Modeste Watershed Riparian Area Assessment

FINAL REPORT

Project 1652
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Prepared for:

NSWA
NORTH SASKATCHEWAN WATERSHED ALLIANCE

Prepared by:

FIERA
Biological Consulting

Front Cover Photo:
Aerial view of a riparian area in the North Saskatchewan River basin, captured from a unmanned aerial vehicle. Credit: Fiera Biological Consulting Ltd.

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Government of Alberta
Clearwater County
County of Wetaskiwin
Parkland County
Leduc County
Brazeau County

Executive Summary

Riparian lands have substantial ecological, economic, and social value, and as such, the North Saskatchewan Watershed Alliance (NSWA) has recognized that the effective management of these habitats is a critical component to the maintenance of watershed health. However, because previous efforts to survey and assess riparian areas have been focused on small-to-medium scales, the extent and condition of the majority of riparian areas in the province is largely unknown. As a result, there is a need for the development and use of automated or semi-automated methods that utilize spatial data and spatial data technologies that can define and assess riparian areas across large scales and in a repeatable and objective way.

The North Saskatchewan Watershed Alliance has recognized the importance of developing a geospatial method to assess riparian areas at large spatial extents, and as such, commissioned Fiera Biological Consulting to develop a remote sensing and GIS approach for inventorying and assessing riparian areas along shorelines in the Modeste watershed. This approach was largely based upon existing videography methods and metrics, and the GIS method was validated against videography results for a selected number of stream and lake shorelines in the Modeste watershed. Following the videography approach, “riparian management areas” (RMAs) were created and used as the unit of analysis for assessing riparian condition. RMAs are defined as an area along the shoreline of a waterbody that includes the near-shore emergent vegetation zone, the riparian zone, and a riparian protective (buffer) zone. For the purpose of this study, RMAs had a fixed width of 50 m and a variable length that was determined based upon major breaks in the amount of natural vegetation cover along the shoreline, and RMAs were created for both the left and right banks of watercourses included in this study.

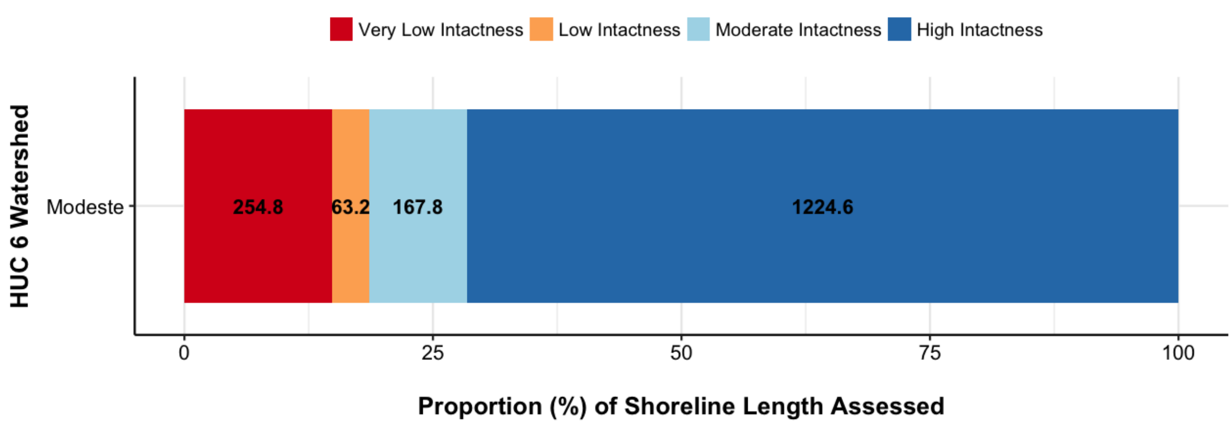
For each metric in the videography method, we developed a comparable GIS metric, and statistically assessed the performance of each GIS metric against the videography validation data to select the best performing GIS metrics. The GIS method includes a total of three metrics: 1) Proportion of cover by land cover classes containing natural vegetation; 2) Proportion of cover by land cover classes containing woody vegetation (e.g. forest, swamp, bog), and 3) Proportion of cover by land cover classes containing human footprint. Each metric was quantified within each RMA using an up to date, high resolution (6 m) land cover derived from SPOT satellite imagery, and the scores for each metric were aggregated into a single value that was then assigned to a condition class. Overall, there was an agreement of 76% between the GIS and videography scores, with the highest agreement in areas of natural cover and lower agreement in areas with a mix of natural and agricultural cover. In order to differentiate the GIS method from the existing videography method, we created “riparian intactness” classes, rather than “riparian condition” classes; however, given the statistical relationship between the GIS and the videography methods, riparian intactness is analogous to riparian condition.

A benefit of employing a geospatial approach to assessing riparian areas is that factors or pressures at larger spatial extents that may affect riparian area function, such as land use, can also be quantified.

Thus, in an effort to identify riparian areas that may be under stress or face impairment of function due to the landscape composition of the uplands that are hydrologically connected through surface flows, we assessed a variety of natural and anthropogenic pressures within local catchment areas adjacent to each water body. Consequently, each RMA was assigned an intactness score and a pressure score, which were combined to develop a prioritization matrix that allowed for the assignment of conservation or restoration priority to each RMA. This prioritization score allows land managers to more precisely target areas for conservation or restoration activities within the watershed. It also allows land managers to target areas where more detailed, site-specific field assessments of riparian condition may be required.

In total, 1,708 km of shoreline was assessed in the Modeste watershed. The results of this study were summarized at a number of spatial extents, including: the entire Modeste watershed; the four subwatersheds contained within the Modeste (Wabamun Creek, North Saskatchewan Above Wabamun, Bucklake Creek, and Wolf Creek); the five major rural municipalities within the Modeste (Brazeau County, Clearwater County, County of Wetaskiwin, Leduc County, and Parkland County); and each of the 25 individual water bodies included in the assessment.

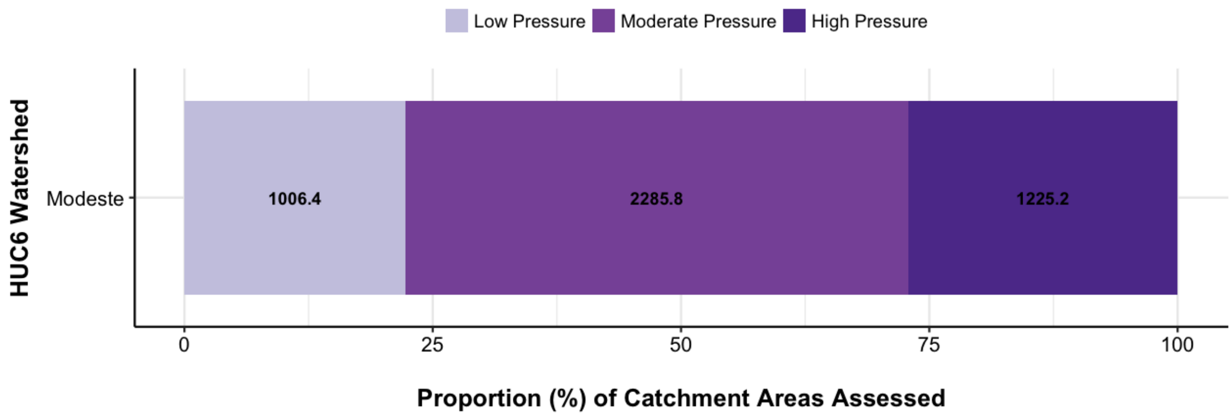
Overall, 72% of the shoreline within the Modeste watershed was classified as High Intactness. A further 10% of the shoreline was classified as Moderate Intactness, with 19% classified as either Very Low (15%) or Low (5%) Intactness. Areas of High Intactness were generally concentrated in the southern and western parts of the watershed, while areas of Low or Very Low Intactness were typically associated with agricultural land use, which is primarily located in the northwest and south eastern portions of the watershed.



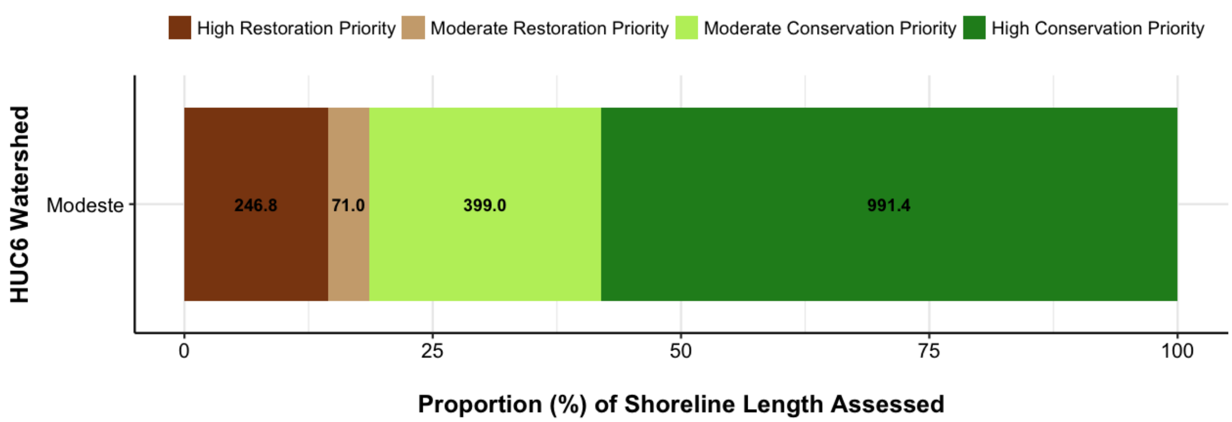
When intactness was summarised and compared for individual waterbodies, 12 out of 25 (48%) had ≥75% of their shorelines characterized as High Intactness. When the Moderate and High Intactness categories were combined, 18 of the 25 (72%) waterbodies had ≥75% of their shorelines classified into one of these two categories. In contrast, 28% of the waterbodies had ≥25% classified as either Low or Very Low Intactness, and the majority of these low condition shorelines were located in the North Saskatchewan Above Wabamun subwatershed.

When intactness was summarized by municipality, the largest proportion of shoreline classified as High Intactness was located in Brazeau County (28%), followed by County of Wetaskiwin (18%) and Clearwater County (13%). Conversely, Parkland County had the largest proportion riparian areas within the Modeste Watershed classified as Very Low (6%), followed closely by County of Wetaskiwin (5%).

Pressure on riparian system function was assessed for 811 local catchment areas, covering an area of nearly 5,500 km². Of that area, 27% was classified as High Pressure, with the majority (50%) of local catchments in the Modeste watershed being classified as Moderate Pressure, and the remaining 22% being classified as Low Pressure. When pressure scores were examined for municipalities, the counties of Leduc, Parkland, and Brazeau all had >25% of local catchments classified as High Pressure. When Moderate and High Pressure categories are considered together, the counties of Brazeau, Wetaskiwin, Leduc and Parkland all had >75% of local catchments within their municipality classified into one of these two categories. Clearwater County had nearly 70% of local catchments classified as Low Pressure, with Brazeau County having the second highest proportion (18%) of Low Pressure catchments.



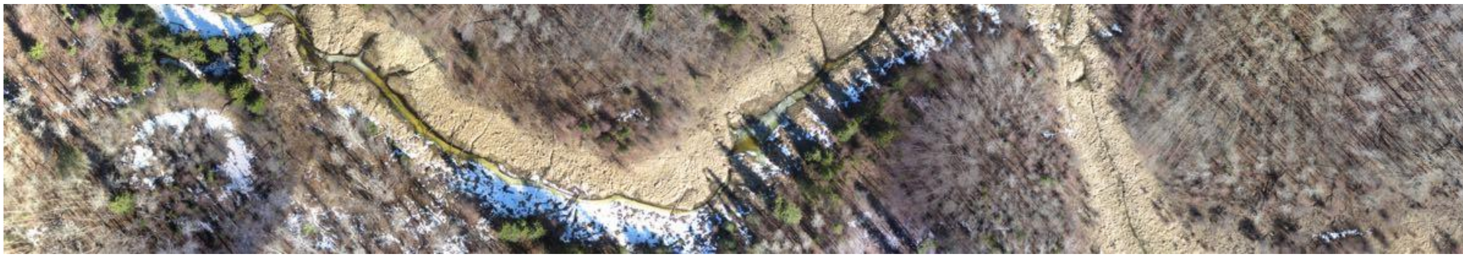
When intactness and pressure scores were combined, 81% of the shoreline in the Modeste watershed was classified as either High Conservation (58%) or Moderate Conservation (23%) Priority, representing approximately 1,390 km of shoreline. Conversely, 18% of the shoreline was classified as either High Restoration (14%) or Moderate Restoration (4%) Priority, representing approximately 318 km of shoreline.



For all subwatersheds within the Modeste, >50% of the shoreline was categorized as either High or Moderate Conservation Priority, with Wolf Creek subwatershed having >95% of its shoreline identified as priority for conservation. Conversely, the North Saskatchewan Above Wabamun subwatershed had the highest proportion of shoreline identified as priority for restoration, with 23% being identified as High

Restoration Priority and 7% being identified as Moderate Restoration Priority. For 12 of the 18 major waterbodies assessed in the watershed, >50% of the shoreline was classified as High Conservation Priority, with 11 of the 18 waterbodies having >75% of the shoreline classified as either High or Moderate Conservation Priority. In contrast, 7 of the 18 (39%) major waterbodies had >25% of their shorelines identified as either High or Moderate Restoration Priority.

This project has resulted in the collection and generation of scientific information that can be used as the basis for the development and implementation of an evidence-based adaptive management framework. Through the commissioning of this study, the NSWA and its stakeholders now have an important foundation of scientific evidence upon which to build a systematic and adaptive framework for riparian habitat management in the Modeste watershed. The next step in the advancement of meaningful riparian management and conservation in the watershed will be to formalize a framework for action that includes a consideration of the current conditions (baseline) and defining achievable outcomes and measurable targets, which can then be used to inform relevant collective action by key stakeholders. These actions can then be monitored on a regular basis to provide an evaluation of outcomes that feed into an adaptive and reflexive approach to riparian management through time.



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

BMP: Best Management Practice

DEM: Digital Elevation Model

GIS: Geographic Information System

HUC: Hydrologic Unit Code

NSWA: North Saskatchewan Watershed Alliance

RMA: Riparian management area

Glossary

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

Catchment: Small local drainage areas ranging in size from 0.03-35 km^2 and with a contributing area of ~2 km^2 that were specifically derived as part of this study to assess pressure on riparian system function. Catchments were derived from a 15-meter LiDAR DEM using Arc Hydro Tools.

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) represents a collection of four 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, and HUC 8, with HUC 2 being the coarsest level of classification and HUC 8 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.

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.

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 in a largely modified or disturbed state, they should be targets of restoration to improve their current state of function and ecological value.

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 ground. These lands are influenced by and/or exert an influence on associated water bodies, 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: 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.

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, such as the North Saskatchewan River watershed) to very small local watersheds (e.g., square metres, such as a small prairie wetland).

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1.0 Introduction

Riparian areas are highly complex and dynamic “transitional habitats” that are found along the edge of water bodies, 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. 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 that are of comparable size.

From the perspective of human communities, riparian areas provide a multitude of beneficial ecosystem functions and services, including water quality improvement, sediment removal, nutrient cycling, bank stabilization, and flood reduction. However, the loss and impairment of riparian lands in Alberta over the last century has been significant, and thus, 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.

1.1. Assessing Condition of Riparian Areas

At present, there is no standardized province-wide mapping method for defining and delineating the extent of riparian areas for hydrologic features of all types and sizes. As a result, little is known about the location and extent of riparian lands in the province, making management of these habitats difficult. In addition, only a small percentage of riparian areas in Alberta have been assessed to determine their condition, and the majority of these assessments have been conducted at a site-specific or reach-scale using either ground-based or airborne videography methods.

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) Riparian Health Assessment, detailed and local-scale traits of riparian areas are evaluated by trained practitioners, and a comprehensive and thorough judgement of riparian condition is made. The metrics used in these assessments 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. The level of site-specific detail offered by this approach cannot be matched, and field assessments can be very useful for identifying and addressing issues that occur along relatively small reaches; however, these same assessments are limited in their ability to provide information for planning and management at municipal, regional, or larger scales.

As an alternative to the highly detailed information required and the substantial time and cost investment associated with field assessments, approaches using recorded video have been applied to assess riparian areas across larger extents. Aerial videography is a tool for assessing riparian habitat with which 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 the video images that have been acquired at altitudes of 60 m or less from an oblique angle. 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 assigns a score to a series of questions regarding different functional attributes of the riparian lands in question, and converts the individual scores into a single aggregated score that is then assigned to one of three health categories akin to the field-based approach. Videography has been applied by various organizations across Alberta (e.g., Mills and Scrimgeour 2004, AENV 2010), as well as within the North Saskatchewan River Watershed (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, if required. The goal is to provide low cost information over large areas so that management at larger scales (i.e. entire lake or river system) can be directed by standardized measurements. To this end, videography can be very cost-effective per kilometer of shoreline observed; however, at a certain scale, the size of the study area and the size of the river (i.e. river width and its associated riparian zone) make assessments by videography cost prohibitive.

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. 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). As a result, a new method for assessing riparian habitats at large spatial extents that is transparent, repeatable, and objective is needed in Alberta.

In response to this need, the North Saskatchewan Watershed Alliance engaged Fiera Biological to develop a new Geographic Information System (GIS) method for assessing riparian areas over large geographic extents. This methods was developed using metrics comparable to existing ground-based and aerial videography methods, and the results were validated against aerial videography data obtained within the Modeste watershed. This new riparian assessment method uses automated and semi-automated GIS techniques to quantify the condition of riparian management areas and pressure on riparian system function using freely availability or low cost spatial data. As such, this GIS method allows for the assessment of riparian condition over large spatial extents, and also introduces a more objective and comparable method to assess difference in riparian condition across space and time.

1.2. Study Objectives

The overall goal of this project was to develop GIS and remote sensing-based methods for undertaking a rapid, repeatable, and large-scale assessment of riparian condition using data that is freely available to the North Saskatchewan Watershed Alliance (NSWA) and other Watershed Planning and Advisory Councils in Alberta. In order to achieve this goal, we identified the following primary objectives for this study:

1) Assess the condition of riparian management areas in a GIS environment using metrics that are comparable to and validated against existing aerial videography methods. In order to differentiate the GIS method from the existing videography method, we created "riparian intactness" classes, rather than "riparian condition" classes; however, given the statistical relationship between the GIS and the videography methods, riparian intactness is analogous to riparian condition.

    The relationship between an intact riparian zone and the integrity of the aquatic environment is well established (Pusey and Arthington 2003). 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). Given the significant role that an intact riparian zone has on healthy aquatic ecosystems, there is a need to manage riparian areas effectively. Understanding the distribution of intact riparian areas across the landscape and identifying areas where riparian intactness has been degraded can provide land managers and conservation agencies critical information as to where resources are needed to restore or conserve riparian zones within the Modeste watershed.

2) Quantify both natural and anthropogenic pressures that exist upslope of riparian areas to generally assess pressures that may result in impairment of riparian system function.

    While the assessment of a riparian area itself provides information about the level of existing impacts, the type of land use and land cover adjacent to riparian areas, as well as the topography of the local catchment area, may mediate or contribute stress externally and affect the function of riparian habitats. The purpose of this pressure assessment is to characterise relative pressure at the local catchment scale, in an effort to identify riparian areas that may be under stress or face impairment of function due to the landscape composition of the uplands that are hydrologically associated with each riparian management area.

3) Provide guidance on how the results from the intactness and pressure assessments can be used in combination to prioritize conservation and restoration efforts within the watershed.

    Automated GIS approaches to assessing riparian condition are not meant to replace finer-scale field-based methods, nor are automated approaches able to replicate certain field-specific metrics, such as the presence or abundance of weedy species. Rather, GIS tools allow managers and stakeholders to more broadly determine where problems may exist, and where more detailed assessments may be required. This allows for spatial targeting and prioritization of areas where resources can be directed, thereby maximizing the benefits of riparian conservation, restoration, and management efforts.

This new and innovative approach to assessing riparian condition will provide stakeholders with an overview of the status of riparian habitat in the Modeste watershed, which will allow organizations to focus restoration, management efforts, and resources in areas of greatest need. Further, this approach can be adapted and applied in other watersheds throughout the province, thereby allowing for a standardization of the methods used to conduct large-scale riparian assessments in Alberta.

1.3. Purpose & Intended Use of this Data

While considerable effort has been made to highlight the importance of restoring riparian areas within Alberta, tools for accurately identifying and characterizing these areas over large spatial extents are lacking. Thus, the overarching objective of this project was to develop tools applicable at large scales that efficiently and consistently characterize the relative intactness of, and pressure on, riparian areas for the purpose of guiding future watershed management and conservation initiatives.

This assessment synthesizes disparate data types from various sources to generally characterize the current condition of riparian management areas within the Modeste watershed, and this report presents the methods, results, and applications of our analyses. Readers are asked to consider the following points regarding the scope of our assessments as they review the methods and interpret results:

- Assessments characterize relative intactness or pressure using collections of indicators and associated metrics that focus on natural attributes of a riparian area that are measurable in a GIS environment. No statement on the absolute condition of any riparian area or catchment area is made and the results do not reflect the influence of factors that were not included in or considered for analysis.
- Intactness and pressure ratings generated by this study are intended to support a screening-level assessment of management and/or conservation priorities across broad geographic areas (e.g., HUC 8 subwatershed, municipality, stream reach). The tool assessments are not meant to replace more detailed, site-specific field assessments of riparian health or condition. Instead, intactness and pressure ratings should be used to highlight smaller, more localized areas where field assessments and further validation may be required.
- The provincial hydrography data for streams, creeks, rivers, and lakes was used to delineate the shoreline of the waterbodies included in this assessment. While we did a cursory assessment of the accuracy of this data and made adjustments to waterbody boundaries where serious errors were noted, these data were not systematically evaluated or manually corrected as part of this project. We acknowledge that there are likely to be areas within the watershed were these boundaries are not 100% accurate, and these spatial inaccuracies will influence the intactness scores; however, manually editing the provincial hydrography data for use in this study would have had serious implications for the timelines and budget of this project.
- For streams, creeks, and rivers the provincial hydrography data represents the approximate centreline of the watercourse. These centrelines were used to generate a left bank and right bank buffer for the watercourses included in this study. As a result, the near shore/emergent zone of the waterbodies was included in this assessment.

2.0 Study Area

The Modeste is a large (~4,736-km^2) HUC 6 watershed located in central Alberta with an extensive hydrological network that includes thousands of kilometers of river, stream, and lake shoreline. With its large size, the hydrological network flows through three Natural Regions: the Foothills, Boreal Forest, and Parkland (Figure 1). The watershed is composed of many smaller hydrologic units, of which we used the HUC 8 subwatershed boundaries to summarize and present the results of this study (Figure 2).

Land cover in the watershed includes a range of natural, semi-natural, and anthropogenic land cover types, with 58% of the watershed consisting of natural and semi-natural cover and 42% of the watershed classified as anthropogenic land cover. Agricultural pastureland and cropland dominate the northern and more central areas of the watershed, while in the southwest, natural forest cover remains intact to a greater degree. Land use in the watershed is similarly varied and includes a number of anthropogenic activities that have impacted riparian habitat condition over the last century, such as urban development, agriculture, mining, forestry, and oil and gas.

Five counties intersect the Modeste watershed (Figure 4), with each county having a unique land cover composition that reflects the ecological and economic conditions within the municipality. The highest proportion human land cover types (e.g., agriculture, urban, and barren) within the watershed are located in Wetaskiwin County (75%) and Leduc County (57%) (Figure 5). Natural land cover (e.g., forest, shrubland, water, and wetlands) in the watershed is highest in Clearwater County (97%) and Brazeau County (57%).

The areas that were assessed as part of this study included the left and right banks of major tributaries of the North Saskatchewan River and the shoreline of Buck Lake (Figure 1, Figure 2, and Table 1). These waterbodies were selected because the NSWA had airborne aerial videography data for these areas, which was collected in the summer of 2016. In total, approximately 871 kilometers of stream, creek, and lake shoreline was assessed as a part of this study (Table 1).

Table 1. Water bodies in the Modeste watershed that were assessed as part of this project.

Creek Name	**Length (km)**
Buck Lake	36.0
Buck Lake Creek	4.9
Bucklake Creek	80.7
Cranberry Creek	17.6
Horseshoe Creek	24.5
Mink Creek (Bucklake Watershed)	22.0
Mink Creek (Wabamun Creek Watershed)	9.3
Mishow Creek	43.6
Modeste Creek	89.8
Muskrat Creek	11.9
Poplar Creek	52.5
Sand Creek	25.3
Shoal Lake Creek	31.7
Sun Creek	10.4
Tomahawk Creek	78.7
Unnamed Tributaries (various)	133.8
Wabamun Creek	32.9
Washout Creek	47.9
Wolf Creek	117.9
TOTAL	**871.4**

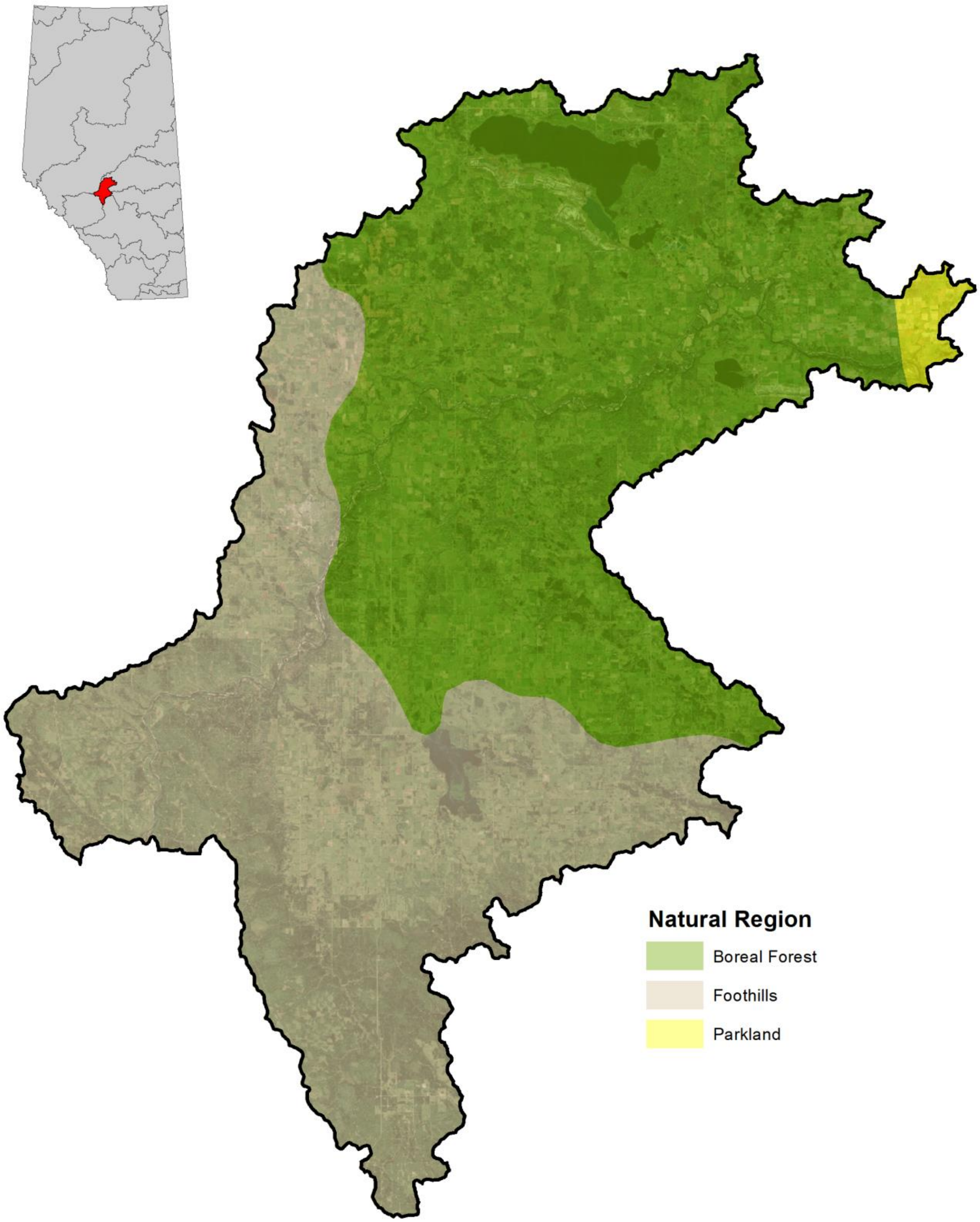


Figure 1. The Modeste watershed in central Alberta includes areas that fall within the Boreal Forest, Foothills and Parkland Natural Regions.

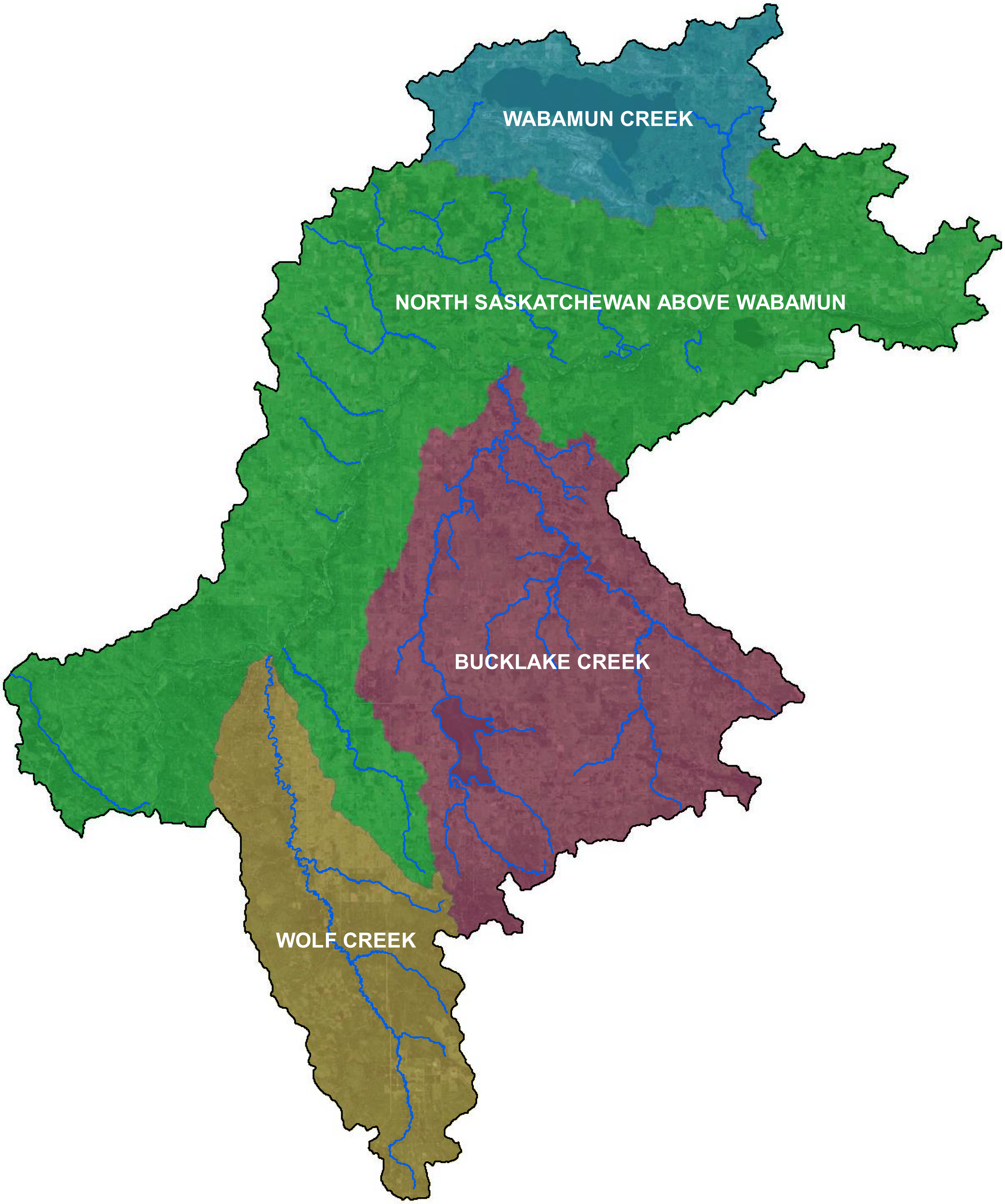


Figure 2. Location and name of each HUC 8 subwatershed located within the Modeste watershed, as well as the waterbodies that were included in the riparian assessment.

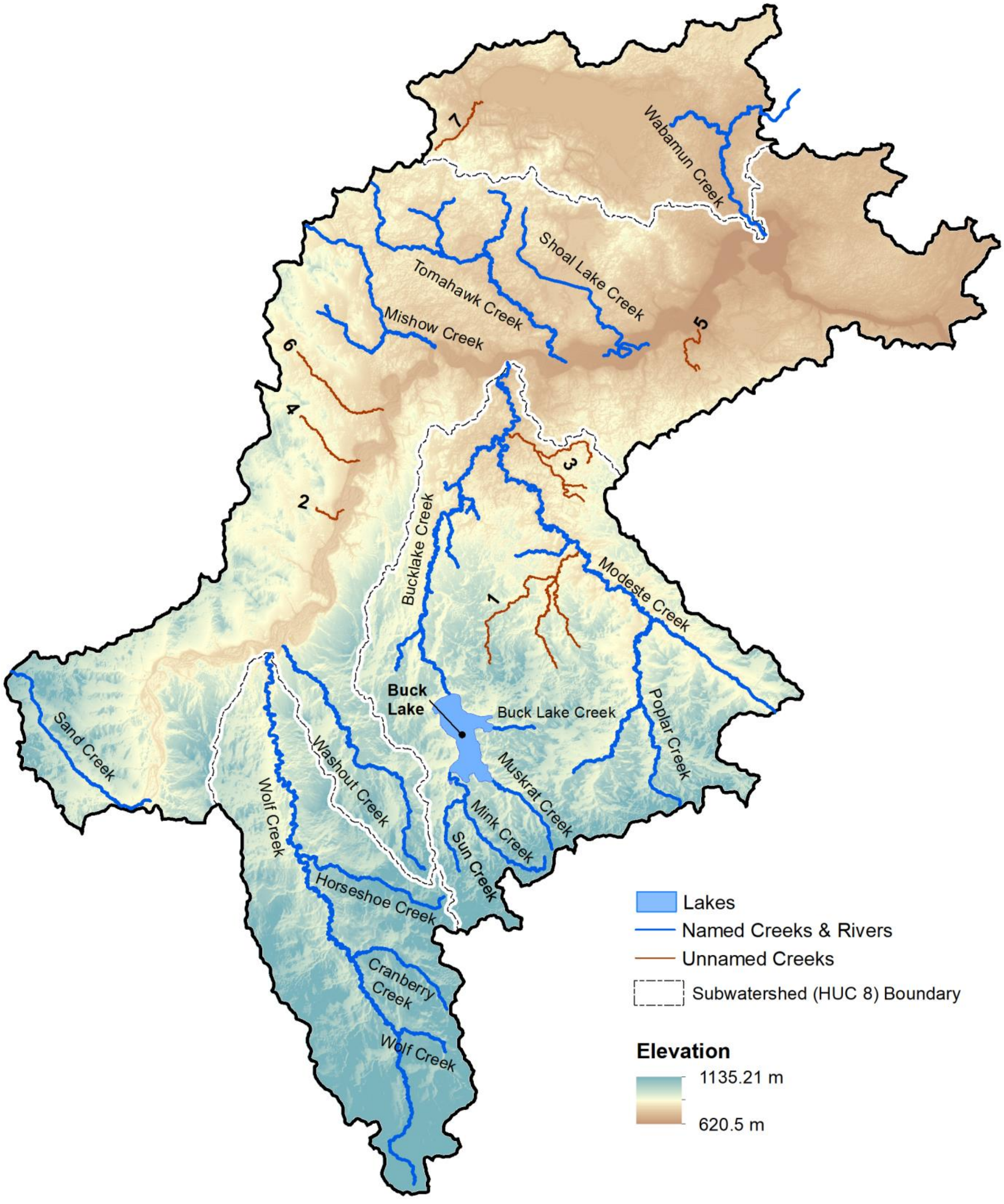


Figure 3. Location and name of waterbody included in this study. Additional maps showing the location of waterbodies are provided in Sections 4 through 8.

