Strawberry Watershed Riparian Area Assessment

FINAL REPORT

Project 1773
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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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Finally, we would like to acknowledge and thank the following organizations for contributing spatial data for use in this project:

Government of Alberta
City of Edmonton
Parkland County
Leduc County
Brazeau County

Executive Summary

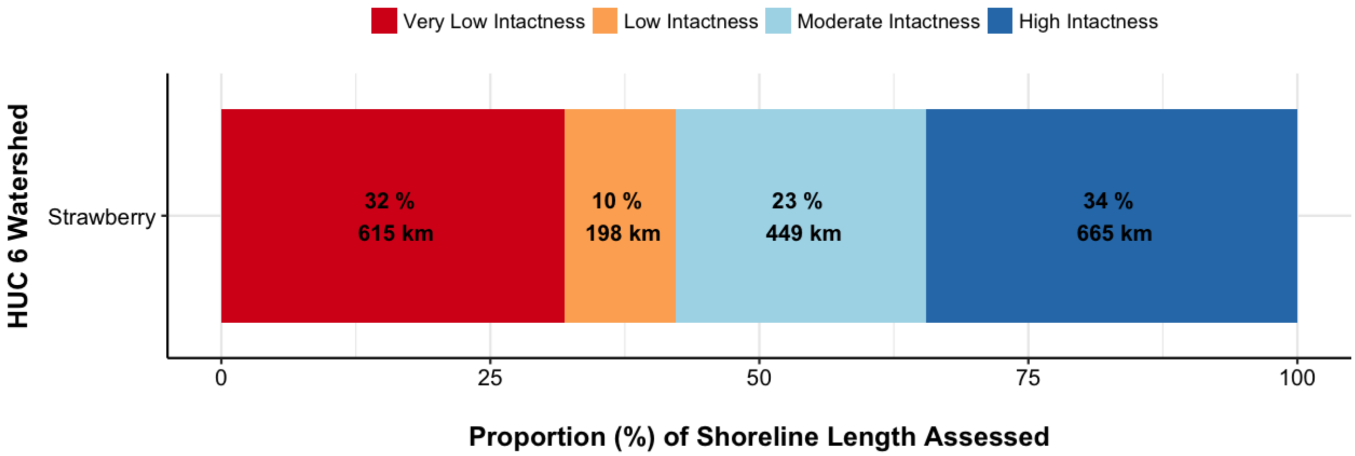
Riparian lands have substantial ecological, economic, and social value, and as such, the North Saskatchewan Watershed Alliance (NSWA) has recognized that the effective management of these habitats is a critical component to the maintenance of watershed health. In an effort to better manage riparian habitats within the Strawberry watershed, the NSWA retained Fiera Biological Consulting to assess the condition of riparian management areas, and to provide information that allows the NSWA and its stakeholders to target areas for restoration and conservation.

Using a geospatial riparian habitat assessment method that was developed and validated in the Modeste watershed (Fiera Biological 2018a), and subsequently applied in the Sturgeon River watershed (Fiera Biological 2018b), the intactness of riparian management areas (RMA) along the shorelines of major water bodies within the Strawberry watershed was quantified. 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. 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 percent cover of natural vegetation.

Intactness was used as the measure of riparian condition in the Strawberry watershed because the relationship between an intact riparian zone and the health or integrity of the aquatic environment is well established. 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. Given the significant role that an intact riparian zone has on healthy aquatic ecosystems, there is a need to manage riparian areas effectively. Thus, understanding the distribution of intact riparian habitat across the landscape and identifying areas where riparian intactness has been degraded, can provide managers and conservation agencies critical information as to where resources are needed to restore or conserve riparian habitats.

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, the natural and anthropogenic pressures within local catchment areas were also assessed. As a result, each RMA was assigned both an intactness score and an associated pressure score. This allowed for the development of a prioritization matrix that combined intactness and pressure scores, allowing for the assignment of conservation or restoration priority to each RMA. This in turn allows land managers to more precisely target areas for management, and prioritize areas for conservation and restoration within the watershed. It also allows land managers to target areas were more detailed, site-specific field assessments of riparian health or condition may be required.

In total, ~1,926 km of shoreline along 14 named and unnamed lakes, 12 named creeks, and 37 unnamed creeks was assessed in the Strawberry watershed as part of this study. Overall, 34% of the shoreline (665 km) was classified as High Intactness. A further 23% of the shoreline (449 km) was classified as Moderate Intactness, with 42% classified as Very Low (32%; 615 km) or Low (10%; 198 km) Intactness.



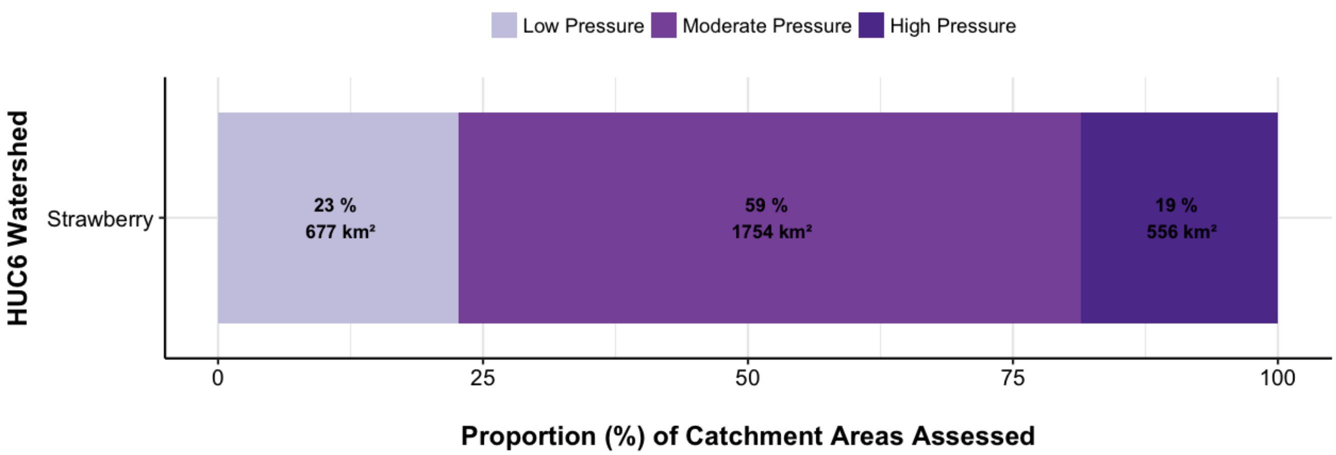
When the proportion of shoreline assigned to each intactness category is compared for each HUC 8 subwatershed, the Strawberry Creek subwatershed had the greatest proportion and length of shoreline (55%; 291 km) rated as High Intactness, followed by North Saskatchewan Below Strawberry (35%; 231 km) and Whitemud Creek (21%; 143 km). The Whitemud Creek subwatershed had the greatest proportion and length of shoreline assessed as Very Low (41%; 255 km) and Low Intactness (56%; 110 km).

With the exception of the City of Edmonton, all municipalities assessed in this study had more than 30% of their shorelines classified as Very Low or Low Intactness. Strathcona County had the greatest proportion (37%; 12 km) of its shoreline classified as Very Low Intactness, followed by Wetaskiwin (36%; 10 km) and Leduc (33%; 556 km). Edmonton had the greatest proportion (70%; 75 km) of its shoreline classified as High Intactness, followed by the County of Wetaskiwin (46%; 13 km) and Brazeau County (41%; 12 km). Leduc County contained the greatest length and proportion (1,664 km; 86%) of the shoreline that was assessed in this study. Edmonton made up the second greatest length (107 km) and proportion (6%) of shoreline assessed, followed by Parkland County (65 km; 3%), Strathcona County (32 km; 2%), Brazeau County (29 km; 2%), and County of Wetaskiwin (28 km; 2%).

Spatial Extent	**Proportion (%) of Shoreline within Intactness Category**					
	Very Low	**Low**	**Moderate**	**High**	**Very Low + Low**	**Moderate + High**
Strawberry (HUC 6) Watershed	32	10	23	35	42	58
N. Sask Below Strawberry Subwatershed	36	8	23	33	44	56
Strawberry Creek Subwatershed	21	6	18	55	27	73
Whitemud Creek Subwatershed	36	16	28	20	52	48
Edmonton	11	6	13	70	17	83
Brazeau County	18	15	27	41	33	68
County of Wetaskiwin	36	4	14	46	40	60
Leduc County	33	11	24	32	44	56
Parkland County	31	9	25	35	40	60
Strathcona County	37	16	32	15	53	47

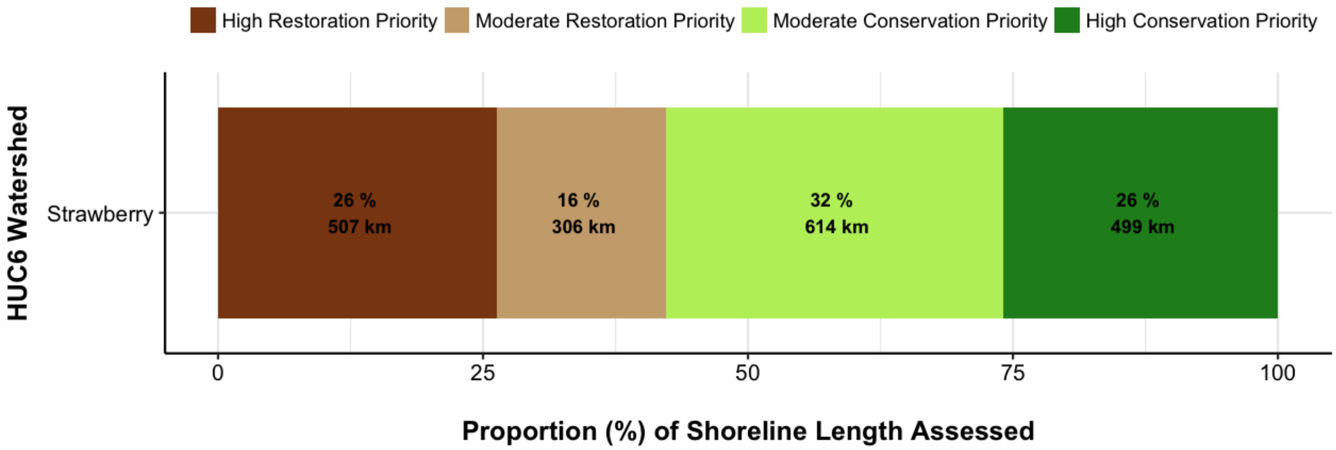
When intactness was summarised and compared for the 14 named and unnamed lakes assessed in this study, all of the named lakes had 50% or more of their shorelines characterized as either High or Moderate Intactness, with eight out of the 10 unnamed lakes having more than 50% of their shorelines characterized as either High or Moderate Intactness. In contrast to the relatively good condition of the lakes, nine out of the 12 named creeks had more than 25% of their shorelines classified as Low or Very Low Intactness. For unnamed creeks, the condition of riparian management areas was generally low, with the 20 of the 37 unnamed creeks having 50% or more of the shoreline classified as Low or Very Low Intactness.

Pressure on riparian system function was assessed for 546 local catchment areas within the Strawberry watershed, covering an area of nearly 3,000 km^2. Of that area, 19% was classified as High Pressure, with the majority (59%) of local catchments being classified as Moderate Pressure, and the remaining 23% being classified as Low Pressure.



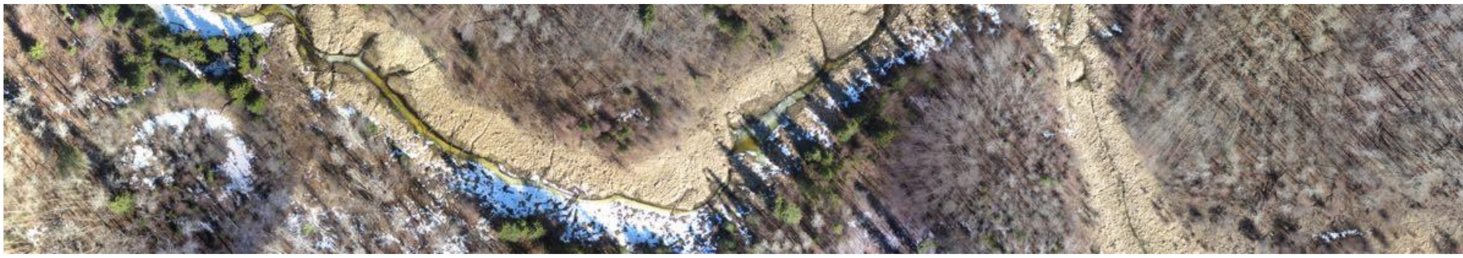
When pressure scores were examined for lakes, it is apparent that land use pressure surrounding lakes in this watershed is relatively high, with three of the four named lakes having more than 75% of the adjacent lands classified as either Moderate or High Pressure. Pressure scores for unnamed lakes were lower than for named lakes, with five of the 10 unnamed lakes having more than 50% of the adjacent lands classified as either Moderate or High Pressure, and 5 of the 10 lakes having more than 50% of adjacent lands classified as Low Pressure. For named creeks, pressure on riparian system function was quite high, with nine out of 11 named creeks having more than 75% of adjacent lands classified as either Moderate or High Pressure. For unnamed creeks, the results were similar, with 31 of the 37 unnamed creeks having more than 75% of adjacent lands classified as Moderate or High Pressure.

Within the Strawberry watershed, 58% of the shoreline length that was assessed was classified as either High Conservation (26%; 499 km) or Moderate Conservation (32%; 614 km) Priority, representing approximately 1,113 km of shoreline. Conversely, 42% of the shoreline was classified as either High Restoration (26%; 507 km) or Moderate Restoration (16%; 306 km) Priority, representing approximately 813 km of shoreline.



For all four named lakes assessed in this study, at least half of each lake shoreline was classified as either High or Moderate Conservation Priority. Of the 10 unnamed lakes that were assessed, eight had more than half of the shoreline classified as either High or Moderate Conservation Priority, while two of the 10 unnamed lakes had more than 50% of their shorelines assessed as High or Moderate Restoration Priority. Of the 12 named creeks assessed, nine had more than 25% of their shoreline identified as either High or Moderate Restoration Priority. Riparian habitats along unnamed creeks in the Strawberry watershed appear to have been particularly impacted by human activities. For 16 out of 37 unnamed creeks, more than half of their shorelines were classified as High or Moderate Restoration Priority, with six unnamed creeks having more than 75% of their shorelines classified as High or Moderate Restoration Priority. Conversely, 20 out of 37 unnamed streams had at least half of their shorelines prioritized for conservation, with only one unnamed creek having more than 50% of its shoreline classified as High Conservation 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 Strawberry 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 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

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 ultra light aircraft.

Catchment: Small local drainage areas ranging in size from 0.10 to 29 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 ArcHydro 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) represent 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.

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

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

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

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

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

Riparian Area, Riparian Habitat, Riparian Land, or Riparian Zone: Riparian lands are transitional areas between upland and aquatic ecosystems. They have variable width and extent both above and below 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

1.1. Background

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, including water quality improvement, sediment removal, nutrient cycling, bank stabilization, and flood and drought resiliency. Despite the importance of these habitats, the loss and impairment of riparian lands in Alberta over the last century has been significant, and as a result, recent watershed management efforts throughout the province have been focused on identifying priority areas for riparian restoration and habitat management. In order to efficiently target habitat restoration efforts and resources across large spatial extents, however, there first needs to be reliable information about the location, condition, and function of riparian habitats.

1.2. 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. 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 assessment of riparian condition is made. Metrics evaluate a wide range of riparian attributes including: vegetation type, structure, and composition; bank characteristics; soil attributes; and land use and disturbance. The final compiled score provides a snapshot of whether a riparian area is “Healthy”, “Healthy, but with problems”, or “Unhealthy”, and gives a land-owner or other interested stakeholders an idea of where to focus management activities. 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 answers a series of questions regarding different functional attributes of the riparian lands in question and converts it into a score that is classified according to 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. The goal is to provide low cost information of large areas so that management at larger scales (i.e. entire lake or river system) can be directed by standardized measurements, and videography can be very cost-effective per kilometer of shoreline observed in some cases. 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, and consistent with goals outlined in the Integrated Watershed Management Plan for the North Saskatchewan River (NSWA 2012), 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 (Fiera Biological 2018a). This new riparian assessment method uses automated and semi-automated GIS techniques to quantify the intactness 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 differences in riparian condition across space and time. To date, this method has been employed in both the Modeste (Fiera Biological 2018a) and the Sturgeon (Fiera Biological 2018b) watersheds, and has been used to assess over 5,000 km of shoreline in the North Saskatchewan River basin. The method has also been used to assess nearly 900 km of shoreline in the Pigeon, Gull, Sylvan, and Buffalo Lake watersheds (Fiera Biological 2018c).

1.3. Study Objectives

The overall goal of this project was to assess riparian areas within the Strawberry watershed, such that areas within the watershed can be targeted for restoration and conservation. In order to achieve this goal, we identified the following primary objectives for this study:

1) Assess riparian condition by quantifying the intactness of riparian management areas in a GIS environment using the method previously developed and validated in the Modeste watershed. (Fiera Biological 2018a). 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 (Fiera Biological 2018a), riparian intactness is considered to be analogous to riparian condition, as measured by the aerial videography method.

    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 with critical information as to where resources are needed to restore or conserve riparian zones within the Strawberry 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 *generally* 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 used to assess 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 identify 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.

The results of this study provide stakeholders with an overview of the status of riparian management areas within the Strawberry watershed. This in turn allows organizations throughout the watershed to focus restoration, management efforts, and/or 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.

1.4. Purpose and Intended Use

This assessment synthesizes disparate data types from various sources to generally characterize the current condition of riparian management areas within the Strawberry 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 at a pixel resolution of 6 m. 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. For example, this analysis does not consider the location or density of stormwater outfalls on the intactness of shorelines, nor does it consider the effects of stormwater or other point and non-point sources on water quality.
- 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 water body 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 Strawberry is a large (~3,000 km^2) HUC 6 watershed located in central Alberta with an extensive hydrological network that flows through the Boreal Forest and Parkland Natural Regions (Map 1). The watershed is composed of three smaller hydrologic (HUC 8) units, including the North Saskatchewan Below Strawberry, Strawberry Creek, and Whitemud Creek subwatersheds (Map 2).

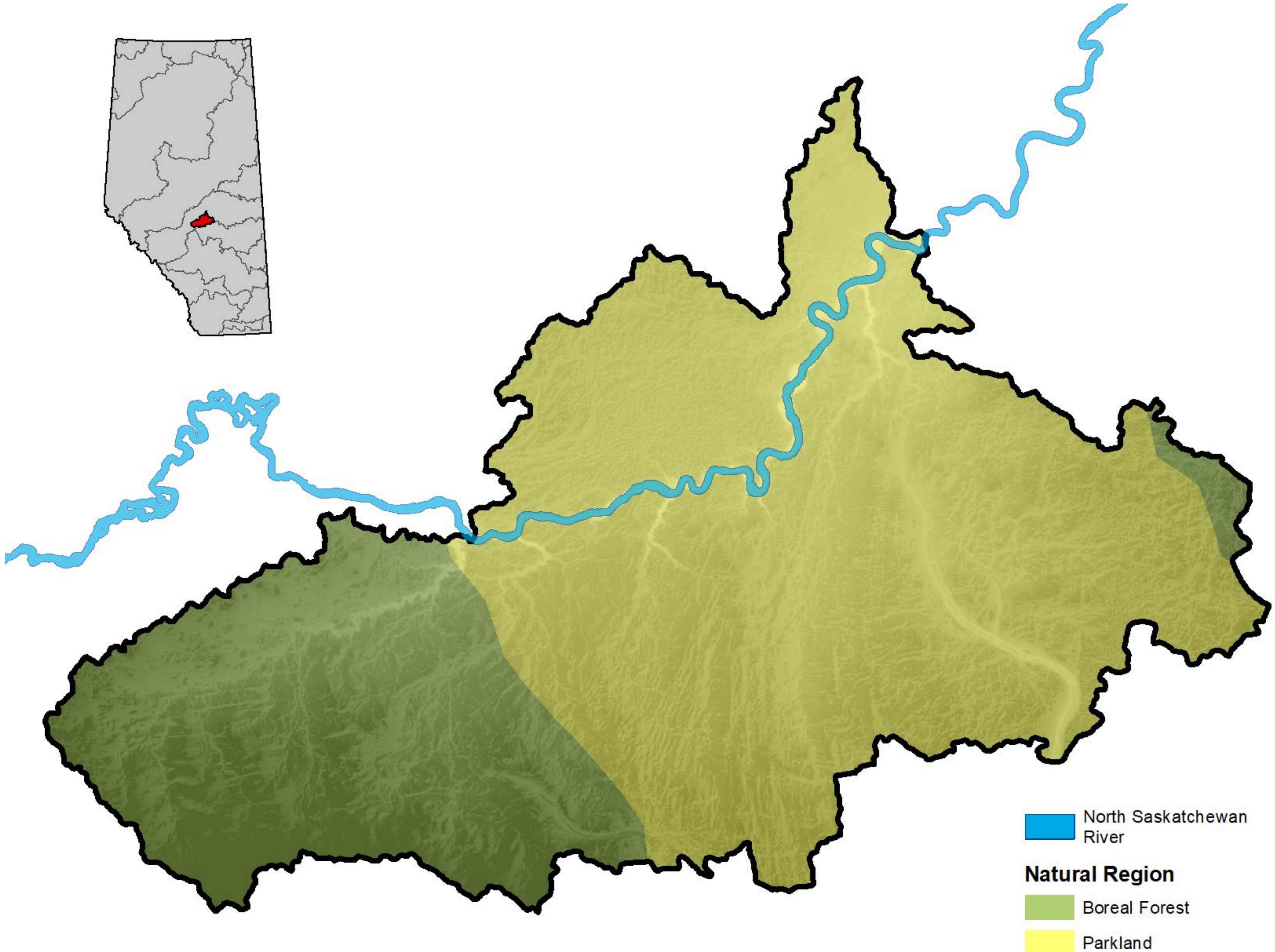
Human activity is prevalent within this watershed, with 79.5% of the lands classified into one of seven anthropogenic land cover types. Agriculture crop (40.6%) and agriculture pasture (23.6%) make up the largest proportion of lands modified by human activity, with the remaining 15.3% of the human land cover being composed of urban (4.6%), road and road verge (5.4%), and other disturbed lands and vegetation (5.3%). Only 20.5% of the watershed consists of natural land cover types, such as wetlands, forests, open water, and other low and open natural vegetative cover (Map 3). Areas of natural cover are generally concentrated, with notable areas of wetland cover in the eastern portion of the watershed, large patches of forest and wetland cover in the north central portion of the watershed, and large patches of forest cover associated with the Strawberry Creek drainage in the western part of the watershed and Wizard Lake in the southern portion of the watershed.

Six rural counties intersect the Strawberry watershed, as well as a number of urban municipalities, the largest of which include the City of Edmonton, the City of St. Albert, the City of Leduc (Map 4). In addition to these large urban areas, there are several towns, including Devon, Calmar, and Thorsby, and industrial areas, including Nisku and the Edmonton International Airport. The Enoch Cree Nation is also located within the watershed.

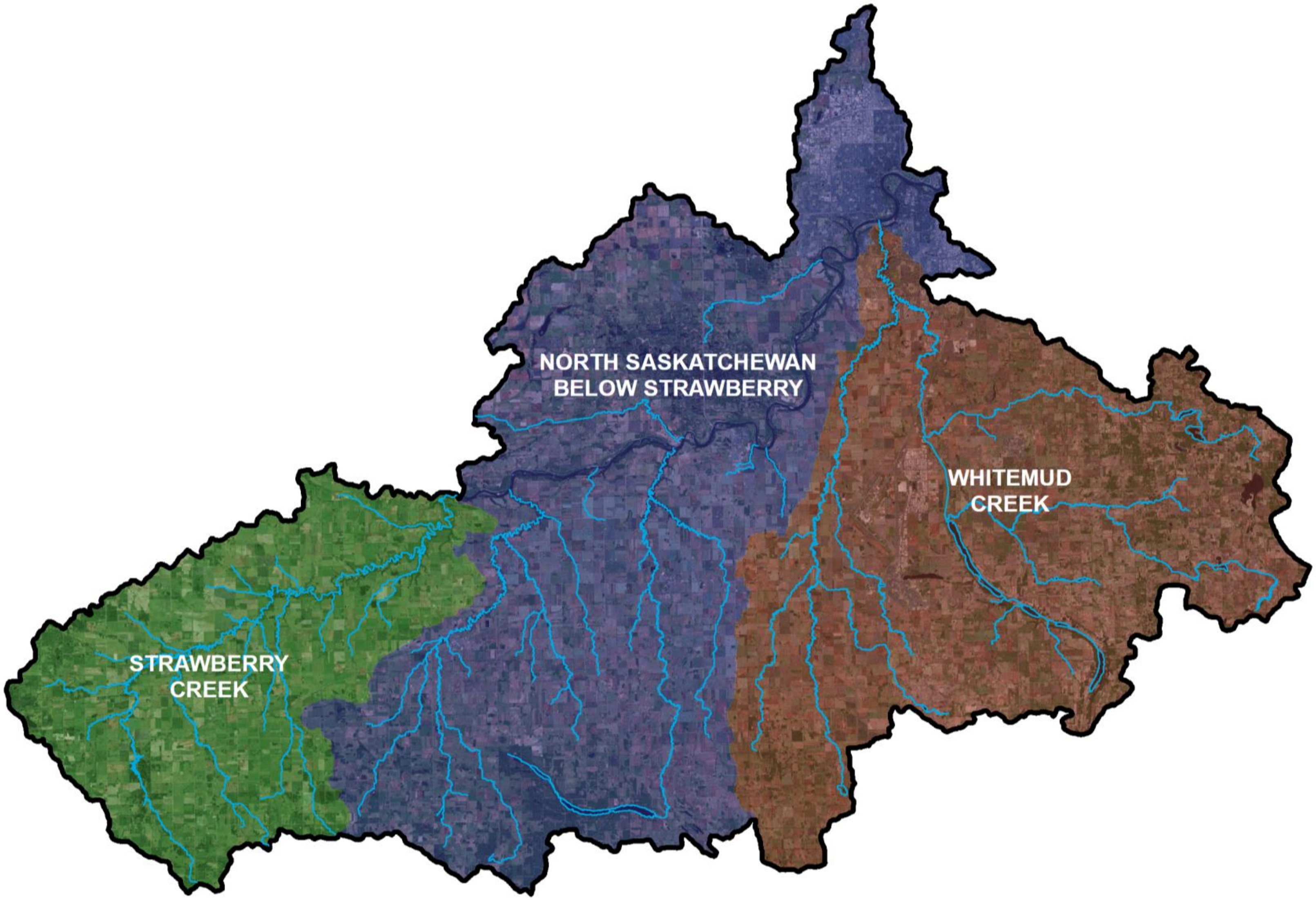
The riparian management areas that were assessed as part of this study were associated with left and right banks of watercourses classified as Strahler Order 3 or greater, which includes Strawberry Creek and its major tributaries (Little Strawberry Creek and Sunnybrook Creek), Whitemud Creek and its major tributaries (West Whitemud Creek), and Blackmud Creek and its major tributaries (Clearwater Creek and Irvine Creek) (Table 1; Map 5). The study also included 37 unnamed creeks that flow into the major named creeks. In addition, 10 unnamed lakes/wetlands and four named lakes were included in the assessment.

Table 1. Waterbodies in the Strawberry watershed that were assessed as part of this project. The shoreline length listed for each creek represents the total length of the stream that was assessed on both the left and right banks.

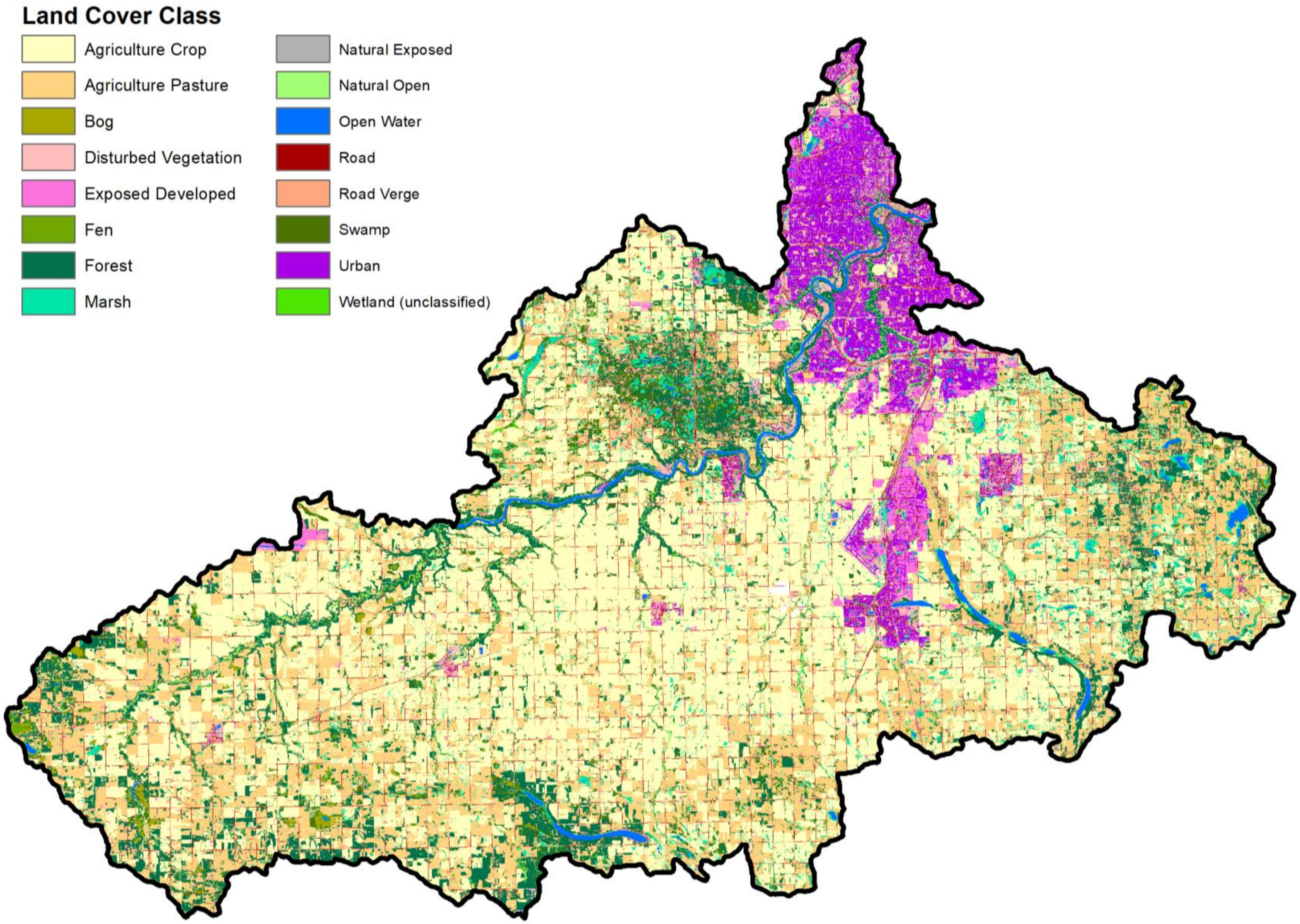
Waterbody Name	Length of Creek or Lake Shoreline (km)
Creeks	
Blackmud Creek	65.5
Clearwater Creek	93.5
Conjuring Creek	118.2
Cutbank Creek	12.1
Irvine Creek	81.0
Little Strawberry Creek	89.0
Strawberry Creek	175.1
Sunnybrook Creek	57.0
Weed Creek	122.5
West Whitemud Creek	47.3
Whitemud Creek	178.9
Willow Creek	42.8
Unnamed Tributaries (37)	773.1
Lakes	
Ord Lake	3.4
Saunders Lake	15.2
Schultz Lake	2.0
Wizard Lake	18.0
Unnamed Lakes (10)	31.5
TOTAL	**1,926.1**



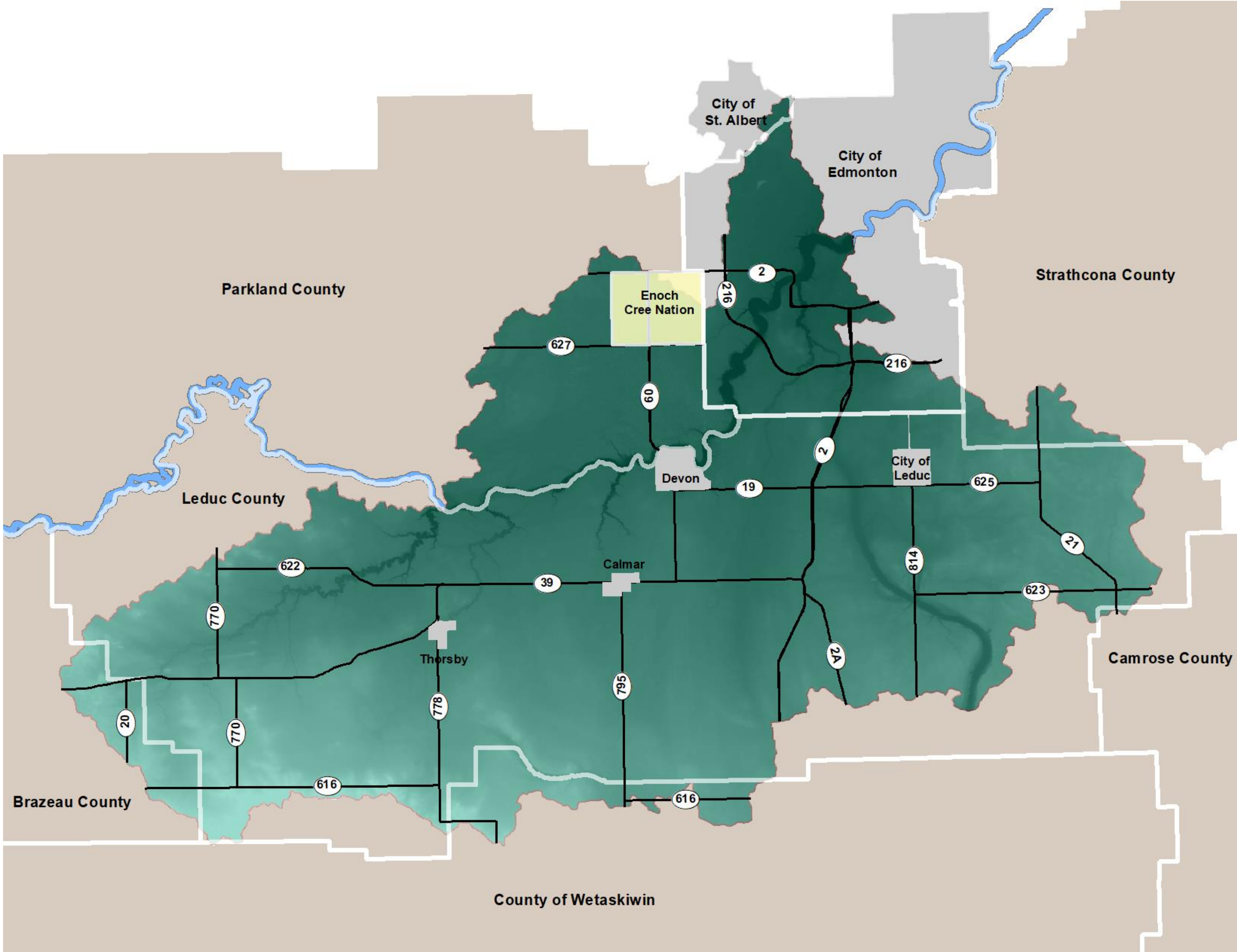
Map 1. The Strawberry watershed in central Alberta includes areas that fall within the Boreal Forest and Parkland Natural Regions. Data source: Government of Alberta.



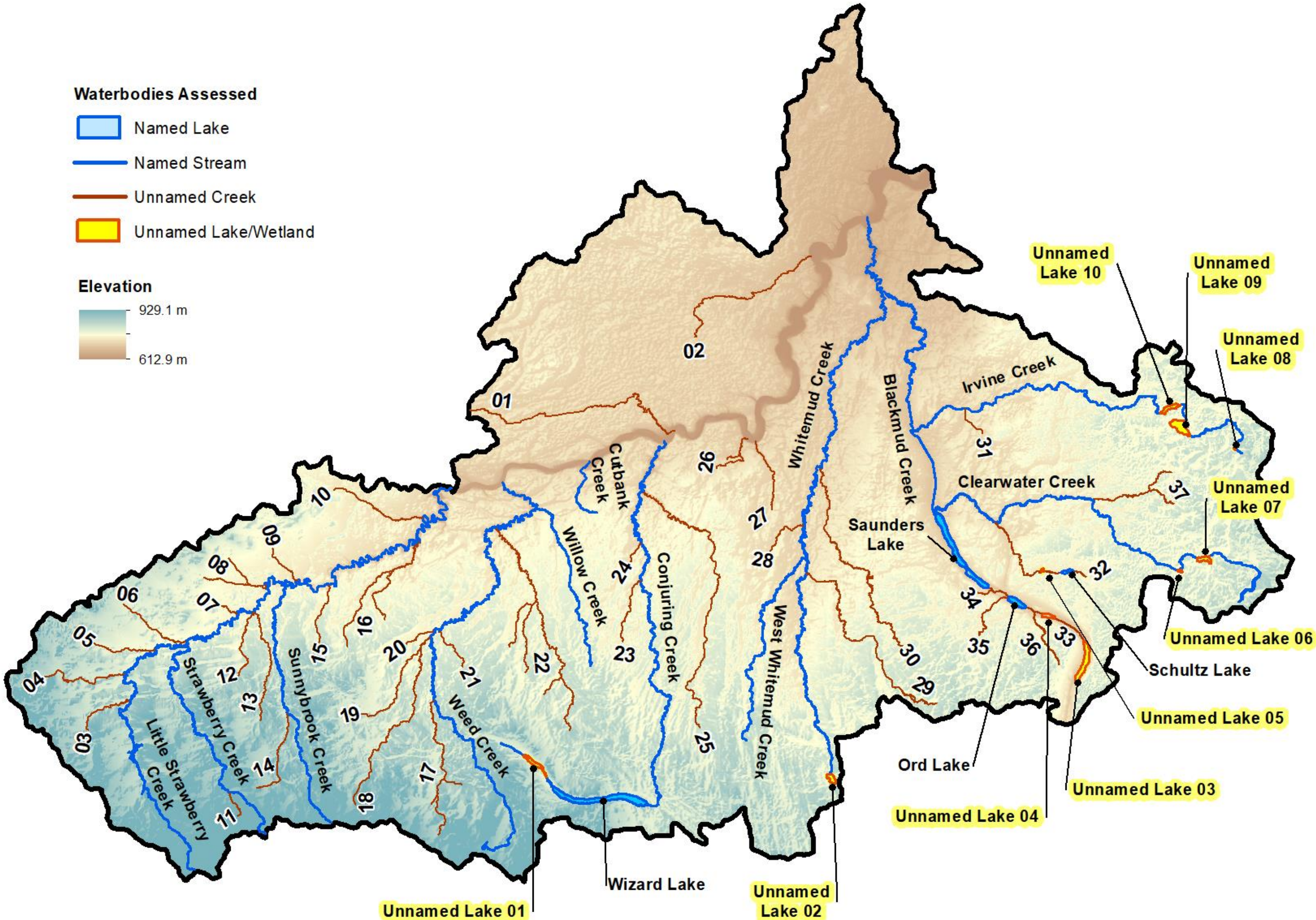
Map 2. Location and name of each HUC 8 subwatershed located within the Strawberry watershed, as well as the creek and lake shorelines included in the riparian assessment. The North Saskatchewan River was not assessed as part of this study. Data source: Government of Alberta



Map 3. Land cover in the Strawberry watershed, created using SPOT satellite imagery from 2016. Approximately 21% of the watershed is covered by natural land cover types, such as wetlands, forests, open water, and other low and open natural vegetative cover. Data source: Fiera Biological Consulting Ltd.



