
# Regional Riparian Spatial Analysis for Restoration Prioritization Technical Report

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Prepared for: Regional District of Nanaimo

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# EXECUTIVE SUMMARY

Healthy riparian areas serve many functions that, under the pressures of climate change, are essential to the functioning of both human infrastructure and natural ecosystems. They play a key role in regulating microclimates and water quality, prevent riverbank erosion, promote soil stability, support aquatic and terrestrial food webs, and provide habitat for a wide range of aquatic, amphibious, and terrestrial organisms. In response to increased air and water temperatures, prolonged drought periods, and increased frequency of high-intensity rainfall events, the Regional District of Nanaimo (RDN) has initiated efforts to prioritize the restoration of riparian areas through the Regional Drinking Water and Watershed Protection (DWWP) Program. To better understand the current state of riparian conditions, the RDN initiated a Regional Riparian Spatial Analysis for Restoration Prioritization of 47 priority watercourses (the "Project").

The intent of the Project is to spatially analyze the current conditions of riparian areas within the RDN and create a more comprehensive understanding of priority locations for potential restoration efforts. The Project is located within the Coast Salish traditional territory of the K'omoks, Qualicum, Snaw-naw-as, and Snuneymuxw First Nations and encompasses the entire area bordered by the Nanaimo Airport to the south, Gabriola Island to the east, Deep Bay to the north, and MacMillan Provincial Park to the west, inclusive of all municipalities and Electoral Areas.

The objectives of the Project included compilation of existing datasets, mapping and analysis of functional riparian cover, identifying priority areas for restoration, creating a prioritization scheme using a defensible methodology, and developing an interactive map tool that incorporates relevant supporting data enabling stakeholders to interact with the results.

A series of attributes were used to describe the current condition of riparian cover. Attributes included land cover classification, biogeoclimatic units, ecosystem attribution (i.e., site series and site deciles), successional status, structural stage, crown closure, canopy height, soil parent material, soil texture class, disturbance, potential vegetation competition severity, potential vegetation complex, autogenetic regeneration potential, and zones of concern. Linework and labelling were completed at a 1:5,000 scale, which allowed for the delineation of small ecologically significant features. A total of 5,409 polygons were delineated over 22,754.3 hectares (ha).

The restoration prioritization scheme was developed for the riparian corridors by assessing eight parameters associated with riparian condition. The parameters included disturbance, zones of concern, vegetation cover, terrestrial habitat cover and continuity, vegetation complexity and structural diversity, soil parent material and texture, water quality, and climate. The main selection criteria were based on accuracy of parameter determination and its potential strength of correlation to riparian ecosystem function. A total of 983 (18%) polygons were identified as priority areas for restoration efforts.

This Project has several key strengths, including a detailed riparian ecosystem inventory, incorporation of LiDAR derived data, an adaptable prioritization scheme built upon expert opinion, and an interactive map tool. Additionally, future recommendations are discussed, including how to incorporate property ownership, ecosystem resilience, and priority ecosystems into future iterations of this Project.

## Table of Contents

## List of Figures

## List of Tables

# LIST OF ACRONYMS

| Acronym | Description |
|---|---|
| A | Anthropogenic |
| a.s.l | Above Sea Level |
| ArcGIS | Aeronautical Reconnaissance Coverage Geographic Information System |
| BC | British Columbia |
| BC CDC | British Columbia Conservation Data Centre |
| BEC | Biogeoclimatic Ecosystem Classification |
| BGC | Biogeoclimatic |
| CDF | Coastal Douglas-fir |
| CDFmm | Coastal Douglas-fir Moist Maritime Subzone |
| Chartwell | Chartwell Resource Group Ltd. |
| CHM | Canopy Height Model |
| CM | Canopy Model |
| CMA | Coastal Mountain-heather Alpine |
| CMAunp | Coastal Mountain-heather, Alpine Undifferentiated and Parkland |
| CR | Cropland |
| Cw | western redcedar |
| CWH | Coastal Western Hemlock |
| CWHmm2 | Coastal Western Hemlock Montane Moist Maritime |
| CWHxm | Coastal Western Hemlock Very Dry Maritime |
| CWHxm1 | Coastal Western Hemlock Eastern Very Dry Maritime Variant |
| CWHxm2 | Coastal Western Hemlock Western Very Dry Maritime Variant |
| CWMN | Community Watershed Monitoring Network |
| DEM | Digital Elevation Model |
| DWWP | Regional Drinking Water and Watershed Protection |
| EMS | Environmental Monitoring System |
| ES | Exposed Soil |
| F | Fire |
| FTEN | Forest Tenure Road Section Lines |
| GIS | Geographical Information System |
| GR | Grassland |
| Ha | Hectare |
| HD | Highly Degraded |
| HE | Herbland |
| L | Logging |
| LA | Lake |
| LCC | Land Cover Classification |
| LiDAR | Light Detection and Ranging |
| LM | Local Maxima |
| LMH | Land Management Handbook |

| Acronym | Description |
|---|---|
| McTavish | McTavish Resource and Management Consultants Ltd. |
| MH | Mountain Hemlock |
| MHmm1 | Windward Moist Maritime Mountain Hemlock |
| OW | Open Water |
| PD | Pond |
| RDN | Regional District of Nanaimo |
| REM | Relative Elevation Model |
| RR | Rural Residential |
| RZ | Road Surfaces |
| S | Soil |
| SD | Somewhat Degraded |
| SEI | Sensitive Ecosystem Inventory |
| SSFP | Stewardship Seed Funding Program |
| STS | Structural Stage |
| T | Terrain |
| TC | Coniferous Forest |
| TEM | Terrestrial Ecosystem Mapping |
| TM | Mixed Forest |
| TRIM | Terrain Resource Information Management |
| UBC | University of British Columbia |
| UR | Urban |
| VRI | Vegetation Resource Inventory |
| Wf | Westland Fen |
| Wi | Wind |
| ZOC | Zones of Concerns |

# 1.0 INTRODUCTION

Identifying riparian areas and their features and functions is important, especially in our changing climate. Riparian areas can be described as areas of moisture-loving vegetation that grow along the edge of a natural water boundary. They occur on the banks of streams, lakes, and wetlands and include areas dominated by continuous high moisture content and the adjacent upland vegetation that exerts an influence on it (BC Environment 1995). Healthy riparian areas serve many functions by playing a key role in regulating microclimates and water quality, preventing riverbank erosion, promoting soil stability, supporting the aquatic and terrestrial food webs, and providing habitat for a wide range of aquatic, amphibious, and terrestrial organisms (Capon 2020). Healthy riparian areas often contain the highest number of plant and animal species found within a forested ecosystem and are often more diverse than the watercourses themselves (BC Environment 1995, Svejcar 1997). Riparian areas also provide linkages through the landscape, connecting hillsides to stream bottoms and upper headwaters to lower valley bottoms; however, the exact boundary of a riparian area can be difficult to delineate due to the transitional nature of upland ecosystems (Hillard and Reedyk 2020).

Streams and riparian areas are sensitive to climate and land-cover change. Under the pressures of climate change and expanding urban centers, it is well documented that the volume and rate of water entering streams are increasing, which is intensifying the risk of erosion, scour, and the alteration of channel dimensions (e.g., bankfull width, depth) (Montgomery and Buffington 1998; Wilhere et al. 2017). In addition, warmer conditions and altered forest hydrology may combine to reduce low flows during the growing season, potentially fragmenting aquatic, and terrestrial wildlife and ecological communities. Restoring stream channel form and function and preparing riparian systems to absorb additional climate-related stresses may help reduce the risks of erosion, channel instability, and degradation of aquatic and riparian habitat (Williams et al. 2015, Palmer et al. 2009).

As a result of climate change, the Regional District of Nanaimo (RDN) has been experiencing increases in air and water temperatures, prolonged drought periods, and increased frequency of high intensity rainfall events. In response, the RDN has initiated efforts to prioritize the restoration of riparian areas through the Regional Drinking Water and Watershed Protection (DWWP) Program.

To support a better understanding of the state of the creeks, rivers, and streams in the RDN, the Community Watershed Monitoring Network (CWMN) conducts long-term monitoring as well as training and execution of physical stream assessments. In some cases, recommendations emerge from the results of CWMN monitoring for next steps to restore or enhance water quality and/or habitat viability in the assessed watercourses. The DWWP Program supports the efforts of stewardship groups like the CWMN that take community-level action to monitor, safeguard, and enhance local watersheds by offering funding for community projects through the Stewardship Seed Funding Program (SSFP). The intention of the SSFP is to support enhancement efforts that have been identified and recommended through the monitoring and assessment process.

To better understand the current state of riparian conditions and to prepare for additional climate-related effects, the RDN initiated a Regional Riparian Spatial Analysis for Restoration Prioritization of 47 priority watercourses (the "Project"). The intent of the Project is to spatially analyze the existing conditions of a selection of the RDN's watercourses to support a comprehensive understanding of priority locations for potential riparian restoration and inform applications of funds for similar efforts across the region. Historically, many riparian restoration programs have occurred without a framework to prioritize restoration efforts, which often resulted in uncertainty associated with policy decisions, poor and random implementation, and questionable success in terms of restoring important ecosystem functions (Timm et al. 2004).

## 1.1 Objectives

The primary goal of the Project was to provide an understanding of the current state of riparian conditions at the regional scale for selected watercourses within the RDN. To achieve this goal, the following objectives were set:

- Compile existing datasets to support the spatial analysis of current functional riparian cover levels across the RDN’s watercourses of interest;
- Map and analyze functional riparian cover, including length, width, depth, and quality of vegetative extents, to identify priority areas for restoration, enhancement, or improvement;
- Develop criteria for the prioritization of areas based on defensible ecological, geomorphological, climate change, regulatory frameworks, and other parameters as advised by the RDN;
- Present the results of the assessment by both catchment and corridor level in both map and tabulated formats; and
- Create an interactive map tool with the capacity to incorporate relevant supporting data (e.g., water quality monitoring locations, previous restoration sites, fish presence, eagle nest trees) to allow decision-makers, practitioners, and community members to interact with the results on multiple scales.

## 1.2 Project Area

The Project is located within the Coast Salish traditional territory of the K’omoks, Qualicum, Snaw-naw-as, and Snuneymuxw First Nations. It encompasses the entire area bordered by the Nanaimo Airport to the south, Gabriola Island to the east, Deep Bay to the north, and MacMillan Provincial Park to the west, inclusive of all municipalities and Electoral Areas. The Project area encompasses 47 watercourses that were chosen by the RDN based on the existence of ongoing water quality monitoring (**Figure 1**).

**Appendix I** provides a detailed list of the selected watercourses, comments on the associated stream data and the primary Environmental Monitoring System (EMS) code associated with the watercourses as well as any additional EMS codes that overlap the watercourses.


REGIONAL DISTRICT OF NANAIMO

Project: Riparian Spatial Analysis for Restoration Prioritization
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Figure 1
Overview of the Regional District of Nanaimo's Boundary and Selected Watercourses for Restoration Prioritization

# 2.0 METHODS

McTavish Resource and Management Consultants (McTavish) completed the following tasks to achieve the objectives of the Project:

1. Data Compilation – compilation of all potential datasets overlapping the area and determining their level of applicability to the Project.
2. Riparian Cover Analysis – creation of a land cover classification coding scheme to describe the current state of the riparian corridors and delineate the functional extent of riparian areas.
3. Restoration Prioritization – creation and application of a restoration prioritization ranking scheme.

## 2.1 Data Compilation

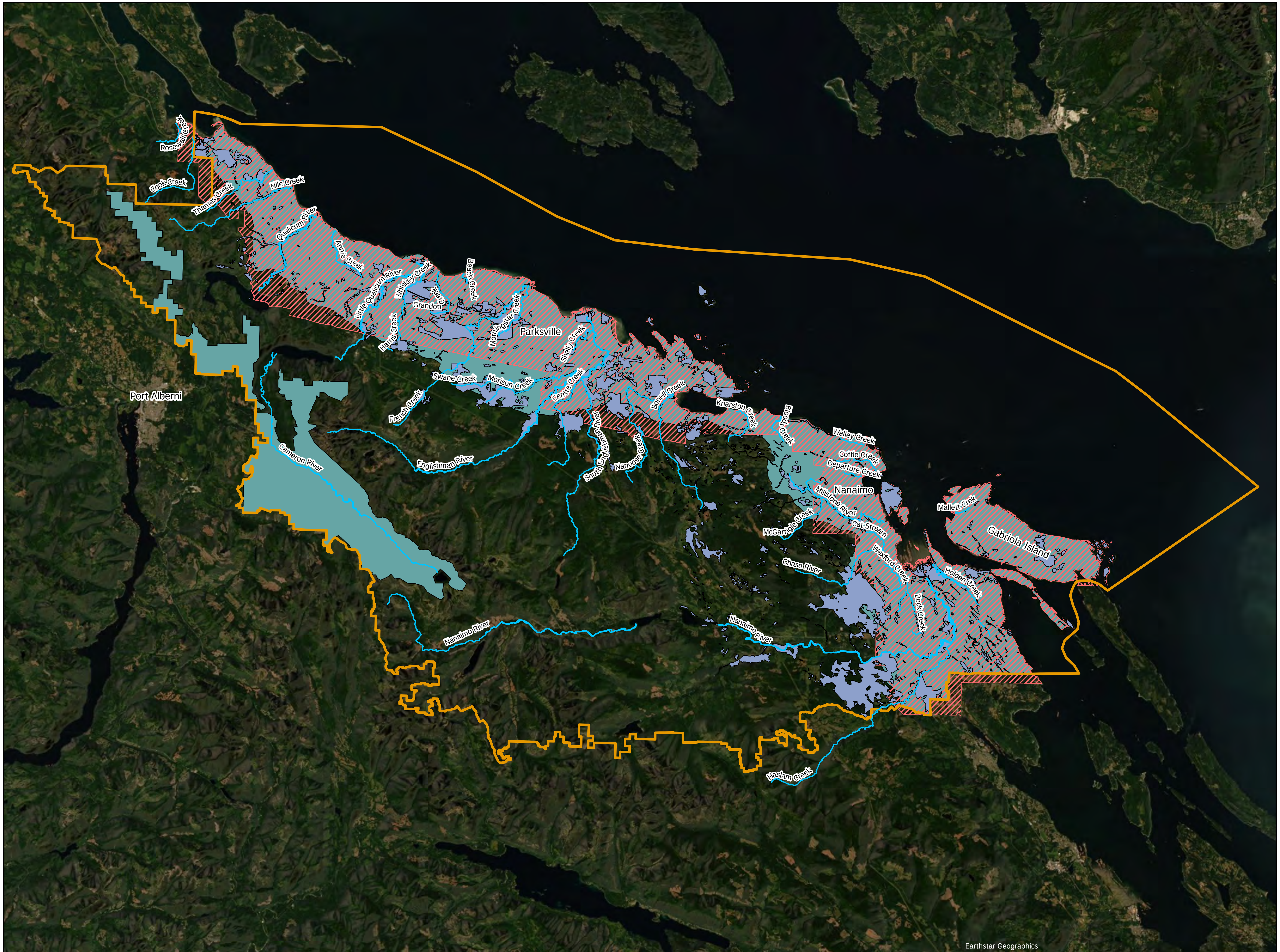
Data compilation included a review of potentially applicable layers from the RDN, DataBC, and LiDARBC. Data compilation focused on new and existing datasets that could be applicable through communication with RDN staff. **Table 1** provides a summary of the data used within the analysis.

Existing Terrestrial Ecosystem Mapping (TEM), Sensitive Ecosystem Inventory (SEI), and Light Detection and Ranging (LiDAR) provided limited coverage for the area (**Figure 2**). Spatial data was largely restricted to the coastline and inland by several hundred meters, depending on location. The Vegetation Resource Inventory (VRI) had complete coverage of the select watercourses.

Table 1: Summary of Data Sources

| Data | Definition | Data Source | Data Year |
|---|---|---|---|
| 2020 Aerial Photos | 15 cm aerial photography resolution. | RDN | 2020 |
| Terrestrial Ecosystem Mapping (TEM) | TEM of the Coastal Douglas-Fir Biogeoclimatic Zone. | DataBC | 2008 |
| Sensitive Ecosystem Inventory (SEI) | SEI for East Vancouver Island and Gulf Islands completed in 1993-97. | DataBC | 1993-97 |
| LiDAR | Light Detection and Ranging point cloud for a proportion of the area. | LidarBC | 2018, 2019 |
| Canopy Cover (25m) | The proportion of the forest covered by the vertical projection of the tree crowns. This data layer was derived from LiDAR for applicable areas and categorized into classes. | Chartwell Derived | 2022 |
| Canopy Height Model | Measurement of the height of trees above the ground topography. This data layer was derived from LiDAR for applicable areas and categorized within classes. | Chartwell Derived | 2022 |
| Community Watershed Monitoring (CWMN) Sites | Active and inactive community watershed monitoring locations. | RDN | 2022 |
| FTEN – Forest Tenure Roads | Reflection of operational activities for road sections contained within a road permit. | DataBC | 2022 |

| Data | Definition | Data Source | Data Year |
|---|---|---|---|
| RDN Boundary | Outline of the Regional District of Nanaimo boundary | Regional District of Nanaimo | 2022 |
| VRI (Vegetation Resource Inventory) | Vegetation cover from the Ministry of Forest. This layer provided information on age, projected age, and project canopy closure. | DataBC | 2020 |
| Watercourses - Other | All watercourses spatially identified within the Regional District of Nanaimo boundary. Watercourses linework are derived from TRIM, SHIM, and unknown sources. | Regional District of Nanaimo | 2022 |
| Watercourses - Selected | The watercourses that were selected for analysis (approx. 47 watercourses). Watercourse linework was derived from TRIM, SHIM, and unknown sources. | Regional District of Nanaimo | 2022 |
| BC Soils Information Finder Tool (SIFT) | Soil survey data, reports, and maps for Soils of Southern Vancouver Island. | DataBC | 1985 |
| Biogeoclimatic Ecosystem Classification (BEC) | BEC boundaries including Zone/Subzone/Variant/Phase. | DataBC | 2022 |




REGIONAL DISTRICT OF NANAIMO

Legend

- Regional District of Nanaimo Municipal Boundary
- Selected Watercourse
- SEI Boundary
- TEM Boundary
- LiDAR Boundary

N

0 2 4 8
Kilometers
Scale: 1:300,000

Project: Riparian Spatial Analysis for Restoration Prioritization
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Figure 2
Overview of LiDAR, Terrestrial Ecosystem Mapping, and Sensitive Ecosystem Inventory for the Project

## 2.2 Riparian Cover Analysis

A series of classification codes were developed for determining riparian cover (See **Appendix II** for a detailed list of codes and definitions). While most codes followed the provincial standards (**Table 2**), some were varied to better suit Project-specific needs.

