Riparian Assessment for North Saskatchewan Region Lakes

FINAL REPORT

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FIERA
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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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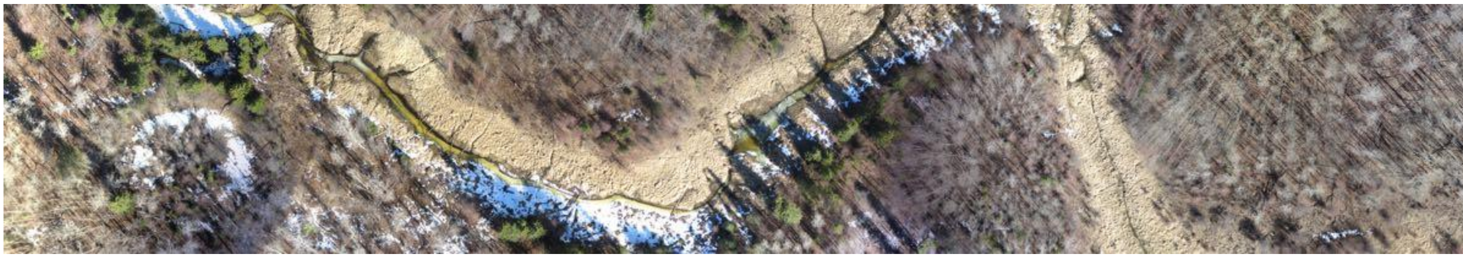
Report Prepared by: Shari Clare, Shantel Koenig, and Bing Lu



List of Terms

Abbreviations

AAFC: Agriculture and Agri-food Canada

AEP: Alberta Environment and Parks

ARHMS: Alberta Riparian Habitat Management Society

GIS: Geographic Information System

GOA: Government of Alberta

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.

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 HUC2, HUC4, HUC6, and HUC8, with HUC2 being the coarsest level of classification and HUC8 being the finest level of classification.

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

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

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

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. Project Background & Context

Riparian areas perform a multitude of ecosystem functions, including water quality improvement, sediment removal, nutrient cycling, bank stabilization, and flood reduction. While these habitats provide a wide range of benefits to human communities, the loss and impairment of riparian lands in Alberta has been significant, and 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 restoration efforts and resources, however, there first needs to be reliable information about the location, condition, and function of riparian habitats.

The need to develop inexpensive, rapid, and reliable assessment methods is particularly relevant for the management of lakes and their associated watersheds in Alberta. Lakes across the province are increasingly becoming the focus of human activities that result in shoreline and riparian area modifications. These modifications, combined with increasing human activity and land use changes in the lake watershed are leading to a degradation of water quality, which in turn, is impacting the quality of life for residents and is threatening aquatic habitats and the species that rely on those habitats. Consequently, there is a pressing need for innovative scientific tools that can be deployed across large scales and at a reasonable cost, and that provide information that can be used to spatially target areas along lake shorelines or within lake watersheds where special management or more detailed assessment may be required.

1.1.1. Existing Approaches to Assessing Riparian Condition

At present, there is no standardized province-wide mapping method for defining and delineating the extent of riparian areas for hydrologic features of all types and sizes. As a result, little is known about the location and extent of riparian lands in the province, making management of these habitats difficult. In addition, only a small percentage of riparian areas in Alberta have been assessed to determine their condition, and until recently, the majority of these assessments have been conducted at a site-specific or reach-scale using either ground-based or airborne videography methods (Clare and Sass 2012).

The finest scale and most detailed evaluations of riparian condition come from “boots-on-the-ground” site-specific field assessments and/or inventories of riparian areas. In this type of assessment, such as the Alberta Riparian Habitat Management Society (ARHMS) Riparian Health Assessment, detailed and local-scale traits of riparian areas are evaluated by trained practitioners, and a comprehensive and thorough judgement of riparian condition is made. 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 or short sections of lake shoreline; however, these same assessments are limited in their ability to provide information that is useful 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 these questions into a score that is classified according to three health categories that area akin to the field-based approach. Videography has been applied by various organizations across Alberta (e.g., Mills and Scrimgeour 2004, AENV 2010), as well as within the North Saskatchewan River Watershed (NSWA 2015).

The benefit of videography is that the entire riparian area of a lake or river can be assessed at one time, while providing a permanent geo-referenced video record of the current status of shoreline. It provides a relatively rapid method to produce a “coarse filter” assessment of riparian health. This approach is not intended to replace field-based assessments, but rather, complement them by allowing larger areas to be evaluated in an approximate fashion, to be followed by more detailed checks on the ground if required. The goal is to provide information across large areas at low cost, allowing for riparian land management at larger scales (i.e. entire lake or river system). While videography can be very cost-effective per kilometer of shoreline observed in some cases, at a certain scale, the size of the study area or 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, Alberta Environment and Parks (AEP) engaged Fiera Biological Consulting Ltd. (Fiera Biological) to develop a Geographic Information System (GIS) method for assessing riparian areas along lake shorelines in the North Saskatchewan Region. This method was developed using metrics comparable to existing ground-based and aerial videography methods, and was largely based upon methods recently developed to assess riparian areas in the Modeste and Sturgeon watersheds (Fiera Biological 2018a and 2018b). This new riparian assessment method uses automated and semi-automated GIS techniques to quantify the intactness of riparian management areas using spatial data that is currently available to the Government of Alberta (GOA) and its partners, such as Watershed Planning and Advisory Councils (WPACs). As such, this GIS method allows for the assessment of riparian condition across the province, and also introduces an objective, standardized, and repeatable method to assess differences in the condition of riparian areas across space and time.

1.2. Study Objectives

The overall goal of this project is to develop a cost-effective, quantitative, and repeatable GIS method to assess the current condition of riparian habitats along the shorelines of Pigeon, Buffalo, Gull, and Sylvan lakes, as well as their associated tributaries. Determining the condition of riparian habitat within each lake watershed will allow for the identification and prioritization of riparian areas for restoration and/or conservation, in addition to establishing a baseline of riparian condition against which future monitoring and restoration efforts can be assessed. In order to accomplish these goals, we have defined the following major objectives for this project:

1) Develop a GIS model for assessing riparian management area condition using spatial data that can be accessed free of charge through the Government of Alberta. In order to leverage recent work that has been done in the North Saskatchewan River basin, the GIS approach for this assessment was largely based upon a model that has been developed and applied in the Modeste, Sturgeon River, and Strawberry watersheds.
2) Document GIS modelling and analysis methods for assessing riparian and watershed condition, including minimum data standards for conducting the analysis. Suggestions for field validation methods are also outlined and described. These standards will allow multiple projects from across the region to be integrated into a provincial-level database of riparian condition.
3) Summarize and visualize the results of the riparian and land cover assessment, including a summary of habitat change within riparian management areas through time.

The results of this study provide the Government of Alberta with an overview of the status of riparian management areas for a number of lakes in the North Saskatchewan region. Additionally, this report outlines minimum standards for undertaking GIS-based riparian assessments, which will allow for the standardization of methods and the creation of data that is comparable across space and time.

1.3. Purpose and Intended Use of this Data Product

While considerable effort has been made to highlight the importance of restoring riparian areas within Alberta, tools for accurately identifying and characterizing these areas over large spatial extents are lacking. Thus, the overarching objective of this project was to develop tools applicable at large scales that efficiently and consistently characterize the relative intactness of riparian areas for the purpose of guiding watershed planning, management, and conservation initiatives. To this end, this project required the synthesis of disparate data types from various sources to generally characterize the condition of riparian management areas, 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 the results presented herein:

- This assessment characterizes the relative intactness of riparain areas using metrics that focus on natural attributes of a shoreline that are measurable in a GIS environment. No statement on the absolute condition of any riparian area is made and the results do not reflect the influence of factors that were not included in or considered for analysis.
- Intactness scores generated by this study are intended to support a screening-level assessment of management and/or protection priorities across broad geographic areas (e.g., subwatershed, municipality, stream reach). This GIS tool is not meant to replace more detailed, site-specific field assessments of riparian health or condition. Instead, the results from this assessment should be used to highlight smaller, more localized areas where field assessments and/or further validation may be required.

- The provincial hydrography data for streams, creeks, rivers, and lakes was used to delineate the shoreline of the waterbodies included in this assessment. While we did a cursory assessment of the accuracy of this data and made adjustments to waterbody boundaries where serious discrepancies 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 where 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.

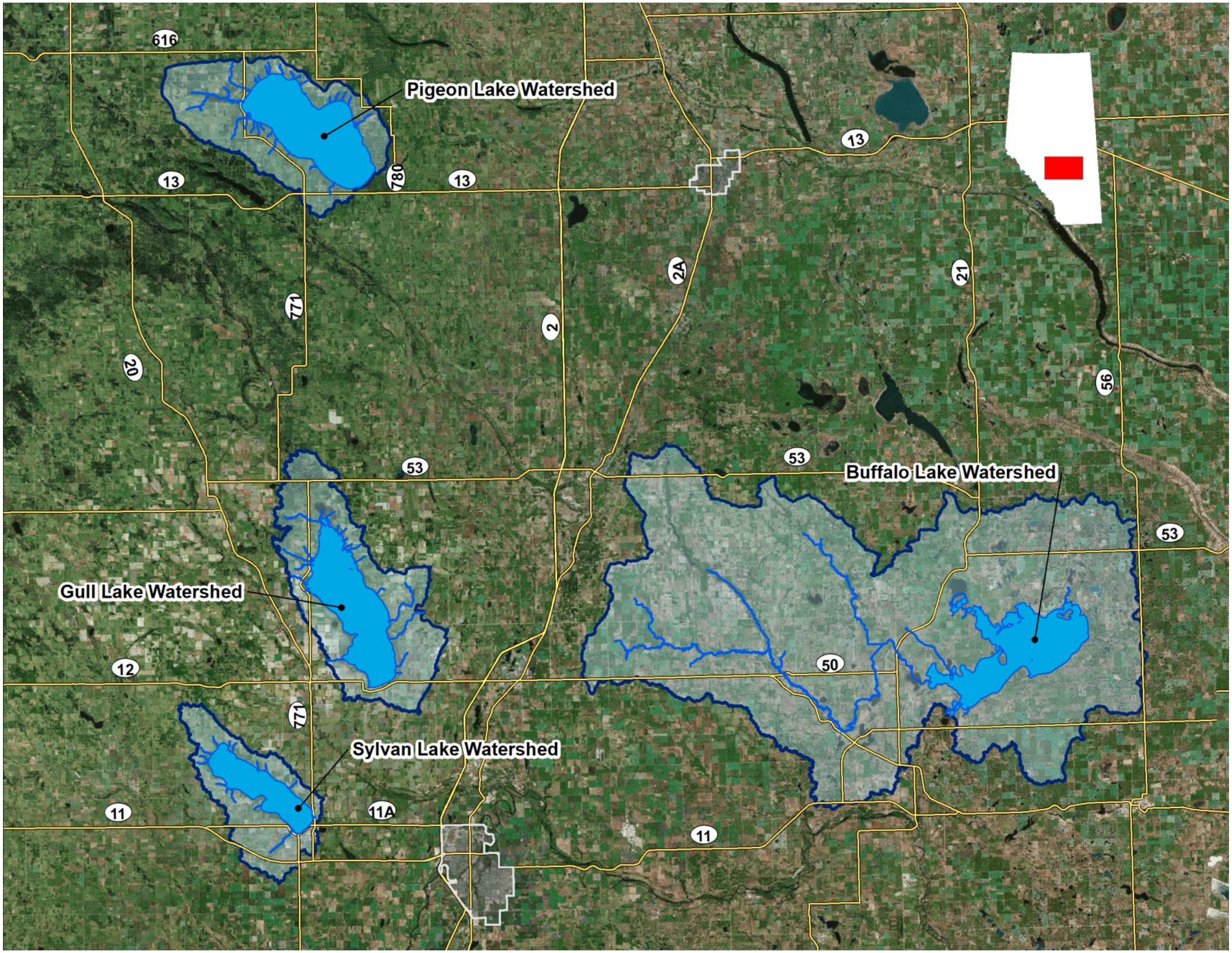
2.0 Study Areas

This study included the watersheds of four lakes: Pigeon Lake, Gull Lake, Sylvan Lake, and Buffalo Lake (Map 1). These large lakes are located in the Parkland Natural region of Alberta, and all of the lakes have some degree of shoreline development and are important recreational lakes in central Alberta.

This riparian assessment included the shorelines of each of the four lakes listed above, as well as the left and right banks of all of the tributaries that flow into each lake. This included a large number of unnamed and named creeks, as well as several other named lakes/wetlands associated with the tributaries or connected to one of the four lakes via a surface water connection. In total, 874 km of shoreline across the four lake watersheds was assessed as part of this study (Table 1).

Table 1. Water bodies in the North Saskatchewan Region that were assessed as part of this project.

Watershed		Shoreline Length Assessed (km)
Pigeon Lake		155.3
Gull Lake		159.4
Sylvan Lake		75.7
Buffalo Lake		483.7
	TOTAL	**874.1**



Map 1. Location of the four lakes and associated lake watersheds included in this study.

3.0 Methods

3.1. Assessing Riparian Intactness

3.1.1. Indicator & Metric Selection

A key objective of this study was to develop a GIS based model that could reliably and objectively assess riparian condition within four lake watersheds in central Alberta, while at the same time being comparable to previously developed and accepted methodologies. Within the last several years, considerable time and effort has been put into the development of a GIS method for assessing riparian areas, and this tool has been used to assess over 5,000 km of shoreline in the North Saskatchewan River basin (Fiera Biological 20018a and 2018b). As such, an objective of this project was to leverage the work that has already been completed, and create formal standards for assessing riparian areas in Alberta using a GIS method.

The riparian assessment work that has been completed to-date in the North Saskatchewan River basin was completed using a GIS model that was intentionally developed to be comparable to existing videography methodologies (Fiera Biological 2018a). As such, GIS indicator and metric selection was focused on determining which aerial videography metrics could be measured in a GIS environment, and where possible, develop analogous GIS metrics (Table 2). The objective of the model development was to replicate the existing videography method to the greatest extent possible, and to select GIS metrics with the strongest statistical relationship to the videography validation data. In total, eight GIS metrics were evaluated as part of the model development. Each GIS metric was tested for redundancy using a correlation analysis and highly correlated metrics (i.e., >0.60) were removed. Further, several of the GIS metrics were not correlated (e.g., <0.10) with the scores derived from the associated aerial videography metric, and thus, were considered poor metrics and were dropped from the model. In total 108 different GIS models were evaluated and the metric combination that had the greatest agreement with the videography validation results was:

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).

These three metrics were used to assess riparian condition for this study.

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

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

3.1.2. Acquisition and Derivation of Required Data

To quantify riparian intactness in a GIS environment using the metrics outlined above, several data layers were required, including a current land cover. While a freely available land cover is available from Agriculture and Agri-Food Canada (AAFC), the resolution of this data (30 m pixel size) is too coarse to accurately assess vegetation cover for the purpose of this assessment. Further, this land cover is not available for the entire province. Thus, we created a land cover using SPOT satellite imagery (6 m pixel resolution) for this study.

Land Cover

SPOT satellite imagery was obtained from the Government of Alberta for each lake watershed (Table 3). Using this imagery, a land cover classification was performed at two scales: a coarse-scale classification of the entire watershed and a fine-scale classification of areas immediately adjacent to the shorelines of interest. Because the lake watersheds were covered by different images, and for some lakes watersheds multiple images were required for full coverage of the watershed, the land cover classification was performed separately for each watershed using separate training data.

The four SPOT imagery bands (Blue, Green, Red, and Near-Infrared) were combined with a set of ancillary raster data products generated for use in the classification, including Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), and Soil Adjusted Vegetation Index (SAVI), which were generated from the four imagery bands (Table 4). An object-based imagery analysis method was applied using the ENVI Feature Extraction (5.3.1). The imagery was segmented into imagery objects (i.e., a group of pixels) based on spectral and textural information to create segmented objects representing different land cover classes, including: Crops, Disturbed Vegetation, Exposed Developed, Forest, Natural Exposed, Natural Open, and Open Water. Training sample datasets for each land cover class were manually selected using the 6 m resolution SPOT imagery and 1.5 m pan-sharped SPOT imagery. The land cover layers created from each watershed were then manually checked and edited to address misclassification errors, and an Open Water Other class was added to account for areas of modified shoreline or constructed water features (e.g., docks, man-made inlets or marinas). Finally, the Alberta Base features road layer was used to create a Road and a Road Verge class, which were added to the final land cover.

Table 3. Description of the spatial data obtained or derived for use in the assessment of Riparian Management Area Intactness.

Lake Watershed	Image Type	Number of Image Scenes	Acquisition Date
Pigeon	SPOT 6	1	August 26, 2017
Gull	SPOT 6	1	August 15, 2016
Sylvan	SPOT 6	2	August 15, 2016
Buffalo	SPOT 7	4	July 6 and 13, 2017

Table 4. Description of the spatial data obtained or derived for use in the assessment of Riparian Management Area Intactness.

Data Layer	Year	Source	Usage
SPOT 6&7 Satellite Imagery	2016 & 2017	Government of Alberta	Derivation of land cover classification
Normalized Difference Vegetation Index (NDVI)	2016 & 2017	Fiera Biological. Layer was created using SPOT satellite data provided by the GOA	Derivation of land cover classification
Normalized Difference Water Index (NDWI)	2016 & 2017	Fiera Biological. Layer was created using SPOT satellite data provided by the GOA	Derivation of land cover classification
Soil Adjusted Vegetation Index (SAVI)	2016 & 2017	Fiera Biological. Layer was created using SPOT satellite data provided by the GOA	Derivation of land cover classification
Roads	2014	Alberta Base Features	Derivation of land cover classification
Land Cover	2016 & 2017	Fiera Biological. Layer was created using SPOT satellite data provided by the GOA and derived layers	Derivation of RMAs and quantification of intactness metrics

To ensure that the land cover classification along the lake shorelines of interest was as accurate as possible, a second, finer-scale classification was performed. An area within 200 m of the shoreline for each lake was clipped from original imagery and was combined with the same image layer stack used in the coarse classification (Table 4). An object-based and a pixel-based method were both applied for this fine-scale classification. The object-based method was firstly applied to segment objects into land cover classes, and these objects were then classified using a pixel-based classification to further classify mixed objects to resolve finer features within the land cover. This fine scale classification was then checked and misclassification errors were manually corrected.

3.1.3. Delineating Riparian Management Area Width and Length

Using the videography method, riparian condition is assessed within a “riparian management area” (RMA), which is defined as an area along the shoreline that includes the near-shore emergent vegetation zone, the riparian zone, and a riparian protective (buffer) zone (Figure 1). Importantly, an RMA has two spatial components: width and length. 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. The width of the RMA is also variable, and is primarily dictated by the field of view of the video, which is determined by both the flight line and the height of the aircraft.

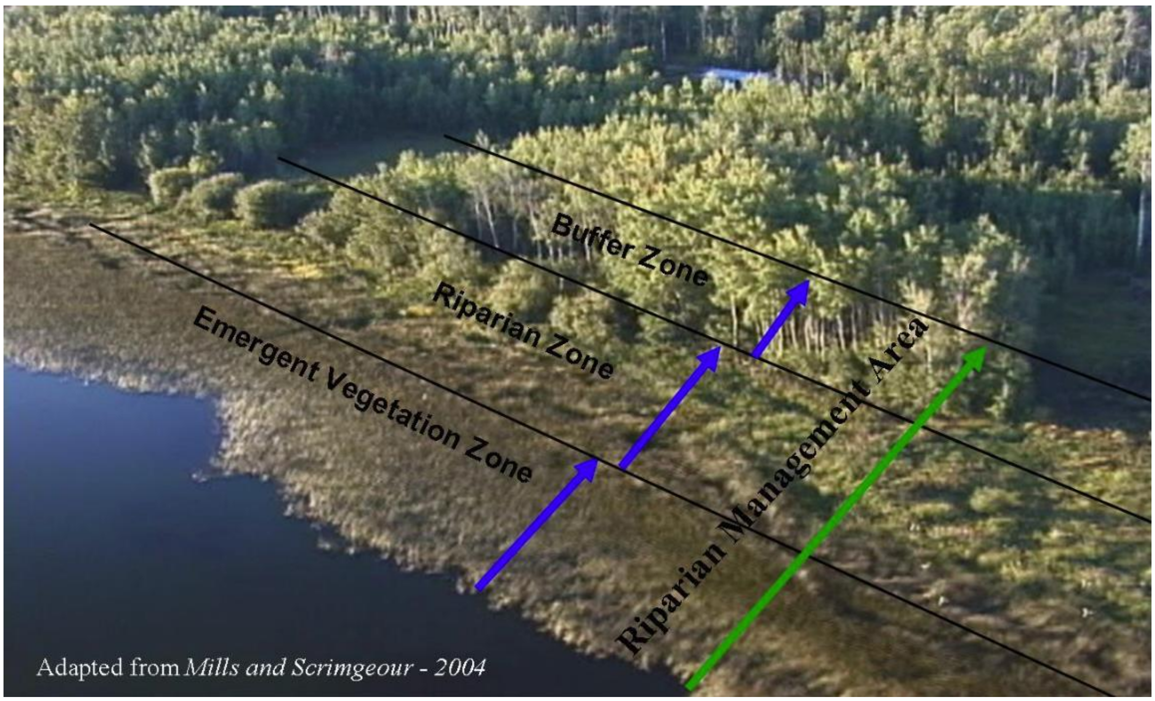


Figure 1. Schematic showing the different shoreline components included in a “Riparian Management Area” (image taken from Teichreb and Walker 2008).

In order to replicate the videography approach for delineating RMAs within a GIS environment, a method for defining both the RMA length and width was required. Following the methods developed for the North Saskatchewan River basin (Fiera Biological 2018), the upstream and downstream extent of each RMA defined for this study was delineated based upon major changes in the proportion of natural cover along the shoreline. To calculate the proportion of natural cover along the shorelines, all natural cover classes in the high-resolution land cover were selected and exported as a single layer. The stream layer was then divided into 10-meter segments on the left and right banks, and the proportion of natural cover within a 25 m moving window was calculated for each segment. All segments were then differentiated based upon the proportion of natural cover within the 25 m window, using 55% natural cover as the threshold to differentiate between the start and end of a new RMA segment.

The width of the RMAs was defined using a 50 m wide static 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. This buffer width was selected from a number of different buffer widths (25 m, 50 m, 100 m) that were tested against a videography validation dataset, and results obtained using the 50 m buffer more closely matched videography scores (Fiera Biological 2018).

3.1.4. Selecting and Refining Hydrography Boundaries

A preliminary review of the provincial water boundary layer for the lakes included in this study revealed that there were large discrepancies between the boundary layer and the water boundaries observed in the SPOT imagery and the corresponding land cover created from the SPOT imagery. If the provincial water boundaries had been used to generate RMAs, there would have been a high occurrence of the RMAs not accurately capturing the riparian area of interest for this study. For example, in many locations the provincial water boundary was located within an area of open water, and the RMAs in this location would have included only open water or only a small proportion of the adjoining riparian area. In other instances, the provincial water boundary extended far beyond the area of open water classified in the land cover, or an over-capture, in which case RMAs would have captured areas well outside the riparian area and into the upland. Therefore, the open water class in the land cover classification was used to define the lake boundary to ensure that RMAs and buffers were most accurately capturing adjoining riparian areas. In this process, the open water areas corresponding to the lake were extracted from the classification and converted to a polyline layer. This polyline boundary was then manually checked against the SPOT imagery and the land cover to confirm that the new boundary was accurate.

The provincial hydrography data for streams, creeks, and rivers (i.e., the Alberta Base Features 1:20,000 dataset available from Altalis) was used to delineate the tributaries included in this assessment. If tributaries had a name assigned in the provincial base feature dataset, this name was adopted for this assessment. In cases where there was no name assigned to the tributary in the base feature dataset, the tributary was considered “Unnamed”, and each Unnamed feature was assigned a unique number (e.g., Unnamed Creek 1, Unnamed Creek 2) within each watershed. Features were also assigned a unique ID by extracting the “WB_ID” field from the Fish and Wildlife Management System (FWMIS) hydrology arc and hydrology polygon datasets. The WB_ID field can be used to identify the Unnamed Creeks in any subsequent or related analyses or assessments.

A cursory assessment of the accuracy of this hydrography dataset was performed and adjustments to stream boundaries were made where serious discrepancies were noted. Where tributaries passed through areas of open water greater than 1 ha, the boundaries were edited to split and follow the boundary of these open water features. The boundary of these open water features were defined using the same process as for the lakes, whereby the open water class of the land cover classification was used to generate the shoreline boundary, and this new boundary was incorporated as part of the tributary’s path.

