Riparian Area Assessment of the North Saskatchewan & Battle River Watersheds

FINAL REPORT

Prepared for:

NSWA
NORTH SASKATCHEWAN WATERSHED ALLIANCE

BATTLE RIVER WATERSHED ALLIANCE

Prepared by:

FIERA Biological Consulting

Project #1987c
October 2021

Suggested Citation:

Fiera Biological Consulting Ltd. 2021. Riparian Area Assessment of the North Saskatchewan and Battle River Watersheds. Prepared for the North Saskatchewan Watershed Alliance and the Battle River Watershed Alliance. Report Number 1987c. Pp. 56 + Appendices.

Acknowledgements

Fiera Biological would like to thank the North Saskatchewan Watershed Alliance and Battle River Watershed Alliances, and in particular Mary Ellen Shain, Sarah Skinner, Leah Kongsrude, and David Samm for their leadership and guidance throughout this project.

The North Saskatchewan Watershed Alliance (NSWA) and the Battle River Watershed Alliance (BRWA) would like to acknowledge the financial support of the Government of Canada and the Government of Alberta through the Canadian Agricultural Partnership. This project was also supported by the NSWA and BRWA annual operating grant, which is provided to Watershed Planning and Advisory Councils through the Government of Alberta Water for Life Strategy. Without this annual grant, this project would not have been possible. Furthermore, the NSWA and BRWA would like to acknowledge the Headwaters Alliance and the Watershed Resiliency and Restoration Program for sponsoring the initial riparian assessment project in the Modeste watershed, where the methods that were used in this study were initially developed. Finally, we would like to thank the Government of Alberta for the substantial contribution of spatial data that was foundational to the success of this project.

Battle River Watershed Alliance

NSWA North Saskatchewan Watershed Alliance

Alberta Government

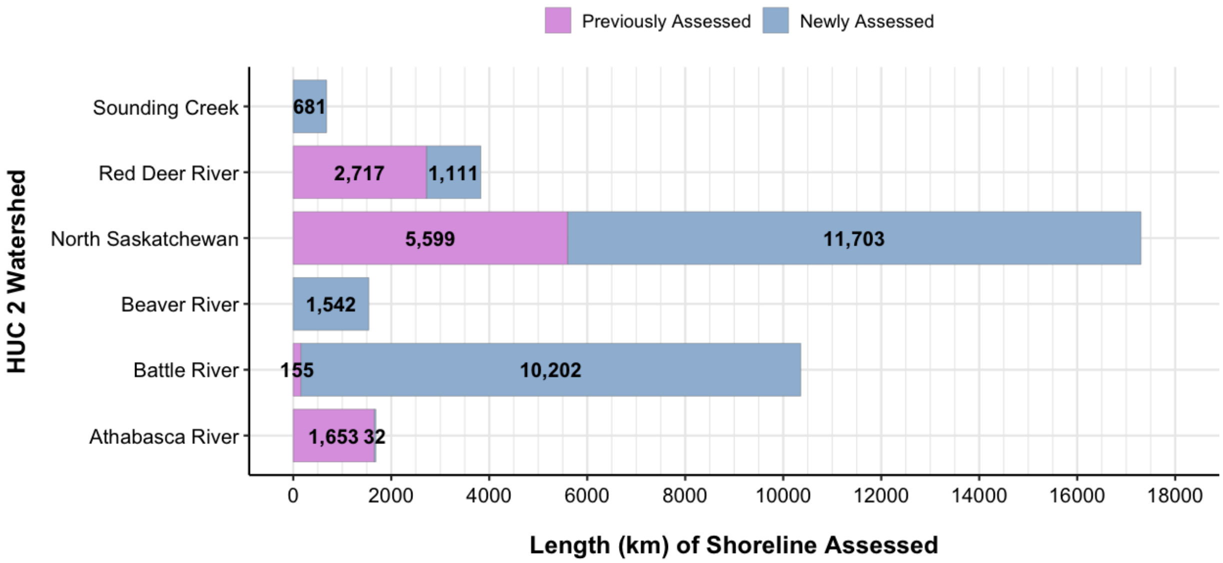
Canada

Executive Summary

Riparian lands have substantial ecological, economic, and social value. For example, intact riparian habitats stabilize the banks of waterbodies and help modulate water velocities and high water events, thereby improving water quality and protecting surrounding lands from flooding. Intact riparian areas also play a vital role in the exchange of inorganic and organic material between terrestrial and aquatic ecosystems and regulate water temperature and the instream light environment, thereby ensuring suitable habitat for a range of aquatic species. Given the significant role that an intact riparian zone has on providing ecosystem services and supporting healthy and functional aquatic ecosystems, there is a need to effectively manage riparian areas. Thus, understanding the distribution of intact riparian habitat across the landscape and identifying areas where riparian intactness has been degraded is essential to improving conservation and management outcomes.

In an effort to better manage riparian habitats within the North Saskatchewan River (NSR) and Battle River watersheds, the North Saskatchewan Watershed Alliance (NSWA) and the Battle River Watershed Alliance (BRWA) retained Fiera Biological Consulting to assess riparian habitat along approximately 25,271 km of lake, creek, stream, and river shoreline. The majority of the shorelines of interest (21,905 km) were located within the NSR or Battle River watersheds; however, an additional ~3,400 km of shoreline was also assessed within municipalities that partially intersect, but are not completely contained within, either the NSR or Battle River watersheds. In addition to assessing new shorelines, an important component of this project was compiling data for ~10,124 km of shoreline that has been previously assessed in central Alberta using the same assessment methodology, and these data were combined together to create a single, seamless riparian assessment dataset that contains ~35,400 km of lake, river, stream, and creek shoreline.

LENGTH OF SHORELINE ASSESSED IN THIS STUDY & PREVIOUSLY COMPLETED STUDIES

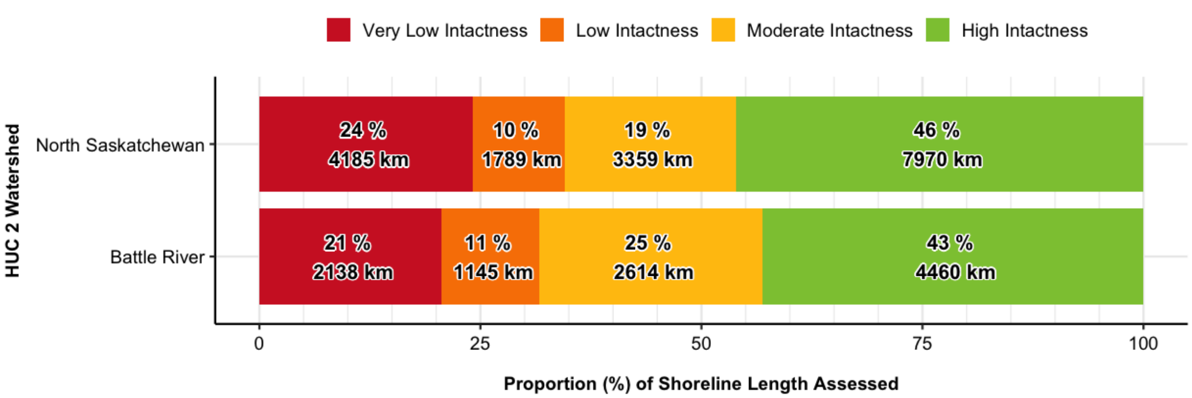


Riparian vegetation intactness was assessed along the shorelines of interest using a desktop-based assessment tool that utilizes a current land cover layer derived from satellite imagery. Intactness was assessed within riparian management areas (RMAs) that had a variable length, as determined by major breaks in the proportion of vegetation cover along the shoreline, and a fixed 50 m buffer that extended perpendicular to the shoreline. Within each RMA, intactness was assessed using metrics that measured the type and extent of vegetation and human disturbance present. Intactness was used as the measure of riparian condition because the relationship between an intact riparian zone and the health or function of the aquatic environment is well established.

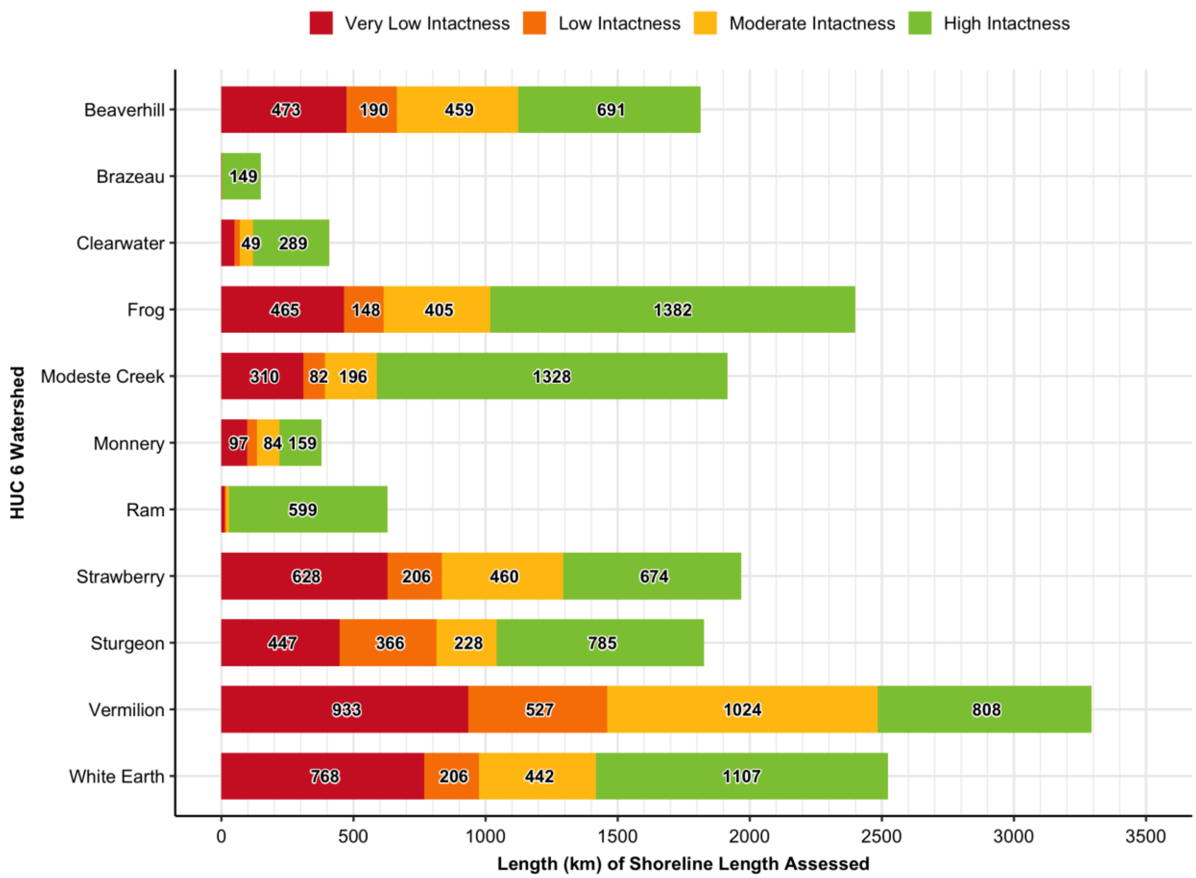
In the North Saskatchewan River watershed, 46% (7,970 km) of the shoreline assessed was classified as High Intactness, with an additional 19% (3,359 km) of the shoreline classified as Moderate Intactness. The remaining 34% was classified as either Low (10%, 1,789 km) or Very Low (24%, 4,185 km) Intactness. Within the North Saskatchewan River watershed, over 3,000 km of shoreline was assessed within the Vermillion HUC 6 watershed, and this watershed also had the greatest length of shoreline assessed as either Low (527 km) or Very Low (933 km) Intactness. The White Earth and Strawberry HUC 6 watersheds also had a substantial amount of shoreline assessed as either Low or Very Low Intactness. Conversely, both the Frog and Modeste Creek watersheds had more than 1,300 km of shoreline assessed as High Intactness.

In the Battle River watershed, 43% (4,460 km) of the shoreline assessed was classified as High Intactness, with 25% (2,614 km) classified as Moderate Intactness. The remaining 32% shoreline was classified as either Low (11%, 1,145 km) or Very Low (21%, 2,138 km) Intactness. Within Battle River watershed, the greatest length of shoreline was assessed within the Bigstone HUC 6 watershed, and this watershed also had the greatest combined length of shoreline assessed as Low (351 km) and Very Low (952 km) Intactness. Conversely, the Paintearth HUC 6 watershed had the greatest length of shoreline assessed as High Intactness.

RIPARIAN INTACTNESS IN THE NORTH SASKATCHEWAN & BATTLE RIVER WATERSHEDS

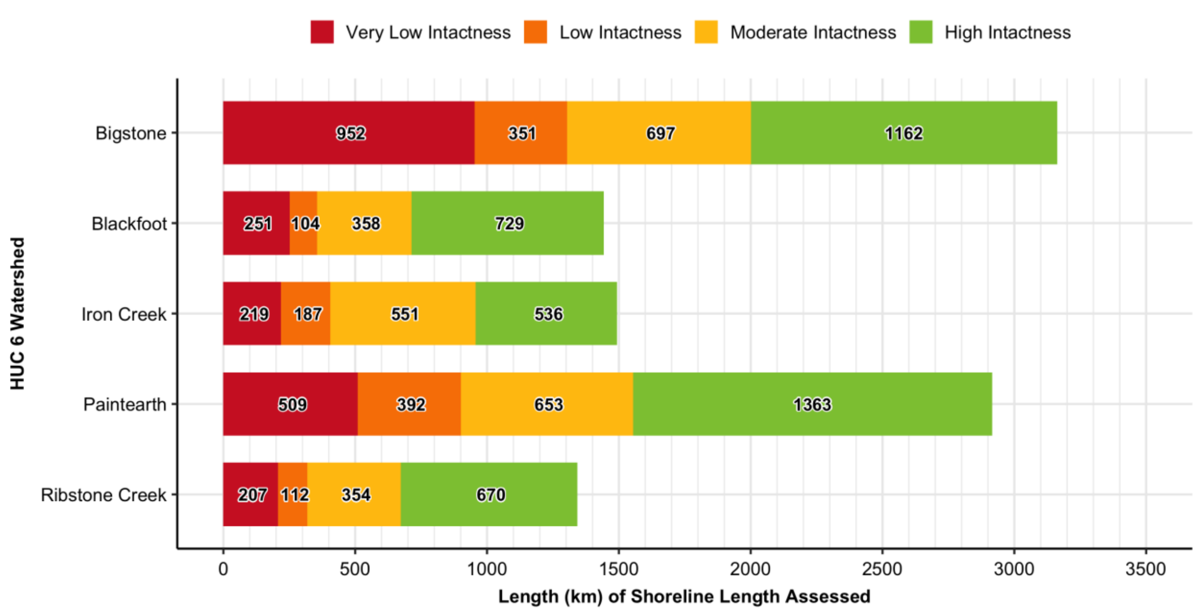


RIPARIAN INTACTNESS FOR HUC 6 WATERSHEDS IN THE NORTH SASKATCHEWAN RIVER WATERSHED



NOTE: Numbers indicate the total length (km) of shoreline associated with each intactness category. Categories with no label contain <15 km of shoreline.

RIPARIAN INTACTNESS FOR HUC 6 WATERSHEDS IN THE BATTLE RIVER WATERSHED



NOTE: Numbers indicate the total length (km) of shoreline associated with each intactness category.

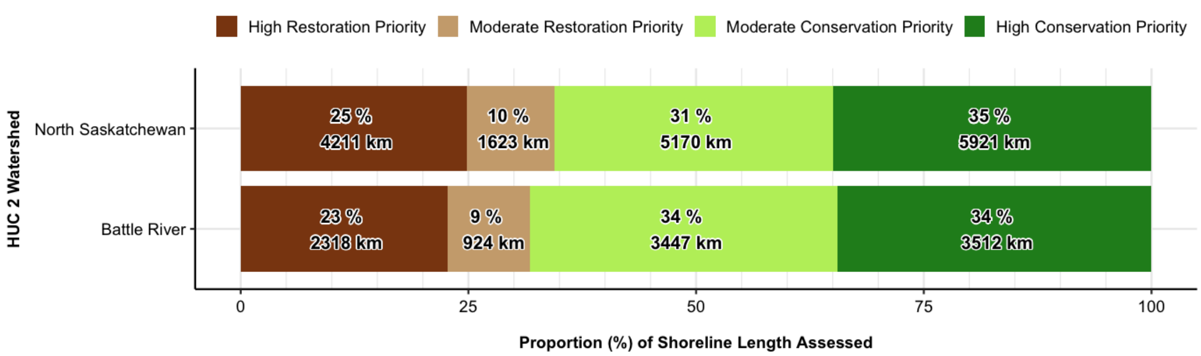
In addition to assessing riparian intactness, natural and anthropogenic pressure within local catchments was evaluated to identify riparian areas that may be functionally impaired due to surrounding land use activities. Each RMA that was assessed was assigned an intactness and pressure score, and these scores were combined using a prioritization matrix that assigned a conservation or restoration priority to each riparian area that was assessed. This allows land managers to target specific areas for conservation and restoration, as well as identify areas where more detailed, site-specific field assessments of riparian health or condition may be required.

In the North Saskatchewan River watershed, 66% (11,091 km) of the shoreline was classified as either High or Moderate priority for conservation, with the remaining 35% (5,834 km) of the shoreline identified as being either High or Moderate Restoration Priority. The Vermillion and White Earth HUC 6 watersheds had both the highest proportion and length of shoreline identified as High Restoration Priority, while the Ram and Brazeau watersheds had the greatest proportion of shoreline classified as High Conservation Priority. In terms of shoreline length, the Modeste Creek and Frog watersheds had the greatest amount of shoreline classified as High Conservation Priority.

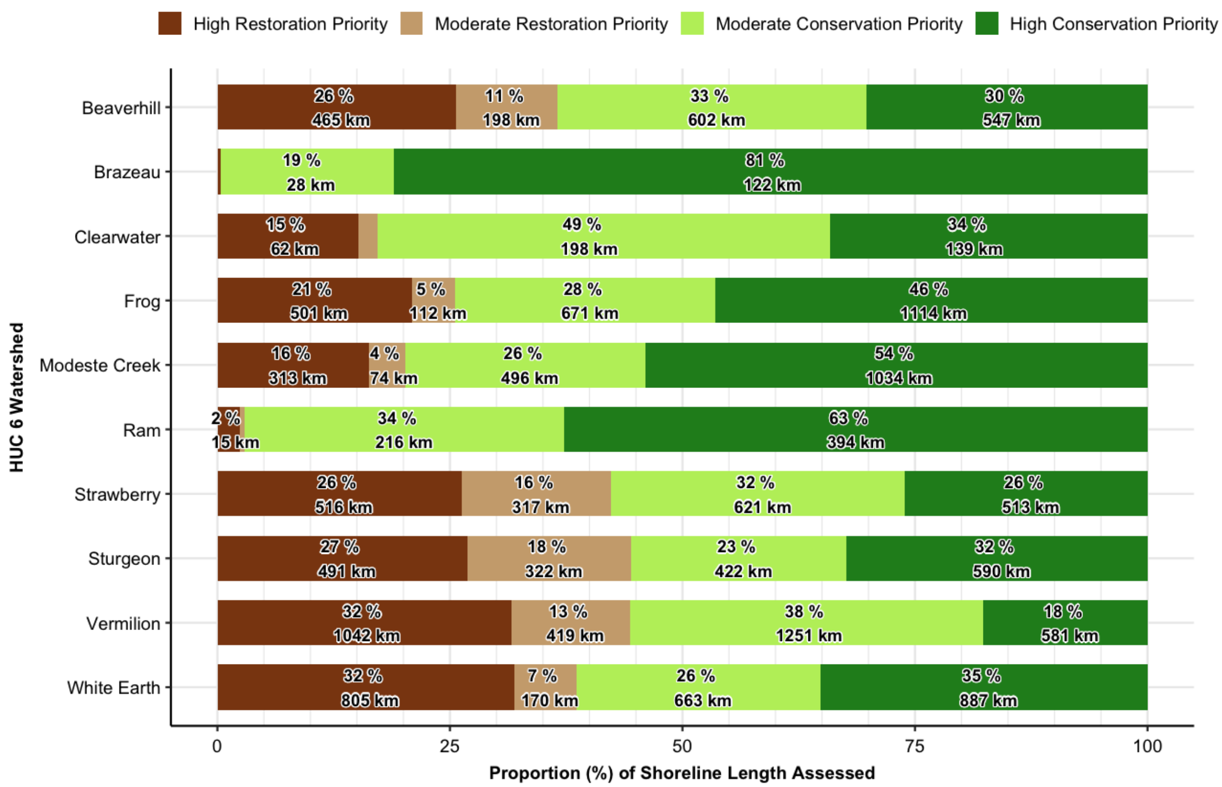
In the Battle River watershed, 68% (6,959 km) of the shoreline that was assessed was classified as High or Moderate Conservation Priority. The remaining 32% was classified as either Low (9%, 924 km) or Very Low (23%, 2,318 km) Restoration Priority. Over 40% of the shoreline within the Bigstone HUC 6 watershed was classified as either High or Moderate Restoration Priority, with the Painteearth watershed having the second largest proportion and length of shoreline assessed as High or Moderate Restoration Priority. Blackfoot and Ribstone Creek watersheds had the highest proportion of shoreline classified as either High or Moderate Conservation Priority.

This project has generated scientific information that can be used as the basis for the development and implementation of an evidence-based framework for adaptively managing riparian areas throughout Central Alberta. Through the commissioning of this study, the NSWA, BRWA, and their stakeholders now have an important foundation of scientific evidence upon which to target restoration and conservation activities that will improve water quality, biodiversity, and drought and flood resilience throughout the North Saskatchewan and Battle River watersheds.

CONSERVATION & RESTORATION PRIORITY IN THE NORTH SASKATCHEWAN & BATTLE RIVER WATERSHEDS

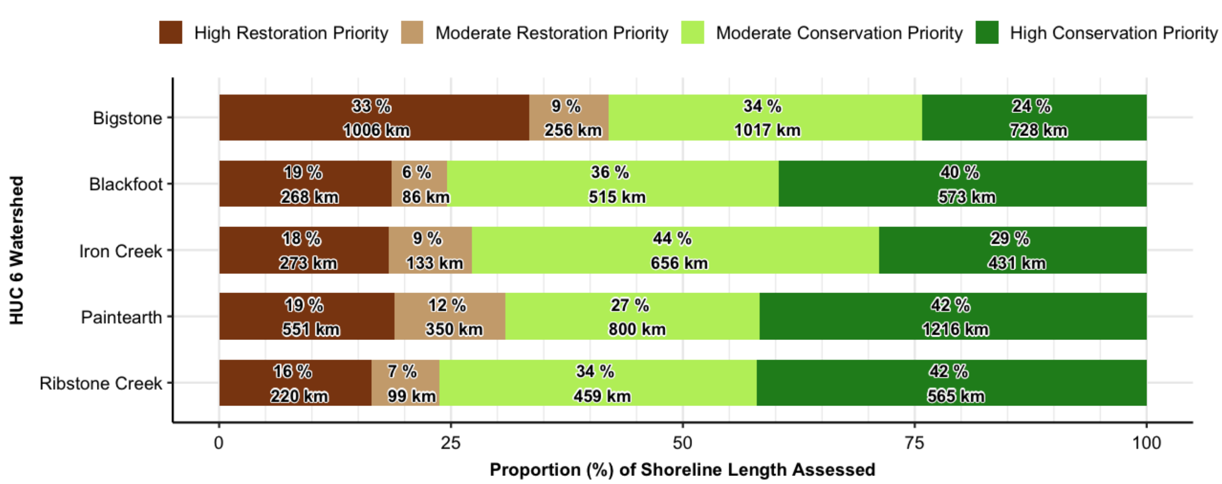


CONSERVATION & RESTORATION PRIORITY FOR HUC 6 WATERSHEDS IN THE NORTH SASKATCHEWAN RIVER WATERSHED

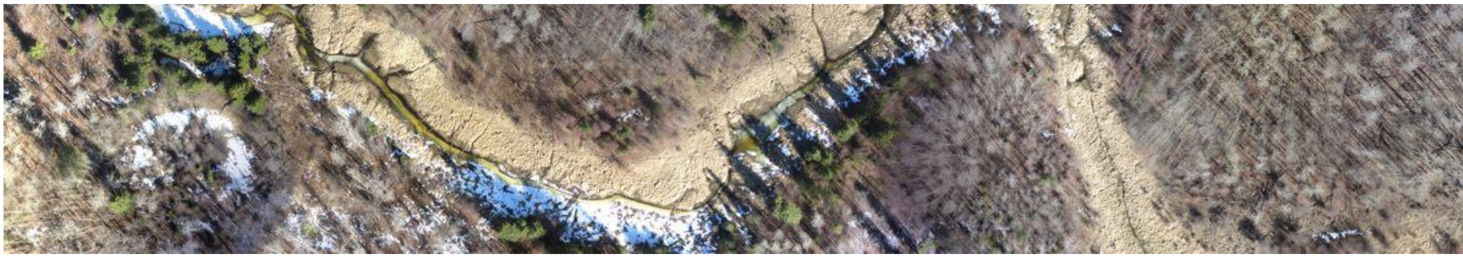


NOTE: Numbers indicate the total length (km) of shoreline associated with each intactness category. Categories with no label contain <15 km of shoreline.