Table 2: Terrestrial Ecosystem Standards and Documentation Used for Photo Interpretation Methods

| Manual Title | Author | Publication Year |
|---|---|---|
| A Field Guide for Site Identification and Interpretation for the Vancouver Forest Region (LMH 28) | Green, R. K. and Klinka, K. | 1994 |
| Standards for Terrestrial Ecosystem Mapping in British Columbia | Resources Inventory Committee (RIC) | 1997 |
| Wetlands of British Columbia: A Guide to Identification (LMH 52) | MacKenzie, W.H., Moran J.R. | 2004 |
| Biogeoclimatic Ecosystem Classification of Non-Forested Ecosystems in BC | MacKenzie, W.H. | 2012 |
| Field Manual for Describing Terrestrial Ecosystems 2$^{nd}$ Edition (LMH 25) | British Columbia Ministry of Forests and Range and British Columbia Ministry of Environment (BCMFR and BCMOE) | 2010 (Reprinted with updates 2015) |

All spatial analysis was completed within ArcGIS Pro 2.1. Additional data sources such as a Hillshade Model, 2 m digital elevation model (DEM) contours, existing TEM, VRI polygons, and soils polygons were used to assist with the delineation and attribution of polygons. Linework and labelling were completed at a 1:5,000 scale, which allowed for the delineation of small ecologically significant features such as wetlands, low bench flood plains, and isolated areas of disturbance.

Individual map polygons were primarily defined using land cover classification. Each polygon was then characterized by Biogeoclimatic Ecosystem Classification (BEC), site series, successional stage, structural stage, canopy height, vegetation density, soil parent material, soil texture, disturbance, potential of vegetation competition, competing vegetation complex, autogenic regeneration potential, and zones of concern.

### 2.2.1 Land Cover Classification

Land cover classification (LCC) was used to determine the primary composition of the functional riparian width. The LCC's were derived and modified from The B.C. Land Cover Classification Scheme (RIC 2022). Additional codes from Land Management Handbook (LMH) 25 (Province of B.C.: Field Manual for Describing Terrestrial Ecosystems [BCMFR and BCMOE 2010]) were also incorporated. Modification of LCC codes from provincial standards was based on the applicability of a code within the Project.

### 2.2.2 BEC Unit

The BEC units provide useful general information on vegetation, soils, and climate anticipated within an ecosystem. The BEC unit for each polygon was derived from BECv12 and was auto populated by overlaying the BEC unit area and the LCC polygons.

Refer to **Section 3.1.2** for a detailed description of the overlapping BEC units and codes for the Project.

### 2.2.3 Ecosystem Attribution

Each LCC polygon was labeled using provincial standards to describe vegetation, site condition, successional status, structural stage, and disturbance (RIC 1998, BCMFR and BCMOE 2010). Polygons were assigned up to three ecosystem types (i.e., components), each component was assigned a portion of the polygon area using deciles that add up to 10. However, pure polygons (i.e., 100% of one ecosystem type) were mapped whenever possible.

Ecosystem attribution for the polygons identified as forested was based on the 2-digit classification coding and descriptions in the Field Guide for Site Identification and Interpretation for the Vancouver Forest Region (LMH 28) (Green and Klinka 1994, BCMFLNRO 2017). Non-forested, sparsely vegetated/non-vegetated, and anthropogenic units not described in LMH 28 were classified following the modified BC correlated TEM code list (TEI Unit 2020) using two upper case letters.

Wetlands were classified either using the first two characters as letters which describe the type of wetland (i.e., the first letter uppercase, and the second lower). For example, a wetland mapped as Wf represents a wetland (W) fen (f).

### 2.2.4 Successional Status

An alphabetic successional status was assigned to each LCC polygon, except for units that did not require one (e.g., pond, road, urban, urban development, etc.). Successional status was derived directly from the LMH 25 classification. Determination of successional status was visually interpreted using a combination of height, estimated cover, and stand structure.

### 2.2.5 Structural Stage

A numerical structural stage designation was assigned to each LCC polygon, except for units that did not require one (e.g., pond, road, urban, urban development, etc.). Structural stage was defined from the LMH 25 classification; however, some codes were removed for simplification.

### 2.2.6 Crown Closure (Vegetation Density)

Vegetation density was based on crown closure and was assigned by two different methods, depending on the data available. In areas where LiDAR coverage was available, crown closure was derived from the point cloud and given a discreet value for each of the polygons. In areas where LiDAR data was not available, crown closure was attributed based upon the VRI attribute “crown_closure_class_cd.”

### 2.2.7 Canopy Height

Canopy height was assigned by three different methods, depending on the data available. In areas where LiDAR coverage was available, a Canopy Model (CM) was generated from the .LAZ files. The CM was smoothened to enhance local high values for subsequent extraction of Local Maxima (LM). A Canopy Height Model (CHM) was then created by subtracting a DEM, representing bare earth elevations. Any negative values in the CHM were assigned zero, while areas with no CM data received the corresponding DEM values. All raster datasets were a 1 m resolution. LM heights were then generated from the CHM and averaged for the polygon. Additionally, the smoothed CHM was averaged for the polygon and a discrete value was prescribed. In areas where the was no LiDAR coverage, the VRI "proj_height_class_cd_1" was used to attribute a canopy height class.

### 2.2.8 Soil Parent Material

Parent material for each of the polygons was derived from the previously mapped Soils of Southern Vancouver Island (Jungen 1985) dataset and assigned a single alphabetic code derived from the parent material classification scheme. The dominant parent material class, "PATM_1", was used. Soil polygons that did not align exactly with the LCC polygon boundaries were assigned the dominant parent material class.

### 2.2.9 Soil Texture Class

Soil textural classes were assigned a single alphabetic code and were based on three soil particle size groups:

- Coarse: sand, loamy sand and sandy loam
- Medium: loam, silt and silt loam
- Fine: clay, clay loam, silty clay, silty clay loam, sandy clay, sandy clay loam

Texture groups were derived from the previously mapped Soils of Southern Vancouver Island data set. To identify the texture class that overlapped the polygon, the "TEXT_1" attribute was used. Soil delineations that did not algin exactly with the polygon boundary were assigned the dominant textural class.

### 2.2.10 Disturbance

Areas of disturbance were identified according to their cause (e.g., human development, forest harvesting practices, fires, geomorphological processes, windthrow, soil related geological processes). Once a disturbance code had been applied, the potential vegetation severity, potential vegetation complex and autogenetic regeneration potential categories were attributed.

### 2.2.11 Potential Vegetation Competition Severity

Potential vegetation severity was derived from LMH 28 with a single alphabetic code. Potential vegetation severity was used to describe the potential for crop trees (i.e., commercial tree species) to be outcompeted by herb and woody shrub species. However, this was modified to focus on the overall development of the ecosystem component once it had been disturbed, rather than the development of crop trees.

### 2.2.12 Potential Vegetation Complex

Potential vegetation complex was derived from LMH 28 and given a single numeric code. Potential vegetation complex was used to describe one or more dominant native species that have the potential to affect the development of crop trees through the natural regeneration of shrubs. Like potential vegetation severity, this code was modified to focus on the development of the ecosystem component; for example, a shrub ecosystem can be highly beneficial for riparian areas.

The category “Mixed Shrub” was modified to also include the potential development of non-native or invasive species in highly urbanized areas or areas where cultivated fields exist. It is used as a default category when sites have departed from the natural forested ecosystem progression.

### 2.2.13 Autogenetic Regeneration Potential

Natural regeneration potential was derived and modified from Rodrigues et al. (2011) and given an alphabetic code. The ability of a polygon to naturally regenerate was based on the given condition and landscape context; has there been a permanent disturbance with no vegetation or a minor disturbance that has yet to regenerate a plant community.

### 2.2.14 Zones of Concern

Zones of concern were based on Rodrigues et al. (2011) terminology that highlighted areas that were either highly degraded or somewhat degraded forest fragments. This includes areas that have experienced a high level of degradation that would require intensive management, those that were becoming impinged by urban development and might require some level of protection, and those that require field assessment to determine if human activities have resulted in understory degradation.

## 2.3 Restoration Prioritization

Ecosystem restoration planning requires an integrated approach that considers the many components of a natural ecosystem. The aim of the restoration prioritization was to identify, through a suite of attributes, impairments and threats to the natural state of these ecosystems.

A restoration prioritization scheme was developed for each riparian polygon by assessing eight parameters associated with riparian condition. The parameters below are based upon research from a variety of sources. The main selection criteria were accuracy of parameter determination and its potential strength of correlation to riparian ecosystem function. Parameters are as follows:

1. Disturbance – Areas of recent disturbance (e.g., logging, fire, development, etc.) that may require mitigation efforts to aid in restoring ecosystem services and functions quicker than natural progression.
2. Zones of Concern – Areas identified as being degraded or impinged through land use activities where mitigation efforts could aid in restoring riparian function and condition.
3. Vegetation Cover – Sites with low natural cover where mitigation could provide or improve riparian function.
4. Terrestrial Habitat Cover and Continuity – Areas of low natural cover that could benefit from increased natural cover and act to connect areas of higher natural cover.
5. Vegetation Complexity and Structural Diversity – Plant communities that could benefit from mitigation efforts to increase species or structural diversity.
6. Soil Parent Materials and Texture – Areas with erodible soils or soils where natural plant succession might be hindered.

7. Water Quality – Areas with exceedances of water quality standards where mitigation could improve water quality.

8. Climate – Riparian corridors that may be more susceptible to climate change where mitigation efforts might help to retain ecosystem function.

Each of the eight (8) parameters were translated into general classes, "representative attributes", to express the parameters so that they could be determined from observation of orthophoto imagery. Representative attributes were divided into detailed subclasses, defined by interpretable ecosystem characteristics or combinations of characteristics. The division of the subclasses was based on successful approaches documented in literature. Each subclass was assigned a score, calculated from an assigned rank for the subclass and a weight. Weights, indicating relative importance, were assigned to each parameter. Scores for each of the 8 parameters were calculated and added to give an overall polygon score. Lower weighted scores identified areas more susceptible to disturbance or in need of potential restoration efforts**. Figure 3** below, provides an illustrated review of applying values to each polygon.

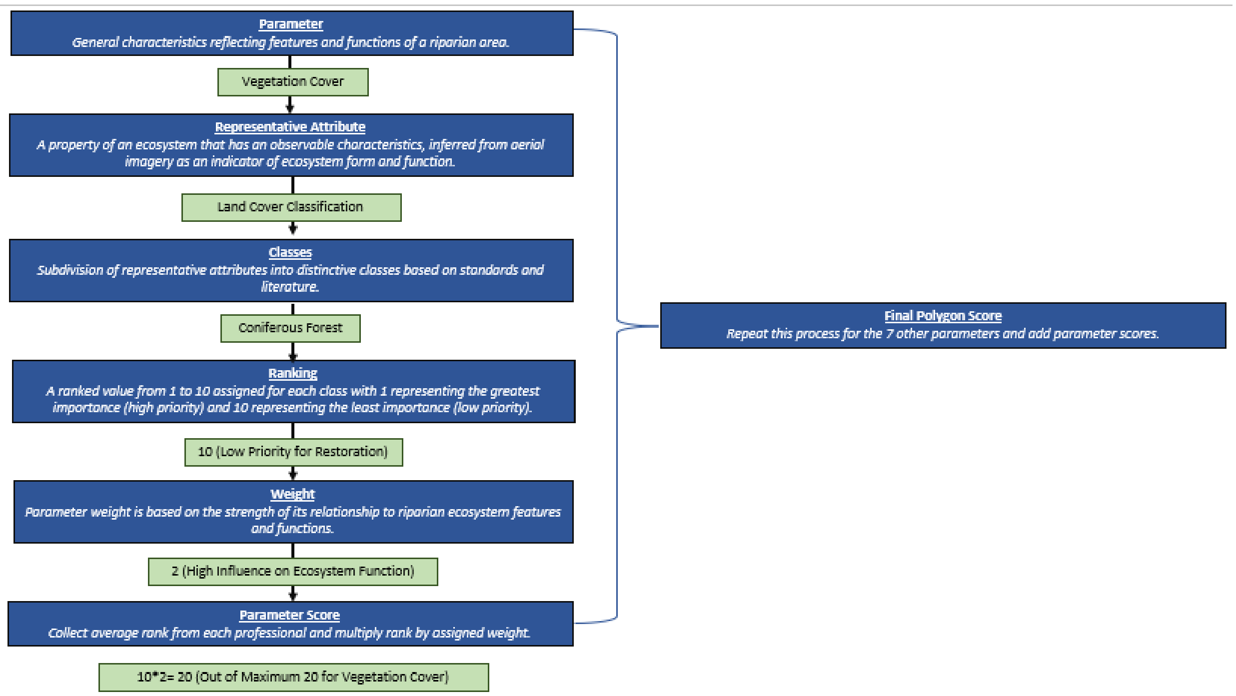


Figure 3: The Process for Assigning Values to a Parameter to Determine the Overall Prioritization Score with an Example for Vegetation Cover

All possible combinations of classes based on representative attributes of a particular parameter was created and scored individually by four (4) professionals experienced in assessing riparian function and condition, and restoration ecology for coastal ecosystems. Scoring for each of the classes was based on a perceived level stress that could occur to the features and functions of the riparian ecosystem represented in each polygon for that class of attribute.

Perceived stressors to riparian ecosystem condition include both anthropogenic and natural disturbances, alteration to various riparian attributes (lack of vegetation, exposed soil, presence refuse dumping, permanent structures, or land cover changes). Scores for each attribute were scaled from highest potential restoration priority, “1” to lowest restoration priority, “10.” **Table 3,** below, summarizes the parameter, the representative attribute used to establish classes, the potential riparian stressors that would results in that class being affected, and an example of how a score might be applied through logic.

Table 3: Representative Attributes and Their Associated Parameter, Along with Indicators of Riparian Stressors Observable in the Attribute for a Priority Restoration Rational

| Parameter | Representative Attribute | Indicators of Riparian Stressors | Priority Restoration Rational |
|---|---|---|---|
| Disturbance | • Disturbance<br>• Autogenetic Regeneration Potential | • Does the disturbance prevent natural growth of vegetation?<br>• Perceived level of severity of disturbance.<br>• Potential for invasive species colonization. | Areas identified as having a disturbance that may need restoration based on the site's capacity for autogenic regeneration receive a lower-ranking score. |
| Zones of Concern | Zone of Concern | • Areas noticeably impinged by development.<br>• Areas noticeably stripped of vegetation, exposed soil, and potential for erosion. | Areas emphasized as having a perceived immediate disruption to the features and functions of a riparian area receive a lower-ranking score. |
| Vegetation Cover | Land Cover Classification | • Areas that prevent growth of vegetation.<br>• Areas of exposed bare ground.<br>• Areas with increased soil compaction.<br>• Areas that are not considered natural environments (i.e., Roads, Urban Areas, Croplands). | Land cover types identified as being natural ecosystems receive a higher-ranking score. Land cover types that have been altered due to human disturbance receive a lower-ranking score. |
| Terrestrial Habitat Connectivity | Crown Closure | Reduction in tree/shrub cover that may have implications for species security. | Areas with a lack of crown closure receive a lower-ranking score. |
| Vegetation Complexity | • Structural Stage<br>• Crown Closure | Non-vegetated, pioneer seral, and young seral stand tend to be less complex and lack features of mature and old forests that may be necessary to the features and functions of a riparian area. | Areas that lack structural diversity, perceived stand complexity, and stand dynamics receive a lower-ranking score. |
| Soils | • Parent Material<br>• Textural Class | Course fragment content and soils with erodibility that may cause sedimentation should the area lack vegetation cover. | Parent material and soil textures with a higher chance for erodibility and sedimentation were given a higher-ranking score. |

| Parameter | Representative Attribute | Indicators of Riparian Stressors | Priority Restoration Rational |
|---|---|---|---|
| Water Quality[1] | • Temperature<br>• Turbidity | Poor water quality affecting the function of the stream. | Ranks were assigned based on a binary metric of pass (score of 10) /fail (score of 1) for all polygons within a 500 m upstream of the sampling station. |
| Climate | BEC Unit | Shifting BEC units that may affect vegetation re-growth and colonization. | BEC areas that were anticipated to expand received a higher ranking than those that were expected to contract. |

### 2.3.1 Riparian Site Priority: Weights and Scores

Weights were assigned to each of the 8 parameters. Weights were based on the perceived relative importance of each parameter to the function of a riparian ecosystems. The parameter with the greatest potential for identifying areas of restoration priority (i.e., Disturbance and Zone of Disturbance) was given a weighted rank of one while the least potential for identifying areas of restoration was given a rank of no more than seven. The final weights were calculated by averaging the individual weights assigned by the professionals.

Scores for each of the riparian cover polygons were assigned using script in Python 2.7 that was developed for the Project. The final scores for each polygon were calculated as the sum of the product of the weight for the trait times the sum of the ranks of the parameters, as seen below:

$$\text{SCORE} = \Sigma\, [W_i\, (\Sigma\, R_j)]$$

# 3.0 RESULTS AND DISCUSSION

There is no debate that riparian areas are an essential component of healthy watercourses and diverse upland ecosystems; however, riparian area protection methods are highly variable. Depending on the priorities of the governing body and their capacity to enforce and oversee implementation, riparian buffers will vary in size and shape and will have different levels of protection. As the results of the Project can inform the RDN's riparian area protection efforts, a discussion of the findings is required to provide the details and context necessary for successful implementation.

## 3.1 Riparian Cover

Riparian areas are diverse ecosystems that provide numerous, valuable ecosystem functions. Various methodologies have been used to determine a riparian buffer, area, or setback distance from a watercourse to quantify and qualify the features and functions. There are three primary methods for delineating riparian corridors: (1) fixed-width delineation, (2) setback distance, and (3) variable width approach.

[1] Assessed through point data provided by the RDN.

Fixed-width riparian delineations vary and are typically based on an arbitrary value deemed to have some ecological influence on the stream or a scientific understanding of the functions of feature of interest. Alternatively, they can be policy driven. In most applications, fixed-width delineation is not considered an appropriate approach, especially when considering floodplain units or dynamic stream environments (Holmes and Goebel 2010). This method can produce significant errors when determining riparian characteristics, as it lacks the ability to identify the functional extent of a riparian area and often attempts to determine a “minimum width” (MacNally et al. 2008; Holmes and Goebel 2010). Additionally, this method has little standing in the professional industry as it does not provide adequate protection on a forestry management level and fails to consider geomorphology or stream order (Stutter et al., 2021; De Sosa et al., 2017). Recent methodologies avoid fixed-width approaches as they can be inaccurate due to the poor and inconsistent relationships between riparian width and ecological functionality (Abood and Maclean 2011; Abood et al., 2012; Aunan et al. 2005).

Watercourse setbacks are typically established with a fixed buffer; however, the distance varies depending on the features and functions that are to be identified. This method is applied under the *Riparian Areas Protection Regulation* (B.C. Reg. 11/2021), with the setback being contingent upon the stream morphology and slope (e.g., channel type, gradient). Similar to fixed-width buffers, watercourse setbacks do not necessarily capture the functional extent of the riparian area and are often viewed as a minimum width by professionals (MacNally et al. 2008).