3.1.5. Metric Quantification and Riparian Intactness Scoring

Once RMA segments were created, each of the three intactness metrics were quantified within each RMA. 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 Natural Open and Forest. To quantify Metric 2, the percent coverage of the Forest 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: Crops, Pasture, Disturbed Vegetation, Exposed Developed, Open Water Other, Road, and Road Verge.

Once each metric was quantified, the values were weighted using values comparable to the aerial videography methods, as follows: Metric 1 = 0.15; Metric 2: 0.25; Metric 3: 0.60. Based on these weightings, intactness was calculated using the following formula:

$$Intactness = (0.15 \times Metric\ 1) + (0.25 \times Metric\ 2) + (0.60 \times Metric\ 3)$$

The summed weighted metric scores gave a final RMA intactness score that ranged between 0 and 100, and these scores were converted into intactness categories using the following percentile 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.

4.0 Pigeon Lake Watershed

4.1. Current Condition of Riparian Areas

A total of 155 km of shoreline in the Pigeon Lake watershed was assessed as part of this study, including Pigeon Lake and 32 unnamed creeks that all flow into the lake (Table 5; Map 2). Overall, 56% of the lake and creek shorelines assessed in the watershed were classified as High Intactness, with 27% classified as either Very Low (20%) or Low (7%) Intactness (Figure 2)

Table 5. Waterbodies in the Pigeon Lake watershed that were assessed as part of this study. The length of shoreline presented for the unnamed creeks includes both the left and the right banks.

Waterbody Name	Shoreline Length (km)
Pigeon Lake	47.3
Unnamed Creeks (32)	108.0
TOTAL	**155.3**

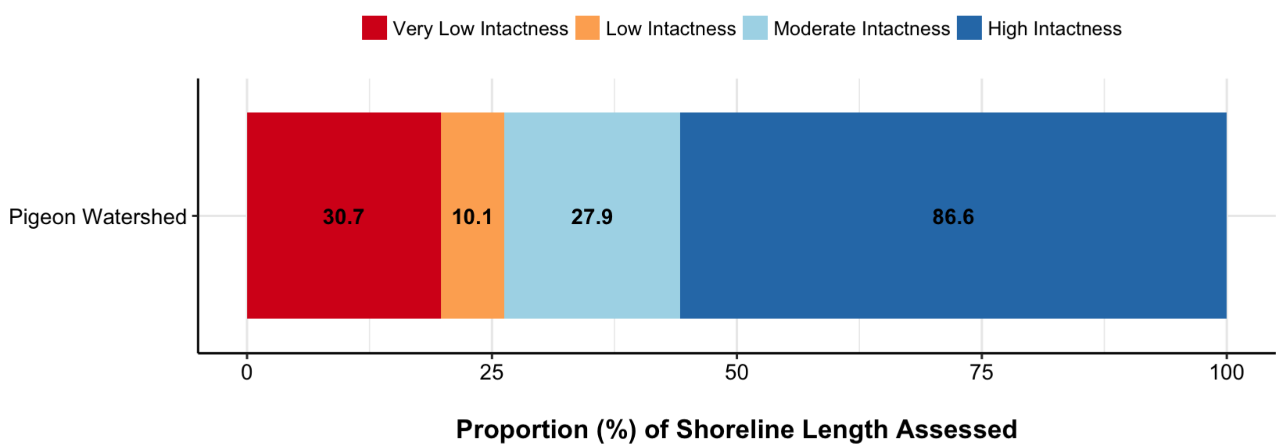
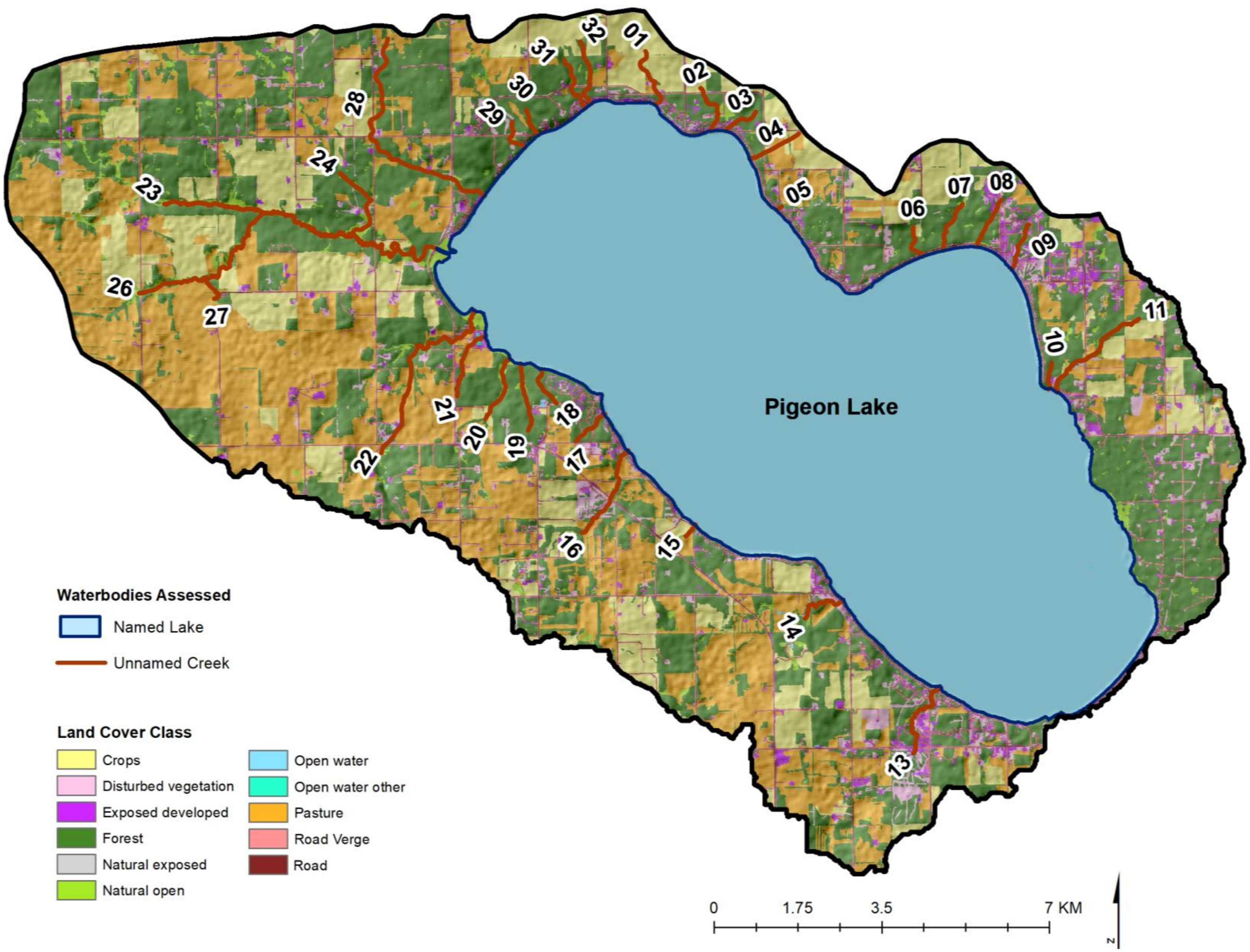


Figure 2. The proportion of shoreline within the Pigeon Lake watershed assigned to each riparian intactness category. The totals include the shorelines of Pigeon Lake as well as 32 unnamed creeks that flow into Pigeon Lake. Numbers within the bars indicate the total length (km) of shoreline associated with each category.



Map 2. Land cover in the Pigeon Lake watershed and the location of the waterbodies included in this assessment.

Just under half (48%) of the shoreline along Pigeon Lake was classified as either Very Low (37%) or Low Intactness (11%), representing a total of 22.8 km (Figure 3). Spatially, the areas that were assessed as Very Low or Low Intactness are concentrated along the northern shoreline between Sundance Beach and Silver Beach, and along the south eastern shoreline near Ma-Me-O Beach (Map 3).

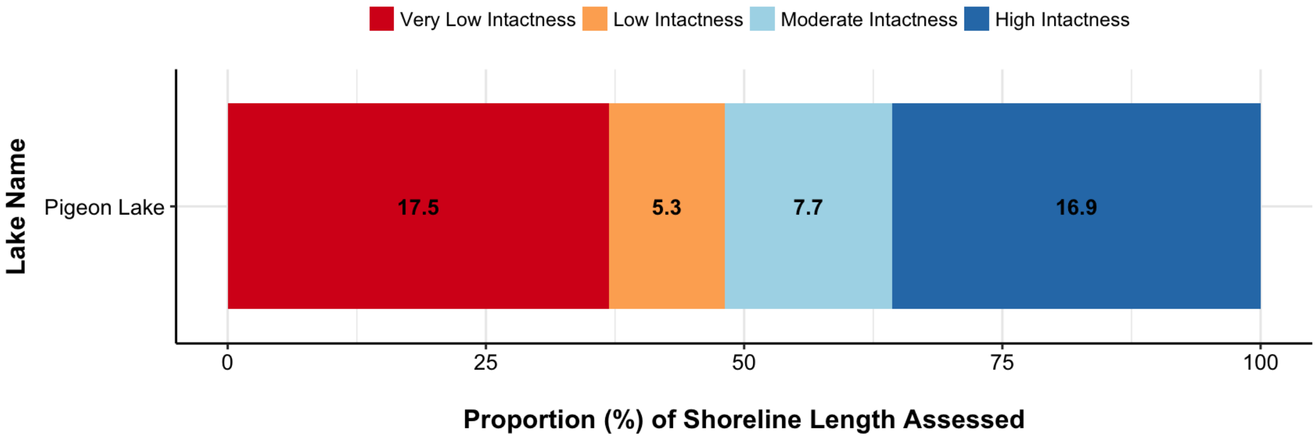


Figure 3. The proportion of shoreline along Pigeon Lake assigned to each riparian intactness category. Numbers within the bars indicate the total length (km) of shoreline associated with each category.

Generally, the tributaries that flow into the lake along the northern shoreline (unnamed creeks 01 to 11) have a higher proportion of their shorelines classified as Very Low or Low Intactness (Figure 4), with creeks in the north west portion of the watershed having a higher proportion of their shorelines classified as either Moderate or High Intactness (Figure 5; Map 3; Map 4).

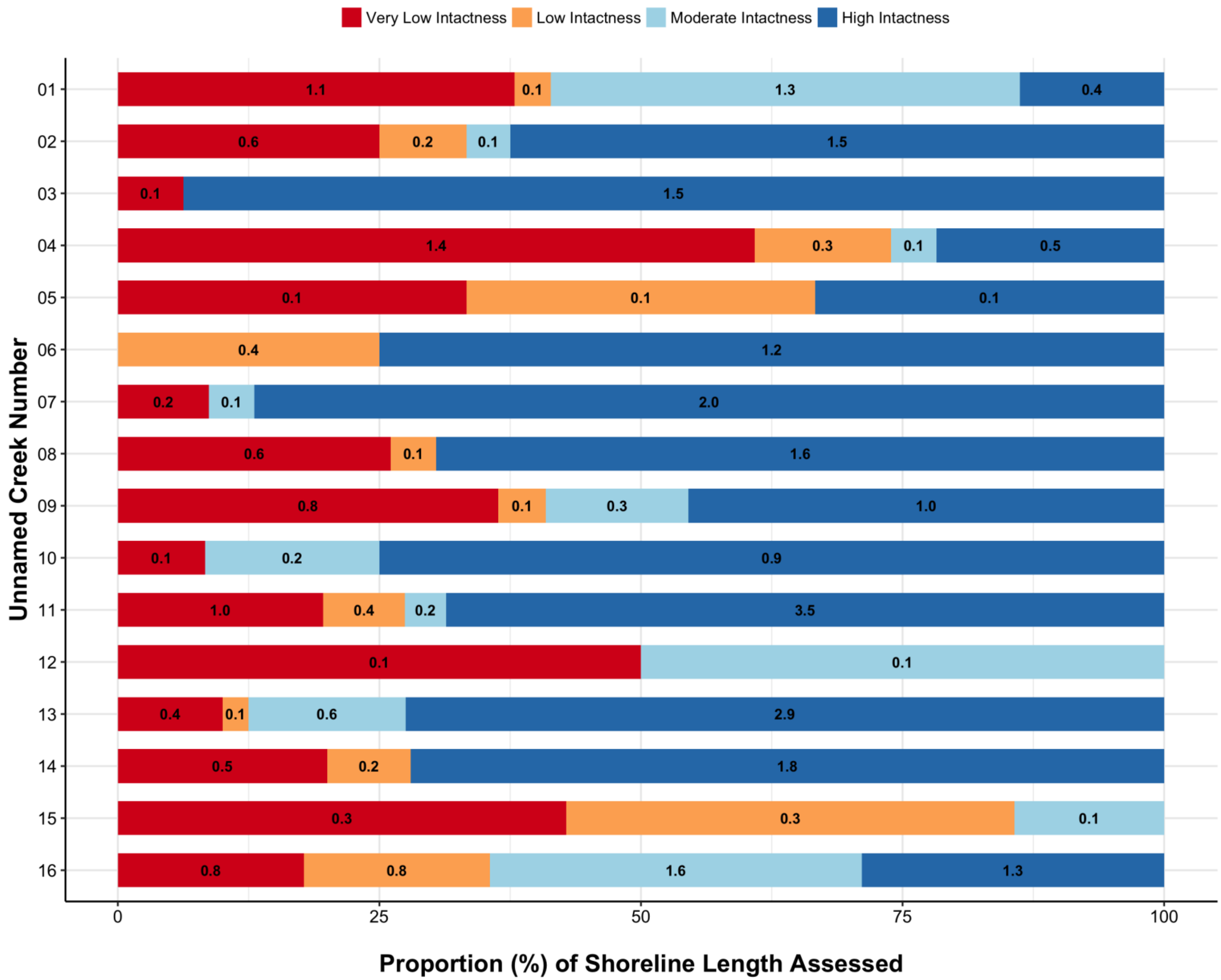


Figure 4. The proportion of shoreline assigned to each riparian intactness category for unnamed creeks 1 through 16 located in the Pigeon Lake watershed. Numbers within the bars indicate the total length (km) of shoreline associated with each category.

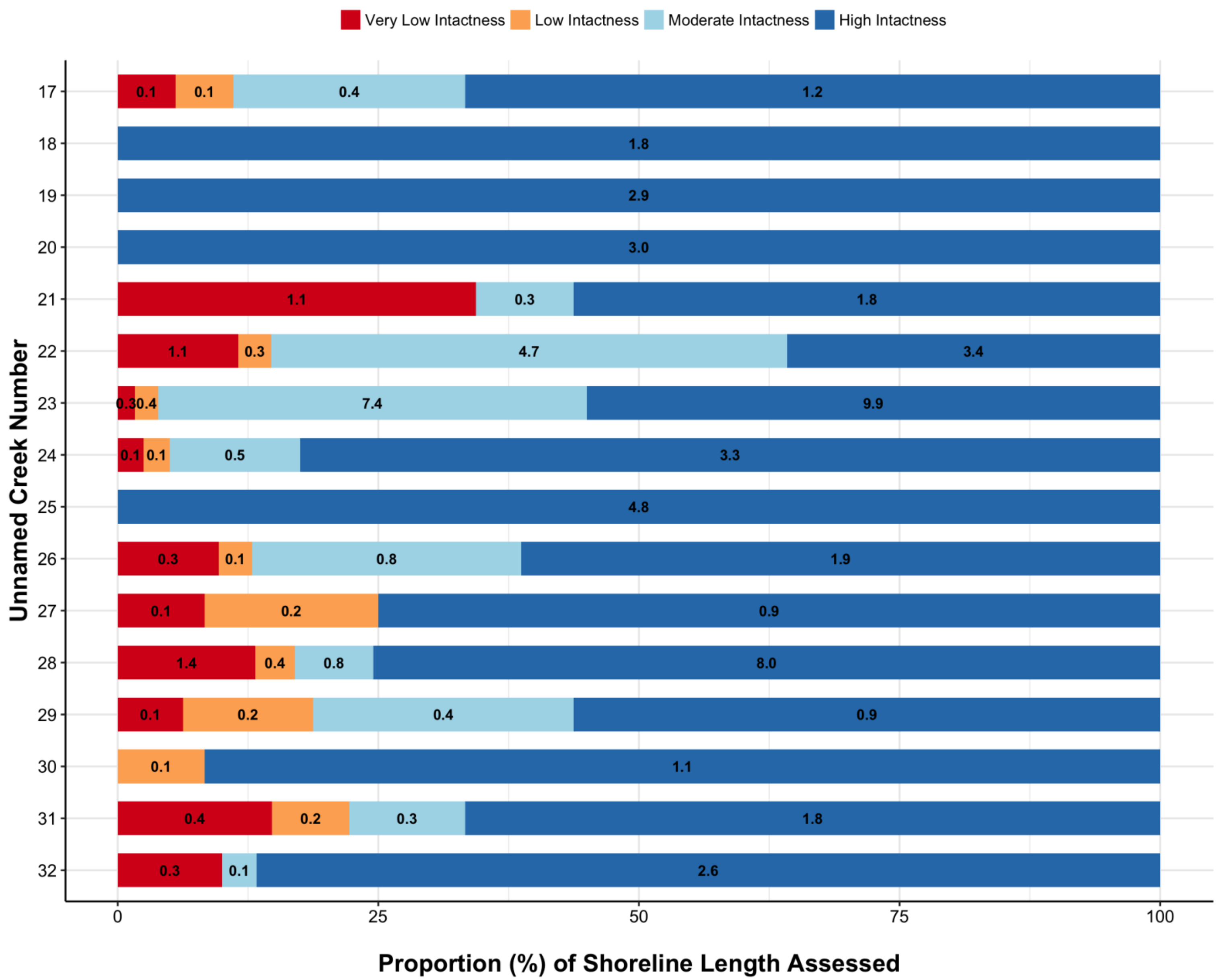
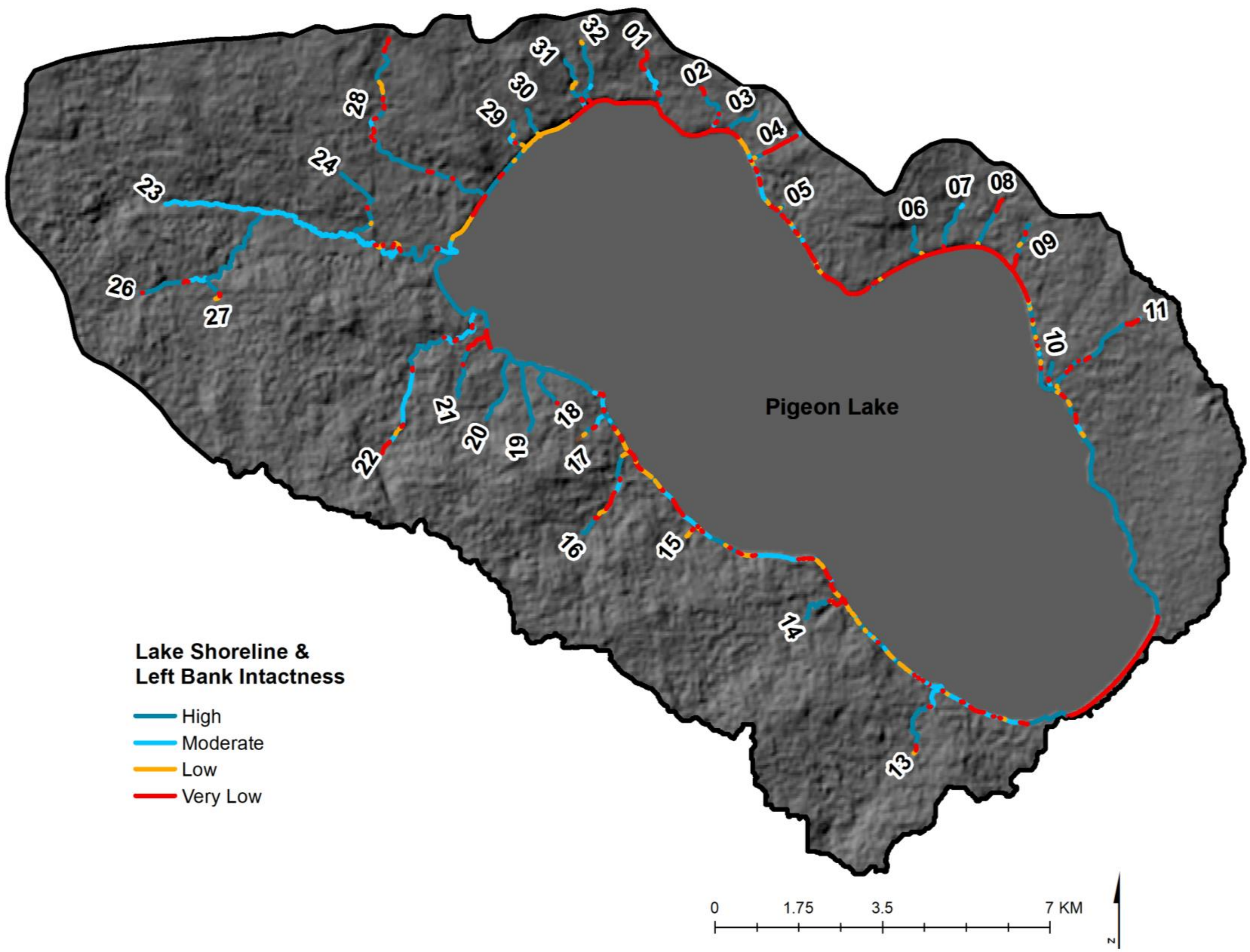
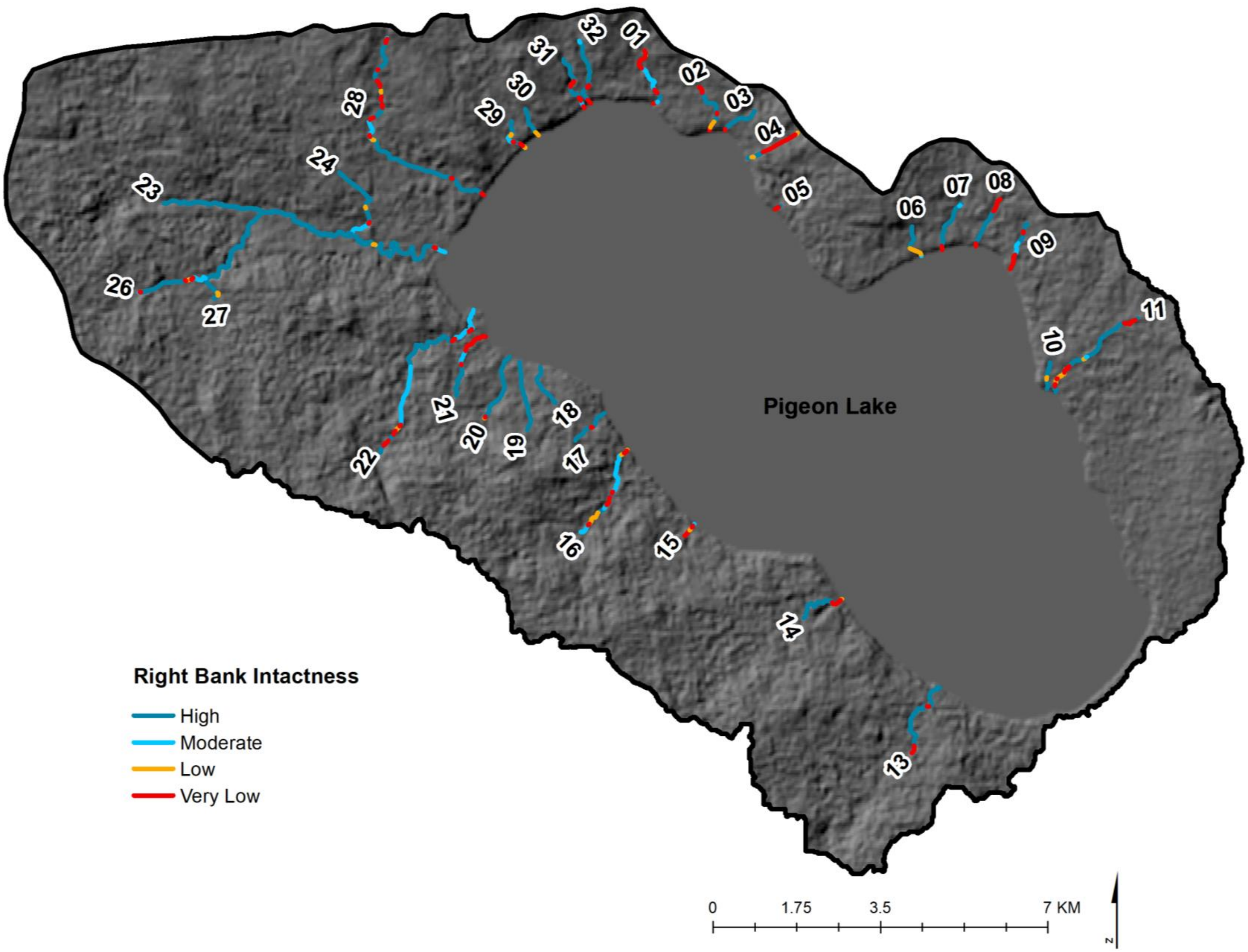


Figure 5. The proportion of shoreline assigned to each riparian intactness category for unnamed creeks 17 through 32 located in the Pigeon Lake watershed. Numbers within the bars indicate the total length (km) of shoreline associated with each category.



