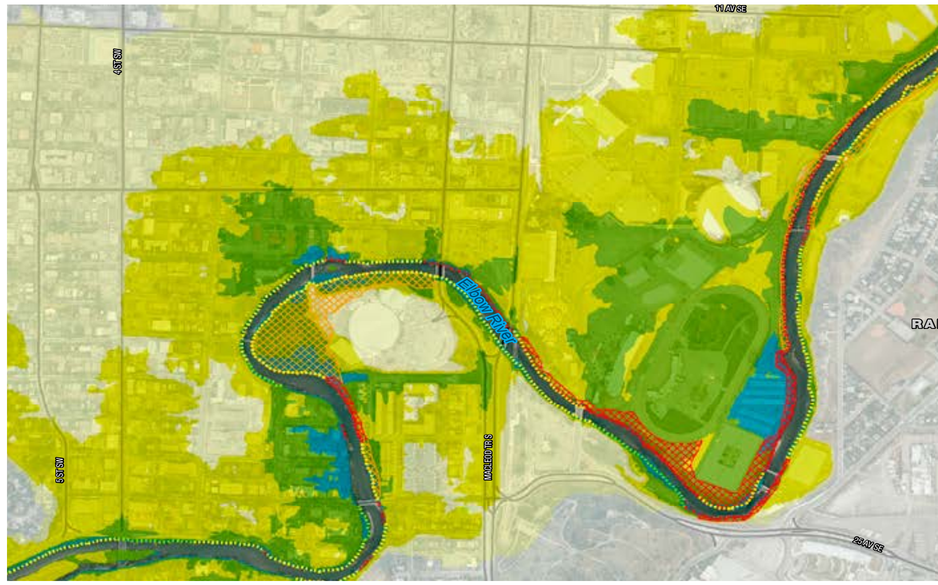
Riparian Areas Mapping Project - Phase 1 Technical Report
Current Conditions Maps



October 25th, 2013

Prepared for:
City of Calgary Water Resources

O2 PLANNING + DESIGN

EXECUTIVE SUMMARY

Vegetated riparian areas adjoining streams and rivers are a vital component of the ecological infrastructure of cities and regions. Networks of well-connected riparian areas provide valuable ecological goods and services, including clean water, flood control, bank stabilization, wildlife and fish habitat, recreational opportunities, and cultural and aesthetics services. Increasingly, municipalities are recognizing the values and benefits of riparian areas, and are making efforts to incorporate, integrate, and restore riparian areas within an urban context.

The City of Calgary is committed to developing strategies to promote the conservation and environmental protection of key resources, including riparian areas. To date, a variety of policies, initiatives, and projects to preserve, enhance, or rehabilitate riparian areas have been implemented by The City of Calgary Water Resources and Parks, among other business units. This project aims to further support riparian area management and ongoing policy development, with a focus on the riparian areas along major streams and rivers in Calgary.

O2 Planning + Design Inc. (O2) was retained by The City of Calgary Water Resources for the Riparian Mapping Project to provide mapping and related analyses to support riparian area management and policy development. To date, mapping efforts have focused on riparian areas along major streams and rivers in Calgary and not along smaller tributaries. A wide variety of spatial data was obtained, explored in detail, and grouped into the themes of Riparian Area Location and Function, Land and Regulatory Issues, and Infrastructure. Mapping was conducted at a scale of 1:7,500 to provide fifty-eight map sheets for each of the three separate themes. A City-wide summary map and map sheet key has also been provided.

A core component of the study was a variable width Geographic Information Systems (GIS) model of riparian areas in Calgary, based on distance from the river, slope profiles from digital models, and field work calibration based on plant community locations. This helped define the most likely extent of both current and historical riparian areas along the major rivers and creeks in Calgary. Not surprisingly, the variable width riparian area adjacent to the Bow and Elbow rivers is substantially greater than for lower order creeks. The variable width model was also used to define four zones as follows:

- **“Inner Riparian Zone”:** this area directly adjacent to the stream is virtually certain to be riparian
- **“Middle Riparian Zone”:** this zone contains areas with strong potential to contain riparian conditions; although in some cases riparian conditions may not arise
- **“Outer Riparian Zone”:** this area is riparian if conditions are right, but in other cases will not show riparian characteristics, although it still functions as an important interface between riparian areas and the surrounding uplands
- **“Potential Outermost Riparian Zone”:** represents areas that are typically *not* riparian but in some cases may be, requiring further detailed investigations

A GIS model of The City of Calgary’s Environmental Reserve (ER) Setback Policy was also developed and mapped for the entire City of Calgary. This is useful not only to be clear on expectations for riparian-associated ER during future development, but also to highlight past lost opportunities. The model accounts for the base setback and slope modifiers, but does not account for policy modifiers related to hydraulic connectivity to groundwater or cover type, which require site-specific investigations.

The Theme 1 maps (*Riparian Area Location and Function*) are primarily focused on the outputs of the variable width model. Also included is information on riparian health and streambank health.

The Theme 2 maps (*Land and Regulatory Issues*) allow for comparisons of the floodplain and associated regulations, the ER Setback Policy, variable width riparian outputs, and land use including developed areas within former riparian areas. The Theme 2 maps also indicate that current policies and regulations do not go far enough to effectively protect what is left of riparian habitat as open space in Calgary. In many areas, delineated riparian areas are considerably larger than either the floodway where land use is highly restricted, or the ER Setback Policy area where riparian ER is intended to be designated during future planning and development.

For Theme 2, it is important to emphasize the difference between riparian biophysical conditions and the recommended riparian setback for interpretation. In many areas with a steep incised ravine or coulee, the riparian area is very limited, but steep valley sides in the creek valley system are subject to much larger ER setback requirements (e.g., lower Coach Creek). Protecting these steep upland slopes – although not technically riparian – remains very important to prevent water pollution and create a sustainable open space

system. Conversely, in areas with flat topography and a wide valley, the ER Setback Policy does not encompass all existing riparian habitat (e.g., upper Nose Creek). In this case, implementation of the ER Setback Policy may lead to a net loss of riparian area in the city during future development. Considering these issues, a policy option could be to recommend that the greater of the variable width riparian area or the ER Setback Policy width be conserved as open space.

The maps and this document are intended to support and complement a wide range of official plans and policies, to serve as a strategic catalyst supporting effective riparian land management, conservation, restoration, and use. The riparian maps are important tools for planning, communication, and further discussion on riparian area land use planning, infrastructure, regulatory issues, and environmental issues.

All of the information compiled and analyzed during Phase 1 of this project was completed in advance of the June 2013 floods. Post-flooding assessments conducted in July 2013 generally concluded that the information in this report remains valid and useful. However, in some locations along the Elbow and Bow Rivers, flooding has changed streambanks and riparian areas. Where large bank erosion has occurred, the mapping will no longer be accurate at site-specific scales. Overall, the riparian model outputs and technical support information remain useful tools for city-wide assessments, but must be complemented by field validation to refine information for the purpose of site-specific planning and design, particularly for those sites affected by flooding. Due to the lack of any major flooding along small tributaries in Calgary during 2013, few changes have occurred to the mapping and information presented for smaller streams assessed by this project.

LIST OF ACRONYMNS

AESRD – Alberta Environment and Sustainable Resource Development

AESA – Aquatic Environmentally Significant Area

ASP – Area Structure Plan

CMP – Calgary Metropolitan Plan

DEM – Digital Elevation Model

ER – Environmental Reserve

GIS – Geographic Information System

HAR – Height Above River

LiDAR – Light Detection and Ranging

MDP – Municipal Development Plan

MR – Municipal Reserve

NAESI – National Agri-Environmental Standards Initiative

O2 – O2 Planning + Design Inc.

SSRP – South Saskatchewan Regional Plan

WMP – Watershed Management Plan

WPAC – Watershed Planning and Advisory Council

WSG – Watershed Stewardship Group

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1. INTRODUCTION

O2 Planning and Design Inc. (O2) was commissioned by The City of Calgary Water Resources to conduct a riparian areas mapping project. This section introduces the study context, including the study background and overview, a brief history of riparian areas and land use in Calgary, goals and objectives for the project, and an overview of the structure of this report.

1.1 Study Background and Overview

Vegetated riparian areas adjoining streams and rivers are a vital component of the ecological infrastructure of cities and regions. Networks of well-connected riparian areas provide valuable ecological goods and services, including clean water, flood control, bank stabilization, wildlife and fish habitat, recreational opportunities, and cultural and aesthetics services. Increasingly, municipalities are recognizing the values and benefits of riparian areas, and are making efforts to incorporate, integrate, and restore riparian areas within an urban context.

The City of Calgary is committed to develop strategies that promote the conservation and environmental protection of key resources, including riparian areas. To date, a variety of policies, initiatives, and projects to preserve, enhance, or rehabilitate riparian areas have been implemented by The City of Calgary Water Resources and Parks, among other business units. It has been identified that additional mapping, planning and information tools are required to support riparian area management and ongoing policy development.

Riparian maps and supporting digital mapping products can function as important planning and communication tools. Such maps can also function as references to inform future land use and development patterns in and around riparian areas. These products can include comprehensive information on vegetation, bank stability, riparian enhancement work, riparian health, as well as policy and regulatory elements such as Environmental Reserve setback policies, floodway and flood fringe locations, land use and other regulatory issues.

Creating riparian maps and associated digital tools will provide a useful resource to inform capital decisions on riparian rehabilitation, as well as to provide a useful resource to inform community planning. They can also be used to develop a potential “vision” of desirable outcomes and opportunities related to Calgary’s riparian areas, with policies associated with specific spatial areas. The overall outcome of the project will be the production of engaging, comprehensive maps and geospatial information that provide a solid foundation for developing guiding plans for riparian area management and policy. Eventually these plans are intended to be adopted by City Council or via other regulatory mechanisms. The mapping provided as an output of this project may also be capable of supporting an update to the 1984 Calgary River Valleys Plan.

Phase 1 of the project focused on mapping ***current conditions*** of riparian areas. This included mapping and modelling of riparian area location and extent, incorporating multiple internal City of Calgary data sources into a GIS database, and determining optimal ways to display and symbolize elements to inform a policy and planning dialogue. Phase 2 of the project, also to be conducted by O2, will build on the current conditions maps to create a set of maps reflecting riparian opportunities (Figure 1). This will be followed by future work developing official riparian area protection policies and a riparian protection plan (Figure 1).

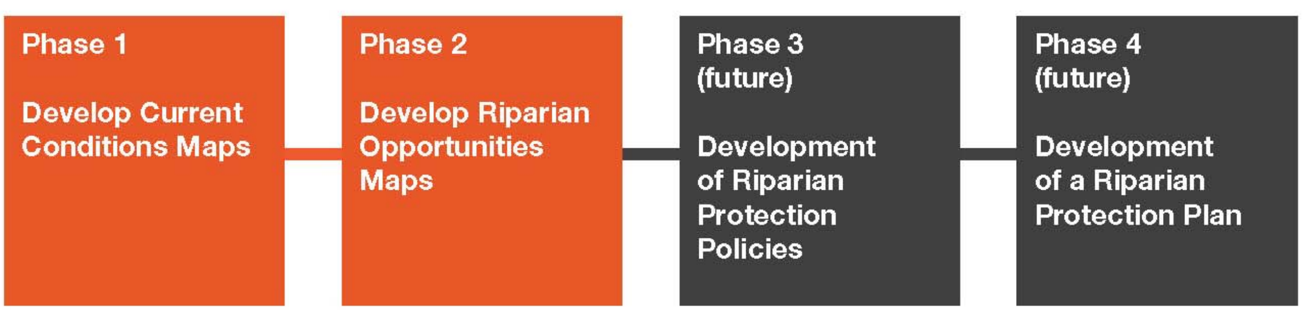


Figure 1. Schematic of Current Project Scope (Orange) + Broader Policy / Plan Development (Grey)

1.2 Project Vision and Objectives

The main purpose of the project is to provide engaging, comprehensive Riparian Maps that will provide a geospatial vision of current conditions, opportunities, and desirable outcomes for Calgary's fluvial riparian areas. More specific project objectives include:

- The maps and documents will serve as a strategic catalyst to support effective riparian land management, conservation, restoration, and use within the City
- The document is intended to support and complement a range of official plans and policies, including but not limited to:
    - *Plan It* Calgary Municipal Development Plan / Calgary Transportation Plan
    - The South Saskatchewan Regional Plan
    - Future Area Structure Plans
    - A range of urban development and land use issues related to riparian areas including ER Setbacks, parks, recreation, biodiversity, watershed management, river engineering (soft and hard), ecological restoration, and the Calgary River Valleys advocacy process

The geographic scope of the project is focused primarily on riparian areas adjacent to major rivers and streams, including the Bow River, Elbow River, Nose Creek, West Nose Creek, Pine Creek, Forest Lawn Creek, 12 Mile Coulee Creek, Radio Tower Creek, Coach Creek, and Confederation Creek. Although Fish Creek will not be evaluated in detail under the scope of this contract due to its provincial jurisdiction, the boundary of the creek and the associated Fish Creek Provincial Park will be shown. Notably, wetland riparian areas as well as non-fluvial groundwater seepage riparian areas will not be part of the project scope due to restrictions on time and/or data availability. It was also decided that small lower-order creeks would not be evaluated in detail under the project scope. A map of the major rivers and streams that were considered for the riparian areas mapping project is shown in Figure 2.

1.3 Phase 1 Project Objectives

During Phase 1 of the project, the objective was to incorporate multiple internal City of Calgary riparian data sources into a GIS database. The compiled GIS data was incorporated into a variety of map products to clearly identify riparian areas. A literature review of technical and cartographic riparian mapping techniques and best practices was also conducted. Since accurate delineation of riparian area boundaries was considered a prerequisite for incorporating information on the condition of those areas, a variable width riparian model delineating the most likely locations of riparian area conditions was constructed. The project team worked together to define appropriate thematic layers, content within each theme and symbology, and scales of analysis to optimize display of the existing information.

1.4 Report Structure

This report is intended as a technical background companion document to the Phase 1 riparian map products. It outlines the background rationale, assumptions, methodology, results and related technical documentation related to Phase 1 of the project.

Section 2 reviews the planning and policy context of this project. Section 3 provides a background literature review on riparian areas, focused in particular on the delineation of riparian areas using Geographic Information Systems (GIS). Section 4 describes the methodologies applied to conduct the study. Section 5 outlines the results of the study, with a focus on reach-specific summaries as well as references to the maps that have been created. Section 6 briefly summarizes conclusions, potential planning and policy applications, and planned activities for Phase 2 of the project.

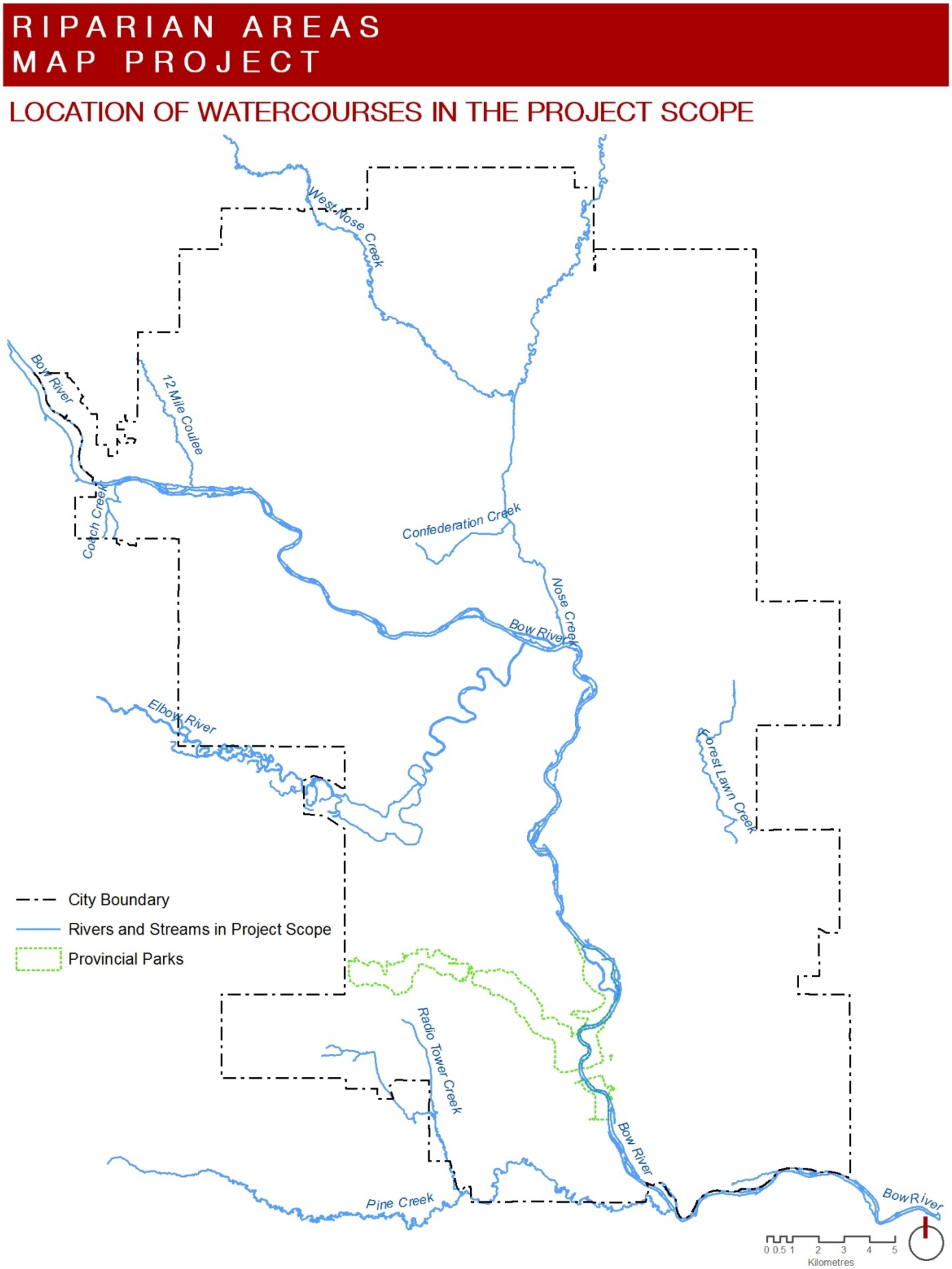


Figure 2. Location of Watercourses in the Project Scope

2. PLANNING AND POLICY CONTEXT

This section provides a brief overview of the planning and policy context of this project. The focus is on drawing direct links between this study and higher level plans and policies related to riparian areas in Calgary. The information provided here was used to help direct and inform specific objectives and geospatial representations provided within the riparian mapping project. Section 2.1 provides a historical policy-based narrative related to riparian areas in Calgary as well as their use, development, management, and public stewardship. Sections 2.2, 2.3, and 2.4 summarize, respectively, relevant federal, provincial, and municipal legislation, policy, and guidelines related to riparian areas in Calgary to provide the planning and policy context of the project.

2.1 A Brief History of Natural Environment Values and Land Use Issues in Calgary's Riparian Areas

People have always been drawn to the area adjacent to rivers and streams. As a source of water, a means of transportation, a node of economic activity, a source of hydropower, a recreational venue, a scenic backdrop, and as a source of spiritual inspiration and cultural identity, riparian areas have served multiple functions. In Calgary, riparian areas adjacent to streams and rivers have a long history of use for settlement and residential development (both pre-contact and European), transportation, industrial and commercial activities, recreation, and civic projects. The environmental values of riparian areas, such as wildlife habitat, water quality filters, and scenic resources, are also important and have become increasingly valued by Calgarians over time.

Many past practices and land use policies have caused the loss or degradation of riparian areas in Calgary. These represent lost opportunities to effectively integrate and manage riparian areas and their associated values into the urban fabric. Some examples include:

- *Residential Development:* extensive reaches of riparian areas along the Bow and Elbow in particular have been developed to urban residential or other uses (Figure 3).
- *Commercial Development:* commercial developments have occurred adjacent to many riparian areas in the city.
- *Industrial Development:* Heavy industrial uses (past and present) have occurred (i.e., oil refinery near Lynnview along the Bow River, Canadian Creosote Company, Eau Claire Lumber mill, Lafarge plant). Light industrial uses have also been concentrated in particular along lower portions of Nose Creek.
- *Major Infrastructure:* Highways, railways, water treatment and sewage treatment plants are some of the major types of infrastructure that have been constructed within riparian areas.
- *Channelization:* channelization of portions of rivers and creeks has occurred throughout the city, and is particularly apparent in lower portions of Nose Creek (Figure 4).
- *Urban Stormwater Outfalls and Related Inputs:* Stormwater outfalls and associated erosion protection works affect local riparian vegetation health and connectivity, while stormwater inputs affect riparian areas downstream due to increased peak flows and pollution loads associated with urban stormwater (Figure 5 and Figure 6).
- *Loss of Lower Order Streams and Riparian Areas:* Many small streams and tributaries have been lost to make way for development and transportation infrastructure. For example, Crowchild Trail between 17th Ave. and the Bow River used to be a ravine (Figure 7).
- *Bank Engineering / Flood Protection:* Driven by the need to protect adjacent developments and transportation corridors, extensive bank engineering and flood protection infrastructure installations on the bank have affected riparian natural environment values (Figure 8 and Figure 9)
- *Excessive Unmanaged Recreation:* Excessive unmanaged recreational uses have caused erosion and exposed bare ground in many urban riparian areas, particularly in popular riverfront parks - we are literally "loving these areas to death" in some cases (Figure 10).

Figures 3 to 10 below illustrate some of these negative impacts that have affected riparian areas in Calgary.

Figure 3. Residential Development adjacent to the Bow River, Cranston, South Calgary (June 2012)

Figure 4. Channelized Portion of Nose Creek (*Credit: AMEC / Cows and Fish)*

Figure 5. Untreated urban runoff entering Nose Creek (*Credit: AMEC / Cows and Fish)*

Figure 6. Example of extensive erosion protection works protecting outfall structures on the Bow River *(Credit: AMEC / Cows and Fish)*

Figure 7. Former Riparian Area, Crowchild Trail, SW Calgary (view N. from 17th Ave.)
In 1964, this former riparian area and ravine was filled to construct Crowchild Trail

Figure 8. Retaining Wall Along the Elbow River *(Credit: AMEC / Cows and Fish)*

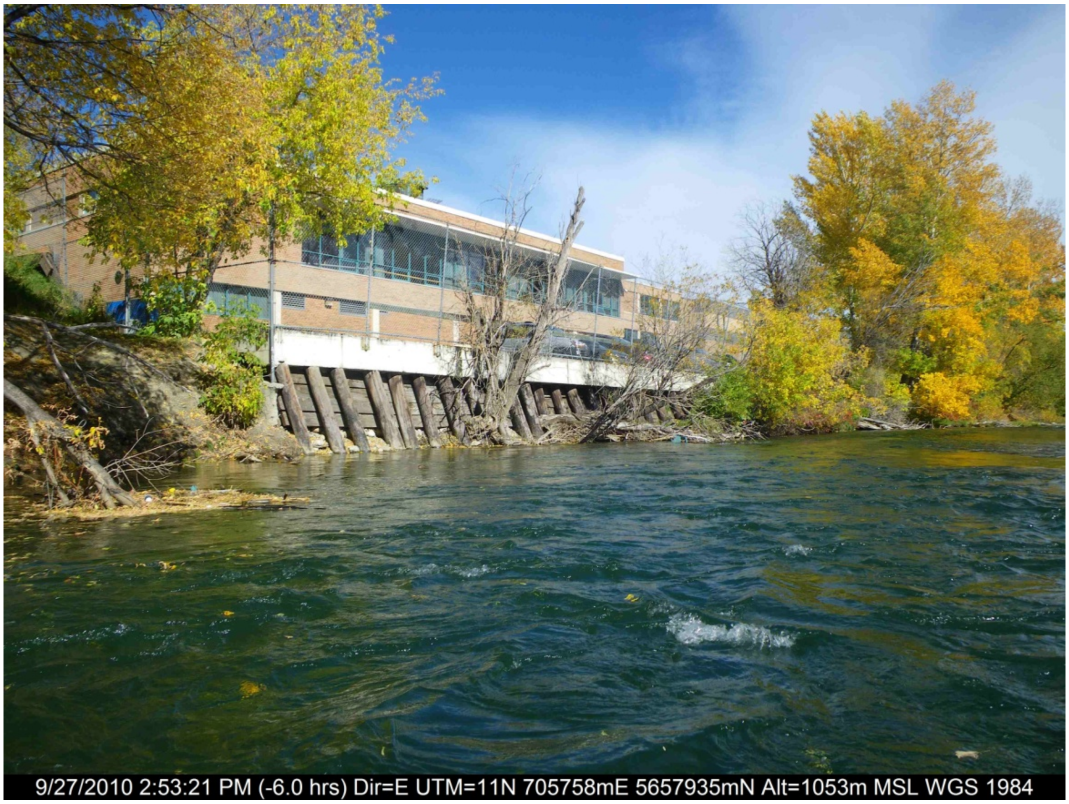


Figure 9. **Retaining Wall Structure Along Elbow River, Mission** (*Credit: AMEC / Cows and Fish*)

Figure 10. **Excessive erosion due to recreational use, Bow River riparian zone, South Calgary** *(Credit: Cows and Fish)*

Despite these changes, there are also many examples where riparian areas were conserved or protected in Calgary, through a process of effective, foresighted policies, practices, and stewardship. Figures 11 to 13 provide examples of parts of the city where effective riparian management and conservation has occurred. Selected examples of success stories include:

- *Revitalization of the Downtown Bow River Waterfront:* The south bank of the Bow River waterfront near downtown Calgary historically was the site of the Eau Claire lumber mill, while also containing somewhat of an urban slum and junkyard (Figure 14 and Figure 15). In 1963, a joint proposal by the city and CP Railway to relocate the railway and build an expressway through the urban core along the south bank of the Bow River precipitated a major controversy that culminated in a polarizing public debate. The outcome of this debate resulted in the riverfront pathway and park system adjacent to downtown that is viewed as such an asset to the city today (Nelles, 2005).
- *Park systems along the Bow River:* Although not contiguous, extensive riverfront park systems occur throughout the city along the Bow River, including Bowness Park, Baker Park, Bowmont Park, Edworthy Park, Prince's Island Park, St. Patrick's Island, Pearce Estate Park, Beaver Dam Flats, Carburn Park, Southland Park, and Douglasbank Park.
- *Fish Creek Park:* This area was initially identified by The City of Calgary as early as 1966 as desirable park space "for the needs of Calgary's future generations". Citizen support for the park, including active participation of 14 south Calgary community associations, led to the purchase of Fish Creek Park lands by the province for a new urban provincial park in February 1973 (Foran, 2009).
- *Elbow River Parks:* The establishment of Natural Environment Parks such as the Weaselhead and Griffith Woods riparian areas (Discover Ridge) along the Elbow River during recent planning, subdivision, and development were major achievements. Further downstream, Sandy Beach / Riverdale Park, Stanley Park, Elbow Island Park, and Talisman Park provide some additional riverfront parkland, although much of the lower Elbow riparian areas have been lost to development.
- *Bioengineering and stewardship:* Throughout the city, "softer" bioengineering techniques for riverbank stabilization and restoration has been occurring. Selected examples include the Sandy Beach riparian restoration project, the Elbow River Bank Stabilization Project near the Stampede grounds, and the live crib wall installation on the Bow River in south Calgary (Figure 12).
- *ER Setback Policy*: This foresighted policy, approved by City Council in 2007, provides an important tool for establishing riparian areas as Environmental Reserve during the process of planning and subdivision.

Riparian areas in Calgary have also varied in response to natural hydrologic cycles and variability. Major floods of the Bow River occurred in 1902, 1915, 1923, and 1928. In 1924, the Bow River contained numerous gravel bars and bare islands, indicating active deposition and erosion caused by the large floods that occurred during the early 20th century (Northwest Hydraulic Consultants Ltd., 1986). At this time, the Elbow River was a meandering, single channel stream actively eroding its banks and forming sand and gravel bars. However, by 1953 these riparian areas along the Elbow were partially treed, while by 1978 they were completely covered in mature vegetation, halting the bank erosion which had been previously occurring (Northwest Hydraulic Consultants Ltd., 1986). Some historical photos illustrating the dynamic, changing interplay of natural and human forces affecting riparian areas in Calgary are shown in Figures 14 to 20.

The complex interplay of human and natural influences makes riparian areas dynamic and ever-changing systems, particularly in an urban context. These properties can also make them challenging environments to delineate on a map and manage properly. Another challenge is that simple fixed width setback approaches from the stream channel may not adequately represent the true extent of riparian corridors and may not protect riparian functions. In this context, this study aims to comprehensively map the location, condition, and status of riparian areas adjacent to the major streams and rivers in Calgary to help provide more information to better inform the future planning and management of riparian areas.

Figure 11. Bow River and Riparian areas, view from Edworthy Park looking northwest

Figure 12. Live Crib Wall along Bow River, near Deerfoot Meadows, South Calgary

Figure 13. The Weaselhead as seen from North Glenmore Park

Figure 14. South Bank of Bow River viewed from Centre St. bridge, Calgary, AB

Figure 15. View NE from 3rd St. SE, garbage and automobiles litter the bank

Figure 16. Bow River in flood, July 1902

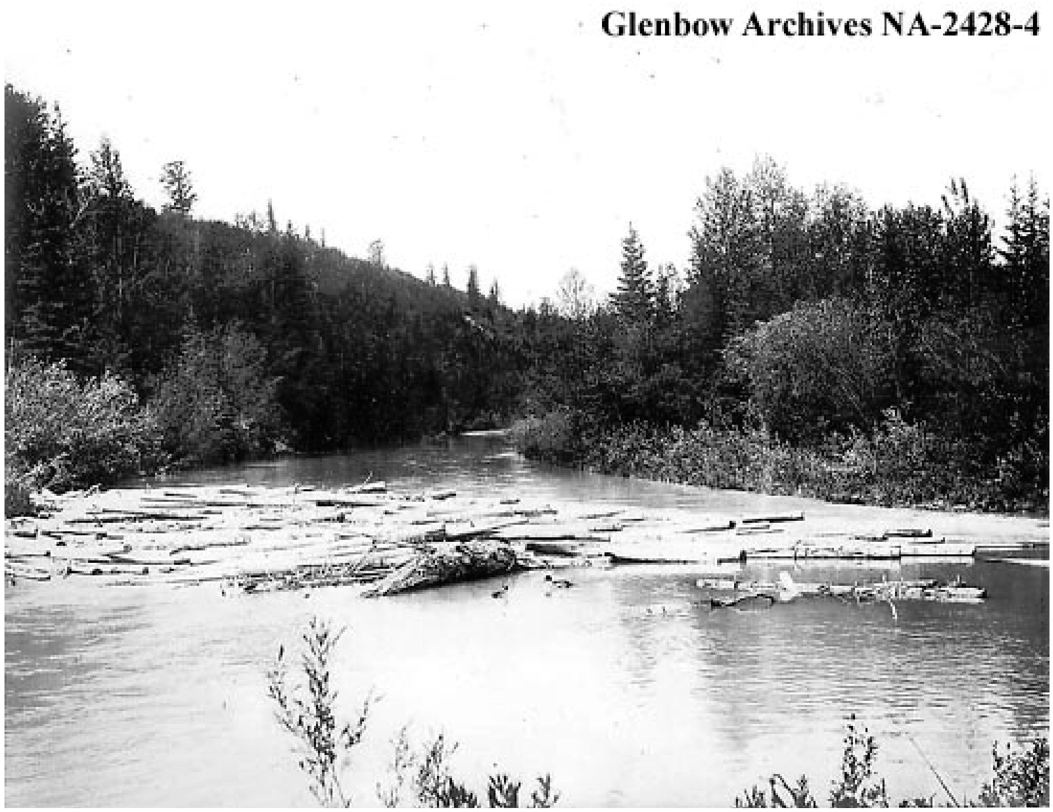


Figure 17. Bow River, Bowness, AB, 1910

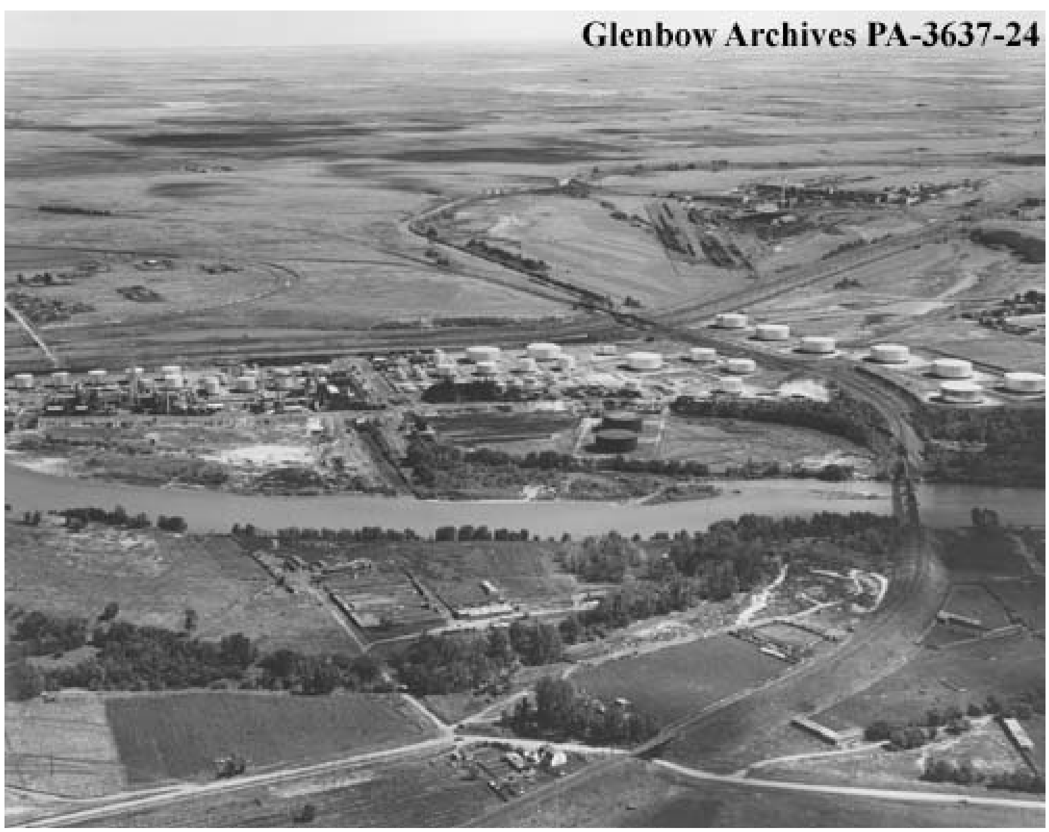


Figure 18. Imperial Oil Refinery, ca. 1950

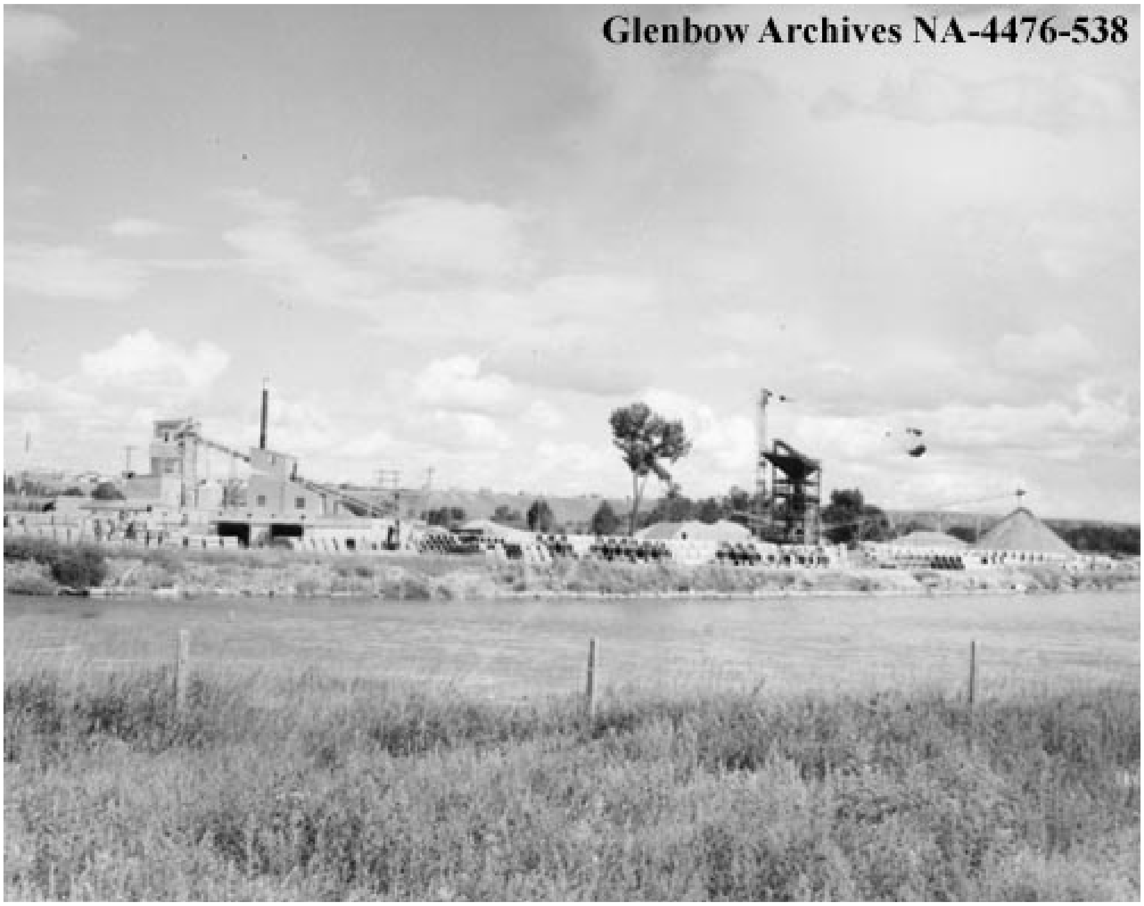


Figure 19. Gravel and concrete plant on bank of Bow River, ca. 1950

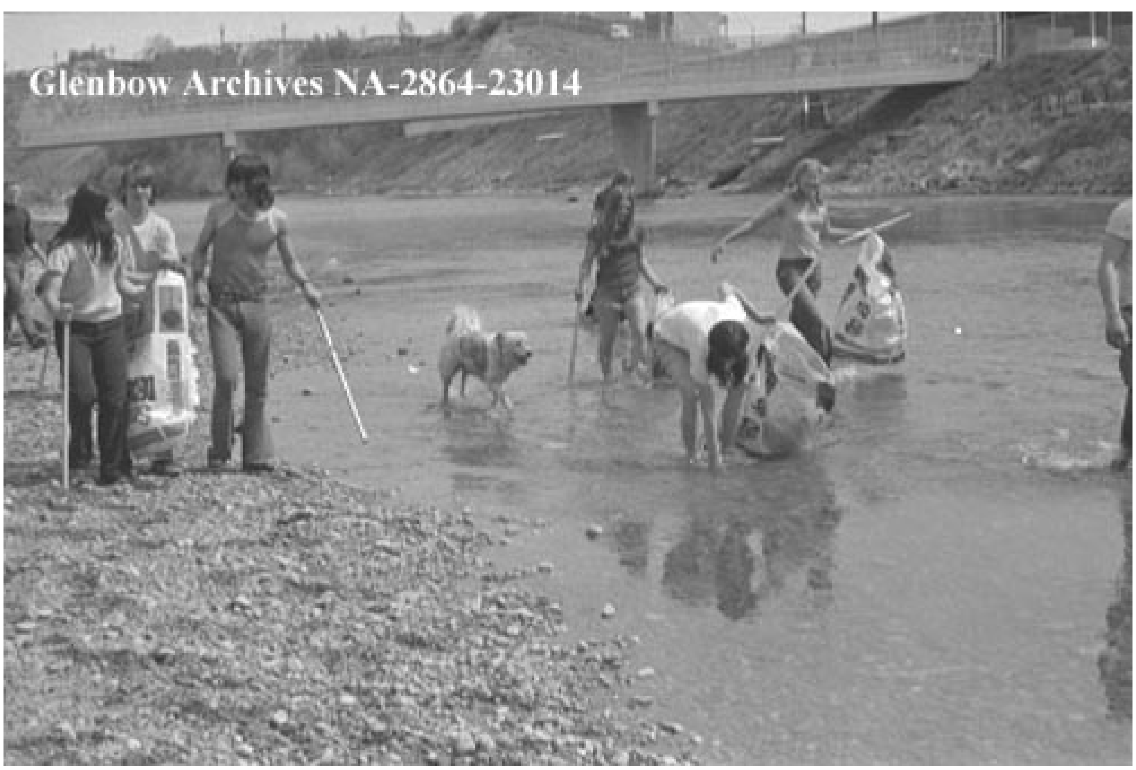


Figure 20. Spring clean-up time along Bow River, May 1973

2.2 Federal Legislation, Policy and Guidelines

The *Fisheries Act* administered by the federal Department of Fisheries and Oceans (DFO) prohibits the harmful alteration, disruption, or destruction of fish habitat, including spawning grounds, nursery, rearing, food supply and migration areas, and some riparian areas. The Act also prohibits the deposition of ‘deleterious’ (harmful or toxic) substances directly into a fish-bearing stream or the top of a bank or storm drain leading to a fish-bearing stream.

