
Photo source: Derek Ray (NHC)

Haida Gwaii Coastal Flood and Erosion Study Community Summary Report: Village of Masset

Prepared by:

Northwest Hydraulic Consultants Ltd.
30 Gostick Place
North Vancouver, BC V7M 3G3
Tel: (604) 980-6011
www.nhcweb.com

NHC Project Contact:
Grant Lamont, P.Eng., MASc
Principal, Senior Coastal Engineer

December 23, 2022
Final Report, Rev. 0

NHC Reference 3006558

Prepared for:

Village of Masset
1686 Main Street
Masset BC V0T 1M0

Village of Masset

1 INTRODUCTION

This report summarizes the coastal flood and erosion hazards identified for the Village of Masset on Haida Gwaii. The objectives of the study were to predict the potential future effects from two independent natural hazards – coastal flooding from storm waves and tsunamis – when sea levels are expected to be higher. The results of the study are intended to inform communities as they make long-term community planning and governance decisions.

2 COASTAL STORM FLOOD HAZARD RESULTS

Maps have been prepared for this study that characterize local conditions with both 1 metre (m) and 2 m of relative sea-level rise (also referred to as SLR in this report). The following figures (Figure 2.1 to Figure 2.4) show the extents and elevations of the coastal flood hazard resulting from a 1-in-200-year[1] storm event with 1 m of SLR for select areas along the Village of Masset shoreline. The study area encompasses the sandy north-facing shorelines of McIntyre Bay, shorelines that face dominantly westward into Masset Sound, and shorelines around the relatively protected Delkatla Inlet. The maps show the coastal flood construction level (or FCL) in each location, which is the minimum elevation needed for the underside of a building's wooden floor or the top of a concrete slab to protect living spaces and areas used for storing goods that could be damaged by floodwaters. Further explanation of the maps is provided in section 5.

Key findings from the analysis include the following:

- Along the north coast, the flood hazard area is wide to reflect the low slopes and potential for 1 m of SLR to cause erosion and allow flooding to extend inland. Low areas inland are at risk of coastal flooding despite sheltering from wave effects (Figure 2.1).
- Extensive flooding occurs adjacent to the shorelines in low areas, including across sections of Highway 16 as it approaches Masset and intersection with Hodges Ave. and Towhill Rd. (Figure 2.2)
- Steeper shoreline areas facing into Masset Sound where waves are smaller have limited areas of coastal storm flood hazard immediately adjacent to the coast. (Figure 2.3)
- The northern part of Masset where the hospital is located has localized storm flood hazard along the shoreline which also covers the main road of Harrison Ave / Raven Rd. Inland areas that are below the coastal flood level area also identified. Detailed surveys beyond the scope of this project are required to confirm connectivity of inland low areas to the inlet. (Figure 2.4)

[1] A 1-in-200-year event corresponds to an annual exceedance probability of 0.5%.