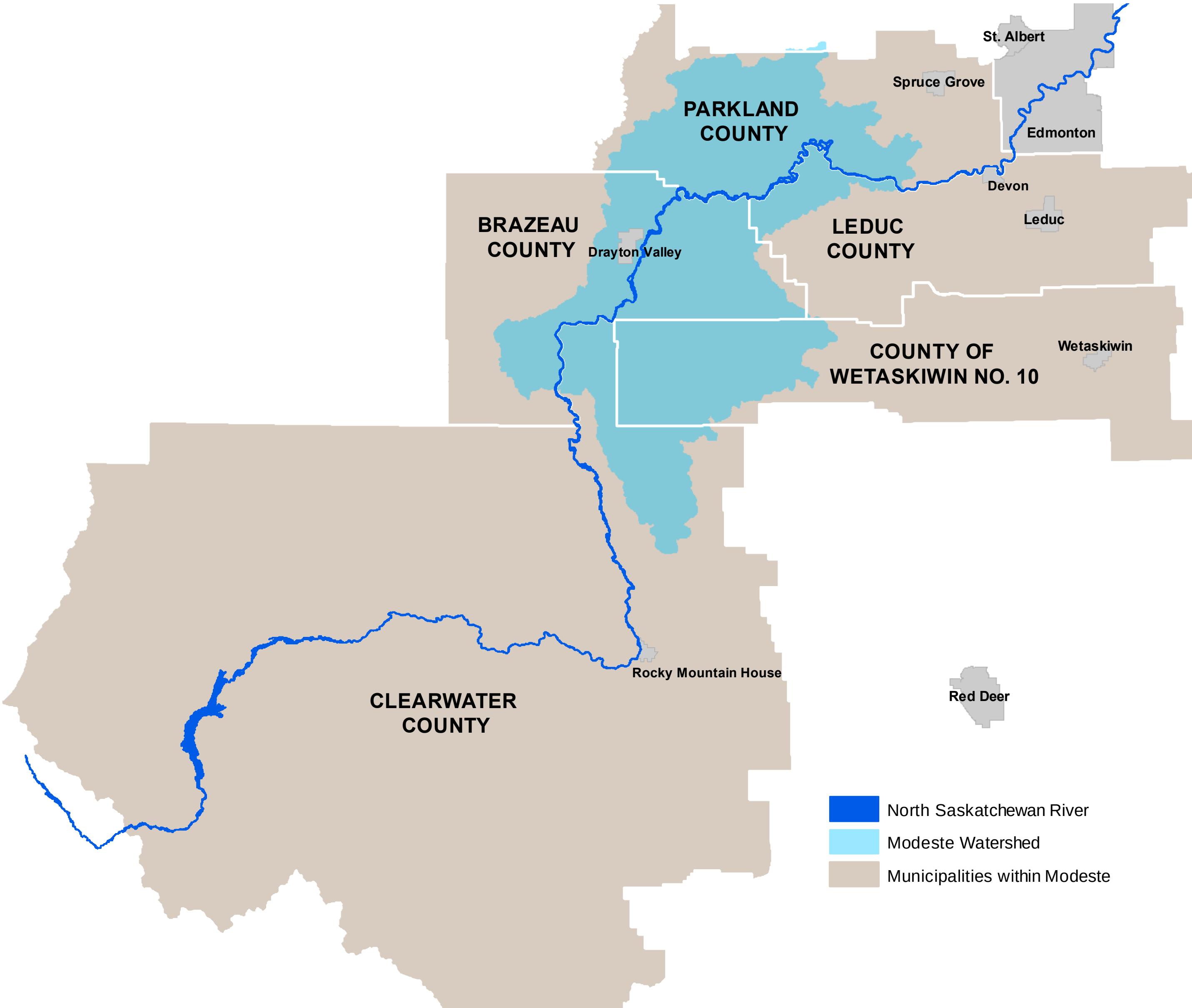


Figure 4. Major municipalities that fall within the Modeste watershed.

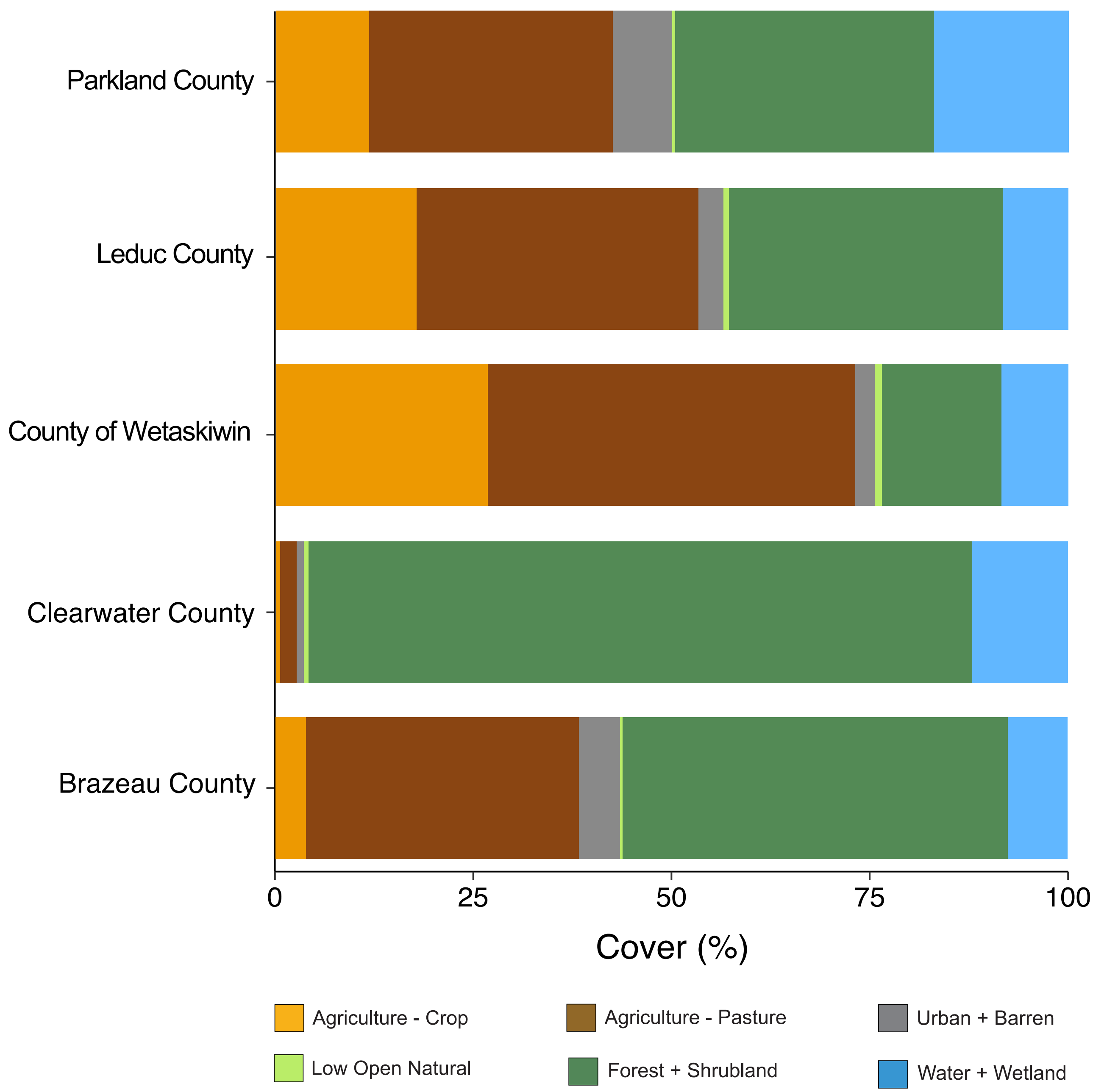


Figure 5. The proportion of different land cover types within the Modeste watershed, summarized by County.

3.0 Methods

3.1. Riparian Intactness Metrics & Data Sources

Indicator Selection

A key objective of this study was to develop a GIS based model that could reliably and objectively assess riparian condition, while at the same time being comparable to previously developed and accepted methodologies. As such, GIS indicator selection was focused on determining which aerial videography indicators could be measured in a GIS environment, and selecting appropriate metrics for quantifying those indicators.

Aerial videography indicators for assessing riparian condition were reviewed, and where possible, analogous GIS indicators and metrics were developed (Table 2). Of the videography metrics that are used to assess riparian condition, only one metric was not replicable in a GIS environment. This metric asked the interpreter to subjectively decide whether the stream reach looked more like a picture of an intact (presumably healthy) riparian zone, or a riparian zone where vegetation had been removed. In total, we developed and tested eight GIS metrics to determine which of these metrics had the strongest statistical relationship to the videography validation dataset. The objective of the method development was to replicate the existing videography method to the greatest extent possible, and to select GIS metrics with the strongest statistical relationship to the videography validation dataset. However, in order to differentiate the GIS method from the existing videography method, we have adopted the term “riparian intactness”, rather than “riparian condition” to describe the resulting scores from this assessment. Despite the difference in language, we consider condition and intactness to be analogous.

Acquisition and Derivation of Required Data

To quantify riparian intactness within a GIS environment, several data layers were required, including a moderate-resolution (15-meter) digital elevation model (DEM), a current land cover layer, and a current human footprint layer. A list of spatial data obtained or derived to quantify riparian intactness is presented in Table 3.

While a freely available and current land cover layer was available for use in this study, we were concerned that the resolution of this data (30 m pixel size) would not be sufficient for assessing vegetation cover within riparian areas. In order to compare model outputs produced using a coarse land cover (30 m), versus outputs produced using a higher resolution land cover, we created a 6 m pixel resolution land cover using SPOT 6 satellite imagery that was obtained by the NSWA free of charge from the Government of Alberta.

The high-resolution land cover classification was created within a 1.5-kilometer buffer on each side of the selected waterbodies. Satellite imagery was calibrated to top of atmosphere reflectance, atmospherically corrected, cloud masked, mosaicked, and used in an unsupervised ISODATA classification with 50 classes. Following the unsupervised classification, class labels were manually assigned and aggregated into six classes: Forest; Bog/Fen; Agriculture Pasture/Disturbed Vegetation; Agriculture Crop; Disturbed/Bare Ground; Water.

Table 2. List of metrics that are used in the videography method to assess riparian condition, and the list of associated GIS metrics that were selected and tested for the development of the GIS model.

<table>
<tr><th>Videography Metric to Assess
“Riparian Condition”</th><th>GIS Metric Tested to Assess
“Riparian Intactness”</th></tr>
<tr><td>1. What percent of the riparian management area is covered with vegetation of any kind?</td><td>1. Proportional cover of all natural vegetation land cover classes</td></tr>
<tr><td>2. What percent of the riparian management area is covered by woody plants like willow, birch, poplars or conifers?</td><td rowspan="2">2. Proportional cover of land cover classes containing woody vegetation (e.g. forest, swamp, bog)
3. Is a “woody” land cover class present: binary classification of “yes” or “no”</td></tr>
<tr><td>3. Is there observable evidence of woody species recruitment and replacement in the riparian management area?</td></tr>
<tr><td>4. What percent of the riparian management area shows visual signs of human/cattle-caused alteration of the vegetation community?</td><td rowspan="2">4. Proportional cover of land cover classes associated with agricultural activities (e.g. crops and pasture)
5. Proportional cover of all land cover classes associated with human activities
6. Proportional cover of bare ground land cover class</td></tr>
<tr><td>5. What percent of the riparian management area shows signs of human/cattle caused bare ground and physical alteration?</td></tr>
<tr><td>6. How would you characterize the overall vertical stability within the riparian management area?</td><td>7. Quantification of the degree to which the channel meanders (channel sinuosity) as a proxy for assessing the erosional regime of the stream
8. Assessment of bank stability using a combination of slope and surficial geology</td></tr>
<tr><td>7. What picture does most of the polygon look like?</td><td>No equivalent GIS metric</td></tr>
</table>

Table 3. Description of the spatial data obtained or derived for use in the assessment of riparian management area intactness.

Data Layer	Year	Source
15 m Digital Elevation Model (DEM)	2010-2016	Government of Alberta (mosaic of numerous acquired tiles)
30 m Land Cover	2015	Agriculture and Agri-Food Canada
6 m Land Cover	2015	Fiera Biological. Layer was created using SPOT 6 satellite data provided by the Government of Alberta
Human Footprint	2014	Alberta Biodiversity Monitoring Institute
Slope	N/A	Fiera Biological, derived from Government of Alberta 15m DEM mosaic

The manual review of the land cover revealed instances where low natural cover adjacent to water bodies was being classified as Agriculture Pasture due to the spectral similarities of natural and agricultural low cover. As such, areas of Agriculture Pasture were reclassified into a new "Natural Open" category if: 1) the pixel/polygon was greater than 100 meters away from pasture, as identified by the AAFC land cover classification, and 2) the pixel/polygon was located outside of an area identified as human disturbance in the ABMI Human Footprint data. Given the importance of accurately differentiating natural low vegetation from pasture lands, we also did a comprehensive manual inspection of the land cover against high-resolution air photo orthoimages acquired from each county, and any areas that were classified as "Agriculture Pasture/Disturbed Vegetation" that appeared to be natural low cover were manually reclassified as "Natural Open". Because the area of interest for assessment was within 50m of the assessed streams, the comprehensive inspection was limited to areas close to streams (approximately within 200m). Therefore, areas further away from the streams in the land cover classification are likely over-classifying Agriculture Pasture/Disturbed Vegetation.

The final land cover classes contained within the high-resolution land cover layer included:

- Forest
- Bog/Fen
- Agriculture Pasture/Disturbed Vegetation
- Agriculture Crop
- Disturbed/Bare Ground
- Natural Exposed
- Natural Open
- Water
- Unclassified

3.2. Riparian Intactness Methodology

Delineating Riparian Management Area Width

In order to create a GIS model that would yield results comparable to the aerial videography methods, it was necessary to first define and delineate a comparable unit of analysis. As per the methods outlined in Teichreb and Walker (2008), and for the purpose of this report, 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 the near-shore emergent vegetation zone, the riparian zone, and a riparian protective (buffer) zone (Figure 6). The RMA is further described by Teichreb and Walker (2008, pg. 2) as follows:

> "… on riverine shorelines with steep banks, the riparian zone is usually very narrow providing little in the way of ecological services - but a reasonable width of healthy, adjacent buffer zone helps provide some of those essential services. Conversely, where the riparian zone is wide and in good condition, the buffer zone could be narrow or absent without serious loss of ecological services. It is essential that effective management/assessment practices include the riparian zone, the protective buffer zone and the emergent vegetation zone. The emergent vegetation zone is often not present on riverine shorelines … The actual width of the riparian management area used during assessment is a matter of reviewer judgement."

Given the inclusion of a "buffer" zone within the RMA, and the overall subjective nature of defining an RMA when conducting an aerial videography assessment, we created a number of RMA widths that were tested against the aerial videography results. The widths selected for evaluation were considered to be representative of the average widths of RMAs assessed using aerial videography methods given the limited field of view of the video. The three RMA widths selected for consideration in the intactness model included 25, 50, and 100 metres.

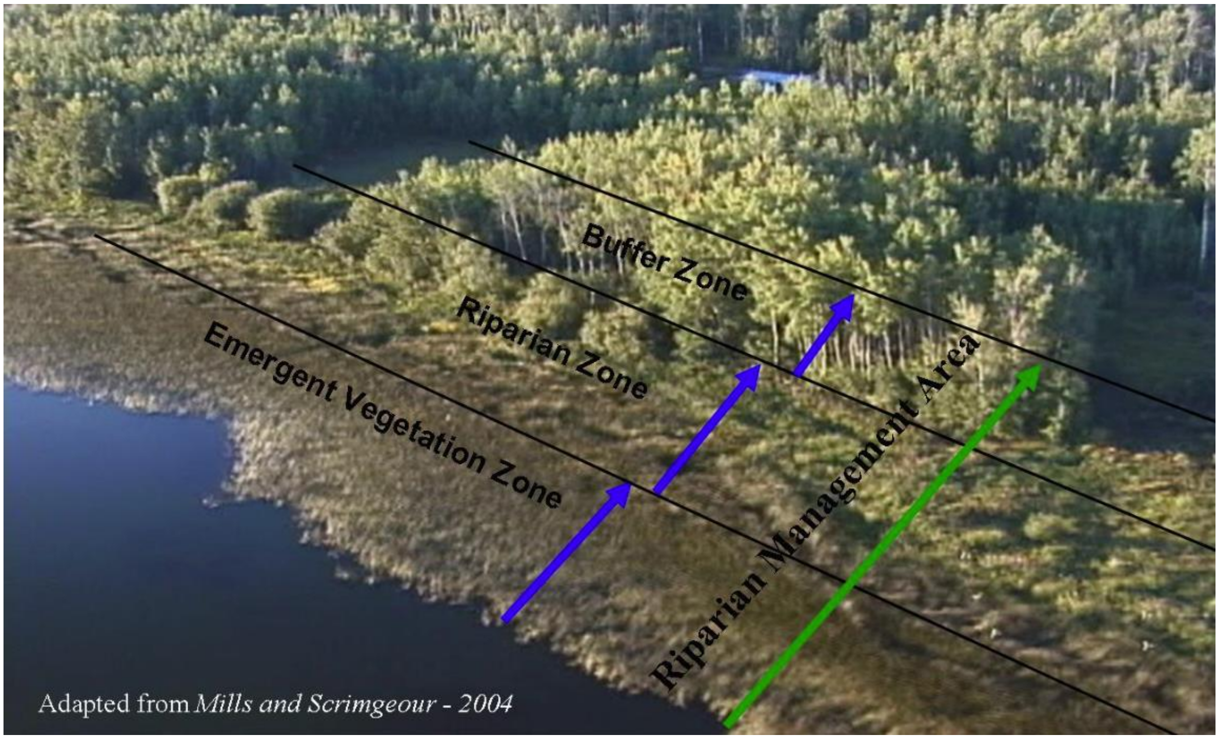


Figure 6. Schematic showing the different shoreline components included in a “riparian management area” (image taken from Teichreb and Walker 2008).

Delineating Riparian Management Area Length

When assessing riparian condition using aerial videography, a new riparian management area (RMA) is created where there is a change in the score of any single metric. In order to replicate this approach, we chose to delineate the upstream and downstream extents of each RMA based upon major changes in the proportion of natural cover along the shoreline.

To calculate the proportion of natural cover along the shorelines of interest, we first selected all natural cover classes from the high-resolution land cover layer (i.e., Forest, Water, Natural Exposed, Natural Open, Bog/Fen) and exported these cover classes 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. All segments were then defined as “intact” or “impacted” based on the proportion of natural cover within the 25 m window, using 55% natural cover as the threshold to differentiate between intact (≥55%) and impacted (<55%). 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. Stream segments of the same type (e.g., intact or impacted) that were directly adjacent to one another were grouped and dissolved into single part features. To eliminate very small RMAs (<20 m), we merged and dissolved short segments with their neighbouring segments.

The intact and impacted shoreline segments were then buffered by the selected widths (25, 50, and 100 meters, as described above) to create three different RMA datasets: RMA-25m, RMA-50m, and RMA-100m. Intactness was then quantified for each RMA dataset, and the results were compared against the videography results to identify the dataset that most closely matched the videography results.

Aerial Videography Assessment

An aerial videography flight in the Modeste watershed was commissioned by the NSWA between September 16 and 18, 2016. To assess the accuracy of the GIS riparian intactness model against an accepted riparian assessment technique, we performed an aerial videography assessment using the methodology developed by Teichreb and Walker (2008) on four validation areas. The four validation areas, which totalled approximately 175 km of shoreline, were selected to represent the range of conditions and land use types found within the Modeste, and included;

- Wolf Creek
- Sand Creek
- Buck Lake
- An Unnamed Creek in the Bucklake Creek watershed (Unnamed Creek 1)

For each of these selected areas, a riparian assessment was undertaken by a trained interpreter using the aerial videography score card (Teichreb and Walker 2008). To test the repeatability of the aerial videography results, Wolf Creek was assessed by two independent observers.

GIS Riparian Intactness Model Metric Quantification

A score for each of the eight GIS intactness metrics was calculated using ArcGIS 10.6 for each RMA dataset (RMA-25m; RMA-50m; RMA-100m). Additionally, metrics were quantified using the freely available 30 m resolution land cover layer. This was done to compare the results obtained using the freely available land cover data against the high-resolution land cover data. Once each metric had been quantified, they were scored in three ways:

1) Using the videography scoring method which binned raw values into categories of 1, 2 or 3;
2) Standardizing raw values to range between 0 and 100;
3) Binning raw values into five categories using statistical (Jenks) breaks.

The metric scores were then aggregated to produce a final riparian intactness model score. Metrics were aggregated in two ways: 1) using a straight average (equal weighting), and 2) weighting each metric to match the weighting of the aerial videography score card.

Once aggregated, riparian intactness scores were converted from raw scores (i.e., 1 to 100) to riparian categories (Healthy, Healthy with Problems, and Impaired). These categories were assigned in three ways: 1) using the same breaks as the aerial videography score card, 2) statistically using percentile breaks, and 3) statistically using a Jenks classification.

Model Evaluation, Refinement & Selection

The different model scoring permutations resulted in a total of 108 riparian intactness models. Each of the 108 riparian intactness models developed using GIS was assessed against the aerial videography scores for each RMA, with the left bank and right bank scores being assessed separately. The total area of agreement between the aerial videography scores and GIS riparian intactness scores was calculated for each of the 108 models. Additionally, each raw indicator score was assessed for performance against the aerial videography for each RMA. Following this analysis, the following was determined:

1) The method developed to define RMA length was comparable to the videography method;
2) The RMA-50m dataset had the highest level of agreement with the videography results;
3) Scores obtained using the high-resolution land cover had better agreement with the videography scores than those derived using the freely available AAFC land cover layer;
4) Standardization of raw values to range between 0 and 100 resulted in scores that most closely matched the aerial videography scores.

Given that inclusion of redundant metrics typically reduces model performance, all metrics within the model were tested for redundancy using a correlation analysis. and highly correlated metrics (i.e., >0.60) were removed. Further, we found that scores from several of the GIS metrics were not correlated (e.g., <0.10) with the scores derived from the associated aerial videography metric, and thus, were considered poor metrics and were dropped from our model. A final model was created selecting only indicators that showed a strong correlation to the aerial videography scores and were not redundant with other metrics.

Final Riparian Intactness Model

The final model for quantifying riparian management area intactness scores consisted of the following three 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 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: Bog/Fen, Forest, Natural Exposed, Natural Open, Open Water. Natural Exposed and Open Water categories were included within the metric in this assessment due to the high likelihood of mixed pixels and the possible inclusion of vegetation within these pixels.

To quantify Metric 2, land cover classes that were composed of a large proportion of woody vegetation (e.g., trees or shrubs) were selected, which included Forest.

For Metric 3, all land cover classes associated with human development were selected, and the percent cover of the combined classes was quantified within each RMA. The land cover classes quantified for this metric included: Agriculture Crops, Agriculture Pasture/Disturbed Vegetation, and Disturbed/Bare Ground.

The final metrics were quantified for each RMA using the high-resolution land cover layer, and the scores were aggregated using weighted values comparable those used in the aerial videography methods, as follows: Metric 1: 0.15; Metric 2: 0.25; Metric 3: 0.60.

Riparian Intactness Scoring

Each of the final three metrics were quantified for all selected waterbodies in the Modeste watershed, and a final riparian intactness score that ranged between 0 and 100 was calculated as the weighted sum of the three riparian intactness metrics. These intactness scores were then used to assign each RMA to an intactness category.

Riparian management area intactness scores (0-100) were then converted into intactness categories using percentile breaks, as follows:

- 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 (0-50): 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.

GIS Model Agreement with Videography Data

The GIS scores from the final model and the videography were compared to assess the agreement between the two approaches. Videography scores obtained from along portions of the shorelines of Sand Creek, Wolf Creek, Unnamed Creek 1, and Buck Lake were compiled in a GIS, and the intersection between the videography scores and the GIS scores for each RMA along the left and right bank of each shoreline was determined. The agreement between methods was then calculated by summing the total length assessed within each categorical combination of scores (e.g., Good-Good, Good-Fair, Good-Poor, Fair-Good, Fair-Fair, etc.) and the totals were tabulated in a confusion matrix that compares the proportion of the total length assessed for each categorical combination.

In total, scores along 174.5 km of shoreline were compared to assess the agreement between the GIS and videography methods. The overall agreement between the GIS and videography scores was 76% (Table 4), with large classification errors (where there is confusion between the Good and Poor categories) occurring for only 2% of the areas that were assessed using both methods. Overall, the disagreement occurred between the two approaches primarily in the Good and Fair categories.
More detailed performance comparisons between the two methods for each of the four waterbodies evaluated are provided below.

Table 4. Comparison of agreement between scores derived with the GIS method and the videography method for different waterbodies located in the Modeste watershed. Values in the table are the proportion of the shoreline that was classified in each category by the two methods. For example, 59% of the shoreline length assessed was classified as Good using the GIS method and as Good by the videography method. The overall agreement is determined by summing the Good-Good, Fair-Fair, and Poor-Poor percentages (e.g., 59% + 9% + 7% = 76%)

Videography Score	**GIS Score**		
	Good	Fair	Poor
Good	**59%**	6%	0.3%
Fair	7%	**9%**	2%
Poor	2%	7%	**7%**

Sand Creek

Sand Creek is in a predominately natural area of high forest cover at the western edge of the Modeste watershed. A total of 50.4 km of shoreline was assessed along Sand Creek and the overall agreement between the GIS and videography scores was 98% (Table 5).

Table 5. Comparison of agreement between scores derived with the GIS method and the videography method for Sand Creek. Values in the table are the proportion of the shoreline that was classified in each category by the two methods. For example, 98% of the shoreline length along Sand Creek was assessed as Good using the GIS method and as Good by the videography method.

Videography Score	**GIS Score**		
	Good	Fair	Poor
Good	**98%**	0.9%	0.3%
Fair	>0.1%	**0%**	>0.1%
Poor	0.3%	0%	**0.5%**

Wolf Creek

Wolf Creek is a main tributary of the North Saskatchewan River, located in the southern portion of the Modeste watershed within a landscape that is a mix of natural forest cover, natural open bog/fen areas, cleared areas for pasture, and areas impacted by resource extraction activities (e.g., well pads, seismic lines). A total of 71.6 km shoreline was assessed for agreement along Wolf Creek, with an overall agreement between the GIS and videography scores of 71% (Table 6). The highest level of agreement between the two methods was within the Good category (GIS: 68%; Videography: 62%), and the GIS tool classified more riparian area as Fair (26%), as compared to the videography tool (23%). The primary area of disagreement was in the Poor category, with the videography classifying more than twice as much area as Poor, compared to the GIS tool (15% versus 6%). A visual assessment of the locations where there was disagreement in scores between the two methods revealed that most of the disagreement could be attributed to confusion between natural open and pasture, and cases in which the videography method appears to be underestimating scores along shorelines that are dominated by natural open cover where there is little or no cover by woody vegetation.

Table 6. Comparison of agreement between scores derived with the GIS method and the videography method for Wolf Creek. Values in the table are the proportion of the shoreline that was classified in each category by the two methods.

Videography Score	**GIS Score**		
	Good	Fair	Poor
Good	**55%**	7%	0.4%
Fair	11%	**11%**	1%
Poor	2%	8%	**5%**

Unnamed Creek 1

Unnamed Creek lies within the agriculturally developed central region of the Modeste and is a tributary of Modeste Creek. A total of 55.6 km of shoreline along this creek was assessed with both methods, with an overall agreement of 56% (Table 7). The primary source of disagreement between the two methods was in the Fair category, where the GIS tool classified 50% of the shoreline as Fair, as compared to the videography method, which classified 35% of the shoreline as Fair. Visual assessment of locations of disagreement along this creek indicated that the differences in scores were being driven by differences in the classification of areas as either natural open cover with no impacts, versus open areas with grazing impacts. Additionally, areas of natural open cover where there is little woody cover (e.g., littoral wetland areas) were being scored lower by the videography method due to a heavy weighting on woody cover in the videography score card. Importantly, large classification errors (where there is confusion between Good and Poor categories) only occurred for 2% of the shoreline.

Table 7. Comparison of agreement between scores derived with the GIS method and the videography method for Unnamed Creek 1. Values in the table are the proportion of the shoreline that was classified in each category by the two methods.

Videography Score	**GIS Score**		
	Good	Fair	Poor
Good	**14%**	13%	>0.1%
Fair	9%	**22%**	5%
Poor	2%	16%	**20%**

Buck Lake

Buck Lake lies within the central region of the Modeste and has a mix of developed and natural shoreline. A total of 16 km of the shoreline was assessed, with 73% overall agreement between the two methods (Table 8). The main source of disagreement was in locations were the GIS tool assigned a score of Poor, but the videography assigned a score of Fair. Overall, the videography assigned a much greater proportion of the shoreline to the Fair category (18%), as compared to the GIS method (7%), with the GIS method assigning more area to the Poor category (24%) than the videography method (20%). A visual assessment of the locations where there was disagreement in scores between the methods showed that the primary disagreement occurred in areas of open natural cover and areas of disturbed vegetation.

Table 8. Comparison of agreement between scores derived with the GIS method and the videography method for Buck Lake. Values in the table are the proportion of the shoreline that was classified in each category by the two methods.

Videography Score	**GIS Score**		
	Good	Fair	Poor
Good	**56%**	3%	1%
Fair	7%	**3%**	9%
Poor	6%	0.6%	**13%**

Comparison Of Videography Scores

In order to compare the repeatability of the videography scores, we assessed the right bank of Wolf Creek with two independent observers who both received videography training from George Walker. The spatial agreement between the start and end of each riparian management area derived by the different observers was low, which is important given that the RMA is the spatial unit of analysis for the condition assessment. Overall, the agreement between observers was 72%, with the greatest area of disagreement being in the Good and Fair categories (Table 9).

Table 9. Comparison of agreement between videography scores for the right bank of Wolf Creek derived by two independent observers.

Observer 1	**Observer 2**		
	Good	Fair	Poor
Good	**49%**	8%	1%
Fair	13%	**11%**	4%
Poor	0%	3%	**12%**

3.3. Catchment Pressure Data and Metrics

Unit of Analysis

Variables that exert pressure on riparian system function range spatially from large-scale (e.g., watershed) to site-specific. We conducted the pressure analysis at a “local catchment” scale (described further below), 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.

Indicator Selection

Within the Modeste watershed, many potential stressors and pressures may affect watershed integrity. Pressures within the watershed can be thought to be comprised of two main sources; 1) human impacts, and 2) natural resiliency. We compiled a preliminary list of potential indicators for assessing pressure on riparian system function and presented this list to members of the Modeste Technical Advisory Committee for feedback and recommendations (Table 10). We then evaluated each of the candidate metrics against the following criteria: 1) The pressure was present within the Modeste watershed, 2) Data were available to assess the metric, and 3) Available data were of sufficient quality and accuracy to quantify the metric.

Table 10. List of stressor indicators that were evaluated during the development of the model for assessing pressure on riparian system function. This list of indicators was refined after consultation with the Modeste Technical Advisory Committee members, and after further examining the suitability of each indicators. The final eight stressor indicators that were selected for the model are identified in bold.

Natural Resilience	Human Impacts
Channel sinuosity	**Intensity of land use**
Wetland cover	**Density of stream crossings**
Forest cover	**Linear disturbance density**
Burned forest area	**Road density**
Landslide susceptibility	Loss of natural cover
Slope	Pollutant point sources

Following the evaluation of each indicator, we determined that there was an insufficient area of forest fire burns within the last 10 years to include burned forest areas as an indicator. Pollutant point sources was eliminated as a metric because the available dataset only included information on one industrial sector, and thus could not accurately quantify pressure from all possible pollutant sources. Channel sinuosity and loss of natural cover were removed from the analysis due to issues with data quality and data accuracy. Similarly, evaluation of the Provincial Merged Wetland Inventory suggested that this data source was of insufficient quality to use in the calculation of wetland cover (e.g., high commission and omission errors leading to accuracy and precision issues). However, given that wetlands are an important component of watershed integrity, we created a more accurate and up to date wetland inventory for the Modeste watershed (methods for how the inventory was created is presented in the section below). After evaluation, eight indicators were selected to assess pressure on riparian system function (Table 10).

Derivation of Required Data

Quantification of pressure on riparian system function using the selected metrics required the acquisition or creation of a number of datasets, which are listed in Table 11.

Table 11. Description of the spatial data obtained or derived for use in the assessment of Catchment Pressure.

Data Layer	Year	Source
15 m Digital Elevation Model (DEM)	2010-2016	Government of Alberta (mosaic of numerous acquired tiles)
30 m Land Cover	2015	Agriculture and Agri-Food Canada (AAFC)
Catchment Areas	N/A	Fiera Biological, derived from 15 m DEM
Human Footprint	2014	Alberta Biodiversity Monitoring Institute (ABMI)
Intensity of Land Use	2016	Fiera Biological, derived from AAFC (2015) and ABMI 2014
Landslide Susceptibility	2016	Alberta Geological Survey
Linear Features	2014	Government of Alberta base features
Slope	N/A	Fiera Biological, derived from 15 m DEM
Wetland Inventory	2016	Fiera Biological

Given the larger scale nature of the pressure model assessment relative to the riparian intactness assessment, we were able to use the freely available AAFC Land Cover and ABMI Human Footprint spatial data to quantify land use and land cover within each local catchment area. In addition, the Landslide Susceptibility Model results were obtained from the Alberta Geological Survey, and the Provincial Base (Linear) Features data were acquired to quantify linear feature density.

In addition to requiring the freely available data that we compiled for use in this model, it was also necessary to create the following datasets: 1) local catchment areas (i.e., gross contributing area of ~2 km^2); 2) an up-to-date wetland inventory; and 3) intensity of land use layer. The methods used to create each of these datasets are detailed below.

Local Catchment Areas

To quantify pressure at a finer resolution than the HUC 8 subwatersheds, we derived local catchment areas from the 15-meter LiDAR DEM. Firstly, the LiDAR DEM was hydrologically corrected by filling sinks and depressions within the watershed and levelling the DEM under known lakes and waterbodies. This hydrologically corrected DEM was then used as an input layer to Arc Hydro Tools to define catchment areas with a flow accumulation threshold of 2 km^2. Once catchments had been created using Arc Hydro Tools, outputs were converted to polygons, and where possible, catchment areas were split into a left and a right half using the stream centerlines. The final processing steps included the removal of any polygon "slivers", as well as waterbodies greater than 10 hectares. A map showing the local catchment areas created for Modeste watershed is presented in Figure 7.

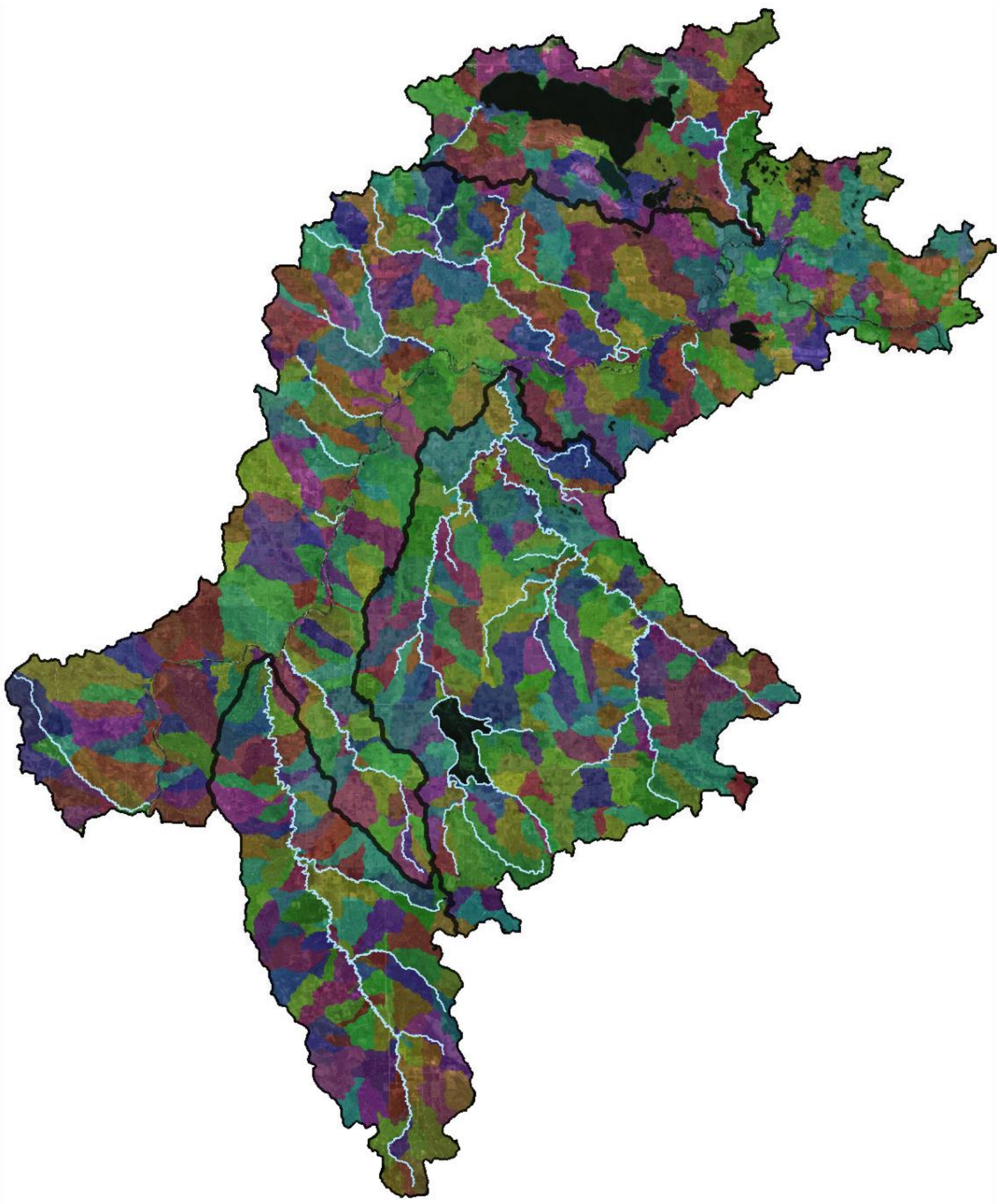


Figure 7. Local catchment areas derived using Arc Hydro Tools. These catchments areas were used as the unit of analysis to quantify and characterize pressure on riparian system function within the Modeste watershed.