Map 4. Major highways and the major rural, urban, and First Nations communities located within the Strawberry watershed. Data source: Government of Alberta.



Map 5. Location of the named and unnamed lakes and creeks included in this study. Data source: Government of Alberta.

3.0 Methods

3.1. Assessing Riparian Intactness

3.1.1. Acquisition and Derivation of Required Data

To quantify riparian intactness in a GIS environment, several data layers were required, including a current land cover layer and a current human footprint layer. A list of spatial data obtained or derived for use in the quantification of riparian management area intactness is presented in Table 2.

While a freely available and current land cover layer was available from Agriculture and Agri-Food Canada (AAFC), the resolution of this data (30 m pixel size) is too coarse to accurately assess vegetation within riparian management areas. Consequently, we created a 6 m pixel resolution land cover using SPOT 6 satellite imagery from 2016, which was obtained by the NSWA free of charge from the Government of Alberta. The high-resolution land cover classification was created for the entire watershed, and consisted of two separate scenes of SPOT 6 imagery. Because of differences in date of acquisition and image quality, each scene was classified individually, but using the same classification methodology. Each satellite image scene was atmospherically corrected and cloud masked, and the four SPOT 6 bands were combined with a set of ancillary raster data products generated for use in the classification. The ancillary data products included Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), and Iron Oxide Index (IOI), which were generated from the SPOT 6 data, a Probability of Depression layer and Slope, which were generated from a 15m LiDAR DEM, and mean and standard deviation maps of NDWI, which were generated using historic image analysis of Landsat 8 imagery in Google Earth Engine. Training data for the following classes were manually selected for each scene using the SPOT 6 RGB imagery and high resolution orthophotos: Forest; Bog; Fen; Marsh; Swamp; Open Water; Agriculture Pasture; Agriculture Crop; Exposed/Developed; and Urban.

A random forest classification was performed on the four SPOT 6 bands and additional ancillary layers, which used 70% of the training data to train the classifier and the remaining 30% to validate the preliminary results. Following this first stage of the classification, decision rules and manual editing were used to fix general classification errors. During this stage, the Natural Open class was added to account for areas of natural, low cover vegetation, the Natural Exposed class was added to account for areas of naturally occurring exposed soil, the Disturbed Vegetation class was added to account for human impacted low vegetation cover and manicured vegetation, and the Wetland (unclassified) class was added for natural wetland landscape features that were misclassified in the original classification, but could not be confidently assigned by the manual interpreter to one of the wetland classes. Once the quality control and editing for each scene were completed, the three scenes were mosaicked to create a complete classified land cover layer for the entire watershed. Finally, the Alberta Base features Roads layer was used to create a Roads class and a Road Verge class, and these two classes were added onto the classification to complete the 16-class land cover classification.

Table 2. Description of the spatial data obtained or derived for use in the assessment of riparian management area Intactness.

Data Layer	Year	Source	Usage
SPOT 6 Satellite Imagery	2016	Government of Alberta	Derivation of land cover classification
High Resolution (25 cm) Orthophotos	2015	Edmonton Regional Joint OrthoPhoto Initiative ((ERJOI) City of Edmonton, Strathcona County, Parkland County, Leduc County)	Derivation of land cover classification (training data and QA/QC)
15 m LiDAR DEM	n/d	Government of Alberta	Derivation of data products for classification
Normalized Difference Vegetation Index (NDVI)	2016	Fiera Biological. Layer was created using SPOT 6 satellite data provided by the Government of Alberta	Derivation of land cover classification
Normalized Difference Water Index (NDWI)	2016	Fiera Biological. Layer was created using SPOT 6 satellite data provided by the Government of Alberta	Derivation of land cover classification
Iron Oxide Index (IOI)	2016	Fiera Biological. Layer was created using SPOT 6 satellite data provided by the Government of Alberta	Derivation of land cover classification
Slope	n/d	Fiera Biological. Layer was created using LiDAR DEM data provided by the Government of Alberta	Derivation of land cover classification
Probability of Depression	n/d	Fiera Biological. Layer was created using LiDAR DEM data provided by the Government of Alberta	Derivation of land cover classification
Roads	2014	Alberta Base Features	Derivation of land cover classification
Mean and Standard Deviation of NDWI	2013–2018	Fiera Biological. Layers created using Landsat 8 imagery	Derivation of land cover classification
6 m Land Cover	2016	Fiera Biological. Layer was created using SPOT 6 satellite data provided by the Government of Alberta and derived layers	Derivation of RMAs and quantification of intactness metrics

3.1.2. Delineating Riparian Management Area Width and Length

In order to allow for comparisons between watersheds, the GIS methods that were developed to assess riparian areas in the Modeste watershed (Fiera Biological 2018a) were applied in the Strawberry watershed. As per the GIS method, which was developed to closely match previously developed aerial videography methods (Teichreb and Walker 2008), riparian intactness was assessed within a “riparian management area” (RMA).

An RMA is defined as an area along the shoreline of a waterbody that includes near-shore emergent vegetation zone, the riparian zone, and a riparian protective (buffer) zone (Figure 1). An RMA has two spatial components: width and length. For this assessment, riparian intactness was evaluated within RMAs that had a static 50 m wide buffer that was applied to both the left and right banks of each watercourse. In the case of lakes, a single 50 m wide buffer was applied to the shoreline. When assessing riparian condition using aerial videography, RMA length is determined by a change in the score of any single metric, and is thus variable. In order to replicate this approach, 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, Bog, Fen, Marsh, Swamp, Wetland (unclassified), Open Water, Natural Open, Natural Exposed) 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 reduce error associated with misclassification in the 6 m land cover, we merged and dissolved very small RMAs (e.g., 10 m) with neighbouring segments.

All municipal data summaries were generated using the "Intersect" tool in ArcGIS, where the results from each analysis (i.e., intactness, pressure, priority) were intersected with the municipal boundary layer. It should be noted that there are spatial discrepancies between the municipal boundary data and the provincial hydrography data that is freely available from AltaLIS. For example, in many instances, municipal boundaries follow the boundary of a water body (e.g., the boundary between Leduc and Parkland County is demarcated by the North Saskatchewan River, see Map 4); however, the boundary topology of these two features do not match. In these instances, minor edits were made to correct the intersection outputs and reassign results from one municipality to another, but in most cases, these layers were not extensively edited to correct topological errors. As a result, the municipal summaries of shoreline length for intactness and priority are approximate.

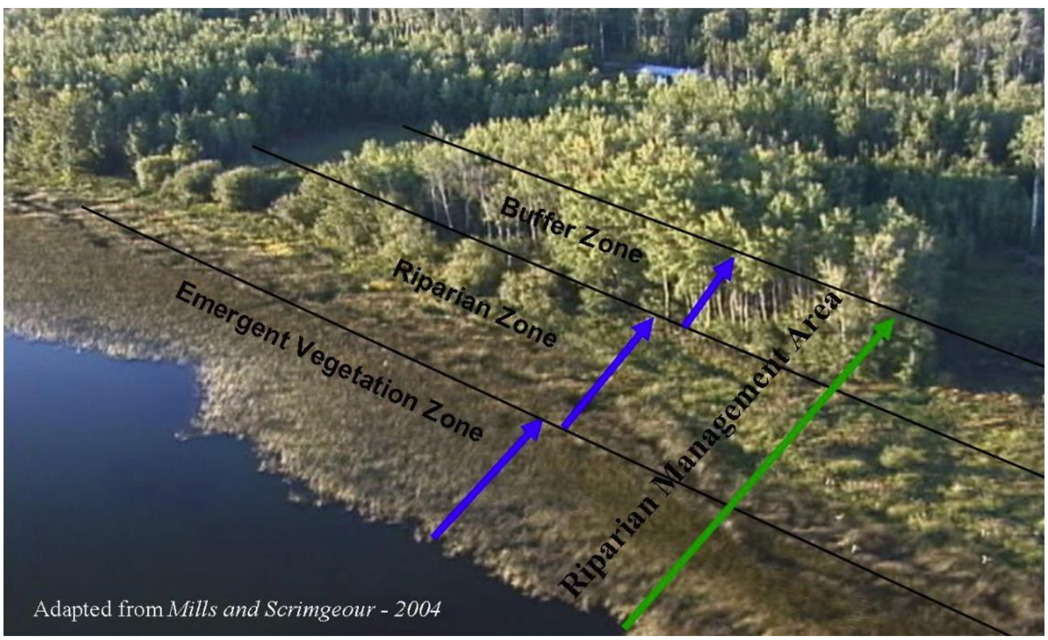


Figure 1. Schematic showing the different shoreline components included in a "riparian management area" (image taken from Teichreb and Walker 2008).

3.1.3. Indicator Quantification and Riparian Intactness Scoring

Intactness with riparian management areas was quantified using the following metrics:

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

To quantify Metric 1, all natural cover classes were selected from the 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, Marsh, Natural Open, Swamp, Wetland (unclassified). To quantify Metric 2, the percent coverage of Forest, Bog, and Swamp land cover classes was quantified for each RMA. For Metric 3, the percent cover of the following land cover classes were used to calculate human footprint within each RMA: Agriculture Crop, Agriculture Pasture, Disturbed Vegetation, Exposed Develop, Road, Road Verge, and Urban.

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

- High Intactness (>75-100): Vegetation within the RMA is present with little or no human footprint.
- Moderate Intactness (>50-75): Vegetation within the RMA is present with some human footprint.
- Low Intactness (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.

3.2. Assessing Pressure on Riparian System Function

We adapted the Watershed Integrity scoring methodology (Flotemersch et al. 2016) to assess Pressure on Riparian System Function in the Strawberry 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 Strawberry 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*). Catchment pressure was calculated using the following equation, with higher scores indicating areas where there may be heightened pressure on riparian system function:

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

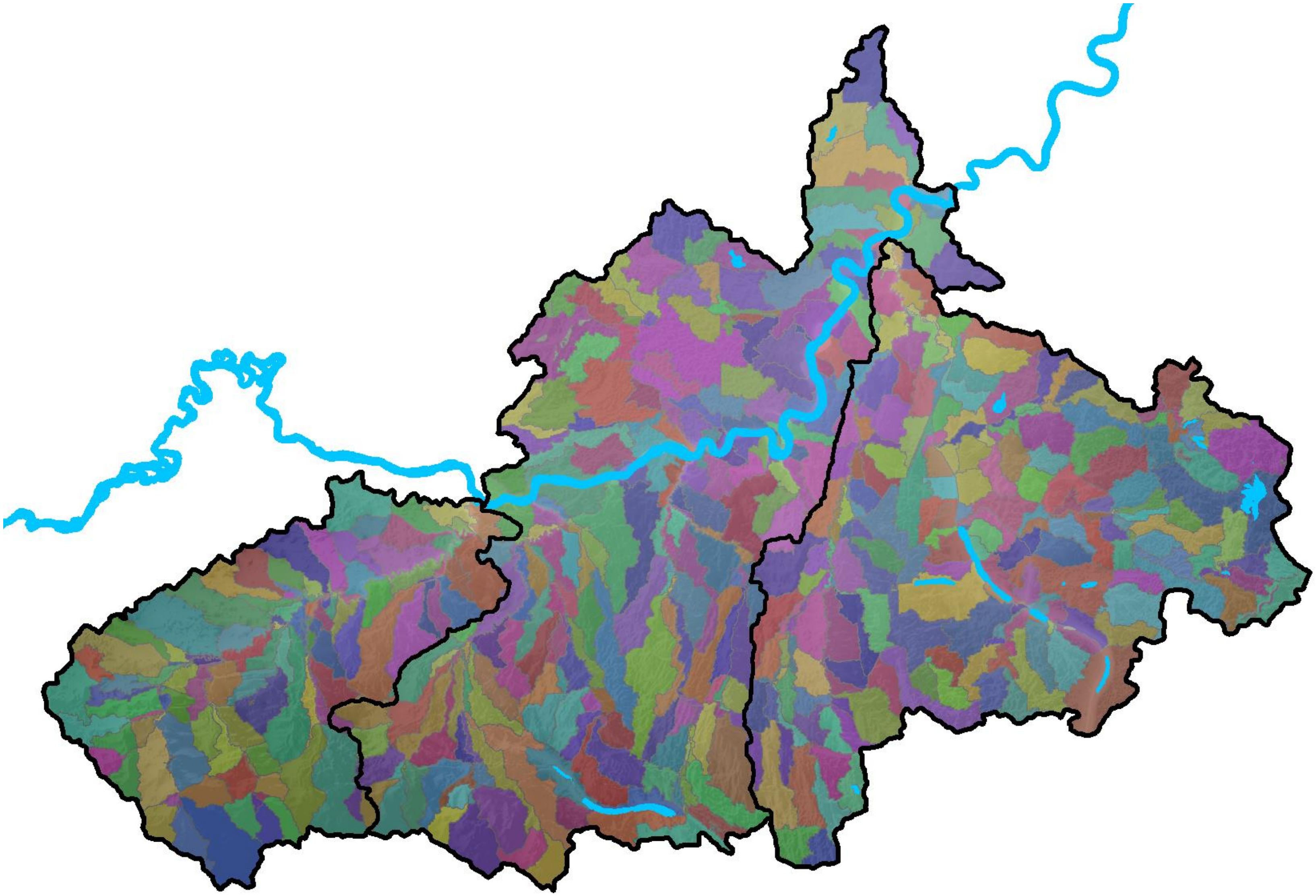
Natural Resilience (*NR*) and Human Impact (*HI*) function scores were calculated from a set of associated stressor metrics (S_i) that are known to affect riparian function and are measurable in a GIS environment. A list of the stressor metrics associated with each function, along with a description of how each stressor was quantified, and the data used for the quantification is provided in Table 3.

Table 3. List of metrics used to assess pressure on riparian system function, along with a description of the methods used to assess each metric and the source and vintage of the data used for metric quantification. Each metric was quantified within local catchment areas that were derived specifically for this assessment using LiDAR 15 m data provided by the Government of Alberta.

Function	Stressor Metric	Metric Quantification	Data Source & Date
Natural Resilience (*NR*)	Forest Cover	Percent cover by forest class	Fiera Biological Strawberry watershed Land Cover (2016)
	Wetland Cover	Percent cover by wetland classes	Fiera Biological Strawberry 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 Strawberry 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)

3.2.1. Deriving Local Catchment Areas

Variables that exert pressure on riparian system function range spatially from large-scale to site-specific. We conducted a pressure assessment at a “local catchment” scale, which we considered to be a scale that was meaningful both from the perspective of ecological and hydrological processes, as well as from the perspective of land management. Local catchment areas were created using a 15-meter LiDAR DEM obtained from the GOA. The 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 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 that were created for the Strawberry watershed is presented in Map 6. Local catchment areas that intersected the RMAs of the waterbodies included in this study were used as the unit of analysis for the pressure assessment.



Map 6. Local catchment areas derived using Arc HydroTools. These catchments areas were used as the unit of analysis to quantify and characterize pressure on riparian system function within the Strawberry watershed.

3.2.2. Quantifying Stressor Metrics & Calculating Function Scores

In order to quantify the Land Use Intensity stressor metric, we had to first assign a land use intensity value to land cover types and human footprint present in the Strawberry watershed. High intensity of use values were assigned to land cover types that are known to be more impactful on riparian system function, and all values were assigned using best professional judgment informed by a 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 for land cover in the Strawberry are provided in Table 4.

Table 4. Intensity of Use values assigned to the various land cover classes present in the Strawberry 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

Scores for each of the eight GIS stressor metrics were calculated using ArcGIS 10.6 in one of two ways. For stressors that have a known measurable biological response, literature-derived thresholds were used to define the maximum feasible value (Table 5). This threshold is the 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 ≤3% cover of wetlands is under maximum pressure for this stressor. For stressors with a known threshold, scores were calculated as:

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

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

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

A description of the stressor threshold values used in this assessment, and the method used to derive each threshold, is provided in Table 5.

Once stressors were quantified, the values were compiled within their associated pressure function (CP_{NR} and CP_{HI}) and were combined mathematically to calculate a final catchment pressure score, as follows:

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

for which,

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

and,

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

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

3.2.3. Assigning Pressure Categories

Catchment integrity was translated into catchment pressure by taking the percent scores and grouping the scores into three pressure categories (Low, Moderate, High) based on the quartile percentile breaks for the distribution of scores. Catchments in the Low Pressure group correspond to the catchments with the top 25% of scores, catchments in the High Pressure group correspond to the catchments with the bottom 25% of scores, and Moderate Pressure catchments correspond to the remaining 50% of scores (i.e., scores between the 25^{th} and 75^{th} percentiles).

Table 5. Thresholds and scoring types used to calculate stressor scores for pressure metrics.

Function	Stressor Metric	Threshold	Scoring Type	References
Natural Resilience *(NR)*	Forest Cover	Minimum 25% cover	Literature review	Target forest cover of 25% for water quantity/quality (Adams and Taratoot 2001)
				30% cover at watershed scale supports less than one half of the potential species richness and marginally healthy aquatic systems (Environment Canada 2014)
				Target cover of at least 35% for subbasins to prevent moderate extirpation of bull trout (Ripley et al. 2005)
				Threshold of 30% natural cover correlated with riverine ecological condition (Deegan et al. 2010)
				6% loss of aquatic species for every 10% loss of natural land cover (Weijters et al. 2009)
	Wetland Cover	Minimum 3% cover	Literature review	Wetlands should comprise at least 3-7% of a watershed for water quality benefits (Mitch and Gosselink 2000)
	Slope	Maximum value	Range of values	N/A
	Landslide Susceptibility	Maximum value	Range of values	N/A
Human Impact *(HI)*	Land Use Intensity	Maximum value	Range of values	N/A
	Stream Crossing Density	$0.6/km^2$	Literature review	Stream crossings impede fish passage, affect water flow, and water quality - adapted thresholds from bull trout and general fish road density thresholds of $0.6 km/km^2$ and $0.7 km/km^2$ (Tchir et al. 2004)
	Road Density	$1.0\ km/km^2$	Literature review	Extirpation of bull trout at $1.0\ km/km^2$ (AESRD 2012)
				Large mammals affected at various thresholds:$0.4\ km/km^2$ for grizzly bear; $1.25\ km/km^2$ for black bear (AESRD 2012); $0.62\ km/km^2$ for elk (AESRD 2012)
	Density of Other Linear Disturbance Types	$3.0\ km/km^2$	Literature review	Adapted general density threshold for watershed health, where >3 km/km^2 is used as an indicator for poor health (AESRD 2012)

3.3. Management Prioritization

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

Combining intactness and pressure scores results in prioritization matrix with 12 scoring categories, and we assigned a unique score ranging between 1 and 12 to each category using best professional judgement (Table 6). The numeric scores were then combined and assigned to one of four prioritization categories, as follows:

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

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

Table 6. Riparian prioritization matrix for RMAs in the Strawberry 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 Strawberry Watershed

4.1. Riparian Management Area Intactness Results

Riparian intactness was calculated for approximately 1,926 km of creek and lake shoreline in the Strawberry watershed (Map 7 and Map 8). Overall, 35% of the shoreline that was assessed was classified as High Intactness, with a further 23% classified as Moderate Intactness (Table 7; Figure 2). Approximately 42% of the shoreline was classified as either Low (10%) or Very Low (32%) Intactness.

When the proportion of shoreline assigned to each intactness category is compared for each HUC 8 subwatershed, the Strawberry Creek subwatershed had the greatest length of shoreline (291 km) rated as High Intactness, followed by North Saskatchewan Below Strawberry (231 km) and Whitemud Creek (143 km) (Table 7; Figure 3). The Whitemud Creek subwatershed had the greatest length of shoreline assessed as Very Low (255 km) and Low Intactness (110 km), followed closely by North Saskatchewan Above Strawberry.

Table 7. Total length of shoreline assessed within each HUC 8 subwatershed, along with a summary of the length of shoreline assigned to each riparian intactness category. The proportion of the total shoreline length assigned to each intactness category at the watershed scale is provided in brackets.

		Length (km) of RMA By Intactness Category			
HUC 8 Subwatershed	**Total Length Assessed (km)**	**Very Low Intactness**	**Low Intactness**	**Moderate Intactness**	**High Intactness**
North Saskatchewan Below Strawberry	692	249 (40)	56 (28)	156 (35)	231 (35)
Strawberry Creek	528	111 (18)	32 (16)	94 (21)	291 (44)
Whitemud Creek	706	255 (41)	110 (56)	198 (44)	143 (21)
Strawberry Watershed Total	**1,926**	**615 (32)**	**198 (10)**	**448 (23)**	**665 (35)**

When intactness scores are summarised and compared for lakes, it is apparent that the majority of the riparian management areas associated with lakes are in fairly good condition, with all of the named lakes having 50% or more of their shorelines characterized as either High or Moderate Intactness (Figure 4), and eight out of the 10 unnamed lakes having 50% or more of their shorelines characterized as either High or Moderate Intactness (Figure 5). Of the named lakes, Wizard Lake and Saunders Lake had the greatest proportion of their shorelines assessed as either Very Low or Low Intactness, with unnamed lake 2 and 5 having over 50% of their shorelines assessed as Low or Very Low Intactness.

Eight out of the 12 named creeks in the watershed had more than 25% of their shorelines assessed as Very Low Intactness (Figure 6). Willow Creek had the largest proportion of shoreline classified as Very Low condition, followed by West Whitemud Creek and Cutbank Creek. When the two lowest intactness categories are considered together, Blackmud, Cutbank , Irvine , West Whitemud, and Willow Creeks all had 50% or more of their shorelines classified as either Very Low or Low Intactness. Conversely, Little Strawberry, Strawberry, and Sunnybrook Creeks all had more than 50% of their shorelines assessed as High Intactness (Figure 6).

Of the 37 Unnamed Creeks that were assessed, the majority had 50% or more of the shoreline classified as Low or Very Low Intactness, with nine (24%) of these waterbodies having more than 50% of the shoreline classified as Very Low Intactness (Figure 7 and Figure 8). Only three unnamed creeks (8%) had more than 50% of their shorelines assessed as High Intactness. When High and Moderate Intactness categories are considered together, 20 out of 37 (54%) of unnamed creeks fall within one of these two categories.

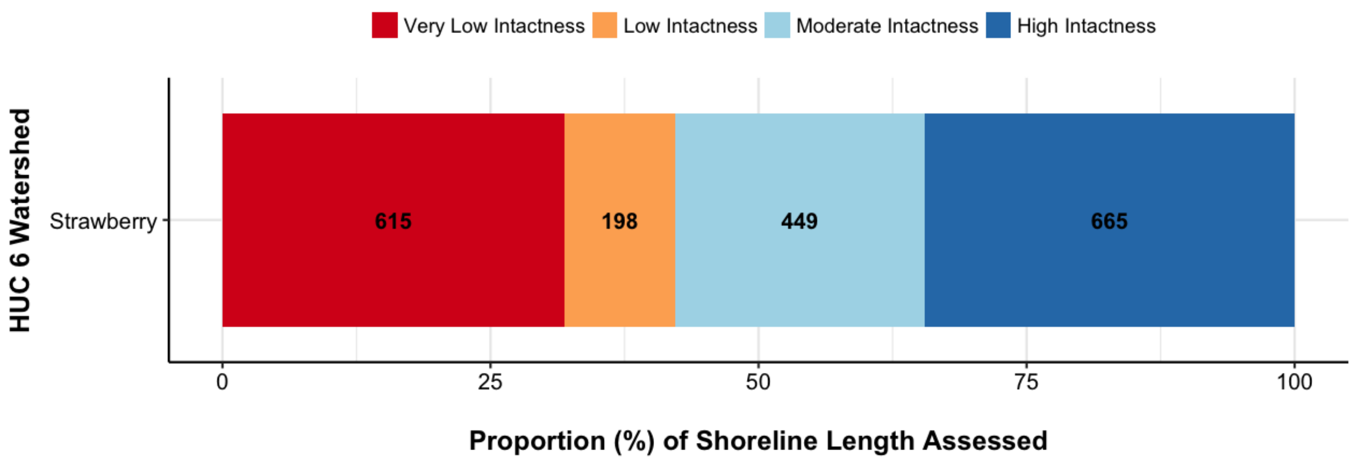


Figure 2. The total proportion of shoreline within the Strawberry watershed assigned to each riparian intactness category. Numbers indicate the total length (km) of shoreline associated with each category.

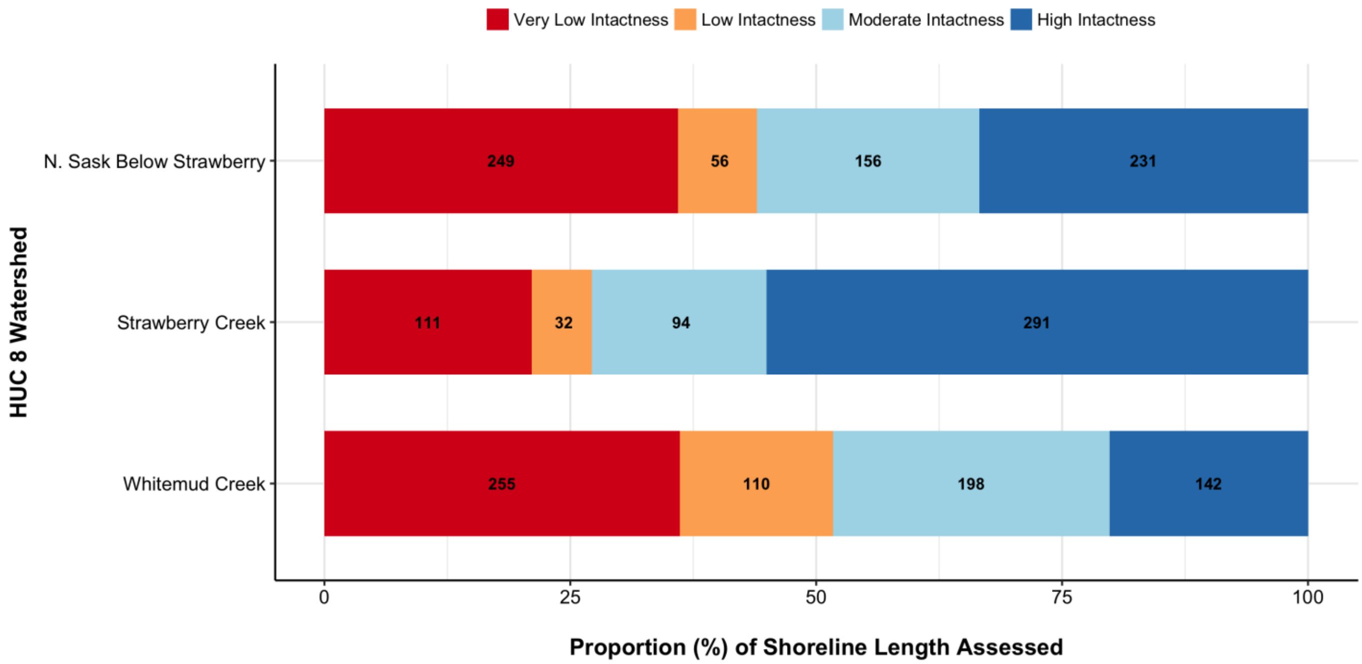
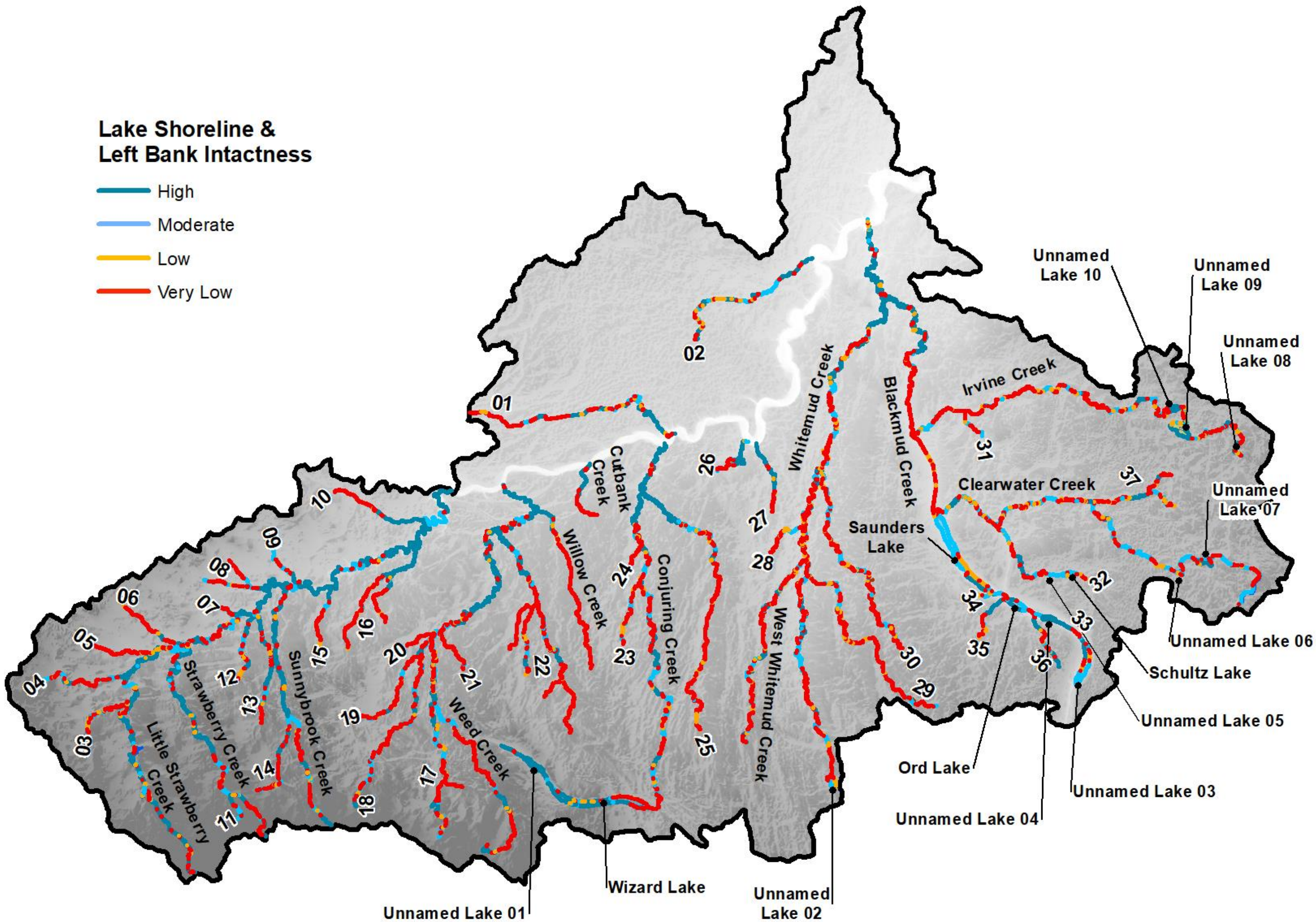
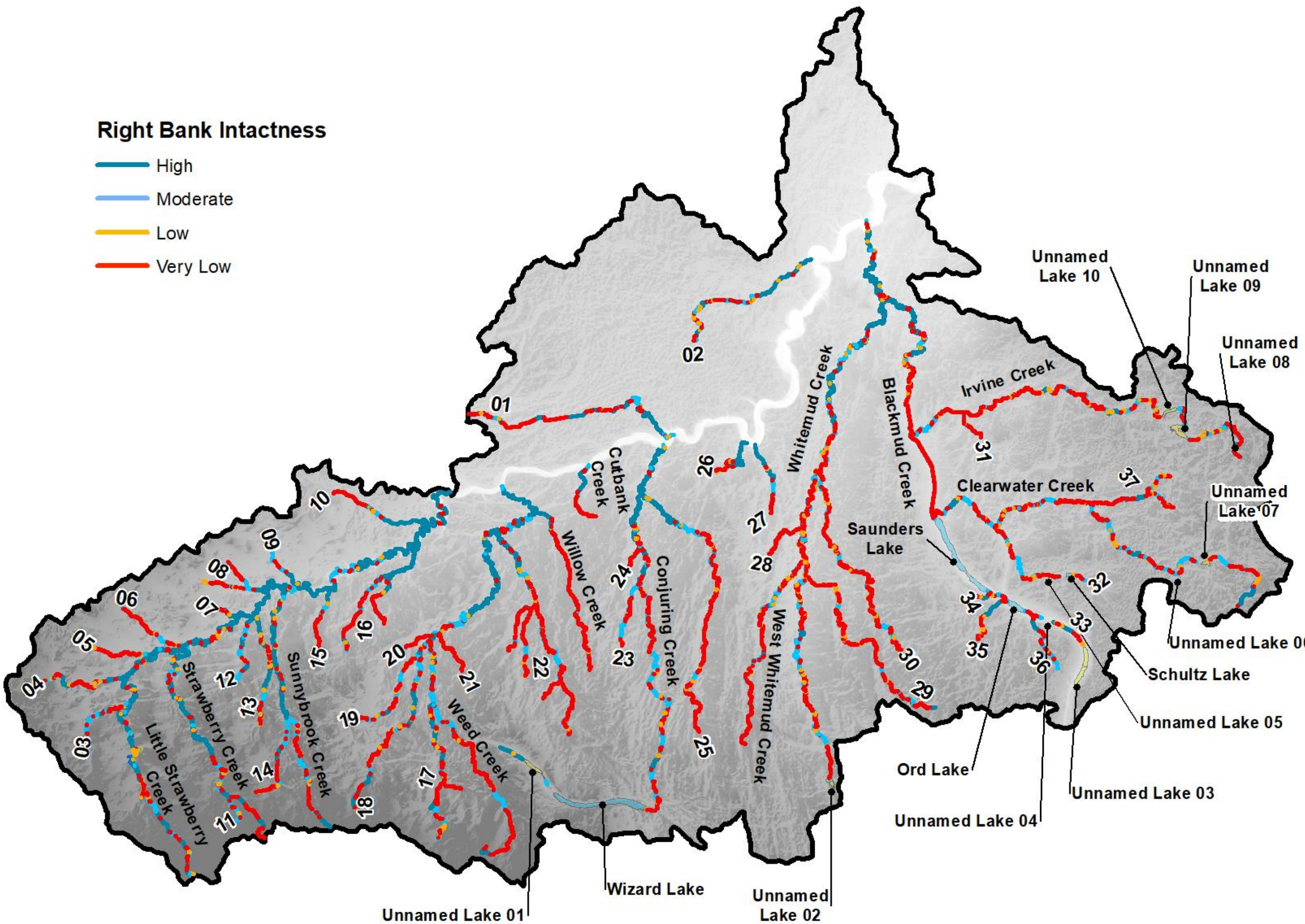


Figure 3. The total proportion of shoreline within the Strawberry watershed assigned to each riparian intactness category, summarized by HUC 8 subwatershed. Numbers indicate the total length (km) of shoreline associated with each intactness category.



Map 7. Intactness for the lake shorelines and the left bank of creeks that were included in this study.



Map 8. Intactness for the right bank of creeks that were included in this study.

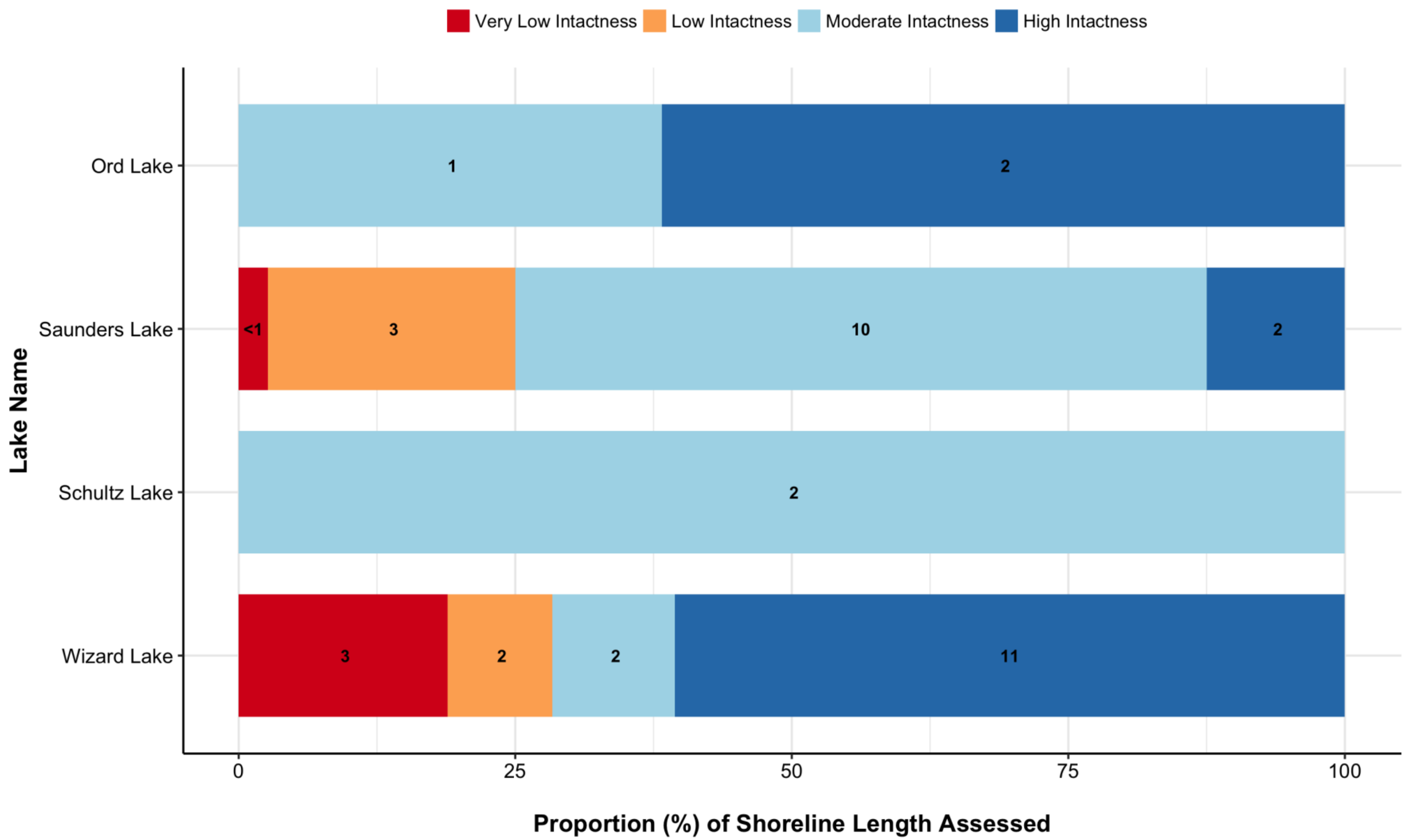


Figure 4. The total proportion of shoreline for named lakes in the Strawberry watershed assigned to each riparian intactness category. Numbers indicate the total length (km) of shoreline associated with each category.

