germination success at 83% and 52% respectively, broadcast seeding for Year 1 and Year 3 age class sites was third and fourth at 37% and 34% respectively, and hydroseeding for Year 3 age class sites was lowest at 21%. The results were not statistically significant but do possibly point to drill seeding as a best practice, where it is feasible. Other techniques remain important due to the cost of drill seeding, but the lower seeding success rates for broadcast seeding and hydroseeding should be noted and incorporated into design and construction planning.

**Table 3-34: Seeding Method Success by Age Class**

| Number of Species | Broadcast Seeding [1] | | | Hydroseeding [1] | | | Drill Seeding [1] | | |
|---|---|---|---|---|---|---|---|---|---|
| | Year 1 | Year 3 | Year 5+ | Year 1 | Year 3 | Year 5+ | Year 1 | Year 3 | Year 5+ |
| Seeded and Found | 87 | 61 | 27 | 62 | 40 | 22 | 5 | n/a | 11 |
| Seeded and Not Found | 148 | 119 | 91 | 159 | 150 | 49 | 1 | n/a | 21 |
| Percent Success by Method | 37% | 34% | 23% | 28% | 21% | 31% | 83% | n/a | 52% |

Note:
1. Values show the total number of times each species has been seeded and either found or not found. Most species have been seeded several times.

### Highest Performing Seed Species

Based on the seeding germination success and failures for the 54 different graminoid and forb species listed above, over 50% of the seeded species were not observed where they were sowed. Based on Table 3-33, the five most successful native graminoid and four most successful forb species are listed below to support seed mix design for future bioengineering projects.

- Graminoids (Grass and Grass-like Species)
  - Slender wheat grass (*Elymus trachycaulus* ssp. *trachycaulus*)
  - Fowl bluegrass (*Poa palustris*)
  - Canada wild rye (*Elymus canadensis*)
  - Northern wheat grass (*Elymus lanceolatus*)
  - Western wheat grass (*Pascopyrum smithii*)
  - Green needle grass (*Nassella viridula*)
- Forbs (Broad-leaved Species)
  - Wild blue flax (Linum lewisii)
  - Wild vetch (Vicia americana)
  - Canada milk vetch (Astragalus canadensis)
  - Purple prairie-clover (Dalea purpurea)

### Seed Mix Best Practices

Best practices for seed mix installation have been compiled as part of the RMP and are listed in Box 10.

**Box 10: Seed Mix Best Practices**

Best practices for seed mix installation are listed below.

- Obtain seed certificates for all species planted. Seed certificates will indicate the age of the seed lot and the proportion of weeds/invasive species in the lot. Old seed and seed with any weeds present, particularly noxious species, should be rejected.
- Only obtain seed from reputable, knowledgeable seed growers and/or suppliers.
- If hand broadcasting, when possible, rake the seed into the soil to ensure good soil contact.
- Irrigate regularly during the growing season. While healthy native seed does not require artificial watering to germinate if there is sufficient natural precipitation, irrigation will improve the chance of successful establishment, particularly during summers with extended warm and dry periods.
- Only seed in the spring and fall. If seeding cannot occur until after mid-June, it should be delayed until the fall. Native grasses are generally slow-growing and need sufficient time during the first growing season to develop their extensive root systems, which will enable them to over-winter successfully.
- Seed native species appropriate to the relevant site conditions. Similar to the discussion above for plantings, native grasses and forbs that favour moist environments should be seeded closer to waterbodies, and upland grasses and forbs should be seeded in drier locations away from water. Consulting a knowledgeable botanist will help inform the species selection process. Such technical expertise will also assist with the selection of suitable replacement species if needed. Consider desirable rooting characteristics and nitrogen fixing capabilities as well as pollinator habitat enhancement attributes when selecting grass and forb species. When possible, sequencing the flowering period of the selected species throughout the season will enhance pollinator habitat. Avoid non-native species to the extent possible. Where seeding is done in conjunction with plantings, aggressive rhizomatous species should be avoided that may out-compete young seedling woody plants.
- Use an appropriate seeding rate for the project conditions. Seeding rates that are too high will result in excessive competition with planted material for projects that involve both seeding and plantings. Seeding rates that are too low could result in low herbaceous cover and high amounts of bare soil that is subject to wind and water erosion and invasion by non-native species.
- Ensure contractors conducting the seeding have an understanding of how to calculate and apply specified application rates by requesting a description of the planned calculation and application procedures. as described in the annual summary reports (KWL, 2023b).
- Fence off seeded areas to prevent disturbance from humans if the project is located in a high-use area.

## Herbaceous Vegetation Cover and Species Diversity

Percent herbaceous cover by age class is shown in Figure 3-11 from the data collected by quadrat. The mean percent herbaceous cover for Year 1 age class is 33% (n = 131), for Year 3 age class is 17% (n = 168), and Year 5+ age class is 14% (n = 157). A possible explanation for the decrease in herbaceous cover over the three age classes could be due to an increase in woody vegetation cover (see Table 3-30). Woody vegetation cover can shade out the herbaceous vegetation and limit its growth.

Percent herbaceous cover by bioengineering technique is shown in Table 3-35. The results show that the seeding technique has the highest mean percent cover for Year 3 and Year 5+ age class sites which is intuitive since it targets herbaceous plant growth. Fascine has the highest mean percent cover for herbaceous species for Year 1 age class sites. The lowest mean percent cover for Year 1 age class sites is the riprap technique (0%; n = 2), for Year 3 age class sites is the brush mattress technique (0%, n = 3), and for the Year 5+ age class sites are the riprap technique (1%; n = 27), vegetated crib wall technique (1%; n = 12), and the vegetated riprap technique (1%; n = 12).

The plantings and brush layers techniques have the highest mean number of species at 11 identified per quadrat for the Year 1 age class sites as shown in Table 3-36. The seeding technique has the highest number of species at 11 identified per quadrat for the Year 3 age class sites. The live staking technique has the highest number of species at 8 identified per quadrat for the Year 5+ age class sites. The lowest number of species was the riprap and vegetated crib wall technique at 2 species identified per quadrat for the Year 1 age class sites, the vegetated retaining wall technique at 0 species identified per quadrat for the Year 3 age class sites, and the riprap technique at 2 species identified per quadrat for the Year 5+ age class sites.

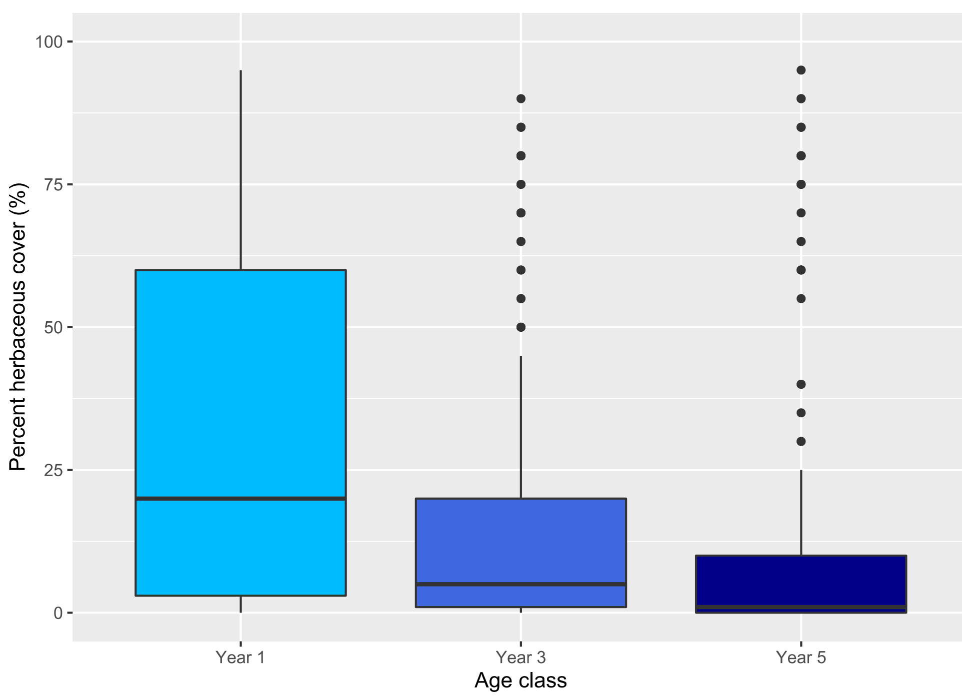



**Figure 3-11: Percent Herbaceous Cover by Age Class**

**Table 3-35: Mean Herbaceous Cover per Quadrat by Bioengineering Technique and Age Class**

| Bioengineering Technique | Mean Herbaceous Cover (%) | | | | | |
|---|---|---|---|---|---|---|
| | Year 1 | No. of Samples | Year 3 | No. of Samples | Year 5+ | No. of Samples |
| Brush layers | 29 | 33 | 15 | 39 | 28 | 13 |
| Brush mattress | n/a | 0 | 0 | 3 | 18 | 6 |
| Fascine | 42 | 3 | 4 | 15 | n/a | 0 |
| Live staking | 37 | 18 | 10 | 15 | 12 | 9 |
| Plantings | 32 | 42 | 16 | 60 | 14 | 45 |
| Riprap | 0 | 2 | n/a | 0 | 1 | 27 |
| Seeding | 39 | 15 | 35 | 12 | 37 | 21 |
| Vegetated crib wall | n/a | 0 | 8 | 6 | 1 | 12 |
| Vegetated retaining wall | n/a | 0 | n/a | 0 | 10 | 12 |
| Vegetated riprap | 34 | 15 | 34 | 18 | 1 | 12 |
| Wattle fencing | 35 | 3 | n/a | 0 | n/a | 0 |

**Table 3-36: Mean Number of Species per Quadrat by Bioengineering Technique and Age Class**

| Bioengineering Technique | Number of Species | | | | | |
|---|---|---|---|---|---|---|
| | Year 1 | No. of Samples | Year 3 | No. of Samples | Year 5+ | No. of Samples |
| Brush layers | 11 | 48 | 7 | 48 | 6 | 16 |
| Brush mattress | 8 | 9 | 5 | 6 | 7 | 6 |
| Fascine | 8 | 18 | 7 | 15 | n/a | 0 |
| Live staking | 7 | 27 | 7 | 21 | 8 | 15 |
| Plantings | 11 | 60 | 8 | 60 | 7 | 45 |
| Riprap | 2 | 30 | 3 | 21 | 2 | 45 |
| Seeding | 9 | 18 | 11 | 15 | 7 | 21 |
| Vegetated crib wall | 2 | 6 | 7 | 6 | 5 | 18 |
| Vegetated retaining wall | n/a | 0 | 0 | 3 | 4 | 18 |
| Vegetated riprap | 10 | 26 | 8 | 24 | 3 | 21 |
| Wattle fencing | 5 | 3 | n/a | 0 | n/a | 0 |

## Invasive Weed Species Monitoring

In total, 19 invasive weed species were observed in the transect and quadrat data as shown in Table 3-37. The most documented invasive weed species was creeping thistle (*Cirsium arvense*). It was observed at all Year 1 age class sites, 27 of 31 Year 3 age class sites, and 22 of 24 Year 5+ age class sites. The second most documented weed species was smooth perennial sow-thistle (*Sonchus arvensis* ssp. *uliginosus*). It was observed at 27 of 32 Year 1 age class sites, 27 of 31 Year 3 age class sites, and 23 of 24 Year 5+ age class sites. Most invasive weeds that were documented are *Noxious* weeds (12 identified) except for nodding thistle (*Carduus nutans*) and common buckthorn (*Rhamnus cathartica*) that are *Prohibited Noxious* weeds with more stringent eradication regulatory requirements. Nodding thistle was found at one Year 3 age class site along the Elbow River in Sandy Beach in 2020. Common buckthorn was found along the Elbow River at Sandy Beach at one Year 5+ age class site in 2020 and at one Year 3 age class site in 2022, and at one Year 3 age class site on the Elbow River at the Riverdale pedestrian bridge (Table 3-37).

These weeds are outcompeting the planted vegetation and should be removed as part of maintenance practices. Invasive species are a concern from a management perspective due to their potential negative effects on native vegetation, wildlife, and ecosystems. Some of the potential negative effects of invasive species include reduced native plant regeneration, altered hydrology, increased erosion and sedimentation, reduced wildlife habitat quality, and altered fire regimes, among other changes (Masters & Sheley, 2001). An approach to reduce invasive species proliferation in riparian sites is to shade them out through the establishment of a dense canopy cover. This can be achieved by using high density planting of 0.5 m or less in target areas and in between structures.

**Table 3-37: Invasive Weed Frequency by Site Age Class (2018-2022)**

| Species | No of Sites per Age Class with Observed Weeds | | |
|---|---|---|---|
| | Year 1[1] | Year 3[2] | Year 5+[3] |
| Creeping (Canada) Thistle (*Cirsium arvense*) [4] | 32 | 27 | 22 |
| Smooth Perennial Sow Thistle (*Sonchus arvensis* ssp. *Uliginosus*) [4] | 27 | 27 | 23 |
| Scentless Chamomile (*Tripleurospermum inodorum*) [4] | 25 | 15 | 5 |
| Black Henbane (*Hyoscyamus niger*) [4] | 18 | 3 | 0 |
| Tufted Vetch (*Vicia cracca*) | 17 | 18 | 18 |
| Common Toadflax (*Linaria vulgaris*) [4] | 16 | 18 | 12 |
| Common Tansy (*Tanacetum vulgare*) [4] | 13 | 20 | 10 |
| Common Burdock (*Arctium minus*) [4] | 10 | 12 | 13 |
| Creeping bellflower (*Campanula rapunculoides*)[4] | 8 | 10 | 7 |
| Yellow Clematis (*Clematis tangutica*) [4] | 4 | 5 | 6 |
| Ox-eye Daisy (*Leucanthemum vulgare*) [4] | 3 | 2 | 2 |
| Leafy Spurge (*Euphorbia esula*) [4] | 2 | 3 | 7 |
| Cleavers (*Galium aparine*) | 1 | 0 | 0 |
| White cockle (*Silene latifolia*) [4] | 1 | 6 | 5 |
| Common Caragana (*Caragana arborescens*) | 0 | 1 | 4 |
| Nodding Thistle (*Carduus nutans*) [5] | 0 | 1 | 0 |
| Hound's Tongue (*Cynoglossum officinale*) [4] | 0 | 1 | 4 |
| Common Buckthorn (*Rhamnus catharticus*)[5] | 0 | 2 | 1 |
| Common Mullein (*Verbascum thapsus*) [4] | 0 | 1 | 0 |

Notes:
1. Total of 32 Year 1 age class sites from 2018-2022, not including failure sites
2. Total of 31 Year 3 age class sites from 2018-2022, not including failure sites
3. Total of 29 Year 5+ age class sites from 2018-2022, not including failure sites
4. *Noxious Weed*.
5. *Prohibited Noxious Weed* with more stringent regulatory eradication requirements

### Invasive Weed Species and Riprap

Another result from bank effectiveness monitoring that mirrors findings in the literature (Cavaille, et al., 2013) is that the number of invasive species was shown to increase according to the proportion of bare riprap used for erosion protection on a riverbank. These results are not statistically significant, but a general increasing trend was observed. This result might indicate the need for a more thoughtful approach to how riprap is being designed when attempting to manage invasive species in Calgary. If reducing the amount of riprap is not possible, perhaps the void spaces in the riprap could be filled with planting materials and river gravels and native species should be seeded or planted so that the riprap is instead colonized with preferential species as described in Section 3.3.1.

### Soil Compaction Impacts on Vegetation Growth

Soil compaction impedes the growth of planting/cutting roots and shoots, impacts survival rates and vigour, and contributes to increased runoff due to decreased water percolation within the soil. Soil compaction was measured at each quadrat within 114 of the total 227 transects that were assessed (e.g., 65 of the total 99 assessments). Two soil compaction parameters are reported below as follows:

- Depth to Compacted Soil (depth to red): indicates the soil depth where pressure exerted on the testing equipment is greater than or equal to 2 MPa (300 psi) and indicates the depth to where soil compaction is greatest and where most roots will grow poorly. A higher depth indicates a larger thickness of uncompacted soil and a larger amount of soil available for plant establishment. A shallow depth indicates less uncompacted soil and a smaller amount of soil available for plant establishment; and
- Maximum depth: indicates the maximum depth at which the tester was able to insert the testing equipment, i.e., depth to refusal up to a maximum measurement depth of 60 cm.

Of the total number of sites that were assessed, 51 of 65 sites (78%) were measured to have Depth to Compacted soil of less than 30 cm and were classified as having significant compaction issues.

Depth to Compacted Soil is shown by typology in Figure 3-12. Of note was that the mean Depth to Compacted Soil for the Planting typology (25 cm; n = 90) and the Primarily Vegetative typology (19 cm; n = 76) were significantly higher than Vegetated Crib Wall typology (14 cm; n = 90) and the Vegetated Riprap typology (9 cm; n = 45). The highest mean Depth to Compacted Soil was the Planting typology, and the lowest was the Vegetated Riprap typology, indicating that Vegetated Riprap sites were the most compacted.

Measured mean shoot length against Depth to Compacted Soil and Maximum Depth are shown in Figure 3-13. Values for the linear regression for Depth to Compacted Soil were $R^2 = 0.005$, p-value = 0.231, and n = 90. Values for the linear regression for Maximum Depth were $R^2 = 0.024$, p-value = 0.077, and n = 90. The results of linear regression fell short of statistical significance but indicate a general trend of the impact that soil compaction has on shoot length, where the depth of uncompacted soil increases (i.e., Depth to Compacted Soil increases), the shoot length also increases. This result indicates that the planted vegetation will grow larger when given access to deeper uncompacted soil.

Soil compaction was also observed in the timber crib wall backfill, in areas of high public use, and at top of bank areas. Highly compacted backfill was commonly observed in timber crib wall sites with 10 out of 14 assessed sites (71%) having notable soil compaction (Photo 3-63). Areas of high public use were also observed to be compacted (Photo 3-64). However, the highest compaction for monitored sites was often measured at the top of bank in the riparian area or seeding zones where the staging/laydown area was located or where construction equipment travelled back and forth. Vegetation establishment was noted to be limited in the areas where soil was highly compacted.

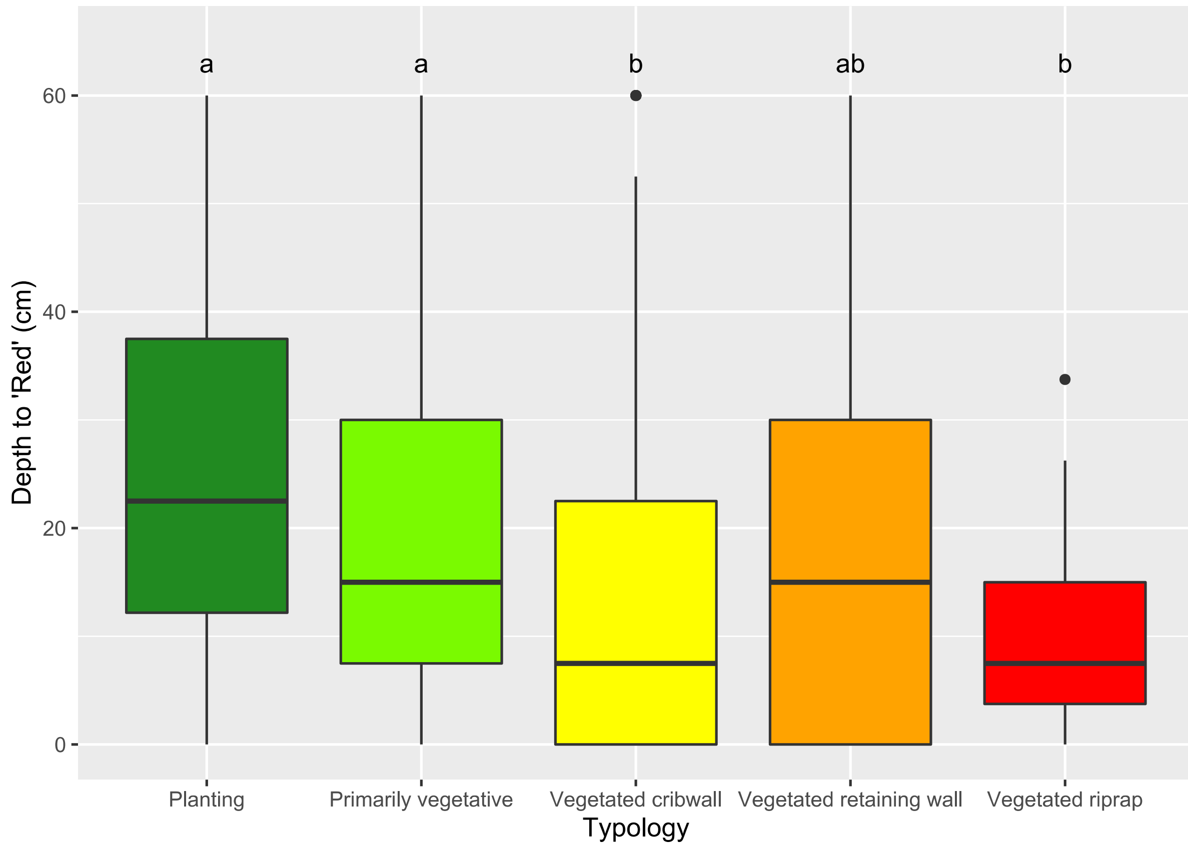



**Figure 3-12: Soil Compaction Depth to Compacted Soil (Depth to 'Red') by Typology**

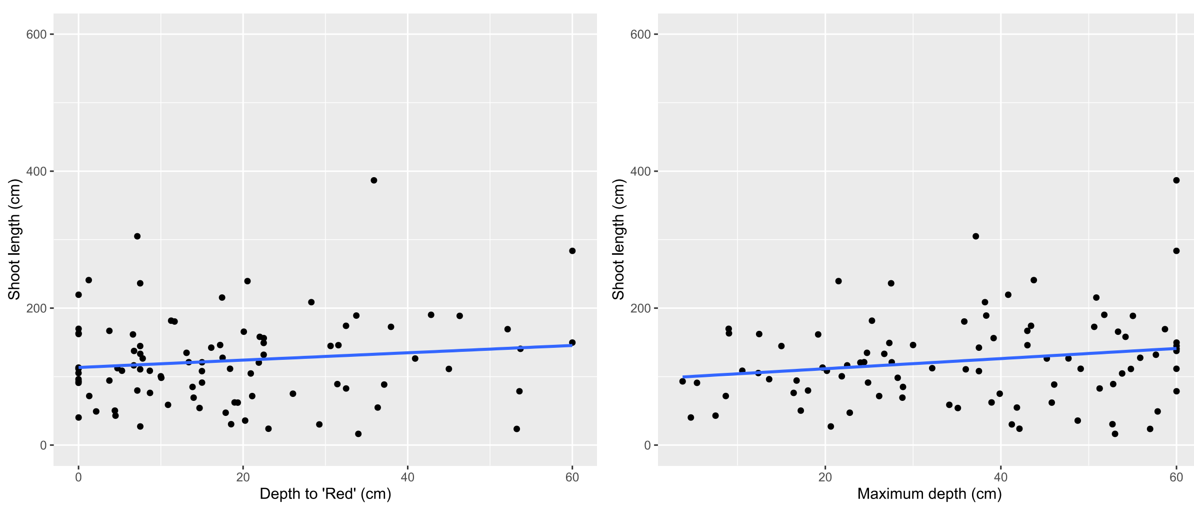



**Figure 3-13: Soil Compaction Effect on Shoot Length**

**Photo 3-63: Example of severe compaction in the timber crib wall backfill at a site on the Bow River**

**Photo 3-64: Example of severe compaction at a site on the Bow River due to public use**

## Bioengineering Technique Success

There are several examples of good use of bioengineering techniques across the City, including brush layers (Photo 3-65), brush mattresses (Photo 3-8 and Photo 3-11), live staking, timber crib walls (Photo **3-66**), vegetated riprap, and vegetated soil wraps, where the sites are stable and planted vegetated is flourishing.

To further identify successful techniques, an analysis was completed according to a ranking of five woody vegetation growth parameters (leader growth, shoot length, diameter, Year 1 survival, and canopy cover) as shown in Table 3-38. Each bioengineering technique was ranked from highest to lowest for each of these five parameters with the highest-ranking technique scoring one, the second highest scoring two, and so on for Year 1, Year 3, and Year 5+ age class data. The five woody vegetation growth parameter rankings were then averaged for each bioengineering technique for each age class, and then the three age class rankings were averaged to generate an overall rating. The bioengineering technique with the lowest average score was considered to the be most successful technique based on the measured parameters. **Note that this method only includes the five parameters listed above and does not include considerations such as cost, construction complexity, or regulatory approval requirements/timelines**. While results show that certain bioengineering techniques may be performing better than others based on the data that was collected, a full evaluation of growing performance, cost, construction, and regulatory complexity should be undertaken when evaluating a particular bioengineering approach or technique.

As shown in Table 3-38, the brush mattress technique ranked first overall (example shown in Photo **3-11**). This technique appears to be doing well at locations where its use is appropriate and where there is sufficient soil moisture. For example, the brush mattresses at BDEP (Photo 3-11) were exceeding establishment targets with measured average shoot densities of 32 stems/m², 30 stems/m², and 17 stems/m² respectively in comparison to the density target for brush mattresses of average 10 stems/m² and minimum 5 stems/m² after five years (Schiechtl & Stern, 1997). However, there are known brush mattress installations[10] in the city where vegetation establishment was not successful due to

[10] These sites were not monitored as part of the RMP because they were no longer present due to disturbance by other City works.

observed excess burial of the live cuttings. Given the moderate complexity of a successful application of this technique, it should be used with caution and only at locations with access to adequate soil moisture.

The vegetated crib wall technique ranked second overall (example shown in **Photo 3-8**). While all other vegetation growth parameters were high, Year 1 age class survival for vegetated crib wall is low (see Table 3-21). Note that while vegetation growth in timber crib walls was found to be doing well, timber crib walls require high levels of design, regulatory and construction efforts. The life cycle of the structure should also be considered during design so that the final arrangement of the bank is anticipated once the timber decomposes and the vegetation is intended to take over the role of bank stabilization. Additional timber crib wall considerations are provided in Section 3.3.1 General Results, Structure Design.

While brush layers (example shown in Photo 3-65) are the fourth highest performing technique overall based on vegetation establishment parameters, they are also often used in vegetated timber crib walls and vegetated retaining walls that ranked higher in this analysis. Thus, they are considered a robust, deeply buried bioengineering technique with a history of good establishment that should be considered for bioengineering projects in Calgary when appropriate. However, brush layers do require heavy equipment and excavation into the bank which may not be preferred for all sites.

The lowest performing bioengineering technique according to the measured vegetation establishment parameters was live staking. Low live staking survivorship may be in part because it is the simplest technique to implement and volunteer efforts typically use this technique. Volunteer-led projects were observed to be less successful than projects implemented by professionals (KWL, 2019b). Live staking can still be an effective and preferred bioengineering technique because it is relatively low cost, with simple design and construction processes. To mitigate low survivorship for this technique, the density of installed live cuttings can be increased so that survivorship targets can still be met. Additionally, it is recommended that projects using this technique are made aware of the lower survivorship in Calgary and are encouraged to closely follow best practices per the Design Guidelines (AMEC, 2012) and as supplemented by the information in Box 5 – particularly installing live cuttings as deeply as practical while burying around 80%-90% of the length. A good live staking example is located at the BDEP site (BE-BOW-46D4 / Site 2-2C).

**Table 3-38: Bioengineering Technique Performance Ranking**

| Bioengineering Technique | Average Rankings[1] | | | Average Ranking[4] | Overall Ranking[5,6] |
|---|---|---|---|---|---|
| | Year 1[2] | Year 3[3] | Year 5+[3] | | |
| Brush layers | 5 | 2 | 4 | 3.7 | 4 |
| Brush mattress | 3 | 3 | 1 | 2.3 | 1 |
| Fascine | 6 | 4 | -- | 5.0 | 5 |
| Live staking | 8 | 8 | 6 | 7.3 | 8 |
| Plantings | 4 | 7 | 6 | 5.7 | 7 |
| Vegetated crib wall | 2 | 1 | 5 | 2.7 | 2 |
| Vegetated retaining wall | -- | 5 | 2 | 3.5 | 3 |
| Vegetated riprap | 7 | 6 | 3 | 5.3 | 6 |
| Wattle fencing [6] | 1 | -- | -- | -- | -- |

Notes:
1. Rankings are 1 for the highest-and 9 for the lowest.
2. Year 1 age class ranking calculation is the average ranking by bioengineering technique for five Year 1 parameters: mean leader growth, mean shoot length, mean stem diameter, mean woody vegetation canopy cover, and mean survival rate.

| Bioengineering Technique | Average Rankings[1] | | | Average Ranking[4] | Overall Ranking[5,6] |
|---|---|---|---|---|---|
| | Year 1[2] | Year 3[3] | Year 5+[3] | | |

3. Year 3 and Year 5+ age class rankings are the average ranking by bioengineering technique for four Year 3 and Year 5+ parameters: mean leader growth, mean shoot length, mean stem diameter, and mean woody vegetation canopy cover.
4. The average ranking was calculated by averaging Year 1, Year 3, and Year 5+ age class rankings for each bioengineering technique.
5. This ranking method only includes the five parameters listed above and does not include considerations such as cost, construction complexity, or regulatory approval requirements/timelines.
6. Wattle fencing was not included in the overall average ranking due to the small sample size for measurements (n = 30) for only one age class.