The *Navigable Waters Protection Act (1985)* is administered by Transport Canada. Section 5 specifies that no work shall be built or placed in, on, over, under, through or across any navigable water without the Minister’s prior approval of the work, its site and the plans for it (Government of Canada, 1985). The intent is to ensure the safe passage of boats including small canoes and other recreational vessels.

The *Migratory Birds Convention Act (1994)* is administered by Environment Canada to protect migratory birds, their eggs, and their nests through the Migratory Birds Regulations. A list of the birds protected in Canada under the *Act* is available in Occasional Paper No. 1 (Environment Canada, 2001). The Migratory Birds Regulations strictly prohibit the harming of migratory birds and the disturbance or destruction of their nests and eggs. However, many are inadvertently destroyed by human activities, including urban and industrial development and incompatible land use practices. This inadvertent destruction is called “incidental take” and is technically illegal. Currently, the regulations do not provide for a permit or exemption for the incidental take of nests or eggs of migratory birds. In the absence of a regulatory system for authorizing incidental take, the Canadian Wildlife Service (CWS) provides guidance on how to avoid the incidental take of migratory bird nests and eggs in the *Avoidance Guidelines and the Summary of Environment Canada’s Approach to the Development of BMPs,* available on the Environment Canada website (Environment Canada 2011a).

The *Species at Risk Act (2002)* is designed to prevent wildlife species from becoming extinct or extirpated and help recover listed “at risk" species. Sec 32 states that no person shall kill, harm, harass, capture, trade or take an individual or part of a wildlife species that is listed as an extirpated, endangered, or threatened species. Importantly, the habitat of such species is also protected (Section 58). Species listed under the *Migratory Birds Convention Act* are also included.

Management of wastewater involves all levels of government in Canada, including the federal government. Effluent from wastewater systems in Canada must comply with applicable federal legislation including the Canadian *Environmental Protection Act*, 1999 and the *Fisheries Act*, as well as applicable provincial permits or licenses (Government of Canada, 2010a).

2.3 Provincial Legislation, Policy and Guidelines

The most relevant pieces of provincial legislation, policy, and guidelines applicable to riparian areas include the *Municipal Government Act*, the Alberta Environment and Sustainable Resource Development (AESRD) *“Stepping Back from the Water”* policy report, Restricted Activity Periods (RAPs) policies, provincial aquatic Environmentally Significant Areas (ESAs).

2.3.1 Municipal Government Act

Under the *Municipal Government Act* (MGA)*,* if the municipality has strong evidence that riparian lands are either *“subject to flooding”* or *“unstable in the opinion of the subdivision authority”* (Section 664(1) (b)), OR that the riparian land and/or associated buffer strip *“prevents pollution or provides public access to and beside the bed and shore”* (Section 664(1) (c)), the municipality can take the land as Environmental Reserve (ER). ER parcels are considered “undevelopable” lands and are transferred to the municipality during subdivision.

Riparian areas are often subject to flooding, unstable, provide public access to and beside the bed and shore, and most certainly prevent pollution when they are intact and functional. Therefore, tools related to ER in the MGA can be used to protect riparian areas during the process of urban development. Although the MGA specifies a “minimum” ER riparian buffer width of 6 m, municipalities can require additional riparian ER, but typically require supporting information and policies to justify this. However, this remains a controversial issue open to interpretation. Multiple scientific studies indicate that the riparian area preventing pollution can be very wide which is bound to be controversial.

The MGA also requires Municipal Reserve (MR) to be taken during subdivision, which are up to 10% of the developable lands. Although, as discussed above, the definition of ER could be expansive to include all riparian areas, it is possible the City could use a portion of the 10% Municipal Reserve (MR) typically dedicated at subdivision to acquire additional riparian areas as municipally owned public lands.

2.3.2 "Stepping Back from the Water" Provincial Report

"Stepping Back from the Water" (released by the province in April 2012) is a guidebook for minimizing impacts and risks associated with development near water bodies with an emphasis on conserving riparian areas (AEW, 2012). The recommendations are "discretionary" and are "intended to assist local authorities and watershed groups with policy creation, decision making and watershed management relative to structural development near water bodies". The document deals with setbacks only for new development adjacent to water bodies in Alberta's settled region. Adequate effective widths for vegetated filter strips (Table 1) are recommended based on:

- water quality function
- effect of slope on effectiveness of filter strips
- risk of shallow groundwater contamination
- floodings
- shoreline migration
- bank stability
- additional buffer considerations are recommended for protecting aquatic and terrestrial habitat, wildlife travel corridors, and rare species

Table 1. Provincial (AEW 2010) Recommended Effective Widths for Vegetated Filter Strips

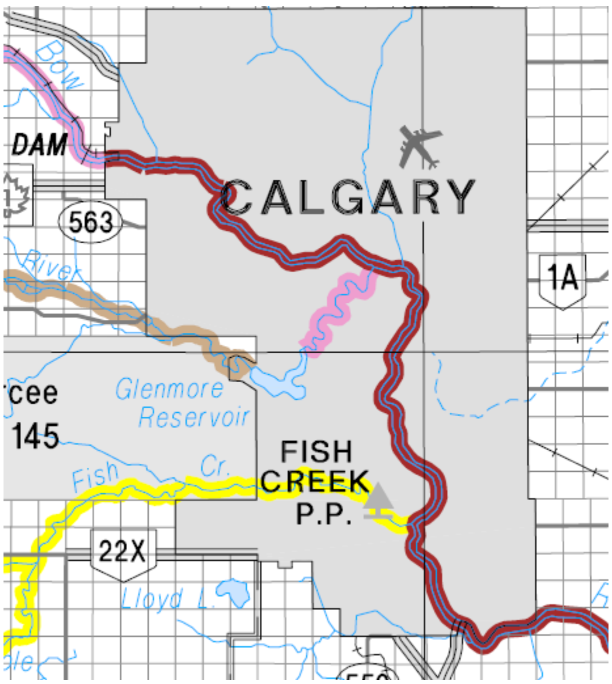
Type of Water Body	Substrate	Width	Modifiers	Notes
Permanent Water Bodies Lakes, Rivers, Streams, Seeps, Springs Class III - VII Wetlands	Glacial till	20m[9]	If the average slope of the strip is more than 5%, increase the width of the strip by 1.5 m for every 1% of slope over 5%	Slopes > 25% are not credited toward the filter strip
	Coarse textured sands & gravels, alluvial sediments	50m[10]	None	Conserve native riparian vegetation and natural flood regimes
Ephemeral and Intermittent Streams, Gullies	Not specified	6m strip of native vegetation or perennial grasses adjacent to the stream channel crest[11]	If the average slope of the strip is more than 5%, increase the width of the strip by 1.5 m for every 1% of slope over 5%	Maintain continuous native vegetation cover along channels and slopes
Class I & II Wetlands	Not specified	10m strip of willow and perennial grasses adjacent to water body[12]	None	Maintain and conserve native wetland or marshland plants on legal bed and shore

The guidebook discusses that choosing to develop in riparian zones has costs, benefits and consequences that may not be shared equally by all watershed residents. It is necessary to understand who or what will bear the additional costs to forgo some or several riparian functions.

2.3.3 Restricted Activity Periods (RAPs) and Riparian Areas

AESRD's *Code of Practice for Watercourse Crossings* identifies Restricted Activity Periods (RAPs) when *works that disrupt the bed or banks of a water body must be avoided to prevent disturbing fish or fish eggs during sensitive periods of their reproductive life cycle (i.e., spawning, egg incubation, fry emergence)*. In general, these times correspond with dry or frozen times of the year to prevent and minimize erosion, and to prevent sedimentation into the water body. Guidelines and best management practices also recommend that route planning minimizes impacts to critical riparian habitat. Potential impacts to riparian areas must also be identified, following an assessment by a qualified aquatic environment specialist.

Figure 21 presents a map of Calgary and surrounding region that identifies RAPs for mapped Class B and Class C water bodies, including the Bow River, Elbow River, and Fish Creek. There are no RAPs established for Class D water bodies. If the construction or maintenance of the watercourse crossing is to be carried out within a RAP, the recommendation and instructions of a qualified aquatic environment specialist is required unless otherwise specified under the Code of Practice.



Water Body Class	Water Body Class Symbol	Restricted Activity Period
Class A	or	– See applicable Code of Practice for specific requirements
Class B	OOOOOO	– May 16 to August 15 and September 1 to April 30
	OOOOOO	– September 16 to April 15
	OOOOOO	– April 16 to July 15
Class C		– May 16 to August 15 and September 1 to April 30
		– September 1 to August 15
		– September 1 to July 15
		– May 1 to July 15 and September 16 to April 15
		– May 1 to July 15 and September 16 to April 5
		– September 16 to April 15
		– October 1 to April 15
		– May 1 to August 15 and September 16 to April 15
		– April 1 to May 31
Class D	None	– No Restricted Activity Period

Figure 21. Code of Practice for Watercourse Crossings - Calgary Area

Note that Trout Unlimited recently found some trout in both Nose Creek and West Nose Creek. They have been working with AESRD to consider reclassification of these water bodies as Class C for the purpose of the Code of Practice for Watercourse Crossings. However, the legal standing of these creeks has not yet been adjusted.

2.3.4 Alberta Wildlife Act

The provincial *Wildlife Act* also pertains to riparian areas, as development in riparian areas that has potential to remove nesting / denning habitat and / or snake hibernacula may contravene this Act. Section 36 of the Act states that: *36(1) A person shall not wilfully molest, disturb or destroy a house, nest or den of prescribed wildlife or a beaver dam in prescribed areas and at prescribed times.*

Under the Wildlife Regulation - 96 Section 36(1) of the Act applies

(a) to the nests and dens, so far as applicable, of
(i) endangered animals that are treated under section 7 the same as non-game animals other than raven, throughout Alberta and throughout the year,

(i.1) upland game birds throughout Alberta and throughout the year,

(ii) migratory game birds, migratory insectivorous birds and migratory nongame birds as defined in the Migratory Birds Convention Act (Canada), throughout Alberta and throughout the year, and

(iii) snakes, except those specified in clause (a.1), and bats, throughout Alberta and from September 1 in one year to April 30 in the next,

(a.1) to the dens of Prairie Rattlesnakes, Western Hognose Snakes and Bull (Gopher) Snakes used as hibernacula, throughout Alberta and throughout the year,

(b) to the houses and dens of beaver, on any land that is not privately owned land described in section 1(1)(z)(i) or (ii) of the Act throughout the year

2.3.5 Provincial Aquatic Environmentally Significant Areas

The province recently identified criteria for Aquatic Environmentally Significant Areas (AESAs) to support land use planning (AESRD, 2011). This work was developed by Alberta Environment and Sustainable Resource Development. The following criteria were used to identify and define AESAs in the province of Alberta and are based on recommendations developed by the Alberta Water Council:

- Presence of aquatic focal species, species groups, or their habitat
- Presence of species of conservation concern
- Presence of rare or unique aquatic ecosystems
- Key areas that contribute to water quality
- Key areas of biological connectivity
- Key areas of intact complexity and/or biodiversity
- Key areas that contribute to water quantity.

When applied in a systematic fashion, these criteria provide the basis for identifying AESAs with the scientific rigor, defensibility, and repeatability that should characterize any conservation planning process. The boundaries of AESAs are expected to be fairly coarse at a municipal scale. In addition, shape files for the AESAs are not yet available as only hard copy maps are available at this point. Howeve,r it is apparent from the map that Calgary contains several AESAs, including the Bow River Corridor, the Weaselhead and Glenmore Reservoir, the Elbow River Corridor, Fish Creek Corridor, and Pine Creek Corridor.

2.4 Regional Plans

Two major regional planning processes have recently occurred which pertain strongly to land use and environmental issues in Calgary. These include the Calgary Metropolitan Plan (CMP) and the South Saskatchewan Regional Plan (SSRP).

2.4.1 Calgary Metropolitan Plan

The Calgary Regional Partnership (CRP) represents a diverse group of municipalities in the Calgary Area that aim to work cooperatively together on regional issues. Applying the motto “thinking regionally and acting locally” the CRP shapes and champions its vision of working together to live in balance with a healthy environment, in enriched communities, with sustainable infrastructure and a prosperous economy.

The CRP’s flagship initiative is the Calgary Metropolitan Plan (CMP). This 70 year strategic plan protects the region's landscape and its associated ecological goods and services. The Plan guides urban growth associated with a forecasted 1.7 million new residents to the region, informing where and how development should take place and where it is best discouraged. The Plan supports major change from the status quo approach to planning, aiming for real change to reduce the region's future predicted development footprint by 60% and reduce future infrastructure costs by 30%.

With respect to riparian areas planning and management, the CMP has specified the following:

CMP Policy 2.9 Riparian Lands. Member municipalities will protect the ecological function of riparian lands within their jurisdiction and will recognize site-specific needs.

CMP Policy 2.10. Integrated Watershed Management (IWM). CRP and member municipalities will actively work with the Province of Alberta, the Bow River Basin Council (BRBC), and other key stakeholders to support the development and implementation of an Integrated Watershed Management (IWM) approach to deal effectively with the relationships between land use, water quality management and water supply in the Calgary Region.

CMP Policy 2.11 Wetland Impacts. Member municipalities will adopt a "no net loss of wetlands" approach by avoiding, minimizing and mitigating impacts to wetlands. Municipalities will determine actions within their jurisdiction and will recognize site-specific needs.

In addition, the CRP Environment report (O2 2009) provides additional supplemental information, strategies, and actions regarding riparian areas to support future implementation of the CMP, including the information summarized in Table 2.

Table 2. Strategies and Actions for riparian areas in the CMP

Recommended Strategy	Actions
Conserve riparian areas with a buffer of permanent, ideally native, vegetative cover.	Conserve buffers on both sides of all streams to conserve water quality. Wider buffers are needed to provide for wildlife habitat / movement and pollination services to surrounding agriculture.
	Though specific buffer width requirements may vary for individual streams, a minimum buffer width of 60 m is suggested.
Establish and restore riparian setbacks along streams.	Create building development setbacks in all riparian lands to sustain and improve water quality and quantity. Establish permitted, discretionary and prohibited uses within the riparian setbacks. New buildings and roadways shall be excluded within the setbacks while non-motorized trails and public access may be permitted where landowners agree. Agricultural uses that maintain permanent vegetated cover (e.g. grazing) within these areas may also be permitted.
	Develop land use bylaw templates for the protection of riparian areas.

2.4.2 South Saskatchewan Regional Plan

The South Saskatchewan Regional Plan (SSRP) is currently being finalized under the provincial Land-use Framework. The Regional Advisory Council's *Advice to the Government of Alberta* for the SSRP included the following principles, issues, objectives, and recommendations with direct relevance to riparian areas:

- **Section 3.2: Strategic Land-use Principles:**
    - **Plan for Water:** *"Headwater and source water protection and the need to manage land use to sustain water production and water quality are critically important."*
- **Section 5.2: Water Management:**
    - **Primary Issues:** "Proper planning, design, and management will…support the management of source water, the region's wetlands and riparian areas as well as the services they provide."
    - **Objective 5.2.1:** "To protect source waters through the maintenance of watershed integrity and ecosystem function"
    - **Objective 5.2.3:** "To protect source water from pollution to ensure the ability to derive good quality water for people and other uses."
    - **Objective 5.2.4:** "To recognize and manage land use for the headwater values where rivers and streams and groundwater originate - especially in critical areas."
    - **Objective 5.2.6:** "To maintain, where reasonably possible, the health and function of aquatic ecosystems affected by disturbance, erosion, invasive species and contamination."
    - **Objective 5.2.7:** "To maintain and restore, where reasonably possible, riparian areas to support watershed integrity"
    - **Objective 5.2.8:** "To maintain the health and function of riparian areas affected by disturbance, erosion, invasive species and contamination."
    - **Recommendation 5.2.9.1:** "Take measures to ensure source water quality and quantity are sustained in co-ordination with measures taken concerning groundwater, riparian areas, wetlands, aquatic biodiversity and headwaters. The priority is to ensure areas that are currently in a desired condition are kept that way.
    - **Recommendation 5.2.9.2:** "Using a risk management approach, identify and facilitate the implementation of practices that reduce point and non-point sources of water pollution."
    - **Recommendation 5.2.9.21:** "Develop new regional riparian area management policies and strategies."
    - **Recommendation 5.2.9.22:** "Maintain and, to the greatest degree possible, restore riparian function. Filling in the flood plains is not an acceptable practice."
    - **Recommendation 5.2.9.23: "**Encourage improved stewardship by increasing education and outreach, and providing stewardship opportunities."
    - **Recommendation 5.2.9.24: "**Develop and encourage practices that restore native plant and animal communities by reducing the spread of noxious and restrictive species."
    - **Recommendation 5.2.9.25: "**Evaluate and improve existing regional co-ordination efforts among government, private organizations and individuals for ensuring protection and maintenance of riparian function."
    - **Recommendation 5.2.9.26:** "Improve our mapping and knowledge of riparian areas."
    - **Recommendation 5.2.9.27:** "Include riparian restoration or retention as part of a broader program to develop an ecological goods and services revenue stream."

In addition, of indirect relevance are aspects related to conservation and stewardship tools, including:

- **Section 3.2: Strategic Land-use Principles:**
    - **Developing conservation and stewardship tools:** *"It is imperative that the Government of Alberta develop an enhanced suite of conservation and stewardship tools (e.g., economic and market-based incentives, conservation easements, transferable development credits, mitigation banking, etc.). New tools, when developed, must be easily accessible, well understood and applicable."* (Note: Also see the *Alberta Land Stewardship Act*)

2.5 Watershed Management Plans

The province's *Water for Life* strategy has established Watershed Planning and Advisory Councils (WPACs) that have been assembled to work in an adaptive cycle of basin planning. WPACs are collaborative, independent, volunteer organizations with representation from key partners within the watershed. Their mandate is to engage governments, stakeholders, other partnerships, and the public in watershed assessment and watershed management planning, while considering the existing land and resource management planning processes and decision-making authorities. Members of WPACs include federal and provincial ministries, as well as municipal and non-government organizations. On a more local scale, Watershed Stewardship Groups (WSGs) consist of community-based groups made up of volunteer citizens, often supported by local businesses or industries, who have taken the initiative to protect their local creek, stream, stretch of river, or lake. These proactive groups develop on-the-ground solutions to ensure the protection of their specific watersheds (AENV, 2008).

Watershed Management Plans[1] addressing water quantity, water quality, point and non-point source pollution, and source water protection have been compiled for the Bow River by the Bow River Basin Council WPAC, Nose Creek by the Nose Creek Watershed Partnership WSG, and the Elbow River Partnership WSG. Key points related to riparian areas found within these plans are summarized below[1].

2.5.1 Bow Basin Watershed Management Plan

The principles and goals of the Bow Basin Watershed Management Plan (Draft Phase II, May 2011) that are related to riparian areas include:

- Riparian and wetland ecosystems are to be kept intact, ecologically functional, appreciated and valued
- Riparian areas are to be in a healthy, functionally connected state
- Core ecological functions of healthy riparian areas should be maintained including:
    - Water quality protection
    - Water storage and flood conveyance
    - Bank stability
    - Biodiversity
- Invasive species should be reduced and native aquatic and riparian communities should be restored
- Identify methods to recognize and quantify the value of ecosystem services,
- A minimum threshold of no net loss of area and functionality of naturally occurring riparian areas is established

Recommendations suggest that conservation and management policies should focus on:

- no net loss of riparian areas
- tools to measure and implement no net loss
- conservation and management policies for recreational use within riparian areas
- best management practices for riparian areas
- an action plan for a determined path forward through a multi-stakeholder workshop

[1] Note that Watershed Management Plans are non-statutory documents and are *not* the same as Water Management Plans. Water Management plans developed under the *Water Act* set clear and strategic directions regarding how water should be managed, or specify actions. An *approved Water* Management Plan under the *Water Act* must be considered by a Director when making water licence and approval decisions. None of the watershed management plans in Calgary fall into this category and as a result, these are therefore discretionary and non statutory.

2.5.2 Nose Creek Watershed Management Plan

The Nose Creek Watershed Partnership (NCWP) was formed to protect riparian areas and improve water quality in the Nose Creek watershed (NCWP, 2008). The NCWP plan has been adopted by The City of Calgary. Some of the most important strategies in the plan for the purpose of this report are reviewed below.

Riparian Setbacks: Desirable riparian setback widths are determined as the greater of the 1:100 year floodplain width, meander belt width (20x bankfull width), or the width of escarpments with >15% slope adjacent to the meander belt and/or floodplain. Moreover, it is suggested that where the floodplain has not been defined by the Province, the meander belt width should be calculated and used as the riparian setback to a minimum width of at least 15 m.

Steep Slopes: All lands with slopes equal to or greater than 15% should be designated as Environmental Reserve and retained as natural area. Where the land is situated adjacent to or includes the banks of any watercourse, including coulees, ravines, gullies, or valleys, an additional setback from the top of bank should be added as follows:

a. The first 12 m from the top of the bank where the bank height is <6 m

b. Twice the bank height from the top of the bank where the bank height is 6 to 23 m or

c. Within 46 m from the top of the bank if the bank height is >23 m

Wetlands: All wetlands should be retained in the watershed, including a minimum 30 m setback.

2.5.3 Elbow River Basin Water Management Plan

The vision of the Elbow River Basin Water Management Plan is "*ample clean water for the benefit of all, while maintaining the integrity of the aquatic environment."* Currently, water quality in the upper Elbow River watershed is excellent. However, there is documented water quality deterioration in the central and lower reaches, that is, the more developed reaches of the watershed. Increasing urban and rural developments are having significant impacts on the watershed (ERWP, 2008).

The goals of the Elbow River Basin Water Management Plan were to manage water source areas to maintain or improve water quality in the Elbow River and its tributaries, and manage riparian areas and wetlands to maintain or improve water quality (ERWP, 2008).

The ERWP Steering Committee presented a final draft of the water management plan, which incorporates a broad range of stakeholder and public input. Understanding that riparian zone conservation contributes to improvement in water quality the following recommendations were presented:

- Create an inventory of riparian areas, assess the need for mitigation and develop a program for protection and restoration.
- Restore damaged riparian areas along tributary streams using ecological restoration techniques to restore natural functions.
- Adopt provincial setback protocol (under development) for riparian setbacks in developing areas. More protective setbacks are encouraged in areas where water quality needs improvement.
- Develop and implement wetland and riparian management plans as part of the BBWMP planning process based on the findings of the comprehensive riparian and wetland inventories.
- Support and implement grazing strategies to eventually eliminate cattle grazing in riparian habitat along rivers and creeks (for grasslands, forested areas and protected areas).

- Limit new development on the alluvial aquifer to those that improve water quality in the central urban and central rural reaches and those that maintain or improve water quality in the upper reach.

2.6 City of Calgary Policies and Plans

This section summarizes The City of Calgary's existing policies, guidelines or plans that relate to the management or treatment of riparian areas. Calgary has working by-laws that pertain to floodplain / floodways and stream setbacks, along with many plans, policies and strategies that identify riparian areas as significant areas to be conserved and maintained.

2.6.1 PLAN IT Calgary Municipal Development Plan

Plan It Calgary was the process carried out to develop an integrated Municipal Development Plan (MDP) and Calgary Transportation Plan (CTP). The new City of Calgary MDP was adopted by council in September 2009 as one of the outputs of this process. This document provides specific direction on watershed management, and the maintenance and establishment of green infrastructure. The goals and objectives with regards to *Greening the City* are to:

- Conserve, protect and restore the natural environment.
- Connect green infrastructure throughout the urban fabric.
- Protect, conserve and enhance water quality and quantity by creating a land use and transportation framework that protects the watershed.
- Protect and integrate critical ecological areas such as wetlands, floodplains and riparian corridors into development areas.
- Maintain biodiversity and landscape diversity, integrating and connecting ecological networks throughout the city.

Figure 22. Green infrastructure shown as an interconnected network of natural and engineered green elements (*Source: PLAN IT Calgary)*

More specifically, the following policies were established under *Greening the City - Ecological Networks - Protecting aquatic and riparian habitats:*

- Ensure "no net loss" principles of significant wetland habitat and preserve existing wetlands as a priority over reconstruction
- Protect aquatic habitats through preservation, restoration and creation of wetland bank sites
- Protect riparian areas to meet habitat, water quality and public access through environmental reserve dedications and design alternatives

- Encourage and enable protection of source water and groundwater recharge areas

2.6.2 Calgary Triple Bottom Line Policy

The Calgary "Triple Bottom Line" policy was adopted by Calgary City Council on September 12, 2005. The policy is a decision-making, planning and reporting framework that has emerged as a tool to achieve sustainable development addressing social, economic, environmental, and smart growth impacts in all City business.

The purposes of the Triple Bottom Line policy include the following (City of Calgary, 2012):

- **Vision:** To advance Council's vision to "create and sustain a vibrant, healthy, safe and caring community"
- **Action:** To embed Triple Bottom Line considerations into The City's Corporate policies, performance measures, actions and implementation procedures, and enhance The City's decision making
- **Community:** To place Calgary's efforts in the broader context of efforts of cities around the world to improve their sustainability performance, and make a contribution to global sustainability

2.6.3 Calgary Environmental Management System ISO 14001 and City of Calgary Environmental Policy

The City of Calgary's Environmental Management System ISO 14001 (EnviroSystem) provides the framework to manage The City's environmental impacts. The City commits to the highest international standard for pollution prevention and continual improvement, audited by the third-party ISO system.

EnviroSystem supports The City of Calgary's Environmental Policy which is to:

- Integrate environmental considerations into all decisions and approvals relating to growth, planning, infrastructure, transportation and development
- Ensure City operations, including work of contractors, comply with environmental legislation, standards and other environmental requirements
- Pursue opportunities to engage, collaborate and partner with organizations and other orders of government on programs and legislative initiatives to improve the environment
- Develop and implement strategies to promote conservation and responsible consumption of natural resources including land, energy and water
- Develop and implement strategies to prevent pollution, reduce waste generation and respond to climate change issues
- Enable citizens to reduce their ecological footprint and contribute to Calgary's long-range urban sustainability plan
- Continually seek out new ways to improve its environmental performance, meet environmental goals and contribute to community sustainability

2.6.4 Calgary River Valleys Plan

The Calgary River Valleys Plan (1984) was prepared on an equal cost sharing basis by The City of Calgary and the Province of Alberta. This plan's objectives were to:

- Maintain and enhance the distinctive characteristics of the riverine environment
- Encourage harmonious and diverse uses adjacent to the rivers and their tributaries

- Develop the rivers / creeks and valleys as a focal point of year-round recreation activities and promote awareness of the river system as related to the overall development of the city
- Minimize the loss of life, threat to health and to reduce economic loss by flooding
- Minimize economic or social hardship upon any individual or community in realizing the plan objectives

The plan included:

- A land use inventory focused on land uses and environmental conditions adjacent to rivers / creeks
- Background information on the development of policies including problems and opportunities in the river / creek valleys
- An official plan and policies including recommendations, implementation procedures, priorities, cost estimates, and land use concept plans

Although the focus of this plan is broader than this project due to the nature of the river valley system which often extends beyond the area with distinct riparian vegetation, some of the information, maps, and analyses within this project can lead towards an update to the Calgary River Valleys Plan.

2.6.5 Calgary Open Space Plan

The City of Calgary Parks developed an Open Space Plan that was adopted and amended by Council in March 2003. The objective of Calgary's Open Space Plan is to maintain biodiversity and landscape diversity, and integrate and connect ecological networks throughout the city. The components of Calgary's ecological network include the river valley system, natural environment parks, regional and neighbourhood parks, pathways, linear parks, school sites, community gardens and urban plazas.

To achieve these objectives, several Open Space policies have been cited in the MDP that support the protection, preservation, conservation and restoration of riparian areas. An Open Space typology has also been developed to guide Local Area Plans (Table 3).

2.6.6 Calgary Wetland Conservation Plan

The City of Calgary *Wetlands Conservation Plan* has policies and procedures for the timely identification of wetlands in Calgary and their associated environmental significance to ensure their conservation and/or mitigation within the development approval process. Guidelines have also been established for the implementation of a monitoring program that will continually evaluate the success of implementing the policies and procedures.

Table 3. Calgary's Open Space Typology (City of Calgary MDP 2010)

	Open Space Type	Type Classification	Type Expression	Type Amenity (Examples)	Function Value	Opportunity Scale
Calgary's Open Space	Patch	Natural patch	Wetlands Remnant forests Remnant forests Natural slopes	Priddis Wetland Griffith Woods Park Nose Hill Park Paskapoo Slopes	Individual well-being Community well-being Biodiversity Storm-water management Air conditioning	City-wide/ Community
		Disturbed patch	Capped landfills	Playfields	Individual well-being Community well-being Storm-water management Air conditioning	
			Brownfields	Southland Off-leash Park Fort Calgary		
			Storm ponds	Elliston Park		
			Modified slopes	McHugh Bluff Natural		
			Graded fields	Playfields Queens Park Cemetery Fox Hollow Golf Course		
	Corridor	Natural corridor	River Valleys	Prince's Island Park Shouldice Park McHugh Bluff Natural Park Edworthy Park Elbow Park Heritage Park Weaselhead Flats	Individual well-being Community well-being Biodiversity Storm-water management Air conditioning	City-wide/ Community
			Creek Coulee	Proposed Calgary Science Centre Confluence Park		
			Creek	Proposed Forest Lawn Creek Park		
			Linear Wetland Complexes	Sheppard Slough Education Centre		
		Disturbed corridor	Boulevards Roads Alleyways Irrigation cannal Utility-rights-of-way	Regional pathway	Individual well-being Community well-being Storm-water management Air conditioning	
	Matrix	Topography	Plain	Prairie and floodplains	Urban form Utility access Public safety and access	City-wide/ Community
			Undulating	East/South Calgary toporaphy		
			Rolling	West Calgary topography		
			Hummocks	Northwest Calgary - hills and small lakes		
			Steep slope	Escarpments and slopes		
			Terrace			
			Watercourses	Rivers and creeks River valleys, coulees and ravines		
		Eco region	Grassland Natural Region – Foothills Fescue Parkland Natural Region – Foothills Parkland Parkland Natural Region – Central Parkland Utility access Public safety and access	Distinct flora and associated fauna	Urban form Utility access Public safety and access	

2.6.7 Calgary Land Use Bylaw and Floodplain / Floodway

Land Use Bylaw (LUB) 1P2007, as well as several recent amendments, is the most current LUB for The City of Calgary. The LUB addresses development in the floodway, flood fringe, and overland flow areas of Calgary's major waterways in Part 3, Division 3 ('Floodway, Flood Fringe and Overland Flow') as well as Part 10, Section 19.1. Floodway / Flood Fringe Maps indicating the location of the floodway, flood fringe and overland flow areas also form part of the LUB. The meaning of the terms floodway, floodplain, and flood fringe are shown in Figure 23. The overland flow area defined in the LUB is technically the shallowest portion of the flood fringe zone.

UPDATE TO THE FLOODPLAIN BOUNDARY UNDERWAY

Note that a study updating the floodplain boundary within Calgary was recently completed by a consultant on behalf of The City of Calgary Water Resources. This new study will need careful consideration and integration with the LUB.

