Cumulative Effects Framework

Assessing and Managing Cumulative Effects in British Columbia

Howe Sound Cumulative Effects Project

Aquatic Ecosystems - Watershed Condition
Current Condition Report

South Coast Natural Resource Region

Ministry of Forests, Lands, Natural Resource Operations and Rural Development

November 8, 2018

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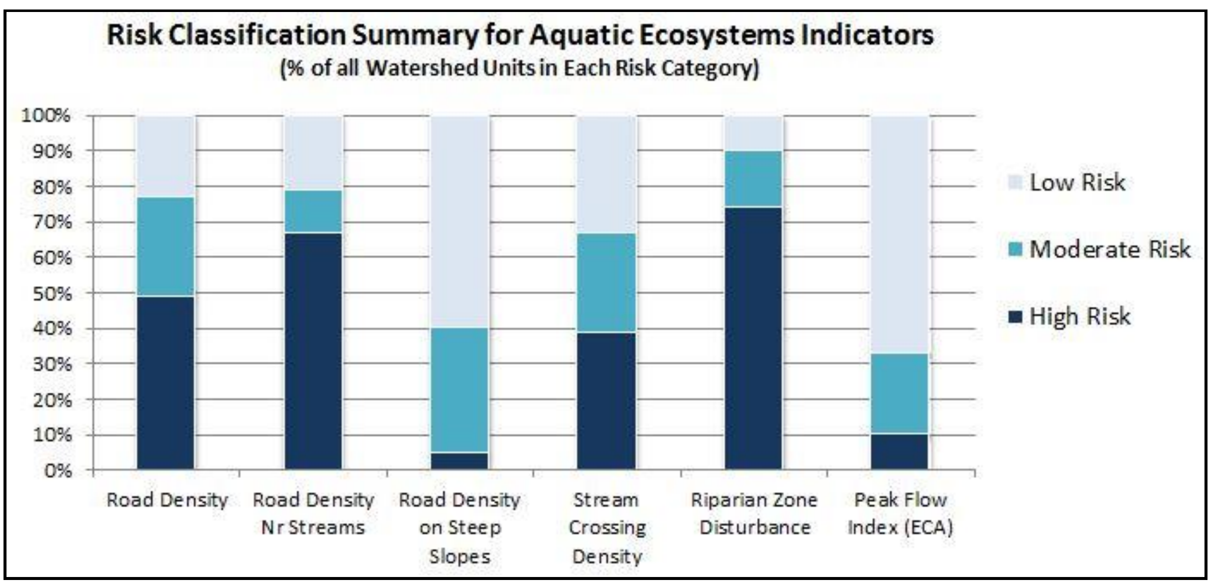
Executive Summary

The Howe Sound Cumulative Effects Project represents the Province's initial application of the Cumulative Effects Framework in the South Coast Natural Resource Region of the Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD). This report presents a current condition assessment of the aquatic ecosystems in the Howe Sound area.

Six key indicators, based upon the Aquatic Ecosystems CE assessment protocol, have been measured for each of the 43 watershed assessment units in the Howe Sound CE Project area to estimate the potential risks to the ecological integrity of freshwater ecosystems. These indicators include: road density; road density close to streams; road density on steep slopes; stream crossing density; percent of riparian zone disturbed; and peak flow index. These indicators predict the potential risk of impacts to the aquatic ecosystems in these watersheds and cannot be used to confirm specific impacts from individual developments.

The current condition assessment results reveal that risks to aquatic ecosystems across the Howe Sound project area vary by indicator. For example, peak flow index (% equivalent clearcut area) (67% of watersheds at Low Risk) and road density on steep slopes (60% of watersheds at Low Risk) are showing a lower risk of potential impacts to aquatic ecosystems in most watersheds, whereas, road density near streams (67% at High Risk) and riparian zone disturbance (74% at High Risk) are showing a higher risk of potential impacts to aquatic ecosystems. The high road density and riparian zone disturbance levels in some areas of Howe Sound are in part a legacy of past resource road development and harvest levels that have declined in recent decades.



FLNRORD is currently exploring a number of actions in response to these results such as: assessing recent trends in these indicators, comparing these predictions to available site-specific aquatic ecosystem health information and applying these risk assessments to land and resource planning and management decisions where possible. The management of lands, forests, riparian habitat, instream activities, water use, fish and aquatic wildlife has evolved considerably over the past several decades. Assessing the indicator trends over time would distinguish between historic and recent management practices and help prioritize actions based on growing versus diminishing risk to aquatic ecosystems. Comparing the assessment results to available on-the-ground riparian, channel condition and biological information will more accurately confirm or reject the accuracy of the results and predictions. These assessment results offer some insights that can be considered immediately in certain statutory decisions (i.e. major projects, urban land development, forest management) and pro-active initiatives (i.e. road deactivation, silviculture practices and habitat restoration).

The results of this assessment will also be incorporated into new decision-support tools and processes that FLNRORD-South Coast is currently developing. These tools and processes will: integrate and communicate resource value objectives, assess how well these objectives are being achieved, and provide the basis for the development of integrated resource management responses.

The data and maps used in this assessment only provide a coarse filter estimate of current condition by watershed assessment unit and may not reflect actual current condition. The assessment protocol used in this assessment is somewhat road-centric and could benefit from some additional metrics in the future to better assess watershed condition and the risk to aquatic ecosystems. It is also acknowledged that the provincial datasets used for this assessment were limited in their scale of application and have some degree of uncertainty associated with them. Therefore, this assessment does not tell the whole story and more investigation is required to better inform land and resource management.

1. Introduction

The Howe Sound Cumulative Effects Project represents the province's initial application of the Cumulative Effects Framework in FLNRORD's South Coast Natural Resource Region. This report presents an initial current condition assessment of the aquatic ecosystems in the Howe Sound CE Project area (Appendix I). Other values being assessed for current condition in the Howe Sound area include: Old Growth Forests, Forest Biodiversity, Visual Quality, Grizzly Bear, Roosevelt Elk and Marbled Murrelet.

The Province of British Columbia views the assessment and management of cumulative effects as a vital part of sustainable and integrated resource management, and an important foundational piece for addressing First Nations rights and interests. As population and resource demands grow, we must be able to measure the effect of all natural resource activities, large and small, on values that are important to the people of British Columbia. In January 2014, cabinet provided direction for the development and phased-implementation of the BC *Cumulative Effects Framework* (CEF). The intent of the CEF is to incorporate the combined effects of all activities and natural processes into decision-making to help avoid unintended impacts to key economic, social and environmental values. For more, see the CEF website: http://www2.gov.bc.ca/gov/content/environment/natural-resource-stewardship/cumulative-effects-framework .

The Howe Sound Cumulative Effects Project will help with the implementation of a coordinated, multi-sector approach to assessing and managing cumulative effects. This will be achieved by providing transparent decision-support information to the province, First Nations, other levels of government, and non-government stakeholders.

The Province of British Columbia has identified aquatic ecosystems as one of its initial core values for CE assessment. Aquatic ecosystems provide fresh water, food, and habitat across the landscape for many species including humans. The function of aquatic ecosystems results from the interaction of many natural and anthropogenic factors that determine the physical, chemical and hydrologic processes in watersheds. For the purpose of this assessment, three major components of aquatic ecosystems have been identified: water quantity, water quality and streams/riparian systems. More information on these components can be found in Appendices II and III.

The intent of this report is to provide an initial indication of the current condition of the aquatic ecosystems value by assessing the status of some initial watershed indicators in the Howe Sound CE Project area, while also providing some additional supplemental information and environmental context. This assessment acts as a coarse filter to help direct further current condition assessment and monitoring work.

This report is largely made up of a series of current condition indicator maps derived from the Provincial CE Assessment Protocol for Aquatic Ecosystems. The results from this assessment will be considered by FLNRORD to inform future assessments, planning projects, management decisions and resource objectives. The current condition results provide some important information on the risk to the integrity of aquatic ecosystems associated with the 43 watershed assessment units in the Howe Sound area. However, further validation, analysis and contextual examination is required before assessing the actual ecological integrity of these watershed assessment units. Therefore, the results in this assessment (relative to a high or low risk benchmark) do not necessarily tell the whole story and more investigation is required to determine if special management actions are warranted.

2. Assessment Approach for Aquatic Ecosystems

Six key indicators have been assessed for each of the 43 watershed units in the Howe Sound CE Project area in an effort to estimate the potential risks to the ecological integrity of freshwater ecosystems. The indicators used in this assessment were derived from the conceptual assessment model (Figure 1) and procedures outlined in the *Cumulative Effects Framework: Interim Assessment Protocol for Aquatic Ecosystems in British Columbia*, 2017. The approach is based upon a scientific understanding of watershed processes. It is intended to provide a consistent approach to province-wide watershed assessments using standardized GIS methodologies and consistent data sources. This approach focuses on a core set of initial indicators. These indicators provide an initial estimate of risk that can then be built upon with other GIS-based and field-based indicators over time to improve watershed assessment.

Water quality, water quantity, and stream-riparian systems are components of aquatic ecosystems that should be managed to maintain well-functioning aquatic ecosystems that support native aquatic species and communities. The indicators assessed under these components are pressure indicators, which measure and report on processes that act upon or influence the condition of a component and serve as useful surrogates for the potential condition of the value. The indicators were assessed at the watershed unit assessment level of (1:20,000 scale) from the BC Freshwater Atlas.

Not all of the factors identified in the conceptual assessment model have been used as core indicators and assessed against benchmarks. Some of the factors identified in the conceptual assessment model do not have benchmarks associated with them but can be provided as further information and context at the watershed level.

Benchmarks for the core indicators evolved from a foundation of existing methodology and policy, namely the Watershed Assessment Procedure guideline documents (WAP) under the former *Forest Practices Code of BC Act*. These procedural documents have served as standard guidance and policy for the assessment of watersheds by watershed managers since their introduction in 1995. Both indicators and benchmarks from the WAP have been updated on the basis of current science and research, augmented with subject matter expert opinion to support assessment assumptions and minimize uncertainty. Identified benchmarks are not “limits” or “thresholds” for disturbance, but provide information and guidance to support management practices which maintain hydrological functions and aquatic ecosystems.

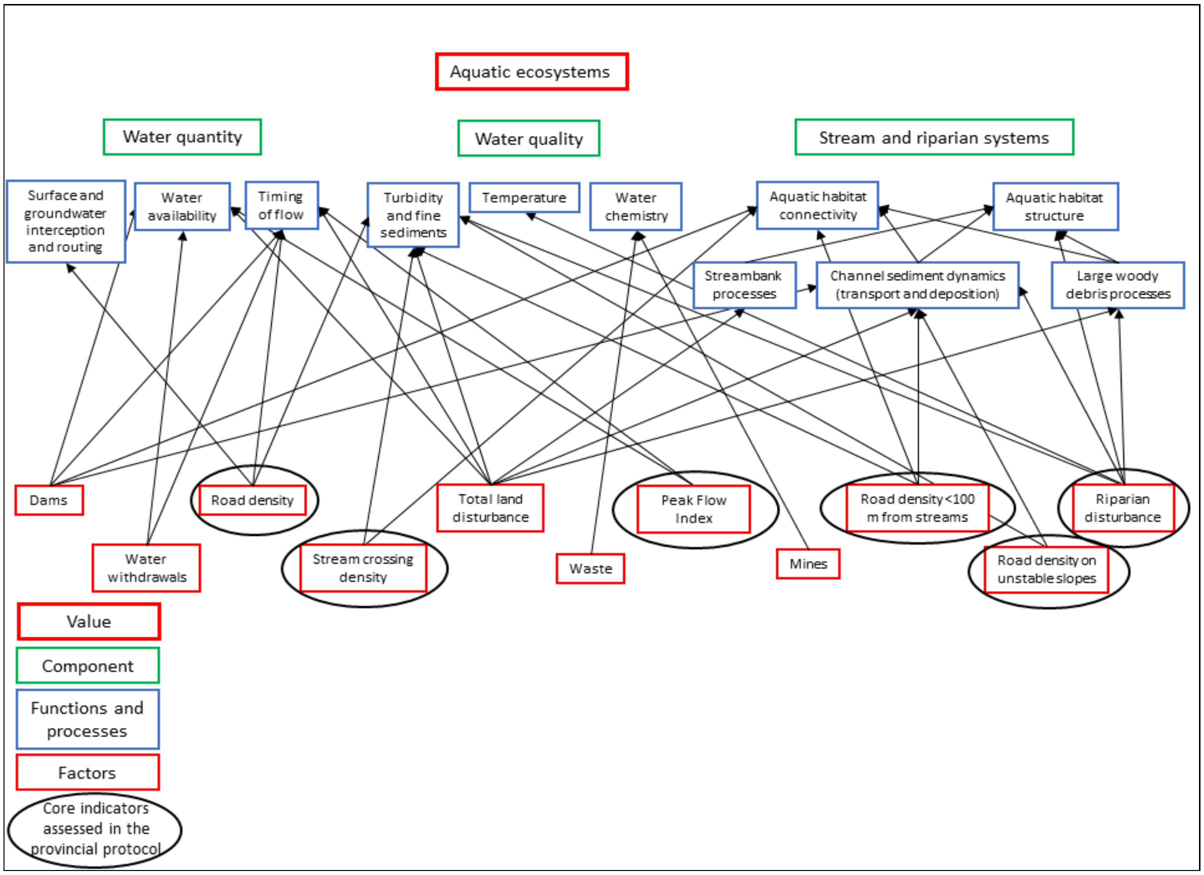


Figure 1. Conceptual Model of Aquatic Ecosystems CE Assessment

Components (**green**) are features and attributes of a value that should be measured and managed to meet objectives associated with values.