CONSERVATION & RESTORATION PRIORITY FOR HUC 6 WATERSHEDS IN THE BATTLE RIVER WATERSHED



NOTE: Numbers indicate the total length (km) of shoreline associated with each intactness category.



List of Terms

Abbreviations

AAFC: Agriculture and Agri-food Canada

ABMI: Alberta Biodiversity Monitoring Institute

AGS: Alberta Geological Survey

ARHMS: Alberta Riparian Habitat Management Society (Cows & Fish)

BRWA: Battle River Watershed Alliance

BMP: Best Management Practice

DEM: Digital Elevation Model

FWMIS: Fisheries & Wildlife Management Information System

HUC: Hydrologic Unit Code

LiDAR: Light Detection and Ranging

NSR: North Saskatchewan River

NSWA: North Saskatchewan Watershed Alliance

RMA: Riparian Management Area

Glossary

Aerial Videography: Video captured from a low flying aerial platform, such as helicopter or ultra-light aircraft.

Catchment: Small local drainage areas ranging in size from 0.032 to 72 km^2 that were acquired as part of this study to assess pressure on riparian system function. The catchment data used in this study are freely available from the provincial government as part of Alberta ArcHydro Phase 2 spatial dataset (Government of Alberta 2018).

Conservation Priority: A riparian management area that has been assessed as being moderately to highly intact and is associated with a catchment assessed as moderately to low pressure. Because these areas are largely in a natural state, they are considered to be targets for conservation and/or protection to maintain their current state of function and ecological value.

Hydrologic Unit Code: The Hydrologic Unit Code Watersheds of Alberta (HUC) represent a collection of nested hierarchically structured drainage basin feature classes that have been created using the Hydrologic Unit Code system of classification developed by the United States Geological Survey (USGS), with accommodation to reflect the pre-existing Canadian classification system. The HUC Watersheds of Alberta consist of successively smaller hydrologic units that nest within larger hydrologic units, resulting in a hierarchal grouping of alphanumerically-coded watershed feature classes. The hydrological unit codes include HUC 2, HUC 4, HUC 6, HUC 8, and HUC 10 with HUC 2 being the coarsest level of classification and HUC 10 being the finest level of classification.

Indicator: A measurable or descriptive characteristic that can be used to observe, evaluate, or describe trends in ecological systems over time.

Intactness: In reference to the condition of natural habitat, intactness refers to the extent to which habitat has been altered or impaired by human activity, with areas where there is no human development being classified as high intactness and areas with extensive human development being considered very low intactness.

Left Bank: The bank of a river, stream, or creek that is located on the left when facing downstream.

Metric: A qualitative or quantitative aspect of an *indicator*; a variable which can be measured (quantified) or described (qualitatively) and demonstrates either a trend in an indicator or whether or not a specific threshold was met.

Named Lake: Lakes or wetlands with an assigned name in the Alberta Base Features hydrography dataset or the provincial Fisheries & Wildlife Management Information System Hydro Arcs dataset.

Named Stream: Streams, creeks, or rivers with an assigned name in the Alberta Base Features hydrography dataset or the provincial Fisheries & Wildlife Management Information System Hydro Arcs dataset.

Resilience: The capacity of an ecosystem to resist, absorb, and recover from the effects of natural and human-caused disturbance to preserve ecological and hydrological services and functions.

Restoration Priority: A riparian management area that has been assessed as being of low or very low intactness and that is associated with a catchment assessed as high pressure. Because these areas are largely in a modified or disturbed state, they should be targets of restoration to improve their current state of function and ecological value.

Right Bank: The bank of a river, stream, or creek that is on the right when facing downstream.

Riparian Area, Riparian Habitat, Riparian Land, or Riparian Zone: Riparian lands are transitional areas between upland and aquatic ecosystems. They have variable width and extent both above and below the ground. These lands are influenced by and/or exert an influence on associated waterbodies, which includes alluvial aquifers and floodplains, when present. Riparian lands usually have soil, biological, and other physical characteristics that reflect the influence of water and/or hydrological processes (Clare and Sass 2012).

Riparian Management Area (RMA): As per Teichreb and Walker (2008), and for the purpose of this report, a riparian management area is defined as an area along the shoreline of a waterbody that includes near-shore emergent vegetation zone, the riparian zone, and a riparian protective (buffer) zone. In this study, an RMA has a fixed 50 m width and a variable length, the extent of which is determined by a major change in the amount of vegetation cover present.

Unnamed Creek: Streams, creeks, or rivers with no assigned name in the Alberta Base Features hydrography dataset or the provincial Fisheries & Wildlife Management Information System Hydro Arcs dataset. These features may be locally known by a particular name; however, local names have not been used in this report.

Unnamed Lake: Lakes or wetlands with no assigned name in the Alberta Base Features hydrography dataset or the provincial Fisheries & Wildlife Management Information System Hydro Arcs dataset. These features may be locally known by a particular name; however, local names have not been used in this report.

Waterbody: 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. This includes, but is not limited to lakes, wetlands, aquifers, streams, creeks, and rivers.

Watercourse: A natural or artificial channel through which water flows, such as in creeks, streams, or rivers.

Watershed: An area that, on the basis of topography, contributes all water to a common outlet or drainage point. Watersheds can be defined and delineated at multiple scales, from very large (e.g., thousands of square kilometers) to very small local watersheds (e.g., square metres, such as a small marsh wetland).

Table of Contents

List of Appendices

Appendix A: North Saskatchewan River HUC 6 Watersheds

Appendix B: Battle River HUC 6 Watersheds

Appendix C: Towns & Cities

Appendix D: Rural Municipalities

List of Maps

List of Figures

List of Tables

1.0 Introduction

1.1. Background

Riparian areas are highly complex and dynamic “transitional habitats” that are found along the edge of waterbodies, including rivers, streams, lakes, wetlands, and springs. Riparian areas show steep hydrological and environmental gradients from the water’s edge to the adjacent uplands, and are critical for facilitating the transfer of energy and materials between terrestrial and aquatic ecosystems (NRC 2002). Hydrology (both groundwater and surface water) is the driving force behind the physical, chemical, and biological processes that characterize riparian habitats, and because riparian lands are under the influence of both terrestrial and aquatic processes (e.g. nutrient and sediment transfer), these areas tend to be more biologically productive and have higher levels of biodiversity than other habitats of comparable size (Ibid).

From the perspective of human communities, riparian areas provide a multitude of beneficial ecosystem functions and services, and the relationship between an intact riparian zone and the integrity of the aquatic environment is well established (Pusey and Arthington 2003). For example, intact riparian zones play a vital role in the exchange of inorganic and organic material between the terrestrial and aquatic ecosystems, via the interception of sediments and nutrients that runoff from adjacent upland habitats and through the supply of leaf litter and woody debris. Furthermore, intact riparian vegetation can modulate the transfer of solar energy to the aquatic ecosystem, regulating water temperatures and the instream light environment, ensuring suitable habitat for a range of aquatic species (Pusey and Arthington 2003). Additionally, riparian habitats stabilize the banks of waterbodies and help modulate water velocities and high water events, thereby improving water quality and protecting surrounding lands from flooding (Orewole et al. 2015; Olokeogun et al. 2020). Riparian vegetation also slows floodwater and increases floodplain residence times, which increases recharge to groundwater aquifers (Swanson et al. 2017). In turn, this allows water to seep back into streams during low water or drought periods (Blackport et al. 1995), thereby stabilizing base water flows (Caissie 1991; Blackport et al. 1995).

Despite the importance of these habitats, the loss and impairment of riparian lands in Alberta over the last century has been significant (Clare and Sass 2012), and as a result, recent watershed management efforts throughout the province have been focused on identifying priority areas for riparian restoration and habitat management. In order to efficiently target habitat restoration efforts and resources across large spatial extents, however, there first needs to be reliable information about the location, condition, and function of riparian habitats.

1.2. Methods for Assessing Riparian Areas

1.2.1. Field Assessment

The finest scale and most detailed evaluations of riparian condition come from “boots-on-the-ground” site-specific field assessments and/or inventories of riparian areas. In this type of assessment, such as the Alberta Riparian Habitat Management Society (ARHMS, also known as “Cows & Fish”) Riparian Health Assessment, detailed and local-scale traits of riparian areas are evaluated by trained practitioners, and a comprehensive and thorough assessment of riparian condition is made. Metrics evaluate a wide range of riparian attributes including: vegetation type, structure, and composition; bank characteristics; soil attributes; and land use and disturbance. The final compiled score provides a snapshot of whether a riparian area is “Healthy”, “Healthy, but with problems”, or “Unhealthy”, and gives a land-owner or other interested stakeholders an idea of where to focus management activities. To date, the vast majority of the field-based riparian assessments completed by Cows and Fish have been in central and southern Alberta, and while the site-specific detail offered by this approach cannot be matched, these assessments are limited in their ability to provide information for planning and management at municipal, regional, or larger scales.

Although existing ground-based assessment methods are useful for gathering information about the general condition of riparian habitat at small spatial extents, the site-specific delineation employed for these assessments cannot be scaled up to provide information about riparian condition across larger geographic areas. Further, the results of these assessments are typically not available publicly due to confidentiality agreements with landowners.

1.2.2. Aerial Videography

As an alternative to the highly detailed information required and the substantial time and cost investment associated with field assessments, alternative approaches that utilize recorded video have been applied to assess riparian areas over larger spatial extents. Aerial videography is a tool for assessing riparian habitat where a trained analyst uses spatially referenced continuous video to evaluate a hydrologic system. Instead of walking around and observing the site, the observation takes place through video images acquired from an oblique angle at altitudes of 60 m or less. Riparian condition is assessed within a “riparian management area” (RMA) polygon, and like the field-based Alberta Riparian Habitat Management Society Riparian Health Assessment, the evaluator answers a series of questions about the functional attributes of the riparian lands to derive a score that is then classified according to three health categories that are akin to the field-based approach.

Videography has been applied by various organizations across Alberta using a variety of airborne video platforms (e.g., Mills and Scrimgeour 2004, AENV 2010, NSWA 2015). The benefit of videography is that the entire riparian area of a lake or river can be assessed at one time, while providing a permanent geo-referenced video record of the current status of shoreline. It provides a relatively rapid method to produce a “coarse filter” assessment of riparian health. This approach is not intended to replace field-based assessments, but rather, complement them by allowing larger areas to be evaluated in an approximate fashion, to be followed by more detailed checks on the ground. The goal of the videography assessments is to provide information over larger areas at a lower cost, such that the management of riparian areas at larger scales (i.e. entire lake or river system) can be directed by standardized measurements. In many cases, videography can be very cost-effective per kilometer of shoreline observed. At a certain scale, however, the size of the study area and the width of the stream or river make assessments by videography cost prohibitive.

Compared to ground-based methods, aerial videography offers a broader scale and relatively coarse assessment of riparian condition; however, at larger scales, such as for entire watersheds, this method becomes limited in practicality and efficiency (i.e., time and cost).

1.2.3. Satellite Remote Sensing & GIS Assessment

In response to a growing need for an assessment method that could evaluate riparian condition at large spatial extents (i.e., entire watersheds), Fiera Biological developed a Geographic Information System (GIS) method to assess thousands of kilometers of shoreline in a reliable and cost-effective way. This method was developed using metrics comparable to existing ground-based and aerial videography methods, and the results have been validated using both aerial videography (Fiera Biological 2018) and field data (Fiera Biological 2019).

The assessment method uses automated and semi-automated GIS techniques to quantify the intactness of riparian management areas using freely available or low cost spatial data. This method combines imagery from satellites with information about the terrain (e.g., relative differences in elevation, location of depressions, etc.,) to create a land cover dataset that is then used to measure and quantify the amount of natural and human cover types present along the shorelines of a water body. The shoreline is then classified into condition categories along a gradient of how “intact” the vegetation is, with areas that are dominated by natural vegetation being considered highly intact, and areas dominated by human-created land cover types (e.g., roads, houses, agricultural crops) being considered to have very low intactness (Figure 1 and 2).

Figure 1. Riparian intactness is a measure of how “natural” a shoreline is. Highly intact shorelines are dominated by natural vegetation and other natural cover types, while shorelines classified as very low intactness are dominated by human-built structures, roads, and manicured or disturbed vegetation.

Figure 2. Using a “bird’s eye view”, the satellite-based GIS riparian assessment method measures the type and amount of natural versus human-created land cover types present within 50 m of the shoreline. Shorelines classified as high intactness are almost entirely covered by natural cover. Shorelines that are considered to have very low intactness are dominated by human structures and modified or disturbed vegetation.

1.3. Study Objectives

The goal of this project is to contribute to the improvement of shoreline management and overall watershed health in the North Saskatchewan and Battle River watersheds by identifying riparian areas that can be targeted for habitat restoration and/or conservation. In order to achieve this goal, this study had the following primary objectives:

1) Create a recent land cover for the North Saskatchewan and Battle River watersheds, as well as for a select number of intersecting municipalities.
2) Quantify riparian management area intactness for selected waterbodies and evaluate natural and anthropogenic pressures within catchments adjacent to riparian areas to generally assess factors that may contribute to the impairment of riparian system function, and identify areas to prioritize for restoration and conservation.
3) Compile riparian assessment results from all of the studies completed to-date across central Alberta that have used the satellite-based GIS method to create a single riparian assessment dataset for central Alberta.

This report includes a summary of the riparian assessment results for the North Saskatchewan and Battle River watersheds. Detailed results for each HUC 6 watershed located within the North Saskatchewan River watershed are also presented in Appendix A, with detailed results for the Battle River HUC 6 watersheds included in Appendix B. Riparian assessment results have also been summarized for 37 municipalities that intersect the study area, and these detailed results are provided in Appendix C and D.

1.4. Purpose and Intended Use

This assessment synthesizes data from a variety of sources, with the goal of generally characterizing the current condition of riparian management areas within the study area. Readers are asked to consider the following points regarding the scope of this assessment as they review the methods and interpret the results of this study:

- Satellite-based GIS assessments characterize the relative intactness of a riparian area using a collection of indicators and associated metrics that focus on natural attributes that can be measured in a GIS environment at a pixel resolution of 6 m. Because of the relatively coarse resolution and the overhead view of riparian areas that is obtained from satellite imagery, these assessments do not provide a statement on the absolute condition of riparian areas, and do not reflect the influence of factors that were not, or cannot, be included or considered for analysis. For example, this analysis cannot assess the occurrence or abundance of weeds within a riparian area, given that this type of cover cannot be resolved in a 6m resolution satellite image. Furthermore, because overhead satellite imagery is used to create the land cover layer used to assess intactness, this assessment is not able to evaluate impacts associated with structures or activities that are obscured by an extensive tree canopy (e.g., small structures, stormwater outfalls, etc.).
- Intactness ratings are intended to support a screening-level assessment of management and/or conservation priorities across broad geographic areas (e.g., HUC 6 watershed, municipality, stream reach). The tool assessments are intended to compliment, not replace, more detailed site-specific field evaluations of riparian health or condition, and intactness ratings should be used to highlight smaller, more localized areas where field assessments and further validation may be required. Especially in areas that are characterized by rough pasture, the level of impact on riparian vegetation that is caused by grazing cattle can be difficult to conclusively determine using satellite imagery. In these areas, the decision between classifying rough pasture as a “natural” or “disturbed” land cover class is somewhat subjective, and thus, the results from the satellite-based

GIS assessment may differ from riparian condition assessment results obtained during a field-based assessment.

- The provincial hydrography data for streams, creeks, rivers, and lakes was used to delineate the shoreline of the waterbodies included in this assessment. Because waterbodies are dynamic and their boundaries change seasonally and annually, the boundaries for the waterbodies included in this study had to be manually adjusted to ensure that the boundary was reflective of the current location of the shoreline, as well as consistent with the imagery that was used to complete the riparian assessment. Notably, the location of the boundaries used in this assessment may not be representative of the location of these same waterbodies in the future. Further, the spatial boundaries of waterbodies that were not assessed as part of this study have not been updated.
- The municipal summaries in this report were based on the boundaries available in the Alberta Base Features dataset and were generated using a spatial intersect rule in the GIS (i.e., if the riparian management area was within the municipality or touched the boundary of the municipality, then it was used to tabulate summaries for that municipality). It should be noted that where a watercourse defines the boundary between municipalities, there is often a substantial spatial offset between the base features municipal boundary and the water boundary digitized in this project for the riparian assessment. Further, it is often unclear which municipality is responsible for the management of the left or right bank of a waterbody that defines the boundary of more than one municipality. Editing municipal boundaries to conform with the water boundaries applied in this project was beyond the scope of work, and as such, there may be instances where the spatial intersect rule applied to generate the summaries does not precisely reflect the riparian areas associated with a municipality. Consequently, the municipal summaries provide a general overview of the amount of shoreline that was assessed in the study, as well as the condition of the associated riparian management areas within each municipality.

2.0 Study Area

This study included the North Saskatchewan and Battle River HUC 2 watersheds, in addition to a number of municipalities that are partially, but not entirely, contained within the watersheds (Map 1). Combined, these areas cover approximately 111,429 km^2, which is approximately 17% of the province of Alberta. A land cover dataset was created for the full extent of the study area, and this data was used as the primary input into the assessment of 1,507 waterbodies and 25,271 km of shoreline within the study area. The majority of the waterbodies (732) and shorelines (11,704 km) were assessed within the North Saskatchewan River watershed, with 496 waterbodies and 10,201 km of shoreline being located within the Battle River watershed (Figure 3). The remaining waterbodies and shoreline were variously located within municipalities associated with other HUC 2 watersheds, including the Sounding Creek, Red Deer River, Beaver River, and Athabasca River watersheds (Figure 3; Map 1).

The shoreline that was assessed as part of this current project was combined together with existing riparian assessment data to create a single riparian dataset for central Alberta. Data were compiled from a number of previous assessments that evaluated ~10,124 km of shoreline in the Modeste (Fiera Biological 2018a), Sturgeon (Fiera Biological 2018b), Strawberry (Fiera Biological 2018b), Medicine-Blindman Rivers (Fiera Biological 2018e and 2020a), and the Upper-, Mid-, and Lower-Pembina River (Fiera Biological 2020b, 2020c, 2021a) HUC 6 watersheds, as well as in the Pigeon, Sylvan, Gull, and Buffalo Lake watersheds (Fiera Biological 2019; Map 2). Combined, the previous and current riparian datasets include ~35,400 km of shoreline, with 78% of that shoreline being located within the North Saskatchewan (~17,302 km) and Battle (~10,357 km) River watersheds (Figure 3; Map 3). The majority of the shorelines that have been assessed within the North Saskatchewan and Battle River watersheds to-date are associated with named and unnamed creeks, streams, and rivers (Figure 4).

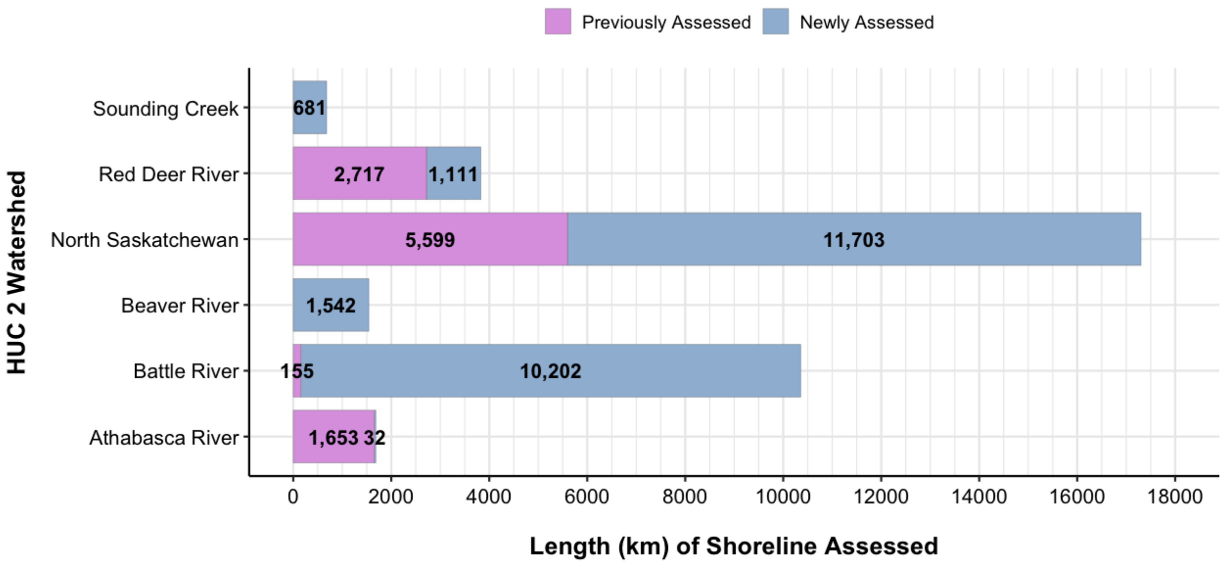


Figure 3. Length of shoreline assessed using the satellite-based GIS riparian assessment tool, summarized by major river (HUC 2) watershed. Data from previous assessments were compiled and combined with data from the current study to create a single riparian assessment dataset for central Alberta.