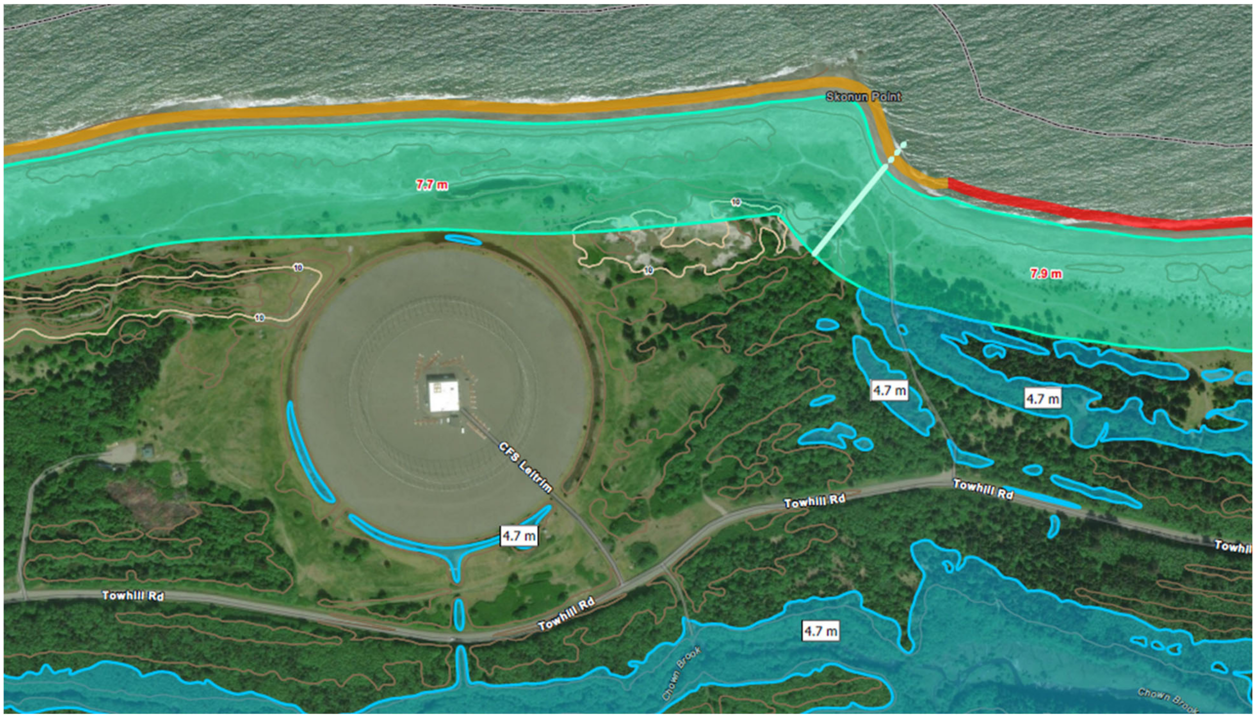

Figure 2.1 Portion of map showing the coastal FCL with 1 m of SLR for a segment of the north coast shoreline in the Village of Masset study area.

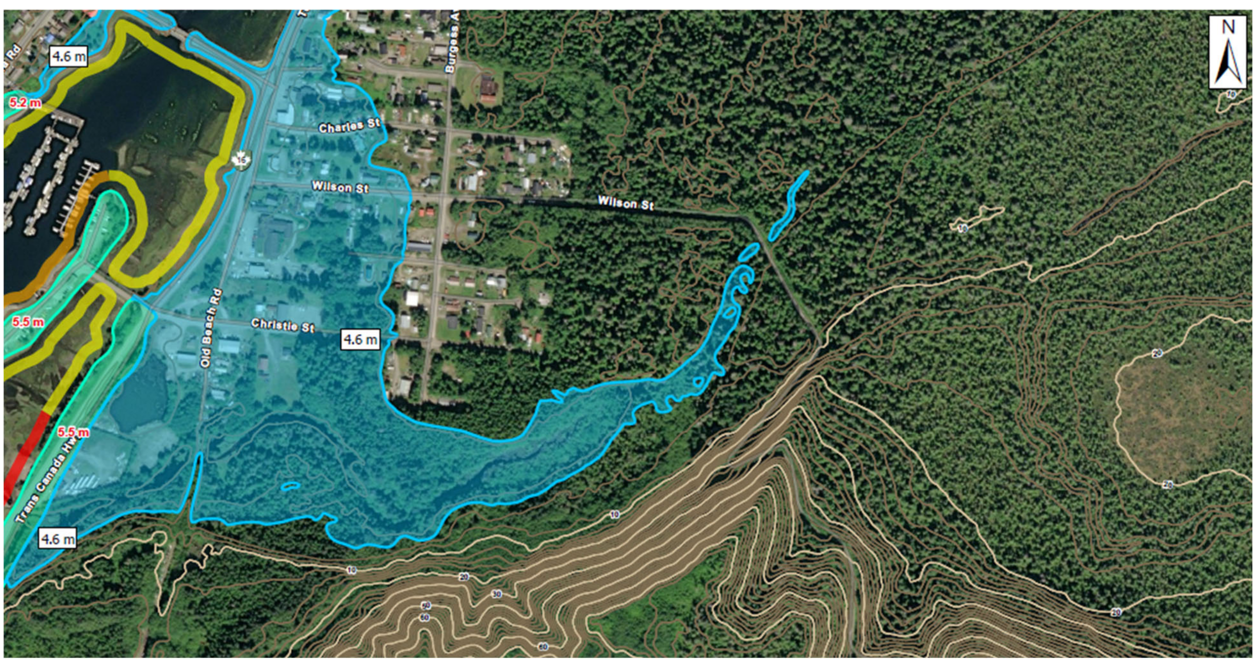

Figure 2.2 Portion of map showing the coastal FCL with 1 m of SLR for the east side of Delkatla Inlet. An extensive portion of the community falls within the coastal FCL zone with no wave effects considered, including the Hodges Avenue causeway and Highway 16.