Functions and processes (**blue**) describe a key role of a component in maintaining the value, that if compromised changes the state or condition of that component.

Factors (**red**) are influential processes or states that act on a component and include both positive and negative effects. They may be used as indicators.

Indicators (**black circles**) are the metrics used to directly or indirectly measure and report on the condition of a component (state indicators) or the processes that act upon or influence the condition of a component (pressure indicators).

Limitations of Aquatic Ecosystems CE Assessment Approach

The key limitations of the current Aquatic Ecosystems CE Assessment Protocol are:

- The data and maps used in this assessment can only provide a coarse filter estimate of current condition by watershed and may not reflect actual current condition. Actual condition will require more detailed information for validation;
- The current CE assessment protocol does not include indicators with supporting legal objectives (e.g. Equivalent Clearcut Area, Riparian objectives);
- The assessment protocol used indicators for which there were available provincial data sets and may be somewhat road-centric. Some additional metrics could be added in the future that might help to better assess watershed condition and the risk to aquatic ecosystems.
- The provincial datasets used for this assessment were limited and have some degree of uncertainty associated with them (e.g. 1:20,000 scale of data for some indicators may underestimate the # of streams);
- Individual watersheds vary in terms of their specific sensitivity, however, for the purpose of this assessment they have all been considered equally sensitive; and
- All watersheds are considered equally important and not prioritized. As such, watershed-specific values (i.e. fisheries, community water supply and special riparian systems) have not been explicitly considered in this assessment.

3. Current Condition Assessment Results

The current condition assessment results provide general coarse filter information about the watersheds in the Howe Sound area. The results vary by watershed but some general observations can be derived from the results. Table 1 and the maps below provide an initial watershed risk classification summary by indicator for the Aquatic Ecosystems value.

Table 1. Summary of Watershed Risk Classification by Aquatic Ecosystems' Indicators

Aquatic Ecosystems Indicator	Lower Risk	Moderate Risk	Higher Risk
Road Density	<0.06 km/km^2	0.06-1.2 km/km^2	>1.2 km/km^2
Number of Watersheds in each Risk Category	**10 (23%)**	**12 (28%)**	**21 (49%)**
Mean: 1.35 km roads/km^2			
Range: 0 to 4.15 km/km^2			
Road Density Near Steams (<100m)	<0.12 km/km^2	0.12-0.30 km/km^2	>0.30 km/km^2
Number of Watersheds in each Risk Category	**9 (21%)**	**5 (12%)**	**29 (67%)**
Mean: 0.46 km of roads/km^2 within 100m of streams			
Range: 0 to 1.17 km/km^2			
Road Density on Steep Slopes	<0.12 km/km^2	0.12-0.25 km/km^2	>0.25 km/km^2
Number of Watersheds in each Risk Category	**26 (60%)**	**15 (35%)**	**2 (5%)**
Mean: 0.1 km of roads/km^2 on steep slopes			
Range: 0 to 0.42 km/km^2			
Stream Crossing Density	<0.60 #/km^2	0.60-1.4 #/km^2	>1.4 #/km^2
Number of Watersheds in each Risk Category	**14 (33%)**	**12 (28%)**	**17 (39%)**
Mean: 1.4 stream crossings /km^2			
Range: 0 to 5.53/km^2			
Riparian Zone Disturbance	<12 Stream Length Disturbed (%)	12-21 Stream Length Disturbed (%)	>21 Stream Length Disturbed (%)
Number of Watersheds in each Risk Category	**4 (10%)**	**7 (16%)**	**32 (74%)**
Mean: 36.61% of stream network length disturbed			
Range: 0 to 74.04%			
Peak Flow Index (Equivalent Clearcut Area)	<20 % ECA in Watershed	20-40 % ECA in Watershed	>40 % ECA in Watershed
Number of Watersheds in each Risk Category	**29 (67%)**	**10 (23%)**	**4 (10%)**
Mean: 17.8%			
Range: 0.59 to 48.75%			

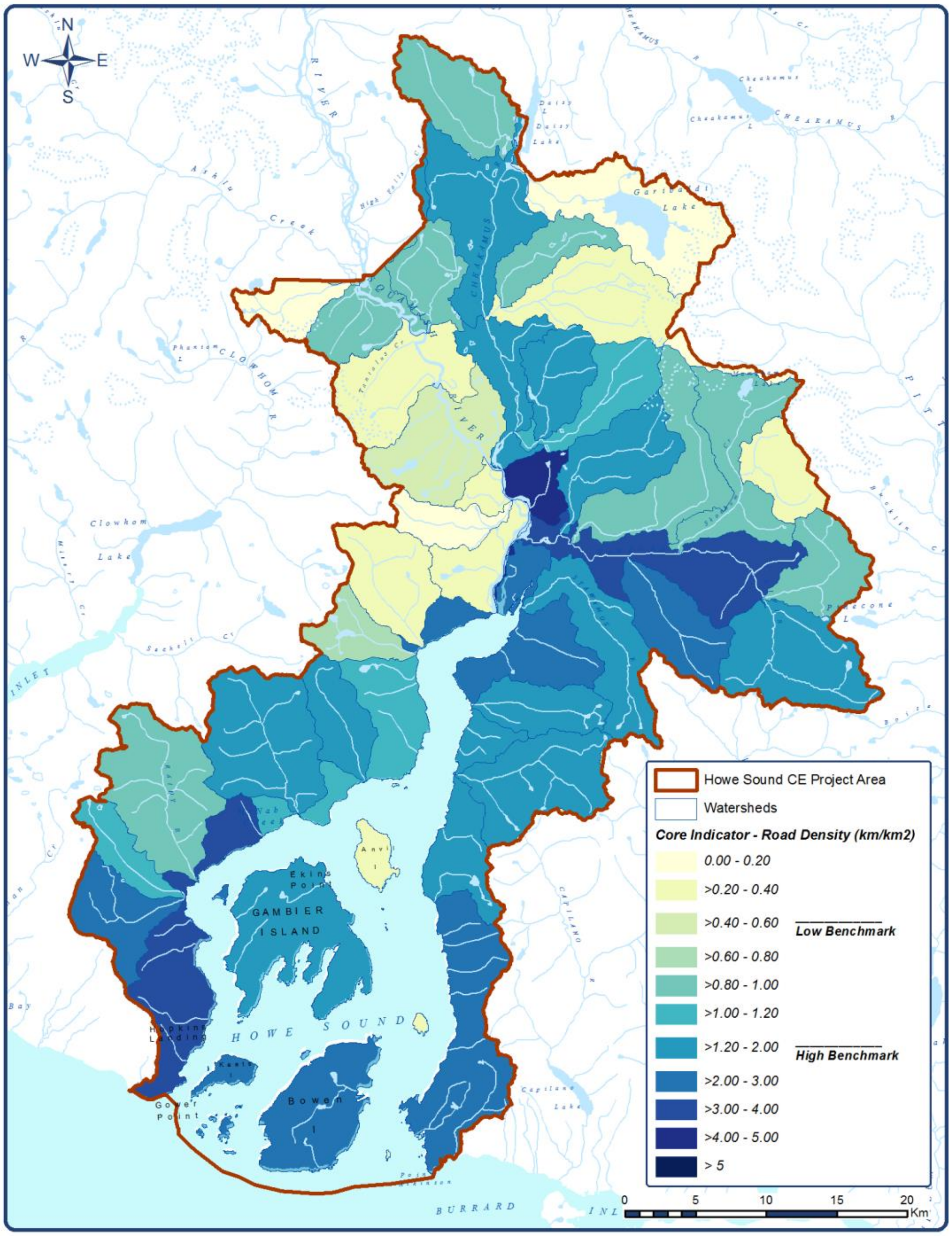
Initial Interpretation of Current Condition Results

The following are some initial observations and possible drivers affecting the CE results:

- Peak Flow Index (% of Equivalent Clearcut Area) represents a relatively low risk to aquatic ecosystems in the vast majority of watersheds assessed. This is likely due to forest management considering a number of other values such as: First Nations Cultural heritage, Visual Quality, Old Growth, Wildlife Habitat, Natural Disturbance Types, Ecological Function etc.;
- The Peak Flow Index Indicator indicates that there is a significant amount of forest cover within the watersheds in the project area at various seral stages/age classes. About 2/3 of the watersheds in the project area (29 out of 43 watershed units) are classified as having low impact to their full hydrological function;
- Watershed units with a moderate to high risk of hydrological impacts occur more in southern Howe Sound and along the Sea-to-Sky corridor in disturbed or regenerating 2nd growth forest areas. These watersheds are primarily disturbed by human residential/industrial development and/or forest harvesting (current or recent history). Of these watersheds, the ones with more recent forest cover disturbance and that are south facing, steep, and at higher elevations will likely have higher peaks in their hydrological flow regimes;
- Considering the steep terrain of much of the project area, Road Density on Steep Slopes appears to be minimized in most watersheds. While there are a variety of possible reasons for this, it has reduced the risk of road failures, debris flows and landslides which can lead to downstream safety issues and increased sedimentation;
- The results also show that there is considerable road density near streams and also significant riparian zone disturbance in the majority of watersheds. While this is to be expected in an urban/wildland interface area that has steep terrain and numerous streams in most watersheds, some further management attention may be needed to mitigate potential impacts;
- The industrial, commercial and residential areas (current or historical) with higher road densities and infrastructure appear to have an increased risk of impact to the aquatic ecosystems value. Some of these areas of higher risk appear to be:
    - Port Melon, Squamish Bulk Port, and Britannia Mines site due to current and historic industrial activities;
    - The Mamquam, McNab Creek, Potlatch Creek, Raffuse Creek and Dakota Creek watersheds due to historic commercial timber harvesting; and
    - Horseshoe Bay, Bowen Island, Gibsons, Britannia Beach, Squamish, and Brackendale due to residential /commercial development and having smaller watersheds;

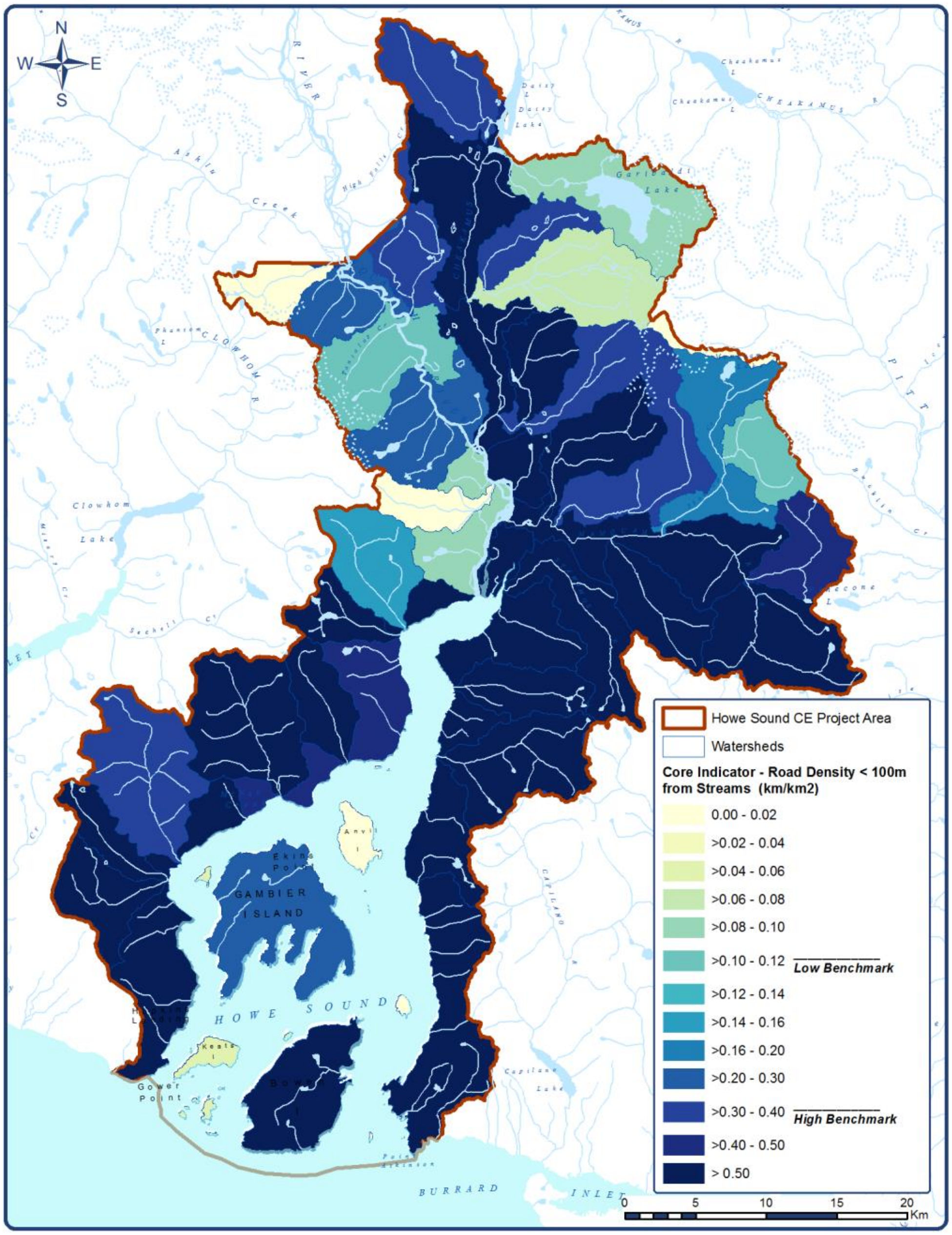
- The Road Density indicator shows a lot of watersheds (that are not in parks) to be above high assessment benchmarks due to the considerable amount of road infrastructure in the area that supports many industrial, commercial, residential and recreational activities. About 65% of the roads in the project area are active or inactive forestry roads;
- The high road density and riparian zone disturbance results are to some degree a legacy of past resource road development and higher harvest levels even though resource road management practices have improved and harvest rates have diminished in recent decades;
- Core protected areas in the project area like Garibaldi Provincial Park and Tantalus Range Provincial Park have low road densities and therefore show better current condition results for the aquatic ecosystems value;
- Smaller watersheds (e.g. on islands) may be more sensitive to higher road densities;
- The Stream Crossing Density indicator shows a significant number of watersheds (that are not in parks) to be above their respective high benchmarks due to the wet mountainous landscape, numerous streams and the large road infrastructure in the area;
- Some of the watershed assessment units do not include full watersheds and actually include portions of more than one watershed for administrative reasons; and
- The principal drivers of impacts to the aquatic ecosystems value in the Howe Sound CE Project area vary by watershed and reflect the variety of land-uses in the area and require further assessment/validation before a management response is developed.