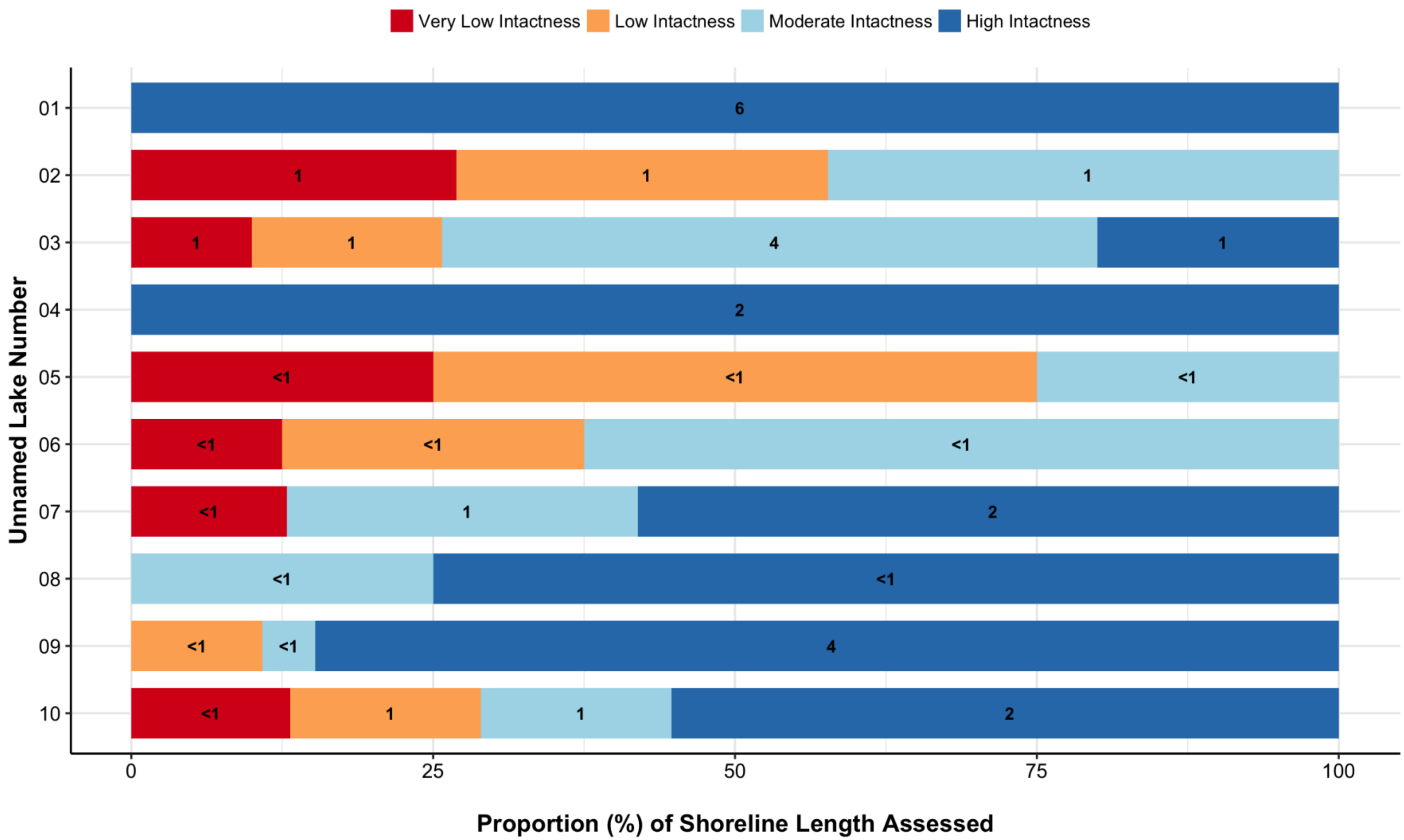


Figure 5. The total proportion of shoreline for unnamed lakes in the Strawberry watershed assigned to each riparian intactness category. Numbers indicate the total length (km) of shoreline associated with each category.

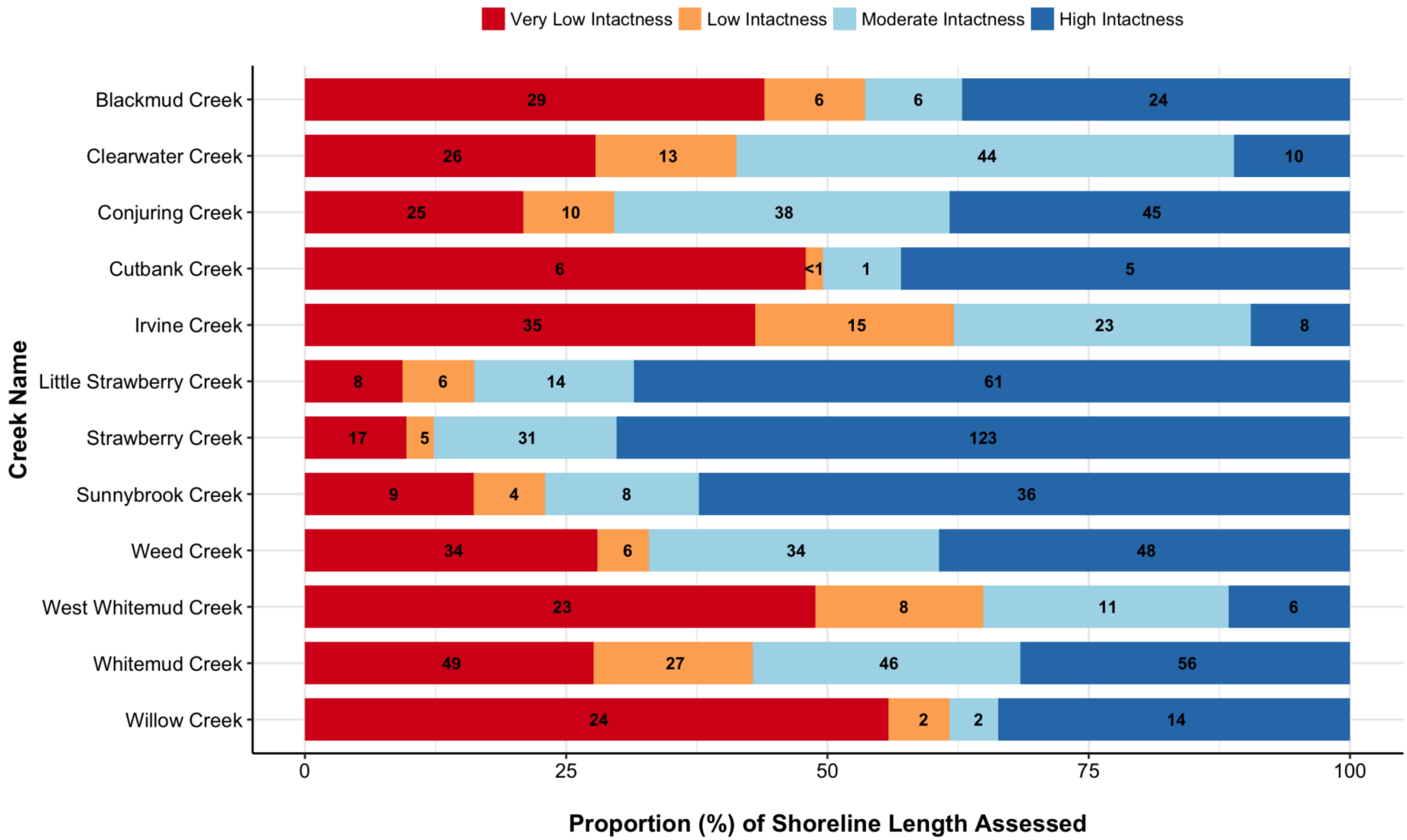


Figure 6. The total proportion of shoreline for named creeks in the Strawberry watershed assigned to each riparian intactness category. Numbers indicate the total length (km) of shoreline associated with each category.

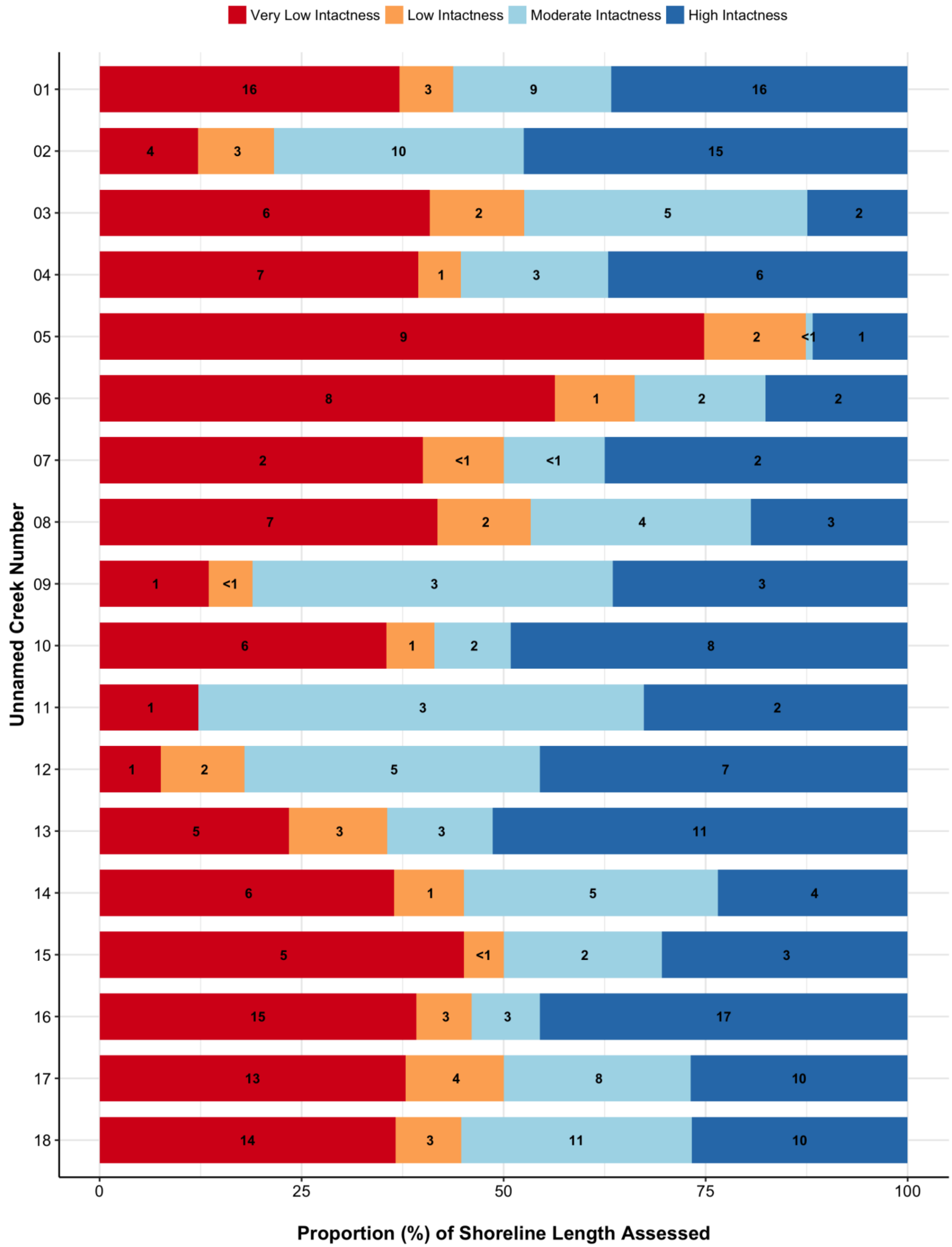


Figure 7. The total proportion of shoreline for Unnamed Creeks 01 to 18 assigned to each riparian intactness category. Numbers indicate the total length (km) of shoreline associated with each category.

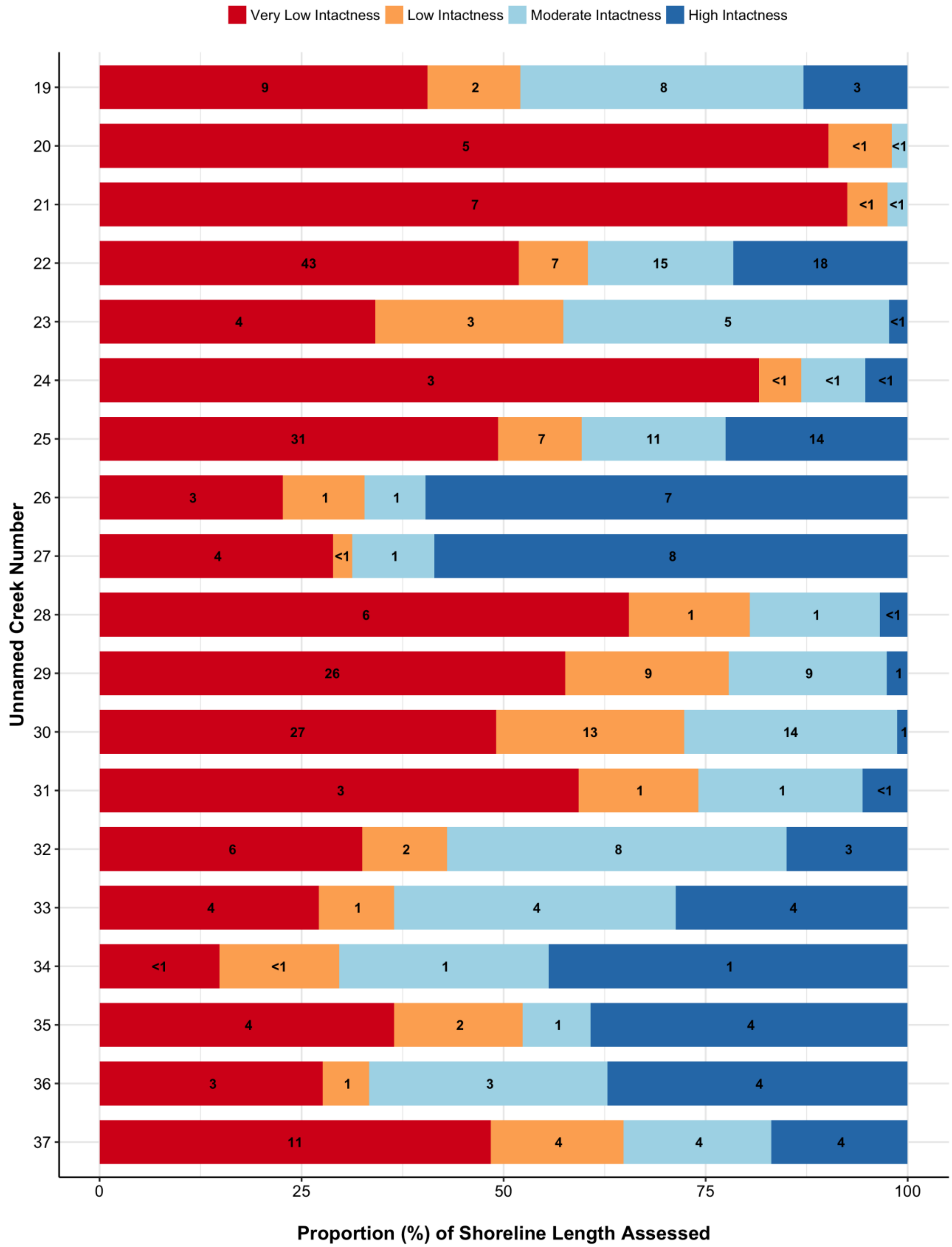


Figure 8. The total proportion of shoreline for Unnamed Creeks 19 to 37 assigned to each riparian intactness category. Numbers indicate the total length (km) of shoreline associated with each category.

4.2. Pressure on Riparian System Function Results

Pressure on riparian system function was assessed for 546 local catchment areas within the Strawberry watershed, covering an area of nearly 3,000 km^2 (Figure 9). Of that area, 19% was classified as High Pressure, with the majority (59%) of local catchments being classified as Moderate Pressure, and the remaining 23% being classified as Low Pressure.

When pressure scores were compared between HUC 8 subwatersheds, North Saskatchewan Below Strawberry and Whitemud Creek had the greatest proportion of local catchments classified as High Pressure; however, Strawberry Creek had the greatest proportion of local catchments (more than 95%) classified as either Moderate or High Pressure (Figure 10). Spatially, areas of High Pressure were concentrated in the northern portion of the watershed, primarily in association with intensively built-up areas like the City of Edmonton (Map 9 and Map 10).

When pressure scores were examined only for those local catchments that intersect lake RMAs, it is apparent that the majority of the lakes assessed in this study are located in areas where land use pressure is relatively high (Figure 11). For all of the lakes assessed more than half of the adjacent lands were classified as either Moderate or High Pressure, with three of the four lakes having more than 75% of the adjacent lands classified as either Moderate or High Pressure. Wizard Lake was the only named lake that had some portion of the adjacent lands classified as Low Pressure.

Pressure scores for unnamed lakes are generally lower than for the named lakes, with three of the 10 lakes having 100% of adjacent lands assessed as Low Pressure and five of the 10 unnamed lakes having more than 50% of the adjacent lands classified as Low Pressure. Two of the 10 unnamed lakes had 100% of the adjacent lands classified as High Pressure, with 5 of the 10 lakes having more than 50% of adjacent lands classified as either Moderate or High Pressure.

For named creeks, pressure on riparian system function is quite high, with nine out of 11 named creeks having more than 75% of adjacent lands classified as either Moderate or High Pressure (Figure 13). Blackmud Creek had the highest proportion of adjacent lands classified as High Pressure; conversely, Willow Creek had the highest proportion of adjacent lands classified as Low Pressure, with Irvine Creek having the second highest proportion of adjacent lands classified as Low Pressure. Results were similar for unnamed creeks, with 47 of the 53 unnamed streams (89%) having more than half of adjacent lands classified as Moderate or High Pressure (Figure 14 and Figure 15).

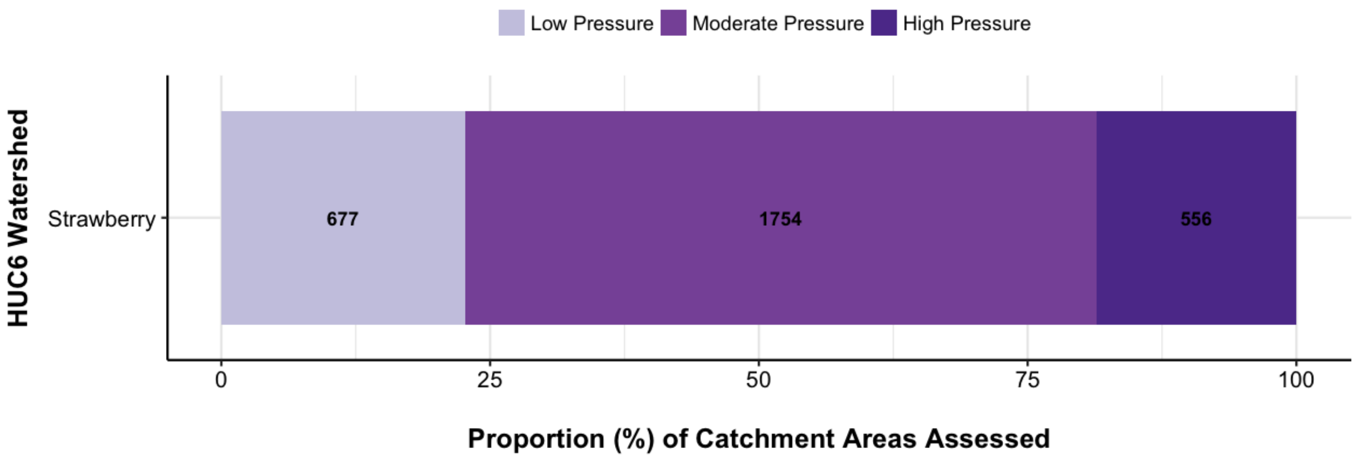


Figure 9. The proportion of local catchments within the Strawberry watershed assigned to each pressure category. Numbers indicate total area (km^2) assigned to each category.

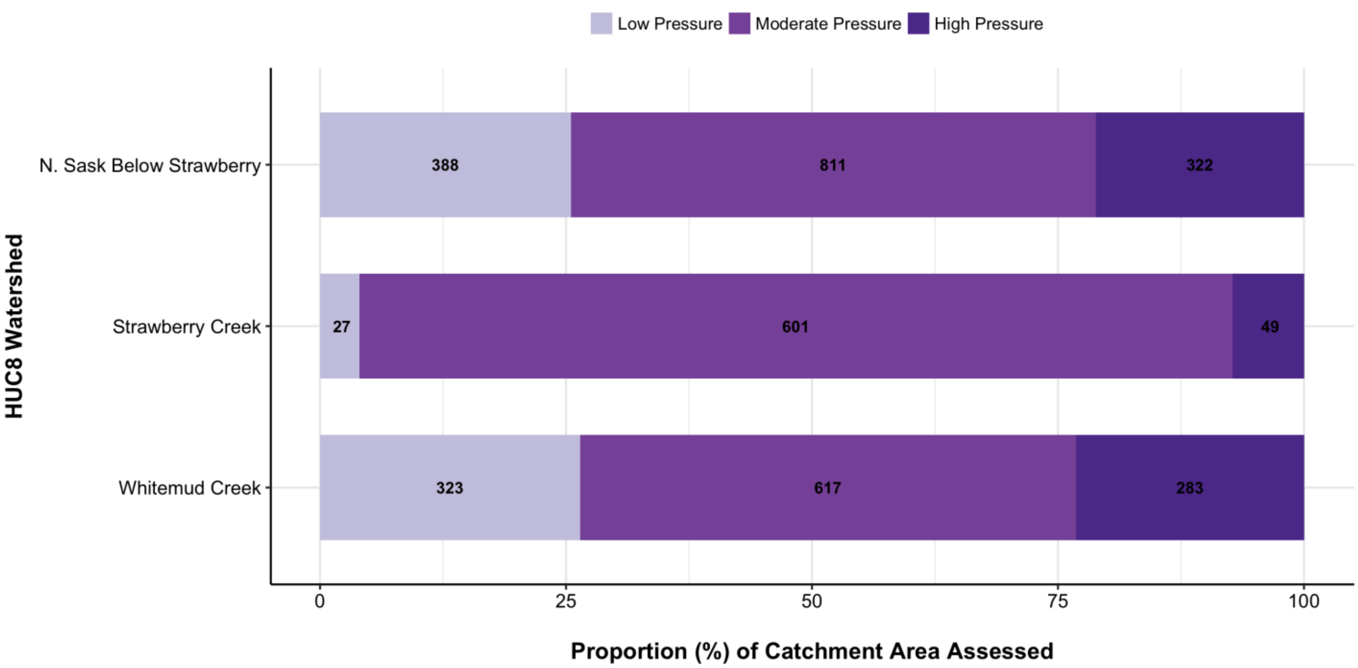
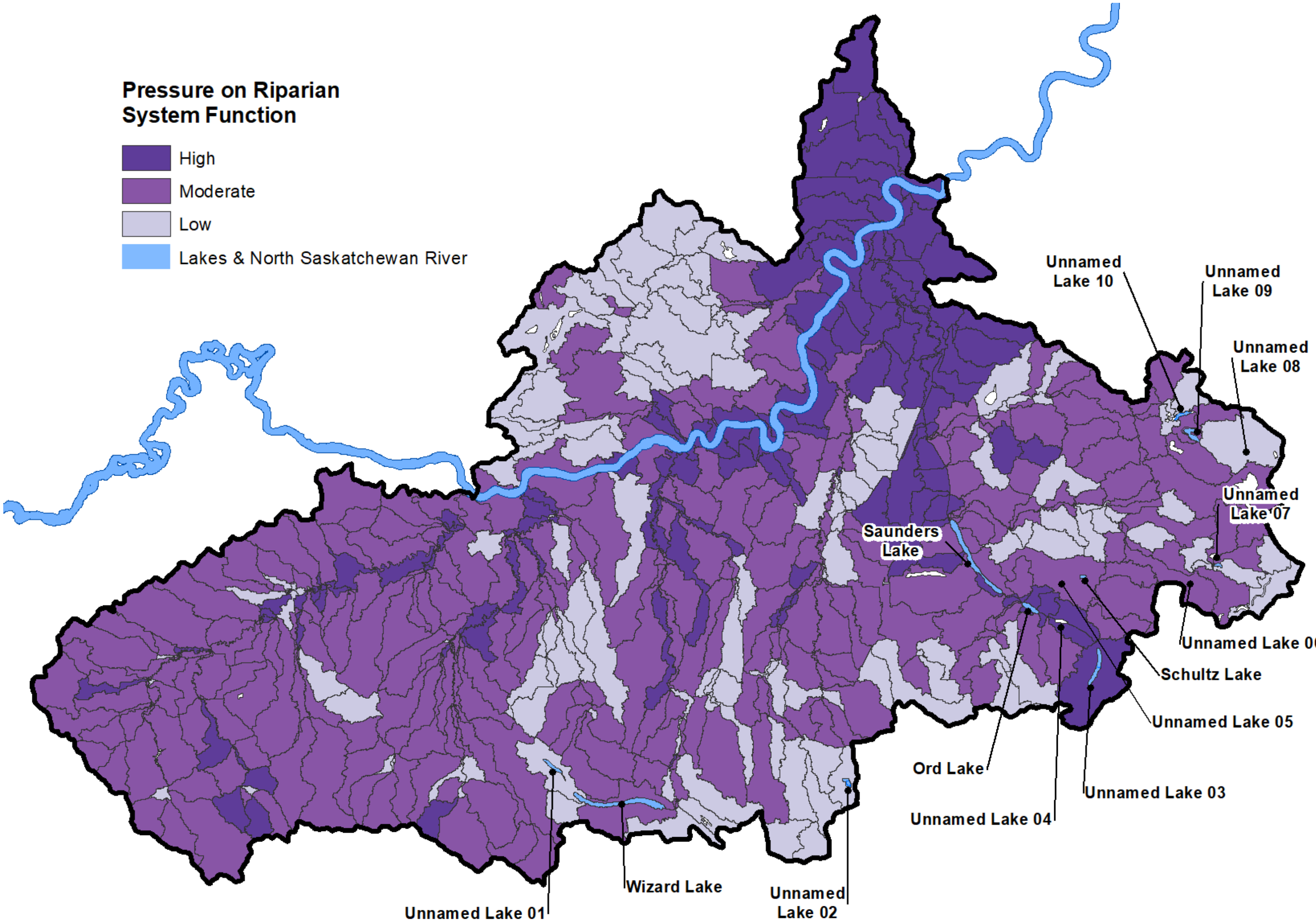
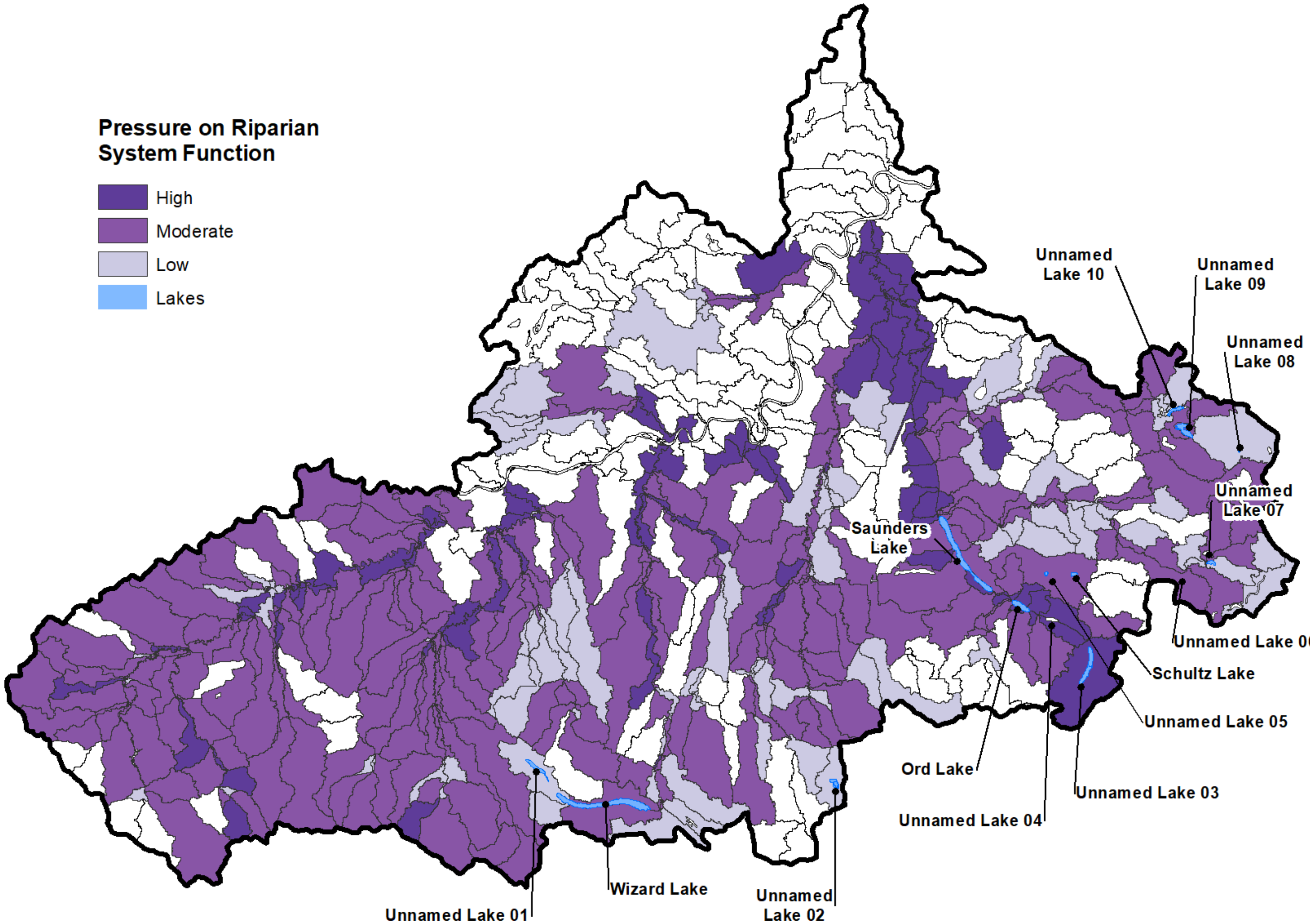


Figure 10. The proportion of local catchments assigned to each pressure category, summarized by HUC 8 subwatershed. Numbers indicate total area (km^2) assigned to each pressure category.



Map 9. Distribution of local catchments classified as High, Moderate, and Low Pressure within the Strawberry watershed.



Map 10. Pressure classification for local catchment areas that intersect the RMAs of waterbodies that were included in this study.

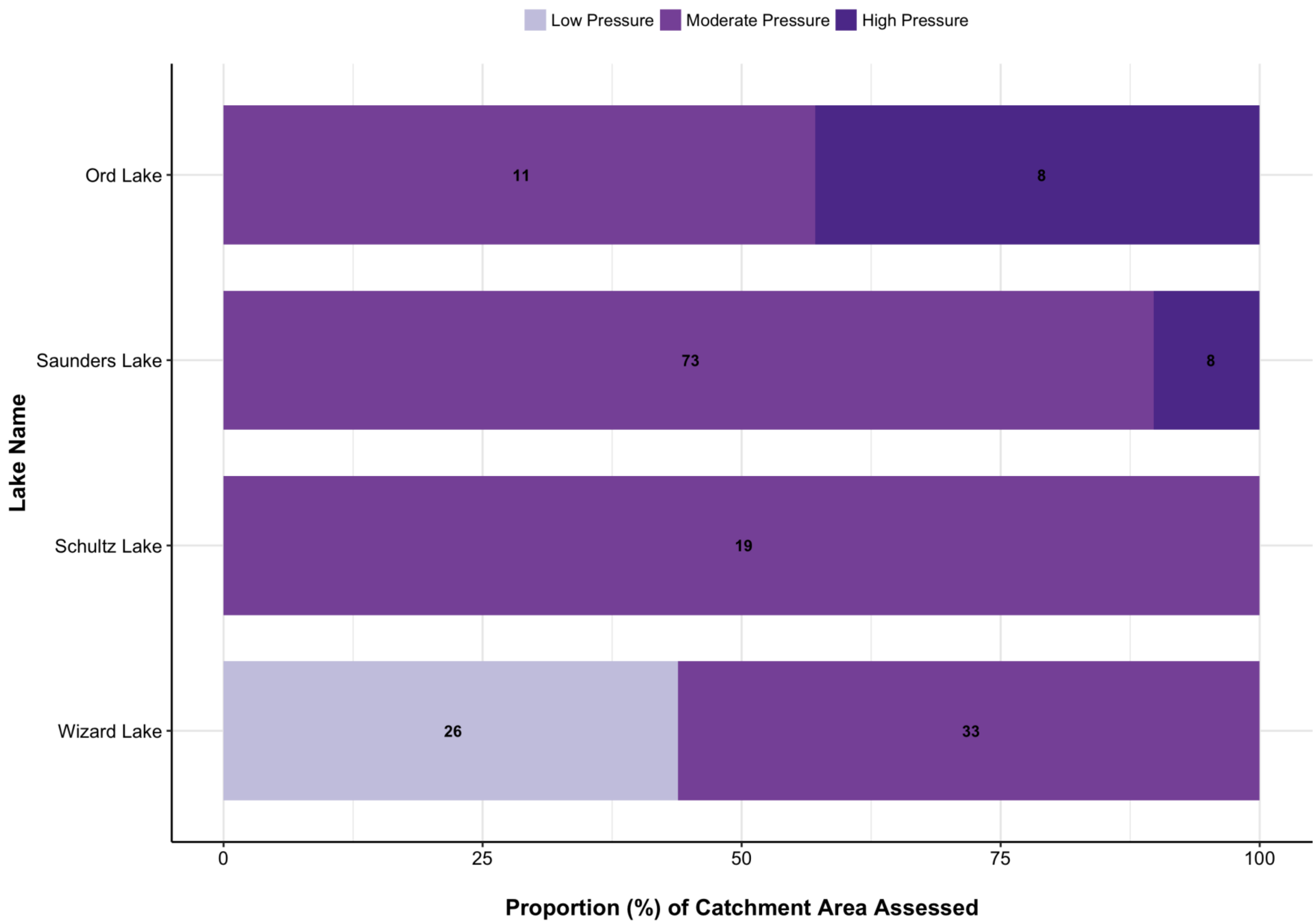


Figure 11. The proportion of catchment area by pressure category associated with RMAs that intersect the shorelines of named lakes in the Strawberry watershed. Numbers indicate the total area (km^2) assigned to each pressure category.

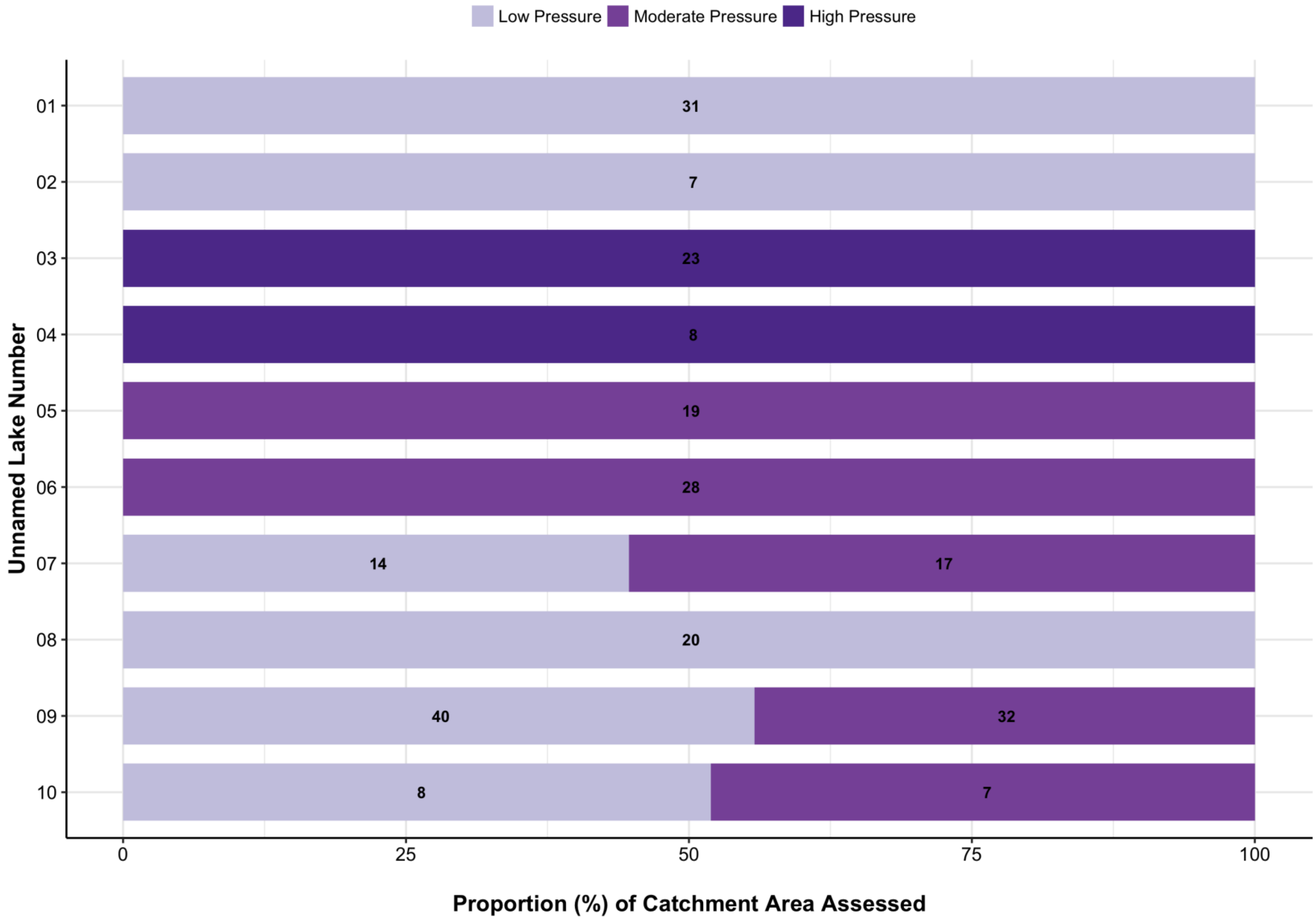


Figure 12. The proportion of catchment area by pressure category associated with RMAs that intersect the shorelines of unnamed lakes in the Strawberry watershed. Numbers indicate the total area (km^2) assigned to each pressure category.

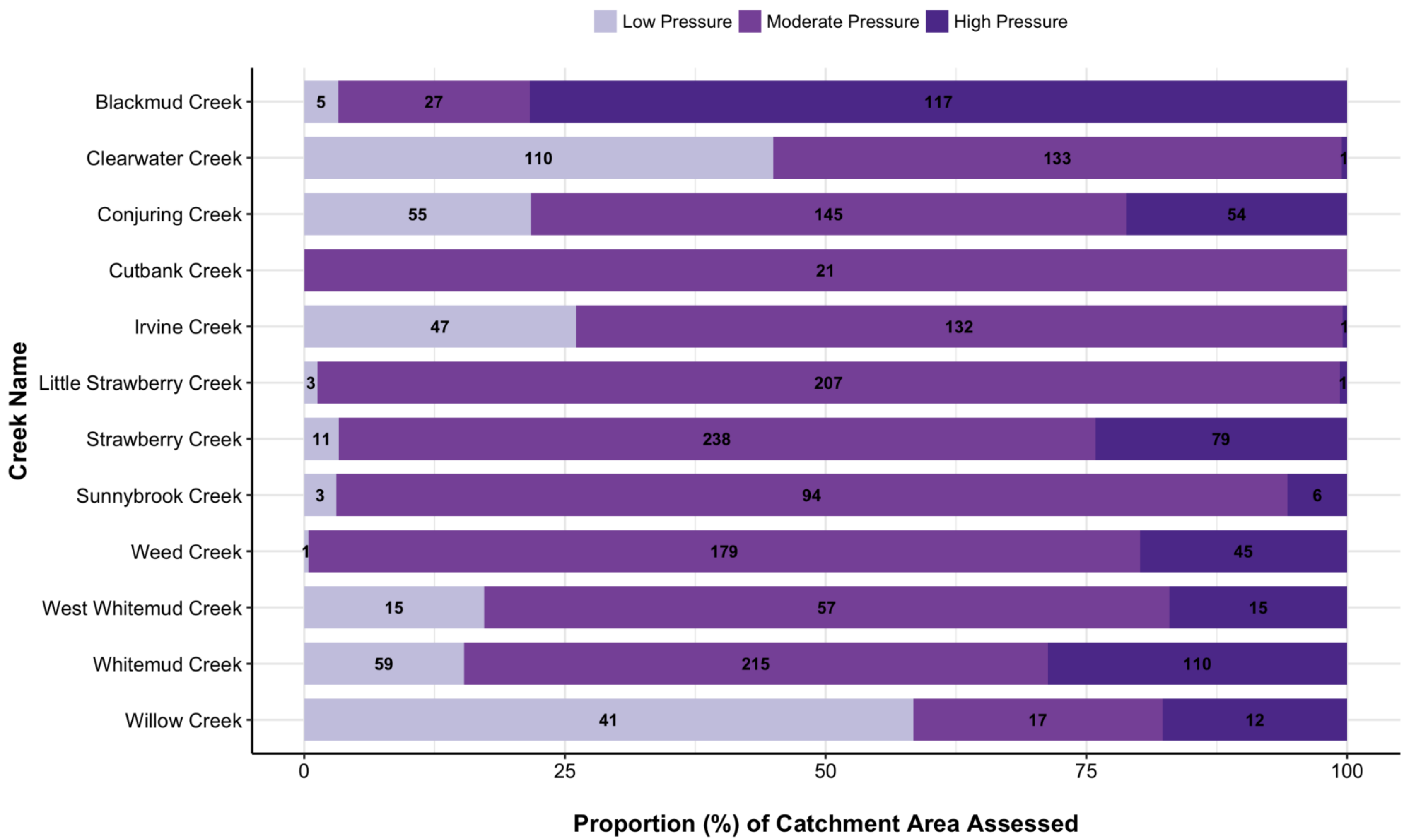


Figure 13. The proportion of catchment area by pressure category associated with RMAs that intersect the shorelines of named creeks in the Strawberry watershed. Numbers indicate the total area (km^2) assigned to each pressure category.