Figure 2.3 Portion of map showing the coastal FCL with 1 m of SLR for the area near the entrance to Delkatla Inlet.

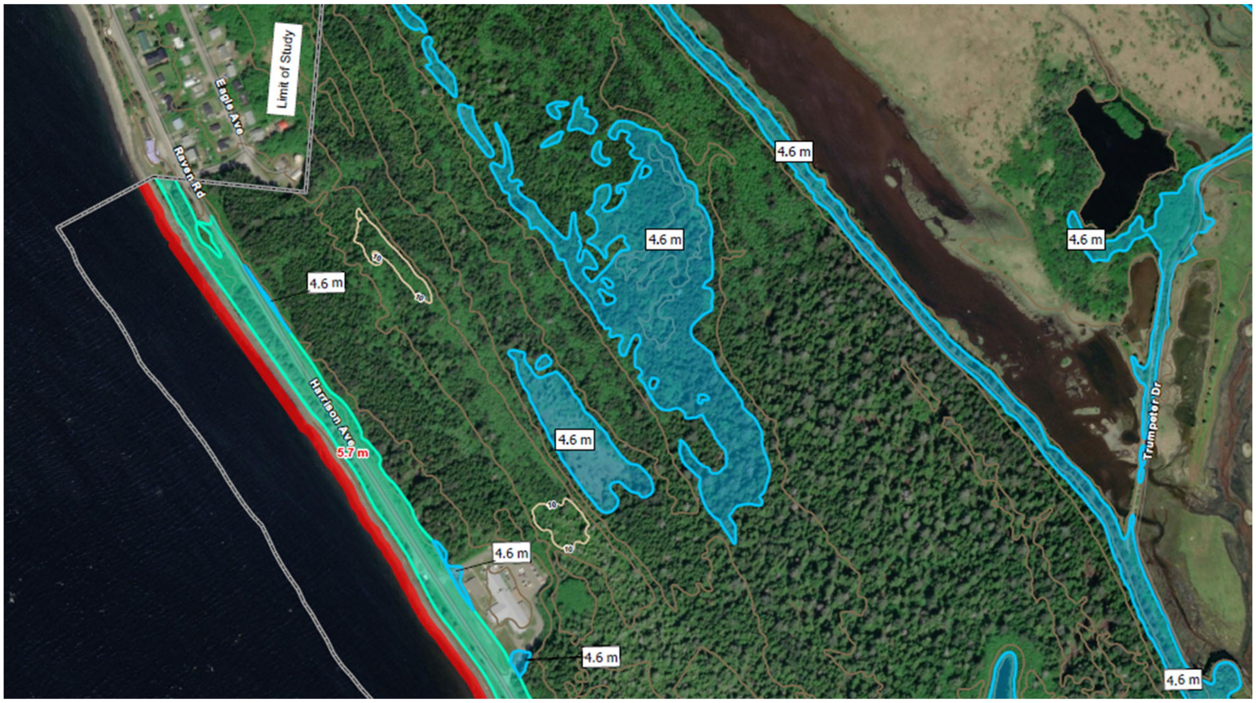

Figure 2.4 Portion of map showing the coastal FCL with 1 m of SLR at the northern segment of shoreline fronting Masset Sound. These results show that the Masset Medical Clinic is not within the FCL zone but that Raven Road, which provides access to the clinic from Masset and Old Massett would be impacted.

The following Figure 2-5 shows wave patterns along the Masset shoreline area from a northwesterly storm in Dixon Entrance. Large storm waves over 3.5 m in significant wave height[2] (denoted by H_s) can occur in this area during such storms. Wave heights reduce from their maximum in Dixon Entrance as the waves approach and refract into McIntyre Bay; however, at times of high tide the waves reaching shorelines can still have large amounts of energy. Dixon Entrance storm waves are notable for their long wave periods which result in high wave runup on shorelines relative to their height.