Aquatic Ecosystems Indicator - Road Density



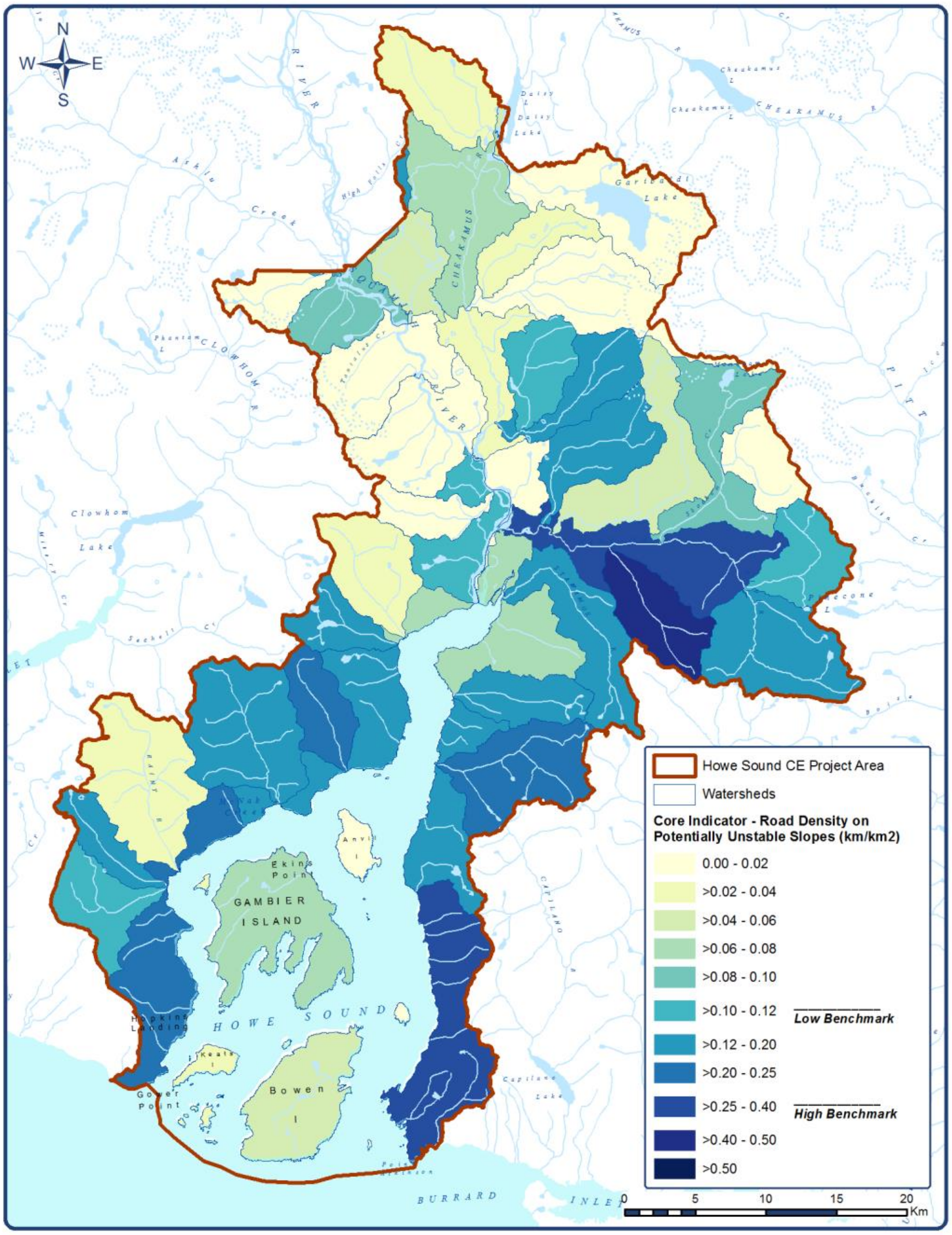
This map shows road density as an indicator for Aquatic Ecosystems Value. Road density influences peak and low flow and water temperature by increasing surface runoff and reducing groundwater storage and release. Roads influence coarse and fine sediment delivery depending on terrain stability and soil texture and on the proximity of roads that are crossing these sensitive features to streams. The darker colours indicate watersheds at higher risk of impacts and where further assessment work may be needed. (Measure: km of roads / km^2 of watershed)

Aquatic Ecosystems Indicator - Road Density Close to Streams

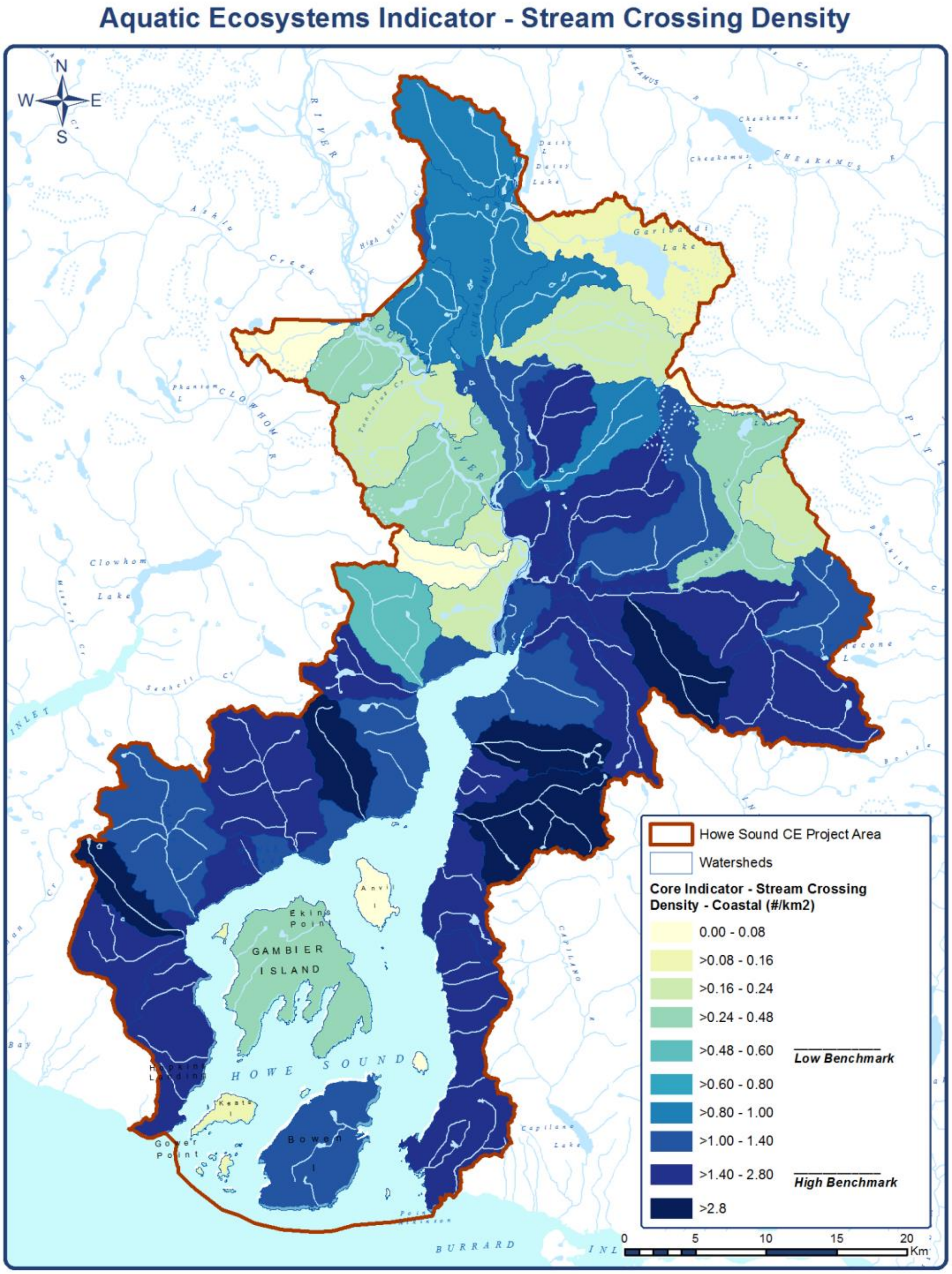


This map shows road density less than a 100m to a stream as an indicator for Aquatic Ecosystems. Roads < 100m from streams are responsible for the majority of fine sediment delivery that affects water quality. Erosion depends on soil texture, road construction and maintenance standards and on precipitation. Roads also represent alterations to riparian vegetation that may modify stream temperatures, the ability of riparian soils to filter runoff, and the ability of streamside forests to supply large woody debris to the channel. The darker colours indicate watersheds at higher risk of impacts and where further assessment work may be needed. (Measure: km of roads <100m from streams / km^2 of watershed)

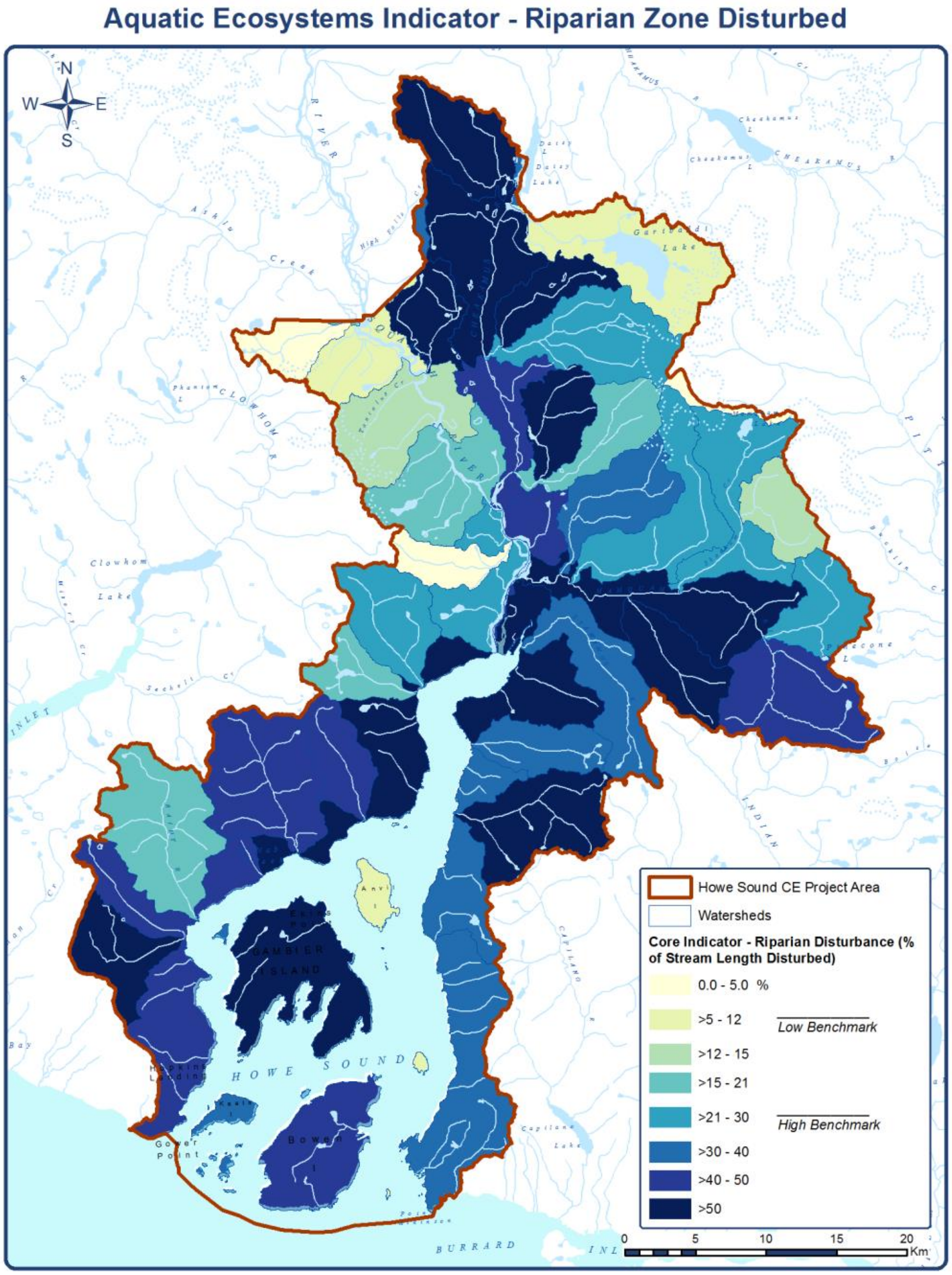
Aquatic Ecosystems Indicator - Road Density on Steep Slopes