The floodway is defined as the river channel and adjoining lands as shown on the City's Floodway / Floodplain Maps, which provide the pathway for floodwaters of a magnitude likely to occur once in one hundred years. In the floodway, the only land uses allowed are:

- Athletic and recreation facilities
- Extensive agriculture
- Horticultural nurseries
- Natural areas
- Parks / playgrounds
- Parking areas in conjunction with parks / playgrounds and not involving buildings or structure
- Utilities

In addition, construction of alterations such as berms, decks, docks, fences, gates, patios, rip-rap or walls is also not permitted in the floodway (Section 58).

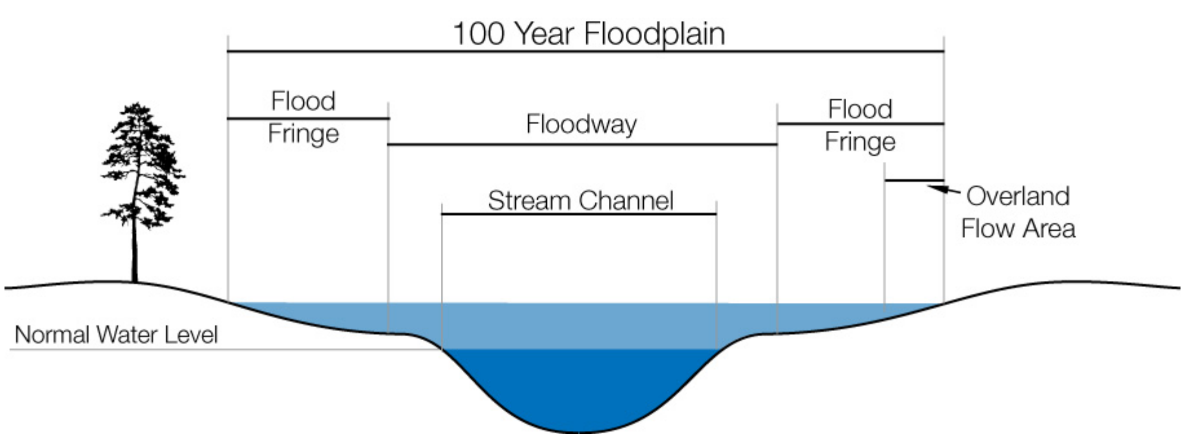


Figure 23. Floodplain, Flood Fringe, and Floodway

The floodplain is defined as lands abutting the floodway, the boundaries of which are indicated on the Floodway / Floodplain Maps that would be inundated by floodwaters of a magnitude likely to occur with a probability of occurrence of 1% in any given year. The floodplain includes the flood fringe and the overland flow areas (the overland flow area is basically that portion of the flood fringe containing very shallow waters). Building in the flood fringe and overland flow areas is subject to special requirements, and also must be set back the greater of (Section 59):

(a) 60.0 m from the edge of the Bow River

(b) 30.0 m from the edge of the Elbow River, Nose Creek, West Nose Creek or

(c) 6.0 m from the edge of the floodway (all other streams / rivers)

Today, buildings constructed in the floodplain typically import fill to change the topography and reduce the risk of flood damage to buildings and property. This practice, though effective in mitigating flood risk to property, is typically highly destructive to riparian area values while also changing floodplain dynamics and hydrology. Another shortcoming of the above approach is that the rigid setback distances specified by the LUB do not consider site variability and the variable nature of riparian environmental conditions.

Moreover, restrictions on development in the floodway and floodplain do not apply to buildings and land uses approved prior to summer 1985, which are grandfathered as permitted or discretionary uses.

In addition, floodplains are not a static entity, due to the meandering of rivers and streams over time (Dunne et al. 1978; Forman 1995). Some locations of streams are subject to rapid shifts, bank cutting, and lateral migration over periods as short as a few years. Due to the shifting location of the stream and its' associated floodplain, specified setbacks may be insufficient to protect from flooding hazards over multi-decadal time scales. This can lead to greater flooding hazards and a progression of engineered streambank hardening to protect buildings from eroding streambanks. This reactive strategy may be more expensive than preventing development in these vulnerable areas in the first place.

Another issue is that climate change will change hydrology and alter the frequency of the 1-in-100 year floodplain (Cunderlik & Ouarda, 2006; Jakob & Church, 2011). Therefore, current floodplain maps do not accurately reflect the future 1-in-100 year floodplain. This issue requires increasing attention in foresighted long-term land use planning for the 21st century.

THE DYNAMIC, CHANGING ENVIRONMENTS OF FLOODPLAINS AND RIPARIAN AREAS

Floodplains and riparian areas are not static entities, as they are affected by the meandering of rivers and streams over time, changes to upstream land use, and climate change (Dunne & Leopold, 1978) (Jakob & Church, 2011). Regime shifts of streams are characterized by rapid bank cutting and lateral migration of meandering streams. Climate change is also occurring, and is predicted to alter the frequency and magnitude of flood events (Cunderlik & Ouarda, 2006) (Jakob & Church, 2011). Upstream development also tends to change land use and watershed dynamics and associated discharges (Jakob & Church, 2011). Consequently, floodplains delineated with historical records of climate and hydrology is not always reliable, particularly for the distant future.

These issues require increasing attention in sustainable long-term land use planning. Due to the shifting location of the floodplain and riparian areas, incorporating the boundaries of the current floodplain and riparian areas within municipal governance may not necessarily protect from long term flood risk. This can "lock" a community in to greater future flood risk, and/or necessitate future engineered streambank hardening projects to protect buildings from eroding streambanks. Such engineering projects not only affect the quality of the riparian environment and the aesthetics of open space, but also tend to be expensive, affecting municipal budgets.

Therefore, far-sighted land use planning prevents development in stream and creek valley corridors.

2.6.8 Urban Parks Master Plan

The Urban Parks Master Plan was approved by City Council in March 1994 and outlined policies around preserving natural landscape features based on the following goal:

"The establishment of significant areas of open space to ensure that urban populations have easy access to natural environments and the development of these areas to enable their sustained and unimpaired use for outdoor recreation"

The river valleys within Calgary were identified as the most significant areas for Urban Parks and the Master Plan further specified land within setback areas of rivers, irrigation canals, river valley corridors, wildlife corridors that link to river valleys, trails that link to river valleys, and other associated riparian ecological systems.

A VISION FOR CALGARY'S RIVER VALLEY PARK SYSTEM

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

2.6.9 Calgary Natural Area Management Plan and Policy

The City's Natural Area Management Plan was completed in 1994. It established an overall policy direction for the protection, management, acquisition and stewardship of Calgary's natural heritage. The plan acknowledges the role of natural areas in watershed protection, preventing flood damage, filtering pollutants, and controlling erosion, as well as providing a host of other recreational and biodiversity benefits. It also provides a summary and framework of options for acquiring natural areas, including developer dedication as Environmental Reserve (ER) or Municipal Reserve (MR), donations, land exchange, or purchase. The report also noted that ER dedication had typically been based on engineering constraints and not environmental quality. However, floodplains, steep escarpments, and permanent wetlands typically contain both engineering constraints and high watershed function values; hence, ER dedication does address some watershed values, although perhaps not optimally. This report also noted that Municipal Reserve has been used very sparingly for protecting natural environments.

2.6.10Calgary Urban Forest Strategic Plan

The purpose of the Urban Forest Strategic Plan (2007) is to provide a framework for City staff and community partners to make key decisions about the management of the urban forest for sustainability today that will have a positive impact for future generations. Tree canopy cover in Calgary is currently at 7%, and the Calgary Parks' Urban Forest Strategic Plan aims to increase this to 20%.

Protection of native forests and trees, which tend to exist only along Calgary's rivers and other locations where suitable moisture conditions exist, has been highlighted as a major component of the strategy.

"Trees serve to define the long term character of the city as a whole and the individual communities within it."

-Calgary Urban Forest Strategic Plan

2.6.11 Calgary ER Setback Policy

Calgary's Environmental Reserve Setback Guidelines were adopted by Council on May 7, 2007. These guidelines were developed to provide better protection of water bodies over and above the 6 m minimum buffer setback outlined in Section 644(1)(c) of the MGA. Site-specific variable setback widths were recommended for designation as Environmental Reserve (ER) based on stream order / wetland class, as well as slope, cover type, and hydraulic connectivity (Table 4).

Table 4. Calgary Environmental Reserve Setback Policy

<table>
<tr><th rowspan="2">Setback Type</th><th rowspan="2">Description of Water Body</th><th rowspan="2">Base Setback</th><th colspan="3">Adjustment Factors</th></tr>
<tr><th>Slope</th><th>Hydraulic Connectivity</th><th>Cover Type</th></tr>
<tr><td>1st order stream</td><td>Typically a vegetated 'draw' that conveys flow primarily during periods of moderate to heavy rainfall and may not convey flow during other periods</td><td>6 m</td><td rowspan="5">+1.5 m for each % of slope greater than 5%</td><td>n/a</td><td>n/a</td></tr>
<tr><td>2nd order stream</td><td>Formed when two 1st order streams meet (e.g. West Nose Creek)</td><td>30 m</td><td rowspan="4">Areas adjacent to water bodies that have shallow groundwater connectivity to surface water are taken as ER (e.g., alluvial aquifer zones)</td><td rowspan="4">Where lands adjacent to the water body are disturbed, double the base setback width to provide improved buffering of water body or restore riparian lands to a condition that will allow it to effectively buffer the water body from pollutants</td></tr>
<tr><td>3rd order stream</td><td>Formed by two 2nd order stream tributaries (e.g. Nose Creek)</td><td>50 m</td></tr>
<tr><td>4th order stream</td><td>Formed by two 3rd order stream tributaries (e.g. Bow River, Elbow River)</td><td>50 m</td></tr>
<tr><td>Wetlands: Class III to VI (Stewart and Kantrud, 1971) (Stewart et al. 1971)*</td><td>III-Seasonal pond
IV-Semi-permanent pond
V-Permanent ponds / lakes
VI-Alkali ponds / lakes</td><td>30 m</td></tr>
<tr><td>Wetlands: Class I & II (Stewart et al. 1971)*</td><td>I-ephemeral pond
II-temporary pond</td><td>none</td><td>n/a</td><td>n/a</td><td>n/a</td></tr>
</table>

2.6.12 Calgary Biodiversity Strategy

The Biodiversity Strategic Initiative implementation plan was presented by The City of Calgary Parks in September 2011, in recognition that Calgary was reported to have one of the highest environmental footprints in the world. Biodiversity provides valuable ecosystem goods and services (e.g., clean air and water, quality habitat, experiential learning opportunities) and biological diversity is an important component of sustainable cities.

This initiative will integrate with Calgary's Municipal Development Plan, Open Space Master Plan, Wetland Conservation Plan and Natural Area Management Plan. Calgary will also sign *the Durban Commitment – Local Governments for Biodiversity* in 2012 which is a globally recognized commitment to promoting, increasing and enhancing biodiversity within administrative areas and integrating biodiversity considerations into all aspects of governance and development planning.

2.6.13 Stormwater Management Strategy

The Stormwater Management Strategy (SMS) was adopted by City of Calgary Council in November, 2005. It was created in response to:

- Environmental monitoring and modelling studies indicating the need to reduce sediment loads to the Bow River to meet regulatory requirements
- Increasing demands by downstream watershed stakeholders that Calgary take proportionate responsibility for watershed protection
- Recognition that stormwater ponds can be a resource (i.e., for irrigation) to reduce potable water demand during the summer months
- Growth-related demands on stormwater infrastructure, including the need for approximately 95 wet ponds and 30 dry ponds prior to 2015 in order to meet requirements for stormwater ponds in newly developing areas
- The need for expensive retrofits in older neighbourhoods prone to flooding during high intensity rainstorms, to provide increased service levels more in line with current standards for new subdivisions.

Key objectives of the SMS include (City of Calgary 2005e):

- Protection from flooding and erosion
- Protection of water quality
- Improving watershed hydrology by reducing stormwater runoff volume and peak flows through reuse and infiltration
- Proper operation and maintenance of facilities (e.g., cleaning of retention ponds)
- Appropriate stakeholder involvement
- Sustainable funding mechanisms

In contrast to the Stormwater Management and Design Manual, the SMS emphasizes source control practices where rainfall is returned to natural hydrologic pathways through infiltration and evapo-transpiration or is reused at the source. Source control is described as "a shift to a proactive approach that eliminates the cause of stormwater problems" (p.8). A development is defined as "low impact" if post-development runoff conditions mimic predevelopment rates and volumes.

The strategy also emphasizes the need for pollution reduction with stormwater treatment facilities such as wet ponds and constructed wetlands. In established neighbourhoods, where land for stormwater treatment is unavailable, retrofit options include purchasing land for stormwater facilities, constructing infiltration basins and bioretention areas, replacing impervious areas, and installing oil / grit separators.

2.6.14Total Loading Management Plan

The City of Calgary has established a Total Loading Management Plan (TLMP) to protect the Bow River from key pollutants (Kobryn, 2008). The plan facilitates joint strategies to manage pollutant loads originating within the city including non-point and point sources. From a riparian health and land use perspective, the most important water quality parameter is Total Suspended Solids (TSS). TSS values in the Bow River often exceed federal surface water quality guidelines. The objective adopted for TSS is an average value of 53,000 kg/day, based on the annual “clear flow” period (August 01 to May 31), including an average non-conformance frequency of one day per year. Actual loadings are not forecast to reach the total loading objective until 2018 or later. However, The City is striving to ensure TSS loadings from 2015 onwards are no higher than those corresponding to 2005.

Streambank erosion in urban areas causes non-point source TSS pollution loadings in many river systems (Dunne & Leopold, 1978), including the Bow River. Healthy, well-vegetated riparian areas can help prevent erosion as well as catch and filter sediment during floods. Consequently, riparian area function and health related to bank stabilization can be directly linked to the City’s TLMP. Maintaining healthy, deep-rooted plants in the riparian corridor as “green infrastructure” may be one of the cheapest, most effective methods to prevent sediment loading to the Bow River from increasing over time.

2.6.15 Streambank Stability and Riparian Assessment Project

The City of Calgary Streambank Stability and Riparian Assessment Project was recently completed by AMEC, the Alberta Riparian Habitat Management Society (Cows and Fish), and Terra Erosion Control (AMEC, 2012). Field work was conducted during 2010 and the final reports were dated February 2012. The project evaluated the condition of both streambanks along 115 km total channel length along the Bow River, Elbow River, Nose Creek, and West Nose Creek. The study documented existing conditions, identified erosion hotspots requiring remedial measures, and assessed and recommended options for remediating high priority sites. In addition to the contiguous analysis of all 115 km of channel length, the study also synthesized the results of riparian health inventory data collected by Cows and Fish from 2007 to 2010 in Calgary, including 59 riparian polygons setback from the stream channel to identify candidate riparian areas for restoration work.

Study components included:

- Project Summary document for Streambank and Riparian Stability
- Design Guidelines for Erosion and Flood Control Projects for Streambank and Riparian Stability Restoration
- A Triple Bottom Line (TBL) Analysis to evaluate environmental, social, and economic criteria for high priority sites. For example, environmental criteria examined in the TBL assessment included habitat flood damage costs, TSS reduction benefits, and bank / riparian health improvement benefits. The TBL also assessed “no project” scenarios for comparison. Related deliverables included:
    - TBL Prioritization Manual for Streambank and Riparian Stability
    - 2010 TBL Prioritization Summary Reports for Streambank and Riparian Stability Restoration, including:
        - Volume 1:Elbow River
        - Volume 2: Bow River
        - Volume 3: Nose Creek and West Nose Creek
        - Volume 4: Riparian Health Inventory Polygons (Cows and Fish report)
- A Geographic Information Systems (GIS) and geodatabase of existing and future erosion, flood protection and riparian restoration works. Included in the database are past and current condition assessments, references / links to relevant reports, photos, drawings, field inspections, estimated capital value, design information, retrofits, maintenance history and related data.

- 2010 Site Characterization Summary Reports for Streambank and Riparian Stability (4 Volumes as per above)
- 2010 Geotechnical Summary Report for Streambank Stability Assessment
- 2010 Conceptual Restoration Design Summary Reports (4 Volumes as per above)
- 2010 Stakeholder Engagement Summary for Streambank and Riparian Stability
- 2010 Streambank and Riparian Stability Assessment Map sheets
- 2007-2010 Riparian Evaluation Synthesis and Riparian Restoration Recommendations (Cows and Fish)
- 2007-2010 Riparian Health Inventory Summary Reports

Some key results from this study are shown in Table 5 and Table 6.

Table 5. Summary of Streambank and Riparian Sites Assessed and High Priority Sites Identified
Source: (AMEC, 2012)

Watercourse	Streambank		Riparian Polygon	
	Total Number of Sites	Number of High Priority Sites	Total Number of Polygons	Number of High Priority Polygons
Elbow River	95	28	16	3
Bow River	300	76	31	13
Nose Creek	15	9	6	3
West Nose Creek	28	21	6	2
Fish Creek	18	0	0	
Grand Total	**456**	**134**	**59**	**21**

Table 6. Summary of Benefit-Cost Ratios, Net Values, and Capital Costs for Prioritized Sites
Source: (AMEC, 2012)

Name	Total # of Sites Prioritized	Avg. Benefit-Cost Ratio	Prioritized Sites with Benefit-Cost Ratios Greater Than 1					
			# of Sites	% of Sites	Net Value of Sites		Capital Cost	
					Total	Average	Total	Average
Elbow River	19	1.00	10	53%	$2,788,641	$278,864	$5,400,875	$540,088
Bow River	72	1.39	36	50%	$7,285,584	$202,377	$6,749,399	$187,483
Nose Creek	9	1.24	3	33%	$525,573	$175,191	$980,816	$326,939
West Nose Creek	21	0.39	0	0%	$0	$0	$0	$0
Riparian Polygon	18	1.48	17	94%	$15,246,056	$896,827	$14,658,859	$862,286
Overall	**139**	**1.19**	**66**	**47%**	**$25,845,854**	**$391,604**	**$27,789,950**	**$421,060**

3. BACKGROUND LITERATURE REVIEW

This section reviews background literature that informs the riparian mapping tasks undertaken as part of this contract. Section 3.1 provides definitions for riparian areas. Section 3.2 discussed approaches others have taken to identify and map riparian areas. Section 3.3 discusses approaches to classify riparian areas. Section 3.4 discusses and presents cartographic and graphic design precedents for riparian area maps.

3.1 Defining Riparian Areas

The Alberta Riparian Habitat Management Society (Cows and Fish) defines riparian areas as: *"the portions of the landscape strongly influenced by water, and are recognized by hydrophytic (water-loving) vegetation along rivers, streams, lakes, springs, ponds and seeps."*

The Alberta Water Council Riparian Land Conservation and Management Project Team, Draft "Riparian Lands" Definition is slightly different as follows:

"Riparian areas are transitional areas between upland[1] and aquatic ecosystems. They have variable width and extent both above and below ground. These lands are influenced by and/or exert an influence on associated water bodies[2], which includes alluvial aquifers[3] and floodplains[4], when present. Riparian lands usually have soil, biological, and other physical characteristics that reflect the influence of water and/or hydrological processes."

[1]For the purpose of this definition, "upland" is considered to be the land that is at a higher elevation than the alluvial plain or stream terrace or similar areas next to still water bodies, which are considered to be "lowlands"

[2]A water body is any location where water flows or is present, whether or not the flow or the presence of water is continuous, intermittent or occurs only during a flood, and includes but is not limited to wetlands and aquifers (generally excludes irrigation works (Source: Water Act).

[3]For the purpose of this definition, alluvial aquifers are defined as groundwater under the direct influence of surface water (GUDI).

[4]For the purpose of this definition, floodplain is synonymous with flood risk area. The flood risk area is the area that would be affected by a 100-year flood. This event has a one percent chance of being equaled or exceeded in any year.

Another well-developed definition for riparian areas is provided by the United States Department of Agriculture's Natural Resource Conservation Service:

"Riparian areas are ecotones that occur along watercourses or water bodies. They are distinctly different from the surrounding lands because of unique soil and vegetation characteristics that are strongly influenced by free or unbound water in the soil. Riparian ecotones occupy the transitional area between the terrestrial and aquatic ecosystems. Typical examples would include perennial and intermittent streambanks, floodplains, and lake shores." (USDA, 2010)

One often-cited definition of riparian areas among North American resource management agencies is:

"areas with three-dimensional ecotones of interaction that include both terrestrial and aquatic ecosystems. They extend down into the groundwater, up above the canopy, outward across the floodplain, up the near-slopes that drain into the water, laterally into the terrestrial ecosystem, and along the watercourse at a variable width." (Ilhardt et al., 2000).

The Calgary Municipal Development Plan defines riparian areas as:

"…those areas where the plants and soils are strongly influenced by the presence of water. They are transitional lands between aquatic ecosystems (wetlands, rivers, streams or lakes) and terrestrial ecosystems."

The South Saskatchewan Regional Advisory Council's Advice to the Government of Alberta document defines riparian areas as:

"The area along streams, lakes, and wetlands where water and land interact. These areas support plants and animals, and protect aquatic ecosystems by filtering out sediments and nutrients originating from upland areas."

All of these definitions have similarities and are generally consistent with one another. Riparian areas are the "green zones" or transitional areas around water bodies, and are characterized by three main features:

- water is present, seasonally or regularly, either on the surface or close to the surface
- hydrophytic vegetation is present that responds to, requires and survives in abundant water
- hydric soils are present that have been modified by abundant water (either by high water tables, sediment deposition or by lush and productive vegetation)

Although all of the above information will be taken into consideration, the official definition adopted for the project is intended to be the Alberta Water Council definition in order to maintain consistency with provincial initiatives and guidelines.

3.2 Summary of Riparian Area Functions in an Urban Context

"*Riparian areas are often densely vegetated and serve as stabilization against the erosive forces associated with lotic systems. Riparian areas provide filtration for surface runoff from the surrounding land and protect the water quality of flowing streams. They trap sediment and reduce the velocity of stream flow, thus reducing erosion in downstream areas. These areas provide detritus to their associated aquatic systems as well as a moderating effect on surface temperatures*."

-Alberta Environment and Sustainable Resource Development (2010)

The importance of riparian areas far exceeds their relatively small area. Some of the most important functions provided by healthy, well vegetated riparian areas include pollution control, bank stability, flood mitigation, the provision of wildlife habitat and movement corridors, fish habitat support, nutrient cycling, recreational opportunities, aquifer recharge, and aesthetic amenities.

Importantly, in the context of Calgary and the Total Loading Plan, healthy riparian vegetation provides bank stability, slows floodwaters, traps sediment and prevents sediment mobilization into waterways (Dunne & Leopold, 1978; Waters, 1995). Bank erosion is often the dominant source of sediment where poor management practices have reduced the health of riparian areas.

Riparian areas also improve water quality by filtering non-point source contaminants such as nitrogen, phosphorus, and a range of other chemicals (Mayer, 2006; Braumann et al., 2007; Worrall et al., 2003) (Figure 24 and Figure 25). Upland areas adjacent to the riparian vegetation are also important for filtering and buffering both the riparian vegetation and the water body from pollution.

TSS, EROSION, AND RIPARIAN AREAS

Dense woody riparian vegetation reduces flow velocities and boundary shear stresses on floodplain surfaces during deep overbank flows. Where woody vegetation is sparse and the slope sufficiently steep, the floodplain surface is vulnerable to high rates of erosion during floods. One study has shown that dense shrubs reduce the boundary shear stresses on floodplain surfaces by up to three orders of magnitude (Griffin & Smith, 2004).

Figure 24. Visual of Suspended Solids Filtration by Vegetation *(Source: State of Oregon)*

To maximize the benefits of riparian buffers, a three-zone approach is now widely accepted, including (AEW, 2012):

- **Inner or Streamside Zone:** consisting of undisturbed vegetation along the bank intended to provide shade, and maintain the integrity of the bank and adjacent aquatic habitat
- **Middle Zone:** inland from the legal bank, to help filter sediments and pollutants, capture pollutants and recharge groundwater, and provide separation between the inner zone and adjacent development
- **Outer Zone:** intended to minimize encroachment of adjacent development and provide initial filtering of runoff

Riparian areas buffer the land from the water, and also the water from the land.

Stepping Back from the Water (AEW, 2012)

Although widening a buffer in an urban area may have less of an effect on water quality than widening a buffer in an agricultural area (AEW 2012, Wenger 1995), on the other hand, keeping development out of flood hazard areas can avoid widespread impact to human life and property.

Urbanization can directly eliminate riparian habitat and associated functions. In addition, loss of upstream wetlands, riparian areas, and pervious cover types tends to have cascading impacts on water quantity, water quality, and downstream riparian and stream health. Riparian health surveys conducted in Calgary in 2007 confirmed that areas downstream from heavier urbanization are characterized by loss of riparian health.

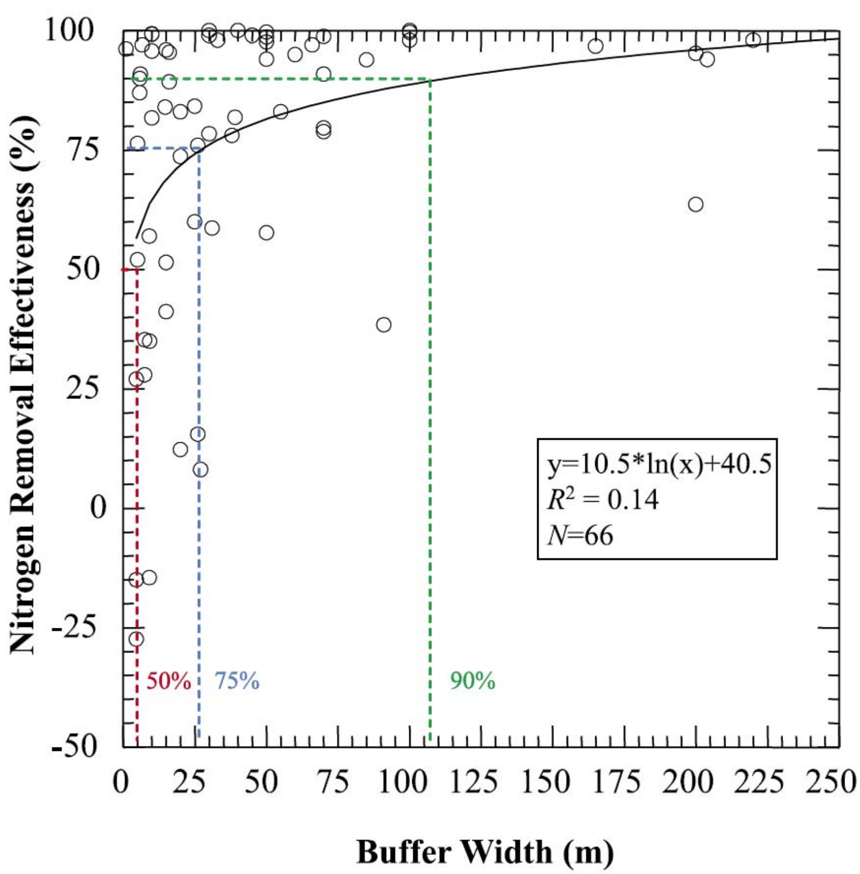


Figure 25. Riparian Buffer Width and Nitrogen Removal in Published Studies *(Source: Mayer et al. 2006) Coloured lines indicate 50%, 75%, and 90% removal efficiencies*

3.3 Identifying and Mapping Riparian Areas

> *"The focus of a riparian areas mapping project within an urban context should in large part be driven by the need to 'reframe' urban areas as part of the watershed."*
>
> *– Lorne Fitch, co-founder, Alberta Riparian Habitat Management Society (Cows and Fish)*

This section reviews the literature on field-based methods as well as semi-automated GIS-based methods for identifying and mapping the geographic location of riparian areas. In an urban context, where the signature of riparian vegetation is often erased by disturbance and weedy species, delineating the location of riparian ecotones can often be challenging; these issues have been carefully considered and integrated within the sections below.

3.3.1 Field-based methods

Riparian areas and related setbacks can be delineated in the field by professionals such as biologists and geographers. In Alberta, the two most commonly applied field-based delineation methods are the Cows and Fish Riparian Health Inventory methods, and the Riparian Setback Matrix Model which has been applied in several municipalities in northern and central Alberta.

3.3.1.1 Cows and Fish Riparian Health Inventory Methods

The Alberta Riparian Habitat Management Society (Cows and Fish) have developed a protocol for the purpose of identifying riparian polygons in the context of a field-based riparian health inventory.

To achieve representative sampling of riparian areas within a project area, the project area is initially stratified based on physical and vegetation features. Using air photo interpretation, stream or river systems are delineated into similar sub-reaches based on valley type / morphology, slope and sinuosity (Silvey et al., 1998). A proportionate number of riparian health inventory (RHI) polygons are assigned to each of these sub-reaches based on length.

Approximately one-third of the total stream / river length is assessed to achieve adequate representative sampling. Project areas are further stratified according to predominant land use, as determined through consultation with resource managers, local knowledge and air photo interpretation. A proportionate number of riparian health inventory polygons are selected based on stream / river length in each land use category. Final field delineation of RHI polygons is refined on the ground by the assessor to best represent land use types and the physical and vegetative characteristics of the stream (Fitch & Adams, 2001). RHI polygons are only assigned within land units with consistent land use and/or land management; assessment reaches do not cross fencelines, roads or other management boundaries.

For representative RHI polygons on smaller streams, the length of the reach assessed generally includes at least two channel meander cycles (Figure 26). For larger systems, generally multiple polygons are needed to best represent inside and outside meander bend conditions.

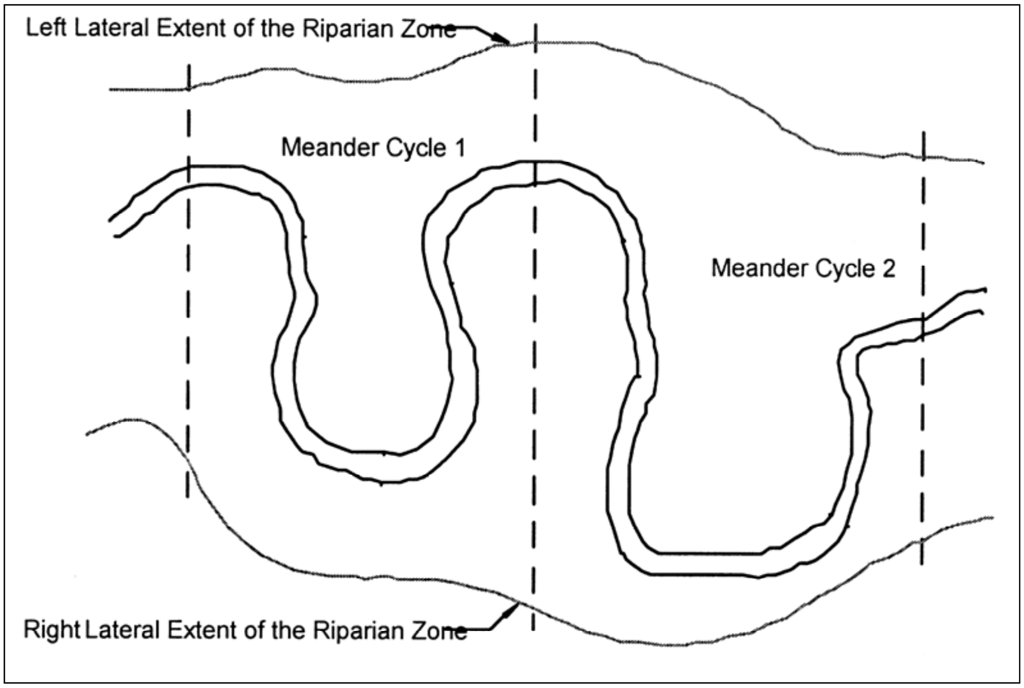


Figure 26. Stream Meander Cycle Diagram *Source: (Fitch & Adams, 2001)*

The locations of the upstream and downstream ends of the riparian polygon (site) are recorded with GPS and benchmark photographs facing upstream and downstream are taken at each end of the site. Additional photographs are taken to document features of interest or concern (e.g. weed infestations, bank erosion etc.).

The RHI assessment area starts at the water's edge and includes the portion of the wetted channel with persistent emergent vegetation (e.g. cattails and sedges). For those situations where there is no emergent vegetation, the wetted channel (aquatic zone) is not included in the assessment. A combination of indicators including vegetation changes, topographic breaks and flood evidence are used to delineate the outer boundary of the riparian area (Figure 27).

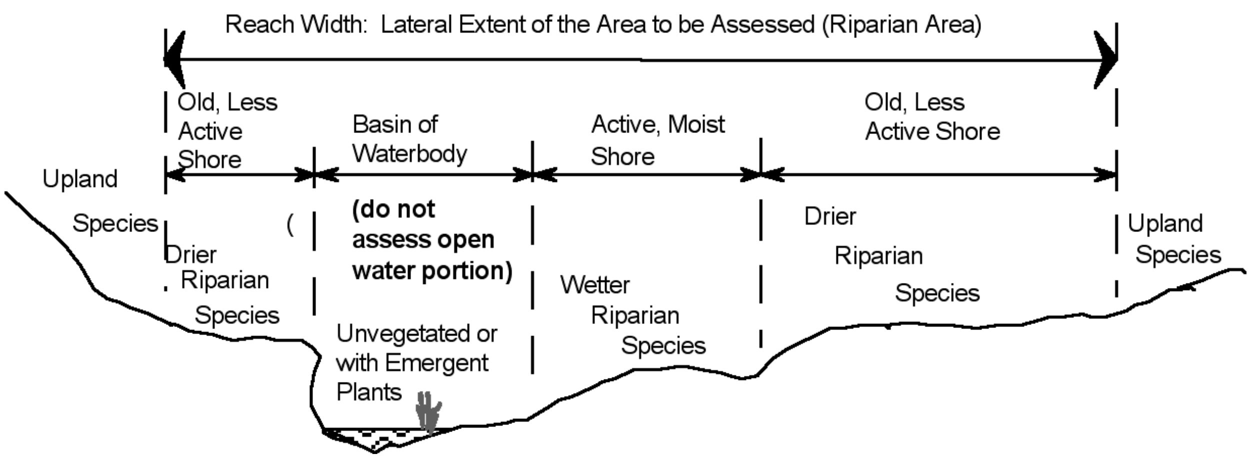


Figure 27. Cross Section Profile of Riparian Area Extent Adjacent to a Stream Channel

Local knowledge regarding flood extent and 1:100 year floodplain maps are used to help discern the extent of the flood-prone zone. For small streams, the flood-prone zone may be determined by measuring the bankfull channel depth, doubling this depth measurement and then projecting a line outward from this height (Figure 28).

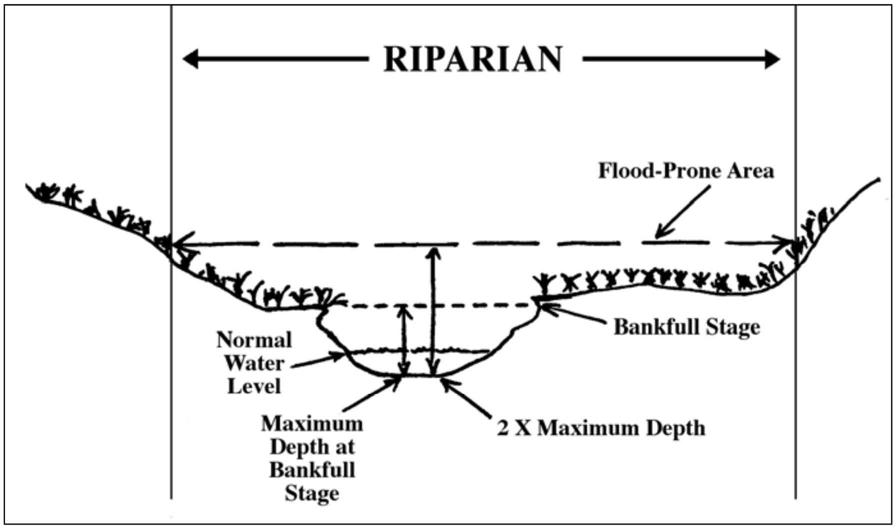


Figure 28. Flood-Prone Area Diagram for Small Stream Systems *Source: (Fitch & Adams, 2001)*

Due to human-caused disturbance of riparian vegetation indicators in Calgary and flood control infrastructure (berms / dykes), it is not always possible to easily discern the outer edge of the functional riparian zone. Many disturbed riparian sites in Calgary are dominated by non-native, introduced disturbance-caused vegetation or introduced tree and shrub plantings. In these situations, the lateral (outer) boundary of RHI sites is otherwise delineated based on topographic breaks or land use / management boundaries (e.g. fencelines, paved trails, roadways, etc.) that provide a means to more easily describe the lateral extent of the site for future monitoring purposes. In some cases this may mean that the extent of the riparian zone delineated during Cows and Fish RHI surveys may not entirely equate to the true 'functional riparian area'.