The variable width approach is typically used for site-specific conditions and is contingent on data availability and funding within the region of interest. It can be a challenging method to implement. There are a variety of methods used when determining the variable width, and typically the spatial delineation of the riparian area is contingent upon the ecological services that are being analyzed (de Sosa et al. 2017). Many of the methods use changes in plant communities, vegetation patterns, presence of wetland species, amphibian habitat linkages, tree heights, and minimum width to conserve maximum species richness as well as the sharp transitions between riparian areas and upslope vegetation in relation to stream order (Mc Nally et al. 2008; Swanson and Franklin 1992). As there may not be a readily viewable relationship between the width of riparian vegetation and stream order, other factors such as local topography should be considered (Mc Nally et al. 2008). It has been recommended that delineation be carried out on a stream-by-stream basis and that a set distance is inappropriate (Mc Nally et al. 2008).

A variable-width buffer was applied to the riparian cover analysis of the Project to incorporate an accurate and representative view of the complexity and functions of the ecological communities surrounding given watercourses. To identify valuable ecosystem services, the ecological function of a complete unit was taken into consideration rather than a set width, which may or may not be ecologically based (Verry et al. 2004; Holmes and Goebel 2011). It was important to not view the watercourse as an independent variable. Riparian corridors typically varied from 30 m to 400 m away from the stream center line where LiDAR data was not available and the stream bankfull width where LiDAR data was available. A 30 m minimum on either side of the valley flood-prone area was instituted, which is consistent with approved methodologies (e.g., Verry et al. 2004); however, if there was a break in the natural ecosystem function from human caused disturbance mapping (i.e., roads, urban development, parks, etc.) riparian corridors were not mapped past that extent as they were considered functional breaks.

The quality of aerial photography influences the ability to map and analyze riparian vegetation along a given functional riparian width. Digital aerial photography with a pixel size of 1–2 m provides an accurate media for analyses. For this reason, satellite remote sensing data for riparian vegetation mapping is considerably more limiting than aerial photography due to the coarser spatial resolution (i.e., pixel size of 20 m or larger) (Yang 2007; Holmes and Goebel 2011). For the Project, the aerial imagery for the riparian cover analysis was from the year 2020 and had a 15 cm pixel resolution, making it more than adequate for delineating LCCs.

Overall, the detailed LCCs derived from the aerial imagery in conjunction with a variable width buffer allowed for a detailed approach on assessing the 2020 riparian conditions and subsequently establishing a prioritization matrix.

### 3.1.1 Land Cover Classification Results

A total of 5,409 polygons were mapped. The most frequently mapped LCC was Coniferous Forest (TC) with 2,083 polygons mapped (39%). Urban (UR) was the second most frequently mapped LCC with 695 polygons mapped (13%). The least mapped LCC was Grassland (GR) with only one polygon mapped. **Figure 4**, below, provides an overview of the distribution of LCC polygons mapped for the Project.

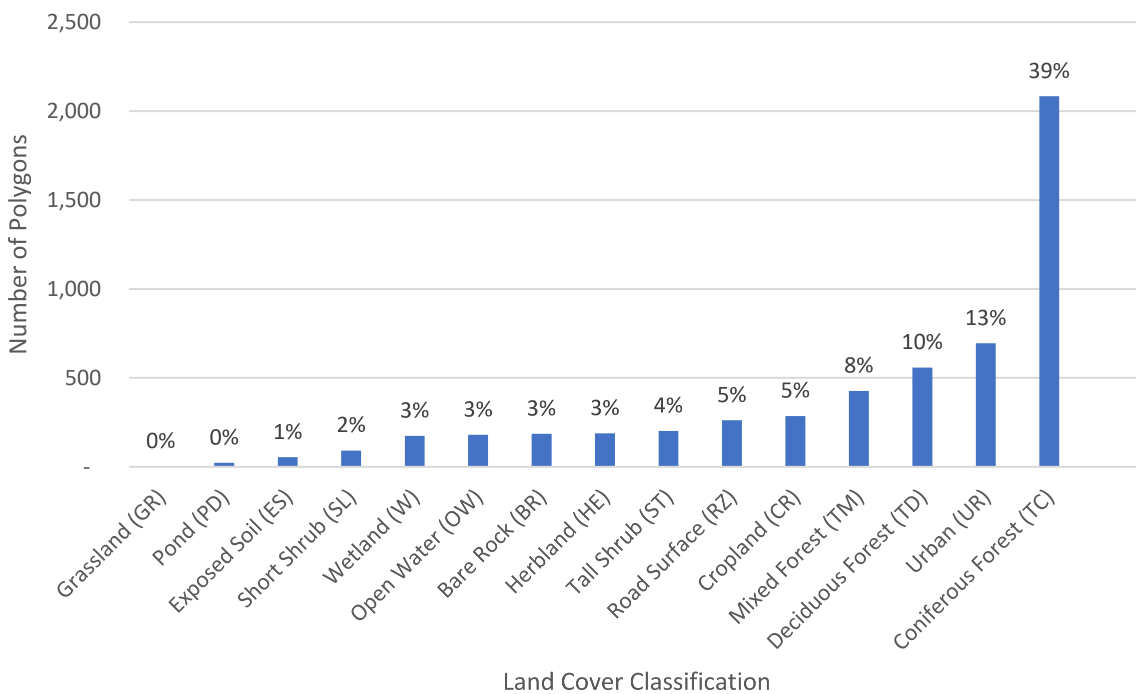


Figure 4: Number of Polygons Mapped per Land Cover Classification Category

The total number of hectares mapped was 227,538.8 ha, with Coniferous Forest (TC) representing approximately 55% of the mapped area. The rest of LCCs were mapped in less than 10% of the polygons. **Table 4** provides the summary of each land cover class mapped (i.e., total area, average area, maximum, and minimum area). The average polygon size was 42.1 ha, with the largest polygons being Coniferous Forest (TC), followed by Cropland (CR), and Mixed Forest (TM).

Table 4: Summary of Each Land Cover Class Mapped

| Land Cover Classification | Total Area (ha) | Average Polygon Area (ha) | Minimum Polygon Area (ha) | Maximum Polygon Area (ha) |
|---|---|---|---|---|
| Grassland (GR) | 0.9 | 0.9 | 0.9 | 0.9 |
| Pond (PD) | 56.1 | 2.4 | 0.1 | 28.7 |
| Exposed Soil (ES) | 139.3 | 2.6 | 0.0 | 41.6 |
| Short Shrub (SL) | 171.5 | 1.9 | 0.0 | 38.5 |
| Bare Rock (BR) | 249.8 | 1.3 | 0.0 | 72.5 |
| Tall Shrub (ST) | 266.0 | 1.3 | 0.0 | 35.7 |
| Herbland (HE) | 322.7 | 1.7 | 0.0 | 19.0 |
| Wetland (W) | 353.8 | 2.0 | 0.1 | 26.3 |
| Road Surface (RZ) | 429.4 | 1.6 | 0.0 | 23.8 |
| Open Water (OW) | 565.8 | 3.1 | 0.0 | 61.5 |
| Cropland (CR) | 1,636.6 | 5.7 | 0.1 | 133.8 |
| Urban (UR) | 1,725.2 | 2.5 | 0.0 | 140.4 |
| Deciduous Forest (TD) | 1,941.8 | 3.5 | 0.0 | 35.1 |
| Mixed Forest (TM) | 2,228.4 | 5.2 | 0.1 | 44.6 |
| Coniferous Forest (CF) | 12,666.9 | 6.1 | 0.0 | 131.1 |
| **Total** | **22,754.3** | **4.2** | **0.0** | **140.4** |

The high proportion of mapped Coniferous Forest (TC) is a result of more natural ecosystems located further up the watersheds where that LCC dominates (i.e., towards the headwaters of each watercourse), whereas urban development and urban densification occurs closer to the shore, where city centers exist. Additionally, a high number of Coniferous Forest (TC) was mapped in areas with recent logging disturbance as they were likely to develop into Coniferous Forest (TC) sites and be ultimately maintained in this successional state.

### 3.1.2 Ecosystem Classification

BEC subzones are basic units of ecosystem classification that define geographic areas with similar ecological communities. They describe the interactions between flora, climate and soil that determine vegetation potential in any given area of the province. Site series are the fundamental, formal unit of classification within a BEC subzone. Site series represent the anticipated mature site condition, and assignments are based on the potential plant community within a site, along with associated soil moisture and soil nutrient regimes at site maturity. The BEC system is useful for providing silvicultural prescriptions (Green and Klinka 1994), setting conservation targets (Price et al., 2021), determining at-risk ecosystems, (MOECC 2022), and ascertaining wildlife suitability and capability (MacKinnon 1992). While both BEC units and site series were attributed for each of the riparian analysis polygons, BEC unit was the only attribute used for prioritization. Site series was included to help stewards think about what potential ecological communities could exist, aid in the development of restoration plans, and provide information that could be used in further analysis outside of the Project.

The RDN is located within the Coastal Douglas-fir (CDF) Coastal Western Hemlock (CWH), Mountain Hemlock (MH) and the Coastal Mountain-heather Alpine (CMA) Biogeoclimatic (BGC) zones. The CDF has only one subzone, the moist maritime (mm). The CWH zone is subdivided into four variants xm1, xm2, vm1, and mm2. The MH is divided into one subzone mm1. The CMA includes the unp subzone.

The CDFmm is characterized as having warm, dry summers and mild, wet winters. These sites occur at low elevations, up to 150 m a.s.l. Zonal CDFmm sites are dominated by Douglas-fir (*Pseudotsuga menziesii*), grand fir (*Abies grandis*) and western redcedar (*Thuja plicata*). Understory species include salal (*Gaultheria shallon*), dull Oregon-grape (*Mahonia nervosa*), ocean-spray (*Holodiscus discolor*), and Oregon beaked moss (*Kindbergia oregana*) (Green and Klinka 1994).

The CWHxm subzone is characterised by warm, dry summers and moist, mild winters. Sites occur from sea level (or just above the CDFmm, if present) to 700 m a.s.l. Zonal CWHxm sites are dominated by Douglas-fir and western hemlock (*Tsuga heterophylla*) with minor amounts of western redcedar. Understory species include salal (*Gaultheria shallon*), dull Oregon-grape, red-huckleberry (*Vaccinium parvifolium*), step moss (*Hylocomium splendens*), and Oregon beaked moss (Green and Klinka 1994). The CWHxm subzone is divided into two variants: Coastal Western Hemlock Eastern Very Dry Maritime (CWHxm1), and Coastal Western Hemlock Western Very Dry Maritime (CWHxm2). CWHxm1 is warmer and a more southern coastal variant, while CWHxm2 is a slightly cooler and more northern montane variant (UBC 2022). The CWHxm1 occurs above the CDFmm but below the CWHxm2.

The CWHmm2 occurs at higher elevations between 700 m a.s.l. and 1,100 m a.s.l. with cooler temperatures. Forests on zonal sites are dominated by western hemlock, amabilis fir (*Abies amabilis*), Douglas-fir, and minor amounts of yellow-cedar (*Chamaecyparis nootkatensis*) and mountain hemlock (*Tsuga mertensiana*). Dominant understory species include Alaskan blueberry (*Vaccinium alaskaense*), step moss and lanky moss (*Rhytidiadelphus loreus*) with lesser amounts of salal, oval-leaved blueberry (*Vaccinium ovalifolium*) and black huckleberry (*Vaccinium membranaceum*) (Green and Klinka 1994).

The MHmm1 occurs at high elevations between 800 m a.s.l. and 1,350 m a.s.l., above the CWHmm2. These sites experience short, cool moist summers and long, wet, cold winters. Zonal MHmm1 sites are dominated by amabilis fir and mountain hemlock with minor amounts of yellow cedar. Prominent understory species include Alaskan blueberry and pipecleaner moss (*Rhytidiopsis robusta*)oval-leaved blueberry (Green and Klinka 1994).

The CMAunp is characterized by cool, moderate summers and cold, snowy winters (PGEC 2010). The CMAunp subzone occurs above the MHmm1 variant. The CMAunp elevation begins at 1,600 m a.s.l. while in the north the alpine begins at 1,000 m elevation (MFR 2006). This subzone is dominated by mountain hemlock, yellow-cedar, and sub-alpine fir (*Abies lasiocarpa)* (PGEC 2010). White mountain-heather (*Cassiope mertensiana*) and pink mountain-heather (*Phyllodoce empetriformis)* are the dominant understory vegetation.

The coastal BEC units are provided at 1:250 000 scale in the BEC linework (BECv12) so that BEC subzone and variant boundaries may not exactly match with conditions on the ground; however, for the purpose of the Project, the BEC units provide a useful reference when distinguishing ecological communities. Most polygons occurred within the CDFmm where 2,920 (54%) polygons were mapped. The CMAunp had the smallest number of polygons with only 6 (0.1%). The only watercourse that reached the CMAunp was Englishman River, while Nanaimo River, Cameron River, Englishman River, and Thames Creek are the only watercourses with upper extents in the MHmm1 (**Table 5, Figure 5**).

Table 5: Biogeoclimatic Units of the Regional District of Nanaimo Boundary (based on BECv12)

| BEC Unit | BEC (Based on broad BECv12) | Area (ha) in the RDN | Number of Polygons | Area of polygons (ha) |
|---|---|---|---|---|
| CDFmm | Coastal Douglas-fir, Moist Maritime | 159,771.6 | 2,921 | 10,628.6 |
| CWHxm1 | Coastal Western Hemlock, Very Dry Maritime | 46,217.0 | 1,425 | 7,520.7 |
| CWHxm2 | Coastal Western Hemlock, Very Dry Maritime | 46,724.8 | 681 | 3,191.7 |
| CWHvm1 | Coastal Western Hemlock, Submontane Very Moist | 4.8 | 0 | 0 |
| CWHmm2 | Coastal Western Hemlock, Windward Moist Maritime | 42,398.5 | 313 | 1,141.6 |
| MHmm1 | Mountain Hemlock, Windward Moist Maritime | 16,527.4 | 63 | 243.5 |
| CMAunp | Coastal Mountain-heather, Alpine Undifferentiated and Parkland | 1,242.3 | 6 | 28.1 |

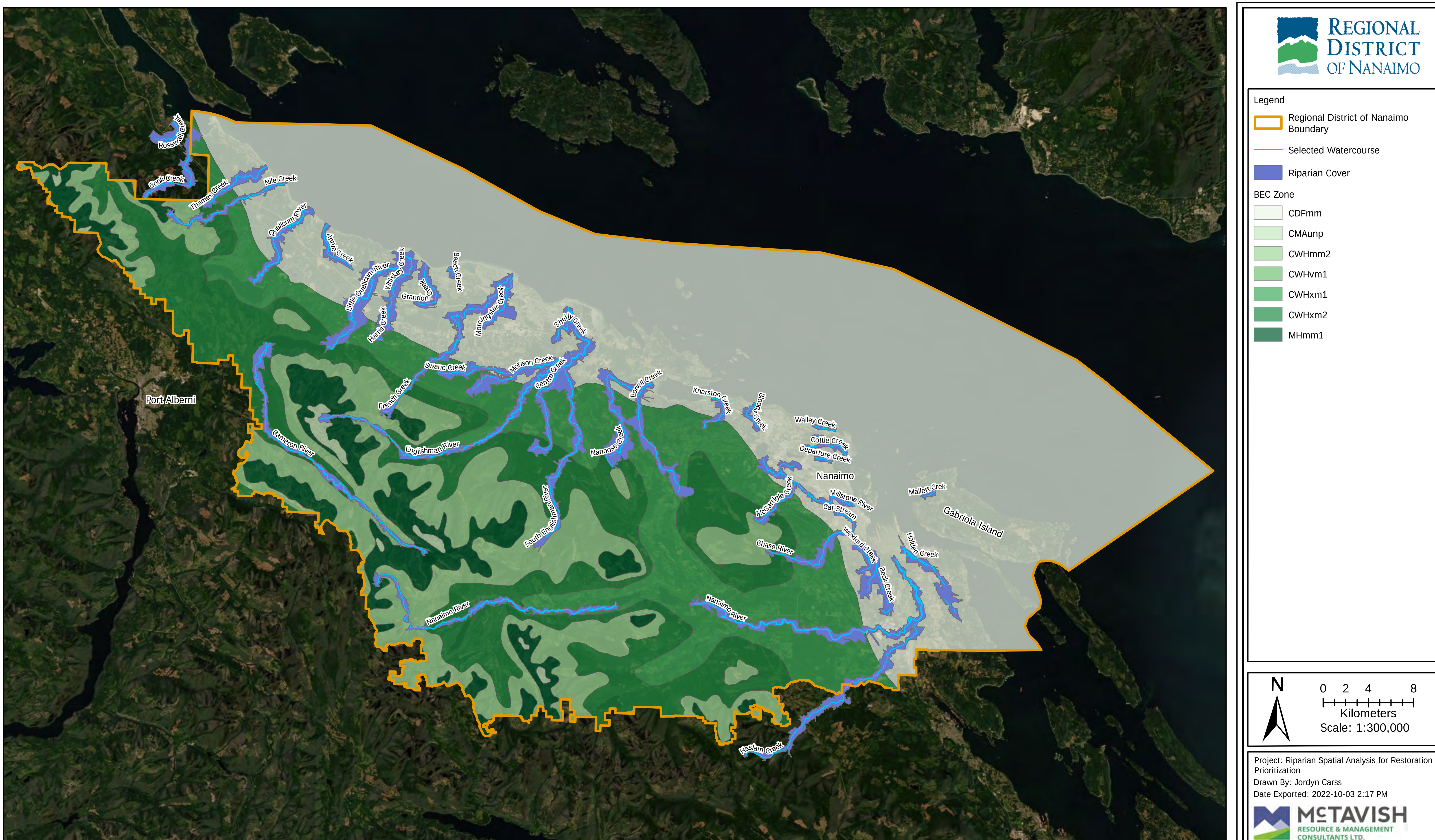


Figure 5
Biogeoclimatic Ecosystem Classification for Riparian Cover Polygons

### 3.1.3 Community Complexity

Plant community complexity is recognized as an important quality of riparian ecosystems and is strongly correlated to ecosystem resilience (Nordin and Malkinson 2022). Ecosystem resilience is important, especially because of its relationship to an ecosystem's ability to respond to climate change (Campbell et al. 2009). Community complexity is addressed through several polygon attributes (i.e., successional status, structural stage, crown closure, canopy height).

While natural vegetation of any kind provides ecological benefits to riparian areas, tree cover is the most efficient at providing flood control, temperature regulation, and shading (Mayer et al., 2006). Studies have shown that sediment removal by trees ranges from 60–90% depending on buffer area, slope, and the volume and velocity of runoff (Nowak et al., 2007); however, the percentage of a stream covered by a canopy decreases naturally with increasing stream order, as a result of increasing stream width. The presence of dense vegetation along the banks of higher order streams has a direct positive benefit to streams (Nowak et al., 2007).