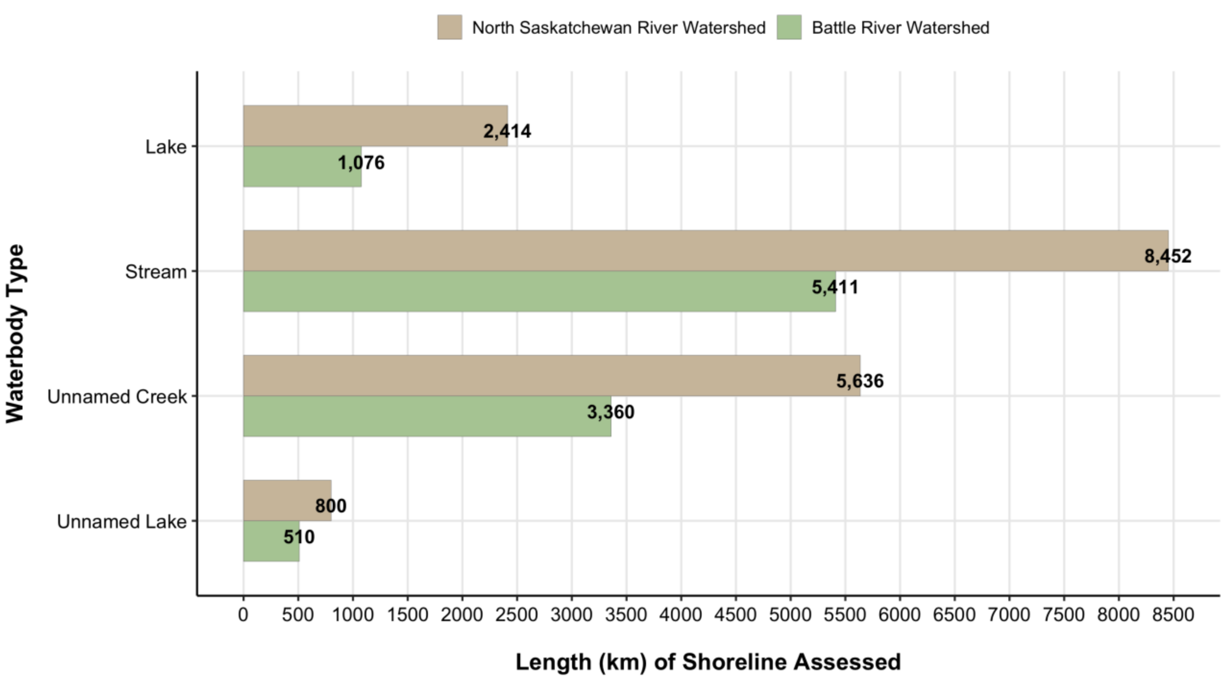
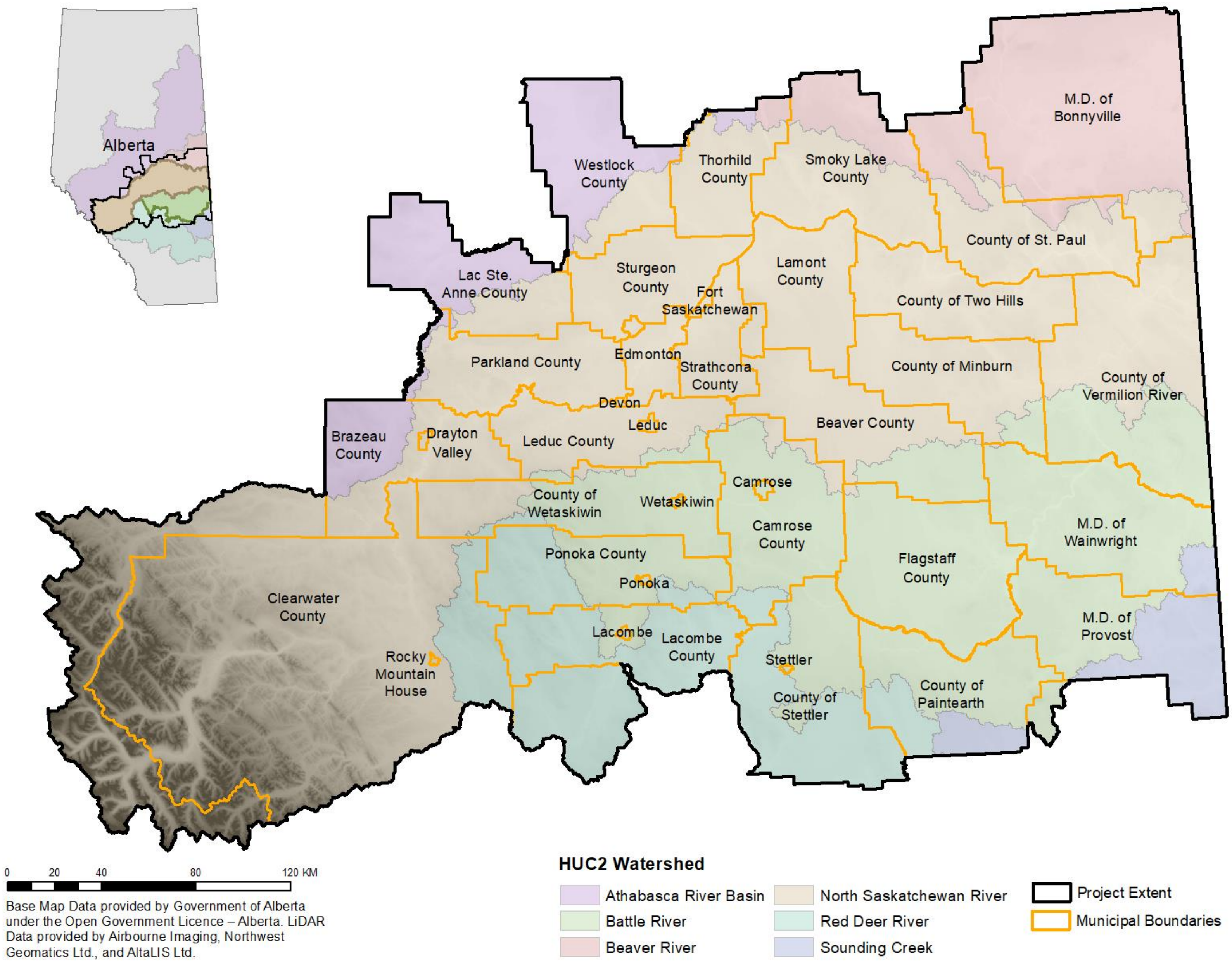
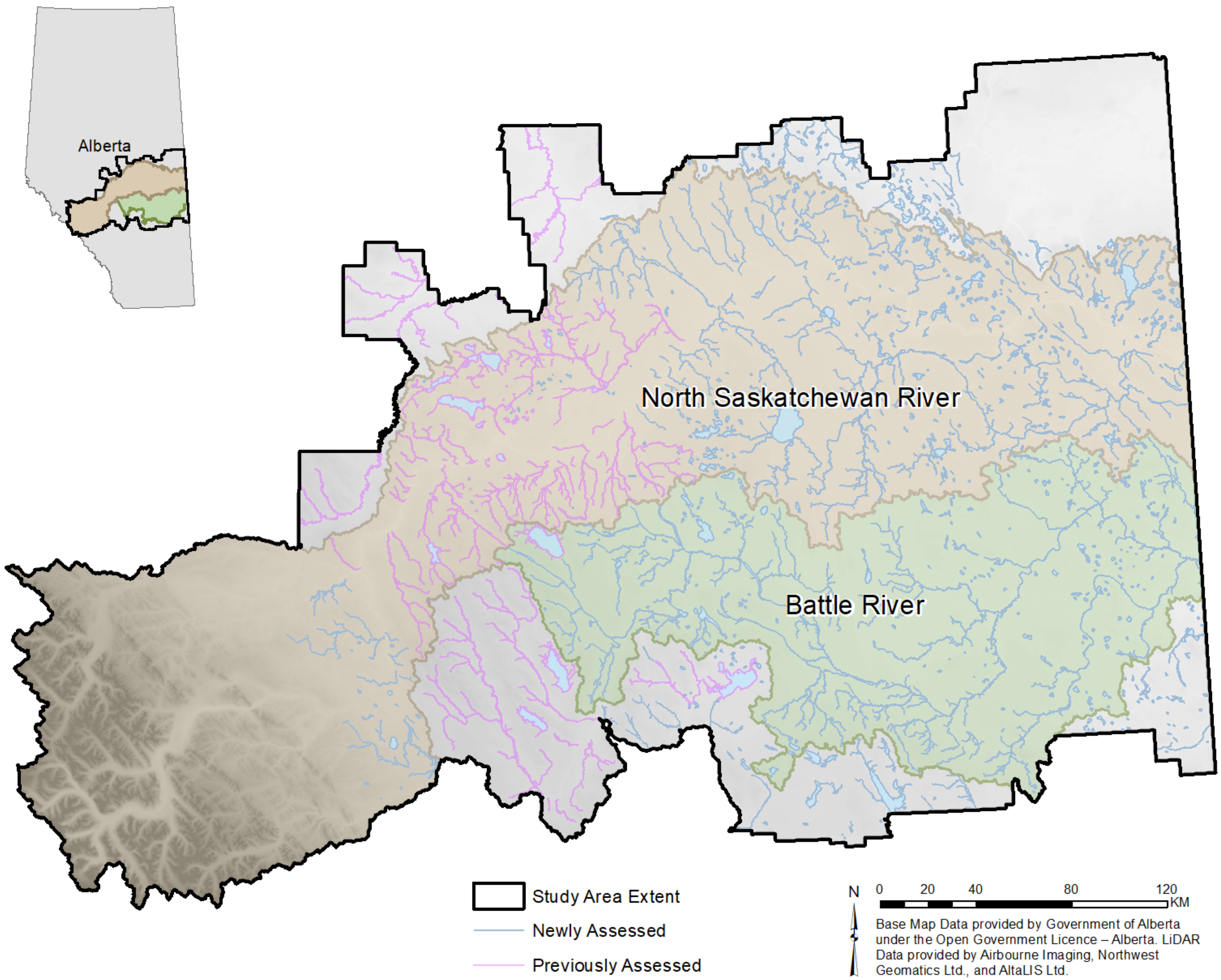


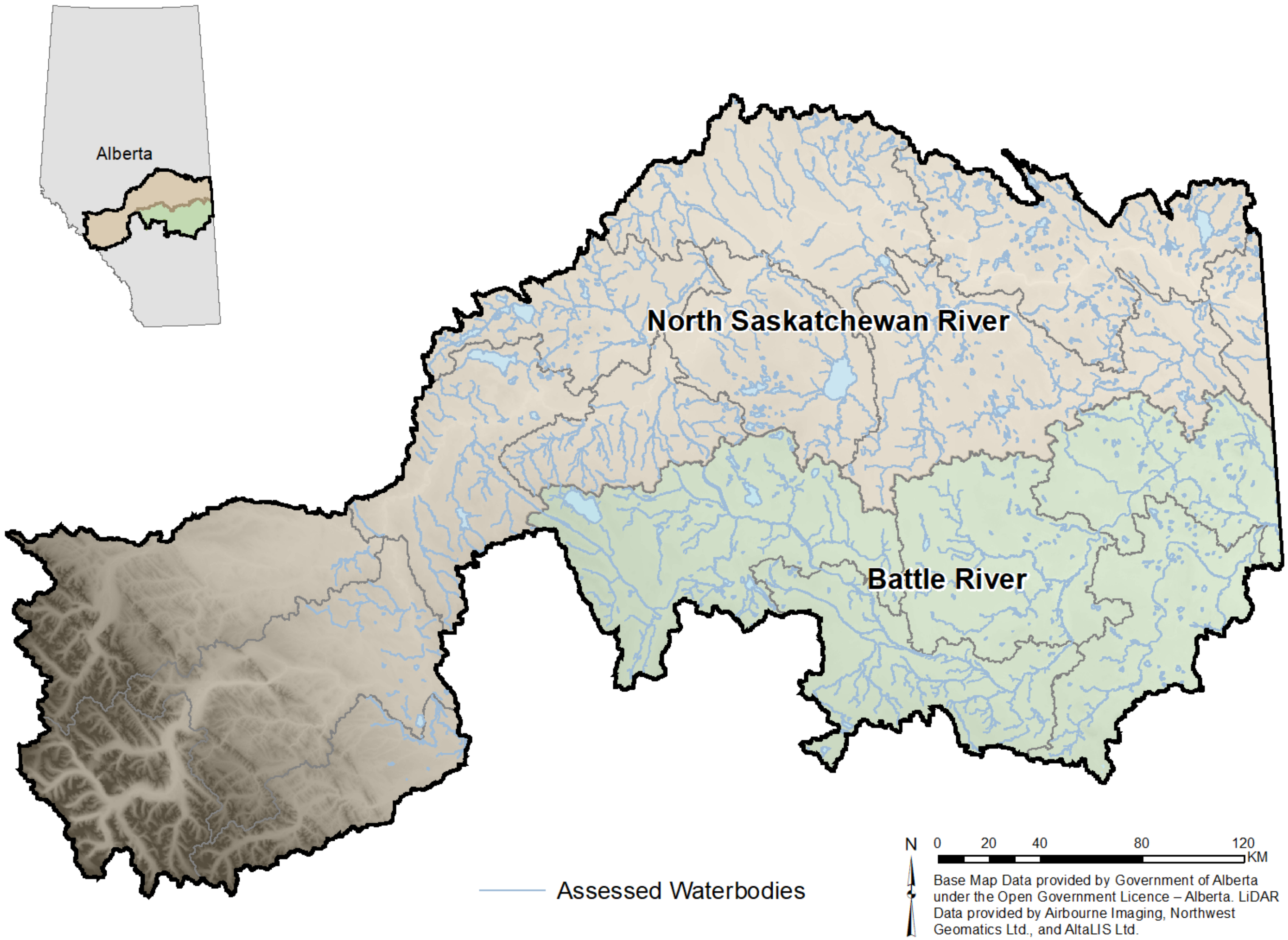
Figure 4. Length of shoreline assessed to-date in the North Saskatchewan and Battle River watersheds, by waterbody type.



Map 1. Overview of the study area showing the location of municipalities that are completely within and overlap with the NSR and Battle River watersheds.



Map 2. Overview of the study area and the location and extent of shorelines that have been assessed using the satellite-based GIS assessment method.



Map 3. Location and extent of the shorelines in the North Saskatchewan and Battle River watershed that have been summarized in this report.

3.0 Methods

3.1. Assessing Riparian Intactness

3.1.1. Land Cover Classification

To quantify riparian intactness in a GIS environment, a current land cover dataset is required. For this study, a 6 m pixel resolution land cover layer was created using SPOT 6 and SPOT 7 satellite imagery from 2017 and 2018. The satellite imagery was supplied by the Government of Alberta. The 6 m land cover classification was created for the entire study area and consisted of 41 separate SPOT 6/7 image scenes. Because of differences in date of acquisition and image quality, each scene was classified individually, but using the same classification methodology. For each satellite image, the four SPOT 6/7 bands were combined with a set of ancillary raster data products that were specifically generated for use in the classification (Table 1). The SPOT 6/7 imagery was used to generate layers for Normalized Difference Vegetation Index (NDVI), Blue Normalized Difference Vegetation Index (BNDVI), Green Ratio Vegetation Index (GRVI), and Iron Oxide Index (IOI), and a 15 m LiDAR DEM was used to derive terrain layers including Probability of Depression, Cost Distance to Water, and Deviation from Mean Elevation. As well, historic image analysis was performed in Google Earth Engine to generate mean summer temperature maps from Landsat 8 imagery, and mean and standard deviation maps of NDVI from Sentinel 2 imagery (Table 1). Three SPOT tiles only had partial cover of elevation data, so these areas were classified separately from the rest of the tile, resulting in 44 separate classifications.

Land cover classes were chosen and organized hierarchically into nested levels to facilitate training data selection and modelling (Table 2). Training data were manually selected for each SPOT 6/7 scene for the following classes: Coniferous; Deciduous; Shrub; Bog; Fen; Marsh; Swamp; Agricultural Depression; Open Water; Agriculture Pasture; Cropland; Human Built; Natural Bare Ground. A random forest classification was performed on each SPOT 6/7 band stack, which included the four SPOT 6/7 bands and additional ancillary layers. Random forest is a classification algorithm that is based on a set of decision trees derived by repeatedly selecting random subsets of training data and applying them to the layers in the band stack to create predictive models. By creating multiple models of decision trees, the best model and combination of information from the information in the band stack is determined and better prediction performance is obtained (Ho 1995). For this classification, 70% of the training data was used to train the classifier and the remaining 30% of the data was held back to validate the classification results.

Following the first stage of the classification, decision rules and manual editing were used to fix general classification errors. During this stage, the Natural Grassland class was added to the classification to account for areas of natural, non-woody low cover vegetation, and the Disturbed Vegetation class was added to account for non-agricultural human impacted low vegetation cover and areas with managed or manicured vegetation. The classification tiles were manually checked and edited at two spatial and thematic scales to create two different land cover products. For the riparian intactness assessment, a five class, fine scale (0.0036 ha; 1 pixel minimum mapping unit) land cover was created within a 50 m buffer that was applied to the shorelines of all lakes and streams that were included in the Intactness analysis (Table 3). A second land cover layer with a minimum mapping unit of 0.022 ha (6 pixels) and 18 classes was created for the entire study area, and this dataset was used for the Pressure analysis (Table 2). Additional detail about the methods used to create the land cover datasets can be found in Fiera Biological (2021b).

Table 1. Description of the spatial data obtained or derived for use in the assessment of riparian management area Intactness.

Data Layer	Year	Source	Usage
SPOT 6/7 Satellite Imagery	2017/2018	Government of Alberta	Derivation of land cover classification
15 m LiDAR DEM	n/d	Government of Alberta	Derivation of data products for classification
Normalized Difference Vegetation Index (NDVI)	2017/2018	Fiera Biological. Layer was created using SPOT 6/7 satellite data provided by the Government of Alberta	Derivation of land cover classification
Blue Normalized Difference Vegetation Index (BNDVI)	2017/2018	Fiera Biological. Layer was created using SPOT 6/7 satellite data provided by the Government of Alberta	Derivation of land cover classification
Green Ratio Vegetation Index (GRVI)	2017/2018	Fiera Biological. Layer was created using SPOT 6/7 satellite data provided by the Government of Alberta	Derivation of land cover classification
Iron Oxide Index (IOI)	2017/2018	Fiera Biological. Layer was created using SPOT 6/7 satellite data provided by the Government of Alberta	Derivation of land cover classification
Probability of Depression	n/d	Fiera Biological. Layer was created using LiDAR DEM data provided by the Government of Alberta	Derivation of land cover classification
Cost Distance to Water	n/d	Fiera Biological. Layer was created using LiDAR DEM data provided by the Government of Alberta	Derivation of land cover classification
Deviation from Mean Elevation	n/d	Fiera Biological. Layer was created using LiDAR DEM data provided by the Government of Alberta	Derivation of land cover classification
Roads	2018	Alberta Base Features	Derivation of land cover classification
Mean Summer Temperature	2013-2018	Fiera Biological. Layers created using Landsat 8 imagery	Derivation of land cover classification
Mean and Standard Deviation of NDVI	2013-2018	Fiera Biological. Layers created using Sentinel 2 imagery	Derivation of land cover classification
ABMI Human Footprint	2016/2017	Alberta Biodiversity Monitoring Institute	Semi-automated clean up of classification
6 m Land Cover	2017/2018	Fiera Biological. Layer was created using SPOT 6/7 satellite data provided by the Government of Alberta and derived layers	Derivation of RMAs and quantification of intactness metrics

Table 2. Land cover classes that were used to derive the wall to wall land cover classification for the study area.

Level 1	Level 2	Description
Forest	Coniferous	Coniferous trees (needle-leaf) cover greater than 75% of treed area.
	Deciduous	Broadleaf trees covering greater than 75% of treed area.
	Shrub	Vegetation cover that is at least 1/3 shrub (low/short woody plants), with little or no presence of tress (<10% tree crown closure). Includes upland shrub and riparian shrub (e.g. shrub on gravel bars, shrub around marshes).
Natural Grassland	Natural Grassland	Naturally grassy areas with <1/3 shrub cover and <10% tree cover.
Open Water	Open Water	Any open water (lakes, permanent wetlands, standing water) and flowing water. Includes artificial waterbodies (e.g., dugouts and reservoirs).
Wetland*	Marsh	Low lying areas dominated by emergent or graminoid vegetation and depressional areas adjacent to streams/creeks and lakes.
	Swamp	Depressional areas dominated by deciduous tree or shrub cover.
	Bog	Areas that appear to be dominated by black spruce cover where no water flow is apparent.
	Woody Fen	Depressional areas dominated by woody vegetation cover (trees or shrubs) where surface water flow is apparent.
	Graminoid Fen	Depressional areas dominated by graminoid vegetation cover where surface water flow is apparent.
Agricultural Depression	Agricultural Depression	Human impacted/altered wetland basins in agricultural areas lacking intact emergent vegetation. In croplands these basins are typically cultivated and/or drained, and in pasture these low lying areas may be drained and/or utilized for agricultural purposes such as providing water for cattle.
Natural Bare Ground	Natural Bare Ground	Naturally occurring bare soil, sand, sediment, banks, and beaches.
Agriculture	Pasture	Agricultural areas used primarily as pasture or hayland.
	Cropland	Agricultural areas used primarily as cereal crop. Tilled most years.
Disturbed Vegetation	Disturbed Vegetation	Non-agricultural human-impacted or managed non-woody vegetation.
Built Up/Exposed	Human Built	Human built features and human-caused exposed/bare areas.
	Roads	Paved and unpaved roads.

*NOTE: The wetland class names included in this land cover classification are similar to those used in the Alberta Wetland Classification System; however, this land cover classification should not be considered to be a wetland inventory.

Table 3. Land cover classes that were used to derive the land cover classification for the 50 m shoreline buffers.

Land Cover Class Label	Level 2 Classes Included	Description of Land Cover Class
Woody	Bog, Coniferous, Deciduous, Swamp, Shrub, Woody Fen	Woody upland or woody wetland vegetation.
Natural Open Vegetation	Graminoid Fen, Marsh, Natural Grassland	Areas dominated by graminoid or emergent vegetation and that have not been disturbed or impacted by human activity.
Open Water	Open Water	Any open water (lakes, permanent wetlands, standing water) and flowing water. Includes artificial waterbodies (e.g., dugouts and reservoirs).
Natural Bare Ground	Natural Bare Ground	Naturally occurring bare soil, sand, sediment, banks, and beaches. Includes bedrock, rubble, talus, blockfield, or other natural impervious surfaces.
Disturbed	Agricultural Depression, Cropland, Disturbed Vegetation, Human Built, Pasture, Roads	Areas of human disturbance, including agricultural areas, human-built features, human-caused bare ground, and human-impacted or managed vegetation.

3.1.2. Land Cover Classification Accuracy Assessment

Accuracy of the land cover was assessed using traditional remote sensing techniques, which provide a measure of accuracy for each land cover class, as well as an overall accuracy for all classes combined. Accuracy of the wall to wall land cover layer was assessed at Level 1 using a stratified validation dataset that was a combination of held back training data points (samples collected at the same time as training data was selected, but were not used to train the random forest model) and randomly selected points that were collected by a trained photo interpreter. Accuracy was assessed for the wall to wall land cover in the North Saskatchewan River watershed and the Battle River watershed separately. Accuracy of the fine scale land cover within the 50 m shoreline buffer was assessed separately for the North Saskatchewan River watershed, Battle River watershed, and for the other areas that were located outside of the North Saskatchewan and Battle River watersheds.

North Saskatchewan River Watershed Wall to Wall Land Cover

A total of 598 samples were used to assess accuracy of the wall to wall land cover that covers the NSR, with a minimum number of 20 samples for each Level 2 class. Overall accuracy at Level 1 (10 thematic classes) was 92.0% with a Kappa statistic of 0.90 (Table 4). Class accuracies were above 80% for all classes except Agricultural Depression and Natural Grassland. Agricultural Depression tended to be confused with Cropland, Pasture, or Marsh. Natural Grassland is a very rare class, covering ~1% of the watershed, and this class was typically confused with other natural classes, particularly in cases where natural grassland patches exist as small openings in forest dominated regions or in areas where grassland is mixed with other natural land cover classes (e.g., a river valley or wetland margin where there is a mix of grass, wetland, and shrub).

Battle River Watershed Wall to Wall Land Cover

A total of 588 samples were used to assess accuracy of the wall to wall land cover that covers the BRW, with a minimum of 20 samples for each Level 2 class. The Bog and Graminoid Fen classes were excluded from the accuracy assessment because they were extremely rare (<0.1% of the land cover), and collecting enough independent validation samples for these classes was not feasible. Overall accuracy at Level 1 (9 thematic classes) was 93.0% with a Kappa statistic of 0.89 (Table 5). Class accuracies were above 80% for all classes except for Agricultural Depression, which was confused with related classes (Cropland, Pasture, or Marsh).

Table 4. Accuracy assessment results for the North Saskatchewan River watershed wall to wall Level 1 land cover classes.

	Agricultural Depression	Agriculture	Disturbed Vegetation	Forest	Built Up / Exposed	Natural Bare Ground	Natural Grassland	Open Water	Snow/Ice	Wetland	Users Accuracy
Agricultural Depression	12	1	0	0	0	0	0	0	0	1	86%
Agriculture	4	169	2	2	0	1	1	0	0	1	94%
Disturbed Vegetation	0	0	18	1	0	0	0	0	0	0	90%
Forest	0	0	0	147	0	0	3	0	0	6	94%
Built Up / Exposed	0	0	0	0	40	1	0	0	0	0	95%
Natural Bare Ground	0	0	0	0	0	16	0	0	1	0	94%
Natural Grassland	0	0	0	0	0	0	13	0	0	0	100%
Open Water	0	0	0	1	0	1	0	20	0	0	91%
Snow/Ice	0	0	0	0	0	0	0	0	16	0	100%
Wetland	4	0	0	11	0	1	3	0	16	95	83%
Producer Accuracy	60%	99%	90%	91%	100%	80%	65%	100%	91%	91%	92%

Table 5. Accuracy assessment results for the Battle River watershed wall to wall Level 1 land cover classes.

	Agricultural Depression	Agriculture	Disturbed Vegetation	Forest	Built Up / Exposed	Natural Bare Ground	Natural Grassland	Open Water	Wetland	Users Accuracy
Agricultural Depression	20	5	0	0	0	0	0	0	0	80%
Agriculture	2	297	2	4	0	0	3	0	2	96%
Disturbed Vegetation	0	0	16	0	0	0	0	0	0	100%
Forest	0	1	0	60	0	0	0	0	3	94%
Built Up / Exposed	0	0	1	1	40	2	0	0	0	91%
Natural Bare Ground	0	0	0	0	0	16	1	0	0	94%
Natural Grassland	0	0	0	0	0	1	20	0	1	91%
Open Water	0	0	0	0	0	1	0	20	0	95%
Wetland	10	1	1	3	0	0	3	0	74	83%
Producer Accuracy	63%	98%	80%	91%	100%	80%	83%	100%	93%	93%

NOTE: Producer accuracy measures errors of omission, which is a measure of how well real-world land cover types can be classified. User accuracy measures errors of commission, which represents the likelihood of a classified pixel matching the land cover type of its corresponding real-world location.

Fine Scale Shoreline Buffer Land Cover

A minimum of 200 samples were used to assess the accuracy in each group. The accuracy assessment focussed on the three classes used in the calculation of the riparian intactness scores (Disturbed, Natural Low Vegetation, Woody). Open Water and Natural Bare Ground were not included as part of the accuracy assessment because they do not factor into the calculation of Intactness and their presence in the buffer is minimal (less than 5% cover combined). Overall accuracy for the buffer land cover in the NSR watershed was 90.6% with a Kappa statistic of 0.86 (Table 6). Class accuracies were above 78%. Overall accuracy for the buffer land cover within the BRW was 90.6% with a Kappa statistic of 0.86 (Table 7). Class accuracies were above 80%. Overall accuracy for the buffer land cover outside the major river basins was 90.8% with a Kappa statistic of 0.86 (Table 8). Class accuracies were above 80%.

Table 6. Accuracy assessment results for the buffer land cover in the North Saskatchewan River watershed.