**Photo 3-65: Example of a brush layer technique installed on the Bow River in 2018 and assessed in 2019 and 2021**

**Photo 3-66: Example of a vegetated timber crib wall technique installed on the Bow River in 2019 and assessed in 2020**

# 4. Riparian Effectiveness Monitoring

The methods, data collection, key results, successes, and areas for improvement for the riparian effectiveness monitoring component of the project are summarized in this section. Riparian effectiveness are projects where the main purpose is enhancing riparian habitat away from the bank, with little to no structural component. An example riparian effectiveness site referred to as Ramsay Along Elbow River is shown in Photo 4-1 . Riparian restoration sites are mostly focused on the top of bank (riparian) areas, and general riparian/floodplain areas but may extend down onto the bank of smaller streams and creeks.

**Photo 4-1: Riparian Effectiveness Monitoring Site Example: Ramsay Along Elbow River**

*Project constructed in 2017 and monitored under the riparian effectiveness component in 2018, 2020 and 2022*

## 4.1 4.1 Data Collection and Organization

Summarized below are the methods used to monitor riparian effectiveness sites, which includes desktop assessments, field assessments, failure assessments, and ratings. The data for each monitoring site were collected and recorded on Microsoft® Excel® data forms that were specifically developed for the RMP effectiveness monitoring component.

### 4.1.1 Desktop Assessment

Potential riparian effectiveness monitoring sites were selected from *The City of Calgary Master List – Riparian Restoration Projects*. Sites chosen needed to have sufficient background information to be included in the monitoring program. All available background information (e.g., design reports, drawings, planting details, additional contact information) was requested from the project manager. Background information was entered in a Desktop form for each site. Included in the Desktop form was a 'Planting Detail,' which included a list of all plant species planted and seeding on the site, if available.

### 4.1.2 Field Assessments

Sites with sufficient background information then underwent a reconnaissance field assessment. A reconnaissance assessment was undertaken to confirm the location of the project, verify if the project was still present and effective, confirm if the background information was accurate, map out the restoration features present (e.g., site boundaries, typologies) if detailed design plans were unavailable, and record any potential limiting factors to success (e.g., wildlife impact) (Table 4-1).

Detailed sampling consisted of four parts (Table 4-1). First, a Monitoring Plot form was completed, recording such information as plot size, typology, aspect, shade, erosion, types of animal disturbance, and limiting factors to success. Second, a Pin-point Transect form was completed, recording percent cover of all plant species in different vegetation layers, percent cover of various ground cover variables (e.g., litter, moss/lichen, bare soil), and other data. Third, a Quadrat form was filled-out, including data on herbaceous species richness, woody species density, seeded herbaceous species cover, and soil compaction. Lastly, a Survivorship form was completed, with data on survivorship, condition, vigour, leader growth, and shoot length of the cuttings and/or plantings installed recorded.

**Table 4-1: Data Collected for the Riparian Restoration Effectiveness Monitoring Component**

| Assessment Form | General Description | Data Collected |
|---|---|---|
| Monitoring Plot | Used to record general environmental and vegetation attributes | • Plot size and coordinates;<br>• Vegetation canopy cover estimates (total vegetation, trees, shrubs, graminoids, forbs, and disturbance-increaser species)<br>• Invasive species canopy cover and density distribution;<br>• Aspect;<br>• Level of shade;<br>• Location along bank (if applicable);<br>• Presence of anoxia;<br>• Presence of seeps or springs;<br>• Degree of erosion;<br>• Amount of coarse woody debris present;<br>• Percent human-caused bare soil cover;<br>• Percent of site affected by human-caused soil compaction;<br>• Litter cover;<br>• Types of animal and human disturbance(s); and<br>• Limiting factors to restoration success. |

| Assessment Form | General Description | Data Collected |
|---|---|---|
| Pin-point Transect | Used to record detailed vegetation data | • Percent cover of individual plant species;<br>• Total vegetation cover;<br>• Percent cover of various ground cover types, including moss and lichen, litter/LFH, and large woody debris;<br>• Percent cover of various physical site attributes, including human-caused and non-human-caused bare soil, sediment, gravel, cobble, riprap, and concrete/asphalt;<br>• Vegetation structure (plant layers); and<br>• Forb and graminoid height and vigour. |
| Quadrat | Used to record detailed vegetation data | • Herbaceous species richness (i.e., total number of different forb and graminoid species present);<br>• Density of plantings/cuttings;<br>• Percent cover of native herbaceous species; and<br>• Soil compaction. |
| Survivorship | Used to record detailed data for installed woody material | • Survivorship (i.e., dead vs. alive);<br>• Condition (e.g., browsing, mechanical damage);<br>• Vigour (scale of 1 to 5);<br>• Pest damage (scale of 1 to 5);<br>• Shoot length;<br>• Diameter;<br>• Leader length; and<br>• Length of exposed cuttings (if applicable). |
| Reconnaissance | Used to record general project attributes | • Verification of project effectiveness;<br>• Verification of project typology;<br>• Verification of project design plan and background information;<br>• Record restoration dimensions and configuration;<br>• Map boundaries of restoration features;<br>• Recommended number of detailed sampling plot;<br>• State of management and maintenance structures (e.g., fencing);<br>• Limiting factors to restoration success;<br>• Management factors of concern (e.g., invasive species); and<br>• Presence of prohibited noxious weeds, including cover and density distribution. |
| Failure | Used to record information on restoration failure | • Possible causes of restoration failure, such as erosion, soil compaction, soil anoxia, wildlife damage, vegetation competition, poor planting/cutting installation, inappropriate plant material type, etc. |

### 4.1.3 Ratings

In the same way as the bank effectiveness sites (see Section 3.1.3), riparian effectiveness sites that underwent a reconnaissance and/or detailed site assessment were given five different ratings that were developed specifically for the RMP project: Design, Implementation, Maintenance, Success, and Bank and Riparian Quality Index (BRQI). The Design rating relates to the specific design approach of the project and whether it is suitable for a particular site. The Implementation rating relates to how well the design was carried out. The Maintenance rating measures if any maintenance is occurring to ensure the project is successful and how well those maintenance activities are being performed. A Success rating was used to measure how well the installed vegetation had established on the site and includes measurements of the survival rate and vigour of the cuttings and/or plantings as well as percent canopy cover of seeded herbaceous species (if applicable). The BRQI rating relates to the ecological success of the project and scores such health indicators as percent cover of total vegetation, invasive plant species, and native woody species as well as percent cover of riprap and concrete and human-caused bare soil, among others.

Each project was then given an overall score after combining the five individual ratings and applying a multiplier to achieve a total weighted score out of 100 (Table 4-2). For the purposes of this project, rating percentages were broken into three colour-coded categories based on range health assessment methodology developed by the Government of Alberta (Adams et al., 2016) (Table 4-3).

**Table 4-2: Overall Score**

| Rating | Max. Score | Multiplier | Weighted Score |
|---|---|---|---|
| BRQI | /100 | 0.22 | /22 |
| Success | /6 | 4 | /24 |
| Design | /6 | 3 | /18 |
| Implementation | /6 | 3 | /18 |
| Maintenance | /6 | 3 | /18 |
| **Total** | | | **/100** |

**Table 4-3: Weighted Scores and Categories**

| Weighted Score | Categories |
|---|---|
| 75-100 | Good |
| 50-74 | Fair |
| 0-49 | Poor |

### 4.1.4 Typologies and Age Classes

Riparian effectiveness monitoring sites were classified into one of four typologies according to the restoration technique(s) utilized (Table 4-4) as discussed in the RMP Monitoring Plan (KWL, 2018). Sites were also classified according to the age of the work, with three age categories used: Year 1, Year 3, and Year 5+.

**Table 4-4: Riparian Effectiveness Typologies**

| Typology | Description | Photo |
|---|---|---|
| Native Tree and Shrub Cuttings | Projects involving primarily the use of live native tree and shrub cuttings. |  |
| Native Tree and Shrub Plantings | Projects involving primarily the use of native tree and shrub rooted plugs and/or potted plants. |  |
| Mixed Techniques | Projects involving a mix of techniques, including live cuttings and rooted stock, in addition to either a native seed mix or herbaceous plantings, site preparation such as weed removal, or in combination with one or more unique features such as Waterboxx® planters. |  |
| Large-Scale Riparian Retrofit | Large-scale construction projects, often involving multiple techniques. Includes the following three projects:<br>• **Site #48B** (Harvie Passage – South Side Channel);<br>• **Site #68** (Quarry Park Fish Compensation Project); and<br>• **Site #92** (Bowmont Natural Area East – A). |  |

### 4.1.5 Effectiveness Monitoring

A complete list of all riparian effectiveness sites assessed over the course of the RMP is provided in Appendix B. Appendix B also contains a figure showing the locations of all sites assessed. A list of priority restoration sites is provided in Appendix C. Lists of successful and failure sites are provided in Appendix D. Also listed in Appendix D are the lowest-scoring riparian effectiveness sites.

Table 4-5 summarizes the number of assessments completed over the course of the five-year RMP. Forty-two unique riparian effectiveness sites were visited over the course of the program. Twenty-one of these sites were visited more than once (n=28 re-assessments). Forty-two reconnaissance and 59 detailed assessments were completed at these sites. It should be noted that statistical analyses were only carried out on 57 of the 59 detailed assessments as two of the assessments were on a failure site (RE-WNO-112B [West Nose Creek – Sage Meadows], Year 1 and Year 3 age classes). In terms of age class, 23 Year 1, 32 Year 3, and 15 Year 5+ age class assessments were completed (Table 4-5)[11]. In terms of typology, 21 Native Tree and Shrub Cuttings, 15 Mixed Techniques, 25 Native Tree and Shrub Plantings, and 9 Large-Scale Riparian Retrofit assessments were completed (Table 4-7).

**Table 4-5: Number of Sites and Assessments for Each Year of the Monitoring Program**

| Year | Recon. Assess. | Detailed Assess. | New Sites[1] | Re-assess-ments[2] | Total Failure | Partial Failure |
|---|---|---|---|---|---|---|
| 2018 | 23 | 15 | 23 | 0 | 9 | 3 |
| 2019 | 9 | 7 | 9 | 0 | 2 | 0 |
| 2020 | 2 | 17 | 2 | 15 | 0 | 0 |
| 2021 | 5 | 10 | 5 | 6 | 1 | 0 |
| 2022 | 3 | 10 | 3 | 7 | 0 | 0 |
| **TOTAL** | **42** | **59[3]** | **42** | **28** | **12** | **3** |

Notes:
1. Refers to sites not previously assessed in an earlier year of the monitoring program.
2. Refers to sites previously assessed in an earlier year of the monitoring program.
3. Total includes 57 detailed assessments of non-failure sites and 2 detailed assessments of a failure site (RE-W NO-112B [West Nose Creek – Sage Meadows]).

**Table 4-6: Number of Assessments and Failures by Age Class**

| Year | Year 1 | | Year 3 | | Year 5+ | |
|---|---|---|---|---|---|---|
| | No. Assess.[1] | No. Failures[2] | No. Assess.[1] | No. Failures[2] | No. Assess.[1] | No. Failures[2] |
| 2018 | 12 | 2 | 11 | 7 | 0 | 0 |
| 2019 | 3 | 0 | 6 | 2 | 0 | 0 |
| 2020 | 2 | 0 | 11 | 0 | 4 | 0 |
| 2021 | 4 | 1 | 3 | 0 | 4 | 0 |
| 2022 | 2 | 0 | 1 | 0 | 7 | 0 |
| **TOTAL** | **23** | **3** | **32[3]** | **9** | **15** | **0** |

Notes:
1. Includes all sites for which a detailed or reconnaissance assessment was completed.
2. Includes only new failure sites. One failure site, RE-WNO-112B (West Nose Creek – Sage Meadows), underwent detailed sampling in both 2018 and 2020.
3. Total includes 31 assessments of non-failure sites and 1 assessment of a Year 3 failure site (RE-W NO-112B [West Nose Creek – Sage Meadows]).

[11] The total for Year 1 sites includes one site, RE-BOW-48B (Harvie Passage – South Side Channel, that is technically a Year 2 site. Throughout this report, discussion of Year 1 sites includes RE-BOW-48B.

**Table 4-7: Number of Assessments and Failures by Typology**

| Year | Cuttings | | Mixed | | Plantings | | Riparian Retrofit | |
|---|---|---|---|---|---|---|---|---|
| | No. Assess.[1] | No. Failures[2] | No. Assess.[1] | No. Failures[2] | No. Assess.[1] | No. Failures[2] | No. Assess.[1] | No. Failures[2] |
| 2018 | 11 | 7 | 7 | 2 | 3 | 0 | 2 | 0 |
| 2019 | 3 | 2 | 0 | 0 | 5 | 0 | 1 | 0 |
| 2020 | 5 | 0 | 4 | 0 | 5 | 0 | 3 | 0 |
| 2021 | 1 | 0 | 2 | 0 | 8 | 0 | 0 | 0 |
| 2022 | 1 | 0 | 2 | 0 | 4 | 0 | 3 | 0 |
| **TOTAL** | **21** | **9** | **15** | **2** | **25** | **0** | **9** | **0** |

Notes:
1. Includes all sites for which a detailed or reconnaissance assessment was completed.
2. Includes only new failure sites. One failure site, RE-WNO-112B (West Nose Creek – Sage Meadows), underwent detailed sampling in both 2018 and 2020.

### 4.1.6 Failure Site Assessments

A failure criterion of 25% Year 1 age class survivorship of woody vegetation was used for riparian effectiveness projects. Unlike the bank effectiveness component of the project, no structural assessments were carried out on riparian effectiveness projects. Therefore, structural failures were not possible (see Section 3.1.7). If a project met the 25% threshold, it was deemed to be successful and subsequently underwent detailed sampling. If a project did not meet this threshold, it was deemed to be a failure and a Failure Assessment form was completed, recording the presence and severity of causal factors such as soil compaction, anoxia, human disturbance, and vegetation competition. Failure sites were generally excluded from detailed monitoring (Table 4-1).

The term ‘partial failure’ was also applied to some riparian effectiveness sites. Partial failure sites are sites where a portion of the site (e.g., one technique) failed but another portion of the site was successful (i.e., it had greater than 25% survival). The successful portions of these sites underwent detailed monitoring.

The vegetation survival failure criteria of < 25% was removed for Year 3 and Year 5+ sites mid-program (in 2020) since it was not always possible to accurately assess the survival of planted woody vegetation for Year 3 and older sites due to either the growth of other vegetation obscuring dead cuttings/plantings and/or state of decay of the dead cuttings/plantings.

In total, 12 total failure and 3 partial failure sites were identified over the course of the RMP.

**Table 4-8: Number of Assessments and Failures by Typology**

| Site Descriptor | Site Name | Typology | Failure/Partial Failure |
|---|---|---|---|
| RE-NOS-10 | Nose Creek – South of Beddington Trail | Native tree and shrub cuttings | Failure |
| RE-WNO-11 | West Nose Creek Confluence Park near Harvest Hills Blvd. | Native tree and shrub cuttings | Failure |
| RE-WNO-12 | West Nose Creek Directly Downstream from Stoney Trail | Native tree and shrub cuttings | Failure |
| RE-WNO-13 | West Nose Creek Directly Upstream from Stoney Trail | Native tree and shrub cuttings | Failure |
| RE-WNO-14 | West Nose Creek Evanston (WNO21) | Native tree and shrub cuttings | Failure |

| Site Descriptor | Site Name | Typology | Failure/Partial Failure |
|---|---|---|---|
| RE-WNO-16 | West Nose Creek Upstream of Country Hills Golf Course | Native tree and shrub cuttings | Failure |
| RE-FIS-18 | Friends of Fish Creek – A – Downstream Bridge 11 | Native tree and shrub cuttings | Failure |
| RE-FIS-20 | Friends of Fish Creek – C | Native tree and shrub cuttings | Failure |
| RE-FIS-22 | Fish Creek – Trout Unlimited – Bridge 9 | Native tree and shrub cuttings | Partial failure |
| RE-BOW-45 | Inglewood North Field | Mixed techniques | Failure |
| RE-ELB-94 | 23rd Ave | Mixed techniques | Partial failure |
| RE-ELB-104 | Mission (MIS248) – RBC Plantings | Mixed techniques | Partial failure |
| RE-BOW-109 | Bowmont Park (SIL245) – 2 Sites – 1 West End, 1 East End | Mixed techniques | Failure |
| RE-WNO-112B | West Nose Creek – Sage Meadows | Native tree and shrub cuttings | Failure |
| RE-BOW-127 | Bow – Nose Creek | Native tree and shrub plantings | Failure |

### 4.1.7 Data Collection Quick Facts Summary

Some interesting quick facts about the riparian effectiveness component of the RMP project are provided in Table 4-11.

**Table 4-9: Riparian Effectiveness Monitoring Quick Facts**

| | |
|---|---|
| Number of years of data collection | 5 |
| Number of unique restoration projects visited | 42 |
| Number of restoration projects visited more than once | 21 |
| Number of City of Calgary restoration projects visited | 25 |
| Number of volunteer restoration projects visited | 16 |
| Watercourse with the greatest number of projects | Bow River |
| Number of detailed assessments completed | 59 |
| Number of transects completed | 81 |
| Number of quadrats sampled | 243 |
| Number of individual trees and shrubs sampled for survivorship and growth characteristics | 5,457 |
| Average Year 1 survivorship of plantings versus cuttings | 93% vs. 47% |
| Average overall rating for all projects assessed by age class | Year 1: 59 (Fair) (n=23)<br>Year 3: 51 (Fair) (n=31)<br>Year 5+: 60 (Fair) (n=15) |
| Most common limiting factor for restoration success | Herbaceous species competition |
| Number of invasive plant species encountered* | 21 |
| Most commonly observed invasive species | Creeping (Canada) thistle |

* Invasive species for this project refer to Prohibited Noxious and Noxious weeds as well as several other species considered invasive by Cows and Fish.

## 4.2 Analysis Methodology

### 4.2.1 Statistical Methods

Various statistical analyses were performed on the riparian effectiveness data collected for the RMP project (see Section 3.2.1). The main analysis utilized was comparison of means tests. Comparisons of means tests were used to compare typologies, age classes, and other parameters (e.g., shoot length, leader growth) to determine if there were any trends or significant findings. Two types of multivariate analyses were also performed to analyze the data. First, a principal components analysis (PCA) was used to analyze each site to understand how the different sites, age classes, and typologies are structured according to the design, implementation, maintenance, success, and BRQI ratings. Second, non-metric multidimensional scaling (NMDS) analyses were performed on the vegetation data collected from the pin-point transects. The purpose of the NMDS analysis was to determine if plant species and communities are affected by typology, age class, or watershed.

### 4.2.2 Sample Size

Table 4-10 presents the final detailed assessment sample sizes for each age class and typology that were used in the statistical analyses. Ideally, the data available for analysis would include a minimum of five sites per age class and typology to make the results statistically significant (KWL, 2018). As shown in Table 4-10, this threshold was met for some categories but not others.

**Table 4-10: Final Number of Detailed Assessments by Age Class & Typology for Statistical Analysis**

| Age Class | Typology | | | | |
|---|---|---|---|---|---|
| | Cuttings | Mixed | Plantings | Riparian Retrofit | Total |
| 1 | 2 | 6 | 9 | 3 | 20 |
| 3 | 5 | 5 | 9 | 3 | 22 |
| 5+ | 4 | 3 | 5 | 3 | 15 |
| **Total** | **11** | **14** | **23** | **9** | **57** |

### 4.2.3 Variables Identified from Data Collection

Independent variables that were identified based on the data that was collected are listed below. The results of the analysis for these variables are described in Section 4.3.

- Age Class: Year 1 age class, Year 3 age class, and Year 5+ age class.
- Typology: Native Tree and Shrub Plantings, Native Tree and Shrub Cuttings, Mixed techniques, Large-scale Riparian Retrofit (see Table 4-4).
- Vegetation stock type: live cuttings and container plants.
- Vegetation species: a complete list of woody species can be found in Table 3-19 and 4-16.
- Aspect: “North, North-East, East”, “North-West”, “Flat”, “South-East”, and “South, South-West, West”.
- Shade: sunny sites versus shady sites.

Dependent variables that were identified based on the data that was collected are listed below.

- Woody vegetation survival and growth parameters: Year 1 survival, leader growth, shoot length, and stem diameter.
- Woody vegetation percent canopy cover.
- Invasive weeds species monitoring.
- Herbaceous seeding germination success.
- Soil compaction: depth to uncompacted soil and maximum depth.

### 4.2.4 Limitations and Statistical Validity of the Data

The riparian effectiveness data collected for the RMP project and discussed in this report has some important limitations. Specifically, sample sizes for typologies and age classes were not always sufficient to make robust statistical conclusions. The target population size was a minimum of five sites per age class and typology to make the results statistically significant (KWL, 2018). As shown in Table 4-10, this threshold was met for some categories but not others. Therefore, the data does have some limitations with respect to sample size, particularly for the Large-Scale Riparian Retrofit typology. The reason that the minimum threshold was not met was simply due to a lack of sites to monitor, which in turn was partly due to the high number of failures. Sample sizes should always be considered when drawing conclusions from the findings in this report.

As previously discussed, a number of riparian effectiveness sites were visited several times, including sites from different age classes. As a result, the same re-visit sites can be found in several age classes for the same analyses. The results of these analyses, presented by age class, should be interpreted temporally with caution, as the presence of repeated data does not allow for statistical comparisons. However, these limitations did not significantly reduce the overall ability of the RMP to produce valuable results for riparian project effectiveness. A number of the results from the overall analysis remain statistically significant.

A thorough discussion of the limitations of the RMP data is provided in Section 3.2.5.

## 4.3 Results

Some of the key findings from the riparian effectiveness monitoring component of the RMP are presented in this section. Results are split into two sections: general findings and statistical results. The former includes some of the general observations noted over the course of the RMP as well as some basic descriptive statistical results. The latter section discusses some of the comparisons of means tests on the data collected, including survivorship of cuttings versus plantings, survivorship according to aspect and shade, and soil compaction. The section on statistical results is brief as many of the statistical analyses performed for this project did not yield any significant results and so are not included in this report. The small sample sizes and presence of the same sites in multiple age classes also limited what could be performed statistically. The results shown in this section provide the foundation for some of the conclusions and recommendations discussed in Section 7.

Some interesting quick facts about the riparian effectiveness component of the RMP project are provided in Table 4-11.

### 4.3.1 General Findings

#### Riparian Effectiveness Failure Sites

One of the important findings of the five-year riparian effectiveness monitoring was the high number of sites that were unsuccessful. Of the 42 unique riparian effectiveness sites assessed, 15 (or 36%) were partial (n=3) or total (n=12) failures (Table 4-12). The Native Tree and Shrub Cuttings typology had the highest proportion of failure sites compared to the other three typologies; indeed, 10 of the 14 native tree and shrub cuttings sites assessed were partial or total failures, or 71% of the total. Part of the reason for the high proportion of failure sites for this particular typology may be due to the fact that many of the projects were volunteer-led and not City of Calgary-led projects. As well, as discussed below, cuttings do not appear to survive as well as plantings in southern Alberta. Half of the partial and total failures for the Mixed Techniques typology were also due to poor survival of cuttings. There was only one failure for the Native Tree and Shrub Plantings typology and none for the Large-Scale Riparian Retrofit typology.

**Table 4-11: Riparian Effectiveness Monitoring Quick Facts**

| | |
|---|---|
| **Number of years of data collection** | 5 |
| **Number of unique restoration projects visited** | 42 |
| **Number of restoration projects visited more than once** | 21 |
| **Number of City of Calgary restoration projects visited** | 25 |
| **Number of volunteer restoration projects visited** | 16 |
| **Watercourse with the greatest number of projects** | Bow River |
| **Number of detailed assessments completed** | 59 |
| **Number of transects completed** | 81 |
| **Number of quadrats sampled** | 243 |
| **Number of individual trees and shrubs sampled for survivorship and growth characteristics** | 5,457 |
| **Average Year 1 survivorship of plantings versus cuttings** | 93% vs. 47% |
| **Average overall rating for all projects assessed by age class** | Year 1: 59 (Fair) (n=23)<br>Year 3: 51 (Fair) (n=31)<br>Year 5+: 60 (Fair) (n=15) |
| **Most common limiting factor for restoration success** | Herbaceous species competition |
| **Number of invasive plant species encountered*** | 21 |
| **Most commonly observed invasive species** | Creeping (Canada) thistle |

* Invasive species for this project refer to Prohibited Noxious and Noxious weeds as well as several other species considered invasive by Cows and Fish.

**Table 4-12: Number of Failure Sites by Typology**

| Typology | Successful | Total Failure | Partial Failure |
|---|---|---|---|
| Native Tree and Shrub Cuttings | 4 | 9 | 1 |
| Native Tree and Shrub Plantings | 15 | 1 | 0 |
| Mixed Techniques | 5 | 2 | 2 |
| Large-Scale Riparian Retrofit | 3 | 0 | 0 |
| **Total** | **27** | **12** | **3** |

## Site-Specific Limiting Factors for Success

When first assessing potential riparian effectiveness sites for monitoring during the reconnaissance site visit, notes were made in the field on what site-specific factors could be limiting the success of the respective projects. Some interesting findings emerged from this analysis, with the top limiting factors to project success listed in Table 4-13. The main site-specific limiting factor for success was competition from herbaceous plant species, with the majority of assessed sites observed with native or non-native grass and forb species competing with installed cuttings and/or plantings. Wildlife impact, human disturbance, shading, and soil compaction were the next most common limiting factors. Damage from humans and wildlife can often be prevented with proper fencing in place to protect installed woody material. Only 54% of riparian effectiveness sites assessed had fencing in place. Moreover, even when fencing was in place, in some cases it was inadequate to protect the planted vegetation from browsing from beavers and other wildlife.

**Table 4-13: Site-Specific Limiting Factors**

| Site-Specific Limiting Factors | Proportion of Sites (%) | | |
|---|---|---|---|
| | Successful Sites (n=30) | Failure Sites (n=12) | All Sites (n=42) |
| Herbaceous species competition | 80.0 | 91.7 | 83.3 |
| Wildlife | 23.3 | 50.0 | 31.0 |
| Human disturbance | 33.3 | 8.3 | 26.2 |
| Shading | 26.7 | 8.3 | 21.4 |
| Soil compaction | 23.3 | 8.3 | 19.0 |
| Other | 3.3 | 16.7 | 7.1 |
| Soil anoxia | 0 | 8.3 | 2.4 |
| Soil type | 0 | 0 | 0 |

## Site-Specific Failure Factors

To avoid future failures, it is important to understand why past projects failed. To that end, all projects that were deemed to be total or partial failures underwent the aforementioned failure analysis to determine what were the likely causal factors of its poor success. The top five site-specific failure factors from this analysis are presented in Table 4-14. As shown, the main reason sites failed was because of vegetation competition, often from non-native perennial grasses. Other common failure factors were poor planting installation, wildlife damage, damage from insects and other pests, and inappropriate source material type.

**Table 4-14: Site-Specific Failure Factors**

| Site-Specific Failure Factors | No. Sites | Proportion of Sites (%) |
|---|---|---|
| Vegetation competition | 12 | 100 |
| Poor planting installation | 8 | 66.7 |
| Wildlife | 7 | 58.3 |
| Insect/pest damage | 4 | 33.3 |
| Inappropriate source material type | 4 | 33.3 |

## Woody Vegetation Survival and Growth Performance

Another key result from the five years of riparian effectiveness monitoring was the plethora of data collected on the performance of individual native shrub and tree species, both in container and cutting form, used in Calgary restoration projects. For all native tree and shrub species sampled, data was collected on shoot length, leader growth, stem diameter, Year 1 age class survivorship, and condition, among other variables. Such data is invaluable for determining which species perform well in Calgary, and conversely, which species perhaps should be avoided in future restoration projects. Some interesting quick facts about the woody vegetation analysis are presented in Table 4-15. Detailed survivorship and growth data for all planting and cutting species sampled over the course of the RMP are presented in Table 4-16 and Table 4-17.