Map 3. Intactness scores for the shoreline of Pigeon Lake and the left bank of creeks included in this study.



Map 4. Intactness scores for the right bank of creeks included in this study.

5.0 Gull Lake Watershed

5.1. Current Condition of Riparian Areas

A total of 159 km of shoreline in the Gull Lake watershed was assessed as part of this study, including Gull Lake, 20 unnamed creeks that flow into Gull Lake, and four unnamed lakes/wetlands (Table 6; Map 5; Map 2). Overall, 30% of the lake and creek shorelines assessed in the watershed were classified as High Intactness, with 39% classified as either Very Low (33%) or Low (6%) Intactness (Figure 6).

Table 6. Water bodies in the Gull Lake watershed that were assessed as part of this project.

Waterbody Name	Shoreline Length (km)
Gull Lake	54.3
Unnamed Creeks (20)	93.2
Unnamed Lakes/Wetlands (4)	11.9
TOTAL	**159.4**

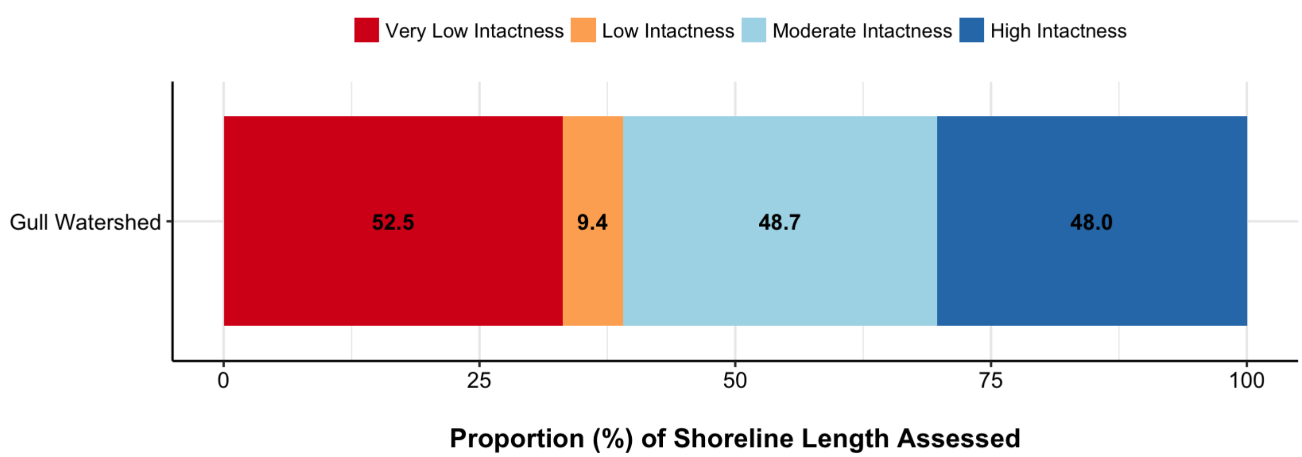
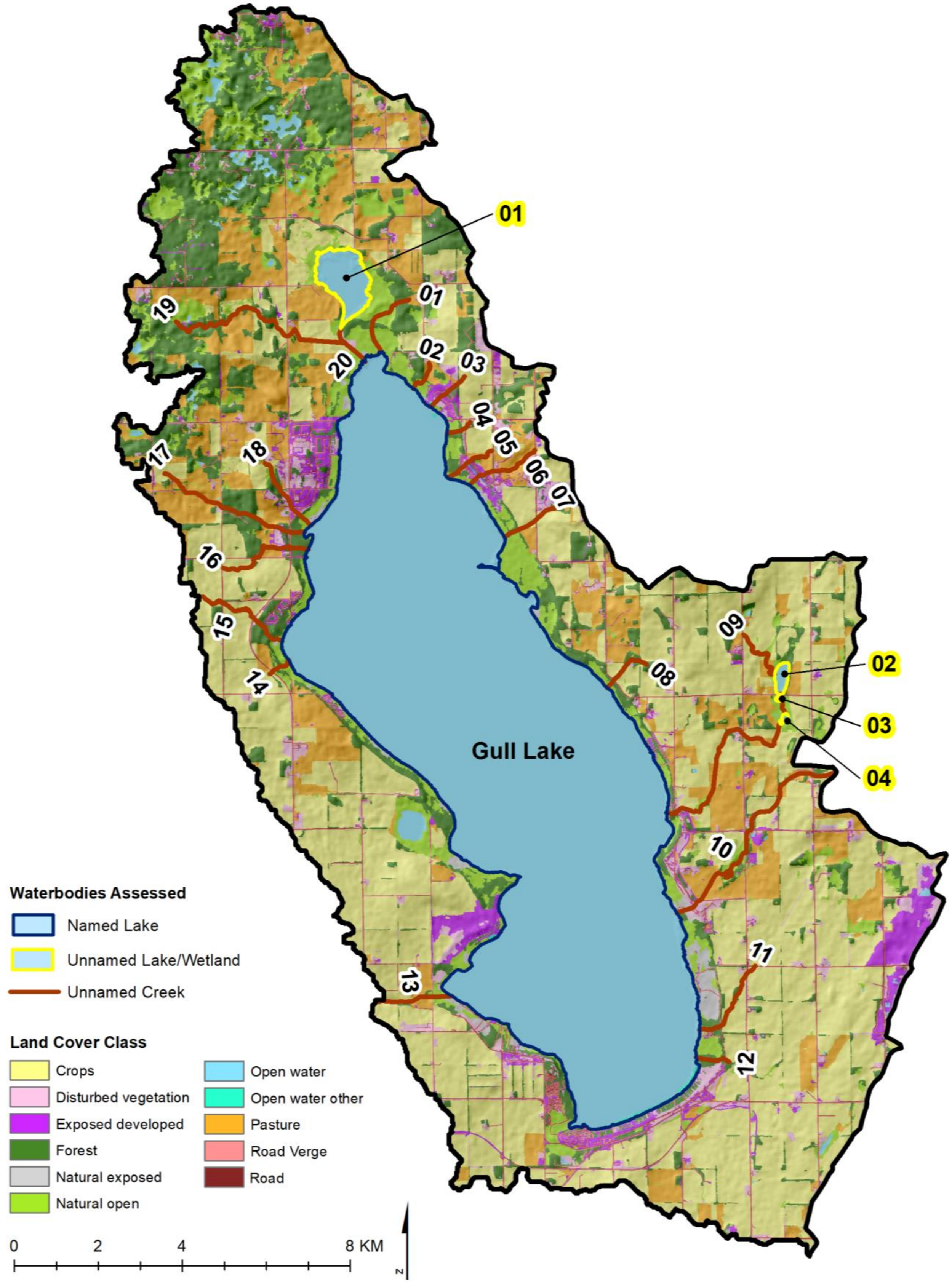


Figure 6. The proportion of shoreline within the Gull Lake watershed assigned to each riparian intactness category. The totals include the shorelines of Gull Lake as well as 20 unnamed creeks that flow into Gull Lake, and four unnamed lakes in the watershed. Numbers within the bars indicate the total length (km) of shoreline associated with each category.



Map 5. Land cover in the Gull Lake watershed and the location of the waterbodies included in this assessment.

Just over 80% of the shoreline of Gull Lake was classified as either Moderate (54%) or High (27%) Intactness, with only 10% of the shoreline being classified as Very Low Intactness (Figure 7). Spatially, the areas that were assessed as Very Low or Low Intactness are concentrated along the southern shoreline, where the summer village of Gull Lake and the Aspen Beach campground are located (Map 6).

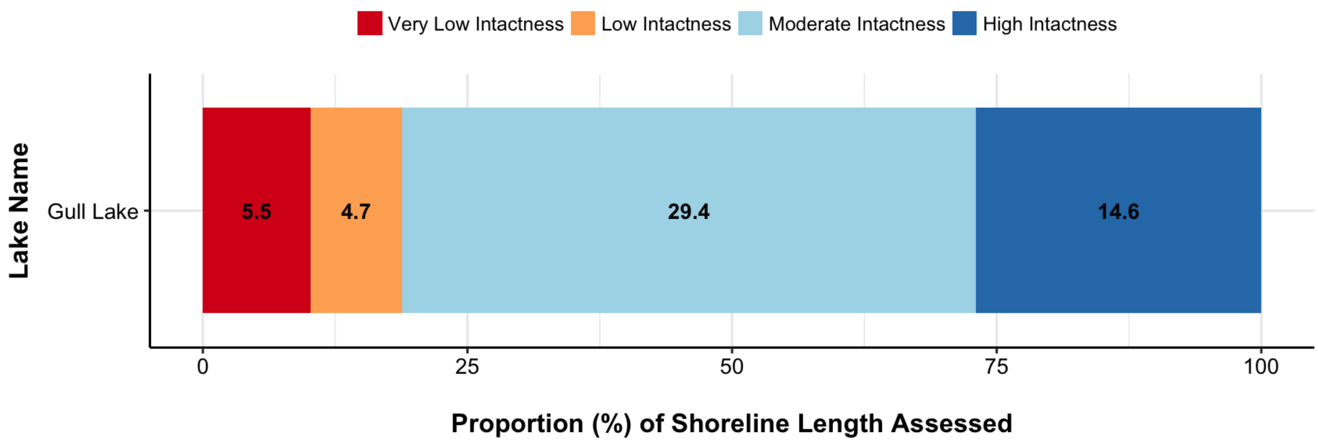


Figure 7. The proportion of shoreline along Gull Lake assigned to each riparian intactness category. Numbers within the bars indicate the total length (km) of shoreline associated with each category.

The shoreline of the tributaries that flow into Gull Lake can be generally characterized as being in poor condition, with 15 out of 20 having >25% of their shorelines assessed as Very Low Intactness, and 11 out of 20 having ≥50% of the shoreline classified as Very Low Intactness (Figure 8; Figure 9; Map 7). The shorelines of the unnamed lakes/wetlands in the watershed (one located at the north end of Gull Lake and three associated with unnamed creek 9) are generally in good condition, with >75% of their shorelines assessed as either Moderate or High Intactness (Figure 10).

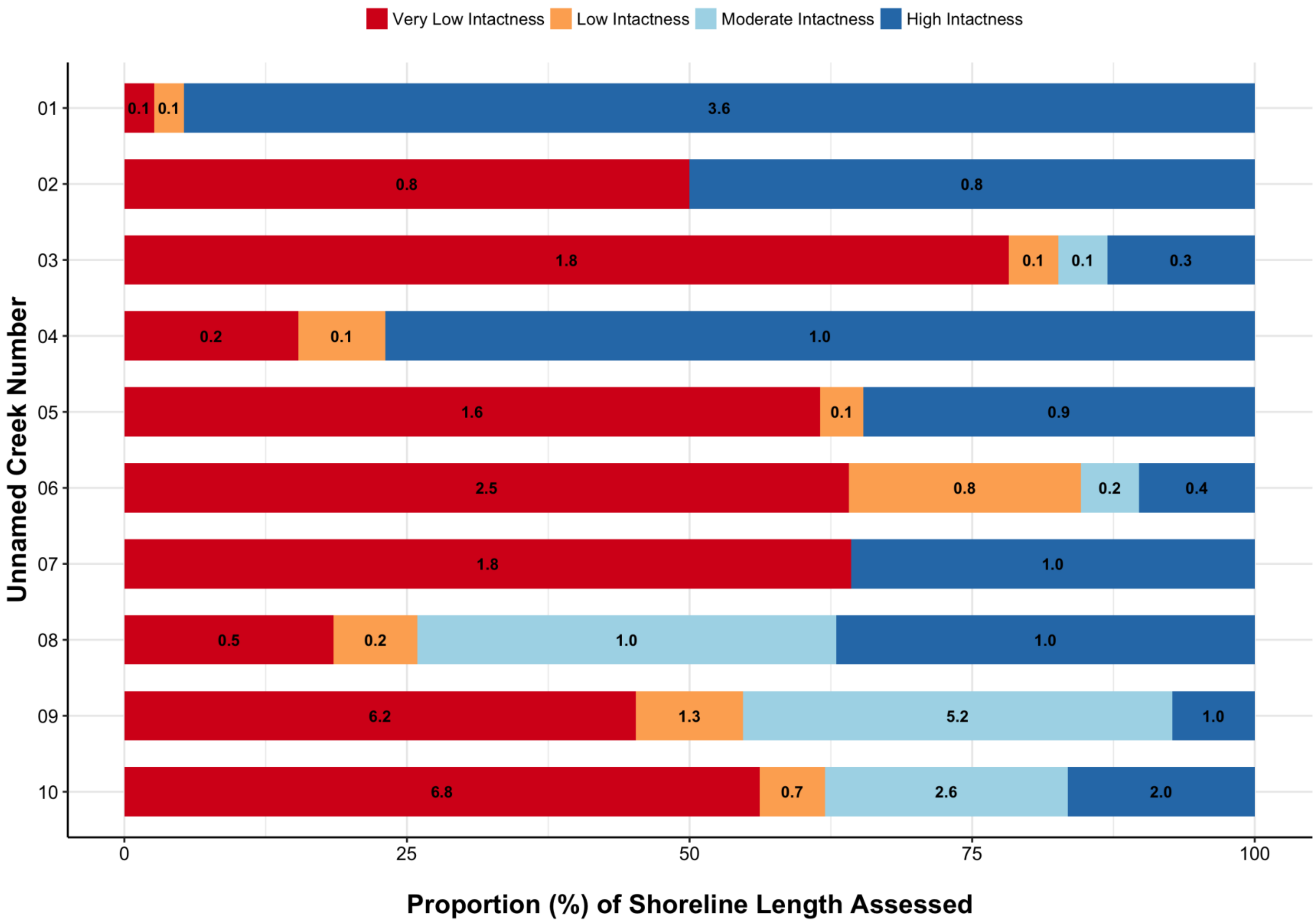


Figure 8. The proportion of shoreline assigned to each riparian intactness category for unnamed creeks 1 through 10 located in the Gull Lake watershed. Numbers within the bars indicate the total length (km) of shoreline associated with each category.

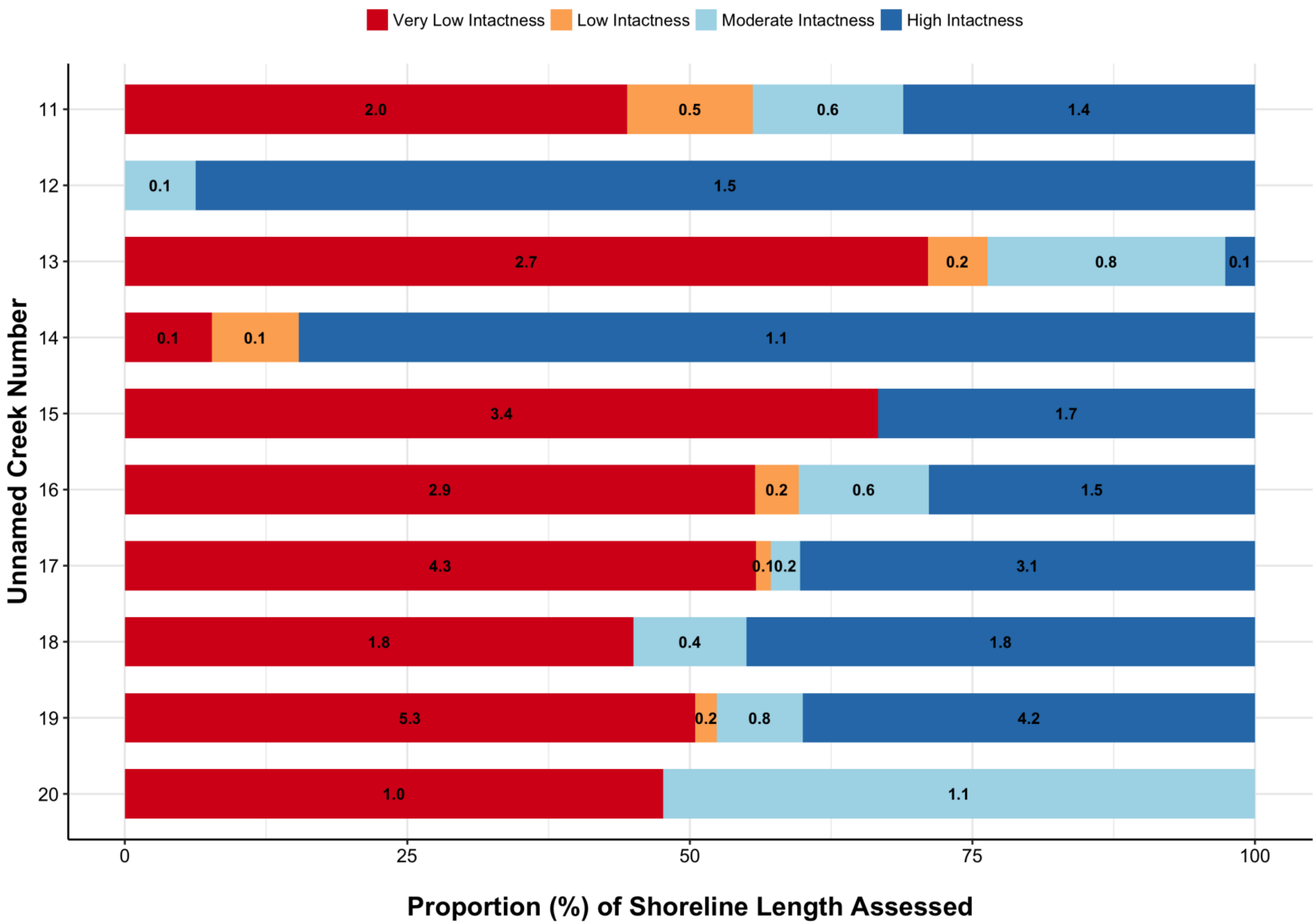


Figure 9. The proportion of shoreline assigned to each riparian intactness category for unnamed creeks 11 through 20 located in the Gull Lake watershed. Numbers indicate the total length (km) of shoreline associated with each category.

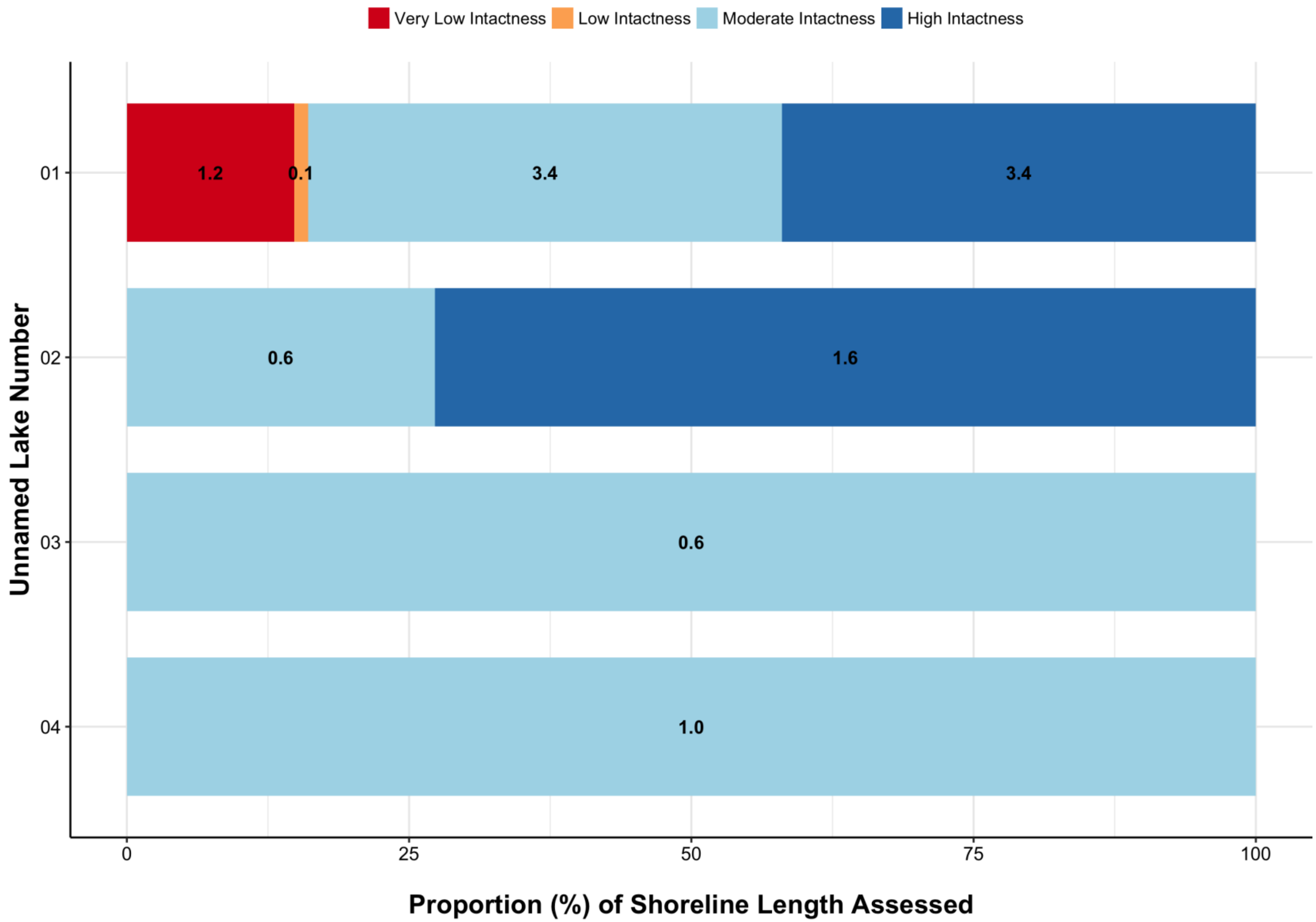
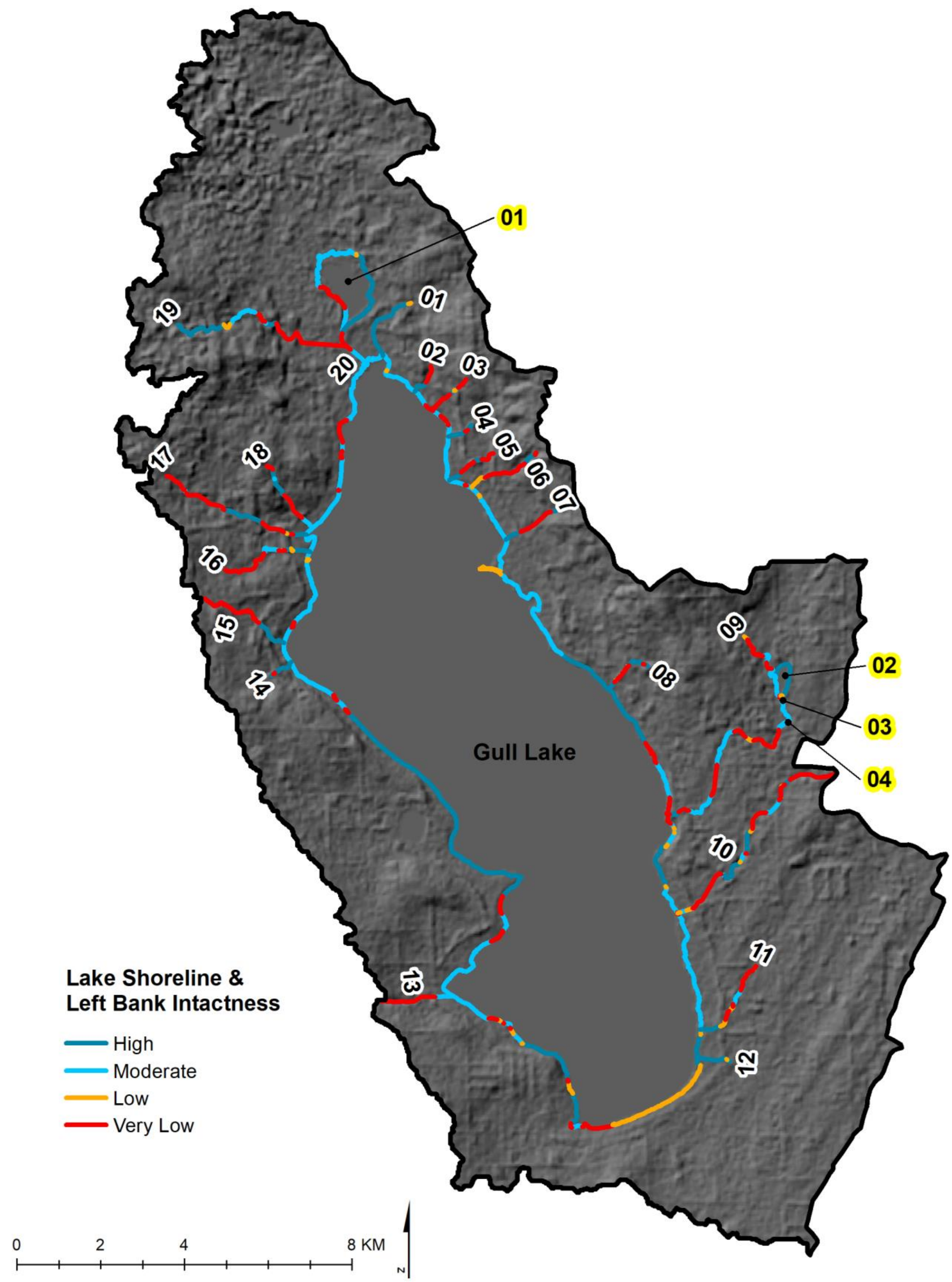
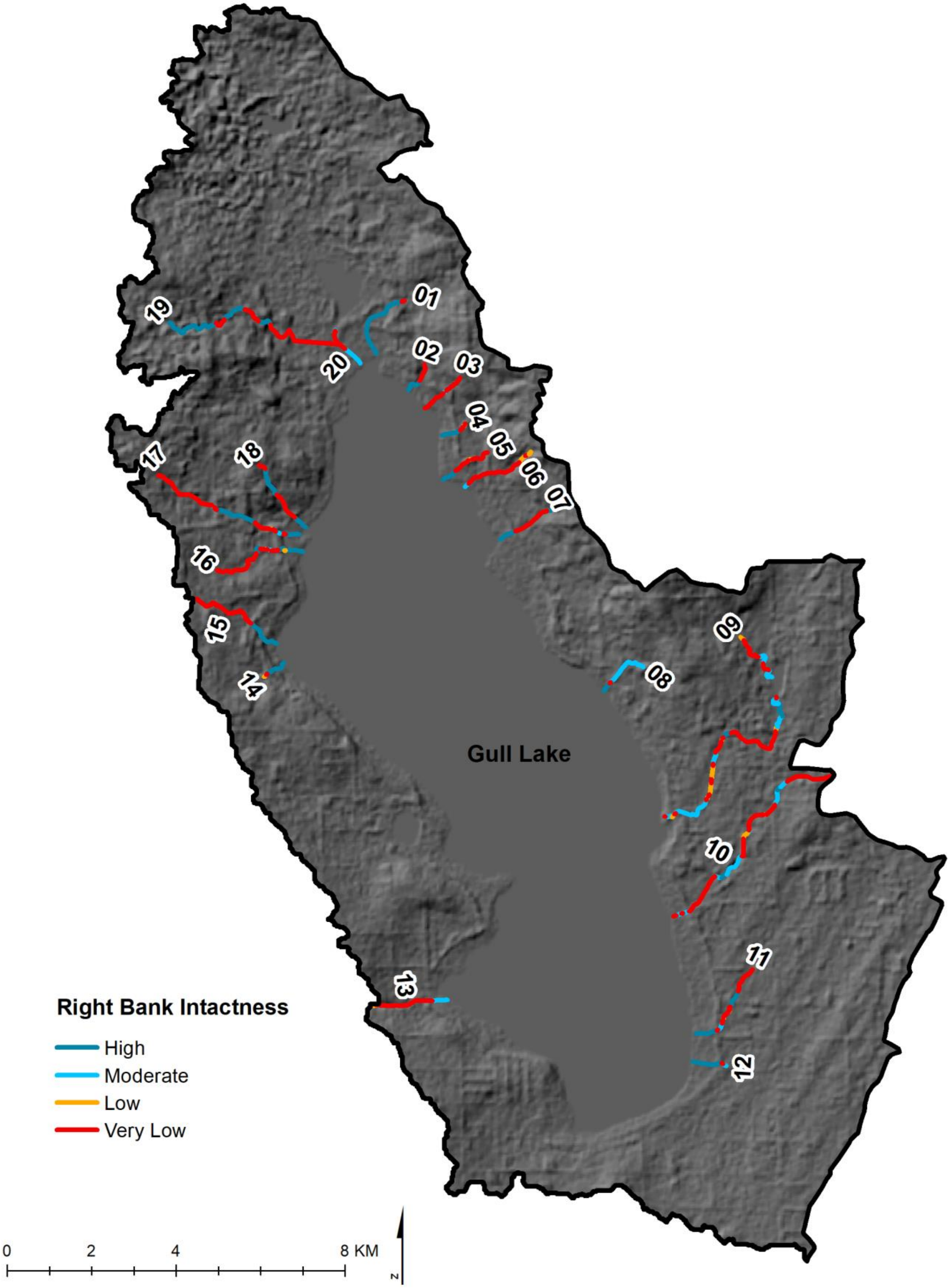