Wetland Inventory

A new, up-to-date wetland inventory was created for the Modeste watershed using remote sensing techniques (Figure 8). Firstly, all available satellite data were compiled, including current (2015) and historical SPOT satellite imagery and freely available Landsat Imagery from 1982 to 2016. All satellite data were radiometrically calibrated and atmospherically corrected. We created spectral indices for each satellite scene, including Normalized Difference Vegetation Index (NDVI), Soil Adjusted Vegetation Index (SAVI), and Normalized Difference Wetness Index (NDWI).

Once spectral indices were calculated, a historical image analysis of the spectral indices was undertaken, whereby for each pixel within the Modeste watershed, we calculated the mean and standard deviation of the NDVI, SAVI, and NDWI from the range of images from 1982 to 2016. The 15-meter LiDAR DEM was processed to calculate slope, probability of depression, and Topographic Wetness Index. All data layers were combined to create a multi-band image containing the following information:

- 2015 SPOT Red Band
- 2015 SPOT NIR Band
- 2015 SPOT Green Band
- 2015 SPOT Blue Band
- 2015 SPOT NDVI
- 2015 SPOT NDWI
- 2015 SPOT SAVI
- Historical SAVI Mean
- Historical SAVI Standard Deviation
- Historical NDVI Mean
- Historical NDVI Standard Deviation
- Historical NDWI Mean
- Historical NDWI Standard Deviation
- LiDAR Slope
- LiDAR Probability of Depression
- LiDAR Topographic Wetness Index
- LiDAR DEM

Training data identifying Bogs, Fens, Marsh, Swamps, and Open Water classes were created using ArcGIS. These training data were rasterized and 1000 random samples were taken from each training class to use within a Random Forest classification. ENMAP Box software was used to apply a Random Forest classifier to the multi-band image following the fitting of the model with the training data. The resulting classification was evaluated against a set of held back training data (96% accuracy) and visual inspection of the classification image against the 2015 SPOT imagery. The final classification was vectorized, further checked for accuracy within ArcGIS, and manually adjusted where necessary to create a final wetland inventory for the Modeste watershed with a minimum mapping unit of 0.036 ha (6m x 6m).

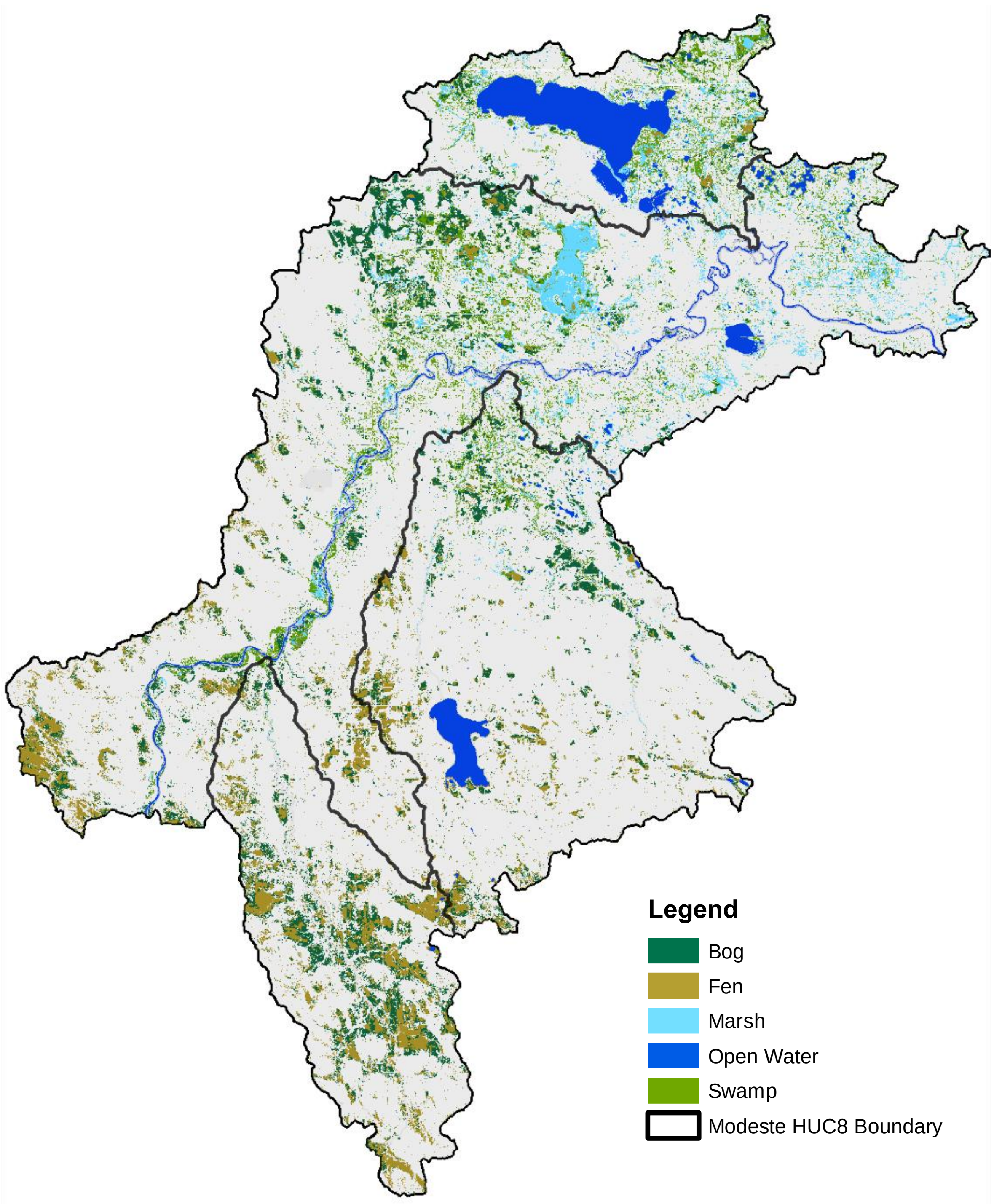


Figure 8. Modeste wetland inventory created from SPOT imagery using machine-learning techniques.

Intensity of Land Use

An Intensity of Land Use layer was generated by extracting human-related land uses from the AAFC and ABMI Human Footprint layers and assigning an intensity of use value to each land cover class. High intensity of use values were assigned to land cover types that are known to be more impactful on riparian system function and were assigned based on best professional judgment and literature review.

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. The final intensity value assignments are provided in Table 12.

Table 12. Intensity of Use values assigned to the various anthropogenic land cover classes present in the Modeste watershed.

Land Cover Class	Intensity of Use Value
Agriculture - Crop	50
Agriculture – Pasture/Forage	50
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	1000
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/Industrial	50
Seismic Line	50
Transmission Line	25
Urban/Developed	1000
Well Site	100

3.4. Assessing Pressure on Riparian System Function

We adapted the Watershed Integrity scoring methodology (Flotemersch et al. 2016) to assess Pressure on Riparian System Function in the Modeste watershed.. 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*, in the Sturgeon watershed, 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*).

Natural resilience and human impacts are determined by many factors that may vary from watershed to watershed; therefore, each pressure function (e.g., *NR* and *HI*) was calculated from a set of component stressors (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 13. Scores for each of the eight stressor metrics were calculated using ArcGIS 10.6 in one of two ways, depending on the type of metric being measured:

Type 1: For stressors that have a known measurable biological response, literature-derived thresholds were used to define the maximum value, above which the stressor impairs function beyond a repairable or reversible state. For example, wetland cover of at least 3% is required to improve water quality (Mitsch and Gosselink 2000), so any catchment with a percent cover of ≤3% is under maximum pressure for this stressor. For stressors with a known threshold, scores were calculated as:

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

Type 2: 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 use), the catchment stressor values were scored against the maximum value from the stressor's range of values within the Modeste watershed (i.e., a range standardized score was calculated). For these stressors, scores were calculated as:

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

See Table 14 for a list of each stressor and its associated type, the threshold values chosen for each metric, and references used to inform the selection of threshold values.

Table 13. List of stressor 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*)	Forest Cover	Percent cover by forest class	Fiera Biological Modeste watershed Land Cover (2016)
	Wetland Cover	Percent cover by wetland classes	Fiera Biological Modeste watershed Land Cover (2016)
	Slope	Mean cover of steep slopes (>5%)	Fiera Biological, derived from Government of Alberta 15 m DEM (2010-2016)
	Landslide Susceptibility	Area weighted average	Alberta Geological Survey (2016)
Human Impacts (*HI*)	Land Use Intensity	Zonal average of land use intensity values	Fiera Biological Modeste watershed Land Cover (2016) and ABMI Human Footprint (2014)
	Stream Crossing Density	Area weighted average of linear features that intersect major streams	Government of Alberta base features (2000)
	Road Density	Area weighted average of roads	Government of Alberta base features (2014)
	Density of Other Linear Disturbance Types	Area weighted average of non-road linear features	Government of Alberta base features (2014)

Table 14. Thresholds and scoring types used to calculate scores for each stressor metric (S_j).

Function	Stressor Metric	Stressor Threshold	Scoring Type	References
Natural Resilience *(NR)*	Forest Cover	Minimum 25% cover	Literature review (Type 1)	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)
	Wetland Cover	Minimum 3% cover	Literature review (Type 1)	Wetlands should comprise at least 3-7% of a watershed for water quality benefits (Mitch and Gosselink 2000)
	Slope	Maximum value	Range of values (Type 2)	N/A
	Landslide Susceptibility	Maximum value	Range of values (Type 2)	N/A
Human Impact *(HI)*	Land Use Intensity	Maximum value	Range of values (Type 2)	N/A
	Stream Crossing Density	0.6/km^2	Literature review (Type 1)	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 (Type 1)	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)
	Other Linear Disturbance Density	3.0 km/km^2	Literature review (Type 1)	Adapted general density threshold for watershed health, where >3 km/km^2 is used as an indicator for poor health (AESRD 2012)

Model Development and Selection

Once stressor metrics were quantified, the stressor scores were compiled within each pressure function (e.g., CP_{NR}, CP_{HI}), and the pressure function scores were combined mathematically to calculate a raw catchment score. Because of the lack of validation data to assist in calibrating and evaluating our model, we used an iterative, logic-based and exploratory approach to develop and refine the individual pressure functions and our catchment pressure model. In this process, many candidate models were developed that varied in how individual functions were calculated and how the stressors were treated in the model (Table 15). The resulting distribution of scores associated with each candidate model were assessed by comparing the model outputs to satellite imagery and the model input layers. This process allowed us to acknowledge where and how each candidate model was performing poorly and enabled us to adjust subsequent candidate model structures accordingly to provide more representative predictions of catchment pressure.

We found that using a simpler model gave better score results, and that the best results came from the model that used an adjusted stressor approach, in which the stressors that measured similar pressures were grouped (e.g., natural cover stressors together, linear disturbance stressors together), and a single score from each group was used in the calculation of the function. Combining stressors in this way reduced the sensitivity of the model and removed redundancy within the model.

The final scoring model consisted of the Natural Resiliency function, which contained the stressor groups of natural cover (forest cover and wetland cover metrics) and physical stress (slope and landslide susceptibility metrics), and the Human Intensity function, which consisted of an intensity of use metric and a stressor group of linear disturbance variables (road density, non-road linear disturbance density, and stream crossing density). In the final model, catchment pressure was measured as:

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

for which,

$$NR = (\max(\%Forest, \%Wetland) + \min(Slope, Landslide\ Susceptibility))$$

and,

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

The maximum was taken from the forest and wetland cover variables because with the additive models (e.g., model 1 in Table 15, in which stressors are added together within the functions), we found that in some areas of the watershed, catchments that may not have had much natural cover of wetlands (or forests) for biogeographical reasons (e.g., a grassland area) were being scored very low. Instead, using the maximum of the two metrics allowed us to capture the most representative natural score for each catchment and to prevent catchments with different types of natural cover from being penalized in the overall score. The minimum was taken from the physical stressors to capture the maximum terrain-based stress within the catchment. The linear stressors were averaged into one score to reduce the sensitivity in the model (i.e., three linear metrics were having an overwhelming influence on final model scores) while still capturing the pressure effects of all three linear metrics.

Once the raw catchment scores were calculated, they 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 score to the theoretical maximum possible score. For the Modeste 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 score by the theoretical maximum score of 4 and multiplying by 100 gives a percent score. The percent score is an absolute score for the catchment, and, in addition to allowing for the ranking of catchments within the watershed, it is useful for comparing the overall range of catchment pressure score results among watersheds. Conceptually, this would be similar to comparing distributions of final grades in different school districts. While the final grade may not have been calculated from the same set of tests or criteria, the final grades and their distribution is representative of how good or poor students have performed. Similarly, the distribution of catchment percent scores for different watersheds can be considered in a similar way. For example, one watershed could have scores that range from 25% to 60%, while a second watershed could have scores that range from 45% to 80%. A conclusion here would be that the second watershed generally has catchments where pressure on riparian system function is higher, as compared to the first watershed. In order to have high scores represent areas of High Pressure and low scores represent areas of Low Pressure, the percentage values were reversed by subtracting the percent score from 100.

The percentage scores were then translated into categorized catchment pressure classes 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, as follows:

- Low Pressure: catchments with scores ranging between 0 and the 25^{th} percentile (i.e., the bottom 25% of scores);
- Moderate Pressure: catchments with scores ranging between the 25^{th} and 75^{th} percentiles (i.e., the middle 50% of scores);
- High Pressure: catchments with scores ranging between the 75^{th} and 100^{th} percentile (i.e., the top 25% of scores).

Table 15. A representative selection of the candidate models explored for calculating catchment pressure scores.

Model	Model Components	Evaluation
NR x *HI*	$\{(\%Forest + \%Wetland + Slope + Landslide\ Susceptibility)\} \times \{(Intensity\ of\ Use + Stream\ Crossing\ Density + Road\ Density + Linear\ Density)\}$	Results skewed to low scores; moderate catchment error
NR x *INT* x *LN*	$\{(\%Forest + \%Wetland + Slope + Landslide\ Susceptibility)\} \times \{Intensity\ of\ Use\} \times \{(Stream\ Crossing\ Density + Road\ Density + Linear\ Density)\}$	Results skewed to low scores; moderate catchment error
NR x *PHY* x *INT* x *LN*	$\{(\%Forest + \%Wetland)\} \times \{(Slope + Landslide\ Susceptibility)\} \times \{Intensity\ of\ Use\} \times \{(Stream\ Crossing\ Density + Road\ Density + Linear\ Density)\}$	Results very skewed to low scores
NR x *PHY* x *HI*	$\{(\%Forest + \%Wetland)\} \times \{(Slope + Landslide\ Susceptibility)\} \times \{(Intensity\ of\ Use + Stream\ Crossing\ Density + Road\ Density + Linear\ Density)\}$	Results skewed to low scores; natural areas underrepresented
NR x *HI*	$\{(max(\%Forest, \%Wetland) + min(Slope, Landslide\ Susceptibility))\} \times \{(Intensity\ of\ Use + min(Stream\ Crossing\ Density, Road\ Density, Linear\ Density))\}$	Better range of scores and natural error/discrepancy removed, but linear features dominating scoring
NR x *HI* (Final Model)	$\{(max(\%Forest, \%Wetland) + min(Slope, Landslide\ Susceptibility))\} \times \{(Intensity\ of\ Use + average(Stream\ Crossing\ Density, Road\ Density, Linear\ Density))\}$	Results have most representative range of values; good agreement with visual interpretation of pressure

3.5. Management Prioritization Methodology

While riparian intactness and catchment pressure scores on their own provide land managers with important information about riparian condition in the Modeste watershed, combining intactness and pressure 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 riparian intactness and catchment pressure together results in prioritization matrix with 12 scoring categories, and we assigned a unique score ranging between 1 and 12 to each score category using best professional judgement (Table 16). The numeric scores were then combined and assigned to one of four prioritization categories, as follows:

- **High Conservation Priority (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 catchment pressure score within the RMA was determined by intersecting the RMA polygons with the catchment pressure polygons. This ensured that the catchment pressure scores, which were calculated as polygons, could be accurately assigned to the RMA polygons. The resulting prioritization polygons were scored and the length of shoreline assigned to each category was calculated.

Table 16. Riparian prioritization matrix for RMAs in the Modeste watershed.

		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

4.0 Modeste Watershed

4.1. Intactness Results

Intactness scores were calculated for approximately 1,708 km of creek, river, and lake shoreline in the Modeste watershed. Overall, 72% of the shoreline that was assessed was classified as High Intactness, with a further 10% classified as Moderate Intactness (Table 17; Figure 9). Approximately 19% of the shoreline was classified as either Low (4%) or Very Low (15%) Intactness.

Within the subwatersheds, the Bucklake Creek subwatershed had the greatest length of shoreline assessed in the Modeste watershed (749.5 km), as well as the greatest length of RMA that was assessed as High Intactness (540.4 km; Table 17). The Wolf Creek and North Saskatchewan Above Wabamun subwatersheds also had over 290 km of shoreline assessed as High Intactness. Conversely, the North Saskatchewan Above Wabamun subwatershed had the greatest length of shoreline assessed as Very Low Intactness (136.6 km), with Bucklake Creek subwatershed having the second greatest length of shoreline assessed as Very Low Intactness (101.8 km). Wolf Creek and Wabamun Creek watersheds both had less than 10 km of shoreline assessed as Very Low Intactness.

When the proportion of shoreline assigned to each intactness categories is compared within each subwatershed, Wolf Creek had the highest proportion of shoreline rated as High Intactness (92%), with Wabamun Creek having the second highest proportion (76%), followed by Bucklake Creek (72%) and North Saskatchewan Above Wabamun (52%) (Figure 10; Table 17). The North Saskatchewan Above Wabamun watershed had the highest proportion of shoreline assessed as Very Low Intactness (25%) and Low Intactness (5%), with Bucklake Creek watershed having the second highest proportion of shoreline falling into the Very Low (14%) and Low Intactness categories (4%).

When intactness scores are summarised and compared for Buck Lake and the named creeks included in this study, it is apparent that the majority of the waterbodies are in fairly good condition, with 14 out of 18 having ≥50% of the shoreline assessed at High Intactness (Figure 11). In contrast, Muskrat Creek has >50% of its shoreline assessed as Low or Very Low Intactness. Additionally, Mink Creek (within the Wabamun subwatershed), Mishow Creek, Shoal Lake Creek, Sun Creek, Tomahawk Creek, and Washout Creek all had >25% of their shorelines assessed as Very Low Intactness. Of the seven Unnamed Creeks that were assessed, all had ≥50% of the shoreline classified as High Intactness (Figure 12).

Spatially, large areas of intact riparian habitat are located in the south and west parts of the watershed, while riparian habitats that were assessed as lower intactness are concentrated in the agricultural regions of the watershed. This pattern of intactness is similar for both the left bank (Figure 13) and the right bank (Figure 14).

Table 17. Total length of shoreline assessed within each subwatershed, along with a summary of the length of shoreline assigned to each riparian intactness category. The proportion of the shoreline assigned to each intactness category is provided in brackets.

		Length (km) of Shoreline By Intactness Category			
HUC 8 Subwatershed	**Total Length Assessed (km)**	**Very Low Intactness**	**Low Intactness**	**Moderate Intactness**	**High Intactness**
Wabamun Creek	101.5	9.8 (10)	3.3 (3)	11.2 (11)	77.2 (76)
North Sask Above Wabamun	537.0	136.6 (25)	25.4 (5)	63.5 (12)	311.5 (58)
Bucklake Creek	749.5	101.8 (14)	29.9 (4)	77.4 (10)	540.4 (72)
Wolf Creek	320.3	6.5 (2)	4.5 (1)	15.7 (5)	293.6 (92)
Modeste Watershed Total	**1,708.3**	**254.7 (15)**	**63.1 (4)**	**167.8 (10)**	**1,222.7 (72)**

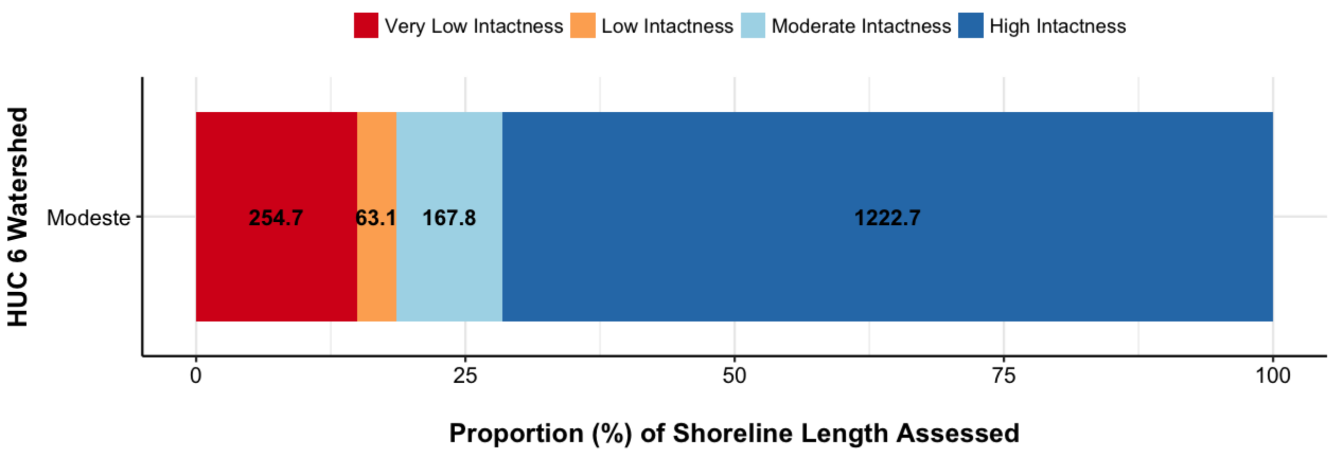


Figure 9. The total proportion of shoreline within the Modeste watershed assigned to each riparian intactness category. Numbers indicate the total length (km) of shoreline associated with each category.

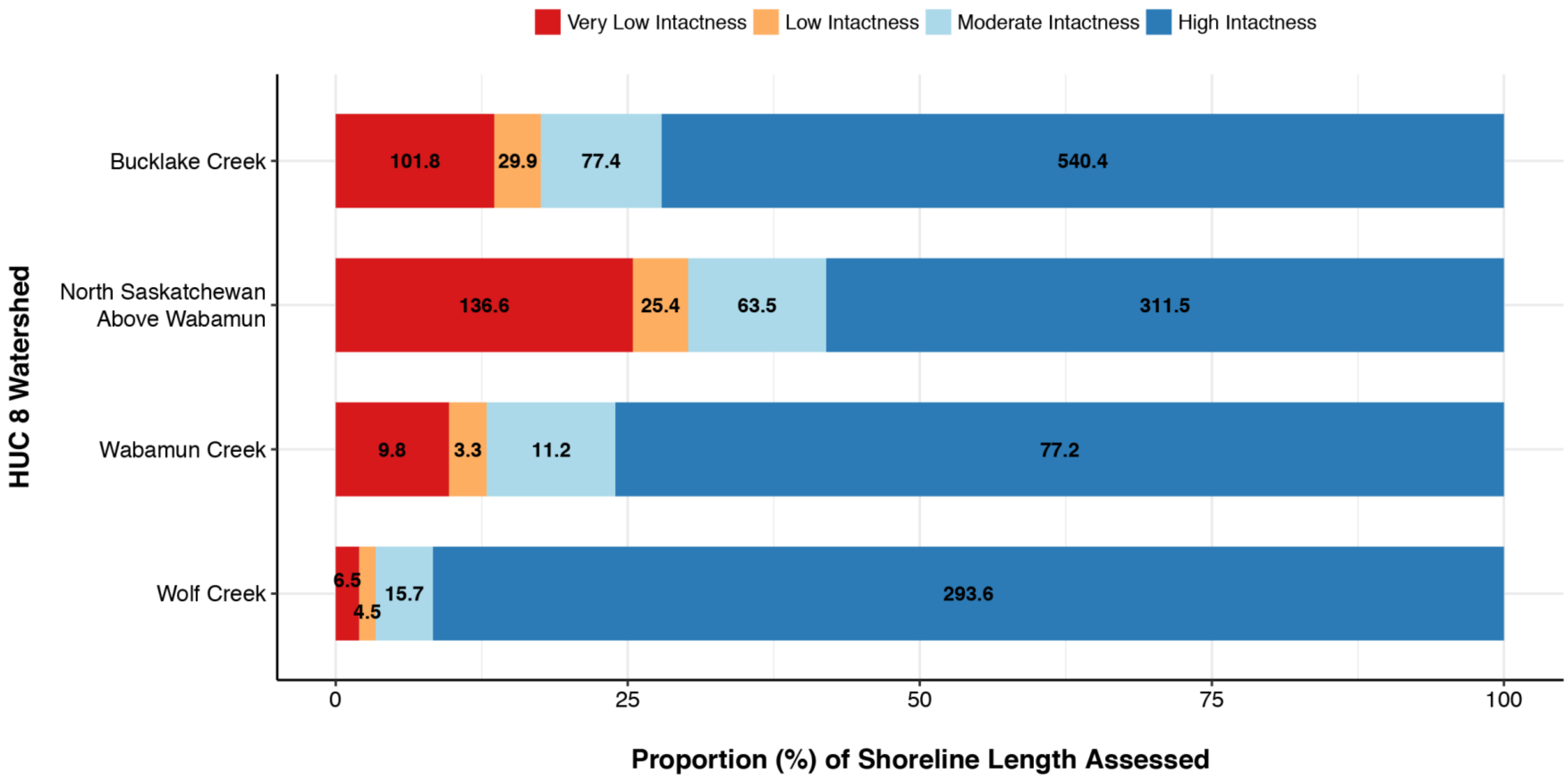


Figure 10. The total proportion of shoreline within the Modeste watershed assigned to each riparian intactness category, summarized by HUC 8 subwatershed. Numbers indicate the total length (km) of shoreline associated with each category.

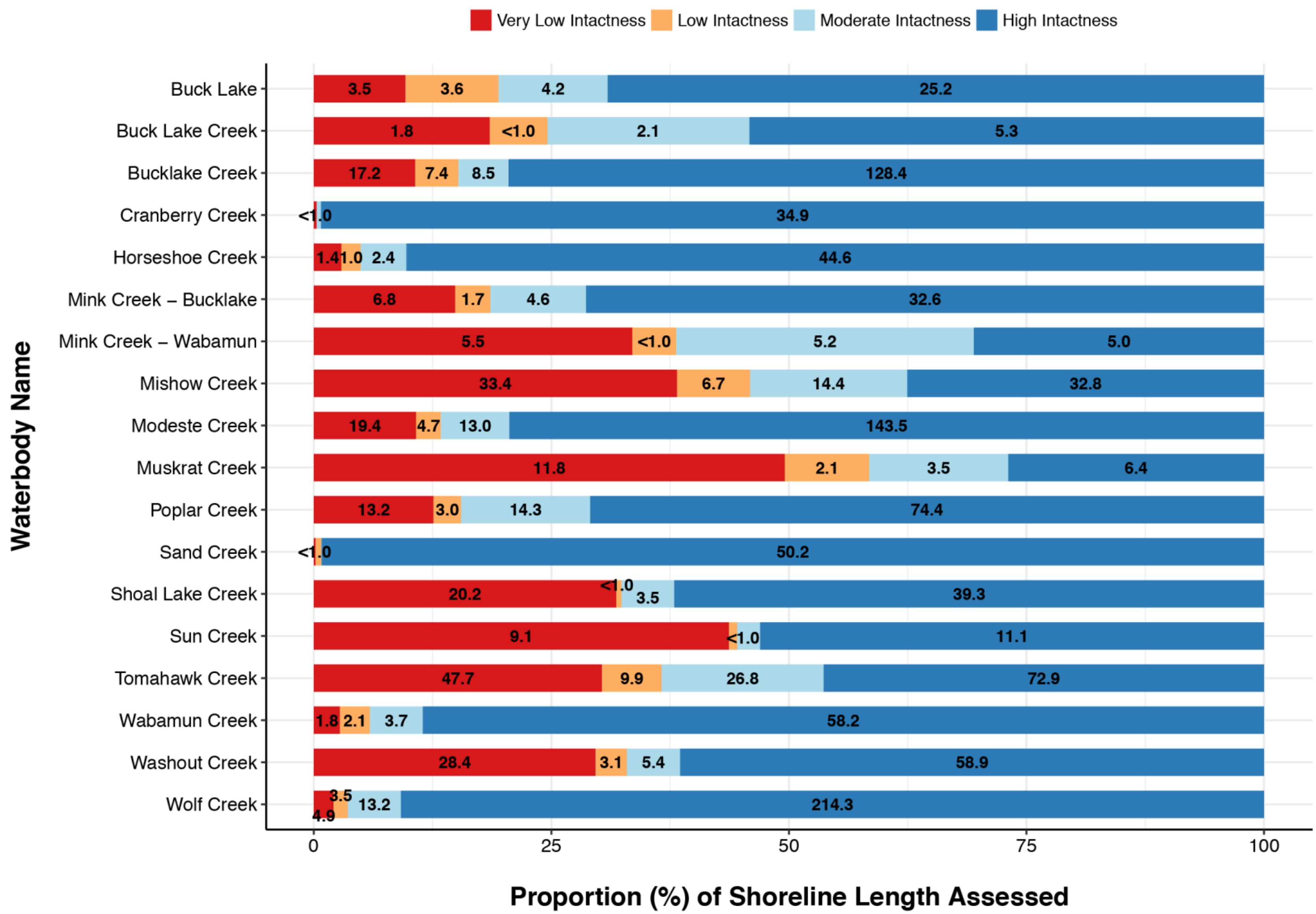


Figure 11. The total proportion of named lake and stream shoreline in the Modeste watershed assigned to each riparian intactness category. Numbers indicate the total length (km) of shoreline associated with each category.

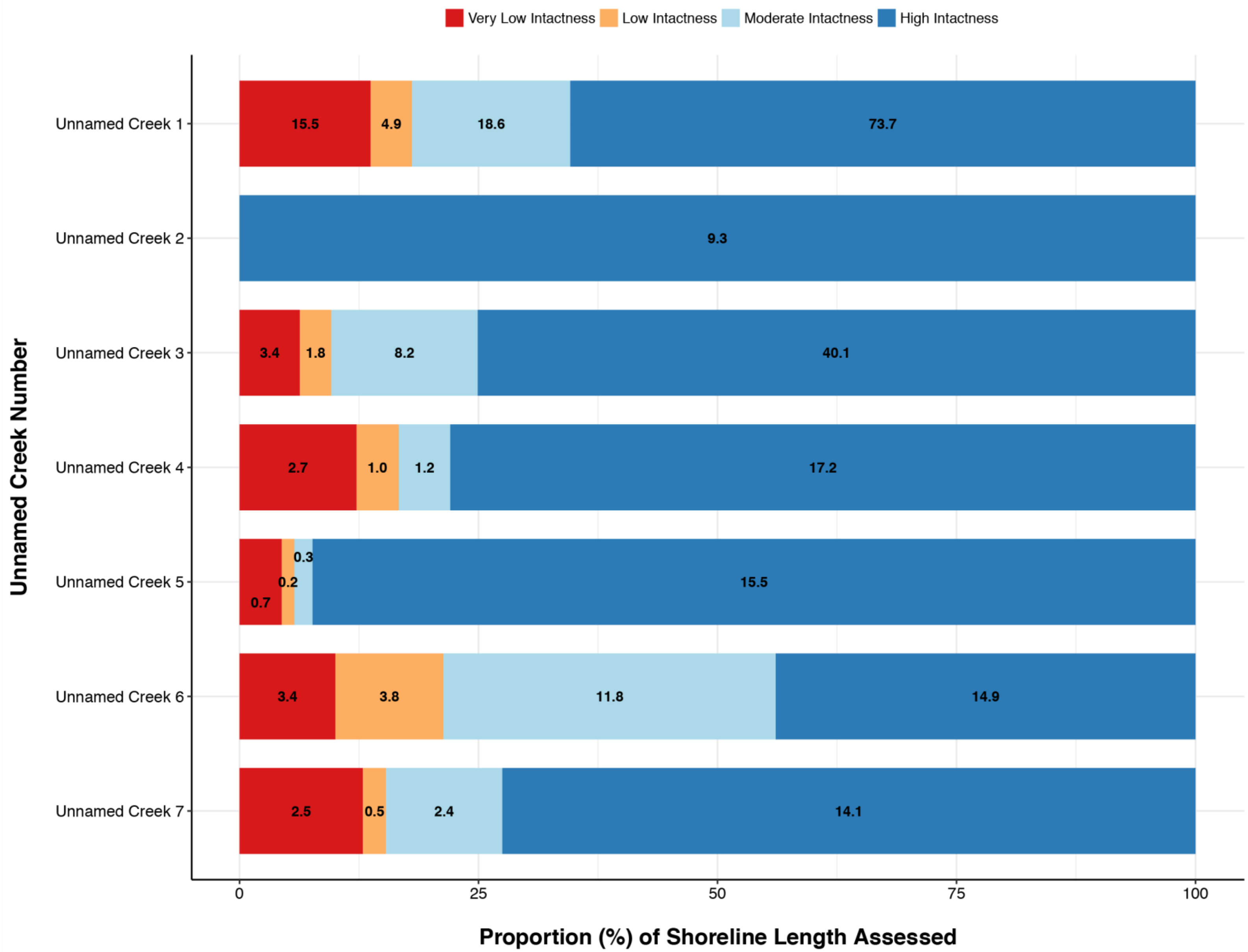


Figure 12. The total proportion of shoreline assigned to each riparian intactness category for each unnamed creek assessed in this study. Numbers indicate the total length (km) of shoreline associated with each category.