**Table 4-15: Riparian Effectiveness Woody Vegetation Analysis Quick Facts**

| | |
|---|---|
| **Number of different tree and shrub species sampled for survivorship, health, and growth variables (live cuttings and container plants combined)** | 31 |
| **Number of different container plant species sampled** | 29 |
| **Number of different live cutting species sampled** | 7 |
| **Number of individual container plants sampled** | 4,063 |
| **Number of individual live cuttings sampled** | 1,394 |
| **Most commonly used container tree/shrub species** | Balsam poplar (*Populus balsamifera*) |
| **Most commonly used live cutting tree/shrub species** | Sandbar willow (*Salix interior*) |
| **Number of container shrub/tree species with an estimated 100% Year 1 survival** | 11 |
| **Number of live cutting shrub/tree species with an estimated 100% Year 1 survival** | 0 |
| **Estimated Year 1 survival rate of sandbar willow cuttings** | 45% (n=393) |

**Table 4-16: Survival Rates and Growth Measurements of Container Plant Species by Age Class[12]**

| Species | No. Sites | Total No. Plants | Year 1 Sites | | | | | Year 3 Sites | | | | Year 5+ Sites | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | No. Plants | Survival Rate (%) | Mean Leader Growth (cm) | Mean Shoot Length (cm) | Mean Diameter (cm) | No. Plants | Mean Leader Growth (cm) | Mean Shoot Length (cm) | Mean Diameter (cm) | No. Plants | Mean Leader Growth (cm) | Mean Shoot Length (cm) | Mean Diameter (cm) |
| Aspen (*Populus tremuloides*) | 4 | 228 | 93 | 86.0 | 13.9 | 217 | 2.7 | 101 | 13.2 | 226 | 3.1 | 34 | 4.7 | 319.2 | 4.5 |
| Balsam poplar (*Populus balsamifera*) | 18 | 603 | 271 | 84.1 | 18.6 | 100.3 | 1.2 | 236 | 15.7 | 144.3 | 2 | 96 | 13.7 | 204.6 | 3.2 |
| Basket willow (*Salix petiolaris*) | 1 | 9 | 5 | 100 | 28.6 | 43.6 | 0.7 | 4 | 30.8 | 52.2 | 0.8 | 0 | n/a | n/a | n/a |
| Beaked willow (*Salix bebbiana*) | 10 | 222 | 92 | 94.6 | 18.9 | 50.6 | 1.1 | 91 | 16 | 64.6 | 1.3 | 39 | 15.7 | 72.6 | 1.7 |
| Buckbrush (*Symphoricarpos occidentalis*) | 5 | 154 | 84 | 96.4 | 13.6 | 38.5 | 0.6 | 50 | 13.1 | 52.9 | 0.6 | 20 | 7.7 | 59.9 | 0.8 |
| Canada buffaloberry (*Shepherdia canadensis*) | 2 | 34 | 24 | 100 | 5.7 | 34.8 | 0.6 | 10 | 5 | 44.6 | 0.9 | 0 | n/a | n/a | n/a |
| Choke cherry (*Prunus virginiana*) | 9 | 224 | 90 | 97.8 | 13.3 | 46.4 | 1.2 | 84 | 14.7 | 58.3 | 1.1 | 50 | 7.3 | 62 | 1.3 |
| Common bearberry (*Arctostaphylos uva-ursi*) | 1 | 4 | 4 | 100 | 10.8 | 29 | 0.3 | 0 | n/a | n/a | n/a | 0 | n/a | n/a | n/a |
| Common wild rose (*Rosa woodsii*) | 10 | 227 | 112 | 99.1 | 15.8 | 56.3 | 0.7 | 80 | 21.5 | 66.8 | 0.7 | 35 | 12.9 | 92.1 | 1 |
| Cottonwood (*Populus* spp.) | 2 | 10 | 2 | 0 | n/a | n/a | n/a | 5 | 50.7 | 222.3 | 2.6 | 3 | 13 | 335.7 | 4 |
| Golden currant (*Ribes aureum*) | 1 | 20 | 7 | 100 | 15.1 | 93.3 | 1.3 | 7 | 52.7 | 175.3 | 1.6 | 6 | 22.7 | 187.8 | 1.7 |
| Golden willow (*Salix alba* 'Vitellina') | 1 | 12 | 12 | 100 | 18.4 | 148.1 | 1.3 | 0 | n/a | n/a | n/a | 0 | n/a | n/a | n/a |

[12] See Section 10 for definitions of terms.

| Species | No. Sites | Total No. Plants | Year 1 Sites | | | | | Year 3 Sites | | | | Year 5+ Sites | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | No. Plants | Survival Rate (%) | Mean Leader Growth (cm) | Mean Shoot Length (cm) | Mean Diameter (cm) | No. Plants | Mean Leader Growth (cm) | Mean Shoot Length (cm) | Mean Diameter (cm) | No. Plants | Mean Leader Growth (cm) | Mean Shoot Length (cm) | Mean Diameter (cm) |
| Hungry willow (*Salix famelica*) | 8 | 214 | 101 | 99.0 | 19.1 | 85 | 1.4 | 98 | 21.1 | 89.8 | 1.6 | 15 | 22.9 | 119.7 | 2.1 |
| Low-bush cranberry (*Viburnum edule*) | 3 | 7 | 5 | 80.0 | 13.2 | 55.2 | 0.9 | 2 | 32.5 | 37.5 | 0.3 | 0 | n/a | n/a | n/a |
| Narrow-leaved cottonwood (*Populus angustifolia*) | 3 | 24 | 21 | 95.2 | 11 | 122.6 | 1 | 0 | n/a | n/a | n/a | 3 | 15.3 | 104 | 1.4 |
| Northern gooseberry (*Ribes oxyacanthoides*) | 9 | 200 | 57 | 100 | 15.2 | 45.6 | 0.6 | 92 | 25.9 | 58.7 | 0.8 | 51 | 10.6 | 76.7 | 0.8 |
| Plains cottonwood (*Populus deltoides*) | 2 | 37 | 8 | 100 | 17 | 319.9 | 3.9 | 9 | 13.3 | 386.4 | 6.7 | 20 | 19 | 397 | 7.9 |
| Red-osier dogwood (*Cornus sericea*) | 11 | 371 | 166 | 95.2 | 17 | 63.8 | 1.3 | 132 | 22.8 | 83.6 | 1.3 | 73 | 16.4 | 88.4 | 1.7 |
| River alder (*Alnus incana* ssp. *tenuifolia*) | 1 | 5 | 5 | 40.0 | 24.5 | 79 | 2.1 | 0 | n/a | n/a | n/a | 0 | n/a | n/a | n/a |
| Prickly rose (*Rosa acicularis*) | 8 | 93 | 0 | n/a | n/a | n/a | n/a | 61 | 20.9 | 62.5 | 0.6 | 32 | 23 | 85 | 0.7 |
| Sandbar willow (*Salix interior*) | 5 | 122 | 70 | 84.3 | 31.3 | 107.6 | 1 | 41 | 61 | 171.1 | 1.5 | 11 | 30.4 | 104.4 | 2 |
| Saskatoon (*Amelanchier alnifolia*) | 17 | 369 | 153 | 98.7 | 13.1 | 46.8 | 1.1 | 145 | 17.7 | 61.2 | 1.2 | 71 | 13.2 | 70 | 1.4 |
| Shining willow (*Salix lasiandra* ssp. *caudata*) | 2 | 42 | 4 | 100 | 17.2 | 72.0 | 1.8 | 24 | 28.3 | 84.7 | 2.2 | 14 | 25.4 | 114.6 | 3.3 |
| Shrubby cinquefoil (*Dasiphora fruticosa*) | 7 | 229 | 61 | 98.4 | 6.4 | 40.4 | 1.0 | 111 | 16.5 | 53.1 | 0.8 | 57 | 5.3 | 64.5 | 0.8 |
| Silverberry (*Elaeagnus commutata*) | 12 | 356 | 143 | 99.3 | 14.2 | 56.6 | 1.0 | 143 | 17.1 | 92.8 | 1.4 | 70 | 13 | 121.8 | 1.6 |
| Thorny buffaloberry (*Shepherdia argentea*) | 2 | 60 | 26 | 100 | 12 | 59.8 | 1.0 | 24 | 11.6 | 89.3 | 1.2 | 10 | 3.2 | 107.9 | 2.5 |
| Twining honeysuckle (*Lonicera dioica*) | 1 | 3 | 3 | 100 | 25.7 | 58.7 | 0.8 | 0 | n/a | n/a | n/a | 0 | n/a | n/a | n/a |

| Species | No. Sites | Total No. Plants | Year 1 Sites | | | | | Year 3 Sites | | | | Year 5+ Sites | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | No. Plants | Survival Rate (%) | Mean Leader Growth (cm) | Mean Shoot Length (cm) | Mean Diameter (cm) | No. Plants | Mean Leader Growth (cm) | Mean Shoot Length (cm) | Mean Diameter (cm) | No. Plants | Mean Leader Growth (cm) | Mean Shoot Length (cm) | Mean Diameter (cm) |
| Water birch (*Betula occidentalis*) | 7 | 152 | 57 | 87.7 | 20 | 139.6 | 1.8 | 59 | 11.9 | 290.1 | 3.9 | 36 | 10.1 | 294.7 | 4 |
| Wild black currant (*Ribes americanum*) | 1 | 6 | 6 | 100 | 32.7 | 78 | 1.4 | 0 | n/a | n/a | n/a | 0 | n/a | n/a | n/a |
| Wild red raspberry (*Rubus idaeus*) | 1 | 12 | 0 | n/a | n/a | n/a | n/a | 12 | 18.9 | 28.6 | 0.5 | 0 | n/a | n/a | n/a |
| Unknown spp. | 2 | 14 | 0 | n/a | n/a | n/a | n/a | 14 | n/a | n/a | n/a | 0 | n/a | n/a | n/a |

**Table 4-17: Survival Rates and Growth Measurements of Live Cutting Species by Age Class[13]**

| Species | No. Sites | Total No. Plants | Year 1 Sites | | | | | Year 3 Sites | | | | Year 5+ Sites | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | No. Plants | Survival Rate (%) | Mean Leader Growth (cm) | Mean Shoot Length (cm) | Mean Diameter (cm) | No. Plants | Mean Leader Growth (cm) | Mean Shoot Length (cm) | Mean Diameter (cm) | No. Plants | Mean Leader Growth (cm) | Mean Shoot Length (cm) | Mean Diameter (cm) |
| Balsam poplar (*Populus balsamifera*) | 4 | 313 | 170 | 51.2 | 19.0 | 55.5 | 0.9 | 97 | 16.9 | 73.1 | 1.2 | 46 | 18.4 | 123.0 | 2.4 |
| Beaked willow (*Salix bebbiana*) | 2 | 29 | 22 | 68.2 | 15.8 | 87.8 | 0.9 | 5 | 28.0 | 75.0 | 1.3 | 2 | 14 | 114.0 | 2.8 |
| Hungry willow (*Salix famelica*) | 5 | 273 | 55 | 83.6 | 33.7 | 49.4 | 0.5 | 110 | 24.0 | 77.2 | 0.9 | 108 | 20.5 | 102.5 | 1.2 |
| False mountain willow (*Salix pseudomonticola*) | 2 | 12 | 6 | 83.3 | 12.4 | 12.4 | 0.3 | 6 | 35.7 | 61.3 | 0.6 | 0 | n/a | n/a | n/a |
| Red-osier dogwood (*Cornus sericea*) | 4 | 214 | 143 | 25.2 | 18.8 | 46.1 | 0.6 | 61 | 18.8 | 52.6 | 1.0 | 10 | 7.2 | 76.1 | 1.7 |
| Sandbar willow (*Salix interior*) | 9 | 393 | 224 | 44.6 | 21.8 | 48.8 | 0.5 | 142 | 32.9 | 68.7 | 0.5 | 27 | 20.8 | 108.4 | 0.9 |
| Shining willow (*Salix lasiandra* ssp. *caudata*) | 2 | 25 | 0 | n/a | n/a | n/a | n/a | 15 | 31.6 | 118.7 | 1.6 | 10 | 25.4 | 200.3 | 3.1 |
| Willow (*Salix* spp.) | 4 | 135 | 1 | 0 | n/a | n/a | n/a | 77 | 6.0 | 62.0 | 0.6 | 57 | n/a | n/a | n/a |

[13] See Section 10 for definitions of terms.

## New Planting Technique Assessment

Some interesting, albeit limited data on a new planting technique for Calgary was also collected over the course of the RMP. City of Calgary Parks is currently employing a restoration technique whereby small plugs of native tree and shrub species are randomly planted on a site in large quantities with minimal follow-up maintenance or monitoring. The objective is to try to improve shrub and/or tree cover in a given area with minimal effort and cost. Although large quantities of plugs are expected to perish, it is hoped that some will survive and grow into mature shrubs and trees over time. This type of planting technique has potential advantages and disadvantages, as discussed in the 2020 Riparian Effectiveness Annual Summary Report (KWL, 2021). The monitoring team was able to collect data on four random planting projects over the course of the five-year monitoring program (Table 4-18). Success, depending on how it is defined, has been mixed. One site was a failure, with only approximately 2% plug survival. Two sites had good initial survivorship, but the plugs showed no discernible shoot growth three to five years after planting. The fourth site was only monitored one year after installation, with the plugs having an estimated 63% survival at that time.

**Table 4-18: Random Planting Projects Assessed**

| Site Descriptor | Site Name | Year(s) Assessed | Success/ Failure | Comments |
|---|---|---|---|---|
| RE-ELB-105A | Griffiths Woods (DIS100) – RBC and Older Plantings | 2018, 2020 | Success | Balsam poplar plugs were planted randomly in a white spruce forest. Waterboxxes© were used with some plugs to improve successful establishment. Estimated 100% Year 1 survival rate. Plugs showed no discernible shoot growth 5 years after planting. |
| RE-ELB-105B | Griffiths Woods (DIS100) – RBC and Older Plantings | 2018, 2020 | Success | Balsam poplar plugs were planted randomly in a white spruce forest, whereas sandbar willow plugs were planted along the bank of the Elbow River. Willow plugs showed excellent survivorship and growth. Balsam poplar plugs showed no discernible shoot growth 3 years after planting. |
| RE-BOW-126 | Inglewood Residential | 2021 | Success | Balsam poplar, beaked willow, and sandbar willow planted. ~63% plug survival after one growing season. |
| RE-BOW-127 | Bow – Nose Creek | 2021 | Failure | Balsam poplar, aspen, beaked willow, and sandbar willow planted. ~2% plug survival after one growing season. Strong herbaceous species competition and south aspect may have limited project success. |

Because only four random planting projects were available for monitoring, the data set is limited for this restoration technique in Calgary. Therefore, making a recommendation regarding its continued use or disuse is not advisable. The slow or even lack of shoot growth five years after planting for some plugs should be weighed heavily against the potential cost savings, however. While random planting is a valid and successful technique in natural areas – for example, for forestry cutblock regeneration – Calgary presents unique issues for this type of restoration, both with respect to its arid environment as well as the challenges that come with an urban environment, such as invasive plant species.

## Woody Vegetation Growth Measurement Analysis

Figure 4-1, Figure 4-2, and Figure 4-3 present some of the results of the shrub and tree planting measurement analyses. The results appear to suggest that live cuttings and container plants show increasing shoot growth and stem diameters over time, which is what would be expected for successful projects. In contrast, leader growth appears to show a different trend, with Year 5+ projects having lower leader lengths that Year 1 and 3 age class projects. Plants are known to show lower leader growths as they mature (Gatsuk et al. 1980). The relationships between shoot length and age class and stem diameter and age class could not be tested statistically due to sample dependence (i.e., the presence of the same sites in multiple age classes).

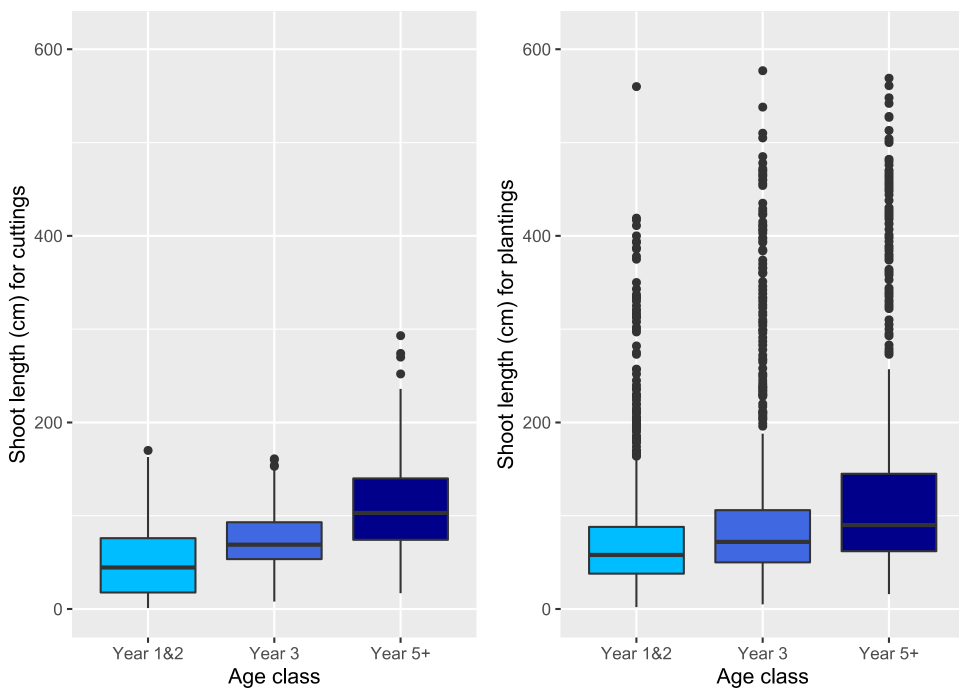



**Figure 4-1: Shoot Length According to Age Class**

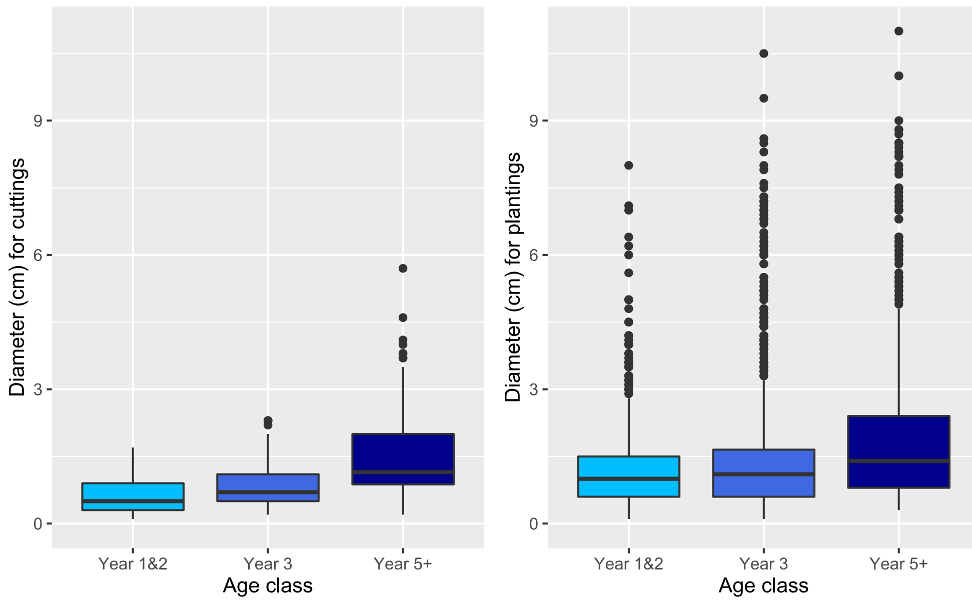



**Figure 4-2: Stem Diameters According to Age Class**

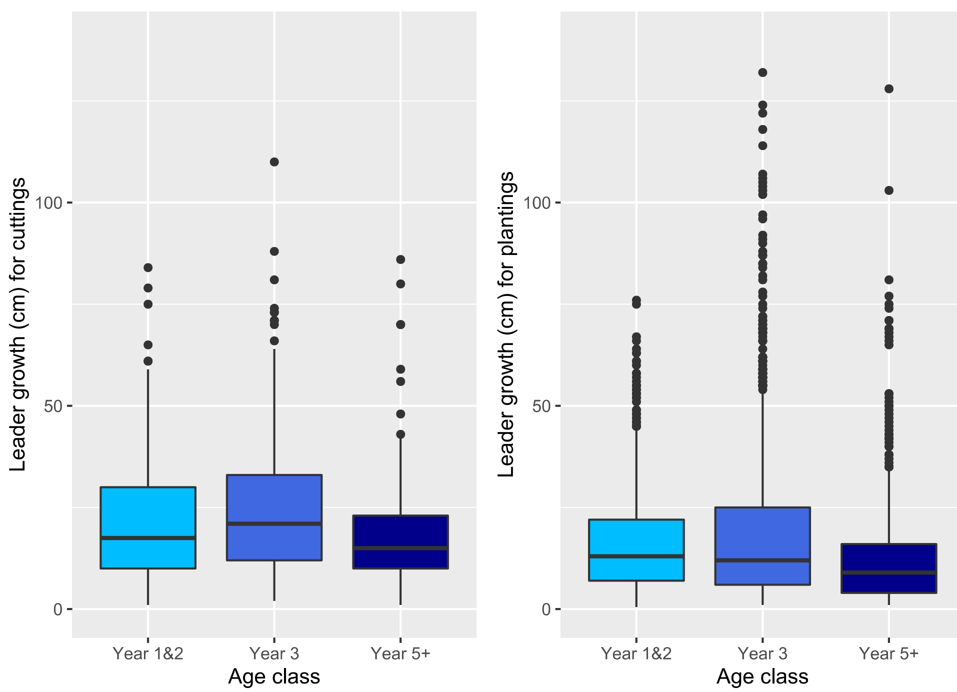



**Figure 4-3: Leader Length According to Age Class**

## Survival and Canopy Cover at Successful Sites

Table 4-19 presents the survival rates of live cuttings and container plants by site for all 57 detailed assessments at successful sites from 2018 to 2022 in conjunction with the estimated woody canopy cover. As presented, there was high variability both in the number of plants sampled at each site as well as the overall Year 1 age class survivorship rates. To balance the need to gather sufficient data for statistical analyses purposes while minimizing the amount of field time, a target of 20 planting and 50 cutting samples per species, respectively, were sampled for survivorship at each Year 1 age class site, and a target of 10 cutting and planting samples per species were sampled for growth and health measurements. The number of plants sampled at each site was also partly dependent on the number of species and the number of individuals of each species installed.

Year 1 age class survivorship ranged from a low of 30% to a high of 100%. Survivorship can be affected by any number of factors, including the species, the quality of the source material, storage, and handling of materials on site, proper installation, and adequacy of maintenance activities (e.g., irrigation).

Similar to the findings presented earlier, Table 4-19 also shows that Native Tree and Shrub Planting projects tend to have higher average survival rates than Native Tree and Shrub Cuttings Projects. Note that survival rates may be exaggerated in cases where dead plant material has been removed, especially if as-built reports were unavailable or inaccurate. Dead shrubs are also easily overlooked, particularly in cases where the surrounding herbaceous vegetation is dense.

Other important data presented in Table 4-19 is the final column, woody canopy cover. The goal of all riparian restoration project is to improve canopy cover of shrubs and trees, collectively referred to as woody species. Trees and shrubs have deeper and stronger roots systems than herbaceous plant species, and thus are important for stream and river bank stability and, thus, flood protection. Sites that have been assessed multiple times as part of the RMP should ideally show increasing woody canopy cover over time. The data presented in Table 4-19 shows mixed results and reflects the variable success of the assessed riparian restoration projects. Some sites showing excellent woody cover improvement over time, including: RE-ELB-23 (Lindsay Park – B – Riparian Uplift), RE-BOW-41 (Wildwood), and RE-BOW-91 (Valley Ridge Golf Course). Other sites appear to have not shown any progression in terms of woody cover, such as RE-BOW-40 (TransAlta), RE-BOW-48B (Harvie Passage – South Side Channel), and RE-BOW-68 (Bowmont Natural Area East – A). Still other sites have showed decreasing woody cover over time (e.g., RE-BOW-31 [Inglewood Bird Sanctuary]). Statistical analysis shows that there is no significant difference in woody canopy cover between Year 1, 3, and 5+ age classes, suggesting that as a whole shrub cover is not improving over time at those sites assessed.

**Table 4-19: Woody Species Survival Rates and Canopy Cover by Site**

| Site Descriptor | Age Class | Typology | Cuttings and Plantings | | Cuttings | | Plantings | | Woody Canopy Cover (%) |
|---|---|---|---|---|---|---|---|---|---|
| | | | No. Samples | Survival Rate (%) | No. Samples | Survival Rate (%) | No. Samples | Survival Rate (%) | |
| RE-WNO-15 | 3 | Cuttings | 33 | n/a | 33 | n/a | n/a | n/a | 10 |
| RE-WNO-15 | 5+ | Cuttings | 38 | n/a | 38 | n/a | n/a | n/a | 6 |
| RE-FIS-19 | 3 | Cuttings | 120 | n/a | 100 | n/a | 20 | n/a | 36 |
| RE-FIS-19 | 5+ (1) | Cuttings | 97 | n/a | 79 | n/a | 18 | n/a | 38 |
| RE-FIS-19 | 5+ (2) | Cuttings | 23 | n/a | 13 | n/a | 10 | n/a | 28 |
| RE-FIS-22 | 3 | Cuttings | 92 | n/a | 92 | n/a | n/a | n/a | 26 |
| RE-FIS-22 | 5+ | Cuttings | 86 | n/a | 86 | n/a | n/a | n/a | 36 |

| Site Descriptor | Age Class | Typology | Cuttings and Plantings | | Cuttings | | Plantings | | Woody Canopy Cover (%) |
|---|---|---|---|---|---|---|---|---|---|
| | | | No. Samples | Survival Rate (%) | No. Samples | Survival Rate (%) | No. Samples | Survival Rate (%) | |
| RE-ELB-23 | 3 | Plantings | 116 | n/a | n/a | n/a | 116 | n/a | 36 |
| RE-ELB-23 | 5+ | Plantings | 101 | n/a | n/a | n/a | 101 | n/a | 68 |
| RE-BOW-31 | 1 | Cuttings | 216 | 29.6 | 216 | 29.6 | n/a | n/a | 25 |
| RE-BOW-31 | 3 | Cuttings | 8 | n/a | 8 | n/a | n/a | n/a | 12 |
| RE-BOW-38 | 1 | Plantings | 191 | 100 | n/a | n/a | 191 | n/a | 7 |
| RE-BOW-38 | 3 | Plantings | 167 | n/a | n/a | n/a | 167 | n/a | 3 |
| RE-BOW-40 | 3 | Plantings | 67 | n/a | n/a | n/a | 67 | n/a | 12 |
| RE-BOW-40 | 5+ | Plantings | 48 | n/a | n/a | n/a | 48 | n/a | 14 |
| RE-BOW-41 | 3 | Plantings | 60 | n/a | n/a | n/a | 60 | n/a | 18 |
| RE-BOW-41 | 5+ | Plantings | 33 | n/a | n/a | n/a | 33 | n/a | 40 |
| RE-BOW-42 | 3 | Plantings | 117 | n/a | n/a | n/a | 117 | n/a | 16 |
| RE-BOW-42 | 5+ | Plantings | 75 | n/a | n/a | n/a | 75 | n/a | 14 |
| RE-BOW-48B | 1 | Riparian retrofit | 283 | 73.1 | 128 | 49.2 | 155 | 92.9 | 5 |
| RE-BOW-48B | 3 | Riparian retrofit | 273 | n/a | 126 | n/a | 147 | n/a | 7 |
| RE-BOW-48B | 5+ | Riparian retrofit | 70 | n/a | 34 | n/a | 36 | n/a | 2 |
| RE-BOW-68 | 1 | Riparian retrofit | 230 | 98.3 | n/a | n/a | 230 | 98.3 | 4 |
| RE-BOW-68 | 3 | Riparian retrofit | 265 | n/a | n/a | n/a | 265 | n/a | 4 |
| RE-BOW-68 | 5+ | Riparian retrofit | 163 | n/a | n/a | n/a | 163 | n/a | 9 |
| RE-BOW-91 | 3 | Plantings | 96 | n/a | n/a | n/a | 96 | n/a | 56 |
| RE-BOW-91 | 5+ | Plantings | 69 | n/a | n/a | n/a | 69 | n/a | 76 |
| RE-BOW-92 | 1 | Riparian retrofit | 323 | 87.3 | n/a | n/a | 323 | 87.3 | 1 |
| RE-BOW-92 | 3 | Riparian retrofit | 246 | n/a | n/a | n/a | 246 | n/a | 1 |
| RE-BOW-92 | 5+ | Riparian retrofit | 137 | n/a | n/a | n/a | 137 | n/a | 0 |
| RE-ELB-94 | 1 | Mixed | 35 | 91.4 | n/a | n/a | 35 | 91.4 | 54 |
| RE-ELB-94 | 3 | Mixed | 59 | n/a | n/a | n/a | 59 | n/a | 72 |
| RE-ELB-94 | 5+ | Mixed | 36 | n/a | n/a | n/a | 36 | n/a | 28 |
| RE-ELB-97A | 1 | Mixed | 74 | 64.9 | 50 | 56.0 | 24 | 83.3 | 22 |
| RE-ELB-97 A | 3 | Mixed | 74 | n/a | 50 | n/a | 24 | n/a | 23 |
| RE-ELB-97 A | 5+ | Mixed | 20 | n/a | 10 | n/a | 10 | n/a | 24 |
| RE-ELB-97B | 1 | Mixed | 84 | 52.4 | 64 | 40.6 | 20 | 90.0 | 15 |
| RE-ELB-97B | 3 | Mixed | 78 | n/a | 58 | n/a | 20 | n/a | 13 |

| Site Descriptor | Age Class | Typology | Cuttings and Plantings | | Cuttings | | Plantings | | Woody Canopy Cover (%) |
|---|---|---|---|---|---|---|---|---|---|
| | | | No. Samples | Survival Rate (%) | No. Samples | Survival Rate (%) | No. Samples | Survival Rate (%) | |
| RE-ELB-104 | 1 | Mixed | 30 | 100 | n/a | n/a | 30 | 100 | 40 |
| RE-ELB-105A | 1 | Mixed | 20 | 100 | n/a | n/a | 20 | 100 | 36 |
| RE-ELB-105A | 3 | Mixed | 20 | n/a | n/a | n/a | 20 | n/a | 20 |
| RE-ELB-105A | 5+ | Mixed | 10 | n/a | n/a | n/a | 10 | n/a | 36 |
| RE-ELB-105B | 1 | Plantings | 40 | 100 | n/a | n/a | 40 | 100 | 20 |
| RE-ELB-105B | 3 | Plantings | 40 | n/a | n/a | n/a | 40 | n/a | 24 |
| RE-WNO-112A | 1 | Cuttings | 55 | 72.7 | 55 | 72.7 | n/a | n/a | 10 |
| RE-WNO-112A | 3 | Cuttings | 35 | n/a | 35 | n/a | n/a | n/a | 4 |
| RE-BOW-124 | 1 | Mixed | 90 | 51.1 | 50 | 22.0 | 40 | 87.5 | 12 |
| RE-BOW-125 | 1 | Plantings | 69 | 89.9 | n/a | n/a | 69 | 89.9 | 28 |
| RE-BOW-126 | 1 | Plantings | 80 | 62.5 | n/a | n/a | 80 | 62.5 | 54 |
| RE-ELB-128 | 3 | Mixed | 47 | n/a | 11 | n/a | 36 | n/a | 32 |
| RE-BOW-137 | 3 | Plantings | 67 | n/a | n/a | n/a | 67 | n/a | 58 |
| RE-BOW-138 | 1 | Plantings | 141 | 96.5 | n/a | n/a | 141 | 96.5 | 2 |
| RE-BOW-139 | 1 | Plantings | 79 | 100 | n/a | n/a | 79 | 100 | 10 |
| RE-BOW-R9 | 1 | Plantings | 141 | 94.3 | n/a | n/a | 141 | 94.3 | 32 |
| RE-BOW-R9 | 3 | Plantings | 70 | n/a | n/a | n/a | 70 | n/a | 38 |
| RE-FIS-R11 | 1 | Plantings | 85 | 97.6 | 58 | 98.3 | 27 | 96.3 | 28 |
| RE-FIS-R12 | 1 | Plantings | 56 | 100 | n/a | n/a | 56 | 100 | 62 |

## Comparison of Vegetation Growth Results for Sites Assessed Twice

Table 4-20 and Table 4-21 provide a comparison of shoot lengths for plantings and cuttings, respectively, for each of the sites that have been assessed multiple times over the course of the RMP. Data is available for 16 sites with plantings and eight sites with cuttings installed. Positively, the majority of sites had trends of increasing shoot lengths over time. For plantings, average growth was approximately 10.3 cm per growing season (n=23 assessments). This encompasses a wide range of values, from 53.5 cm to -6.7 cm. Two sites – RE-BOW-41 (Wildwood) and RE-ELB-105a (Griffiths Woods – [DIS100] RBC and Other Plantings) – had negative growth over the assessment time period. Cutting growth averaged 13.0 cm per year. Shoot length differences between assessments ranged from 51.9 cm to -40.5 cm. Only one cuttings site – RE-WNO-15 (West Nose Creek – Hidden Valley) – had negative growth between the two assessment years. These tables provide novel information on how much shoot growth might be expected for riparian restoration projects in Calgary over the course of two and sometimes four growing seasons. The data presented here also suggests that if cuttings successfully establish, which as previously discussed is less likely than for plantings, then they have higher growth performance than plantings, all else being equal.