3.3.1.2 Riparian Setback Matrix Model

The Riparian Setback Matrix Model offers a site-specific approach to the development of riparian setbacks based on field-measured environmental parameters that include slope, height of bank, distance to groundwater table, vegetative cover, and soil texture / type (Aquality 2010). Environmental reserves are therefore inherently variable depending on these parameters.

In general, the following categories are used to determine the model in a given area.

Number and location of setback points – The location of the point is determined by the boundary between upland and wetland vegetation. The number of points will depend on the length of land bordering the riparian area. The setback distance parameters will be collected from these points. The final setback distances will be measured from these points after the matrix has been completed.

Slope of the land – The slope is determined at the setback point and the setback distance greater with increasing slope. Slopes greater than 10% may require a geotechnical survey.

Height of bank – A surveyor will determine the height from the setback points. The Environmental Reserve allocation is determined horizontally, perpendicular to the water body, stream or wetland from the setback point. The higher the bank results in a greater distance adjustment.

Depth of water table – This information can be gathered from a geotechnical report or data from a local well. There is a greater setback distance adjustment with a shallower depth to water table.

Type of vegetation cover – The setback distance is adjusted by the percentage of each cover type in a 1 m by 10 m area at the setback point. Areas that have impermeable surfaces or bare ground will require a greater setback distance than areas that have dense vegetation cover.

At this point in the assessment, a baseline setback distance is determined. In most cases, it reflects the maximum of the setback distances calculated in the previous steps.

Soil type and texture – Once this is determined by a qualified professional, a multiplier is applied against the baseline setback distance. In general, very coarse (gravel) or very fine (clay) material will result in an increase in the baseline setback distance.

The final setback distance is calculated from multiplying the baseline setback distance by the soil multiplier. The Environmental Reserve is generated by measuring this distance back from the setback points and connecting those points to create a polygon.

3.3.2 Semi-Automated Geographic Information Systems methods

Consistent evaluation of riparian areas over a broad study area requires automated spatial analysis for efficiency and consistency. While many riparian areas require some degree of field work to confirm small scale details, these efforts should generally be guided by remote sensing and spatial analysis. Semi-automated methods allow rapid delineation of areas, highlighting those which may benefit most from detailed expert assessment, while ensuring that time-consuming field work is not directed towards areas which have easy answers. The extent to which GIS may play a role in riparian area assessment highly depends on the nature of the available data. In areas with a good supply of high-resolution aerial imagery and terrain data, semi-automated GIS approaches can describe the landscape in greater detail than possible through field work and expert judgment alone. The principle limitation to these approaches arises from the data available. If existing elevation data is too coarse, then detailed assessment is not possible. If aerial photography is not available at sufficient resolution, interpretation or classification of landscape elements such as vegetation is unlikely to produce useful products. Similarly, if available data is from a period far in the past, then the data may not accurately represent current conditions, leading to inaccuracies. In any case, it is always prudent to follow spatial desktop analysis with field work ground-truth confirmation. This will ensure that field work is well-directed and that experts on the ground are well-versed in the specifics of the region before they begin.

Semi-automated GIS methods to delineate riparian areas can be based on fixed width buffer approaches, or variable width buffer approaches.

3.3.2.1 Fixed Width Buffer Approaches

Delineation of riparian management zones using GIS analysis is often accomplished by applying a standard-width buffer around previously mapped hydrographic features. Buffering is a simple and straightforward GIS procedure, and a fixed width riparian setback is easily transferable from GIS to the field or among different geographic regions. In many GIS environments, a fixed-width buffer may be the only choice permitted by time and resource constraints; a variety of studies have resorted to this method (Bentrup & Kellerman, 2004) (e.g., Bentrup and Kellerman 2004; Allan 2005; Alpine Environmental 2005; Dark et al. 2006) due to data constraints, study area size, or legal requirements. Some analyses adopted a different fixed width buffer setback for different stream orders, or for different watersheds; for example, Alpine Environmental (2005) suggested a 30m buffer for surface water bodies, and a 50m buffer around the Elbow River. However, while different widths may be assigned to different classifications of water bodies, these methods should still be considered fixed width buffers, as they do not vary the width in response to local conditions along the length of the water body, rather they are coarse classifications that apply to the water body as a whole.

While these fixed-width buffer approaches may be simpler to implement and enforce, they may result in gross inaccuracies when estimating amount of a land base that might be considered riparian (Aunan 2005). Fixed-width buffers may miss lands that are riparian, as when wide floodplains or low terraces extend beyond the standard buffer width. Alternatively, lands that are arguably not riparian can be included within a fixed-width buffer, such as lands that are spatially adjacent, but due to terrain are unable to contribute to the hydrologic functioning of the water body.

3.3.2.2 Variable Width Buffer Approaches

In circumstances that require or allow for a variable width riparian buffer, the question becomes how to best represent the true underlying ecological gradient which drives the establishment and persistence of the riparian ecotone. Fieldwork-based methods may be useful for small scale evaluations of riparian areas, but extensive assessment by trained field staff is impractical. Manual interpretation and digitizing of riparian areas can also be time consuming and requires good aerial imagery. For this reason, automated procedures which rely on available or easily collectable remote sensed data are preferred. In the absence of such thorough efforts, the most appropriate strategy is to adopt a 'functional approach' to delineation, by identifying the underlying environmental factors which affect the area. This 'functional approach' may be based primarily on stream valley geomorphology, using information on the terrain surrounding water bodies to assess the typical extent of inundation, which in turn drives the establishment and maintenance of riparian vegetation communities.

Vegetation Type and Density

In circumstances which allow for a thorough vegetation survey of the area, riparian boundaries may best be defined by the extent of riparian vegetation. Given the high level of disturbance to riparian plant communities in Calgary, vegetation layers do not always provide a good correspondence with the extent of the functional riparian area in Calgary except for protected natural areas or parks where native vegetation communities are intact. In disturbed areas, native riparian plant communities have been replaced by non-native introduced disturbance grasses / weeds / non-native plantings.

The existing condition, diversity and structure of vegetation can be a good indicator of the present riparian area. The absence of riparian vegetation from an area may indicate changes to the water table, disturbance from urban development, exclusion via competition from invasive species, or other undetected factors. This data may be available via field surveys, or derived from remote-sensed products such as aerial photography. Existing land cover data may be used, but often these classes are too coarse to be used for fine scale delineation of a large area.

Soils

Where available, soil information can also play an important role in understanding the hydrologic characteristics of the study area (Dark et al. 2006, Baker 2009, Abood and Maclean 2011, Haag et al. 2010, Tschaplinski and Pike 2009), as soil characteristics influence the retention time of incoming water, and control how the water leaves the area (by ground water infiltration or overland travel, for example).
This data is usefully incorporated into riparian area delineation, but is often not available at a sufficiently fine scale.

Terrain

The topography of the land surrounding the water body in question is of particular importance, as it has a direct control of the way in which water collects and drains. Deriving a slope raster from the Digital Elevation Model (DEM) is a straightforward operation, and often forms an important aspect of riparian area identification (Baker 2009; Caslys Consulting Ltd. 2009; Gabor et al. 2001; Hemstrom et al. 2002; Haag et al. 2010; Holmes and Goebel 2011; Illhardt et al. 2000; Laes et al. 2004; Lemoine et al. 2006; Mapili 2006). Hydrologic functions in the ArcGIS Spatial Analyst extension can be used to calculate flow direction and flow accumulation for the study area (Dilts et al. 2010).

The Floodplain

Using the DEM and historical records, a floodplain area can be defined, as the areas surrounding the water body that have or are likely to experience recurring flooding events (Baker 2009; Dilts et al. 2010; Mason and Maclean 2007; Abood and Maclean 2011; Aunan 2005; Alpine Environmental 2005; Caslys Consulting Ltd. 2009; Haag et al. 2010; Illhardt et al. 2000). This inundation greatly contributes to the development and maintenance of riparian vegetation communities. The most appropriate length of time over which to plan for high water flooding events may vary from place to place in accordance to the observed or historical severity of floods, but the 50 year floodplain is the most commonly chosen (Abood and Maclean 2011; Aunan 2005), however in some areas, planning around 100 year or even 500 year floodplains may be prudent (Baker 2009).

The nature of the floodplain surrounding a water body is a product of the magnitude and frequency of flooding events, and the constraints of the terrain, which affects how floodwaters are distributed across the landscape; narrow, steep walled valleys constrain flooding, while large open valley floors allow a similar volume of water to spread across a wider area. The soils that develop on the fluvial deposits of the floodplain reflect wet environmental conditions and show signs of periodic inundation. The unique assemblage of plant species and communities that establish in the floodplain are well adapted to these wet environmental conditions. This influence is a primary reason why a fixed width buffer will fail to adequately represent the true extent of the riparian area, as these fixed buffers do not consistently follow the floodplain.

Elevation and Height-Above-River

Changes in elevation relative to the height of the river play an important role in determining the degree of soil saturation, and therefore the distribution of riparian vegetation. As elevation increases, plant roots are forced to move deeper into the soil in order to access the water table. In a shallow valley with a broad floodplain, the relatively level ground surrounding the banks means plants growing in these areas are presented with similar growing conditions. In a steeper valley with a smaller floodplain, the rapid changes in elevation mean that soils are found increasingly removed from the water table, which leads to a more rapid change in vegetation. As this effect is a result of the distance from the water table, and not a product of absolute elevation, the challenge is to assess the ‘Height-Above-River’ (HAR).

Cost Distance Methods

A useful technique for riparian area identification involves the use of a ‘cost-distance’ function (Strager et al. 2000; Hemstrom et al. 2002; Dilts et al. 2010). This approach makes use of a DEM-derived slope raster to identify areas which will be inundated in response to rising water levels. Slope information is used to model the impact of terrain on the spread of water from the river. Shallow slopes allow a small increase in water volume to spread out and cover a broad area, while steeper slopes restrict the distance that water can travel away from the water body. A cost-distance analysis spreads outwards from the water body up to a specified unit-cost. Movement through a pixel costs 1 cost-unit, multiplied by the slope of the pixel. A flat area will cost zero, while an area with a 15% slope will cost 15. A cost threshold is used to limit the total spread away from the water body. However, this approach is limited by the potentially confounding influence of man-made dykes / berms. These sharp discontinuities have steep slopes on each side, and therefore the cost-distance approach may underestimate riparian extent, especially those structures placed very close to the water body.

Vegetation Classification

The nature of vegetation communities is a useful indicator of riparian areas (Laes et al. 2004; Dark et al. 2006; Gabor et al. 2001; Goetz 2006; U.S. Fish and Wildlife Service 1997; Evans and Graham 2009; Rabe and Calonje 2009; Shoutis et al. 2010; Weber and Dunno 2001; Hemstrom et al. 2002; Haag et al. 2010; Tschaplinski and Pike 2009; Illhardt et al. 2000). However, in the absence of extensive field surveys, vegetation classification via aerial imagery is necessary. Two principle sources of data informing vegetation classification can be derived from imagery: the pixel colour, and the local texture. Combined with additional information (HAR, soil type), this imagery information can be used to train a classification model, identifying different classes of ground-cover, which can then be verified using targeted field work.

3.3.2.3 Summary

Over 25 articles and papers on riparian area delineation were reviewed as a component of the study. Factors incorporated into the modelling approaches for these papers are summarized in Table 7. Trends and summary conclusions include:

- The majority of studies utilize DEMs of various accuracies including Light Detection and Ranging (LiDAR)
- Three separate studies referred to the 50-year floodplain as a descriptor of a riparian ecotone
- Most studies included either vegetation or soils in conjunction with elevation data; however, a difficulty lies in finding detailed soils or vegetation suitable for use with high resolution LiDAR data; this challenge is particularly difficult in urban areas where riparian vegetation signatures may have been erased due to disturbance or invasion by weedy species
- Possible data constraints may include the DEM resolution, flood history and peculiarities of individual drainage basins, differences in resolution and scale between different data sets, and differences between polygon stream and raster layers (the latter issue can be solved by deriving the river path from the DEM itself to prevent mismatches)

Table 7. Summary of Literature Review on Riparian Area Modelling in GIS

Citation	Factors Incorporated Into Modelling Approaches												
	Slope	Height above river	Vegetation classification	Floodplain	Stream/ drainage network	Imagery	Field verification	Soils	Fixed buffer	Land Cover	LiDAR	10m DEM	30m DEM
Abood and Maclean 2011				✓	✓			✓				✓	✓
Allan 2005					✓				✓	✓			
Alpine Environmental 2005				✓			✓		✓				
Aunan 2005		✓		✓	✓								✓
Baker 2009	✓			✓		✓		✓			✓		
Bentrup and Kellerman 2004					✓				✓	✓			
Caslys Consulting Ltd. 2009	✓			✓	✓					✓			✓
Dark et al. 2006			✓		✓	✓		✓	✓			✓	
Dilts et al. 2010		✓		✓							✓		
Evans and Graham 2009			✓		✓		✓						✓
Gabor et al. 2001	✓		✓							✓			
Goetz 2006			✓		✓					✓	✓		✓
Haag et al. 2010	✓	✓	✓	✓			✓	✓					
Hemstrom et al. 2002	✓		✓		✓	✓	✓					✓	
Holmes and Goebel 2011	✓				✓								✓
Illhardt et al. 2000	✓		✓	✓	✓		✓						
Laes et al. 2004	✓		✓			✓	✓						
Lemoine et al. 2006	✓				✓	✓	✓						
Mapili 2006	✓				✓								
Mason and Maclean 2007				✓	✓							✓	✓
Rabe and Calonje 2009			✓			✓				✓	✓		
Shoutis et al. 2010			✓				✓				✓	✓	
Tschaplinski and Pike 2009			✓		✓			✓					
U.S. Fish and Wildlife Service 1997			✓			✓							
Weber and Dunno 2001			✓			✓				✓			

4. METHODOLOGY

This section reviews the methods applied by O2 in the project, including those related to identifying, gathering, and reviewing data, developing and managing a geodatabase, conducting variable width riparian modelling, classifying riparian areas, determining grouped themes for mapping exercises, mapping the Calgary ER Setback Policy for riparian areas, and overlaying and combining elements for statistical analysis purposes.

4.1 Gathering and Reviewing Data

During initial stages of the project, existing data and information was identified, requested, discussed, and reviewed for context and applicability to the project. Data sources were provided by The City of Calgary Water Resources, The City of Calgary Parks, The City of Calgary Land Use Planning and Policy, The City of Calgary Infrastructure and Information Services, and other parties.

Incoming data was tracked against the originally requested items using an Excel Spreadsheet. This spreadsheet included key information such as file names (if known), contact person, contract organization, most applicable project phase, map scale and requested date. Received data was entered into the spreadsheet with date received and its new file location on the O2 GIS servers.

The data spreadsheet was periodically distributed to the steering committee to help identify any outstanding data requests that could potentially delay mapping and analysis. As map templates were refined, data was assigned to a series of proposed map themes. Originally, ten themes were proposed but this was eventually narrowed down to the following three broad map themes within which data were grouped into a further series of sub-themes:

- Theme 1 – Riparian Area Location and Function
- Theme 2 – Land and Regulatory Issues
- Theme 3 – Existing Infrastructure and Utilities

The data tracking spreadsheet was a critical tool due to the large amounts of data, both spatial and non-spatial that was received for this project. It served several key roles including that of request tracking, data inventory, geodatabase development and management, and map assignment. In total, over 185 potentially relevant data layers were identified and requested, and the majority of these were received and reviewed during February 2012 to March 2012.

4.2 Variable Width Riparian Modelling

In the absence of detailed and comprehensive hydrographic, soil and vegetation field surveys, a GIS-based spatial model provides the best estimate of the extent of riparian areas around notable water bodies. By using a digital terrain model, topographical influences on riparian conditions can be estimated across the entire study area using a cost-distance approach. Using GPS data collection, field personnel then collect a series of sample points representing the riparian vegetation edge under natural riparian to upland transition for each water body. GIS is then used to delineate appropriate boundaries that best match field observations.

In the GIS, all areas with cost values less than the observed threshold are grouped together. The result is an estimate of the riparian extent surrounding each water body. Within this boundary, four classes are further defined based on the statistical distribution of field points as follows:

- **"Inner Riparian Zone":** this area directly adjacent to the stream exhibits the lowest cost values and is therefore virtually certain to be riparian
- **"Middle Riparian Zone":** this zone contains areas with strong potential to contain riparian features; although in some cases riparian conditions may not arise
- **"Outer Riparian Zone":** this area is riparian if conditions are right, but in other cases will not show riparian characteristics, although it still functions as an important interface between riparian areas and the surrounding uplands

- **"Potential Outermost Riparian Zone":** represents areas that are typically *not* riparian but in some cases may be, requiring further detailed investigations

The first three zones contain areas with strong potential to contain riparian features or an important riparian interface zone, while the fourth zone identifies areas which require field verification as to its riparian nature.

Additional details on the variable width modelling procedure are provided below.

4.2.1 Stream and River Polylines

The provincial Strahler Stream order dataset was initially used as the source of stream locations. The Bow and Elbow riverbank lines from the HydroNet dataset were used for these two large rivers, as the wider nature of these higher order water bodies make the use of centre-lines unrealistic when conducting riparian delineation.

For many of the smaller order streams and rivers such as Pine Creek and Forest Lawn Creek, the provincial stream vector layer contained visible mismatches between the stream vector and the actual location of the channel on the aerial photography. Therefore, it was considered necessary to digitize the actual location of the stream channel based on the aerial photo (Figure 29). This was undertaken to improve the inputs of the riparian cost distance model, and consequently, the accuracy of the model outputs. Oxbow wetlands within river valley bottom corridors were also digitized so that the riparian cost distance model would spread from those features as well (Figure 29 and Figure 30).

4.2.2 Cost Distance Analysis

Using the best available Digital Elevation Model data (1m DEM[2] along the Bow and Elbow Rivers, 10m DEM used elsewhere), a slope raster was produced, which indicates the steepness between each pixel and its neighbours. Flat areas have slope approaching zero, increasing with the elevation difference with the surrounding pixels. The slope raster forms the cost layer used in a cost-distance analysis, a technique which produces a raster layer which denotes the slope-weighted distance from each segment. As distance from streamlines is radiated outwards, the total cost for each pixel is calculated as the sum of the slope values in each pixel, multiplied by the pixel unit distance (Figure 31). A separate cost-distance raster was created from the 1m and 10m DEM data.

4.2.3 Field Observations

Field verification was used to establish appropriate thresholds for each stream, by collecting GPS points along the boundary of existing riparian vegetation types). Field work for all streams was conducted during June 2012 by O2 staff, with some assistance from Cows and Fish staff. All streams were sampled in the field on publicly accessible lands, except for Forest Lawn Creek where there was a lack of access due to ongoing construction of the Ring Road. In lieu of direct access, interpretation of existing orthoimagery combined with the previously mapped Riparian Health polygons from Cows and Fish were used to create points for the riparian edge of Forest Lawn Creek. Where necessary due to access restrictions (e.g., Pine Creek), riparian observations were taken outside the city limits in similar conditions as those found within the city.

Figure 32 depicts a map of the location of all riparian edge field observations. A total of over 175 point locations were obtained at the edge of riparian areas along rivers and streams. GPS point locations were recorded at the edge of the existing riparian area, as denoted by visible changes in vegetation composition. Presence of balsam poplar, willow, water birch, in addition to riparian shrub and grass species typical to Calgary were some of the most typical riparian indicator species (e.g., Table 13).

Field observation points were located strategically, so that the riparian edge represented a "natural" transition between a riparian plant community type and an upland plant community. In other words, locations with an abrupt transition from riparian to non-riparian due to infrastructure (roads, pathways, houses, turf, etc.) were avoided. The intention was to identify the true riparian extent in the absence of alteration, which has a range of

[2] Provided by the City of Calgary, this was derived based on a combination of a raster DEM combined with ground survey points

benefits including the ability to subsequently determine how much riparian area has been lost to past development. However, this was not always straightforward, as in some locations (e.g., Confederation Creek), virtually all natural vegetation patterns had been altered.

In addition, locations close to where lower order streams feed into the main stream were avoided, as the runoff from these streams made it difficult to ascribe the existence of riparian vegetation solely to the influence of water from the Bow River.

Figure 29. Sample Screenshot: Digitization of Stream Vectors to Improve Accuracy (light blue and orange lines)

Figure 30. Sample Screenshot: Digitization of Oxbow Wetland Vectors in the Nose Creek Corridor (light blue and orange lines)

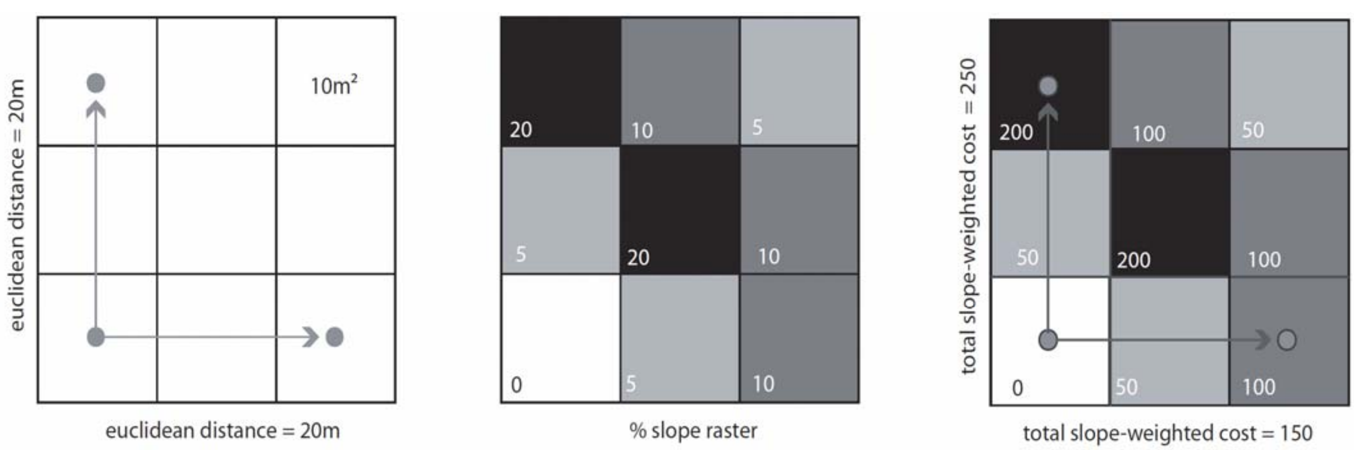


Figure 31. Illustration of the Cost-Distance Raster Modelling Approach for a 10 m DEM

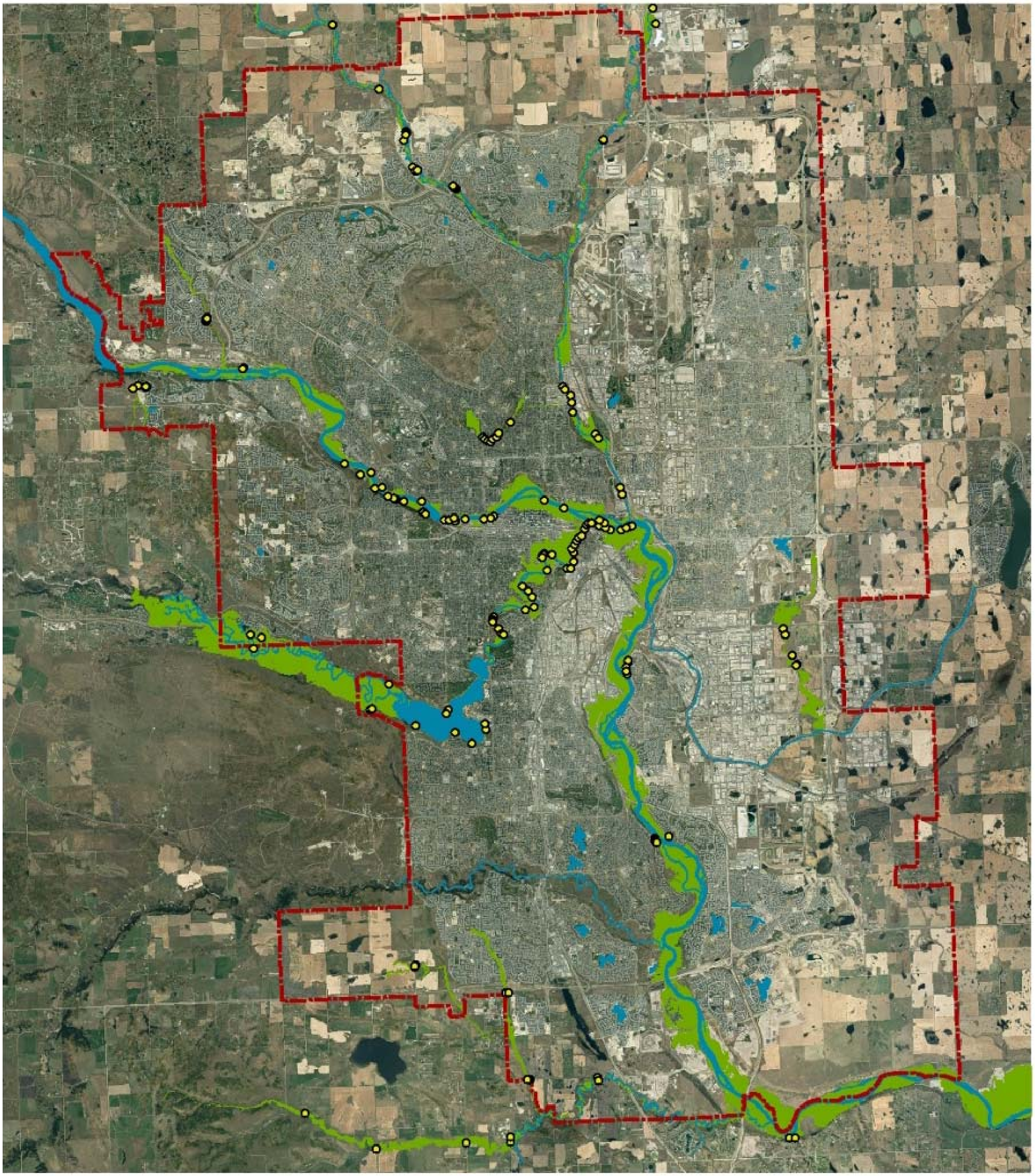


Figure 32. Location of 175 field observations conducted to support variable width riparian mapping using a cost-distance threshold approach

4.2.4 Riparian Extent Delineation

The cost-distance raster surface was intersected with the field-derived GPS riparian edge points in a GIS, and the statistical distribution of cost threshold values along the observed biophysical riparian edge was analyzed to determine the appropriate riparian extent.

Statistical analyses were used to generate a series of threshold values derived from the field work analysis, and the cost-distance raster was then reclassified into a four class raster. Classes were based on the first, second, third, and fourth quartiles of the cost distance raster values observed at the riparian edge during the field sampling. Field sampling statistics for each of the individual streams were used to generate the four zone classification system. A separate riparian extent is delimited for each stream to account for the observed major differences between watercourse riparian extents.

The four class raster generated from the statistical analyses described above was converted to polygons in the GIS model. The separate riparian shapefiles were merged together to form a single dataset. Following this, any small polygon holes in the data were filled using a union / no gaps procedure in the GIS.

4.3 Mapping the Calgary ER Setback Policy

The City of Calgary's ER Setback policy establishes base riparian setbacks based on stream order. Adjustments to these setbacks are then applied based on adjacent slopes, hydraulic connectivity and cover type. For this project, one of the primary goals was to map the ER setback policy extent for all in-scope rivers and streams within the City boundary.

ER setbacks are currently calculated in the field on a site-by-site basis during the process of planning and subdivision. The field procedure is summarized as follows (personal communication from George Stalker – Natural Areas Project Coordinator – Parks, Planning and Development):

- Measure slope perpendicular from the edge of the water body to the maximum extent of the base setback (e.g., 50 m)
- Round slope along this length to the nearest % value (e.g., 5.4% measured = 5% and 5.6% measured = 6%)
- Add 1.5 m of setback distance for every 1% of slope above 5% to the base setback

There is currently no city-wide map showing the boundary of these ER Setbacks. Therefore, a GIS model was developed to create slope modified ER setbacks for all in-scope rivers and streams identified. This was conducted city-wide, regardless of whether areas had been subdivided and zoned yet or not.

Note that, currently, hydraulic connectivity to groundwater under the direct influence of surface water as well as cover type adjustments are not reflected in the ER Setback Policy conducted by O2. The rationale for this is that connectivity to groundwater is based on travel time and it would be too speculative to model this without more detailed, site-specific hydrogeological data. In addition, the cover type setback is a difficult variable to model up front, as the ER Setback Policy provides developers with the option to restore natural cover conditions rather than take additional setback if cover conditions are poor. As it is impossible to predict, on a site-specific basis, which option a developer would be willing to pursue, the adjustment factor for cover condition was not modelled at this point in time.

Note that, despite the utility of the automated model, full application of the ER Setback policy in practice necessitates a case-by-case examination of site conditions, including adjustment factors based on hydraulic connectivity as well as cover type.

4.3.1 Description of Calgary ER Setback Policy GIS Model

The ER setback policy GIS model maps the base riparian setbacks and additional slope-based offsets. The starting point is the custom stream and river bank GIS vector dataset created by O2. The assigned Strahler stream order values were based on the accepted Alberta Environment and Sustainable Resource Development values assigned to streams provincially as this was considered to be the most defensible manner to assign stream order (e.g., least open to interpretation and critique).

The base ER setbacks were created using a simple buffer operation based on the stream order values:

1st order stream = 6 m (from bank or each side of stream centerline)

2nd order stream = 30 m (from bank or each side of stream centerline)

3rd order stream = 50 m (from bank or each side of stream centerline)

Buffers were generated on each side of stream vector centerlines and up the bank from river shoreline vectors (Figure 33).

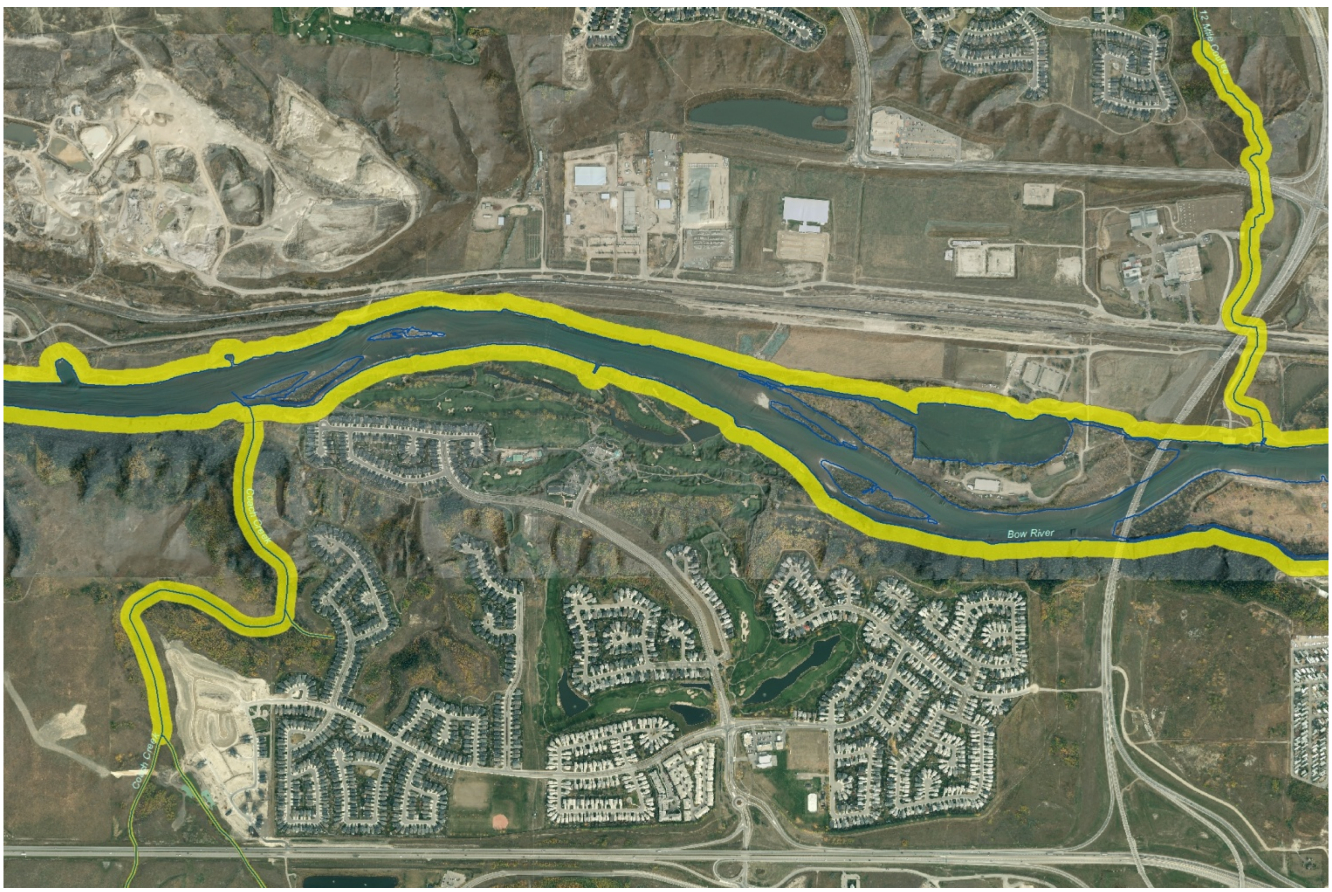


Figure 33. GIS model of base ER setback requirements (based on Strahler stream order only)

Slope modifications to the basic riparian setbacks were calculated as an additional buffer based on average slope values within sample polygons. Sample polygons were created from a segmented version of the stream centerline and river bank vector file created in an ArcMap edit session using the Edit – Divide function. The stream and bank vectors were divided on a stream by stream basis into 10m long stream segments. The 10m value was chosen as a workable compromise that would provide sufficient detail without requiring excessively long processing times.

Sample buffers were radiated out from the segments to the appropriate stream-order based setback distance. Buffers were radiated out from both sides of stream vectors and in the upslope direction from riverbank vectors. Each sample buffer was assigned a unique ID number. In areas of complex stream or bank geometry some overlapping of buffers occurred. Any major conflicts were removed via manual editing. Other overlaps provided a way of sampling complex slope features from multiple angles and as such were retained.

Sample buffers were loaded into an ArcMap document along with a slope % raster (calculated from 1m DEM data). Where 1 m data was not available (primarily outside the main Bow and Elbow river corridors) a slope % raster calculated from a 10 DEM layer was used. The ArcGIS Spatial Analyst Zonal Statistics as Table function was used to extract the average slope within each sample buffer and populate the results into a table. This table was then joined to the sample buffers polygon files based on the Unique ID field values created previously (Figure 34).

Figure 34. Sampled average slope values extracted from 1m DEM

The additional slope setbacks are triggered when slopes exceed 5%. A new slope setback field was added to the sample buffer files (now populated with mean slope %) and calculated as per the City slope adjustment policy which specifies an extra 1.5 m of setback distance for every 1% of slope above 5%.

*(Mean Slope value – 5) * 1.5*

All slope values equal or less than 5% were given a slope setback value of zero. All samples with above 5% mean slope had the slope setback field calculated with the above formula.

The final slope modified ER setback was generated by buffering based on the distance value calculated in the slope setback field. The resulting buffer matches the base riparian setback in areas of less than 5% slope but expands out beyond that limit when slopes exceed this value (Figure 35).