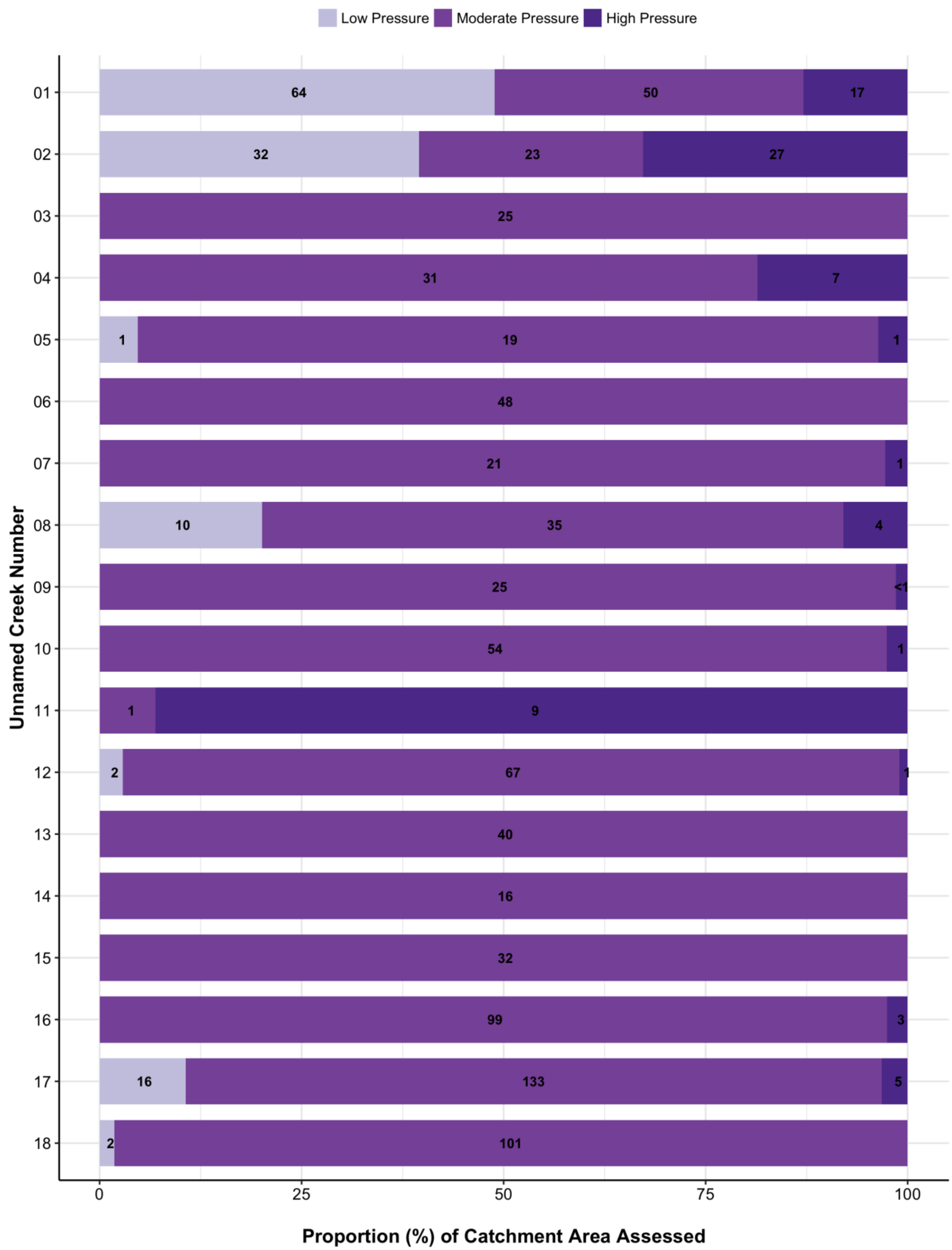


Figure 14. The proportion of catchment area by pressure category associated with RMAs that intersect the shorelines of Unnamed Creeks 01 to 18. Numbers indicate the total area (km^2) assigned to each pressure category.

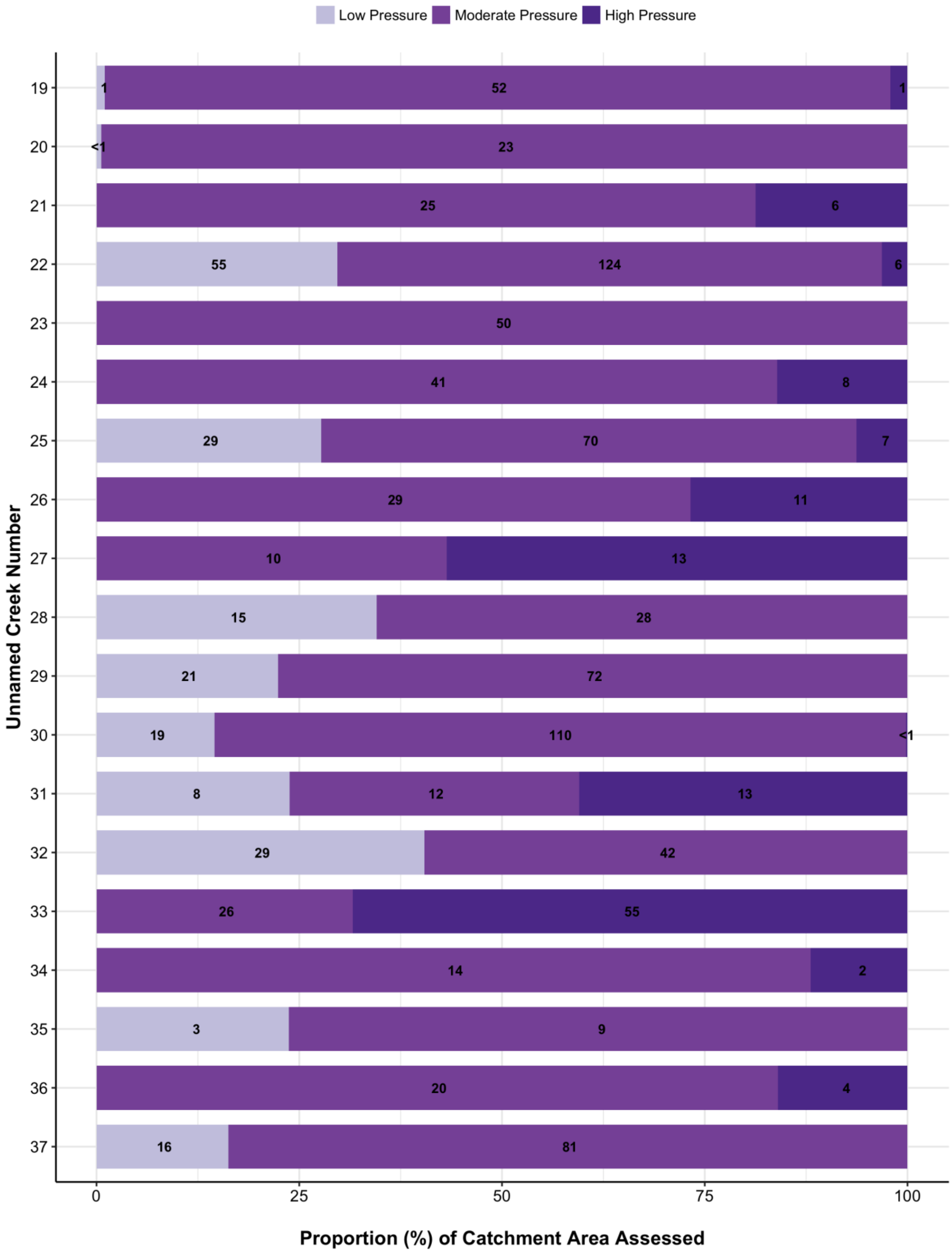


Figure 15. The proportion of catchment area by pressure category associated with RMAs that intersect the shorelines of Unnamed Creeks 19 to 37. Numbers indicate the total area (km^2) assigned to each pressure category.

4.3. Conservation & Restoration Prioritization Results

Conservation and restoration priority was assigned to the RMAs of all lakes and creeks that were included in this study (Map 11 and Map 12), and the results have been summarized as the total length of shoreline that has been assigned to each priority category. Within the Strawberry watershed, 58% of the shoreline length that was assessed was classified as either High Conservation (26%) or Moderate Conservation (32%) Priority, representing approximately 1,113 km of shoreline (Figure 16). Conversely, 42% of the shoreline was classified as either High Restoration (26%) or Moderate Restoration (16%) Priority, representing approximately 813 km of shoreline.

When summarized by HUC 8 subwatershed, Strawberry Creek had the highest proportion of shoreline prioritized for conservation, with more than 40% of the shoreline being identified as High Conservation Priority (Figure 17). For the North Saskatchewan Below Strawberry subwatershed, just over 50% of the shoreline was identified as High or Moderate Conservation Priority. Conversely, Whitemud Creek had the highest proportion (52%) of shoreline assessed as either High or Moderate Restoration Priority, with North Saskatchewan Below Strawberry having more than 40% shoreline prioritized for restoration.

For all four named lakes assessed in this study, more than half their shorelines were classified as either High or Moderate Conservation Priority, with Wizard Lake having 66% of its shoreline classified as High Conservation Priority. Conversely, Wizard Lake also had the highest proportion (18%) of its shoreline identified as High Restoration Priority (Figure 18). Of the 10 unnamed lakes that were assessed, eight had more than half of their shorelines classified as High or Moderate Conservation Priority, while two of the unnamed lakes had more than half of their shorelines assessed as High or Moderate Restoration Priority (Figure 19).

Of the 12 named creeks assessed, nine had at least 25% of their shorelines identified as either High or Moderate Restoration Priority (Figure 20). Both Blackmud Creek and West Whitemud Creek had more than 50% of their shorelines assessed as High Priority for Restoration. When High and Moderate Restoration Priority categories were considered together, Irvine Creek and Willow Creeks also had more than half of their shorelines prioritized for restoration. Conversely, Little Strawberry, Strawberry, and Sunnybrook Creeks had more than 75% of their shorelines classified as either High or Moderate Conservation Priority. When unnamed creeks were considered, 20 out of 37 creeks that were assessed had more than half of their shorelines classified as High or Moderate Restoration Priority, with four unnamed creeks having more than 75% of their shorelines classified as High or Moderate Restoration Priority (Figure 21 and Figure 22). Conversely, 20 out of 37 (54%) of unnamed creeks had more than half of their shorelines prioritized for conservation, with only one unnamed creek (#13) having more than 50% of its shoreline classified as High Conservation Priority.

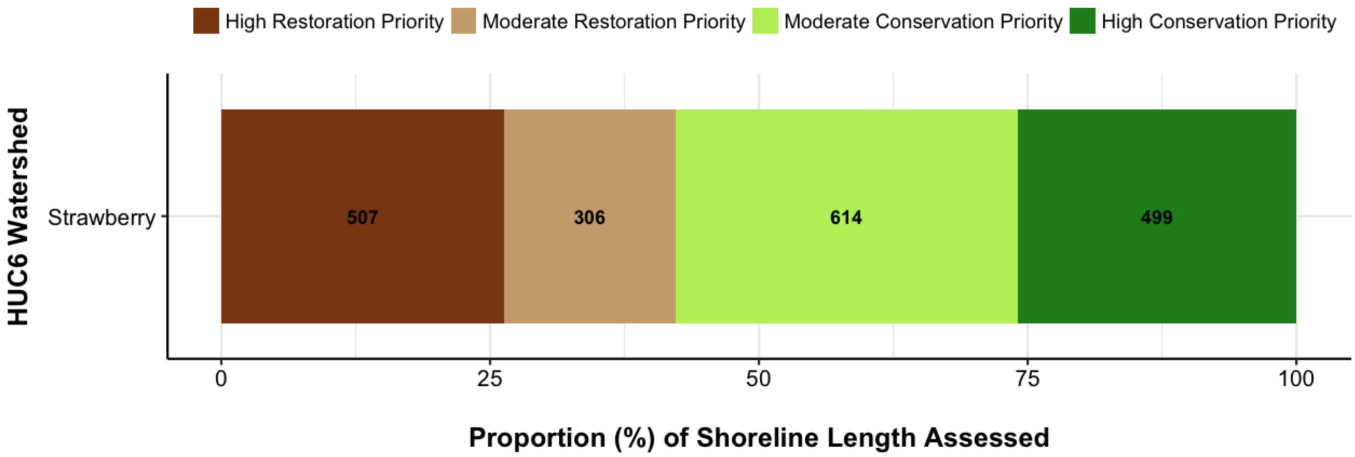


Figure 16. The total proportion of shoreline within the Strawberry watershed assigned to each priority category. Numbers indicate the total length (km) of shoreline associated with each category.

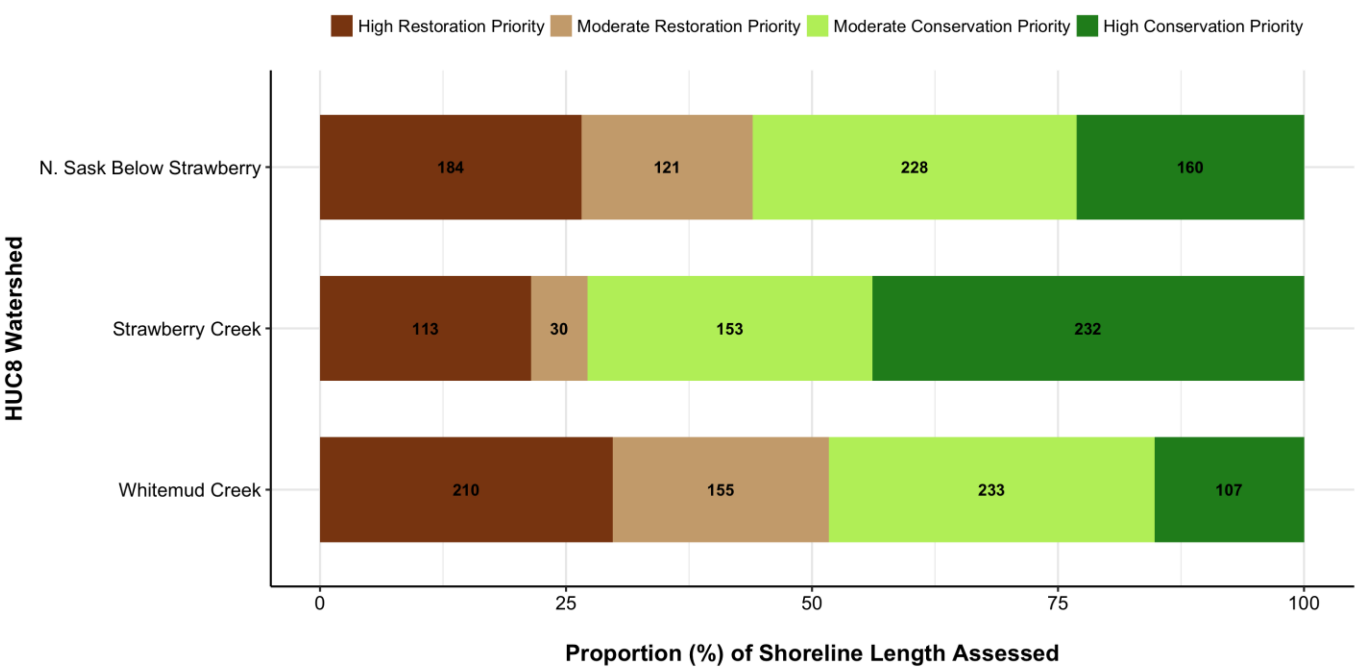
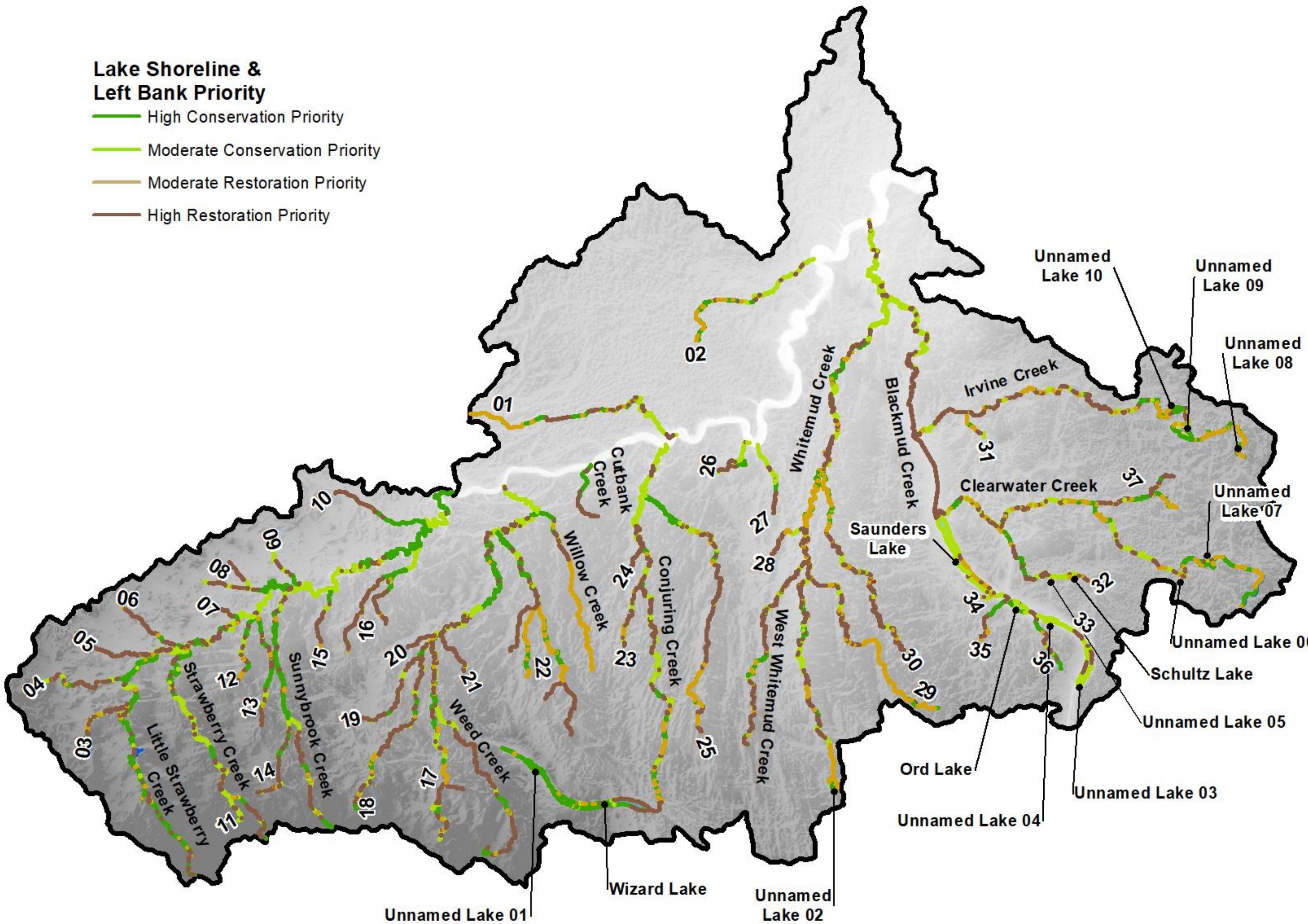
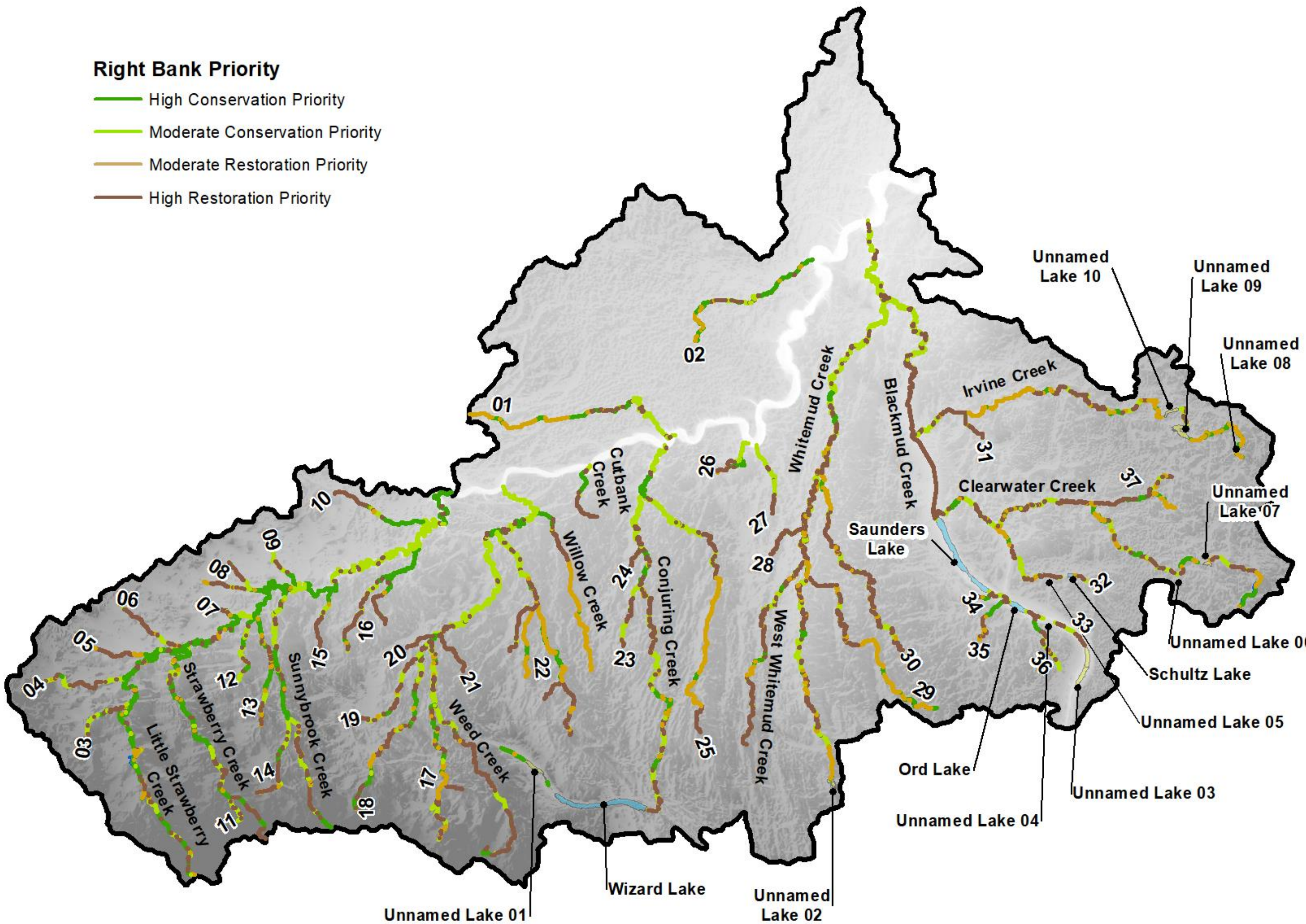


Figure 17. The total proportion of shoreline within the Strawberry watershed assigned to each priority category, summarized by HUC 8 subwatershed. Numbers indicate the total length (km) of shoreline associated with each category.



Map 11. Restoration and conservation priority for lake shorelines and the left bank of creeks that were included in this study.



Map 12. Restoration and conservation priority for the right bank of creeks that were included in this study.

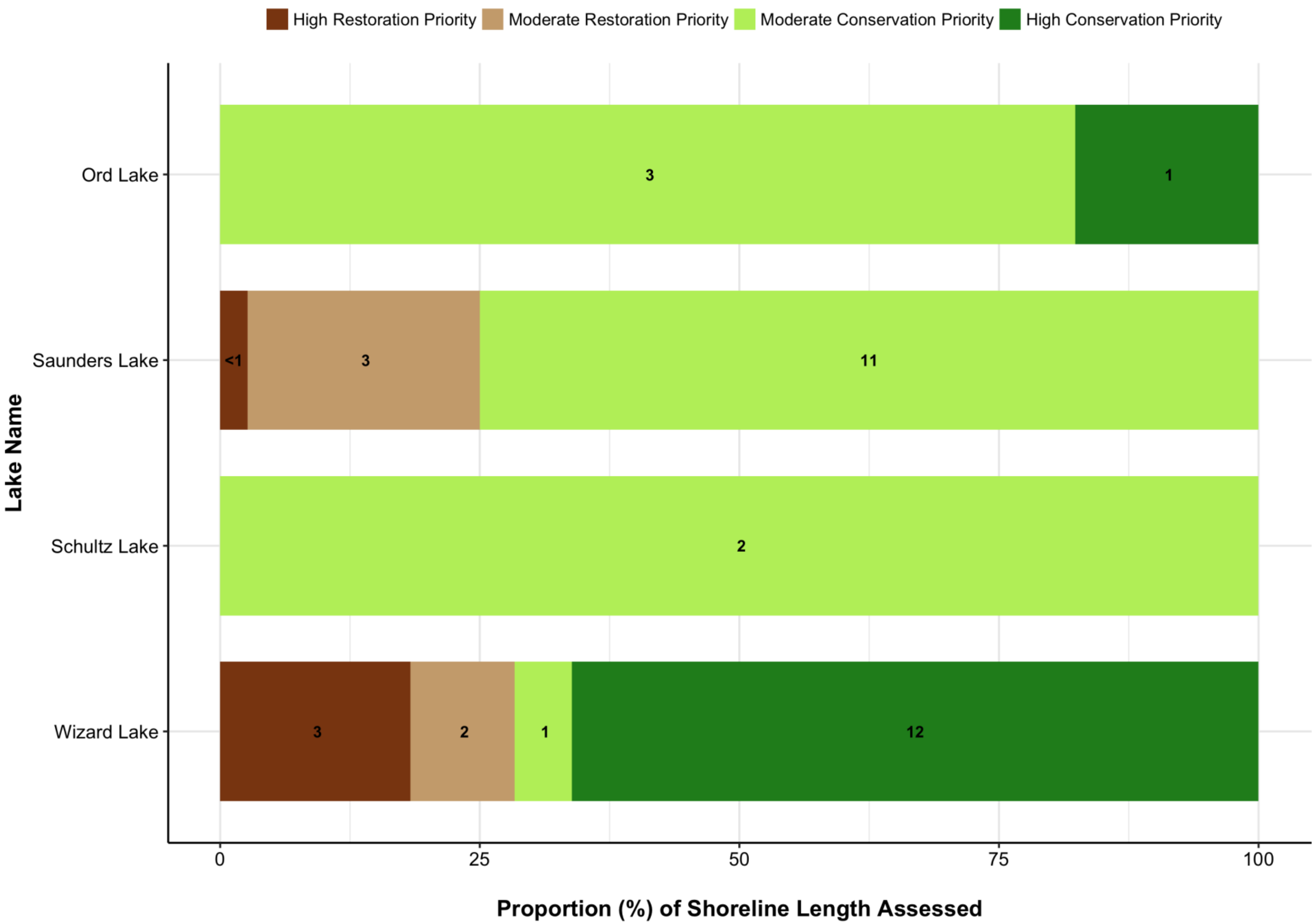


Figure 18. The total proportion of shoreline of named lakes in the Strawberry watershed assigned to each priority category. Numbers indicate the total length (km) of shoreline associated with each category.

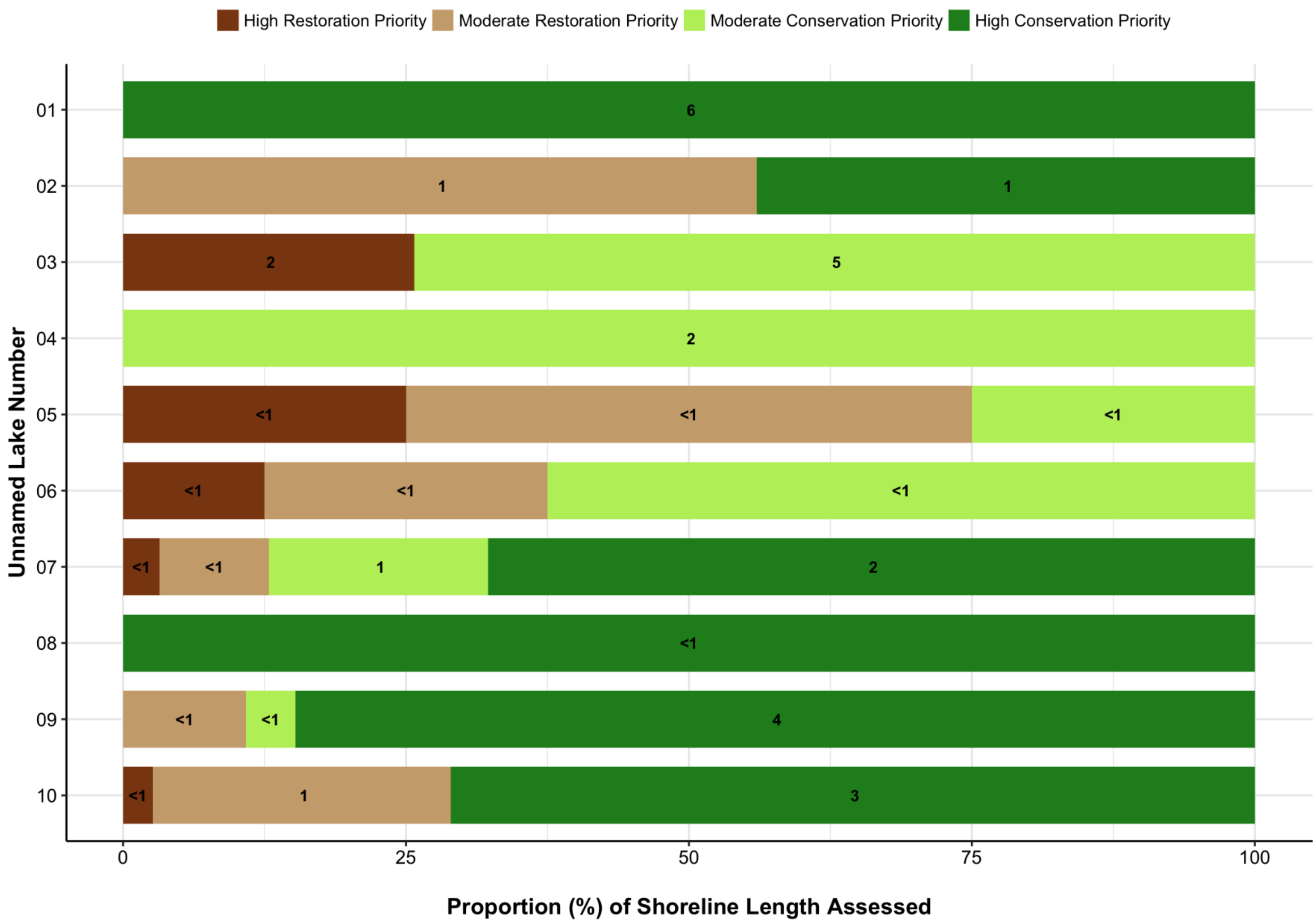


Figure 19. The total proportion of shoreline of unnamed lakes in the Strawberry watershed assigned to each priority category. Numbers indicate the total length (km) of shoreline associated with each category.

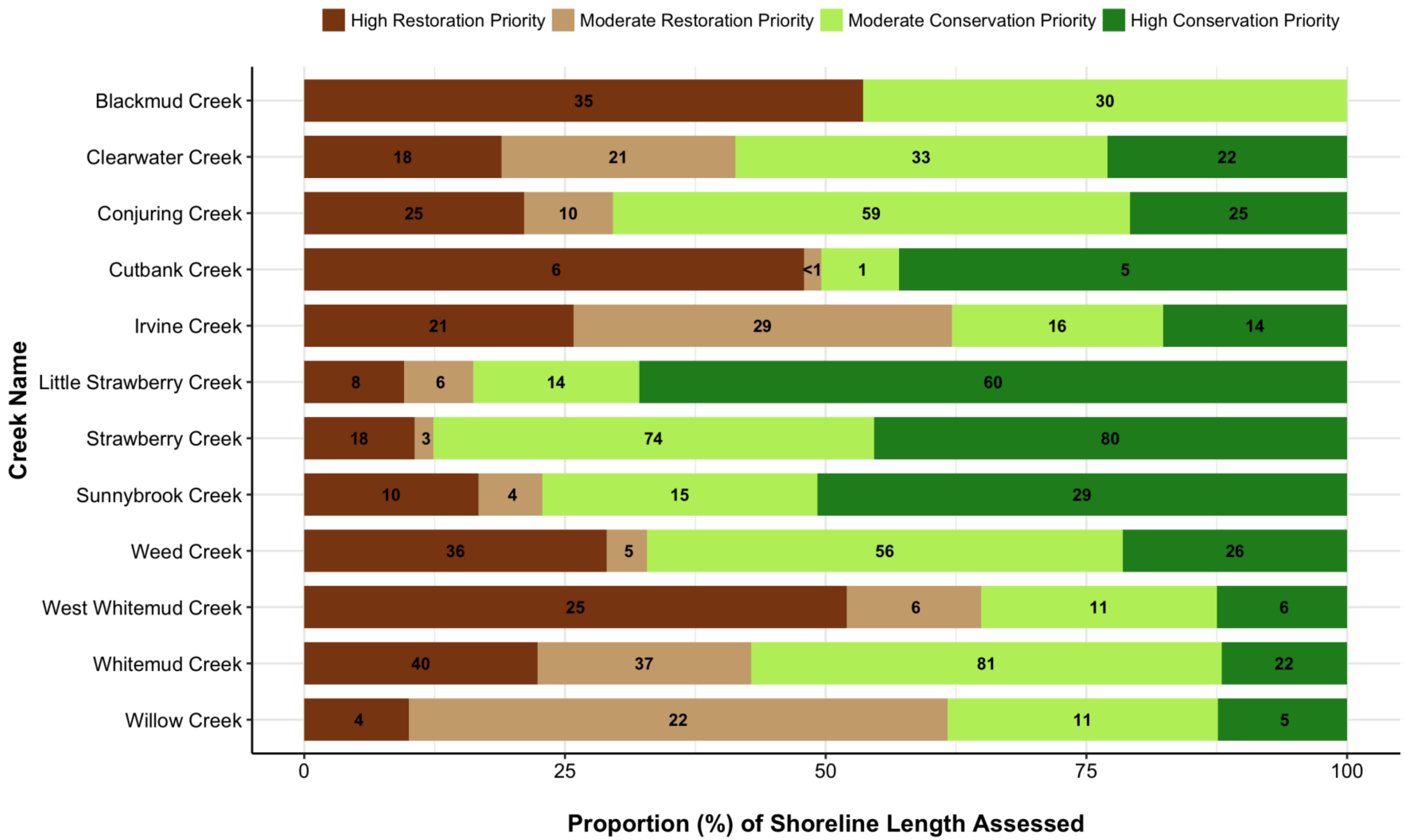


Figure 20. The total proportion of shoreline for named creeks in the Strawberry watershed assigned to each priority category. Numbers indicate the total length (km) of shoreline associated with each category.

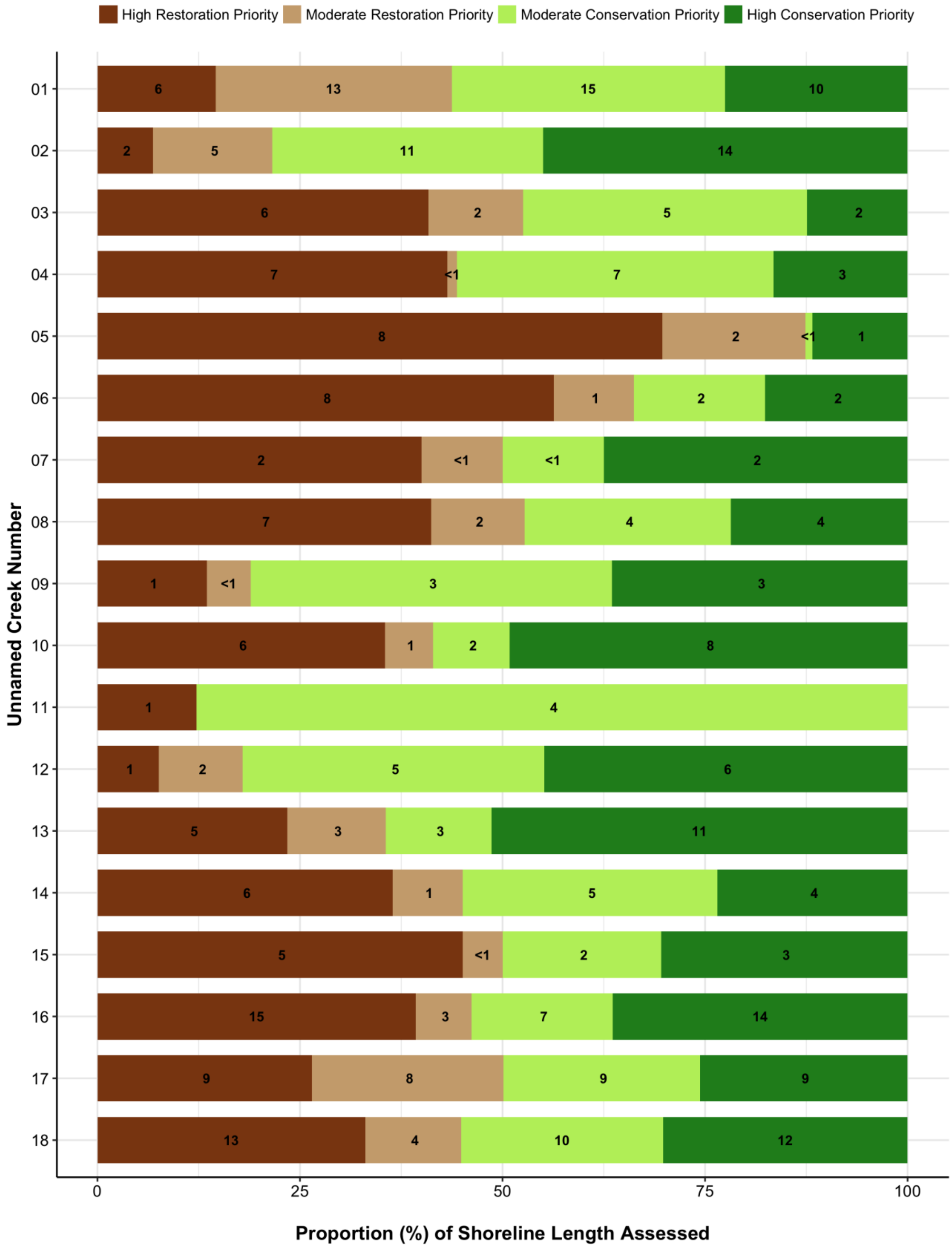


Figure 21. The total proportion of shoreline for Unnamed Creeks 01 to 18 assigned to each priority category. Numbers indicate the total length (km) of shoreline associated with each category.