**Table 4-20: Comparison of Container Plant Shoot Growth for Sites Assessed Twice**

| Site Descriptor | Difference between 1st and 2nd Assessments | Difference between 2nd and 3rd Assessments | Year 1 | | Year 3 | | Year 5+ (1) | | Year 5+ (2) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Mean Shoot Length (cm) | No. Samples | Mean Shoot Length (cm) | No. Samples | Mean Shoot Length (cm) | No. Samples | Mean Shoot Length (cm) | No. Samples |
| RE-ELB-97B | 51.2 | n/a | 50.7 | 20 | 101.9 | 20 | n/a | n/a | n/a | n/a |
| RE-BOW-68 | 39.4 | 33.3 | 146.3 | 230 | 185.7 | 265 | 219.0 | 163 | n/a | n/a |
| RE-BOW-91 | 36.0 | n/a | n/a | n/a | 85.4 | 96 | 121.4 | 69 | n/a | n/a |
| RE-ELB-97A | 34.6 | 13.2 | 44.3 | 24 | 78.9 | 24 | 92.2 | 10 | n/a | n/a |
| RE-ELB-23 | 31.3 | n/a | n/a | n/a | 143.3 | 116 | 174.6 | 101 | n/a | n/a |
| RE-FIS-19 | 27.7 | 3.2 | n/a | n/a | 79.9 | 20 | 107.6 | 18 | 110.8 | 10 |
| RE-BOW-R9 | 24.9 | n/a | 56.7 | 141 | 81.6 | 70 | n/a | n/a | n/a | n/a |
| RE-BOW-92 | 22.2 | 16.4 | 65.8 | 323 | 88.0 | 246 | 104.4 | 137 | n/a | n/a |
| RE-ELB-105B | 21.8 | n/a | 102.4 | 40 | 124.2 | 40 | n/a | n/a | n/a | n/a |
| RE-BOW-42 | 20.3 | n/a | n/a | n/a | 67.3 | 117 | 87.6 | 75 | n/a | n/a |
| RE-BOW-48B | 12.8 | 53.5 | 70.6 | 155 | 83.4 | 147 | 137.0 | 36 | n/a | n/a |
| RE-BOW-38 | 12.4 | n/a | 69.6 | 191 | 82.0 | 167 | n/a | n/a | n/a | n/a |
| RE-ELB-94 | 7.9 | 17.2 | 93.8 | 35 | 101.6 | 59 | 118.9 | 36 | n/a | n/a |
| RE-BOW-40 | 2.6 | n/a | n/a | n/a | 50.9 | 67 | 53.5 | 48 | n/a | n/a |
| RE-BOW-41 | -4.2 | n/a | n/a | n/a | 56.6 | 60 | 52.4 | 33 | n/a | n/a |
| RE-ELB-105A | -6.7 | 3.7 | 78.9 | 20 | 72.2 | 20 | 76.0 | 10 | n/a | n/a |

**Table 4-21: Comparison of Live Cutting Shoot Growth for Sites Assessed Twice**

| Site Descriptor | Difference between 1st and 2nd Assessments | Difference between 2nd and 3rd Assessments | Year 1 | | Year 3 | | Year 5+ (1) | | Year 5+ (2) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Mean Shoot Length (cm) | No. Samples | Mean Shoot Length (cm) | No. Samples | Mean Shoot Length (cm) | No. Samples | Mean Shoot Length (cm) | No. Samples |
| RE-FIS-19 | 51.9 | 17.2 | n/a | n/a | 66.6 | 100 | 118.4 | 79 | 135.7 | 13 |
| RE-WNO-112A | 39.7 | n/a | 25.3 | 55 | 65 | 35 | n/a | n/a | n/a | n/a |
| RE-ELB-97B | 39.1 | n/a | 37.3 | 64 | 76.4 | 58 | n/a | n/a | n/a | n/a |
| RE-BOW-31 | 33.4 | n/a | 18 | 216 | 51.4 | 8 | n/a | n/a | n/a | n/a |
| RE-FIS-22 | 25 | n/a | n/a | n/a | 61.2 | 92 | 86.2 | 86 | n/a | n/a |
| RE-BOW-48B | 20.5 | 50.3 | 69.4 | 128 | 90 | 126 | 140.2 | 34 | n/a | n/a |
| RE-ELB-97A | 15.8 | 32.7 | 44.8 | 50 | 60.6 | 50 | 93.3 | 10 | n/a | n/a |
| RE-WNO-15 | -40.5 | n/a | n/a | n/a | 101.3 | 33 | 60.8 | 38 | n/a | n/a |

## Ratings

Another one of the main findings from the riparian effectiveness monitoring relates to the different ratings given to each site. Table 4-22 summarizes the mean scores by age class for each the five different ratings used. As shown, sites often did not receive low overall scores because of their designs. Indeed, the riparian effectiveness sites usually scored well for design parameters such as appropriate native species selection for project goals and the habitat type(s) present, planting densities, and herbaceous seed mix species selection and applications rates. However, it should be noted that one area of improvement for the design phase is proper record keeping and storage, as discussed below. Where sites often received below optimal overall scores was due to issues with implementation and maintenance. With respect to implementation, sites often had no as-built reports nor any information on quality and handling of plant material. As well, some sites lacked fencing, or were planted differently than the design, or had issues with planting quality (e.g., cuttings not buried deep enough, plantings with exposed roots). With respect to maintenance, sites often had no maintenance records. In addition, some sites had issues with effective weed control, irrigation, replacing dead plantings. Success ratings also scored moderately on average, indicating that Year 1 age class sites could have improved survivorship and Year 3 and 5+ age class sites could have higher planting densities. BRQI ratings for riparian effectiveness sites are discussed below.

**Table 4-22: Mean Ratings**

| Rating Type | Mean Score | | |
|---|---|---|---|
| | Year 1 (n=23) | Year 3 (n=31) | Year 5+ (n=15) |
| Design (/6) | 5.4 | 5.2 | 5.4 |
| Implementation (/6) | 3.4 | 3.5 | 3.5 |
| Maintenance (/6) | 2.7 | 2.1 | 2.2 |
| Success (6) | 3.5 | 2.5 | 3.6 |
| BRQI (/100) | 53.2 | 53.7 | 52.7 |
| **Overall (/100)** | **59.0** | **50.6** | **59.7** |

## Bank and Riparian Quality Index

As discussed above, a novel rating system called BRQI was developed specifically for this project. BRQI is a measure of health similar to riparian health, and indeed rates many of the same indicators as riparian health (e.g., vegetation cover, human-caused bare soil cover, and cover of invasive plant species). Ideally, as restoration projects establish over time, BRQI ratings should be expected to increase as, for example, woody species cover increases, plant community structure develops. However, riparian effectiveness sites that have been assessed twice or more have shown mixed results for BRQI trends, with some sites increasing, some decreasing, and others remaining stable. Statistical analysis of the BRQI data suggests that there is no significant difference among age classes for riparian restoration projects. The highly variable trends point to mixed success among riparian restoration projects. With respect to typology, large-scale riparian retrofit projects have significantly lower BRQI ratings than the other three typologies. All three large-scale riparian retrofit projects underwent substantial amounts of disturbance during construction and would therefore be expected to have low BRQI ratings immediately after construction, whereas as disturbance during construction was generally limited for the other typologies. However, after five years these projects should be showing signs of improvement.

Figure 4-4 shows how each of the eight BRQI parameters scored on average for all successful riparian effectiveness sites assessed from 2018 to 2022. Most riparian restoration sites scored well for having high total vegetation cover and low cover of riprap and/or concrete. Riparian effectiveness sites most often received low BRQI scores due to high cover of invasive and disturbance-increaser plant species, low regeneration of preferred tree and shrub species, below optimal cover of native trees and shrubs, and low structural diversity (i.e., few vegetation layers). The amount of human-caused bare soil cover scored moderately overall, with some sites having low amounts and others having high amounts.

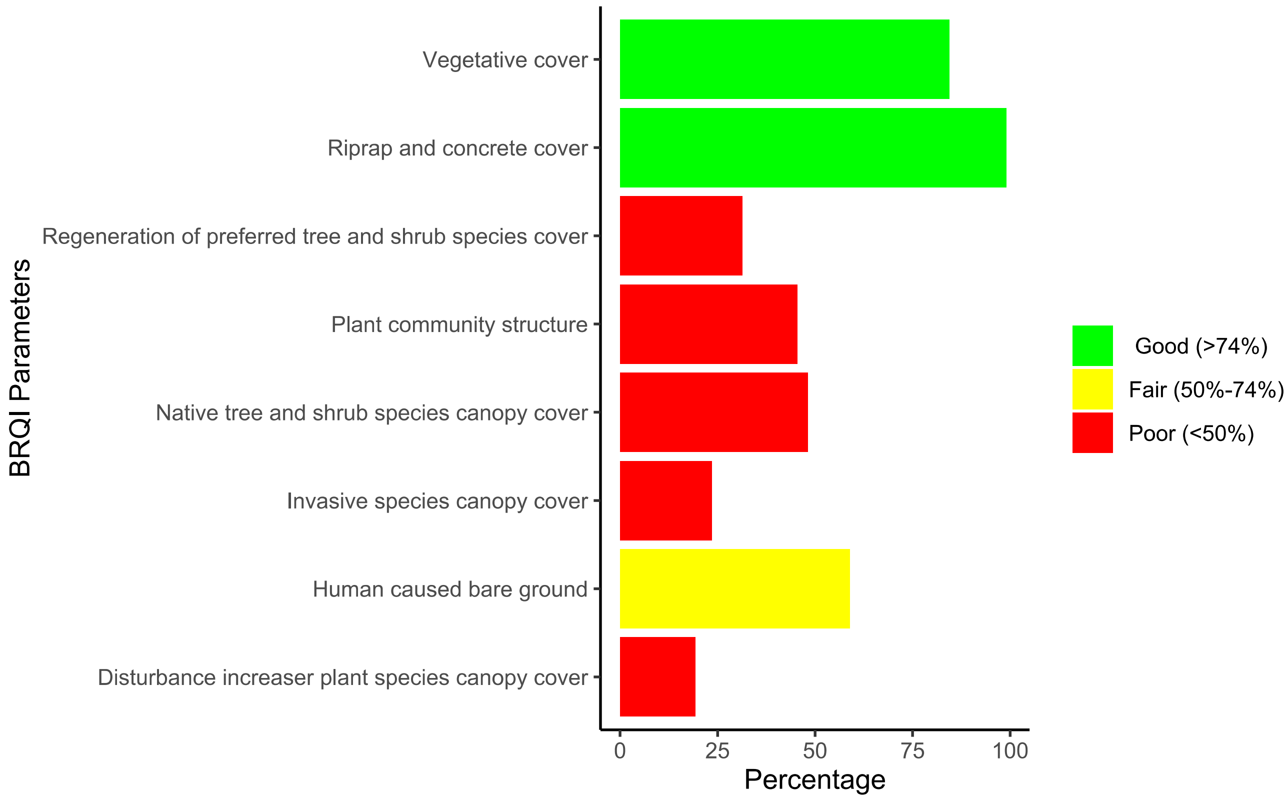



**Figure 4-4: Average Scores (%) for each BRQI Parameter**

### Record Keeping

One general finding from the five-year riparian effectiveness monitoring was that few background documents were available for the projects assessed. It was not clear if these documents were simply not provided to the project team or if they were not available to The City either. Proper record keeping, with all project information stored together in a central location, allows for effective project tracking and is important, for example, to determine potential failure causes if projects have challenges. Record keeping should include the following information, if possible:

- Site name and location, including maps and coordinates;
- Project description, goals, and objectives;
- Project Manager;
- Contractor and Consultant names and contact information;
- Lists of plant species installed, including species scientific names, numbers planted, types (e.g., cuttings vs. potted shrubs), sizes, provenance of plant material (i.e., region of harvest for live cuttings, including dates of harvest), stock handling (i.e., storage, soaking, etc.), nursery suppliers for rooted species, genetic source (if available), and seed mixes (including percent compositions and application rates);
- Project schedule, including planting dates and completion dates for each project component;
- Project budget and actual cost of work;
- Maintenance records, including dates and specifics of weed control, plant replacement, and irrigation activities;
- Photo-monitoring, including pre- and post-construction or installation photographs; and
- An as-built or completion report, including drawings that show the planting locations if possible.

Digital applications (apps) may offer potential for improved record keeping and sharing among project partners, at least for maintenance work.

## 4.3.2 Statistical Analysis Results

### Live Cutting and Container Plants Year 1 Survivorship

Perhaps the most important finding from the five-year monitoring of riparian restoration projects was the difference in observed success of container plants (or plantings) versus live cuttings. The main success measure for Year 1 age class projects was the survivorship of installed woody vegetation, or the number of alive plants versus the number that have died. As shown in Figure 4-5, for the projects assessed, container plants had a much higher Year 1 age class survivorship than did live cuttings: 93% for container plants (n=1,701) versus 47% for live cuttings (n=621). Similarly, when analyzing typologies, the Native Tree and Shrub Planting projects tended to have higher survivorship than other types of projects, although the sample size of Year 1 age class Native Tree and Shrub Cuttings Projects was too small to include in the analysis (Figure 4-6). It is believed that Calgary's harsh arid climate causes live cuttings to desiccate, particularly if not buried deep enough. Many live cutting projects also involved installing stakes into existing vegetation with no site-pretreatment, which creates challenges with competition from established native and non-native species. As a result of the poor performance of live cuttings in Calgary restoration projects, one of the main recommendations stemming from this project is to use container plants wherever possible, unless the primary goal is bank stabilization, in which case properly installed and sufficiently long live cuttings should do better; and to take steps to alleviate herbaceous species competition prior to installing new plant material (see Section 7).

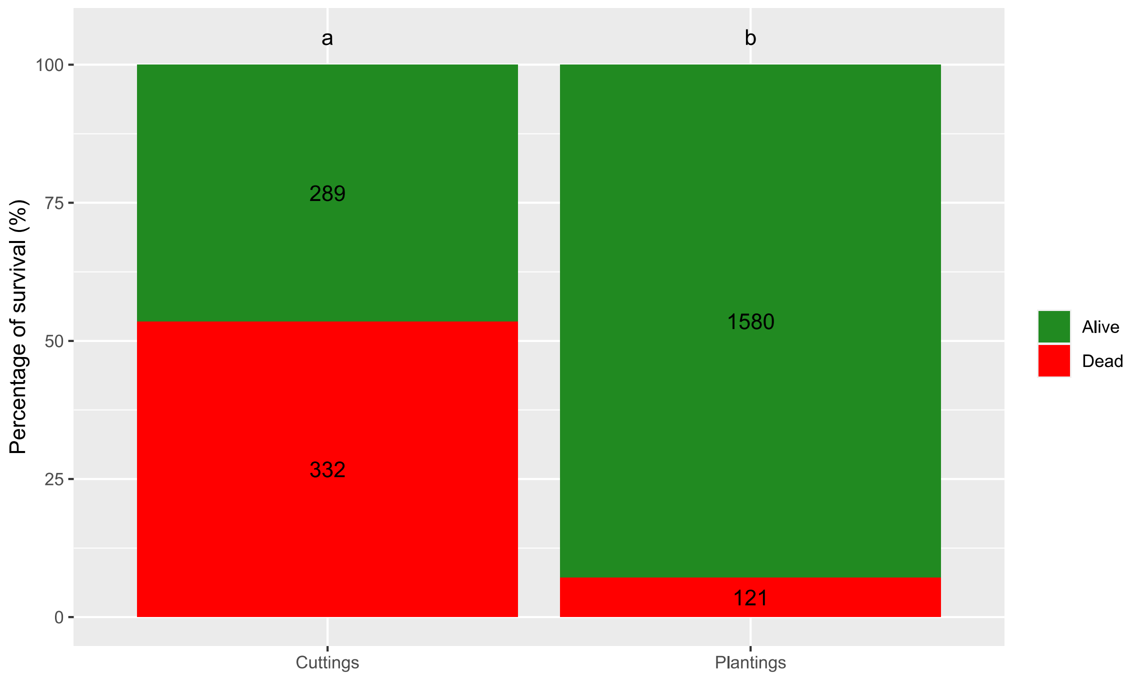



**Figure 4-5: Year 1 Survivorship of Cuttings Versus Plantings**

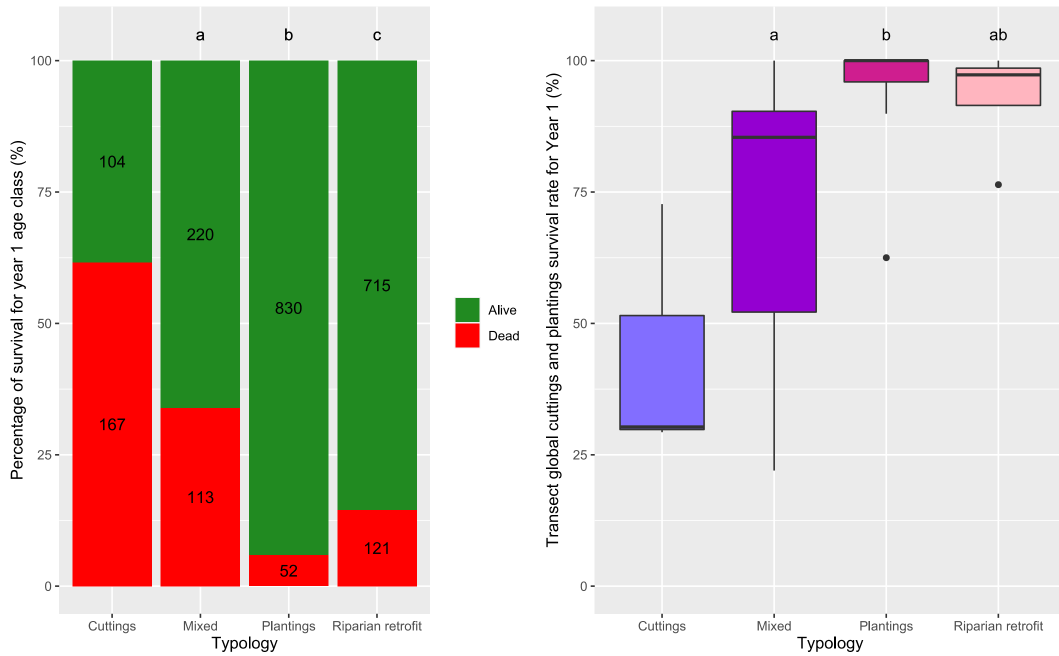



**Figure 4-6: Year 1 Survivorship by Typology**

## Year 1 Survivorship According to Aspect

Vegetation survivorship was also analyzed based on the aspect of the planting site. Aspect refers to orientation or direction of a slope. Different aspects have different levels of solar insolation, which in turn affects the growing conditions for vegetation. In southern Alberta, south aspects are typically hotter and drier than north aspects, which are more protected from direct solar insolation. In the analyses carried out for this project, five aspect categories were used, with some aspects grouped because of similar solar insolation characteristics: (1) North, Northeast, and East; (2) Southeast; (3) South, Southwest, and West; (4) Northwest; and (5) Flat (i.e., no slope). Year 1 age class survivorship values for live cuttings and container plants based on aspect showed no clear results (Figure 4-7).

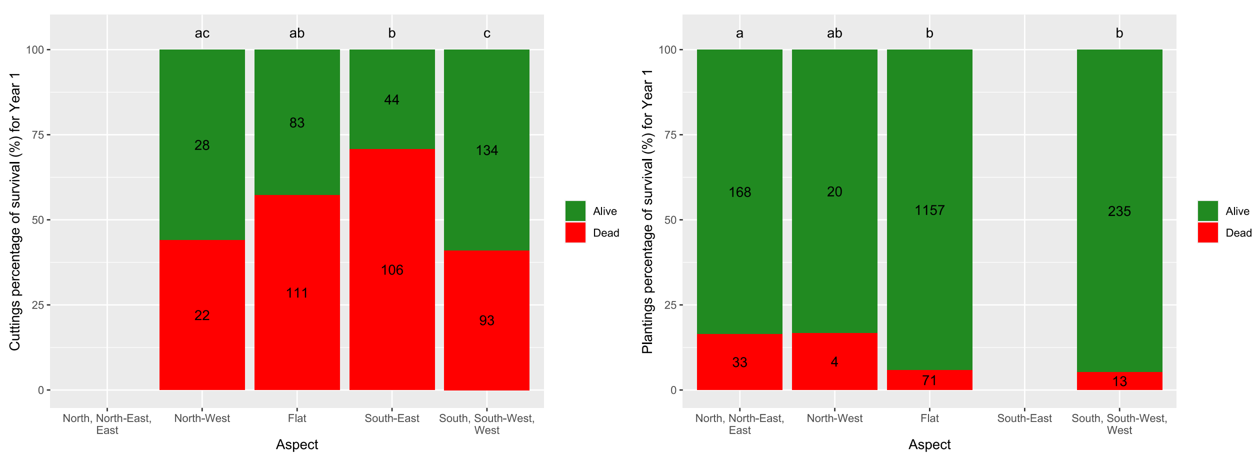



**Figure 4-7: Survivorship of Live Cuttings and Container Plants According to Aspect**

## Year 1 Survivorship According to Shade

Year 1 survivorship of live cuttings and container plants was also analyzed according to the level of shade. Along with water and nutrients, sunlight is one of the main resources needed for growing plants, and the relative sunniness or shadiness of a riparian restoration site may influence the success of that site. The results show that the survival rate of Year 1 age class live cuttings was not significantly different in sunny versus shady locations, although the sample size for the latter is quite small (Figure 4-8). In contrast, the survival rate for Year 1 age class container plants was higher in sunny locations compared to shady locations.

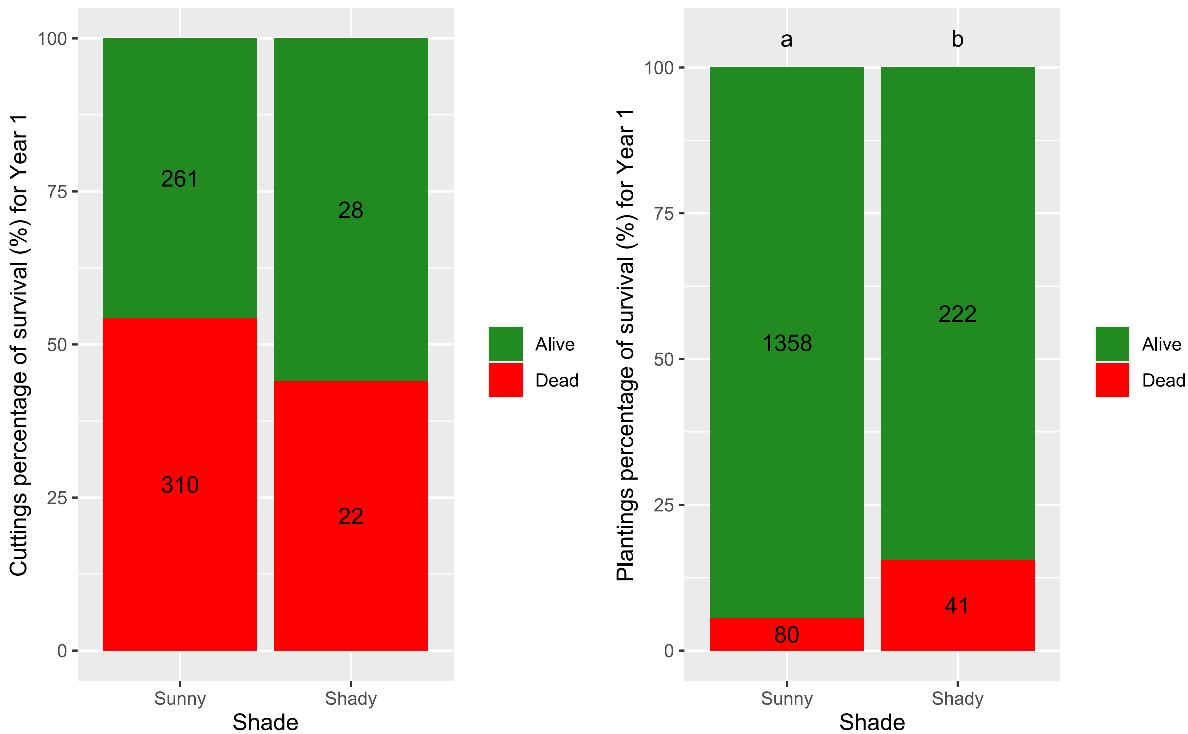



**Figure 4-8: Survivorship of Live Cuttings and Container Plants According to the Level of Shade**

## Soil Compaction

Some interesting findings were also observed for soil compaction. Soil compaction is important to know for restoration projects as it can negatively impact vegetation health and growth. Soil compaction was measured at every riparian effectiveness site beginning in 2020 (n=30 sites). Three soil compaction tests were carried out along each transect wherever a quadrat was sampled (n=153 quadrats). Two data points related to soil compaction were collected and analyzed: 'Depth to Compacted Soil' and 'Maximum Depth'. The former refers to the maximum depth the soil compaction tester can reach below the soil surface before the substrate becomes unconducive to plant growth (i.e., 2 MPa [300 psi] or greater), whereas the latter value refers to the maximum depth the compaction tester can reach, up to a maximum of 60 cm. Analyses showed that there were no significant differences in terms of age class for the two soil compaction variables analyzed. However, some significant differences were apparent with respect to typology.

Soil compaction data by typology is presented in Table 4-23. As can be seen, the Native Tree and Shrub Cuttings, Native Tree and Shrub Plantings, and Mixed Techniques projects all had similar soil compaction values, with no statistically significant differences. Indeed, all of the sites falling under these three typologies had little to no soil disturbance during restoration. In contrast, Large-Scale Riparian Retrofit Projects had significantly lower depth to compacted soil and maximum depth values than the other types of projects. Indeed, on average these sites only had 4 cm of uncompacted soil. Unlike the other projects assessed, Large-Scale Riparian Retrofit Projects were sizable construction undertakings with use of heavy machinery. Such machinery can easily lead to compacted soils if mitigation measures are not employed. These results show that future Large-Scale Riparian Retrofit Projects should have measures in place to address soil compaction during and after construction.

**Table 4-23: Soil Compaction by Typology**

| Typology | Depth to Compacted Soil (cm) | Maximum Depth (cm) | Number of Quadrats |
|---|---|---|---|
| Native tree and shrub cuttings | 25.6 | 42.1 | 18 |
| Native tree and shrub plantings | 19.2 | 38.2 | 54 |
| Mixed techniques | 20.5 | 38.4 | 30 |
| Large-scale riparian retrofit | 4.4* | 14.8 | 18 |
| * Values are significantly different than the values from the other typologies. | | | |

Other analyses completed looked at the relationship between soil compaction and bare soil cover, herbaceous cover, shoot lengths, and vegetation height classes, respectively. However, these analyses did not yield any significant results.

## Seeding Success

Some interesting results were also observed from the analyses on the use of seed mixes in riparian restoration projects. Riparian effectiveness projects that involved the use of an herbaceous seed mix were analyzed to compare what was supposed to have been seeded with what was actually present. The purpose of this analysis was to determine which grass and forb species actually do well in Calgary, and conversely, which species perhaps should be avoided in future restoration projects. Herbaceous species play an important role in providing ground cover, enhanced biodiversity, and preventing erosion while woody vegetation is establishing. Native seed mixes are also expensive, so the data gathered for this project will hopefully result in less money spent on species that do not establish well from seed. Note that there are some limitations with the data, with 19 transects not being a large sample size.