A total of 1,460 polygons (27%) were mapped with a canopy closure class of 0 (i.e., 0 – 5%). Of the 695 polygons identified as Urban (UR), 576 (83%) were mapped with a canopy closure class of 0. Canopy closure class 9 (i.e., 86 – 95%) was mapped for 737 polygons (14%) and canopy closure class 8 (i.e., 76 – 85%) was mapped for 632 polygons (12%). Every other canopy closure class was mapped in 10% or less of the polygons. **Figure 6** illustrates the number of polygons in all 11 canopy closure classes.

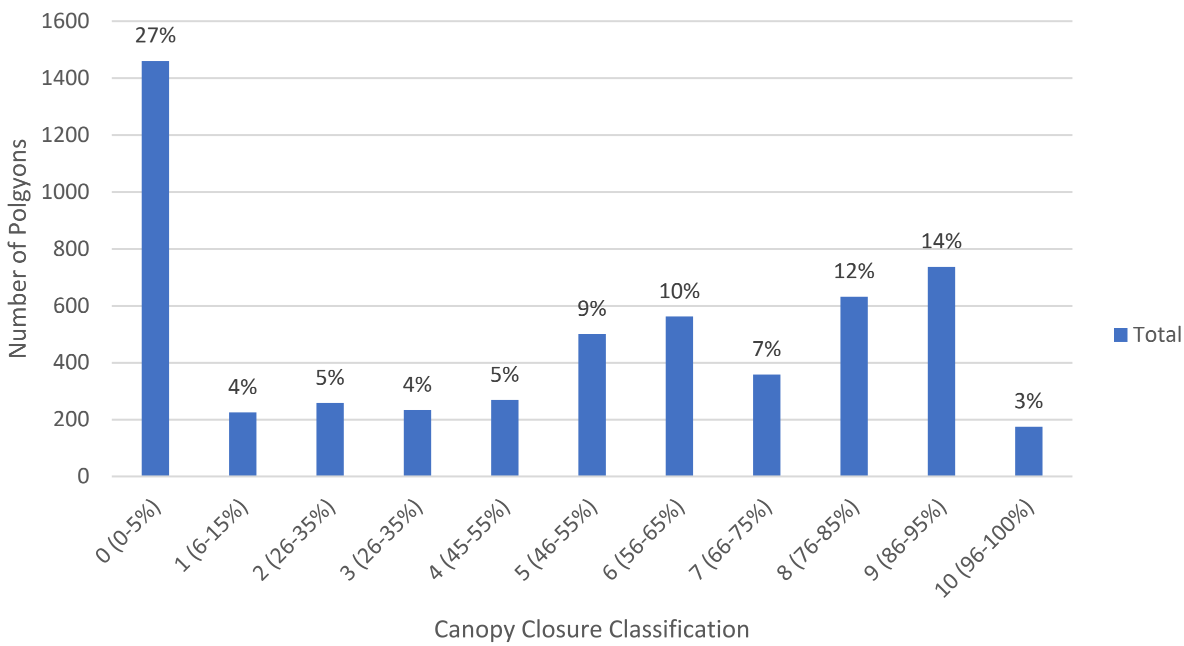


Figure 6: Number of Mapped Polygons Within Each Canopy Closure Class and the Corresponding Percentage

Canopy height provides information on stand height and development. It is also related to stream shading and potential input of large organic woody debris. It was not included within the prioritization scheme for the Project as structural stage and canopy closure are considered better indicators of current riparian conditions and limitations.

Forest succession provides a description of the orderly predictable change in the dominant species of a forest plant community after a disturbance. Each successional stage also has a variety of management practices that, depending on the objectives, can support the development of treatment or management plans (BCMFR and BCMOE 2010). While successional status was included as an attribute of the riparian cover analysis for the Project, the level of confidence in assigning successional status was low. This low confidence was due to the inability to review the Project in 3D; therefore, 2D indicators such as crown density and texture, crown colour (i.e., hue), and crown topography, were relied upon. Due to the relatively low level of confidence, successional status was not included within the prioritization scheme but should help provide users with potential restoration prescriptions. Riparian cover polygons that were not assigned a successional status included Cropland (CR), Urban (UR), and Wetland (W) LCCs. While croplands are vegetated, they are not forested ecosystems and will undergo the natural succession of a forested ecosystem in the foreseeable future. Additionally, wetland ecosystems were not given a successional status, function differently from forested ecosystems, and should be recognized as having a separate successional trajectory.

There was a higher level of confidence in assigning structural stage, as it is an age-based parameter and age estimates derived from the VRI could support the analysis. As such, structural status was a more appropriate surrogate for community complexity. The top three mapped structural stage (STS) were STS 5, Young Forest (1,239 polygons, 23%), no structural stage (1,213 polygons, 22%) and STS 6, Mature Forest (1,094 polygons, 20%). Structural stages 3a, Low Shrub, and 3b, Tall Shrub, were used to describe shrub communities that are likely to exist in a near permanent state in areas that experience frequent disturbance (e.g., floodplain areas, avalanche tracks, wetlands). Wetlands were mapped in additional STSs to 3a and 8b, but 3a and 3b were most commonly used due to the ecological nature of fens, bogs, and marshes being predominantly herbaceous shrubs and graminoid communities. A total of 98 polygons were mapped as STS 7, Old Growth. **Figure 7** illustrates the number of polygons in each successional stage along with the distribution of structural stage within each successional category.

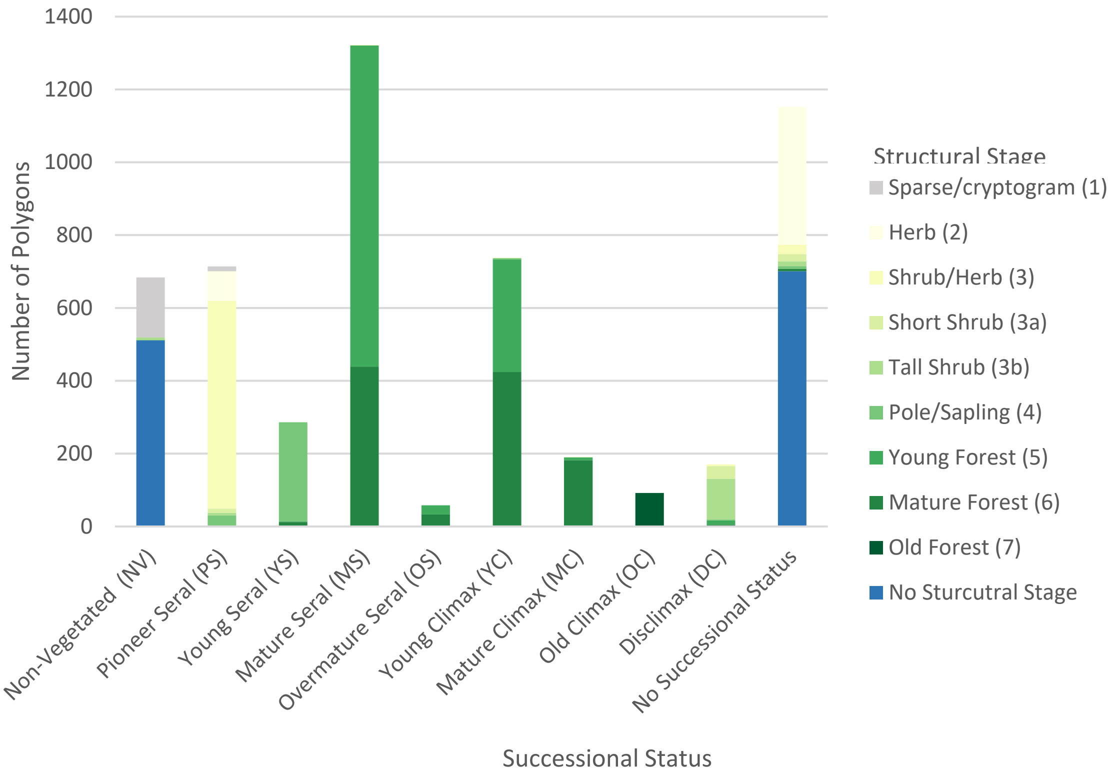


Figure 7: Number of Mapped Polygons Within Each Successional Status Category and Distribution of Structural Stage

### 3.1.4 Parent Materials and Soil Texture Classes

Between sea level and 600 m a.s.l., the Project is within the Nanaimo Lowlands Physiographic Subdivision; higher elevations are in the Vancouver Island Ranges Physiographic Subdivision (Holland 1976). Deep glacial drift, including colluvial, fluvial, glaciofluvial, marine and morainal soil parent materials covers most of the area. Many of the soils are coarse textured (e.g.., gravelly, sandy). Medium textured, loamier soils are typically associated with some recent fluvial, marine and morainal parent materials. Organic soils are relatively uncommon and are associated with wetlands.

Soils closer to the coast and at lower elevations are predominantly in the Brunisolic soil order. They include Orthic Dystric Brunisols, Duric Dystric Brunisols, Gleyed Dystric Brunisols, Orthic Sombric Brunisols, and Duric Sombric Brunisols. At higher elevations,(i.e., in the Coastal Western Hemlock biogeoclimatic zone), Humo Ferric Podzols, including Orthic, Duric, Gleyed and Gleyed Ortstein soil subgroups, are common. Orthic Humic Gleysols occur in level or depressional terrain or in lower slope positions, typically on loamy soils. Relatively small areas of poorly or very poorly drained, level or depressional terrain have organic soils in the Typic Mesisol and Typic Humisol soil subgroups. At some high elevations along the western margin of the RDN Boundary, Orthic and Duric Ferro Humic Podzols occur.

Cemented subsoil horizons are common in many of the soils derived from medium and coarse textured glaciofluvial and morainal parent materials. Duric horizons are the most common; however, Ortstein horizons occur in some coarse textured soils with fluctuating water tables. The presence of cemented horizons restricts soil drainage and creates less droughty soil moisture conditions than otherwise might be expected from gravelly and sandy soils.

Over the entire area under the jurisdiction of the RDN, nearly 50% of soils are coarse textured, most of which are derived from glaciofluvial or morainal parent materials. Medium textured soils (i.e., those derived from fluvial, morainal and marine parent materials) cover less than 20% of the area. Fine textured soils are found in less than 1% of the area. Organic soils cover about 2% of the area. Anthropogenic soils of various textures cover about 10% of the area. Of all the polygons, 51% have coarse textured soils, 18% have medium textured soils, and 1% have fine textured soils. **Figure 8** illustrates the number of polygons in each parent material category along with the distribution of textural classes.

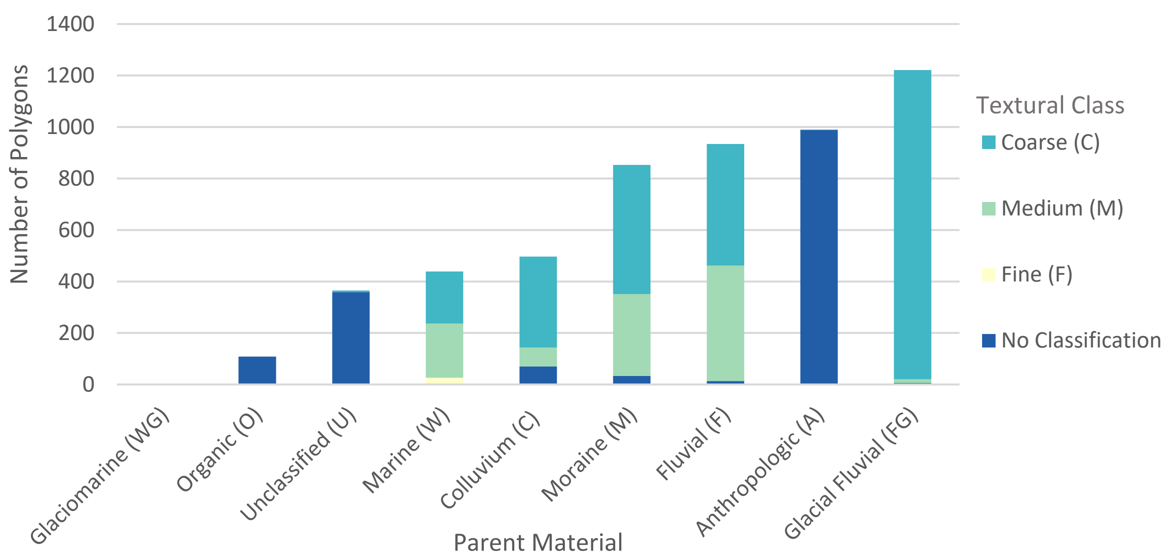


Figure 8: Number of Mapped Polygons Within Each Parent Material Category and Distribution of Broad Textural Classes

### 3.1.5 Disturbance and Natural Regeneration

Both anthropogenic and natural disturbances can have a large impact on riparian areas and their features and functions. Road construction may accelerate erosion and introduce oils and other pollutants. Farming can increase erosion of stream banks, cause sedimentation, and introduce pollutants that may affect organisms. Urban development can increase the intensity of floods, increase direct inputs of pollutants into watercourses and degrade wildlife habitat. Logging operations can affect streamflow, which may lead to bank erosion, increase channel depth, and can create narrow channels and reduced riparian zones (Noss et al. 2009). Natural disturbance (e.g., floods, slides, avalanches) can have similar effects, including sedimentation, stream blockages and removal of riparian vegetation. The frequency at which these disturbances occur should be taken into consideration when analyzing riparian functions.

When a disturbance was identified, additional information on potential vegetation competition severity, potential vegetation complex, and potential autogenic regeneration for each disturbed area was incorporated. The only exception to this is areas that have a permanent disturbance (i.e., industrial areas, residential areas, permanent road surfaces).

"Potential severity" is a term typically used in forest management that indicates the expected severity of competition from non-commercial plant species with commercial tree species. A high degree of severity is considered a negative outcome from the viewpoint of timber production (i.e., the focus of LMH 28) but is considered a positive indicator for the revegetation of riparian areas as it indicates a potential for increased growth of native herbaceous and shrub vegetation. The potential vegetation complex identifies species or species groups that are expected to compete with commercial tree species. For example, the "Cottonwood-alder" complex represents a group of species that commonly compete with commercial tree species on floodplain sites and sites with strongly fluctuating water tables in the CDFmm and CWHxm subzones. Typical species in the group are black cottonwood, red alder, salmonberry, red osier dogwood, devil's club, red elderberry, and thimbleberry. Vegetation of this complex, while detrimental to timber production, can constitute a high-quality riparian plant community. This information was not included within the prioritization scheme; however, is useful when determining appropriate species for planting and what is likely to regenerate after a disturbance.

Within the riparian cover analysis, approximately 2,349 polygons (43%) were mapped as having some form of disturbance, while 3,060 (57%) of polygons were mapped as having no disturbance. The most common disturbance mapped was Anthropogenic (A), accounting for 22% of all disturbed areas. Areas that had anthropogenic disturbance varied in regeneration potential depending on the extent of the disturbance. Disturbance associated with logging made up 11% of all polygons (622 polygons). Logged areas were mostly (i.e., 581 polygons, 93%) mapped as having fair regeneration potential, as the majority of these occurred within forest tenures where a high level of management and professional due diligence is required. Some logging activities were identified outside managed forest tenures, including areas that appeared to be cleared but no development activities had yet taken place. Few areas were assigned very low (4 polygons), poor (14 polygons), and high (23 polygons) regeneration potential, due to the perceived level of disturbance. Soil disturbance was largely associated with road building (i.e., gravel roads) and farming. Soil (S) disturbances were identified for 534 polygons (10%) and were predominantly mapped as having very low to poor natural regeneration because of significant soil alteration (e.g., scalping, compaction) and the high likelihood of soil remediation being required for restoration. **Figure 9** illustrates the distribution of disturbance polygons and regeneration potential.

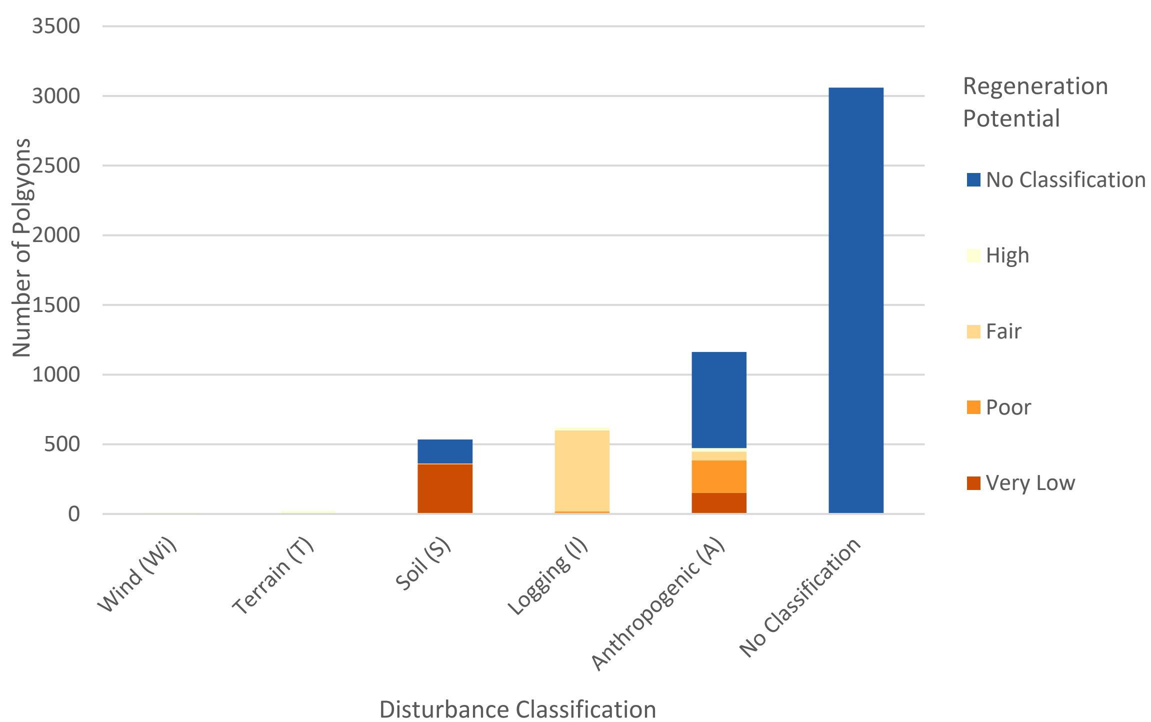


Figure 9: Number of Mapped Polygons Within Each Disturbance Category and Distribution of Regeneration Potential

### 3.1.6 Zones of Concern

Areas that show a significant level of disturbance, either immediately adjacent to the watercourse or overlapping the watercourse, have the potential to have an adverse affect on the features and functions of riparian areas and were flagged as a zone of concern (ZOC). Additionally, riparian areas that had narrow vegetation widths and were bound by urban, rural, or industrial development were also flagged, as there may be forms of encroachment that are not discernable from aerial imagery (e.g., human activity under the tree canopy). These areas were split up into two categories: highly degraded and somewhat degraded. Out of the 5,409 polygons delineated, 129 (2%) were identified as being highly degraded and 241 (4%) were identified as being slightly degraded.