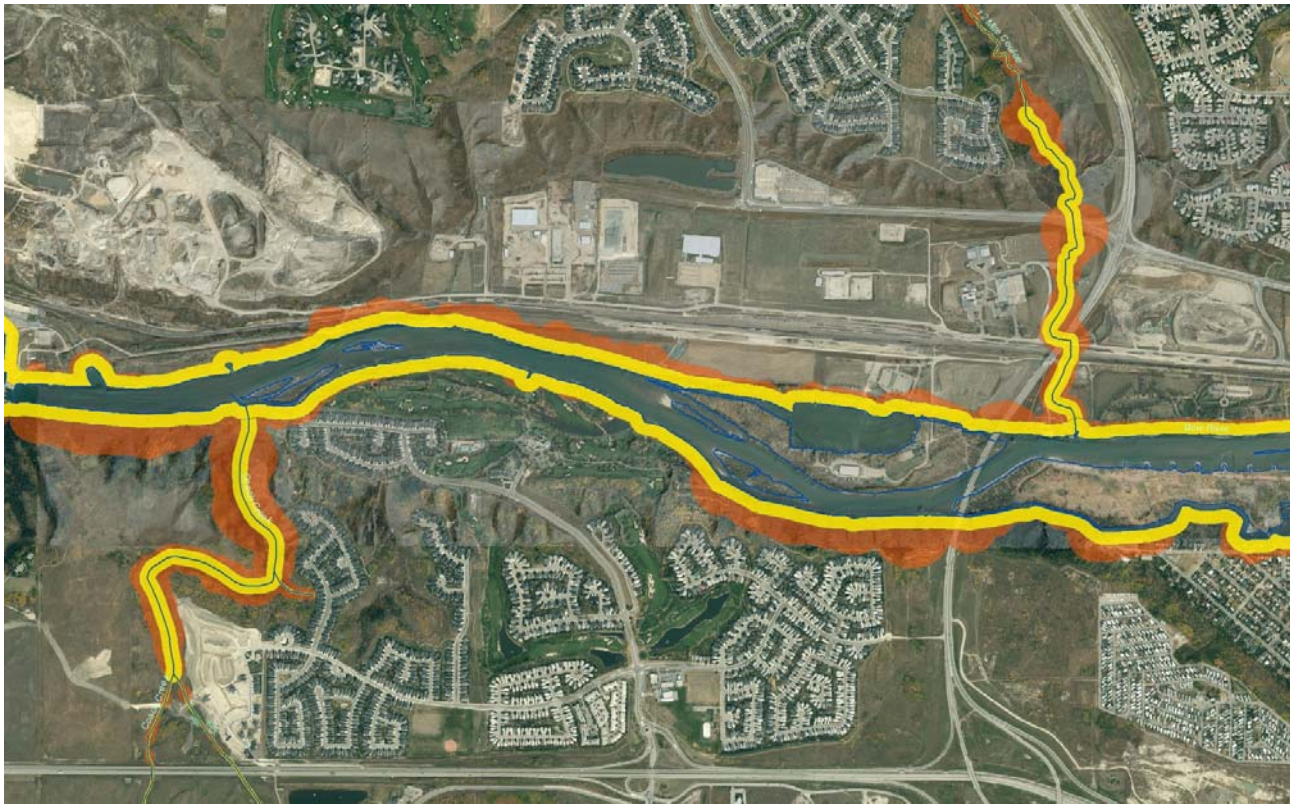


Figure 35. Basic riparian setbacks (yellow) and slope modified riparian setbacks (red)

5. RESULTS AND DISCUSSION

This section reviews and briefly discusses key points from the results of the analyses and mapping conducted as part of the project. Section 5.1 provides an overview of the map and geodatabase contents. Section 5.2 describes the variable width riparian model outputs. Section 5.3 describes land and regulatory issues within riparian areas.

5.1 Overview of Map and Geodatabase Contents

The final maps required considerable experimentation and an iterative process to achieve a balance between the density and amount of information displayed and the clarity and interpretability of the maps. The resulting thematic content of the maps were grouped into three themes:

- **Theme 1 - Riparian Location and Function**
- **Theme 2 - Land and Regulatory Issues**
- **Theme 3 - Existing Infrastructure and Possible Improvements**

Many subthemes under each theme were also identified by the project team. However , eventually some of these needed to be removed from the printed maps, so as to represent the information with minimal confusion and interference between layers to maximize legibility and clarity. Table 8 summarizes the nested themes and subthemes displayed on the final cartographic .pdf deliverables for Phase 1. In cases where subthemes are not displayed, a rationale and explanation is provided under the “comments” column.

The appropriate scale to represent as much detail as possible, while minimizing the need for a very large number of cumbersome map sheets also required considerable experimentation. The conclusion of this process was the creation of 58 separate colour .pdf maps at a scale of 1:7500, printed on 11” x 17” sheets. Depending on the orientation of the river, either a "landscape" 11" x 17" sheet (predominantly east-west orientation) or a "portrait" 17" x 11" sheet (predominantly north-south orientation) was specified. A master city-wide map showing the location of all .pdf maps is shown in Figure 36.

In addition to the printed map deliverables, O2 will also provide a geodatabase as part of the final project deliverables.

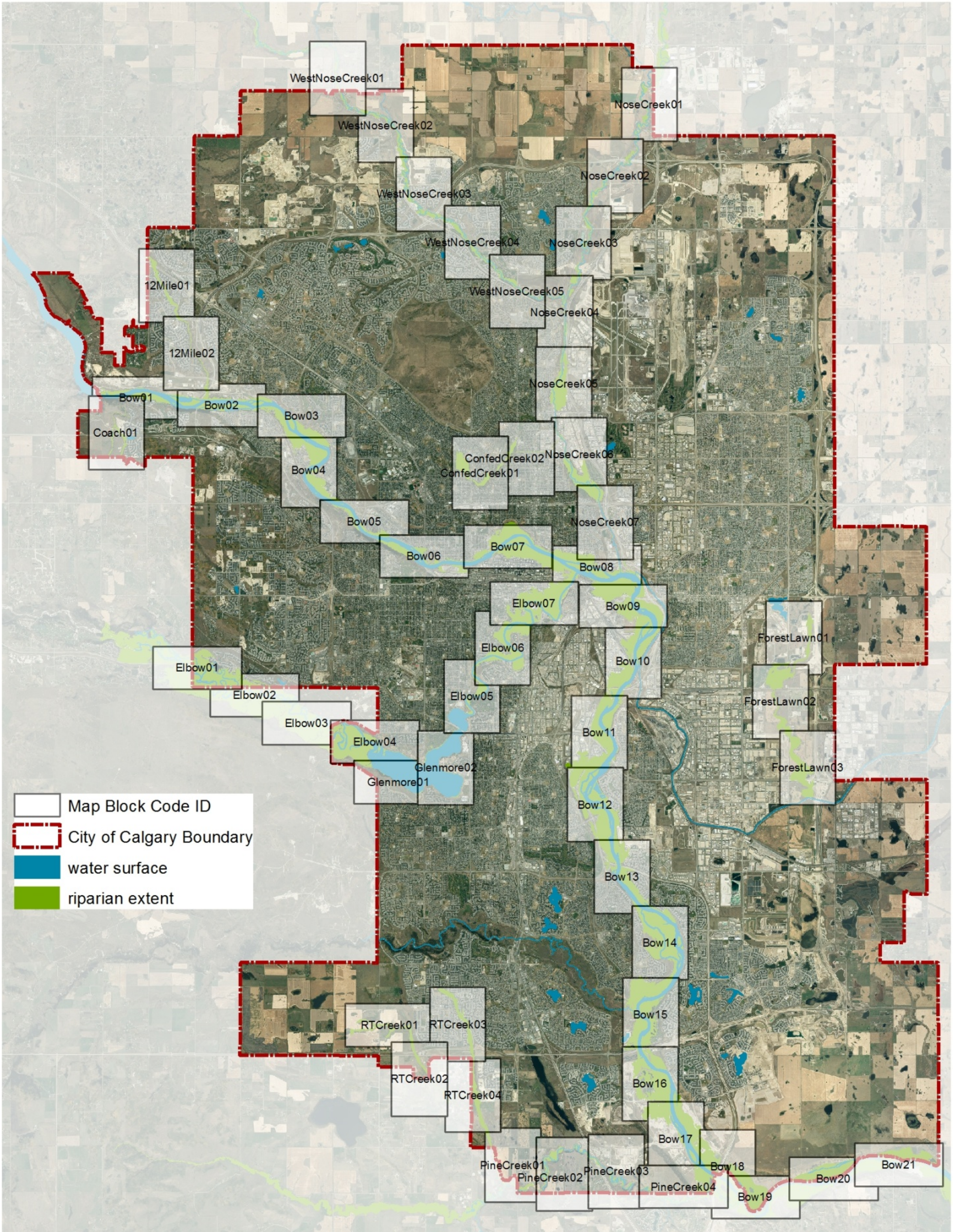


Figure 36. Map Sheet Key for Detailed 1:7,500 Scale Maps

Table 8. Riparian Map Themes and Subthemes: Summary and Notes

Subtheme	Description	Cartographic Output (.pdf)? (Notes)	Geodatabase and Potential Web Mapping Application?
THEME 1: RIPARIAN AREA LOCATION AND FUNCTION (where is the riparian area and how useful / functional is it today?)			
Extent and location	Variable width setback model outputs	**Yes** -Displayed on Theme 1, with three-zone details and a potential area for further investigation (*Note: Edge of zone 3 (outer riparian zone) also displayed on Themes 2 and 3 for contextual comparison*)	Yes
Soil information	Soil classification – Soil Survey of the Calgary Urban Perimeter (MacMillan, 1987), as well as other City data	**No** -Not critical and creates cartographic confusion -Spatial resolution and accuracy is coarse and there are obvious mismatches in location	Yes
Aquifer	Alluvial aquifers based on a recent 2010 Alberta Research Council study completed for the city for upstream portions of the Bow and Elbow rivers, as well as available regional geology mapping information (Moran, 1986)	**Yes**-but only city-wide map -Large extents in some areas do not overlap with floodplain or riparian areas	Yes
Habitat/biological information	Plant communities (Parks PARIS updated habitat data, Calgary Annexation Territory data, potential Cows and Fish plant community data in RHI polygons) Wildlife movement (requires a model to be developed-potential scope for Phase 2)	**No** -Creates confusion with other layers -non-contiguous data layers with many gaps -Inconsistent classification schemes It is recommended to continue to pursue and refine an image segmentation vegetation classification, in combination with the City-led eCognition urban forestry initiative	Yes
Erosion hotspots	Obtained from the AMEC study to maximize synergies	**No** Moved to Theme 3 Maps as they are indicative of potential capital improvement opportunities	Yes
Fish habitat / spawning data	Incorporate existing information from ASRD / Golder fish habitat study for context	**No** -Originally shown but was removed because of sensitivity of the information, concerns that data may be out of date because the 2005 flood moved substrate around, incomplete coverage, and essentially not “riparian” as it is in the stream channel itself	Yes but need to consider possible restricted passwords for specific users
Existing riparian health data and conditions	GIS data from AMEC / Cows and Fish Geodataset (Including health scores (i.e., *healthy, etc.*) and boundaries of assessed polygons	**Yes** -Shown as cross-hatching with three different colours based on overall health scores	Yes but need to consider possible restricted passwords for specific users
Existing streambank health data	Including health scores (i.e., *good, moderate, poor*). AMEC (2012) Geodataset.	**Yes** -Shown as thick solid lines colour coded based on bank health scores	Yes but need to consider possible restricted passwords for specific users
THEME 2: LAND AND REGULATORY ISSUES (Who has control, interest in riparian lands and what is constrained and protected?)			
Land ownership / stewardship	Private vs. public	**No** -Attempted to roll up land use layer to public vs. private but there were some inconsistencies, finer scale details missing, and potentially misleading information -However, in general most of the parks / rec zones, “Major Infrastructure”, and many of the institutions are publicly owned	N/A
Land use	Generalized land use (Residential-High Density, Residential-Medium Density, Residential-Low Density, Commercial, Industrial, Institutional, Mixed Use, TUC / Major Infrastructure, Parks /	**Yes** -Displayed using cross hatching -The large number of “Direct Control” zones did not provide information on the general type of use; to address this considerable	Yes

Subtheme	Description	Cartographic Output (.pdf)? (Notes)	Geodatabase and Potential Web Mapping Application?
	Rec, Future Urban Development)	hand editing and interpretation based on imagery by O2 was required to create a consistent and more useful layer for interpretation and city-wide summaries. Consequently, this layer is *not* zoning as all of the "DC" zones were reclassified by O2 for summary purposes.	
Land use constraints: Floodway / Flood Fringe	Floodway / Floodplain restrictions in current LUB (*Note: this is **not** the updated floodway / floodplain based on the 2011/2012 study-see below)* Also, the 100 Year flood extent for Nose Creek is displayed, (as delineated by Westhoff Engineering and appearing in the Nose Creek Watershed Water Management Plan)	**Yes** -Displayed as semi-transparent underneath the cross-hatched land use. Nose Creek 100 Year flood extent is symbolized separately	Yes
Flood plain boundaries / flood risk areas	There is a new Golder HEC / RAS updated floodplain study for Calgary, but this is confidential information and cannot yet be displayed on a map until all issues and complexities have been sorted out.	**No** Only one floodplain boundary should be shown on this map. Until further policy direction is provided it makes more sense to include the approved boundary currently depicted in the Land Use Bylaw.	Potentially but need to be aware of confidentiality issues and potential requirement for password restrictions.
Land use constraints: steep slopes	Steep slopes >15%	**No** -Attempts were made to include these but they increased the visual complexity of the map and were eventually removed	Yes
Nose Creek meander belt	From NC WMP	**Yes** -But only relevant for the Nose Creek corridor	Yes
ER setback policy mapping	As discussed elsewhere in the report, the model, created and run by O2, represents the base setback and slope modifier, including both zoned and unzoned lands	**Yes**	Yes
Provincial policy and guidelines mapping	The new recommended setback guidelines in the released 2012 provincial "Stepping Back from the Water" document were considered. Restricted Activity Periods (RAPs) for fish under the Code of Practice for Watercourse Crossings was also considered	**No** There are no shape files representing the provincial setback guidelines. Although this could potentially be modelled, it may be complex and may also create conflicting and confusing information on the maps. The RAPs are available from provincial hard copy maps and O2 has not yet approached the province about potentially including this on the maps.	Yes
General Area Structure Plan information	During email communications and follow-up, LUPP was unsure about what level of detail would be appropriate	**No** The City project contact from LUPP did not recommend using this for the project and/or did not have time to provide this information at an appropriate level of detail to fit the project.	To be discussed and revisited during Phase 2
THEME 3: EXISTING INFRASTRUCTURE AND POSSIBLE IMPROVEMENTS			
Infrastructure-Buildings	Building footprints	**Yes** Opaque gray polygons	Yes
Infrastructure- Roads	Major Roads as provided by City of Calgary data	**Yes** Dark black vector lines (*Note: also displayed on Themes 1 and 2 as base layers*)	Yes
Infrastructure-Railways	Railways as provided by City of Calgary data	**Yes** Standard railway vector line in black (*Note: also displayed on Themes 1 and 2 as base layers*)	Yes
Infrastructure-Stormwater Outfalls	Storm Outfalls shown as provided by City of Calgary data	**Yes** Bright orange circles	Yes
Infrastructure-Stormwater Ponds	Existing storm ponds as provided by City of Calgary data	**Yes** Bright blue-however several stormwater ponds on the edge of Calgary are missing	Yes
Infrastructure-Existing	From city-provided data and AMEC	**Yes**	Yes

Subtheme	Description	Cartographic Output (.pdf)? (Notes)	Geodatabase and Potential Web Mapping Application?
Bank Infrastructure	Geodatabase, includes rip rap, gabions, retaining walls, weirs, etc. Note that Harvie Passage and Bow River Weir is missing in the data and was added from a separate individual AutoCAD file	Shown as solid pink lines. CAD linework and label was added to denote Harvie Passage	
Maintained turf grass	Turf (city owned and maintained) as documented by City of Calgary data	**Yes** Shown as dark green	Yes
Existing storm retrofit pond	New GIS layers created for existing stormwater ponds (As per May 15 spreadsheet). Ponds digitized from airphoto or pulled from Site boundary shapefiles. Future stormwater ponds (As per May 15 spreadsheet) created from custom merge of site boundary shapefile polygons. Mapped as two new layers: "Existing Storm Retrofit Pond" and "Possible Location of Storm Retrofit Pond" Subsequent discussion Sept.13th identified locations with very low probability of construction that were removed from final maps	**Yes** Shown as cross-hatched light blue to differentiate from stormwater ponds not constructed based on this program	Yes
Possible Location of Storm Retrofit Pond		**Yes** Shown as light green cross-hatching	Yes
Pathways	Pathways including paved trails and gravel trails	**Yes** Paved trails and gravel trails are symbolized differently	Yes
Candidate flood and erosion protection sites / works	Information sent by Lily Ma via email March 30th Note that there are also sites identified in the West Nose Creek Stream Corridor Assessment (Westhoff 2003) which are not currently included	**Yes** Shown as bright green triangles Notation also displayed on the map	Yes
AMEC priority sites	From recent AMEC study	**No** -Left off for now as it seemed too redundant with Theme #1 riparian polygons and bank stability hotspots. Also may be more suitable for a city-wide summary map as part of Phase 2 as well as web mapping as opposed to being included on this map	Yes
Siphons	Selected from CALGIS base layer	**Yes**	
Stormwater Pipes	Selected from CALGIS_STORM_PIPE GIS layer	**Yes-but only if >900 mm**	
Sanitary Pipes	Selected from CALGIS_SANITARY_PIPE GIS layer	**Yes- but only if > 600 mm**	
Water Main Pipes	Selected from CALGIS base layer	**Yes- but only if > 400 mm**	

5.2 Variable Width Riparian Model Outputs

This section summarizes the results of the variable width riparian model outputs, with a focus on how the field work was used to derive appropriate cost distance thresholds to delineate boundaries on the maps. The first subsection highlights the statistical results of the abstract *cost distance* model values in the GIS (Figure 31). The second subsection focuses on the statistical results of metric values calculated for each riparian system.

5.2.1 Cost Distance Model Outputs

Table 9 displays mean and standard deviations for cost values along observed riparian edges for each stream and river sampled. Figure 37 and Figure 38 display box plots to visualize the distribution of cost values along observed riparian edges for Calgary's streams and rivers, respectively. Table 10 translates the more abstract cost distance values into riparian width distances calculated in metres.

Clearly, the Bow and Elbow Rivers show the greatest riparian extents, with the Elbow River displaying much greater variability in riparian extent compared to the Bow. The very wide riparian vegetation zone observed in the Weaselhead Natural Area and Griffith Woods may account for this high variability in th Elbow River system.

When sampling some streams using the 10m DEM-based cost distance raster, the sample points fell within the 10m pixel covering the stream vector. This results in a '0' cost value sample, and highlights a limitation of this method in delimiting riparian extents which are smaller in scale than the available digital elevation data (note: the planned future acquisition of city-wide LiDAR would help to address this limitation).

As well, around streams such as Confederation Creek, where extensive modification of the natural topography and land cover has occurred, cost values associated with the visible riparian area extent tend to be lower than might have been observed for streams where more natural boundaries between vegetation communities could be observed. Areas sampled with extensive bank modification, such as around the Glenmore Reservoir, may likewise not provide an accurate assessment of the natural riparian area extent.

Table 9. Summary Statistics of cost-values at GPS riparian field observation points

Steams in Scope	# points	Mean	Std deviation
12 Mile Coulee	11	55	58
Coach Creek	5	40	58
Confederation Creek	8	1	1
Forest Lawn Creek	5	18	23
Nose Creek	17	28	42
Pine Creek	8	49	60
Radio Tower Creek	10	46	28
West Nose Creek	17	42	39
Rivers In Scope	**# points**	**Mean**	**Std deviation**
Bow River	52	387	216
Elbow River	42	409	343

*Note that cost values are unitless, dimensionless measures

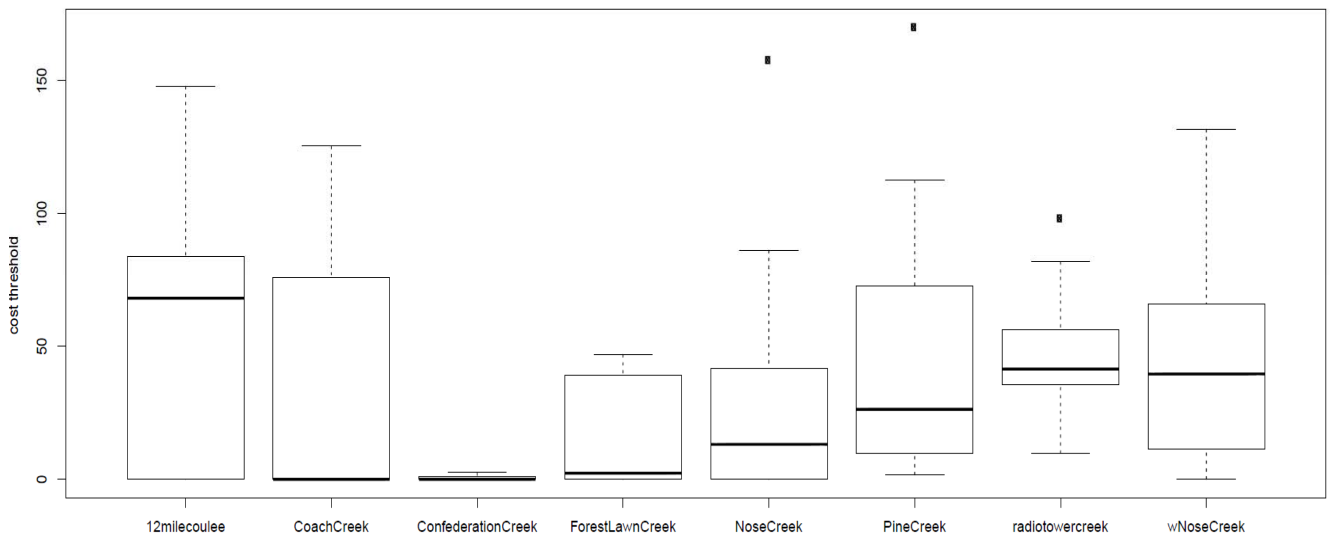


Figure 37. Boxplots showing the distributions of sampled point cost-values (streams)
The dark line represents the median, the area within the boxes represents the interquartile region (IQR) of the data (contains 50% of all values on either side of the median), whiskers (dotted lines) extend to 1.5x the IQR, and black points are used for any outlying observations

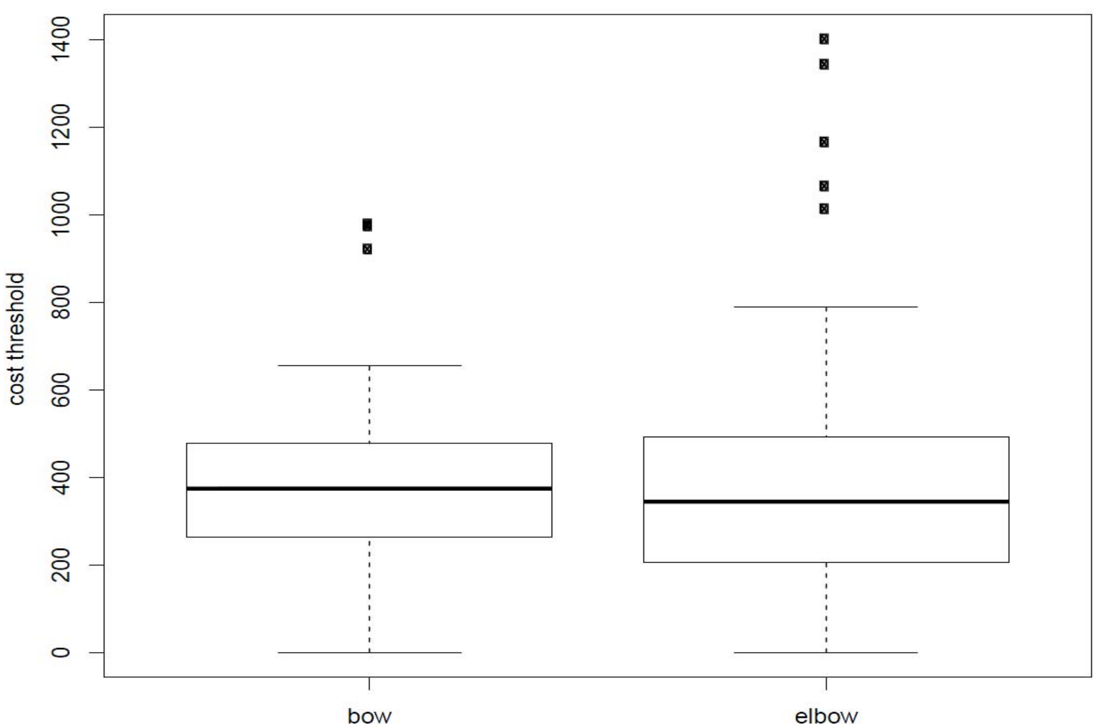


Figure 38. Boxplots showing the distributions of sampled point cost-values (rivers)
The dark line represents the median, the area within the boxes represents the interquartile region (IQR) of the data (contains 50% of all values on either side of the median), whiskers (dotted lines) extend to 1.5x the IQR, and black points are used for any outlying observations

The four quartiles (Figure 37, Figure 38) were represented as follows for the purposes of the project:

- **"Inner Riparian Zone":** this area directly adjacent to the stream exhibits the lowest cost values and is therefore virtually certain to be riparian
- **"Middle Riparian Zone":** this zone contains areas with strong potential to contain riparian features; although in some cases riparian conditions may not arise
- **"Outer Riparian Zone":** this area is riparian if conditions are right, but in other cases will not show riparian characteristics, although it still functions as an important interface between riparian areas and the surrounding uplands
- **"Potential Outermost Riparian Zone":** represents areas that are typically *not* riparian but in some cases may be, requiring further detailed investigations. Riparian conditions here may occur and warrant due diligence when developing these areas to ensure that riparian communities in the outermost extent are not disturbed.

The large differences in thresholds from stream to stream are not a surprise. Likely the largest explanatory factor is the large differences in average flow volumes and seasonal distributions of flow peaks and minimums, which obviously vary considerably when comparing the very large Bow River system, to, for example, West Nose Creek.

Other variables possibly accounting for the differences (although not necessarily constant for individual rivers / streams within the city) include the nature of the alluvial aquifer, soil texture and organic matter, topographic variations, aspect, microclimate (e.g., total precipitation variations, snow drift sites), natural and human disturbance histories of individual sites, and vegetation succession patterns.

5.2.2 Width Statistics Results (m) for Riparian Classes

Table 10 summarizes calculated mean widths (in m) and standard deviations defining the outer edges of the four riparian classes for each river or stream system. Notably, the Bow River and Elbow River systems have much greater riparian area widths than smaller streams in Calgary. In addition, although the defined Inner Riparian Zone is a mean of 37 m for the Bow River and 46 m for the Elbow River, the outer riparian edge is a mean of 247 m for the Bow River and 172 m for the Elbow River. This indicates that, generally, the existing ER Setback Policy in many cases will not fully protect the riparian area along these two river systems during future development.

It should be noted that Confederation Creek has a very wide riparian area in comparison to other small creek systems, and that furthermore, virtually all of this area has been mapped as the "Inner Riparian" zone (See Theme 1 Map Sheets for Confederation Creek). The width of the riparian area is primarily a function of the very flat topography within Confederation Park, combined with a potential artifact caused by the poor resolution of the 10m Digital Elevation Model in this area. Observations of riparian edges during field work also posed difficulties for this creek, as these all occurred at a very low cost distance within 10 m of the bank. Therefore, all field points for this particular stream are associated with the same cost distance interval. The result is that splitting these areas into a finer scale is not possible. Acquiring an improved DEM for this park (e.g., LiDAR) would be the only solution to delineate the four zones for Confederation Creek, as well as to improve on the boundary delineation. Another possible solution would be to apply a different cost distance distribution for quartiles to Confederation Creek, based on a similar creek system (e.g., Radio Tower Creek). Although this may be somewhat speculative, this may be more appropriate since the riparian edge field points for this creek are unlikely to represent former natural conditions due to the heavily altered nature of Confederation Park and associated difficulties observing a natural riparian / upland ecotone edge along this creek.

Table 10. Mean widths (m) and standard deviations for the outer edges of the four riparian classes*

	Bow River		Elbow River		12 Mile Coulee		Coach Creek		Confederation Creek	
	Width (m)		Width (m)		Width (m)		Width (m)		Width (m)	
Riparian Zone	mean	st.dev	mean	st.dev	mean	st.dev	mean	st.dev	mean	st.dev
1st Quartile: Inner Riparian	37	64	46	58	9	10	7	7	67	98
2nd Quartile: Middle Riparian	145	157	106	109	22	16	16	9	139	118
3rd Quartile: Outer Riparian	247	231	172	165	25	20	18	14	130	123
4th Quartile: Potential Riparian	350	286	287	291	34	26	25	22	179	134

	Forest Lawn Creek		Nose Creek		West Nose Creek		Radio Tower Creek		Pine Creek	
	Width (m)		Width (m)		Width (m)		Width (m)		Width (m)	
Riparian Zone	mean	st.dev	mean	st.dev	mean	st.dev	mean	st.dev	mean	st.dev
1st Quartile: Inner Riparian	40	64	29	62	10	13	12	14	12	20
2nd Quartile: Middle Riparian	67	70	54	81	26	22	28	19	35	34
3rd Quartile: Outer Riparian	87	81	44	69	29	29	36	28	39	45
4th Quartile: Potential Riparian	120	93	63	81	41	37	51	45	50	56

*Based on the quartile distribution of field observation-based point sampling of the cost-distance model

5.3 Land and Regulatory Issues

Table 11 summarizes the results of land uses within the slope modified ER setbacks as well as the variable width riparian model outputs. The area (ha) for major land use zoning within the two different overlays is summarized for each river and stream modelled for this study. Note that, as previously described in Section 5.1, this is based on the major land use classification in the City Zoning layer information, but also includes a manual reclassification of the "Direct Control" class, which was completed by O2 for the purpose of this project.

The map of the ER Setback policy and associated statistics in Table 11 are perhaps most useful for all undeveloped, unsubdivided lands in the "Future Urban Development (FUD)" category. In these areas, the intention is to apply the ER Setback policy during future planning and development. Yet, mapping the ER Setback policy and summarizing associated land use for zoned lands was also judged useful, as it indicates lands that may have been zoned as ER during the process of past subdivision if the City had had this policy in the past. In this respect, the map and statistics represent past lost opportunities for conserving riparian ecosystems and associated functions as well as adjacent buffer lands.

In a similar fashion, the numbers for land use in the variable width riparian boundary indicate areas where riparian ecological functions, services, and values appear to have been lost due to past development and land use practices and decisions. The amount of acreage (ha) developed within this boundary is significantly higher than that developed within the ER Setback policy boundary. This indicates even more strongly that past development practices have led to considerable lost opportunities for more ecologically sensitive and sustainable land use patterns in Calgary (Table 11).

The type of land use within each riparian area and/or ER Setback policy area is informative for future planning considerations. The relative percentage of land zoned as Parks and Recreation or Future Urban Development indicates how undisturbed the riparian corridor is. In contrast, industrial uses or major infrastructure indicates a fairly heavy, permanent disturbance within the riparian corridor. A more detailed discussion of land use trends for different streams and rivers is also provided below.

Appendix A also provides a description of the average widths of ER Setback Policy as mapped for different stream systems, as well as a discussion of variations observed along the ER Setback corridor for each stream.

CAVEAT AND LIMITATION:
ZONING VS. ACTUAL LAND USE

The land use information derived from city zoning layers cannot provide a completely accurate summary of the actual ground condition, as the data itself makes no distinction between developed areas vs. areas that are zoned but remain undeveloped. This introduces some inaccuracies; however, these are unlikely to affect any of the interpretations and conclusions.

Table 11. Major Land Uses in the Variable Riparian Area + Mapped ER Setback Policy Boundary

River / Stream Name		Commercial (ha)	Industrial (ha)	Residential (ha)[1]	Institutional (ha)	TUC / Major Infrastructure (ha)[2]	Mixed Use (ha)	Parks / Rec (ha)[3]	Future Urban Development (ha)
Bow River	**Variable Width Riparian Boundary**	116.5 (4%)	33.7 (1%)	297.5 (11%)	20.0 (1%)	231.2 (8%)	17.5 (1%)	1452.25 (52%)	626.64 (23%)
	ER Setback Boundary	3.36 (<1%)	8.88 (1%)	70.54 (8%)	3.44 (<1%)	109.53 (12%)	2.58 (<1%)	549.79 (60%)	164.1 (18%)
Coach Creek	**Variable Width Riparian Boundary**	0	0	0.84 (5%)	0	0.71 (4%)	0	2.92 (17%)	13.03 (74%)
	ER Setback Boundary	0	0	0.01 (0.03%)	0	0 0.15 (0.5%)	0	5.97 (19.9%)	23.91 (79.6%)
Confed-eration	**Variable Width Riparian Boundary**	0.67 (1%)	0.51 (1%)	8.35 (16%)	0.21 (<1%)	6.13 (12%)	0	35.59 (69%)	0
Creek	**ER Setback Boundary**	0	0	0.10 (0.4%)	0	0	0	26.76 (99.6%)	0
Elbow River	**Variable Width Riparian Boundary**	35.28 (5%)	0.09 (<1%)	148.12 (20%)	4.06 (<1%)	76.92 (10%)	8.63 (1%)	412.19 (56%)	42.45 (6%)
	ER Setback Boundary	4.75 (1.8%)	0	55.19 (21.3%)	2.74 (1.1%)	27.12 (10.5%)	0	157.92 (60.9%)	11.79 (4.5%)
Forest Lawn Creek	**Variable Width Riparian Boundary**	0	2.11 (1%)	0	0	21.43 (12%)	0	0	156.32 (87%)
	ER Setback Boundary	0	0.17 (0.4%)	0	0	6.93 (15.3%)	0	0	38.34 (84.4%)
Glenmore Reservoir**	**Variable Width Riparian Boundary**	0	0	0	0	0		35.44 (100%)	0
	ER Setback Boundary	0	0	0.19 (0.1%)	2.86 (2.0%)	3.97 (2.8%)	0	134.49 (95.0%)	0
Nose Creek	**Variable Width Riparian Boundary**	5.74 (2%)	33.56 (12%)	2.53 (1%)	0.02 (<1%)	42.77 (17%)	0	156.36 (61%)	29.54 (12%)
	ER Setback Boundary	3.30 (1.2%)	2.59 (0.9%)	1.33 (0.5%)	0.55 (0.2%)	71.22 (26%)	0	80.1 (30%)	112.38 (41%)
Pine Creek	**Variable Width Riparian Boundary**	0	0.04 (<1%)	0	0	16.75 (12%)	0	43.84 (31%)	77.62 (55%)
	ER Setback Boundary	0	0	2.48 (1.7%)	0	2.56 (1.7%)	0	14.96 (10.1%)	128.36 (86.5%)
Radio Tower Creek	**Variable Width Riparian Boundary**	0.75 (1%)	0	21.5 (17%)	0	29.08 (23%)	0	29.59 (23%)	46.58 (37%)
	ER Setback Boundary	0.01 (< 0.1%)	0	0.09 (0.1%)	0	18.35 (24.6%)	0	16.50 (22.1%)	39.77 (53.2%)
West Nose Creek	**Variable Width Riparian Boundary**	3.03 (2%)	0	5.92 (4%)	0	17.97 (13%)	0	82.33 (56%)	37.05 (25%)
	ER Setback Boundary	3.3 (1.6%)	0	7.67 (3.6%)	0.16 (0.1%)	21.27 (10%)	0	118.39 (55.8%)	61.42 (28.9%)
12 Mile Coulee	**Variable Width Riparian Boundary**	0	0	5.7 (15%)	0	17.32 (45%)	0	15.93 (41%)	0.03 (<1%)
	ER Setback Boundary	0	0	0.04 (0.1%)	0	22.62 (64.4%)	0	12.44 (35.4%)	0

[1]Includes the combined sum of low, medium and high density residential land zone classes
[2]Includes the Transportation and Utility Corridor (TUC), highways and major roads, water and wastewater treatment plants, railways, etc.
[3]Includes all Parks, Recreation and Public Education zones-note St. Patrick's island / zoo was reassigned by O2 from FUD to Parks / Rec

5.3.1 Bow River

In the Bow River ER Setback corridor, the dominant land use is Parks and Recreation (60%) and Future Urban Development (18%), indicating that 78% of this area is currently unaffected by development. This means that over 198 ha (22%) of the area mapped within the ER Setback Policy (2007) has been developed. Major Infrastructure is the most significant development type in the ER setback boundary for the Bow (12% total). This includes highways and major roads, railways, and water and wastewater treatment plants. Other land uses include existing residential (8%) and industrial (1%) developments. These represent missed past opportunities to protect riparian open space values during planning and development. However, overall, the Bow River ER setback area remains mostly undeveloped, with impacts primarily due to transportation and older residential areas established prior to the establishment of the current ER Setback Policy.