[2] The significant wave height corresponds to the mean height of the highest one-third of all waves.

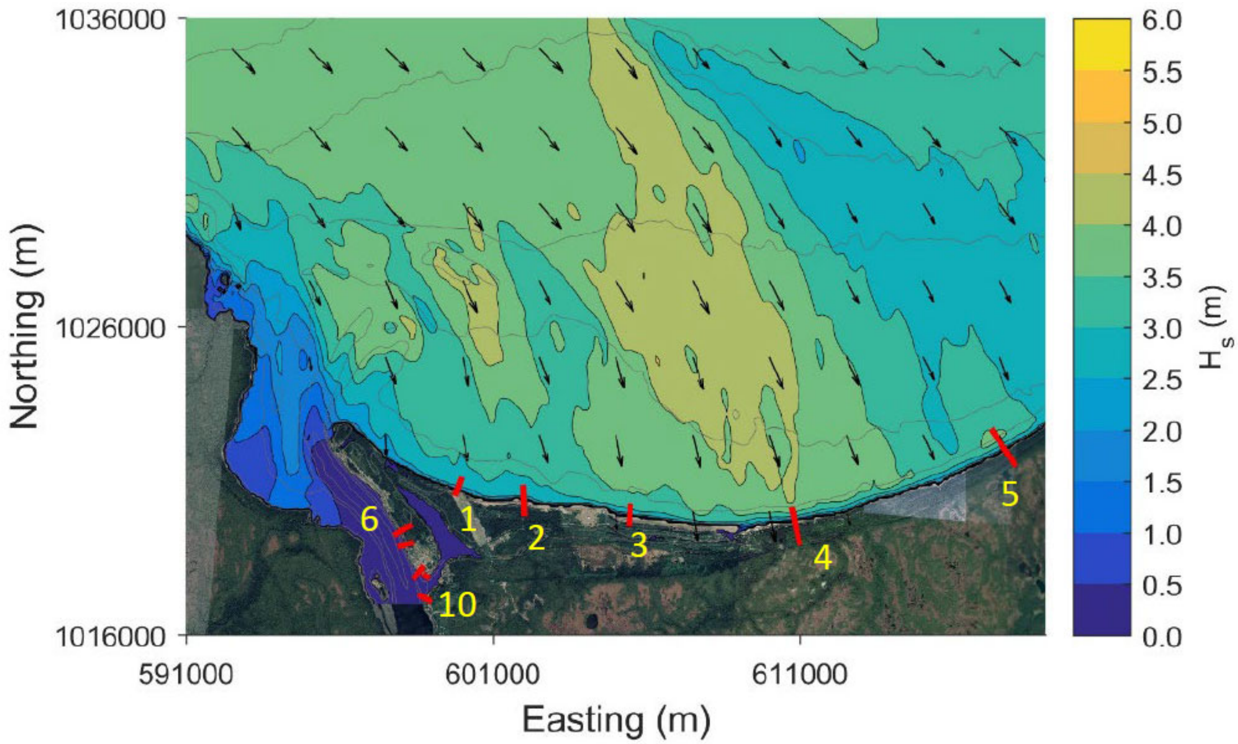

Figure 2-5. The pattern of wave propagation at Masset during the design storm event in Dixon Entrance. Colour contours on this image are given for the significant wave height (H_S), while vectors show the direction of wave propagation. Red lines are transect locations where wave runup is estimated for representative sections of shoreline in the study areas.

3 EROSION SUSCEPTIBILITY

The following figures (Figure 3-1 and Figure 3-2) show the varying classification of erosion susceptibility for the Village of Masset shoreline areas, with many areas identified as highly susceptible to erosion. Further explanation of the erosion susceptibility classification is provided in section 5. Shorelines in Masset Sound area are typically exposed to moderately energetic coastal processes and are composed of coarse gravels and small cobbles or are dominated by bedrock control, while finer sediments are found near Delkatla Inlet and also in areas on the north coast in McIntyre Bay. The presence of extensive armour rock placed as protection in Masset Sound demonstrates how susceptible these shorelines are to erosion, particularly at the upper shoreline. In general, these armouring structures are non-standard, show signs of damage, and provide visual evidence of the expected effects of future sea-level rise.