Figure 10. The proportion of shoreline assigned to each riparian intactness category for unnamed lakes located in the Gull Lake watershed. Numbers indicate the total length (km) of shoreline associated with each category.



Map 6. Intactness scores for the shoreline of Gull Lake and other unnamed lakes/wetlands, as well as the left bank of creeks included in this study.



Map 7. Intactness scores for the right bank of creeks included in this study.

6.0 Sylvan Lake Watershed

6.1. Current Condition of Riparian Areas

A total of 76 km of shoreline in the Sylvan Lake watershed was assessed as part of this study, including Sylvan Lake and 15 unnamed creeks that flow into Sylvan Lake (Table 7; Map 8; Table 6). The majority (68%) of the shorelines that were assessed in the watershed were classified as either Moderate (23%) or High (45%) Intactness, with 25% of the shoreline that was assessed being classified as Very Low Intactness (Figure 11).

Table 7. Water bodies in the Sylvan Lake watershed that were assessed as part of this project.

Waterbody Name	Shoreline Length (km)
Sylvan Lake	36.9
Unnamed Creek (15)	38.8
TOTAL	**75.7**

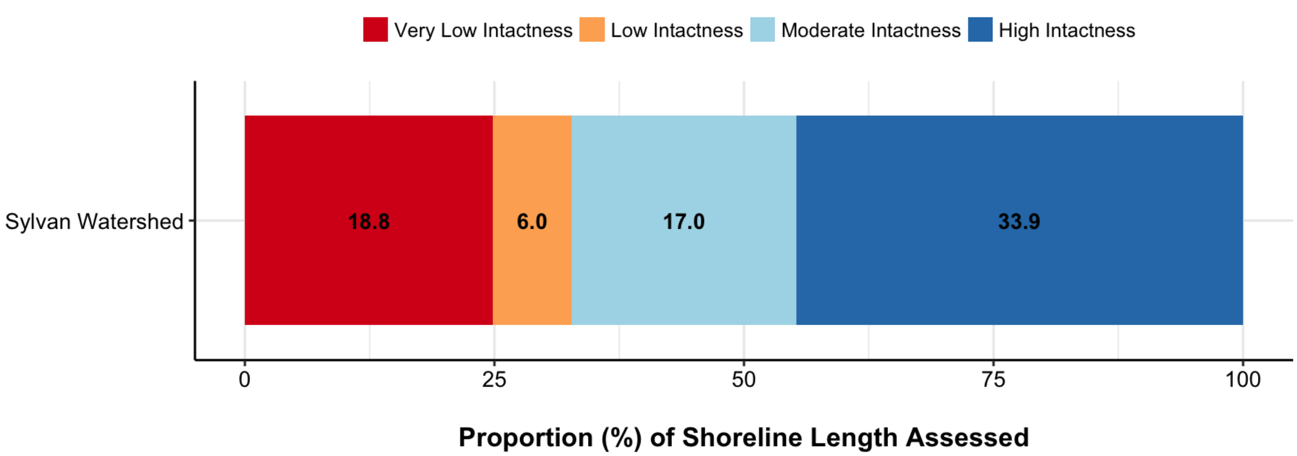
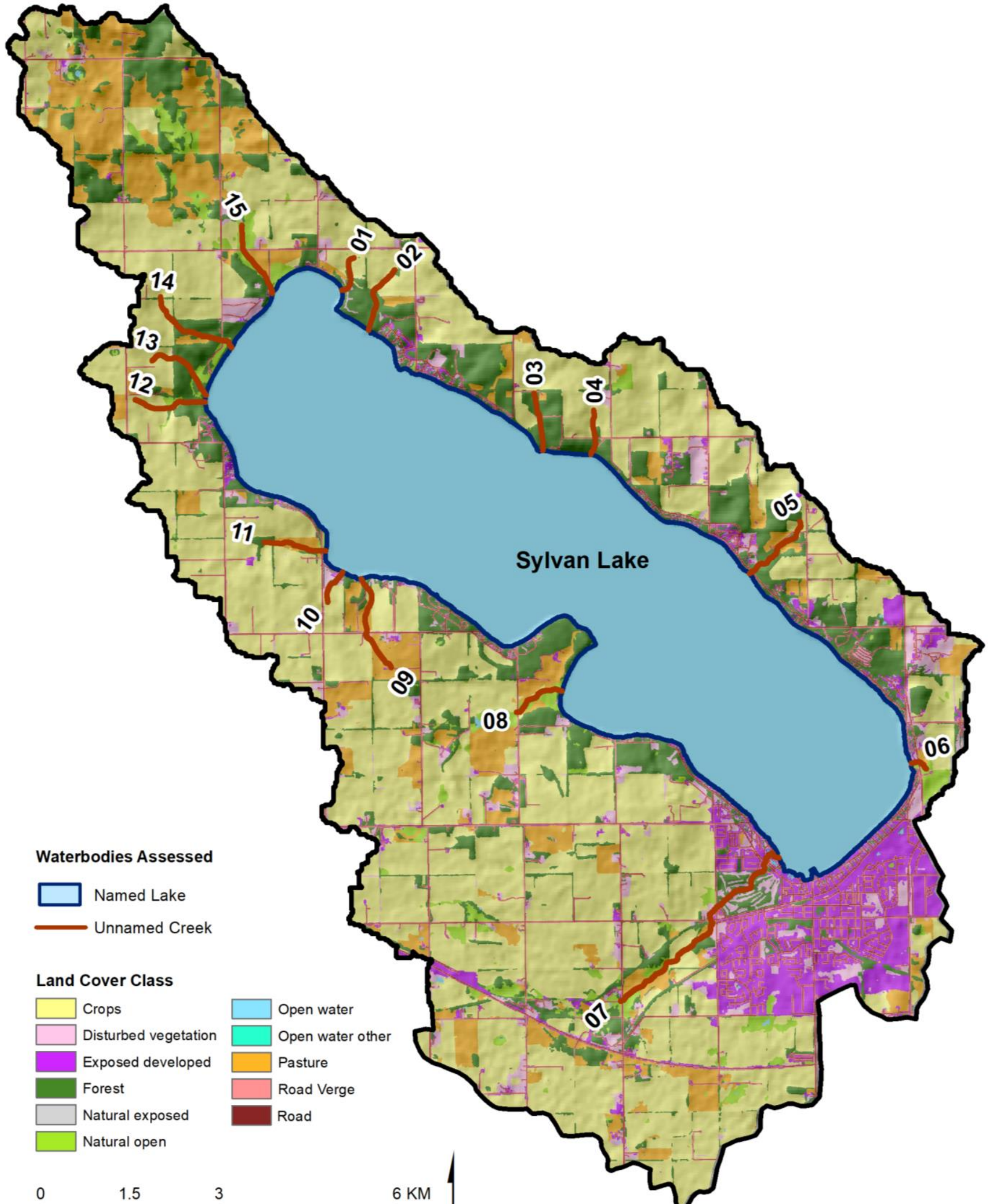


Figure 11. The proportion of shoreline within the Sylvan Lake watershed assigned to each riparian intactness category. The totals include the shorelines of Sylvan Lake and 15 unnamed creeks that are tributaries to the lake. Numbers within the bars indicate the total length (km) of shoreline associated with each category.



Map 8. Land cover in the Sylvan Lake watershed and the location of the waterbodies included in this assessment.

Half (50%) of the shoreline of Sylvan Lake was classified as High Intactness, with an additional 23% classified as Moderate Intactness (Figure 12). Just over a quarter (26%) of the shoreline was assessed as either Very Low (17%) or Low (11%) Intactness. Spatially, areas assessed as Very Low Intactness are concentrated along the south eastern shoreline, where the Town of Sylvan Lake is located (Map 9). Other areas of Low and Very Low Intactness are located along the northern shoreline in areas associated with Jarvis Bay, Birchcliff, and Sunbreaker Cove.

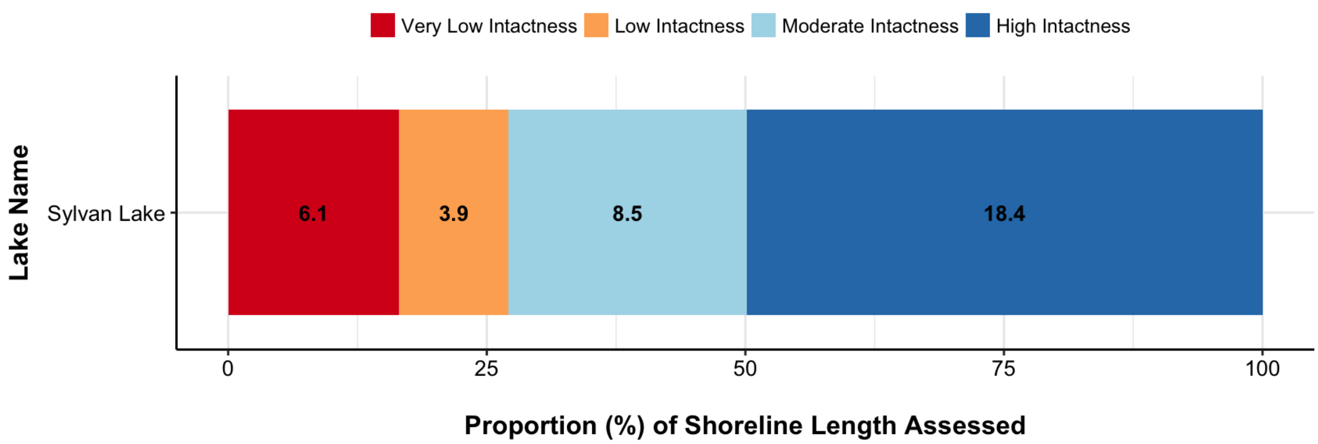


Figure 12. The proportion of shoreline along Sylvan Lake assigned to each riparian intactness category. Numbers within the bars indicate the total length (km) of shoreline associated with each category.

The shorelines of the tributaries flowing into Sylvan Lake vary in condition, with 9 out of 15 having >25% of their shorelines assessed as Very Low condition, and 10 out of 15 having >25% of their shorelines classified as High Intactness (Figure 13). Unnamed creek 09, located along the south shore, has the largest proportion and the greatest length of its shoreline assessed as Very Low Intactness (Figure 13; Map 9 and Map 10).

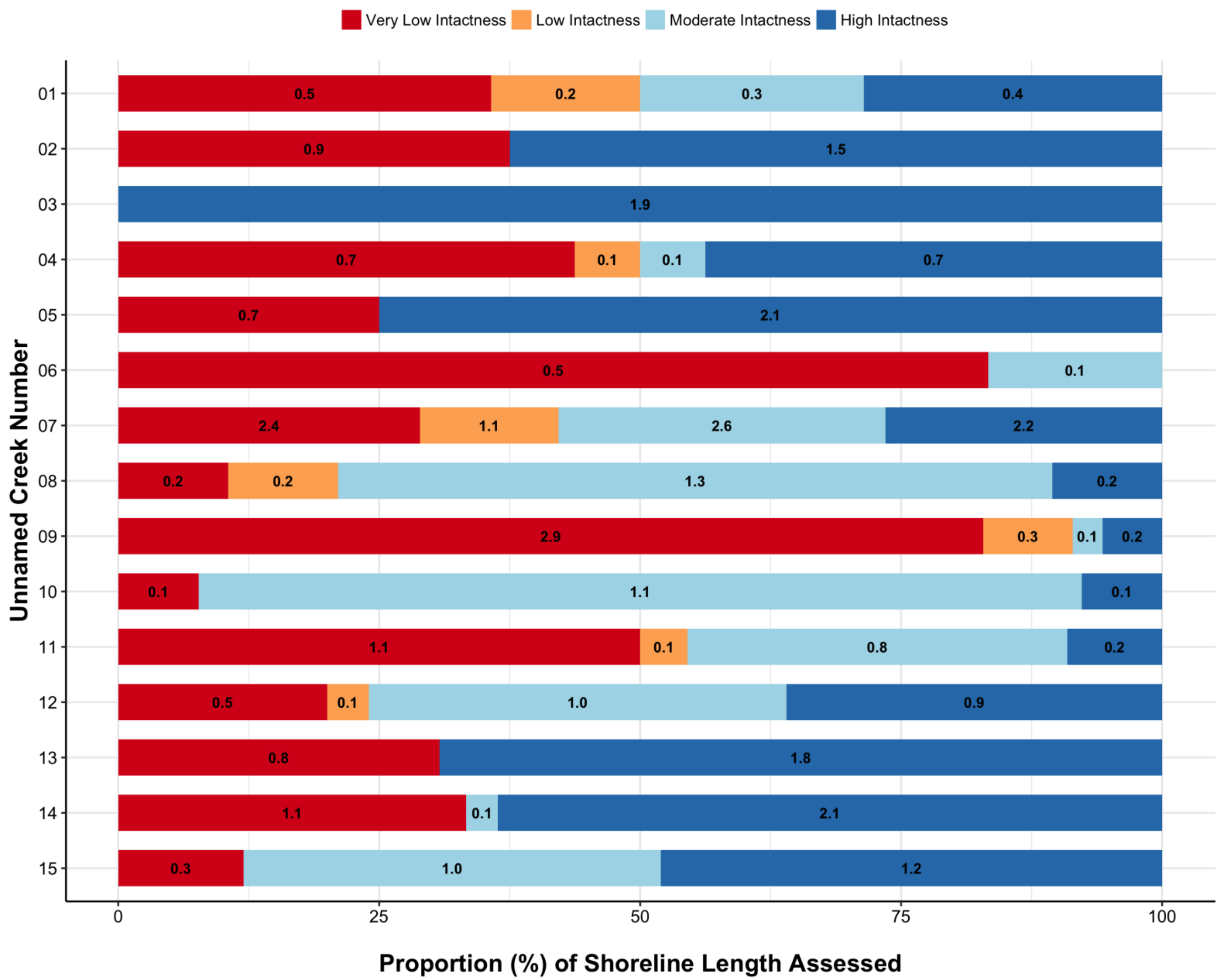
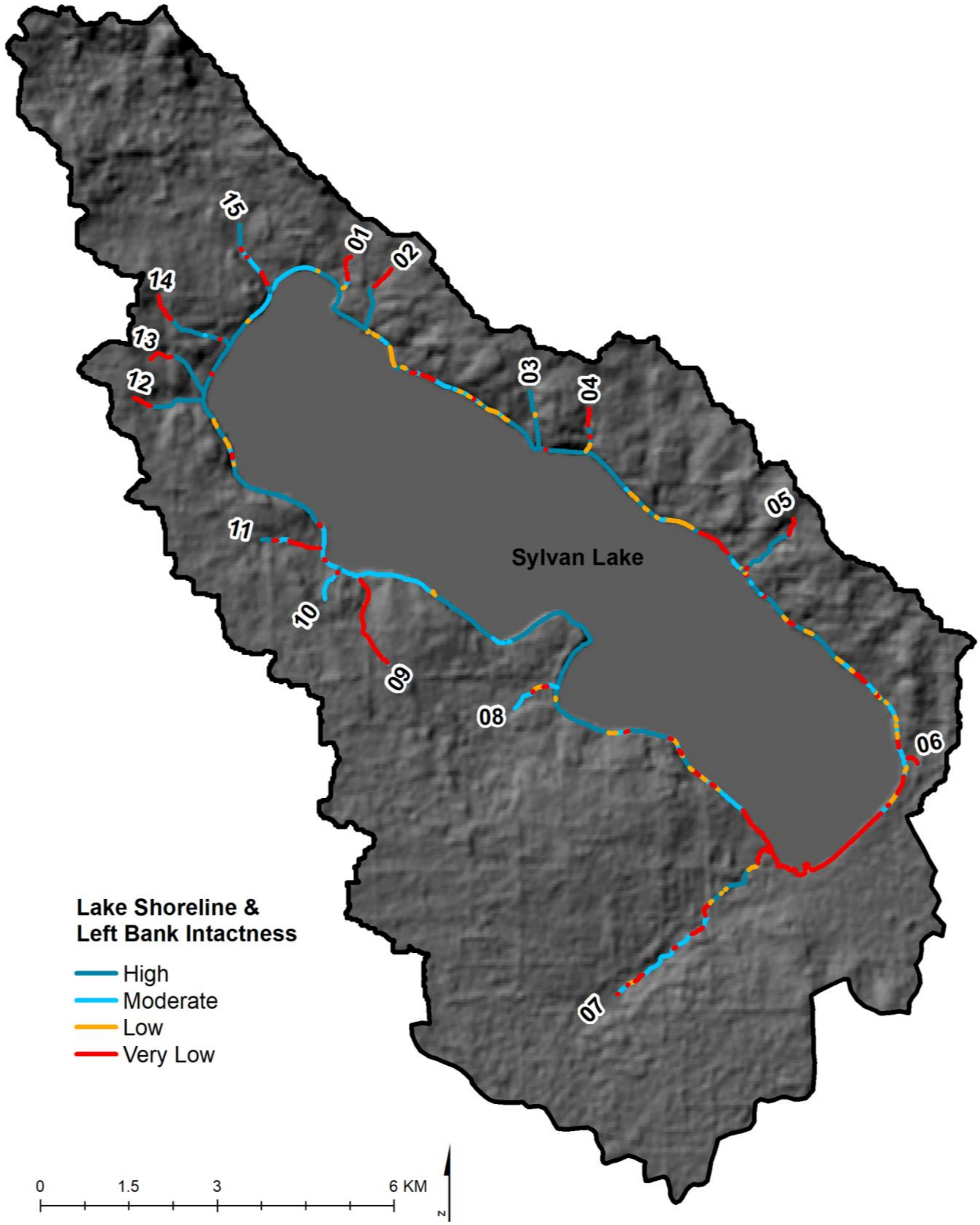
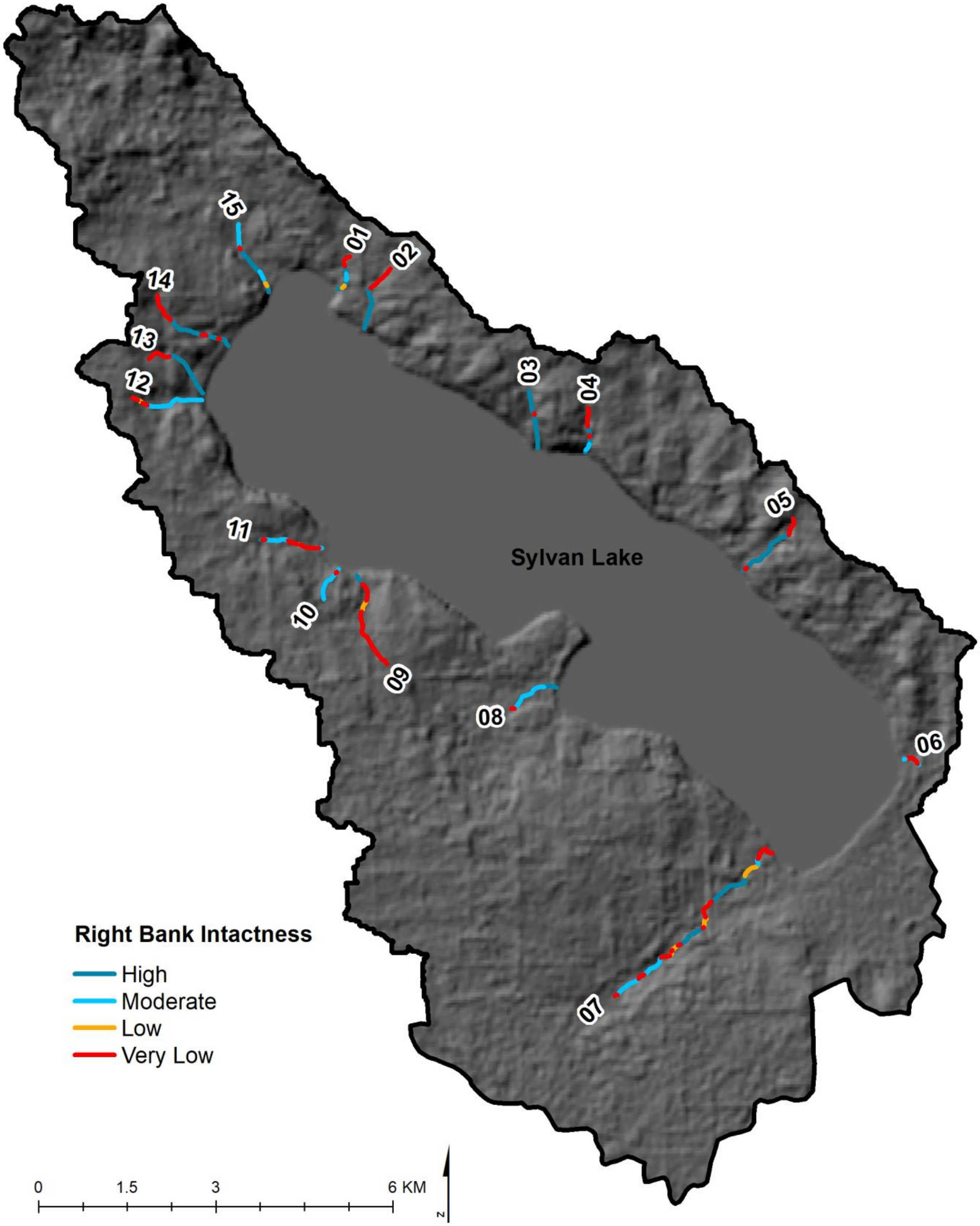


Figure 13. The proportion of shoreline assigned to each riparian intactness category for unnamed creeks located in the Sylvan Lake watershed. Numbers indicate the total length (km) of shoreline associated with each category.