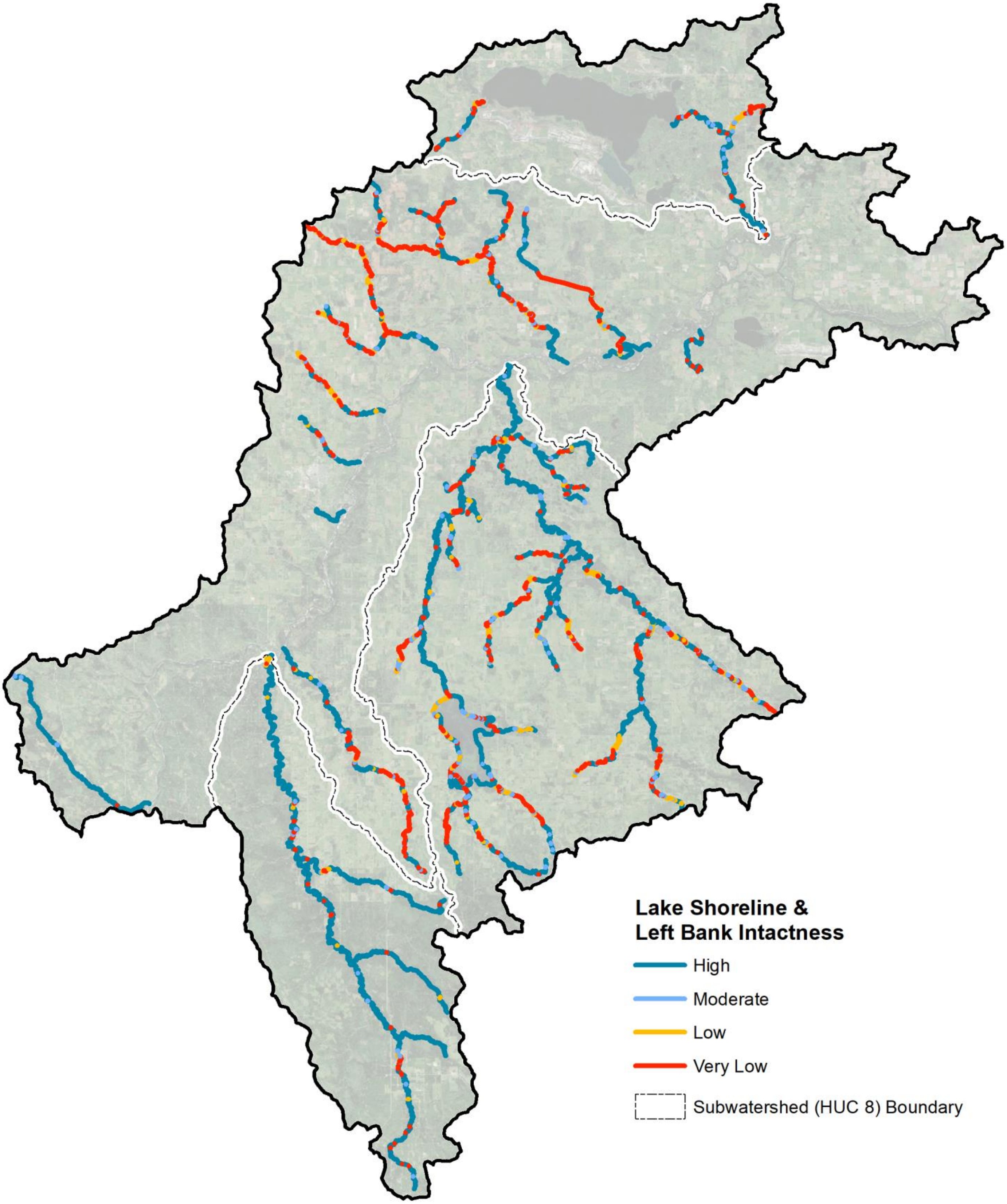


Figure 13. RMA intactness for lake shorelines and the left bank of creeks that were included in this study

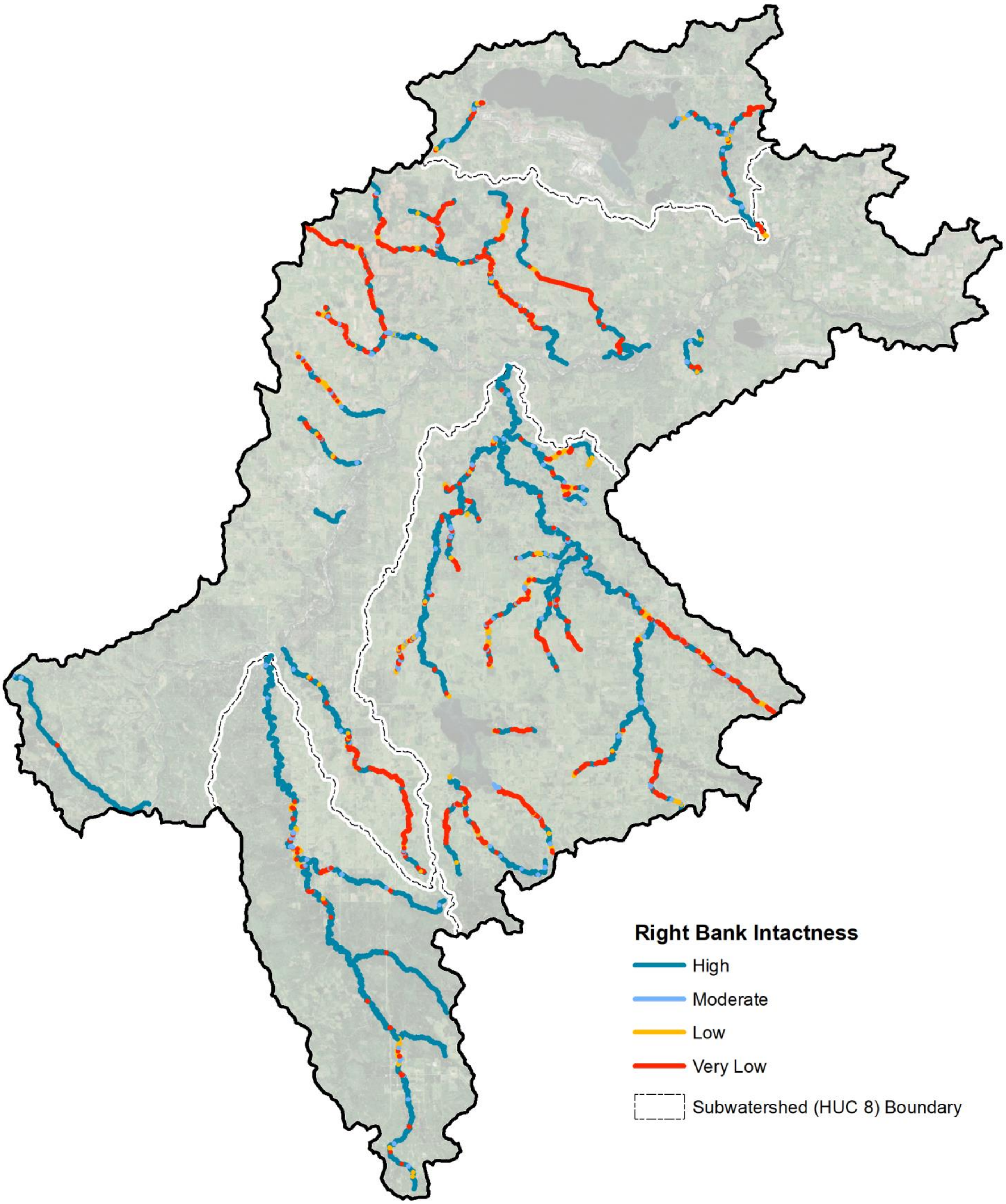


Figure 14. RMA intactness for the right bank of creeks that were included in this study

4.2. Pressure on Riparian System Function Results

Pressure on riparian system function was quantified for 811 catchments within the Modeste watershed, covering an area of approximately 4,517 km^2 . Of that area, just over 27% was classified as High Pressure, with the majority (50%) of local catchments being classified as Moderate Pressure, and the remaining 22% being classified as Low Pressure (Figure 15).

When pressure scores were compared between HUC 8 subwatersheds, Wabamun Creek had the largest proportion (58%) of local catchments classified as High Pressure; however, the Bucklake Creek subwatershed had the largest proportion of catchments (>90%) classified as either High (25%) or Moderate (67%) Pressure (Figure 16). In contrast, the Wolf Creek subwatershed had the majority (60%) of its catchments classified as Low Pressure.

When pressure scores were examined only for those local catchments that intersect RMAs of Buck Lake and other named creeks, it is apparent that the majority of the major waterbodies assessed in this study are located in areas where land use pressure is moderate or high Figure 16). For 15 of the 18 waterbodies, >50% of the adjacent lands were classified as either Moderate or High Pressure, with only Cranberry, Horseshoe, and Sand Creeks having >50% of adjacent lands classified as Low Pressure. A similar patter was seen for Unnamed Creeks, with all seven Unnamed Creeks having >75% of adjacent lands classified as Moderate or High Pressure, and five of the seven creeks having 100% of adjacent catchments classified as either Moderate or High Pressure (Figure 18).

Spatially, Low Pressure catchments were primarily concentrated in the southwest part of the watershed, while High Pressure catchments occurred primarily in the north and northeast parts of the watershed (Figure 19). High Pressure catchments were most often associated with areas of high intensity human use, such as mining or intensively built-up areas such as towns or cities.

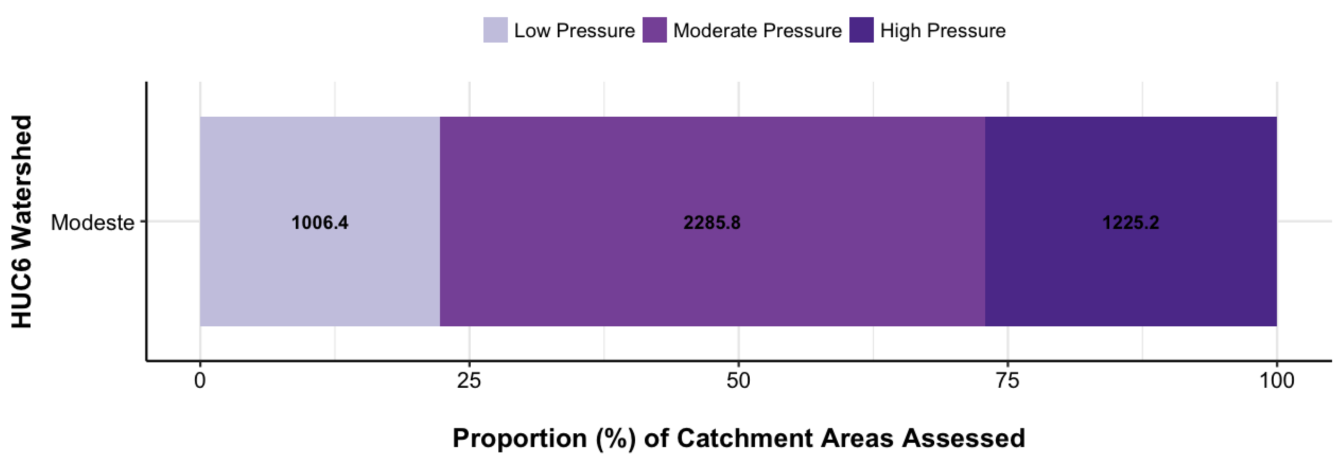


Figure 15. The proportion of local catchments within the Modeste watershed assigned to each pressure category. Numbers indicate total area (km^2) assigned to each category.

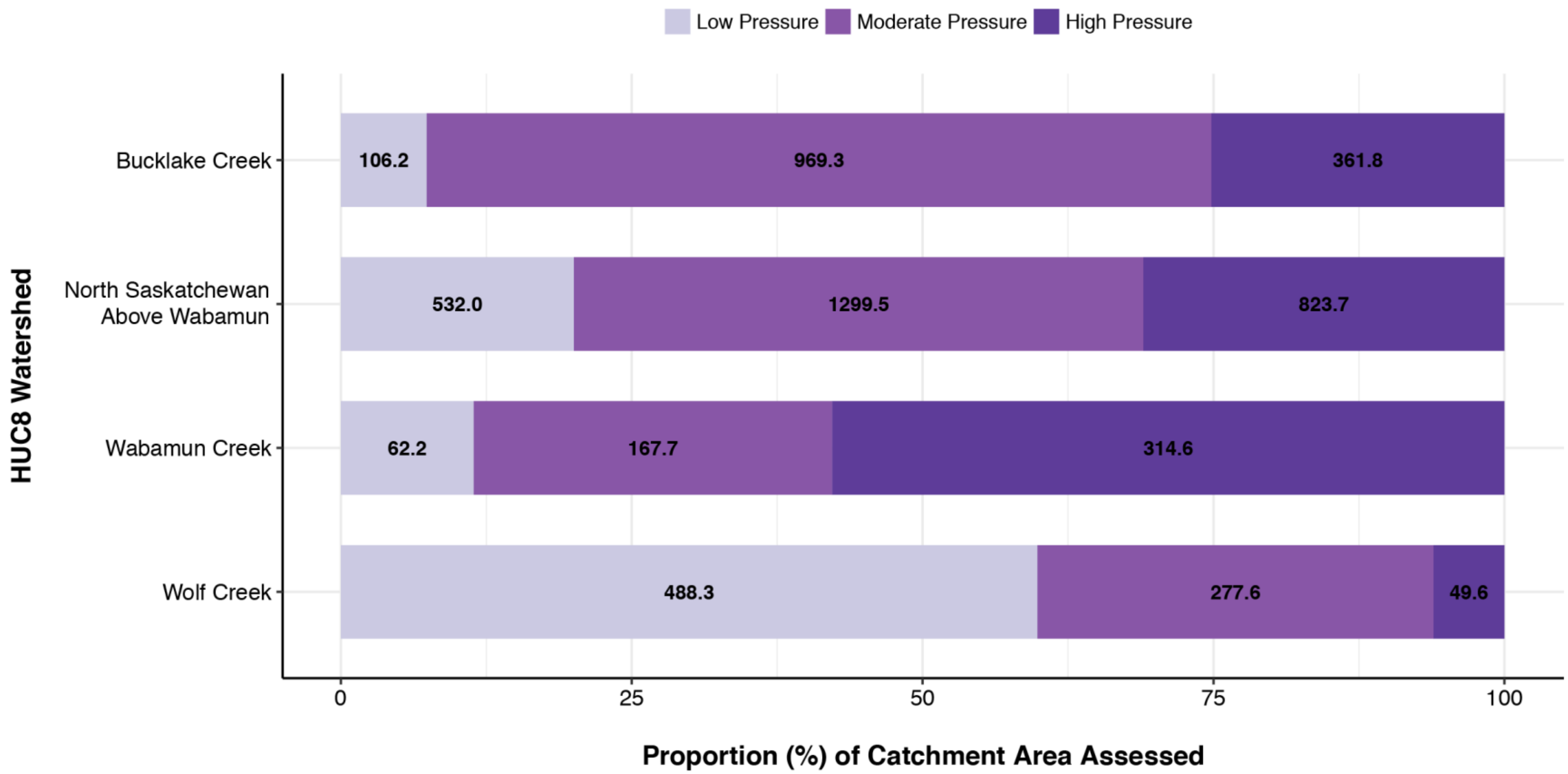


Figure 16. The proportion of local catchments assigned to each pressure category, summarized by HUC 8 subwatershed. Numbers indicate total area (km^2) assigned to each pressure category.

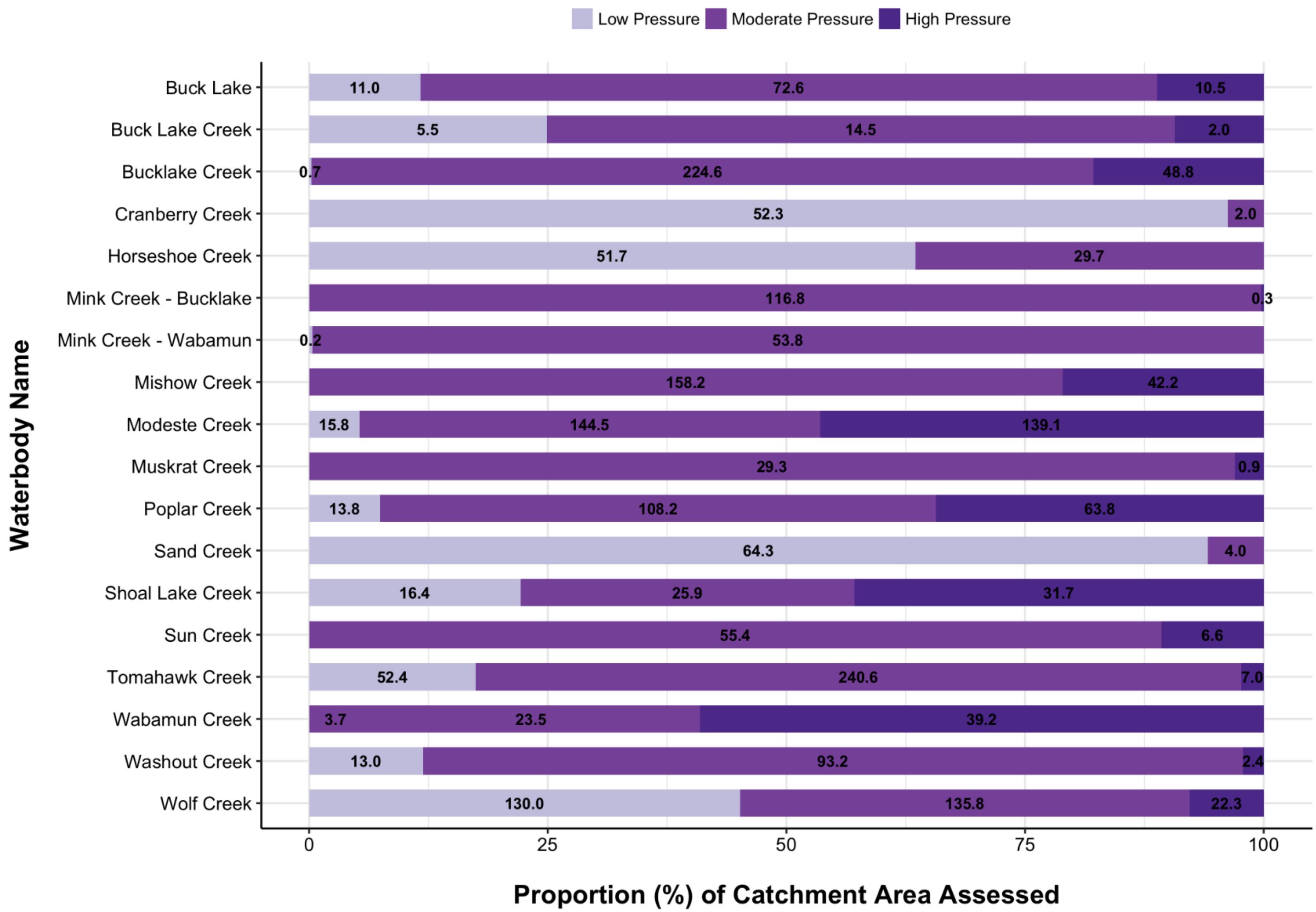


Figure 17. The proportion of catchments by pressure category that intersect RMAs associated with the shorelines of named lakes and creeks in the Modeste watershed. Numbers indicate the total area (km^2) assigned to each pressure category.

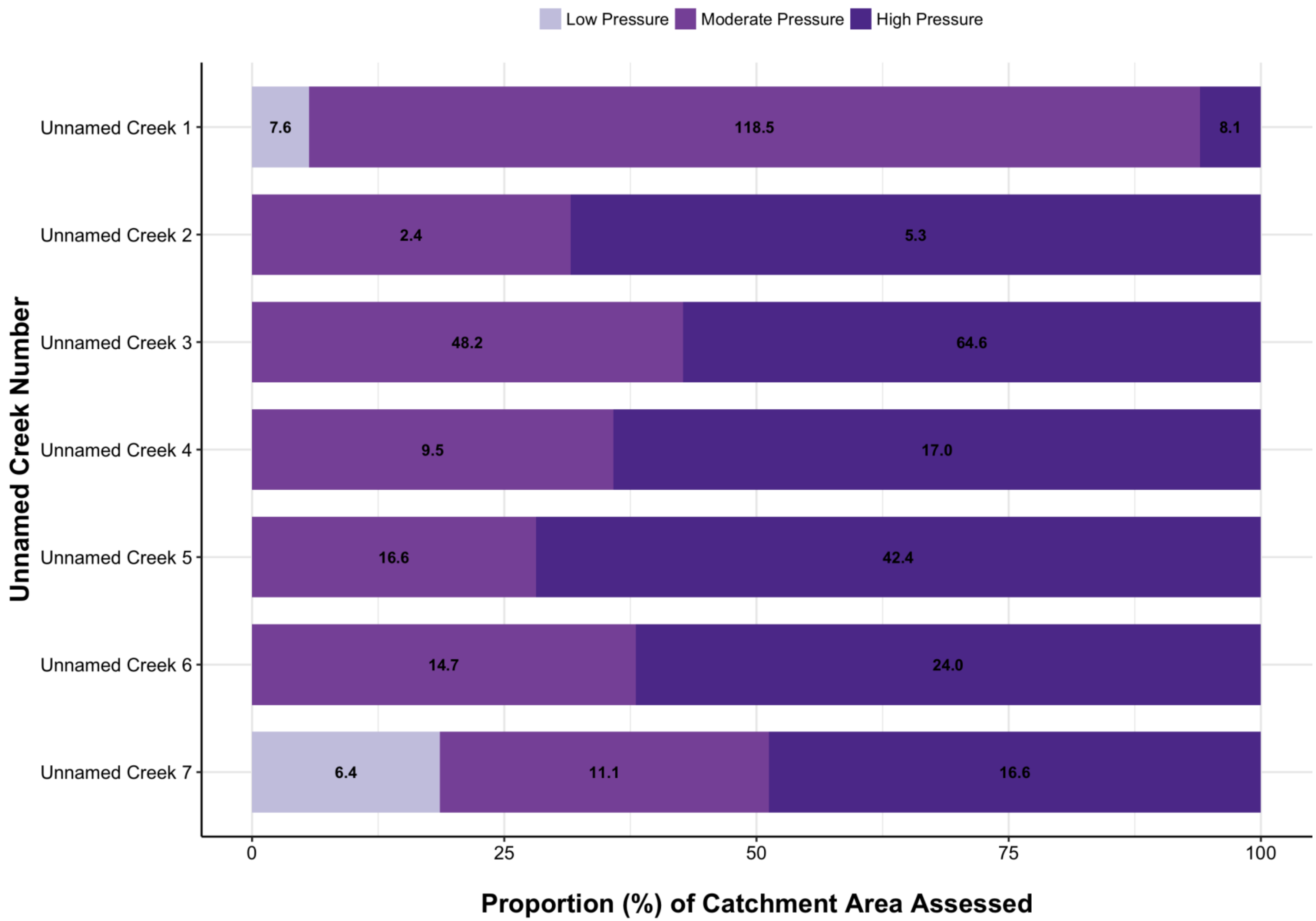


Figure 18. The proportion of catchments by pressure category that intersect RMAs associated with the shorelines of unnamed creeks in the Modeste watershed. Numbers indicate the total area (km^2) assigned to each pressure category.

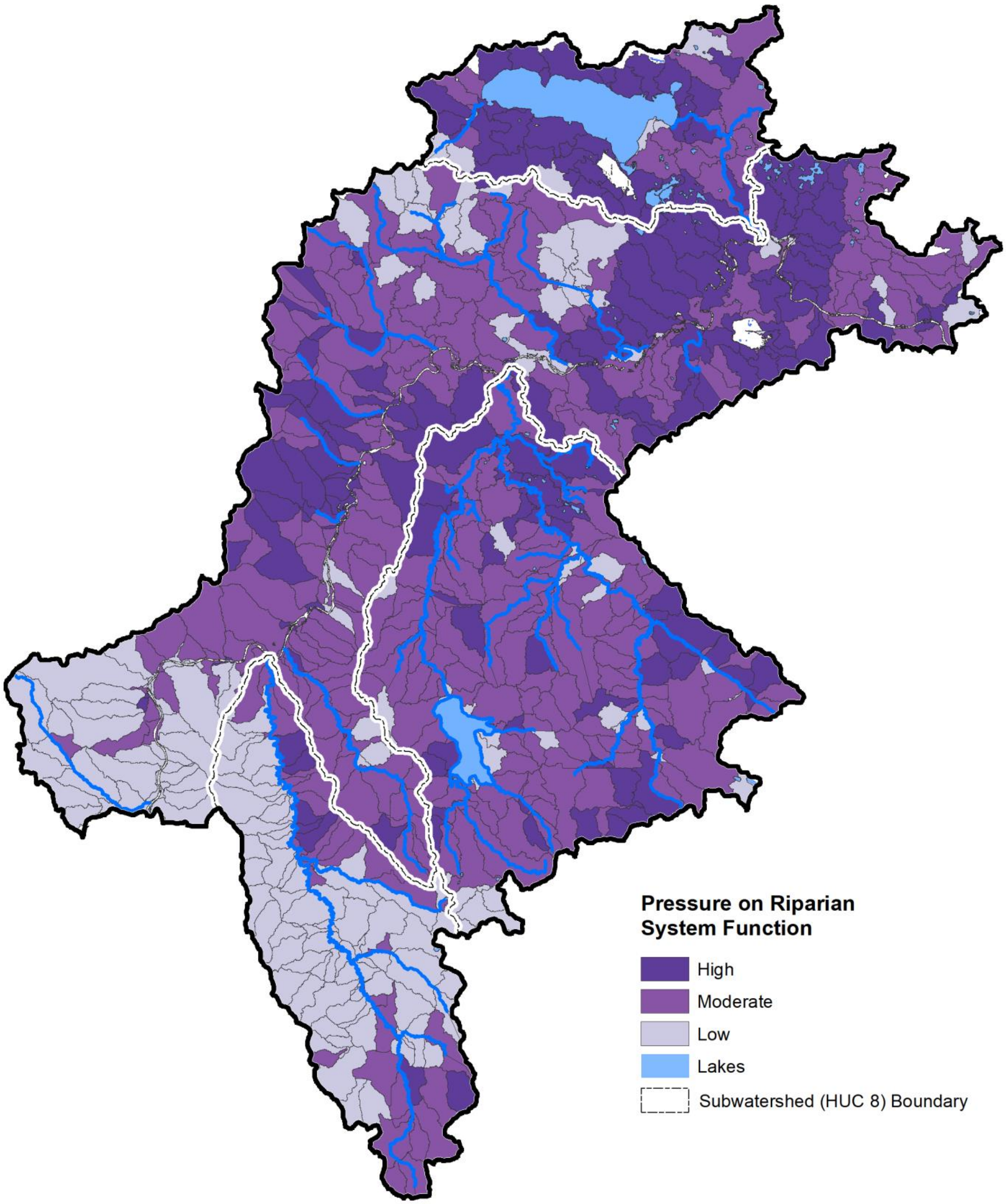


Figure 19. Scores characterizing the pressure on riparian system function assessed for each local catchment area in the Modeste watershed. Pressure scores were calculated using a combination of information regarding the land use, land cover, and topography for each catchment.

4.3. Conservation & Restoration Prioritization Results

Within the Modeste watershed, 81% of the shoreline that was assessed was classified as either High Conservation (58%) or Moderate Conservation (23%) Priority, representing approximately 1,390 km of shoreline (Figure 20). Conversely, 18% of the shoreline was classified as either High Restoration (14%) or Moderate Restoration (4%) Priority, representing approximately 318 km of shoreline.

For all HUC 8 subwatersheds within the Modeste, >50% of the shoreline that was assessed was categorized as either High or Moderate Conservation Priority, with Wolf Creek subwatershed having >95% of its shoreline identified as priority for conservation (Figure 21). Conversely, the North Saskatchewan Above Wabamun subwatershed had the highest proportion of shoreline identified as priority for restoration, with 23% being identified as High Restoration Priority and 7% being identified as Moderate Restoration Priority.

For 12 of the 18 major waterbodies assessed in the watershed, >50% of the shoreline was classified as High Conservation Priority, with 11 of the 18 waterbodies have >75% of the shoreline classified as either High or Moderate Conservation Priority (Figure 24). In particular, nearly the entire shorelines of Cranberry, Horseshoe, Sand, and Wolf Creek were identified for conservation. In contrast, 7 of the 18 (39%) major waterbodies had >25% of their shorelines identified as either High or Moderate Restoration Priority. Muskrat Creek had the largest proportion of shoreline identified as High Restoration Priority, followed closely by Sun Creek and Mishow Creek. For the unnamed creeks that were assessed, three of the seven had ≥50% of their shorelines classified as High Conservation Priority, with all seven having >75% of their shoreline assessed as either High or Moderate Conservation Priority (Figure 23).

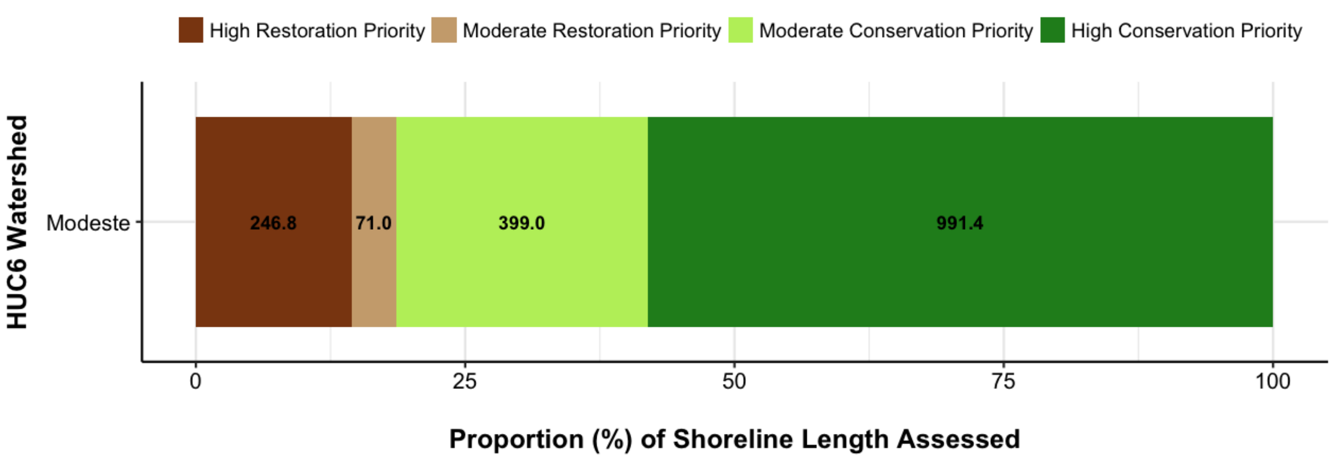


Figure 20. The total proportion of shoreline within the Modeste watershed assigned to each priority category. Numbers indicate the total length (km) of shoreline associated with each category.

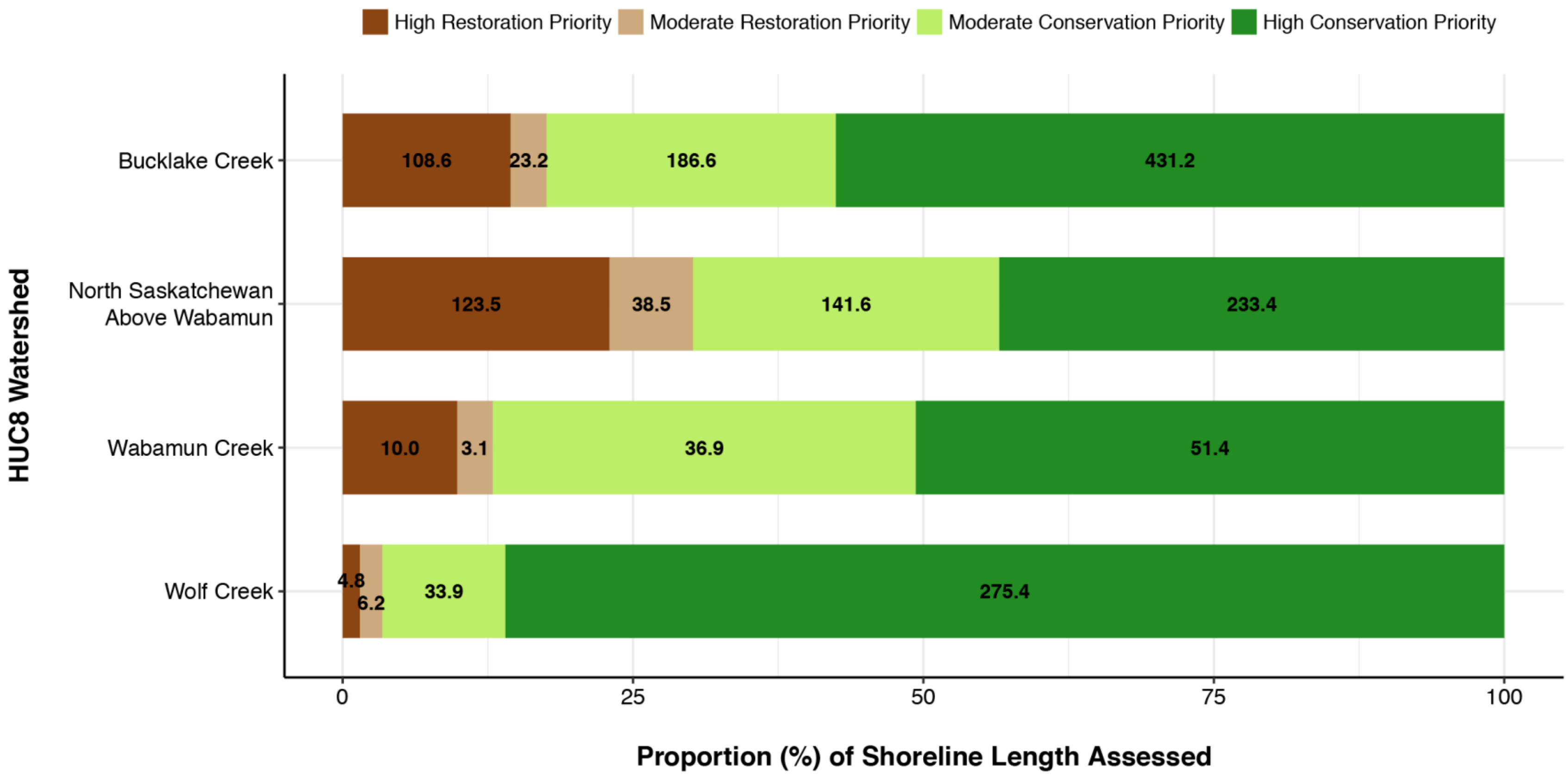


Figure 21. The total proportion of shoreline within the Modeste watershed assigned to each priority category, summarized by HUC 8 subwatershed. Numbers indicate the total length (km) of shoreline associated with each category.

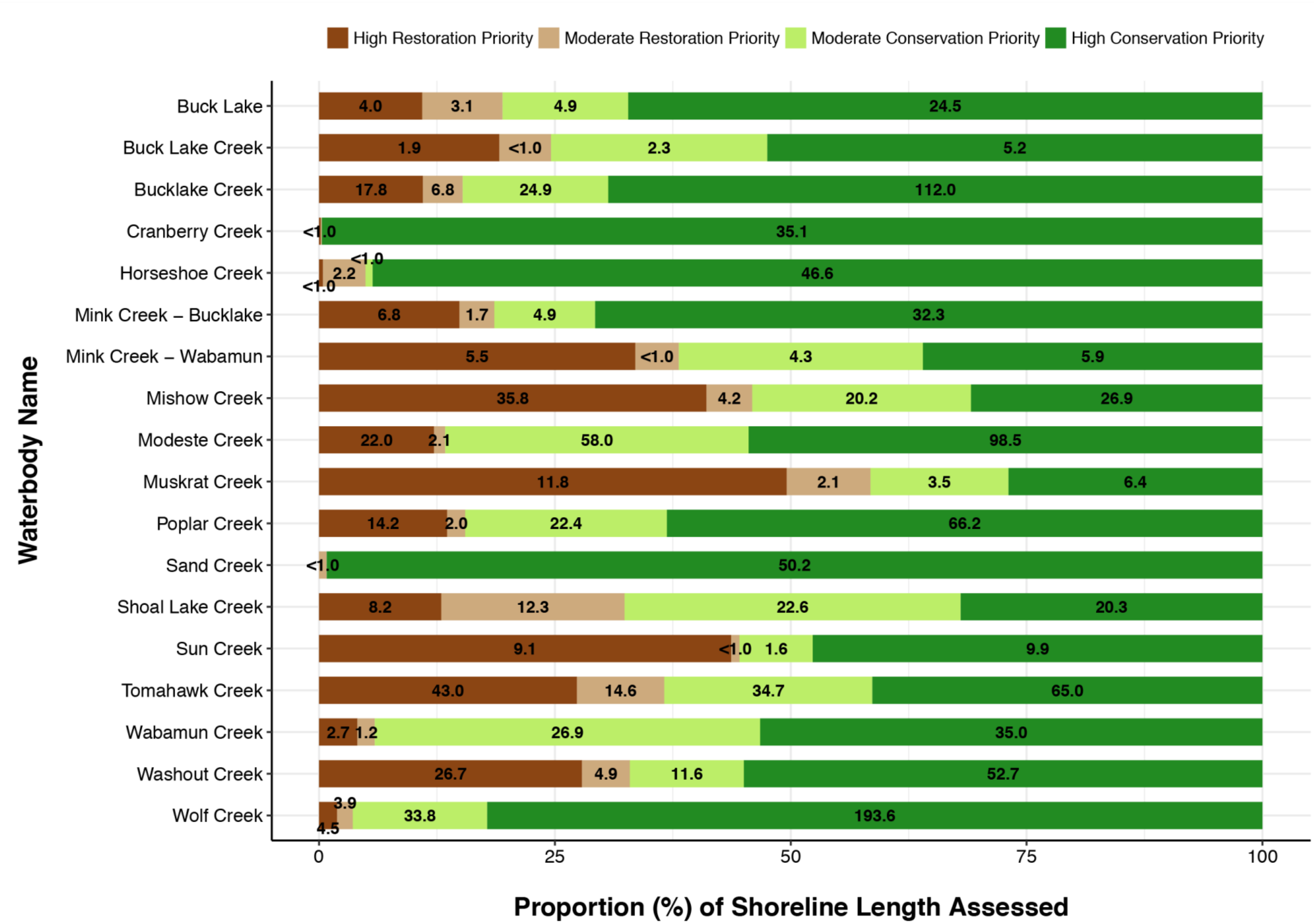


Figure 22. The total proportion of named lake and stream shoreline in the Modeste watershed assigned to each priority category. Numbers indicate the total length (km) of shoreline associated with each category.