Within the variable width riparian boundary of the Bow River corridor, much more total land (over 716 ha) has been developed (Table 11). This is due to the much larger average width of the variable width riparian zone in contrast to the ER Setback Policy area. The most common land use types within the Bow corridor variable width riparian area remain as Parks and Recreation (52%) and Future Urban Development (FUD) (23%), indicating that 75% of this area is still free from development, despite the very large total acreages involved. However, in comparison to the ER Setback Policy area, far more total area within the variable width riparian area has been developed as either residential (298 ha vs. 71 ha), commercial (116 ha vs. 3.4 ha) or industrial use (33.7 ha vs. 8.9 ha). Major Infrastructure also intersects a large proportion of this area, representing 8% of the total area.

Notably, the much larger amount of "Future Urban Development" within the variable width boundary vs. the ER Setback boundary (almost four times as much land area) indicates more opportunities to include river valley riparian areas in future open space systems if a policy change can be developed as a result of this study.

5.3.2 Elbow River

In the Elbow River ER Setback corridor, dominant land uses classes include Parks and Recreation (61%) with comparatively little land zoned for Future Urban Development (4.5%) (predominantly located on the Elbow Sheet 1 map). At only 66% undeveloped, proportionally there are more examples of missed opportunities for open space establishment in the Elbow River ER setback corridor compared to the Bow. Over 89 ha within the area mapped as the ER Setback Policy falls into categories other than parks and recreation. Areas zoned residential represent over 21% of the area within the ER setback corridor. This development is concentrated in older neighbourhoods such as Britannia, Elbow Park, Rideau Park, Roxboro, Erlton, and Mission. In low lying areas of Elbow Park and Rideau Park there are numerous examples of residential development that occupy the full width of the ER setback. Residential development within the top of slope setback buffer is apparent in parts of Ramsay, Britannia and Bel-Aire that were built out long before the ER setback policy was defined. In addition, the Calgary Stampede grounds which extend from the outer extent of the ER boundary almost right down to the river bank itself also represents a major land use that has impacted the Elbow River's riparian area and associated values. Many neighbourhoods along the Elbow River exhibit extensive areas of private land with no Environmental Reserver buffer along the river (Figure 39, Figure 40). However, there are no industrial uses at all within the Elbow ER Setback corridor.

The summary of land use in the Elbow River's mapped variable width riparian boundary indicates much more total land (over 273 ha) has been developed in contrast to the ER Setback area (Table 11). This is due to the much larger average width of the variable width riparian zone in contrast to the ER Setback Policy area for the Elbow River. The most common land use type in the Elbow corridor variable width riparian area is also Parks and Recreation (57%), with Future Urban Development (FUD) making up 6% of the area. However, in comparison to the ER Setback Policy area, far more total area within the Elbow's variable width riparian area has been developed as either residential (148 ha vs. 55 ha), commercial (35 ha vs. 4.8 ha) or mixed use (8.6 ha vs. 0 ha). The TUC / Major Infrastructure also intersects a large proportion of the Elbow's variable width riparian extent, representing 10% of the total area (Table 11).

Figure 39. Private Riparian Land with no ER, Elbow River (Erlton)

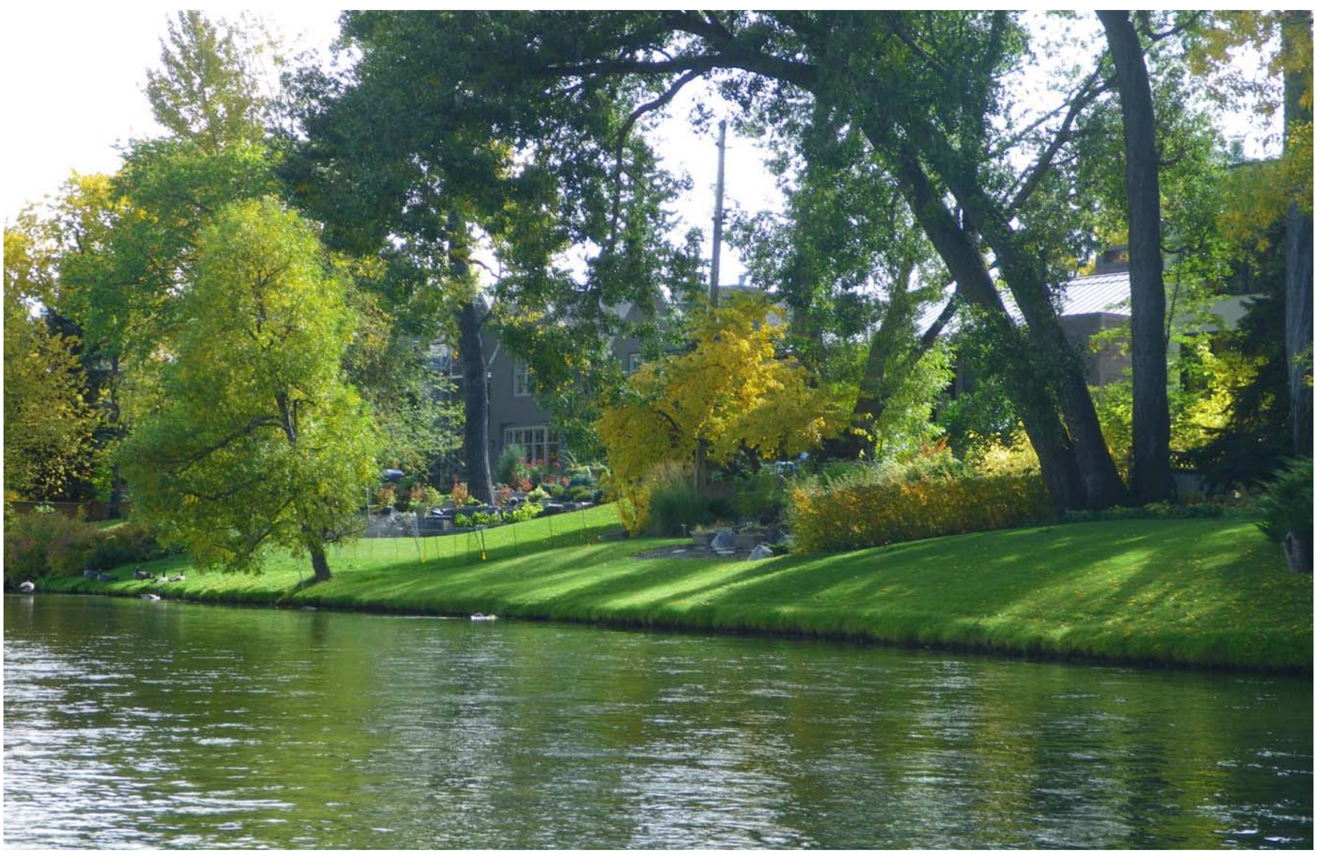


Figure 40. Private Riparian Land with no ER, Elbow River (Elbow Park)

5.3.3 Glenmore Reservoir

Along the Glenmore Reservoir, there are several steeply sloped banks with variation in the width of the mapped ER Setback policy beyond the base 50m setback width. Despite being surrounded by established communities on the north, east and south side, the majority of the ER setback area (95%) is undeveloped and is zoned for parks and recreational uses. The most significant development impact within the ER setback zone is from the Glenmore Trail causeway (2.8%) There is also a small amount of zoned Institutional land use (hospital buildings) that has intruded into the top of slope setback area.

With respect to the mapped variable width riparian boundary, due to the steep banks rising up from the boundary of the Glenmore Reservoir, the riparian extent is actually very narrow around the whole perimeter and is consistently smaller than the ER Setback policy boundary.

The banks of the Glenmore reservoir are largely unaffected by development and land use has been zoned to provide a continuous belt of natural recreational opportunities. This highlights a common observation throughout the maps that the ER Setback boundary does a much better job delineating steep valley slopes and associated upland communities than the variable width model which strictly identifies riparian areas associated with ecosystems heavily influenced by water in the valley bottoms.

5.3.4 Nose Creek

Within the boundaries of Calgary, Nose Creek is surrounded by residential, commercial, and industrial land uses as well as major transportation corridors. About 30% of the Nose Creek ER Setback Corridor is used as parks or recreational areas, and about 41% is currently zoned as Future Urban Development, primarily north of the Calgary Airport. The ER Setback Policy protects this portion of the corridor from new development pressures.

In older, more established areas, Nose Creek has seen varying degrees of development within the corridor now defined by the ER Setback Policy. Further south in the more developed parts of the City, there are large sections of the Nose Creek ER setback boundary affected by previous development. Land uses associated with Major Infrastructure / TUC are the major impacts within the ER boundary (26% of the total area). These conflicts occur in several locations where Nose Creek, Deerfoot Trail and the CP Rail tracks occur in narrow corridors in close proximity to Nose Creek. Compared with infrastructure, the amount of commercial, industrial and residential land uses within the ER boundary are much lower and represent less than 3% of the total ER setback policy area.

In contrast, the variable width riparian corridor for Nose Creek shows very different trends than the ER Setback Policy (Table 11). This is likely due to the highly meandering, dynamic geomorphology of Nose Creek, characterized by several former oxbows, many low-lying areas in the valley bottom, as well as several contrasting areas with steep slopes and a more confined valley that limits the physical riparian area. Consequently, in areas with wide valley bottoms and oxbows, the variable width riparian boundary encompasses a wider area than the ER Setback policy. Conversely, in areas with more confined valley walls and steep slopes closer to the creek (which dominate many areas in the north of the city), the ER Setback Policy boundary encompasses a wider area in comparison, as it includes adjacent steep slopes in addition to valley-bottom riparian ecosystems close to the creek. One might conclude that the two separate boundaries are complementary to one another in terms of protecting riparian values.

About 61% of the Nose Creek variable width riparian corridor is currently used as parks or recreation areas-about double the total acreage in the Nose Creek ER Setback Policy corridor. Much of this difference is accounted for by the wide riparian area delineated in the Elks Golf Club near Mountview. In addition, there is considerably *less* area zoned Future Urban Development in the Nose Creek variable width riparian corridor than in the ER Setback corridor (30 ha vs. 112 ha), primarily due to the differences observed on map sheets 1 and 2. A similar pattern is observed for the Major Infrastructure / TUC land use category (Table 11). In contrast, there is far more industrial land use (34 ha vs. 2.6 ha) in the Nose Creek variable width riparian corridor than in the Nose Creek ER Setback Policy corridor. These observed differences are due to the issues discussed above.

Recommended development setbacks of the Nose Creek Watershed Partnership (NCWP) are also displayed on the map sheets for Nose Creek. Boundaries for these were based on several criteria (Section 2.5.2), including identified floodplains, meander belt width (20x bankful width), width of escarpments with >15% slope adjacent to the meander belt and/or floodplain, and additional top of slope setbacks for steep slopes. Due to the nature of these criteria, the NCWP recommended setbacks tend to include all lands identified as riparian by the variable width model, as well as steep slopes, and often an additional area beyond the top of the steep slopes. Note that there have been challenges incorporating the NCWP recommended setbacks during planning and subdivision due to difficulties determining what can legally qualify as ER (Chris Manderson, personal communications).

5.3.5 West Nose Creek

In contrast to much of Nose Creek, West Nose Creek is bounded by more recent urban development including newer northwest communities such as Sage Hill, Evanston, Hidden Valley and Panorama Hills. Some of the newer and ongoing developments have been built out since the ER Setback policy was in place. Interpretation of 2011 airphoto imagery shows new construction in Kincora and Sage Hill occurring right up to the edge of the ER Setback Policy area as modelled using GIS.

The north end of the West Nose Creek ER setback corridor (and a small part at the Nose Creek confluence) is zoned for Future Urban Development. This accounts for 28.9% of the setback policy area for West Nose Creek. Park and recreational uses are the dominant land use in the setback policy area (55.8%), representing a largely unbroken green belt from Sage Hill to the Nose Creek confluence. Infrastructure land uses (primarily roads) represent 10% of the setback area, with only very minor incursions by residential (3.6%) and commercial (1.6%).

There are some differences between the West Nose Creek ER setback corridor and the West Nose Creek variable width riparian corridor. Perhaps most notably, as for Nose Creek, the total area in the Future Urban Development zoning category is lower in the case of the variable width boundary (37 ha) than in the case of the ER Setback boundary (61 ha). As is the case for Nose Creek, this is due to the nature of the variability within the creek and valley systems in undeveloped portions of the city. Again, one might conclude that the two separate boundaries are actually complementary to one another in terms of protecting riparian values.

5.3.6 Coach Creek

Coach Creek is a small stream feeding into the Bow River in northwest Calgary. It is located immediately to the west of the Valley Ridge and Crestmont neighbourhoods. The Crestmont neighbourhood has affected a portion of the former upstream riparian corridor of Coach Creek, as has the Trans Canada Highway, and a new stormwater pond adjacent to Valley Ridge. However, overall, the ER Setback Policy area of Coach Creek remains relatively undisturbed within the corridor defined by the slope modified ER setback. The ER setback policy has been and continues to be used to help define ongoing planning and development of these neighbourhoods. The edge of residential construction in Valley Ridge (as interpreted from 2011 airphotos) conforms closely to the GIS model of the top of slope setback boundary.

Land within the Coach Creek ER Setback corridor is primarily zoned for Future Urban Development (79.6%) and for Parks and Recreation (19.9%). With the ER setback policy in place and guiding development, no actual construction should intrude into this corridor leaving it undisturbed except for recreational use.

Coach Creek is an excellent example of a clear, formal ER setback policy that can protect a riparian corridor from encroachment by newer residential development. In this case the additional top of slope setbacks are critical in preventing housing from being established too close to the ridge line of the deeply incised Coach Creek valley sides.

In contrast to the ER Setback corridor, the variable width riparian corridor for Coach Creek shows very similar trends and in many cases edges match up together very nicely. The main difference is that the variable width riparian boundary is much narrower in areas with a more well defined and incised valley.

5.3.7 Confederation Creek

A large portion of Confederation Creek has been channeled underground. The ER Setback model was run on the section of the stream that is still above ground. This section runs in a U shape between the neighbourhoods of Collingwood in the west and Mount Pleasant in the east. Despite being surrounded by older established residential neighbourhoods, the ER setback corridor has not seen any significant urban development within its extent. Although this is a very “manicured” open space with little natural environment values present, 99.6% of the ER Setback corridor is zoned for parks and recreation and the ground condition reflects this. The major land uses in the corridor are parks and a golf course.

This indicates a level of foresight from previous generations that, even in the absence of a formal ER setback policy, this stretch of Confederation Creek was retained as open space. The channelized underground sections of the stream are obvious missed opportunities however and, given the density of established residential development now in place, it is unrealistic to assume that these could be restored to their former condition.

The variable width riparian boundary for Confederation Creek indicates slightly different trends. A low-lying residential area within the neighbourhood of Collingwood has been developed within the identified riparian corridor (See Confederation Creek 01 Map Sheet). In addition, a small “finger” of identified low-lying riparian area runs through the Queen’s Park cemetery and includes small amounts of residential and commercial areas (See Confederation Creek 02 Map Sheet). The combination of the very flat topography in the vicinity of Confederation Creek and relatively poor resolution of the Digital Elevation Model (DEM) in the area may be responsible for the very wide riparian area identified for this water body and the consequent large differences between the ER Setback policy and the riparian area mapped by O2. Further investigations would be required to determine whether the riparian area associated with Confederation Creek is in fact realistic or not. In the case of this waterbody the estimated riparian area boundary may be an overestimate as an artifact of the data.

5.3.8 Forest Lawn Creek

Forest Lawn Creek runs through a heavily industrialized area of Southeast Calgary. Due to the flat terrain along its course the majority of the ER setback is a basic 50m total width. Additional slope dependent setbacks are infrequent and the additional widths are small. Sections of Forest Lawn Creek have been channelized and re-routed to circumvent large road intersections associated with the development of the east leg of the Calgary ring road.

Overall, 84.4% of the Forest Lawn Creek ER setback corridor is zoned for Future Urban Development. The current ground condition is largely undeveloped, and the existence of the ER Setback policy will likely help to prevent any future development encroachment within the setback corridor. Land classified as either Major Infrastructure / TUC represents the next largest (15.3%) type. This is largely concentrated around areas of the Ring Road currently under construction. Interpretation of 2011 airphoto imagery shows that the disturbance due to construction is generally contained behind the ER setback boundary.

In contrast to the ER Setback Policy area, the variable width riparian zone boundary is much larger (See Forest Lawn Creek Map Sheets). For example, there are over 155 ha of area currently zoned as Future Urban Development (FUD) within the variable width riparian area, but only 38 ha of FUD zoned within the ER Setback Policy area. Similarly, there are over 21 ha currently classified as “Major Infrastructure” within the variable width riparian area, but only 6.9 ha falling under this classification within the ER Setback Policy area. This is a clear illustration of a situation where, in low lying flat areas, the ER Setback Policy is insufficient to capture the full extent of the riparian zone. Incorporation of the study results into potential future policies would therefore be required to protect riparian area values of Forest Lawn Creek during future planning and development of this area.

5.3.9 Pine Creek

The Pine Creek corridor within the City boundary is largely undeveloped at this point. The majority of the ER Setback policy area (86.5%) is zoned for Future Urban Development. Park and recreational uses currently represent 27% of the setback policy area. There is a very small amount of residential land use zoning (1.7%) in the ER setback corridor. This is associated with the Legacy development currently under construction.

The Pine Creek ER setback corridor and the Pine Creek variable width riparian corridor do show some differences. Most notably, as is the case for Nose Creek and West Nose Creek, the Future Urban Development (FUD) category contains less total land within the variable width riparian boundary (78 ha) than is the case for the ER Setback policy boundary (128 ha). Similarly, the interpretation from an analysis of the maps is that the two boundaries are complementary to one another in terms of protecting riparian values. Steeper areas within the Pine Creek valley system are encompassed by the ER Setback policy but not by the variable riparian width boundary. Conversely, some small areas included in the mapped variable riparian boundary are not included in the ER Setback policy boundary and perhaps should be to encompass all riparian values. However, the vast majority of the mapped riparian area is included in the ER Setback Policy in the case of Pine Creek.

Pine Creek is in the advantageous position of having the ER setback policy in place in advance of development pressures. This will help to preserve the riparian corridor and adjacent slope setbacks as preserved green space with the potential to offer many benefits including parks and recreation.

5.3.10 Radio Tower Creek

Radio Tower Creek, located in the southwest of the City comprises two separate small tributaries that feed into Pine Creek. The eastern tributary is the longer of the two and is more deeply incised. Consequently its setback width is more variable. The eastern tributary is surrounded by the communities of Bridlewood and Somerset at its north end, and is bordered by the under-development Silverado community on its eastern flank. The western tributary is largely undeveloped at this time.

Land use / zoning for the Radio Tower Creek ER Setback policy area is 53% Future Urban Development and 22% Parks and Recreation. Major Infrastructure / TUC also makes up 25% of the area.

Land use / zoning for the Radio Tower Creek variable width riparian corridor is more variable, with some small amounts of commercial (0.8 ha), considerably more residential (22 ha), slightly more parks / recreation areas, and slightly more area encompassed within the FUD category (46.6 ha FUD vs. 39.8 ha FUD).

5.3.11Twelve Mile Coulee

Twelve Mile Coulee is a small stream that enters the Bow River in northwest Calgary. It runs between the neighbourhoods of Tuscany and Scenic Acres. It is deeply incised at several locations and consequently the ER setback policy width is quite variable. Despite running through residential areas there is virtually no (0.1%) residential encroachment into the ER Setback policy area. TUC and Major Infrastructure land uses represent the major zoning within the ER Setback policy area (64.4%) but very little of the area designated as such has actually been built out as roads. Parks and recreational zoning represents 35.4% of the ER Setback policy area. This forms a narrow and winding greenbelt area running through the Tuscany neighbourhood.

The variable width riparian corridor for 12 Mile Coulee tells a different story, with over 5.7 ha (15%) developed to residential land use. This highlights the importance of using multiple sources of information when deciding on appropriate land use patterns to protect riparian values.

5.4 Limitations and Caveats

This study was based on the best available scientific, technical, and planning information. Overall, the information presented in the report is robust and can be utilized as a heuristic tool to inform decision making, policy-making, planning, and analysis. As with any study, there are certain limitations to what the information and data does and does not tell you. Some of the key limitations and caveats are included in the following sections.

5.4.1 General Thematic Map Limitations

- The thematic information presented in the maps is based on the most up to date and comprehensive information available from the City of Calgary; however, information gaps, though limited in nature, may still be present

5.4.2 Variable Width Model Limitations and Caveats

- The variable width riparian model is **not** a representation of a recommended ER Setback Policy, which should also consider factors unrelated to riparian habitat per se such as steep slopes, a buffer from the water body, etc.
- The variable width riparian model indicates **likely** locations of riparian conditions, and is **not** an exact representation of where riparian conditions exist which may require further site-specific investigations.
    - **"Inner Riparian Zone":** this area directly adjacent to the stream exhibits the lowest cost values and is therefore virtually certain to be riparian
    - **"Middle Riparian Zone":** this zone contains areas with strong potential to contain riparian features; although *in some cases riparian conditions may not arise*
    - **"Outer Riparian Zone":** this area is riparian if conditions are right*, but in other cases will not show riparian characteristics*, although it still functions as an important interface between riparian areas and the surrounding uplands
    - **"Potential Outermost Riparian Zone":** represents areas that are typically not riparian but in some cases may be, requiring further detailed investigations
- The variable width riparian model **does** include both undeveloped and developed riparian areas, and **does not** represent riparian "habitat" or riparian "vegetation" as human disturbance and development precludes riparian vegetation establishment in many areas that are otherwise suitable
- The variable width model **does** use the slope-based cost-distance raster and therefore depends on topographic variation and distance to the river channel, combined with thresholds determined from field work verification based on vegetation indicators
- Primarily due to the lack of high resolution accurate data, the variable width model does not consider other variables which may affect riparian conditions, including but not limited to: soil permeability / texture / structure, subsurface flows, site aspect, site disturbance history, and increasing upstream to downstream inputs of water volume (e.g., the Bow near Bearspaw may have a different riparian threshold than the Bow River near Cranston)
- The coarse resolution DEM data applied may introduce inaccuracies, as the within-pixel topographic variation is not represented in the model
- During field work to calibrate the variable width model, the exact riparian vegetation boundary was in some cases difficult to discern as human disturbance, invasive species, and runoff at some sites has precluded characteristic riparian vegetation from establishing on suitable areas - although expert judgment was used to select sample sites to minimize this effect, on some grassland sites in particular this was not always possible, leading to some potential errors in the field sample data

5.4.3 ER Setback Model Limitations and Caveats

- The ER Setback policy incorporates basic riparian width setbacks and additional setback modification due to steep slopes. It is mapped for all in-scope rivers and streams. The ER Setback Policy boundary as mapped incorporates many developed areas. The policy does not apply to already developed areas and should not be interpreted as applying in any retroactive fashion. The modelled boundary simply shows the extent of the current policy boundary and provides for 'what-if' discussions of opportunities lost due to development prior to the initiation date of the policy.
- The ER Setback model does not include the modifiers based on hydraulic connectivity and cover type as stipulated in the ER Setback Policy, which require site specific investigations
- In some cases, the use of a relatively coarse DEM (10 m data was used outside the Bow and Elbow corridors) may introduce inaccuracies, as the within-pixel topographic variation is not represented in the model (although these are expected to have only a minor effect in the case of the ER Setback model)

6. CONCLUSIONS AND FUTURE WORK

Phase 1 of the project focused on mapping and modelling riparian areas, incorporating multiple internal City of Calgary data sources into a GIS database, and determining optimal ways to display and symbolize elements to inform a policy and planning dialogue. This section briefly summarizes conclusions, as well as potential planned activities for Phase 2 of the project.

6.1 Summary and Conclusions

- A wide variety of spatial data was obtained, explored in detail, and grouped into thematic categories to enable thematic cartographic mapping of riparian areas within Calgary
- Three themes were decided upon and mapped, including Riparian Area Location and Function, Land and Regulatory Issues, and Existing Infrastructure and Possible Improvements
- Mapped riparian areas included all those adjacent to the Bow River, Elbow River, Nose Creek, West Nose Creek, Pine Creek, Forest Lawn Creek, 12 Mile Coulee Creek, Radio Tower Creek, Coach Creek, and Confederation Creek
- Maps were created at a scale of 1:7,500 to provide an appropriate balance between the level of detail and minimizing the total number of map sheets; 58 Map Sheets covering all of the city were created, for a total of 174 map sheets
- The variable extent of riparian areas in Calgary was mapped using a GIS cost distance model, with primary inputs including distance from the river and slope
- Field work was used to calibrate the variable riparian width model for each individual river / stream
- Three classes within the riparian area were mapped, including an Inner Riparian Zone, a Middle Riparian Zone, and an Outer Riparian Zone; in addition, a fourth "Potential Outermost Riparian Zone" was also delineated
- Due to the observed high variability and the imperfect nature of any model, further investigations may be required in particular within the Potential Outermost Riparian Zone and the Outer Riparian Zone, in order to confirm the presence or absence of riparian conditions
- The variable width riparian area adjacent to the Bow and Elbow rivers is substantially greater than for lower order creeks
- A GIS model of The City of Calgary's Environmental Reserve Setback Policy (including base setback and slope modifiers) was developed, run, and mapped for the entire City of Calgary; this is useful not only to be clear on expectations for riparian-associated ER during future development, but also to highlight past lost opportunities from not having had the ER Setback Policy prior to 2007
- Spatial and descriptive comparisons of the ER Setback Policy vs. the delineated variable width riparian area model helps highlight mismatches and implications for riparian area protection within the process of sustainable land use planning
- Current floodplain regulations in the Land Use Bylaw and the Environmental Reserve Setback Policy largely do not go far enough to effectively protect what is left of riparian habitat within Calgary
- The maps and this document are intended to support and complement a wide range of official plans and policies, and are intended to serve as a strategic catalyst supporting effective riparian land management, conservation, restoration, and use within the City
- The riparian maps are important tools for planning, communication, and further discussion on riparian area land use planning, infrastructure, regulatory issues, conservation and environmental issues
- Phase 2 of the project will build upon Phase 1 by consulting more widely with internal and external stakeholder groups to obtain feedback, fill in existing identified data gaps, create a policy and management vision of riparian opportunities, and ultimately improve the final products and recommendations to Council

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APPENDIX A: ER Setback Model Results: Statistics and Discussion

Table 12 contains statistical summaries of ER setback distances for all streams and rivers modelled in this study. Statistics are for the ER setback within the City boundary only. The statistics refer to the slope modified ER Setback as described in Section 4.7.

Table 12. Statistics on Calculated Slope Modified ER Setback Distances for Rivers and Creeks

River / Stream Name	Average ER Setback Distance	Max ER Setback Distance	Min ER Setback Distance*	Standard Deviation
Bow River	64.79 m	194.0 m	50.0 m	19.69
Coach Creek	55.5 m	135.0 m	6.0 m	22.63
Confederation Creek	51.3 m	75.5 m	50.0 m	3.94
Elbow River	64.12 m	173.0 m	50.0 m	18.7
Forest Lawn Creek	21.3 m	37.5 m	6.0 m	11.59
Glenmore Reservoir	82.08 m	156.5 m	50.0 m	21.13
Nose Creek	60.10 m	113.0 m	50.0 m	7.25
Pine Creek	60.27 m	141.5 m	50.0 m	15.37
Radio Tower Creek	34.83 m	74.0 m	6.0 m	15.55
West Nose Creek	55.24 m	131.0 m	50.0 m	10.55
12 Mile Coulee	27.82 m	102.75 m	6.0 m	12.96

The minimum setback distance is the base setback determined by stream order. This varies from 6 m for 1st order streams to 30 m for 2nd order streams to 50 m for streams and rivers of 3rd order and higher. The maximum setback distance is dependent upon the highest average slope value measured within the base setback width as derived from GIS modeling (Section 4.7).

Bow River

Along the Bow River the average ER setback distance from the river bank is 65 m. This is however highly variable due to the continuous variability in the steepness of neighbouring slopes. In relatively flat areas (average slope less than 5%) the ER setback only extends out to the minimum base 50 m width. The maximum setback distance (194 m) occurs along the top of extremely steep (up to 100%) slopes in the Valley Ridge neighbourhood just west of Stoney Trail.

In northwest Calgary there are several other areas with very large setback distances. These include the top of bank above the south slope just west of the confluence with Coach Creek. The steepness of slopes in this area ranges from 70% to 80% with corresponding setbacks ranging from 150 to 167 m. The top of bank adjacent to certain slopes in the Bowmont Natural Environment Park have large setbacks also. Slopes in this area are as steep as 80% to 100% and corresponding setbacks range up to 192 m from the north bank of the Bow River in these locations. Other northwest Calgary locations with significant ER setbacks include the top of bank above Edworthy Park and the top of bank adjacent to the Shaganappi golf course

Setback distances along the Bow River in southeast Calgary are not as variable in the northwest. Some specific top of bank locations in the Ogden area have slopes in the 40 to 65% range and corresponding setbacks of 100 to 111 m. The Diamond Cove neighbourhood just north of Fish Creek Provincial Park has a 1km length of bank with slopes ranging in steepness from 25% to 60%. Setbacks adjacent to the steepest slopes are up to 132 m from the south bank of the Bow River. Interpretation of 2011 imagery shows a significant number of properties had previously been built within what is now the top of slope component of the ER setback policy area.

The community of Mackenzie Lake is adjacent to some steep slopes to the west. Some of these slopes are as steep as 90% resulting in setbacks up to 179 m from the river bank. There are a large number of properties that are outside the basic 50m setback but are within the additional slope setback boundary. This reflects the fact that the neighbourhood was established before the setback policy was.

Elbow River

Along the Elbow River the average ER setback distance within the City boundary is 64.12 m. This varies widely based on steepness of adjacent slopes. The minimum ER setback distance is 50 m which is the basic setback defined for a river of this stream order level. The maximum ER setback distance is 173 m. This occurs within a particularly steep (87%) section of slope just east of the Glenmore Athletic Park.

Other notable large setbacks include the neighbourhood of Bel-Aire immediately downstream of the Glenmore Dam. Slopes in this area are as high as 70% and 80% with corresponding top of slope setbacks exceeding 160 m. Many of the older houses in this neighbourhood are well within what is now defined as the top of slope setback. A crescent shaped section of steep slopes occurs along the east bank of the Elbow River between the Windsor Park and Britannia neighbourhoods. On the west side of the Elbow River equally steep slopes occur along the edge of River Park in Altadore. Several properties in both neighbourhoods are within the current top of slope setback area.

In lower lying neighbourhoods such as Elboya, Elbow Park Roxboro and Mission, residential development frequently extends right down to the river banks. The only significant open area within the ER setback zone is Lindsay Park. Downstream of Lindsay Park the ER setback zone is largely developed by land use associated with the Calgary Stampede grounds. Some older Ramsay properties are within the top-of slope component of the setback area due to the very steep slopes opposite the Stampede grounds.

Glenmore Reservoir

The average setback distance around the reservoir is 82.08 m. The minimum setback is 50 m and the maximum is 156.5 m. The largest setback distances are associated with an area of steep slopes at the northwest corner or North Glenmore Park just south of the Weaselhead parking area. Slopes in this area range from 50% to 70% and the associated setback distances range from 120 to 149 m.

Coach Creek

The ER setback width along Coach Creek averages 55.5 m. In the upper reaches where Coach Creek is a 1st order stream the setback width is as narrow as 6 m. As the creek flows north it becomes deeply incised and the setback distance increases to a maximum of 135 m in some locations. No development existing or under construction extends into the ER setback boundary.

Confederation Creek

The non-channelized portion of Conferderation Creek runs through Confederation Park. The average ER setback distance for this section is 51.3 m. There are a few areas in the northwest part of the park where steeper slopes (15% to 18%) push the setback distance out to 75.5 m. These areas are still well within Park land uses however. Despite older residential development surrounding the watercourse there are virtually no developments within the area currently defined as ER setback.

Forest Lawn Creek

Forest Lawn Creek runs through flat land in Industrial east Calgary. In its upper reaches it has a class 1 stream order designation and a 6 m ER setback. The majority of its length however is class 3 or above and has a 50 m setback. The average ER setback over the entire length of Forest Lawn Creek is 21.3 m. There are no significant steep slopes along the watercourse. A few isolated locations have small sections of slope ranging from 8% to 10%. These increase the ER setback width to 37.5 m along short sections of river bank.

Nose Creek

The average setback distance along Nose Creek is 60.1 m within the City boundary. The largest setback distance is 113.0 m. This is associated with some isolated steep slopes along the east side of the CP Rail line directly west from the Cross Iron Mills shopping centre. Other areas with large setbacks include a section of the east bank just northwest of the Deerfoot Trail / Airport Trail intersection. Slopes in this area range from 25 to 37%. Corresponding setbacks range from 80 m to 98 m. The largest setback distances generally occur in isolated locations north of the confluence with West Nose Creek. Nose Creek has a more meandering course in this part of the City and is also somewhat more deeply incised. South of the confluence with West Nose Creek, the setback distances are close to the minimum value (50 m).

West Nose Creek

West Nose Creek has a highly meandering channel and is somewhat incised, especially in its upper reaches. Consequently there are many locations with small stretches of steep slope and larger setback distances. The average ER setback distance for the whole stream is 55.24 m within the City boundary. This is only slightly greater than the base 50 m setback.

The largest setback distance is 131.0 m. This occurs at a steeply sloping meander belt location north of the intersection of Beddington Trail and Deerfoot Trail. There are numerous other incised locations along the north side of Beddington Trail. Slopes are typically in the 30% to 50% range with associated setbacks up to 117 m. There are many locations along West Nose Creek where steep slopes drive an increase in the ER setback distance. They are usually very small however and do not dramatically increase the average ER setback distance for the stream as a whole.

Pine Creek

Pine Creek follows a meandering course along the southern boundary of Calgary. It is bordered on each side by occasional bluffs. The average ER setback distance for Pine Creek within the City boundary is 60.27 m. The largest setback distance is 141.5 m. This is associated with an area of steep (53% to 66%) wooded slopes on the south bank of Pine Creek just east of Hwy #2. West of Hwy #2 there are several outer bank locations with steep slopes in the 30% to 40% range. The ER setback in these locations ranges from 90 m to 104 m. Due to the tightly meandering course of Pine Creek the setback distances are highly site specific.

Radio Tower Creek

The upper reaches of Radio Tower Creek are comprised of class 1 and class 2 tributaries which have basic setbacks of 6 m and 30 m respectively. The topography in these upper reaches is generally flat and the streams follow a relatively linear course. Consequently additional setbacks due to slope are infrequent.

The lower reaches where Radio Tower Creek becomes a class 3 stream are more meandering, but the topography is still generally flat. The average ER setback distance for Radio Tower Creek as a whole is 34.83 m. The largest setback distance is 74.0 m. This occurs along a short stretch of the west bank which forms the outer edge of a meander belt. The location is about 750 m south of the confluence of the two 2nd order tributaries. Slopes in this location range from 13% to 21% with associated ER setbacks in the 62 m to 74 m range.

12 Mile Coulee

Twelve Mile Coulee is deeply incised at several locations along its length and consequently the ER setback policy width is quite variable. The average setback width along the entire stream is 27.72 m. The minimum width is 6.0 m which is the basic setback distance in the upper reaches where it is a class 1 stream. The maximum setback width is 126.0 m.