**Figure 10** provides an example of areas classified as slightly degraded and highly degraded. Both areas are along Millstone River, as it is located within a relatively urban area and has experienced a high rate of disturbance. In the slightly degraded area, a small strip of riparian vegetation is discernible around the wetland complex; however, it is bordered by urban development to the northwest and the natural extent of the riparian area is limited and puts the watercourse at risk for further encroachment and degradation. In the highly degraded area, the watercourse is bounded to the north and south by cropland, in which there is a significant lack of tree cover and almost no riparian area that extends past the banks.

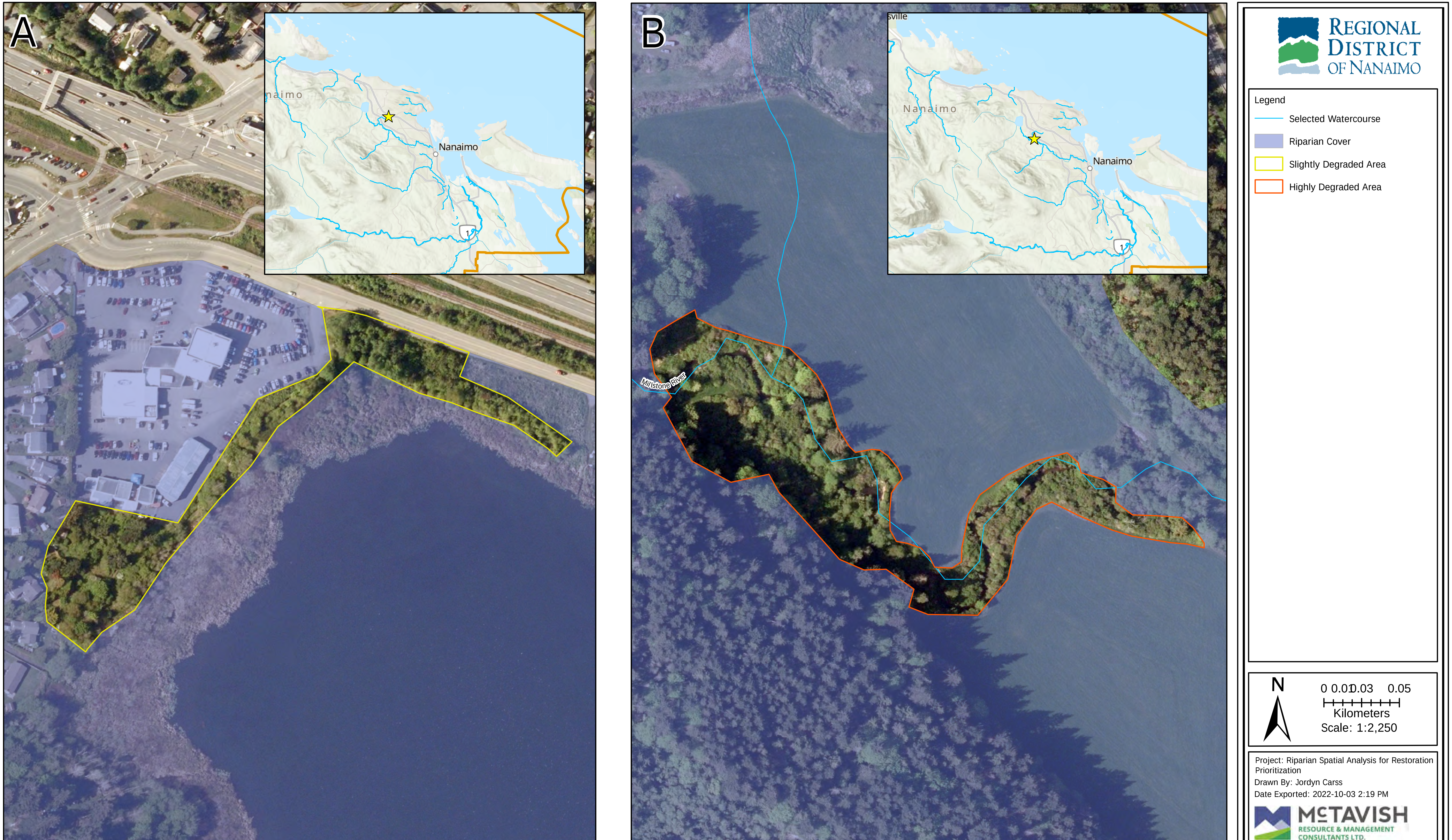


Figure 10
Examples of Areas Mapped as Slightly Disturbed Along an Unnamed Tributary of Millstone River (A) and Highly Disturbed Along Millstone River (B)

## 3.2 Riparian Prioritization for Restoration

When functioning riparian areas are intact, they provide highly valued ecosystem services; however, in rapidly urbanizing watersheds, riparian areas are susceptible to development modifications that adversely affect ecosystem services (Atkinson and Lake 2020). Riparian areas are generally considered functioning if they are well-vegetated with a diverse group of plants, have a range of vegetated age classes, and have a suitable functional riparian width. Riparian areas that are considered less healthy show (Hillard and Reedyk 2020):

- An abundance of weedy and non-native plant species that can cause displacement of native vegetation. Often, weedy, non-native vegetation lacks deep, binding root masses, resulting in streambank instability and erosion;
- Lack of shade-providing trees that can lead to warmer stream temperatures and a decreased capacity to hold dissolved oxygen, causing an increase algal growth and a decrease in the abundance of aquatic organisms;
- Lack of tree saplings caused by over-grazing or farming practices – young trees are required to help establish mature dynamic ecosystems; and
- Lack of large woody debris, which limits available habitat for fish or aquatic organisms; however, some stream types (i.e., larger rivers, watercourses occurring in natural grassland ecosystems) may not have large woody plants that would contribute to woody debris in the system.

Prioritization tools can be helpful in identifying areas that require intervention to return ecosystem function to riparian areas. A prioritization scheme was developed to assess the current condition of the riparian area by developing a defensible criterion for prioritization based upon attributes that would illustrate a decline in riparian cover. The following sections provide a description and rationale of the development of the ranking scheme. Each parameter was given a weight based on perceived level of importance to riparian function and confidence in deriving ranking values, **Table 6** below provides a summary of the weights.

Table 6: Weighted Ranking for Each of the Restoration Prioritization Ranking Parameters

| Parameter | Weighted Value |
|---|---|
| Disturbance | 1 |
| Zones of Concern | 1 |
| Vegetation Cover | 2 |
| Terrestrial Habitat Continuity | 3 |
| Vegetation Complexity | 4 |
| Soil (Parent Material) | 5 |
| Water Quality | 6 |
| Climate | 7 |

Note: Weighted value of 1 indicates highest level of importance while weighted value of 7 indicates lowest.

### 3.2.1 Disturbance

Prioritization scores for disturbance and regeneration potential are shown in **Table 7**, below. Disturbance identification and regeneration potential show areas that have been altered from their mature seral stage and are areas where restoration is likely needed to see an immediate return to natural succession. Disturbance was given a weight of 1 as noticeably disturbed riparian areas likely have plant communities and ecosystem functions that have been significantly altered. That being said, natural disturbances are largely considered integral for the long-term function and evolution of riparian ecosystems and can play an important role in stream morphology and riparian habitat complexity and are generally viewed as beneficial to an ecosystem. Natural disturbance (e.g., wind, mass erosion, fire) are largely thought to be good conduits for passive restoration (Zahner 1992) and disturbed areas can be left alone to heal through natural processes (Noss et al. 2009); however, non-natural disturbances may take centuries to recover after experiencing intensive vegetation removal, soil scalping and compaction, or agricultural use (Duffy and Meier 1992; Bellemare et al. 2002; Finn and Vellend 2005).

Numerically higher scores (i.e., lower restoration priority) were assigned to disturbance classes that represented natural disturbance such as Fire (F), Wind (Wi), and Terrain (T) related events. Disturbance classes caused by humans, such as, Soils (S) and Anthropogenic (A), were given lower scores (i.e., higher restoration priority). Logging (L) has potential to alter vegetation and is sometimes considered a severe kind of disturbance; however, in managed forest lands, forest practices regulations and responsible professional oversight normally result in prompt site revegetation and little or no site degradation. Compared to Soil (S) and Anthropogenic (A) disturbance, Logging (L) activities on managed forest lands have minimal and shorter duration impacts on riparian ecosystems; therefore, managed forests were assigned higher scores. Restoration activities within managed forest lands by members of the public should not be carried out without consultation with the respective Forest Licensees. Any disturbance with no regeneration potential were given a score of 0. Areas included in this category are permanent road surfaces and urban developments where houses and buildings exist.

Most of the riparian cover polygons (i.e., 3,060 or 57%) were mapped as having no disturbance and received a high score. The most common disturbance was Anthropogenic (A), related to urban development. Of the polygons identified as having experienced Anthropogenic (A) disturbance, the greatest number (i.e., 690 or 13%) received a score of 0. Most polygons identified as having experienced Logging (L) disturbance received an intermediate score, due to their assumed level of forest management; however, certain areas were given a high score (i.e., low restoration prioritization) when they appeared to have different harvesting prescriptions than clearcuts and forest structure was retained. The vast majority (i.e., 355 polygons or 7%) of areas identified as having a Soil (S) disturbance were croplands, which received a low score due the change in soil structure and the likelihood of the area needing intensive restoration to return to a more natural state.

Table 7: Disturbance Scoring Matrix and Results from the Riparian Cover Analysis

| Disturbance Classification (Code) | Autogenic Potential (Code) | Disturbance Score | Number of Polygons Mapped | Total Area Mapped (ha) |
|---|---|---|---|---|
| Anthropogenic (A) | Very Low (V Low) | 4 | 161 | 265.1 |
| | Poor (P) | 5 | 234 | 359.1 |
| | Fair (F) | 5 | 62 | 107.4 |
| | High (H) | 7 | 26 | 22.9 |
| | NULL | 0 | 690 | 1,702.9 |
| Fire (F) | Very Low (V Low) | 3 | 0 | 0 |
| | Poor (P) | 3 | 0 | 0 |

| Disturbance Classification (Code) | Autogenic Potential (Code) | Disturbance Score | Number of Polygons Mapped | Total Area Mapped (ha) |
|---|---|---|---|---|
| Fire (F) | Fair (F) | 8 | 0 | 0 |
| | High (H) | 8 | 0 | 0 |
| Logging (l) | Very Low (V Low) | 8 | 4 | 19.1 |
| | Poor (P) | 8 | 14 | 53.3 |
| | Fair (F) | 9 | 581 | 4,604.3 |
| | High (H) | 10 | 23 | 141.0 |
| Soil (S) | Very Low (V Low) | 2 | 355 | 1,687.8 |
| | Poor (P) | 3 | 6 | 28.7 |
| | Fair (F) | 5 | 0 | 0 |
| | High (H) | 7 | 1 | 0.1 |
| | NULL | 0 | 172 | 307.1 |
| Terrain (T) | Very Low (V Low) | 3 | 0 | 0 |
| | Poor (P) | 2 | 0 | 0 |
| | Fair (F) | 6 | 1 | 0.8 |
| | High (H) | 8 | 21 | 16.8 |
| Wind (Wi) | Very Low (V Low) | 2 | 0 | 0 |
| | Poor (P) | 2 | 0 | 0 |
| | Fair (F) | 4 | 0 | 0 |
| | High (H) | 8 | 8 | 71.6 |
| No Disturbance | No Regeneration | 10 | 3,060 | 13,366.6 |

### 3.2.2 Zones of Concern

Prioritization scores for ZOC are shown in **Table 8** below, along with the distribution of scores and total mapped area. ZOC were areas that visually appeared to have a significant level of disturbance and, as such, the features and function of the riparian area are considered at risk or within immediate risk of alteration, degradation, or further encroachment. As a result, ZOC were given a weight of 1. The lowest score (i.e., highest restoration priority) was assigned to the Highly Degraded (HD) category, while the Somewhat Degraded (SD) was assigned a slightly higher score. Areas that were not identified as a ZOC were given a blanket score of 5.

Table 8: Zone of Concern Scoring Matrix and Results from the Riparian Cover Analysis

| Zone of Concern Class (Code) | Score | Number of Polygons Mapped | Total Area Mapped (ha) |
|---|---|---|---|
| Highly Degraded (HD) | 1 | 129 | 286.6 |
| Somewhat Degraded (SD) | 2 | 241 | 466.7 |
| Not a Zone of Concern | 5 | 5,039 | 22,001.0 |

### 3.2.3 Vegetation Cover

Vegetation cover, a.k.a. canopy closure, is a measurement of the extent to which a riparian area is shaded by trees, brushes, and tall grasses. Canopy closure is largely diminished by human activities (e.g., logging, farming, urban development). Prioritization scores for vegetation cover are shown in **Table 9**. Vegetation cover class has high information value because it can be readily determined with relatively high accuracy and is strongly correlated with riparian ecosystem function. Vegetation cover was given a weight of 2 within the ranking scheme. Lowest priority scores were assigned to LCCs representing areas with sparse vegetation (e.g., Urban [UR], Cropland [CR], Exposed Soil [ES]). Classes with short vegetation (e.g., Herbland [HE], Grassland [GR]) were given slightly higher scores. Forest and wetland vegetation classes, which account for more than half of all the polygons mapped, were assigned intermediate scores, reflecting their variable potential for improvement. The Open Water (OW) class was also assigned an intermediate score because it can include emergent vegetation. The highest scores were assigned to purely aquatic habitats, namely Ponds (PD) and Lakes (LA), because a lack of terrestrial vegetation is their natural condition. More than half of the polygons (i.e., 3,138 polygons or 58%) have been given a score of 20, including forested ecosystems (e.g., Coniferous Forest [TC]) and Road Surfaces (RZ) because they are either capable of natural regeneration (e.g., forests) or are unlikely to be restored due to the importance of their existing function (e.g., roads).

Table 9: Vegetation Cover Scoring Matrix and Results from the Riparian Cover Analysis

| Land Cover Classification (Code) | Score | Number of Polygons Mapped | Total Area Mapped (ha) |
|---|---|---|---|
| Urban (UR) | 0 | 695 | 1,725.2 |
| Cropland (CR) | 2 | 285 | 1,636.6 |
| Exposed Soil (ES) | 2 | 54 | 139.3 |
| Herbland (HE) | 6 | 188 | 322.7 |
| Grassland (GR) | 7 | 1 | 0.9 |
| Short Shrub (SL) | 10 | 91 | 171.5 |
| Tall Shrub (ST) | 14 | 202 | 266.0 |
| Deciduous Forest (TD) | 19 | 558 | 1,941.8 |
| Bare Rock (BR) | 20 | 186 | 249.8 |
| Open Water (OW) | 20 | 180 | 565.8 |
| Pond (PD) | 40 | 23 | 56.1 |
| Road Surface (RZ) | 20 | 262 | 429.4 |
| Coniferous Forest (TC) | 20 | 2,083 | 12,666.9 |
| Mixed Forest (TM) | 20 | 427 | 2,228.4 |
| Wetland (W) | 20 | 174 | 353.8 |

### 3.2.4 Terrestrial Habitat Continuity

High species richness and occurrence of rare species are often associated with long temporary continuous habitats, sites, or landscapes (Nilsson et al. 2001, Dullinger et al. 2013). Areas with lower crown closure (i.e., < class 4, < 45% crown closure) indicate areas of openness that could represent breaks in continuous cover and an alteration in continuous habitat. While there are natural breaks in habitats (e.g., ponds, lakes, rock outcrops), many other breaks are not natural (e.g., urban development, forest harvesting practices, roads). As such, terrestrial habitat continuity was given a weight of 3. The Prioritization scores for vegetation cover are show in **Table 10**. Lower scores were based on the potential for restoration and revegetation to facilitate riparian habitat connectivity, while higher scores were based on the potential for areas to have a higher level of crown closure with continuous habitat. Crown closure class 5 (i.e., > 46% crown closure) was used as the threshold for establishing areas of higher crown closure versus areas of lower crown closure. Higher crown closure areas were often related to high density shrub areas (e.g., floodplains). A total of 2,445 polygons (45%) were given a crown closure class less than 4 (i.e., 0-45%

crown closure) and 2,964 polygons (55%) were given a crown closure class greater than 5 (i.e., ≥ 56%% crown closure). Most polygons mapped were split between crown closure class 0 and crown closure class ≥ 8, with a relatively even distribution between the remaining scores.

Table 10: Terrestrial Habitat Continuity Scoring Matrix and Results from the Riparian Cover Analysis

| Crown Closure Class | Score | Number of Polygons Mapped | Total Area Mapped (ha) |
|---|---|---|---|
| 0 | 0 | 1,460 | 5,067.8 |
| 1 | 4 | 225 | 1,057.5 |
| 2 | 4 | 258 | 1,106.4 |
| 3 | 5 | 233 | 8,22.5 |
| 4 | 8 | 269 | 1,009.3 |
| 5 | 21 | 500 | 2,101.8 |
| 6 | 24 | 562 | 2,566.4 |
| 7 | 26 | 358 | 1,069.9 |
| ≥ 8 | 29 | 1,544 | 7,952.7 |

### 3.2.5 Vegetation Complexity

Vegetation complexity is a measurement of the diversity of the riparian area based on structure and crown closure. It was assumed that sites with sparse or short vegetation and low canopy cover lack diversity and thus, have the greatest potential for restoration. Areas of greater complexity are likely to promote complex ecosystem structures that benefit a multitude of organisms, while areas of lower riparian vegetation complexity likely experience limited future input of woody debris as a habitat structure element, limited foraging opportunities, and limited predator avoidance (Quinn 2005; Schmetterling et al. 2001; Spence et al. 1996). As high complexity can contribute to the maintenance of bank stability, provide bank structure and overhanging vegetation, alterations to vegetation complexity can result in adverse affects for various mammals. Vegetation complexity was given a weight of 4.

Prioritization scores for vegetation cover are shown in **Table 11**, below. The lowest scores were assigned to STS class 1 (Sparse/cryptogram) and 2 (Herb), regardless of canopy cover. The highest scores were assigned to STS class 3a (Short Shrub), 3b (Tall Shrub), and 7 (Old Forest), regardless of canopy cover. STS class 3a and 3b are viewed as being in a continuous shrub state due to environmental factors (e.g., saturated water tables, avalanche shoots, rocky outcrops lacking soil and moisture, active floodplain areas). Additionally, STS class 7 is complex by nature with trees of all ages, and stages; as such crown closure class was not considered a factor in vegetation complexity.