Unfortunately, while some individual species have shown modest success, overall many riparian effectiveness sites had poor establishment of herbaceous seed mixes as a whole. Insufficient background information prevented an in-depth analysis of the cause(s) of seed mix failures by the RMP monitoring team. Possible causes of poor seed mix establishment could be not following best practices or possibly due to weed control activities (i.e., mowing/weed-whacking) that treat all herbaceous species as equal, as opposed to only targeting invasive and non-native species. A number of best practices for seeding, including timing, species selection, and rates, are discussed in Section 7. Contractors can also be referred to *The City of Calgary Seed Mixes* document (The City of Calgary 2018).

Table 4-24 presents some quick facts about the use of herbaceous seed mixes on riparian effectiveness projects. Table 4-25 lists the most successful graminoid and forb species observed. Success rate in this table can be thought of as presence versus absence, or the number of times the species was observed (in any amount) compared to the number of times it was seeded, expressed as a percentage. Mean cover is a measure of how abundant the seeded species were on the sites where they were seeded and is calculated by counting the number of times it was observed along a transect compared to the total number of sample points (e.g., 20 hits out of 50 sample points = 40% cover). Abundance is a factor of both how successful the species were as well as their relative amounts or proportions in the seed mixes. No analyses were carried out on seeding method due to time constraints and the fact that all seeding methods except for broadcast seeding had very low sample sizes (i.e., 2 or less).

**Table 4-24: Seeding Analysis Quick Facts**

| | |
|---|---|
| **Total Number of Unique Riparian Effectiveness Projects Monitored** | 42 |
| **Of the total number of unique projects, those involving an herbaceous seed mix** | 16 |
| **Number of transects analyzed** | 19 |
| **Number of different herbaceous species seeded at the various projects** | 40 |
| **Of the herbaceous species seeded, number that were native** | 39 |
| **Number of herbaceous species that were never observed growing where they were seeded** | 22 (55%) |
| **Most commonly seeded herbaceous species** | Green needle grass (*Nassella viridula*) (n=16)<br>Western wheat grass (*Pascopyrum smithii*) (n=16) |

**Table 4-25: Most Successful Seeded Herbaceous Species**

| Species | Plant Habit | No. Trans-ects | Seeding Success Rate on Quadrats and Transects | | | | | | Mean Cover Rate on Transects | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Yr. 1 | No. Samples | Yr. 3 | No. Samples | Yr. 5 | No. Samples | Min. | Max. | Yr. 1 | Yr. 3 | Yr. 5 |
| **Graminoids** | | | | | | | | | | | | | |
| Slender wheat grass (*Elymus trachycaulus* ssp. *trachycaulus*) | Grass | 15 | 90.0 | 10 | 50.0 | 12 | 100 | 8 | 2 | 98 | 24.7 | 53.0 | 15.2 |
| Northern wheat grass (*Elymus lanceolatus*) | Grass | 11 | 80.0 | 5 | 60.0 | 10 | 16.7 | 6 | 2 | 38 | 17 | 8.0 | 2.0 |
| Canada wild rye (*Elymus canadensis*) | Grass | 8 | 60.0 | 5 | 42.9 | 7 | 40.0 | 5 | 2 | 66 | 29.3 | 35.0 | 64.0 |
| Fowl bluegrass (*Poa palustris*) | Grass | 10 | 37.5 | 8 | 50.0 | 6 | 80.0 | 5 | 2 | 48 | 12.7 | 37.3 | 16.0 |
| Western wheat grass (*Pascopyrum smithii*) | Grass | 16 | 20.0 | 10 | 38.5 | 13 | 27.3 | 11 | 2 | 20 | 11 | 6.0 | 3.3 |
| Green needle grass (*Nassella viridula*) | Grass | 16 | 27.3 | 11 | 33.3 | 12 | 25.0 | 8 | 2 | 10 | 4.0 | 6.5 | 6.0 |
| Tufted hair grass (*Deschampsia cespitosa*) | Grass | 9 | 28.6 | 7 | 33.3 | 6 | 0 | 6 | 2 | 18 | 12.0 | 10.0 | n/a |

| Species | Plant Habit | No. Trans-ects | Seeding Success Rate on Quadrats and Transects | | | | | | Mean Cover Rate on Transects | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Yr. 1 | No. Samples | Yr. 3 | No. Samples | Yr. 5 | No. Samples | Min. | Max. | Yr. 1 | Yr. 3 | Yr. 5 |
| **Forbs** | | | | | | | | | | | | | |
| Tall goldenrod (*Solidago altissima*) | Forb | 3 | 0 | 2 | 33.3 | 3 | 66.7 | 3 | 4 | 8 | n/a | 8.0 | 5.0 |
| Canada milk vetch (*Astragalus canadensis*) | Forb | 8 | 0 | 3 | 28.6 | 7 | 50.0 | 4 | 2 | 2 | n/a | 2.0 | 2.0 |
| Purple milk vetch (*Dalea purpurea*) | Forb | 12 | 14.3 | 7 | 22.2 | 9 | 0 | 5 | n/a | n/a | n/a | n/a | n/a |
| Wild blue flax (*Linum lewisii*) | Forb | 4 | 25.0 | 4 | n/a | 0 | n/a | 0 | 24 | 24 | 24.0 | n/a | n/a |
| Wild vetch (*Vicia americana*) | Forb | 5 | 0 | 3 | 20.0 | 5 | 0 | 4 | 2 | 2 | n/a | 2.0 | n/a |

## Invasive Weed Species

Another observation from the riparian effectiveness monitoring was the widespread presence and abundance of invasive plant species. For this project, the term 'invasive species' refers to plant species listed as *Noxious* and *Prohibited Noxious* on the Alberta Weed Control Regulation of the Weed Control Act as well as nine additional species that Cows and Fish considers invasive in riparian habitats. These introduced plant species are a concern from a management perspective due to their potential negative effects on native vegetation, wildlife, and ecosystems as well as their ability to negatively affect restoration success. In total, 21 different invasive plant species were observed over the course of the five-year monitoring.

The top five invasive species in terms of commonality are presented in Table 4-26. As shown, the two most common species were creeping (Canada) thistle (*Cirsium arvense*) and smooth perennial sow-thistle (*Sonchus arvensis ssp. uliginosus*). A common and often abundant invasive species in Calgary – currently with no legislated status – is tufted vetch (*Vicia americana*). *Prohibited Noxious* weeds were less common than *Noxious* or other invasive species, although two species – common buckthorn (*Rhamnus cathartica*) and nodding thistle (*Carduus nutans*) – were each observed at a small number of sites. The mean number of invasive species observed at each riparian effectiveness site was five. The greatest number of invasive species observed at a single site was 13. Invasive species were observed at every site assessed. High cover of invasive species was one of the main reasons for reduced BRQI scores, as discussed above.

**Table 4-26: Proportion of Sites Concerned by Invasive Species**

| Species | Legislated Status[1] | Proportion of Sites (%) | | |
|---|---|---|---|---|
| | | Year 1 (n=20) | Year 3 (n=22) | Year 5+ (n=15) |
| Creeping (Canada) thistle (*Cirsium arvense*) | Noxious | 90 | 96 | 93 |
| Smooth perennial sow-thistle (*Sonchus arvensis* ssp. *uliginosus*) | Noxious | 75 | 82 | 87 |
| Tufted vetch (*Vicia cracca*) | Other | 60 | 59 | 53 |
| Common burdock (*Arctium minus*) | Noxious | 55 | 55 | 47 |
| Toadflax (*Linaria vulgaris*) | Noxious | 45 | 41 | 47 |

[1] Source: *Weed Control Regulation*. Other refers to additional species considered invasive by Cows and Fish.

# 5. Global and Climate Change Implications

Ongoing global change includes numerous factors not only climate change, but also land use change, land degradation, atmospheric $CO_2$ and N deposition, stratospheric ozone depletion, biotic exchanges with the development of invasive alien species and new pathogens – with the main threat for biodiversity being land-use change (Thuiller 2007). Rivers are not spared from these pressures. Habitat change has drastically modified river systems through channelization, damming, pollution, pumping or dredging. River ecosystems are also highly prone to invasion by alien plants, largely because of their high level of disturbance through floods and because rivers act as conduits for the efficient dispersal of propagules. All these changes have led to a reduction in the diversity and quality of habitats associated with a decline in biodiversity and associated ecosystem services (Strayer & Dudgeon 2010).

These abiotic and biotic pressures can lead to irreversible degradation of the riparian ecosystem, making ecological restoration to its historical conditions impossible. We then shift from historical systems to “novel ecosystems” “that differ in composition and/or function from present and past systems (Hobbs, Higgs, & Harris, 2009).

In the future, prolonged drought or human caused flow reductions can lead to a lowering of riparian water tables and ultimately mortality in riparian trees (Strayer & Dudgeon 2010). Increasing summer drought associated with higher temperature will increase drought stress. Modification of temperature will also lead to a change in flooding regime and ice cover, modifying the stress and disturbance regimes and changing the zonation of riparian vegetation (Lind et al 2014).

For instance, balsam poplar (cottonwood) riparian forests in Calgary have already faced some past drought stresses that should occur more frequently in the future. Furthermore, riparian cottonwood regeneration from seed (via sexual reproduction) is affected by damming and consequent modification of the hydrological regime of the Bow River (Rood et al. 1993). Without adequately mitigating these factors, most regeneration of riparian cottonwood is anticipated to be from asexual replenishment through root suckering (Rood et al 1993). This has long-term implications to the health of cottonwood populations and genetic diversity.

Another emerging concern globally is the appearance of new diseases caused by alien invasive pathogens associated with the rapidly increasing intensification of international trade and travels (e.g., *Phytophthora* spp.). In several parts of the world, this has led to the possible decline of some riparian tree species (Desprez-Loustau, et al., 2015).

Cumulatively, the aforementioned stressors may potentially lead to the decline of many riparian native species and to the perpetuation and/or acceleration of exotic species invasion. This will contribute to ongoing degradation of ecosystem functioning, consequences that are already seen in several parts of the world (Moss, et al., 2009; Richardson, et al., 2007).

### 5.1.1 Drought

Drought and other vegetation threats are known to be one of the main cause of failure of soil bioengineering works (Pezeshki, Li, Shields, & Martin, 2007; Leblois, Evette, Jaymond, Piton, & Recking, 2022), and these constraints will increase with climate change. Specific efforts must be made to keep plants alive in the first few years of the soil and water bioengineering works. This is the period when they are most fragile as their root system is still underdeveloped. Particular attention must therefore be paid to water availability. This implies the following:

- ensure irrigation is adaptable to changing site conditions;
- limit competition for water by herbaceous vegetation (e.g., ensure appropriate seeding rates; frequently remove weeds; use a clustered planting design);
- increase planting densities to create shade over growing spaces;
- use mulching techniques and other devices to retain soil moisture; and
- use soil amendment to improve soil microbial life and improve drought resistance of plants.

### 5.1.2 Bioengineering Technique and Plant Species Selection

Judicious selection of the most appropriate soil bioengineering technique(s) is another important factor for better resistance to drought. Depending on the conditions, planting will be preferred to cuttings, and deep techniques (e.g. brush layers) to superficial ones (e.g. wattles or contour fascines) that are more sensitive to drought.

Beside the use of the best drought resistant techniques, plant species selection and drought tolerance are also crucial. Preference should be given to selecting a mix of drought resistant tree, shrub, and herbaceous species. If the use of local native species is recommended, in areas where they are already no longer adapted or have been decimated by disease, it may be preferable to use species from other natural subregions (e.g., drier Alberta grassland subregion species). This approach is referred to as 'assisted migration', promoting the use of species from adjacent subregions that likely will be favoured by predicted climate change shifts based on drought performance and other resilience to pest/land use stressors.

### 5.1.3 Invasive Weed Control

To limit invasion by exotic species, various best practices should be carefully followed. For example, special and constant efforts must be made to avoid contaminating construction sites with invasive weed species. This implies reducing the import of topsoil; carefully removing weed infested sediment prior to project implementation where appropriate; and ensuring construction equipment is properly cleaned prior to arrival on site. Stringent invasive weed control should be done prior to, during, and for several years after implementation of bioengineering projects. Where sites are especially vulnerable to invasive weed incursion, bioengineering techniques that promote dense, rapid woody cover establishment are preferred. For example, canopy shading from dense willow cover through soil bioengineering techniques has been shown to be effective in reducing invasive weeds (Dommanget, et al., 2019; Hoerbinger & Rauch, 2019).

# 6. Conclusions

The following section includes the key conclusions from the trend monitoring and effectiveness monitoring components of the RMP. The conclusions are organized according to the RMP objectives as listed in Section 1.1.

## 6.1 Trend Monitoring Conclusions

**Trend Monitoring Objectives 1 and 2**

The first objective of the trend monitoring component was to assess changes in city-wide riparian health primarily for major rivers and streams, excluding private residential land. The second objective of the trend monitoring component was to measure and inform The City of progress toward riparian health target identified in the *Riparian Action Program* (City of Calgary, 2017): *an average city-wide riparian health score of 72% by 2026*. Key conclusions related to this objective are listed below. Key conclusions related to these objectives are listed below.

- Trend monitoring was completed for 58 sites along major streams and rivers within the City, including the Bow River, Elbow River, Nose Creek, West Nose Creek and Beddington Creek. The average riparian health score for these 58 sites with long-term data has improved compared to baseline and has **increased from 61% to approximately 65%** (remaining in the *healthy, with problems* category).
- Improvements in riparian health since 2007 were attributed to a combination of factors including beneficial impacts along the Bow and Elbow Rivers from the 2013 flood and improved management or restoration in sites allowing for natural recovery. Appendix A includes case studies that focus on sites where improved management and restoration benefited riparian health. Common factors limiting riparian health included extensive bank and floodplain structural alterations due to recreation use and infrastructure (pathways, stormwater outfalls, bridges and other parks facilities).
- Trend analysis results are currently informing the progress to meet the 2026 target and the results show that great strides have been made to improve riparian health in the city. As of 2022 the updated city-wide riparian health scores are **69%** and the 2026 target has not yet been achieved. Based on the improvement trend for the subset of 58 sites (trend information not yet available for the city-wide 101 sites) riparian health has increased 4% over approximately 10 years. There are four more years to achieve the 2026 target and an increase of 3% is required, suggesting that enhanced efforts to improve riparian health such as riparian restoration and the conservation of existing undeveloped riparian areas are needed to accelerate the improvement trend to meet the 2026 target.
- In addition to ongoing restoration work, proactive conservation of existing undeveloped riparian areas is essential to achieving The City's *Riparian Action Program* goals including the Land Use Planning target of "No Net Loss" of riparian open spaces along major perennial creeks and rivers at a city-wide scale. Monitoring riparian health trends is integral to assessing success/failure and for informing and directing ongoing riparian restoration, stewardship and management efforts in Calgary.

**Trend Monitoring Objective 3**

The third objective of the trend monitoring component was to expand monitoring sites to be more representative of city-wide conditions for a larger cross section of sites including tributaries and priority source-water protection areas. The key conclusion related to this objective is listed below.

- In addition to the expanded area encompassing 101 sites, there were an additional 21 sites assessed which including 18 sites on ephemeral and intermittent streams in priority source-water areas for a total of 122 sites city wide. Gap analyses identified areas where additional sites were needed in order to meet a target of a city-wide representative sample for riparian health (30% coverage by length of named permanent streams/rivers). Sites identified in this analysis were completed as part of the 2018-2022 project achieving this 30% target. Therefore, no additional sites are needed for a representative sample under the current objectives.

## 6.2 Effectiveness Monitoring Conclusions

A large volume of informative and novel data was collected for this component of the project. These data will help inform future bioengineering riverbank and riparian restoration projects in the City and ultimately lead to improved practices.

Conclusions regarding monitoring key results are presented below. Quick facts regarding effectiveness key results are followed by conclusions organized according the RMP objectives.

### 6.2.1 Key Results – Quick Facts

A brief summary of the data collection results for the bank and riparian effectiveness components is shown in Table 6-1. A brief summary of the key results for the bank and riparian effectiveness components is shown in Table 6-2. No safety incidents were reported over the entire five-year program. The project team was also able to work successfully through the COVID-19 pandemic without incident.

**Table 6-1: Quick Facts – Bank and Riparian Effectiveness Monitoring Data**

| Data Collection Quick Facts | Bank | Riparian |
|---|---|---|
| **Number of years of data collection** | 5 (2018-2022) | 5 (2018-2022) |
| **Total number of unique bank / riparian projects that underwent detailed assessments** | 69 | 42 |
| **Number of bank / riparian sites that have been assessed only once** | 42 | 21 |
| **Number of bank / riparian sites that have been assessed twice** | 24 | 14 |
| **Number of bank / riparian sites that have been assessed three times** | 3 | 7 |
| **Total number of revisit assessments** | 30 | 28 |
| **Number of detailed assessments completed – not including failure sites** | 92 | 59 |
| **Number of failure sites** | 7 | 12 total and 3 partial |

| Data Collection Quick Facts | Bank | Riparian |
|---|---|---|
| **Number of City of Calgary-delivered projects visited** | 51 | 25 |
| **Number of external organization-delivered projects visited** | 18 | 17 |
| **Watercourse with the greatest number of projects** | Bow River (41) | Bow River (19) |
| **Number of sampled transects** | 227 | 81 |
| **Number of sampled quadrats** | 669 | 243 |
| **Number of individual trees and shrubs sampled for survivorship and growth characteristics** | 10,912 | 5,457 |

**Table 6-2: Quick Facts – Bank and Riparian Effectiveness Monitoring Results**

| Effectiveness Results Quick Facts | Bank | Riparian |
|---|---|---|
| **Average Year 1 age class survivorship of container plants versus live cuttings** | 94% vs. 69% | 93% vs. 47% |
| **Average overall rating by age class for all projects assessed** | Year 1 sites: 67 (Fair)<br>Year 3 sites: 64 (Fair)<br>Year 5+ sites: 69 (Fair) | Year 1 sites: 59 (Fair)<br>Year 3 sites: 51 (Fair)<br>Year 5+ sites: 60 (Fair) |
| **Most common site-specific limiting factor for project success** | Soil moisture[1],<br>Maintenance issues | Soil moisture[1],<br>Herbaceous species competition |
| **Number of invasive plant species encountered[2]*** | 19 | 21 |
| **Percentage of sites by age class at which Canada thistle (the most common invasive species) was found (successful sites only)** | Year 1 sites: 100% (32 of 32)<br>Year 3 sites: 87% (27 of 31)<br>Year 5+ sites: 76% (22 of 29) | Year 1 sites: 90% (18 of 20)<br>Year 3 sites: 96% (21 of 22)<br>Year 5+ sites: 93% (14 of 15) |

Notes:
1. Calgary's dry climate that results in low soil moisture conditions is considered a consistent limiting factor for vegetation establishment across all sites. This result is for additional, site-specific limiting factors.
2. Invasive species for this project refer to *Prohibited Noxious* and *Noxious* weeds as well as several other species considered invasive by Cows and Fish.

### 6.2.2 Key Conclusions by RMP Objective

Key conclusions for bank and riparian effectiveness monitoring have been summarized below with respect to project objectives.

**Effectiveness Monitoring Objective 1 – Project Effectiveness Monitoring**

The first objective of the RMP was to determine the effectiveness of bank and riparian sites against the desired goals and objectives of each project. Key conclusions are summarized below.

- Based on the ratings system developed for the RMP, the overall average rating for all sites (67 / 100) was in the fair category which means that there is room for improvement in the way that bioengineering and riparian restoration projects in Calgary are delivered. Based on the ratings, projects were designed better than they were implemented and maintained. Improving maintenance practices such as weeding, irrigation, and documentation will also improve BRQI ratings, which points to improved maintenance as the focus for overall bioengineering and riparian restoration project improvement.
- Mean design, implementation, maintenance, success, and BRQI ratings were relatively consistent between Year 1, Year 3 and Year 5+ age classes for both bank and riparian effectiveness. So the age of the site did not have a strong influence on the ratings.
- Many sites have been assessed for outstanding vegetation establishment and growth across the city that will serve as benchmarks for future bioengineering and riparian planting projects. The Riverdale Avenue Retaining Wall Replacement Phase 2 – Downstream (Age Class: Year 1, Typology: Vegetated Crib Wall) on the Elbow River was identified as the highest rated bank effectiveness site and is featured in Box 11. The Griffiths Woods – RBC and Other Plantings site (Age Class: Year 1, Typology: Native Tree and Shrub Plantings) on the Elbow River was the highest rated riparian effectiveness site and is shown in Box 12.

**Effectiveness Monitoring Objective 2 – Site Selection and Typology**

The second objective of the RMP was to select a representative number of bank and riparian effectiveness monitoring sites from The City's *Master List – Riparian Restoration Projects* based on age class and typology. Key conclusions related to this objective are listed below.

- There were adequate monitoring sites available to develop protocols and categorize bank effectiveness sites into five typologies (Vegetated Riprap, Vegetated Retaining Wall, Vegetated Crib Wall, Primarily Vegetative, and Planting) and three age classes (Year 1, Year 3 and Year 5+) and riparian effectiveness sites into four typologies (Native Tree and Shrub Cuttings, Native Tree and Shrub Plantings, Mixed Techniques, and Large-scale Riparian Retrofit) and three age classes (Year 1, Year 3 and Year 5+).
- There were adequate sample sizes for most combinations of typology and age class for bank effectiveness statistical analysis.
- Only half of the age class / typology combinations had adequate sample sizes for the riparian effectiveness component.
- Unless related to the key issues identified in the report, results of the statistical analysis that were not statistically valid are not included.

**Effectiveness Monitoring Objectives 3, 4 and 5 – Evaluate Success of Year 1, Year 3 and Year 5+ Age Class Sites**

The third, fourth and fifth objective are combined due to data similarities. The third objective of the RMP was to evaluate vegetation establishment success after the first growing season post construction. The fourth objective of the RMP was to evaluate the effectiveness of each Year 3 age class project relative to their intended restoration objectives (e.g., improved bank stability, erosion control, and establishment and improvement of native plant cover). The fifth objective of the RMP was to evaluate the effectiveness of each Year 5 and older age class project relative to improvement of key ecological function/riparian health indicators, biodiversity indicators or progress toward a desired reference plant community or habitat type. Key conclusions related to these objectives are listed below.

*Bank Effectiveness Key Conclusions*

- Year 1, Year 3 and Year 5+ age class bank effectiveness projects have mostly been successful in relation to vegetation establishment and structure effectiveness with no major erosion or scour issues observed at most sites (exceptions have been classified as failure sites).
- The design, construction and maintenance of permanent materials appears to be satisfactory as almost all of the permanent materials used at the bank sites remain in good to very good condition, with the exception of decaying timber at the older timber crib wall sites prior to vegetation establishment. The implementation of temporary erosion and sediment control materials could be improved since they were observed to be in variable condition and did not always meet their intended function due to premature degradation, not using the material for its intended purpose, or poor installation. Additionally, synthetic materials were observed to have been used when biodegradable products would have been suitable and would have less impact on the environment.
- Live cutting survival rates were found to be typically lower than container plants. The brush mattresses technique and plantings technique were the highest Year 1 age class survivorship out of all the techniques with a large number of samples. Woody vegetation canopy cover was measured to increase over the Year 1, Year 3, and Year 5+ age classes; however, the overall mean canopy cover was not measured to be as high as expected in comparison to the literature values.
- Based on leader growth, shoot length, stem diameter, and condition data, sandbar willow was the best performing species for both container plants and live cuttings.
- Higher soil moisture conditions are typically found at locations with lower sun exposure which can lead to higher growth, which was observed in the results for measured growth parameters for the "North, North-East, East" aspect category
- Top herbaceous species performers with good germination success that are native species were slender wheat grass, fowl bluegrass, Canada wild rye, wild blue flax, and northern wheat grass. Many native seed species did not germinate which confirms the general understanding that native herbaceous species are difficult to establish.
- Poor vegetation growth and high mortality was observed at sites where best practices for plant installation schedule or appropriate stock selection were not followed. High vegetation mortality was also the most often reason that sites were identified as failure sites. Site stability and vegetation success were also limited by erosion, existing vegetation competition, and maintenance issues.

*Riparian Effectiveness Key Conclusions*

- Container plants were found to have high survival rates that were much higher than live cuttings survival rates. However, when live cuttings successfully established, they were measured to have higher growth performance than container plants.
- Sandbar willow was the best performing species for container plants as it consistently measured in the top two or three for all measured parameters. For live cuttings species, hungry willow and beaked willow performed well for the Year 1 age class, shining willow and false mountain willow performed well for the Year 3 age class, and shining willow performed well for the Year 5+ age class.
- The majority of sites that were assessed multiple times had increasing shoot lengths over the monitoring period. This data provides an indication of the shoot growth that might be expected for riparian restoration projects.
- Top herbaceous species performers with good germination success that are native species included slender wheat grass, tall goldenrod, northern wheat grass, Canada wild rye, and fowl bluegrass. Otherwise, many native seed species did not germinate.
- The most common reason for failure was low survival of live cuttings that was often a result of existing vegetation competition in the form of non-native perennial grasses such as reed canary grass. Failure was also observed when best practices for plant installation were not followed.

**Effectiveness Monitoring Objective 6 – Techniques**

The sixth objective of the RMP was to identify advantages and limitations of riverbank bioengineering and streambank/riparian restoration techniques and if required, identify preferred techniques and plant species including plant material type (i.e., pot sizes, plugs, bare roots and/ or live cuttings) considered best suited to the site. Key conclusions related to this objective are listed below.

*Bank Effectiveness Key Conclusions*

- Based on the data from five woody vegetation growth parameters (leader growth, shoot length, diameter, Year 1 age class survival, and canopy cover), the highest rated technique was brush mattress, followed by vegetated crib wall, vegetated retaining wall, and brush layers techniques. The lowest performing technique was live staking. Note that this analysis does not include cost, construction complexity, and regulatory approval requirements/timelines which may affect the technique selected for a project.
- When container plants were installed in exposed, high velocity locations, they were observed to be easily eroded and displaced due to shallow root systems. This wasn't the case for live cuttings where they were installed in similar conditions as they resisted high velocity flows due to deep burial and deep root systems.
- There was limited site data for tall rooted stakes (TRS) but where they were installed according to best practices, they were observed to be establishing well. The use of TRS as substitution for live cuttings during summer construction appears to be confirmed.

*Riparian Effectiveness Key Conclusion*

- Based on Year 1 survivorship data, plantings are the preferred restoration technique over live staking.
- Because of the limited data collected, the effectiveness of the new planting technique where small plugs of native tree and shrub species are randomly planted on a site in large quantities with minimal follow-up maintenance or monitoring cannot be confirmed. More research on the effectiveness of this technique is needed.

**Effectiveness Monitoring Objective 7 – Material Supply**

The seventh objective of the RMP was to identify advantages and limitations in plant material supply and make recommendations for involvement of local nurseries in the development of specific plant materials (i.e., species and stock type) to accommodate soil bioengineering design and local climate. Key conclusions related to this objective are listed below.

- TRS were observed to successfully support construction of bioengineering projects outside of the typical dormancy period for live cuttings.

**Effectiveness Monitoring Objective 8 – Maintenance**

The eighth objective of the RMP was to evaluate the effectiveness of maintenance procedures. In general, improvements to maintenance practices were noted for many of the assessed sites with irrigation, existing vegetation competition, herbaceous species competition, weeding, and site repairs were often noted. Key conclusions related to this objective are listed below.

- The lack of documentation was a common reason for low maintenance ratings that contributed to lower overall ratings. Improvements to contractor requirements for documentation and more stringent maintenance requirements would have quickly increased overall maintenance ratings.
- Specific data on irrigation method (drip or spray), volume, and duration were not available so specific conclusions were not possible. However, it was observed that moisture stress was occurring on some vegetation, particularly container plants on the top of bank.
- Maintenance issues and competition from herbaceous plant species (e.g., seeded graminoids and forbs) were the most common site-specific limiting factor for vegetation establishment success cited at both the bank effectiveness and riparian effectiveness monitored sites.
- Mechanical weeding using a weed whacker resulted in damage to the planted vegetation. Manual weed removal provided better results. The mowing of native grasses did not allow for proper establishment and reseeding.
- *Noxious* weeds were observed at most monitoring sites but *Prohibited noxious* weeds are currently not prevalent across all sites.
- Temporary browsing protection fencing has an important effect on vegetation establishment. Browsing by beavers was observed when the fencing was in disrepair. Depending on the site, damaged fencing was also causing a safety risk to the public.

**Effectiveness Monitoring Objective 9 – Citizen Science**

The ninth objective of the RMP was to integrate citizen science opportunities, where possible, into project effectiveness monitoring to support the *Riparian Action Program*'s education and outreach goals for improving community engagement and riparian awareness (City of Calgary, 2017).

Due to changes in the work program, this objective was no longer completed under the effectiveness monitoring component.

**Effectiveness Monitoring Objective 10 – Design Improvements**

The tenth objective of the RMP was to provide recommendations for design improvement to develop more adapted techniques/approaches for the Calgary local conditions and watercourses for future applications that can be considered as part of an update to *the Design Guidelines for Erosion and Flood Control Projects for Streambank and Riparian Stability Restoration* (AMEC, 2012).

The results of Phase 2 of the RMP provided valuable information for updating the Bioengineering Design Guidelines including significant data and results to improve design, implementation, and maintenance practices. Recommendations for design improvements were developed based on the results of the program and are discussed in Section 7.2.3 of the report. Based on the data that was collected, there are potential improvements to the design guidelines including updates to existing sections, tables, figures, appendices, and bioengineering technique design guidelines; recommended new sections; and additional recommendations to include specific results and observations from the RMP.

**Effectiveness Monitoring Objective 11 – Monitoring Recommendations**

The eleventh objective of the RMP was to provide recommendations for future long-term monitoring needs.

Recommendations for future long-term monitoring needs were developed based on the results of the program and are discussed below and in Section 7 of this report.