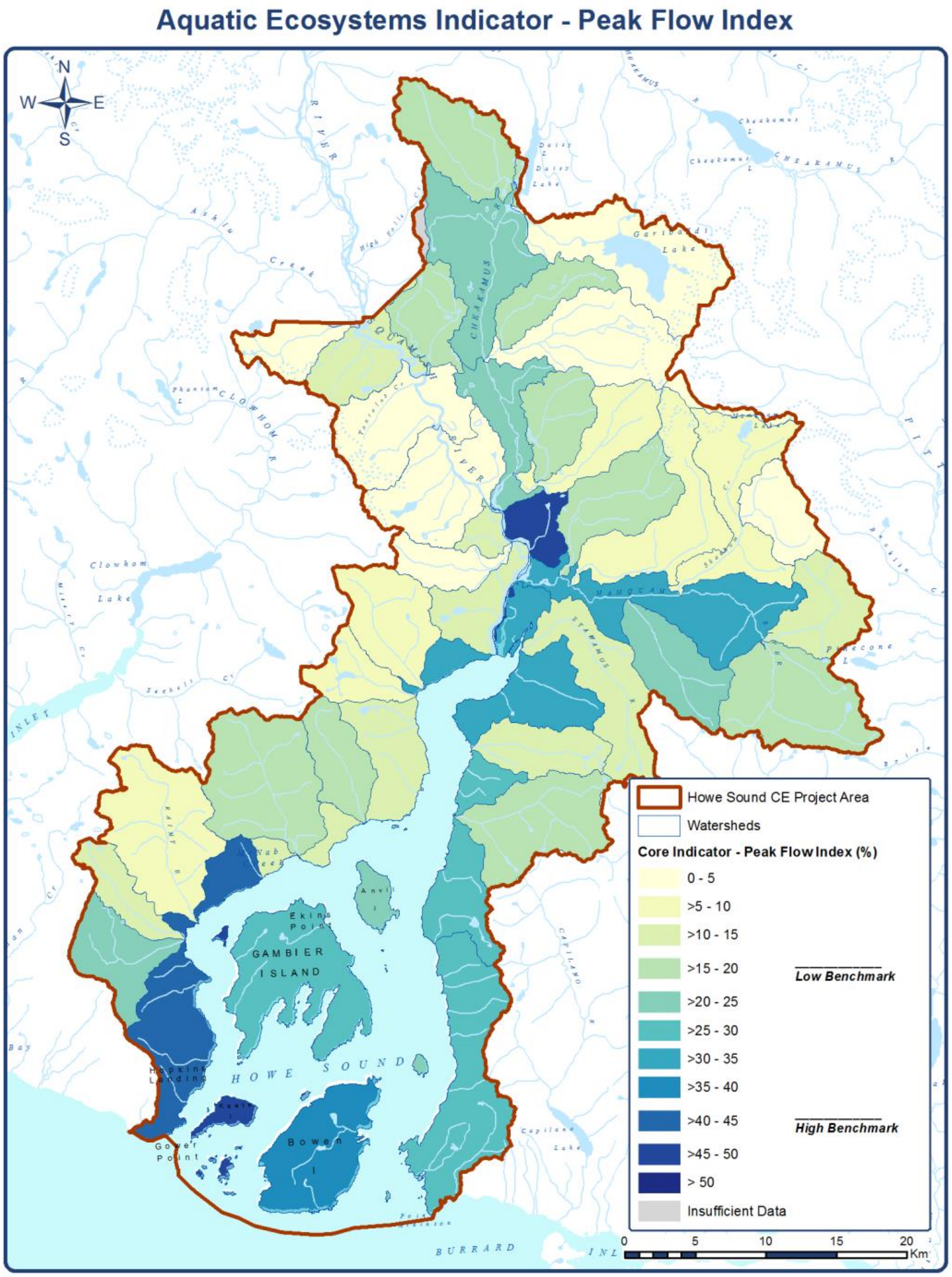
This map shows road density on steep slopes as an indicator for Aquatic Ecosystems. While steep slopes do not always equate to unstable terrain, roads on steep slopes with unstable terrain increase the chance of mass wasting by undermining or loading slopes, by saturating soils, and by reducing soil root networks. Roads on steep slopes can alter surface drainage patterns and divert subsurface flow to the surface increasing the chance of soil saturation and gulley erosion. The darker colours indicate watersheds at higher risk of impacts and where further assessment work may be needed.
(Measure: km of roads on steep slopes [>60%] / km^2 of watershed)



This map shows stream crossing density as an indicator for Aquatic Ecosystems. Exposed soils associated with culverts and bridge structures contribute fine sediment to streams. Stream crossings serve as points of entry for road-related sediment transported along ditches. Stream crossings also reduce the connectivity of aquatic ecosystems, sometimes acting as barriers to the movement of fish and other aquatic organisms. The darker colours indicate watersheds at higher risk of impacts and where further assessment work may be needed. (Measure: # of stream crossings / km^2 of watershed)



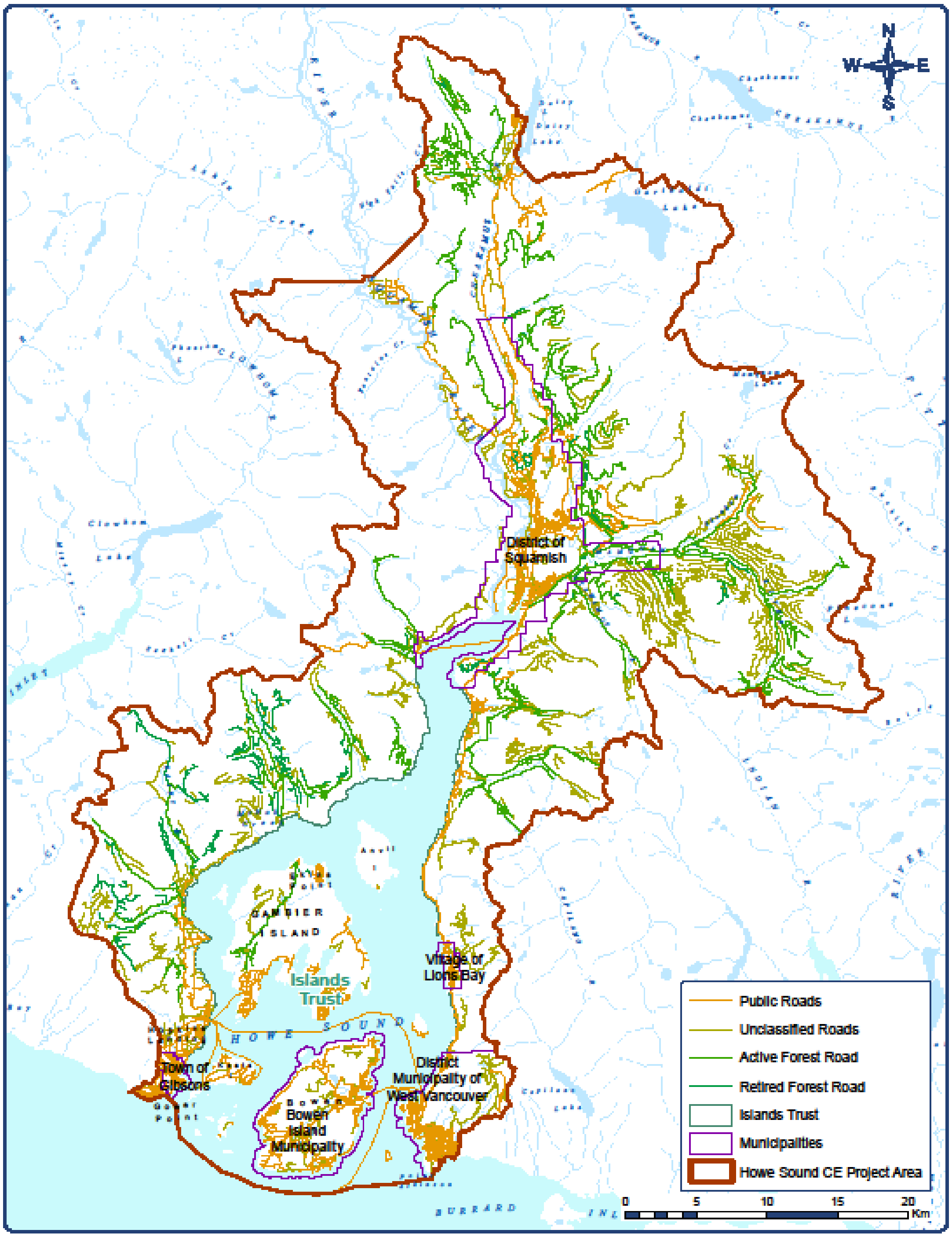
This map shows riparian forest disturbance as an indicator for Aquatic Ecosystems. Riparian areas are intimately connected with stream ecosystems, providing the majority of nutrients and organic materials supporting aquatic food webs, a varied light environment, and hiding cover. Riparian areas affect channel morphology: downed wood from riparian areas (LWD); reduces stream velocities; anchors sediment; and creates structurally complex habitats in the form of shallow riffles and deep pools important for aquatic species including fish. Riparian areas affect water quality in many ways: they shade streams thus moderating summer water temperature; capture sediment; and filter chemical and nutrient pollutants. The darker colours indicate watersheds at higher risk of impacts and where further assessment work may be needed. (Measure: % of stream network length disturbed in watershed)



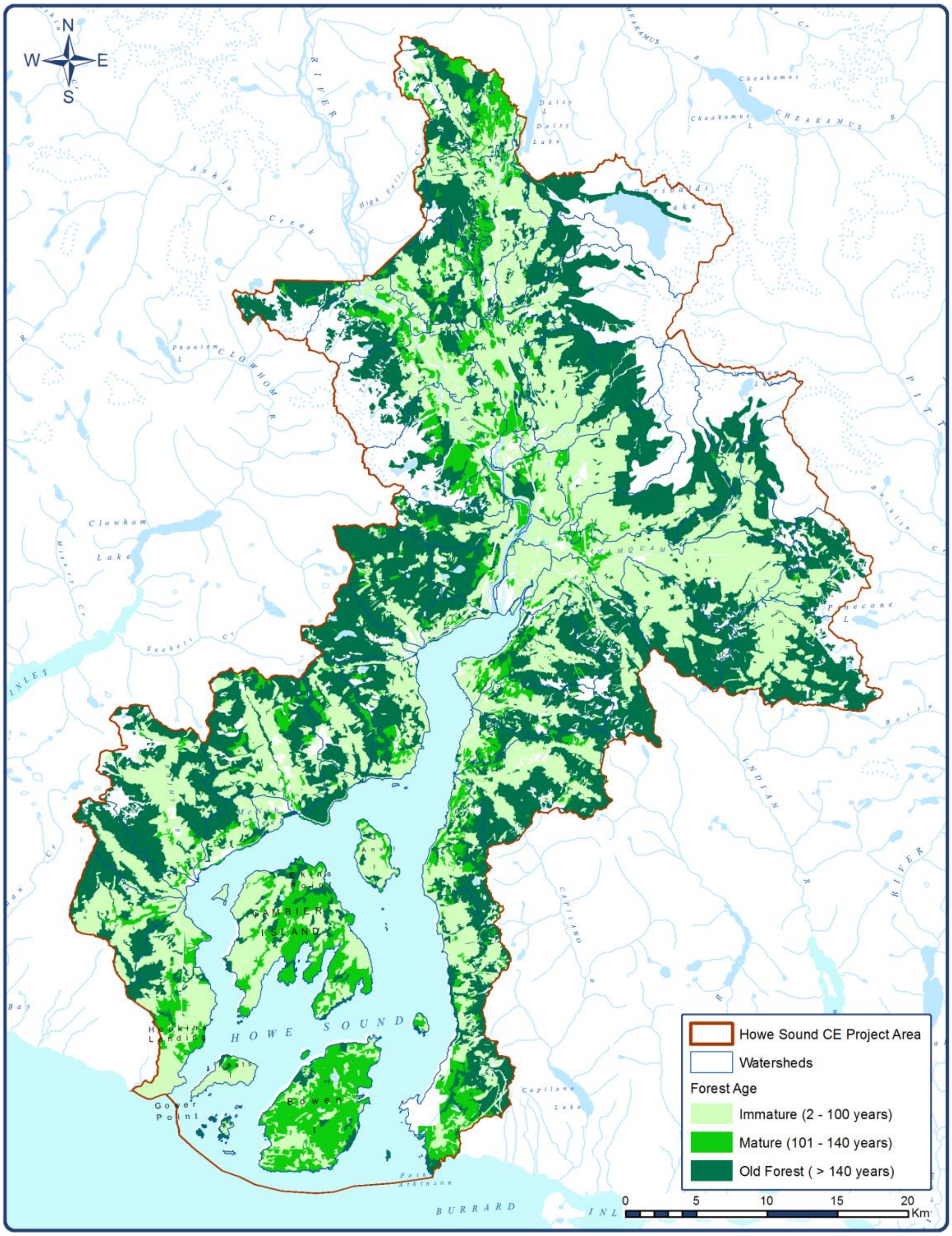
This map shows the peak flow index as an indicator for Aquatic Ecosystems. For this assessment, the peak flow index is the Equivalent Clearcut Area (ECA) within a watershed unit divided by the total watershed unit area (% of watershed). ECA is a metric that attempts to relate the influence of forest cover disturbance (e.g. land clearing, forest harvesting) to changes in stream flow. It expresses the relative hydrologic impacts of disturbed forests compared to a mature intact forest canopy. The darker colours indicate watersheds at higher risk of impacts and where further assessment work may be needed. (Measure: ECA as a % of watershed)