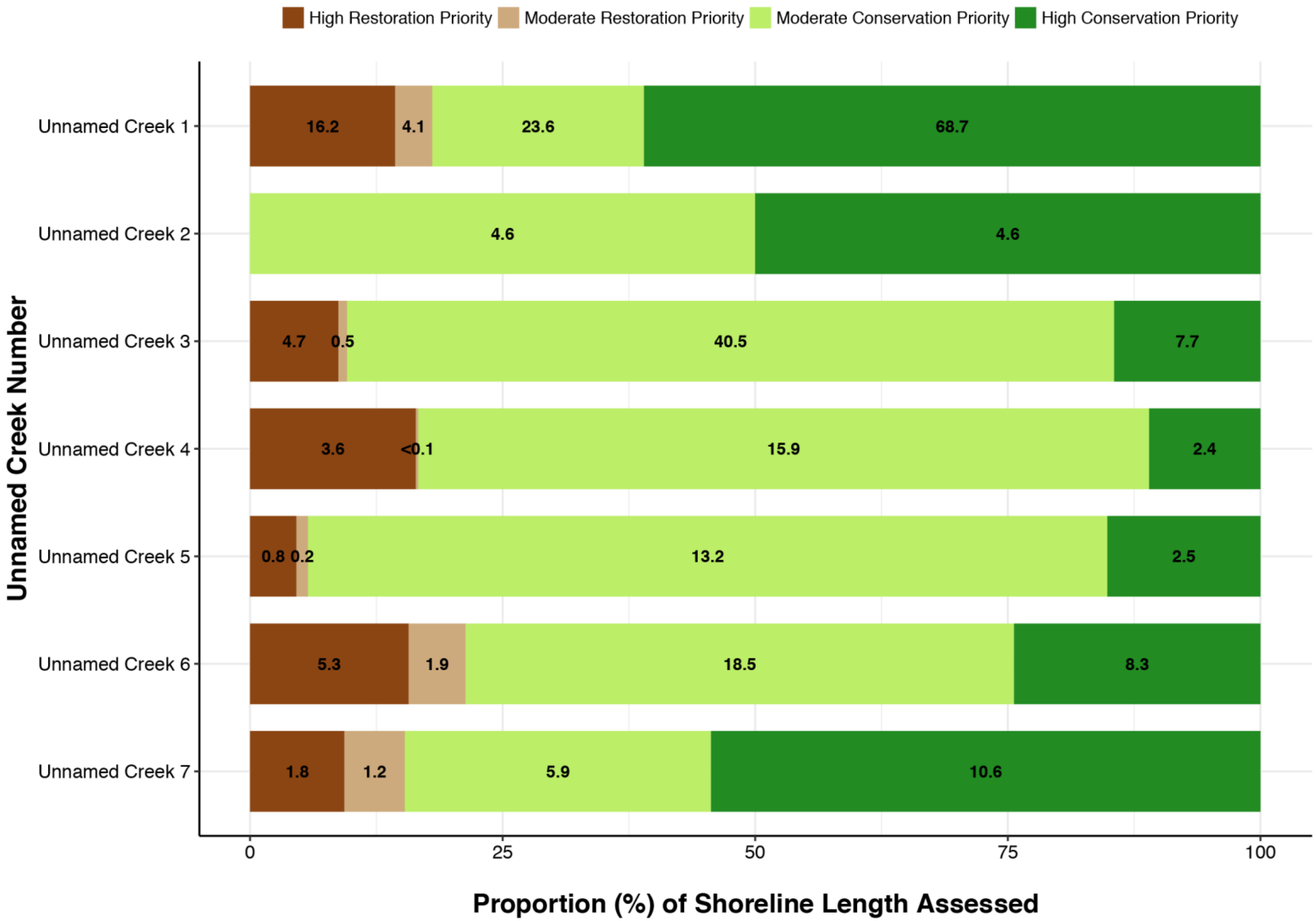


Figure 23. The total proportion of shoreline for unnamed creeks assigned to each priority category. Numbers indicate the total length (km) of shoreline associated with each category.

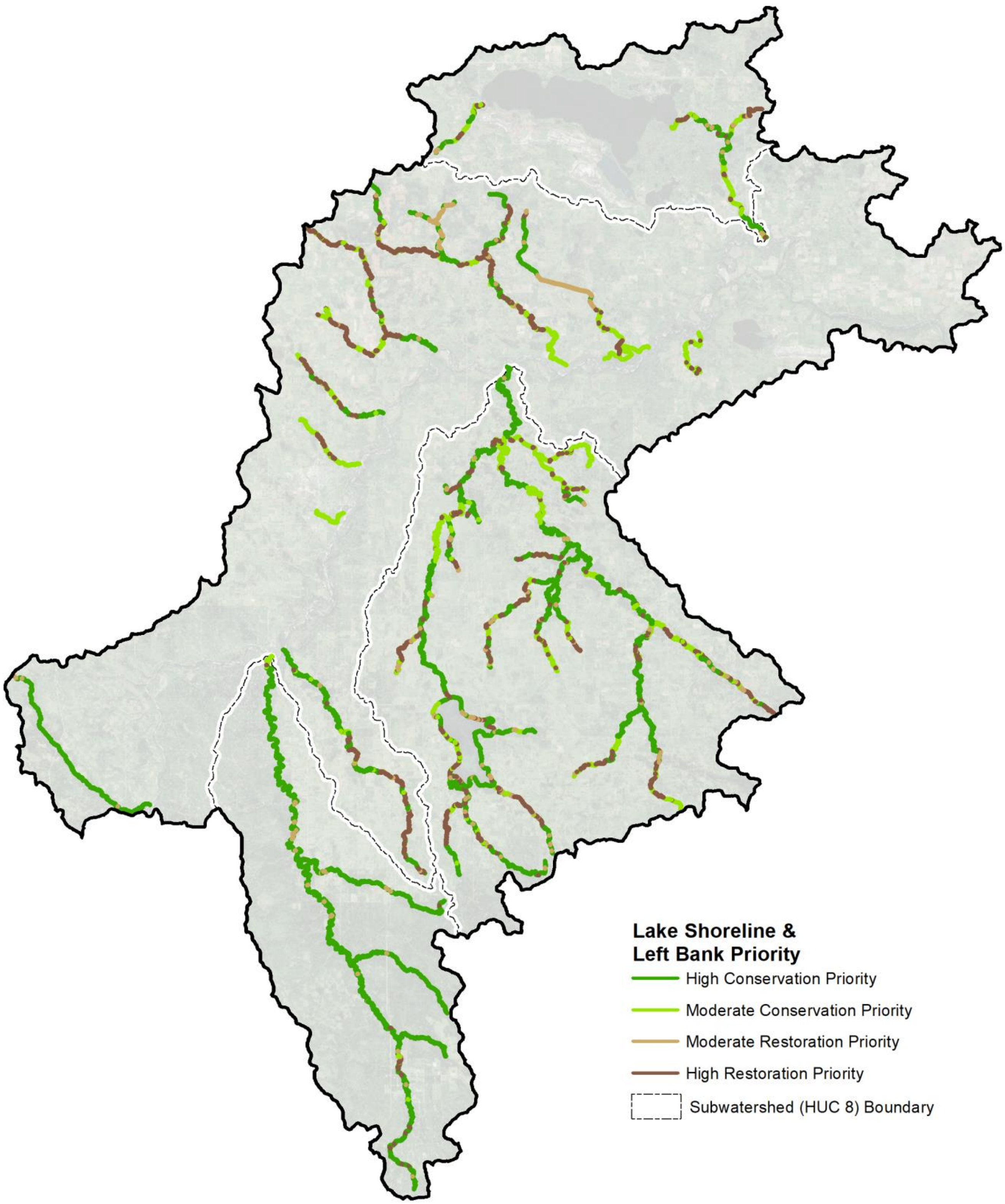


Figure 24. RMA priority for lake shorelines and the left bank of creeks that were included in this study. Prioritization scores are a combination of the riparian intactness and the catchment pressure scores.

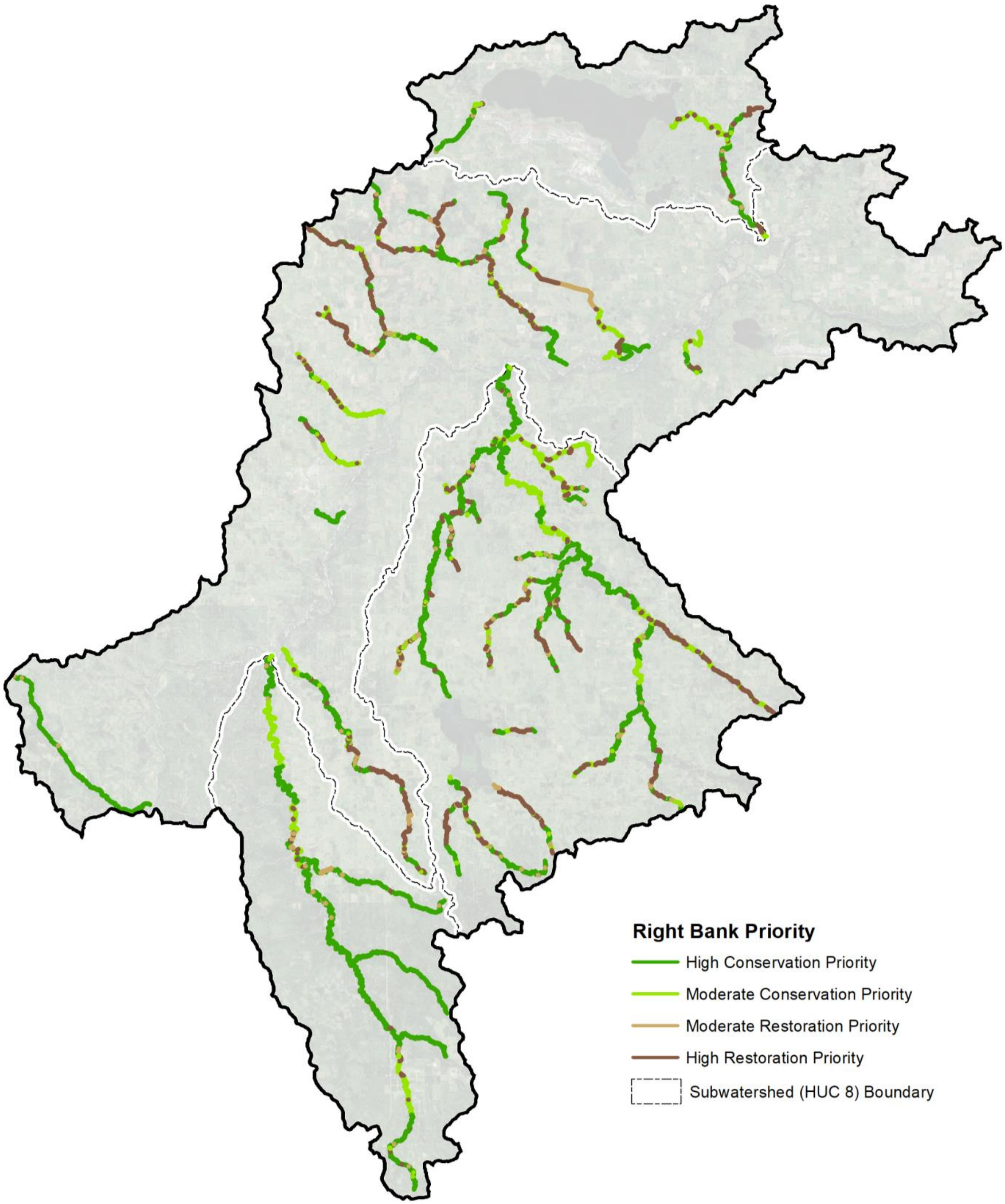


Figure 25. Riparian prioritization scores for RMAs located on the right bank of waterbodies that were assessed as part of this study. Prioritization scores are a combination of the riparian intactness and the catchment pressure scores.

5.0 Wabamun Creek Subwatershed

5.1. Summary of Results

Wabamun Creek subwatershed is located in the northern-most portion of the Modeste watershed. The riparian assessment for this subwatershed evaluated 101.5 km of shoreline associated with three waterbodies: Mink Creek, Wabamun Creek, and Unnamed Creek #7. A riparian assessment of Wabamun Lake has been previously completed by the NSWA (NSWA 2015); therefore, the lake shoreline was not included in this riparian assessment.

The Wabamun Creek subwatershed is covered by roughly equal parts forest (33%), water & wetlands (30%), and anthropogenic land cover (36%). Agriculture pasture lands account for a large proportion of the human-dominated land cover (20%); however, urban and human-caused bare land also comprise a substantial proportion of the subwatershed (11%). This includes the Highvale coal mine, Canada's largest surface-strip cola mine, which covers an area of approximately 12,600 ha within the southern portion of the subwatershed. The Wabamun Creek subwatershed is contained almost entirely within the municipality of Parkland County.

Overall, 87% of the shoreline assessed within the Wabamun Creek subwatershed was classified as High or Moderate Intactness, with 13% of the riparian area assessed classified as Low or Very Low Intactness (Figure 26A). The majority of the catchment area in the subwatershed was assessed as either High (58%) or Moderate (31%) Pressure, with only 11% of the catchment area classified as Low Pressure (Figure 26B).

When intactness and pressure were combined to identify areas of restoration and conservation priority, 10% of the shoreline assessed in this subwatershed was classified as High Restoration Priority, with 51% being classified as High Conservation Priority (Figure 26C).

5.2. Results by Waterbody

When intactness is examined for each waterbody that was assessed in the subwatershed (Figure 27), the results indicate that Mink Creek had the largest proportion of shoreline classified as Very Low intactness, followed by Unnamed Creek 7.

While Mink Creek had the highest proportion of shoreline classified as Low Intactness, it had the lowest proportion of High Pressure catchments, with Wabamun Creek having the highest proportion of High Pressure catchments located adjacent to its shoreline (Figure 28). Unnamed Creek 7 had the lowest proportion of catchments classified in the Low Pressure category.

When management prioritization is evaluated by waterbody, Unnamed Creek 7 had the highest proportion of riparian area classified as High Conservation Priority, followed closely by Wabamun Creek Figure 29). When High and Moderate Conservation Priority categories are considered together, both Unnamed Creek 7 and Wabamun Creek have more than 75% of their shorelines identified for conservation, Mink Creek had the largest proportion of its shoreline identified as either High or Moderate Restoration Priority.

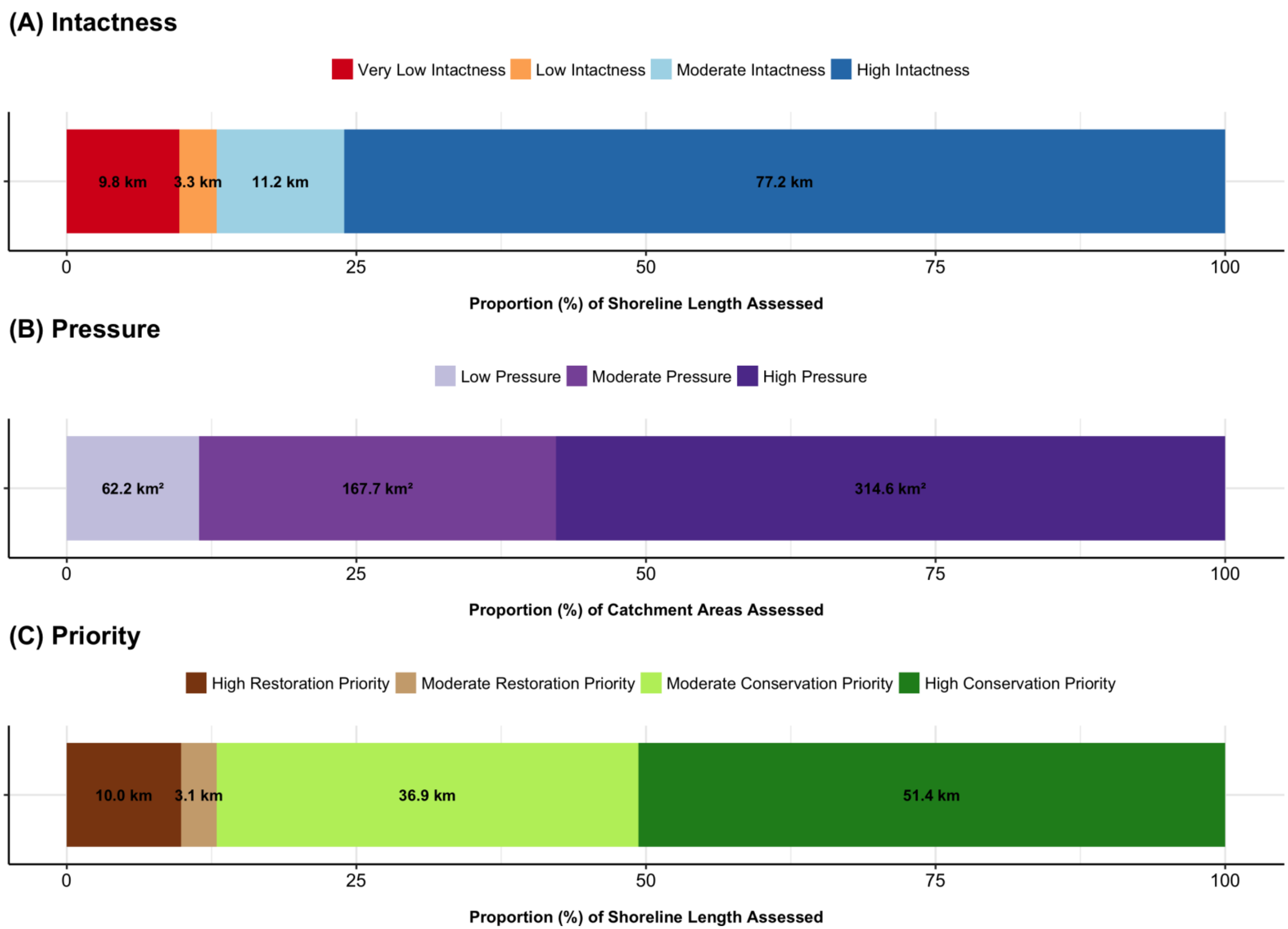


Figure 26. Summary of RMA intactness (A), pressure on riparian system function (B), and management prioritization (C) in the Wabamun Creek subwatershed.

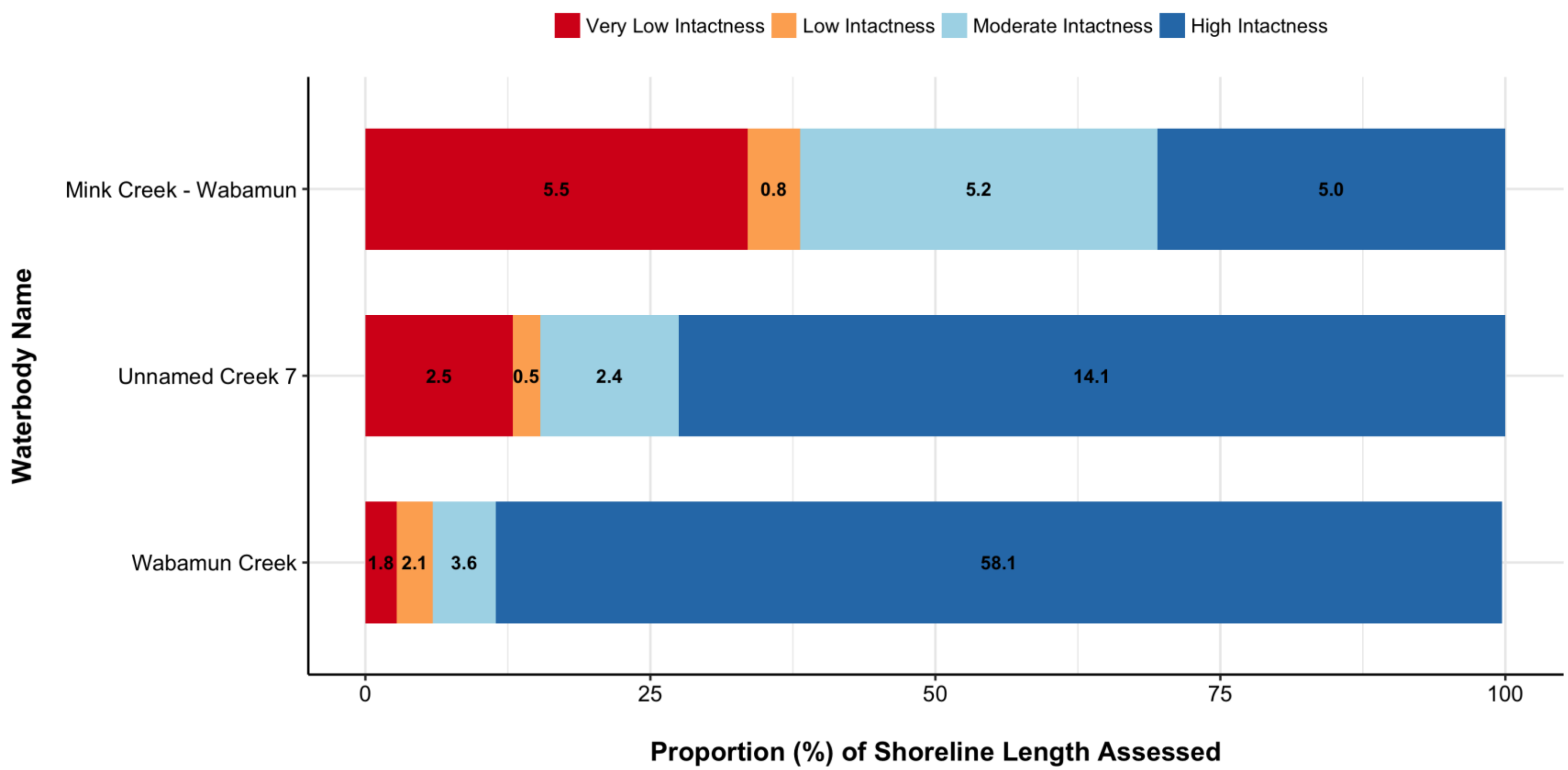


Figure 27. The proportion of shoreline length assigned to each riparian intactness category for waterbodies in the Wabamun Creek subwatershed. Numbers indicate the total length (km) of shoreline associated with each category.

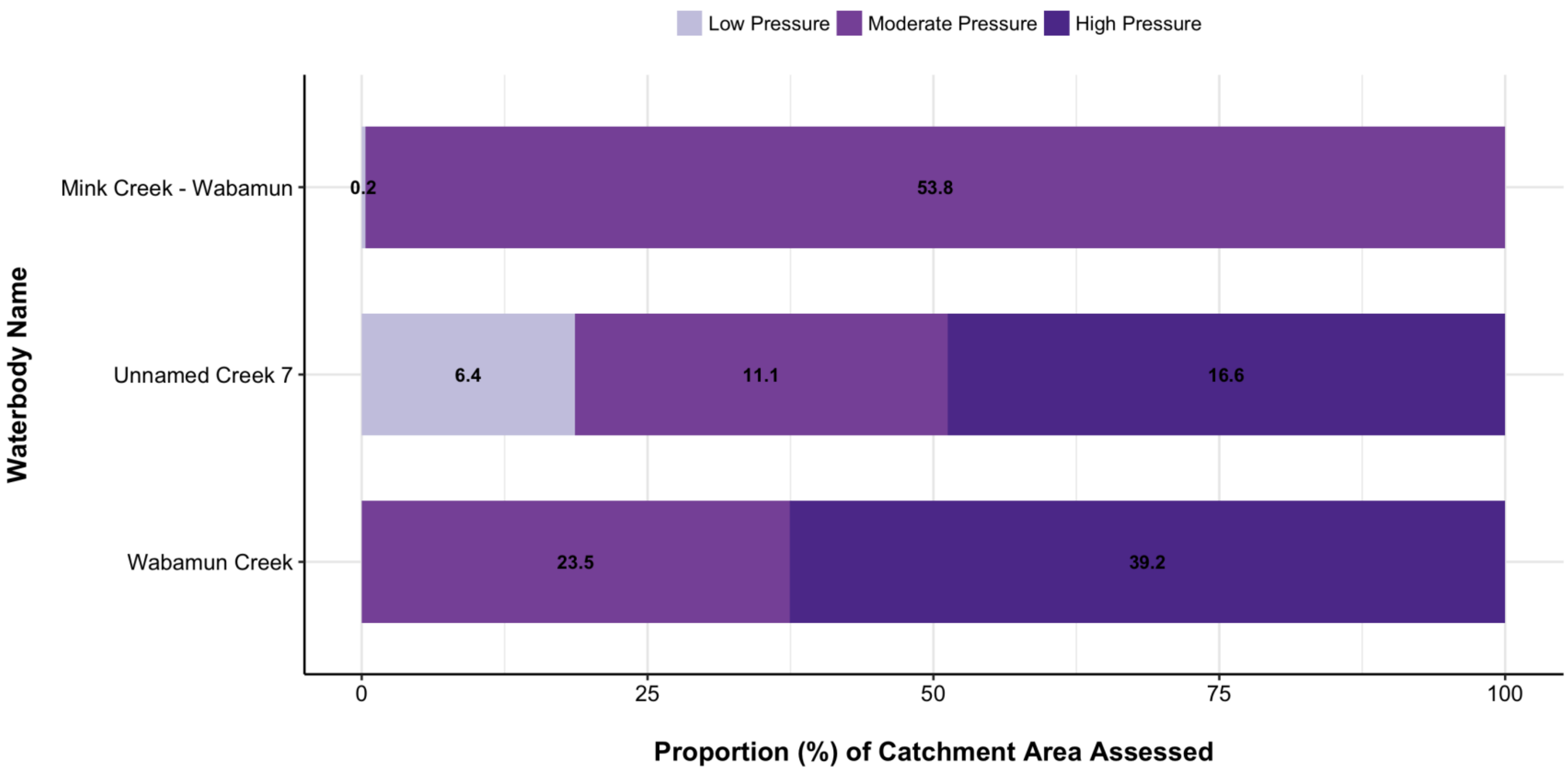


Figure 28. The proportion of catchments by pressure category that intersect RMAs associated with waterbodies in Wabamun Creek subwatershed. Numbers indicate the total area (km^2) assigned to each pressure category.

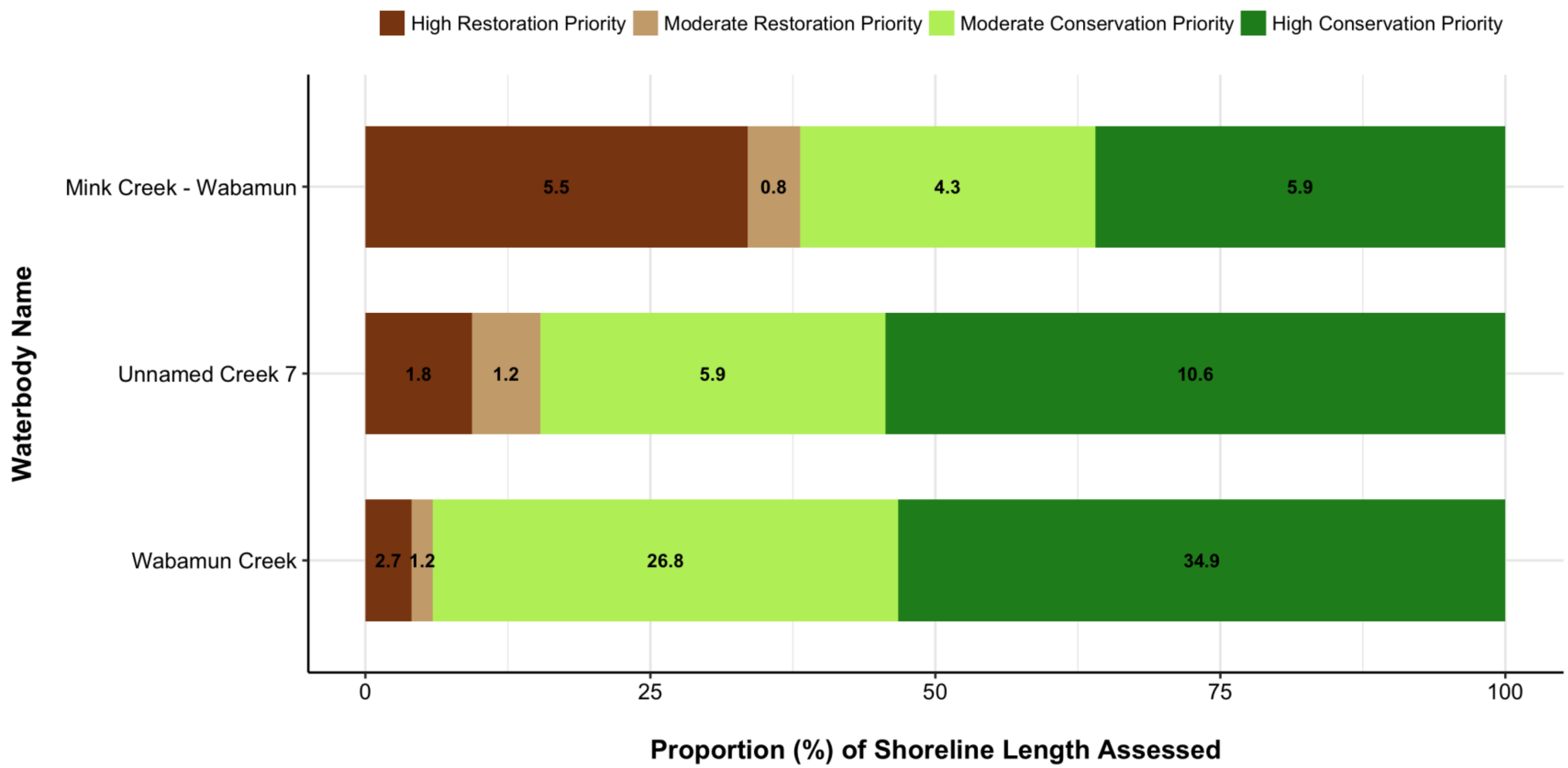
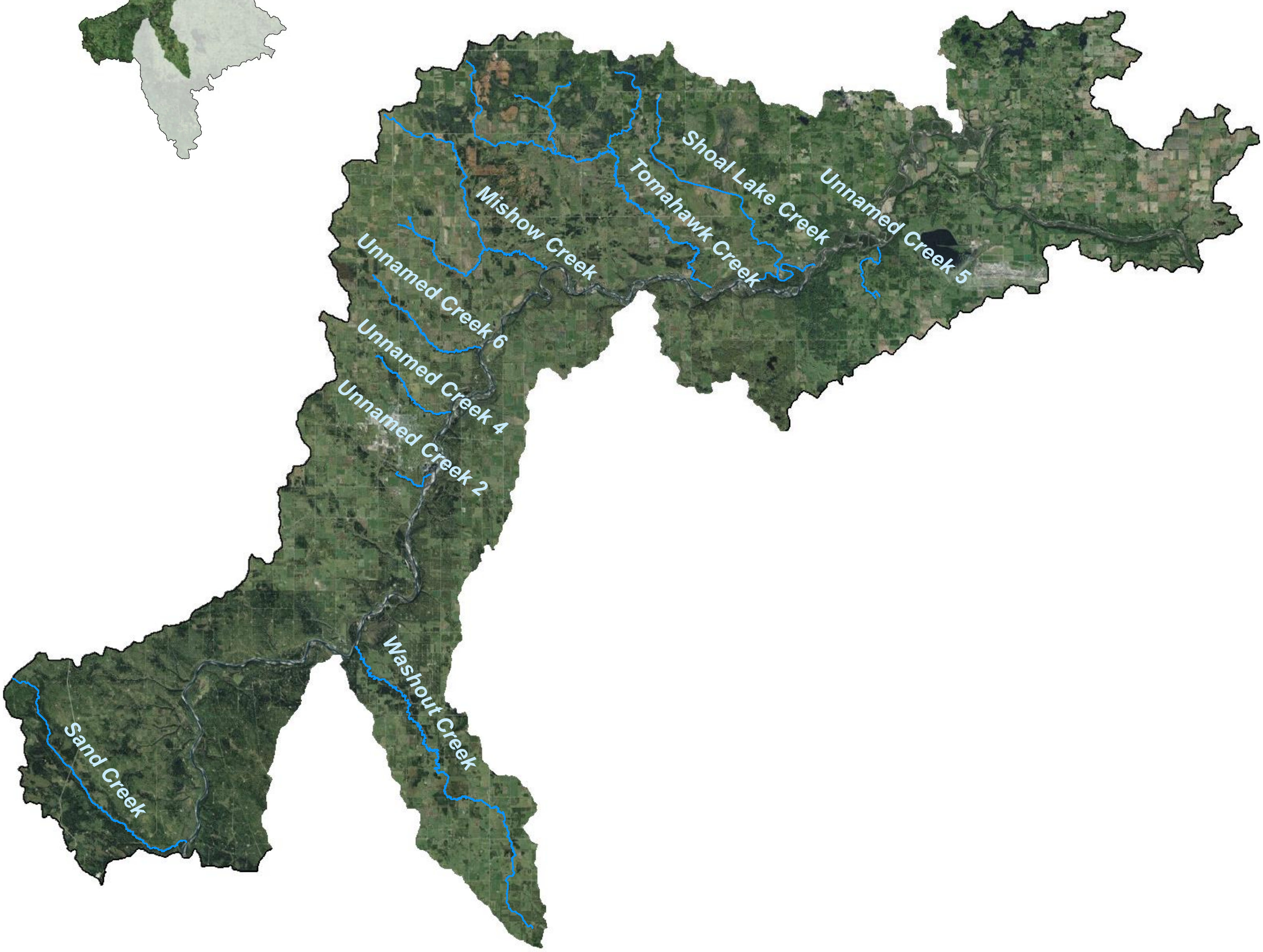


Figure 29. The proportion of shoreline length assigned to each priority category for waterbodies in Wabamun Creek subwatershed. Numbers indicate the total length (km) of shoreline associated with each priority category.

6.0 North Saskatchewan Above Wabamun Subwatershed



6.1. Summary of Results

The North Saskatchewan above Wabamun Creek subwatershed is the largest HUC 8 subwatershed in the Modeste. The riparian assessment of this subwatershed included nine waterbodies, for a total of 537 km of shoreline. The waterbodies that were assessed as part of this study included: Washout Creek, Tomahawk Creek, Shoal Lake Creek, Sand Creek, Mishow Creek and four Unnamed Creeks (2, 4, 5, and 6). The North Saskatchewan River was not included in this assessment.

Land cover in this subwatershed is roughly an even mix of natural vegetation and human-modified landscapes. The western portion of the subwatershed is dominated by forest cover (45%), while the reminder of the subwatershed is dominated by agriculture pasture (32%) and crop (9%). Urban and other highly developed areas make up 5% of the subwatershed, which includes the town of Drayton Valley and the Genesee Mine. This subwatershed overlaps with portions of all five of rural municipalities that occur in the greater Modeste watershed.

Overall, 70% the shoreline assessed was classified as High or Moderate Intactness, with 30% of the shoreline length being categorized as Low or Very Low intactness (Figure 30A). The majority of the catchment area in the subwatershed was assessed as Moderate Pressure (49%), with 31% of the catchment area being classified as High Pressure, and 20% of the catchment area classified as Low Pressure (Figure 30B).

When intactness and pressure were combined to identify areas of restoration and conservation priority, 23% of the shoreline length was classified as High Restoration Priority, with 43% of the riparian area assessed classified as High Conservation Priority (Figure 30C).