### Box 11: Overall Highest Rated Riverbank Bioengineering Monitoring Site

**Site Name**: Riverdale Avenue Retaining Wall Replacement Phase 2 – Downstream

**Watercourse**: Elbow River

**Delivering Agency**: City of Calgary, Water Resources

**Date of Substantial Completion**: 2017

**Typology**: Vegetated Crib Wall

**Age Class**: Year 1

**Description**: At the Riverdale Avenue Retaining Wall Replacement Phase 2 – Downstream site, the design featured live grating and brush layers, with a rock toe below to prevent toe erosion. Some of the highlights of the site include: brush layers composed of deeply planted live cuttings; a high density of cuttings per linear meter that are providing a large root mass to assist in bank stabilization; substantial top growth that is shading invasive weeds over the site; shade tolerant rooted species planted between the brush layer rows; soil amendment used on the live cuttings and rooted trees and shrubs; native grasses seeded at prescribed application rate and applied under the coir erosion control matting; large logs used as part of the live grating that support bank stability and help to retain soil moisture; and, rock toe to prevent toe scour. Additionally, good quality plant materials, low levels of soil compaction, good installation that were in accordance with the design, and good maintenance practices and scheduling led to high ratings for this site.

**Rating:** The site was rated the highest rated site in 2018 (Year 1 post-construction) where the rating was 92/100. This site was also assessed in 2020 (Year 3 post-construction) as the highest rated site and received a rating of 87/100 (Good).

**Photo 6-1: Riverdale Avenue Retaining Wall Replacement Phase 2 – Downstream in 2020**

**Looking downstream in the photo to the left. The photo on the right shows a close-up of the live grating structure, the brush layer above, and the shade tolerant container plants between the live grating logs.**

## Box 12: Overall Highest Rated Riparian Restoration Monitoring Site

**Site Name**: Griffiths Woods – RBC and Other Plantings

**Watercourse**: Elbow River

**Delivering Agency**: City of Calgary, Parks

**Date of Substantial Completion**: 2017

**Typology**: Native Tree and Shrub Plantings

**Age Class**: Year 1

**Description**: Success factors included: appropriate timing of planting; appropriate species selection (native riparian shrubs and shrubs); appropriate planting locations; appropriate material type selection (plugs/potted shrubs/trees); good planting quality; plant material supplied appeared to be healthy and vigorous; although no irrigation occurred, shrubs were planted close to the river where there is a high water table; and overall high survival rate of shrubs and trees due to the factors listed above; and sufficient background information to conduct monitoring program.

**Rating**: 79 / 100 (Good)

**Photo 6-2: Griffiths Woods Park along the Elbow River in 2018**

**The photo on the left shows the view west from the end (30 m) of the pin-point transect, whereas the photo on the right shows the view east from the start (0 m) of the same pin-point transect.**

# 7. Recommendations

This section contains recommendations developed from the riparian health trend monitoring and bank/riparian effectiveness monitoring components of the RMP. The trend monitoring recommendations include timing and continued RHI data collection, in addition to a hybrid approach to capture net loss or change to riparian habitat and the urban context. The bank and riparian effectiveness recommendations are combined into one section and include recommendations for improved structural design practices; vegetation design, installation, and maintenance practices; general program recommendations; improved City of Calgary project management practices; and updates to The City of Calgary bioengineering design guidelines.

## 7.1 Riparian Health Trend Monitoring Recommendations

In general, RHI monitoring is recommended on a five-year revisit interval. This allows for tracking the progression of riparian health over time in response to ongoing management efforts and land use pressures. In addition to providing scoring metrics for key riparian health indicators (parameters), RHIs also entail photography monitoring and collection of detailed vegetation data, physical site data, some wildlife data, and trend commentary (Hansen, et al., 2000). Vegetation data includes incidental vascular plant species canopy cover ocular estimations, as well as age class breakouts for each tree and shrub species (i.e., proportional cover from seedling/sapling, mature, decadent and/or dead individuals). In addition, riparian plant community types are characterized by comparison to described reference riparian plant community types for the Grassland and Parkland Natural Regions of Alberta (Thompson & Hansen, 2002). Physical site RHI data includes channel morphology and condition, non-vegetated ground cover breakouts, as well as qualitative and quantitative data related to causes/kinds of natural versus human-caused bare ground and bank/polygon alterations. Supporting data collected as part of RHIs does not all directly inform riparian health scores, but it is useful for monitoring and site management purposes. For all RHIs, geo-referenced benchmark photographs looking upstream and downstream are taken at each end of the site. Additional geo-referenced photographs are taken where warranted to document features of interest or concern (e.g., weed infestations, bank erosion, etc.). In 2021, The Calgary Parks Weed App template was built into the Cows and Fish ArcGIS Collector platform to facilitate direct GIS data integration *for Prohibited Noxious* weeds.

As a field-based monitoring tool, RHIs can provide comprehensive, site-specific information coupled with on the ground photography monitoring. However, like all ground-based monitoring methods, these can be costly and as such generally cannot be applied at a geographic scale to capture comprehensive riparian conditions with full coverage across the city. Moreover, to date, RHI polygon boundaries conform to discrete management units primarily within the inner riparian zone (O2, 2014). Riparian habitat in the mid to outer floodplain zones is generally not well represented by RHI polygons. Consequently, net loss or change to riparian habitat at a city-wide scale is not readily captured by RHI data. Another limitation of continuing forward with the RHI metric on its own is that it is premised on comparison to an undisturbed, natural reference condition. A hybrid approach may be warranted moving forward that better accounts for the urban context (Ehrenfeld, 2000). Such a method should consider “aesthetic, emotional, and practical values” riparian areas provide to urban residents versus a strictly ecological approach (Ehrenfeld, 2000). Some of the key constraints of using ecological based success criteria in an urban versus a natural environment are outlined by (Ehrenfeld, 2000):

| *Natural* | *Urban* |
|---|---|
| *Watershed-based approach is ideal* | *Municipality-based approach is often necessary* |
| *Ecological characteristics and functions are readily identified and are primary* | *Ecological functions may be less important than human values, which may be difficult to specify* |
| *Natural disturbance regimes are critical* | *Natural disturbance regimes may be impossible to restore* |
| *Habitat patches can vary greatly in size and connectedness* | *Habitat patches are often small and isolated; connections are difficult or impossible to re-establish* |
| *Climate and microclimate reflect regional geography* | *Climate and microclimate are significantly altered from the geographically based expectations* |
| *Hydrology is a function of regional climate, geology, physiography* | *Hydrology is usually highly altered, in amounts, sources, and flow rates of water* |

Since the Riparian Action Program was developed, there have been recent advances in riparian intactness (Fiera 2022), 'habitat condition rating' (Fiera 2015), and 'aquatic health indicator' (Lee *et al.* 2020) monitoring tools being applied locally and provincially in Alberta. Table 8, below, gives a brief overview of each of these approaches and how it may be useful for informing the underlying goals of Calgary's Riparian Action Program (i.e., no net riparian habitat loss; improved riparian health and function city-wide).

**Table 7-1: A Comparative Overview of Riparian Monitoring Tools**

| Riparian Monitoring Tool | Overview | Application Considerations |
|---|---|---|
| 1. *Riparian Intactness (Fiera 2022)* | • A desktop, Geographic Information System (GIS) method. Intactness is assessed within 'Riparian Management Areas' that have a fixed 50 m buffer from the shoreline. The method combines satellite imagery with information about the terrain to create a current land cover dataset. This is then used to measure and quantify the amount of natural and human cover types within each RMA.<br>• Three primary metrics are used to quantify riparian intactness: 1) percent cover of natural vegetation; 2) percent cover of woody species; and 3) percent cover of human impact and development.<br>• Riparian intactness categories:<br>– High Intactness (≥75-100): Vegetation within the RMA is present with little or no human footprint. | • Could utilize Calgary's riparian area mapping GIS layer (02 2014) (i.e., inner, mid, and outer riparian zones) versus a fixed 50 m buffer to better capture the full extent of riparian habitat in Calgary.<br>• Benefits:<br>-easily and accurately repeatable<br>- possible to be done at frequent intervals to capture current conditions within a fast changing urban landscape |

| Riparian Monitoring Tool | Overview | Application Considerations |
|---|---|---|
| | – Moderate Intactness (≥50-75): Vegetation within the RMA is present with some human footprint.<br>– Low Intactness (≥25-50): Vegetation cover within the RMA is limited and human footprint is prevalent.<br>– Very Low Intactness (0-25): Vegetation cover within the RMA is mostly cleared and human footprint is the most dominant land cover. | -low cost<br>- wide geographic scope<br>- desktop (digitally) based tool |
| 2. *Habitat Condition Rating (HCR) (Fiera 2015)* | • The HCR tool was built for Calgary Parks to track changes in park terrestrial health over time and to prioritize restoration and habitat conservation efforts. The tool includes a Human Disturbance Index (HDI) to predict human footprint impacts on local, natural environment parks. Habitat condition ratings indicate the extent to which a site departs from full ecological integrity. This can be measured from a benchmark condition or against an ecological disturbance gradient. The predicted habitat condition from the HDI can be rapidly confirmed using a rapid field-based site assessment.<br>• HCR scores are derived using spatial data in a GIS platform. Predicted condition scores can be updated at regular intervals (assuming spatial data sources are updated accordingly). Updates can be done in 5 year intervals or following natural disturbance events or climate change shifts.<br>• HCR ratings are determined for "park" sampling units, which has direct applicability to park managers and as an asset rating / accounting system.<br>• The HCR tool summarizes condition of contiguous areas by primary cover type which is easily recognizable in a GIS platform.<br>• HCR ratings are informed by a relative gradient of disturbance within an urban context.<br>• The HCR approach is based on broadly assessing condition scores for three habitat categories (grassland, forest, and shrubland) within entire park management units. Riparian habitat types are not distinguished from upland habitat types. | • A limitation of the HCR approach is that this tool cannot adequately predict park condition where 10% of the park consists of aquatic features. The HCR model does not capture the unique biophysical characteristics of aquatic and adjacent riparian environments.<br>• HCR ratings for those parks within proximity to major watercourses could be used to inform *Riparian Action Program* targets or to help prioritize and inform riparian restoration initiatives. HCR trends for parks with a majorly riparian component could be monitored at a city-wide scale. |

| Riparian Monitoring Tool | Overview | Application Considerations |
|---|---|---|
| 3. *Aquatic Health Indicator for the City of Calgary Natural Environment Parks (Lee et al. 2020)* | • To address deficiencies of the HCR tool, an Aquatic Health Indicator (AHI) tool was developed for Natural Environment Parks consisting of more than 10% aquatic features. The AHI focuses on wetland aquatic features but does also consider stream and river features.<br>• A common set of 36 indicators was developed from a review of 40 different wetland assessment methodologies. The indicators selected represent “primary drivers of wetland health, including hydrology, soil substrate, vegetation, and landscape elements”. AHI indicators may be considered at landscape, rapid assessment, and intensive site-level assessment scales. | • The AHI tool may be applicable to informing baseline conditions and monitoring the efficacy of restoration works where aquatic wetland environments are a major project focus.<br>• Riparian Action Program objectives could expand in the future to encompass wetland AHI targets. |

To allow more flexibility and judicious use of funding resources, a combination of monitoring approaches at various spatial scales is recommended for the long-term:

- A GIS-based landscape assessment utilizing land cover data; satellite image analysis; terrain data (example: a “Riparian Intactness Assessment” and/or a “Habitat Condition Rating” [HCR] approach);
- A rapid assessment to field check and complement the landscape assessment at locations of interest (e.g., an HCR field-based rapid assessment or an Aquatic Health Indicator rapid assessment); and;
- Continued intensive field-based RHI monitoring within a subset of representative sites city-wide and where appropriate to provide long-term trend data as well as detailed baseline and post-monitoring conditions for discrete habitat restoration projects.

In determining a long-term riparian health monitoring framework, it is recommended that there is consistency and alignment among the monitoring approaches being applied by various City Business Units responsible for jointly managing natural assets (e.g., riparian city parks). *Riparian Action Program* targets linked to riparian health should be reviewed to reflect a more comprehensive monitoring approach. For example, reporting on progress toward riparian health targets should be integrated directly with reporting on city-wide riparian intactness (city or sub-watershed scale) and city-wide riparian habitat loss. This will account for spatial RHI data gaps; non-conformance of RHI polygons to the 2013 city-wide riparian area maps developed by O2 (O2 2014); and the continuing expansion of Calgary’s footprint.

## 7.2 Effectiveness Monitoring Recommendations

Based on the results of the five-year effectiveness monitoring activities, several recommendations have been developed to improve the implementation of bank restoration projects. The following observations and findings are recommended to be incorporated into the future design of bank restoration projects. The recommendations were ordered according to their perceived priority based on the RMP team's site observations, understanding of the results, and professional judgement.

### 7.2.1 Recommendations for Improved Design, Construction and Maintenance Practices

Recommendations for improvements to design, construction and maintenance practices are provided in Table 7-2, improvements to vegetation design, installation, and maintenance practices in Table 7-3, and general program recommendations in Table 7-4.

**Table 7-2: Recommendations for Improved Structural Design Practices**

| No. | Item | Recommendation | Rationale | Report Section |
|---|---|---|---|---|
| S1 | Provide Irrigation for Two to Three Years Post-Construction | • Provide adequate watering for new plantings for at least two to three full growing seasons per the water schedule shown in Box 7. Irrigation volume should be measured using a water meter. | The key limiting factor in Calgary for vegetation growth is soil moisture due to the dry climate. Providing irrigation for two to three years should allow adequate time for the planted vegetation to develop a well-established root system and also coincides with the typical maintenance/ warranty period length. | 3.3.1, p. 3-45 |
| S2 | Install Fencing | • Fencing should be placed around live cuttings and container plants and maintained for a minimum of three growing seasons to allow vegetation to establish and prevent disturbance from wildlife, humans, and dogs. Secure the bottom of the fence into soil trench or underlying riprap. | Fencing was shown to statistically improve vegetation survival and growth. The time period of two to three years corresponds with the typical maintenance/ warranty period. | 3.3.1, p.3-47<br>3.3.2, p. 3-63 |

| No. | Item | Recommendation | Rationale | Report Section |
|---|---|---|---|---|
| S3 | Reduce Soil Compaction due to Construction Activities | • Assess the level of soil compaction at each new site prior to planting and take measures to alleviate any observed compacted soil. Reduce soil compaction by using low ground pressure equipment and establishing travel corridors for equipment then by decompacting soil at travelled areas after heavy equipment work is completed but before planting and seeding occurs.<br>• Where vegetation is planted, specify no compaction or a maximum compaction of 80% to 85% of the standard Proctor maximum dry density (SPMDD) since this target provides many of the stabilizing benefits of soil compaction without jeopardizing the viability of vegetation establishment (Goldsmith, Silva, & Fischenich, 2001). This level of compaction is equivalent to the compaction achieved using the excavator bucket. | Soil compaction was found to have an influence on inhibiting vegetation growth. | 3.3.2, p. 3-83<br>4.3.2, p. 4-33 |
| S4 | Use Biodegradable Erosion Control Matting Products | • Use biodegradable erosion control matting and avoid the use of synthetic erosion control matting on the riverbank. Install erosion control matting per manufacturers' recommended practices for upstream and downstream keys and matting overlaps. | Synthetic materials were observed at 30% of monitored sites. Synthetic products often create hazards for wildlife and will likely persist in the river environment at the end of the structure life cycle. | 3.3.1, p. 3-22 |
| S5 | Properly Install Straw Wattles | • Install per the City of Calgary Design Guideline 'I' (AMEC, 2012) by using the proper spacing between wattles based on the existing slope and trenching in and securing to the slope to reduce surface erosion and to assist vegetation establishment. | Improperly designed and installed wattles were observed at several monitoring sites. | 3.3.1, p. 3-29 |

| No. | Item | Recommendation | Rationale | Report Section |
|---|---|---|---|---|
| S6 | Infill Voids in Riprap | • Infill riprap with river gravel and smaller diameter rocks in conjunction with the implementation of the structure. | Infilled riprap provides a better growth substrate for roots and is a more natural and even surface for wildlife passage and human use. | 3.3.1, p. 3-27 |
| S7 | Timber Crib Walls – Design and Construction | • Specify cedar timber Select Structural, No.1/ No.2, or Construction grade for the dimensional timber used in timber crib walls. Use square timber instead of round logs due to ease of construction and additional stability. Note: that peeled cedar logs (or recycled power poles with creosote removed) will have a longer life cycle than square timber.<br>• Use staggered diagonal joint between headers, do not overlap headers between adjacent cribs as all crib walls monitored to date with overlapping timber joints on the face have some level of washed-out fill material at the overlap locations due to erosion from hydraulic turbulence. Diagonal joints will also shed water resulting in reduced timber decay. Spreaders should also be cut flush with the outside (river side) of the headers to further reduce hydraulic turbulence.<br>• Use biodegradable material containment matting in the cribbing such as double layered coir geogrid (1,000 g/m² or higher) with a functional longevity of minimum three years.<br>• Place suitable matting material such as stitched coir combined with double coir matting behind riprap in the lower rows of the timber crib wall and use a gravel filter per Guideline 'O' in the design guidelines (AMEC, 2012) and drainage gravel behind the structure to allow root penetration and growth to bind the structure | Several observations were made on improvements that could be made to timber crib walls during the detailed assessments of 15 timber crib walls in Calgary. | 3.3.1, p. 3-25 |

| No. | Item | Recommendation | Rationale | Report Section |
|---|---|---|---|---|
| | | together with the native bank materials and to reach the water table. Use a gravel filter per Guideline 'O' in the design guidelines (AMEC, 2012) behind and infilled within the riprpap (dimension to riprap size) to prevent washing out of fines and drainage gravel behind the structure to allow root penetration and growth to bind the structure together with the native bank materials and for roots to reach the water table.<br>• Use a mix of coarse granular material (e.g., Class 1M riprap mixed with river gravel), topsoil, and soil amendment as timber crib wall backfill. This will allow the vegetation root mass to bind the aggregates together and secure the bank after the decay of timber over the structure life cycle.<br>• Filling in voids in crib wall backfill materials can be achieved using cobbles mixed with Class 1M riprap and planted with live stakes. | | |
| S8 | Install Sprinkler Heads at Adequate Height | • Sprinkler heads on raised irrigation lines should be installed at a height of about 1.3 m when the irrigation system is first installed. Irrigate in early morning and late evening to reduce evaporation and improve percolation. | This will allow for better and more consistent watering coverage as the vegetation grows and will reduce soil erosion created by the interference of the spray from vegetation stems and canopy. | 3.3.1, p. 3-45 |
| S9 | Use Updated Box Fascine Design | • Use the box fascine design from *Le génie végétal - Un manuel technique au service de l'aménagement et de la restauration des milieux aquatiques* (Adam, Debiais, Gerber, & Lachat, 2008) Use native river gravel to fill in the structure to mitigate washout of fine material. | The recommended design is easier to construct and allows better contact for the live cuttings with native bank material soil and moisture behind the structure than the design from site Bioengineering Demonstration and Education Project Site 2. | Refer to bank effectiveness annual summary reports |

| No. | Item | Recommendation | Rationale | Report Section |
|---|---|---|---|---|
| S10 | Try Rarely Used Techniques where Appropriate | • Live pole drains were not observed at any site assessed during the five-year RMP but are useful where seepage is causing slope instability. The live pole drain acts to wick excess moisture and stabilize the location, allowing vegetation to establish. This approach can be combined with various bank protection approaches.<br>• Brush grids are used for stabilizing banks from erosion caused by boat wakes and heavy use by the public and dogs. | These rarely used techniques have a history of successful use elsewhere and may be useful for the applications noted. | Refer to bank effectiveness annual summary reports |
| S11 | Use Soil Bags for Repair Option | • Use available fill material suitable as growing substrate wrapped with jute matting. This approach can be combined with seeding and/or large woody debris. | Using jute wrapped growing medium is a more economical approach than using soil bags such as HenDen bags | Refer to bank effectiveness annual summary reports |

**Table 7-3: Recommendations for Improvements to Vegetation Design, Installation, & Maintenance Practices**

| No. | Item | Recommendation | Rationale | Report Section |
|---|---|---|---|---|
| V1 | Use Recommended Bioengineering Techniques and Species | • Bioengineering techniques that are planted deeply and use a higher density and diversity of live cuttings such as brush layers / hedge brush layers, and live staking and techniques that are slightly exposed such as fascines and brush mattresses on appropriate aspects and moisture conditions appear to be the best technique choices based on the results from the RMP.<br>• If the live staking bioengineering technique is being used in Calgary, it is important to be aware of the low survivorship (70%), and corresponding low woody vegetation canopy cover (45% for Year 1 age class, 55% for Year 3 age class, and 50% for Year 5+ age class) observed through the RMP. It is encouraged to closely follow best practices when using this technique for live cutting harvesting/handling/storage/ soaking/installation, construction scheduling, soil compaction, and soil amendment use as described in Box 8 of this report. Additionally, higher density planting of 0.3-0.6 stems/m$^2$ should be considered.<br>• Select live cuttings species that have been shown to establish well in Calgary's climate including sandbar willow, hungry willow (*Salix famelica*), and balsam poplar.<br>• Avoid using red-osier dogwood as a cutting, but instead use rooted stock and plant them in partial to full shade, at an elevation slightly higher than the toe of the bank due to low survival rates of this species used as live cuttings. | The RMP effectiveness monitoring results provide guidance toward bioengineering technique, species, and stock selection. | 3.3.1, p. 3-21<br>3.3.2, p. 3-55<br>4.3.1, p. 4-11<br>4.3.2, p. 4-29 |

| No. | Item | Recommendation | Rationale | Report Section |
|---|---|---|---|---|
| V2 | Increase the Use of Container Plants in Combination with Live Cuttings Where Possible | • Use more container plants in combination with live cuttings in bioengineering structures such as hedge brush layers. Container plants should also be used instead of live cuttings where the project objective is to enhance riparian habitat versus providing earth stabilization on slopes or banks.<br>• Shade-tolerant species such as red-osier dogwood and golden currant (*Ribes aureum*) and partially shade-intolerant species such as choke cherry (*Prunus virginiana*), saskatoon (*Amelanchier alnifolia*), water birch (*Betula occidentalis*), common wild rose (*Rosa woodsii*), and prickly rose (*Rosa acicularis*) can be used between rows of brush layers as they have shown to be successfully establishing at monitored sites. | Adding container plants in combination with live cuttings will increase species diversity, further enhance wildlife habitat with fruit bearing species, and enhance soil properties with nitrogen-fixing species. | 3.5, p. 3-55<br>4.6, p. 4-29 |
| V3 | Use Best Practices for Live Cuttings, Potted Plants, and Seed Mix Installation | • Live cuttings should be installed according to the best practices listed in Box 5 of this report. Potted plant material should be installed according to the best practices listed in Box 6 of this report. Herbaceous seed mixes should be installed according to the best practices listed in Box 8 of this report. | Best practices have been compiled based on the findings in of the RMP, literature, and the RMP team professional experience. | 3.3.1, p. 3-39<br>3.3.1, p. 3-40 |
| V4 | Use Tall Rooted Stakes when Construction is Outside of the Live Cutting Dormancy Period | • Use tall rooted stakes (TRS) when construction is scheduled from July to September as this period is outside of the construction window for live cuttings. The City should develop a standard for the supply of TRS to ensure consistent properties (e.g., root to shoot ratio, rooting substrate, growing procedures) with the aim of achieving target survival and establishment. TRS can be used as tall plants which will provide direct shade in riparian areas (e.g., over invasive herbaceous weeds) and planted as a regular rooted stock. When designing and installing TRS within a structure where cuttings would be mostly buried such as a hedge brush layer or vegetated riprap, the root ball and two-thirds of the main stem must be buried. | TRS have been observed to establish well where used correctly and provide an important option for summer construction in Calgary. | 3.3.1, p. 3-31 |

| No. | Item | Recommendation | Rationale | Report Section |
|---|---|---|---|---|
| V5 | Better Invasive Weed Control Needed | • Better weeding/removal of invasive weeds is required, including better understanding by contractors on what species to target, when to schedule removal (e.g., spring/summer before flowering, and later summer/early fall), what methods to use (some weeds cannot be mowed and must be hand-pulled, removed from the site, or sprayed with herbicide) and ensure that adequate resourcing and scheduling is provided to properly complete the work. | Weeds were observed to be an important issue for the successful establishment of sites during the RMP monitoring. | 3.3.2, p. 3-81 |
| V6 | Use Soil Amendment on Live Cuttings and Container Plants | • The soil amendment described in AMEC (2012) and as amended in Box 5 should be placed on all live cuttings and container plants and thoroughly watered during application to improve initial vegetation establishment and survival. | Soil amendment was shown to have a statistical influence on vegetation survival and growth. The additional cost for soil amendment is marginal in comparison to its benefits as demonstrated by the RMP results. | 3.3.2, p. 3-60 |
| V7 | Use Native Bank Material instead of Imported Topsoil | • Avoid using imported topsoil when native bank soil material (including river gravel) can be used around live cuttings. Add soil amendment to the native bank soil per Recommendation V6. | Since pioneer species such as willows (*Salix* spp.) have a natural ability to grow and establish in disturbed soil and river gravel, topsoil is not necessarily needed and can introduce invasive weeds. | 5.1.3, p. 5-2 |
| V8 | Further Investigate Low Cutting Survival | • Further study is needed to better understand the limiting factors affecting the low to moderate survival of key species used as cuttings in bioengineering projects in Calgary. | While results for low survival were theorized by the RMP team, exact causes were not identified. | 3.3.2, p. 3-55<br>4.3.2, p. 4-29 |

| No. | Item | Recommendation | Rationale | Report Section |
|---|---|---|---|---|
| V9 | Further Investigate Seed Mix Failures | • If possible, further investigate the cause(s) of persistent herbaceous seed mix failures in riparian restoration projects. | Herbaceous seed mix germination rates were observed to very low. Seeding is important for erosion and sediment control efforts, habitat, and native species establishment. A better understanding of the mechanisms may result in higher germination success. | 3.3.2, p. 3-70<br>4.3.1, p. 4-34 |
| V10 | Select Species According to Site Conditions | • Select species based on project site-specific conditions such as aspect, moisture regime, expected shading, and species stratification up the bank and consideration of surrounding existing mature trees, taller vegetation, and infrastructure. Also, when possible, inventorying the native species growing adjacent to the site is recommended. | Selecting species according to their tolerances for site conditions will improve overall survival and establishment. | 3.3.1, p. 3-34 |
| V11 | Enforce and Monitor Invasive Weed Control Activities | • Better enforcement and monitoring of the maintenance program by the City and/or the contract administrator with knowledge of the local native and invasive species should be conducted, and contract documents could include penalties or withholding payment. | Analysis of the limited documentation showed that some site maintenance activities (or lack thereof) were not reported accurately. | 3.3.1, p. 3-47<br>4.3.1, p. 4-35 |
| V12 | Weed Seeded Grasses Around Planted Shrubs | • Weeding of seeded grasses around planted shrubs should be included in maintenance contract specifications when grasses are competing with the establishment of planted trees and shrubs. This could also be avoided or reduced by using a lower seeding application rate. | Herbaceous vegetation was often observed to be competing with woody vegetation during the site assessments and was listed as key a limiting factor to site success. | 3.3.1, p.3-47 |

| No. | Item | Recommendation | Rationale | Report Section |
|---|---|---|---|---|
| V13 | Prohibit Mechanical Weeding Activities | • The use of gas-powered weed wackers should be prohibited on soil bioengineering sites where shrubs have been planted at the recommended riparian planting density (i.e., 1/m² or 10,000 stems/ha or less). A manual tool should be used to remove invasive weeds and seeded graminoids that are competing with the plantings. It is recommended that weeds are cut using a cutting action in an outward or away motion from the base of the planting and to remove the roots using a long screwdriver or a small pitchfork. | During the 2020 monitoring year, 8 out of 21 sites were observed with mechanical damage to the planted vegetation. Due to the proximity of the plantings, it is difficult to not damage the plants when operating a weed whacker. | 3.3.1, p.3-47 |
| V14 | Do Not Mow Native Grasses | • Native grasses should not be mowed throughout the growing season unless they are competing with planted woody vegetation and then should be removed to promote woody vegetation establishment. | Mowing tends to cause a reduction in native grass cover and an increase in cover of invasive perennial grasses. Avoiding mowing allows native grasses to establish properly and reseed themselves | 3.3.1, p.3-47 |
| V15 | Place Milorganite Around Planted Vegetation | • Include the use of milorganite around planted shrubs and cuttings in the fall during the maintenance period. Especially recommended in areas of thick herbaceous and where erosion control matting and/or wattles are used. | Using milorganite will deter rodents from girdling stems of woody plants over winter and increase overall woody vegetation survival. Milorganite has been used in commercial nurseries in Alberta and is proven to be efficient at deterring rodent damage over winter. It has been used by Parks at a few sites. The issue is that voles will eat the bark all the way around the stem of the shrub (i.e., girdling) which can kill the shrub or tree. This has been observed at several sites including at BDEP. | 3.3.1, p. 3-40 |

| No. | Item | Recommendation | Rationale | Report Section |
|---|---|---|---|---|
| V16 | Design Container Plants in Clusters | • Use cluster planting within a mulched bed, or place mulching/ cardboard at the base of planted shrubs. | Using this method will create a buffer around the planting to reduce the potential for herbaceous competition and to make it easier to weed with less potential to damage plantings | 3.3.1, p. 3-40 |
| V17 | Increase the Use of Woody Material | • Increase the use of woody material (small and/or large) within the soil and on the soil surface. | Adding woody debris to a site will improve biodiversity, add organic material, retain moisture, and contribute to increased levels of soil micro-organisms which are beneficial to plant establishment and long-term growth | 3.3.1, p. 3-25 |
| V18 | Incorporate Emergent Vegetation | • Use plugs of emergent species such as sedges (*Carex* spp.) and rushes (*Juncus* spp.) when emergent vegetation is desired in low velocity locations that are inundated during peak flows. Plant emergent plugs in groups and deep enough so that the top of the plug is buried approximately 2 cm and protect the plugs against wildlife using nets and light wooden frames (bamboo) arranged in a rectangular tent for a minimum of the first two growing seasons. Plugs or rhizomes of emergent species can also be used as plant material within rolls of aquatic species and used to protect the toe of an eroding streambank per Guideline ‘A’ in the design guidelines (AMEC, 2012). | Emergent species are tolerant of inundation during peak flows but must be used in low velocity locations. | 3.3.1, p 3-31 |
| V19 | Improve Contractor Compliance with Seeding Rate | • Project specifications should include the seeding rate procedure on how to calculate and apply a prescribed seeding application rate. This procedure must be followed by the contractor and monitored/enforced during construction so that seeding does not result in high herbaceous competition to the planted native woody shrubs and trees or, conversely, large patches of bare soil. | It was observed at many of the monitoring sites that remarkably higher than prescribed seeding application rates are being used resulting in high herbaceous competition to the planted native woody shrubs and trees. | 3.3.2, p. 3-78 |

| No. | Item | Recommendation | Rationale | Report Section |
|---|---|---|---|---|
| V20 | Assess Success of Random Planting Projects | • If possible, assess more random planting projects in the future. Random planting projects involve the installation of large numbers of native tree and/or shrubs plugs in a random distribution with minimal or no follow-up monitoring or maintenance. | These projects are of interest since if the method is successful, they could provide a cost-effective restoration technique for future projects. | 4.3.1, p. 4-19 |
| V21 | Excavate Bioengineering Site(s) to Observe Root System | • Perform excavations of specific sites to assess root mass growth (e.g., root area ratio and tensile strength) and effectiveness in strengthening soil (e.g., for vegetated riprap, assess the displacement force and tensile strength required to remove rocks enveloped by roots). | This research would confirm the visual results for deep, binding root mass and gain better understanding of the root system growth in the bank effectiveness sites in Calgary. It would support the understanding of rooting depth and vegetation impacts to flood berms and earth dam structures. | 3.3.1, p. 3-37 |

**Table 7-4: General Program Recommendations**

| No. | Item | Recommendation | Rationale | Report Section |
|---|---|---|---|---|
| G1 | Continue BDEP Monitoring | • It is recommended to continue monitoring the BDEP in 2023 and 2028 using the RMP protocols. | The efforts will further build on the results to date so that more robust statistical conclusions and recommendations for project improvement will be possible | Refer to bank effectiveness annual summary reports |
| G2 | Share RMP Results via Field Days/Workshops | • It is recommended to schedule at least one educational activity per year to share RMP results and best practices with the bioengineering community of practice. | Sharing RMP lessons learned and technical design/vegetation information via report summaries, field visits and workshops with practitioners, consultants, contractors, etc., would provide an important means to improve bioengineering project outcomes in Calgary. | Refer to bank effectiveness annual summary reports |
| G3 | Update Bioengineering Design Guidelines | • Update the *Design Guidelines for Erosion and Flood Control Projects for Streambank and Riparian Stability Restoration* (AMEC, 2012) based on the results of the RMP and the experience gained since the guidelines were published over 10 years ago. Include ranges of construction costs and labour productivity estimates for the bioengineering techniques described in the guidelines. | The RMP results provide many opportunities for updating the guidelines as described in Section 7.2.3 below. | 7.2.3, p. 7-11 |
| G4 | Share RMP Results in Scientific Journals | • It is recommended to publish the results of the RMP in one or more scientific journals. | There is a benefit to the overall practice of bioengineering of sharing the original data collected in the RMP and the results with other practitioners and researchers. | Refer to bank effectiveness annual summary reports |
| G5 | Continue Bioengineering Research | • Continue research on soil moisture in riverbank bioengineering sites in general and at BDEP in particular and consider researching the long-term durability of the timber/logs used in crib wall structures. | Soil moisture and irrigation effectiveness are key limiting factors for vegetation establishment in Calgary. The long-term durability of timber used in the crib walls in Calgary is not well understood. Results from this research would improve practices and long-term durability of structures. | 3.3.1, p.3-38 |

### 7.2.2 Recommendations for Improved City of Calgary Project Management Practices

Recommendations for improvements to City of Calgary Project Management practices are provided in Table 7-5.