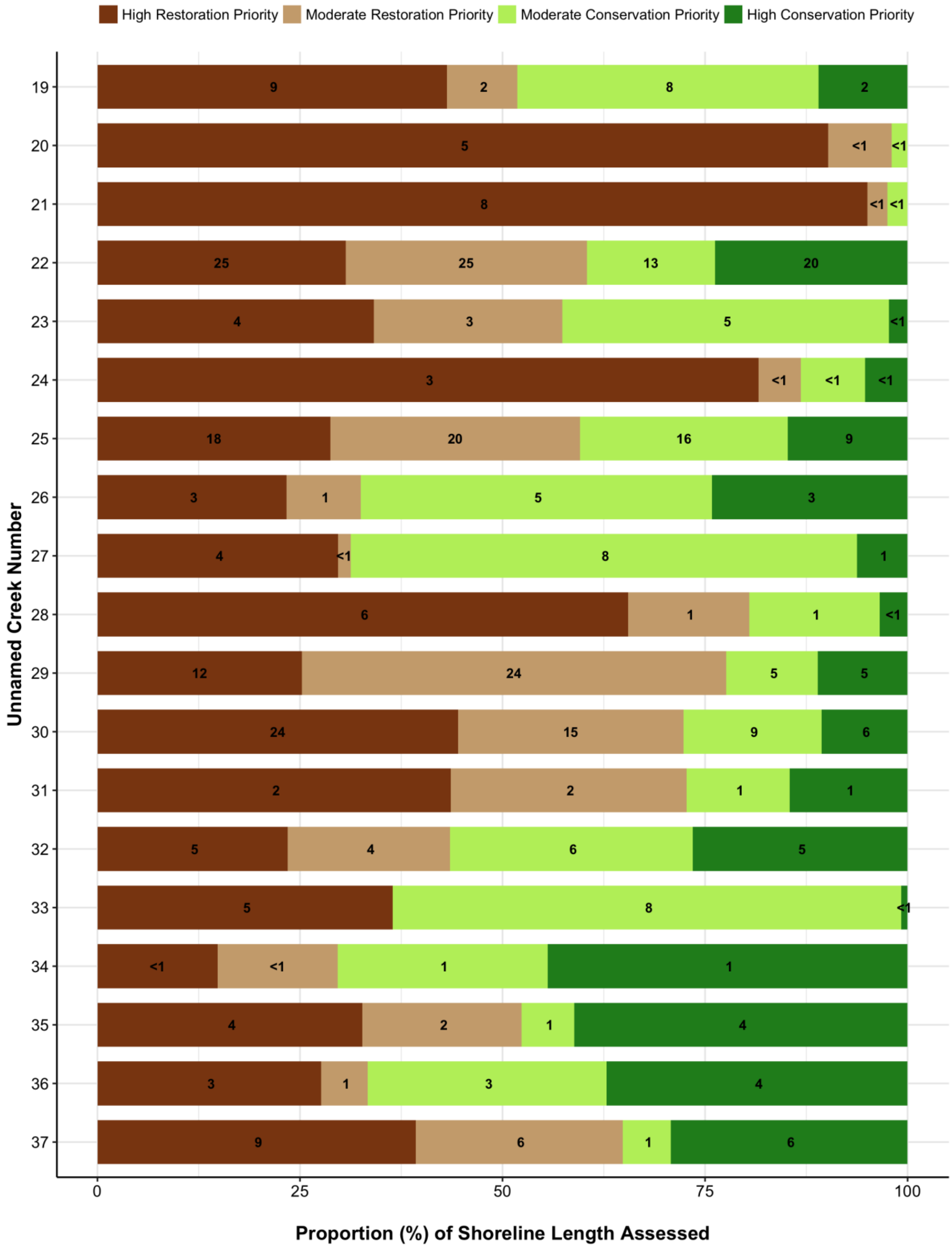


Figure 22. The total proportion of shoreline for Unnamed Creeks 19 to 37 assigned to each priority category. Numbers indicate the total length (km) of shoreline associated with each category.

5.0 Municipal Summary

5.1. Comparison of Intactness, Pressure & Priority

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 within the Strawberry watershed by municipality. Specifically, the results of this study were summarized for the City of Edmonton and the rural municipalities of Brazeau, Leduc, Parkland, Strathcona, and Wetaskiwin (Map 4). While the City of St. Albert and Camrose County also intersect the Strawberry watershed, none of the waterbodies that were assessed as part of this study were located within these municipalities. Leduc County contained the greatest length (1,664 km) and proportion (86%) of shoreline within the Strawberry watershed that was assessed in this study. The City of Edmonton made up the second greatest length (107 km) and proportion (6%) of shoreline assessed, followed by Parkland County (65 km; 3%), Strathcona County (32 km; 2%), Brazeau County (29 km; 2%), and County of Wetaskiwin (28 km; 2%).

When the proportion of shoreline length assigned to each intactness category was evaluated for each municipality, all municipalities, with the exception of Edmonton, had at least 30% of their shorelines classified as either Very Low or Low Intactness (Figure 23; Map 13 and Map 14). Strathcona County had the greatest proportion (37%; 12 km) of its shoreline classified as Very Low Intactness, followed by Wetaskiwin (36%; 10 km) and Leduc (33%; 556 km). Edmonton had the greatest proportion (70%; 75 km) of its shoreline classified as High Intactness, followed by the County of Wetaskiwin (46%; 13 km) and Brazeau County (41%; 12 km).

Not unexpectedly, when pressure was compared between municipalities, the City of Edmonton had a much greater proportion of local catchment areas classified as High Pressure, as compared to other municipalities (Figure 24; Map 15). When High and Moderate Pressure categories are considered together, Brazeau County has the highest proportion of area classified into these two categories, followed by Edmonton and Leduc County. Parkland County had the greatest proportion of local catchment areas adjacent to assessed shorelines classified as Low Pressure.

When conservation and restoration priority is considered, all municipalities other than Edmonton had more than 25% of their shorelines classified as either High or Moderate Restoration Priority (Figure 25; Map 16). For Leduc County, this represents over 732 km of shoreline, while for every other municipality, this proportion represents 25 km or less of shoreline, for a combined total of 81 km. For all municipalities other than Strathcona County, more than half of the shorelines falling within their jurisdiction were classified as either Moderate or High Conservation Priority, with Leduc County having 435 km classified as High Conservation Priority.

A more detailed breakdown of results by municipality is provided in sections 5.2 through 5.7.

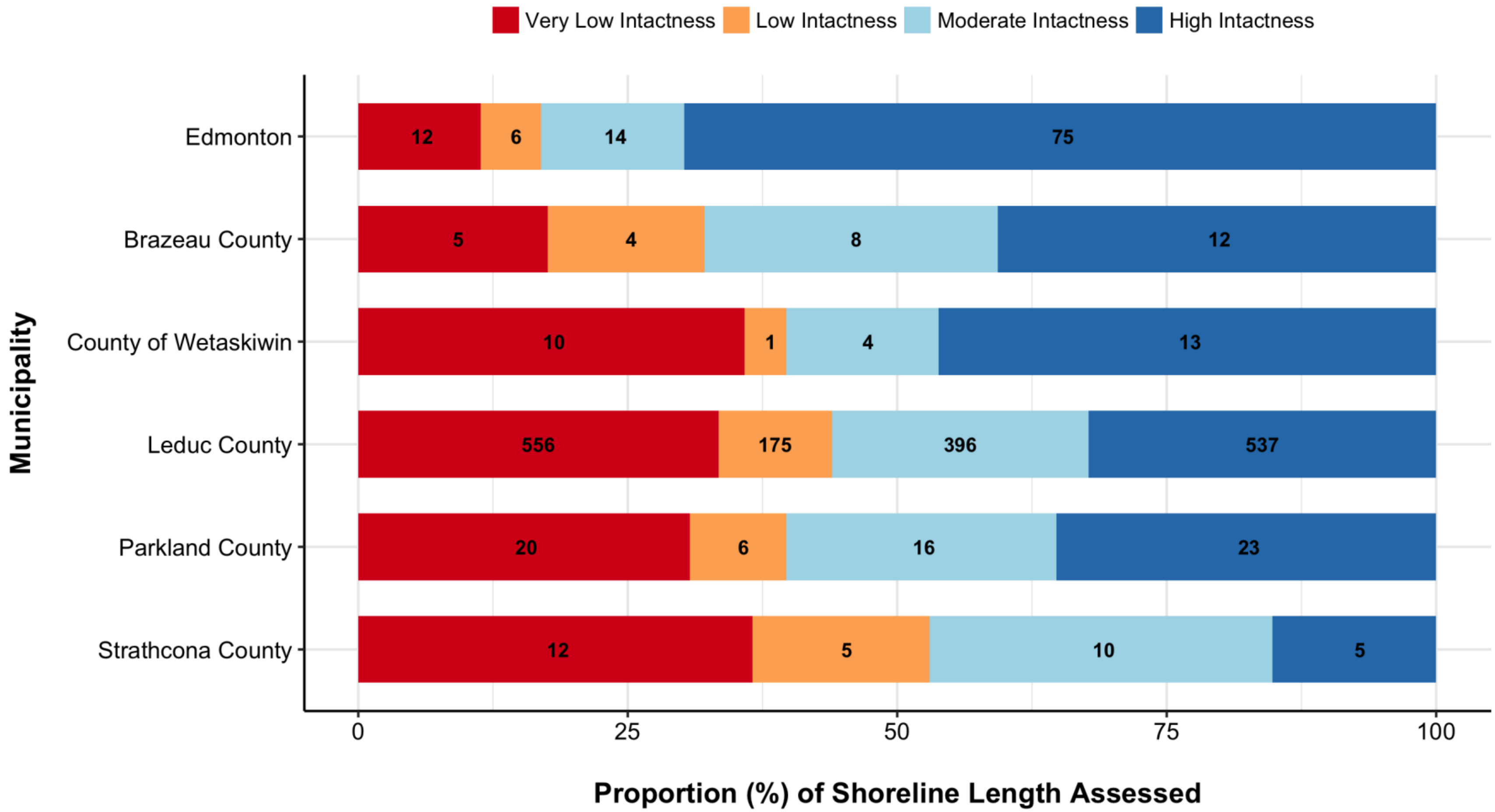


Figure 23. The proportion of shoreline length assigned to each riparian intactness category, summarized by municipality. Numbers indicate the approximate length (km) of shoreline associated with each intactness category.

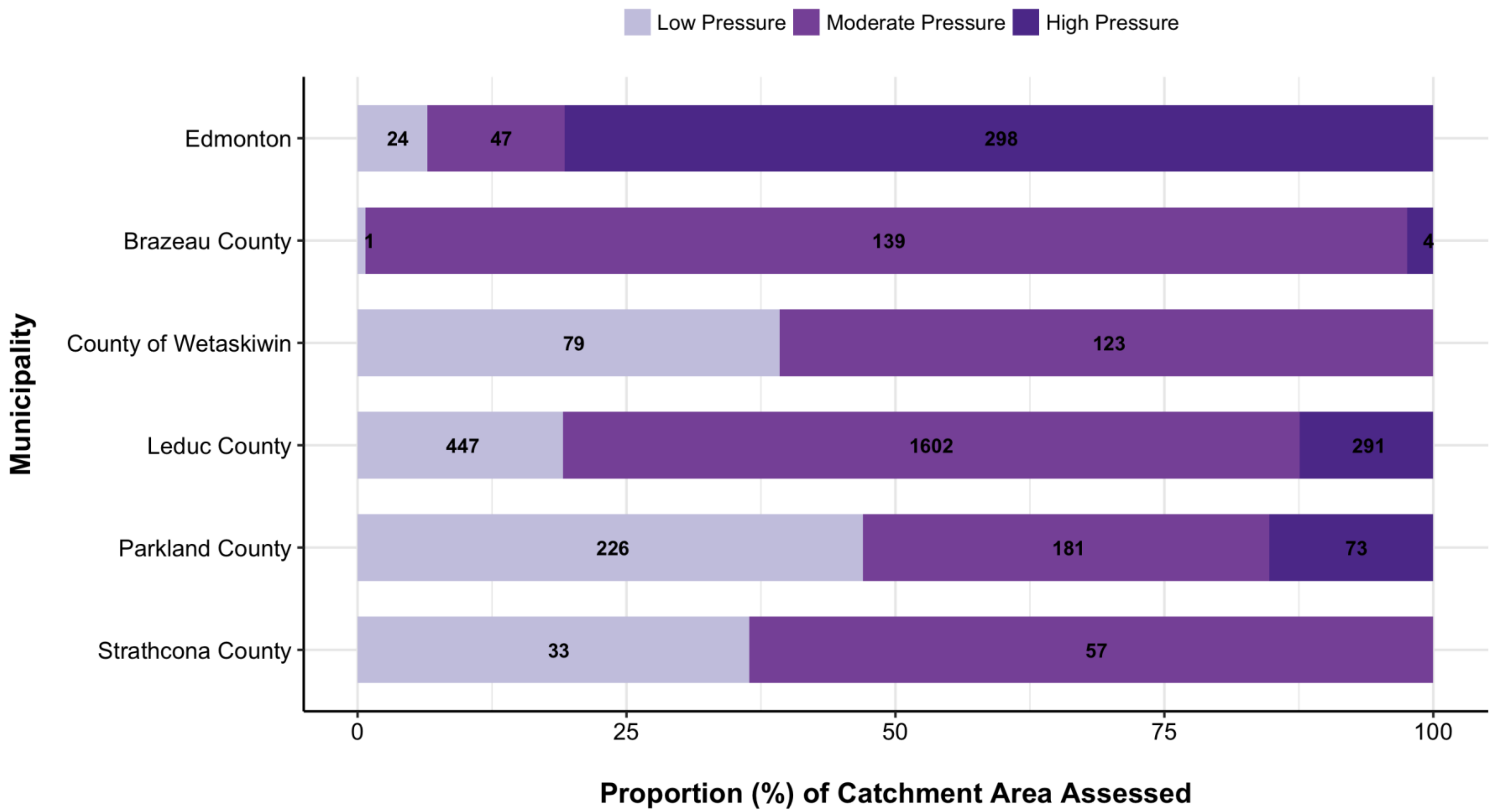


Figure 24. The proportion of catchment area by pressure category associated with RMAs that intersect the shorelines of waterbodies contained within each municipality. Numbers indicate the total area (km^2) assigned to each pressure category.

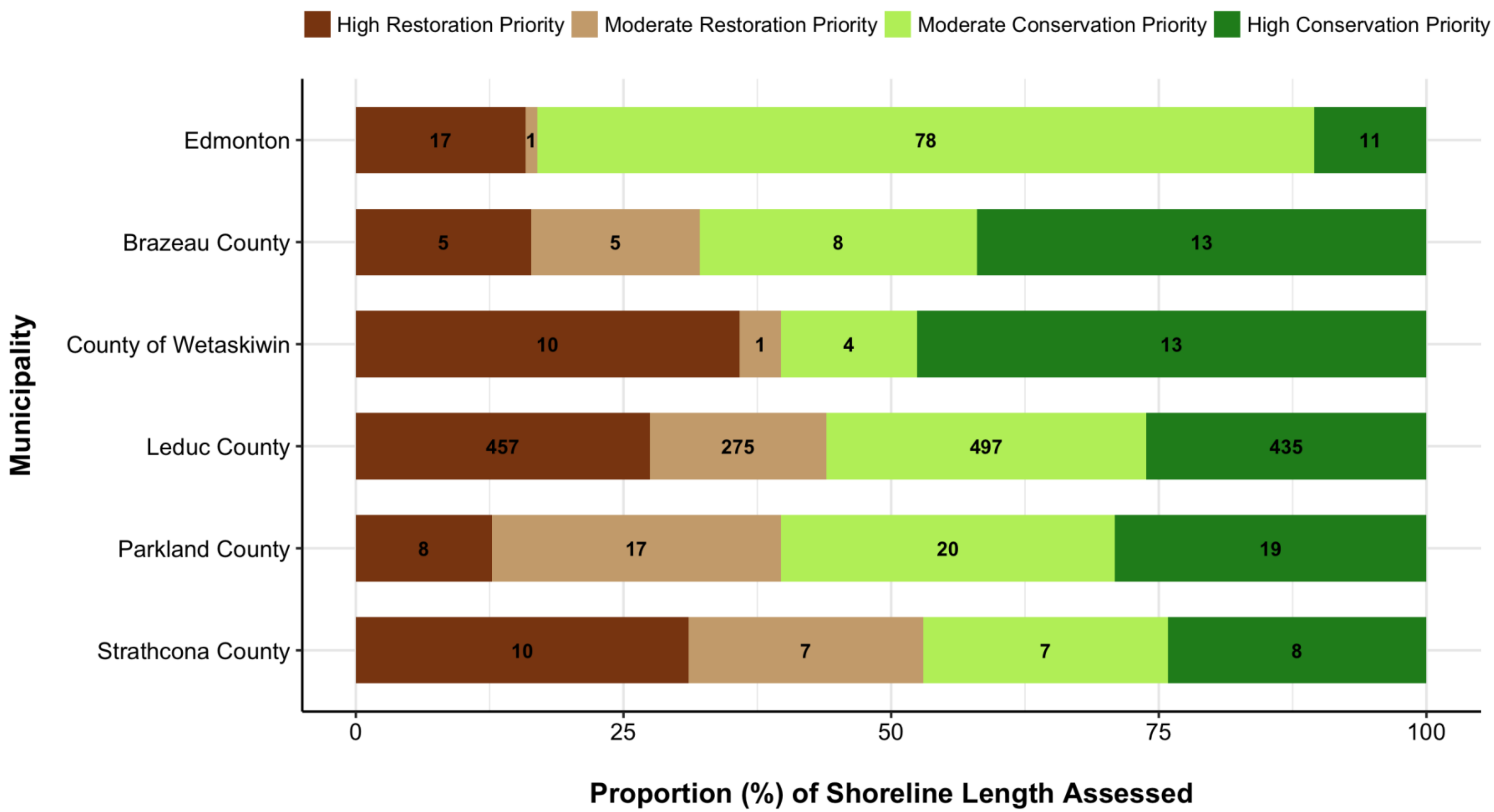
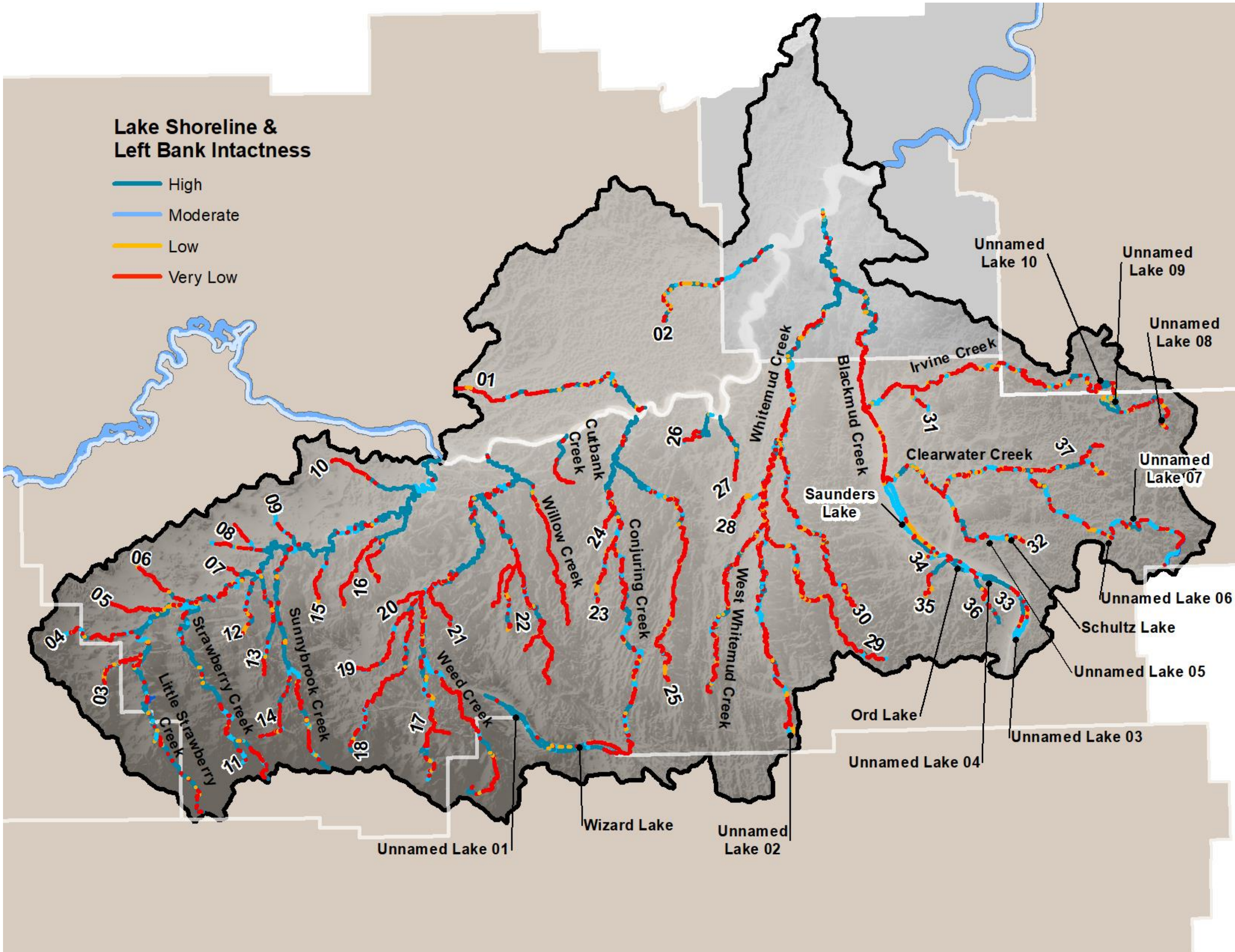
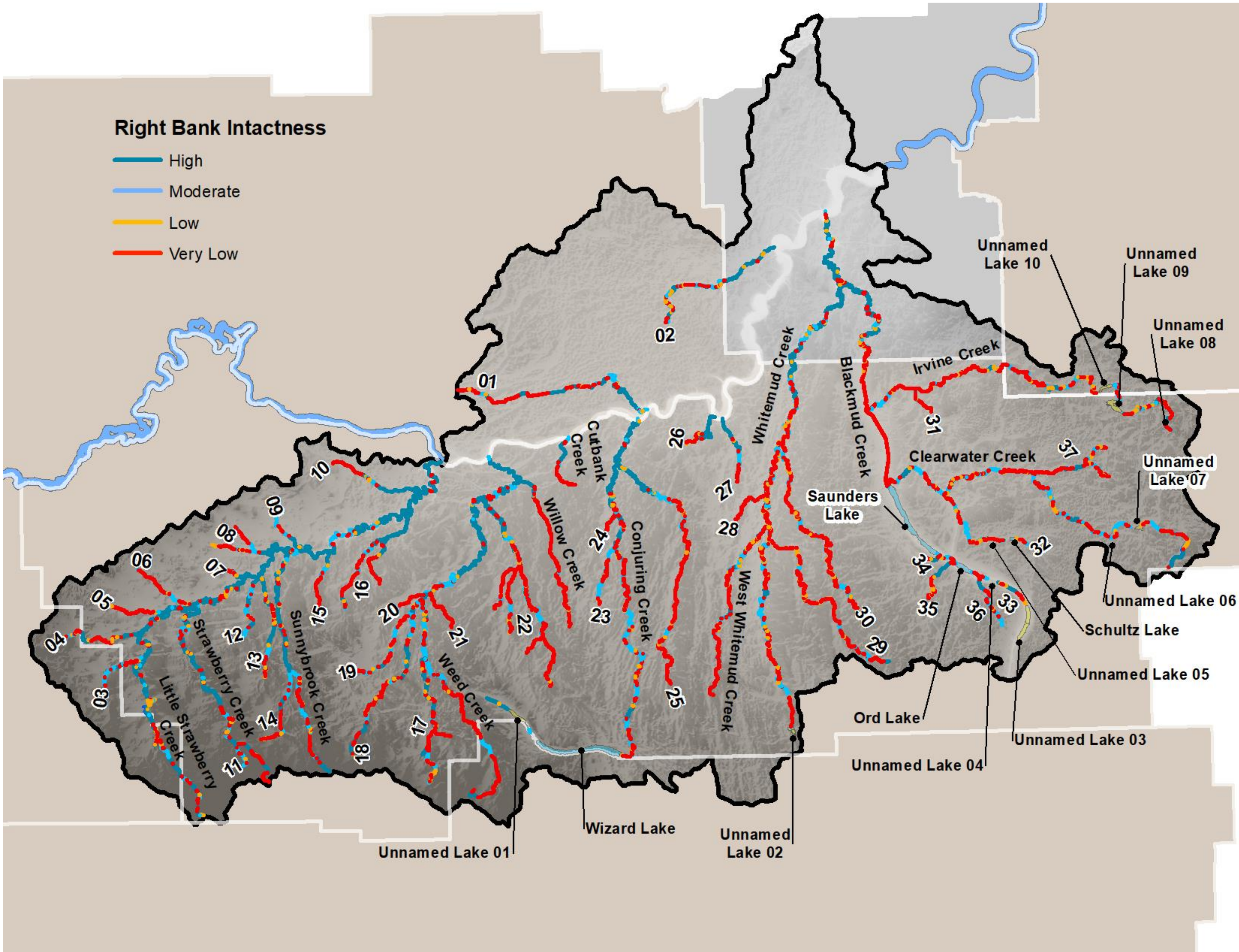


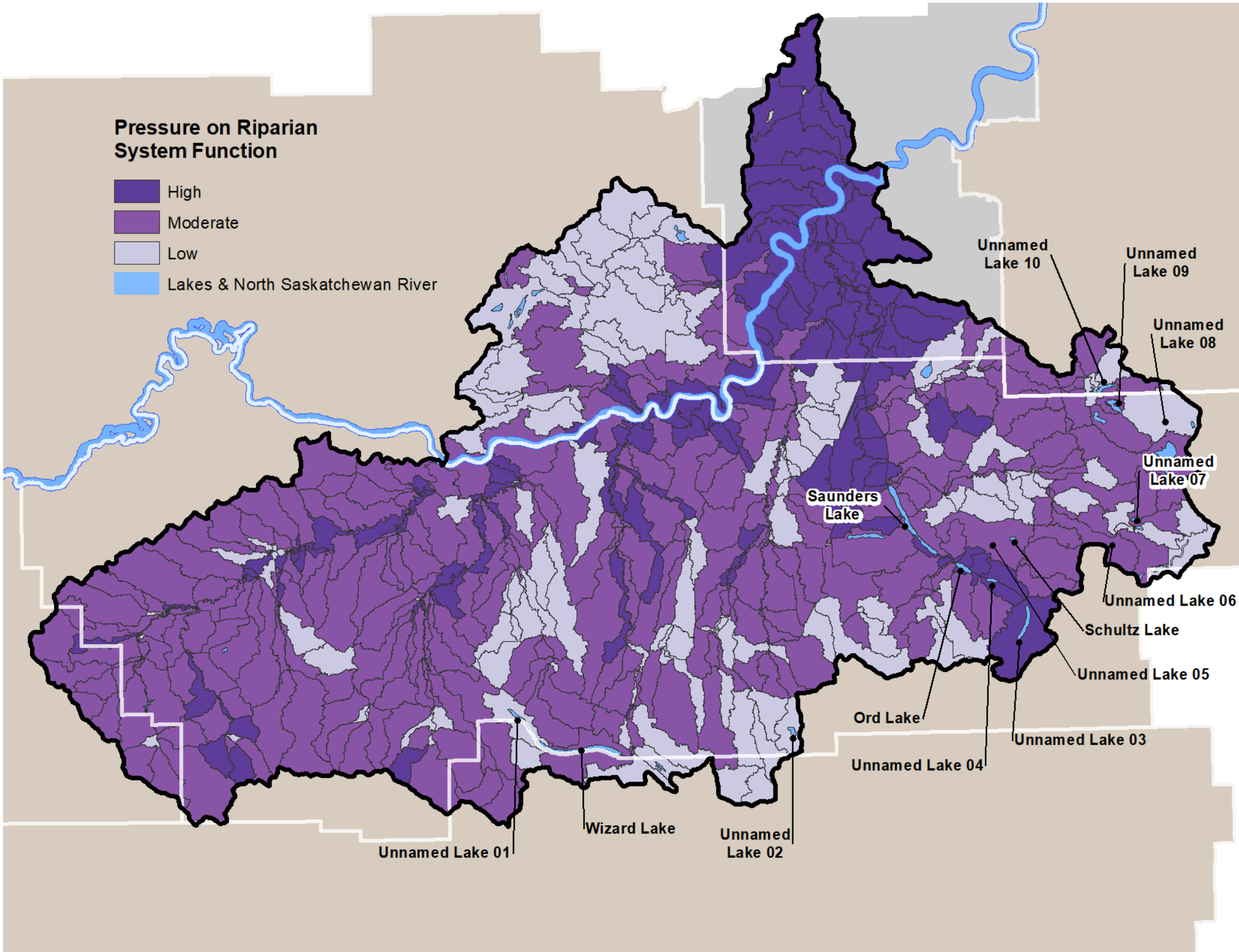
Figure 25. The proportion of shoreline length assigned to each priority category, summarized by municipality. Numbers indicate the approximate length (km) of shoreline associated to each priority category.



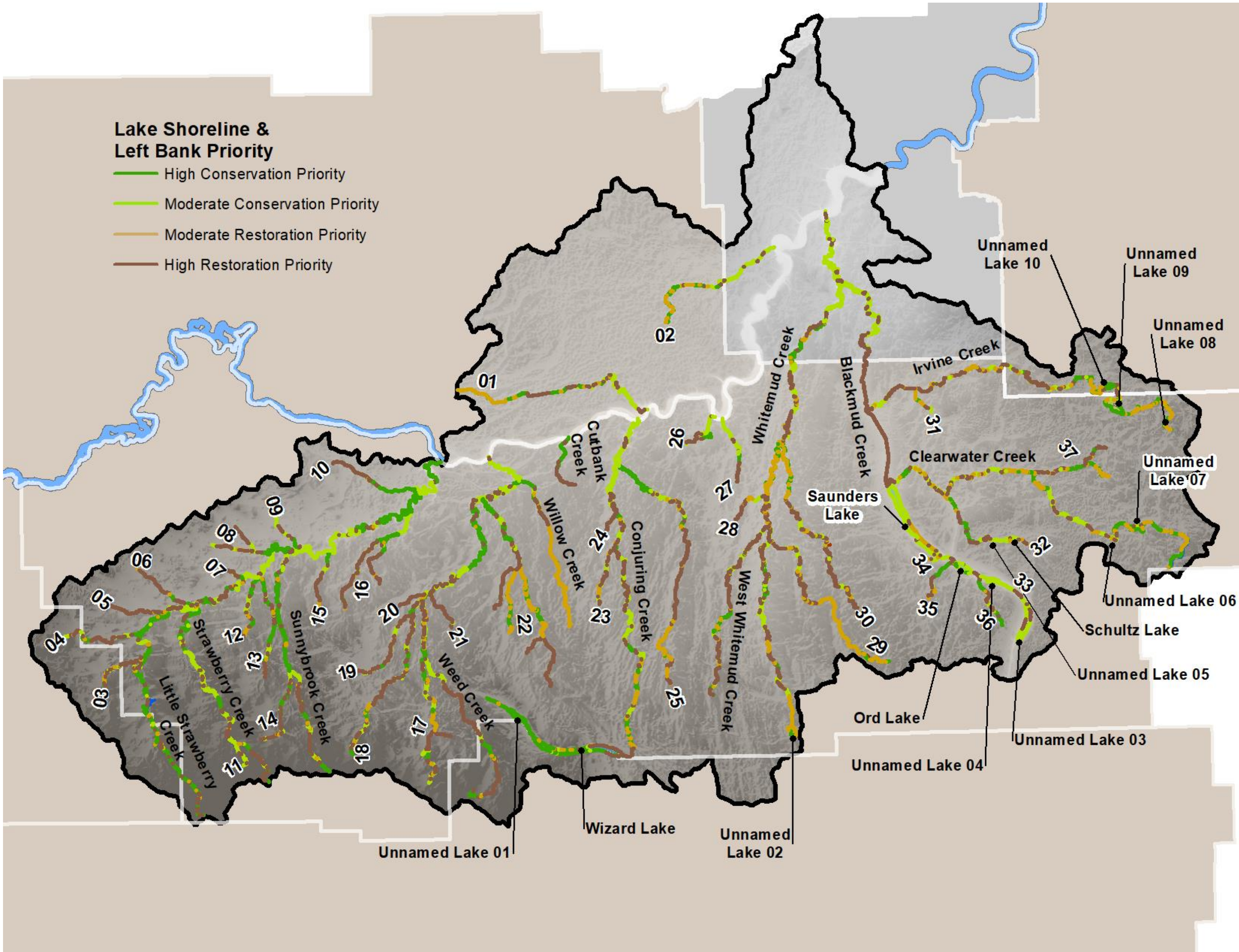
Map 13. Intactness for lake shorelines and the left bank of creeks that were included in this study, by municipality.



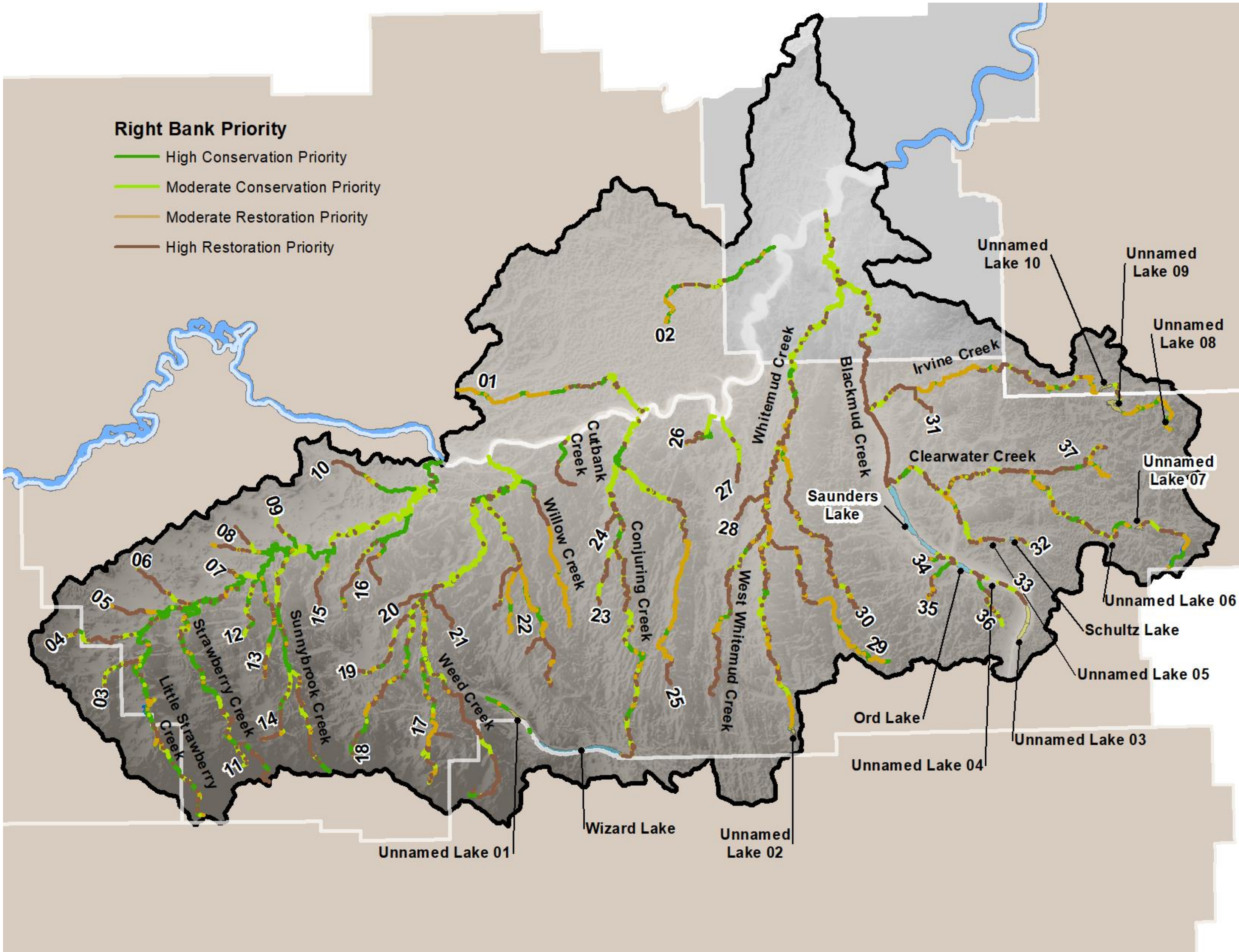
Map 14. Intactness for the right bank of creeks that were included in this study, by municipality.



Map 15. Distribution of local catchments classified as High, Moderate, and Low Pressure, by municipality.



Map 16. Restoration and conservation priority for the lake shorelines and the left bank of creeks that were included in this study, by municipality.



Map 17. Restoration and conservation priority for the right bank of creeks that were included in this study, by municipality.

5.2. City of Edmonton

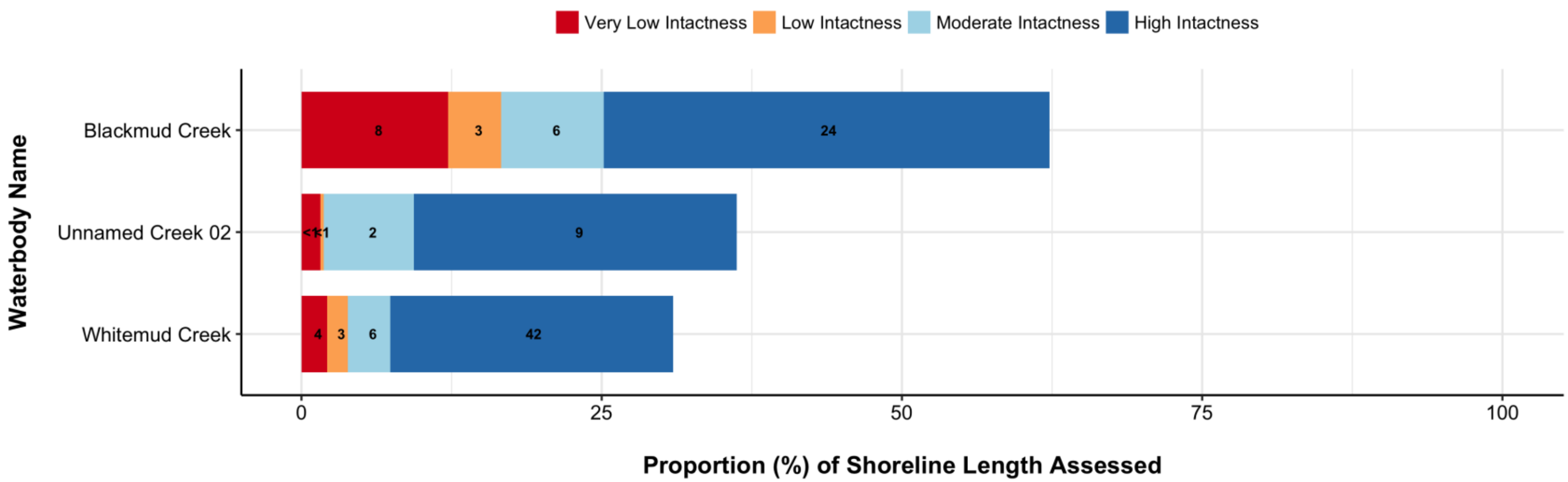


Figure 26. The proportion of shoreline length assigned to each riparian intactness category for waterbodies within the City of Edmonton. Numbers indicate the approximate length (km) of shoreline associated with each category.