Table 11: Vegetation Complexity Scoring Matrix and Results from the Riparian Cover Analysis

| Structural Stage Attribute (Code) | Crown Closure Class | Score | Number of Polygons Mapped | Total Area Mapped (ha) |
|---|---|---|---|---|
| NULL | ANY | 0 | 1,213 | 3,002.9 |
| Sparse/Cryptogram (1) | ANY | 5 | 178 | 110.8 |
| Herb (2) | ANY | 5 | 462 | 1,910.8 |
| Short Shrub (3a) | ANY | 40 | 67 | 90.5 |
| Tall Shrub (3b) | ANY | 40 | 139 | 204.9 |
| Shrub/Herb (3) | ≤4 | 16 | 426 | 2,627.9 |

| Structural Stage Attribute (Code) | Crown Closure Class | Score | Number of Polygons Mapped | Total Area Mapped (ha) |
|---|---|---|---|---|
| Shrub/Herb (3) | ≥ 5 | 24 | 177 | 821.5 |
| Pole/Sapling (4) | ≥ 7 | 18 | 146 | 993.5 |
| Pole/Sapling (4);<br>Young Forest (5);<br>Mature Forest (6) | ≤ 6 | 24 | 1,068 | 5,118.3 |
| Young Forest (5) | ≥ 7 | 24 | 729 | 3,333.9 |
| Mature Forest (6) | ≥ 7 | 29 | 706 | 3,878.0 |
| Old Forest (7) | ANY | 40 | 98 | 661.3 |

### 3.2.6 Soil (Parent Material)

Soil texture is an important property that is related to soil erodibility and the establishment and growth of vegetation. Medium textured soils (e.g., fine sands, silty sands, silty loam) are associated with fluvial, morainal and marine parent materials. They are relatively easily eroded and are a potential sediment source that can degrade water quality. They cover less than 20% of the area within the RDN boundary.

Sandy and gravelly soils are regarded to be more difficult to regenerate. Seed germination and productivity may be relatively low within coarse soils due to low soil moisture and nutrients; however, some limitations are offset by naturally cemented subsoils and from anthropogenic activities (i.e., farming) that may restrict soil drainage and promote subsurface seepage, at least at lower slope positions of moderate to steep slopes (see **Section 3.1.4**).

Prioritization scores for soil parent material and textural classification are provided in **Table 12**, below. The soils with the greatest priority (i.e., lowest scores) include those that are anthropogenic and those that are derived from fluvial parent materials. Both of these soils have variable textural composition as anthropogenic soils have diverse history and origins, and fluvial-derived soils are typically water-sorted into a strata of variable textures. Soils with lowest priority (i.e., highest scores) include coarse textured soils derived from glaciofluvial, morainal and marine parent materials.

Table 12: Soil Parent Material and Textural Classification Scoring Matrix and Results from the Riparian Cover Analysis

| Soil Parent Material (Code) | Soil Textural Class (Code) | Score | Number of Polygons Mapped | Total Area Mapped (ha) |
|---|---|---|---|---|
| Fluvial Glacial (FG) | No Texture Class | 33 | 6 | 17.9 |
| | Coarse (C) | 40 | 1,201 | 5,079.0 |
| | Medium (M) | 35 | 14 | 42.0 |
| | Fine (F) | 0 | 0 | 0 |
| Colluvium (C) | No Texture Class | 27 | 70 | 606.8 |
| | Coarse (C) | 25 | 353 | 2,042.0 |
| | Medium (M) | 27 | 74 | 287.9 |
| | Fine (F) | 27 | 0 | 0 |
| Moraine (M) | No Texture Class | 40 | 33 | 90.7 |
| | Coarse (C) | 47 | 502 | 3,018.3 |
| | Medium (M) | 40 | 318 | 1,551.5 |

| Soil Parent Material (Code) | Soil Textural Class (Code) | Score | Number of Polygons Mapped | Total Area Mapped (ha) |
|---|---|---|---|---|
| Moraine (M) | Fine (F) | 0 | 0 | 0 |
| Fluvial (F) | No Texture Class | 22 | 13 | 72.9 |
| | Coarse (C) | 13 | 472 | 1,948.1 |
| | Medium (M) | 22 | 449 | 1,958.4 |
| | Fine (F) | 28 | 0 | 0 |
| Marine (W) | No Texture Class | 23 | 1 | 5.7 |
| | Coarse (C) | 53 | 202 | 712.9 |
| | Medium (M) | 23 | 211 | 930.3 |
| | Fine (F) | 32 | 25 | 114.4 |
| Organic (O) | No Texture Class | 37 | 108 | 489.8 |
| Glaciomarine (WG) | No Texture Class | 40 | 0 | 0 |
| | Coarse (C) | 47 | 1 | 3.3 |
| | Medium (M) | 40 | 1 | 2.6 |
| | Fine (F) | 0 | 0 | 0 |
| Unclassified (U) | All Texture Classes | 33 | 365 | 1,508.4 |
| Anthropologic (A) | All Texture Classes | 7 | 990 | 2,271.3 |

### 3.2.7 Water Quality

Water quality data was provided by the Monitoring Network Coordinator for the RDN and contained information on exceedances pertaining to temperature and turbidity. Due to various parameters stored within the data and in consultation with the RDN, sampling stations where temperature and turbidity exceedances were above the approved threshold were integrated into the Project. Based on previous work completed with water quality data in the RDN, a 500 m zone of influence upstream of each water quality station was established, and any riparian cover polygons within this zone received a score of 3. All other areas received a blanketed score of 30. This allowed distinguishment between areas that may influence temperature and turbidity. However, because exceedance values could be derived from a variety of factors, and assessment into these exceedances through imagery is impractical, water quality was given a weighted rank of 6. Prioritization scores for water quality are shown in **Table 13**.

Table 13: Water Quality Scoring Matrix and Results from the Riparian Cover Analysis

| Water Quality Class | Score | Number of Polygons Mapped | Total Area Mapped (ha) |
|---|---|---|---|
| Exceedance | 3 | 804 | 3,352.3 |
| No Exceedance | 30 | 4,605 | 19,402.0 |

### 3.2.8 Climate

The complex uncertainties in climate modeling compounded by a lack of detailed information on how ecosystems will respond to any given change in climatic variables leads to uncertainties in incorporating climate variables into prioritization (Utzing and Holt 2009). One approach to forecasting future climate is to predict changes to vegetation or ecological zones. An example is projected BEC maps for British Columbia in 2025, 2055 and 2085 (Hamman and Wang 2006). As BEC zones are based on integration of climate, vegetation, and soils, they can provide a benchmark for judging climate change (Delong et al.

2010) and for approximating future conditions. The 25-, 30-, and 75-year intervals presented by Hamman and Wang (2006) correspond to about 2-8 generations for herbaceous plants and 1 or less generations for trees (i.e., 1 generation for most broadleaf deciduous species and less for conifers). BEC areas that were anticipated to expand received a higher score (35) than those that were expected to contract. Given the general nature of using BEC units to describe climatic shifts within riparian ecosystems, and the uncertainty of predictions it was given the lowest weighted rank, a rank of 7. Prioritization scores for BEC zones are shown in **Table 14**.

Table 14: Climate Scoring Matrix and Results from the Riparian Cover Analysis.

| BEC Unit (Code) | BEC Name | Score | Number of Polygons Mapped | Total Area Mapped (ha) |
|---|---|---|---|---|
| CDFmm | Coastal Douglas-fir, Moist Maritime | 35 | 2,921 | 10,628.6 |
| CWHxm1 | Coastal Western Hemlock, Very Dry Maritime | 35 | 1,424 | 7,520.2 |
| CWHxm2 | Coastal Western Hemlock, Very Dry Maritime | 35 | 681 | 3191.7 |
| CWHmm2 | Coastal Western Hemlock, Windward Moist Maritime | 35 | 313 | 1141.6 |
| MHmm1 | Mountain Hemlock, Windward Moist Maritime | 16 | 63 | 243.5 |
| CMAunp | CMAunpCoastal Mountain-heather, Alpine Undifferentiated and Parkland | 16 | 6 | 28.1 |

### 3.2.9 Final Score

Weighted scores were used to rank potential restoration prioritization. Areas assigned priority 1 represented the highest restoration priority and areas assigned priority 5 represented the lowest restoration priority. The division of these classes was based upon Natural Breaks classification (Jenks 1967) where breaks in the data are created in a way that best groups similar values together and maximizes the difference between-classes (de Smith et al. 2017). The distribution of the data within each of these priority classes are provided in **Figure 11**.

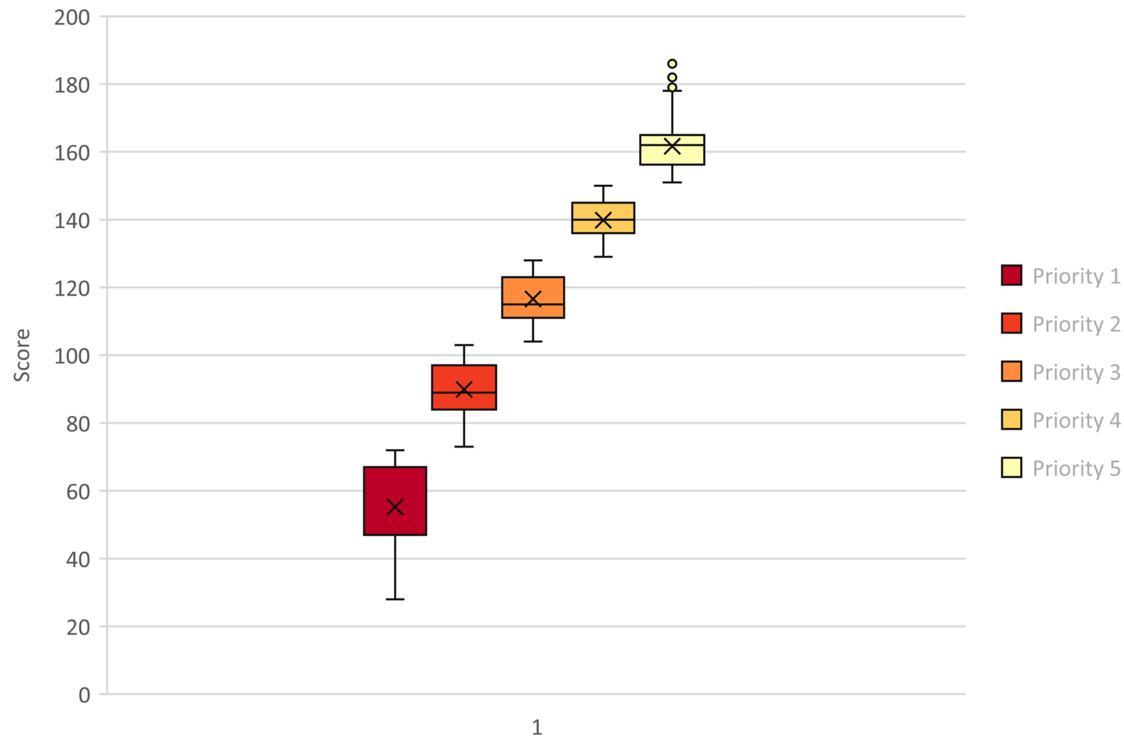


Figure 11: Distribution of Scores for Priority Ranking Using a Whisker Plot to Show the upper Limits, Lower Limits and Median

Of the 5,409 polygons assessed, 31% (1,656 polygons) were classified as priority 5 rank with a maximum score of 186. Areas ranked as priority 5 are likely to be fully functioning riparian areas. The average score for priority 1 rank was 55.3, with a minimum score of 28 and a maximum score of 72, with 18% (983 polygons) assessed as areas that should be considered for some level of restoration efforts **(Table 15**). Priority rank 2, which is also a notable category for restoration activities, comprised 552 polygons (10%) with an average score of 90, a minimum score of 73, and a maximum score of 103. Areas that fall into priority rank 3 and 4 should be analyzed at the ground level to determine which conditions are impacting that area and if riparian restoration efforts could help improve overall riparian function. **Figure 12** provides an overview of Annie Creek and the priority rankings.

Table 15: Summary of Restoration Prioritization Ranks of the Project.

| Ranking | Count | Minimum Score | Maximum Score | Average Score |
|---|---|---|---|---|
| 1 | 983 | 28 | 72 | 55.3 |
| 2 | 552 | 73 | 103 | 90.0 |
| 3 | 779 | 104 | 128 | 116.6 |
| 4 | 1,439 | 129 | 150 | 139.8 |
| 5 | 1,656 | 151 | 186 | 161.7 |
| **Total** | **5,409** | **28** | **186** | **122.71** |

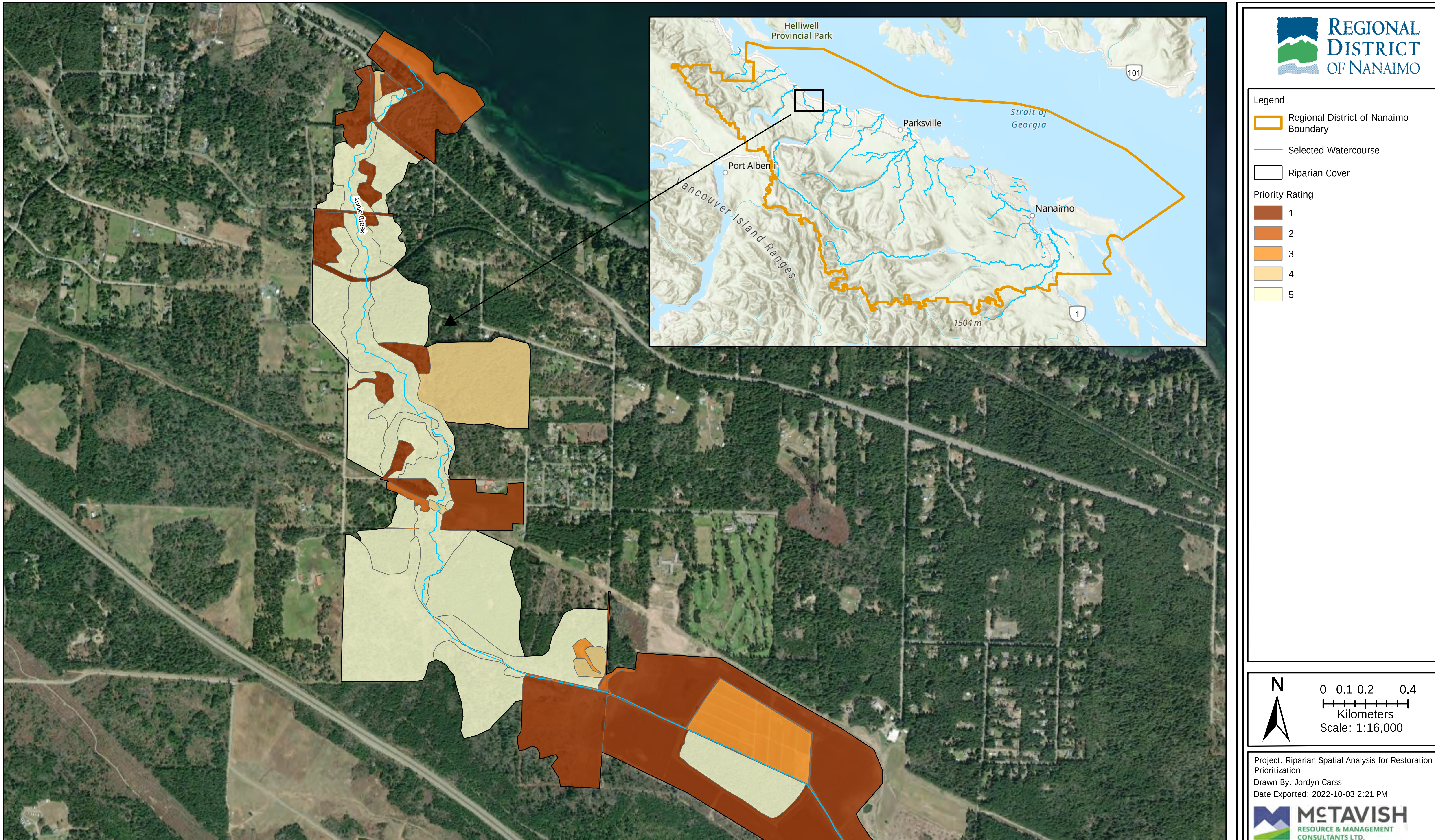


Figure 12
Priority Rankings for an Example Watercourse (Annie Creek)

### 3.3 Mapping Tool

An online interactive map was developed to present the results of the riparian analysis. This map tool allows users to zoom in to areas of interest, toggle layers on/off, click on features to explore their attributes, and provides tools for analysis such as filtering data, measuring, and printing GeoPDFs. The map was developed on Esri's ArcGIS Online platform using the online edition of their JavaScript Web AppBuilder SDK. Esri's hosted feature layers were used to store the data on ArcGIS Online, with the hosted layers published from ArcGIS Pro. In addition to the spatial data, tabular data for CWMN Monitoring Site exceedances and PDF data dictionaries are also stored on ArcGIS Online and can be accessed through the map tool.

## 4.0 LIMITATIONS

Overall, the Project is comprehensive in nature and has several strengths, including a detailed riparian ecosystem inventory, incorporation of LiDAR derived data, an adaptable prioritization scheme built upon expert opinion, and an interactive map tool. Despite the comprehensive nature of the work, there are limitations, including no site-specific ground truthing, potentially outdated aerial imagery, a lack of information on land access or ownership, a lack of specific climate information, and riparian restoration prescriptions. Many of these limitations can be assessed and adapted in future iterations of the Project, should the RDN deem it appropriate.

### 4.1 Prioritization Scores

Ranks and weights were based on perceived stressors that have direct impacts to the function and condition of a riparian corridor, for example, loss of natural vegetation, exposure of bare ground, reduced tree, or shrub cover, and natural vs. anthropogenic disturbance. Translating these stressors into a measurable numerical value to create a prioritization scheme relies on a combination of literature and professional judgment. McTavish provided a team of professionals knowledgeable in riparian function, vegetation, and condition to develop a scoring system. However, the number of individuals that contributed to the ranking matrix was limited to four. For three of the parameters, Zones of Concern, Water Quality, and Climate, only two professionals were able to contribute at that time. To better refine the scoring matrix and reduce potential variability amongst professionals, increasing the sample size of scoring professionals and conducting a statistical analysis to assess variability amongst scoring would help provide increased certainty of the values.

Input into the scoring matrix would require individuals to be familiar with coastal riparian ecosystems, their functions, and stressors and working knowledge ecological restoration. A working group made up of representatives from RDN, the regional ecologist, and additional qualified professionals could be incorporated into future iterations and with the script, results and layers displayed in the webtool being update.