6.2. Results by Waterbody

When intactness is examined for each waterbody that was assessed in this subwatershed, Mishow Creek had the largest proportion (46%) of its shoreline length classified as Very Low or Low Intactness (Figure 31). Shoal Lake Creek, Tomahawk Creek, and Washout Creek also had over 30% of their shorelines classified as Very Low or Low Intactness. In contrast, all or nearly all of the shoreline associated with Sand Creek and Unnamed Creek 2 was classified as High Intactness, with Unnamed Creeks 4, 5, and 6 also having a large proportion (>75%) of their shoreline classified as High or Moderate Intactness.

While Unnamed Creeks 2, 4, 5, and 6 had a large proportion of their shorelines classified as High or Moderate Intactness, these creeks also had over 50% of adjacent catchments classified as High Pressure (Figure 32). In contrast, nearly all of the adjacent catchments along Sand Creek were classified as Low Pressure, with Shoal Creek having the second highest proportion of Low Pressure catchments in this subwatershed.

When intactness and pressure scores were combined to derive management priority, the majority of waterbodies in this subwatershed had a greater proportion of their shoreline identified for conservation, rather than restoration (Figure 33). For example, Sand Creek and Unnamed Creeks 2, 4, 5, and 6 had >75% of their shorelines classified as High or Moderate Conservation Priority. In contrast, Mishow Creek Shoal Lake Creek, Tomahawk Creek, and Washout Creek had over 25% of their shorelines classified as either High or Moderate Restoration Priority.

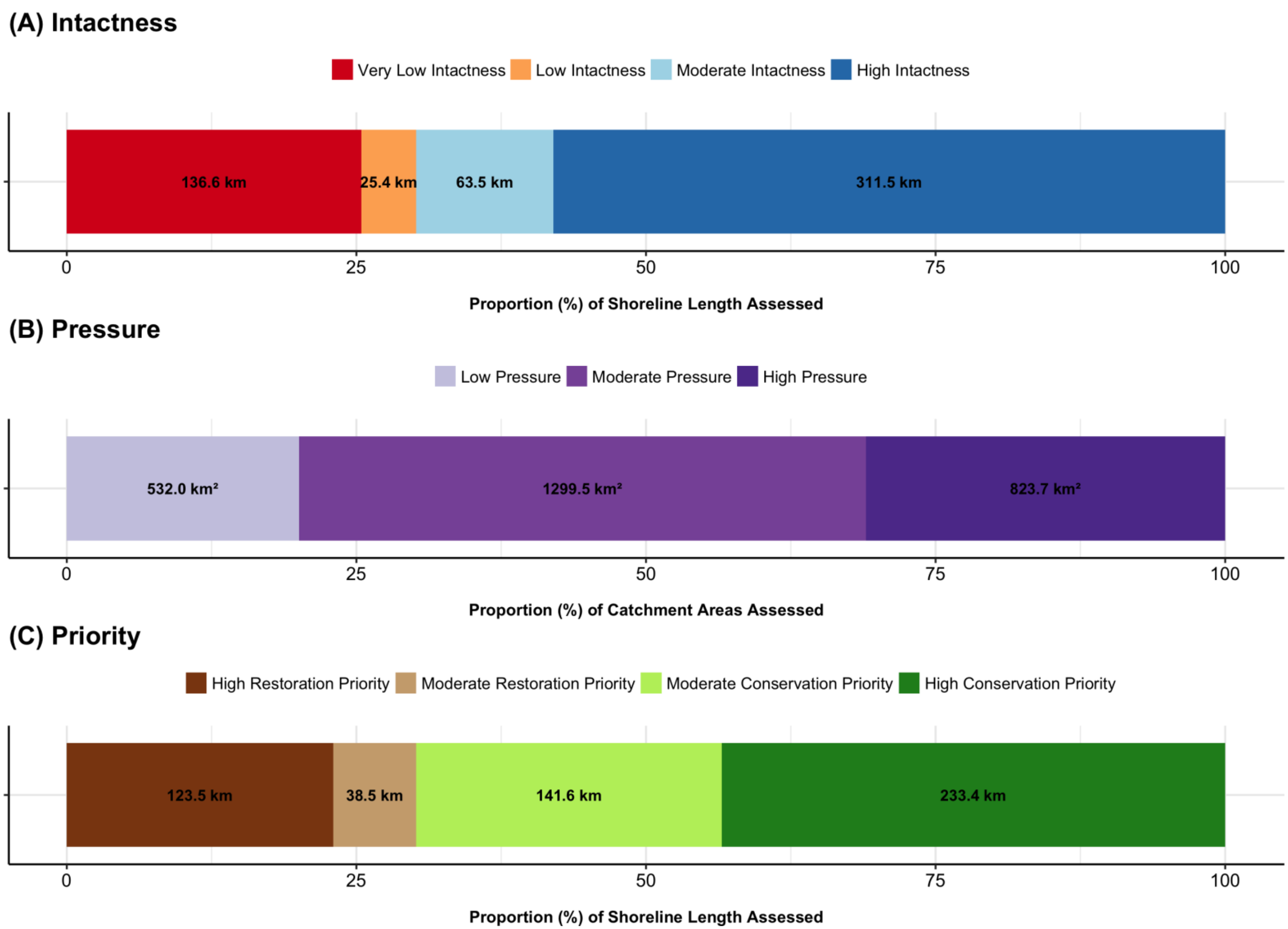


Figure 30. Summary of RMA intactness (A), pressure on riparian system function (B), and management prioritization (C) in the North Saskatchewan Above Wabamun subwatershed.

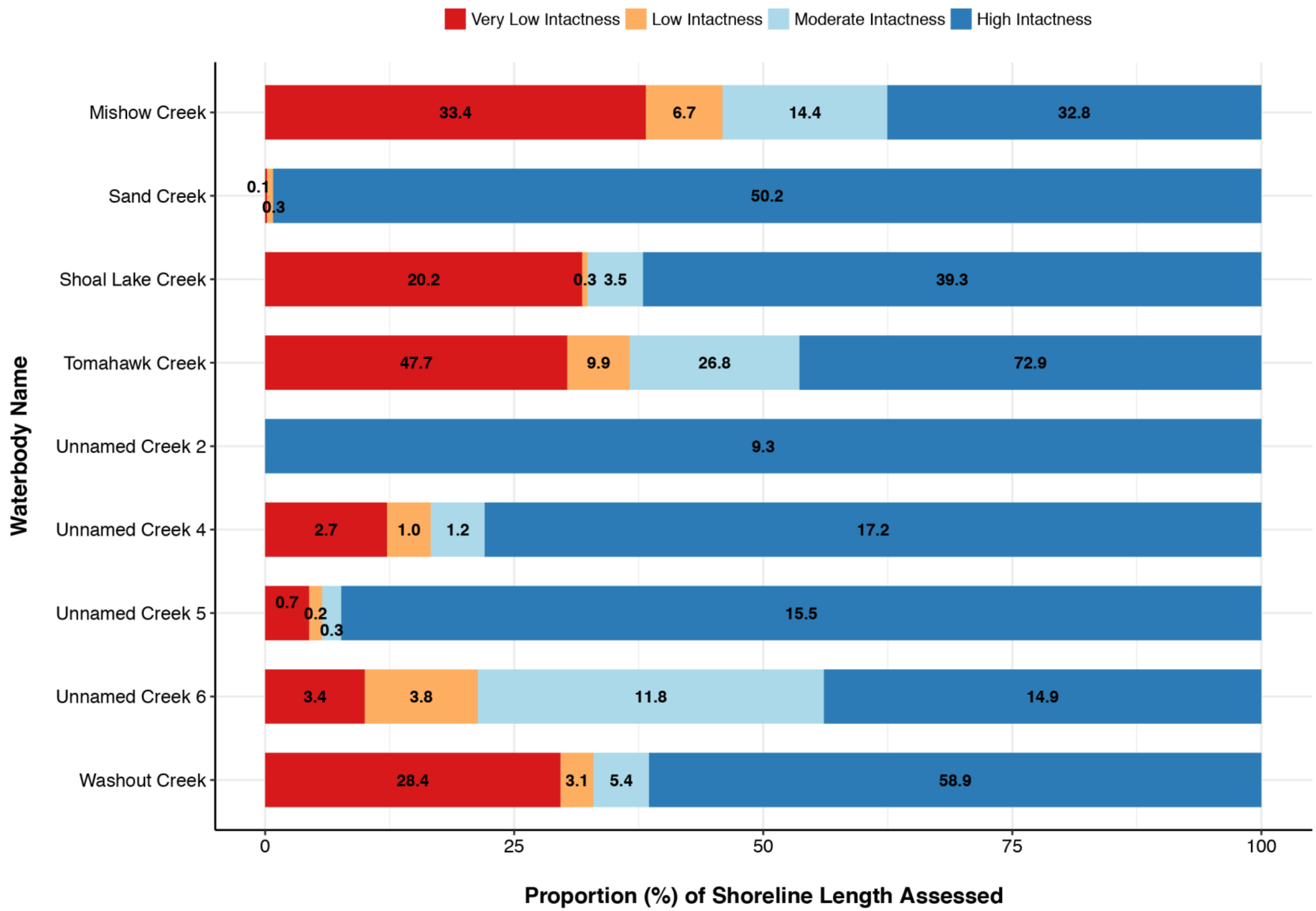


Figure 31. The proportion of shoreline length assigned to each riparian intactness category for waterbodies in the North Saskatchewan Above Wabamun subwatershed. Numbers indicate the total length (km) of shoreline associated with each category.

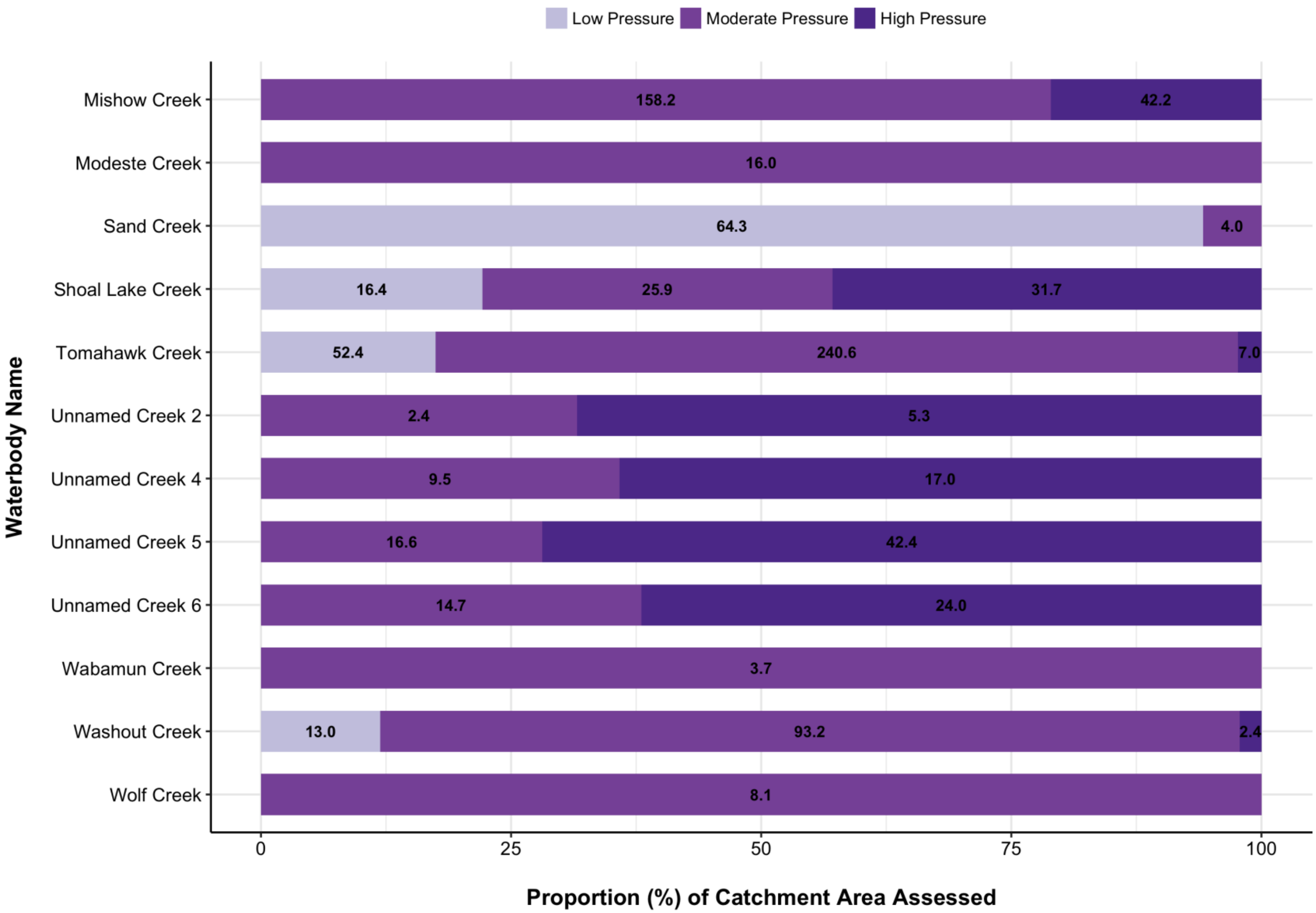


Figure 32. The proportion of catchments by pressure category that intersect RMAs associated with waterbodies in North Saskatchewan Above Wabamun subwatershed. Numbers indicate the total area (km^2) assigned to each pressure category.

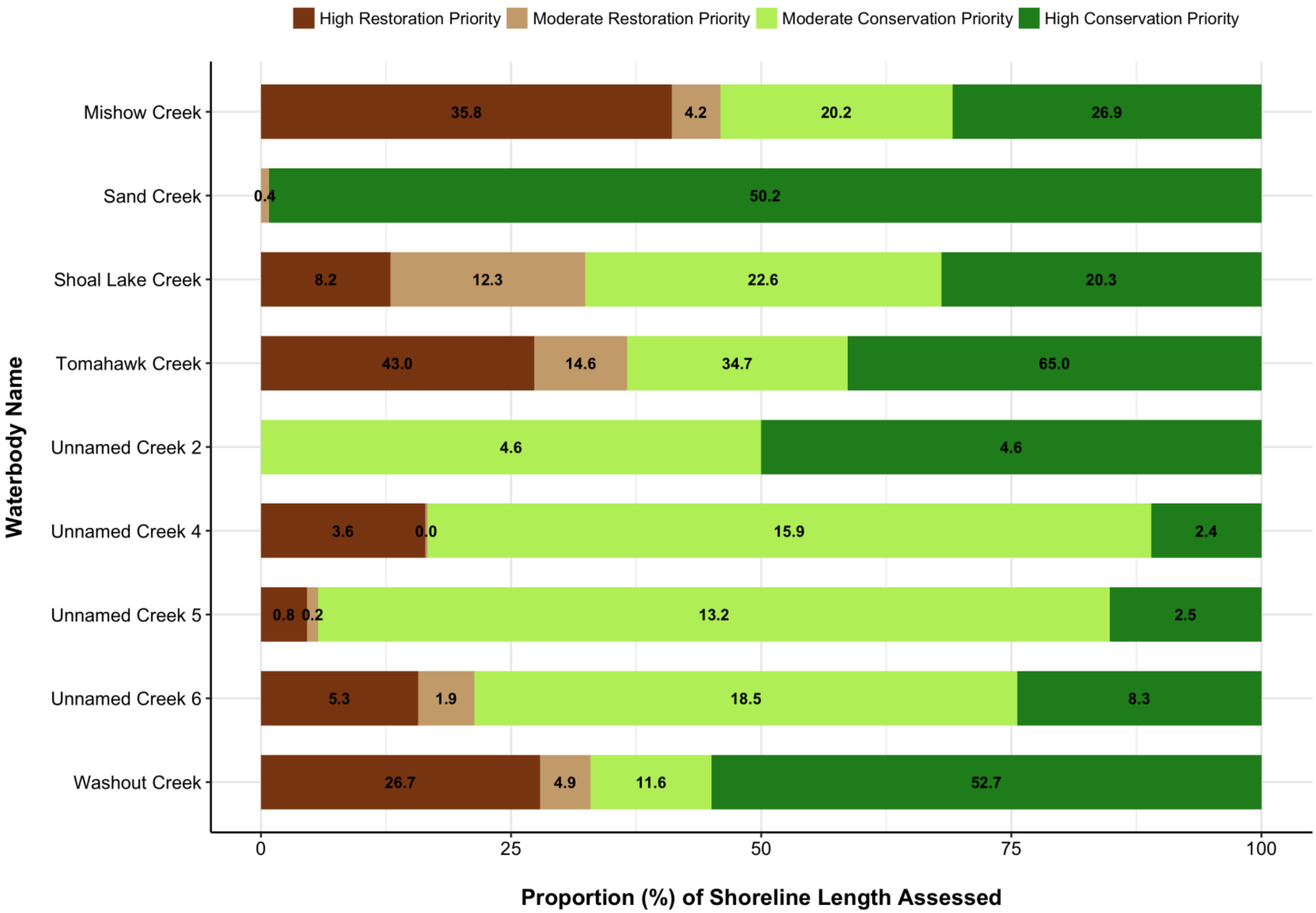
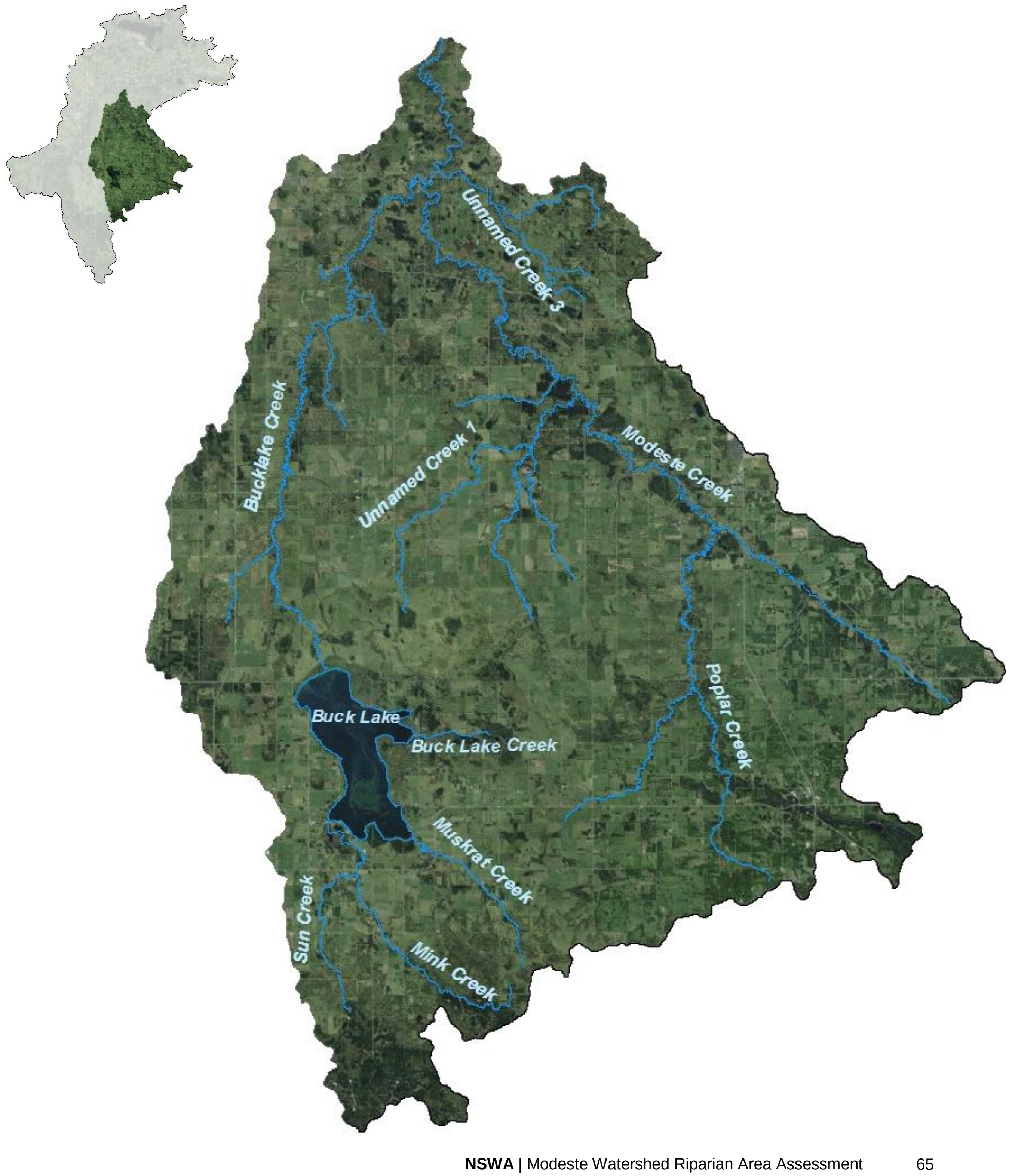


Figure 33. The proportion of shoreline length assigned to each priority category for waterbodies in North Saskatchewan Above Wabamun subwatershed. Numbers indicate the total length (km) of shoreline associated with each priority category.

7.0 Bucklake Creek Subwatershed



7.1. Summary of Results

The Bucklake Creek subwatershed is located in the east-central portion of the Modeste watershed. The riparian assessment of the Bucklake Creek watershed included 749.5 km of shoreline and 10 waterbodies: Sun Creek, Poplar Creek, Muskrat Creek, Modeste Creek, Mink Creek, Bucklake Creek, Buck Lake Creek, Unnamed Creeks 1 and 3, and Buck Lake.

This HUC 8 subwatershed has a high proportion of agricultural land cover (49%), but also has a substantial amount of natural cover in the form of forest and shrubland (39%) and water and wetlands (8%). A large proportion of this watershed falls into the County of Wetaskiwin and Brazeau County, with a very small area along the eastern edge of the watershed falling into Parkland County.

Overall, the majority (82%) of the shoreline assessed within the Bucklake Creek subwatershed was classified as either High (72%) or Moderate (10%) Intactness (Figure 34A), and the majority of the catchment area (93%) was assessed as either Moderate (67%) or High (25%) Pressure (Figure 34B).

When intactness and pressure were combined to identify areas of restoration and conservation priority, 14% of the shoreline was classified as High Priority for restoration, with 58% of the shoreline classified as High Conservation Priority (Figure 34C).

7.2. Results by Waterbody

The majority (90%) of waterbodies assessed in the Bucklake Creek subwatershed had >50% of their shoreline length classified as High Intactness; however, all of the waterbodies had at least 10% of their shorelines classified as either Very Low or Low Intactness (Figure 35). Muskrat Creek and Sun Creek had the highest proportion of their shorelines assessed as Very Low or Low Intactness, with 58% of Muskrat Creek's shoreline assessed as Very Low Intactness.

All of the waterbodies assessed in this study had ≥75% of adjacent catchments classified as Moderate or High Pressure, with three of the ten waterbodies having 25% or more of their associated catchment areas assessed as High Pressure (Figure 36). Unnamed Creek 3 had the highest proportion of High Pressure catchment area, followed by Modeste Creek. Buck Lake Creek and Buck Lake had the highest proportion of their associated catchments classified as Low Pressure.

When intactness and pressure scores were combined to derive management priority, all of the waterbodies assessed in this subwatershed had portions of their shorelines classified as High Restoration Priority (Figure 37), with six of the ten waterbodies (Buck Lake Creek, Modeste Creek, Poplar Creek, Sun Creek, and Unnamed Creek 1 and 3) having >10% of their riparian area classified as High Restoration Priority. Conversely, seven out of the ten waterbodies had >50% of their riparian areas classified as High Conservation Priority.

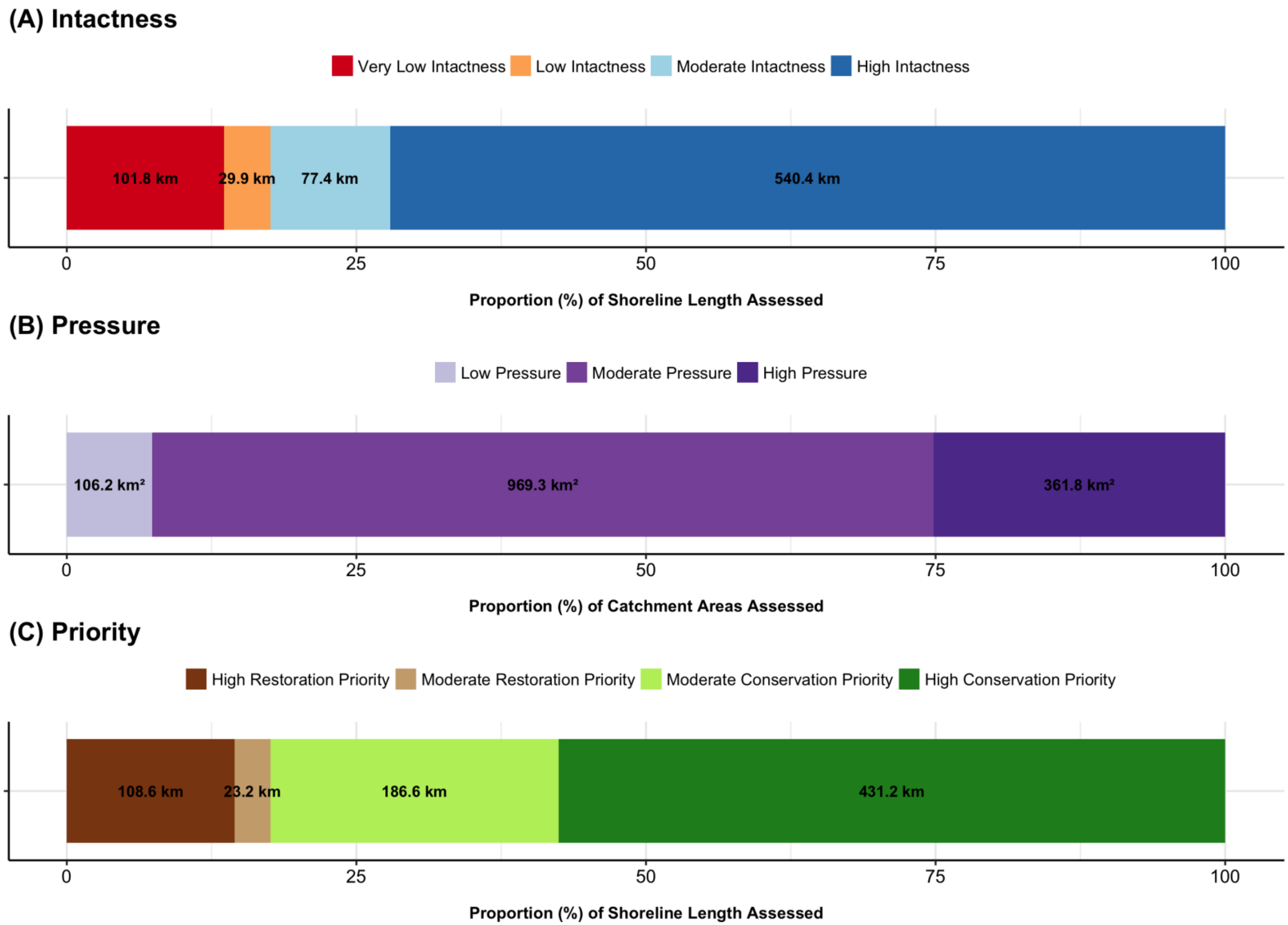


Figure 34. Summary of RMA intactness (A), pressure on riparian system function (B), and management prioritization (C) in the Bucklake Creek Watershed.

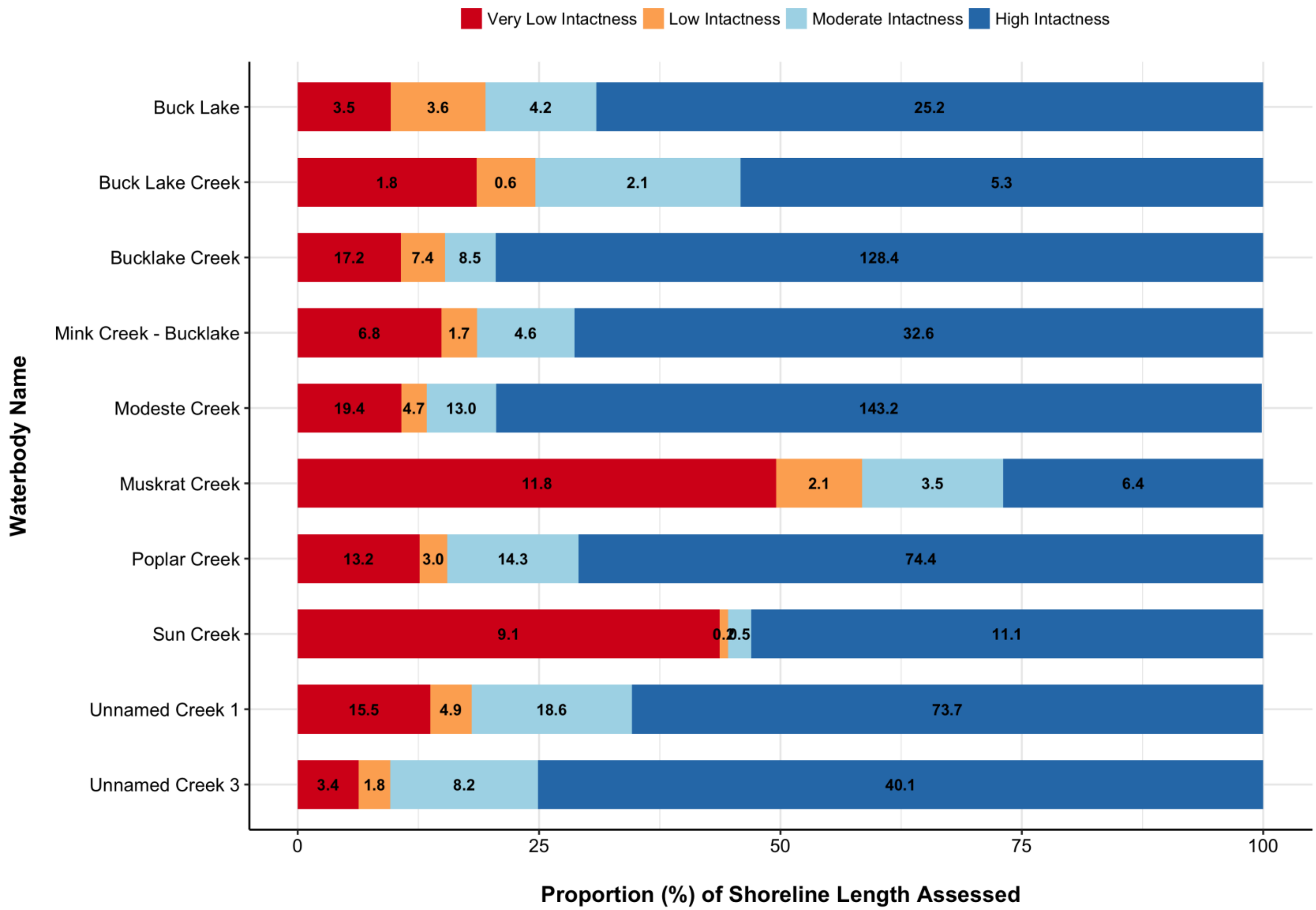


Figure 35. The proportion of shoreline length assigned to each riparian intactness category for waterbodies in the Bucklake Creek subwatershed. Numbers indicate the total length (km) of shoreline associated with each category.

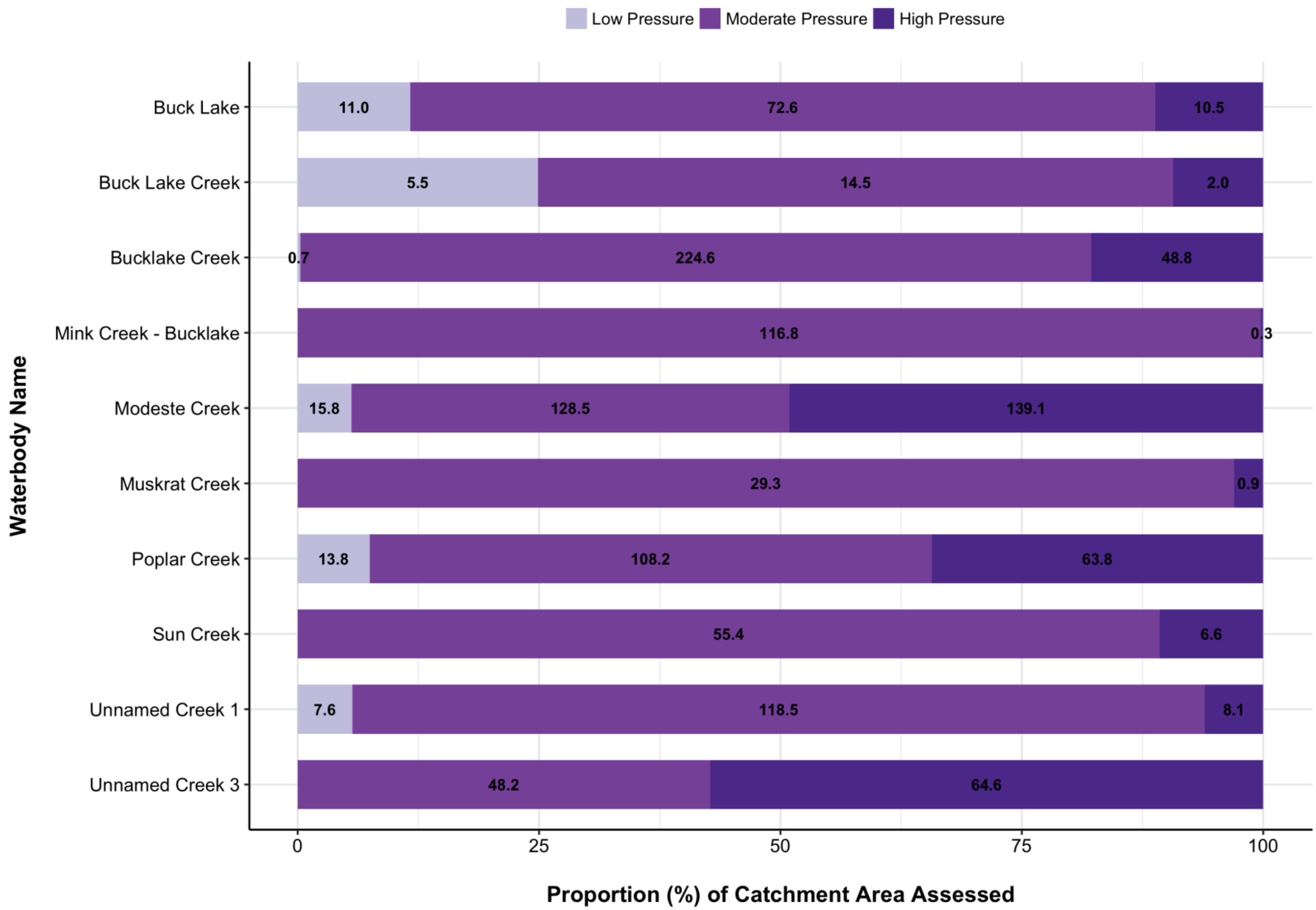


Figure 36. The proportion of catchments by pressure category that intersect RMAs associated with waterbodies in Bucklake Creek subwatershed. Numbers indicate the total area (km^2) assigned to each pressure category.