**Table 7-5: Recommendations for Improved City of Calgary Project Management Practices**

| No. | Item | Recommendation | Rationale | Report Section |
|---|---|---|---|---|
| PM1 | Improve Document Control and Record Keeping | • Improve documentation and record keeping for construction contracts including restoration plans, maintenance, and as-built records. All records should be accurate.<br>• Monthly maintenance reports must reflect the actual activities conducted by the contractor, and the contract administrator should verify the accuracy of maintenance reports to confirm that the reported activities have been performed in the field according to the contract specifications. | As noted in Section 3.3.1, project documentation for design, construction, and maintenance was not always available to the RMP team for review. Background documentation is an important component of a construction project and very important to the RMP to track the effectiveness of the monitoring sites, based on actual or adjusted design implemented against the project objectives. | 3.3.1, p. 3-21<br>4.3.1, p. 4-35 |
| PM2 | Address Failure Sites and Implement Remedial Measures | • The Year 1 failure sites and recommended remedial measures on Years 3 and 5+ sites should be addressed by The City and/or the contractors depending on the stage of the project. Recommended remedial measures have been documented by the RMP team within the dashboard summaries and are provided in Appendix D.<br>• Site-specific recommendations for upgrades or repairs of monitored sites documented in the Dashboards (Appendix D) should be followed up by The City in a timely matter to improve project outcomes. | Failure sites should be repaired as either vegetation establishment is well below expectations, or the site is structurally failing. Recommendations for repairs are documented in the dashboards and are submitted to The City typically in the spring of each year as an update on site conditions and to aid in remedial planning for the upcoming field season. In several instances, the recommendations have been provided to the City during the field assessments when immediate actions were required based on the opinion of the RMP field crew. | Appendix D |

| No. | Item | Recommendation | Rationale | Report Section |
|---|---|---|---|---|
| PM3 | Incorporate Survival and Woody Vegetation Canopy Cover Targets | • It is recommended to initiate a discussion with regulators as part of each bioengineering project execution about live-cutting survival targets as described in Section 3.3.1. While it is recommended to maintain the typical Year 1 post-construction survival target of 70% to 80%, targets for woody vegetation canopy cover and living shoot density that are bioengineering technique-based for years two to five post-construction are recommended to be included as well. Based on the RMP results, it recommended that the contract warranty targets in Calgary should be adjusted to use targets developed by Schiechtl and Stern (1997) as they seem to be more appropriate and compatible to the data collected than the use of percent survival after Year 1 alone. | Targets as recommended by the literature will allow for vegetation self-thinning over time and allow for more realistic regulatory targets. | 3.3.1, p. 3-49 |
| PM4 | Enforce Contract Specifications During Maintenance | • The City and design professionals should develop adequate contract language and enforce contract-mandated maintenance activities. | Maintenance of bioengineering projects is of primary importance to ensure plant establishment, survival, and growth and to conduct any structural integrity/erosion repairs as needed. | 3.3.1, p. 3-47 |
| PM5 | Replace Plant Material Annually | • Required plant replacements and seeding establishment should be addressed annually versus at the end of the maintenance period. | The intent is to avoid extension of the maintenance period and ensure timely overall establishment of native vegetation on-site, reducing the opportunities for invasive weeds to get established. | Refer to bank effectiveness annual summary reports |

| No. | Item | Recommendation | Rationale | Report Section |
|---|---|---|---|---|
| PM6 | Develop Mandatory Container Plant Installation Training Certificate | • The City should develop a mandatory on site, hands-on training for container plant installation for all bioengineering projects within the City. The training would include two parts 1) demonstration of a properly installed container plant by the instructor; and 2) participant planting of ten container plants inspected and approved by the instructor. The participant would obtain a simple accreditation card (e.g.,ticket) to carry-out planting on City of Calgary projects that would be valid for one year. | The intent of this training is to address the general observation of a need to improve the quality of container plant installation by contractors in Calgary. | Refer to bank effectiveness annual summary reports |
| PM7 | Perform Field Evaluations Using Knowledgeable Personnel | • Field evaluations of maintenance activities should be performed with the assistance of professionals with a detailed understanding of vegetation requirements such as a horticulturist working along with the City Project Manager. | In the same manner as PM4, maintenance of bioengineering projects is of primary importance to ensure plant establishment, survival, and growth and to conduct any structural integrity/erosion repairs as needed. | Refer to bank effectiveness annual summary reports |
| PM8 | Develop a Final Acceptance Certificate Checklist | • It is recommended for The City to develop a checklist to be used during Final Acceptance Certificate so that all key items related to bioengineering and riparian planting sites are successfully completed. | Checklists are requirements for the FAC process for other City infrastructure projects. The bioengineering project checklist would help to ensure that important project components such as vegetation survival/cover/density are reviewed and approved prior to sign-off. | 7.2.3, p. 7-2 |
| PM9 | Create a City Position for the Inspection, Review and Quality Control of Bioengineering and Riparian Planting Projects | • The City should create a high-level specialist position that is responsible for overall review of proposed designs and quality control during construction for soil and water bioengineering projects. | The objectives of the professional would be to ensure that both structural and vegetation aspects of the proposed design are met so that both civil/geotechnical engineering and bioengineering components are properly integrated. Construction oversight would be coordinated in collaboration with The City project manager and consulting engineers to ensure that the design features and requirements are met. | Refer to bank effectiveness annual summary reports |

### 7.2.3 Recommendations for Updates to The City of Calgary Bioengineering Design Guidelines

Per Section 1.2, one of the goals of the RMP was to recommend updates to *the Design Guidelines for Erosion and Flood Control Projects for Streambank and Riparian Stability Restoration* (AMEC, 2012), commonly referred to as the 'Design Guidelines'. Based on the results from the RMP effectiveness monitoring, it is recommended that the following upgrades and changes be included in the Design Guidelines. These upgrades and changes could be implemented either as a new version or addendum to the original.

The recommendations below are based on the results from the effectiveness monitoring, and other research-related information from the detailed technical reports.

**Existing Sections to be Updated**

The existing sections listed below should be updated due to changes in policies/strategies that have occurred since the Design Guidelines were published in 2012.

- Section 2.0 Regulatory Requirements, City Policies and Watershed Management Plans
- Section 3.0 Management Strategy for Erosion and Flood Control and Riparian Restoration Projects

**Bioengineering Techniques Design Guidelines to be Updated**

The results of the effectiveness monitoring have provided guidance on adjustments to the techniques design in the Design Guidelines as listed below.

- Fascines with double poles design guidance to be renamed as box or toe fascines and installation procedure to be adjusted per the *2022 Annual Report - Bank Effectiveness Monitoring* (KWL, 2023b).
- Vegetated riprap to be updated with different material than O.S.B. and recommendation to void fill the riprap to be added.
- Vegetation of existing riprap to be updated using examples from successful sites at BDEP.
- Brush layers to have hedge brush layers technique included.
- Brush mattresses to include option with coir matting.
- Erosion and sedimentation control products to include Curlex® Sediment Logs® or equivalent.
- Vegetated crib wall to be updated with timber quality guidance, timber backfill specification, material containment matting guidance, recommendations for joints between cribbing, and recommendations for timber cuts.
- Update critical shear stress for bioengineering design techniques using new research. An updated reference table is provided in Table E-4, Appendix E.

### Tables to be Updated

The list of tables below should be updated with new information gleaned from the effectiveness monitoring results.

- Table 5.1 Design Guideline Techniques
- Table 8.1 List of Basic Information to Collect During Site Assessment
- Table 8.4 Design Guideline Selection Matrix
- Table 10.1 Typical Maintenance Regime for Bioengineering Projects
- Add a table with a modified version of the survey high water level, elevation table (use for RMP) of planted and native vegetation to be used for determining design elevations of proposed vegetations within structures (see final report).

### Figure to be Updated

- Figure 8.1 Schematic for Determining Angle of Attack on Bank should be updated to include sites located on internal bends.

### Appendices to be Updated

- Appendix A: The City of Calgary Policies and Bylaws
- Appendix B: Environmental Regulatory Review and Responsibilities: Calgary Construction Sites.

### New Section to be Added

It is recommended to add a new '*Planning and Design*' section in the Design Guidelines that covers the information described below.

- Project documentation list that should be requested and filed as reference material for future project follow-up:
  - Design documentation: design reports, design drawings, technical specifications, cost estimate, regulatory approvals.
  - Construction documentation: contract tender, actual cost, inspection records, as-built drawings, and as-built reports.
  - Maintenance documentation: records including watering regime and duration.
- Live cuttings harvest and stock handling plan and rooted stock availability should be established ahead of time based on design requirement and a separate contract could be developed to address timeline issues and availability.
- Measures to avoid soil compaction such as travel corridors for equipment's and decompactions of the travelled areas should be included in the planning and design/drawings.
- Check list and peer review of proposed designs by soil and water bioengineering matter expert should be recommended within the revised guidelines. A section could be developed with a check list to assist with preliminary reviews.

**Additional Recommended Updates**

- Technique selection based on collected site data and site-specific limitation factors
  - Consideration should be given to results such as the highest survivorship of 96% for plantings and brush mattresses and to the buried structure types such as brush layers considering the Calgary climate.
  - While the lowest survivorship was live staking at 49%, it can still be an effective technique. To mitigate low survivorship, the density of installed live cuttings can be increased so that survivorship targets can still be met. Additionally, it is recommended that projects using this technique are made aware of the lower survivorship in Calgary and are encouraged to closely follow best practices per the Design Guidelines.
- Addition of new techniques observed and assessed but not in the guidelines.
  - Live grating / slope grid technique has been used successfully on some of the Calgary projects and is very useful to blend constructed structures with existing very steep near vertical riverbank.
  - Addition of new techniques not observed or assessed to be included in the guidelines.
  - Add section on emergent fascines and top of bank application and aquatic. List suitable species to the Calgary region and various material types i.e., size of containers and recommended planting densities.
  - Emergent bench technique are being designed currently on a Calgary project when applicable to the site they provide a good transition between emergent and woody vegetation.
  - Include section on Brush grid, as a potential solution for shoreline erosion caused by overused of public or dogs (see RMP 2022 Final Report recommendations).
- Costs and production rates for bioengineering and planting techniques
  - Compiling cost for project sites with similar applications as planning reference for future projects.
- Species and stock availability and selection based on collected site data and site-specific limitations.
  - Woody trees and shrubs as well as forbs and graminoids species for seed mixture.
  - Vegetation stock types should be determine based on the site-specific requirement.
  - Native graminoids species found to be successfully germinating and establishing should be recommended in seed mixes (see KWL (2023a), and KWL (2023b) and City of Calgary (2018)).
  - Current Guideline 'L' Native seeds, seedlings, and nursery stock. Table L1 & L2 plants available from the different nurseries. These table should be removed as they are not current and can not be current due to the ongoing distribution of plant materials between suppliers and users. The list of nurseries names and contact at the end should be updated and the type of material and services they provide should be listed i.e., Native trees and shrubs or wetlands and aquatic plants, installations etc.

- Construction material recommendations (e.g., matting/ESC product recommendations to avoid synthetic materials).
  - Consideration should be given to 100% biodegradable material and to the use of sediment filtering system such gravel filters.
- Beneficial practices (soil amendment, temporary fencing, signage, etc.)
  - Soil amendments mixture in current Guideline ‘M’ Soil Amendment should be updated due to a lack of product availability. A replacement was found and is suggested in the final RMP 2022 Report.
  - Public and rodent fencing should be included in the new design guidelines revision as it is not included in the current version.
  - Project signage is recommended to be included on all CoC projects; currently it does not appear to be consistent.
- Construction timing schedules to accommodate vegetation best practices.
  - As demonstrated through the RMP, timing schedules and vegetation types used is critical for the survival and establishment and overall success of the projects. The description of planting schedule along with the selection of vegetation types should be extended in current Guidelines K as per RMP 2022 Final Report recommendations.
- Recommended procedures to avoid and / or mitigate soil compaction.
  - The RMP has demonstrated that compacted soil deters vegetation growth and establishment as well as it increases surface run off by decreasing the infiltration of water within the soil structure.
  - Specific measures to avoid soil compaction as recommended in RMP Final Report should be included in the current Guidelines N Construction and Environmental Practices.
- Performance targets (survival, woody vegetation density, canopy cover, % herbaceous coverage).
  - A dedicated section within the revised Design Guidelines should include acceptance standards based on type of techniques and years of establishment. It is recommended that first year’s survival be based on % and second and third years up to 5 years be based on density per l/m or square m and canopy cover. These standards could be used for FAC’s final project inspections. See RMP Final Report for specific recommendations using the Schiechtl & Stern standard (1997).
  - The same section mentioned above should include a Checklists for assessment of vegetation establishment at CCC / FAC this check list would have to be developed.
- Construction
  - Recommended procedures for seeding volume calculation (specifications)
  - The new revised Guidelines should include a section within Guideline ‘L’ Native Seeds, Seedlings and Nursery Stock demonstrating proposed seeding rate application calculation procedures along with the selected graminoids species as per the recommendations of the RMP 2022 Final Report.

- Plant installation training recommendations
  - The new revised Guidelines should include a section within ''Guideline 'H' Planting of Live Stakes or Seedlings with Mulch'' on planting common issues to encourage proper planting rooted stocks.
  - Hands on training is recommended at the beginning of each contract to demonstrate and teach proper procedures to field crews.
- Maintenance
  - Recommended maintenance practices (weeding, irrigation, and fencing and erosion repair)
  - It is recommended to update existing section 10.0 (p.49) of current Design Guidelines with recommendations developed in the RMP 2022 Final Report and to include inspection template developed for the BDEP project. This should include a section on recommendations for enforcing proper administration of maintenance practices.
- Post-Construction Monitoring
  - An appendix could be developed to demonstrate riparian monitoring methods outlining the methods used through the RMP for both structural and botanical assessments.
- Drawings
  - All technique drawings should be updated to line drawings where concepts of the various structural designs could be better visualized and developed.
- Other
  - Allocation of resources (time and training) for City staff to become familiar with the Design Guidelines
  - Recommendations for enforcing the incorporation of Design Guidelines

### 7.2.4 Recommendations for City-Wide Riparian Health Improvement

Riparian health improvement in Calgary is constrained by local land use and watershed-scale factors (e.g., historic channelization, and upstream dams and water diversions). Nonetheless, RHI trend monitoring results confirm beneficial outcomes from ongoing restoration and beneficial management efforts. Highest average riparian health scores for the "Conservation Management Zone" demonstrates the importance of conservation efforts for large, natural riverine parks such as Griffith Woods and Weaselhead Flats. Proactive conservation of intact riparian corridors and floodplain habitats will continue to be key to achieving Calgary's *Riparian Action Program* goals. Going forward, riparian health improvement targets should be reported on in concert with reporting on progress toward achieving the 2026 target of 'no net loss' of riparian habitat. This would provide a more holistic perspective on whether or not key goals and objectives of this program and the overarching *Riparian Strategy* are being met. Table 6, below, summarizes other considerations for an integrated, adaptive riparian management framework in Calgary.

**Table 7-6: Key Considerations and Management Suggestions**

| Riparian Health Indicator | Key Considerations and Management Suggestions |
|---|---|
| **Invasive Plant Species** (i.e. provincially regulated weeds) | • Invasive weeds are a growing management concern in Calgary's riparian areas. Invasive plants have increased in abundance and distribution in most RHI sites since baseline conditions. Notably, tufted vetch (*Vicia cracca*) (city-wide), common tansy (*Tanacetum vulgare*) (Bow River), common burdock (*Arctium minus*) (Elbow River), and yellow toadflax (*Linaria vulgaris*) (Nose Creek watershed) infestations have expanded since 2014/2015.<br>• Several previously undocumented invasive weeds were recorded from 2019-2022 in addition to expanded and/or new occurrences of *Prohibited Noxious Weeds*. A total of 7 *Prohibited Noxious Weed* species were recorded city-wide (n=122), with occurrences documented in 36 RHI sites. There are more stringent provincial regulations as per Alberta's *Weed Control Act* for eradication of *Prohibited Noxious* weeds. Of concern is nodding thistle (a *Prohibited Noxious Weed*) which is now present and spreading in all sub-basins city-wide (it was previously absent from the Bow and Elbow River sites). Nodding thistle infestations are most prolific in the upper reaches of Nose Creek. Also, of concern are increasing infestations of spotted knapweed (*Centaurea stoebe*) along the upper reaches of the Elbow River. Despite ongoing control efforts, spotted knapweed continues to proliferate along gravel bars from pre-existing populations in Weaselhead Flats on either side of the river (ELB63 and ELB64).<br>• Another emerging concern is the spread of thesium (*Thesium ramosum*), introduced from southeastern Europe and central Asia. The first known Canadian occurrence of this species was in 2001 in Fish Creek Provincial Park, where it has subsequently spread to hundreds of sites within the park (McLean 2018). Thesium was detected in multiple Bow River sites downstream from FCPP primarily in gravel bar areas suggesting it is being dispersed by river flows. Ongoing research and monitoring is recommended for this species. |

| Riparian Health Indicator | Key Considerations and Management Suggestions |
|---|---|
| | *Management Suggestions:*<br>• Avoid and limit new ground disturbance within riparian areas to the extent possible.<br>• Maintain and conserve dense native tree and shrub cover that beneficially helps to shade-out and limit the spread of invasive and disturbance-caused herbaceous plants.<br>• Conduct frequent and rigorous monitoring and weed removal programs focused on ensuring early detection and rapid removal of *Prohibited Noxious Weeds* in Calgary. A second focus should be on removing those weeds that are currently limited in distribution and abundance.<br>• Continue integrated weed management programs with demonstrated successful outcomes. Goat grazing, as an example, seems to have promise as a weed suppression tool in Confluence Park. Biocontrol options, where available, should continue to be pursued and monitored. An example is the use of flea beetles (genera *Aphothona*) for control of leafy spurge.<br>• Locally elevate tufted vetch to *Noxious Weed* status in Calgary and implement a city-wide integrated management plan for this species.<br>• Continue invasive weed removal and control efforts in conjunction with adjacent municipalities, private landowners, homeowners and local stewardship groups with direction and guidance from the Alberta Invasive Species Council. Of note, a comprehensive integrated invasive weed management program has been recently initiated by the Friends of Fish Creek Provincial Park Society. This program utilizes citizen science involvement with monitoring weed infestations and tracking the success of integrated weed control initiatives. The program could serve as a useful model for similar invasive management efforts elsewhere across the city in collaboration with local user groups.<br>• Continue to engage local plant nurseries and landscaping companies to avoid the sale of potentially invasive ornamental plants (e.g., yellow clematis).<br>• Collaborate with the Alberta Invasive Species Council on a Plant Wise public education campaign targeted at private developers, landowners, land managers, and homeowners backing onto Environmental Reserves and riparian areas. This includes distribution of the "Grow me instead" brochure that describes alternative plants to use in place of potentially invasive ornamental species (https://abinvasives.ca/take-action/). A Plant Wise campaign is focused on promoting education about invasive plant threats and legal requirements; appropriate disposal techniques for invasive plants; non-invasive plant alternatives; and cautions against the use of generic birdseed mixes, generic 'wildflower' seed mixes and/or plants labelled as 'fast spreaders', 'vigorous self-seeders' and/or 'drought resistant'. |

| Riparian Health Indicator | Key Considerations and Management Suggestions |
|---|---|
| **Balsam Poplar Forest Health and Sustainability** | • Continue to monitor balsam poplar recruitment in Calgary in collaboration with Dr. Stewart Rood and colleagues from the University of Lethbridge.<br>• Consult with Dr. Stewart Rood and upstream dam operators (TransAlta) to implement suitable flow “stage ramping” criteria to enhance poplar recruitment into the future. The objective would be to imitate natural hydrographs by optimizing June peak spring flows of 350-375 $m^3/s$ on the Bow in downtown Calgary, followed by a gradual decrease in stage elevations of 2.5 cm per day in June/July, and 1 cm per day in August (City of Calgary 2017). Enabling a flow regime to sustain natural poplar recruitment would be a sustainable and cost-effective option to maintain this keystone species city-wide. Riparian planting projects by comparison can be costly, localized, and management or maintenance intensive requiring periodic replenishment.<br>• Promote continued natural recovery of balsam poplars and native shrubs (e.g., willows and red-osier dogwood) in riparian areas beneficially affected by the flood. Use fencing where warranted to limit human-use impacts to naturally regenerating young tree and shrub stands. |
| **Native Tree and Shrub Community Health** | • Avoid or minimize future clearing or disturbance to riparian forests and other native riparian vegetation.<br>• Continue to conduct native tree and shrub plantings in disturbed habitats, following best practices as per RMP effectiveness monitoring recommendations.<br>• Promote expansion of natural riparian buffers city-wide including city-owned lands but also within privately owned/managed lands (e.g., golf courses).<br>• Restrict public access where appropriate to avoid new trails, soil compaction, or damage to riparian plants. Continue to implement river/streambank exclusion fencing where appropriate to protect and allow for improved natural regeneration of trees and shrubs, except for designated access nodes. Continue to direct off-leash dog use and other more intensive activities to designated disturbed, grassy meadows in outer riparian zone areas.<br>• Monitor and manage beaver use as appropriate to prevent unsustainable levels of woody plant removal. Relocate problem beavers, where appropriate, to natural environment parks where there is adequate habitat. Promote the use of non-lethal beaver control and management tools (e.g., pond leveling devices, culvert protectors, and effective tree wrapping) where appropriate. |

| Riparian Health Indicator | Key Considerations and Management Suggestions |
|---|---|
| **Disturbance-Caused, Undesirable Herbaceous Vegetation** | • Like many urban catchments, historic land use disturbance has resulted in a prevalence of disturbance-caused plants in Calgary. Monocultures of smooth brome (*Bromus inermis*) (Bow River) and incursion of invasive strains of reed canary grass (*Phalaris arundinacea*) (Nose Creek basin) are common, constraining natural tree and shrub establishment and succession processes.<br>• Continue efforts to replace undesirable herbaceous (non-woody) plant communities with preferred native species or deeper-rooted turf alternatives where it is practical to do so.<br>• Ensure future restoration projects adhere to Calgary's 2018 seed mix and guidelines document intended to inform revegetation work in Calgary (City of Calgary, 2018).<br>• Preferentially use native grass and forb seed mixes for riparian restoration projects to improve native herbaceous biodiversity.<br>• Where possible, investigate the use of beavers or beaver-dam-analogs as a restoration tool to create localized flooding of disturbed areas dominated by agronomic, non-native grasses. Prolonged flooding will benefit recovery of native riparian plant communities that are better adapted to saturated soil conditions. |
| **Soil and Hydrology Health** | • Avoid new soil disturbance in riparian habitats to the extent possible and minimize addition of paved, hardened, or compacted surfaces in riparian areas and adjacent uplands.<br>• Continue to encourage designated trail use only throughout Calgary's riparian park network. As a priority, close and reclaim undesignated trails that pose a high erosion or bank stability risk.<br>• Avoid new trail creation in intact riparian habitats especially within "Conservation Management Zones".<br>• Continue to support and implement watershed management plan priorities for the Bow River, Elbow River, and Nose Creek.<br>• Continue to participate in ongoing Nose Creek watershed hydrologic, hydraulic, and water quality modelling initiatives to inform land use development practices, stormwater management, and habitat conservation efforts.<br>• Continue to work with the Alberta Low Impact Development Partnership (ALIDP) to promote widespread adoption and implementation of low impact development (LID) practices.<br>• Continue to set progressive stormwater management targets for runoff rates (L/s/ha), runoff volumes (mm/ha), and stormwater quality treatment.<br>• Continue efforts to strengthen and improve Calgary's stormwater management strategy.<br>• Continue efforts to strengthen Calgary's riparian protection planning and policy tools to promote better protection of all riparian habitats including ephemeral and intermittent tributaries and wetlands. |

| Riparian Health Indicator | Key Considerations and Management Suggestions |
|---|---|
| | • Continue to promote 'soft' bioengineering approaches to bank stabilization where appropriate. Allow for retention of natural bank forms and erosion processes where possible. Avoid bank stabilization where this will impact active Bank Swallow nest colonies. |
| **Public Education and Outreach** | • Continue public education and outreach efforts in progress as part of the *Riparian Action Program*. Promote new outreach tools such as the City's new webpage dedicated to the Bioengineering Demonstration and Education Project and the newly created "Healthy Rivers Story Map" (https://maps.calgary.ca/healthyrivers/).<br>• Continue to use educational signage to promote a greater general awareness of the importance of riparian areas in Calgary, emphasizing ongoing riparian restoration works where appropriate.<br>• Where appropriate, continue to install interpretive signage at soil bioengineering and riparian restoration project sites to indicate the purpose and intended beneficial outcomes of the project.<br>• Continue to model recreational use management in riparian parks based on successful case-studies such as Sue Higgins Park (Bow River) and River Park (Elbow River).<br>• Continue to work with community and local stewardship groups on trail maintenance, weed removal, garbage removal, and tree or shrub planting projects (where possible).<br>• Continue to support citizen science riparian health monitoring and restoration initiatives (such as the Friends of Fish Creek Provincial Park Society's "Re-Wilding Through Restoration Program" (https://friendsoffishcreek.org/programs/rtr/). |