APPENDIX B: Classification of Riparian Areas

Riparian areas can be classified in many different ways, including basic classification based on Strahler stream order, stream morphology, vegetation and biophysical habitat type (varying levels of detail), and effectiveness for water quality improvement.

B.1 Riparian Classification Based on Stream Order

One of the most basic methods for classifying fluvial riparian areas is based on the Strahler stream order system (Horton, 1945; Strahler, 1952). Each segment of a stream or river within a river network is treated as a node in a tree, with the next segment downstream as its parent. Figure 41 illustrates the classification. In order to qualify as a stream and be entered into the algorithm, the stream must be either perennial (water is in the bed continuously throughout the year) or recurring / intermittent (water is in the channel for at least part of the year).

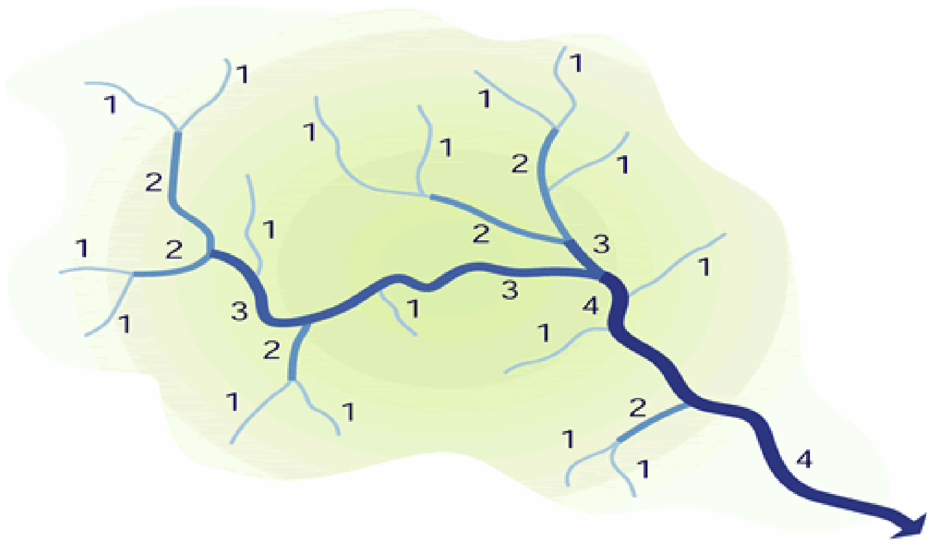


Figure 41. Illustration of Strahler Stream Order Concept
Source: Federal Interagency Stream Restoration Working Group

B.2 Riparian Classification Based on Stream Morphology

Although more applicable to the classification of stream types as opposed to riparian areas, a brief review of fluvial geomorphological classification may also be of some value. A basic stream morphological classification system based on sinuosity measured as the ratio of thalweg length to valley length was described over 50 years ago (Leopold & Wolman, 1957). Straight channels (often uncommon in natural systems), meandering channels (transition based on sinuosity value of 1.5) and braided channels were part of this classification system. Meandering channels shift their positions over time by eroding on the outer banks of meander mends and simultaneously depositing point bars on the inside of meander belts. Braided channels are typically dominated by erodible banks and sediment transport processes.

In Calgary, Northwest Hydraulic Consultants (1986) described streams in Calgary as having 4 degrees of freedom: width, depth, longitudinal slope, and plan form. The purpose of their study on the Bow and Elbow Rivers was to determine whether long term adjustments had occurred due to human or natural influences.

One of the most common fluvial geomorphology references is the Rosgen stream morphology classification system (Rosgen 1996). Presented in Figure 42, this system is based on channel entrenchment ratio, width / depth ratio, sinuosity, slope, and channel material. Although this is a classification system developed for natural rivers, it may have some applicability to studies of urban rivers as well. Generally, channel stability is *lowest* for streams with high sinuousity and finer grained particles (sand, silt); conversely, channel stability is *highest* for streams with low sinuosity, and coarser particles such as boulders.

For the purposes of this study, further consideration of the Rosgen system in methods and procedures was not conducted as it was determined that the amount of value provided in the context of riparian areas and the study scope would be sub-optimal, primarily due to potential overlaps with the AMEC study on streambank and riparian stability, which has already identified actively eroding erosion hotspots throughout Calgary.

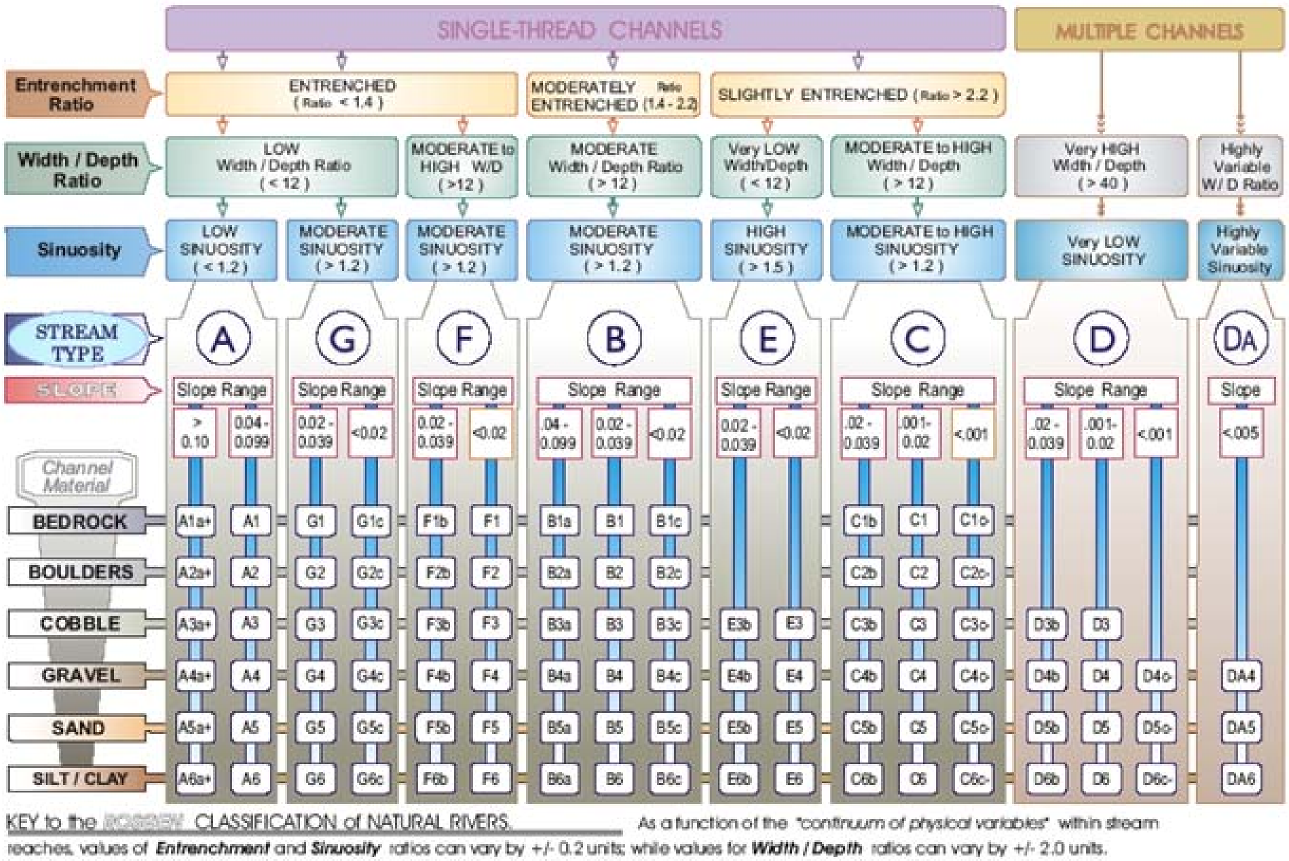


Figure 42. Key to the Rosgen Classification of Natural Rivers *(Rosgen, 1996)*

B.3 City of Calgary Parks Biophysical Habitat Classification System

The following habitat classification system is outlined in The City of Calgary Parks Biophysical Update Maps, completed by Fiera Biological Consulting, and is used by The City to describe vegetation zones:

- Aspen Forest (likely not riparian most of the time)
- Balsam Poplar Forest (can easily be riparian—likely includes all cottonwoods)
- Disturbed
- Douglas Fir / White Spruce Forest
- Grassland
- Riparian Gravel Sand Shoulders
- Riparian Tall Shrub
- Streams / Open Water
- Upland Low Shrub (likely not in riparian areas)
- Upland Tall Shrub

- Wetland Emergent Vegetation (likely not in riverine riparian areas)
- Wetland Open Water (likely not in riverine riparian areas)
- White Spruce Forest (likely not in riverine riparian areas)

B.4 City of Calgary Parks Calgary Annexation Territory Habitat Classification System

The following is the land cover classification system that is used to map the greenfield areas on the periphery of Calgary (O2 2010):

- Anthropogenic – predominantly human altered land cover
- Cropland – tilled cropland
- Coulee Complex – areas with very fine-scale variation between grassland, shrubs, and wetlands, typically within coulees or ravines with complex topography
- Grassland – native or non-native grasses
- Open Water – lakes or open water wetland zones
- Shrubland – shrubs and bushes
- Trees
- Wet Cropland – tilled cropland in minor depressions
- Wetland – untilled, wet vegetated areas

B.5 Cows and Fish Riparian Health Classification System

Riparian "health", a system developed by Cows and Fish, is a type of riparian classification system based primarily on field investigations, whereby detailed vegetation and physical site information is collected.

A riparian health field survey includes the following:

- *Vegetation Data:* Percent cover of vegetation species and comments on health, based on factors such as the presence of invasive species
- *Physical Site Data:* characterizations of channel bottom and streambank material; evidence of lateral erosion, unstable banks, human and beaver caused alterations; presence of binding root mass and braided channels
- *Riparian Health Parameters:* evaluation of 11 key vegetation and soil / hydrology health parameters based on estimations by trained observers

B.6 Cows and Fish Riparian Classification Based on Plant Species / Plant Communities

The following guides (developed by William Thompson and Dr. Paul Hansen of the Ecological Solutions Group LLC) have been used to classify riparian plant communities in The City of Calgary: *Riparian Classification for the Parkland and Dry Mixedwood Natural Region* (Thompson & Hansen, 2003) and *Riparian Classification for the Grassland Natural Region* (Thompson & Hansen, 2002). Using these Riparian Plant Classification guides, riparian plant communities are described as either "Habitat Types" or "Community Types". "Habitat Types" represent '*climax plant communities'* or, final state plant communities that are self-perpetuating and in dynamic equilibrium with their environment. \ "Community Types" represent 'seral plant communities', or interim plant communities that are replaced by another community or species as succession progresses.

Riparian plant community types are described as Tree, Shrub or Grassland communities and are determined by the dominant vegetation (e.g., Manitoba maple / chokecherry, snowberry, beaked sedge). Communities that are not described in the Thompson and Hansen guides are considered "Unclassified Communities".

Unclassified types may include human-disturbed vegetation types dominated by introduced, planted trees or shrubs and non-native herbaceous plants.

Vegetation layers for "Deciduous Tree" should be further defined where possible into "Deciduous tree / tall shrub" and "Deciduous tree / disturbance herbaceous" to account for the differences in function of a multi-structured, self-sustaining plant community versus a manicured park setting with mature trees and a mowed grass understory. It is also important, where possible, to distinguish native versus non-native / disturbed riparian plant communities, as the focus for management / policies should be to ensure protection of existing native communities. Table 13 provides examples of common riparian plant community types along major streams and rivers in Calgary.

B.7 BC Sensitive Habitat Inventory Mapping (SHIM) Riparian Classification System

The Community Mapping Network of British Columbia has developed a finely detailed mapping system for riparian habitats that involves a GIS desktop mapping component and a field data collection component. The purpose is to make information on riparian habitats publically available to provide a foundation for improving integrated resource management and planning in rural and urban areas.

SHIM classifies riparian areas using the following criteria:

- **Coniferous forest:** at least 80% of the trees are conifers
- **Broadleaf forest:** at least 65% of the trees are broadleaf
- **Mixed forest:** no more than 80% conifer and no more than 65% broadleaf
- **Shrubs:** multi-stemmed woody perennial plants, both evergreen and deciduous
- **Herbs / grasses:** grass-like vascular plants, including ferns and forbs, without a woody stem
- **Bryophytes:** mosses and lichens, such as in rock outcrops
- **Rock:** exposed rock, such as in natural rock faces, boulders, bedrock, or fragmented rock
- **Exposed soil:** human or natural, exposed soil under active erosion processes
- **Highly impervious man-made surfaces**: industrial, commercial, and residential areas as well as roads and greenhouses
- **Medium imperviousness human-made surfaces**
- **Low impervious human made surfaces**: low density suburban houses, barns, horse tracks, paddocks, or gravel or packed soil parking lots
- **Row Crops**: agricultural crops and farmland
- **Planted tree farm:** Christmas tree farms, ornamental tree nurseries, and fruit orchards
- **Dug-out ponds:** natural or man made
- **Natural wetland:** largely undisturbed by human modification

Table 13. Common Lotic Riparian Plant Communities in Calgary (Cows and Fish)

Plant Community Type	***Successional Class***	***Comments***
Tree Communities		
white spruce / red-osier dogwood	Habitat Type	• This is a climax plant community found along undisturbed north facing slopes of the Bow River valley and in the Weaselhead and Griffith Woods Special Protection Natural Areas upstream of the Glenmore Reservoir along the Elbow River. • Small parcels of this Habitat Type also occur in protected parks along the Elbow River immediately downstream of the Glenmore dam. • Balsam poplar is typically also present in the overstory.
Manitoba maple / choke cherry	Habitat Type	• Manitoba maple is considered 'native' to parts of Alberta where it is the climax species in some riparian sites. In Calgary, Manitoba maple has been commonly incorporated in historical plantings along the Bow and Elbow Rivers, where it has now naturalized. • This community type is most common along altered reaches of the Elbow River downstream of the Glenmore dam, where only a narrow band of riparian vegetation remains intact, included along historically planted berms.
balsam poplar / red-osier dogwood	Community Type	• **This is the dominant riparian tree community along the Bow River and downstream reaches of the Elbow River (downstream of the dam).** It is found in Natural Environment City Parks and remnant, undisturbed low lying floodplains. • On relatively undisturbed sites, the balsam poplar understory will contain a diverse, dense tall and medium height shrub layer dominated by red-osier dogwood, saskatoon, choke-cherry, various willow species and currants. • If white spruce is able to establish in this community type it will usually progress to a white / red-osier dogwood Habitat Type.
balsam poplar / buckbrush	Community Type	• This plant community type represents a "**moderately disturbed** secondary successional stage of the balsam poplar / red-osier community type".[11 (page 8)] • This community type has few or no remaining tall native shrubs due to human disturbance to the riparian shrub community or moderate long-term livestock use or heavy browse. Low-stature, browse resistant 'increaser' species such as buckbrush and rose are common in the understory.
balsam poplar / herbaceous	Community Type	• This community is characteristic of **heavily disturbed** riparian plant communities where the understory shrub layer has been removed due to human land uses or clearing. This community is characteristic of manicured parks along the Bow and Elbow River in Calgary that have an overstory of natural or planted poplar trees and Kentucky bluegrass lawn understory. Absence of understory shrubs significantly reduces health or ecological functionality.
Shrub Communities		
yellow willow / red-osier dogwood	Habitat Type	• This plant community is found in Natural Environment Parks and undisturbed low lying floodplains along the Bow and Elbow Rivers that have frequent moisture inundation from flooding. A good example is the Sandy Beach restoration site along the Elbow River (west side – downstream from the suspension bridge). **This is a diverse, functional plant community type with high value to wildlife.**
sandbar willow	Community Type	• This plant community is characteristic of newly re-vegetating flood deposited point bars with sandy substrate. Sandbar willow stands occur along undisturbed point bars along the Bow and the Elbow Rivers and also along portions of Nose Creek and West Nose Creek where moisture conditions are adequate. Often a variety of native sedges and rushes (e.g. wire rush) occur in the sandbar willow understory.

Plant Community Type	***Successional Class***	***Comments***
snowberry (buckbrush)	Community Type	• Snowberry dominated riparian sites represent disturbed areas that in some instances may have been influenced by historical heavy grazing or clearing of other native trees and shrubs. This community type is mostly found in drier portions of the floodplain along Nose Creek and West Nose Creek. Common wild rose and non-native grasses typically are co-dominant.
Graminoid Communities		
beaked sedge	Habitat Type	• Emergent beaked sedge and in some areas water sedge (*Carex aquatilis*) Habitat Types occur along the wetted channel edge of parts of the Bow and Elbow Rivers and side channels as well as along undisturbed reaches of Nose Creek and West Nose Creek. Sedges are deeply rooted and provide excellent soil stabilization and bank protection especially for slow moving, small streams.
reed canary grass	Habitat Type	• This plant community is particularly prevalent along Nose Creek and West Nose Creek. • Reed canary grass is a fast growing rhizomatous species that provides rapid bank stabilization, **but it can out-compete newly establishing shrub seedlings**. **Introduced (non-native) varieties of reed canary grass are common** and may occur in Calgary.
Kentucky bluegrass	Community Type	• Non-native, introduced disturbance-caused grass communities, including Kentucky bluegrass and smooth brome, occur along all stream and river systems in Calgary in areas that have been altered due to ground disturbance associated with development, recreation or channelization / berms. Lawns, golf courses, road ditches and industrial sites area common sources of these disturbance-caused species. In some areas, high cover from these grasses may also be indicative of historical farming and agricultural land uses in the project area. Invasive weeds are usually common in these unhealthy community types.
smooth brome	Community Type	

For more details about these plant communities and associated plant species, refer to Thompson and Hansen (2002, 2003).

B.8 Riparian Classification Based on Water Quality Improvement and Other Functions

Riparian water quality improvement and other functions differ depending on the type of riparian vegetation present. Dosskey et al. (1997) provided a good summary of riparian vegetation types in relation to water quality improvement and a range of other functions (Table 14).

Generally, trees are very effective at reducing bank erosion and related TSS mobilization, as well as flood protection, fish habitat support, and visual diversity. However, grass communities tend to be best at filtering sediment from overland flow processes. Other studies (Mayer et al., 2007; Mayer, 2006) indicate that, with respect to nitrogen, riparian shrubs provide the highest degree of nitrogen removal effectiveness.

Table 14. Relative effectiveness of different vegetation types for providing specific benefits
Source: (Dosskey et al., 1997)

	Vegetation Type		
Benefit	**Grass**	**Shrub**	**Tree**
Stabilize bank erosion	low	high	high
Filter sediment	high	low	low
Filter nutrients, pesticides, microbes			
sediment-bound	high	low	low
soluble	medium	low	medium
Aquatic habitat	low	medium	high
Wildlife habitat			
range/pasture/prairie wildlife	high	medium	low
forest wildlife	low	medium	high
Economic products	medium	low	medium
Visual diversity	low	medium	high
Flood protection	low	medium	high

One might conclude that riparian trees may be preferred cover types in an urban context for several reasons with respect to functions. Furthermore, riparian trees with a diverse understory as well as riparian complexes with different habitats in close proximity to one another (wetland, shrub, trees, grass) may provide the most diverse array of riparian functions. However, all riparian cover types have the potential to provide some functions, though in differing amounts for different types. What is very simple to conclude is that maintaining natural cover within riparian areas is beneficial for a variety of functions and services that are valued by people.

APPENDIX C: CARTOGRAPHY AND RIPARIAN AREAS MAPPING REVIEW

Cartographic precedents of other riparian projects were examined in the context of the project to generate ideas and options and summarized as below.

C.1 Cows and Fish Urban Stream and River Riparian Mapping Projects

Cows and Fish has completed extensive riparian health inventory projects for The City of Calgary and the City of Lethbridge. The Streambank Stability and Riparian Assessment Project (Cows and Fish, 2012) provides examples of some riparian health mapping conducted within Calgary (Figure 43).

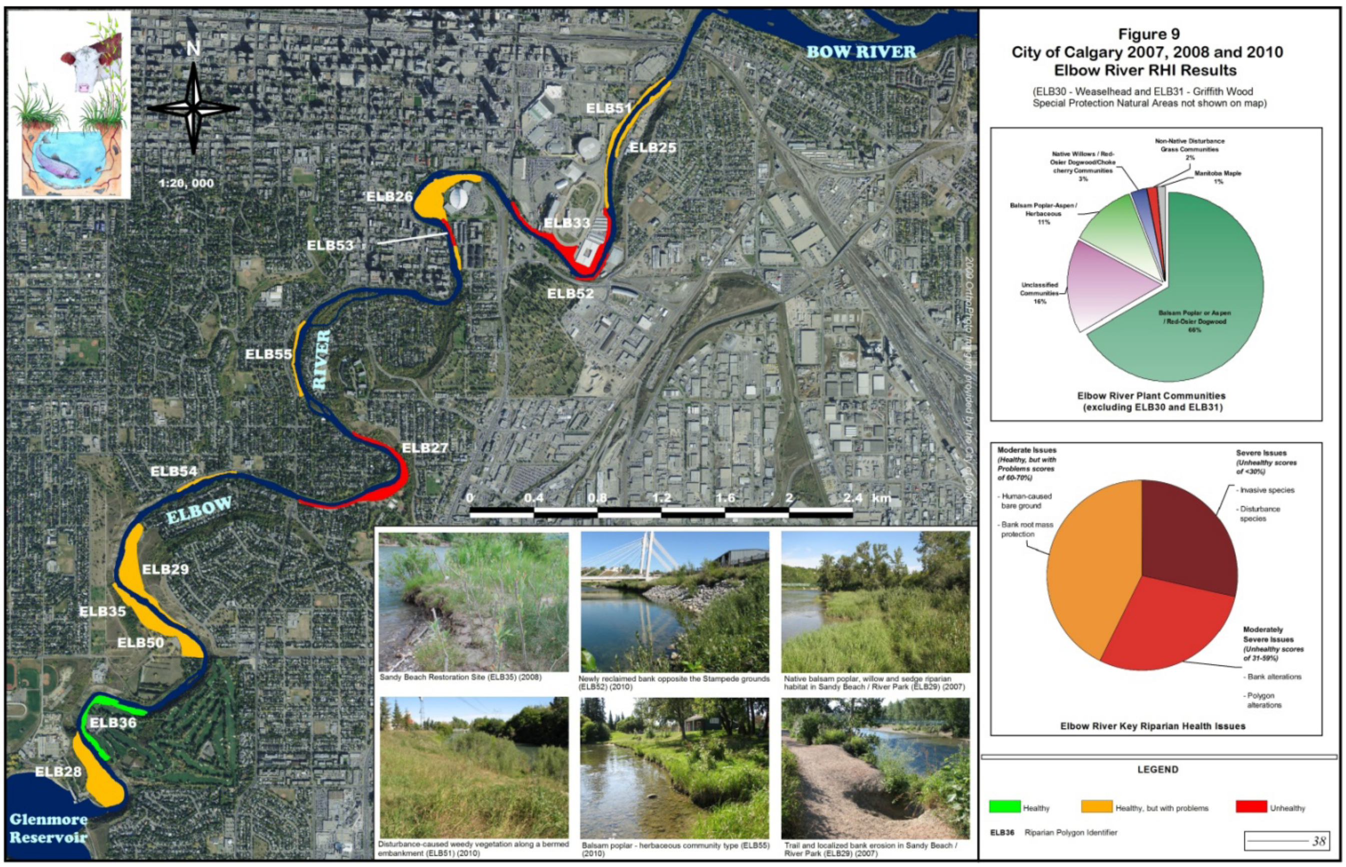
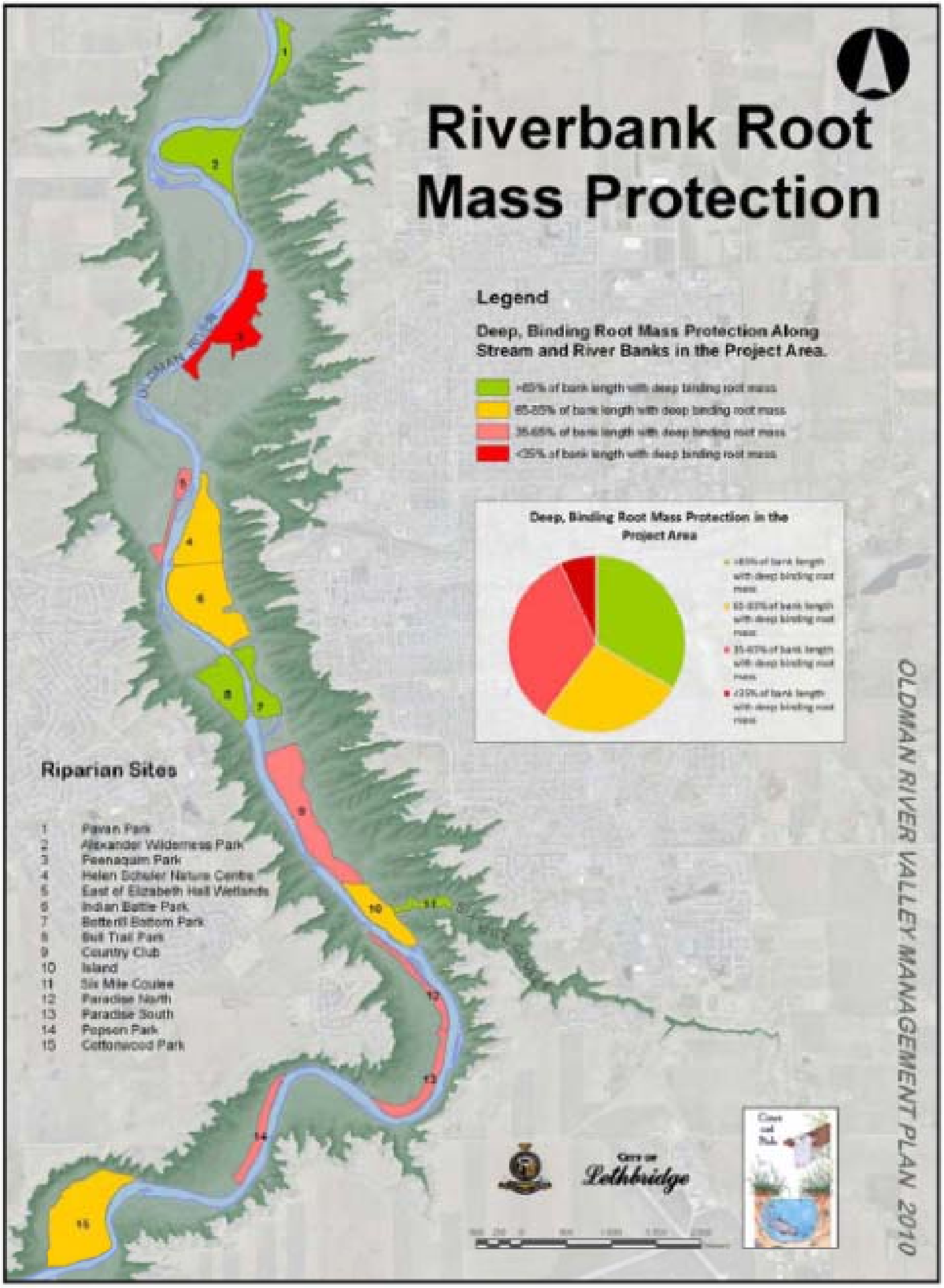


Figure 43. **Sample of Riparian Health Index Results Within Calgary, Elbow River (2007-2010)** *(Cows and Fish, 2012)*

Examples of riparian health mapping products developed for the City of Lethbridge project are also presented below. These maps were developed in collaboration with the City of Lethbridge's GIS department using Cows and Fish RHI data.

The approach used by Cows and Fish on both the City of Calgary and City of Lethbridge products was to distill the large amounts of field collected riparian health information into simple and graphically pleasing maps. The example map (Figure 44) shows riverbank root mass protection (a subcomponent of the riparian health score) presented as bold coloured polygons with an intuitive colour scheme (green for healthy, red for unhealthy). Polygons are numbered to orient the viewer to key parks and City landmarks. Notable is the use of a river valley corridor in a dark green colour on the Lethbridge map, as well as assessed riparian polygons embedded within the river valley in bright colours. In this manner, non riparian areas are displayed as almost completely transparent. This helps draw the eye to the riparian corridor and eliminates the underlying airphoto as a source of distraction.



Note: This mapping product was developed by the City of Lethbridge with data inputs provided by Cows and Fish.

Figure 44. **Lethbridge Riverbank Root Mass Protection Map**
(*Source: City of Lethbridge and Cows and Fish*)

Figure 45 shows another mapping approach where map elements, charts and site photographs are combined in one view. In this case this works because there is a low density of information on the map itself (one linear polygon denoting Six Mile Coulee as being 'healthy'). This removes the need for a complex legend and allows space for photographs, intuitive charts and management recommendations. The resulting map is easy to navigate, informative and graphically pleasing.

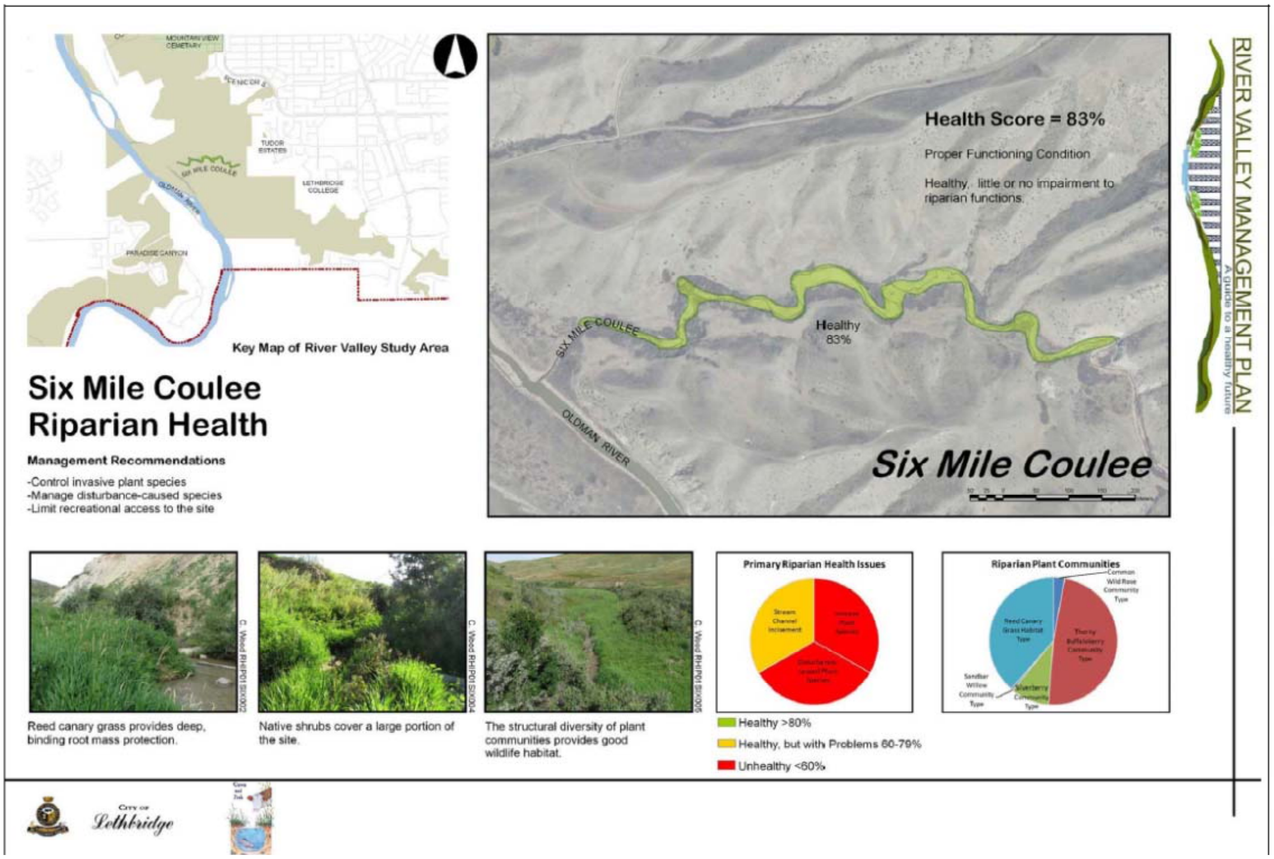


Figure 45. Six Mile Coulee Riparian Health Map Example
(*Source: City of Lethbridge and Cows and Fish*)

C.2 Red Deer River Valley and Tributaries Project

In 2010, O2 Planning and Design worked with the City of Red Deer to develop the River Valley and Tributaries Park Concept Plan (RVTPC Plan). The RVTPC Plan's the goal is to identify lands best suited for potential trails and parks while protecting ecologically sensitive lands. O2 used a series of GIS analyses of environmental conditions to help understand the landscape. A key component of the project was public engagement in the design and conceptualization phases. Appealing and intuitive maps were key to the success of this aspect of the project.

Figure 46 shows a regional overview of the proposed plan. This broad scale map presents a challenge of conveying a lot of essential information while avoiding overcrowding. Simple white and grey background colours help denote the City boundary from the growth area. Base features are kept to a minimum and graphical symbols are used for avoid excessive labeling within the map frame. Existing and proposed park and trail features are distinguished from each other using custom colour and symbology. Omitting a base airphoto layer represents good cartographic design at this scale. It would provide a distraction if it were included, even as a transparency.