4. Supplemental Information

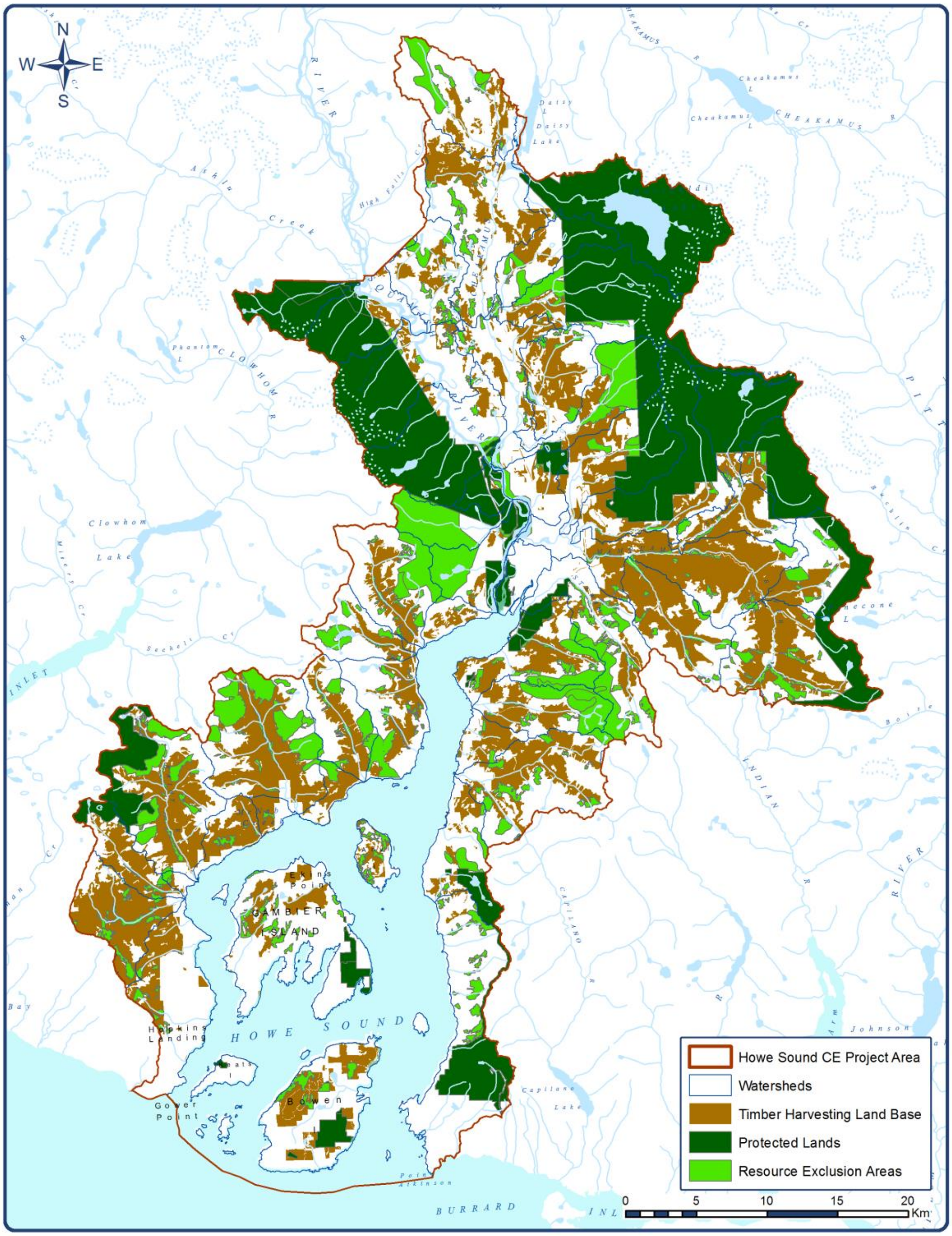
Roads and Land Jurisdiction



Forest Age and Watersheds

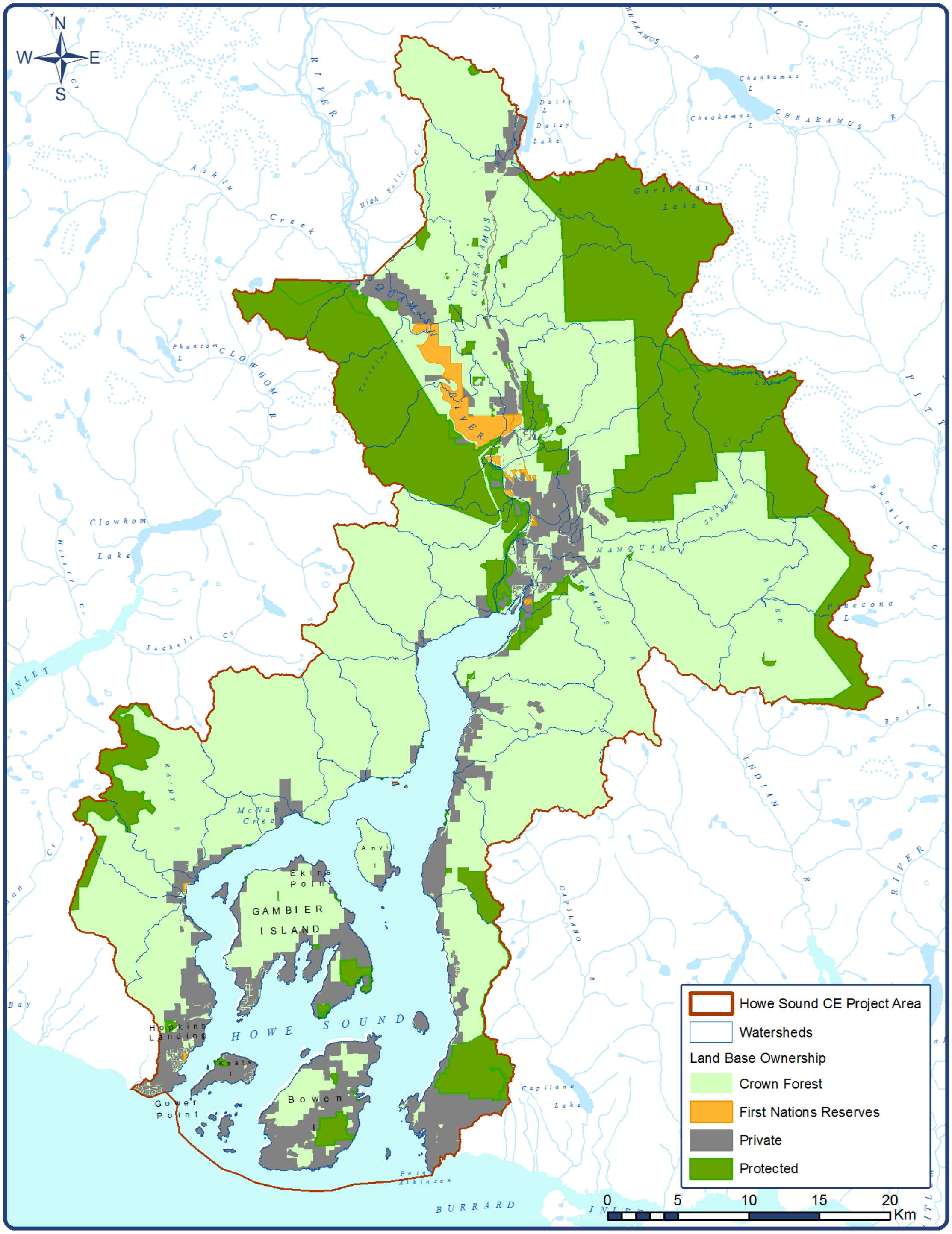


Protected Lands, Resource Exclusion Areas and Timber Harvesting Land Base



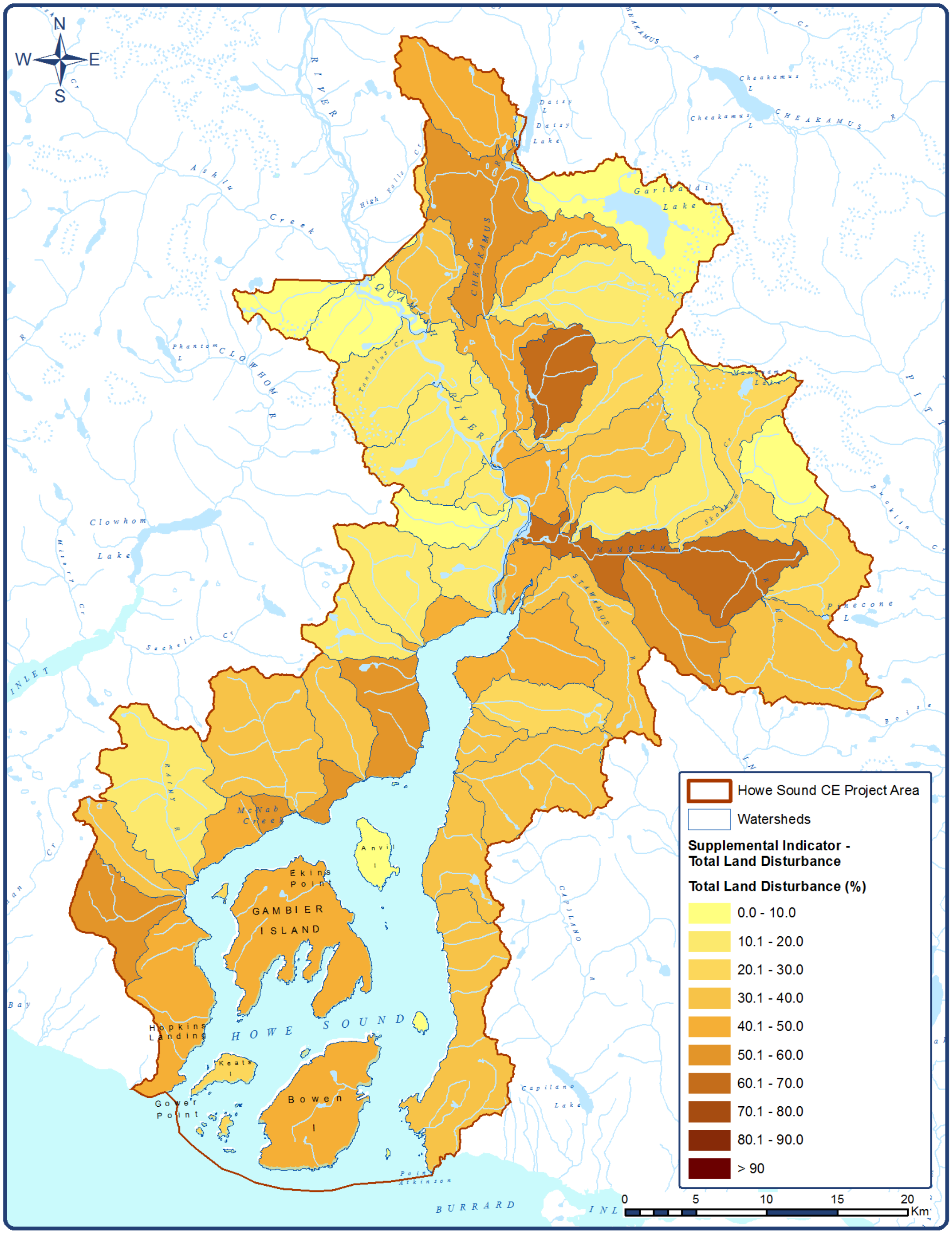
Note: For a description of *Protected Lands* and *Resource Exclusion Areas*, please go to: http://wwwd.env.gov.bc.ca/soe/indicators/land/land-designations.html

Land Base Ownership and Watersheds

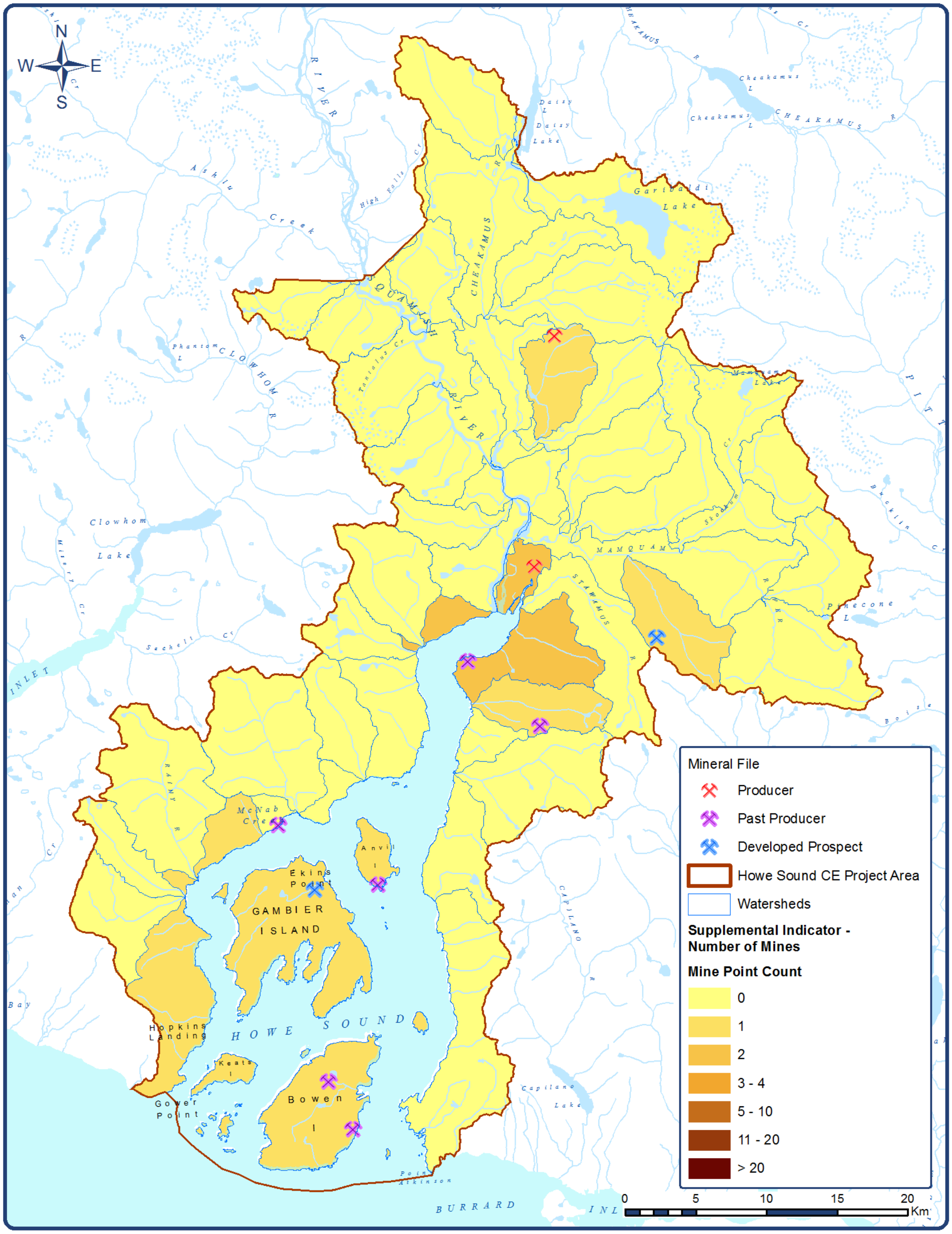


Note: The Province of British Columbia recognizes that aboriginal rights (including assertions of aboriginal title) exist for First Nations in the area.