### 4.2 Watercourse and Site-Specific Ground Truthing

Site-specific ground truthing was outside of the scope of this Project and may be used as a subsequent step when addressing areas identified for restoration prioritization. The riparian cover analysis is largely built upon existing watercourse linework derived from Terrain Resource Information Management (TRIM) data. While TRIM data can be accurate, the watercourse linework has not been field verified and discrepancies were noted between the linework, aerial imagery and LiDAR. Riparian cover polygons that had overlapping LiDAR data were mapped with a higher degree of confidence as being able to discern topographic relief, bankfull width, and floodplains allowed mappers to better approximate the extent of watercourse boundaries and potential influencing vegetation. Because LiDAR data was not available for all watercourses (i.e., the upper reaches), there is an added level of uncertainty to the extent of the influential riparian areas. While contour lines can help describe topographic relief, the nuances obtained from DEM provided far better accuracy. Additionally, site specific ground truthing of areas to ensure alignment with the mapped attributes and prioritization ranking would allow for a higher degree of confidence in the product.

## 4.3 Aerial Imagery

Riparian cover polygon delineation was conducted using aerial imagery from 2020. Given the complex nature of the area, which comprises urbanization, natural forested ecosystems, ponds, wetland communities, and forest harvesting, it is likely that areas within the riparian cover analysis may have already changed due to disturbance. If the RDN were to get updated imagery, then the riparian cover polygons could be updated, and the restoration prioritization scoring could be recalculated; however, annual aerial imagery can be a time/cost constraint.

## 4.4 Property Ownership

The Project was designed to be an ecologically focused analysis that centered on the features and function of riparian corridors. As such, it did not take into consideration property ownership or municipal land planning. Specifically, the prioritization scheme did not include analysis on property ownership, zoning, or policy planning. The various types of ownership or land management that occur over the area may influence the ability to carry out restoration efforts. For example, areas that fall within timber licenses are highly managed and are more likely to be restored to a more natural state, whereas farmlands, which are also highly managed, are unlikely to be restored to their natural state. The inclusion of tenure information and policy planning could be incorporated into the prioritization scheme; however, this will require a high level of effort from regional planners and various stakeholder groups.

## 4.5 Climate Change

A fundamental obstacle to incorporating climate change into the prioritization scheme is the uncertainty surrounding future climatic conditions and the effects on individual ecological communities. Predictions are sensitive to small differences in climatic variables, and species response is unique, complex, and interactive (Brubaker 1988; Walther et al. 2002). The broad approach of using BEC zones as a surrogate for climate in the restoration prioritization, though based on the best available science, is a coarse filter approach that does not account for the individual ecological community.

## 4.6 Restoration Prescriptions

Restoration prescriptions for areas identified as having the highest prioritization was outside the scope of the Project. The attributes within the riparian cover layer may provide guidance on the level of restoration required and help distinguish between areas requiring active restoration (i.e., brush clearing, planting, bank stabilization) and those requiring passive restoration (i.e., protection of narrow riparian areas).

Restoration efforts may be relatively cost-effective and could be limited to planting a selection of trees to improve forest cover. In many other cases, restoration may be more intensive and require ongoing efforts, including irrigation, nutrient inputs, vegetation management (e.g., thinning of small trees from overgrown forests, removing invasive vegetation), slope stabilization, decommissioning and revegetating roads, replacing canals and ditches with more natural watercourses, enhancing fish habitat, and reintroducing native species (Noss and Cooperrider 1994). The webtool will help guide individuals while considering the types of management that may be required.

# 5.0 FUTURE STEPS

Riparian areas are dynamic ecosystems that change according to many factors (e.g., development and restoration activities, watercourses processes) and should not be viewed as static environments. As such, the results and outputs of the Project should also be treated as dynamic. To ensure that the map tool and the data it presents remains relevant, additional actions beyond the scope of the Project are required, including increasing LiDAR coverage, delineating riparian functional widths, and expanding and improving the prioritization scheme overall.

## 5.1 LiDAR Coverage

One of the most beneficial ways to improve accuracy of the riparian cover analysis and subsequent prioritization scheme, would be to obtain complete LiDAR coverage. There are multiple benefits to complete LiDAR coverage for the RDN, but those that apply to the Project include:

- Conducting watercourse modelling to obtain updated and more accurate watercourse centre lines.
- Creating a Relative Elevation Model (REM) to derive the bankfull widths above the channel (Fernández et al. 2012), which contributes to a better understating of the riparian area. A REM would allow for modelling of a fixed-width variable corridor to be overlain on the riparian cover polygons to determine a primary zone of sensitivity that could receive a higher weight of ranking and prioritization. A REM would also indicate areas in need of immediate assessment for restoration efforts. To illustrate this, a subset analysis could be conducted on a current watercourse that has full LiDAR coverage (e.g., Millstone River).
- Updating canopy height and canopy closure for all riparian cover polygons, which would provide a better understanding of these two metrics; VRI is largely a product based on interpretation of passive photographic imagery. LiDAR provides more accurate information.
- Conducting a suitability analysis of each riparian cover polygon and its potential for erodibility and subsequent sedimentation that may impact watercourses, should a disturbance occur.

## 5.2 Riparian Functional Widths

While GIS based techniques are cost-effective and allow for largescale analysis, on-the ground delineation is considered the most accurate measurement for determining riparian functional widths, ecological makeup, and restoration needs (Verry et al. 2004, Holmes and Goebel 2011). A field-program should be developed to determine the functional widths of priority riparian areas (i.e., those that received a priority ranking of 1 or 2). Additionally, a field-program would assist in ensuing that the attributes derived through the Project are appropriate and that the subsequent restoration prioritization scheme reflects actual ecological characteristics.

## 5.3 Restoration Prioritization Scheme

There are possibilities for integration of additional data and improvements to the prioritization scheme, based on additional funds and data. Potential future steps include:

- Assigning priority for restoration of riparian areas based on site-specific ecological resilience, which can be derived from site series attributes within riparian cover polygons. Weighted rank scores would be developed based on their correlation to drought or temperature sensitivity, plant community diversity, and habitat connectivity. This strategy focuses on ecological resilience through the identification of sites that are likely to require species with greater drought and heat tolerance to climate change. Ranks and weights would be assigned based on estimated soil moisture regime (SMR) categories.
- Assigning priority to ecosystems according to their BC Conservation Data Centre ranking (i.e., Red or Blue-listed ecological communities) to ensure species at risk information is accounted for and inventoried within each of the riparian cover polygons.

## 5.4 Stakeholder Feedback

An initial demonstration with community members was held to review the Riparian Spatial Analysis Mapping Tool. During this review, methods of the riparian cover analysis and restoration prioritization were presented. While this initial meeting was beneficial to community members it is suggested that follow up meetings be held once community members and the RDN have had time to interact with the data and the Map Tool. The review should be focused on how individuals are using the tool and to determine potential updates to ensure the features and function are a benefit to the RDN and its community members.

# 6.0 CLOSURE

Ecological restoration is the 'process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed' (SERI 2004). From the perspective of biodiversity conservation, restoration will ideally result in an assemblage of species that is well adapted to current and anticipated future site conditions and is diverse in terms of composition, structure, and function, contains viable populations of species of conservation concern, provides ecosystem services, and is resilient under current and potential future conditions (Noss et al. 2009). In many cases, active restoration is needed to guide an ecosystem towards recovery. The area within the municipal boundaries of the RDN contains a diverse range of forested and non-forest ecosystems that influence the features and functions of riparian areas that were mapped and assessed through a restoration prioritization scheme.

To guide restoration activities, a total of 5,409 polygons were delineated over 22,754.3 ha, with 983 (18%) of polygons being identified as having the highest level of prioritization for restoration efforts. These areas are lacking key features that help maintain the quality of the riparian area. To promote effective and resilient restoration efforts, care should be taken during planning, field verification should occur, and detailed restoration perceptions should be developed.

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# APPENDIX I. WATERCOURSES OF INTEREST

| Water Region Code | Active in 2021? | Primary EMS Code | 2021 Watercourse Name | Associated Watercourse Linework | EMS Numbers Overlapping Watercourses | Comments |
|---|---|---|---|---|---|---|
| WR 1 | Yes | E240141 | Annie Creek | Yes | E240141 | |
| WR 3 | Yes | E288092 | Beach Creek | Yes | E288092<br>E288093 | |
| WR 5 - 2 | Yes | E321394 | Beaver Creek | Yes | E321394 | Listed as an unknow watercourse in feature layer provided by RDN |
| WR 6 | Yes | E290487 | Beck Creek | Yes | E290487 | |
| WR 1 | Yes | E298597 | Big Qualicum River | Yes | E298597<br>E298598 | |
| WR 5 - 1 | Yes | E294010 | Bloods Creek | Yes | E294010 | |
| WR 2 | Yes | E220635 | Cameron River | Yes | E220635 | |
| WR 5 - 2 | Yes | E325371 | Cat Stream | | E290486<br>E325371<br>E325372<br>E325373 | |
| WR 4 | Yes | E299852 | Centre Creek | Yes | E299852 | |
| WR 5 - 2 | Yes | E290483 | Chase River | Yes | E290483<br>E290484<br>E290485<br>E309280 | |
| WR 1 | Yes | E309086 | Cook Creek | Yes | E309086 | |
| WR 5 - 1 | No | E290473 | Cottle Creek | Yes | E290473<br>E290475<br>E309186 | |
| WR 1 | Yes | E306375 | Deep Bay Creek | No | E306375 | |
| WR 5 - 1 | Yes | E290469 | Departure Creek | Yes | E290469<br>E290470<br>E290471<br>E290472 | |

| Water Region Code | Active in 2021? | Primary EMS Code | 2021 Watercourse Name | Associated Watercourse Linework | EMS Numbers Overlapping Watercourses | Comments |
|---|---|---|---|---|---|---|
| WR 4 | Yes | 121580 | Englishman River | Yes | 121580<br>E248834<br>E282969 | |
| WR 3 | Yes | E243022 | French Creek | Yes | E243021<br>E243022<br>E243024<br>E288091 | |
| WR 3 | Yes | E304070 | Grandon Creek | Yes | E288090 | |
| WR 2 | Yes | E318150 | Harris Creek | Yes | E318150 | |
| WR 6 | Yes | E321392 | Holden Creek and Unknown Tributary (Haley Creek) | Yes | E310147<br>E321392<br>E321393 | Stream channel that connects to Holden, subsurface flows is likely. |
| WR 5 - 1 | Yes | E290470 | Joseph's Creek | No | E290470 | Tributary of Depature Creek that is conflated with Departure Creek. |
| WR 5 - 1 | Yes | E294013 | Knarston Creek | Yes | E294013 | |
| WR 2 | Yes | E268993 | Little Qualicum River | Yes | E268993<br>E256394 | |
| WR 7 | Yes | E304070 | Mallet Creek | Yes | E299852 | |
| WR 5 - 2 | Yes | E290479 | McGarrigle Creek | Yes | E290479 | |
| WR 5 - 2 | Yes | E290478 | Millstone River | Yes | E290478<br>E290480<br>E290481<br>E306294 | |
| WR 4 | Yes | E248835 | Morison Creek | Yes | E248835 | |
| WR 3 | Yes | E318151 | Morningstar Creek | Yes | E318151 | |
| WR 6 | Yes | E215789 | Nanaimo River | Yes | E215789<br>E287699 | |
| WR 1 | Yes | E286553 | Nile Creek | Yes | E286553 | |
| WR 6 | Yes | E321395 | Richards Creek | Yes | E321395 | Stream name is called "Unknown" but has connectivity to Beck Creek. |

| Water Region Code | Active in 2021? | Primary EMS Code | 2021 Watercourse Name | Associated Watercourse Linework | EMS Numbers Overlapping Watercourses | Comments |
|---|---|---|---|---|---|---|
| WR 1 | Yes | E306374 | Rosewall Creek | Yes | E306374 | |
| WR 4 | Yes | E290452 | Shelly Creek | Yes | E287131<br>E290452 | |
| WR 4 | Yes | E248836 | South Englishman River | Yes | E248836 | |
| WR 4 | Yes | E308186 | Swayne Creek | Yes | E308186 | |
| WR 1 | Yes | E286549 | Thames Creek | Yes | E286549 | |
| WR 5 - 1 | No | E306257 | Walley Creek | Yes | E306256<br>E306257<br>E306434 | |
| WR 6 | Yes | E318154 | Wexford Creek | Yes | E318152<br>E318153<br>E318155<br>E318172<br>E318154 | |
| WR 2 | Yes | E287697 | Whiskey Creek | Yes | E287697 | |
| WR 5 - 1 | Yes | E294015 | Bonnell Creek | Yes | E294016<br>E294015<br>E294014 | |
| WR 6 | No | E287700 | Haslam Creek | Yes | E287700 | |
| WR 5 - 2 | No | E309280 | McClure Creek (Extension of Chase River) | No | E309280 | Estray of Chance River |
| WR 5 - 1 | Yes | E294020 | Nanoose Creek | Yes | E294019<br>E294020 | |
| WR 5 - 1 | No | E290474 | North Cottle Creek | Yes | E290474 | Listed as an unknow watercourse in feature layer provided by RDN with connection to Cottle Lake |
| WR 5 - 1 | No | E290482 | Northfield Creek | No | E290482 | |
| WR 5 - 1 | No | E294011 | Slogar Brook (Steward Creek) | No | E294011 | |

# APPENDIX II. DATA DICTIONARY

This data dictionary is used to provide a description of the LCC found within the ***Riparian Analysis Viewer*** developed for the Project The values found within this table corresponded to the LCCs within the “Riparian Cover Analysis” Layer.

| Possible Values | Code | Value Definition |
|---|---|---|
| Land Cover Classification<br>*The observed (bio)physical cover of the riparian corridor surface* | | |
| Bare Rock | BR | Areas characterized by exposed bare rock. |
| Cropland | CR | Areas characterized by flat or gently rolling, non-forested and open terrain that are subject to human agricultural practices (e.g., plowing, fertilization, non-native crop production) which often result in long-term soil and vegetation changes. This class may also include areas of large lawns (e.g., soccer fields). |
| Exposed Soil | ES | Areas characterized by exposed soil where vegetation cover is < 5%. |
| Grassland | GR | Areas characterized by natural grasses, rushes, or sedges. |
| Herbland | HE | Areas characterized by vascular plants without a woody stem, including ferns, fern allies, some dwarf woody plants, grasses, and grass-like plants. |
| Lake | LA | Naturally occurring, static bodies of water greater than 2 m deep and greater than 50 ha in size. |
| Open Water | OW | Areas of permanent shallow, standing water that lacks extensive emergent plant cover. Vegetation can be absent or emergent plants can cover up to 10% of the surface. |
| Pond | PD | Small bodies of water greater than 2 m deep and less than 50 ha in size. |
| Road Surface | RZ | Areas cleared and compacted for transporting goods and services by vehicles. |
| Snow/Ice | SI | Areas characterized by perennial cover of ice and/or snow, generally accounting for more than 25% of total cover. |
| Short Shrub | SL | Areas characterized by shrubby vegetation that is < 2 m tall. Includes multi-stemmed woody perennial plants, both evergreen and deciduous. |
| Tall Shrub | ST | Areas characterized by shrubby vegetation that is 2–10 m tall. Includes multi-stemmed woody perennial plants, both evergreen and deciduous. |
| Coniferous Forest | TC | Areas where coniferous trees cover > 75% or more of the total area. Trees must be taller than 10 m. |
| Deciduous Forest | TD | Areas where deciduous trees cover >75% of the total area. Trees must be taller than 10 m. |
| Mixed Forest | TM | Areas where neither coniferous nor deciduous tree species comprise > 75% of the total tree cover. |
| Urban | UR | Areas characterized by buildings and associated developments (e.g., roads, parking areas) which form an almost continuous cover of the landscape. |

| Possible Values | Code | Value Definition |
|---|---|---|
| Wetland | W | Areas characterized by perennial herbaceous and woody wetland vegetation which is influenced by a water table that is at or near the surface over extensive periods of time. This includes marshes, swamps, bogs, etc., both coastal and inland, where water is present for a substantial period annually. |
| Biogeoclimatic Unit<br>*A geographic area with a uniform regional climate characterized by distinct climax vegetation with relatively uniform mean temperature and precipitation* | | |
| Biogeoclimatic Units overlapping study area. | CDFmm | Coastal Douglas-fir, Moist Maritime |
| | CWHxm1 | Coastal Western Hemlock, Very Dry Maritime |
| | CWHxm2 | Coastal Western Hemlock, Very Dry Maritime |
| | CWHvm1 | Coastal Western Hemlock, Submontane Very Moist |
| | CWHmm2 | Coastal Western Hemlock, Windward Moist Maritime |
| | MHmm1 | Mountain Hemlock, Windward Moist Maritime |
| | CMAunp | Coastal Mountain-heather, Alpine Undifferentiated and Parkland |
| Site Decile 1, 2, and 3<br>*The proportion of the site series that can be divided based on its perceived occurrence* | | |
| Numeric values 1 - 10 | 0 - 10 | - |
| Site Series 1, 2, and 3<br>*All sites within a biogeoclimatic unit that can produce the same mature or climax vegetation unit (plant association) or non-forested sites* | | |
| Refer to Ecosystem Classification Data Dictionaries (Appendix III, IV) | | |
| Successional Status<br>*The temporal stage in a pathway of a plant communities' development for a particular environment* | | |
| Non-Vegetated | NV | Stage where vegetation is either absent or <5% cover because of substrate conditions (e.g., down-slope movement, frost heaving) or recent severe disturbance (e.g., fire, mass-wasting, flooding, anthropogenic causes). |
| Pioneer Seral | PS | Stage where vegetation occupies a site following either the elimination of the original plant cover by a disturbance (e.g., fire, logging, scalping of the soil surface), or the recent creation or exposure of parent material by mass wasting, glacier melt, flooding, or wind action (e.g., dunes). Herb or shrub species are usually dominant, but mosses, liverworts or lichens may dominate. |
| Young Seral | YS | Community comprising early-successional species where competition has not yet imparted structural complexity. Generally characterized by young stands (i.e., < 60 years old) of a single cohort of early-successional, shade-intolerant tree species with an even canopy height. Understorey vegetation may retain pioneer or 'disturbance' species; however, in dense stands, competitive exclusion of understorey will occur due to shading. |