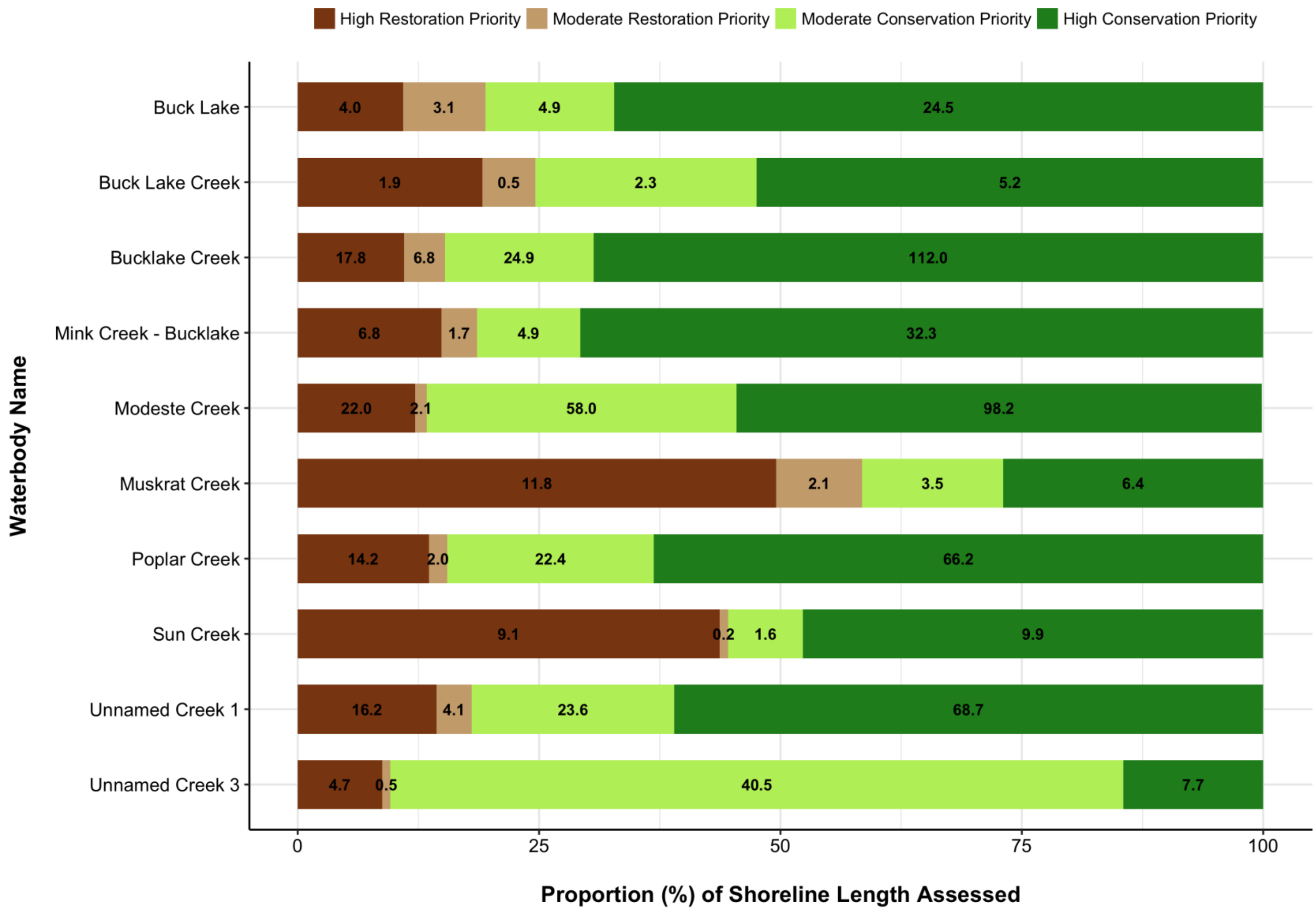
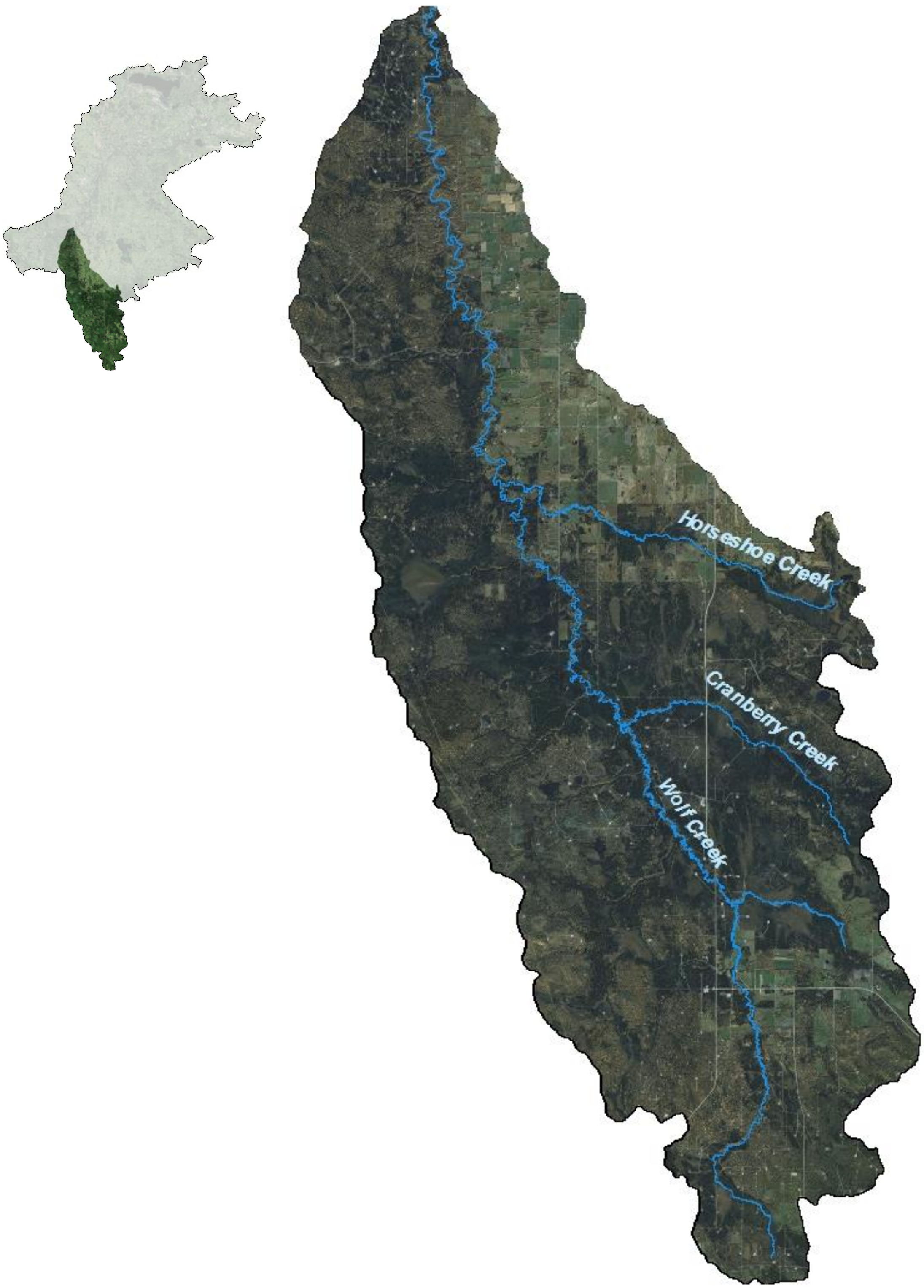


Figure 37. The proportion of shoreline length assigned to each priority category for waterbodies in Bucklake Creek subwatershed. Numbers indicate the total length (km) of shoreline associated with each priority category.

8.0 Wolf Creek Subwatershed



8.1. Summary of Results

The Wolf Creek subwatershed is located in the southern portion of the Modeste watershed. The riparian assessment of this subwatershed included 320.3 km of shoreline and three waterbodies: Wolf Creek, Horseshoe Creek, and Cranberry Creek.

The Wolf Creek watershed is dominated by natural cover, with 76% of the area covered by forest and 12% covered by open water and wetlands. Agricultural pasture is the dominant human land use type (10%) and portions of Brazeau County, Clearwater County, and the County of Wetaskiwin fall within this subwatershed.

Nearly 100% of the riparian areas assessed within this watershed were classified as either High (92%) or Moderate (5%) Intactness, with only 3% of the area assessed as Low (1%) or Very Low (2%) Intactness (Figure 38A). In terms of catchment pressure, Wolf Creek subwatershed has the highest proportion of catchment area classified as Low Pressure (60%) and the lowest proportion of catchment area classified as High Pressure (6%) of all subwatersheds in the Modeste (Figure 38B).

When intactness and pressure scores were combined to derive management priority, only 3% of the shoreline length assessed in this subwatershed has been classified as High or Moderate Restoration Priority, with 86% being classified as High Conservation Priority (Figure 38C).

8.2. Results by Waterbody

All of the waterbodies assessed in this watershed had >90% of their shoreline length classified as Moderate or High Intactness (Figure 39), with Horseshoe Creek having the largest proportion (5%) of its shoreline classified as either Low or Very Low Intactness.

Catchments classified as Low Pressure made up the majority of the area adjacent to Cranberry Creek and Horseshoe Creek (Figure 40); Wolf Creek was the only waterbody in this subwatershed that had any adjacent catchments classified as High Pressure.

Over 95% of the shoreline length assessed in the Wolf Creek subwatershed was classified as either Moderate (11%) or High (86%) Conservation Priority, with nearly the entire shoreline of Cranberry Creek being classified as High Conservation Priority (Figure 41). Wolf Creek has the highest proportion of its shoreline classified as either High or Moderate Restoration Priority.

Figure 38. Summary of RMA intactness (A), pressure on riparian system function (B), and management prioritization (C) in the Wolf Creek Watershed.

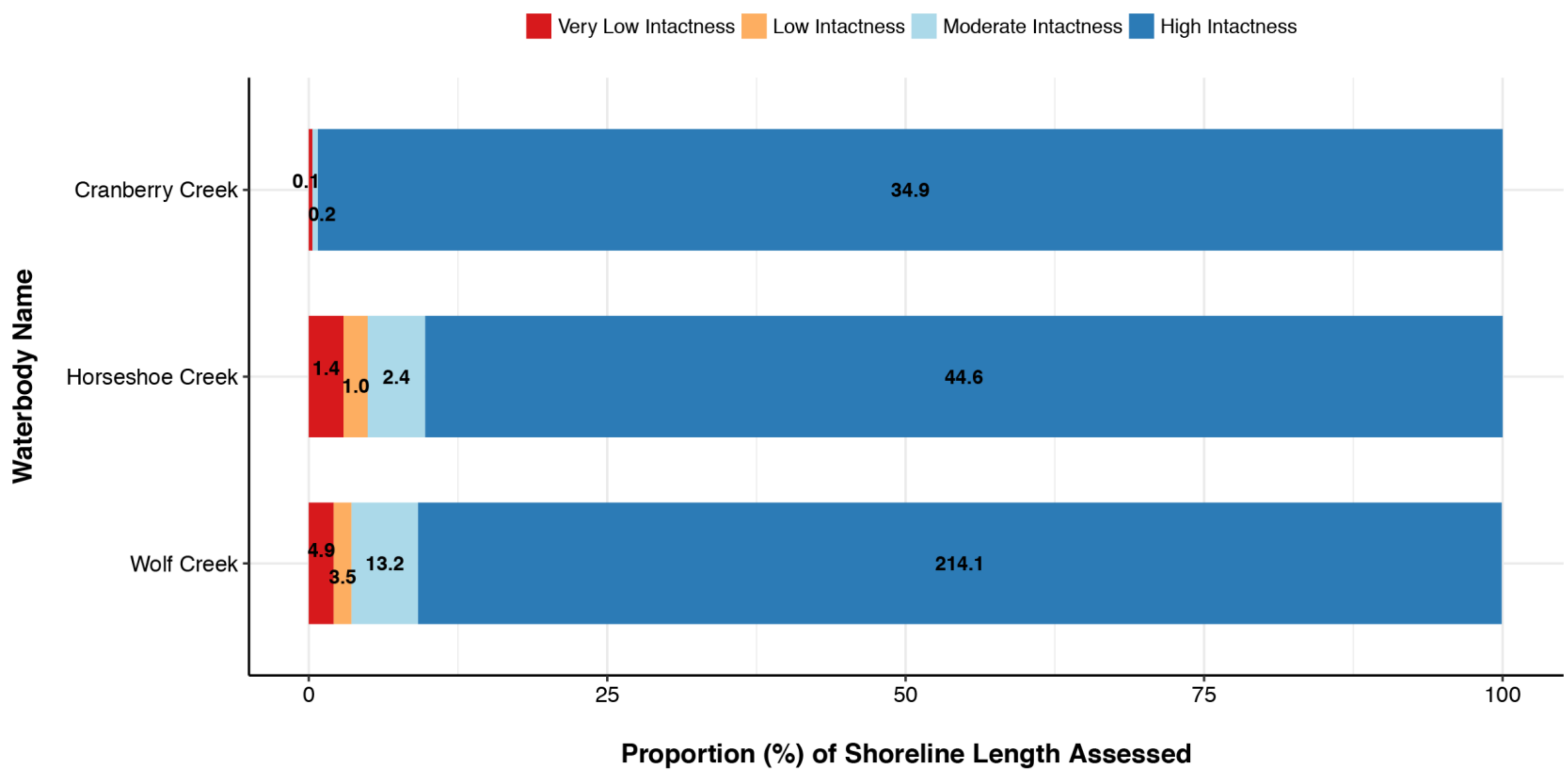


Figure 39. The proportion of shoreline length assigned to each riparian intactness category for waterbodies in the Wolf Creek subwatershed. Numbers indicate the total length (km) of shoreline associated with each category.

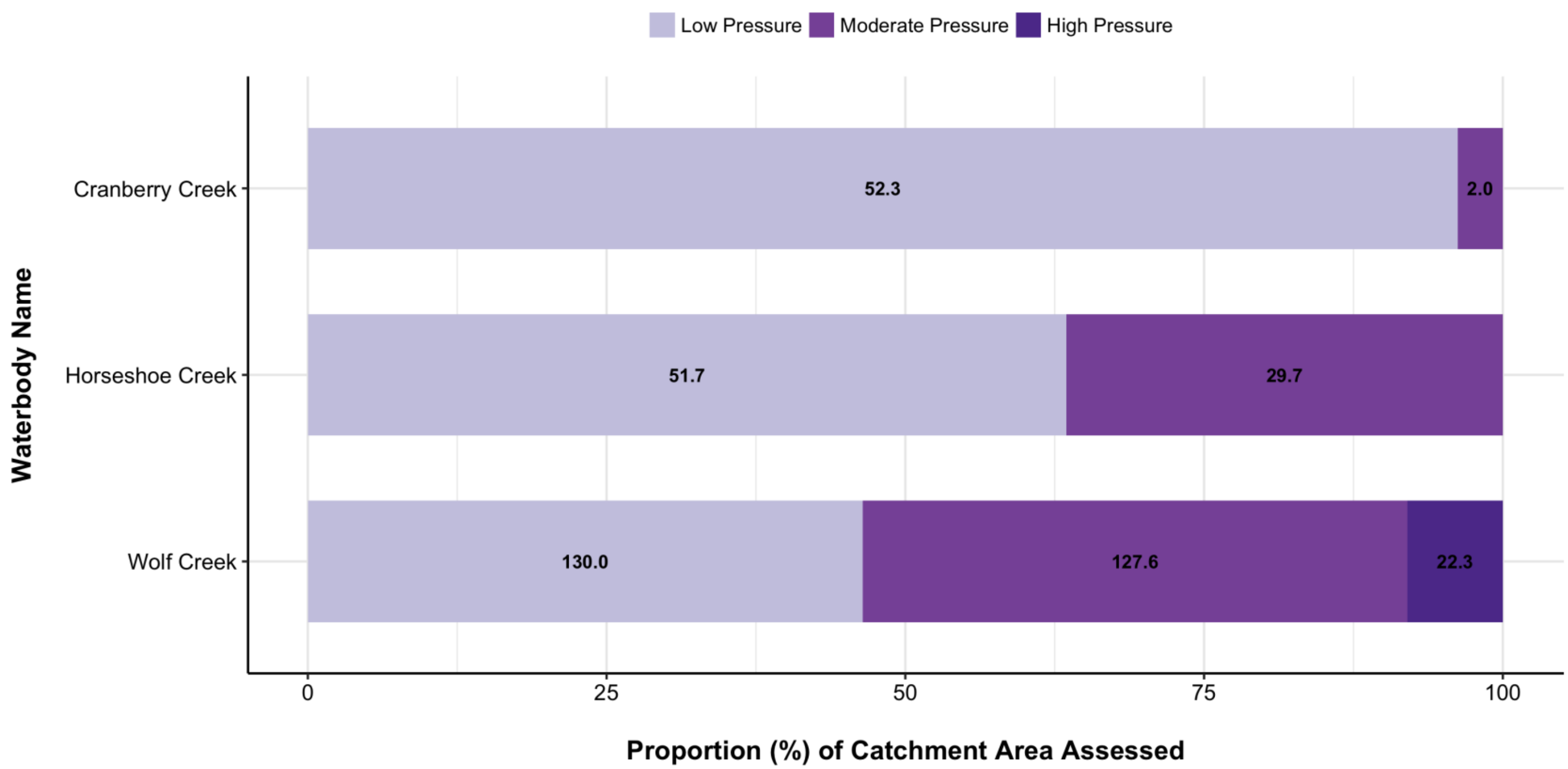


Figure 40. The proportion of catchments by pressure category that intersect RMAs associated with waterbodies in Wolf Creek subwatershed. Numbers indicate the total area (km^2) assigned to each pressure category.

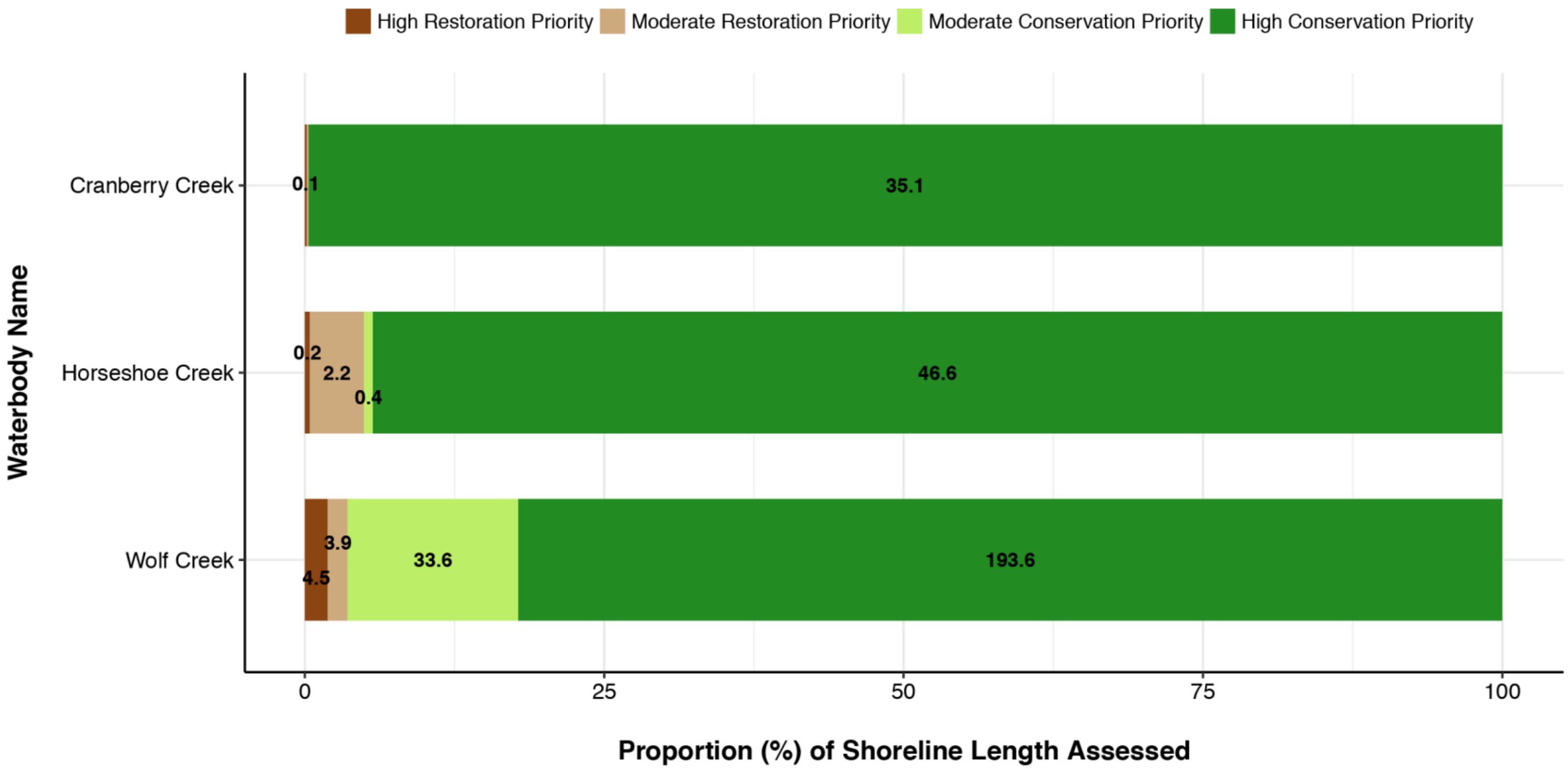


Figure 41. The proportion of shoreline length assigned to each priority category for waterbodies in Wolf Creek subwatershed. Numbers indicate the total length (km) of shoreline associated with each priority category.

9.0 Municipal Summary

In order to provide riparian assessment information that is relevant from a municipal planning and policy perspective, this section summarizes riparian intactness, pressure on riparian system function, and management prioritization by each of the major rural municipalities located within the Modeste watershed.

9.1. Intactness Results

Of the five major rural municipalities located within the Modeste watershed, Brazeau County had the greatest length of shoreline assessed as part of this study (37% or 630 km; Table 18). Additionally, the County of Wetaskiwin, Parkland County, and Clearwater County all had over 200 km of shoreline assessed, while Leduc County had only 17 km, or 1% of the total shoreline length assessed, located within its municipal boundaries.

When riparian intactness for each municipality is summarised as a proportion of the total area assessed within the Modeste watershed, the data indicate that the largest proportion of shoreline classified as High Intactness was located in Brazeau County (28%), followed by County of Wetaskiwin (18%) and Clearwater County (13%; Table 18). Brazeau County and County of Wetaskiwin also had the greatest proportion of shoreline classified as Moderate Intactness. Conversely, Parkland County had the largest proportion riparian areas within the Modeste watershed classified as Very Low (6%), followed closely by County of Wetaskiwin (5%), while Parkland County and County of Wetaskiwin had the highest proportion of shoreline classified as Low Intactness (Table 18).

When riparian intactness is summarized as a proportion of the total length of shoreline assessed within each municipality (Figure 42; Table 19), Clearwater County had the highest proportion classified as High Intactness (95%; 227.2 km), followed by Leduc County (92%; 15.4 km). Conversely, 31% of the shoreline assessed in Parkland County was classified as Very Low (27%, 97.8 km) or Low (4%, 15.4 km) Intactness. At 24%, the County of Wetaskiwin had the second highest combined proportion of shoreline assessed as Very Low (20%; 92.1 km) and Low (4%, 20.0 km).

When the total length of shoreline is considered, Brazeau County had the greatest length assessed as High Intactness (476.9 km), followed by County of Wetaskiwin (300.9 km) (Figure 42). Parkland County has the greatest number of kilometers assessed as Very Low Intactness (97.8 km), followed by County of Wetaskiwin (92.1 km).

Table 18. The proportion of shoreline assigned to each intactness category by municipality, summarized by the percentage of the total length of shoreline assessed within the Modeste watershed.

Municipality	Total Length Assessed (%)	Proportion (%) of Shoreline By Intactness Category			
		Very Low Intactness	Low Intactness	Moderate Intactness	High Intactness
Brazeau County	36.9	3.6	1.5	3.9	27.9
Clearwater County	14.0	0.2	0.1	0.4	13.3
County of Wetaskiwin	26.8	5.4	1.2	2.6	17.6
Leduc County	1.0	0.04	0.01	0.02	0.9
Parkland County	21.3	5.7	0.9	2.8	11.8
Modeste Total (%)	**100**	**14.9**	**3.7**	**9.8**	**71.6**

Table 19. The proportion of shoreline assigned to each intactness category by municipality, summarized as a percentage of the total amount assessed within each municipality.

Municipality	Proportion (%) of Shoreline By Intactness Category			
	Very Low Intactness	Low Intactness	Moderate Intactness	High Intactness
Brazeau County	9.6	4.1	10.6	75.7
Clearwater County	1.4	0.8	3	94.8
County of Wetaskiwin	20.1	4.4	9.8	65.7
Leduc County	4.4	1.3	1.9	92.3
Parkland County	26.9	4.2	13.4	55.5

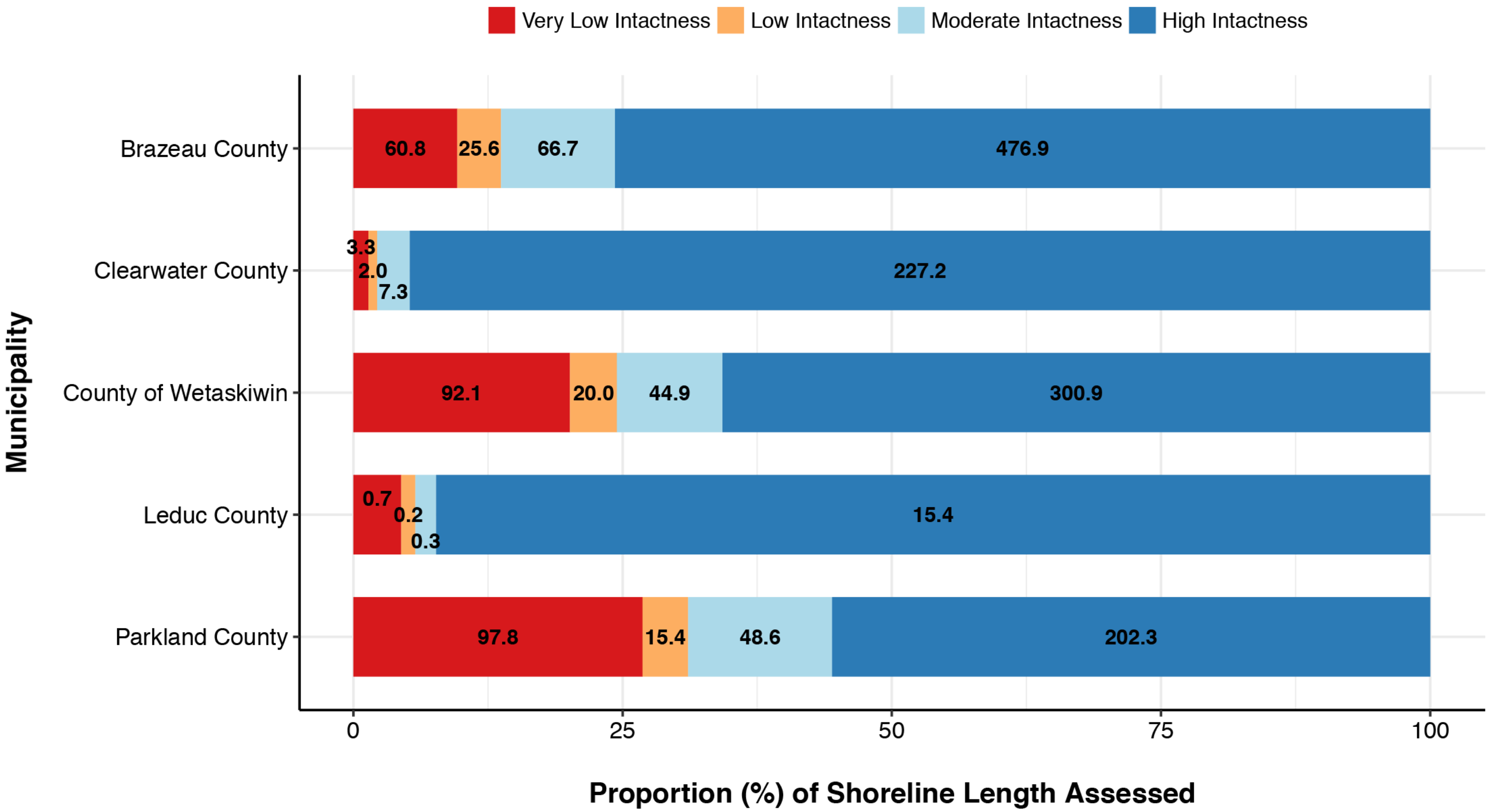


Figure 42. The proportion of shoreline length assigned to each riparian intactness category, summarized by the total length of shoreline assessed within each municipality. Numbers indicate the total length (km) of shoreline associated with each category.

9.2. Pressure on Riparian System Function Results

The Counties of Brazeau, Parkland, and Wetaskiwin all had over 1,000 km^2 of local catchment area associated with the shorelines assessed as part of this study (Table 20; Figure 43). Overall, the pressure within local catchments was relatively high, with Leduc, Parkland, and Brazeau all having >25% of local catchments classified as High Pressure. When Moderate and High Pressure categories are considered together, Brazeau, Wetaskiwin, Leduc and Parkland all had >75% of local catchments classified into one of these two categories. In contrast, Clearwater County had nearly 70% of local catchments classified as Low Pressure, with Brazeau County having the second highest proportion (18%) of Low Pressure catchments.

Table 20. Total area of local catchments assigned to each pressure category. Numbers in brackets indicate the proportion of area assigned to each category.

Municipality	**Number of Catchments**	**Total Area (km^2)**	**Catchment Area (km^2) within each Pressure Category**		
			Low	**Moderate**	**High**
Brazeau County	284	1,692.8	309.3 (18)	915.9 (54)	467.7 (28)
Clearwater County	156	770.9	535.7 (69)	202.8 (26)	32.4 (4)
County of Wetaskiwin	226	1,171.7	174.8 (15)	804. 5 (69)	192.4 (16)
Leduc County	60	358.2	4.3 (1)	140.8 (39)	213.1 (60)
Parkland County	246	1,495.7	203.8 (14)	701.9 (47)	590.0 (39)
Total:	972	5,489.3	1,227.8 (22)	2,766.0 (50)	1,495.5 (27)

*Local catchment boundaries do not align perfectly with municipal boundaries; therefore, some catchments were included and summarized for more than one municipality.

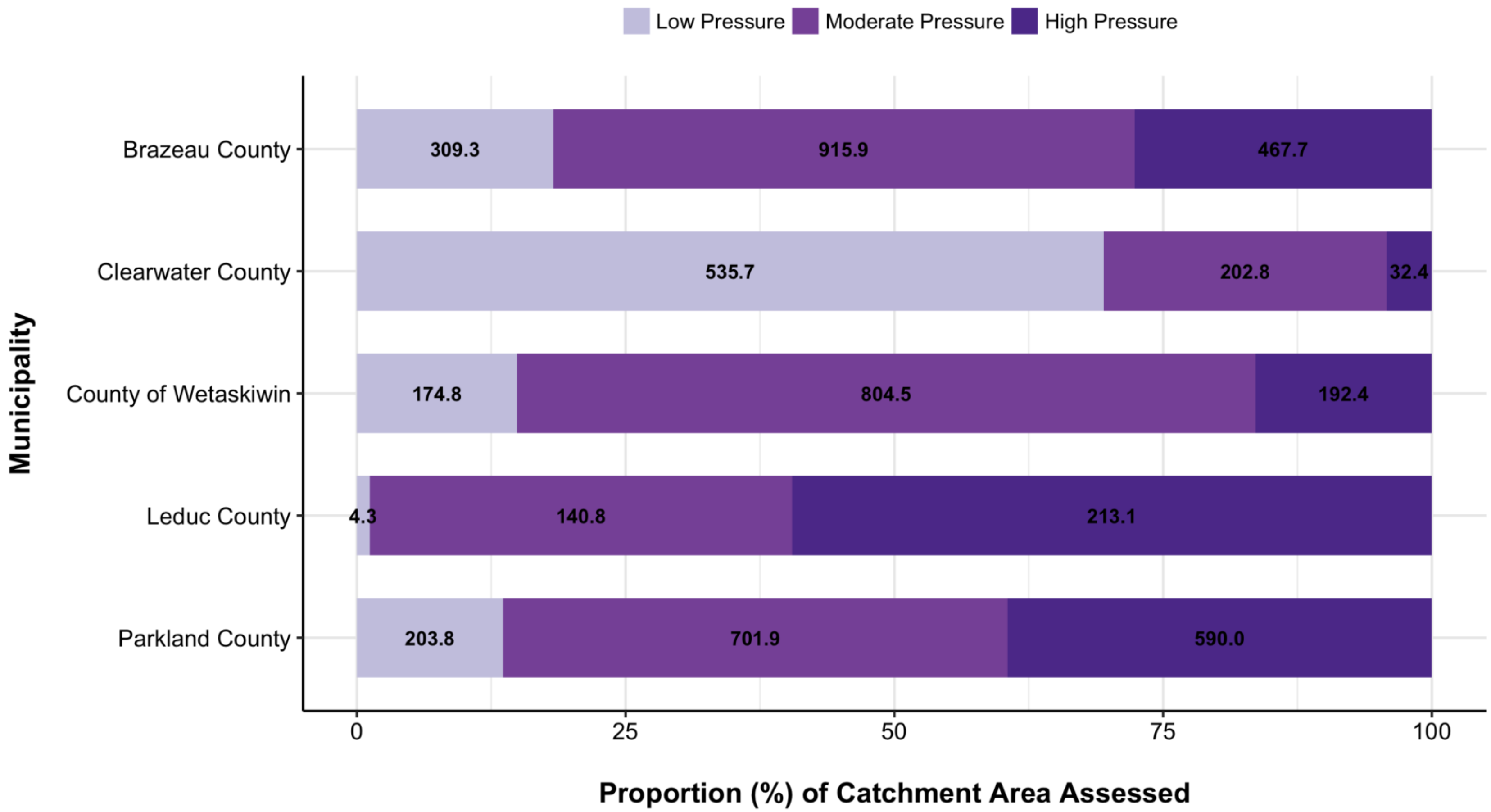


Figure 43. The proportion of shoreline length assigned to each riparian intactness category, summarized by municipality. Numbers indicate total area (km^2) by category.

9.3. Conservation & Restoration Prioritization Results

When summarized by total length of shoreline, Brazeau County had the greatest amount of shoreline classified as High (351.9 km) and Moderate Conservation Priority (191.7 km), with the County of Wetaskiwin (90.4 km) and Parkland County (81.4 km) having the greatest length of shoreline classified as High Priority for Restoration (Table 21; Figure 44).

When the proportion of shoreline assigned to each prioritization category is examined, all counties have a greater proportion of their shorelines identified as priority for conservation, rather than restoration (Figure 44). The counties of Clearwater, Wetaskiwin, and Brazeau all have >50% of their shorelines assessed as High Conservation Priority, while Leduc, Clearwater, Brazeau, and Wetaskiwin all have 75% or more of their shorelines assigned to the Moderate or High Conservation Priority category. Parkland County and County of Wetaskiwin have the highest proportion of their shorelines classified as either High or Moderate Restoration Priority.

Table 21. Total length of shoreline assigned to each prioritization category, summarized by municipality. Numbers in brackets indicate the total proportion assigned to each category.

Municipality	Total Length (km)	Length (km) of Shoreline within each Intactness Category			
		High Restoration Priority	Moderate Restoration Priority	Moderate Conservation Priority	High Conservation Priority
Brazeau County	629.9	70.5 (11)	15.8 (3)	191.7 (30)	351.9 (56)
Clearwater County	239.7	3.7 (2)	1.6 (1)	24.8 (10)	209.7 (87)
County of Wetaskiwin	457.8	90.4 (20)	21.7 (5)	67.4 (15)	278.3 (61)
Leduc County	16.7	0. 8 (5)	0.2 (1)	13.2 (79)	2.5 (15)
Parkland County	364.2	81.4 (22)	31.8 (9)	102.0 (28)	149.0 (41)
Total:	1708.3	246.8 (14)	71.0 (4)	399.0 (23)	991.4 (58)

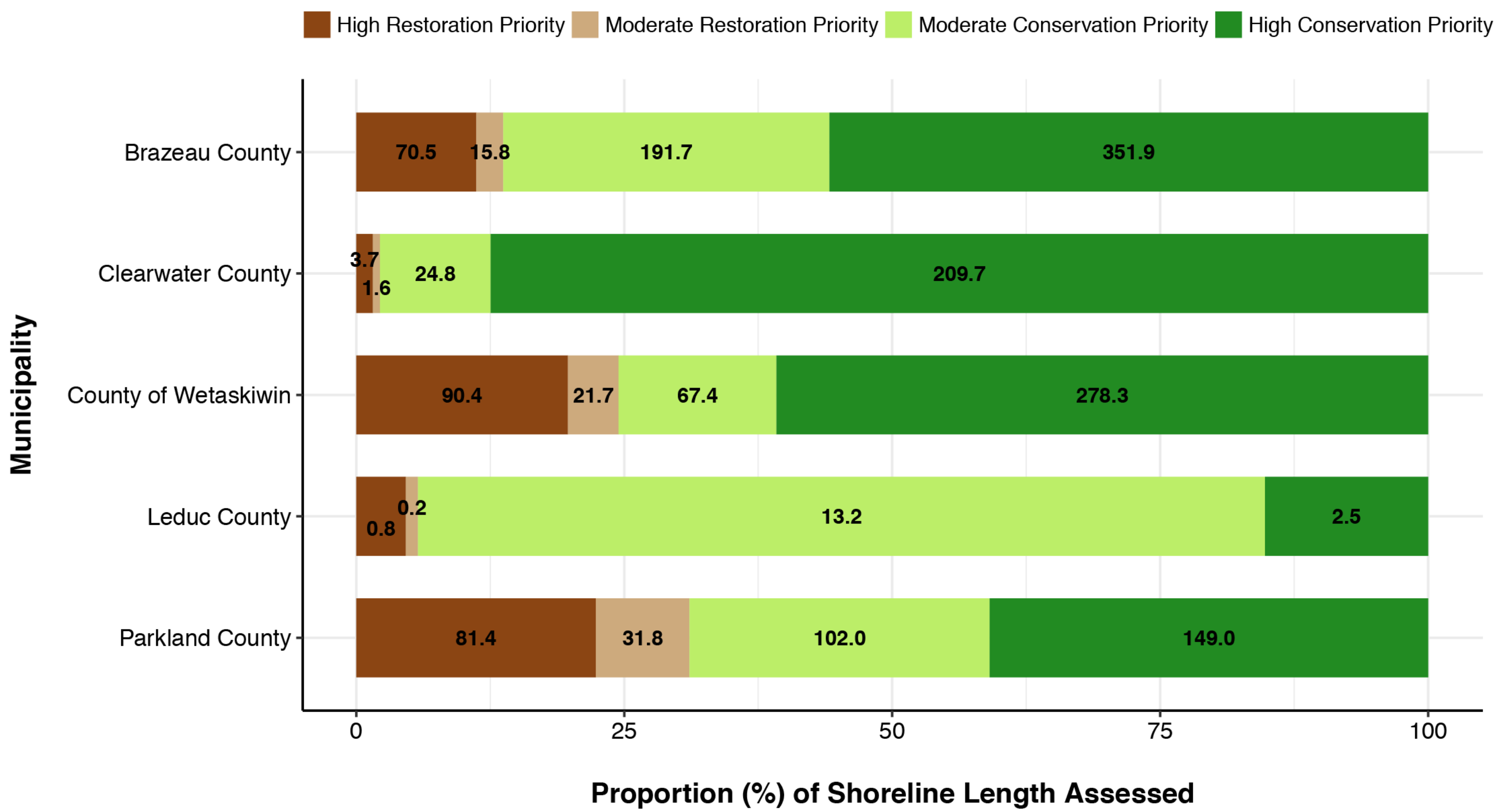


Figure 44. The proportion of shoreline length assigned to each priority category, summarized by municipality. Numbers indicate the total length (km) of shoreline associated with each category.