	Disturbed	Natural Low Vegetation	Woody	User Accuracy
Disturbed	90	1	0	99%
Natural Low Vegetation	8	46	5	78%
Woody	1	7	76	90%
Producer Accuracy	91%	85%	94%	91%

Table 7. Accuracy assessment results for the buffer land cover in the Battle River watershed.

	Disturbed	Natural Low Vegetation	Woody	User Accuracy
Disturbed	75	4	0	95%
Natural Low Vegetation	8	65	4	84%
Woody	0	6	73	92%
Producer Accuracy	90%	87%	95%	91%

Table 8. Accuracy assessment results for the buffer land cover in areas outside of the North Saskatchewan and Battle River watersheds.

	Disturbed	Natural Low Vegetation	Woody	User Accuracy
Disturbed	46	4	0	92%
Natural Low Vegetation	3	66	3	92%
Woody	1	10	95	90%
Producer Accuracy	92%	83%	97%	91%

NOTE: Producer accuracy measures errors of omission, which is a measure of how well real-world land cover types can be classified. User accuracy measures errors of commission, which represents the likelihood of a classified pixel matching the land cover type of its corresponding real-world location.

3.1.3. Editing Water Boundary Data

The provincial hydrography data for the waterbodies of interest were used to delineate the shorelines included in this assessment. Due to the dynamic nature of waterbodies and the vintage of the provincial data, the location of the hydrography data does not always correspond well with shorelines in current imagery. Thus, in order to ensure the generation of RMAs and quantification of the intactness metrics were accurate, the hydrography data was manually edited, where necessary, to ensure that the boundaries corresponded with the SPOT 6/7 imagery and the land cover classification. For streams, the edited water boundary represents the approximate centreline of the watercourse. Where the width of a stream or creek was greater than 20 m for a distance of more than 50 m in the SPOT imagery, or the stream passed through an area of open water greater than 1.0 ha, the stream was split and edited to have a unique left and right bank. Lake and open water shorelines were edited to approximate the location of the boundary between the upland and riparian zone. The edited water boundaries for assessed features have an approximate mean accuracy of +/- 5 m relative to their location in the SPOT imagery that was used to derived the land cover layer for this project.

Figure 5. Example of the spatial inaccuracies associated with stream boundaries, where the location of the stream centre line does not match the actual location of the stream and exceeds the 5 m accuracy tolerance in the SPOT imagery. In this example, the yellow lines represent the location of the streamline from the provincial data and the blue line represents the manually edited location of the new stream centre line.

3.1.4. Assigning Unique IDs to Edited Water Boundary Data

Many of the waterbodies in the provincial hydrography data are unnamed features with no unique identification code. Additionally, some names are duplicated several times for features across the province, which can result in confusion and also makes reporting results complicated. As part of this project, a naming schema for newly assessed waterbodies was developed and applied at the HUC 6-level to ensure each waterbody could be identified uniquely and summarized individually. Features were named using the following set of rules:

- **Named Streams** – Streams, creeks, or rivers with an existing name in the Alberta Base Features hydrography dataset or the FWMIS Hydro Arcs dataset retained their existing name. If a name was duplicated in a HUC 6 (e.g., two different streams both named Happy Stream), they were numbered sequentially from west to east (i.e., Happy Stream 1, Happy Stream 2).
- **Named Lakes** – Lakes with an existing name in the Alberta Base Features hydrography dataset or the FWMIS Hydro Arcs dataset retained their existing name. If a named was duplicated in a HUC 6 (e.g., two different lakes both named Pleasant Lake), they were numbered sequentially from west to east (i.e., Pleasant Lake 1, Pleasant Lake 2).
- **Unnamed Lakes** – Lakes with no name in either of the provincial hydrography datasets were assigned a unique ID by combining "UL" with the HUC 6 numeric ID code, along with a number starting at 01 and increasing sequentially moving north to south and west to east (e.g., for unnamed lakes assessed in the Frog HUC 6, the IDs are "UL-110302-01", "UL-110302-02", etc.).
- **Unnamed Creeks** – Streams and creeks with no name assigned in either provincial hydrography datasets were named based on the type of waterbody they flowed into, as follows:
    - **Unnamed Creek into Named Stream** – Unnamed creeks were named based on the Named Stream they flowed into and numbered sequentially starting at the furthest point upstream (e.g., Hooray River-01, Hooray River-02, Hooray River-03). All branches upstream from where a given tributary entered a named stream were considered the same unnamed creek for the purposes of this project.
    - **Unnamed Creek into Named Lake** – Unnamed creeks were named based on the Named Lake they flowed into and numbered sequentially starting at the "12-o-clock" position (e.g., Smiling Lake-01, Smiling Lake -02, Smiling Lake -03). All branches upstream from where a given tributary entered a named lake were considered the same unnamed creek for the purposes of this project.
    - **Unnamed Creek into Unnamed Lake** – Unnamed creeks were named based on the Unnamed Lake they flowed into and numbered sequentially starting at the "12-o-clock" position starting with "US" (e.g., UL-110302-01-US01, UL-110302-01-US02, UL-110302-01-US03). All branches upstream from where a given tributary entered an unnamed lake were considered the same unnamed creek for the purposes of this project .
    - **Isolated Unnamed Creek** – Isolated unnamed creeks (i.e., does not flow downstream into any other water body) were named by combining "US" with the HUC 6 numeric ID code, along with a number starting at 01 and increasing sequentially moving north to south and west to east (e.g., for isolated unnamed creeks assessed in the Paintearth HUC 6, the IDs are "US-090201-01", "US-090201-02", etc.).
    - **Unnamed Creek into Unnamed Creek** – Unnamed creeks were named based on the Isolated Unnamed Creek they flowed into and numbered sequentially starting at furthest point upstream (e.g., US-090201-01-US01, US-090201-01-US02).

3.1.5. Delineating Riparian Management Area Width and Length

In order to allow for comparisons between watersheds, the GIS methods that were developed to assess riparian areas in the Modeste watershed (Fiera Biological 2018) were applied in this study. As per the GIS method, which was developed to closely match previously developed aerial videography methods (Teichreb and Walker 2008), riparian intactness was assessed within a “riparian management area” (RMA). An RMA is defined as an area along the shoreline of a waterbody that includes near-shore emergent vegetation zone, the riparian zone, and a riparian protective (buffer) zone (Figure 6).

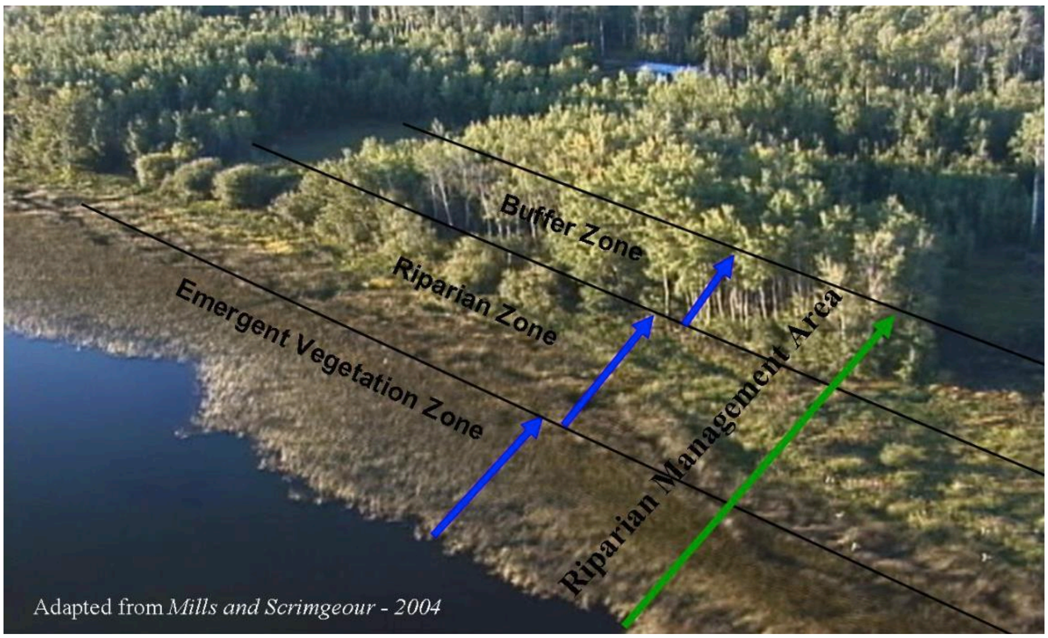


Figure 6. Schematic showing the different shoreline components included in a “riparian management area” (image taken from Teichreb and Walker 2008).

An RMA has two spatial components: width and length. For this assessment, riparian intactness was evaluated within a static 50 m wide buffer applied to the left and right banks of each watercourse. In the case of lakes, a single 50 m wide buffer was applied to the shoreline. When assessing riparian condition using aerial videography, RMA length is determined by a change in the score of any single metric, and is thus variable. In order to replicate this approach, the upstream and downstream extents of each RMA were delineated based upon major changes in the proportion of natural cover along the shoreline. To determine locations along the shoreline where there are major changes in the proportion of natural vegetation, all natural cover classes in the buffer land cover (i.e., Woody Cover, Open Water, Natural Open Vegetation, Natural Bare Ground) were selected and exported as a single layer. The stream layer was then divided into 10-meter segments on the left and right banks, and the proportion of natural cover within a 25 m moving window was calculated for each segment. A threshold was used to identify locations along the shoreline within the moving window where there was greater than or less than 55% natural cover. All adjoining homogeneous segments of less than or more than 55% natural cover were then merged to became a single RMA. This threshold value was selected based upon an iterative threshold testing procedure to determine the percent of natural vegetative cover that best approximated the videography RMA boundaries (Fiera Biological 2018). To reduce error associated with misclassification in the 6 m land cover, very small RMAs (≤10 m) were merged and dissolved with neighbouring segments.

3.1.6. Indicator Quantification and Riparian Intactness Scoring

Once RMAs were delineated, intactness within each riparian management area was quantified using the following metrics:

Metric 1: Percent cover of natural vegetation;
Metric 2: Percent cover of woody species;
Metric 3: Percent cover of all human impact and development (human footprint).

To quantify Metric 1, all natural cover classes were selected from the buffer land cover layer and the proportion of the RMA covered by those cover classes was calculated. The natural classes used to quantify this metric included: Natural Open Vegetation and Woody Cover. To quantify Metric 2, the percent Woody Cover was quantified for each RMA. For Metric 3, the percent cover of Disturbed (human cover and disturbance) was calculated within each RMA.

Once each metric was quantified, the values were range standardized and were aggregated using a weighting comparable to the aerial videography methods. The metrics were weighted as follows: Metric 1: 0.15; Metric 2: 0.25; Metric 3: 0.60. The weighted scores were aggregated to derive a final RMA score that ranged between 0 and 100, and these scores were converted into intactness categories using the following categorical breaks:

- High Intactness (≥75-100): Vegetation within the RMA is present with little or no human footprint.
- Moderate Intactness (≥50-75): Vegetation within the RMA is present with some human footprint.
- Low Intactness (≥25-50): Vegetation cover within the RMA is limited and human footprint is prevalent.
- Very Low Intactness (0-25): Vegetation cover within the RMA is mostly cleared and human footprint is the most dominant land cover.

While the land cover and riparian assessment results for the study were not validated using field data, previous riparian assessments completed using this GIS method have been validated using aerial videography data (Fiera Biological 2018), as well as high resolution imagery and data collected in the field (Fiera Biological 2019). In each case, the riparian assessment results were considered to be very robust when compared against the validation data.

3.2. Assessing Pressure on Riparian System Function

We adapted the Watershed Integrity scoring methodology (Flotemersch et al. 2016) to assess Pressure on Riparian System Function for HUC 6 watersheds with complete wall to wall land cover. In this method, Watershed Integrity, *WI*, is the product of different watershed functions, with the underlying premise being that *"A high level of integrity exists when all functions are operating at levels that support and maintain the full range of ecological processes and functions essential to the long-term sustainability of biodiversity and ecosystem services" (*Flotemersch et al. 2016, pg. 1660).

With this approach, when any one of the functional components are compromised, the integrity of the watershed is also compromised, and as more functions are compromised, the integrity is compromised in a multiplicative way. We applied this watershed integrity approach to define and calculate Catchment Pressure, *CP*, with the objective of measuring the factors that increase or decrease the ecological and hydrological function of riparian habitats.

In our model, catchment pressure is the product of two functions that describe pressures that may occur within a local catchment area: Natural Resilience (*NR*) and Human Impacts (*HI*). Catchment pressure was calculated using the following equation, with higher scores indicating areas where there may be heightened pressure on riparian system function:

$$CP = CP_{NR} \times CP_{HI}$$

Function scores for Natural Resilience (*NR*) and Human Impacts (*HI*) were calculated from a set of associated stressor metrics (S_i) that are known to affect riparian function and are measurable in a GIS environment. A list of the stressor metrics associated with each function, along with a description of how each stressor was quantified and the data used for the quantification, is provided in Table 3. The Landslide Susceptibility layer does not provide complete coverage for some watersheds; where this occurred, the Landslide Susceptibility metric was removed from the Pressure formula. The 15 m DEM also did not provide complete coverage for some watersheds; where this occurred, the freely-available 25 m Provincial DEM was used to calculate Slope.

Variables that exert pressure on riparian system function range spatially from large-scale to site-specific. We conducted a pressure assessment at a local "catchment" scale, which we considered to be a scale that was meaningful both from the perspective of ecological and hydrological processes, as well as from the perspective of land management. Local catchment areas were identified using the Government of Alberta ArcHydro Phase 2 dataset (GOA 2018). Catchments were edited to reflect the left and right contributing areas of the streams in the assessment by splitting them with the streams of interest. Local catchment areas that intersected the RMAs of the waterbodies included in this study were used as the unit of analysis for the pressure assessment.

Table 9. List of metrics used to assess pressure on riparian system function, along with a description of the methods used to assess each metric and the source and vintage of the data used for metric quantification. Each metric was quantified within local catchment areas that were derived specifically for this assessment using LiDAR 15 m data provided by the Government of Alberta.

Function	Stressor Metric	Metric Quantification	Data Source & Date
Natural Resilience (*NR*)	Natural Cover	Percent cover by natural vegetation cover classes	Fiera Biological Central Alberta Land Cover (2017/2018)
	Slope	Mean cover of steep slopes (>5%)	Fiera Biological, derived from Government of Alberta 15 m DEM; Government of Alberta 25 m DEM
	Landslide Susceptibility	Area weighted average	Alberta Geological Survey (2016)
Human Impacts (*HI*)	Land Use Intensity	Zonal average of land use intensity values	Fiera Biological Central Alberta Land Cover (2017/2018) and ABMI Human Footprint (2016)
	Stream Crossing Density	Area weighted average of linear features that intersect major streams	Government of Alberta base features (2018)
	Road Density	Area weighted average of roads	Government of Alberta base features (2018)
	Density of Other Linear Disturbance Types	Area weighted average of non-road linear features	Government of Alberta base features (2018)

3.2.1. Quantifying Stressor Metrics & Calculating Function Scores

In order to quantify the Land Use Intensity stressor metric, a land use intensity value was assigned to each land cover and human footprint type present in the watershed (Table 10). To quantify this metric, the SPOT land cover and ABMI human footprint layers were used together, which allowed for intensity characterization by human use type. High intensity of use values were assigned to land cover types that are known to exert pressure on riparian system function, and all values were assigned using best professional judgment informed by a literature review (Donahue 2013). We tested several different schemes for assigning intensity of land use values, and an appropriate range of values and magnitudes was selected by iteratively inspecting output maps and intensity values and ranges. Where the SPOT land cover and ABMI human footprint overlapped, the maximum Intensity of Use Value was applied.

Table 10. Intensity of Use values assigned to the various land cover classes present in the HUC 6 watershed.

Land Cover Class	Intensity of Use Value
Agriculture – Crop	50
Agriculture – Pasture/Forage	50
Airport	1000
Canals	10
Cultivation (Crop/Pasture/Bare Ground)	50
Cut Block	50
Dugout/Burrow-Pit/Sump	10
Exposed/Barren	1000
High-Density Livestock Operation	1000
Industrial Site (Urban/Heavy Industry)	1000
Industrial Site (Rural)	500
Mine Site	1000
Municipal Water/Sewage	50
Disturbed Vegetation (Other)	25
Peat Mine	100
Pipeline	50
Rail – Hard Surface	100
Rail – Vegetated Verge	50
Reservoir	10
Road – Hard surface	100
Road Vegetated Verge	50
Road/Trail – Vegetated	100
Rural Residential	50
Seismic Line	50
Transmission Line	25
Urban/Developed	1000
Well Site	100

Scores for each of the GIS stressor metrics were calculated using ArcGIS 10.8 in one of two ways. For stressors that have a known measurable biological response, literature-derived thresholds were used to define the maximum feasible value (Table 11). This threshold is the value above which the stressor impairs function beyond a repairable or reversible state. For example, forest cover of at least 25% is required to improve water quantity/quality (Adams and Taratoot 2001), so any catchment with ≤25% cover of forest cover is under maximum pressure for this stressor. For stressors with a known threshold, scores were calculated as:

$$S_i = 1 - \left(\frac{S_{observed}}{S_{threshold}}\right)$$

For stressors that are physical variables (e.g., slope), or for variables for which the biological response threshold value is not known (e.g., intensity of land use), the catchment stressor values were scored against the maximum value from the stressor's range of values within the watershed (i.e., a range standardized score was calculated). For these stressors, scores were calculated as:

$$S_i = 1 - \left(\frac{S_{observed}}{S_{maximum}}\right)$$

A description of the stressor threshold values used in this assessment, and the method used to derive each threshold, is provided in Table 11.

Table 11. Thresholds and scoring types used to calculate stressor scores for pressure metrics.

Function	Stressor Metric	Threshold	Scoring Type	References
Natural Resilience *(NR)*	Natural Cover	Minimum 25% cover	Literature review	Target forest cover of 25% for water quantity/quality (Adams and Taratoot 2001) 30% cover at watershed scale supports less than one half of the potential species richness and marginally healthy aquatic systems (Environment Canada 2014) Target cover of at least 35% for subbasins to prevent moderate extirpation of bull trout (Ripley et al. 2005) Threshold of 30% natural cover correlated with riverine ecological condition (Deegan et al. 2010) 6% loss of aquatic species for every 10% loss of natural land cover (Weijters et al. 2009)
	Slope	Maximum value	Range of values	N/A
	Landslide Susceptibility	Maximum value	Range of values	N/A
Human Impacts *(HI)*	Land Use Intensity	Maximum value	Range of values	N/A
	Stream Crossing Density	$0.6/km^2$	Literature review	Stream crossings impede fish passage, affect water flow, and water quality - adapted thresholds from bull trout and general fish road density thresholds of $0.6km/km^2$ and $0.7km/km^2$ (Tchir et al. 2004)
	Road Density	$1.0\ km/km^2$	Literature review	Extirpation of bull trout at $1.0\ km/km^2$ (AESRD 2012) Large mammals affected at various thresholds: $0.4\ km/km^2$ for grizzly bear; $1.25\ km/km^2$ for black bear (AESRD 2012); $0.62\ km/km^2$ for elk (AESRD 2012)
	Density of Other Linear Disturbance Types	$3.0\ km/km^2$	Literature review	Adapted general density threshold for watershed health, where >3 km/km^2 is used as an indicator for poor health (AESRD 2012)

Once stressors were quantified, the values were compiled within their associated pressure function (CP_{NR} and CP_{HI}) and were combined mathematically to calculate a final catchment pressure score, where "*W*" is a weighting value applied to the natural cover and terrain variables:

$$CP = CP_{NR} \times CP_{HI}$$

for which,

$$NR = ((\mathrm{W} * \%Natural\ Cover) + \mathrm{W} * (\min(Slope, Landslide\ Susceptibility)))$$

and,

$$HI = (Intensity\ of\ Use + average(Stream\ Crossing\ Density, Road\ Density, Linear\ Density))$$

For most HUC 6 watersheds, the weighting for the natural cover and slope metrics is equally applied; however, in catchments with a large amount of natural cover and a high degree of topographic relief, an equal weighting of the slope metric can result in an unreasonably high pressure score. Thus, in watersheds with a high degree of topographic relief, different weightings for the natural cover and terrain metrics were tested and adjusted to better capture the local conditions and the relationship between natural cover and slope in the watershed. Additionally, for the HUC 6 watersheds located in the headwaters region of the North Saskatchewan River watershed (i.e., Ram, Clearwater, and Brazeau), refining the weightings was not sufficient to give reasonable results. Consequently, for these HUC 6 watersheds, catchments that were characterized by extremely steep terrain with exposed slopes, minimal human disturbance, and high natural cover (i.e., mountainous areas) were excluded from the stressor scoring and formula calculation. Instead, these catchments were manually assigned a pressure score of Low.

Once calculated, the raw catchment pressure scores were scaled to allow for better interpretation of the values. Scaling can be performed and applied in different ways, and for this study, a percentage score was calculated by taking the ratio of the raw catchment pressure score to the theoretical maximum possible score. For each watershed, there are two stressor scores for each function, and all stressors have a maximum score of 1, so the maximum possible score is (1+1) x (1+1) = 4. Dividing the raw catchment pressure score by the theoretical maximum (4) and multiplying by 100 gives a percent score. In order to have high scores represent areas of High Pressure and low scores represent areas of Low Pressure, values were reversed by subtracting the percentage score from 100.

Notably, pressure assessments that are conducted as part of a riparian assessment are typically completed at the HUC 6 watershed scale; therefore, in order to conduct a pressure assessment, a complete wall-to-wall land cover layer must be available. For this study, a pressure assessment for the Monnery HUC 6 watershed could not be completed because the majority of the watershed is located in Saskatchewan, and land cover data for this portion of the watershed was not available.

3.2.2. Assigning Pressure Categories

Catchment integrity was translated into catchment pressure by taking the percent scores and grouping the scores into three pressure categories (Low, Moderate, High) based on the quartile percentile breaks for the distribution of scores. Again, for each HUC 6 watershed, the percent scores were reviewed, and breaks were manually adjusted where required to provide a more meaningful break between Pressure categories. Roughly, catchments in the Low Pressure group correspond to the catchments with scores in the bottom 25% of the scoring range (i.e., lowest set of scores in the 0 to 100% range), catchments in the High Pressure group correspond to the catchments with scores in the top 25% of the scoring range (i.e., scores at the high end of the 0 to 100% range), and Moderate Pressure catchments correspond to the remaining 50% of scores (i.e., scores between the 25^{th} and 75^{th} percentiles).

3.3. Management Prioritization

While riparian intactness and catchment pressure scores on their own provide land managers with important information about riparian condition, combining these scores together to create a prioritization matrix that identifies high priority areas for both conservation and restoration allows land managers to more precisely target areas for management.

Combining intactness and pressure scores results in a prioritization matrix with 12 scoring categories, and we assigned a unique score ranging between 1 and 12 to each category using best professional judgement (Table 12). The numeric scores were then combined and assigned to one of four prioritization categories, as follows:

- **High Conservation Priority (Category 1-3):** High/Moderate Intactness and Low/Moderate Pressure
- **Moderate Conservation Priority (4-6):** High/Moderate Intactness and Moderate/High Pressure
- **Moderate Restoration Priority (7-9):** Low/Very Low Intactness and Low/Moderate Pressure
- **High Restoration Priority (10-12):** Low/Very Low Intactness and Moderate/High Pressure

For each riparian management area, the pressure score was determined by intersecting the RMA polygons with the catchment polygons. This ensured that the pressure scores, which were calculated as polygons, could be accurately assigned to the RMA polygons. The resulting prioritization polygons were then scored, and the length of each RMA assigned to each priority category was calculated.

Table 12. Prioritization matrix for assigning conservation and restoration priority to riparian management areas in the study area.

		RIPARIAN INTACTNESS			
		High	Moderate	Low	Very Low
CATCHMENT PRESSURE	Low	1	3	7	9
	Moderate	2	5	8	11
	High	4	6	10	12

High Conservation Priority
Moderate Conservation Priority
High Restoration Priority
Moderate Restoration Priority

3.4. Data Summaries

HUC 2 and HUC 6 data summaries were generated using the watershed boundaries to define the watershed assignment. All municipal data summaries were generated using a spatial intersect rule in ArcGIS, where the results from each analysis (i.e., intactness, pressure, priority) were intersected with the municipal boundary layer. Summarizing the data in this way captures the assessed shorelines that fall within the municipal boundary; however, it should be noted that there are spatial discrepancies between the municipal boundary data and the provincial hydrography data that are freely available from AltaLIS. For example, in many instances, municipal boundaries follow the boundary of a waterbody (e.g., the boundary between two Counties follows a creek or river) and often, the boundary topology of these two features do not match. In these instances, some minor edits may have been made to correct the intersection outputs and reassign results from one municipality to another, but in most cases, municipal boundary layers were not extensively edited to correct topological errors. As a result, the municipal summaries of shoreline length for intactness and priority are approximate and should be considered estimates that reflect relative differences between municipalities.