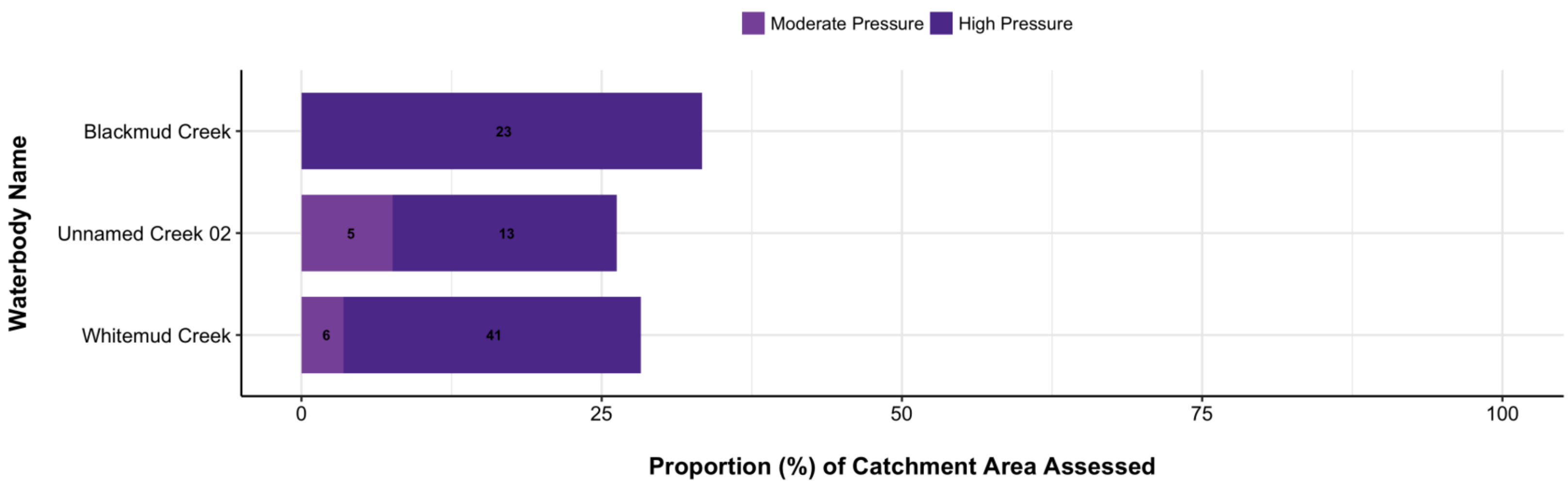


Figure 27. The proportion of catchment area by pressure category associated with RMAs that intersect the shorelines of waterbodies in the City of Edmonton. Numbers indicate the total area (km^2) assigned to each pressure category.

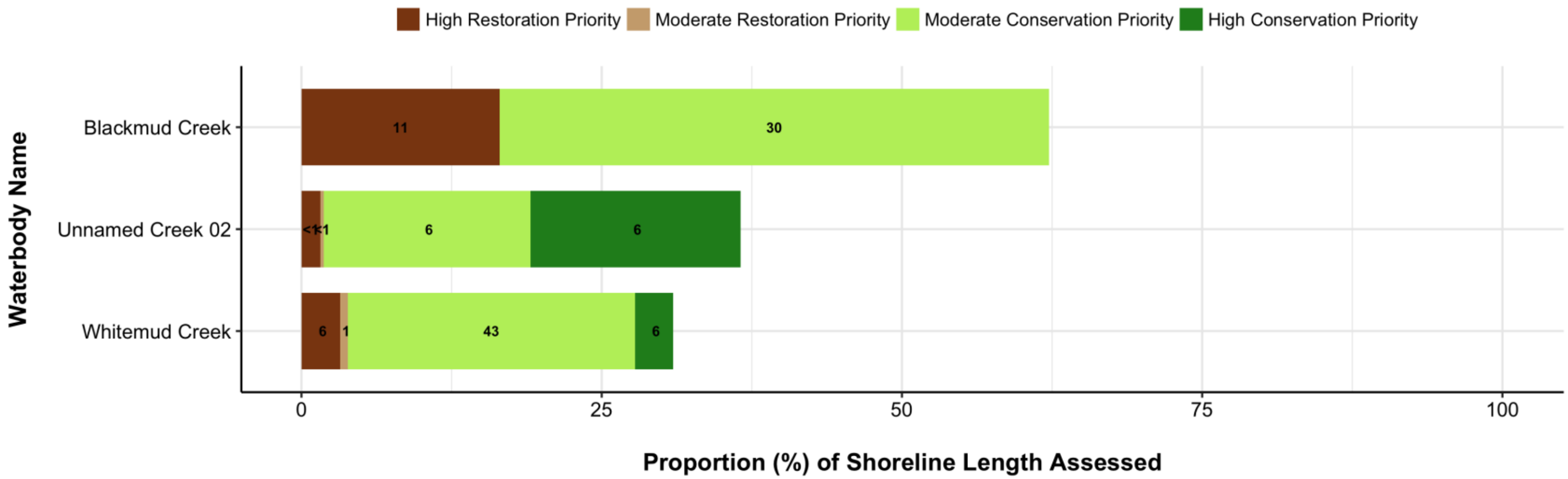


Figure 28. The proportion of shoreline length assigned to each priority category for waterbodies within the City of Edmonton. Numbers indicate the approximate length (km) of shoreline associated with each category.

5.3. Brazeau County

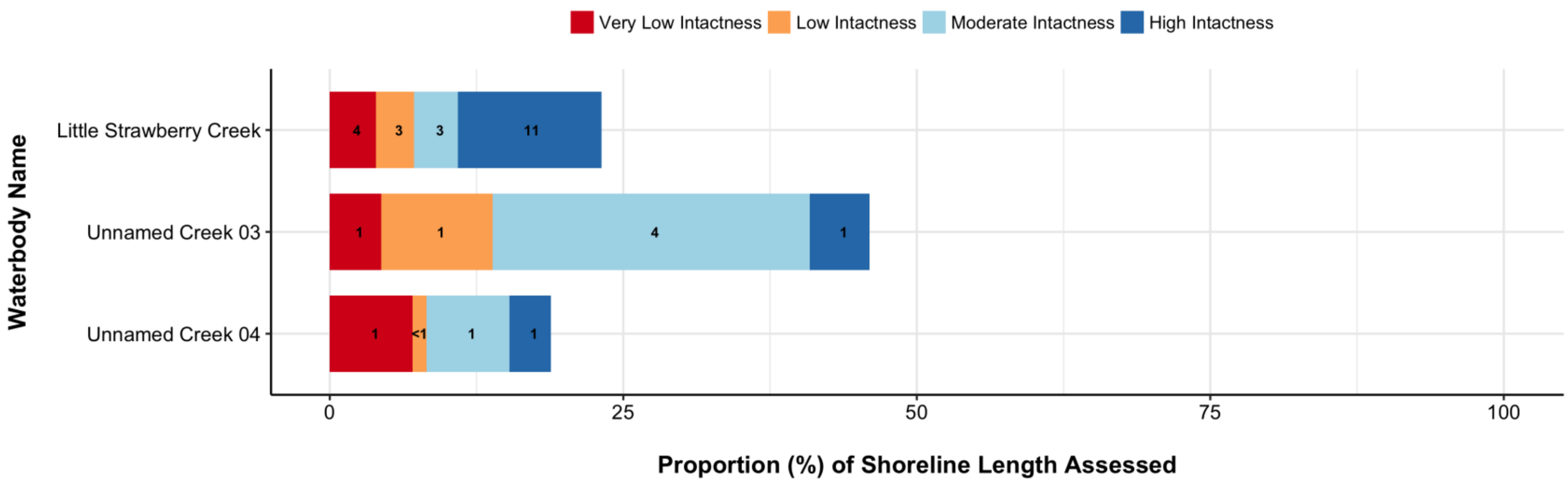


Figure 29. The proportion of shoreline length assigned to each riparian intactness category for waterbodies in Brazeau County. Numbers indicate the approximate length (km) of shoreline associated with each category.

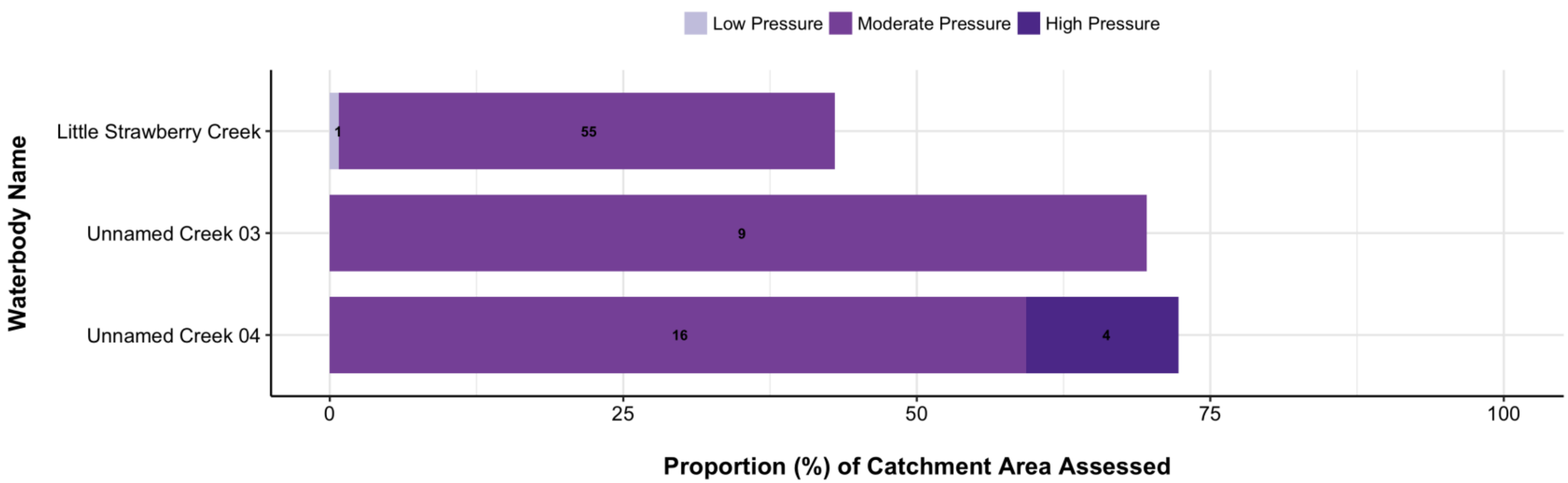


Figure 30. The proportion of catchment area by pressure category associated with RMAs that intersect the shorelines of waterbodies in Brazeau County. Numbers indicate the total area (km^2) assigned to each pressure category.

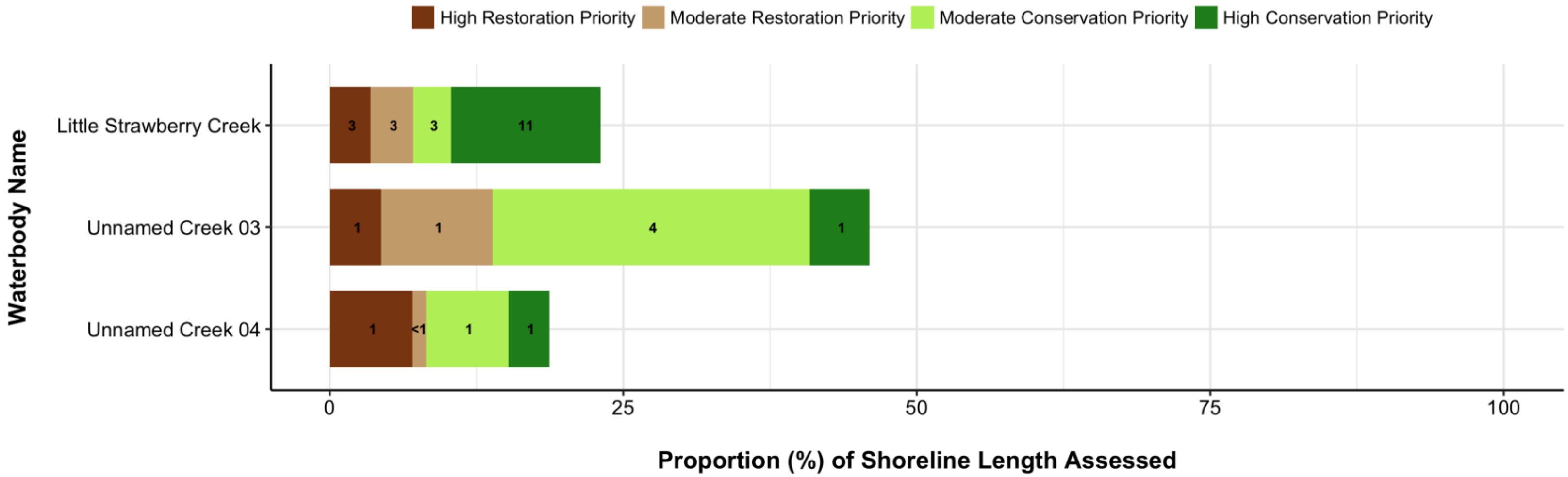


Figure 31. The proportion of shoreline length assigned to each priority category for waterbodies within Brazeau County. Numbers indicate the approximate length (km) of shoreline associated with each category.

5.4. County of Wetaskiwin

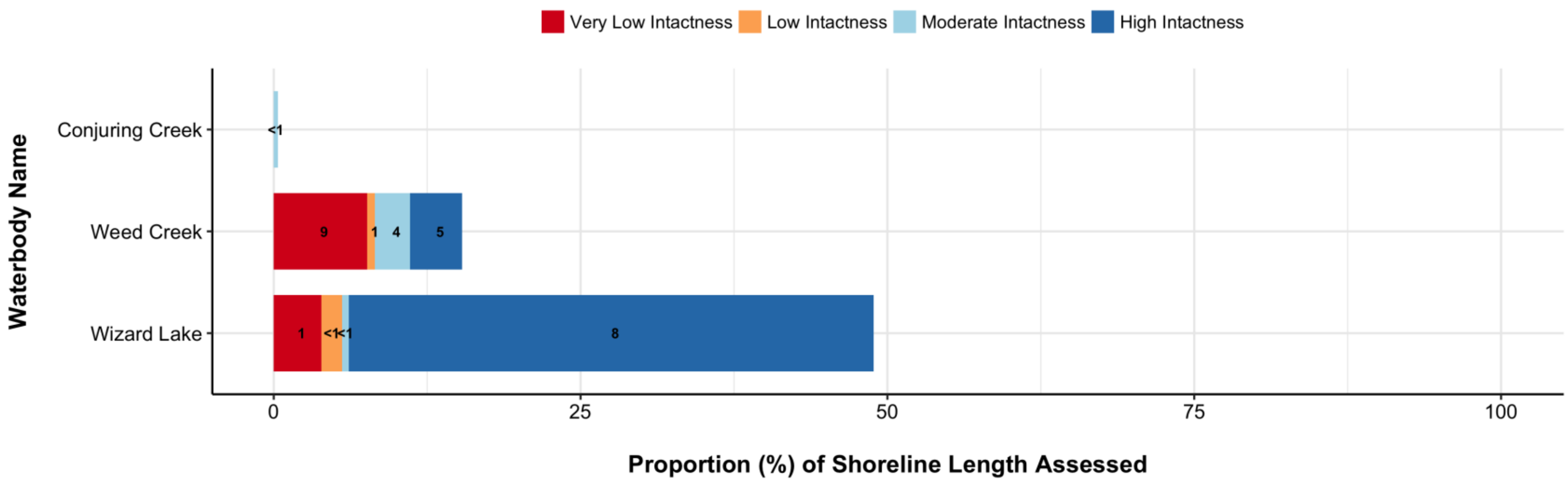


Figure 32. The proportion of shoreline length assigned to each riparian intactness category for waterbodies in the County of Wetaskiwin. Numbers indicate the approximate length (km) of shoreline associated with each category.

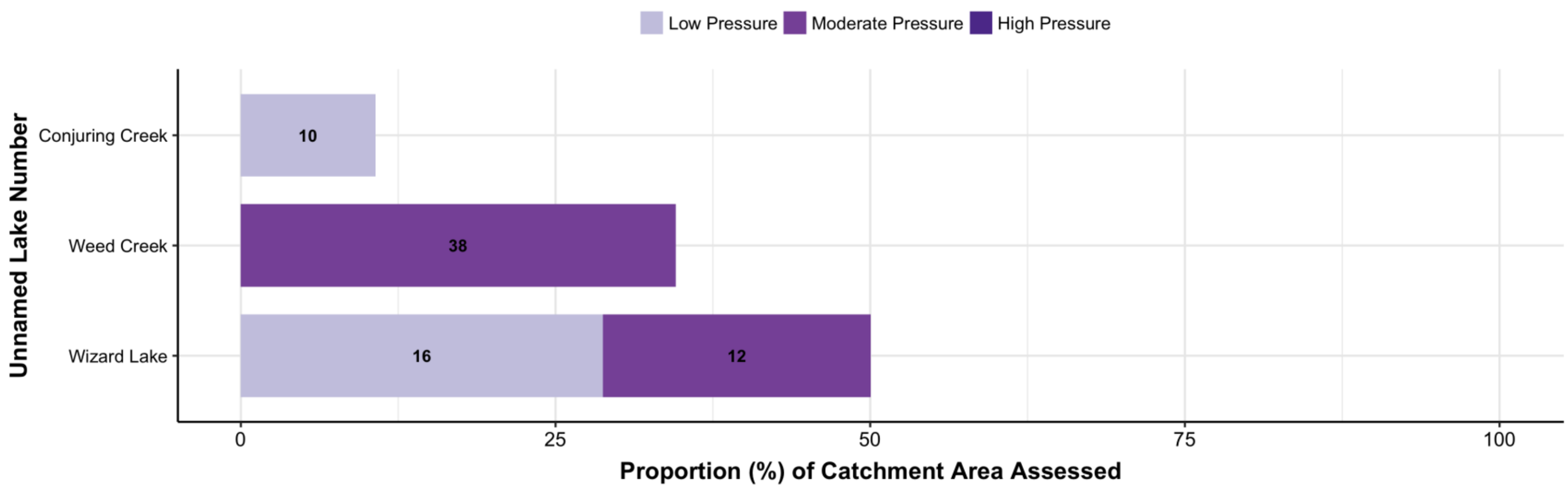


Figure 33. The proportion of catchment area by pressure category associated with RMAs that intersect the shorelines of waterbodies in the County of Wetaskiwin. Numbers indicate the total area (km^2) assigned to each pressure category.

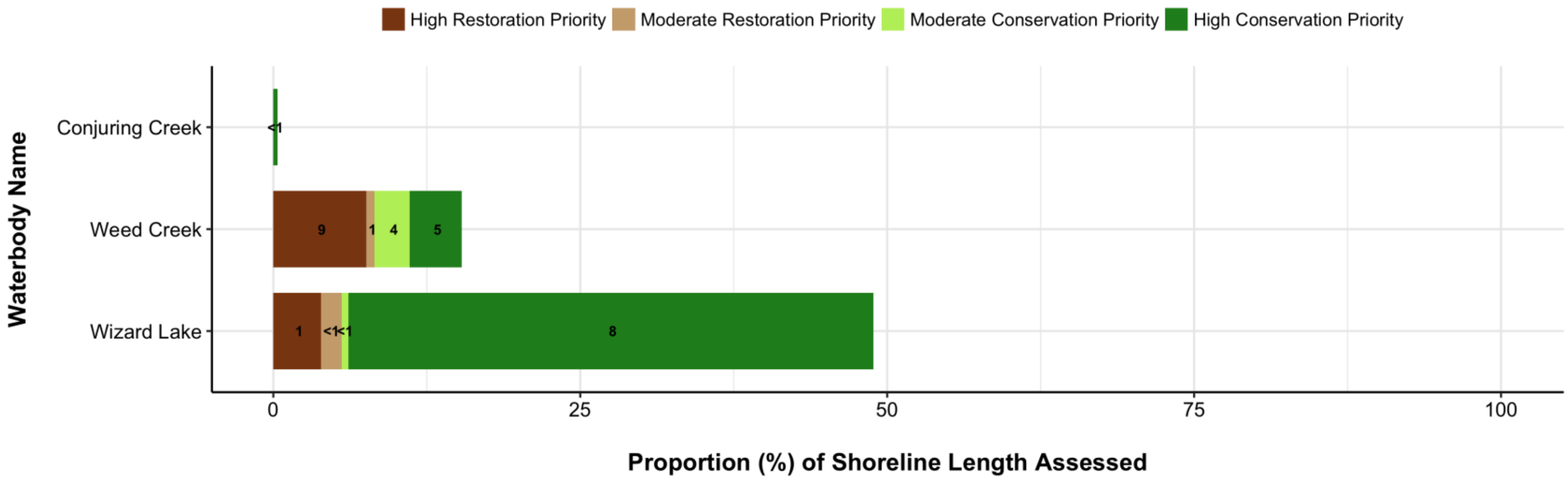


Figure 34. The proportion of shoreline length assigned to each priority category for waterbodies in the County of Wetaskiwin. Numbers indicate the approximate length (km) assigned to each priority category.

5.5. Leduc County

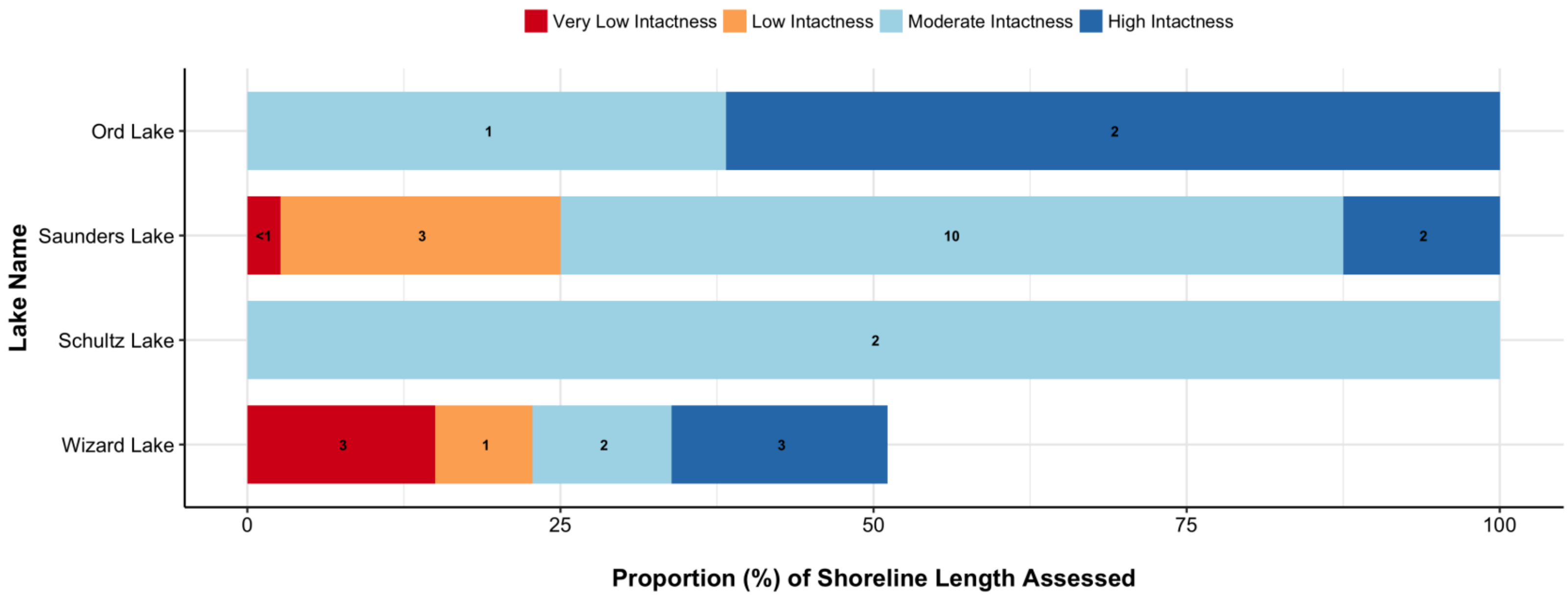


Figure 35. The proportion of shoreline length assigned to each riparian intactness category for named lakes within Leduc County. Numbers indicate the approximate length (km) of shoreline associated with each category.

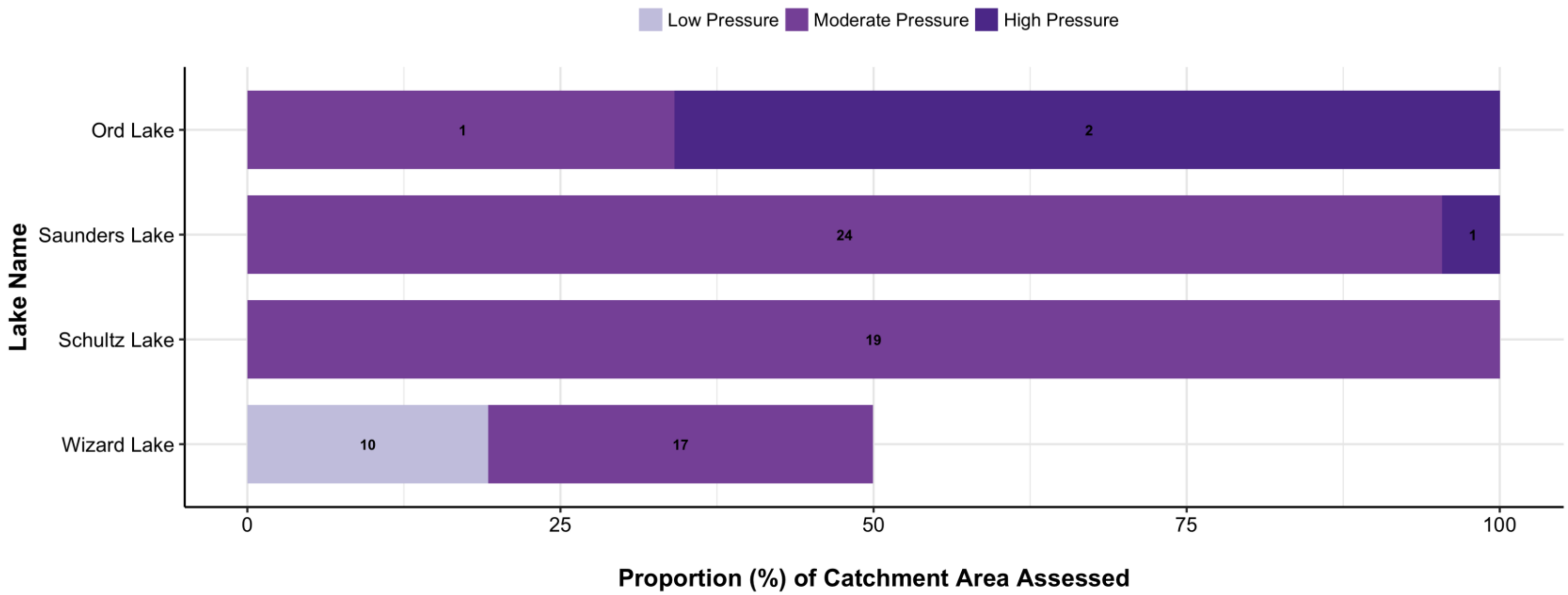


Figure 36. . The proportion of catchment area by pressure category associated with RMAs that intersect the shorelines of named lakes in Leduc County. Numbers indicate the total area (km^2) assigned to each pressure category.

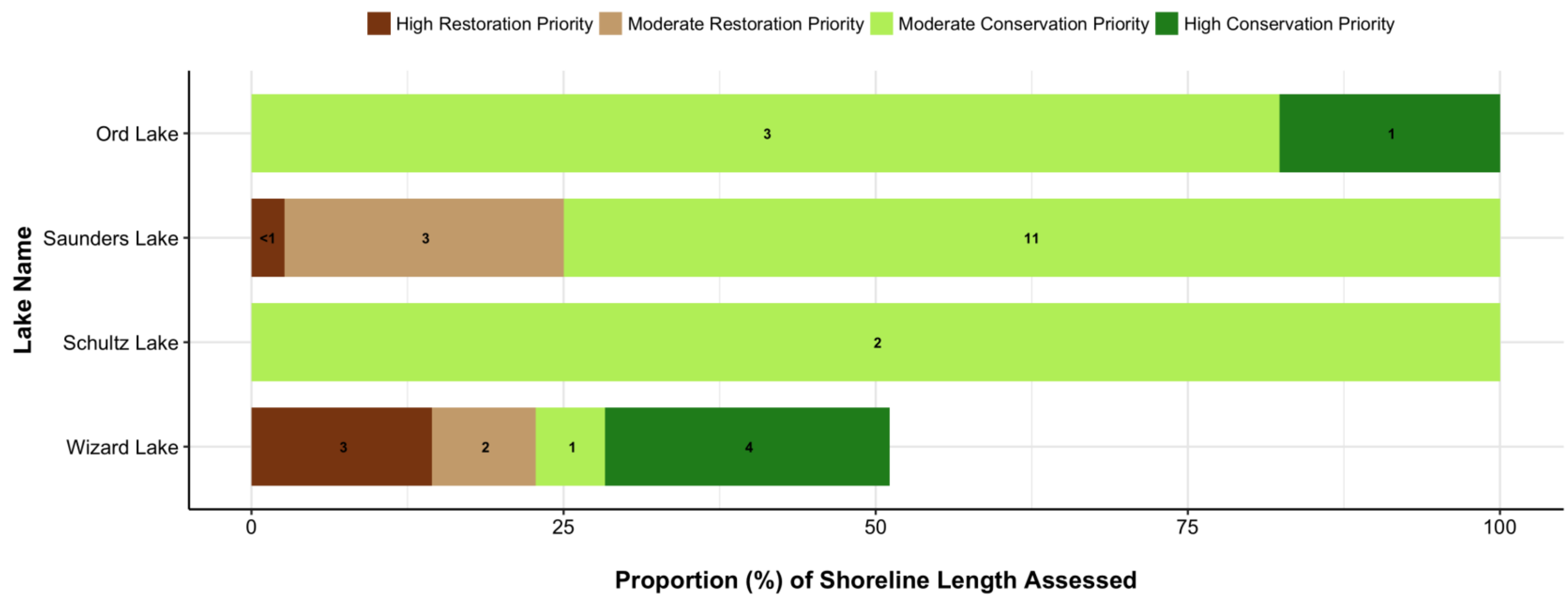


Figure 37. The proportion of shoreline length assigned to each priority category for named lakes within Leduc County. Numbers indicate the total length (km) of shoreline associated with each category.

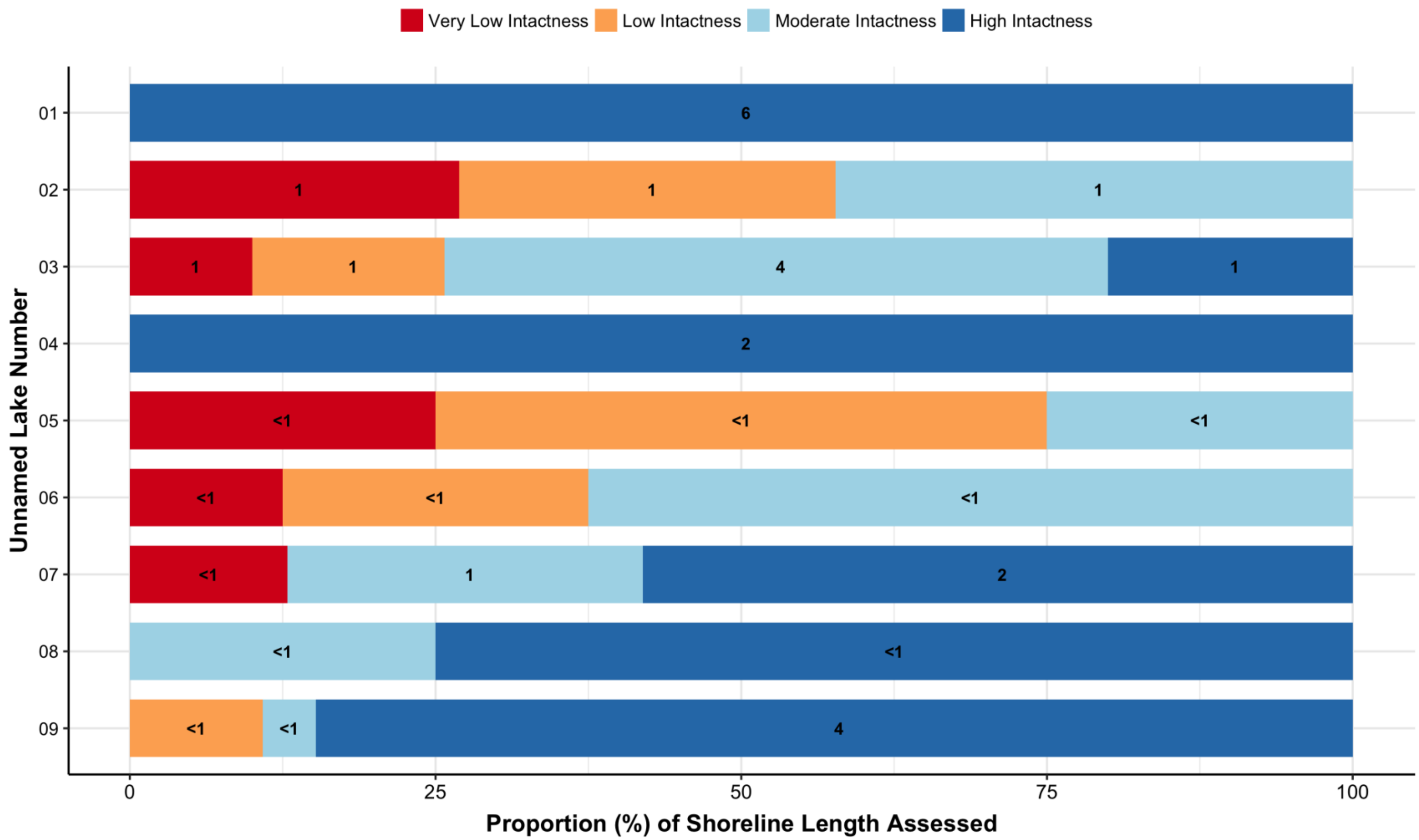


Figure 38. The proportion of shoreline length assigned to each riparian intactness category for unnamed lakes within Leduc County. Numbers indicate the approximate length (km) of shoreline associated with each category.

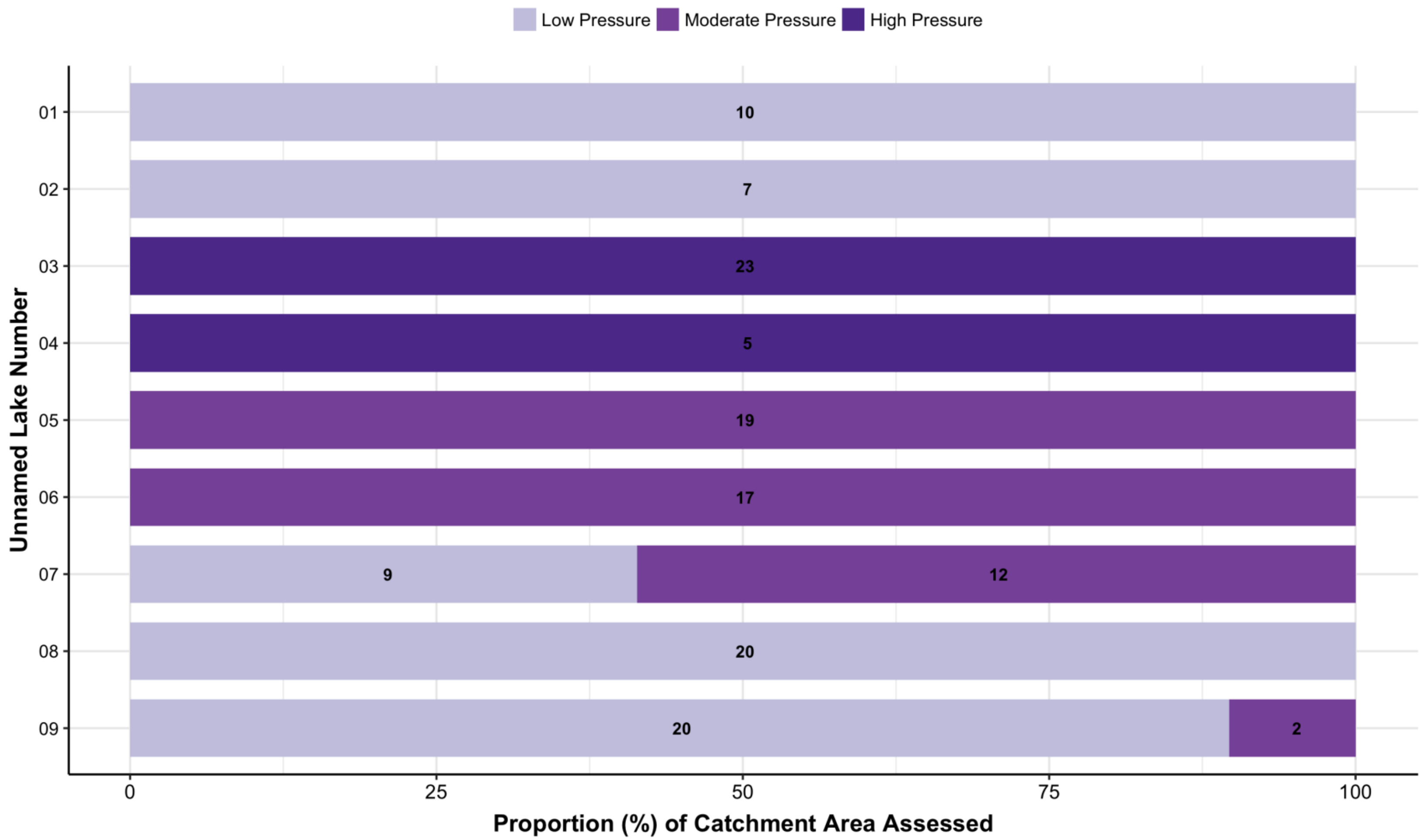


Figure 39. The proportion of catchment area by pressure category associated with RMAs that intersect the shorelines of unnamed lakes in Leduc County. Numbers indicate the total area (km^2) assigned to each pressure category.