Total Land Disturbance

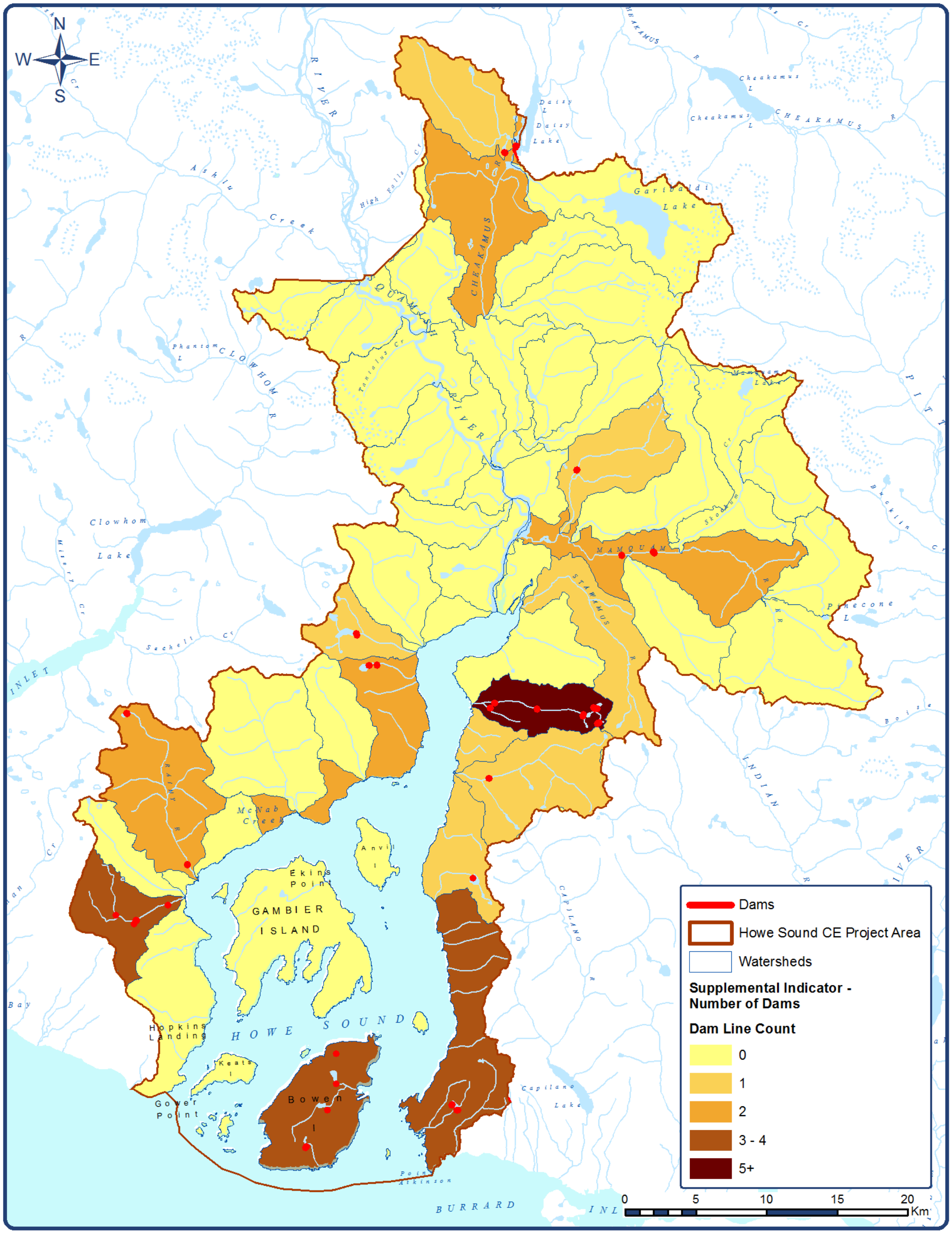


Number of Mines



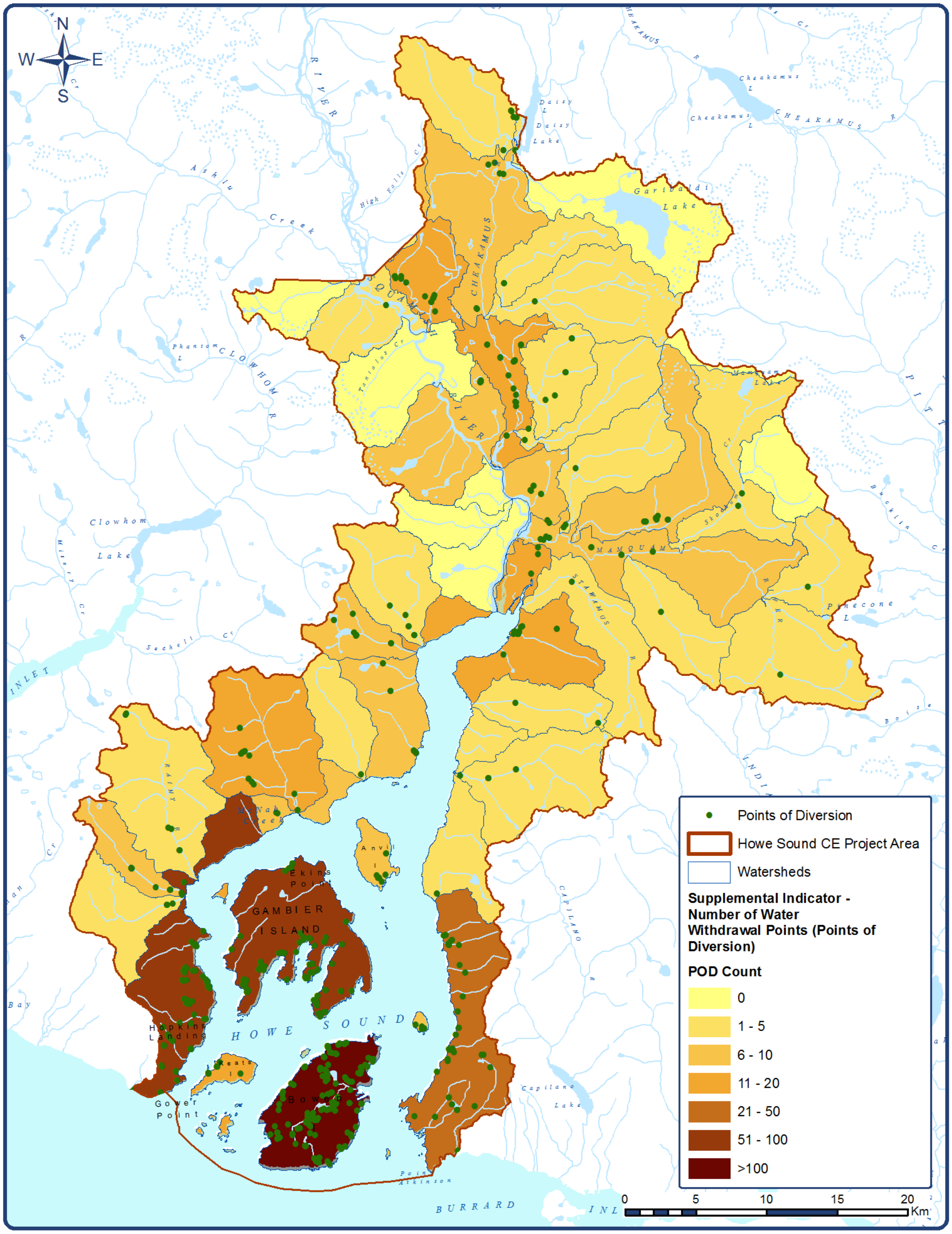
Note: This map only identifies mines as of 2016.

Number of Dams

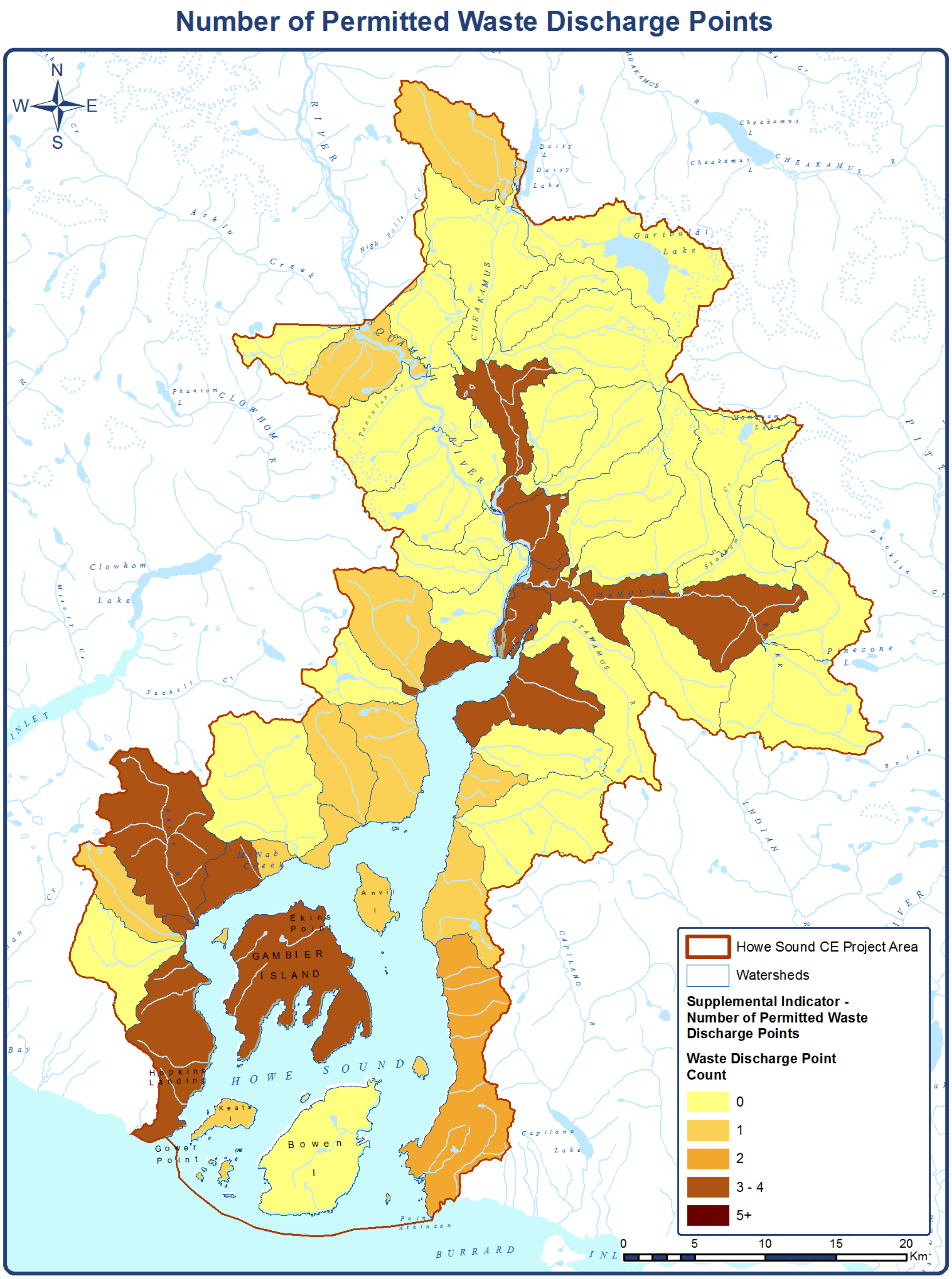


Note: This map only identifies dams as of 2016.

Number of Water Withdrawal Points



Note: This map only identifies known authorized water withdrawls points as of 2016.



Note: This map is based off of a Waste Discharge Point count from 2016.

5. Discussion of Assessment Results

The current condition assessment results in this report should be viewed as initial coarse filter information for consideration in strategic, tactical and operational decision-making at all levels of governance. These initial assessment results would benefit from further validation and assessment work. The assessment results should also be considered in the context of: any trend information, First Nations' interests, unique watershed characteristics, competing resource values, climate change, public safety and other important contextual information before determining if, and what kind of, a management response is warranted.