Map 9. Intactness scores for the shoreline of Sylvan Lake and the left bank of creeks included in this study.



Map 10. Intactness scores for the right bank of creeks included in this study.

7.0 Buffalo Lake Watershed

7.1. Current Condition of Riparian Areas

The Buffalo Lake watershed was the largest lake watershed assessed in this study, with a total of 484 km of shoreline along four named lakes, three unnamed lakes/wetlands, two named creeks, and 11 unnamed creeks (Table 8; Map 11). Overall, 38% of the shoreline assessed in this watershed were classified as Very Low (32%) or Low (6%) Intactness, with 37% classified as High Intactness (Figure 14).

Table 8. Water bodies in the North Saskatchewan Region that were assessed as part of this project.

Waterbody Name	Shoreline Length (km)
Buffalo Lake	115.1
Magee Lake	11.8
Mirror Bay	14.3
Rockeling Bay	24.2
Unnamed Lakes/Wetlands (3)	12.9
Parlby Creek	132.4
Spotted Creek	52.0
Unnamed Creeks (11)	121.0
TOTAL	**483.7**

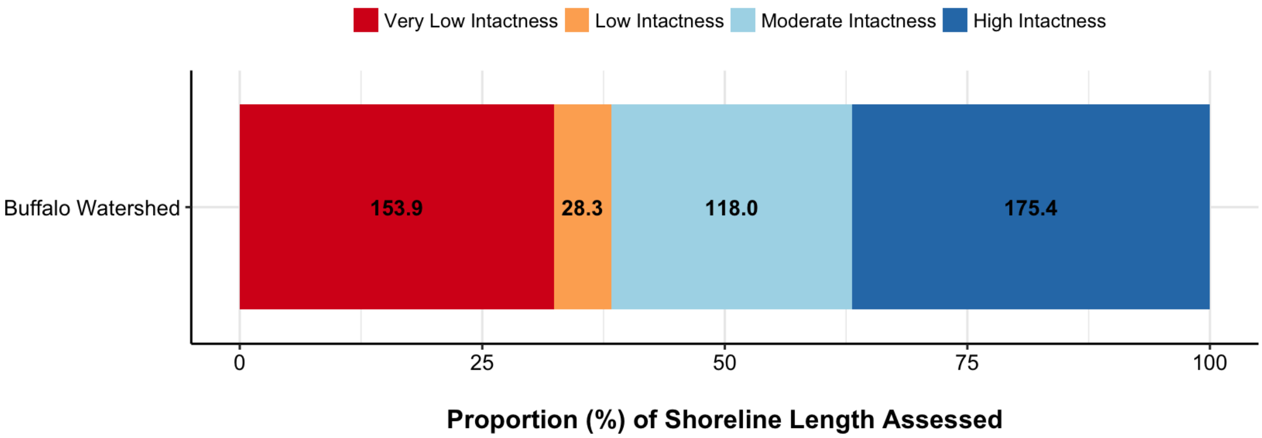
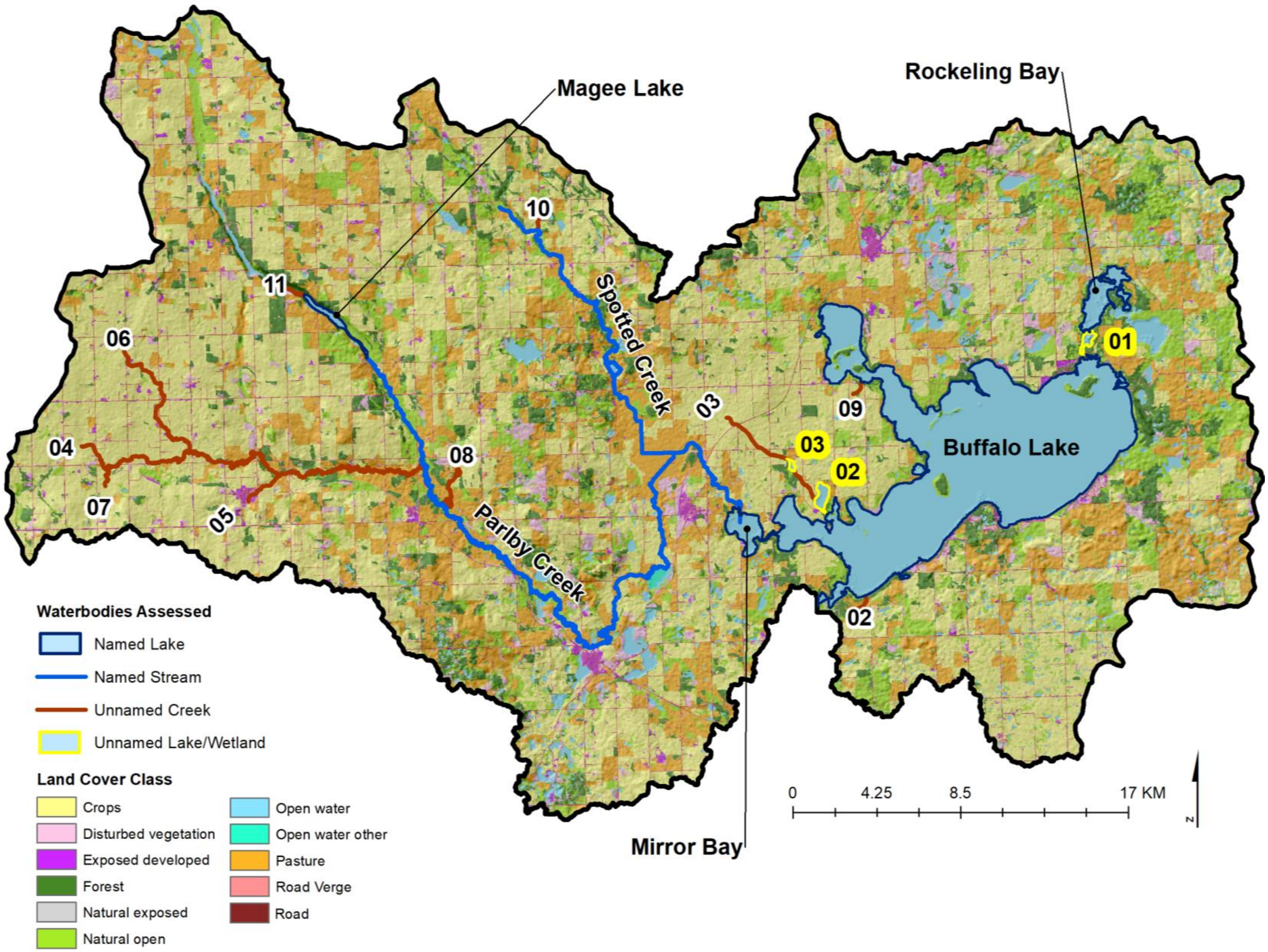


Figure 14. The proportion of shoreline within the Buffalo Lake watershed assigned to each riparian intactness category. The totals include the shorelines of four named lakes, three unnamed lakes, two named creeks, and 11 unnamed creeks. Numbers within the bars indicate the total length (km) of shoreline associated with each category.



Map 11. Land cover in the Buffalo Lake watershed and the location of the waterbodies included in this assessment.

The majority (70%) of the shoreline along Buffalo Lake was classified as High Intactness, representing nearly 81 km, with an additional 13% of the shoreline (14.5 km) classified as Moderate Intactness (Figure 15). Areas classified as Very Low Intactness accounted for 14% of the shoreline, for a total of 15.5 km. Spatially, the areas that were assessed as Very Low or Low Intactness are associated with lakeshore developments such as Pelican Point, White Sands and Rochon Sands, but also with areas that have been impacted by agricultural development along the western and northern shores (Map 12).

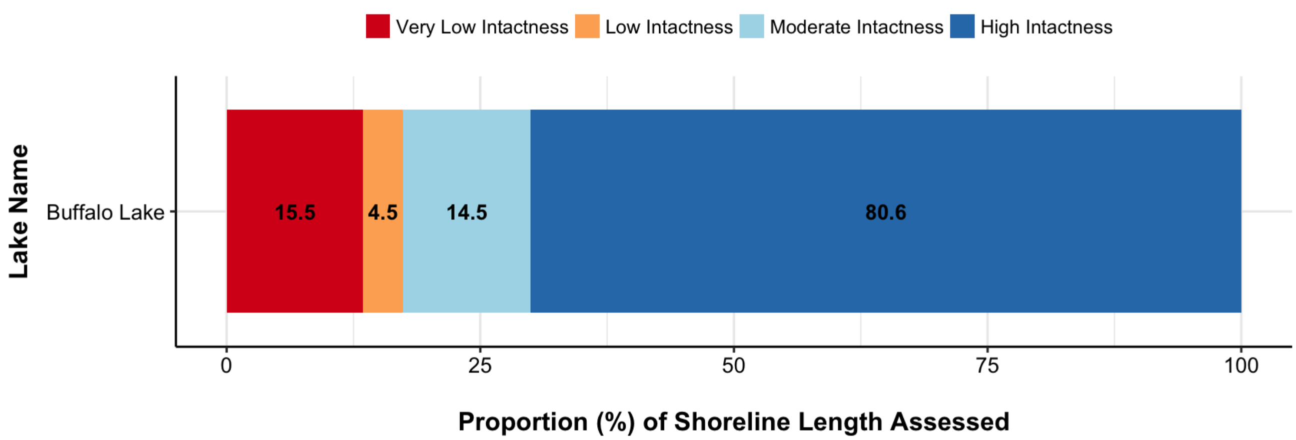


Figure 15. The proportion of shoreline along Buffalo Lake assigned to each riparian intactness category. Numbers within the bars indicate the total length (km) of shoreline associated with each category.

Three other named lakes/wetlands were included in this assessment: Magee Lake at the headwaters of Parlby Creek, Mirror Bay at the west end of Buffalo Lake, and Rockeling Bay at the north east end of Buffalo Lake (Map 11). Generally, these lakes are in relatively good condition, with only Mirror Bay having >25% of its shoreline assessed as either Very Low or Low Intactness (Figure 16). Three unnamed lakes/wetlands were also assessed, all of which were located along the north shore of Buffalo Lake (Map 11). Two out of the three waterbodies had >25% of their shorelines classified as Very Low Intactness, with one of the three (01) having nearly 100% of its shoreline classified as High Intactness (Figure 17).

Two named creeks, Parlby and Spotted, as well as 11 unnamed creeks were also assessed as part of this study. Both Parlby and Spotted Creek have >25% of their shorelines classified as Very Low Intactness, with Parlby Creek having >50% of its shoreline classified as Very Low (Figure 18; Map 12 and Map 13). Similarly, 8 of the 11 unnamed creeks have >25% of their shorelines assed as Very Low Intactness, with 5 of the 11 having >50% of their shorelines assessed as Very Low (Figure 19).

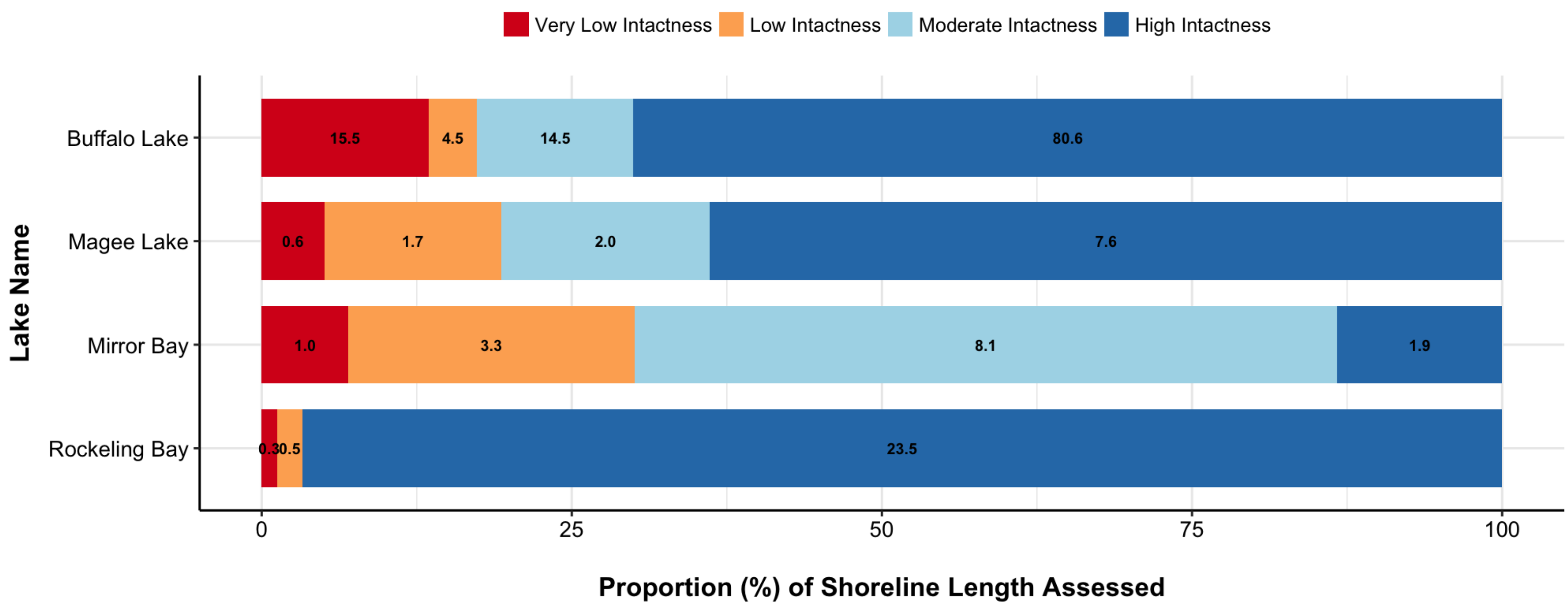


Figure 16. The proportion of shoreline assigned to each riparian intactness category for all named lakes in the Buffalo Lake watershed. Numbers within the bars indicate the total length (km) of shoreline associated with each category.

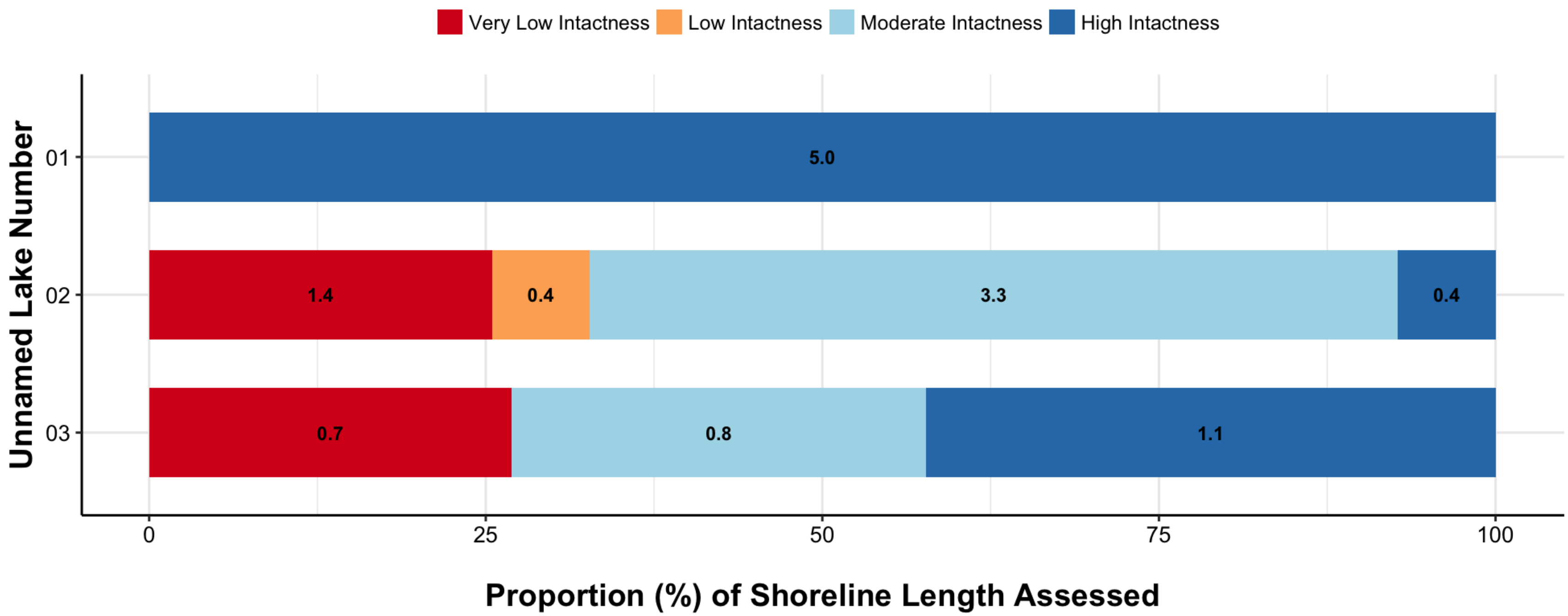


Figure 17. The proportion of shoreline assigned to each riparian intactness category for unnamed lakes in the Buffalo Lake watershed. Numbers within the bars indicate the total length (km) of shoreline associated with each category.

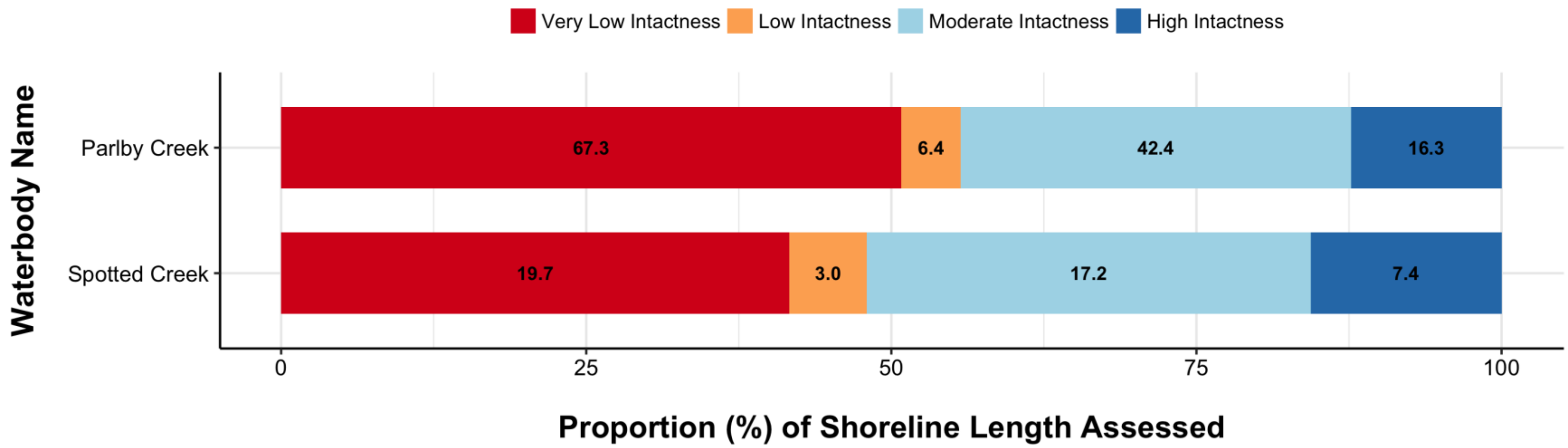


Figure 18. The proportion of shoreline assigned to each riparian intactness category for named creeks in the Buffalo Lake watershed. Numbers within the bars indicate the total length (km) of shoreline associated with each category.