# 8. Glossary

**Table 8-1: Glossary**

| Term | Definition and Source |
|---|---|
| Adaptive Management | (i) A dynamic process of task organization and execution that recognizes the future cannot be predicted perfectly. Adaptive management applies scientific principles and methods to improve management activities incrementally as decision-makers learn from experience, collect new scientific findings, and adapt to changing social expectations and demands (AESRD, 2008). (ii) A systematic process for continually improving management policies and practices by learning from the outcomes of operational programs. Its' most effective form – 'active' adaptive management – employs management programs designed to experimentally compare selected policies or practices, by evaluating alternative hypotheses about the system being managed (BCMFR, 2014) |
| Anoxic/Anaerobic | The absence of oxygen, usually referring to zones of a lake or soil that are devoid of oxygen. (McCullah & Gray, 2005) |
| Bioengineering | An approach incorporating living and nonliving plant materials in combination with natural and synthetic support materials for slope stabilization, erosion reduction, and vegetation establishment (USDA NRCS, 2007) |
| Box Fascine | Fascine bundles placed at the toe of an eroding bank and secured between wooden poles (AMEC, 2012) |
| Brush Layer | Row(s) of live cuttings placed in a criss-cross or overlapping manner between layers of soil, with tips protruding beyond the face of the fill (Gray & Sotir, 1996) |
| Brush Mattress | A layer of interlaced/adjacent live cuttings placed on the face of the riverbank (AMEC, 2012) |
| Container Shrub Planting | Planting of container stock seedling species that are selected for beneficial attributes such as fast-growing, natural colonizer, deep rooting, nitrogen fixing, and food production (AMEC, 2012) |
| Cover (canopy) | The percentage of the surface of the ground which is shaded by the leaves and branches of trees (Collin, 2004) |
| Desiccation | The act or process of removing water (drying out) (Collin, 2004) |
| Effectiveness Monitoring | Monitoring is a process of regular checking on the progress of something (Collin, 2004). Effectiveness monitoring is regularly checking to determine if desired goals and objectives of a project are being achieved (Lewis, Lennox, & Nossaman, 2009). |
| Fascine (contour) | Fascines are live cuttings that are tied together in long bundles. Contour fascines are installed in shallow trenches constructed on contour, and anchored in the trench using stakes (AMEC, 2012) |
| Forb | Herbaceous plants other than graminoids, including ferns, clubmosses, and horsetails (BC MSRM, 2002) |

| Term | Definition and Source |
|---|---|
| Graminoid | Herbaceous plants with long, narrow leaves characterized by linear venation; including grasses, sedges, rushes, and other related species (BC MSRM, 2002) |
| Hedge Brush Layer | A layer of interlaced/adjacent live cuttings and rooted stock placed on the face of the riverbank (Schiechtl & Stern, 1997; Alaska Department of Fish and Game, 2005) |
| Homoscedasticity | A random variable is homoscedastic if its variance does not depend on the values of another variable (Everitt & Skrondal, 2010) |
| Implementation | To give practical effect to and ensure of actual fulfillment by concrete measures (Merriam-Webster, 2019) |
| Invasive Species | Refers to non-native species that have an adverse effect on the environment, human health, or the economy (Masters & Sheley, 2001). Also refers to species listed as noxious and prohibited noxious on the Alberta Weed Control Regulation of the Weed Control Act. |
| Joint Planting | Live staking planting within existing riprap voids to improve riparian, aquatic and terrestrial habitats while also improving aesthetics (AMEC, 2012) |
| Leader | A primary or terminal shoot of a plant (Merriam-Webster, 2019) |
| Live Cuttings | Live, cut stems and branches of plants that will root when embedded or inserted into the ground (USDA SCS, 1992). In bioengineering, typically woody shrub and/or tree species are used (Eubanks & Meadows, 2002). The most common plants used as live stakes include willows, balsam poplar, and red osier dogwood in Alberta (AMEC, 2012) |
| Live pole staking | Placement of live stakes into the ground in such a way that they can establish and grow into new plants (AMEC, 2012). |
| Live Staking | Insertion of live cuttings into the ground in such a manner as to promote root growth and leaf-out (Gray & Sotir, 1996) |
| Multivariate Analysis | A generic term for the many methods of analysis important in investigating multivariate data. Examples include cluster analysis, principal components analysis and factor analysis. (Everitt & Skrondal, 2010) |
| Native Species | A species which exists naturally in an area. (Collin, 2004) |
| Native Species Seeding | Planting of native streambank/riparian species that are selected for beneficial attributes such as fast-growing, natural colonizer, deep rooting, nitrogen fixing, and food production (AMEC, 2012) |
| Non-parametric Analysis (Distribution free methods) | Statistical techniques of estimation and inference that are based on a function of the sample observations, the probability distribution of which does not depend on a complete specification of the probability distribution of the population from which the sample was drawn. Consequently, the techniques are valid under relatively general assumptions about the underlying population. (Everitt & Skrondal, 2010) |
| Non-metric Multidimensional Scaling | A form of multidimensional scaling in which only the ranks of the observed dissimilarity coefficients or similarity coefficients are used in producing the required low dimensional representation of the data. (Everitt & Skrondal, 2010) |

| Term | Definition and Source |
|---|---|
| Normality | A term used to indicate that some variable of interest has a normal distribution. (Everitt & Skrondal, 2010) |
| Parametric Analysis | Procedures for testing hypotheses about parameters in a population described by a specified distributional form, often, a normal distribution. Student's t-test is an example of such a method. (Everitt & Skrondal, 2010) |
| Pitrun Gravel | Gravel as found in natural deposits without screening. Typically, well graded (a wide range of material sizes) such that it is reasonably stable and free draining when placed. |
| Principal Component Analysis | A procedure for analysing multivariate data which transforms the original variables into new ones that are uncorrelated and account for decreasing proportions of the variance in the data. The aim of the method is to reduce the dimensionality of the data. The new variables, the principal components, are defined as linear functions of the original variables. If the first few principal components account for a large percentage of the variance of the observations (say above 70%) they can be used both to simplify subsequent analyses and to display and summarize the data in a parsimonious manner. (Everitt & Skrondal, 2010) |
| Quadrat | An area of land measuring one square metre, chosen as a sample for research on plant populations (Collin, 2004) |
| Restoration | Full re-establishment of a degraded habitat to the target level of ecosystem function and biodiversity as defined by the reference habitat, including species composition and vegetation community structure. (City of Calgary, 2014) |
| Rhizome | A plant stem that lies on or under the ground and has leaf buds and adventitious roots (Collin, 2004) |
| Riparian Area | Riparian lands are transitional areas between upland and aquatic ecosystems. They have variable width and extent above and below ground and perform various functions. These lands are influenced by and exert an influence on associated water bodies, including alluvial aquifers and floodplains. Riparian lands usually have soil, biological, and other physical characteristics that reflect the influence of water and hydrological processes (AWC, 2013) |
| Riprap | A layer of stone, pre-cast blocks, bags of concrete, or other suitable materials, generally placed on the upstream slopes of an embankment or along a watercourse as protection against wave action, erosion, or scour (AEP, 2008) |
| Shoot | A stem or branch with its leaves and appendages especially when not yet mature (Merriam-Webster, 2019) |
| Soil Amendment | Application of soil amendments within bioengineering techniques 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 (AMEC, 2012) |

| Term | Definition and Source |
|---|---|
| Soil-Covered Riprap | Covering existing riprap bank protection with soil and vegetation to improve riparian, aquatic and terrestrial habitats while also improving aesthetics (McCullah & Gray, 2005) |
| Sucker | A shoot from the roots or lower part of the stem of a plant (Merriam-Webster, 2019) |
| Technique | Refers to a specific method or type of soil bioengineering approach such as brush layer, brush mattress, live staking, contour fascine, or box fascine. |
| Transect | A line used in ecological surveys to provide a way of measuring and showing the distribution of organisms (Collin, 2004) |
| Treatment | The overall approach taken to stabilize/restore an eroding riverbank. A treatment can include one or more soil bioengineering techniques. |
| Trend Monitoring | Monitoring is a process of regular checking on the progress of something (Collin, 2004). Trend monitoring is regularly collecting information and attempting to spot a pattern of change. |
| Typology | A classification based on types or categories (Merriam-Webster, 2019). For the bank effectiveness component of the Riparian Monitoring Program, 5 typologies were developed (KWL, 2018): Vegetated Riprap, Vegetated Retaining Wall, Vegetated Crib Wall, Primarily Vegetation, and Planting. |
| Vegetated retaining wall | (1) A vegetated structure used to resist unbalance lateral earth forces, retain earthen masses, and protect against scour and undermining.<br>(2) A vertical vegetated structure used to maintain an elevation differential between the water surface and top bank while at the same time preventing bank erosion and instability. (McCullah & Gray, 2005) |
| Vegetated riprap | A layer of stone and/or boulder armoring that is vegetated, optimally during construction, using pole planting, brush layering and live staking techniques. (McCullah & Gray, 2005) |
| Vegetated Soil Wraps | Consists of brush layers interspersed between layers of soil wrapped in natural geotextile materials that provides reinforcement (Gray & Sotir, 1996; McCullah & Gray, 2005; Alaska Department of Fish and Game, 2005) |
| Vegetated Timber Crib Wall | Consists of a hollow, box-like interlocking arrangement of structural timber, filled with suitable backfill material and layers of live cuttings (Gray & Sotir, 1996) |
| Vigor | Active healthy well-balanced plant growth (Merriam-Webster, 2019) |
| Void-filled Riprap | Planting material inserted into void-spaces in existing riprap bank protection and planted with live cuttings or container shrub plantings to improve riparian, aquatic and terrestrial habitats while also improving aesthetics (Wulliman & Johns, 2011) |

# 9. References

ACIMS. (2022). *Alberta Conservation Information Management System*. Retrieved from Alberta Parks: https://www.albertaparks.ca/albertaparksca/management-land-use/alberta-conservation-information-management-system-acims/

Adam, P., Debiais, N., Gerber, F., & Lachat, B. (2008). *Le génie végétal - Un manuel technique au service de l'aménagement et de la restauration des milieux aquatiques.* Ministère de l'écologie, du développement et de l'aménagement durables.

Adams, B., Ehlert, G., Stone, C., Alexander, M., Lawrence, D., Willoughby, M., . . . Miller, A. (2016). *Rangeland Health Assessment for Grassland, Forest and Tame Pasture.* Alberta Environment and Parks, Rangeland Resource Stewardship Section .

AEP. (2008). *Glossary of terms related to water and watershed management in Alberta. 1st edition.* Edmonton, AB: Partnerships & Strategies Section Alberta Environment.

AEP. (2020). *2020 Alberta Wild Species Status List.* Retrieved from https://extranet.gov.ab.ca/env/wild-species-status/

Alaska Department of Fish and Game. (2005). *Streambank Revegetation and Protection: A Guide for Alaska .*

AMEC. (2012). *Design Guidelines for Erosion and Flood Control Projects Streambank and Riparian Stability Restoration.* Report submitted to The City of Calgary .

AWC. (2013). *Riparian Land Conservation and Management Report and Recommendations.* Edmonton, AB: Alberta Water Council.

BC MSRM. (2002). *Vegetation Resources Inventory - The B.C. Land Cover Classification Scheme.* Victoria, BC: Report by the Ministry of Sustainable Resource Management Terrestrial Information Branch for the Terrestrial Ecosystems Task Force - Vegetation Resources Inventory Committee, Government of BC.

BCMFR. (2014). *Defining Adaptive Management.* Retrieved from http://www.for.gov.bc.ca/hfp/amhome/Admin/index.htm

Cavaille, P., Dommanget, F., Daumergue, N., Loucougaray, G., Spiegelberger, T., Tabacchi, E., & Evette, A. (2013). Biodiversity assessment following a naturality gradient of riverbank protection structures in French prealps rivers. *Ecological Engineering*, vol. 53 . pp. 23-30.

City of Calgary. (2013). *Riparian Strategy: Sustaining Healthy Rivers and Communities.*

City of Calgary. (2014). *Habitat Restoration Project Framework.* Calgary, AB: City of Calgary Parks.

City of Calgary. (2017). *The Riparian Action Program: A Blueprint for Resilience.*

City of Calgary. (2018). *City of Calgary Seed Mixes - Recommendations and guidelines to inform revegetation work in Calgary.* Calgary, AB: City of Calgary Parks, Urban Conservation.

Collin, S. (2004). *Dictionary of Environment & Ecology.* London, UK: Bloomsbury Publishing Plc.

COSEWIC. (2013). *COSEWIC assessment and status report on the bank swallow (Riparia riparia) in Canada.* Ottawa: Committee on the Status of Endangered Wildlife in Canada.

Cows and Fish. (2016). *Alberta Lotic Wetland Inventory Form, User Manual.* Alberta Riparian Habitat Management Society (Cows and Fish). Retrieved from https://cowsandfish.org/health-assessment-and-inventory-forms/

Desprez-Loustau, M., Aguayo, J., Dutech, C., Hayden, K., Husson, C., Jakushkin, B., . . . Vacher, C. (2015). An evolutionary perspective to address forest pathology challenges of today and tomorrow. *Annals of Forest Science*, 73(1): 45-67.

Dommanget, F., Evette, A., Breton, V., Daumergue, N., Forestier, O., Poupart, P., . . . Navas, M. (2019). Fast-growing willows significantly reduce invasive knotweed spread. *Journal of Environmental Management*, 231: 1-9.

Ehrenfeld, J. (2000). Evaluating wetlands within an urban context. *Ecological Engineering*, 15(3-4), 253-265.

Eubanks, C., & Meadows, D. (2002). *A Soil Bioengineering Guide for Streambank and Lakeshore Stabilization.* San Dimas, CA: United States Department of Agriculture Forest Service.

Everitt, B., & Skrondal, A. (2010). *The Cambridge Dictionary of Statistics, Fourth Edition.* New York: Cambridge University Press.

Evette, A., Gallant, M., Raymond, P., Dodd, A., Hull, K., Jaymond, D., . . . Nelson, M. (2021). RMP Key Learning's in an International Perspective. *Riparian Monitoring Program - A Conversation with Andre Evette.* Calgary, AB: Virtual presentation delivered to The City of Calgary .

Fiera. (2022). *Jumpingpound Creek Watershed Riparian Area Assessment.* Report prepared by Fiera Biological Consulting for the Jumpingpound Creek Watershed Partnership.

Fischenich, C. (2001). *Stability Thresholds for Stream Restoration Materials - EMRRP Technical Notes Collection (ERDC TN EMRRP-SR-29).* Vicksburg, MS: US Army Corps of Engineers Research and Development Center.

Fitch, L., Adams, B., & Hale, G. (2014). *Riparian Health Assessment for Streams and Small Rivers – Field Workbook.* Lethbridge, Alberta: Cows and Fish Program (Original publication date, 2001).

Gatsuk, L., Smirnova, O., Vorontzova, L., Zaugalnova, L., & Zhukova, L. (1980). Age states of plants of various growth forms: a review. *Journal of Ecology*, 68(2):675-696.

Gerling, H., Willoughby, M., Schoepf, A., Tannas, C., & Tannas, K. (1996). *A Guide to Using Native Plants on Disturbed Lands.* Edmonton, AB: Alberta Agriculture, Food and Rural Development.

Goldsmith, W., Silva, M., & Fischenich, C. (2001). *Determining Optimal Degree of Soil Compaction for Balancing Mechanical Stability and Plant Growth Capacity (ERDC TN-EMRRP-SR-26).* Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Gray, D., & Sotir, R. (1996). *Biotechnical & Soil Bioengineering Slope Stabilization: A Practical Guide for Erosion Control.* John Wiley & Sons.

Haissig, B. (1973). Origins of Adventitious Roots. *N.Z. J. For. Sci.*, 4 (2): 299-310.

Hansen, P. L., Thompson, W. H., Ehrhart, R. C., Hinckley, D. K., Haglan, B., & Rice, K. (2000). Development of methodologies to evaluate the health of riparian and wetland areas. *In Proceedings of the Fifth International Symposium of Fish Physiology, Toxicology and Water Quality.* Hong Kong, China: United States Environmental Protection Agency.

Hoag, J. (2007). *How to Plant Willows and Cottonwoods for Riparian Restoration - Technical Note Plant Materials No. 23.* Boise, Idaho: USDA-Natural Resources Conservation Service.

Hobbs, R., Higgs, E., & Harris, J. (2009). Novel ecosystems: implications for conservation and restoration. *Trends in Ecology & Evolution (personal edition)*, 24(11): 599-605.

Hoerbinger, S., & Rauch, H. (2019). A Case Study: The Implementation of a Nature-Based Engineering Solution to Restore a Fallopia japonica-Dominated Brook Embankment. *Open Journal of Forestry*, 9: 183-194.

KWL. (2018). *The City of Calgary Riparian Monitoring Program Monitoring Plan.* Calgary, AB: Report prepared by Kerr Wood Leidal Associates Ltd. for The City of Calgary.

KWL. (2019a). *Riparian Monitoring Program: Riparian Effectiveness Annual Report (2018).* Calgary, AB: Report prepared by Kerr Wood Leidal Associates Ltd. (KWL) and submitted to The City of Calgary.

KWL. (2019b). *2018 Annual Report - Bank Effectiveness Monitoring.* Calgary, AB: Report prepared by Kerr Wood Leidal Associates Ltd. (KWL) and submitted to The City of Calgary.

KWL. (2020a). *Riparian Monitoring Program: Riparian Effectiveness Annual Report (2019).* Calgary, AB: Report prepared by Kerr Wood Leidal Associates Ltd. (KWL) and submitted to The City of Calgary.

KWL. (2020b). *Riparian Monitoring Program 2019 Annual Report - Bank Effectiveness Monitoring.* Calgary, AB: Report prepared by Kerr Wood Leidal Associates Ltd. for The City of Calgary.

KWL. (2020c). *Bioengineering Demonstration and Education Project - 2019 Monitoring Report.* Calgary, AB: Report prepared by Kerr Wood Leidal Associates Ltd. for The City of Calgary.

KWL. (2021a). *Riparian Monitoring Program - Riparian Effectiveness Annual Report (2020).* Calgary, AB: Report prepared by Kerr Wood Leidal Associates Ltd. for The City of Calgary.

KWL. (2021b). *2020 Annual Report - Bank Effectiveness Monitoring.* Calgary, AB: Report prepared by Kerr Wood Leidal Associates Ltd. (KWL) for The City of Calgary.

KWL. (2021c). *Bioengineering Demonstration and Education Project - 2020 Monitoring Report.* Calgary, AB: Report prepared by Kerr Wood Leidal Associates Ltd. for The City of Calgary.

KWL. (2022a). *Riparian Monitoring Program - Riparian Effectiveness Annual Report (2021).* Calgary, AB: Report prepared by Kerr Wood Leidal Associates Ltd. for The City of Calgary.

KWL. (2022b). *2021 Annual Report - Bank Effectiveness Monitoring.* Calgary, AB: Report prepared by Kerr Wood Leidal Associates Ltd. for The City of Calgary.

KWL. (2022c). *Bioengineering Demonstration and Education Project - 2021 Monitoring Report.* Calgary, AB: Report prepared by Kerr Wood Leidal Associates Ltd. for The City of Calgary.

KWL. (2023a). *Riparian Monitoring Program - Riparian Effectiveness Annual Report - 2022.* Calgary, AB: Report prepared by Kerr Wood Leidal Associates Ltd. for The City of Calgary.

KWL. (2023b). *2022 Annual Report - Bank Effectiveness Monitoring.* Calgary. AB: Report prepared by Kerr Wood Leidal Associates Ltd. for The City of Calgary.

Leblois, S., Evette, A., Jaymond, D., Piton, G., & Recking, A. (2022). Processus et causes de defaillance du genie vegetal pour la stabilisation des berges de riviere: retour d'experiences sur un large jeu de donnees issues de la BD GeniVeg. *Geomorphologie: relief, processus, environnement*, 28(2).

Lee, T., Kinnas, H., & Duke, D. (2020). *Aquatic Health Indicator for the City of Calgary Natural Environment Parks.* Calgary, AB: Report prepared by the Miistakis Institute for The City of Calgary.

Lewis, D., Lennox, M., & Nossaman, S. (2009). *Developing a Monitoring Program for Riparian Revegetation Projects - Publication 8363.* University of California Division of Agriculture and Natural Resources.

Lezberg, A., & Giordanengo, J. (2008). *A Guide for Harvesting, Storing, and Planting Dormant Willow Cuttings.* Colorado, USA: Wildlands Restoration Volunteers.

Lind, L., Nilsson, C., Polvi, E., & Weber, C. (2014). The role of ice dynamics in shaping vegetation in flowing waters. *Biological Reviews*, 89(4): 791-804.

Mahoney, J., & Rood, S. (1998). Streamflow requirements for cottonwood seedling recruitment - an integrative model. *Wetlands*, 18(4): 634-645.

Masters, R., & Sheley, R. (2001). Invited Synthesis Paper: Principles and practices for managing rangeland invasive plants. *J. Range Manage.*, 54: 502–517.

McCullah, J., & Gray, D. (2005). *Environmentally Sensitive Channel- and Bank-Protection Measures - NCHRP Report 544.* Washington, DC: National Cooperative Highway Research Program.

McLean, M. (2018). Personal communication.

Merriam-Webster. (2019, March 27). *Online dictionary*. Retrieved from https://www.merriam-webster.com/dictionary/typology

Moss, B., Hering, A., Green, A., Aidoud, A., Becares, M., Beklioglu, M., . . . Carvalho, L. (2009). Climate change and the future of freshwater biodiversity in Europe: a primer for policy-makers. *Freshwater Reviews*, 2(2): 103-130.

Mosseler, A., Major, J., & Labrecque, M. (2014). Growth and survival of seven native willows species on highly disturbed coal mine sites in eastern Canada. *Can. J. For. Res.*, 44: 340-349.

O2. (2014). *Riparian Areas Map Project - Riparian Management Category Maps.* Calgary, AB: Maps prepared by O2 Planning + Design Inc. (O2) for The City of Calgary.

Pezeshki, S., Li, S., Shields, F., & Martin, L. (2007). Factors governing survival of black willow (Salix nigra) cuttings in a streambank restoration project. *Ecological Engineering*, 29(1): 56-65.

Pinno, B., Schoonmaker, C., Yucel, C., & Albricht, R. (2017). Clustered planting: early establishment of structural diversity in a reclaimed boreal forest. *Journal of American Society of Mining and Reclamation*, 6(2):37-50.

Polster, D. (1997). Restoration of Landslides and Unstable Slopes: Considerations for Bioengineering in Interior Locations. *Proceedings of the 21st Annual British Columbia Mine Reclamation Symposium* (pp. 153-166). Cranbrook, BC: The Technical and Research Committee on Reclamation.

Polster, D. (2020). *Living on the Edge: A Manual for the Restoration of Drastically Disturbed Sites.* Duncan, BC: Polster Environmental Services Ltd.

R Core Team. (2019). R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. ISBN 3-900051-07-0, URL http://www.R-project.org/.

Reich, P. (2002). Root-Shoot Relations: Optimality in Acclimation and Adaptation or the "Emperor's New Clothes"? In Y. Waisel, A. Eshel, & U. Kafkafi, *Plant Roots: The Hidden Half, Third Edition* (pp. 314-338). New York: Marcel Dekker, Inc.

Rey, F., Bifulco, C., Bischetti, G., Bourrier, F., De Cesare, G., Florineth, F., . . . Stokes, A. (2019). Soil and water bioengineering: Practice and research needs for reconciling natural hazard control and ecological restoration. *Science of the Total Environment*, 648: 1210-1218.

Richardson, D., Holmes, P., Esler, K., Galatowitsch, S., Stromberg, J., Kirkman, S., . . . Hobbs, R. (2007). Riparian vegetation: Degradation, alien plant invasions, and restoration prospects. *Diversity and Distributions*, 13(1): 126-139.

Roman, D. (2009). *Ouvrages en bois dans les cours d'eau: Etat de l'art, applications et dimensionnements - Guide technique.* Direction Territoriale Rhone-Alpes, France: Office National des Forets.

Rood, S., & Bradley, C. (1993). *Assessment of riparian cottonwoods along the Bow RIiver downstream from Calgary, Alberta.* Calgary, Alberta: Final Report to Trout Unlimited Canada, University of Lethbridge.

Rood, S., & Mahoney, J. (1990). Collapse of riparian poplar forests downstream from dams in western prairies: probable causes and prospects for mitigation. *Environ Manage*, 14: 451-464.

Rood, S., Taboulchanas, K., Bradley, C., & Kalischuk, A. (1999). Influence of flow regulation on channel dynamics and riparian cottonwood recruitment along the Bow River. *Rivers*, 7:33-48.

Saxton, K., & Rawls, W. (2006). Soil water characteristic estimates by texture and organic matter for hydrologic solutions. *Soil Science Society of America Journal*, 70:1569-1578.

Schiechtl, H., & Stern, R. (1997). *Water Bioengineering Techniques for Watercourse Bank and Shoreline Protection.* London, UK: Blackwell Science.

Small, C., Degenhardt, D., & McDonald, T. (2019). Plant growth regulators for enhancing Alberta native grass and forb seed germination. *Ecological Engineering*, 142S:100003.

Stokes, A., Douglas, G., Fourcaud, T., Giadrossich, F., Gillies, C., Hubble, T., . . . Walker, L. (2014). Ecological mitigation of hillslope instability: ten key issues facing researchers and practitioners. *Plant Soil*, 377: 1-23.

Strayer, D., & Dudgeon, D. (2010). Freshwater biodiversity conservation: recent progress and future challenges. *Journal of the North American Benthological Society*, 29(1): 344-358.

Tannas, K. (2003). *Common Plants of the Western Rangelands: Volume 2 - Trees and Shrubs.* Olds College: Alberta Agriculture.

Thompson, W. H., & Hansen, P. L. (2002). *Classification and Management of Riparian and Wetland Sites of Alberta's Grasslands Natural Region and Adjacent Subregions.* Missoula, Monta: Bitterroot Restoration, Inc. prepared for the Alberta Riparian Habitat Management Society (Cows and Fish).

Thompson, W., & Hansen, P. (2003). *Classification and Management of Riparian and Wetland Sites of Alberta's Parkland Region and Dry Mixedwood Natural Subregion.* Lethbridge, Alberta: Report prepared by Bitterroot Restoration Inc. for the Alberta Riparian Habitat Management Society (Cows and Fish).

Thuiller, W. (2007). Biodiversity, climate change and the ecologist. *Nature*, 448: 550-552.

Tron, S., & Raymond, P. (2014). Effects of the Root System on Vegetated Riprap. *EGU General Assembly* (p. 16(4928)). Vienna, Austria: European Geosciences Union.

USDA NRCS. (1996). *Streambank and Shoreline Protection. Chapter 16 in Engineering Field Handbook, Part 650.* Washington, D.C.: U.S. Department of Agriculture.

USDA NRCS. (2007). *Stream Restoration Design. Part 654, National Engineering Handbook.* U.S. Department of Agriculture National Resources Conservation Service.

USDA NRCS. (2013). *Biology Fact Sheet: Guidelines for Use of Snake-Friendly Erosion Control Blankets.* Indiana: United States Department of Agriculture Natural Resources Conservation Service (USDA NRCS).

USDA SCS. (1992). *Chapter 18: Soil bioengineering for upland slope protection and erosion reduction. Part 650, 201-EFH, Engineering Field Handbook.* United States Department of Agriculture, Soil Conservation Service.

Wulliman, J., & Johns, D. (2011). *Demonstration Project Illustrating Void-Filled Riprap Applications in Stream Restoration .* Denver, CO: Prepared for Urban Drainage and Flood Control District .

Zaimes, G., Tardio, G., Iakovoglou, V., Gimenez, M., Garcia-Rodriguez, J., & Sangalli, P. (2019). New tools and approaches to promote soil and water bioengineering in the Mediterranean. *Science of the Total Environment*, 693.

# 10. Report Submission

Prepared by:

**KERR WOOD LEIDAL ASSOCIATES LTD.**

Prepared By:

PROFESSIONAL ENGINEER
MICHAEL J. GALLANT
ALBERTA
2023-12-14

Mike Gallant, MScE, P.Eng., CPESC
Senior Water Resources Engineer
Kerr Wood Leidal Associates Ltd.

Kristina Boehler, M.Sc., P. Biol.
Riparian Health Specialist
Alberta Riparian Habitat Management Society
(Cows and Fish)

Alan Dodd, B.Sc., P.Ag.
Owner, Ecologist
Longview Ecological

Pierre Raymond
Soil Bioengineering Specialist
Terra Erosion Control Ltd.

Andre Evette, PhD
Soil Bioengineering Specialist
INRAE

**PERMIT TO PRACTICE**
**KERR WOOD LEIDAL ASSOCIATES LTD**
RM SIGNATURE:
RM APEGA ID #: 90096
DATE: 2023-12-14
**PERMIT NUMBER: P007929**
The Association of Professional Engineers and Geoscientists of Alberta (APEGA)

Reviewed by:

Craig Kipkie, M.Sc., P.Eng.
Vice President, Principal
Kerr Wood Leidal Associates Ltd.

## Statement of Limitations

This document has been prepared by Kerr Wood Leidal Associates Ltd. (KWL) for The City of Calgary (The City) as part of the Riparian Monitoring Program (the Project). KWL accepts no responsibility for any use that The City may make of this document or other projects or at other locations. The City may reproduce this document for archiving and for distribution to third parties to conduct business relating to the Project. KWL accepts no responsibility for any use of this document by parties other than The City. This document represents KWL's professional judgement based on the information available at the time of completion and as appropriate for the Project scope of work. Services performed in preparing the document have been conducted in a manner consistent with that level and skill ordinarily exercised by members of the engineering profession currently practicing under similar conditions. No warranty, express or implied, is made.

## Revision History

| Revision # | Date | Status | Revision | Author |
|---|---|---|---|---|
| | | | | |
| | | | | |
| 0 | December 14, 2023 | FINAL | Issued for Use | MG/AD/KB |

APEGA Permit # P07929