The assessment results in this report provide some general insight into where aquatic ecosystems are potentially at higher or lower risk and what some of those risk factors likely are. From this assessment, it appears that roads are a factor that should receive some further attention in terms of exploring precisely what amount of risk they pose and what management actions can be taken over time to reduce those risks. Some further validation work could be conducted on some individual sample watersheds to ground truth the results. Even this type of individual watershed assessment will, in most cases, require further consideration to determine appropriate management responses.

At the individual watershed scale, the ministry is exploring a number of actions in response to these results such as assessing the recent trends in these indicators, comparing these predictions to available, on-the-ground aquatic ecosystem health information (e.g. Forest and Range Evaluation Program data) and applying these risk assessments, where possible, to land and resource management decisions. Some examples of these potential provincial responses are offered in Table 2. The table provides some sample management responses for three watershed assessment units that were selected for their varying levels of assessed risk, to demonstrate how this information could be applied in varying circumstances. It also provides some potential interpretations of the assessment results, some types of further assessment that could be undertaken and some potential management responses to the observed risks.

The regulation and management of lands, forests, riparian habitat, instream activities, water use, fish and aquatic wildlife has evolved considerably in recent decades. Assessing the indicator trends over time would distinguish between historic and recent management practices and help prioritize actions based on growing versus diminishing risk. Comparing the current condition data to available on-the-ground riparian, channel condition and biological information will more accurately confirm or reject the accuracy of these assessments.

Table 2. Examples of Potential Interpretation, Further Assessment & Management Responses

	Indicators for the Aquatic Ecosystems Value & Risk Level **(H,M,L)**					
Watershed Unit & Interpretation	Road Density	Roads Near Streams	Roads on Steep Slopes	Stream Crossing Density	Riparian Zone Disturbance	Peak Flow Index
Rubble Creek (e.g. Watershed in BC Park)	**0.16** km/km2 **L**	**0.08** km/km2 **L**	**0** km/km2 **L**	**0.14** #/km2 **L**	**6.69** % **L**	**1.82** % ECA **L**
Initial Interpretation	➢ Risks are low as the entire watershed is within Garibaldi Prov. Park; ➢ This watershed has one of BC Parks busiest back-country access areas and receives high recreational use and parking demand along portions of Rubble Creek and Garibaldi Lake; and ➢ Risk to aquatic ecosystem health is expected to remain low.					
Recommended Further Assessment	➢ Some assessment of available on-the-ground riparian lake/channel condition and biological data could be undertaken to further calibrate and/or validate the risk assessment model.					
Potential Management Responses	➢ Ensure a high standard of site-level management of the streams and riparian areas within the park are maintained.					
Squamish River-Brackendale (e.g. Urban Area Watershed)	**4.15** km/km2 **H**	**1.17** km/km2 **H**	**0.07** km/km2 **L**	**1.66** #/km2 **H**	**43.04** % **H**	**48.75** % ECA **H**
Initial Interpretation	➢ Risks largely driven by historic and current urban land development in the lower portions of the watershed and development also in Alice Lake Provincial Park (access road and campground); ➢ Impacts of urban storm water (increased peak flows and degraded water quality) are anticipated in the more hardened developed areas ➢ Risks from urban development tend to be more permanent and more difficult to manage;					
Recommended Further Assessment	➢ Compare available on-the-ground riparian and channel condition assessments to validate assessment predictions; and ➢ Compare available on-the-ground biological (aquatic invertebrates, fish & aquatic wildlife) assessments to validate assessment predictions.					
Potential Management Responses	➢ Apply results to inform future land development patterns; ➢ Explore innovative storm water practices to reduce changes to channel-forming flows and improve water quality through infrastructure upgrades, incentives and by-laws; and ➢ Maintain and improve riparian habitat on public and private land, where possible.					

	***Indicators for the Aquatic Ecosystems Value & Risk Level* (H,M,L)**					
Watershed Unit & Interpretation	Road Density	Roads Near Streams	Roads on Steep Slopes	Stream Crossing Density	Riparian Zone Disturbance	Peak Flow Index
Mamquam River (e.g. Forestry Watershed)	**3.19** km/km2 **H**	**0.88** km/km2 **H**	**0.27** km/km2 **H**	**2.32** #/km2 **H**	**70.7** % **H**	**30.81** % ECA **M**
Initial Interpretation	➢ Risks largely driven by historic forest harvest dating back to intensive logging in 1970's; ➢ Recent practices suggest considerable improvements in road building, riparian management and harvest rotation that may not be reflected in risk assessment; ➢ The watershed is an economically valued forest harvest area in the Sea-to-sky District; and ➢ Despite being an intensive forest harvesting area, improved forest harvesting practices have resulted in a Moderate Peak Flow Index rating					
Recommended Further Assessment	➢ 20 year trend analyses of road densities, forest age, equivalent clearcut area and riparian disturbance will indicate the direction and significance of changing risks in the watershed; ➢ A 20 year predictive analysis based upon harvest trends, anticipated urban development and forest age class will indicate the anticipated future direction and significance of risks to aquatic ecosystems in the watershed; ➢ Compare available on-the-ground riparian and channel condition assessments to validate assessment predictions; and ➢ Compare available on-the-ground biological (aquatic invertebrates, fish & aquatic wildlife) assessments to validate assessment predictions.					
Potential Management Responses	➢ Apply results to inform road deactivation activities of FLNRORD and forest licensees; ➢ Apply results to inform riparian habitat restoration and silviculture practices; and ➢ Consider results in the development Forest Stewardship Plans, cutting permits and road construction permits within the watershed, seeking opportunities to reduce road density and riparian disturbance.					

FLNRORD staff are developing tools and processes designed to integrate and communicate resource value objectives, assess how well these objectives are being achieved (including results from this report) and respond with integrated resource management approaches to help achieve these objectives. In the spirit of the United Nations Declaration on the Rights of Indigenous Peoples, FLNRORD will share these assessments with key local First Nations in the Howe Sound CE Project area and collaborate on the development of any warranted management responses.

6. References

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Ministry of Environment and Ministry of Forests, Lands and Natural Resource Operations. 2016. *Cumulative Effects Framework: Knowledge and Policy Summary for British Columbia's Aquatic Ecosystems Value.* Version 2.0. Prepared by the Aquatic Ecosystems Working Group for the Value Foundation Steering Committee. 51p.

Ministry of Forests, Lands and Natural Resource Operations. 2016. *Adapting Natural Resource Management to Climate Change in the West and South Coast Regions: Considerations for Practitioners and Government Staff*. South Coast Extension Note for Ministry of Forests, Lands and Natural Resource Operations. 19pp.

Province of British Columbia. *Water.* Web. October 25 2017. https://www2.gov.bc.ca/gov/content/environment/air-land-water/water

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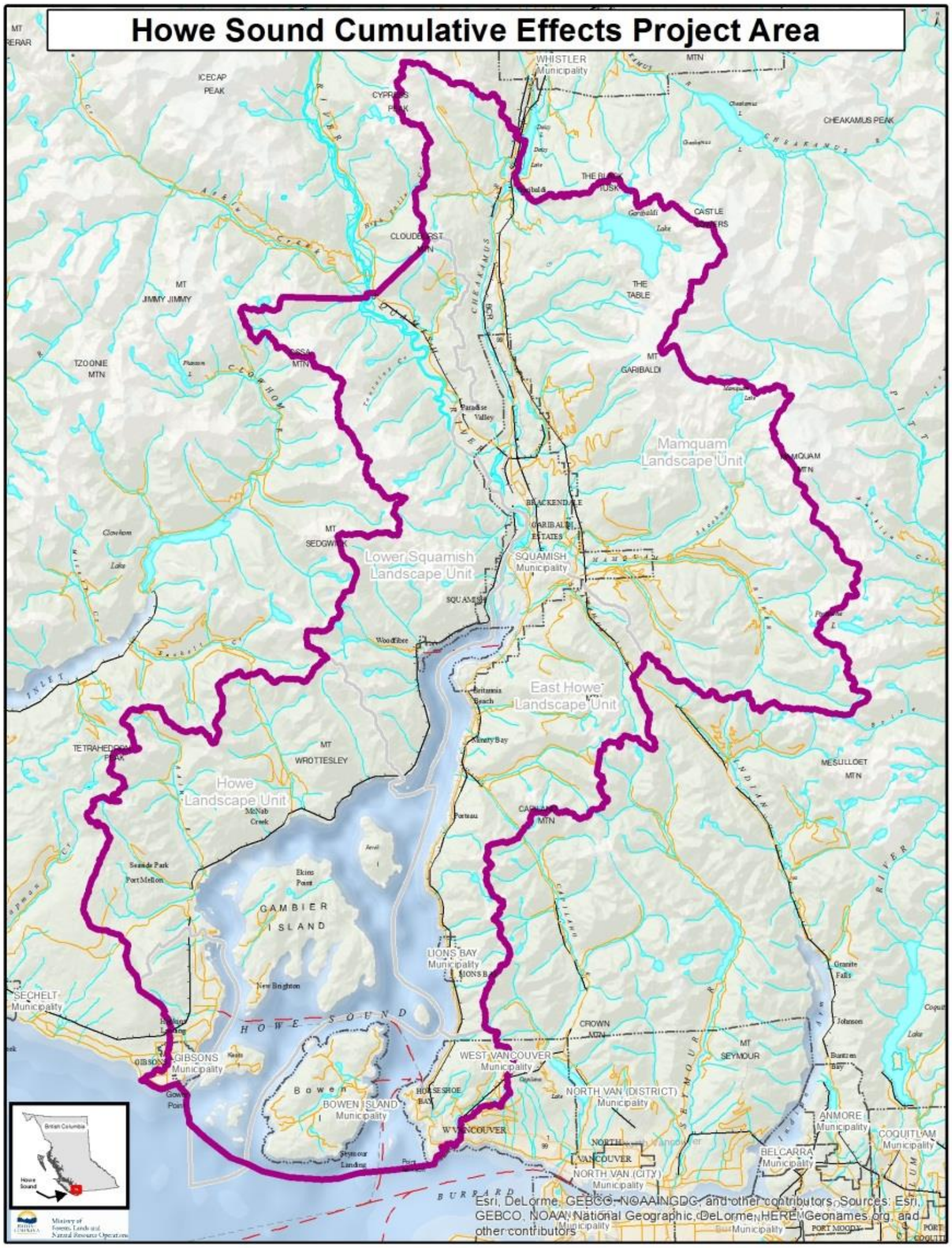
Appendix I

Map of Howe Sound Cumulative Effects Project Area



The Project area was tailored to the Howe Sound area to meet the expressed interests of local stakeholders. Local communities expressed a shared interest in CE value assessments that were focussed on a more natural boundary like the Howe Sound watershed instead of the three separate provincial administrative districts that straddle the Howe Sound area. The project area essentially follows the height of land around Howe Sound and aligns with Provincial Landscape Unit boundaries except at the entrance to Howe Sound where the boundary was extended to capture the area from West Vancouver around Bowen Island to Gibsons considering bathometry lines.

Appendix II

Description of Aquatic Ecosystems Value

The Province of British Columbia has identified aquatic ecosystems as one of its initial core values for CE assessment. Aquatic ecosystems provide fresh water, food, and habitat across the landscape for many species including humans. The function of aquatic ecosystems results from the interaction of many natural and anthropogenic factors that determine the physical, chemical and hydrologic processes in watersheds. There are three major components of aquatic ecosystems: streams and riparian systems, water quantity and water quality.

Stream and Riparian Systems

Most coastal streams and riparian areas function as integrated systems and provide the following when functioning properly: filter run-off water; store and slowly release water; maintain fully connected fish habitat; maintain an adequate root network and large woody debris supply; provide shade and minimize bank change; and withstand normal peak flood events without accelerated soil loss, abnormal stream or bank movement. Natural disturbance (e.g. landslides, forest fire, disease) and human development (e.g. housing, roads, forest harvesting, culverts) can have multiple impacts on stream and riparian systems function.

Water Quantity

Hydrological flow regimes provide critical habitat conditions for various aquatic lifeforms. Extreme peak and low stream flows and changes in the timing of flows can have significant impacts on aquatic biota and other downstream users. Natural factors that affect these instream flows include: levels of precipitation, snowpack levels, watershed shape, forest cover, soil-types and drainage efficiency. Human development behaviour such as road density, impervious surfaces, drainage networks and the layout of forest cutblocks (elevation, aspect and size) can also have significant impacts on watershed flow regimes and aquatic ecosystems.

Water Quality

Water temperature, turbidity/sediment loads, chemistry and nutrients can all affect aquatic ecosystems in different ways: high or freezing temperatures can kill fish and affect the balance of invertebrate species; increased turbidity/sediment load adversely affects fish; levels of dissolved oxygen are critical to the survival of fish; and persistent toxic chemicals can kill or displace aquatic biota and/or degrade human water sources.

Some of the main elements of aquatic ecosystems include:

River Drainages/Watersheds

Surface water flows downhill through a drainage area contained by topographical/watershed boundaries into a river, lake or ocean system. In coastal BC, these watersheds and river drainage areas are critical to the movement of nutrients, sediment and anadromous species like salmonids in coastal areas. Larger drainage areas are made up of smaller drainages/watersheds and they can be defined and assessed at various scales.

Lakes

Lakes support a variety of species and food webs due to seasonal water level fluctuation patterns. Lakes can act like freshwater reservoirs and capture sediment loads and nutrients before water heads downstream. Some larger lakes can have more stable lake levels which are critical to spawning sockeye salmon.

Wetlands

Wetlands include bogs, fens, swamps, and marshes and are areas of high species richness and diversity. A large proportion of the terrestrial wildlife in BC rely on wetlands for part of their ecological needs. Wetlands play an important hydrological function by: storing and filtering water; reducing runoff; recharging groundwater; maintaining streamflows and water quality; reducing erosion and sediment levels; and by reducing excess nutrients and toxic chemicals.