3.5. Mapping & Labelling

Maps have been produced to communicate the results of this study at the HUC 6 watershed (Appendix A and B) and municipal (Appendix C and D) scales. Due to the large number of waterbodies included in this study, some of the features have been abbreviated to facilitate the interpretation of each map, as follows:

- Named Lakes: Abbreviated by removing the terms “Lake”, “Lakes”, or “Lac”.
- Unnamed Lakes:
    - For HUC 6 mapping, all unnamed lakes have the same HUC 6 numeric code; thus, for labelling, the HUC 6 code was removed and features were labelled with the numeric ID code only (e.g., 01, 02, 03, 04).
    - For municipal mapping, municipalities can span several HUC 6 watersheds and the two digit IDs for features are often duplicated; therefore, unnamed lakes on municipal maps retained the HUC 6 numeric code (e.g., 110302-01, 110302-02).
    - Where a HUC 6 or municipality included data from a previously completed riparian assessment project, these features were mapped using the numeric component of their original name (e.g., Unnamed Lake 08 was labelled 08).
- Named Streams: No change; full name retained on all maps.
- Unnamed Creeks: Labels vary based on the type of waterbody the stream flows into, as follows:
    - Named Stream or Named Lake – Label abbreviated by using the first letters of the Named Stream or Lake (e.g., Hooray River-01 and Hooray River-02 abbreviated as HR-01 and HR-02). Where an abbreviation was duplicated within a HUC 6 or municipality, the next letter in the name was used to distinguish the feature (e.g., Hooray River-01 and Hello River-01 were abbreviated as HoR-01 and HeR-01).
    - Unnamed Lake - The Unnamed Lake component of the name was abbreviated (UL) and was combined with the two digit code of the Unnamed Stream (e.g., UL-110302-01-US01, UL-110302-36-US02 were abbreviated as UL01-01 and UL36-02).
    - Isolated Unnamed Creek – These features were rare and were labelled on a map-by-map basis; however, these features were generally labelled by removing the “US” from the name (e.g., US-090201-01 was labelled 090201-01).
    - Unnamed Creek – These features were rare and were labelled on a map-by-map basis; however, these features were generally labelled by removing the “US” from the name (US-070101-01-US01 and US-070101-01-US02 in the County of Paintearth were abbreviated to 070101-US01 and 070101-US02).

4.0 NSR Watershed Results

4.1. Shorelines of Interest

The North Saskatchewan River (NSR) watershed is a very large (~56,789 km^2) HUC 2 watershed that is located in central Alberta, and is composed of 12 smaller (HUC 6) watersheds (
Map 4). To-date, approximately 17,302 km of shoreline in the NSR watershed has been evaluated using the satellite-based riparian assessment method. The majority of the shoreline that has been assessed is located within the central and eastern portions of the watershed, with nearly half (47%) of the assessed shoreline being located within the Vermillion, White Earth, and Frog HUC 6 watersheds (Figure 7). Named and unnamed creeks, streams, and rivers account for the greatest proportion (81%; 14,088 km) of the shoreline that has been assessed in the watershed to-date (Figure 8).

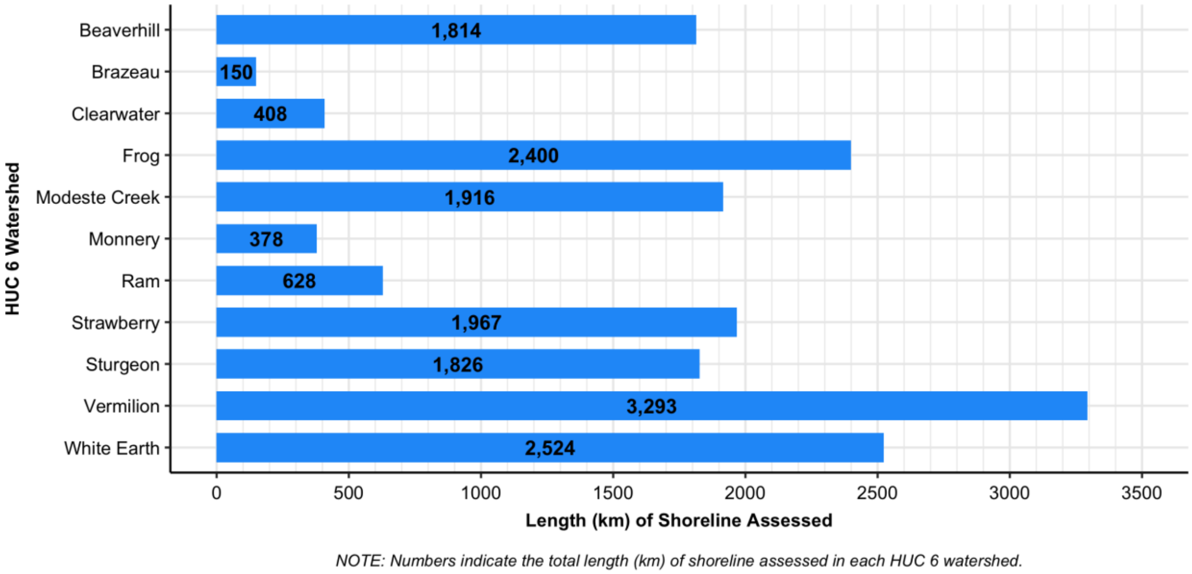


Figure 7. Length of shoreline assessed in each HUC 6 watershed in the North Saskatchewan River watershed.

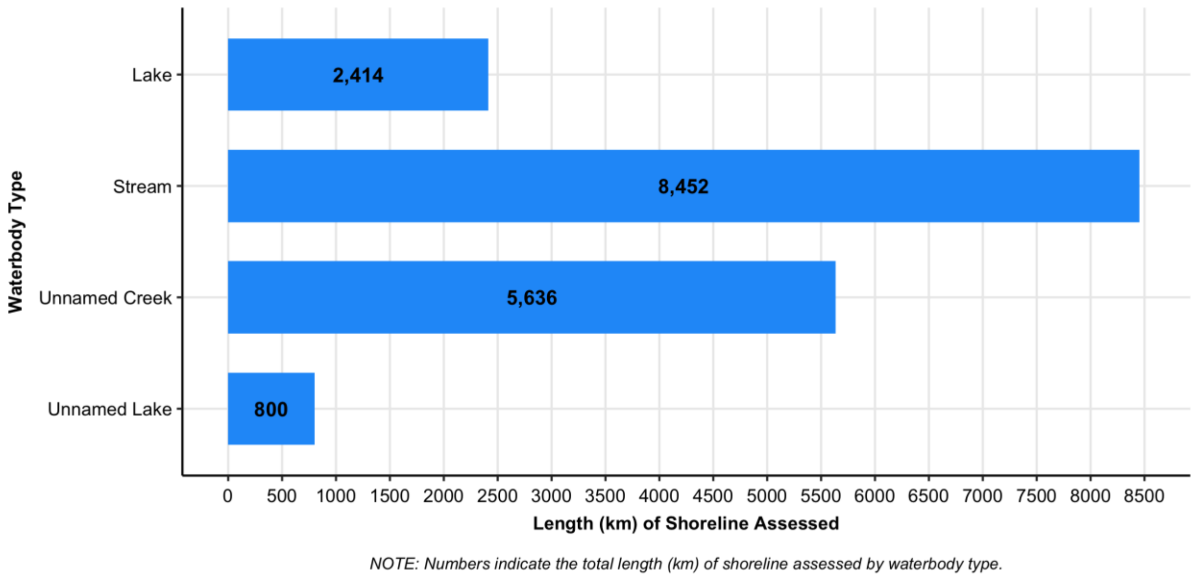
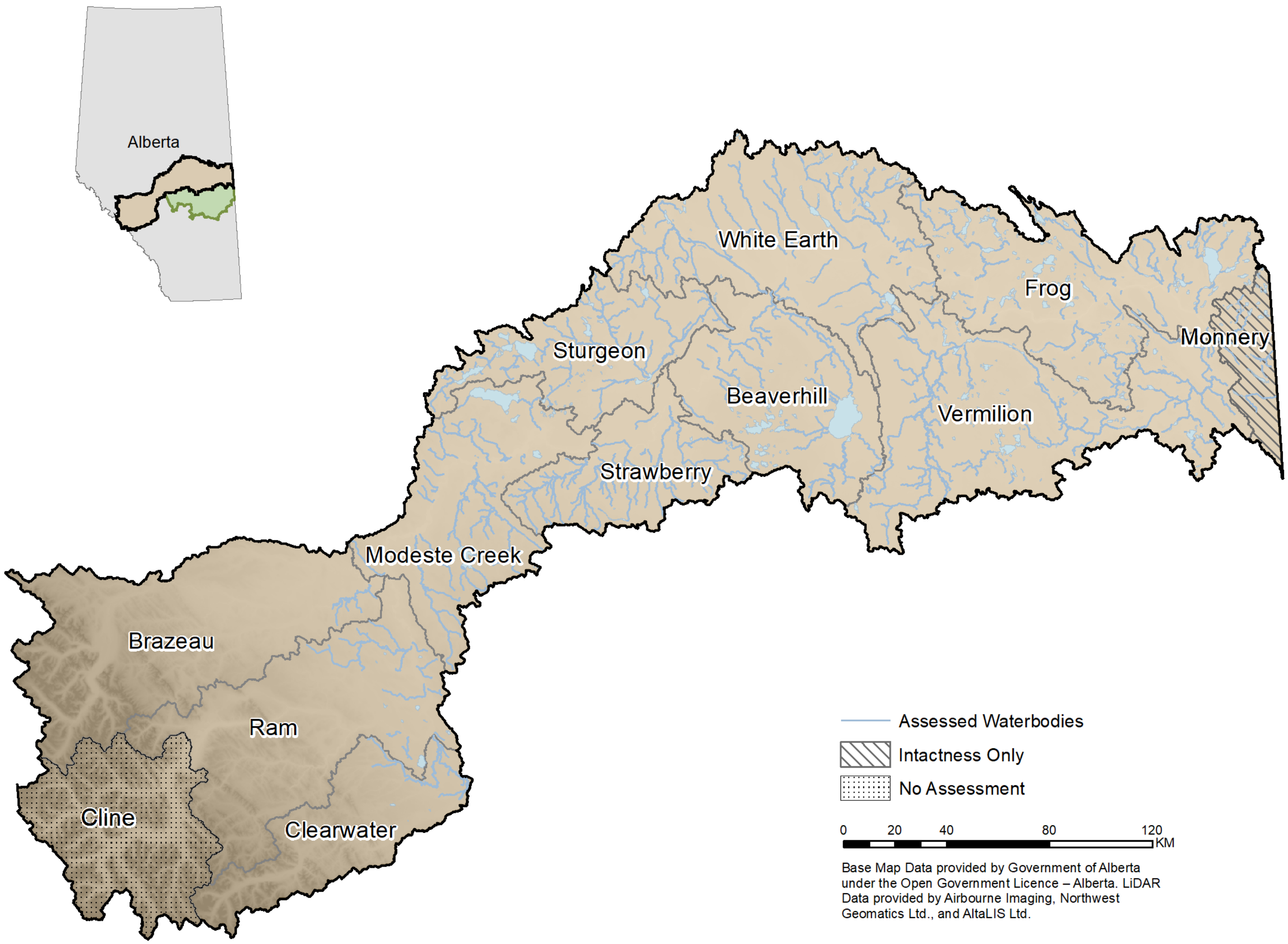


Figure 8. Length of shoreline assessed in in the North Saskatchewan River watershed, summarized by waterbody type.



Map 4. Location of HUC 6 watersheds in the North Saskatchewan River watershed, including the location and extent of shorelines that have been assessed to-date in each watershed.

4.2. Land Cover

Approximately 44% of the lands in the North Saskatchewan River watershed were classified as an anthropogenic land cover type (Figure 9; Map 5). Agriculture (cropland and pasture) lands cover approximately 34% of the watershed, and this cover type makes up the largest proportion of the lands modified by human activity, with the remaining human land cover being composed of agricultural depression (4%), built up/exposed (3%) and disturbed vegetation (3%). Approximately 56% of the watershed consists of natural land cover types, such as wetlands, forests, open water, and other low and open natural vegetative cover types. Because the North Saskatchewan River originates in the Rocky Mountains, nearly 10% of the land cover includes natural bare ground and snow/ice, the majority of which is located in the western, mountainous region of the watershed. Wetlands and open water covers approximately 14% of the watershed, with the predominant wetland land cover types being marsh (38%), woody fen (38%), and swamp (18%; Figure 10).

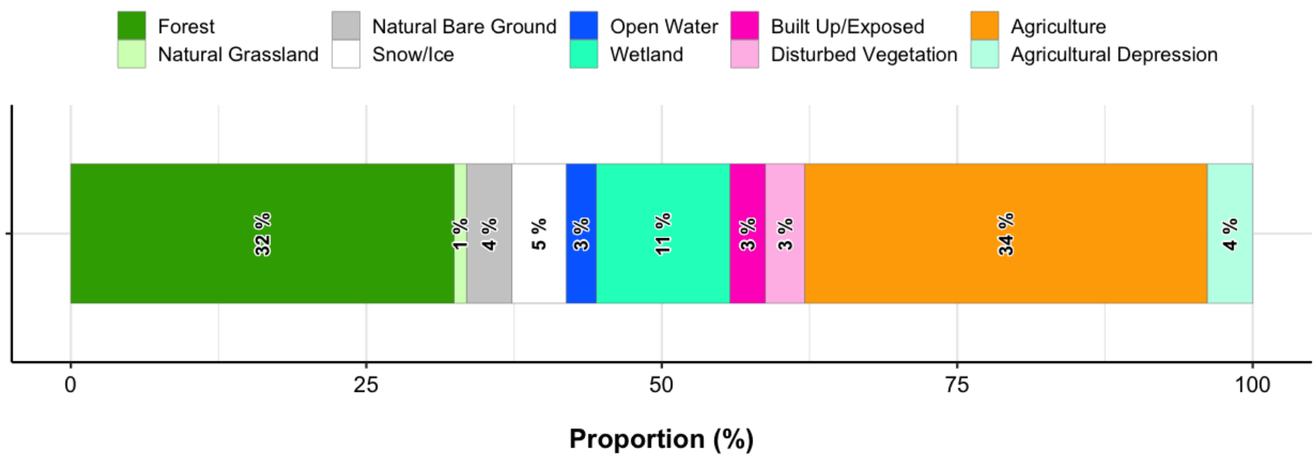


Figure 9. The proportion of the North Saskatchewan River watershed assigned to each Level 1 land cover class.

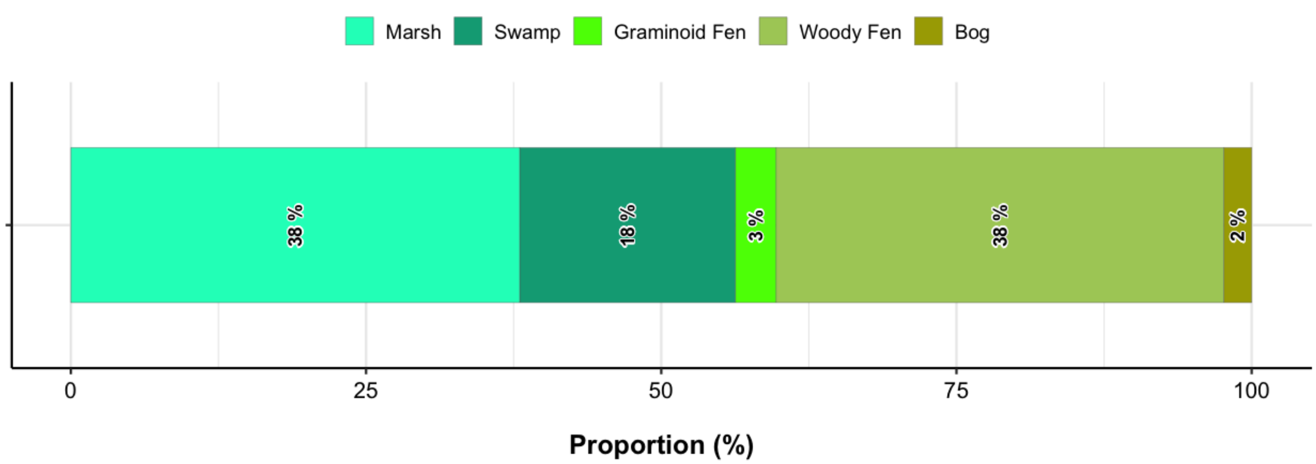
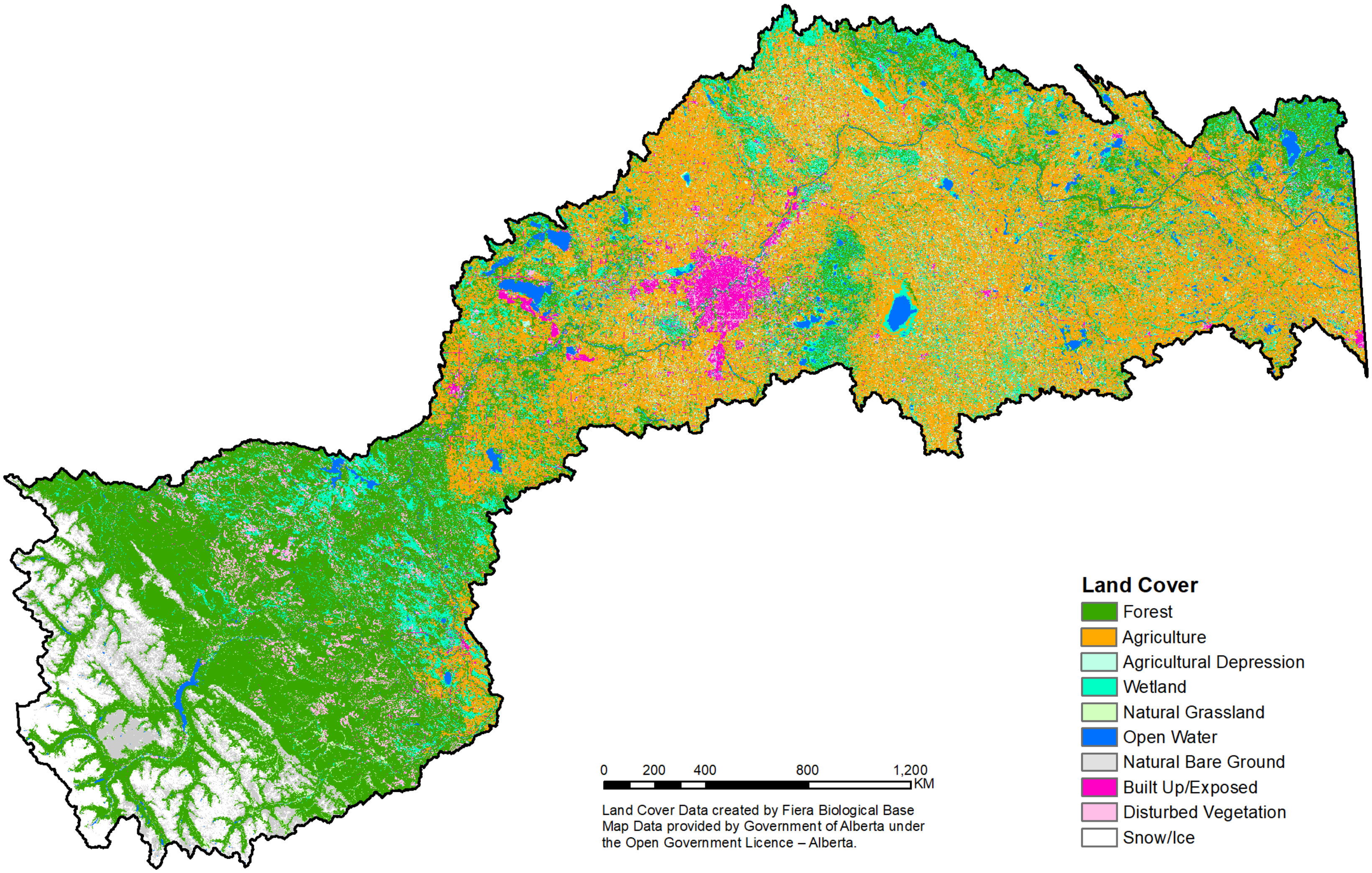


Figure 10. The proportion of wetland cover within North Saskatchewan River watershed assigned to each Level 2 wetland class.



Map 5. Land cover in the North Saskatchewan River watershed.

4.3. Riparian Management Area Intactness

Of the ~17,302 km of shoreline that has been assessed in the North Saskatchewan River watershed, approximately 46% has been classified as High Intactness, with a further 19% classified as Moderate Intactness (Figure 11; Table 13). The remaining 34% of the shoreline has been classified as either Low (10%) or Very Low (24%) Intactness, which combined, accounts for nearly 6,000 km of shoreline.

Shorelines were assessed in 11 of the 12 HUC 6 watersheds in the NSR (Map 3). When intactness is compared across the HUC 6 watersheds, the Strawberry, White Earth, and Vermilion watersheds all have a substantial amount (>600 km) of shoreline classified as Very Low Intactness (Figure 12). When the length of shoreline classified as Very Low Intactness is expressed as a proportion of the total length of shoreline assessed within the HUC 6, the Beaverhill, Monnery, Strawberry, Vermilion, and White Earth watersheds all have >25% of their assessed shorelines classified as Very Low Intactness (Figure 13). Conversely, the Frog, Modeste Creek, and White Earth watersheds all have more than 1,000 km of shoreline classified as High Intactness (Figure 12), while the Brazeau, Clearwater, Ram, and Modeste watersheds all have >60% of the shoreline length assessed as High Intactness (Figure 13). Additional detail about the condition of shorelines in each HUC 6 watershed is provided in Appendix A.

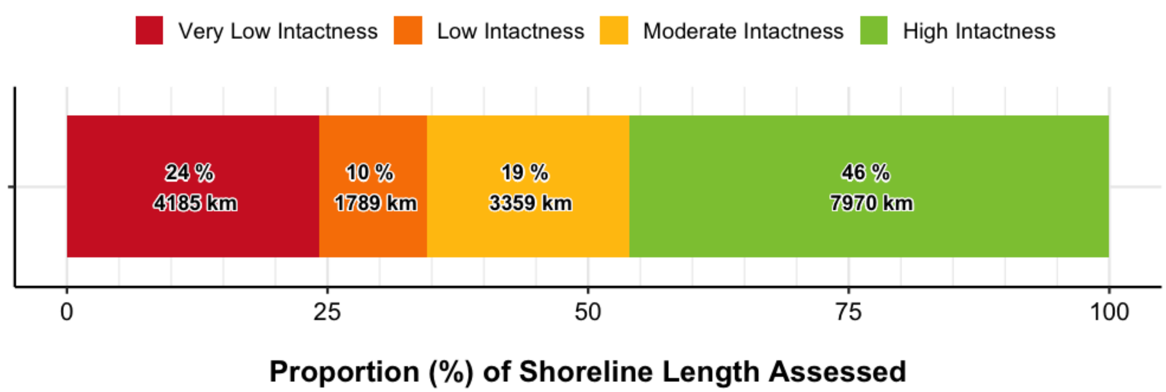


Figure 11. The total proportion and length of shoreline assessed within the North Saskatchewan River watershed assigned to each riparian intactness category.

Table 13. Total length of shoreline assessed within each HUC 6 watershed, along with a summary of the length and proportion of shoreline assigned to each riparian intactness category.