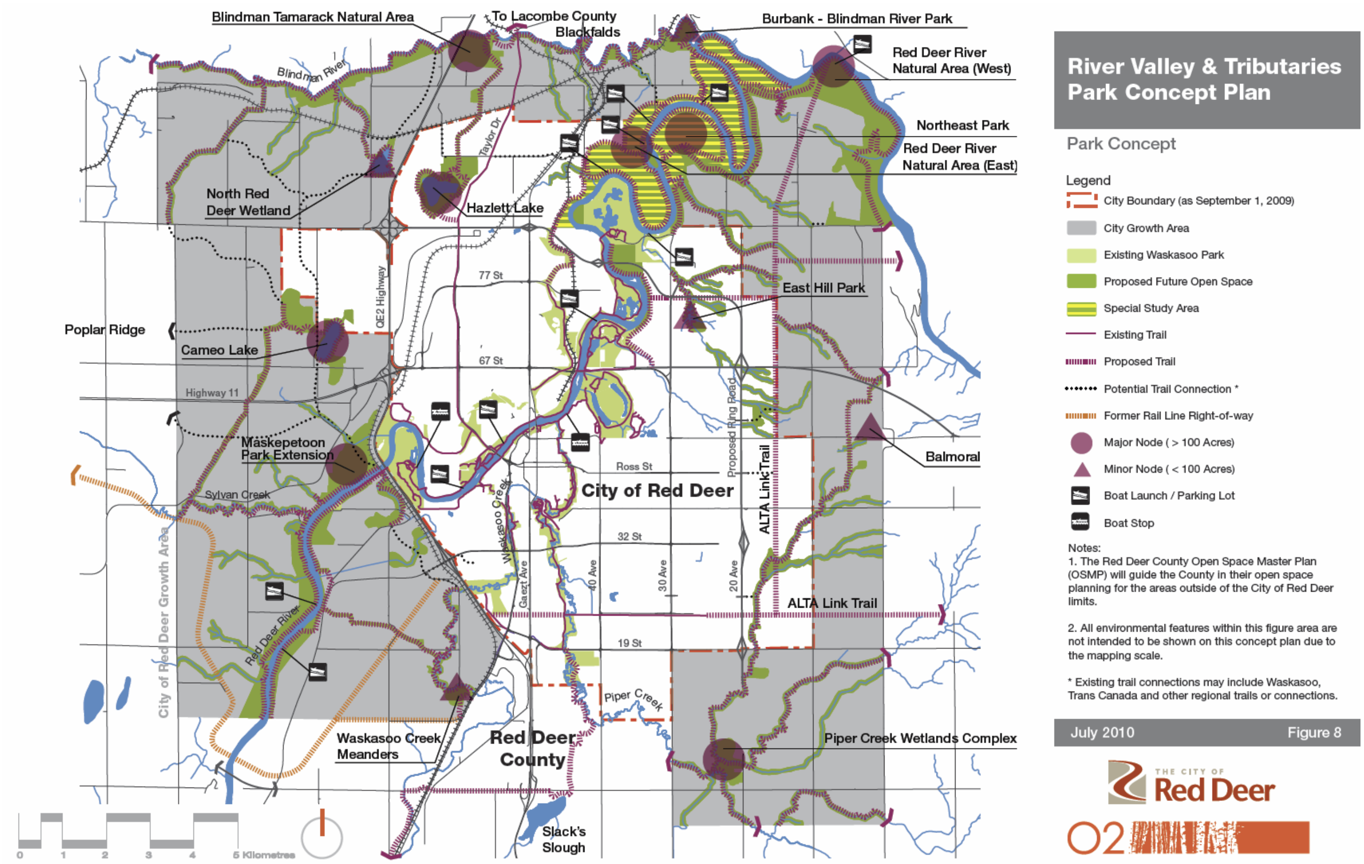


Figure 46. O2 / City of Red Deer River Valley and Tributaries Park Concept Plan Map Sample

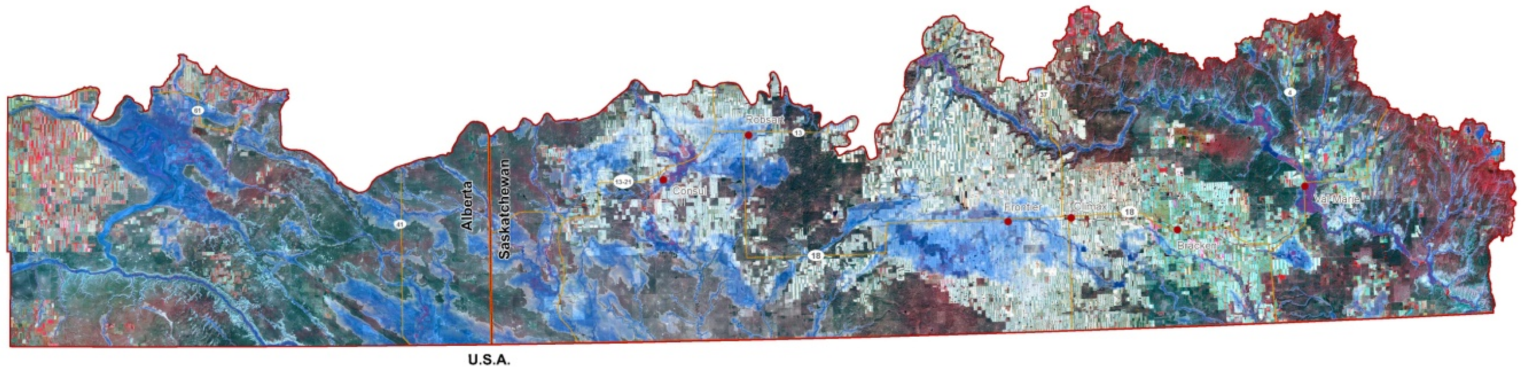
C.3 NAESI Project Riparian Maps

The National Agri-Environmental Standards Initiative (NAESI) reflects the goal of the Environment Chapter under the Federal Agricultural Policy Framework. This goal is to decrease the risks of agriculture while increasing benefits to air, water, biodiversity and soil. NAESI sets performance standards for agriculture that address air, water, biodiversity and soil issues. O2 Planning and Design worked with Environment Canada to develop biodiversity standards by identifying high priority areas using a number of GIS analyses. Part of the project was the identification and mapping of sensitive riparian areas.

O2 used a cost surface spread function to define riparian areas associated with watercourses, lakes, as well as associated low lying buffer areas within the NAESI study area. The cost surface function considers the relative friction of the surrounding landscape based on its topography. Incised valley sides have a high cost and the resulting output defines the riparian zone as a relatively narrow strip. Topographically flat areas have a low cost the output spreads much further creating very broad riparian zones.

Figure 47 shows the presentation of this concept. The top map panel presents the generated topographic cost values as a blue semi-transparent overlay on top of a false colour mosaic of Landsat imagery. This allows the underlying land cover to be seen in the context of the riparian model. The bottom panel shows a land cover analysis within the defined riparian boundary of low cost distance. This map layer is the result of a simple intersection between land use / land cover classification data and the cost distance model from third order streams and lakes. When presented with minimal background data it allows for easy interpretation of key land cover types within riparian areas.

Topographic Cost Analysis of 3rd Order and Greater Watercourses in the Mixed-Grass Study Area



Generalized Landcover Within a Topographic Buffer of Watercourses and Associated Waterbodies in the Mixed-Grass Study Area

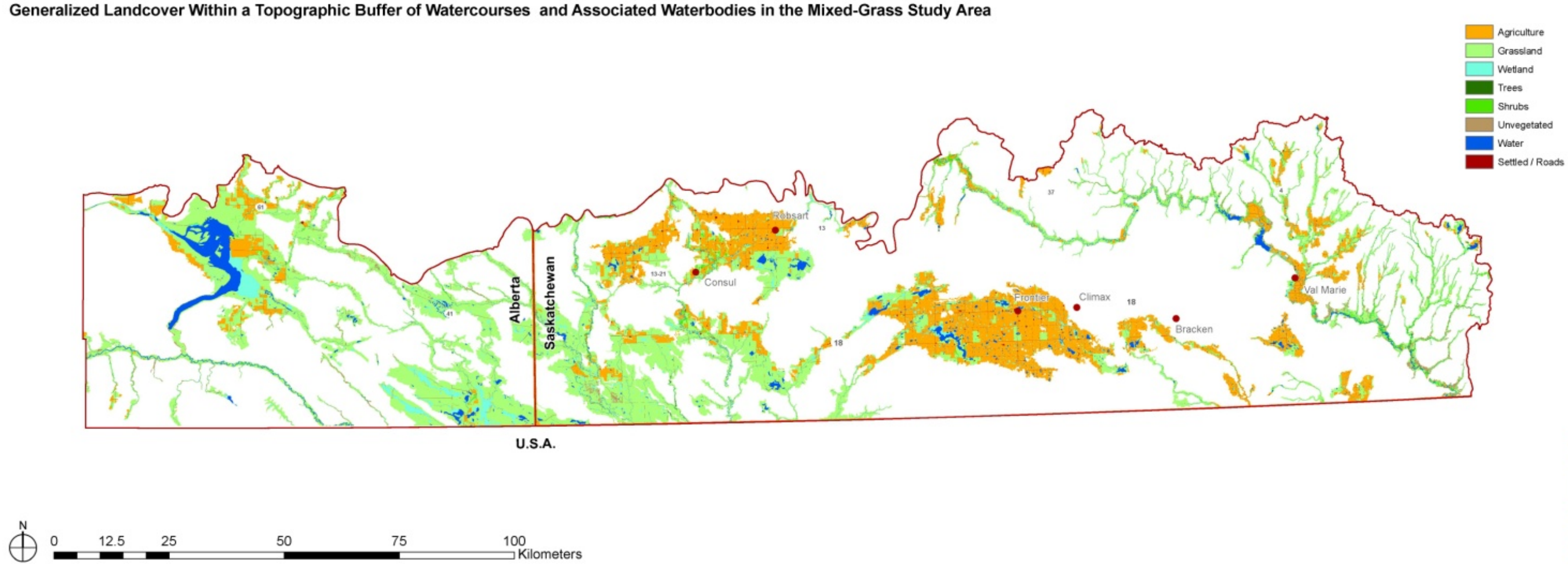


Figure 47. O2 / Environment Canada NAESI Riparian Areas Map Example

C.4 City of Richmond Riparian Areas Map

An example of a municipal riparian areas map for the City of Richmond is provided in Figure 48. This example uses linear symbology to denote specific management corridors. Base features are kept to a minimum and are excluded entirely from areas outside of Richmond. Photos are tied to the map features by arrows to provide examples of difference in appearance between the 5 m and 15 m Riparian Management Areas. This map works well because its focus is solely on showing management areas. If there were other themes (riparian health, bank stability, parks) included as well it would rapidly become crowded and difficult to interpret.

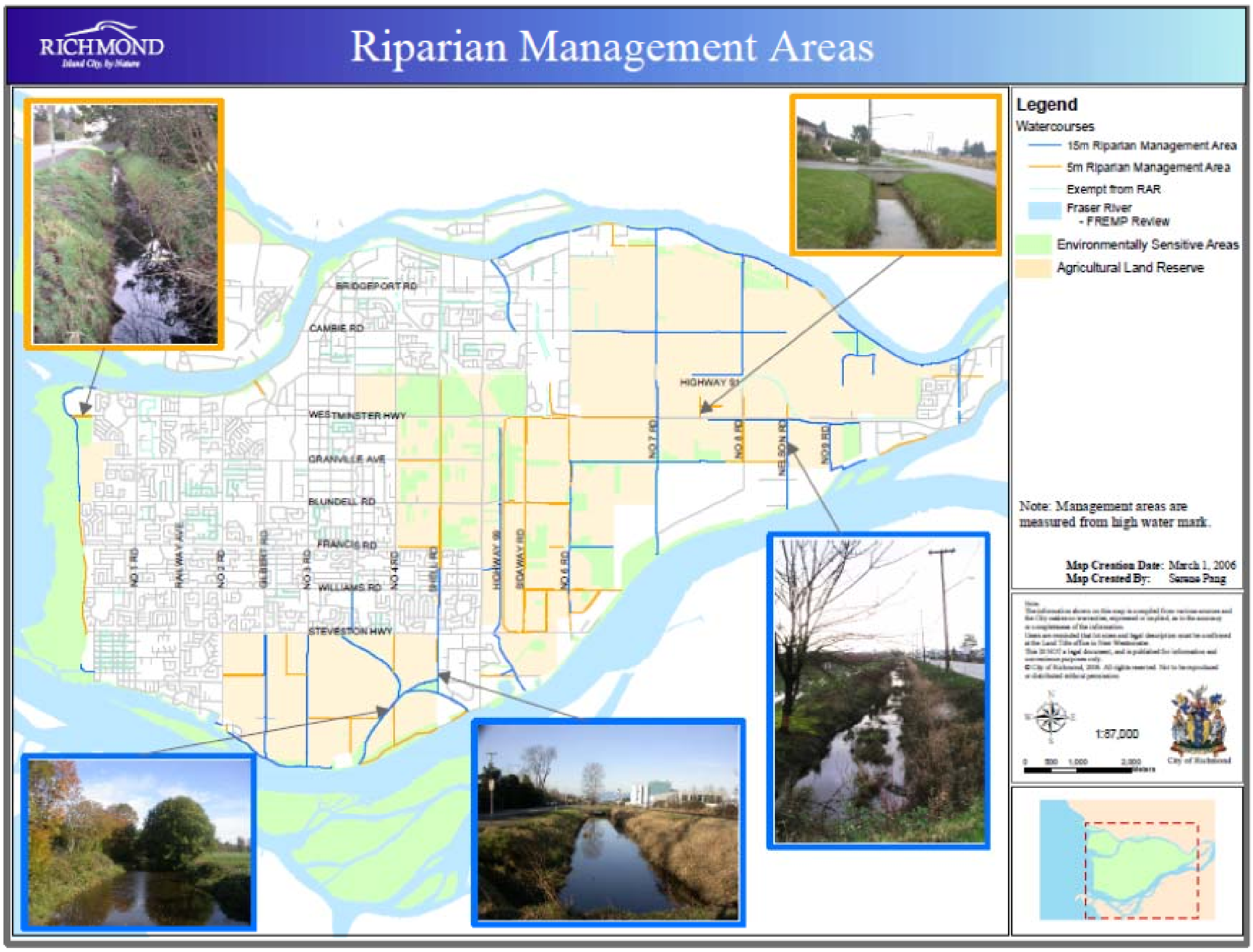


Figure 48. **City of Richmond, BC Riparian Management Areas Map Example**

C.5 Natural Asset Management for Urban Waterways – Hills Shire Council, New South Wales, Australia

The Maps contained in this report use symbology of stream segments to denote specific riparian environments and conditions. Figure 49 shows the classification of stream vectors into what are termed 'river styles'.

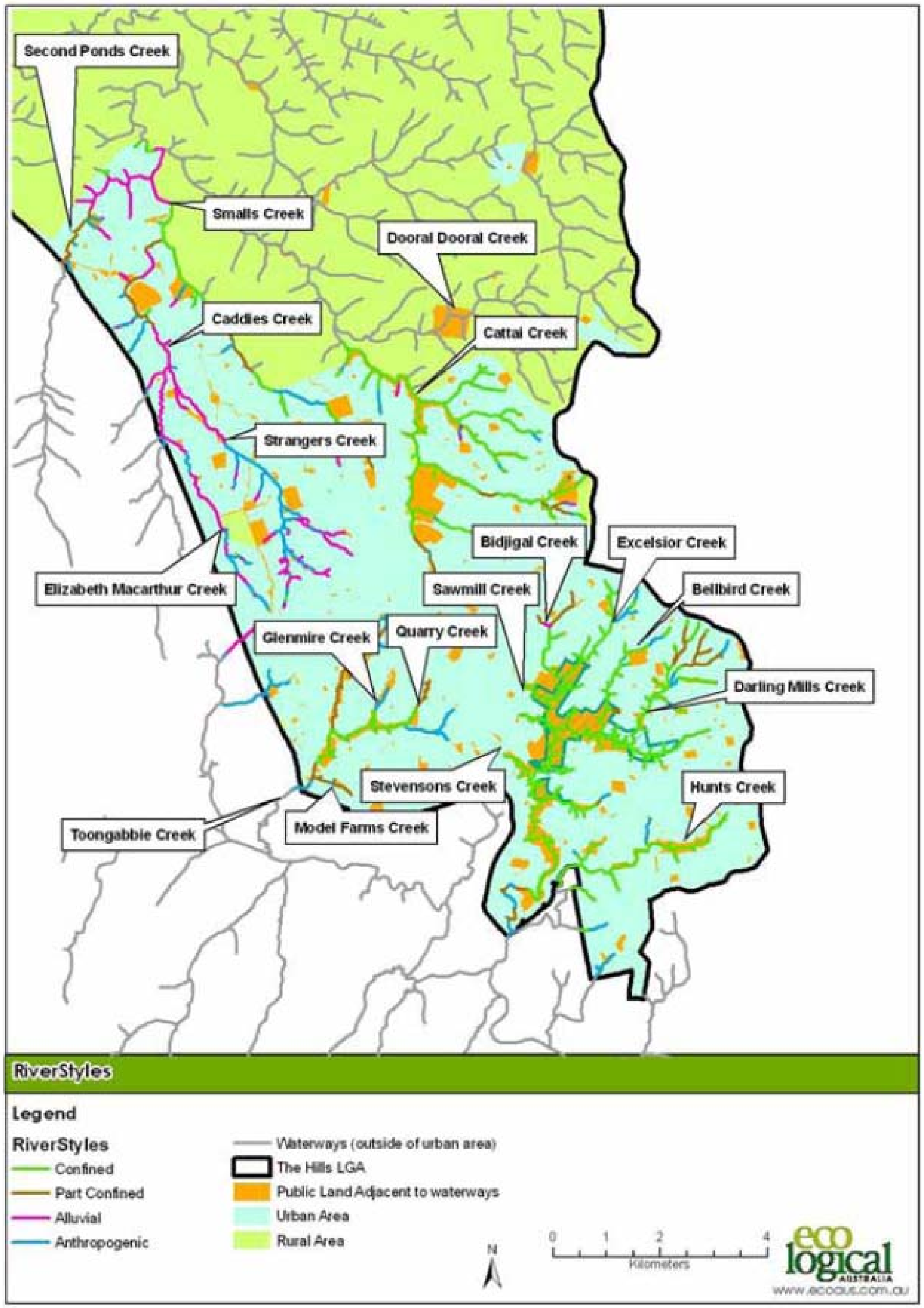


Figure 49. Natural Asset Management for Urban Waterways – River Styles Map Example
Source: (HCCREMS, 2010)

River styles are broad classifications of the chief characteristic of that section of stream. By symbolizing just the vector segments this allows a lot of information to be presented at a fairly broad scale. This approach also works well for the condition assessment (Figure 50), which simply applies a colour code to segmented stream vectors to show their relative health.

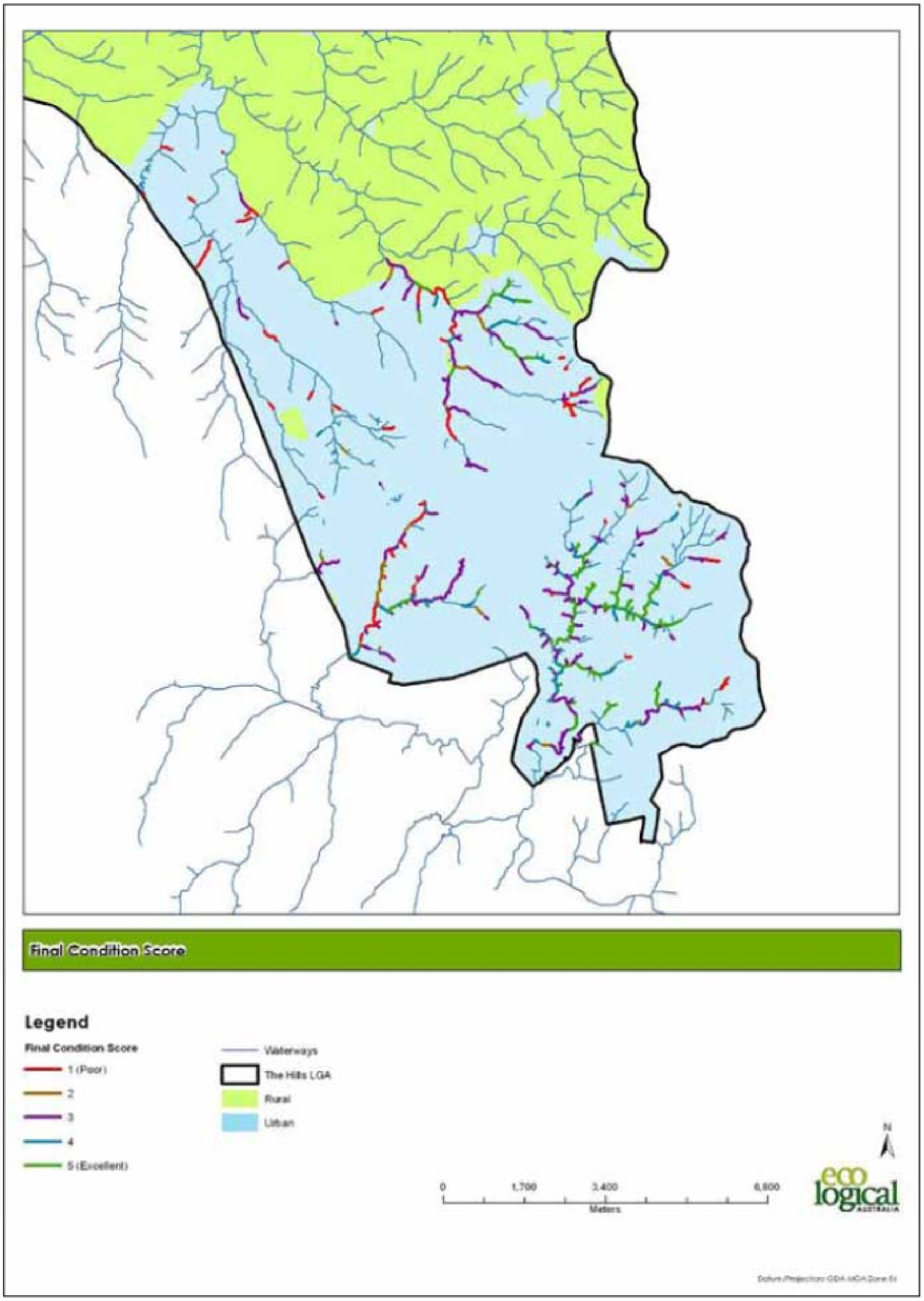


Figure 50. Natural Asset Management for Urban Waterways – River Condition Map Example
Source: (HCCREMS, 2010)

C.6 Other Examples

Samples from other riparian area mapping projects are also provided below, including the Klamath River partnership's riparian maps for the Sprague - Lower Williamson Watershed Assessment (Figure 51 and Figure 52), a map comparing fixed-width riparian buffers to variable width riparian buffers for the Cuyahoga Valley National Park in Ohio (Figure 53), a height-above-river GIS output model for the Walker River in Nevada (Figure 54).

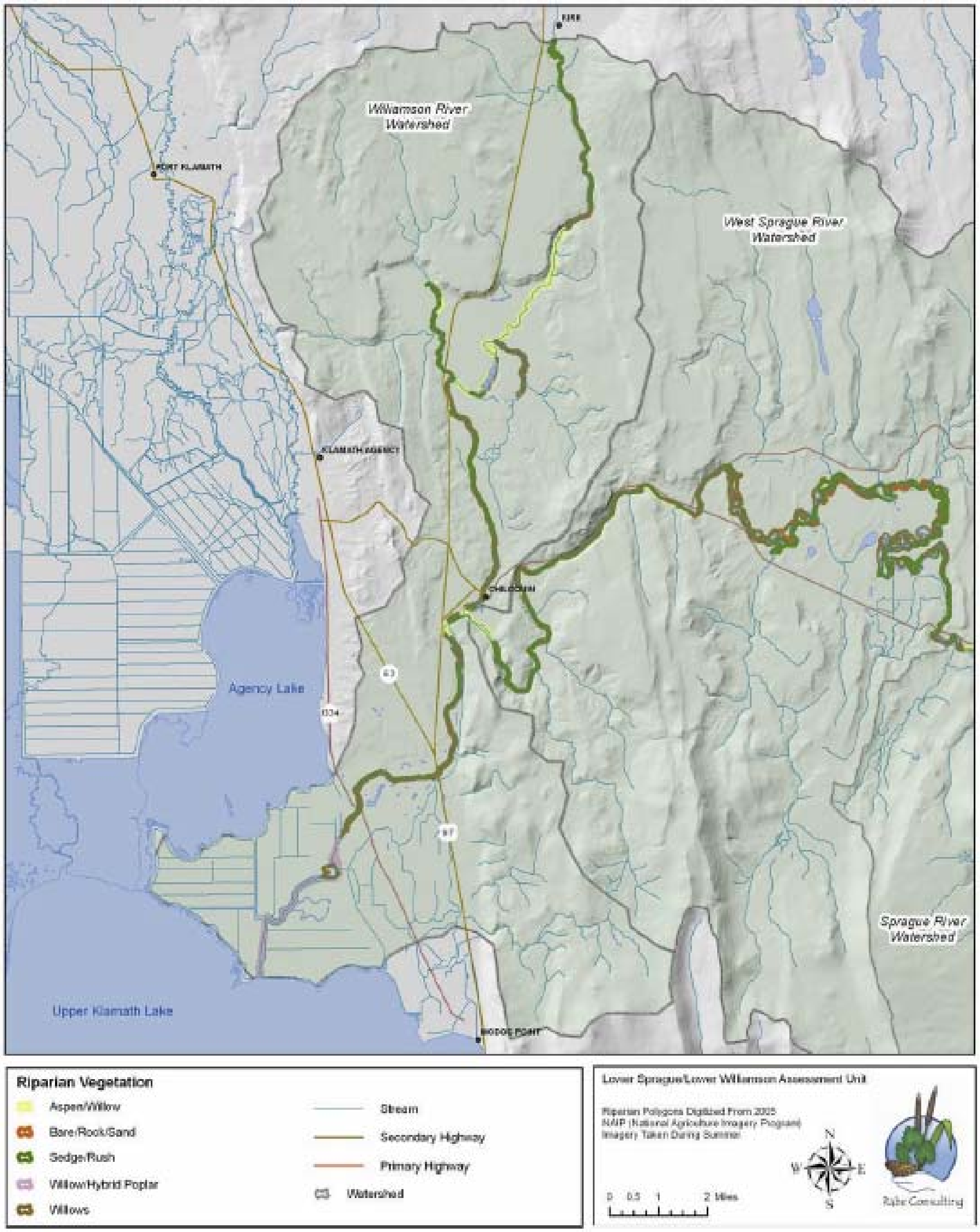


Figure 51. Sprague - Lower Williamson Watershed Assessment Riparian Maps, Oregon
Source: Klamatth Partnership (2005)

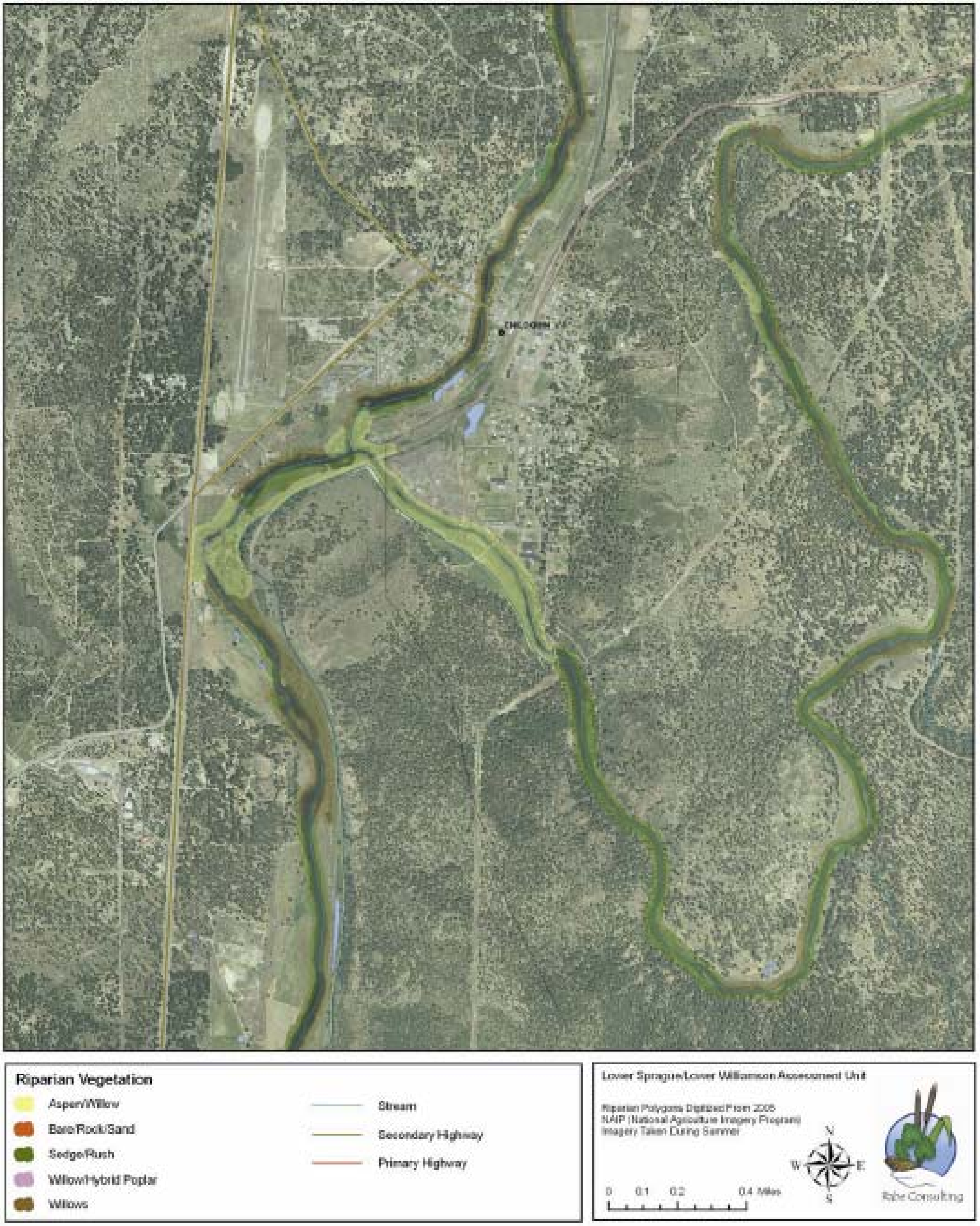


Figure 52. **Sprague - Lower Williamson Watershed Assessment, Oregon, Close-Up of Aerial Photography Interpretation**

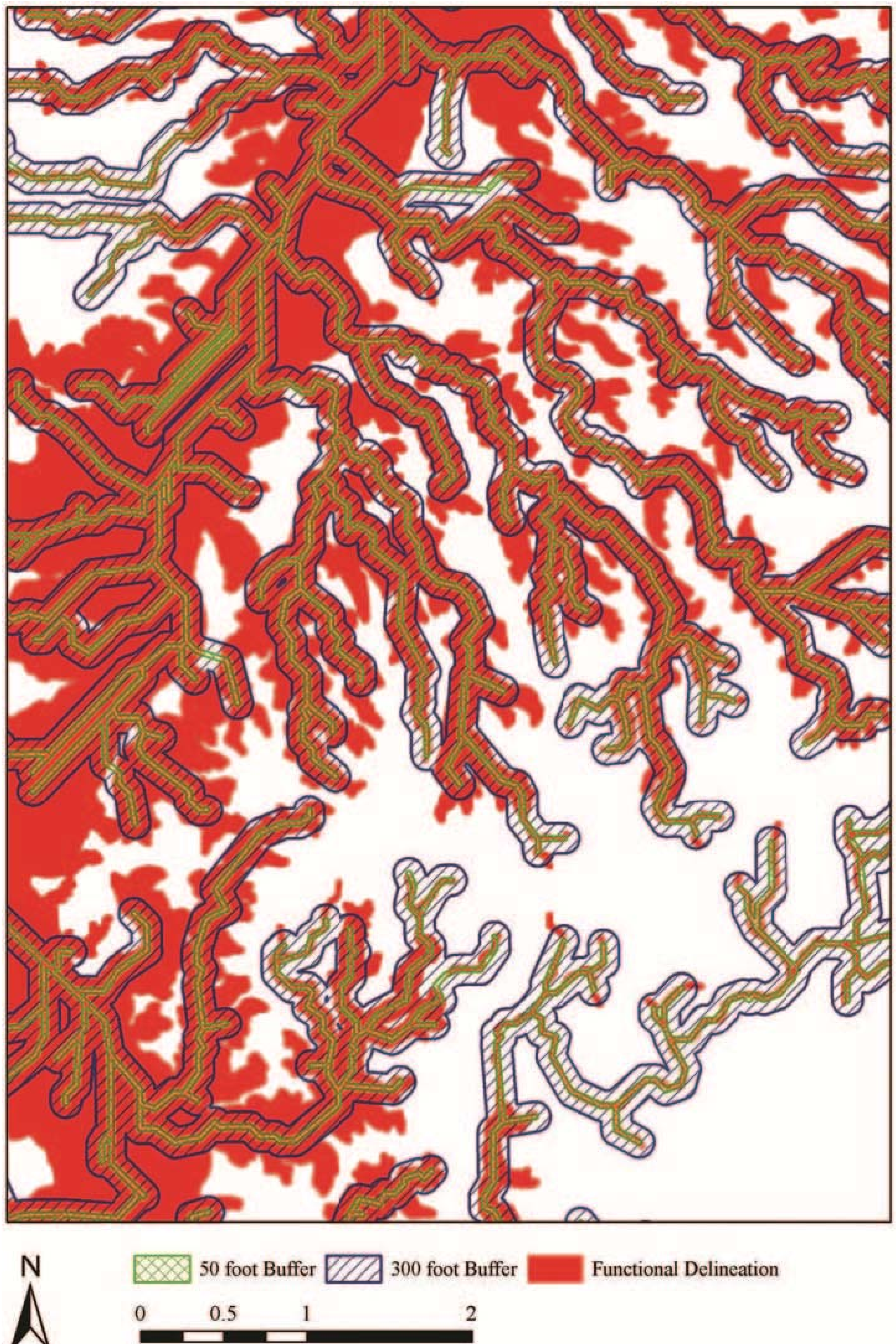
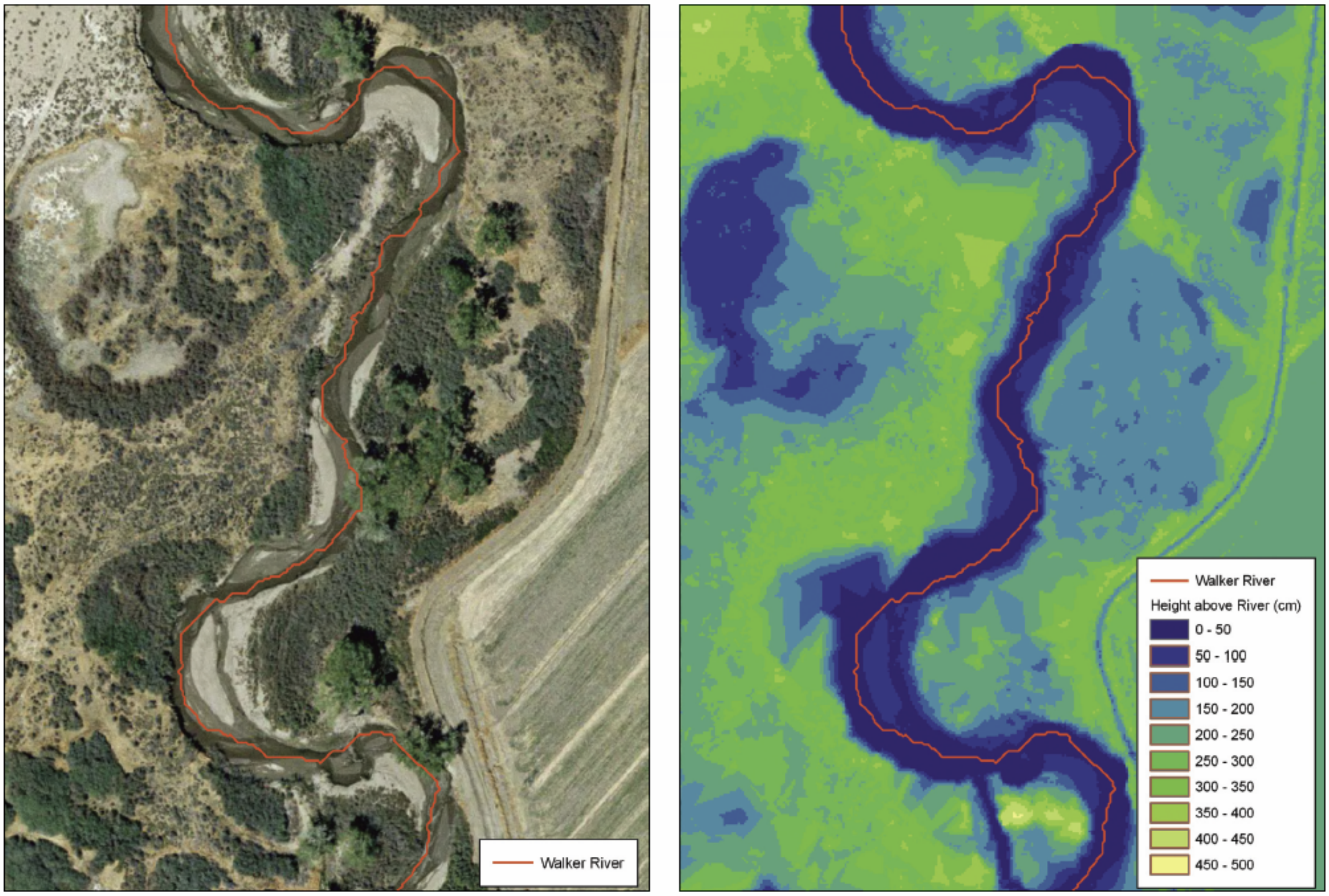


Figure 53. GIS comparison of 50 and 300 ft fixed-width buffers and the functionally delineated riparian areas, Cuyahoga Valley National Park *(Holmes and Goebel 2011)*



The figure on the left is a 0.3048-meter-resolution aerial photograph of the Walker River in Nevada. The image on the right is the height-above-river map using a 300-meter kernel size and classified into 50-centimeter vertical intervals. In the upper left-hand corner is a eutrophic oxbow lake that is low lying yet disconnected from the river channel. Near the bottom of the map is a shallow river channel that periodically fills with water, cutting off the point bar. An irrigation ditch is visible on the right-hand side of the image.

Figure 54. Height Above River model, Walker River, United States *Source: (Dilts et al., 2010)*