| Possible Values | Code | Value Definition |
|---|---|---|
| Mature Seral | MS | Community comprising early-successional tree species that have generally gone through an initial natural thinning due to species interactions (e.g., within-stand competition for light or root-growing space), or a community where mid-successional species dominate. Generally characterized by trees of mature age (i.e., 60 – 140 years old) and comprise two cohorts: one in the overstory and a younger one in the regeneration layer. |
| Overmature Seral | OS | Community comprising dying seral overstorey species that form the main upper canopy. Generally characterized by trees that are > 140 years old and have with a secondary tree canopy consisting of more shade-tolerant species, or some of the same species as those that are dying. Some individuals belonging to the secondary cohort may have entered the main canopy. |
| Young Climax | YC | Community comprising species typical of the climax expected for the site, but the proportional composition and structure expected at later climax stages has not yet developed and understorey seral species are usually still present. This stage may follow the development and death of a stand of seral species or may develop from climax species regeneration on a recently disturbed site. |
| Maturing Climax | MC | Community comprising species in proportions more or less typical of late succession for the site. Stands have undergone natural thinning, and vertical structure has developed, but the complex structure typical of old forests is lacking. |
| Old Climax | OC | Community comprising species expected to be present in the climax stand. The vertical structure is well developed, live-tree decay is evident, and tree death has led to canopy gaps and large woody debris on the forest floor. Often have well-developed and distinct epiphytic communities. |
| Disclimax | DC | A persistent community that strongly differs in species composition from the edaphic or climatic climax expected for the site, either due to repeated disturbance events or a historic disturbance event that, through “competitive exclusion”, has halted succession. Only applies in special situations where natural processes or events are holding “normal” succession at bay (e.g., wetlands). |
| Structural Stage<br>*A description of the appearance of a stand community using the visual characteristics, assists with depicting stand development features along a certain trajectory* | | |
| Sparse/cryptogram | 1 | Initial stage of primary succession; very early stage of cohort establishment following a stand-destroying disturbance; cryptogam community maintained by environmental conditions (e.g., bedrock, boulder fields, talus). |
| Herb | 2 | Early succession stage or herbaceous community maintained by environmental conditions or disturbance. Dominated by herbs (e.g., forbs, graminoids, ferns); however, some residual trees and shrubs may be present. The tree layer covers <10% and the shrub layer covers ≤20%. The time since disturbance is typically <20 years for normal forest succession. Many herbaceous communities are perpetually maintained in this stage. |
| Shrub/Herb | 3 | Early successional stage or shrub communities where the tree layer covers <10%. |
| Short Shrub | 3a | Shrub community dominated or characterized by shrubby vegetation that is < 2 m tall. May be perpetuated indefinitely by environmental conditions (e.g., cold air basins) or disturbance conditions (e.g., cold air basins) or physical disturbances. |
| Tall Shrub | 3b | Shrub community dominated or characterized by shrubby vegetation that is 2–10 m tall. The time since disturbance is <40 years. May be perpetuated indefinitely. |

| Possible Values | Code | Value Definition |
|---|---|---|
| Pole/Sapling | 4 | Trees >10 m tall that are typically densely stocked and have overtopped shrub and herb layers. Younger stands are vigorous and are usually >15–20 years old. Older stagnated stands (i.e., up to 100 years old) are also included. Self-thinning and vertical structure are not yet evident in the canopy. The time since disturbance is usually <40 years. |
| Young Forest | 5 | Self-thinning has become evident, and the forest canopy has begun to differentiate into distinct layers (i.e., dominant, main canopy, overtopped). Vigorous growth and a more open stand than in the Pole/Sapling stage is established. Can begin as early as age 30 (e.g., broadleaf or vigorous conifer stands) and extend to 50–80 years. |
| Mature Forest | 6 | The trees that established after the last stand-replacing disturbance have matured, and a second cycle of shade-tolerant trees may have also become established. Shrub and herb understories have become well developed as the canopy opened. The time since disturbance is generally 80 – 250 years. |
| Old Forest | 7 | Stands of old age with complex structure and patchy shrub and herb understories. Regeneration is usually of shade-tolerant species with composition similar to the overstorey, and long-lived seral species may be present in some ecosystem types or on edaphic sites. Old growth structural attributes will differ across biogeoclimatic units and ecosystems. |
| Crown Closure<br>*Class code for the ground area covered by the vertically projected crowns of the tree cover for each tree layer within a polygon, based on VRI data* | | |
| Numeric values 1 - 10 | 0 | 0 – 5% crown closures |
| | 1 | 6 – 15% crown closures |
| | 2 | 16 – 25% crown closures |
| | 3 | 26 – 35% crown closures |
| | 4 | 36 – 45% crown closures |
| | 5 | 46 – 55% crown closures |
| | 6 | 56 – 65% crown closures |
| | 7 | 66 – 75% crown closures |
| | 8 | 76 – 85% crown closures |
| | 9 | 86 – 95% crown closures |
| | 10 | 96 – 100% crown closures |
| Canopy Height<br>*The projected heigh class for the current leading species, based on VRI crown closure data* | | |
| Numeric values 1 - 10 | 0 | 0 m |
| | 1 | 0.1 – 10.4 m |

| Possible Values | Code | Value Definition |
| --- | --- | --- |
| | 2 | 10.5 – 19.4 m |
| | 3 | 19.5 – 28.4 m |
| | 4 | 28.5 – 37.4 m |
| | 5 | 37.5 – 46.4 m |
| | 6 | 46.5 – 55.4 m |
| | 7 | 55.5 – 64.4 m |
| | 8 | 64.5 + m |
| Soil Parent Material<br>*Parent material for each of the polygons, derived from Soils of Southern Vancouver Island data* | | |
| Anthropogenic | A | Disturbed soils altered by human practices. |
| Colluvium | C | A heterogenous mixture of material that, because of gravitational action, has moved down a slope and settled at its base. |
| Fluvial | F | Pertaining to streams. Fluvial parent materials are all sediments past and present, deposited by flowing water. |
| Organic | O | Parent materials derived mainly from the decomposition of plant residues. |
| Glacial Fluvial | FG | Material moved by glaciers and subsequently sorted and deposited by streams flowing from melting ice. |
| Glaciomarine | WG | Marine sediments that contain glacial material. |
| Marine | W | Parent materials deposited in the sea. |
| Unclassified | U | Nature of the parent material is unknown. |
| Soil Textural Class<br>*A single alphabetic code based upon a broad textural class, derived from Soils of Southern Vancouver Island data* | | |
| Coarse | C | Soils textures classified as sandy loam, loamy sand, or sand. |
| Medium | M | Soils textures classified as loam, silt, or silty loam. |
| Fine | F | Soil textures classified as silty clay loam, clay loam, clay, silty clay, sandy clay loam, or sandy clay. |
| Disturbance<br>*Discernable disturbance events that have caused vegetation and soil characteristics to differ from those expected* | | |
| Anthropogenic | A | A visually distinguishable disturbance to the environment originating in human activity but is not related to harvesting practices. |
| Fire | F | A visually distinguishable disturbance to the landscape from fire. |
| Logging | L | A visually distinguishable disturbance to the landscape resulting from forest management practices. |

| Possible Values | Code | Value Definition |
| --- | --- | --- |
| Terrain-related Effects | T | A visually distinguishable disturbance resulting from avalanches and terrain failures. |
| Soil Disturbance | S | A visually distinguishable compaction, cultivation, gouging, excavation, and mining effects. |
| Windthrow | Wi | Visually distinguishable disturbance resulting from wind related effects. |
| Potential Vegetation Severity<br>*The potential for crop trees (i.e., commercial tree species) to be outcompeted by herb and woody shrub species. Modified to focus on the overall development of the ecosystem component once it had been disturbed, rather than the development of crop trees* | | |
| Low | L | Shrub and herb species are unlikely to impede the development of advanced seral or climax communities. |
| Medium | M | Shrub and herb species will likely affect tree growth but will not significantly reduce regeneration survival and development of advanced seral or climax communities. |
| High | H | Shrub and herb species will significantly decrease growth and survival of trees and may affect the development of advance seral or climax communities. Typically, high to very high classes characterize fresh to wet, nutrient-rich to -very rich sites. For the scope of this project, they have been associated with urbanized or anthropogenetic disturbances separate from forest harvesting practices. |
| Very High | VH | Shrub and herb species will significantly decrease growth and survival of trees and may affect the development of advance seral or climax communities. High to very high classes characterize fresh to wet, nutrient-rich to -very rich sites. For the scope of this project, they have been associated with urbanized or anthropogenetic disturbances separate from forest harvesting practices. |
| Potential Vegetation Complexity<br>*One or more dominant species that have the potential to affect the development of crop trees. Modified to focus on the overall development of the ecosystem component* | | |
| Cottonwood-alder | 1 | - |
| Bigleaf maple | 2 | - |
| Red alder-shrub | 3 | - |
| Salal | 4 | - |
| Mixed shrub | 5 | Includes the potential for invasive/non-native plant species to colonize. |
| Ericaceous shrub | 6 | - |
| Dry shrub | 7 | - |
| Subalpine herb | 8 | - |
| Regeneration Potential<br>*The ability of an area to naturally regenerate based on the perceived condition (i.e., does it have a permanent disturbance or is it a site that has minor disturbance but has not yet reached its typical site condition as identified in the ecosystem attribution?)* | | |

| Possible Values | Code | Value Definition |
|---|---|---|
| Very Low | V Low | Areas that are unlikely to have natural regeneration without some form of intervention (parks, farm fields, or herbaceous areas that are largely maintained as herbaceous). |
| Poor | Poor | Site remediation or preparation, invasive species control, planting, or other measures are required. |
| Fair | Fair | Presence of pioneer species but may require planting of native tree species to help with diversity. Planting is mandatory in sites far from any seed sources and recommended in non-isolated sites. Areas that have been harvested for forestry purposes were given a Fair score due to the natural environment and the licensees responsibility to ensure the stand reaches a stable free to grow state. |
| High | High | No tree planting required, might have a few invasive species but could easily be controlled. Largely applies to areas that have minor disturbances within native settings, such as small-scale natural disturbances such as windthrow. |
| Zones of Concern<br>*Areas of note identified by the mappers as being impinged, encroached, or highly disturbed where the natural features and functions of a riparian area are at risk or non-functioning* | | |
| Highly Degraded | HD | Site-specific management will be required to restore diversity, structure, and functionality of this forest. Requires active control and management Includes areas that have exposed soil or have industrial disturbance (e.g., gravel pits). |
| Slightly Degraded | SD | The establishment of a protection zone would reduce the effects of more encroachment. Largely used in riparian zones with narrow vegetated widths. |

# APPENDIX III. FORESTED SITE SERIES DESCRIPTIONS

This data dictionary is used to provide the names for forested ecosystems (i.e., sites series) for the Project. The values found within this table corresponded to the BEC Units and Site Series mapped within the "Riparian Cover Analysis" Layer. Both BEC Unit and Site Series are derived from LMH28.

| Site Series | Site Series Name |
|---|---|
| CDFmm<br>*Coastal Douglas-fir moist maritime* | |
| 01 | Douglas-fir - Salal |
| 02 | Douglas-fir/Lodgepole pine - Arbutus |
| 03 | Douglas-fir - Oniongrass |
| 04 | Douglas-fir/Grand fir - Oregon grape |
| 05 | Western redcedar/Douglas fir - Kindbergia |
| 06 | Western redcedar/Grand fir - Foamflower |
| 07 | Western redcedar - Snowberry |
| 08 | Black cottonwood - Red-osier dogwood |
| 09 | Black cottonwood - Willow |
| 10 | Lodgepole pine - Sphagnum |
| 11 | Western redcedar - Skunk cabbage |
| 12 | Western redcedar - Vanilla-leaf |
| 13 | Western redcedar - Indian-plum |
| 14 | Western redcedar - Slough sedge |
| SC | Cladina-Wallace's selaginella |
| QB | Garry oak - Brome/Mixed grasses |
| CWHmm2<br>*Coastal Western Hemlock montane moist maritime* | |
| 01 | Western hemlock/Amabilis fir - Pipecleaner moss |
| 02 | Douglas-fir/Western hemlock - Salal |
| 03 | Western hemlock/Western red cedar - Salal |
| 04 | Western redcedar/Western hemlock - Swordfern |
| 05 | Amabilis fir/Western red cedar - Foamflower |
| 06 | Western hemlock/Amabilis fir - Deer fern |
| 07 | Western redcedar/Yellow cypress - Goldthread |
| 08 | Amabilis fir/Western redcedar - Salmonberry |
| 09 | Lodgepole pine - Sphagnum |
| 10 | Western redcedar/Sitka spruce - Skunk cabbage |
| CWHxm1<br>*Coastal Western Hemlock eastern very dry maritime* | |
| 01 | Western hemlock/Douglas fir - Kindbergia |
| 02 | Douglas-fir/Lodgepole pine - Cladina |
| 03 | Douglas-fir/Western hemlock - Salal |
| 04 | Douglas-fir - Sword fern |
| 05 | Western redcedar - Sword fern |
| 06 | Western hemlock/Western redcedar - Deer fern |

| Site Series | Site Series Name |
|---|---|
| 07 | Western red cedar - Foamflower |
| 08 | Sitka spruce - Salmonberry |
| 09 | Black cottonwood - Red-osier dogwood |
| 10 | Black cottonwood - Willow |
| 11 | Lodgepole pine - Sphagnum |
| 12 | Western redcedar/Sitka spruce - Skunk cabbage |
| 13 | Western redcedar - Salmonberry |
| 14 | Western redcedar - Black twinberry |
| 15 | Western redcedar - Slough sedge |
| CWHxm2<br>*Coastal Western Hemlock western very dry maritime* | |
| 01 | Western hemlock/Douglas fir - Kindbergia |
| 02 | Douglas-fir/Lodgepole pine - Cladina |
| 03 | Douglas-fir/Western hemlock - Salal |
| 04 | Douglas-fir - Sword fern |
| 05 | Western redcedar - Sword fern |
| 06 | Western hemlcok/Western redcedar - Deer fern |
| 07 | Western redcedar - Foamflower |
| 08 | Sitkas spruce - Salmonberry |
| 09 | Black cottonwood - Red-osier dogwood |
| 10 | Black cottonwood - Willow |
| 11 | Lodgepole pine - Sphagnum |
| 12 | Western redcedar/Sitka spruce - Skunk cabbage |
| 13 | Western redcedar - Salmonberry |
| 14 | Western redcedar - Black twinberry |
| 15 | Western redcedar - Slough sedge |
| MHmm1<br>*Mountain Hemlock windward moist maritime* | |
| 01 | Mountain hemlock/Amabilis fir - Blueberry |
| 02 | Mountain hemlock/Amabilis fir - Mountain-heather |
| 03 | Amabilis fir/Mountain hemlock - Oak fern |
| 04 | Mountain hemlock/Amabilis fir - Bramble |
| 05 | Amabilis fir/Mountain hemlock - Twistedstalk |
| 06 | Mountain hemlock/Yellow cypress - Deer-cabbage |
| 07 | Yellow cypress/Mountian hemlock - Hellebore |
| 08 | Mountain hemlock/Yellow cypress - Sphagnum |
| 09 | Yellow cypress/Mountain hemlock - Skunk cabbage |

# APPENDIX IV. NON-FORESTED SITE SERIES DESCRIPTIONS

This data dictionary is used to provide a description of the non-Forested codes for the Project. The values found within this table corresponded to the site series mapped within the "Riparian Cover Analysis" Layer. Codes were largely derived from *Biogeoclimatic Ecosystem Classification of Non-forested Ecosystems in British Columbia* .

| Code | Label | Description |
|---|---|---|
| Bb | Beachland | Unconsolidated beach sediments (sands/gravels/shells/cobbles) in the supra-tidal zone of the marine environment. |
| CA | Canal | An artificial watercourse created for transport, drainage, and/or irrigation purposes such as a canal or ditch. |
| CF | Cultivated Field | A flat or gently rolling, non-forested, open area that is subject to human agricultural practices (including plowing, fertilization, and non-native crop production) which often result in long term soil and vegetation changes. |
| CX | Corridor/Industry-Related Disturbance | Areas of recent human-made disturbance due to road rights-of-ways including temporary/ abandoned roads and associated right-of ways, transmission lines, pipelines, seismic activity, or other industry-related disturbance. These sites can be non or sparsely vegetated but typically the vegetation cover is maintained in earlier seral stages. |
| DZ | Dam | Hydroelectric dam actively used for power production. |
| ES | Exposed Soil | Any area of exposed soil that is not included in any of the other definitions and is non-anthropogenic (or uncertain) in origin. |
| Et | Estuary Tidal Flat | Estuarine tidal flat sites are intertidal ecosystems dominated by benthic/burrowing fauna and macroalgae. These ecosystems occur in the mid to lower tidal zones of estuaries, where freshwater and saltwater mix. |
| Fa | Floodplain (Active Channel) | Active channel ecosystems occur on sites that are annually flooded, and often scoured, for prolonged periods. Sites are usually immediately adjacent to the river channel at lower water conditions, includes non-vegetated gravel bars. |
| GC | Golf Course | Grass-covered throughways and open areas set out for the playing of golf. |
| GP | Gravel Pit | A non-vegetated area exposed through the removal of sand and gravel. |
| LA | Lake | A naturally occurring static body of water, 10 ha or greater in size and at least 2 m deep in some portion. |
| PD | Pond | A small naturally occurring static body of water, less than 10 ha in size and at least 2m deep in some portion. |
| RI | River | A watercourse formed when water flows between continuous, definable banks. Flow may be intermittent or perennial |
| RN | Railway Surface | A non-vegetated roadbed with fixed rails for possibly single or multiple rail lines. |
| Ro | Rock Outcrop | Bluffs and knobs of bedrock with limited soil development and high cover of exposed rock. |
| RP | Road Permanent | An area cleared and compacted for the purpose of transporting goods and services by vehicles. Associated with permanent maintained paved or gravel roads. |
| RR | Rural Residential | Any area in which residences and other human developments are scattered and intermingled with forest, range, farmland, and native vegetation or cultivated crops. |
| Rt | Rock Talus | Active and inactive talus (large rocks) and scree (smaller rocks and more soil) slopes. These ecosystems typically have a low herb layer cover because of mobile substrates or lack of soil. |

| Code | Label | Description |
| --- | --- | --- |
| UR | Urban/Suburban | An area in which residences and other human developments form an almost continuous covering of the landscape (approximately ≥90% coverage). These areas include cities, towns, commercial and industrial parks, and similar developments. |
| Vt | Avalanche Tree Class | Avalanche treed ecosystems are dominated by shrub-sized trees that are continually pruned by snow slides and are prevented from becoming forest. |
| Wb | Wetland bog | A nutrient-poor, Sphagnum-dominated peatland ecosystem in which the rooting zone is isolated from mineral-enriched groundwater, soils are acidic, and few minerotrophic plant species occur. |
| Wf | Wetland fen | A nutrient-medium peatland ecosystem dominated by sedges and brown mosses, where mineral-bearing groundwater is within the rooting zone and minerotrophic plant species are common. |
| Wm | Wetland marsh | Permanently to seasonally flooded non-tidal mineral wetland dominated by emergent grass-like vegetation |
| Ws | Wetland swamp | Nutrient-rich wetland where significant ground-water inflow, periodic surface aeration, and/or elevated microsites allows for growth of trees or shrubs. |
| Ww | Wetland shallow-waters | Aquatic wetlands permanently flooded by still or slow-moving water and dominated by rooted submerged and floating-leaved aquatic plants. |