HUC 6 Watershed Name	Total Length Assessed (km)	Intactness							
		Very Low		Low		Moderate		High	
		km	%	km	%	km	%	km	%
Beaverhill	1,814	473	26	190	10	459	25	691	38
Brazeau	150	1	0	0	0	0	0	149	100
Clearwater	408	50	12	21	5	49	12	289	71
Frog	2,400	465	19	149	6	405	17	1,382	58
Modeste Creek	1,916	310	16	82	4	196	10	1,328	69
Monnery	378	97	26	38	10	84	22	159	42
Ram	628	12	2	6	1	11	2	599	95
Strawberry	1,967	628	32	206	10	460	23	674	34
Sturgeon	1,826	447	24	366	20	228	13	785	43
Vermillion	3,293	933	28	527	16	1,024	31	808	25
White Earth	2,524	768	30	206	8	442	18	1,107	44
Watershed Total	**17,302**	**4,185**	**24**	**1,789**	**10**	**3,359**	**19**	**7,970**	**46**

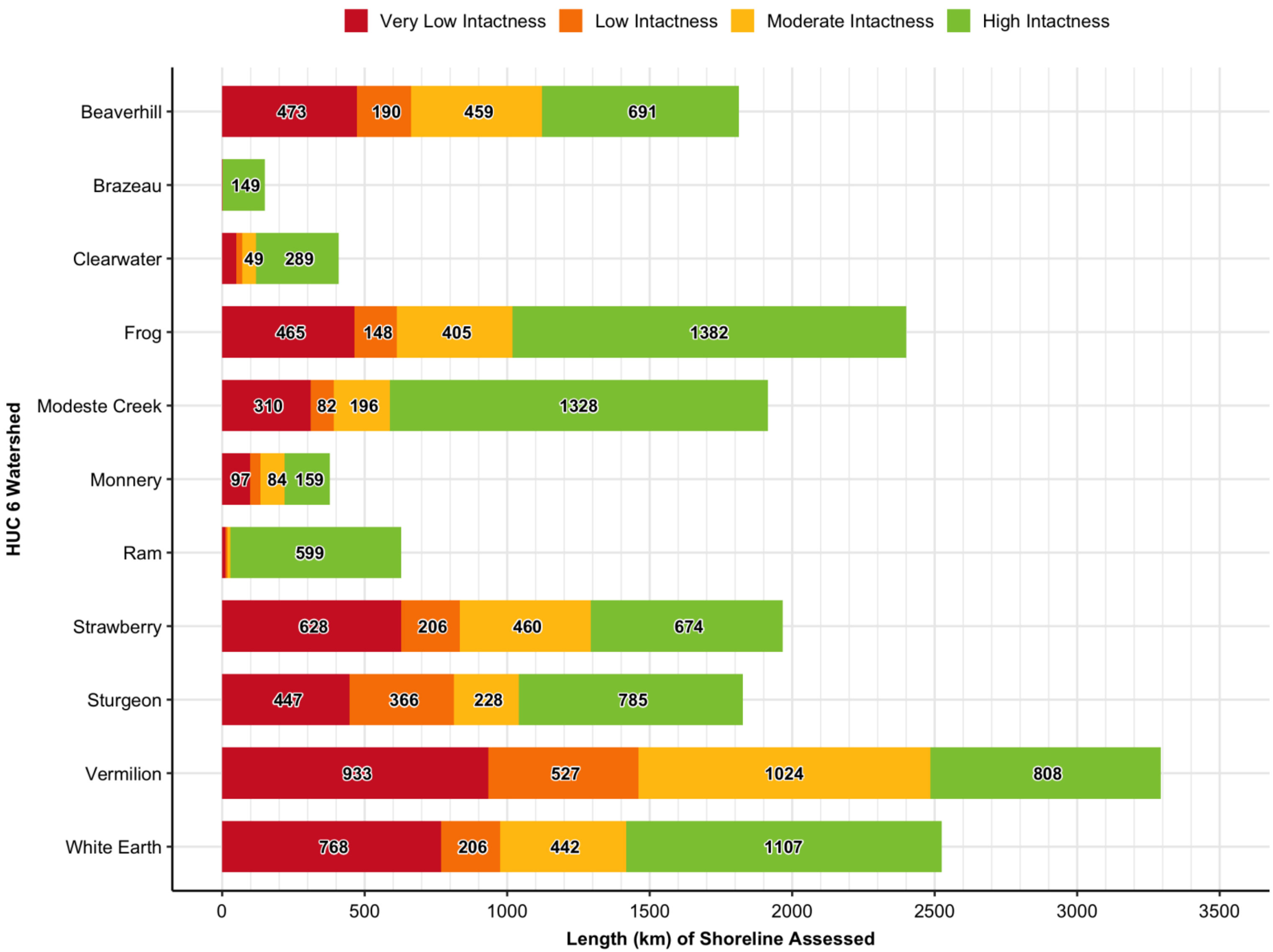


Figure 12. The length of shoreline in the North Saskatchewan River watershed assigned to each riparian intactness category, summarized by HUC 6 watershed.

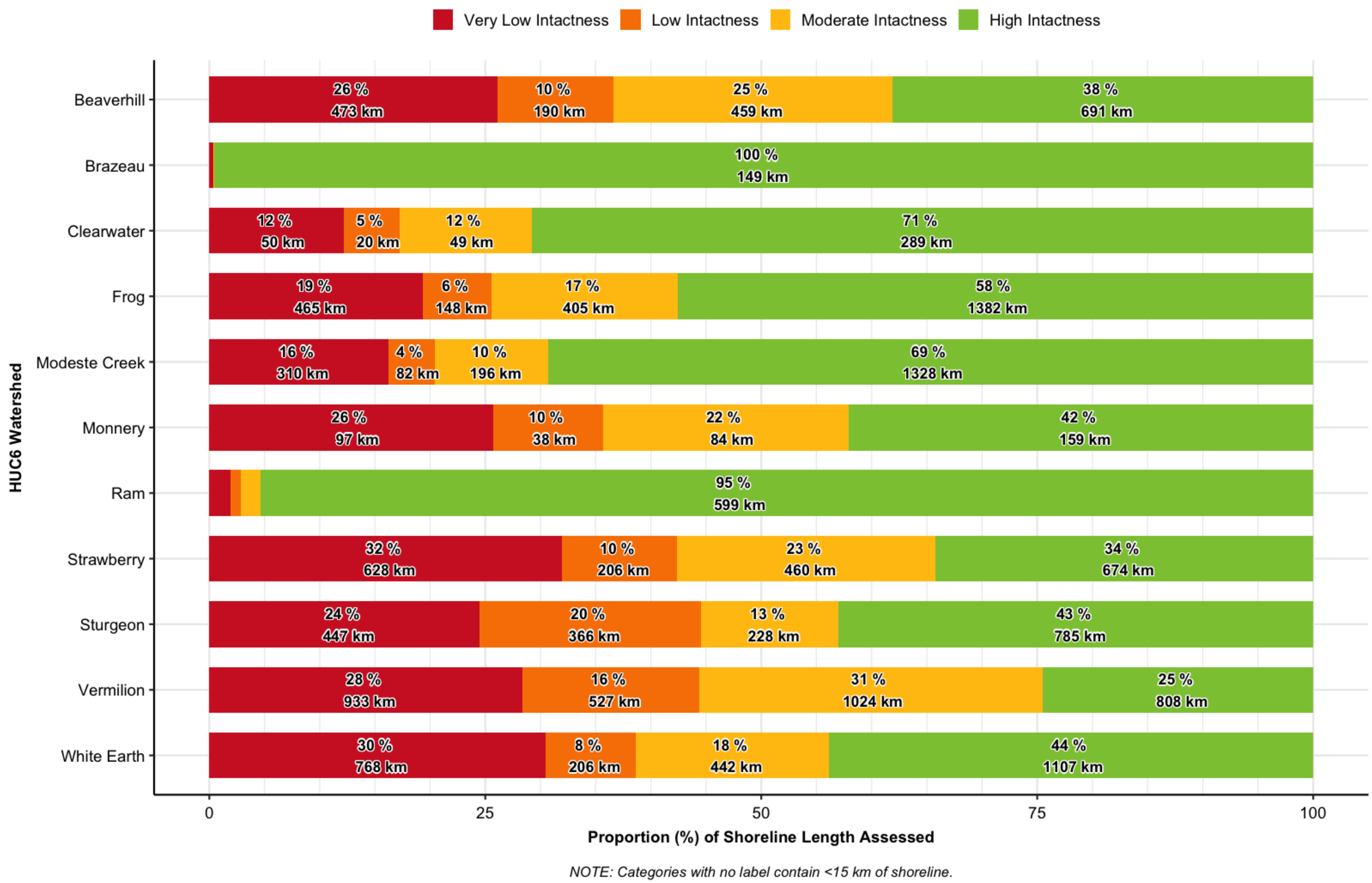


Figure 13. Proportion of shoreline within the North Saskatchewan River watershed assigned to each riparian intactness category, summarized by HUC 6 watershed.

4.4. Pressure on Riparian System Function

Pressure on riparian system function was assessed for 10 of the 12 HUC 6 watersheds in the NSR; the Cline was excluded because there was no shoreline assessed in this HUC 6, while the Monnery was excluded because a large proportion of this watershed is located in the province of Saskatchewan, and a full wall-to-wall land cover dataset is not available.

Within the ten HUC 6 watersheds that were assessed, 28% of the local catchments that intersect the shorelines of interest were classified as High Pressure, with the majority (55%) being classified as Moderate Pressure, and the remaining 17% being classified as Low Pressure (Figure 14).

When pressure scores were compared between HUC 6 watersheds, the shorelines that were assessed in the Clearwater watershed had the greatest proportion of local catchments classified as High Pressure, while the Beaverhill, White Earth, and Frog HUC 6 watersheds had the highest proportion of local catchments classified as either Low or Moderate Pressure (Figure 15).

A more detailed breakdown of Pressure results for each HUC 6 watershed in the North Saskatchewan River watershed is provided in Appendix A.

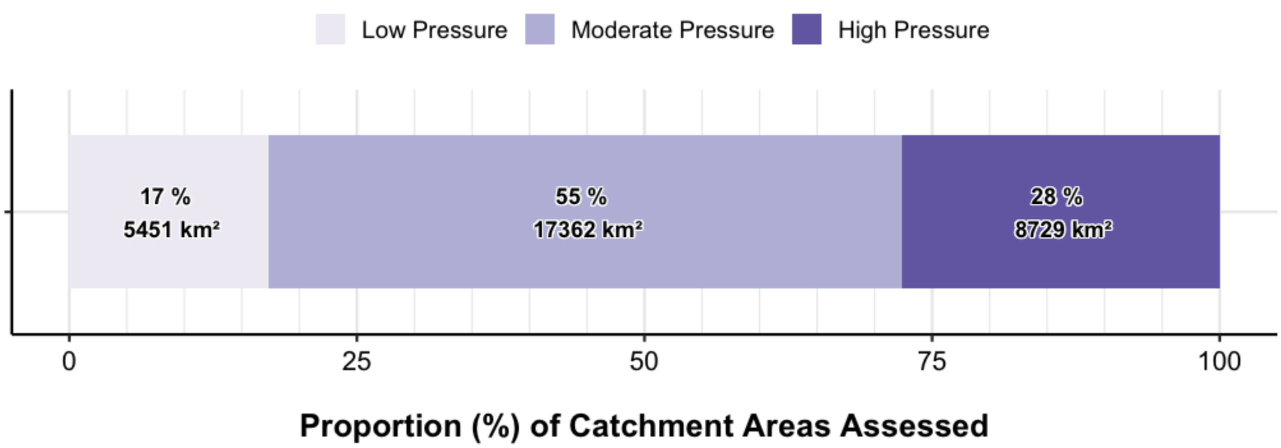


Figure 14. The proportion and area of local catchments within the North Saskatchewan River watershed that intersect the shorelines of interest assigned to each pressure category.

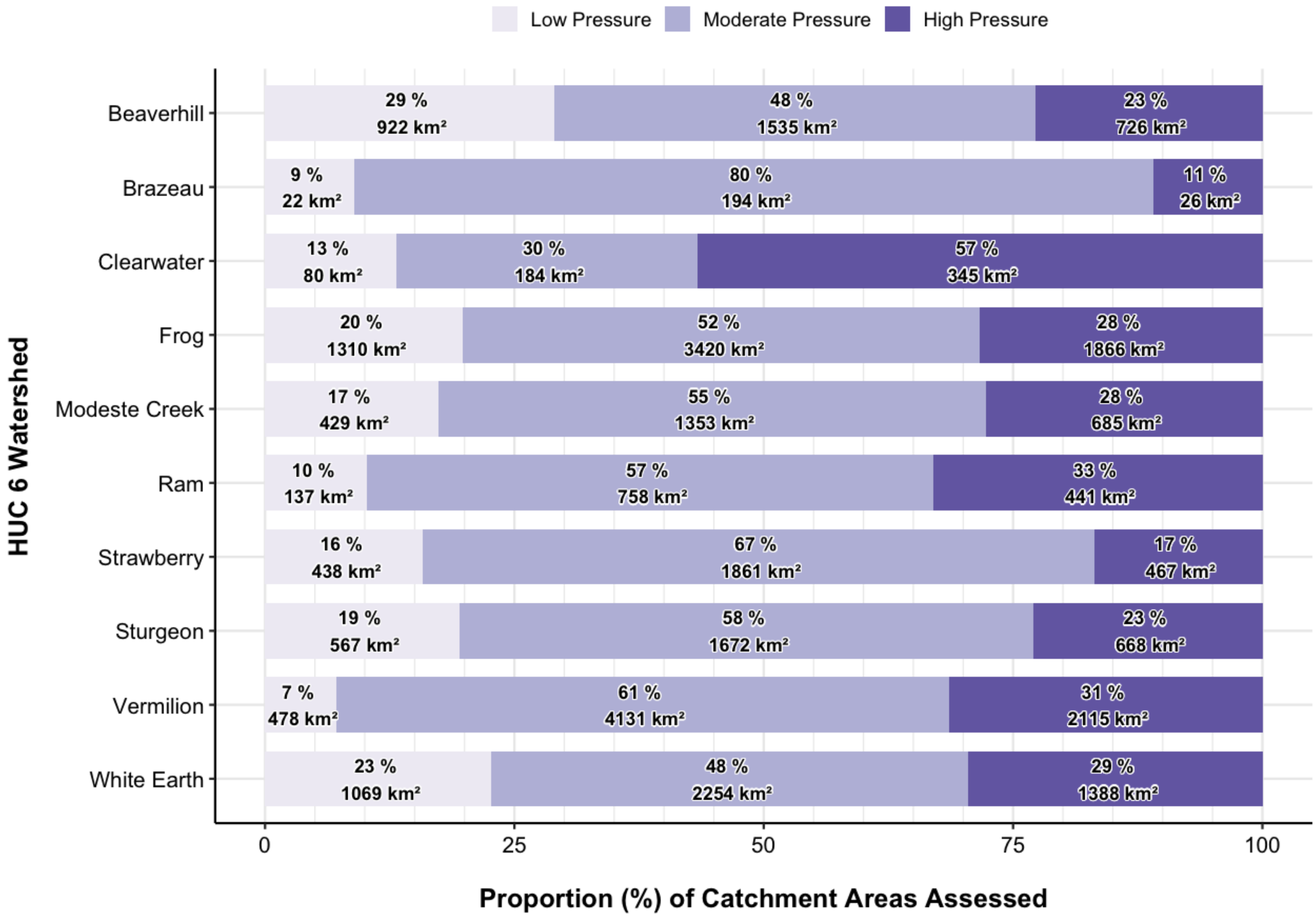


Figure 15. The proportion and area of local catchments assigned to each pressure category, summarized by HUC 6 watershed.

4.5. Conservation & Restoration Prioritization

Restoration and conservation priority was assigned to shorelines located within 10 of the 12 HUC 6 watersheds in the NSR; the Cline was excluded because no shoreline was assessed in this watershed, and the Monnery was excluded because there were no pressure scores derived for local catchments in this HUC 6 due to the lack of a complete wall-to-wall land cover layer. For the shoreline that was evaluated in the NSR, 66% was classified as either High or Moderate Conservation Priority, representing approximately 11,091 km of shoreline, while 35% (5,834 km) of the shoreline was assigned to either the High or Moderate Restoration Priority category (Figure 16).

The greatest length of shoreline classified as priority for conservation was located within the Frog, Modeste Creek, and White Earth HUC 6 watersheds, while the proportion of high priority conservation shorelines was also very high in the Ram and Brazeau watersheds (Figure 17; Table 14). Conversely, the greatest length and proportion of shoreline classified as either High or Moderate Restoration Priority was located in the Vermilion HUC 6 watershed, with the White Earth, Strawberry, Sturgeon, and Beaverhill watersheds also having a substantial amount of shoreline that has been classified as high priority for restoration. Additional detail about the conservation and restoration status of shorelines within each HUC 6 watershed is provided in Appendix A.

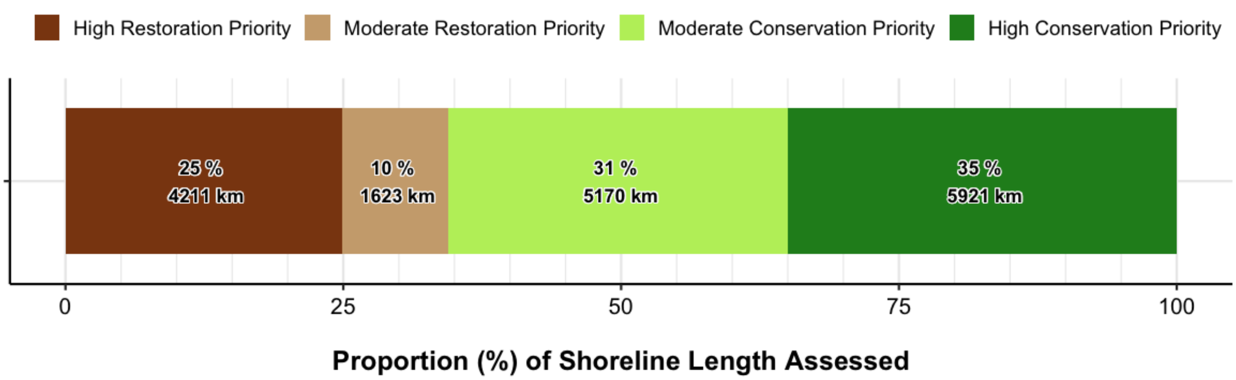


Figure 16. The total proportion of shoreline within the North Saskatchewan River watershed assigned to each priority category.

Table 14. Summary of restoration and conservation priority in the North Saskatchewan River watershed, summarized by HUC 6 watershed.

HUC 6 Watershed Name	Total Length Assessed (km)	Prioritization: High Restoration		Moderate Restoration		Moderate Conservation		High Conservation	
		km	%	km	%	km	%	km	%
Beaverhill	1,812	465	26	198	11	602	33	547	30
Brazeau	150	1	<1	0	0	28	19	122	81
Clearwater	407	62	15	8	2	198	49	139	34
Frog	2,399	501	21	112	5	671	28	1,114	46
Modeste Creek	1,917	313	16	74	4	496	26	1,034	54
Ram	629	15	2	3	<1	216	34	394	63
Strawberry	1,967	516	26	317	16	621	32	513	26
Sturgeon	1,825	491	27	322	18	422	23	590	32
Vermillion	3,293	1,042	32	419	13	1,251	38	581	18
White Earth	2,525	805	32	170	7	663	26	887	35
Watershed Total	**16,925**	**4,211**	**25**	**1,623**	**10**	**5,170**	**31**	**5,921**	**35**

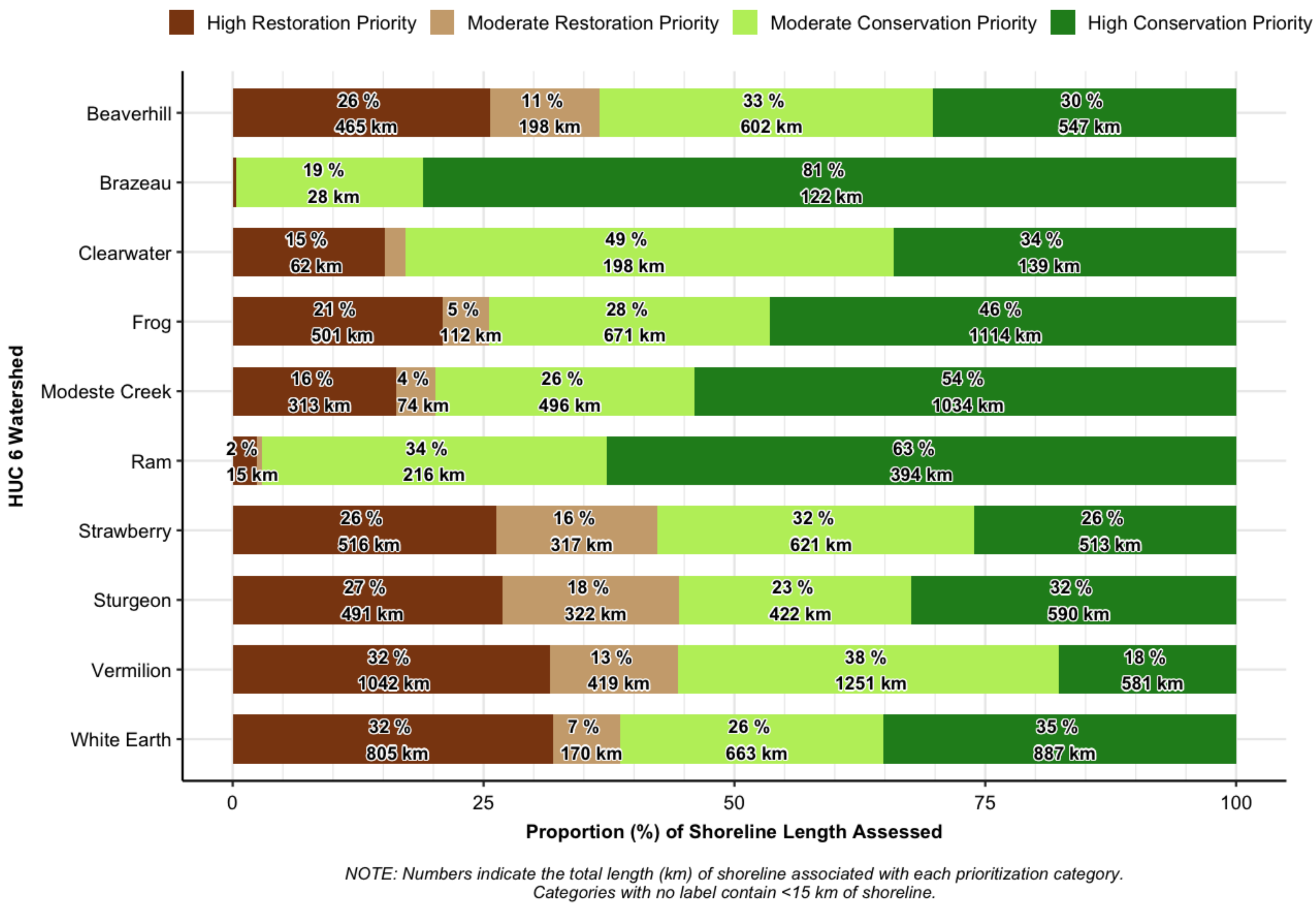
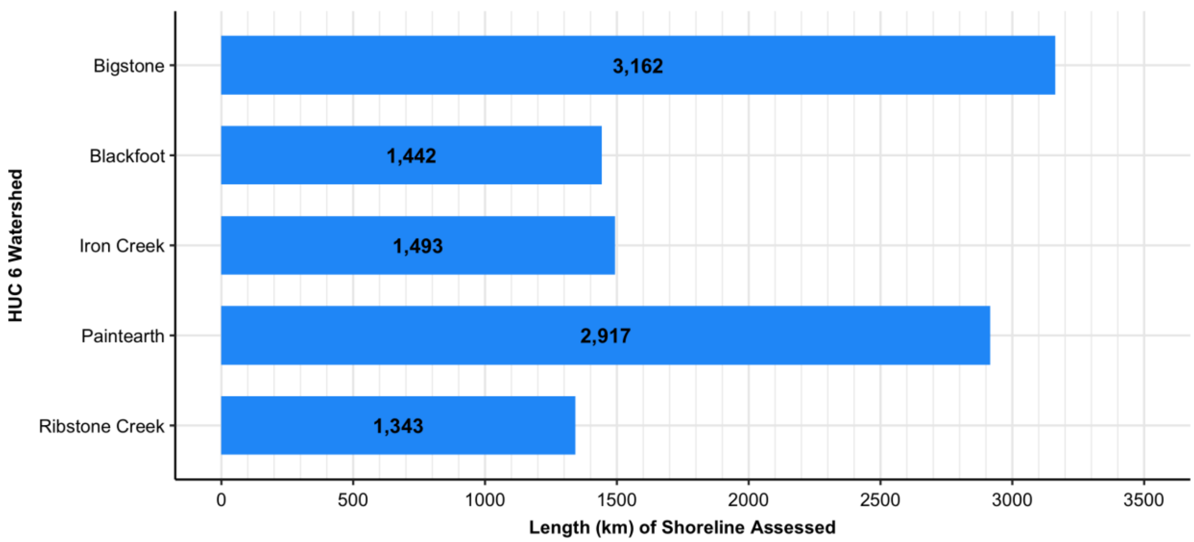


Figure 17. The total proportion of shoreline within the North Saskatchewan River watershed assigned to each priority category, summarized by HUC 6 watershed.

5.0 Battle River Watershed Results

5.1. Shorelines of Interest

The Battle River HUC 2 watershed covers an area of ~25,592 km^2 in east-central Alberta, and this watershed is composed of five smaller (HUC 6) watersheds: Blackfoot, Bigstone, Iron Creek, Paintearth, and Ribstone Creek (Map 6). Approximately 10,357 km of shoreline has been assessed in the Battle River watershed, with over half of that shoreline being located within the Bigstone and Paintearth HUC 6 watersheds (Figure 18). To-date, named and unnamed creeks, streams, and rivers make up the majority (85%; 8,771 km) of the shoreline that has been assessed in the Battle River watershed (Figure 19).



NOTE: Numbers indicate the total length (km) of shoreline assessed in each HUC 6 watershed.

Figure 18. Length of shoreline assessed in each HUC 6 watershed in the Battle River watershed.