10.0 Creating a Riparian Habitat Management Framework

Foundational to any conservation planning exercise is the collection and generation of scientific information that can be used as the basis for the development and implementation of an evidence-based adaptive management framework. Through the commissioning of this study, the NSWA and its stakeholders now have an important foundation of scientific evidence upon which to build a systematic and adaptive framework for riparian habitat management in the Modeste watershed.

Importantly, the next step in the advancement of meaningful riparian management and conservation in the Modeste watershed will be to formalize a framework for action that includes a consideration of the current conditions (baseline) and defining achievable outcomes and measurable targets, which can then be used to inform relevant collective action by key stakeholders. These actions can then be monitored on a regular basis to provide an evaluation of outcomes that feed into an adaptive and reflexive approach to riparian management through time.

Central to the goal of improving riparian habitat management and conservation outcomes in the Modeste watershed is the development of a framework with specific objectives for riparian land management. Importantly, objectives may address different types of goals, such as environmental (e.g., % targets of intact riparian area), social (e.g., % increase in awareness or workshops), and programmatic (e.g., development of municipal policy or application of BMPs). Each defined objective should also have specific measures, targets, and actions that are developed to ensure that the associated objective is achievable, and success towards achieving each objective can be measured. A definition for each of the key building blocks for the development of a riparian management framework for the Modeste watershed is provided below:

Objective: High-level statements of desired future conditions (outcomes).

Measure: Specific metrics that can be quantified to assess the progress towards, and the degree to which, desired future conditions have been achieved.

Target: Values of measurable items (metrics) that indicate the attainment of a desired condition. In the current context these may be expressed as a single value or as a range to acknowledge the inherent variability of ecosystems.

Action: Management actions, plans, or policies for achieving stated objectives.

While the development of a riparian management framework and associated objectives for the Modeste watershed should be undertaken collectively by key stakeholders, below we provide a number of key management recommendations that we feel should be considered in the development of any riparian habitat action plan.

10.1. Key Recommendations

The development of management objectives must consider ecological, social, and economic factors, and must acknowledge that maintaining functional and resilient ecological and hydrological systems is fundamental to maintaining healthy and vibrant human communities and economies.

Below we outline what we consider to be important riparian management objectives for the Modeste watershed, and offer consideration and suggestions for the selection of measures and targets for each objective. We also offer a list of high-level actions for each objective; further discussion about potential actions that can be undertaken to improve riparian habitat management is provided in Section 11.

Note that this list of management objectives is not exhaustive, and there may be other important riparian habitat management objectives defined by stakeholders in the watershed.

Objective 1:

- Conserve high quality riparian habitat.

Measure:

- Proportion (%) of riparian management areas assessed as Moderate and/or High Intactness.

This objective can include a measure of conservation at multiple and nested spatial extents. For example, a target for conservation of high quality riparian habitat can be developed for the Modeste watershed as a whole, and can also include measures and targets for riparian habitat conservation at the scale of the HUC 8 subwatershed, municipality, and/or individual stream.

Further, measures for riparian habitat conservation may also be specific to the type (order) and the location (e.g., headwaters) of the stream. For example, riparian vegetation provides proportionately greater benefits to stream aquatic habitat along the headwaters of streams specifically as it relates to the regulation of temperature, flow, and sediment regimes. Thus, there may be a desire to preferentially target riparian habitat along headwater streams for conservation. Alternatively, retention of riparian habitats along higher order streams could be prioritized in areas where habitat connectivity is a primary objective to support biodiversity conservation.

Targets:

There is no universally accepted scientific target for the total amount of riparian habitat that should be maintained within a watershed; however, there is scientific consensus that the higher the quality and the greater the amount of riparian habitat that is maintained on the landscape, the better the outcomes for biodiversity, water quality, and water quantity. Further, there is no universal consensus on the width of vegetation along streams that should be maintained; however, there is general scientific agreement that factors such as the size (order) of the stream, the steepness of the banks, and the specific management concerns of the local system (e.g., soils, type of adjacent land use and land cover) should all be factors considered when determining the amount (width) of vegetation retained adjacent to a stream. For example, Environment and Climate Change Canada suggests as a riparian management guideline that 75% of a stream's length should be naturally vegetated, and that both sides of a stream should have a minimum 30-meter-wide naturally vegetated zone, while also acknowledging that wider buffers may be appropriate in some circumstances (Environment Canada 2013).

Results from this study provide an important baseline that can be used to inform the selection of targets for this objective, as well as to measure improvement and progress towards achieving set targets. For example, currently, 10% of the shoreline assessed in the Modeste watershed has been classified as Moderate Intactness, with an additional 72% classified as High Intactness, for a combined total of 82% (Table 22). A target for this objective could include specifying an individual target for the desired amount of Moderate and High Intactness habitat separately, (e.g., ≥25% Moderate and ≥75% High), or as a combined target (e.g., ≥75% Moderate + High). In addition, or as an alternative, overall targets for this objective can be set for each HUC 8 subwatershed and/or for each municipality.

Once watershed or municipal targets have been set, finer scale spatial targets can be set for individual streams. For example, riparian habitat along streams in the headwaters of the Modeste and/or each HUC 8 could be prioritized for conservation, or as an alternative, riparian areas along streams with important ecological values, such as threatened fisheries, could be prioritized for conservation. Alternatively, a target such as having ≥75% of each stream's shoreline classified as High Intactness could be applied to all streams in the watershed (Environment Canada 2014). If such a target were to be adopted, data from this study suggests that 48% of the streams assessed in the Modeste already meet or exceed this target (Table 23).

Actions:

There are a number of actions that could be taken to achieve conservation targets specified under this objective, including (but not limited to):

- Incentivize voluntary conservation of riparian habitat on private land through payment for ecosystem services, changes to tax regimes, or other BMP programs.
- Develop education and outreach programs to encourage stewardship and conservation of riparian habitats on private land.
- Secure high conservation priority riparian habitats through purchase or through other land securement mechanisms available to conservation groups, land trusts, or municipalities.
- Develop provincial and/or municipal development setback and riparian land management policies.
- Create a municipal habitat conservation and restoration fund to allow for the securement of high priority riparian conservation areas.

Table 22. Proportion of riparian areas that have been classified in each of the riparian intactness categories, summarised by various spatial extents (HUC 6, HUC 8, Municipality).

Spatial Extent	Proportion (%) of Shoreline within Intactness Category					
	Very Low	Low	Moderate	High	Very Low + Low	Moderate + High
Modeste Watershed	14.9	3.7	9.8	71.6	18.6	81.4
Wabamun Creek Watershed	9.7	3.3	11.0	76.1	13.0	87.0
North Sask Above Wabamun Watershed	25.4	4.7	11.8	58.0	30.2	69.8
Bucklake Creek Watershed	13.6	4.0	10.3	72.1	17.6	82.4
Wolf Creek Watershed	2.0	1.4	4.9	91.7	3.4	96.6
Parkland County	10.9	32.9	23.0	33.2	43.8	56.2
Leduc County	2.4	9.6	11.4	76.6	12.0	88.0
Brazeau County	3.8	25.3	20.1	50.9	29.1	71.0
County of Wetaskiwin	3.0	34.7	19.5	42.8	37.7	62.3
Clearwater County	0.6	6.1	15.6	77.8	6.7	93.4

Table 23. Proportion of riparian areas that have been classified in each of the riparian intactness categories, summarised by individual streams within each HUC 8 subwatershed.

HUC 8 Watershed	Stream	Proportion (%) of Shoreline within Intactness Category					
		Very Low	Low	Moderate	High	Very Low + Low	Moderate + High
Wabamun Creek	Mink Creek	33.3	4.8	31.5	30.3	38.2	61.8
	Unnamed Creek 7	12.8	2.6	12.3	72.3	15.4	84.6
	Wabamun Creek	2.7	3.2	5.5	88.6	5.9	94.1
North Sask Above Wabamun	Mishow Creek	38.3	7.7	16.5	37.6	45.9	54.1
	Sand Creek	0.2	0.6	0.0	99.2	0.8	99.2
	Shoal Lake Creek	31.9	0.5	5.5	62.1	32.4	67.6
	Tomahawk Creek	30.3	6.3	17.0	46.3	36.6	63.4
	Unnamed Creek 2	0.0	0.0	0.0	100.0	0.0	100.0
	Unnamed Creek 4	12.2	4.5	5.4	77.8	16.7	83.3
	Unnamed Creek 5	4.2	1.2	1.8	92.8	5.4	94.6
	Unnamed Creek 6	10.0	11.2	34.8	44.0	21.2	78.8
	Washout Creek	29.6	3.2	5.6	61.5	32.9	67.1
Bucklake Creek	Buck Lake	9.6	9.9	11.5	69.0	19.5	80.5
	Buck Lake Creek	18.4	6.1	21.4	54.1	24.5	75.5
	Bucklake Creek	10.7	4.6	5.3	79.5	15.2	84.8
	Mink Creek	14.9	3.7	10.1	71.3	18.6	81.4
	Modeste Creek	10.8	2.6	7.2	79.4	13.4	86.6
	Muskrat Creek	49.6	8.8	14.7	26.9	58.4	41.6
	Poplar Creek	12.6	2.9	13.6	70.9	15.4	84.6
	Sun Creek	43.5	1.0	2.4	53.1	44.5	55.5
	Unnamed Creek 1	13.8	4.3	16.5	65.4	18.1	81.9
	Unnamed Creek 3	6.4	3.4	15.3	75.0	9.7	90.3
Wolf Creek	Cranberry Creek	0.3	0.0	0.6	99.1	0.3	99.7
	Horseshoe Creek	2.8	2.0	4.9	90.3	4.9	95.1
	Wolf Creek	2.1	1.5	5.6	90.8	3.6	96.4

Objective 2:

- Restore riparian habitats that have been impacted or impaired.

Measure:

- Proportion (%) of riparian management areas assessed as Very Low and/or Low Intactness.

Similar to Objective 1, this measure can include multiple and nested spatial extents, and can also include finer scale spatial targeting of particular regions or high-priority waterbodies.

Targets:

Limiting the amount and extent of riparian habitat that has been severely impacted and restoring these areas should be an important goal for riparian habitat management in the Modeste watershed. At present, 5% of the Modeste watershed has been classified as Very Low Intactness, while an additional 27% has been classified as Low Intactness, for a combined total of 32% (Table 22). A target for this objective could include specifying a desire to reduce to zero the number of riparian areas that have been classified as Very Low Intactness at the watershed, subwatershed, and municipal scale. Alternatively, individual (e.g., ≥5% Very Low and ≥20% Low) or combined targets (e.g., ≥25% Very Low + Low Intactness) for the proportion of Very Low and Low Intactness could be specified at a range of landscape scales. As with Objective 1, finer scale targets can also be set for individual streams under this objective.

Actions:

There are a number of actions that could be taken to achieve conservation targets specified under Objective 2, including (but not limited to):

- Incentivize riparian habitat restoration on private land through payment for ecosystem services, changes to tax regimes, or other BMP programs.
- Develop education and outreach programs to encourage private land restoration.
- Partner with conservation organizations to promote and encourage restoration on private lands.
- Create a municipal habitat conservation and restoration fund to pay for riparian habitat restoration on public lands.

Objective 3:

- Manage external pressures on riparian system function.

Measure:

- Pressure score of local catchments adjacent to streams.

As part of this study, local catchment areas throughout the Modeste watershed have been delineated, and pressure scores have been calculated, which broadly characterize the existing condition of each catchment as it relates to the type of land cover and the intensity of land use that is present. These catchments and their associated scores offer good measures for generally assessing and tracking land use and land cover changes through time.

Targets:

- No net increase in the pressure score of local catchments adjacent to streams.
- Net increase in the cover of natural vegetation (e.g., forest) and/or wetlands within high pressure catchments adjacent to streams.

Generally, the focus of this objective should be on minimizing the impacts of large scale and cumulative land cover or land use change on riparian areas and associated stream habitats. While it is unlikely that there will be reversals to existing land use or land cover to create an improvement to pressure scores, a realistic goal for this objective would be to identify high priority local catchments where the target for management is no net decrease in the current local catchment pressure score.

An additional target for this objective could include a net increase in the cover of natural vegetation (e.g., forest, shrubs, grassland), and/or wetlands. An increase in the amount of permeable surfaces and low intensity land uses in areas adjacent to riparian habitats will have a net positive effect on riparian and stream function and condition.

Actions:

The following is a list of actions that could be undertaken to achieve conservation targets specified under Objective 3:

- Incentivize voluntary conservation of wetland habitat and natural vegetative cover on private land through payment for ecosystem services, changes to tax regimes, or other BMP programs.
- Develop education and outreach programs to encourage stewardship and conservation of wetlands and other natural vegetation on private land.
- Secure wetland and other natural habitats in high priority catchments through purchase or through other land securement mechanisms available to conservation groups, land trusts, or municipalities.
- Create municipal land use bylaws that restrict land clearing or high intensity land use activities in local catchments designated as high priority for conservation.

11.0 Existing Tools for Riparian Habitat Management

Riparian land management in Alberta falls under the jurisdiction of the federal, provincial, and municipal governments. While Alberta does not have legislation or policy that explicitly manages riparian lands, there are a number of laws, regulations, standards, policies, and voluntary programs that can be used to direct the management of riparian lands, or land that directly adjoins riparian lands. The following sections highlights the key legislation, policies, and programs that are currently in place for riparian land management in the province of Alberta. Note that this is not intended to be an exhaustive list; rather, it is intended to highlight legislation, policy, and programs that are considered to be the most relevant and commonly employed to achieve riparian land conservation in the province.

11.1. Guidelines, Policies, and Legislation

Federal jurisdiction over riparian areas in Alberta is somewhat limited in scope. Exceptions to this include the authority to manage natural habitats and associated wildlife on federal land (e.g., First Nation Reserves, National Parks), as well as the authority to regulate migratory birds, fish and fish habitat, navigable waters, and species at risk. A summary of relevant federal laws and regulations that may apply to riparian management in the Modeste watershed are listed in Table 24.

At the provincial level, there a number of statutory laws, regulations, and standards that directly or indirectly relate to the management of riparian habitat on both private and public land. The responsibility for managing riparian land falls to a number of provincial ministries and departments, and the mechanisms through which riparian lands are managed varies with respect to whether these habitats are located on private land (White Zone) or public land (Green Zone). In addition, the nature of the disposition and the activities associated with the land use(s) (e.g., forestry, oil and gas, agriculture, or urban development) influences how riparian lands are managed on both private and public land.

In instances of overlapping land use or activities (e.g., forest harvest operating together with oil and gas exploration), the manner in which riparian lands are managed is directed by the laws, regulations, and standards that are specific to that particular land use or activity. In these situations, coordination between the various government ministries responsible for enacting those laws, regulations, or standards is an important aspect of successful riparian management outcomes. Regardless of where the riparian land is located, or what the land use and associated activities may be, the provincial government has jurisdiction over the management of all water in the province under the *Water Act*, as well as all lands that are defined as “public” (regulated under the *Public Lands Act*), which includes the bed and shore of all permanent water bodies, regardless of whether these water bodies are located on private land.

In addition to provincial laws and regulations, the Government of Alberta has a wide range of policies, standards, or guidelines that provide direction for the management of natural areas, wildlife, and wildlife habitat. The majority of these policies are voluntary and require the application of best management practices to achieve the desired management goals. One exception to this is the provincial wetland policy. Wetlands are regulated as water bodies under the *Water Act*, and as such, an approval is required to undertake any works that may impact a wetland. Thus, the principles and goals of the wetland policy and the associated wetland compensation guide are enforced through the *Water Act* application process.

A list and description of provincial laws, regulations, and policies that may apply to the management of riparian areas in the Modeste watershed is provided in Table 25.

Table 24. List and description of Federal laws and regulations that may apply to the management of riparian areas in the Modeste watershed.

Federal Law or Regulation	**Application to the Management of Riparian Areas**
Migratory Bird Convention Act	This legislation is based on international treaty signed by Canada and the United States of America that aims to protect migratory birds from indiscriminate harvesting and destruction on all lands within Canada. Under this Act, efforts should be made to provide for and protect habitat necessary for the conservation of migratory birds, and to conserve habitats that are essential to migratory bird populations, such as nesting, wintering grounds, and migratory corridors.
Fisheries Act	Includes provisions for the protection of fish and fish habitat, and requires an authorization for activities that cause harmful alteration, disruption and destruction of fish habitat.
Navigable Waters Protection Act	Prohibits the placement of any work in, on, over, under, through, or across any navigable water unless the work, the site, and the plans have been approved and the work is built and maintained according to approved plans. This includes construction of structures on the shore of a water body (e.g., docks) that may impact riparian habitat.
Species At Risk Act	The Federal government has jurisdiction over all SARA-listed species on federally owned lands, including national parks, Department of National Defence lands, and First Nations Reserve lands. Management of SARA-listed species on provincial crown land, or on lands held by private citizens of Alberta, falls under the jurisdiction of the provincial government. In these cases, the provincial government is obligated to protect listed species to the same standards set forth by the Federal government. In cases where provincial governments do not meet these standards, the Federal Minister may issue an order in council to protect federally listed species that occur on provincial or private lands

Table 25. List and description of Provincial laws, regulations, and policies that may apply to the management of riparian areas in the Modeste watershed.

Legislation, Regulation, or Policies	**Application to the Management of Riparian Areas**
Agricultural Operation Practices Act	Regulates and enforces confined livestock feeding operations planning for siting, manure handling/storage, and environment standards.
Alberta Land Stewardship Act	Creates authority of regional plans and enables the development of conservation and stewardship tools that can be used to acquire and manage natural areas. These tools include conservation easements, conservation directives, conservation offsets, and transfer of development credits.
Alberta Wetland Policy & Wetland Mitigation Directive	Pursuant to the *Water Act*, the provincial wetland policy prohibits the unauthorized drainage or disturbance of wetlands. The stated goal of the policy is to "conserve, restore, protect, and manage Alberta's wetlands to sustain the benefits they provide to the environment, society, and economy". If wetland loss or impacts are authorized by the province under the Water Act, the permittee is responsible for the replacement of lost wetland habitat at the ratio stipulated by the province. While this policy does not explicitly manage riparian land, there is opportunity within the stated goals and intent of this policy to extend the policy to include riparian lands.
Environmental Protection and Enhancement Act (EPEA)	This legislation aims to protect air, land and water by regulating the process for environmental assessments, approvals, and registrations. In particular, stormwater drainage that is directed to any surface water body requires an EPEA approval. Further, the Environmental Code of Practice for Pesticides provides a standard for operating practices that restrict the deposition of pesticides into or onto any open water body.
Municipal Government Act (MGA)	Provides municipalities with the authority to adopt statutory plans and bylaws that direct land use and development at subdivision. The Act also grants limited rights to designate reserves at subdivision that can be used to conserve natural areas. The Act also gives municipalities authority to regulate water on municipal lands, manage private land to control non-point source pollution, and adopt land use practices that are compatible with the protection of the aquatic environment, including development setbacks on water bodies.
Municipal Land Use Policies	Pursuant to Section 622 of the MGA, these Policies were established by Municipal Affairs to supplement planning provisions in the MGA and the Subdivision and Development Regulation, and to create a conformity of standard with respect to planning in Alberta. Section 5 of the Land Use Policies encourages municipalities to identify significant water bodies and watercourses in their jurisdiction, and to minimize habitat loss and other negative impacts of development through appropriate land use planning and practices. In addition, Section 6 encourages municipalities to incorporate measures into planning and land use practice that minimizes negative impacts on water resources, including surface and groundwater quality & quantity, water flow, soil erosion, sensitive fisheries habitat, and other aquatic resources.

Continued …

Table 25 *continued …* List and description of Provincial laws, regulations, and policies that may apply to the management of riparian areas in the Modeste watershed.

Legislation, Regulation, or Policies	Application to the Management of Natural Areas
Public Lands Act	Regulates and enforces activities that affect the Crown-owned bed and shore of water bodies, as well as Crown-owned riparian and upland habitats (e.g., forest and grazing leases).
Stepping Back from the Water: A Beneficial Management Practices Guide for New Developments Near Water Bodies	This document provides discretionary guidance to local authorities to assist with "decision making and watershed management relative to structural development near water bodies", and includes recommendations for development setbacks (buffers) on water bodies to protect aquatic and riparian habitats.
Soil Conservation Act & Regulations	Regulates activities that may cause erosion and sedimentation of a water body.
Surveys Act	Definitions for the "legal bank" of a water body, upon which the Crown-owned "bed and shore" is defined. The legal boundary between the bed and shore and the adjacent lands is the naturally occurring high water mark, and may not extend to include the full extent of riparian lands adjacent to a water body.
Water Act	The stated purpose of this Act is to support and promote water conservation and management. Under the Act, any activity that causes or has the potential to cause an effect on the aquatic environment requires an approval. Regulations and Codes of Practice under this Act apply to water and water use management, the aquatic environment, fish habitat protection practices, in-stream construction practices, and storm water management.
Weed Control Act	Noxious and prohibited noxious weeds listed under Schedule 1 must be controlled (noxious weed) or destroyed (prohibited noxious weed) by the owner of the land on which the listed weed occurs.
Wildlife Act & Species at Risk Program	Regulates and enforces protection of wildlife species and their habitats, which may include riparian dependent species

While the provincial government holds the authority to regulate water and public land throughout the province, municipalities are given the authority to manage lands within their jurisdiction under the *Municipal Government Act* (MGA). Section three of the MGA outlines three primary purposes of a municipality, which include:

1) Providing good governance;
2) Providing services that are in the opinion of council to be necessary or desirable; and
3) Developing and maintaining safe and viable communities.

A primary power given to municipalities under the MGA is for land use planning and development, which allows municipalities to set the conditions under which lands are subdivided and developed. Further, the *Municipal Government Act* requires each municipality to develop statutory planning documents that provide a framework and vision for development and land use within their jurisdictions. Statutory planning documents that are required under the MGA include:

- Municipal Development Plans

- Intermunicipal Development Plans
- Area Structure Plans
- Area Redevelopment Plans

Within these planning documents, municipalities can provide specific direction for development requirements that may influence the conservation of riparian habitat. In addition to statutory planning documents, municipalities can influence the management of riparian areas by enacting Land Use Bylaws that set forth requirements for development setbacks on environmentally sensitive lands. For example, municipalities can provide specific direction for development requirements in or near riparian habitat, or set forth minimum development setback widths on Environmental Reserve (ER), environmentally sensitive land, or water bodies and watercourses.

The MGA also gives municipalities the power to enact land use bylaws, as well as the authority to designate land as Environmental Reserve at the time of subdivision. Environmental Reserves are defined in Section 664 of the MGA as water bodies or watercourses, lands that are unstable or subject to flooding, and lands "not less than 6 metres in width abutting the bed and shore" of a water body or watercourse. While the MGA allows municipalities to take a 6 metre (or more) setback on Environmental Reserve lands, the conditions under which this taking is permitted is limited to cases where the setback is required to prevent pollution or provide public access to the bed and shore of the water body or watercourse. In addition to the limited opportunities that are available for conserving riparian land as Environmental Reserve, Section 640(4)(l) of the MGA allows municipalities to establish development setbacks on lands subject to flooding, low lying or marshy areas, or within a specified distance to the bed and shore of any water body.

It is important to note that the Municipal Government Act is currently under review, and it is possible that revisions to the legislation as a result of this review may influence the power of municipalities to regulate and manage riparian areas in the future. The timeline for the finalization of the MGA revisions is not currently known.

11.2. Acquisition of Riparian Lands

It is important to note that while there is a wide range of different federal, provincial, and municipal laws and policies that regulate activities within or near riparian areas, these regulations by themselves to do not necessarily result in the conservation of riparian habitat. In many cases, existing laws regulate *activities* that may impact riparian habitats (e.g., the provincial *Water Act*), but do not regulate the habitats themselves. As a result, many of the existing laws result in approvals that allow for the removal or alteration of riparian areas under certain conditions outlined within the approval. In some cases, these regulations require compensation or replacement of impacted habitats (e.g., the Provincial wetland policy and the federal *Fisheries Act*), but typically, existing laws and policies do not prevent land development, and there is very little provision for riparian habitat conservation in existing laws and policies, particularly as it relates to federal and provincial regulation.

At the municipal level, most municipalities have environmental and land use legislation, policies, and guidelines that provide direction for how to target riparian habitats and other natural areas for conservation, as well as guidance for how to integrate these habitats into a neighbourhood post-development. However, there are only a small number of tools or mechanisms available that enable the *acquisition* of lands by the municipality (or a third party) for the purpose of conservation. In some cases, these tools are only available to municipalities at particular times during the development process (e.g., at subdivision). In other instances, there may be restrictions on the amount of land that municipalities can set aside for conservation, as there are requirements to balance natural area conservation with other land use demands, such as school and park sites. In many cases, municipalities may have undertaken an ecological inventory to identify high priority areas for conservation, and have the appropriate legislation or policies in place to manage these areas, but may lack the appropriate tools (or associated resources) to acquire high priority conservation areas.

One of the most effective conservation mechanisms for aquatic habitats within municipalities is the *Public Lands Act*. Pursuant to this legislation, the Province of Alberta owns the bed and shore of all permanent and naturally occurring water bodies, including lakes, rivers, streams, and wetlands. Under this Act, all permanent and naturally occurring water bodies are Crown land, and development must avoid these features. If development can not be avoided, the Crown determines whether temporary construction or permanent occupation will be authorized, and in many cases, authorized activities that result in the loss of Crown land is subject to compensation. In the case of riparian habitats along streams and rivers and permanent wetlands, the determination of whether riparian areas are considered to be part of the Crown claimed waterbody is contingent on the existence of a legal survey, and the location of the water boundary that is determined by the surveyor, as per the Surveyors Act. In this regard there are known inconsistencies with respect to how surveyors determine the location of the water boundary, and this may or may not include riparian habitat.

The second provincial legislation that enables municipalities to develop and implement land conservation and stewardship tools is the *Alberta Land Stewardship Act* (ALSA). Under ALSA, the following tools may be utilized to conserve riparian areas in municipalities:

Conservation Easement:

A conservation easement is a voluntary contractual agreement between a private landowner and a qualified organization, such as a municipality, land trust organization, or conservation group. There are only three allowable purposes for a conservation easement under the *Alberta Land Stewardship Act*, and these include the protection, conservation and enhancement of 1) the environment, 2) natural scenic or aesthetic values, or 3) agricultural land or land for agricultural purposes. Under a conservation easement, the landowner retains title to the land, but certain land use rights are extinguished in the interest of conserving and protecting the land. The land use restrictions that apply to the property are negotiated and agreed to at the outset (for example, a restriction on subdivision), and the conservation easement (and the land use restrictions) are registered on title and are transferred to a new land owner if the land is sold. Conservation easements can be negotiated by a private land owner at any time, but the easement must be held by a qualified organization.

Conservation Directive:

A conservation directive allows the Alberta Government to identify private lands within a regional plan for the purpose of protection, conservation, or enhancement of environmental, natural scenic, or aesthetic values. Ownership of the lands is retained by the land owner, and the directive describes the precise nature and intended purpose for the protection, conservation, or enhancement of the lands. A conservation directive must be initiated by the provincial government, and to date, this tool remains largely untested (Environmental Law Centre 2015).

Conservation Offset:

A conservation offset is a tool that allows industry to offset the adverse environmental effects of their activities and development by supporting conservation activities and/or efforts on other lands. In order for conservation offsets to be effective, there must first be guidelines and rules for where offsets can be applied, and provisions for accountability, including monitoring and compliance. While conservation offsets are available as a tool for the conservation of natural areas in the Modeste watershed, work would first have to be done to create a proper framework to create eligibility rules, pricing and bidding rules for selling and buying offsets, and rules for combining buyers and sellers.

Transfer of Development Credits (TDCs):

Transfer of development credits is a tool that creates and incentive to redirect development away from specific landscapes in order to conserve areas for agricultural or environmental purposes. This tool allows land development and conservation to occur at the same time, while also allowing owners of the developed and undeveloped lands to share in the financial benefits of the development activity. A TDC program can be used to designate lands as a conservation area for one or more of the following purposes:

- The protection, conservation and enhancement of the environment;
- The protection, conservation and enhancement of natural scenic or aesthetic values;
- The protection, conservation and enhancement of agricultural land or land for agricultural purposes;
- Providing for all or any of the following uses of the land that are consistent with the following purposes: recreational use, open space use, environmental education use, or use for research and scientific studies of natural ecosystems; and
- Designation as a Provincial Historic Resource or a Municipal Historic Resource under the *Historical Resources Act*.

Before TDCs can be used by municipalities as a conservation tool, they must be established through a regional plan, or they must be approved by the Provincial Government.

Outside of the conservation tools that have been created through the *Alberta Land Stewardship Act*, there are other mechanisms through which municipalities may acquire lands for conservation, most of which rely on voluntary conservation action taken by private land owners. These tools may be utilized at any time during the municipal planning and development process, and include:

Land Purchase:

Municipalities can purchase land from a private land owner at any time for the purpose of conservation. For example, the City of Edmonton established a Natural Areas Reserve Fund in 1999, with the purpose of using these funds to purchase and protect natural areas. While land purchase for conservation is an option that is available, many municipalities do not have the financial resources available to purchase lands within their municipal boundaries, as the market value for these lands can be very high.

Land Swap:

In some cases, a land developer may be willing to “swap” or exchange natural areas for other developable lands that are owned by the municipality. In this case, the municipality and the developer would enter into an agreement to exchange the lands, such that the natural areas can be conserved.

Land Donation:

Land donation involves the transfer of ownership from a private land owner to the municipality, or to a conservation organization or land trust, who would hold the land for conservation in perpetuity. Lands that are donated to a conservation organization or land trust are eligible for the federal government's Ecological Gifts program which provides donors with significant tax benefits.

The final set of conservation tools are directly available to municipalities, and are the most common and frequently used tools for acquiring riparian areas as part of land development and planning. However, these tools are enabled through the *Municipal Government Act*, which only gives municipalities the authority to use these tools at the time of subdivision. Thus, municipalities can only utilize these tools through formal land development and planning processes.

Environmental Reserve (ER):

Environmental Reserves are defined in the MGA as water bodies, watercourses, lands that are unstable or subject to flooding, and lands "not less than 6 metres in width abutting the bed and shore" of a water body or watercourse. While the MGA allows municipalities to take a *minimum* of a 6 metre setback on Environmental Reserve lands (with no stated maximum), the conditions under which this taking is permitted is limited to cases where the setback is required to prevent pollution or provide public access to the bed and shore of the water body or watercourse. In addition, Section 640(4)(l) of the MGA allows municipalities to establish development setbacks on lands subject to flooding, low lying or marshy areas, or within a specified distance to the bed and shore of any water body.

Environmental Reserve Easement:

In instances where the municipality and the landowner agree, Environmental Reserve lands may be designated as an Environmental Reserve Easement. An ER Easement serves the same purpose as ER, but differs in that the title of the reserve lands remains with the land owner; however, ER easements are registered on title by caveat in favour of the municipality.

11.3. Public Engagement

Public engagement is a critical component to the successful conservation and management of riparian areas. Without the support of the public, the successful implementation of restoration and management programs and activities that are required to maintain healthy and resistant riparian areas are not possible. Further, many of the acquisition tools outlined above rely on voluntary participation by the public (e.g., land donations and conservation easement). Thus, ensuring that the public are aware of the various voluntary programs that exist for riparian habitat conservation, as well as formulating active partnerships that can capitalize on the public's willingness to participate in such programs, is critical to the conservation and restoration of riparian habitats. Public engagement can take several forms, including the following:

Education, Extension and Outreach:

Increasing public awareness and appreciation for natural areas is a critical component to effective conservation and management. Thus, creating educational opportunities and programs, as well as supporting local conservation and stewardship groups is critical to achieving desired riparian conservation and restoration objectives in the Modeste watershed.

Partnerships:

Given the limited number of tools available to municipalities for the acquisition of riparian areas on private lands, engaging in strategic partnerships to promote voluntary land conservation and management activities is essential. Central to this is developing partnerships with land trusts and conservation organizations (e.g., Alternative Land Use Services, Nature Conservancy, Land Stewardship Centre), developing strong inter-municipal policies, and partnerships with the provincial government to promote and enhance collaboration and improve conservation outcomes

All of the tools outlined in this section are currently available to stakeholders in the Modeste watershed for the purpose of conserving and managing riparian habitats. However, in order to focus management action in the watershed, it is essential that the NSWA and its partners first define objectives and targets for the conservation, restoration, and management of riparian habitats. Once these objectives and targets have been outlined, specific actions and the relevant tools associated with those actions can be identified. In some cases, there may be existing tools in place to achieve the desired management outcomes. In other cases, there may be gaps in the available tools, and new policies, partnerships, or programs may need to be developed in order to achieve the desired management objectives.

12.0 Conclusion

The overall goal of this project was to develop a rapid, rigorous, and repeatable remote sensing and GIS method for assessing riparian areas over a large spatial extent through the quantification of riparian habitat intactness and pressures on riparian system function. The results of this work provide the North Saskatchewan Watershed Alliance and its stakeholders with an overview of the status of riparian management area in the Modeste watershed, and further provides a foundation of scientific evidence upon which to build a systematic and adaptive framework for riparian habitat management throughout the watershed.

In total, 1,708 km of shoreline was assessed in the Modeste watershed as part of this study, and 72% of the shoreline was classified as High Intactness. A further 10% of the shoreline was classified as Moderate Intactness, with 19% classified as either Very Low (15%) or Low (5%) Intactness. Within the Modeste watershed, the greatest proportion and length of shoreline classified as Very Low or Low Intactness was located within the North Saskatchewan Above Wabamun and the Bucklake Creek subwatersheds, and primarily within the jurisdictions of Parkland County and the County of Wetaskiwin. The subwatershed with the greatest proportion of riparian areas classified as Moderate and High Intactness was the Wolf Creek watershed, which is primarily within the jurisdiction of Clearwater County.

The next step in the advancement of meaningful riparian management and conservation in the Modeste watershed will be to formalize a framework for action that includes defining achievable management outcomes and measurable targets, which can then be used to inform relevant collective action by key stakeholders. These actions can then be monitored on a regular basis to provide an evaluation of outcomes that feed into an adaptive and reflexive approach to riparian management through time.

12.1. Closure

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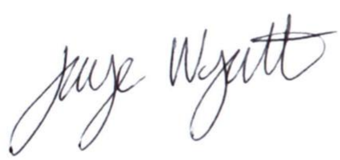

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