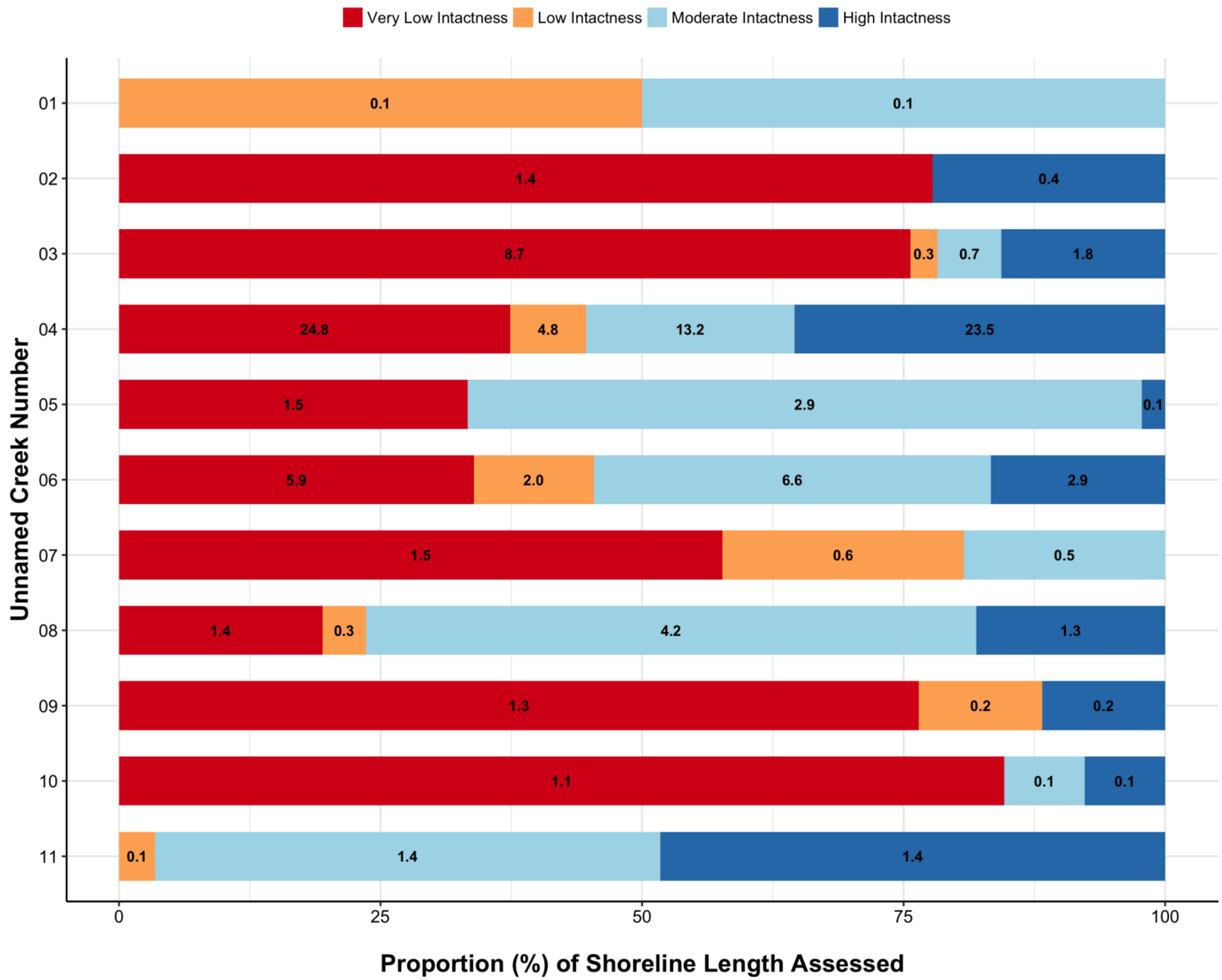
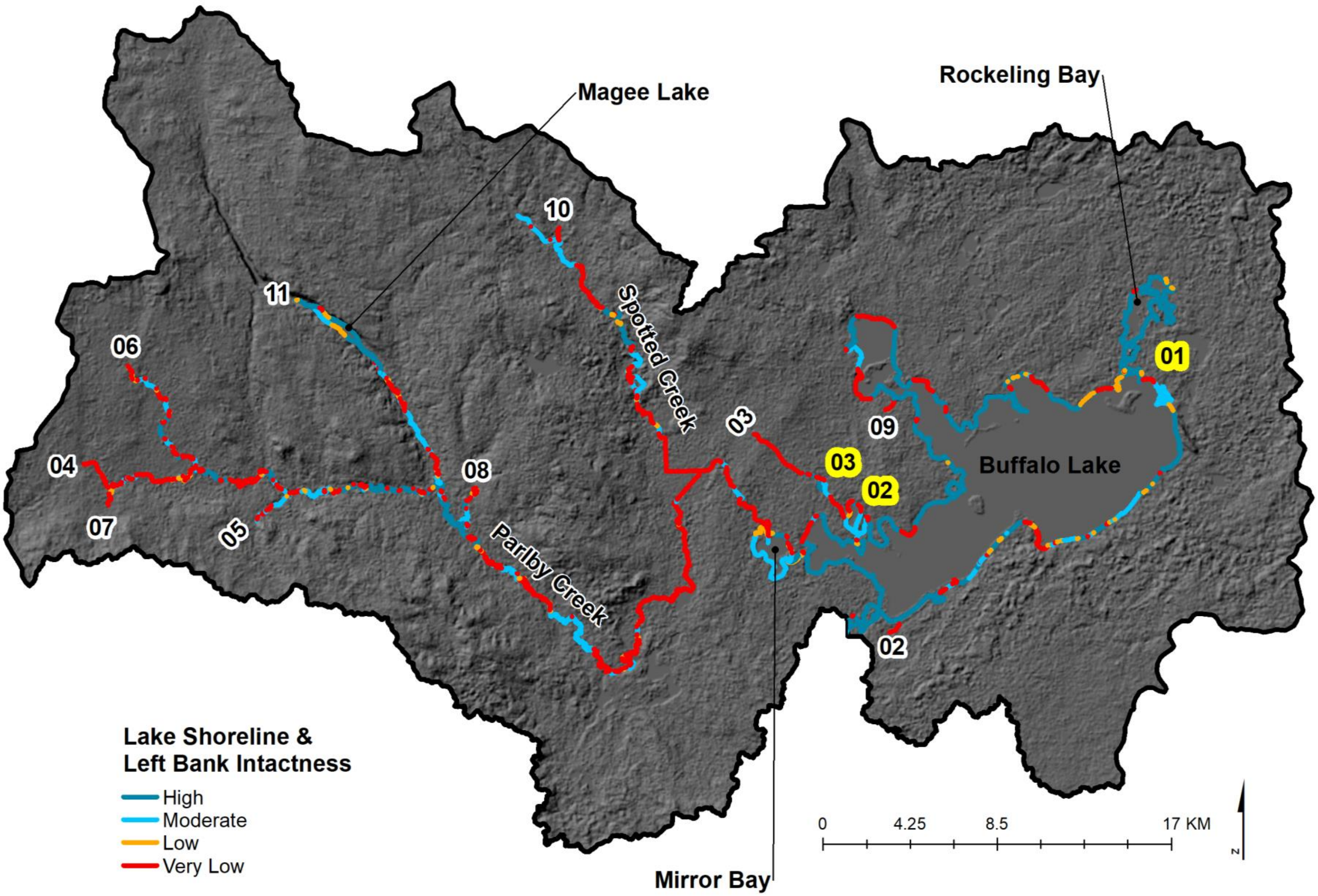
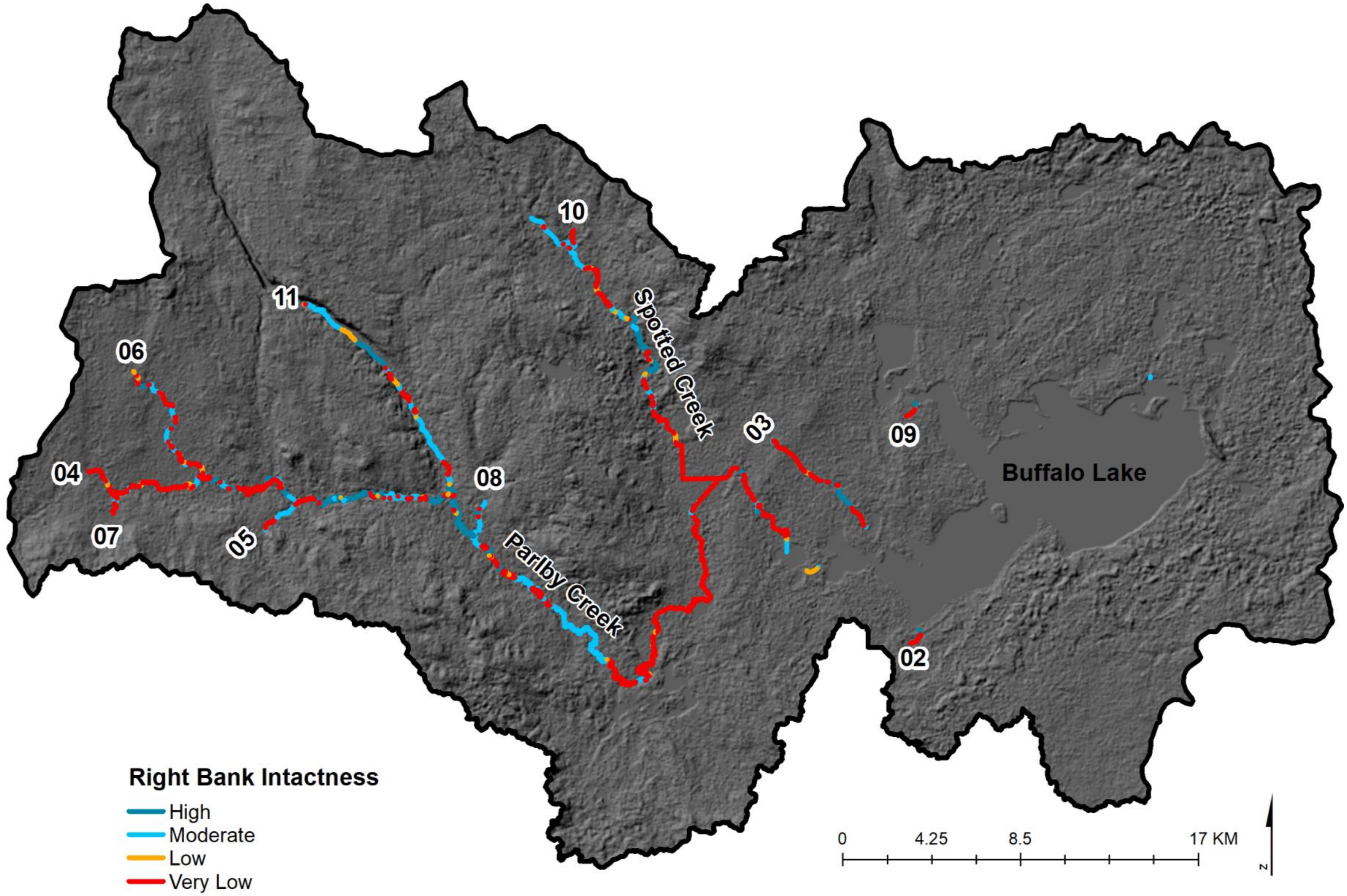


Figure 19. The proportion of shoreline assigned to each riparian intactness category for unnamed creeks in the Buffalo Lake watershed. Numbers within the bars indicate the total length (km) of shoreline associated with each category.



Map 12. Intactness scores for the shoreline of Buffalo Lake and other unnamed lakes/wetlands, as well as the left bank of named and unnamed creeks included in this study.



Map 13. Intactness scores for the right bank of named and unnamed creeks included in this study.

8.0 Historical Condition Comparison

Each of the four lakes included in this study have been previously assessed using the videography method. Gull, Sylvan, and Buffalo Lakes were all assessed in 2007, while Pigeon Lake was assessed in 2008. Part of the objective of this study was to do a comparison between the previously completed videography results (i.e., the “historic” condition) and the GIS results (i.e., the “current” condition).

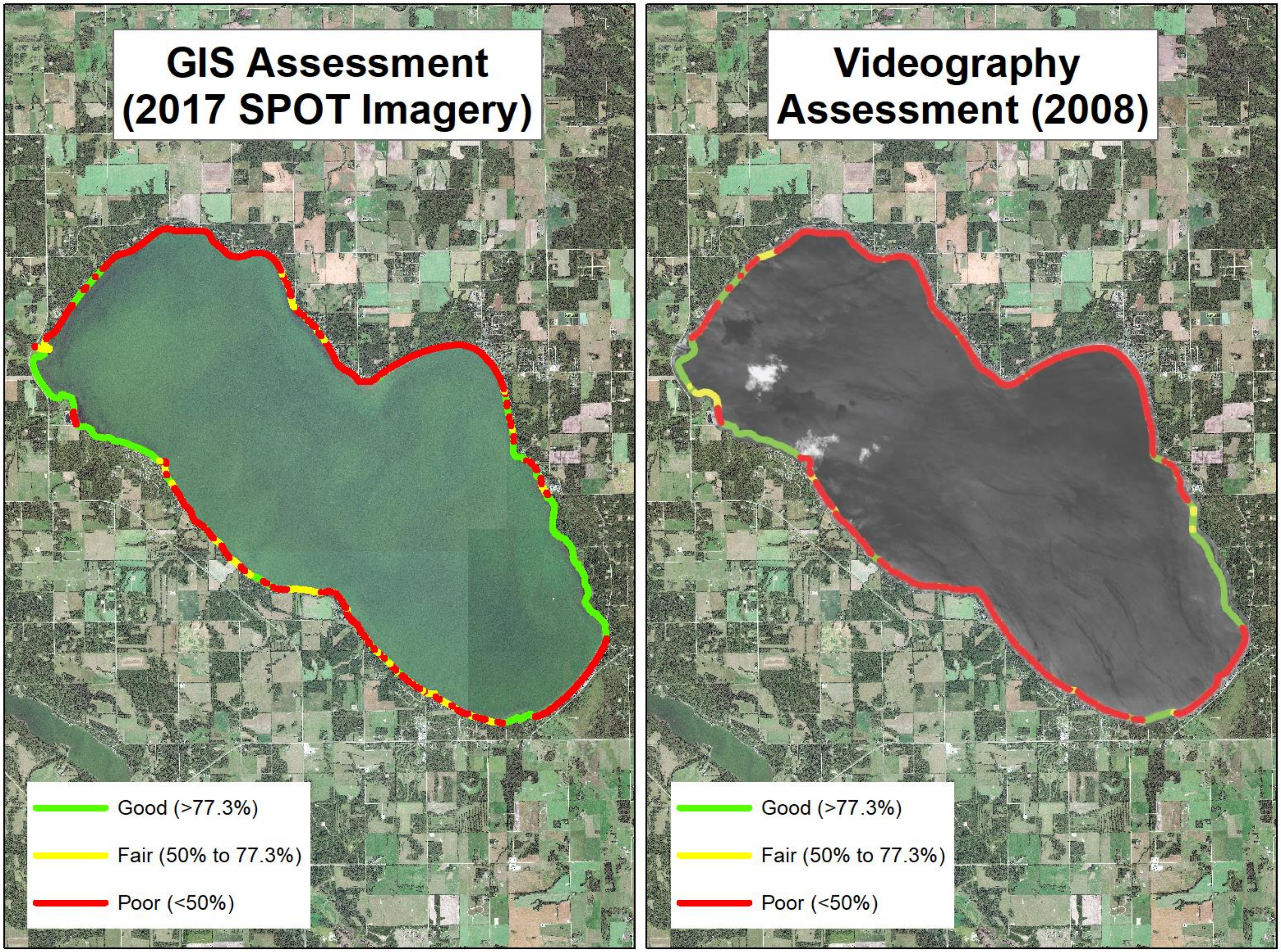
Results from the historical surveys for Gull, Sylvan, and Buffalo Lakes were provided by the GOA, and maps with videography results for Pigeon Lake was downloaded from the internet. Given that the videography results were not available in a format that allowed for direct spatial comparisons in a GIS environment, we were not able to calculate the historical proportions of shoreline assigned to each condition category. Instead, we georeferenced the historical maps and presented a side-by-side comparison to the current results using the videography scoring thresholds between condition categories, as well as using the scoring threshold categories adopted for the GIS assessment.

While direct comparisons between the results derived from the videography and GIS methods should be approached with some caution, given that the methods used to derive the scores are different, generally, these results provide us with some interesting observations about the condition of the lakes through time. For example, the videography and GIS results classified using the three videography condition categories of “Good”, “Fair”, and “Poor” for Pigeon Lake suggest quite a high level of agreement between the two methods, with little substantial change in overall condition of the shoreline between 2008 and 2017 (Map 14). When the current data is classified using the four GIS condition categories, there is much more detail provided along the shoreline, particularly in areas that were classified in 2008 as “Poor”. Because the GIS method splits this “Poor” category into “Low” and “Very Low” categories, there is more differentiation in areas where the shoreline has been impacted by human activity (Map 15).

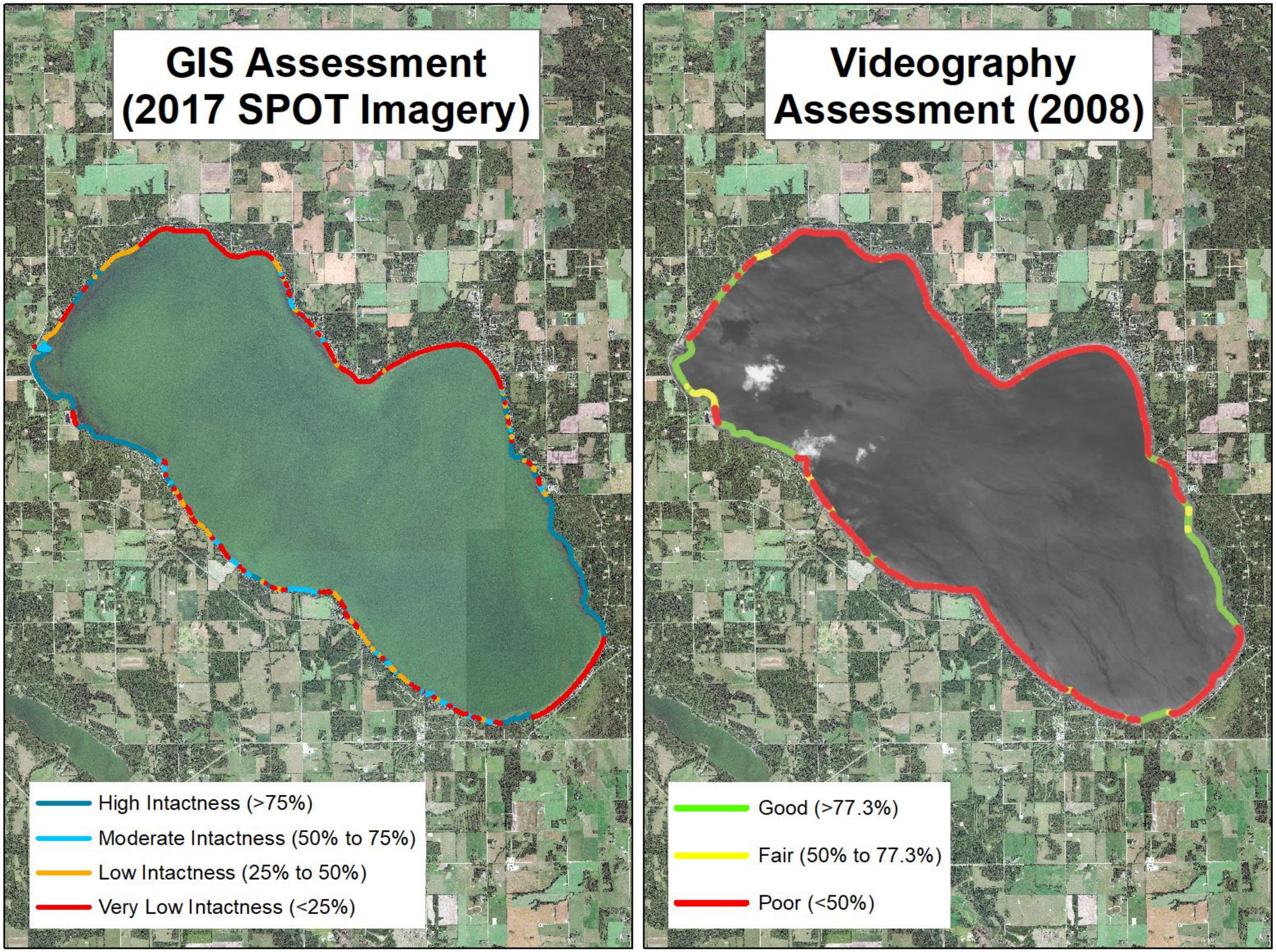
A comparison of the historic and current results for Gull Lake using the three condition classes suggests that there has been an overall reduction in the area of shoreline classified as “Good”, particularly along the shoreline in the northern portion of the lake, and along the eastern shoreline (Map 16). However, when the four category GIS scores are used to classify the shoreline, a substantial amount of the shoreline that falls into the “Fair” category using the videography scoring approach, is classified as “High Intactness”, and these areas are those with scores that fall within a very small range 75 and 77.2% (Map 17). The question of which threshold break is “correct” is one that can not be answered by this study.

For Sylvan Lake, there is good general agreement between those areas assessed as “Poor” in 2007 and those assessed as “Poor” in 2016, using the three category scoring approach (Map 18). There are also some areas along the western and northern shoreline that were scored as “Good” in 2007, that are now being classified as “Fair” in 2016. This suggests that these areas may have experienced further impacts over the last 10 years. A comparison of the four category GIS scores to the three category videography scores again provides more resolution in the “Poor” areas, with differentiation between areas assessed as “Low” and “Very Low” (Map 19).

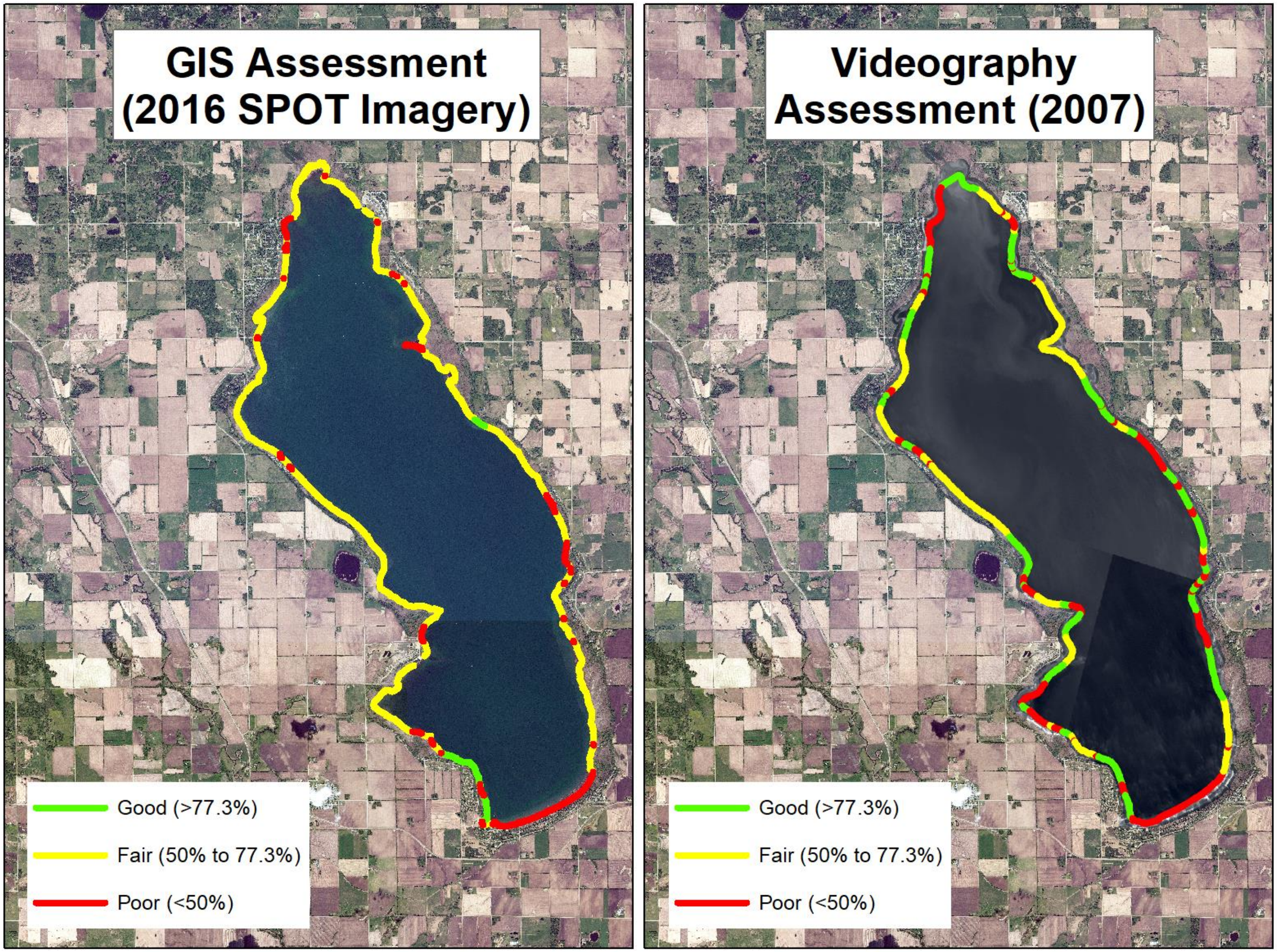
While the agreement between the GIS and the videography scores for Pigeon, Gull, and Sylvan Lakes are generally very good, the results for Buffalo Lake are less so. For this lake, there are some areas along the shoreline where there are large disagreements between the historic and current scores (e.g., the shoreline is scored as “Poor” in 2007 but “Good” in 2017, or vice versa) when the three category videography scores are compared (Map 20 and Map 21). Further, it is difficult to discern from the data that we have for this lake the area of the shoreline that was being assessed by the videography. For example, the data on the videography maps appear to represent the flight line, and in some locations, this flight line deviates substantively from the lake shoreline. Thus, it is difficult to know how much of the “buffer” area within the RMA was being evaluated in this videography assessment, and a lack of spatial correspondence between the RMA areas that was being assessed between the two methods could substantively influence the scores.