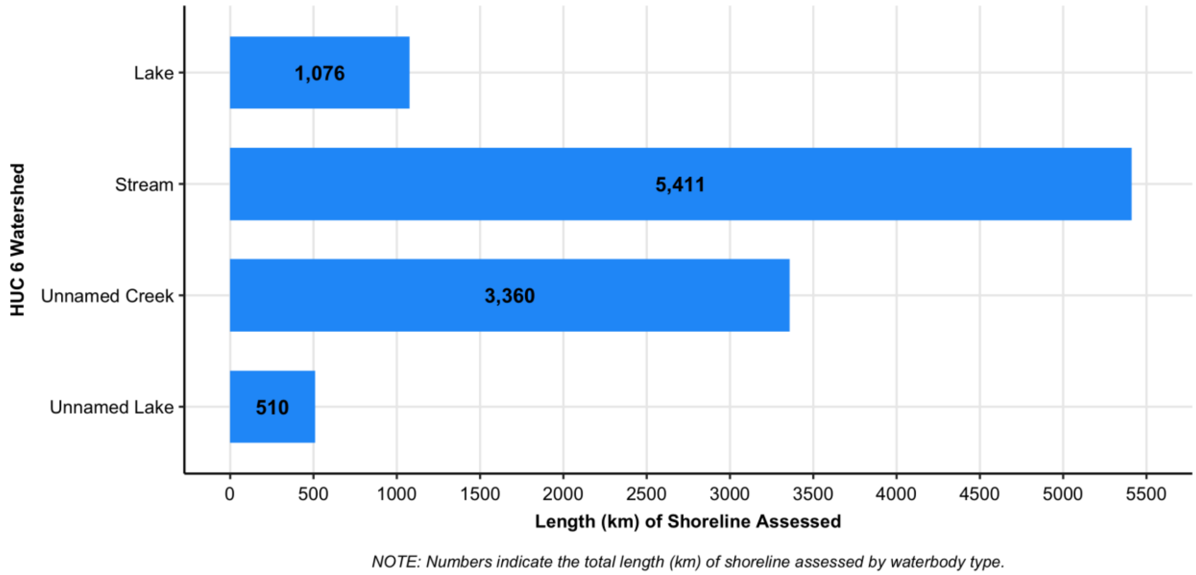
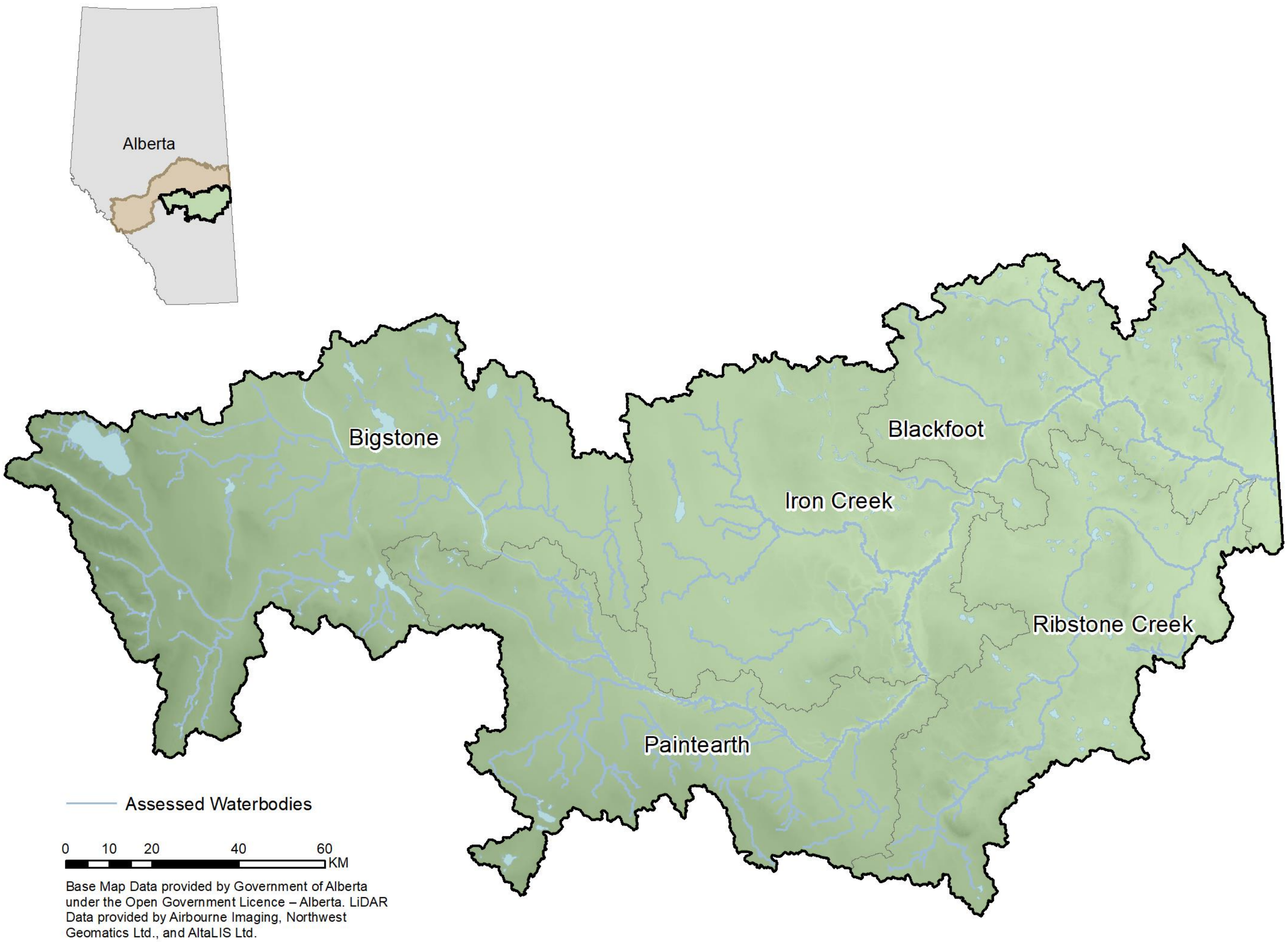


Figure 19. Length of shoreline assessed in the Battle River watershed, summarized by waterbody type.



Map 6. Overview of the shorelines in the Battle River watershed that were included in this riparian assessment project.

5.2. Land Cover

Human activity is extensive throughout the Battle River watershed, with approximately 70% of lands being classified into an anthropogenic land cover type (Figure 20). Agriculture (cropland and pasture) accounts for the largest proportion of the human footprint and is also the single largest land cover class, covering ~61% of the watershed (Map 7). Agricultural depression (6%), built up/exposed (2%) and disturbed vegetation (<1%) make up the remainder of the human land cover types. Approximately 30% of the watershed is covered by natural land cover types that are generally associated with major river valleys or within federal or provincially-managed lands in the east-central portion of the watershed (e.g., CFB Wainwright, Wainwright Dunes, Dillberry Provincial Park). Wetlands make up approximately 12% of the land cover, with marsh and swamp wetland land cover types making up 97% of the wetland cover in the watershed (Figure 21). Open water accounts for roughly 3% of the land cover in the watershed.

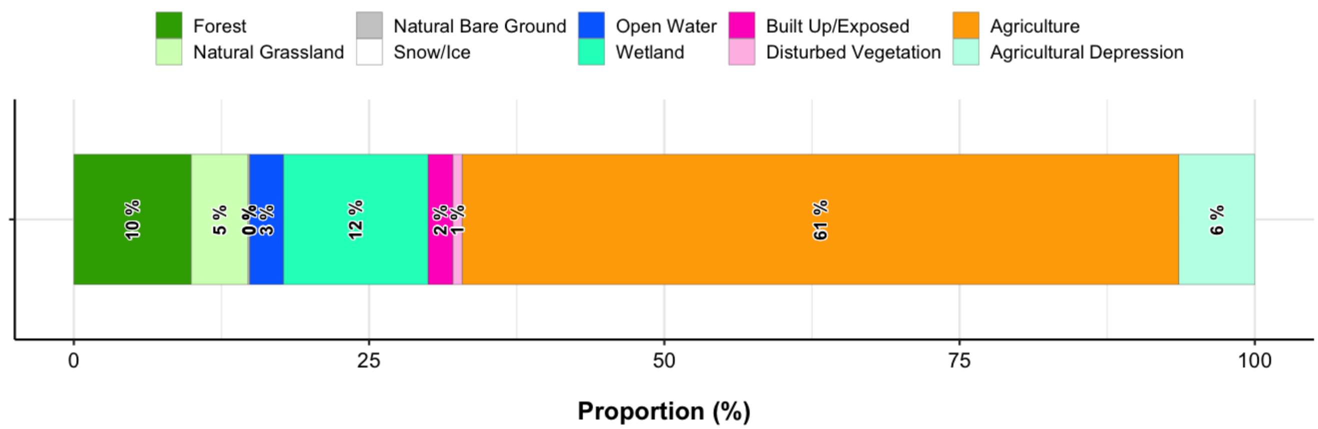


Figure 20. The proportion of the Battle River watershed assigned to each Level 1 land cover class.

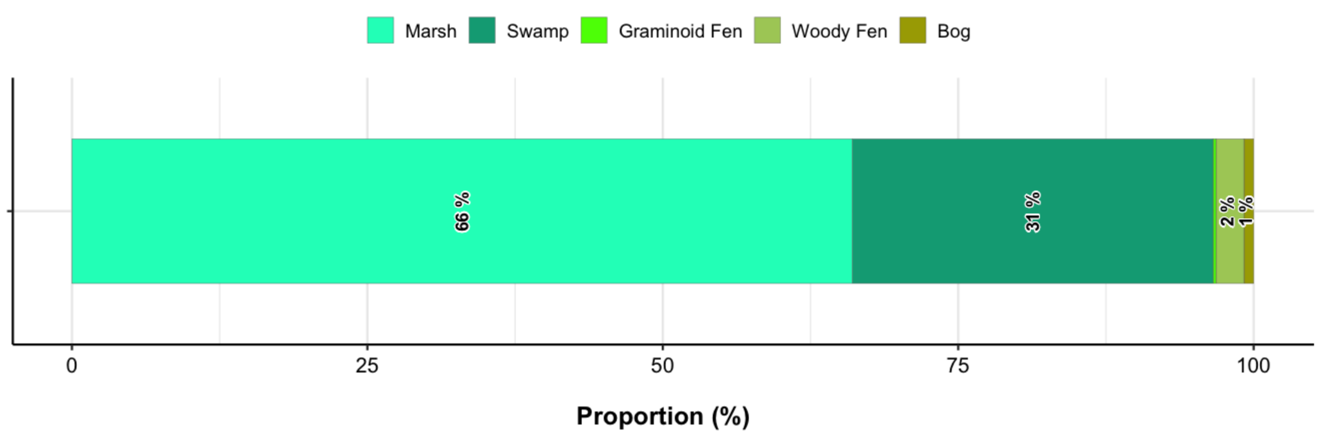
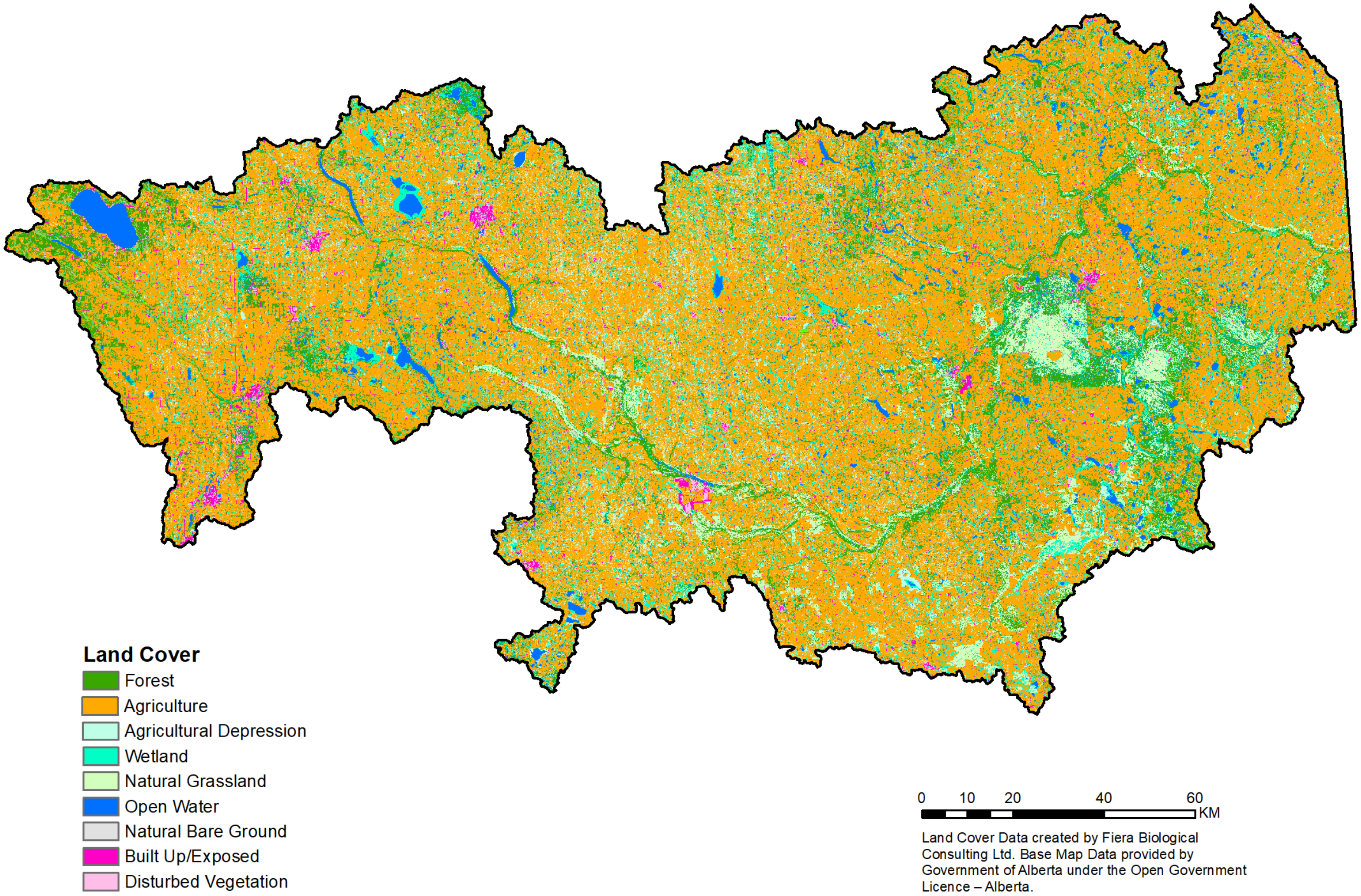


Figure 21. The proportion of wetland cover within Battle River watershed assigned to each Level 2 wetland class.



Map 7. Land cover in the Battle River watershed.

5.3. Riparian Management Area Intactness

Overall, 43% of the shoreline assessed in the Battle River watershed was classified as High Intactness, with a further 25% classified as Moderate Intactness (Figure 22; Table 15). The remaining 32% (3,283 km) of shoreline was assessed as either Low (11%; 1,145 km) or Very low (21%; 2138 km) Intactness.

When intactness is compared across HUC 6 watersheds, the Bigstone and Paintearth watersheds both have more than 500 km of shoreline assessed as Very Low Intactness (Figure 23). When the length of shoreline classified as Very Low Intactness is expressed as a proportion of the total length assessed within a HUC 6 watershed, between 15 and 30% of shorelines were classified as Very Low Intactness (Figure 24), with the Bigstone watershed having the greatest proportion of shorelines classified as Very Low Intactness. Conversely, the Paintearth and Bigstone watersheds both have more than 1,100 km of shoreline classified as High Intactness (Figure 23), with Ribstone Creek and Blackfoot watersheds having more than 50% of the assessed shorelines classified as High Intactness (Figure 24). Additional detail about the intactness of shorelines assessed in each of the Battle River HUC 6 watersheds is provided in Appendix B.

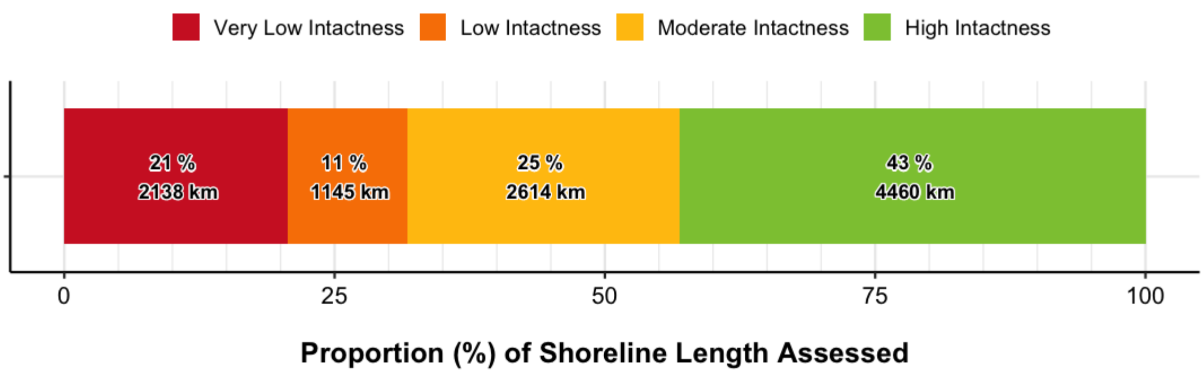


Figure 22. The total proportion of shoreline within the Battle River watershed assigned to each riparian intactness category. Numbers indicate the total proportion (%) and length (km) of shoreline associated with each category.

Table 15. Total length of shoreline assessed within each HUC 6 watershed, along with a summary of the length and proportion of shoreline assigned to each riparian intactness category.

HUC 6 Watershed Name	Total Length Assessed (km)	Intactness							
		Very Low		Low		Moderate		High	
		km	%	km	%	km	%	km	%
Bigstone	3,162	952	30	351	11	697	22	1,162	37
Blackfoot	1,442	251	17	104	7	358	25	729	51
Iron Creek	1,493	219	15	187	13	551	37	536	36
Paintearth	2,917	509	17	392	13	653	22	1,363	47
Ribstone Creek	1,343	207	15	112	8	354	26	670	50
Watershed Total	10,357	2,138	21	1,145	11	2,614	25	4,460	43

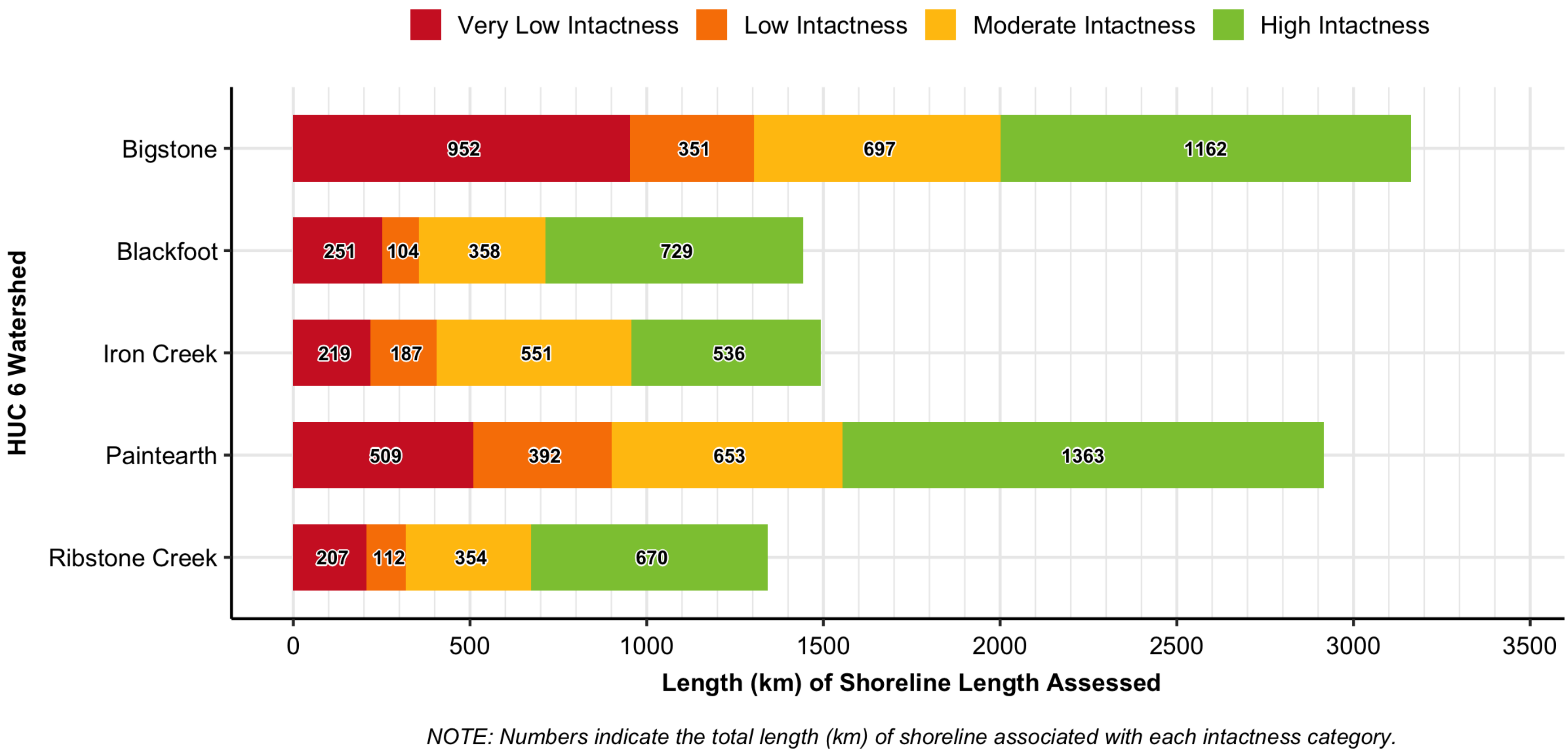


Figure 23. The length of shoreline within each HUC 6 watershed in the Battle River watershed assigned to each riparian intactness category.

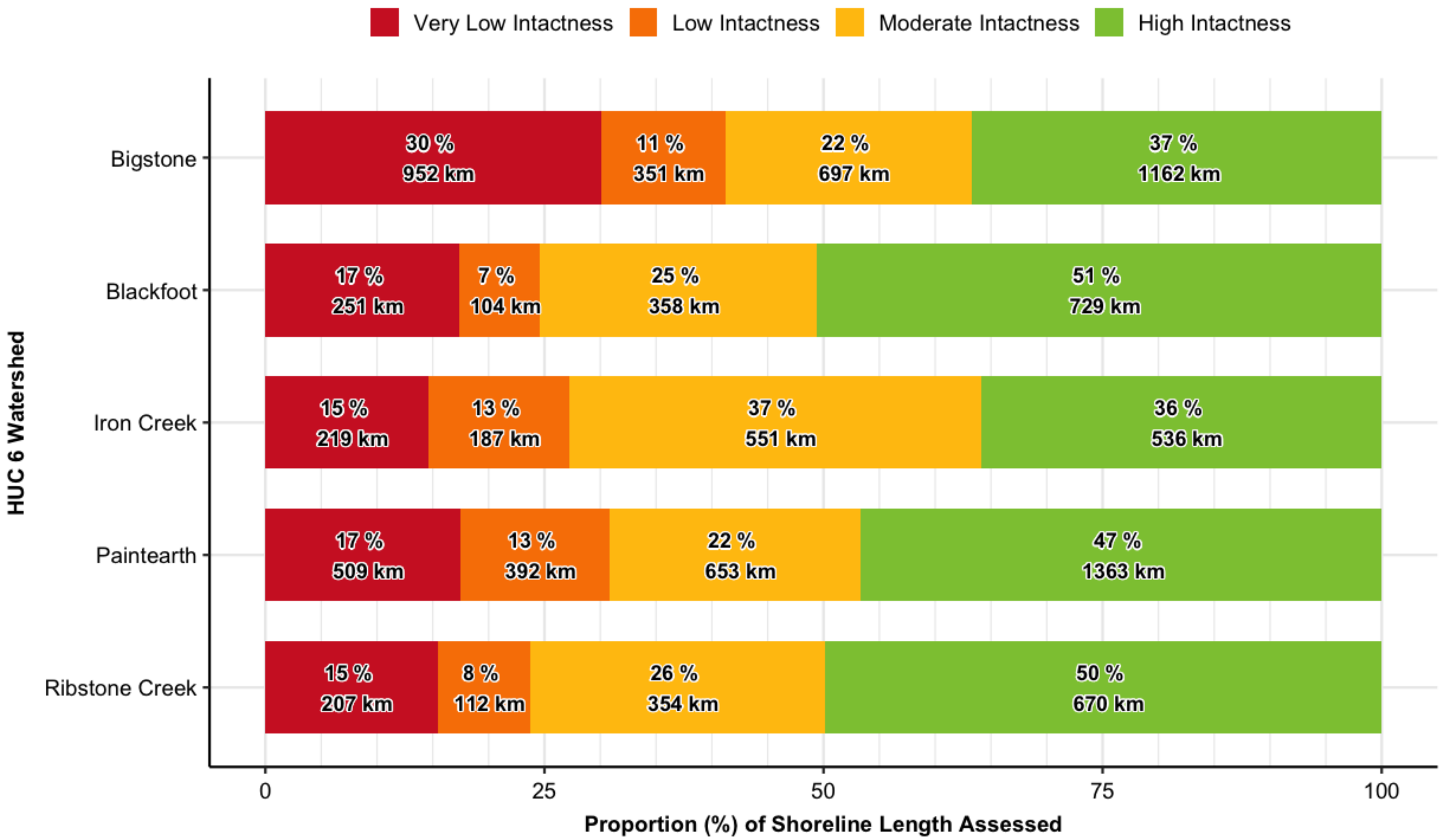


Figure 24. The total length of shoreline within the Battle River watershed assigned to each riparian intactness category, summarized by HUC 6 watershed. Numbers indicate the total proportion (%) and length (km) of shoreline associated with each intactness category.