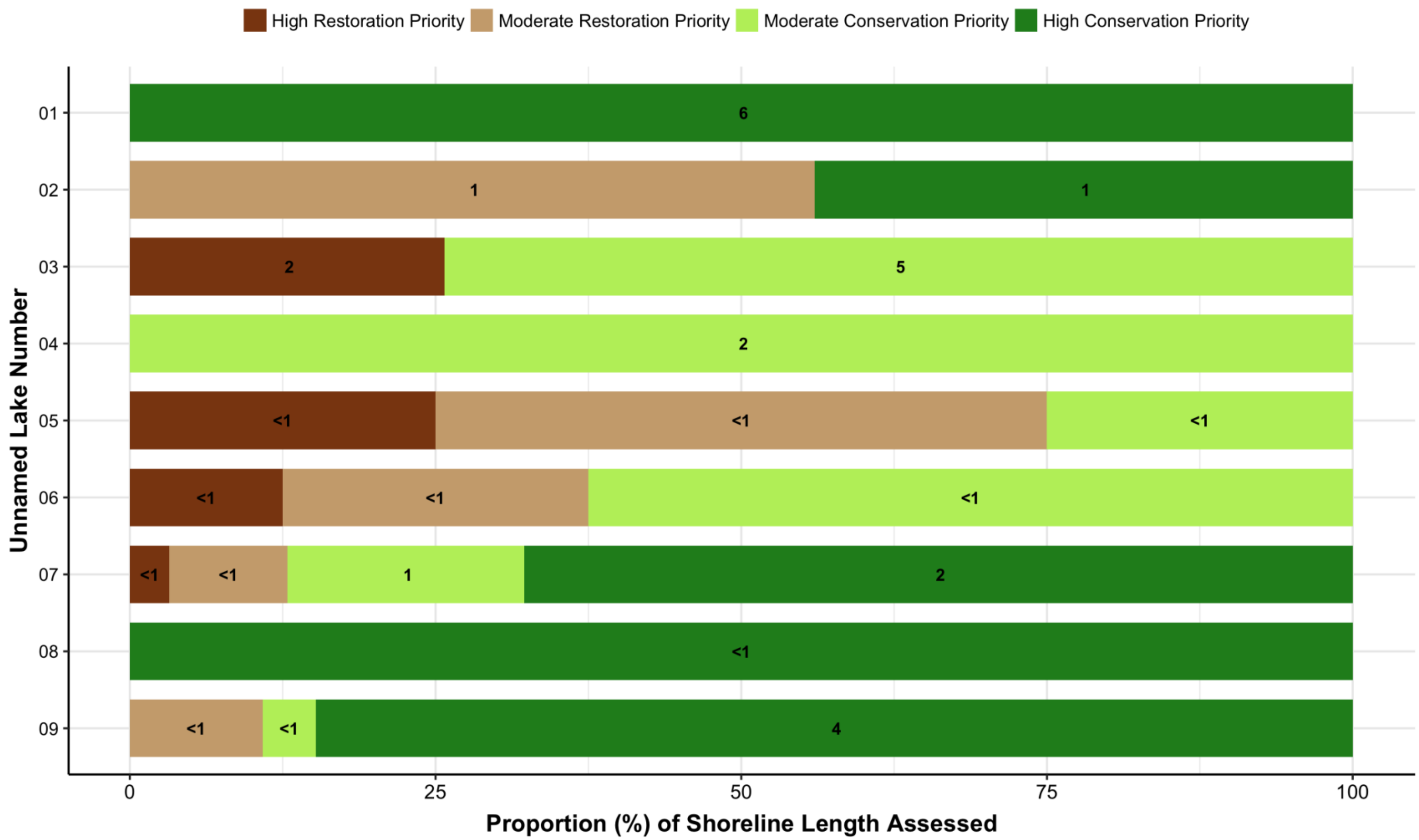


Figure 40. The proportion of shoreline length assigned to each priority category for unnamed lakes within Leduc County. Numbers indicate the approximate length (km) of shoreline associated with each category.

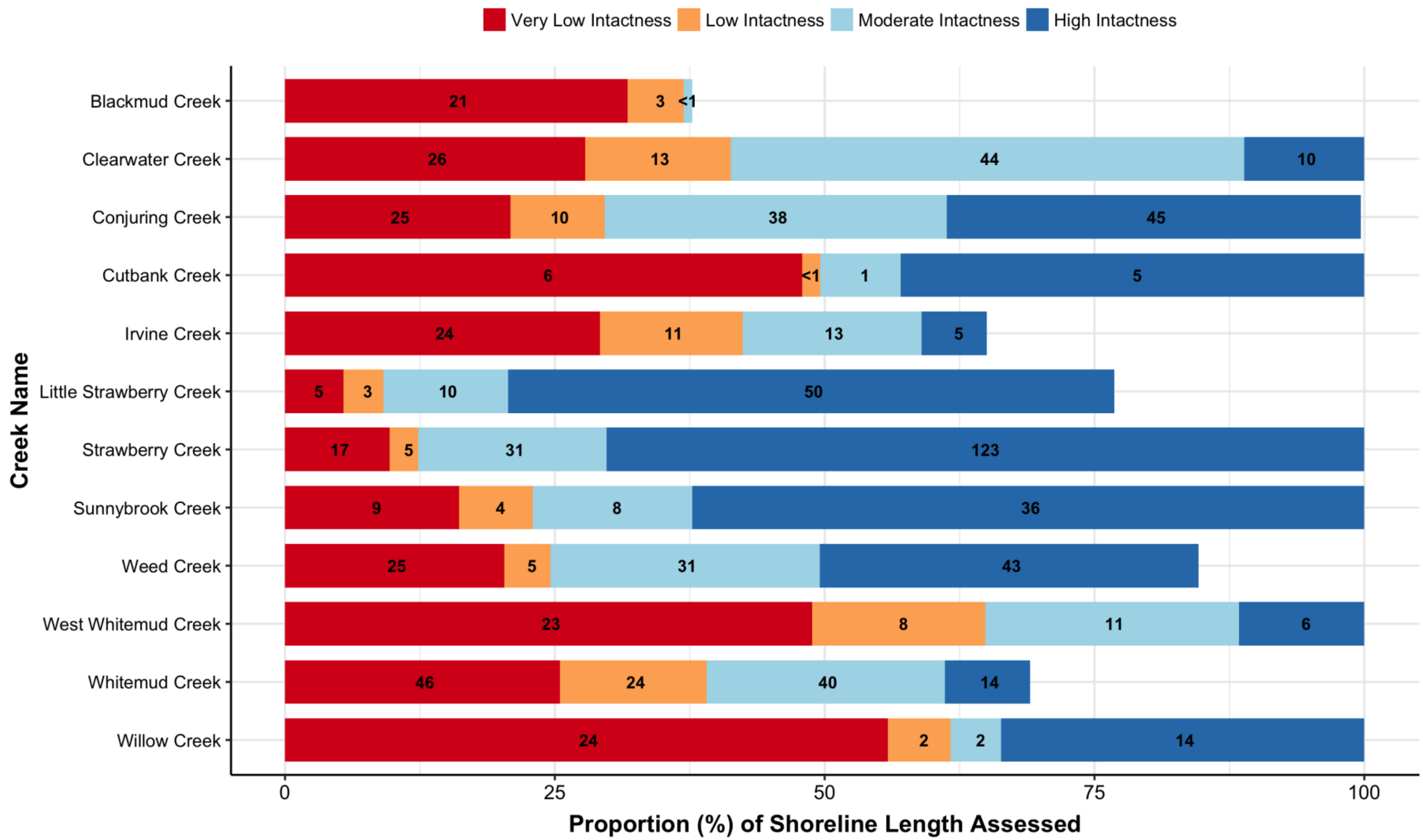


Figure 41. The proportion of shoreline length assigned to each riparian intactness category for named creeks in Leduc County. Numbers indicate the approximate length (km) of shoreline associated with each category.

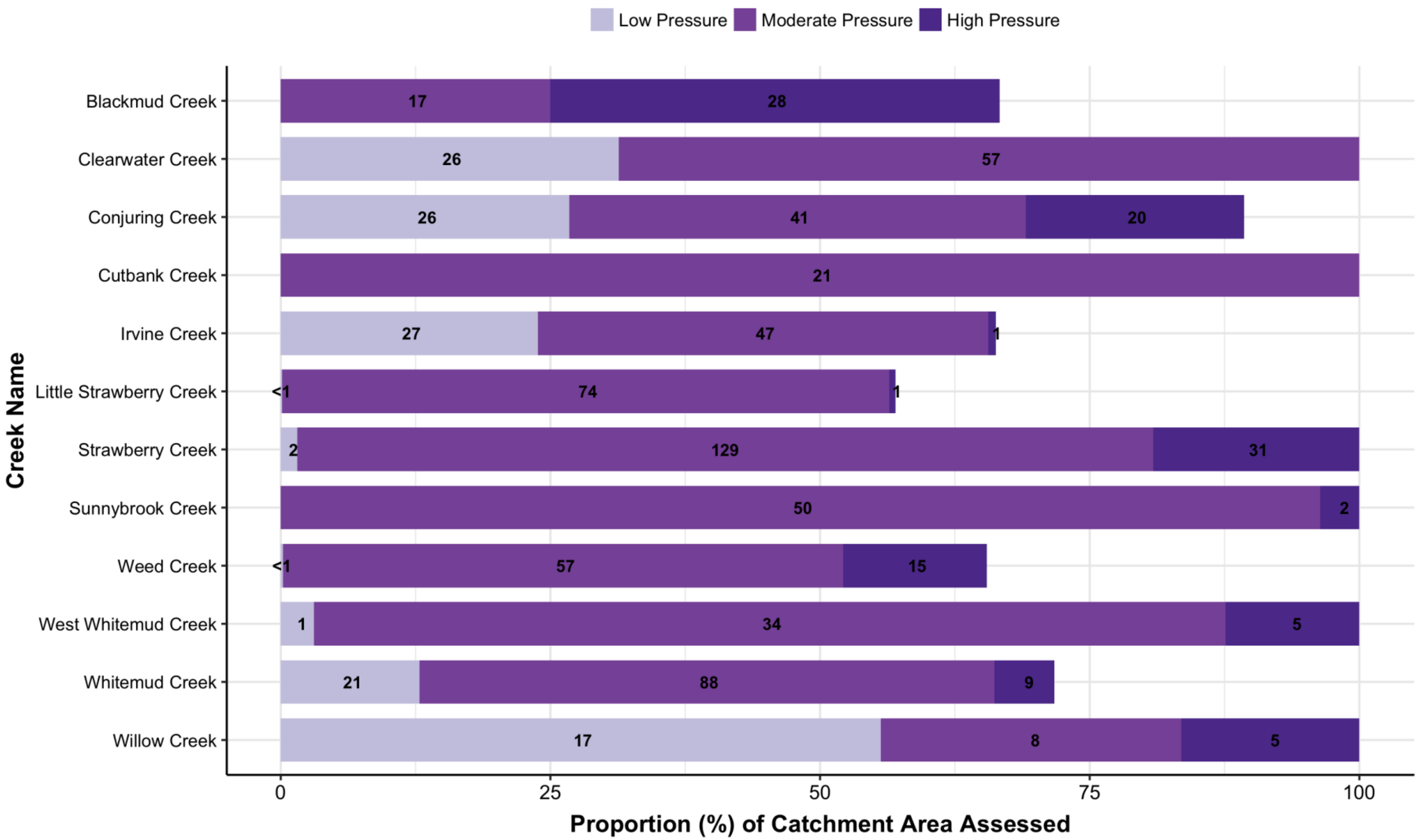


Figure 42. The proportion of catchment area by pressure category associated with RMAs that intersect the shorelines of named creeks in Leduc County. Numbers indicate the total area (km^2) assigned to each pressure category.

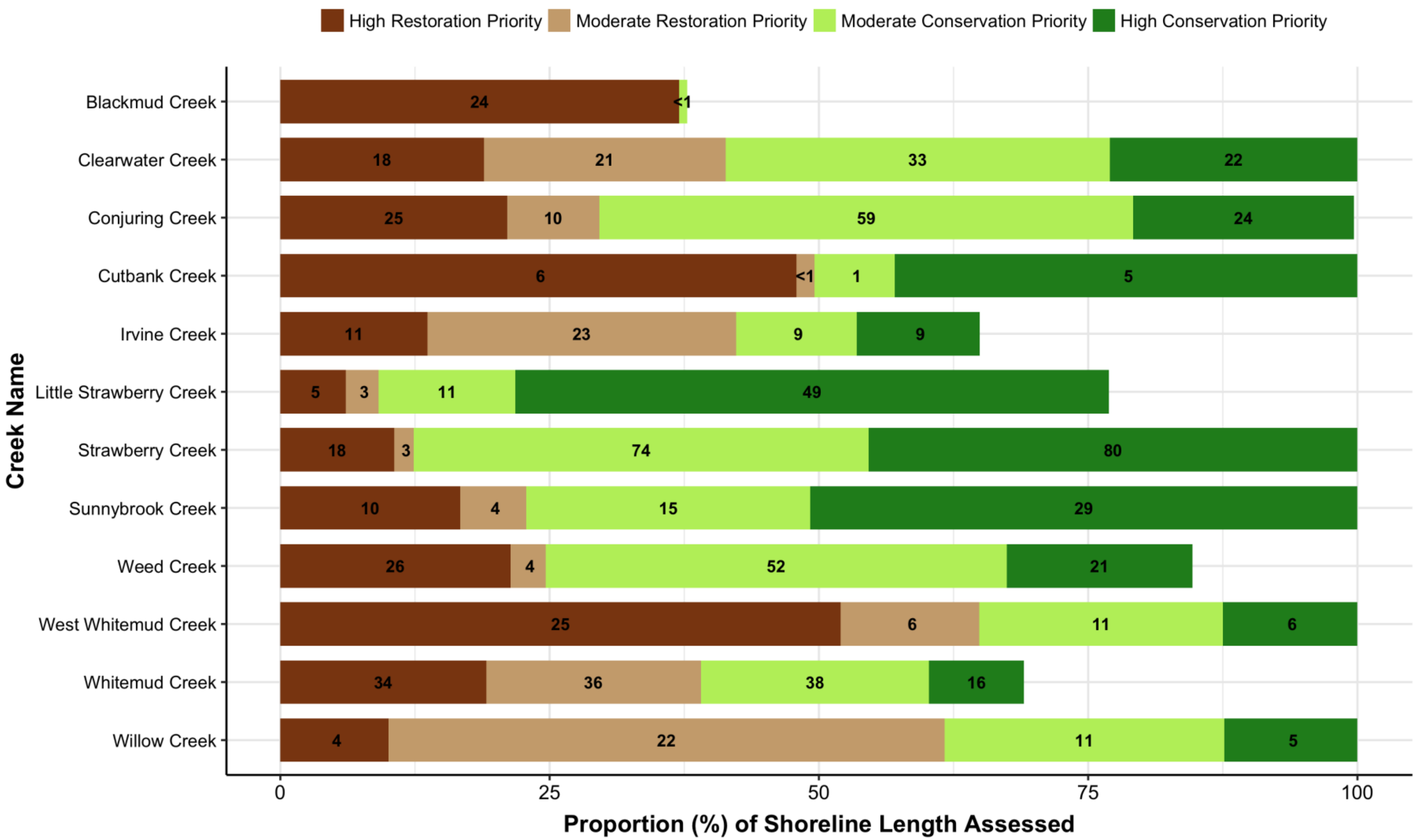


Figure 43. The proportion of shoreline length assigned to each priority category for named creeks in Leduc County. Numbers indicate the total length (km) of shoreline associated with each category.

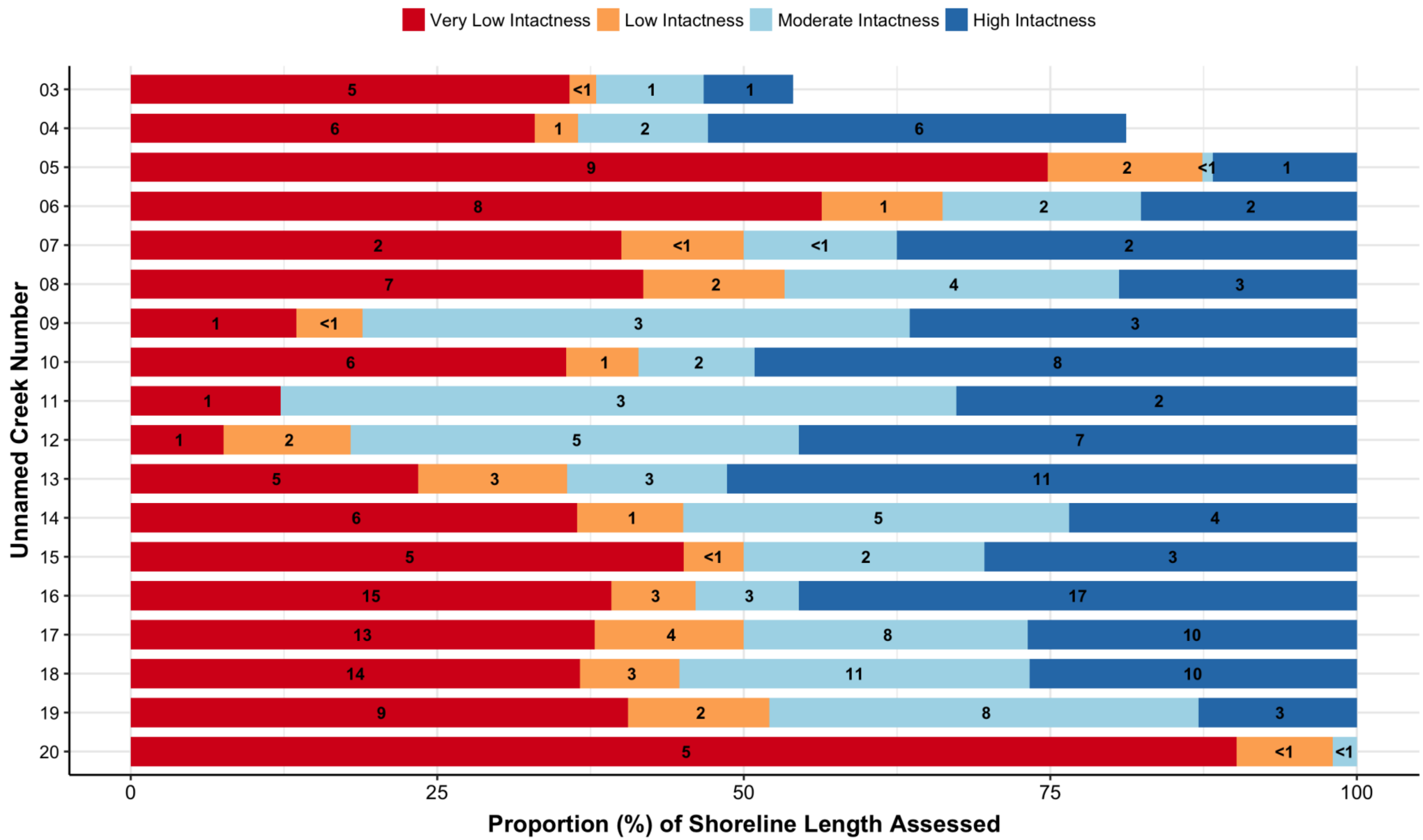


Figure 44. The proportion of shoreline length assigned to each riparian intactness category for Unnamed Creeks 03 to 20 in Leduc County. Numbers indicate the approximate length (km) of shoreline associated with each category.

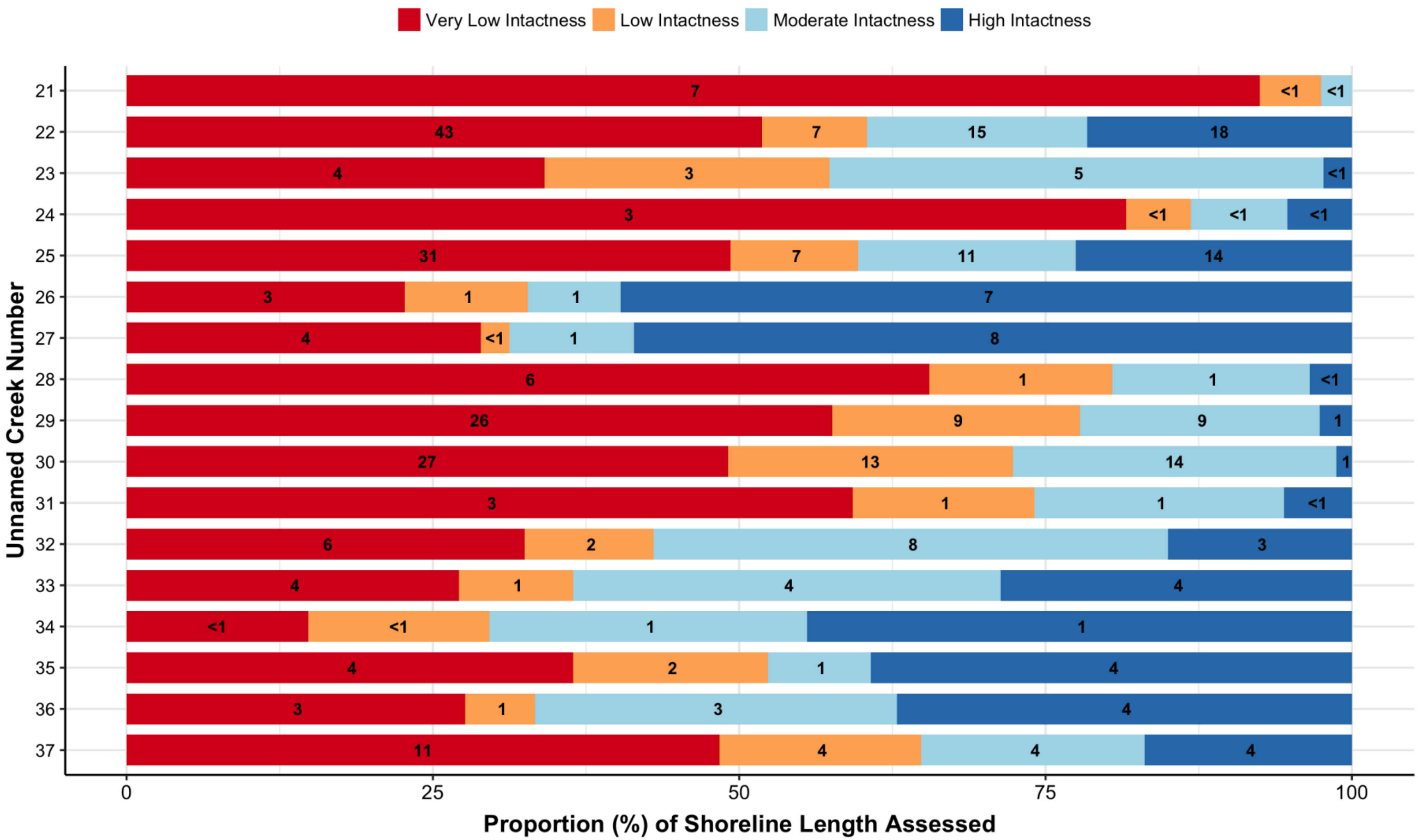


Figure 45. The proportion of shoreline length assigned to each riparian intactness category for Unnamed Creeks 21 to 37 in Leduc County. Numbers indicate the approximate length (km) of shoreline associated with each category.

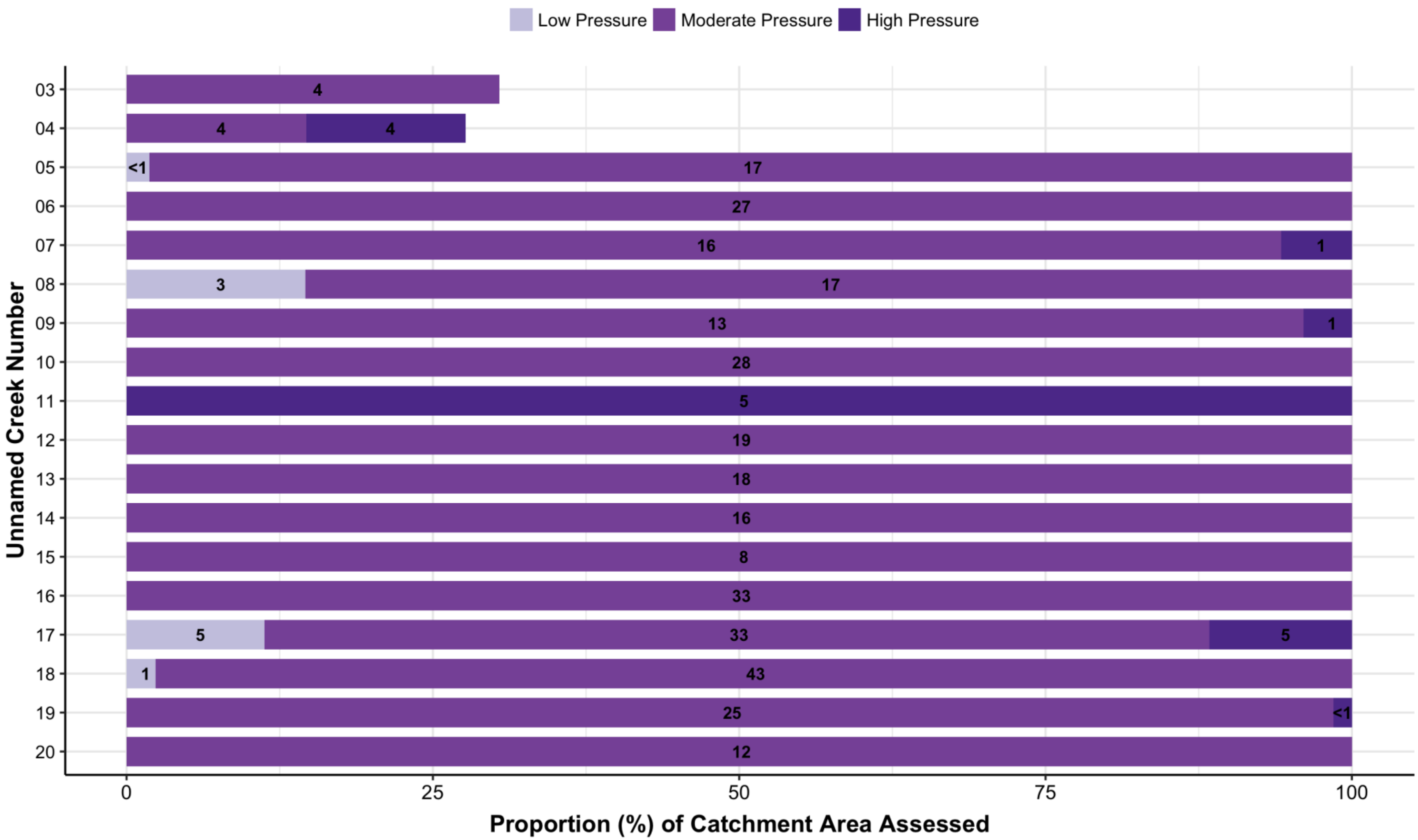


Figure 46. The proportion of catchment area by pressure category associated with RMAs that intersect the shorelines of Unnamed Creeks 03 to 20 in Leduc County. Numbers indicate the total area (km^2) assigned to each pressure category.

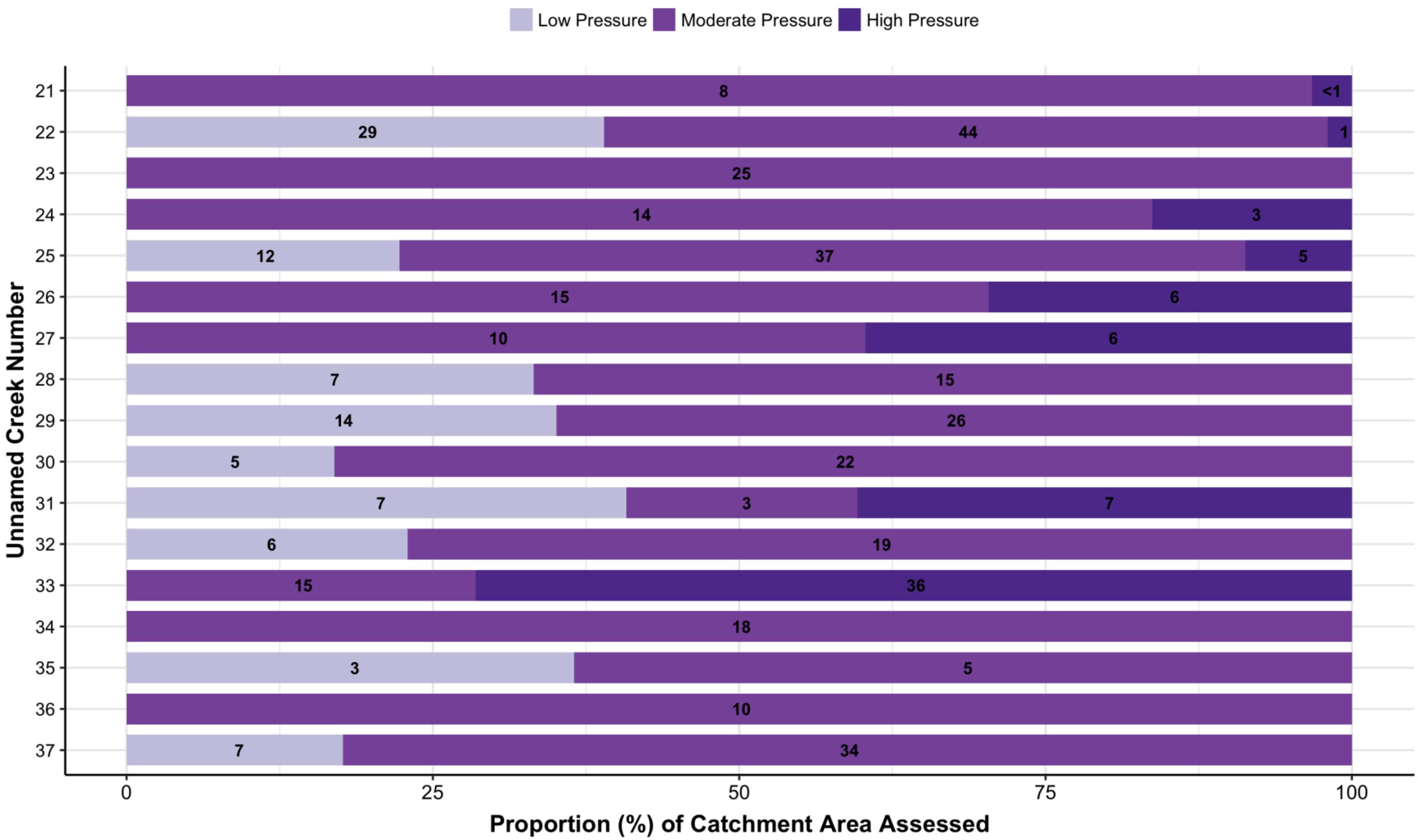


Figure 47. The proportion of catchment area by pressure category associated with RMAs that intersect the shorelines of Unnamed Creeks 21 to 37 in Leduc County. Numbers indicate the total area (km^2) assigned to each pressure category.

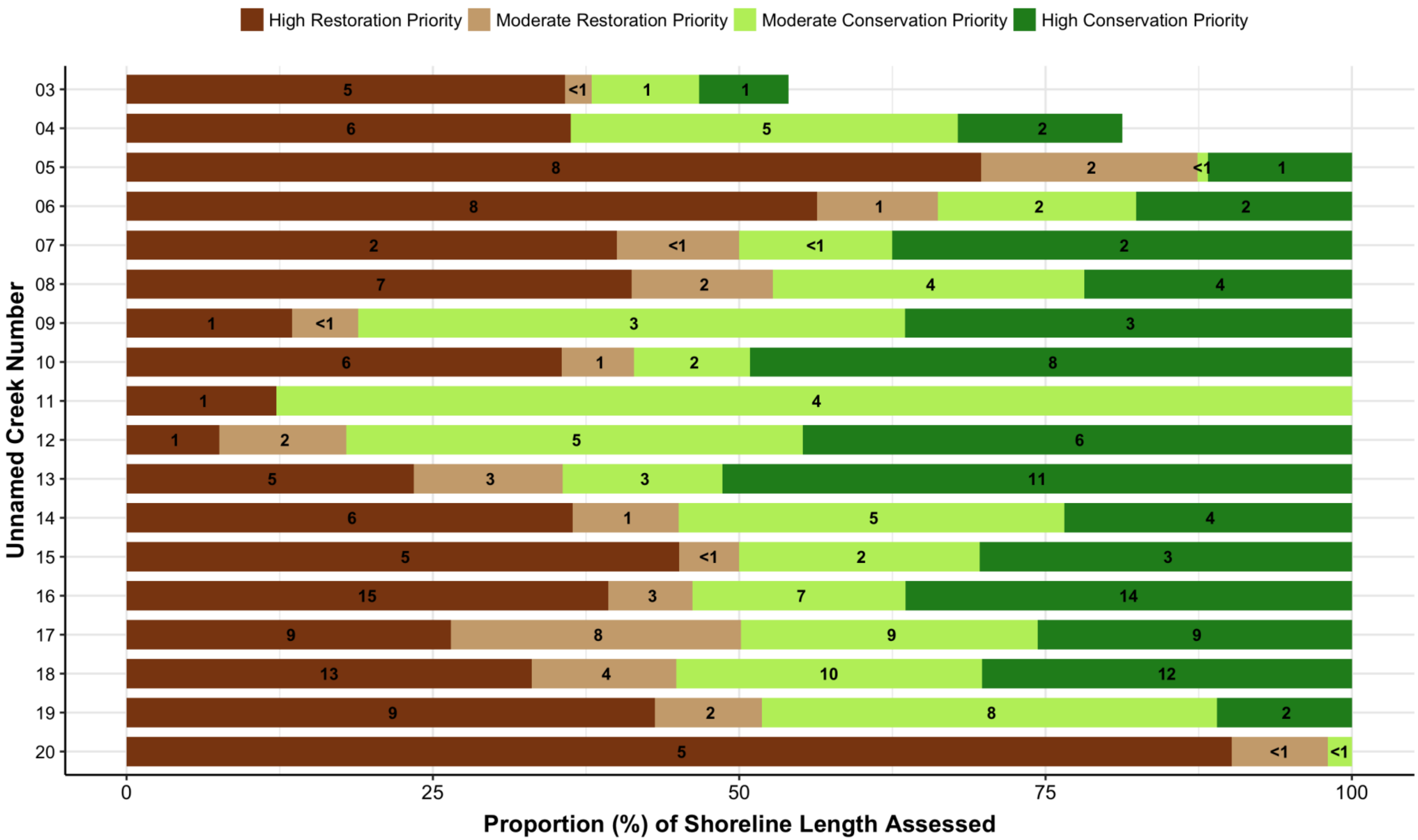


Figure 48. The proportion of shoreline length assigned to each priority category for Unnamed Creeks 03 to 20 in Leduc County. Numbers indicate the approximate length (km) of shoreline associated with each category.

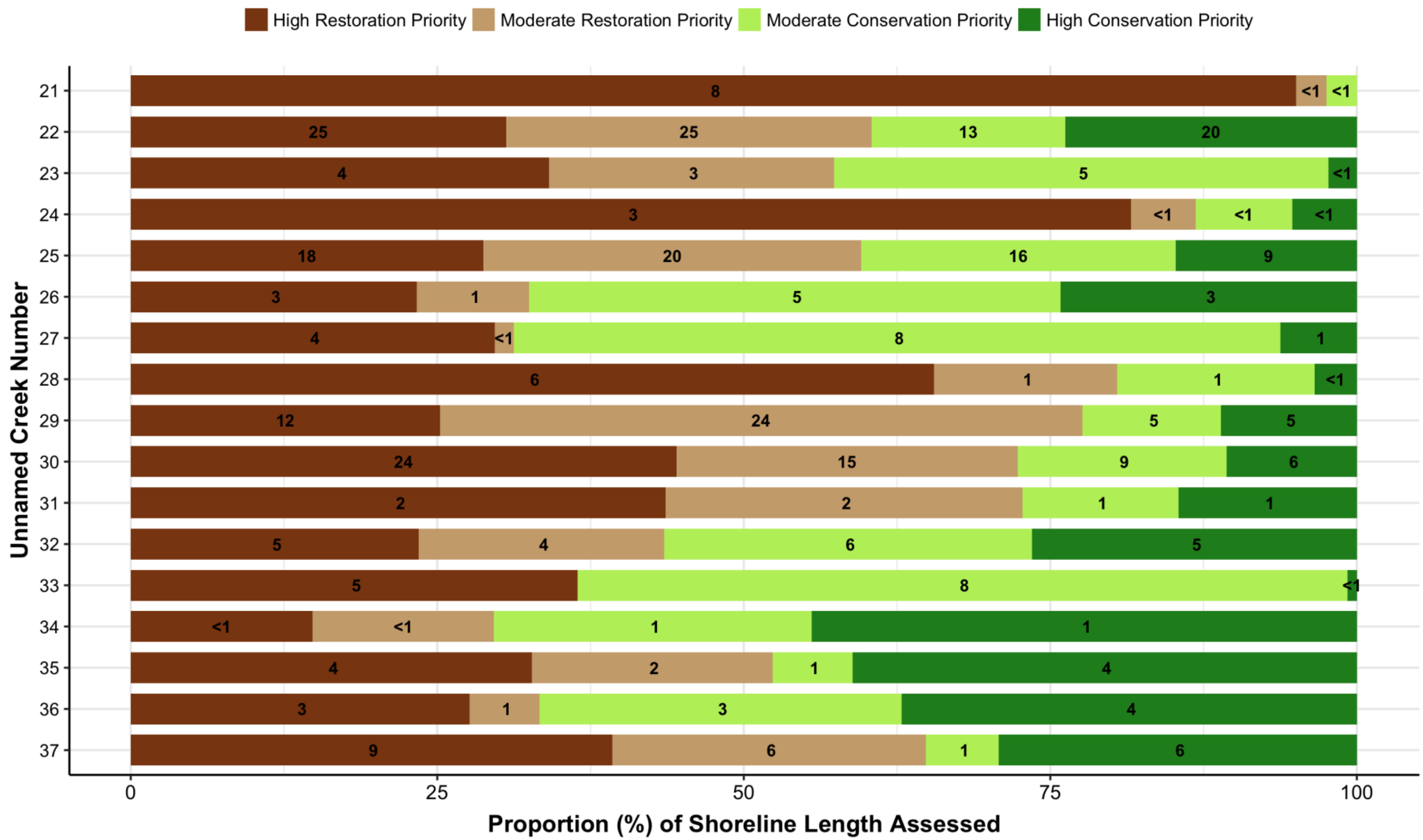


Figure 49. The proportion of shoreline length assigned to each priority category for Unnamed Creeks 21 to 37 in Leduc County. Numbers indicate the approximate length (km) of shoreline associated with each category.

5.6. Parkland County

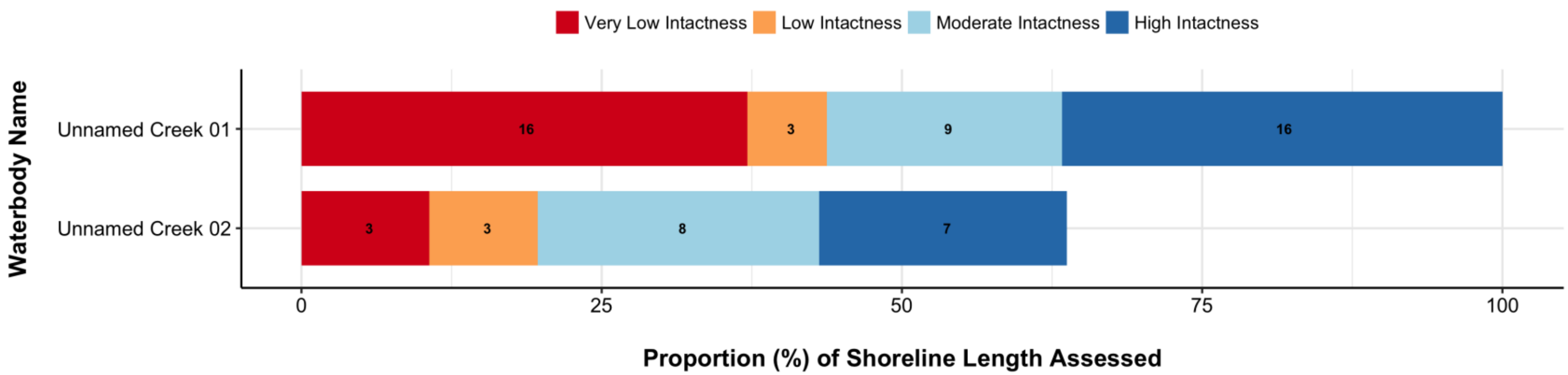


Figure 50. The proportion of shoreline length assigned to each riparian intactness category for waterbodies in Parkland County. Numbers indicate the approximate length (km) of shoreline associated with each category.