Riparian Areas

Riparian areas are ecotones (transition areas) between aquatic and terrestrial ecosystems within watersheds. They are often located adjacent rivers, streams, lakes, wetlands or estuaries. Riparian areas essential provide an ecotone of aquatic interface (subsurface, surface, above surface) that can link landscapes by providing corridors for: animal and plant movement; sediment transport and water transport. Riparian area services include: water temperature moderation; water input; sediment filtration; bank stabilization; and the provision of habitat structure and nutrients to aquatic ecosystems.

Estuaries

Estuaries are ecotones (transition areas) between freshwater and marine ecosystems in coastal areas. Estuaries cover only 2.3% of BC coastline and basically range in size from 1-10 ha but are very important to aquatic ecosystems. Estuaries are highly productive environments and are used by about 80% of all coastal wildlife. They are critically important to the survival of Pacific Salmon, especially juvenile Salmonids.

Groundwater

Several freshwater aquatic features and ecosystems like springs, headwaters, wetlands and floodplains are dependent on groundwater. Groundwater provides most of the base flow for many streams during periods of low precipitation or when precipitation is locked up in some snow or ice (seasonal low flow periods). Groundwater can help sustain flows of suitable water temperature for many aquatic lifeforms. Groundwater also provides drinking water for about 25% of BC residents.

Threats to Aquatic Ecosystems

Aquatic ecosystems are often subject to cumulative impacts from various human-related and natural disturbances. In particular, human development activities have the potential to impact the natural state of hydrological processes within a watershed by altering the timing and intensity of peak flows, accelerating surface erosion, degrading the condition of riparian zones, and/or triggering mass wasting events. Some of the more common types of human development that could impact aquatic ecosystems (watersheds) include: forest harvesting; forest silvicultural practices; urban and industrial land development; road building; dam development; agricultural practices; oil and gas extraction; mining development; groundwater extraction; river diversion/augmentation; and chemical and nutrient pollution (Table 1).

Table 3. Sources of Major Impacts to Freshwater Ecosystem Elements.

Element	Key Sources of Major of Impact and Related Human Developments
Stream/riparian systems	*Key Sources of Impact*: Disruption of colluvial streams; channelization, loss of large woody debris and other organic material; loss of connectivity; sedimentation; alterations to water chemistry; and climate change. *Key Related Human Developments:* Dams, water impoundment and diversion; stream crossings; linear developments like roads, pipelines and seismic lines; mining; gravel removal; and pollution.
Lakes	*Key Sources of Impact*: Water extractions and diversions; alien species; water chemistry; and climate change; *Key Related Human Developments:* Agricultural and urban development; and pollution
Wetlands	*Key Sources of Impact*: Ecosystem conversion (draining and filling-in); water chemistry *Key Related Human Developments:* Agricultural and urban development; pollution
Estuaries	*Key Sources of Impact:* Ecosystem modification (armouring, vegetation removal, change of freshwater flows, water chemistry, sediment contamination, alien species); climate change and sea level rise *Key Related Human Developments:* Agricultural and urban development; pollution
Groundwater	*Key Sources of Impact*: Water levels dropping (diversion and withdrawal); alterations to water chemistry; and climate change *Key Related Human Developments:* Water consumption, forestry; urban development

More natural watershed disturbances like wildfire, floods, landslides or forest health can also have impacts on hydrological processes that can influence water quality, water quantity, and overall aquatic ecosystem function. Factors related to climate change are also important to consider when estimating future impacts to watersheds and aquatic ecosystems.

Appendix III

Management Objectives for Aquatic Ecosystems

The importance of sustaining functioning aquatic ecosystems is reflected in British Columbia's current legal and policy objectives that exist for key aquatic ecosystem components like: water quality; water quantity and stream-riparian systems. These objectives vary by the: content of the objective; spatial scale of the objective; area of the province the objective applies to; and the resolution of the objective (broad or specific direction). The objectives for the aquatic ecosystems value include both "broad objectives" relating to a desired overarching condition and "specific objectives" that tend to have a more focussed application and metrics. According to the *Cumulative Effects Framework: Knowledge and Policy Summary for British Columbia's Aquatic Ecosystems Value*, three broad management objective themes can be extracted from legislation, policy and agreements with First Nations to guide CE assessment for the aquatic ecosystems value:

1) Sustain, conserve or restore water quality;
2) Sustain, conserve or restore water quantity; and
3) Sustain, conserve or restore hydrological and aquatic ecosystem functions and processes

It should be noted that the new *Water Sustainability Act* gives the Lieutenant Governor in Council the authority under the *Act* to make regulations and objectives for the purpose of sustaining water quantity, water quality, and aquatic ecosystems. As a result, future current condition assessments for the aquatic ecosystems value may include some new more "specific objectives" developed for watersheds, streams, aquifers and/or other specified area or environmental feature under the new *Water Sustainability Act*: http://www.bclaws.ca/civix/document/id/complete/statreg/14015 .

Appendix IV

Howe Sound Context for Aquatic Ecosystems

Location and Topography

Howe Sound contains one of the southernmost fiords on British Columbia's coast. The entrance to Howe Sound is located about 10 km northwest of the city of Vancouver and stretches from the Strait of Georgia heading north for about 43 km up to the Squamish River Estuary. The sound itself is a triangular shaped inlet bounded by steep coastal mountains ranging from 1,200m in the south up to about 2,700m in the north. The southern portion of the sound contains four major islands (Bowen, Keats, Gambier and Anvil) and numerous smaller islands while the northern portion of the sound narrows to a 3 km wide channel becoming a fiord for 15 km before reaching the Squamish estuary. The estuary is fed by the Squamish River and the associated Cheakamus and Mamquam river drainages.

Precipitation and Climate Change

In general, the Howe Sound area is warm and dry during the summer months and cool and very wet (snow at higher elevations) during the winter months. Annual mean precipitation in the area is influenced by orographic precipitation along the coastal mountains and ranges from 1250 mm/yr in West Vancouver to 2250 mm/yr in Squamish. In the coming years, warming from climate change is expected to affect weather conditions and seasonal precipitation in the Howe Sound area. More winter precipitation will likely fall as rain rather than snow and result in: lower snowpacks, earlier/more rapid snowmelt and longer fire seasons. Snowfall in the South Coast is projected to decrease by 10 to 40% in the winter and 14 to 73% in the spring by the year 2050. Forest fire risk and seasons are expected to increase as periods of relative summer drought become more common. In addition, more severe winter rainstorms are projected which can lead to an increased risk of flooding, landslides and windthrow.

Hydrology and Climate Change

The Squamish River and its major tributaries (Ashlu, Elaho, Cheakamus and Mamquam) supply the vast majority of freshwater input into Howe Sound by draining water from high elevation snow/ice fields and lower elevation areas. The larger drainages that receive summer meltwater from higher elevation snow and ice fields have peak downstream flows during the summer but also experience secondary peak flows during heavy rain events in the late fall. The temperate rain forests of the Howe Sound area provide an excellent example of a sub-soil flow regime, where a lot of water moves downslope below the ground surface. The vegetation and organic soils act as a sponge absorbing much of this precipitation.

Climate change in the South Coast will likely shift the current rain/snow-driven hydrological regime to a more rain-driven regime over the next 35 years. This will alter the timing, variability and magnitude of stream and river flows year round in the area. Projected hydrological changes related to climate change may increase the risk of floods, debris flows and/or landslides in the Howe Sound area over time. The mountains surrounding Howe Sound have many steep forested drainages that can periodically become obstructed and lead to channelized debris flows or debris torrents during peak flow periods. Damaging debris torrents can occur in any of these steep drainages but tend to happen more frequently on the east side of Howe Sound possibly due to the different bedrock conditions and higher rainfall amounts. Loss of vegetation through natural or anthropogenic disturbance (i.e. forestry cutblocks and roads), combined with the shifting of hydrological patterns due to climate change (i.e. shift to a rain-driven hydrological regime), have the potential to decrease the capacity of certain landscapes to buffer rainfall, potentially leading to a higher risk of: flashier streams, increased stream loads; floods; debris flows and channel instability. These possible changes in hydrology have the potential to adversely affect downstream water quality, water quantity, aquatic ecosystems, public infrastructure and perhaps public safety in some higher risk areas if not proactively managed.

Ecology and Climate Change

The numerous watersheds surrounding Howe Sound provide fresh water, sediment and nutrients to downstream environments and support the general ecology of the area. The unique conditions of each watershed provide complex physical and chemical processes and food-webs that sustain a diversity of aquatic and riparian-dependent wildlife species. Steep, high-elevation streams can provide a home for Dolly Varden, Bull Trout and Pacific Tailed-frog. The matrices of small streams and wetlands can provide habitat for the Coastal Cutthroat Trout and the endangered Pacific Water Shrew. Larger valley-bottom rivers can be important spawning and rearing areas for Steelhead Trout and several species of Pacific salmon. In addition, these watersheds also provide an important water supply for various human uses such as: residential, industrial, and commercial activities.

The ecosystems in the Howe Sound watersheds are currently experiencing the cumulative impacts of natural disturbances (i.e. fire, landslides, floods), anthropogenic disturbances (i.e. energy development, resource extraction, recreation and housing development) and climate change. Climate change alone is projected to affect aquatic ecosystems by altering temperature, hydrological and fire regimes in the South Coast.

Human Settlement

The Howe Sound area falls within the traditional homelands of the Coast Salish people and include the Tsleil-Waututh, Musqueam and Squamish First Nations. The Squamish Nation has numerous reserves and cultural sites within the Howe Sound area and Squamish river watersheds. Sustainable and healthy aquatic ecosystems are important to supporting First Nations' quality and way of life and are important to their rights and interests.

About 40-50,000 people currently live in the Howe Sound area with the majority of people residing in the communities of Squamish, Britannia Beach, Lions Bay, Horseshoe Bay, Gibsons and Bowen Island. To date, the topography in the area has restricted most of the settlement to the coastline, valley bottoms and lower portions of islands. It is estimated that the population in the Sea-to-Sky corridor could increase by almost 30% over the next 25 years. It is anticipated that associated commercial services, tourism and recreational use will also continue to grow in the area during this period. Approximately 13,000 units are currently being planned in the broader Howe Sound area through resort and housing development proposals.

Land Use

The Howe Sound area, with its close proximity to Vancouver, has long been an interface area between wilderness and increasing human settlement, development and recreational activity. The area has multiple competing economic, social, cultural and environmental values and is now being exposed to a new era of development interests and potential cumulative impacts on terrestrial and marine ecosystems. The area's economy is diversifying and becoming less reliant on natural resource extraction as improved highway access and tourism infrastructure spur new resort, housing, recreation, commercial and industrial development interests. Development pressure is expected to increase in the coming years due to a number of new development proposals (i.e. Squamish Oceanfront, Garibaldi at Squamish Resort, Britannia Beach housing developments, Woodfibre Liquefied Natural Gas Plant, and McNab Creek aggregate mine).

The Forestry sector has historically had an impact on aquatic ecosystems in the Howe Sound area through road development, timber harvesting and other industrial practices. About 79% of the land in the Howe Sound CE Project area is forested and about 29% of this forested land is available for timber harvesting. By contrast, 24% of the land in the project area falls within parks and protected areas and about 37% of the land area has some form of forest protection status.

Several watersheds in the Howe Sound area are heavily roaded from a history of natural resource extraction, hydro development, industrial development, recreational access and community development. The forestry sector has the greatest number of roads in the Howe Sound area but recent community development in the Sea-to-Sky corridor is also increasing the number of roads. Roads can affect watersheds by having a downstream impact on water quality, water quantity and aquatic ecosystems. There are an estimated 2,300 km of total roads within the Howe Sound CE Project area and approximately 65% of these roads are active or inactive forestry roads.

Over the past 30 years, the forest sector has improved its forest management and road building practices in an effort to minimize its impact on aquatic ecosystems. The forest industry now more commonly uses heli-logging to avoid building roads in steep or unstable terrain. Professional Geologists are also employed to assess all existing roads on >60% gradient slopes to help prevent road failures/slide erosion. The forest sector also uses the Forest and Range Evaluation Program (FREP) to conduct long-term spot monitoring to ensure sustainable resource management as it relates to 11 provincial values that include: water quality, watersheds, riparian habitat, forests and soils. There is now more than five years of FREP monitoring from various locations in the Howe Sound area.

The Sea-to-Sky area, which includes Howe Sound, is seeing an increase in backcountry recreation from visitors that primarily come from outside the Sea-to-Sky corridor. The number of existing roads in the Howe Sound area can also create watershed access opportunities for motorized and non-motorized recreationalists. The increased recreational use and activity in the area has the potential to cause cumulative impacts on the hydrological function and health of watersheds. Some high use recreational activities like: mountain biking, motor biking, ATV use and camping on non-designated sites can remove vegetation, encourage erosion and/or cause pollution in some portions of watersheds. The majority of recreational traffic and focus occurs within the watersheds associated with the Cheakamus River and the Sea-to-Sky corridor.

Some other potential impacts to aquatic ecosystems in Howe Sound include the number and location of mines, dams, authorized water withdrawal points and permitted waste discharge points. In 2016, the project area contained: 13 mines in 12 watershed units; 35 dam structures in 16 watershed units; 552 authorized water withdrawal points in 58 watershed units; and 40 permitted waste discharge points in 21 watershed units.

Cumulative impacts will need to be carefully considered by respective land and water decision-makers/managers in this time of development, recreational use and climate change, in order to sustain water quality, water quantity, riparian systems and the overall function of aquatic ecosystems in the Howe Sound project area.