5.4. Pressure on Riparian System Function

Pressure on riparian system function was assessed for all five of the HUC 6 watersheds within the Battle River watershed; however, a pressure assessment was not completed as part of prior riparian assessment work completed for Alberta Environment and Parks for the Pigeon, Sylvan, Gull, and Buffalo Lakes watersheds (Fiera Biological 2018d). Consequently, shorelines previously assessed in these lake watersheds were not included in this pressure assessment.

Overall, 29% of the local catchments that intersected shorelines of interest within the Battle River watershed were classified as High Pressure, with the majority (57%) being classified as Moderate Pressure, and the remaining 14% being classified as Low Pressure (Figure 25).

When pressure scores were compared between HUC 6 watersheds, the shorelines that were assessed in the Blackfoot watershed had the greatest proportion of local catchments classified as High Pressure, while the Paintearth and Ribstone Creek HUC 6 watersheds had the highest proportion of local catchments classified as Low Pressure (Figure 26).

A more detailed breakdown of Pressure results for each HUC 6 watershed in the Battle River watershed is provided in Appendix B.

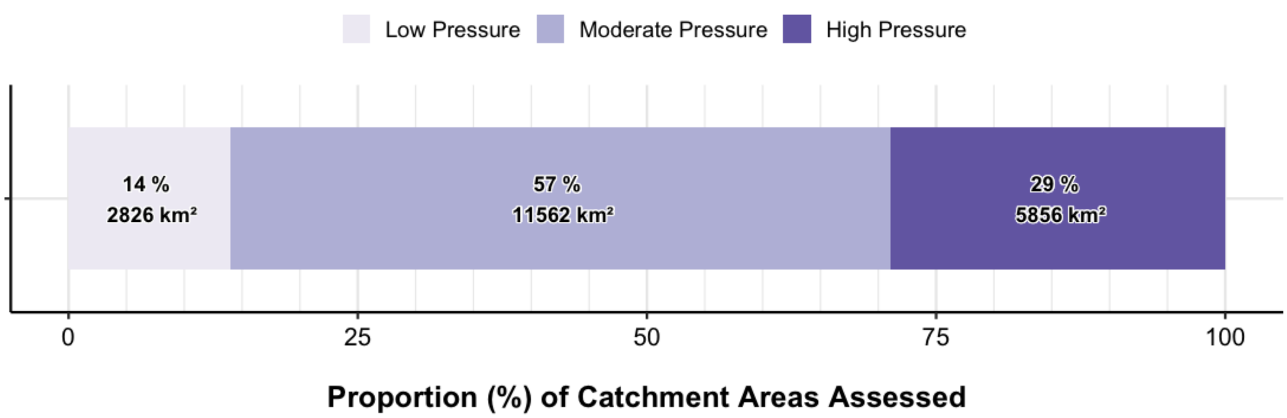


Figure 25. The proportion and area of local catchments that intersect shorelines of interest within the Battle River watershed assigned to each pressure category.

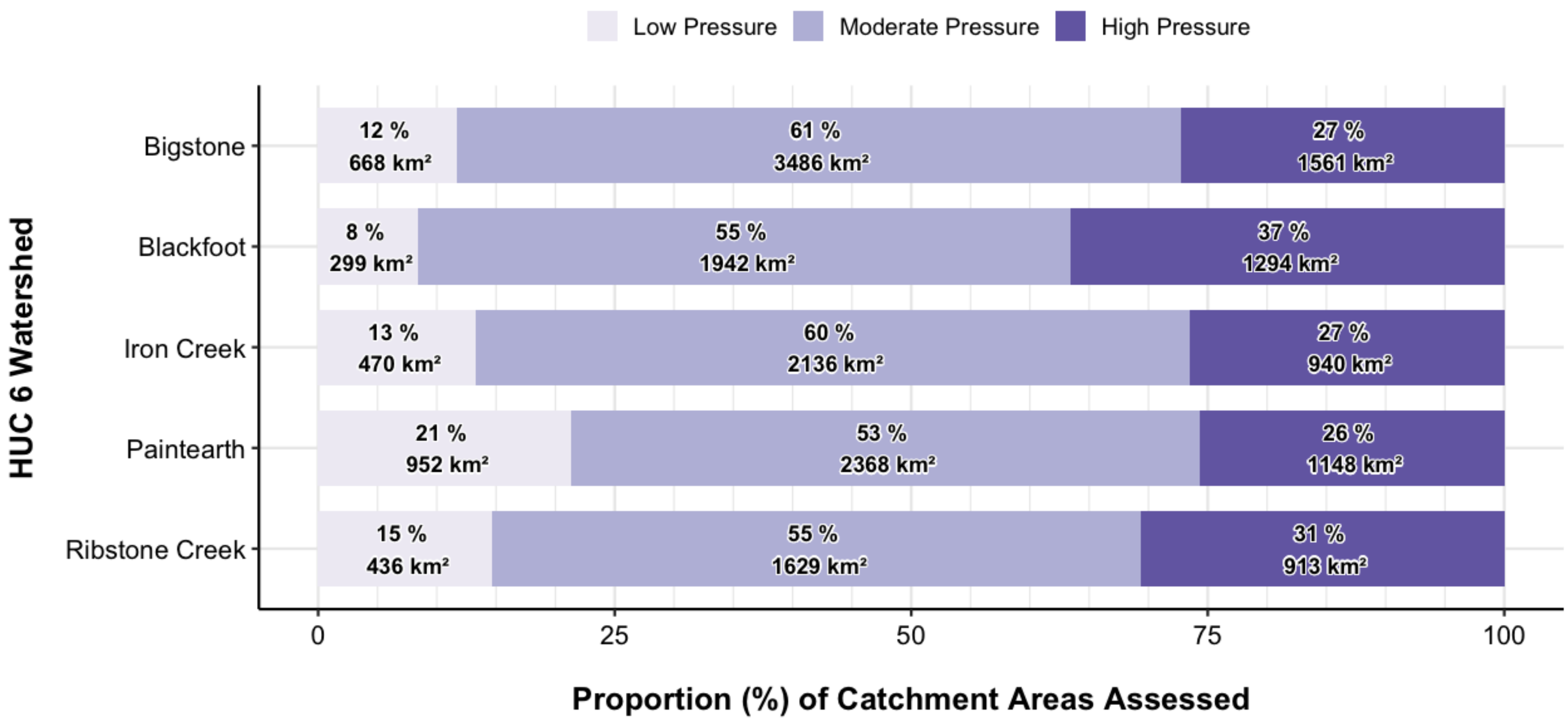


Figure 26. The proportion and area of local catchments assigned to each pressure category, summarized by HUC 6 watershed.

5.5. Conservation & Restoration Prioritization

In the Battle River watershed, 68% of the shoreline that was assessed was classified as either High (3,512 km) or Moderate (3,447 km) Conservation Priority (Figure 27). Conversely, 32% (3,242 km) of the shoreline was assigned to either the High or Moderate Restoration Priority category.

The greatest length of shoreline classified as either High or Moderate Conservation Priority was located within the Paintearth and Bigstone HUC 6 watersheds, while the proportion of priority conservation shorelines was also high in the Ribstone Creek and Blackfoot watersheds (Figure 28; Table 16). When restoration priority is considered, the greatest length and proportion of shoreline classified as either High or Moderate Restoration Priority was located in the Bigstone HUC 6 watershed, with the Paintearth and Iron Creek watersheds also having >25% of their shorelines assessed as High or Moderate Restoration Priority.

Additional detail about the conservation and restoration status of shorelines within each of the HUC 6 watersheds in the Battle River watershed is provided in Appendix B.

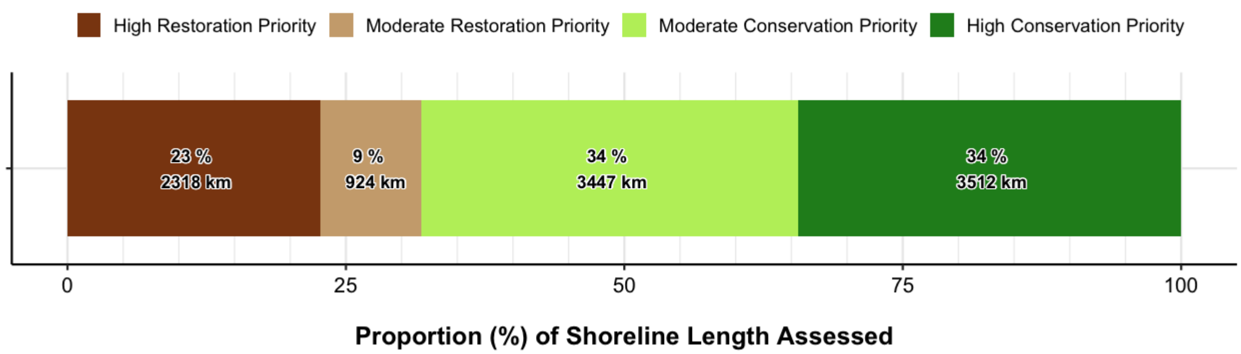


Figure 27. The total proportion of shoreline within the Battle River watershed assigned to each priority category.

Table 16. Summary of restoration and conservation priority in the Battle River watershed, summarized by HUC 6 watershed.

HUC 6 Watershed Name	Total Length Assessed (km)	Prioritization							
		High Restoration		Moderate Restoration		Moderate Conservation		High Conservation	
		km	%	km	%	km	%	km	%
Bigstone	3,006	1,006	33	256	9	1,017	34	728	24
Blackfoot	1,442	268	19	86	6	515	36	573	40
Iron Creek	1,493	273	18	133	9	656	44	431	29
Paintearth	2,917	551	19	350	12	800	27	1,216	42
Ribstone Creek	1,343	220	16	99	7	459	34	565	42
Watershed Total	**10,201**	**2,318**	**23**	**924**	**9**	**3,447**	**34**	**3,512**	**34**

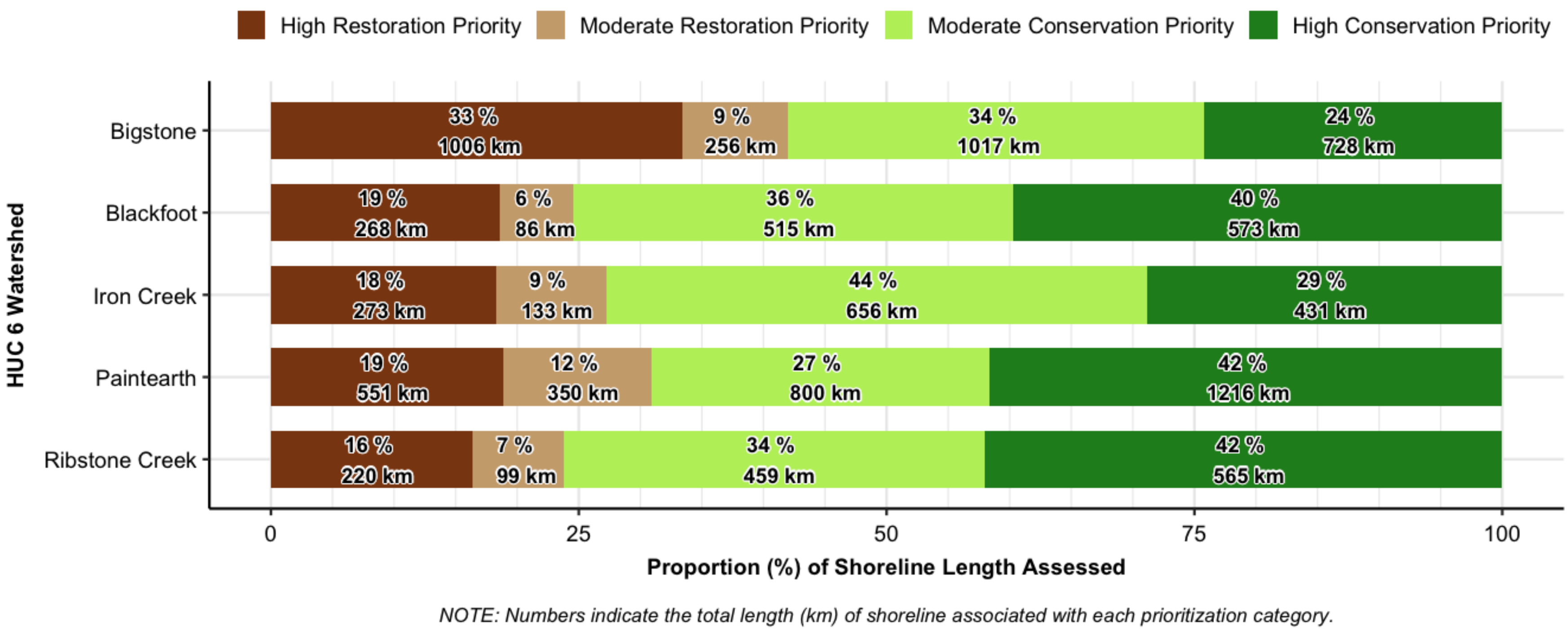


Figure 28. The total proportion of shoreline within the Battle River watershed assigned to each priority category, summarized by HUC 6 watershed.

6.0 Conclusion

Both the North Saskatchewan Watershed Alliance and the Battle River Watershed Alliance have identified riparian areas as key habitats for management action, as these areas contribute substantially to the maintenance of watershed health and biodiversity. Given the recognized importance and value of riparian areas, the overall goal of this project was to contribute to the management of riparian habitats within the North Saskatchewan and Battle River watersheds by quantifying shoreline intactness across large spatial extents using a satellite-based GIS riparian assessment tool.

To date, ~35,400 km of shoreline in the North Saskatchewan and Battle River watersheds and adjoining municipalities has been evaluated using the satellite-based GIS riparian assessment method. Within the North Saskatchewan River watershed, 65% of the shoreline that has been assessed has been classified as either High or Moderate Intactness, representing 11,329 km of shoreline. The remaining 34% (5,974 km) of the shoreline has been classified as Very Low or Low Intactness. The greatest length of shoreline classified as Very Low or Low Intactness is located within the Vermilion HUC 6 watershed, while the greatest length of High intactness shoreline is located in the Frog HUC 6 watershed.

In the Battle River watershed, 68% (7,074 km) of the shoreline that has been assessed to-date has been classified as High or Moderate Intactness. Riparian management areas classified as either Low or Very Low Intactness make up the remaining 32% (3,283 km) of the assessed shoreline. Notably, 40% (1,303 km) of the shoreline that has been classified as Low and Very Low Intactness in the Battle River watershed is located within the Bigstone HUC 6 watershed. Conversely, the greatest length of shoreline assessed as High Intactness is located in the Paintearth HUC 6 watershed.

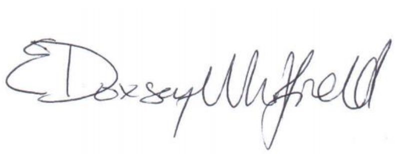
The results of this study represent the single largest assessment of riparian shoreline in the province of Alberta, and significantly advances our understanding of riparian habitat condition in the North Saskatchewan and Battle River watersheds. This knowledge can be used by a wide range of stakeholders to assist with watershed planning and stewardship activities, including the development of riparian policies or action plans, the design of riparian conservation programs, and/or the targeting of riparian restoration projects.

6.1. Closure

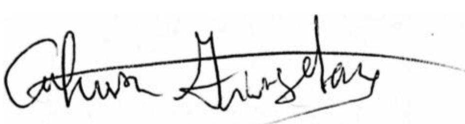
This report was written by:

Shari Clare, PhD, PBiol
Director, Sr. Biologist

Shantel Koenig, MGIS, PhD
Sr. Landscape Ecologist and GIS Specialist



Erin Doxsey-Whitfield, MSc
GIS Specialist



Calum Grimshaw, BSc
GIS Specialist

7.0 Literature Cited

Adams, P.W. and M. Taratoot. 2001. Municipal water supplies from forest watersheds in Oregon: Fact book and catalogue. Oregon Forest Resources Institute, Portland. 100 p.

Alberta Biodiversity Monitoring Institute (ABMI). 2017. Wall-to-wall Human Footprint Inventory. Available: http://www.abmi.ca/home/data-analytics/da-top/da-product-overview/GIS-Land-Surface/HF-inventory.html.

Alberta Environment (AENV). 2010. Using Aerial Videography to Assess Riparian Areas in Southern Alberta: a Pilot Study. Alberta Environment, Calgary. 40 pp.

Alberta Environment and Sustainable Resource Development (AESRD). 2012. Guide to Reporting on Common Indicators Used in State of the Watershed Reports. Government of Alberta, Edmonton, Alberta.

Alberta Geological Survey. 2016. Relative Landslide Susceptibility Model of the Alberta Plains and Shield Regions. Available: http://ags.aer.ca/publications/MAP_605.html.

Blackport R, R. MacGregor, and J. Imhof. 1995. An approach to the management of groundwater resources to protect and enhance fish habitat. Canadian Manuscript Report of Fisheries and Aquatic Sciences, No. 2284, Ontario, Canada.

Caissie D. 1991. The importance of groundwater to fish habitat: Base flow characteristics for three Gulf Region Rivers. Canadian Data Report of Fisheries and Aquatic Sciences, No. 814, Ontario, Canada.

Clare and Sass. 2012. Riparian lands in Alberta: Current state, conservation tools, and management approaches. Report prepared for Riparian Land Conservation & Management Team, Alberta Water Council, Edmonton, Alberta. Fiera Biological Consulting Ltd. Report #1163.

Deegan, B.M., Ganf, G., and Brookes, J.D. 2010. Assessment of Riverine Ecological Condition in the Fleurieu Peninsula, South Australia: Implications for Restoration. Transactions of the Royal Society of South Australia 134: 228-242.

Donahue, W.F. 2013. Determining Appropriate Nutrient and Sediment Loading Coefficients for Modeling Effects of Changes in Landuse and Landcover in Alberta Watersheds (technical report). Water Matters Society of Alberta, Canmore, AB. http://hdl.handle.net/1880/111976

Environment Canada. 2014. How Much Habitat is Enough? Third Edition. Environment Canada, Toronto, Ontario. Pp. 130.

Fiera Biological Consulting Ltd. 2018a. Modeste Watershed Riparian Area Assessment. Prepared for the North Saskatchewan Watershed Alliance, Edmonton, Alberta. Report Number 1652. Pp. 101.

Fiera Biological Consulting Ltd. 2018b. Sturgeon Riparian Area Assessment. Prepared for the North Saskatchewan Watershed Alliance, Edmonton, Alberta. Report Number 1762. Pp. 113.

Fiera Biological Consulting Ltd. 2018c. Strawberry Riparian Area Assessment. Prepared for the North Saskatchewan Watershed Alliance, Edmonton, Alberta. Report Number 1773. Pp. 110.

Fiera Biological Consulting Ltd. 2018d. Riparian Assessment for North Saskatchewan Region Lakes. Prepared for the Alberta Environment and Parks, Policy and Planning Division, Edmonton, Alberta. Report Number 179910. Pp. 65.

Fiera Biological Consulting Ltd. 2018e. Blindman River Riparian Assessment. Prepared for Agroforestry & Woodlot Extension Society (AWES), Edmonton, Alberta. Report Number 1834. Pp. 39.

Fiera Biological Consulting Ltd. 2019. Riparian Assessment Validation for North Saskatchewan Region Lakes. Prepared for the Alberta Environment and Parks, Policy and Planning Division, Edmonton, Alberta. Report Number 1853. Pp. 45.

Fiera Biological Consulting Ltd. 2020a. Riparian Area Assessment for the Medicine-Blindman Rivers Watershed. Prepared for the Red Deer River Watershed Alliance, Red Deer, Alberta. Report Number 2011. Pp. 104.

Fiera Biological Consulting Ltd. 2020b. Mid-Pembina Watershed Riparian Area Assessment. Fiera Biological Consulting Report #2012. Prepared for the Athabasca Watershed Council, Athabasca, Alberta. Pp. 80.

Fiera Biological Consulting Ltd. 2020c. Upper Pembina Watershed Riparian Area Assessment. Fiera Biological Consulting Report #2012c. Prepared for the Athabasca Watershed Council, Athabasca, Alberta. Pp. 74.

Fiera Biological Consulting Ltd. 2021. Lower Pembina Watershed Riparian Area Assessment. Fiera Biological Consulting Report #2012b. Prepared for the Athabasca Watershed Council, Athabasca, Alberta. Pp. 76.

Fiera Biological Consulting Ltd. 2021b. Creation of a Land Cover Dataset for the North Saskatchewan and Battle River Watersheds. Prepared for the North Saskatchewan Watershed alliance and the Battle River Watershed Alliance. Report Number 1987. Pp. 24

Flotemersch J.E., Leibowitz S.G., Hill R.A., Stoddard J.L., Thoms M.C., Tharme R.E. 2015. A Watershed Integrity Definition and Assessment Approach to Support Strategic Management of Watersheds. River Research and Applications 32: 1654–1671.
GOA (Government of Alberta). 2018. Alberta ArcHydro Phase 2. ArcGIS Geodatabase. Available: https://open.alberta.ca/dataset/bcf911fd-741e-4c8c-9f90-9e191b1d6ed3.
Ho, T.K. 1995. Random decision forests. Proceedings of the 3rd International Conference on Document Analysis and Recognition, Montreal, QC, 14–16 August 1995. pp. 278–282.
Mills, B. and Scrimgeour, G. 2004. The Effectiveness of Aerial Videography to Characterize Lakeshore Condition. Data Report (D-2005-017) produced by Alberta Conservation Association, Alberta, Canada. 52 pp. + App.
North Saskatchewan Watershed Alliance (NSWA). 2015. Riparian Health Assessment of Wabamun Lake: An Aerial Assessment Using an Unmanned Air Vehicle (UAV). Prepared for the Wabamun Watershed Management Council, Edmonton, AB. 20pp + Appendix.
NRC (National Research Council). 2002. Riparian Areas: functions and strategies for management. National Academy Press, Washington, D.C. 428 pp.
Olokeogun, O. S., A. Ayanlade, and O.O. Popoola. 2020. Assessment of riparian zone dynamics and its flood-related implications in Eleyele area of Ibadan, Nigeria. Environmental Systems Research, 9(1), 1-11.
Orewole, M. O., D.B. Alaigba, and O. Oviasu. 2015. Riparian corridors encroachment and flood risk assessment in Ile-Ife: A GIS perspective. Open Transactions on Geosciences. 2(1): 17-32.
Pusey, B.J. and A.H. Arthington. 2003. Importance of the riparian zone to the conservation and management of freshwater fish: a review. Marine and Freshwater Research 54: 1-16.
Ripley, T., Scrimgeour, G., and M.S. Boyce. 2005. Bull trout (*Salvelinus confluentus*) occurrence and abundance influenced by cumulative industrial developments in a Canadian boreal forest watershed. Canadian Journal of Fisheries and Aquatic Sciences 62: 2431-2442.
Swanson, S., D. Kozlowski, R. Hall, D. Heggem, and J. Lin. 2017. Riparian proper functioning condition assessment to improve watershed management for water quality. Journal of Soil and Water Conservation. 72(2): 168–182. doi:10.2489/jswc.72.2.168.
Tchir, J.P., Hvenegaard, P.J., and Scrimgeour, G.J. 2004. Stream Crossing Inventories in the Swan and Notikewin River Basins of Northwest Alberta: Resolution at the Watershed Scale. Available: http://www.ab-conservation.com/downloads/report_series/stream-crossing-inventories-in-the-swan-and-notikewin-river-basins-of-nw-alberta-resolution-at-the-watershed-scale-2004.pdf.
Teichreb C. and Walker G, 2008. Aerial Videograhic Health and Integrity Assessment of the Riparian Management Area for Selected Reaches of the Battle River. Alberta Environnent Technical Report. Available: https://www.battleriverwatershed.ca/sites/default/files/2007_Battle_River_H_and_I_Final_Report_George_24_Mar_08.pdf.