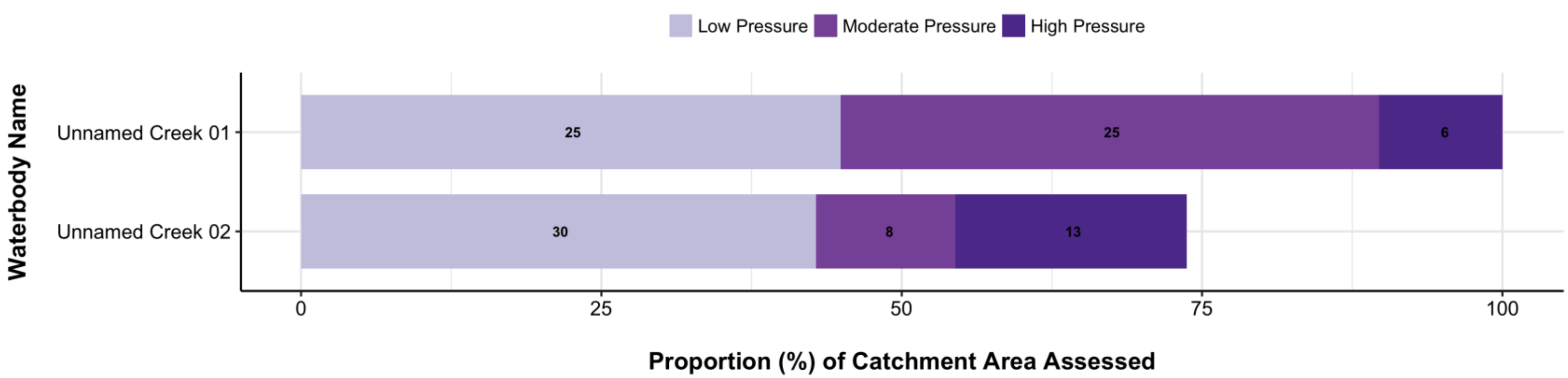


Figure 51. The proportion of catchment area by pressure category associated with RMAs that intersect the shorelines of waterbodies in Parkland County. Numbers indicate the total area (km^2) assigned to each pressure category.

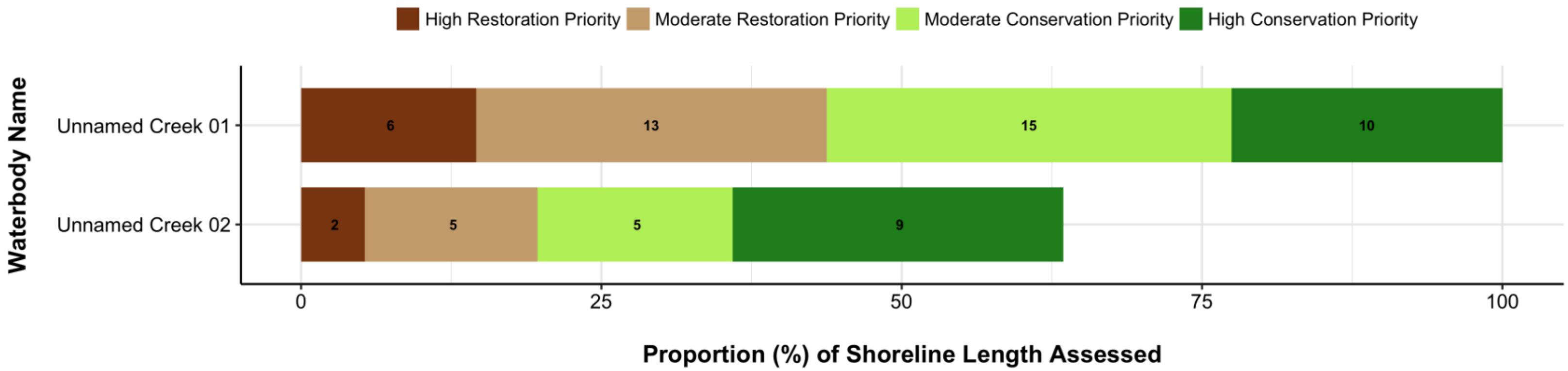


Figure 52. The proportion of shoreline length assigned to each priority category for waterbodies in Parkland County. Numbers indicate the approximate length (km) of shoreline associated with each priority category.

5.7. Strathcona County

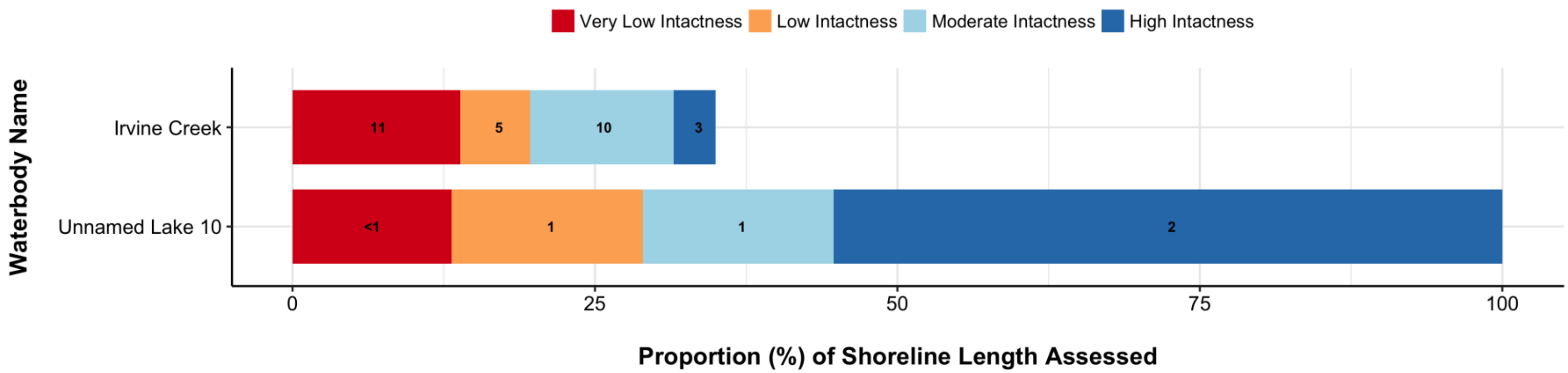


Figure 53. The proportion of shoreline length assigned to each riparian intactness category for waterbodies in Strathcona County. Numbers indicate the total length (km) of shoreline associated with each category.

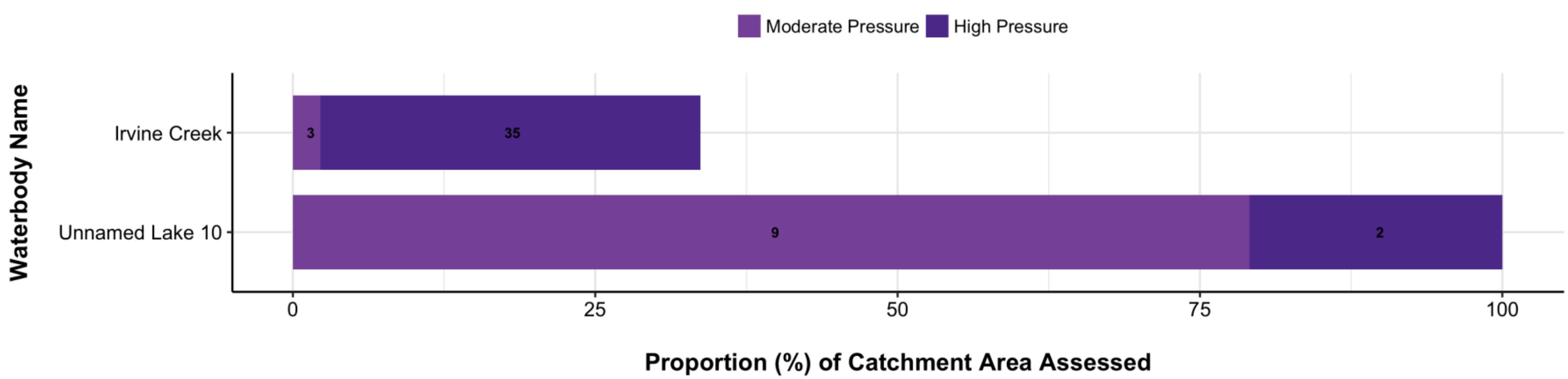


Figure 54. The proportion of catchment area by pressure category associated with RMAs that intersect the shorelines of waterbodies in Strathcona County. Numbers indicate the total area (km^2) assigned to each pressure category.

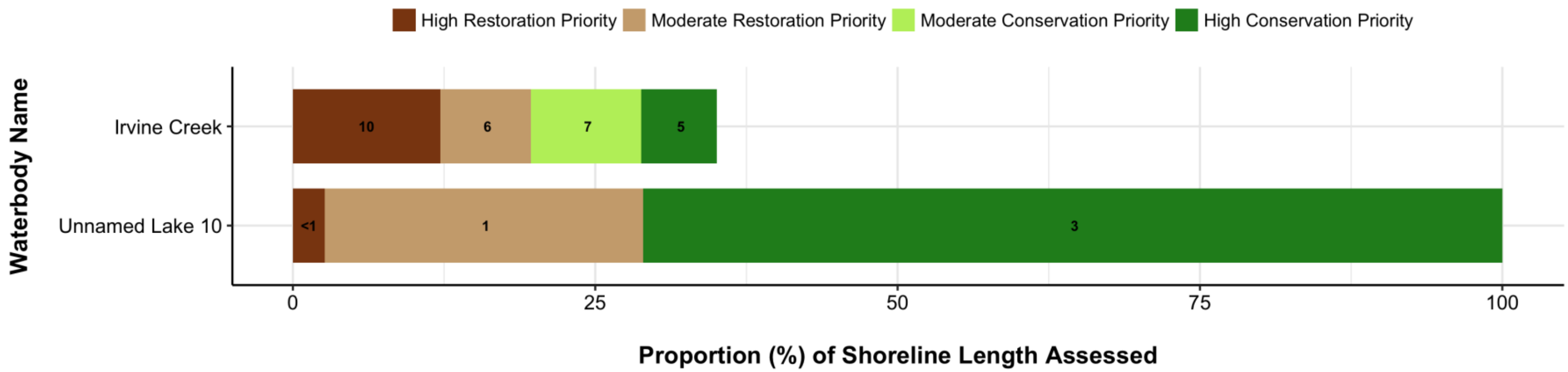


Figure 55. The proportion of shoreline length assigned to each priority category for waterbodies in Strathcona County. Numbers indicate the approximate length (km) of shoreline associated with each priority category.

6.0 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 Strawberry watershed.

Importantly, the next step in the advancement of meaningful riparian management and conservation in the Strawberry 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 land management through time.

Central to the goal of improving riparian habitat management and conservation outcomes in the Strawberry 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 for amount of intact riparian area), social (e.g., increase in awareness), 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 Strawberry 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 Strawberry watershed should be undertaken collectively by key stakeholders, we provide a number of key recommendations below that should be considered in the development of any riparian management plan.

6.1. 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 Strawberry 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 7.

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 shoreline 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 Strawberry watershed as a whole, and can also include measures and targets for riparian habitat conservation at the scale of the HUC 8 subwatershed, municipality, lake, 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 2014).

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, 23% of the shoreline assessed within the Strawberry watershed has been classified as Moderate Intactness, with an additional 35% classified as High Intactness, for a combined total of 58% (Table 8). 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 ≥50% 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.

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

Spatial Extent	Proportion (%) of Shoreline within Intactness Category					
	Very Low	Low	Moderate	High	Very Low + Low	Moderate + High
Strawberry (HUC 6) Watershed	32	10	23	35	42	58
N. Sask Below Strawberry Subwatershed	36	8	23	33	44	56
Strawberry Creek Subwatershed	21	6	18	55	27	73
Whitemud Creek Subwatershed	36	16	28	20	52	48
Edmonton	11	6	13	70	17	83
Brazeau County	18	15	27	41	33	68
County of Wetaskiwin	36	4	14	46	40	60
Leduc County	33	11	24	32	44	56
Parkland County	31	9	25	35	40	60
Strathcona County	37	16	32	15	53	47

Once watershed or municipal targets have been set, finer scale spatial targets can be set for individual lakes or creeks. For example, riparian habitat along creeks in the headwaters of the Strawberry and/or each HUC 8 subwatershed could be prioritized for conservation, or as an alternative, riparian areas along creeks with important ecological values, such as threatened or sensitive fisheries, could be prioritized for conservation.

Alternatively, a target such as having ≥75% of each waterbody's shoreline classified as Moderate or High Intactness could be applied to throughout the watershed (Environment Canada 2014). If such a target were to be adopted for the Strawberry watershed, data from this study suggests that 11% of the shoreline assessed in the North Saskatchewan Below Strawberry subwatershed (Table 9), 35% of the shoreline in the Strawberry Creek subwatershed (Table 10), and 26% of the shoreline in the Whitemud Creek subwatershed (Table 11) meet or exceed this target. If this target was reduced to 50% then the number of waterbodies that meet this target increases to 47% in the North Saskatchewan Below Strawberry subwatershed, 77% in the Strawberry Creek subwatershed, and 56% in the Whitemud Creek Subwatershed.

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 9. Proportion of shoreline length that has been classified in each of the riparian intactness categories, summarised by individual waterbody within the North Saskatchewan Below Strawberry HUC 8 subwatershed.

HUC 8 Subwatershed	**Waterbody**	**Proportion (%) of Shoreline within Intactness Category**					
		Very Low	**Low**	**Moderate**	**High**	**Very Low + Low**	**Moderate + High**
N. Sask Below Strawberry	Conjuring Creek	21	9	32	38	30	70
	Cutbank Creek	48	2	7	43	50	50
	Weed Creek	28	5	28	39	33	67
	Willow Creek	56	6	5	34	62	38
	Unnamed Creek 01	37	7	20	37	44	56
	Unnamed Creek 02	12	9	31	48	22	78
	Unnamed Creek 17	38	12	23	27	50	50
	Unnamed Creek 18	37	8	29	27	45	55
	Unnamed Creek 19	41	12	35	13	52	48
	Unnamed Creek 20	90	8	2	0	98	2
	Unnamed Creek 21	93	5	3	0	98	3
	Unnamed Creek 22	52	9	18	22	60	40
	Unnamed Creek 23	34	23	40	2	57	43
	Unnamed Creek 24	82	5	8	5	87	13
	Unnamed Creek 25	49	10	18	23	60	40
	Unnamed Creek 26	23	10	8	60	33	67
	Unnamed Creek 27	29	2	10	59	31	69
	Wizard Lake	19	9	11	61	28	72
	Unnamed Lake 01	0	0	0	100	0	100

Table 10. Proportion of shoreline length that has been classified in each of the riparian intactness categories, summarised by individual waterbody within the Strawberry Creek HUC 8 subwatershed.

HUC 8 Subwatershed	Waterbody	Proportion (%) of Shoreline within Intactness Category					
		Very Low	Low	Moderate	High	Very Low + Low	Moderate + High
Strawberry Creek	Little Strawberry Creek	9	7	15	69	16	84
	Strawberry Creek	10	3	17	70	13	87
	Sunnybrook Creek	16	7	15	62	23	77
	Unnamed Creek 03	41	12	35	12	53	47
	Unnamed Creek 04	39	5	18	37	44	55
	Unnamed Creek 05	75	13	1	12	88	13
	Unnamed Creek 06	56	10	16	18	66	34
	Unnamed Creek 07	40	10	13	38	50	51
	Unnamed Creek 08	42	12	27	19	54	46
	Unnamed Creek 09	14	5	45	36	19	81
	Unnamed Creek 10	36	6	9	49	42	58
	Unnamed Creek 11	12	0	55	33	12	88
	Unnamed Creek 12	8	10	37	46	18	83
	Unnamed Creek 13	23	12	13	51	35	64
	Unnamed Creek 14	36	9	31	23	45	54
	Unnamed Creek 15	45	5	20	30	50	50
	Unnamed Creek 16	39	7	8	46	46	54

Table 11. Proportion of shoreline length that has been classified in each of the riparian intactness categories, summarised by individual waterbody within the Whitemud Creek HUC 8 subwatershed.

HUC 8 Subwatershed	Waterbody	Proportion (%) of RMA within Intactness Category					
		Very Low	Low	Moderate	High	Very Low + Low	Moderate + High
Whitemud Creek	Blackmud Creek	44	10	9	37	54	46
	Clearwater Creek	28	13	48	11	41	59
	Irvine Creek	43	19	28	10	62	38
	West Whitemud Creek	49	16	23	12	65	35
	Whitemud Creek	28	15	26	32	43	57
	Unnamed Creek 28	66	15	16	3	80	20
	Unnamed Creek 29	58	20	20	3	78	22
	Unnamed Creek 30	49	23	26	1	72	28
	Unnamed Creek 31	59	15	20	6	74	26
	Unnamed Creek 32	33	11	42	15	43	57
	Unnamed Creek 33	27	9	35	29	36	64
	Unnamed Creek 34	15	15	26	44	30	70
	Unnamed Creek 35	36	16	8	39	52	48
	Unnamed Creek 36	28	6	30	37	33	67
	Unnamed Creek 37	48	16	18	17	65	35
	Ord Lake	0	0	38	62	0	100
	Saunders Lake	3	22	63	13	25	75
	Schultz Lake	0	0	100	0	0	100
	Unnamed Lake 02	27	31	42	0	58	42
	Unnamed Lake 03	10	16	54	20	26	74
	Unnamed Lake 04	0	0	0	100	0	100
	Unnamed Lake 05	25	50	25	0	75	25
	Unnamed Lake 06	13	25	63	0	38	63
	Unnamed Lake 07	13	0	29	58	13	87
	Unnamed Lake 08	0	0	25	75	0	100
	Unnamed Lake 09	0	11	4	85	11	89
	Unnamed Lake 10	13	16	16	55	29	71

Objective 2:

- Restore riparian habitats that have been impacted or impaired.

Measure:

- Proportion (%) of shoreline 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 Strawberry watershed. At present, 32% of the Strawberry watershed has been classified as Very Low Intactness, while an additional 10% has been classified as Low Intactness, for a combined total of 42% (Table 8). A target for this objective could include specifying a desire to reduce to zero the length of shoreline that has been classified as Very Low Intactness at the watershed, sub-watershed, and/or 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 lakes or streams under this objective.

Actions:

There are a number of actions that could be taken to achieve the 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 Strawberry 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 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 a no net increase 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 the 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.

6.2. Utilizing Data from This Study to Set Objectives

This study has created valuable data products that can be used to help inform the development of management targets at multiple spatial scales, from the entire watershed, down to a single lake. Once management targets have been set, the data from this study can be used to spatially target areas where specific action can be focused. In addition, the data can be used to track change through time and serves as an important benchmark against which the success of future management actions can be measured and compared.

To illustrate how the data from this study can be used for practical management applications, we can look to Wizard Lake as an example. This large lake intersects multiple local catchment areas (Map 10), and the majority of the lands within those local catchment areas were classified as Moderate Pressure (Figure 11). At present, approximately 28% of the shoreline along Wizard Lake is classified as either Very Low or Low Intactness, and the mapping products from this study allow land managers to identify spatially where the areas of lower intactness are located along the shoreline (Figure 56). While there are several areas along the shoreline of Wizard Lake that have been impacted by previous land development, this lake also has a large proportion (61%) and length (10.9 km) of its shoreline that has been classified as High Intactness.

This information can first be used to engage stakeholders and land owners in conversations about appropriate and desirable riparian management targets, and second, it can be used to spatially focus management efforts. For example, this information could be used to set a target of no net change in shoreline condition, or alternatively, a target that specifies a minimum of 70% of the shoreline be classified as Moderate or High Intactness.

In both of these cases, this data help to focus the type of management action that could be used to achieve these targets. For example, at present there is 9% of the lake's shoreline, which is equivalent to only 1.7 km, that has been rated as Low Intactness. This represents a relatively small area (but large proportion of the shoreline) where restoration efforts, such as shrub and tree plantings, could elevate these areas from the Low Intactness category to the Moderate Intactness category. In doing so, the overall proportion of the lake shoreline classified as either Moderate or High Intactness could be elevated from 72% to 83%.

Other examples of specific management action that could be informed by this data includes targeting areas classified as High Intactness for conservation. This could include land purchase by the County, the designation of a conservation easement on lands within 50 m of the lake, or the adoption of minimum development setbacks of 30 m for new land development adjacent to the lake.

This is only one example of the many ways in which this information can be utilized by land owners, local land stewardship groups, and municipalities to help inform land development decisions and riparian management policies and action at multiple scales.

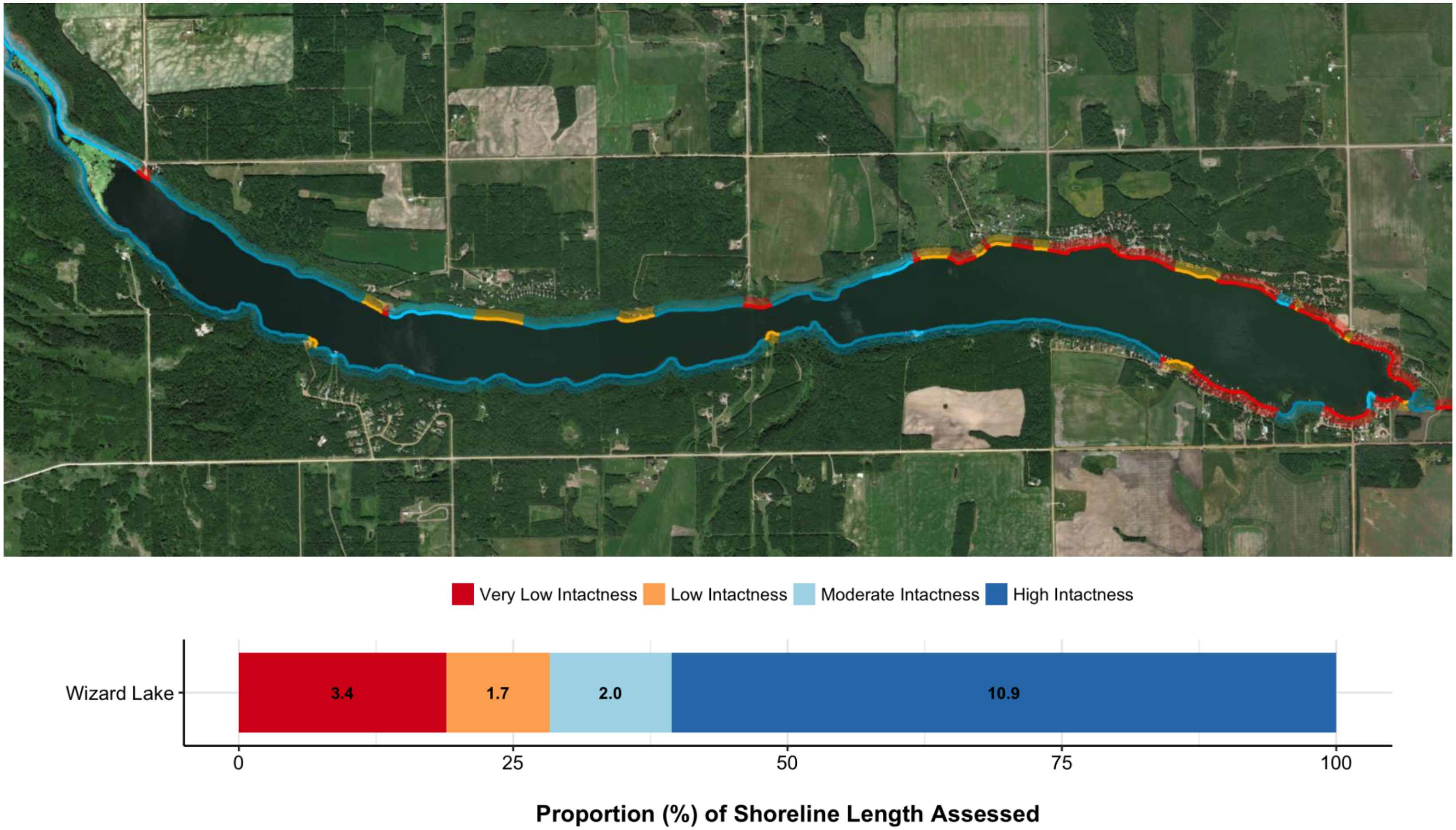


Figure 56. Data from this study indicates that ~25% (5 km) of the shoreline along Wizard Lake has been classified as Very Low or Low Intactness. This information can be used by a wide range of different organizations to spatially targeted areas for future management activities, such as field assessment, land acquisition of conservation, or engagement of land owners to implement restoration projects.

7.0 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.

7.1. 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 Strawberry watershed are listed in Table 12.

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 Strawberry watershed is provided in Table 13.

Table 12. List and description of Federal laws and regulations that may apply to the management of riparian areas in the Strawberry 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 serious harm to fish.
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 13. List and description of Provincial laws, regulations, and policies that may apply to the management of riparian areas in the Strawberry 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)	Updated in June 2018, the modernized 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, and 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 13 *continued …* List and description of Provincial laws, regulations, and policies that may apply to the management of riparian areas in the Strawberry 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), which was modernized and revised in July 2018. Under Part 1, Section 3, the Act outlines the following purposes of a municipality:

1) To provide good governance and foster the well-being of the environment;
2) To provide services that are in the opinion of council to be necessary or desirable;
3) To develop and maintain safe and viable communities; and
4) To work collaboratively with neighbouring municipalities to plan, deliver, and fund intermunicipal services.

A primary power given to municipalities is land use planning and development, which allows municipalities to set the conditions under which lands are subdivided and developed. Further, each municipality must develop statutory planning documents that provide a framework and vision for development and land use within their jurisdictions. Statutory planning documents that are required 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. These policies must be consistent with guidance provided by the Edmonton Metropolitan Region Board and with Regional Plans developed under the Alberta Land-Use Framework.

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 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 Act 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 Act 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.

7.2. 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 Strawberry 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 Act 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 Act 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 Act 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.

Conservation Reserve:

Under Section 664.2(1), municipalities may designate an area as a Conservation Reserve if the area contains significant environmental features that are not required to be provided as Environmental Reserve. Under the Act, the purpose of taking the Conservation Reserve is to protect and conserve the significant environmental features in a manner that is consistent with other statutory planning documents. In designating a Conservation Reserve, the municipality must compensate the landowner in an amount that is equal to the market value at the time of the subdivision approval application.

7.3. 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 resilient 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 Strawberry 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., ALUS, 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 Strawberry 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 action 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.

8.0 Conclusion

The overall goal of this project was to quantify and characterize the intactness of riparian management areas in the Strawberry watershed, and to further assess pressure on riparian system function by evaluating land use and land cover within local catchments immediately adjacent to the waterbodies included in this study. The results of this work provide the North Saskatchewan Watershed Alliance and its stakeholders with an overview of the status of riparian areas, 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, approximately 1,926 km of shoreline was assessed in the Strawberry watershed as part of this study, with 35% of the shoreline length that was assessed being classified as High Intactness. A further 23% of shoreline was classified as Moderate Intactness, with 42% classified as either Very Low (32%) or Low (10%) Intactness. Within the Strawberry watershed, the greatest length of shoreline classified as Very Low or Low Intactness were located within the Whitemud Creek subwatershed, and primarily within the jurisdiction of Leduc County.

The next step in the advancement of meaningful riparian management and conservation in the Strawberry 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.

8.1. Closure

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Appendix A: Intactness Summary Table

Table 14. Length (km) and proportion (%) of shoreline classified into each Intactness category, summarized by waterbody. For each waterbody, length and proportion is also summarized by municipality.

Waterbody Name	Intactness								TOTAL	
	Very Low		Low		Moderate		High			
	km	%	km	%	km	%	km	%	km	%
Ord Lake	**<1**	**<1**	**0**	**0**	**1**	**38**	**2**	**62**	**3**	**100**
Leduc County	<1	<1	0	0	1	38	2	62	3	100
Saunders Lake	**<1**	**3**	**3**	**22**	**10**	**63**	**2**	**13**	**15**	**100**
Leduc County	<1	3	3	22	10	63	2	13	15	100
Schultz Lake	**<1**	**<1**	**<1**	**<1**	**2**	**100**	**0**	**0**	**2**	**100**
Leduc County	<1	<1	<1	<1	2	100	0	0	2	100
Wizard Lake	**3**	**19**	**2**	**9**	**2**	**12**	**11**	**60**	**18**	**100**
County of Wetaskiwin	1	4	<1	2	<1	1	8	43	9	49
Leduc County	3	15	1	8	2	11	3	17	9	51
Unnamed Lake 01	**0**	**0**	**0**	**0**	**0**	**0**	**6**	**100**	**6**	**100**
Leduc County	0	0	0	0	0	0	6	100	6	100
Unnamed Lake 02	**1**	**27**	**1**	**31**	**1**	**42**	**0**	**0**	**3**	**100**
Leduc County	1	27	1	31	1	42	0	0	3	100
Unnamed Lake 03	**1**	**10**	**1**	**16**	**4**	**54**	**1**	**20**	**7**	**100**
Leduc County	1	10	1	16	4	54	1	20	7	100
Unnamed Lake 04	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**100**	**2**	**100**
Leduc County	0	0	0	0	0	0	2	100	2	100
Unnamed Lake 05	**<1**	**25**	**<1**	**50**	**<1**	**25**	**0**	**0**	**1**	**100**
Leduc County	<1	25	<1	50	<1	25	0	0	1	100
Unnamed Lake 06	**<1**	**13**	**<1**	**25**	**1**	**63**	**0**	**0**	**1**	**100**
Leduc County	<1	13	<1	25	1	63	0	0	1	100
Unnamed Lake 07	**<1**	**13**	**<1**	**<1**	**1**	**29**	**2**	**58**	**3**	**100**
Leduc County	<1	13	<1	<1	1	29	2	58	3	100
Unnamed Lake 08	**<1**	**<1**	**0**	**0**	**<1**	**25**	**<1**	**75**	**<1**	**100**
Leduc County	<1	<1	0	0	<1	25	<1	75	<1	100
Unnamed Lake 09	**0**	**0**	**1**	**11**	**<1**	**4**	**4**	**85**	**5**	**100**
Leduc County	0	0	1	11	<1	4	4	85	5	100
Unnamed Lake 10	**1**	**13**	**1**	**16**	**1**	**16**	**2**	**55**	**4**	**100**
Strathcona County	1	13	1	16	1	16	2	55	4	100
Blackmud Creek	**29**	**44**	**6**	**10**	**6**	**9**	**24**	**37**	**66**	**100**
Edmonton	8	12	3	4	6	9	24	37	41	62
Leduc County	21	32	3	5	1	1	0	0	25	38
Clearwater Creek	**26**	**28**	**13**	**13**	**45**	**48**	**10**	**11**	**94**	**100**
Leduc County	26	28	13	13	45	48	10	11	94	100
Conjuring Creek	**25**	**21**	**10**	**9**	**38**	**32**	**45**	**38**	**118**	**100**
County of Wetaskiwin	0	0	0	0	<1	<1	0	0	<1	<1
Leduc County	25	21	10	9	38	32	45	38	118	100
Cutbank Creek	**6**	**48**	**0**	**2**	**1**	**7**	**5**	**43**	**12**	**100**
Leduc County	6	48	0	2	1	7	5	43	12	100
Irvine Creek	**35**	**43**	**15**	**19**	**23**	**28**	**8**	**10**	**81**	**100**
Leduc County	24	29	11	13	13	17	5	6	53	65
Strathcona County	11	14	5	6	10	12	3	3	28	35
Little Strawberry Creek	**8**	**9**	**6**	**7**	**14**	**15**	**61**	**68**	**89**	**100**
Brazeau County	4	4	3	3	3	4	11	12	21	23
Leduc County	5	5	3	4	10	12	50	56	68	77

Continued …

Table 14 *continued*. Length (km) and proportion (%) of shoreline classified into each Intactness category, summarized by waterbody. For each waterbody, length and proportion is also summarized by municipality.

Waterbody Name	Intactness								TOTAL	
	Very Low		Low		Moderate		High			
	km	%	km	%	km	%	km	%	km	%
Strawberry Creek	**17**	**10**	**5**	**3**	**31**	**17**	**123**	**70**	**175**	**100**
Leduc County	17	10	5	3	31	17	123	70	175	100
Sunnybrook Creek	**9**	**16**	**4**	**7**	**8**	**15**	**36**	**62**	**57**	**100**
Leduc County	9	16	4	7	8	15	36	62	57	100
Weed Creek	**34**	**28**	**6**	**5**	**34**	**28**	**48**	**39**	**123**	**100**
County of Wetaskiwin	9	8	1	1	4	3	5	4	19	15
Leduc County	25	20	5	4	31	25	43	35	104	85
West Whitemud Creek	**23**	**49**	**8**	**16**	**11**	**23**	**6**	**12**	**47**	**100**
Leduc County	23	49	8	16	11	23	6	12	47	100
Whitemud Creek	**49**	**28**	**27**	**15**	**46**	**26**	**56**	**31**	**179**	**100**
Edmonton	4	2	3	2	6	4	42	24	55	31
Leduc County	46	25	24	14	40	22	14	8	124	69
Willow Creek	**24**	**56**	**3**	**6**	**2**	**5**	**14**	**34**	**43**	**100**
Leduc County	24	56	3	6	2	5	14	34	43	100
Unnamed Creek 01	**16**	**37**	**3**	**7**	**9**	**20**	**16**	**37**	**44**	**100**
Parkland County	16	37	3	7	9	20	16	37	44	100
Unnamed Creek 02	**4**	**12**	**3**	**9**	**10**	**31**	**15**	**48**	**32**	**100**
Edmonton	1	2	<1	<1	2	8	9	27	12	36
Parkland County	3	11	3	9	8	23	7	21	20	64
Unnamed Creek 03	**6**	**40**	**2**	**12**	**5**	**36**	**2**	**12**	**14**	**100**
Brazeau County	1	4	1	9	4	27	1	5	6	46
Leduc County	5	36	<1	2	1	9	1	7	7	54
Unnamed Creek 04	**7**	**40**	**1**	**5**	**3**	**18**	**6**	**38**	**17**	**100**
Brazeau County	1	7	<1	1	1	7	1	4	3	19
Leduc County	6	33	1	4	2	11	6	34	14	81
Unnamed Creek 05	**9**	**75**	**2**	**13**	**<1**	**1**	**1**	**12**	**12**	**100**
Leduc County	9	75	2	13	<1	1	1	12	12	100
Unnamed Creek 06	**8**	**56**	**1**	**10**	**2**	**16**	**3**	**18**	**14**	**100**
Leduc County	8	56	1	10	2	16	3	18	14	100
Unnamed Creek 07	**2**	**40**	**<1**	**10**	**1**	**13**	**2**	**38**	**4**	**100**
Leduc County	2	40	<1	10	1	13	2	38	4	100
Unnamed Creek 08	**7**	**42**	**2**	**12**	**5**	**27**	**3**	**19**	**17**	**100**
Leduc County	7	42	2	12	5	27	3	19	17	100
Unnamed Creek 09	**1**	**14**	**<1**	**5**	**3**	**45**	**3**	**36**	**7**	**100**
Leduc County	1	14	<1	5	3	45	3	36	7	100
Unnamed Creek 10	**6**	**36**	**1**	**6**	**2**	**9**	**8**	**49**	**17**	**100**
Leduc County	6	36	1	6	2	9	8	49	17	100
Unnamed Creek 11	**1**	**12**	**<1**	**<1**	**3**	**55**	**2**	**33**	**5**	**100**
Leduc County	1	12	<1	<1	3	55	2	33	5	100
Unnamed Creek 12	**1**	**8**	**2**	**10**	**5**	**37**	**7**	**46**	**15**	**100**
Leduc County	1	8	2	10	5	37	7	46	15	100
Unnamed Creek 13	**5**	**23**	**3**	**12**	**3**	**13**	**11**	**51**	**22**	**100**
Leduc County	5	23	3	12	3	13	11	51	22	100
Unnamed Creek 14	**6**	**36**	**1**	**9**	**5**	**31**	**4**	**23**	**16**	**100**
Leduc County	6	36	1	9	5	31	4	23	16	100
Unnamed Creek 15	**5**	**45**	**1**	**5**	**2**	**20**	**3**	**30**	**10**	**100**
Leduc County	5	45	1	5	2	20	3	30	10	100

Continued …

Table 14 *continued*. Length (km) and proportion (%) of shoreline classified into each Intactness category, summarized by waterbody. For each waterbody, length and proportion is also summarized by municipality.

Waterbody Name	Intactness								TOTAL	
	Very Low		Low		Moderate		High			
	km	%	km	%	km	%	km	%	km	%
Unnamed Creek 16	**15**	**39**	**3**	**7**	**3**	**8**	**17**	**46**	**38**	**100**
Leduc County	15	39	3	7	3	8	17	46	38	100
Unnamed Creek 17	**13**	**38**	**4**	**12**	**8**	**23**	**10**	**27**	**35**	**100**
Leduc County	13	38	4	12	8	23	10	27	35	100
Unnamed Creek 18	**14**	**37**	**3**	**8**	**11**	**29**	**10**	**27**	**38**	**100**
Leduc County	14	37	3	8	11	29	10	27	38	100
Unnamed Creek 19	**9**	**41**	**3**	**12**	**8**	**35**	**3**	**13**	**22**	**100**
Leduc County	9	41	3	12	8	35	3	13	22	100
Unnamed Creek 20	**5**	**90**	**<1**	**8**	**<1**	**2**	**0**	**0**	**5**	**100**
Leduc County	5	90	<1	8	<1	2	0	0	5	100
Unnamed Creek 21	**7**	**93**	**<1**	**5**	**<1**	**3**	**<1**	**<1**	**8**	**100**
Leduc County	7	93	<1	5	<1	3	<1	<1	8	100
Unnamed Creek 22	**43**	**52**	**7**	**9**	**15**	**18**	**18**	**22**	**83**	**100**
Leduc County	43	52	7	9	15	18	18	22	83	100
Unnamed Creek 23	**4**	**34**	**3**	**23**	**5**	**40**	**<1**	**2**	**13**	**100**
Leduc County	4	34	3	23	5	40	<1	2	13	100
Unnamed Creek 24	**3**	**82**	**<1**	**5**	**<1**	**8**	**<1**	**5**	**4**	**100**
Leduc County	3	82	<1	5	<1	8	<1	5	4	100
Unnamed Creek 25	**31**	**49**	**7**	**10**	**11**	**18**	**14**	**23**	**64**	**100**
Leduc County	31	49	7	10	11	18	14	23	64	100
Unnamed Creek 26	**3**	**23**	**1**	**10**	**1**	**8**	**7**	**60**	**12**	**100**
Leduc County	3	23	1	10	1	8	7	60	12	100
Unnamed Creek 27	**4**	**29**	**<1**	**2**	**1**	**10**	**8**	**59**	**13**	**100**
Leduc County	4	29	<1	2	1	10	8	59	13	100
Unnamed Creek 28	**6**	**66**	**1**	**15**	**1**	**16**	**<1**	**3**	**9**	**100**
Leduc County	6	66	1	15	1	16	<1	3	9	100
Unnamed Creek 29	**27**	**58**	**9**	**20**	**9**	**20**	**1**	**3**	**46**	**100**
Leduc County	27	58	9	20	9	20	1	3	46	100
Unnamed Creek 30	**27**	**49**	**13**	**23**	**14**	**26**	**1**	**1**	**55**	**100**
Leduc County	27	49	13	23	14	26	1	1	55	100
Unnamed Creek 31	**3**	**59**	**1**	**15**	**1**	**20**	**<1**	**6**	**5**	**100**
Leduc County	3	59	1	15	1	20	<1	6	5	100
Unnamed Creek 32	**7**	**33**	**2**	**11**	**8**	**42**	**3**	**15**	**20**	**100**
Leduc County	7	33	2	11	8	42	3	15	20	100
Unnamed Creek 33	**4**	**27**	**1**	**9**	**5**	**35**	**4**	**29**	**13**	**100**
Leduc County	4	27	1	9	5	35	4	29	13	100
Unnamed Creek 34	**<1**	**15**	**<1**	**15**	**1**	**26**	**1**	**44**	**3**	**100**
Leduc County	<1	15	<1	15	1	26	1	44	3	100
Unnamed Creek 35	**4**	**36**	**2**	**16**	**1**	**8**	**4**	**39**	**11**	**100**
Leduc County	4	36	2	16	1	8	4	39	11	100
Unnamed Creek 36	**3**	**28**	**1**	**6**	**3**	**30**	**4**	**37**	**11**	**100**
Leduc County	3	28	1	6	3	30	4	37	11	100
Unnamed Creek 37	**11**	**48**	**4**	**16**	**4**	**18**	**4**	**17**	**22**	**100**
Leduc County	11	48	4	16	4	18	4	17	22	100
TOTAL	**615**	**32**	**198**	**10**	**449**	**23**	**664**	**34**	**1926**	**100**