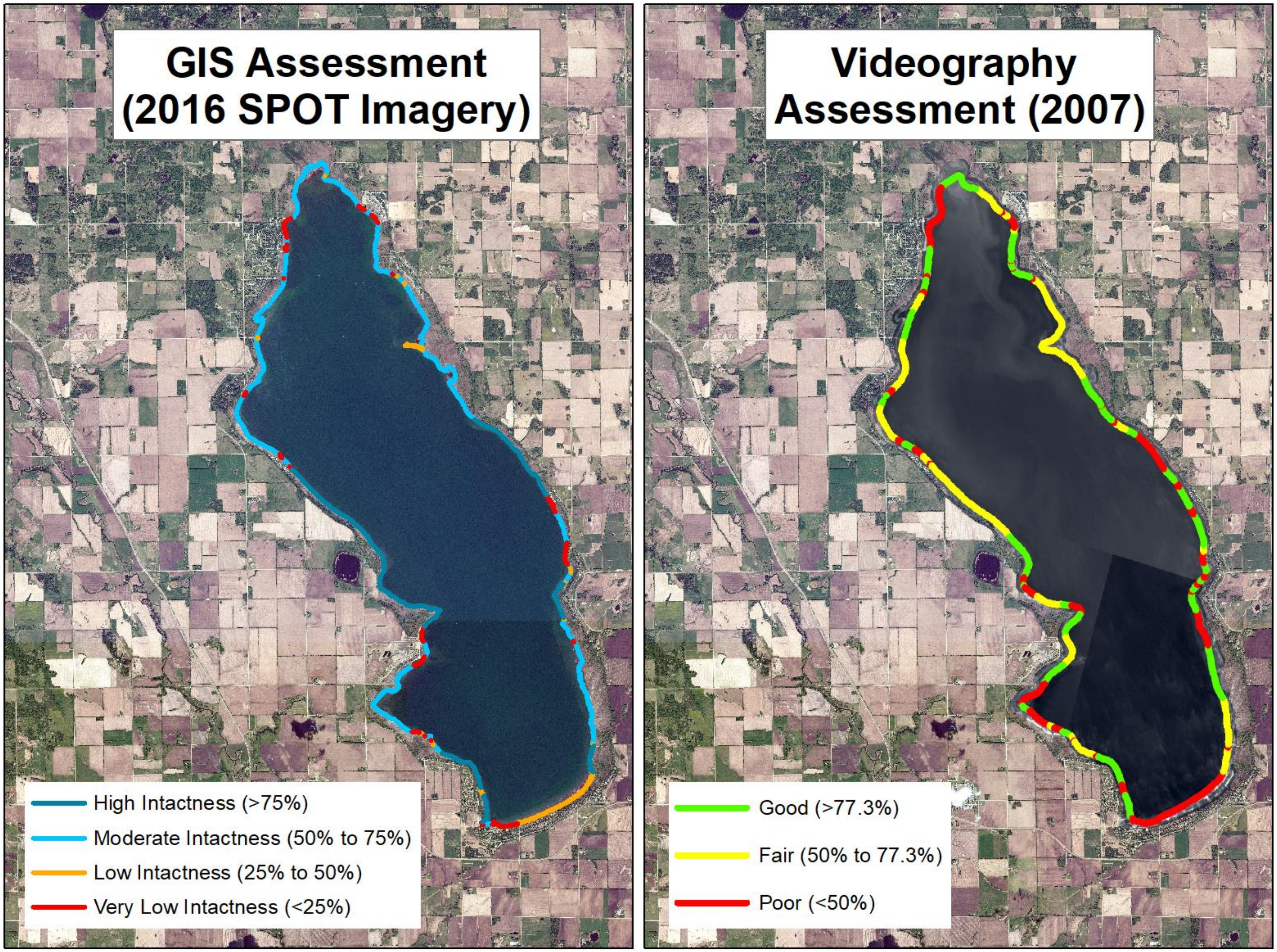
Map 14. Comparison of the 2017 riparian condition scores of Pigeon Lake derived using the GIS method (left) and the “historic” condition of the shoreline as assessed in 2008 using the aerial videography method. For this comparison, the GIS scores were classified into three condition categories using the same class thresholds as the videography assessment.



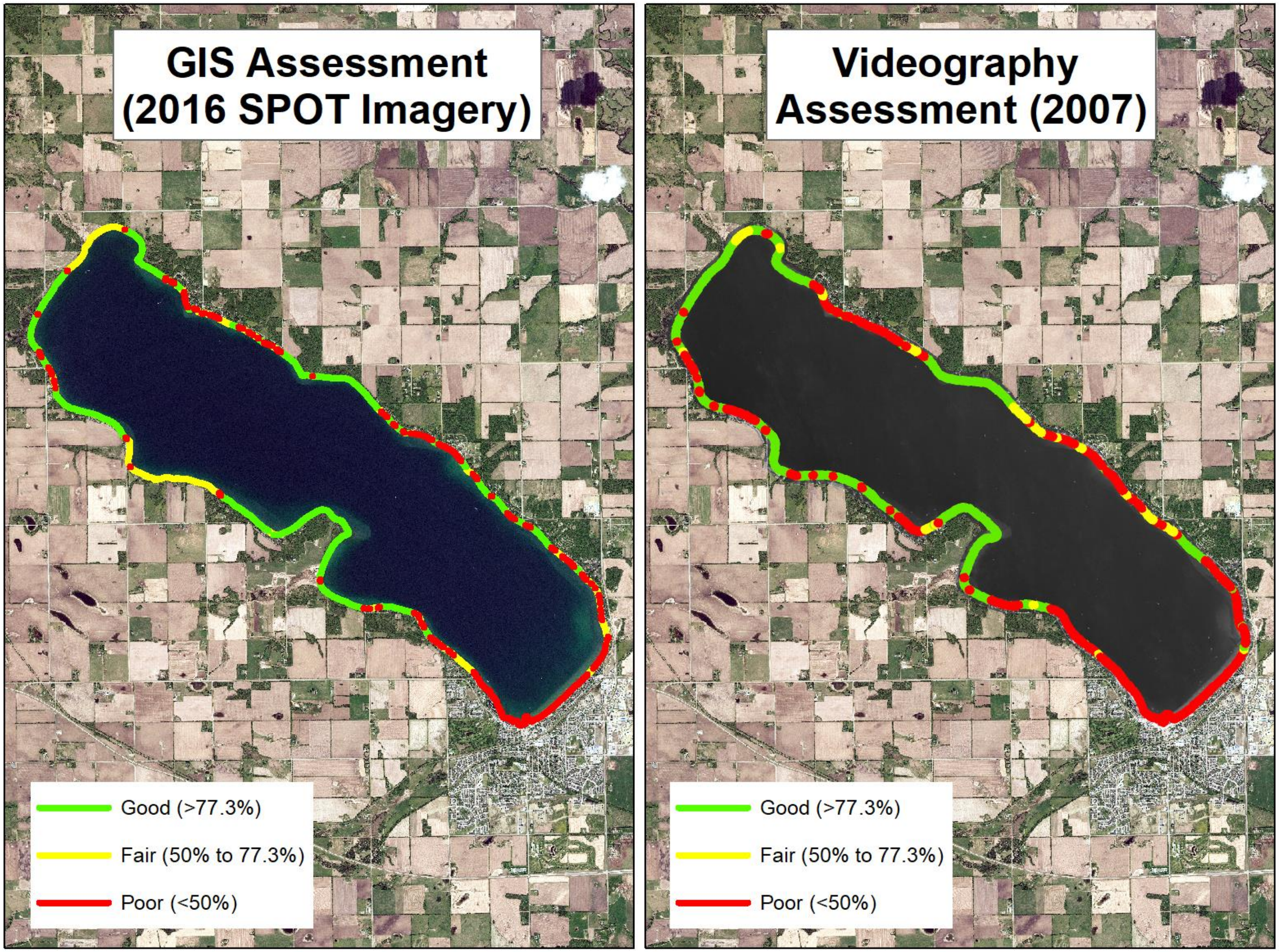
Map 15. Comparison of the 2017 GIS scores (left) and the "historic" 2008 videography scores for Pigeon Lake. For this comparison, the GIS scores were classified into the four condition categories using percentile breaks.



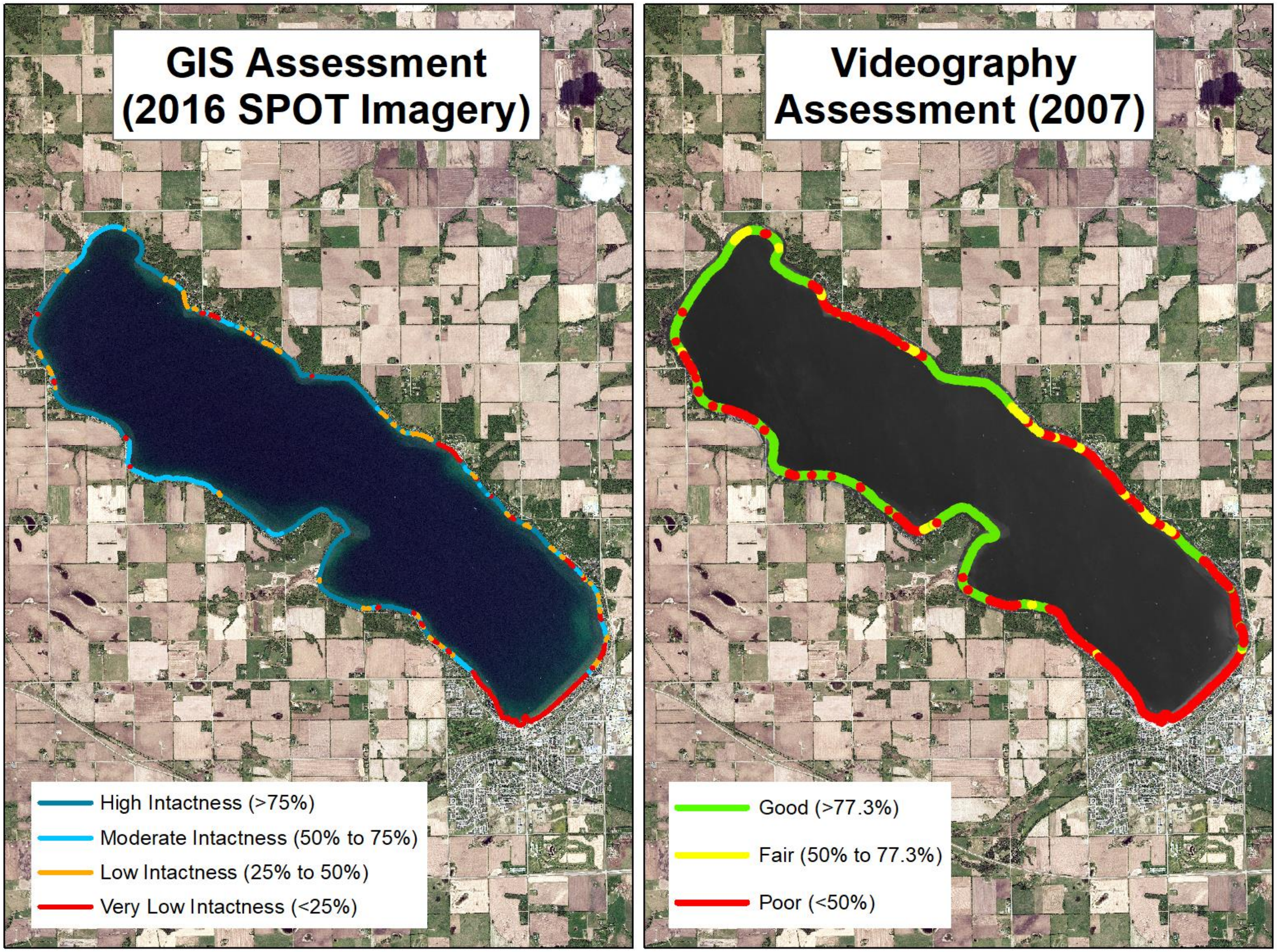
Map 16. Comparison of the 2016 riparian condition scores of Gull Lake derived using the GIS method (left) and the "historic" condition of the shoreline as assessed in 2007 using the aerial videography method. For this comparison, the GIS scores were classified into three condition categories using the same class thresholds as the videography assessment.



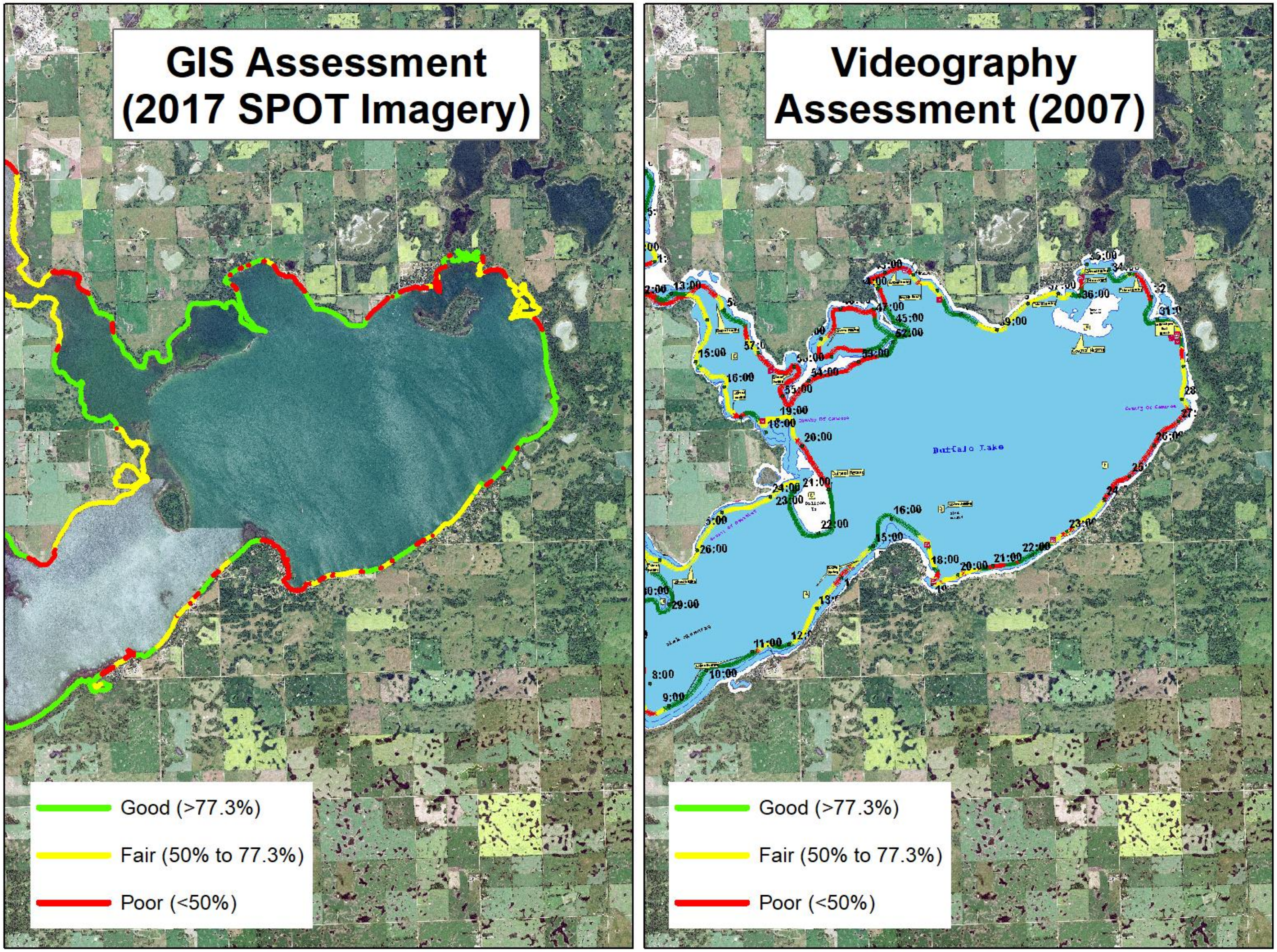
Map 17. Comparison of the 2016 GIS scores (left) and the "historic" 2007 videography scores for Gull Lake. For this comparison, the GIS scores were classified into the four condition categories using percentile breaks.



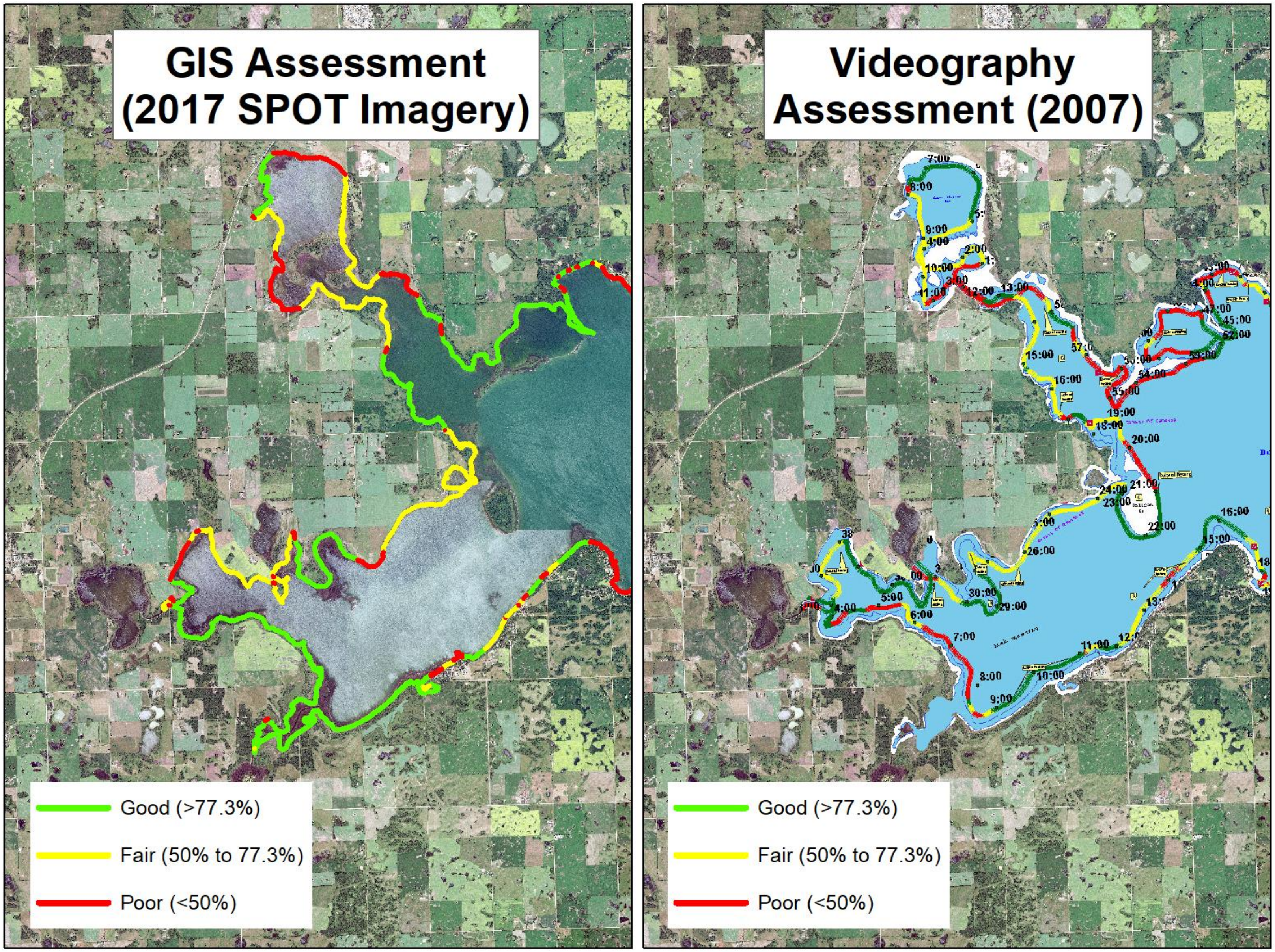
Map 18. Comparison of the 2017 riparian condition scores of Sylvan Lake derived using the GIS method (left) and the "historic" condition of the shoreline as assessed in 2007 using the aerial videography method. For this comparison, the GIS scores were classified into three condition categories using the same class thresholds as the videography assessment.



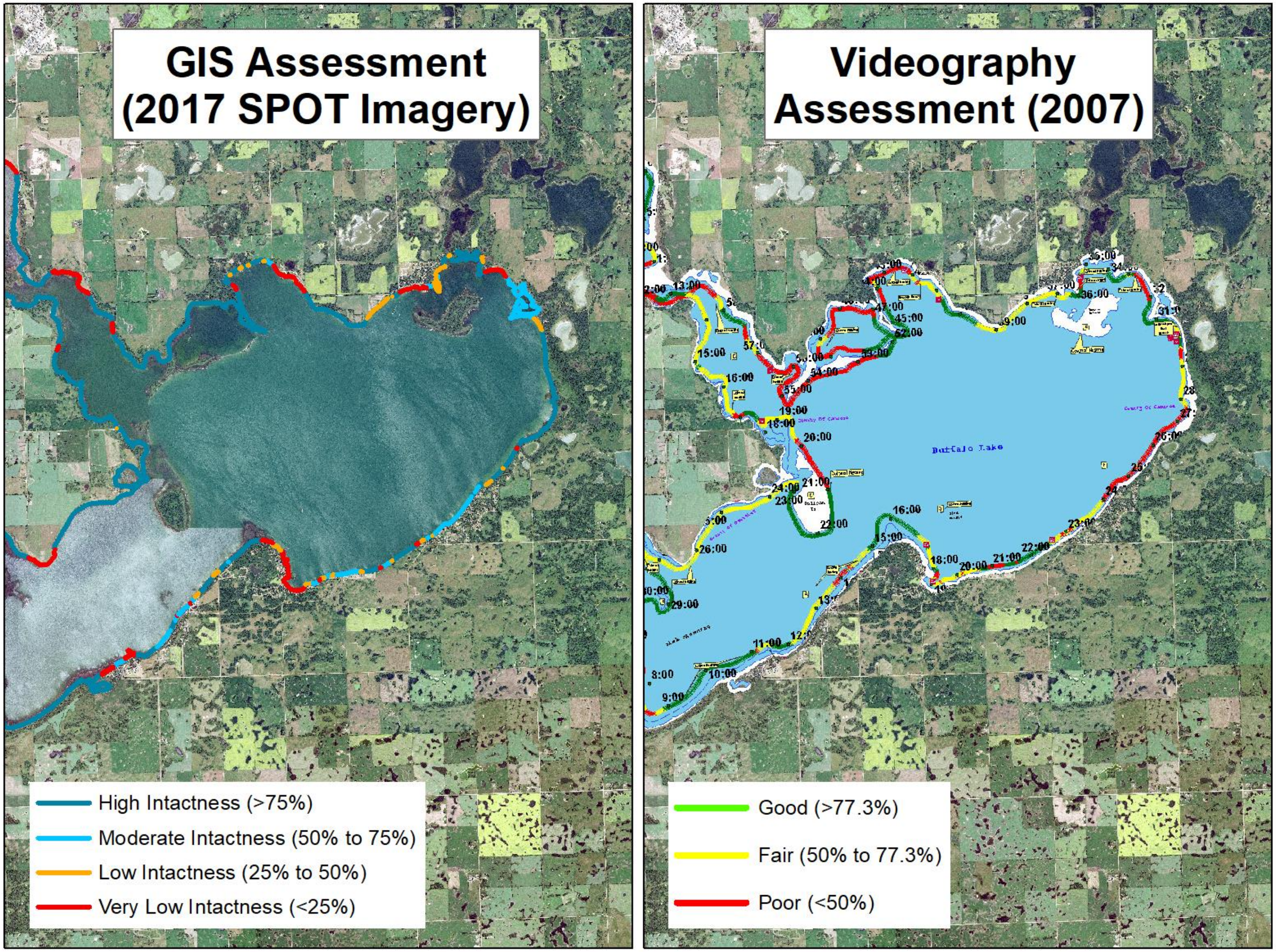
Map 19. Comparison of the 2016 GIS scores (left) and the “historic” 2007 videography scores for Sylvan Lake. For this comparison, the GIS scores were classified into the four condition categories using percentile breaks.



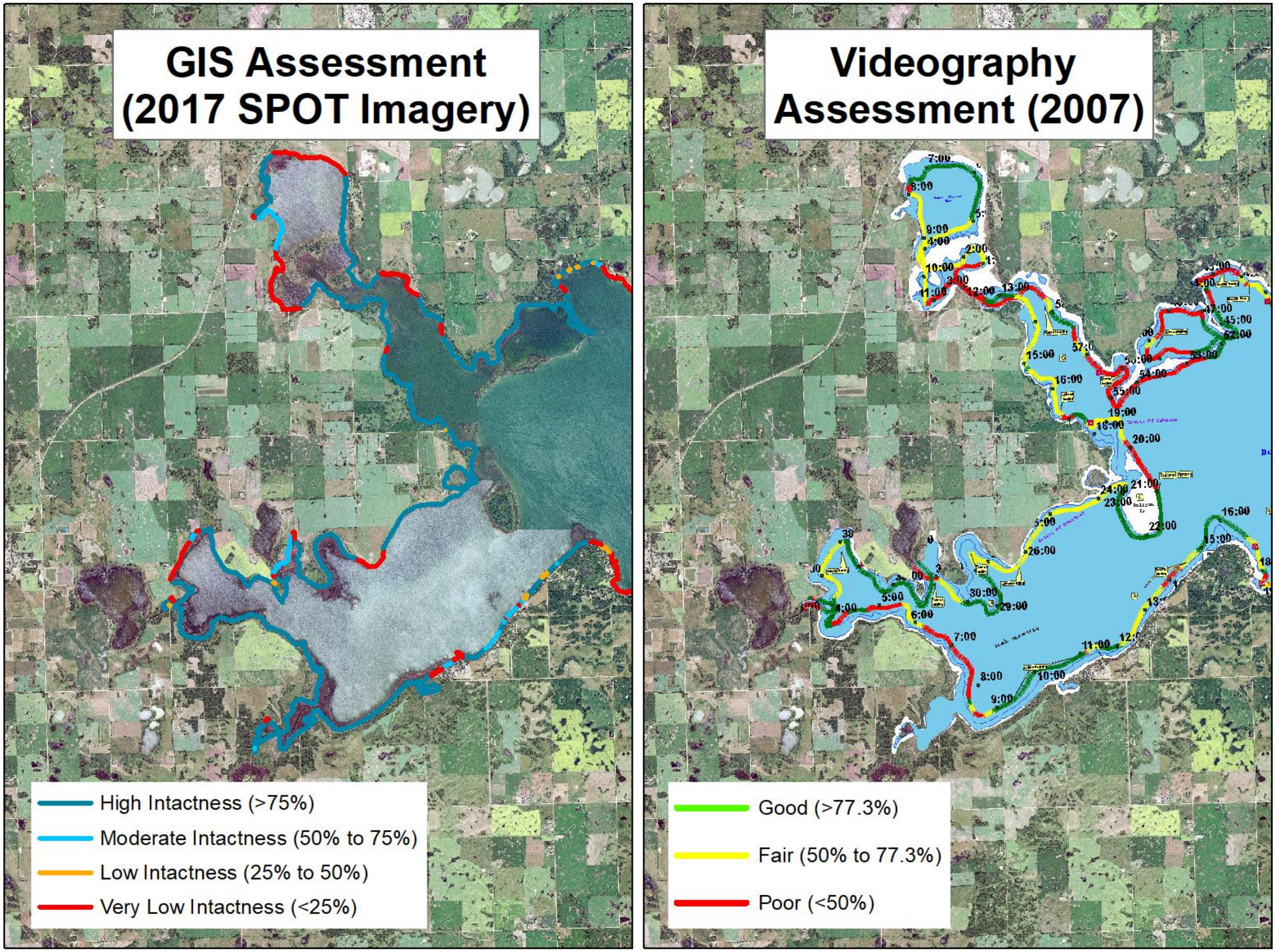
Map 20. Comparison of the 2017 riparian condition scores of the east portion of Buffalo Lake derived using the GIS method (left) and the “historic” condition of the shoreline as assessed in 2007 using the aerial videography method. For this comparison, the GIS scores were classified into three condition categories using the same class thresholds as the videography assessment.



Map 21. Comparison of the 2017 riparian condition scores of the west portion of Buffalo Lake derived using the GIS method (left) and the “historic” condition of the shoreline as assessed in 2007 using the aerial videography method. For this comparison, the GIS scores were classified into three condition categories using the same class thresholds as the videography assessment.



Map 22. Comparison of the 2017 GIS scores (left) and the “historic” 2007 videography scores for the east portion of Buffalo Lake. For this comparison, the GIS scores were classified into the four condition categories using percentile breaks.



Map 23. Comparison of the 2017 GIS scores (left) and the “historic” 2007 videography scores for the east portion of Buffalo Lake. For this comparison, the GIS scores were classified into the four condition categories using percentile breaks.

9.0 Data Standards

Riparian areas have been identified as important components of watershed health, and with this recognition, there has been a great deal of recent work done across the province to develop inventories that provide land managers with information about riparian condition over large spatial extents. Much of this work, however, is being done by different organizations using a variety of methods, which makes it difficult or impossible to compare results between studies. Thus, there is a pressing need to create an objective and repeatable GIS-based riparian assessment method that allows for a direct comparison of assessment results across space and through time, and to create minimum standards for conducting these assessments, such that the data can be compiled into a provincial dataset.

In order to create a provincial dataset for GIS-based riparian assessments, standards must first be developed and specified. This should include a structured list of individual data items that are required for conducting the riparian assessment (e.g., RMAs, land cover), as well as naming convention and data format standards that are consistent with pre-existing provincial data sets (e.g., Wetland Inventory, HUC datasets). In this way, secondary information can be derived or complied, which can be used to monitor, manage, and improve riparian areas across the province.

In this section, we provide recommendations for data standards for conducting a GIS-based riparian assessment. When defining data standards, two levels of standards have been considered :

- Minimum data standards – minimum standards outline the minimum set of data elements, their associated attributes, and processing standards that are agreed upon for mandatory collection and reporting at the provincial level. Providing minimum standards ensures that compiled data will be accurate, consistent, and comparable across space and over time
- Best practices or best endeavours – provide guidelines on developing data elements or performing data processes that are not necessarily mandated or enforced, but are recommended as a best practice. Best practices may become standards over time as spatial data and spatial data technologies improve in the future.

We consider standards for the key components of the GIS-based riparian intactness assessment method, including: land cover, hydrography and water boundaries, riparian management areas, and assessment deliverables. We also provide thoughts and recommendations regarding potential validation objectives and techniques.

9.1. Land Cover

The land cover is the foundation of a GIS-based riparian assessment, given that it is the primary source of information used to quantify the intactness metrics; therefore, the accuracy of the riparian assessment is directly related to the quality and accuracy of the land cover. In rare cases, a pre-existing land cover layer may be available to perform an assessment; however, in most cases, an up-to-date land cover will need to be created, and this land cover must capture the appropriate size and detail of land cover features that are meaningful to the assessment of riparian areas. With this in mind, important standards to consider with respect to the land cover include spatial resolution (i.e., pixel size), thematic resolution (i.e., number and types of land cover classes), spectral resolution (i.e., number of image bands and spectral information), and date of the image (i.e., year and time of year) used to develop the land cover.

9.1.1. Minimum Standards

Spatial Resolution

The GIS method used to assess intactness in this project was developed using a land cover classification of SPOT imagery with a resolution of 6 m, and therefore, this should be the minimum standard for spatial resolution and the minimum mapping unit for any future riparian assessments applying this approach.

Thematic Resolution

The metrics used to calculate intactness are based on land cover classes that discern between forest/woody cover, natural open/low natural vegetation cover, natural exposed areas, open water, and human disturbance. Any land cover used to assess riparian areas using this GIS method should contain these classes as a minimum, adhering to the following class definitions:

1) Forest/woody cover: areas with tree and shrub cover;
2) Natural open/low natural vegetation cover: naturally non-wooded areas predominantly covered by grasses or forbs;
3) Natural exposed: naturally non-vegetated areas of bare rock/mineral soil or sand. Of particular note here is the difficulty of differentiating naturally sandy shorelines from areas that may have been constructed or modified by human activities, which is not possible without manual interpretation and some knowledge of the previous condition of the shoreline prior to human development;
4) Open water: areas dominated by open water, including areas covered by floating vegetation;
5) Human disturbance: vegetated or non-vegetated areas that have been disturbed or modified by human use or human presence. Vegetated areas include agriculture use such as pasture or crops, cleared areas, and manicured areas (e.g., lawns, gardens), and non-vegetated areas include built-up areas and man-made features (e.g., buildings, roads).

Further, a minimum standard should be defined for the accuracy (i.e., validation) of the land cover. The accuracy of the land cover should be highest adjacent to the water bodies and water courses included in the assessment. A single standard overall accuracy (e.g., overall accuracy) may be defined, or more detailed and defined class-specific accuracies (e.g., omission and commission as determined from a confusion matrix) could be prescribed.

Spectral Resolution

Images or imagery used to develop the land cover must have the necessary spectral information to accurately differentiate between forest/woody cover, natural open cover, and human disturbance. What determines an appropriate image/imagery type (e.g., black and white air photo versus multispectral satellite imagery) will depend in part on the study area size and location and the chosen classification method (e.g., manual delineation, automated classification methods). Therefore, as long as the required classes (forest/woody cover, natural open/low natural vegetation cover, natural exposed areas, open water, and human disturbance) are distinguishable in the chosen imagery, then the image is suitable to assess intactness.

Image Date

The most up-to-date imagery available should be used to develop the land cover. Images or imagery used to develop the land cover must be from a time of year in which a representative amount of natural vegetation cover is growing and detectable. If an existing classification is being used, it should be acknowledged that the assessment is assessing past conditions representative of the year that the classification was generated, or the existing classification should be updated/edited using current images.

9.1.2. Best Practices

Spatial Resolution

Higher spatial resolution imagery may provide more spatial detail, although whether the increase in spatial detail has a significant impact on the overall assessment of intactness is as of yet untested. As the availability of higher spatial resolution imagery increases, the comparability of assessments at different scales should be tested to ensure different assessments can be compared. Currently, we suggest that when high spatial resolution images or imagery are available (e.g., high resolution air photos, WorldView) they can be applied when assessing the accuracy of a land cover classification or when assessing metric scores and overall intactness scores.

Thematic Resolution

Land cover classifications may be developed that have more land cover or land use classes, especially in cases where the land cover may be used in multiple types of projects or assessments. We suggest that in the initial stages of the classification when class labels are being defined, that "sub-classes" are selected that can easily and logically be aggregated into the classes required to assess riparian intactness. For example, a classification could include the more detailed classes of deciduous forest, coniferous forest, and shrubs, which could be aggregated into forest/woody cover for the purposes of assessing intactness.

It should also be recognized that as the availability of high spatial and spectral resolution imagery improves, so will the ability to resolve more land cover classes (e.g., wetlands by type, different types of human disturbance). These finer detailed classifications should also look to government mapping standards to define sub-classes to ensure newly developed datasets are complimentary to and can be merged with existing datasets. If and how more specific and detailed classes affect or improve the assessment, or if they should change how intactness is quantified, should be an ongoing area of research and testing.

Spectral Resolution

Relying on one type of information (e.g., one satellite image) to generate a land cover can limit the accuracy of and increase the confusion between certain landscape classes (e.g., pasture and natural low vegetation cover). This confusion can be expected to increase as the thematic resolution of the land cover classification increases. Increasing the amount of information contributing to developing the land cover, either by leveraging other image products (e.g., other satellite images, orthophotos, synthetic aperture radar) or other data products (e.g., Alberta base features, human footprint data) can help to improve class accuracy. Whenever possible, the use of ancillary sources of information should be considered in order to inform and assess the land cover classification and to ensure that the metrics are being quantified as accurately as possible.

Image Date

Depending on the size and location of the study area, more than one image may be required to create a land cover that completely covers the area of interest. When more than one image is required to cover a study area, imagery from the same year and time of year should be used. Using images from the same time of year across years (e.g., late April 2016 and early May 2017) is preferable to using images from the same year from largely different months (e.g., April and August), so that the amount and type of vegetation cover are relatively similar and thus comparable across space.

9.2. Hydrography & Water Boundaries

The GIS-based riparian assessment method is based on a buffer that extends out from the edge of the bank of the waterbody or watercourse of interest. The spatial delineation of the water boundary and how accurate it is have large implications on the accuracy of the intactness score. Therefore, standards need to be set that ensure that the extent of the riparian area is being accurately captured and quantified in any assessment. Additionally, many water features in the province are “unnamed” or share names with another water feature; if a provincial inventory of riparian areas is desired, a system to uniquely identify waterbodies and watercourses is required.

9.2.1. Minimum Standards

Several pre-existing data sources exist that define the boundaries of waterbodies and paths of water courses; however, the accuracy of these data ranges dramatically. We suggest a minimum accuracy standard for lake boundaries and watercourses of +/- 5 m accuracy based on the location of the open water boundary within the images being used to develop the classification. This will mean that in many cases, existing data will need to be edited or new boundaries developed to ensure assessments are representative and accurate. Further to the implementation of this standard should be the consideration of hydrological connections (e.g., littoral wetlands), emergent vegetation, and human disturbance (e.g., docks, channels, marinas), and how they are treated with respect to defining the water boundary.

There are several approaches to delineating water boundaries, such as manual interpretation or remote-sensing based methods (e.g., thresholding, edge-detection techniques). We suggest that the approach used in this project and previous NSWA projects (Fiera Biological 2018a and 2018b), in which the water class from the land cover classification was used to create a water boundary edge for lakes, be adopted as a standard for defining the water boundary. This approach ensures that the assessment of intactness does not falsely include areas of open water and underestimate the cover of natural vegetation or human disturbance. We would similarly suggest implementing our approach to editing watercourse locations and boundaries, in which watercourse locations were manually edited where spatial location did not match the classification imagery, and new watercourse boundaries were drawn in locations where the watercourse widens or passes through large areas of open water (> 1 ha) (Figure 20). Again, this tactic ensured that the assessment did not underestimate the cover of natural vegetation or human disturbance by falsely including areas of open water within the RMA boundary. Comparable approaches should be used for future assessments.

A naming convention for unnamed waterbodies and watercourses must be developed and implemented to ensure that assessed areas are uniquely identified, which will ensure that future repeat assessments can be linked easily and efficiently to previous assessments. For example, the Fisheries and Wildlife Management System (FWMIS) Stream and Lakes datasets include fields (e.g., WB_ID, GlobalID) that could be used to attribute and “tag” RMAs to correspond with existing spatial datasets.

9.2.2. Best Practices

Lakes and streams are dynamic over both the short and long term. It should be recognized that the spatial location of water boundaries will change over time, and therefore, the approach to how to compare assessments in areas where the water boundary has changed dramatically will need to be addressed in the future.

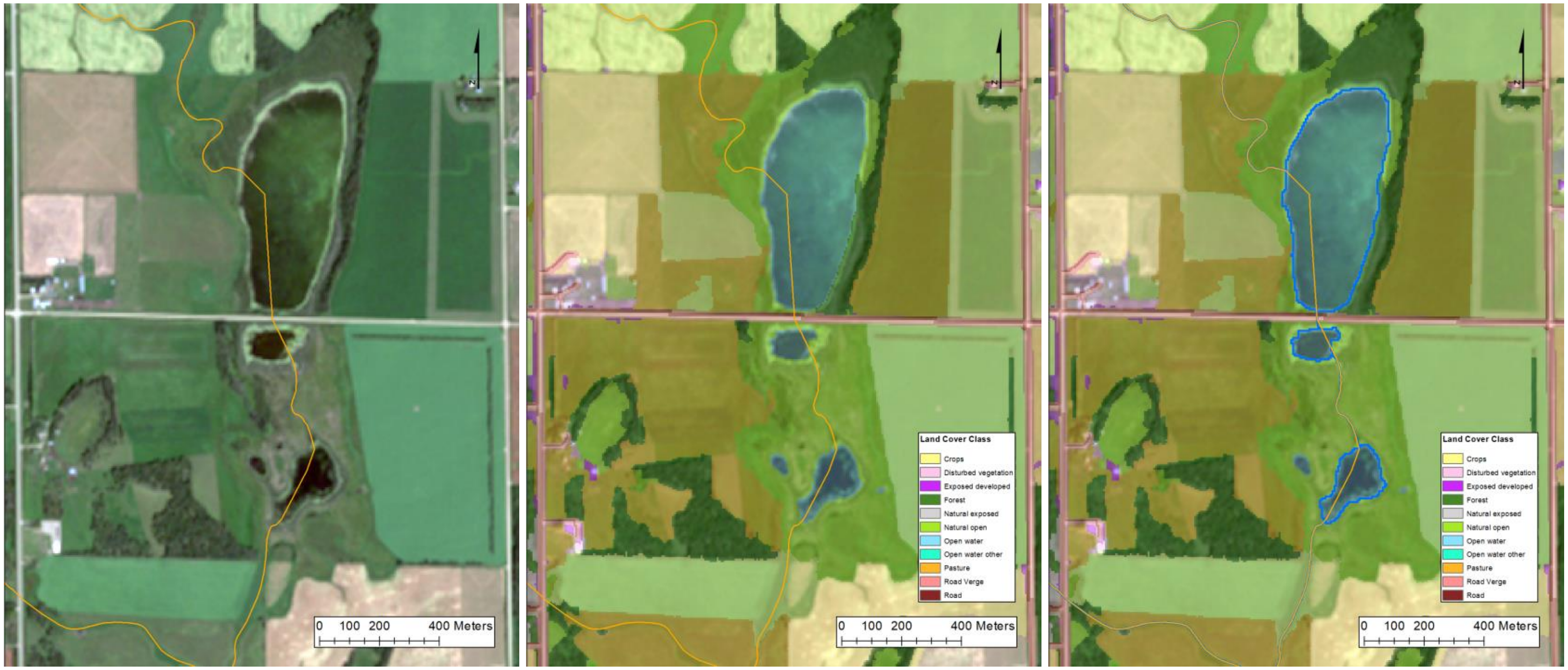


Figure 20. Suggested approach for modifying water boundaries to ensure the RMA correctly captures the riparian area and that metrics are calculated correctly. In the first figure, the orange line represents the existing hydrography stream layer. In the second figure, the land cover classification shows that parts of the existing stream delineation pass through large areas of open water (> 1 ha). A buffer generated using this delineation would cover primarily open water and would not capture the riparian zone. The third figure shows the edited water boundaries (blue lines) generated from the open water class of the land cover classification. This edited boundary now captures the riparian area and provides a better assessment of intactness. The same technique would be applied to lake boundaries.

9.3. Riparian Management Areas

The riparian management area (RMA) constitutes the unit of analysis for a GIS-based intactness assessment, and the "best approach" for defining the spatial extent of an RMA is highly debatable; however the RMA definition must balance ecological relevance with what is possible and practical within a GIS environment from a technical and processing perspective. The length and width of an RMA can be specified by either designating a fixed value or by allowing the value to vary. Therefore, there are four possible ways to delineate RMAs: fixed length and fixed width; fixed length and variable width; variable length and fixed width; or variable length and variable width. Each approach has benefits and limitations with respect to computational complexity and how well it replicates the location and extent of riparian habitat.

9.3.1. Minimum Standards

A methodology for defining RMAs should be standardized and required for future riparian assessments to ensure assessments are comparable. Choice of an approach should consider both computational complexity and the universality of the method (i.e., ability for any group to use the method). A repeatable and objective semi-automated method for developing RMAs has been developed as part of this project and previous NSWA riparian assessment projects (Fiera Biological 2018a and 2018b). We suggest the adoption of this method since it would permit integration with the results from assessments performed previously in other watersheds (e.g., Modeste, Sturgeon, Strawberry). This method uses a fixed width of 50 m and a variable length based on the proportion of natural cover in close proximity to the water boundary and has also validated well against videography-based riparian assessments. Alternative models have been developed that generate a variable width riparian area; however, such models are either computationally expensive, or require input data that are not available for the entire province (e.g., historic water levels, flood models).

9.4. Derived Data & Deliverables

The results of a riparian assessment will ultimately be delivered to the province so that they may be compiled with existing assessment results. Receiving data in standardized formats and with appropriately detailed information describing the data and the methods used to perform the assessment will ensure that riparian assessments are comparable spatially and temporally.

9.4.1. Minimum Standards

Data Files

The required data files for delivery to the province should be defined (e.g., all data products versus only RMAs with scores), and the preferred data format should be specified (e.g., shapefiles versus geodatabases, spatial reference system). As well, for each spatial data product, a standardized set of data attributes could be outlined (e.g., included fields, field names, data types, naming conventions for attributes). For the purposes of this project and to coincide with previous NSWA datasets, datasets have included both individual metric scores and final continuous and categorical intactness scores. An example of the field names and a description of the attributes that were included in the spatial data that were delivered for this project is provided in Table 9.

Table 9. Example of the field names and a description of each field for the attributes included in the spatial data delivered as part of this project.

Field Name	Field Description
BID	Unique ID field used to link buffers to RMA segments
Bank	Side of bank (L - left or R - right)
RMA_Length	Length (km) of the RMA associated with the buffer
VegCover	Percent cover of all vegetated land cover classes within RMA; ranges from 0% to 100%
WoodyCover	Percent cover of all land cover classes within RMA that contain woody vegetation; ranges from 0% to 100%
HumanCover	Percent cover of all anthropogenic land cover classes within RMA; ranges from 0% to 100%
FinalScore	Final aggregated and weighted Intactness score calculated from the VegCover, WoodyCover and HumanCover values; ranges from 0% to 100%
Intactness	Intactness category (High, Moderate, Low, Very Low)
Name	Name of water body or water course. Unnamed waterbodies or watercourses should be designated as “Unnamed” and assigned a unique number

Metadata

To maintain consistency with other provincial datasets, Provincial metadata requirements and standards should be outlined and included as part of any request for proposals or request for services.

Reporting

Along with any delivery of data and results, a standard should be set for the required level and detail of any reports or written documents that accompany the spatial data. This may include requirements to detail methods used for developing the land cover classification, details on acquisition and use of any ancillary data, reporting of land cover accuracy, details on the methods used to define water boundaries, and any other information that may be deemed important to the province or end users of the data.

9.4.2. Best Practices

Data Files

The future use or other possible uses of the data may be considered, such as through integration into online webmaps or portals. Preparing data to allow for easy integration into data-sharing platforms or for use in other projects or analyses will increase the overall usability and value of the data.

Reporting

While GIS-based riparian assessments are currently in a “baseline” determination phase, there may be opportunities to compare assessments to previous, alternative-format assessments (e.g., videography), or in the future, to compare baseline and “current” conditions. Defining methods to compare disparate assessments and comparable assessments will become increasingly important as the prevalence of GIS-based riparian assessments increases.

9.5. Validation

The GIS-based approach for assessing intactness was originally tested and validated against videography assessments and performed very well (accuracy of 76%). With the goal and scale of the GIS-based approach in mind, any validation would be best directed by focusing on assessing the accuracy of the metrics (i.e., the land cover classification) and by testing the ability of the approach to accurately capture the relative differences in intactness of RMAs both locally (e.g., the shoreline of a single lake) and regionally (e.g., among lakes or watersheds). Additionally, the class breaks applied to define the intactness categories could be evaluated to confirm whether the breaks in the distribution of categorical scores align with stakeholder-perceived levels of intactness.

The accuracy of the land cover can be assessed in many different ways. Overall classification accuracy and class accuracies (see Section 9.1) provide a reliable assessment of how accurately the metrics are being quantified. Further validation to this could involve comparisons of the classification to higher resolution imagery, or additional accuracy assessments based on a random selection of classified pixels that are validated against high resolution-truthed (e.g., drone-collected imagery) or ground-truthed data.

The hypothetical ideal for validation has and will likely continue to be “field validation”, in which an assessed location is visited in person on the ground and this assessment is considered to be the most accurate representation of the condition of the riparian area. It should be noted, however, that any field validation of riparian areas is likely to be limited in coverage and in locations (e.g., determined by private landowners). Additionally, the scale at which this assessment method is performed and the types of metrics used (i.e., percent cover of broad classes) make applying current fine-scale assessments as a validation method (e.g., Cows and Fish) or designing a new field validation protocol challenging. For example, for an RMA that is 600 m long and 50 m wide, how does one feasibly or accurately measure the percent cover of natural vegetation on the ground? How does one use a metric that assesses weed cover to validate GIS-calculated human disturbance? We suggest that the approach to designing any validation method be considered thoughtfully and take into account the goal and purpose of the GIS-based method.

One alternative to assessing final metric scores and intactness scores and categories for the RMAs would be to use a field campaign to instead assess where or for what types of land use/land cover the remote-sensing based approach may be over or under-estimating condition. For example, there may be areas where canopy cover is obscuring human footprint that may be impacting the riparian area, or the amount of impact or use of sandy beaches may not be discernable from imagery. In these cases, field visits would help to inform users of the intactness data and aide in ameliorating discrepancies between the coarse-scale assessment from above and fine-scale assessment on the ground.

10.0 Conclusion

The overall goal of this project was to quantify and characterize the intactness of riparian management areas within four lake watersheds in the North Saskatchewan region, and to establish standards for conducting riparian assessments using a GIS-based method.

The results of this work provide the Government of Alberta with an overview of the status of riparian areas in Pigeon, Gull, Sylvan, and Buffalo Lake watersheds, the results of which were generated using an objective, transparent, and repeatable method. This provides a foundation of scientific evidence upon which to track change in these watersheds through time, and compare condition across watersheds in different regions of the province.

In total, 874.1 km of shoreline was assessed as part of this study, with the Pigeon and Sylvan Lake watersheds having the greatest proportion of waterbody shoreline assessed as High Intactness. The Gull and Buffalo Lake watersheds had the greatest proportion of shoreline classified as Very Low Intactness, which combined represents over 200 km of shoreline. These results provide important information to land managers, allowing them to focus management and conservation activities within the watersheds, and providing information with which to reliably track change in condition through time.

10.1. Closure

This report was written by:

Shari Clare, PhD, PBiol
Director, Sr. Biologist

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

Bing Lu, PhD
Sr. Remote Sensing Scientist

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