Figure 3-1. Portion of map of erosion susceptibility for the southern portion of the Village of Masset study area.

Figure 3-2. Portion of map of erosion susceptibility for the shorelines in the north portion of the Village of Masset study area.

The following series of photographs presented in Figure 3-3 to Figure 3-5 show the main types of shorelines at the Village of Masset and display some of the active coastal processes at work in this area. The shorelines along the north coast of the study area are dominated by highly mobile sands that form dunes inland of the active shore. Due to past glacial processes, there is a series of undulating dunes and swales inland of the present-day active coast.

In contrast, the coastline facing west into Masset Sound is dominated by gravel and cobble, with active wave cutting at the upper shoreline. Within Delkatla Inlet, the shorelines are relatively sheltered from waves and the lower foreshore exhibits a fine-textured material, grading coarser into the upper foreshore. Wave cutting of the upper shoreline is also readily apparent in this part of the study area. Sections of both these shoreline types have been armoured with rock in response to the wave cutting processes; however, the armouring is typically non-standard and most shows signs of damage from waves.

Figure 3-3. Photo looking east along the sand-dominated shoreline of the northern portion of the Village of Masset study area. Sand dunes define the upper shoreline and a series of paleo dunes and swales extend inland. Tow Hill can be seen in the middle distance.

Figure 3-4. An outcropping of rock at Skonun Point is one of the few interruptions to the otherwise sand-dominated northern shoreline of the Village of Masset study area. Skonun Point lies seaward of Canadian Forces Station Leitrim (formerly CFS Masset), protruding from the shoreline and locally altering longshore sediment transport processes.

Figure 3-5. Typical west-facing shoreline in Masset Sound. Gravel and cobble material dominate the foreshore and rock armouring has been installed to address wave cutting erosion at the upper shoreline. The armour rock shown in this photo is relatively new but already showing signs of failure from undercutting.

Figure 3-6. The more protected shorelines within Delkatla Inlet feature fine material in the lower foreshore, grading to gravels at the upper foreshore. Wave cutting of the upper shoreline is prevalent and rock armour has been installed at many locations to address this.

4 TSUNAMI HAZARD RESULTS

NHC produced overland inundation (i.e., flood) maps for the most adverse scenario between tsunamis originating from the Alaska-Aleutian and the Cascadia subduction zones. While both modelled tsunamis have similar effects, a tsunami from the Alaska-Aleutian subduction zone is predicted to be more adverse with greater tsunami amplitude. The extent of inundation shown on the maps corresponds to 1 m and 2 m of SLR. The coverage of the maps includes shorelines opened to Dixon Entrance, in Masset Sound, and Delkatla Inlet. While simulations were undertaken for current-day sea level, these simulations are not mapped. NHC also produced inundation maps for the community of Tow Hill, although the hazard in that area is not discussed in this report.

Key findings of the assessment are:

- Extensive tsunami flooding would occur across the Village of Masset study area.
- Tsunami flooding would propagate from the shorelines opened to Dixon Entrance towards Delkatla Inlet, inundating the airport and runway along the way.
- The low-lying topography of the village center exposes residents to large extents of tsunami inundation coming from Masset Sound (Figure 4-1 and Figure 4-2).
- The Hodges Avenue bridge crossing Delkatla Inlet is at risk of being inundated or damaged by the effects of a tsunami. This could affect access and egress of the village area located on the western shore of Delkatla Inlet, which would be surrounded by tsunami flooding (Figure 4-2).

- Several marine facilities are at risk of being damaged.

The arrival time[3] of a distant tsunami at Masset is between two and three hours after the triggering earthquake. Maximum inundation could occur on the onset of the arrival of the first tsunami wave, but equally or potentially worst flooding could occur for an extended period of time, as effects of tsunamis in coastal areas can last several hours and even days.

Figure 4-1. Tsunami inundation predicted in Masset on the eastern shore of Delkatla Inlet with 1 m (light blue) and 2 m (dark blue) of SLR. North direction pointing upward.

[3] Tsunami arrival time is defined as the time of the first maximum height of the first tsunami wave; flooding may begin before this moment is reached.

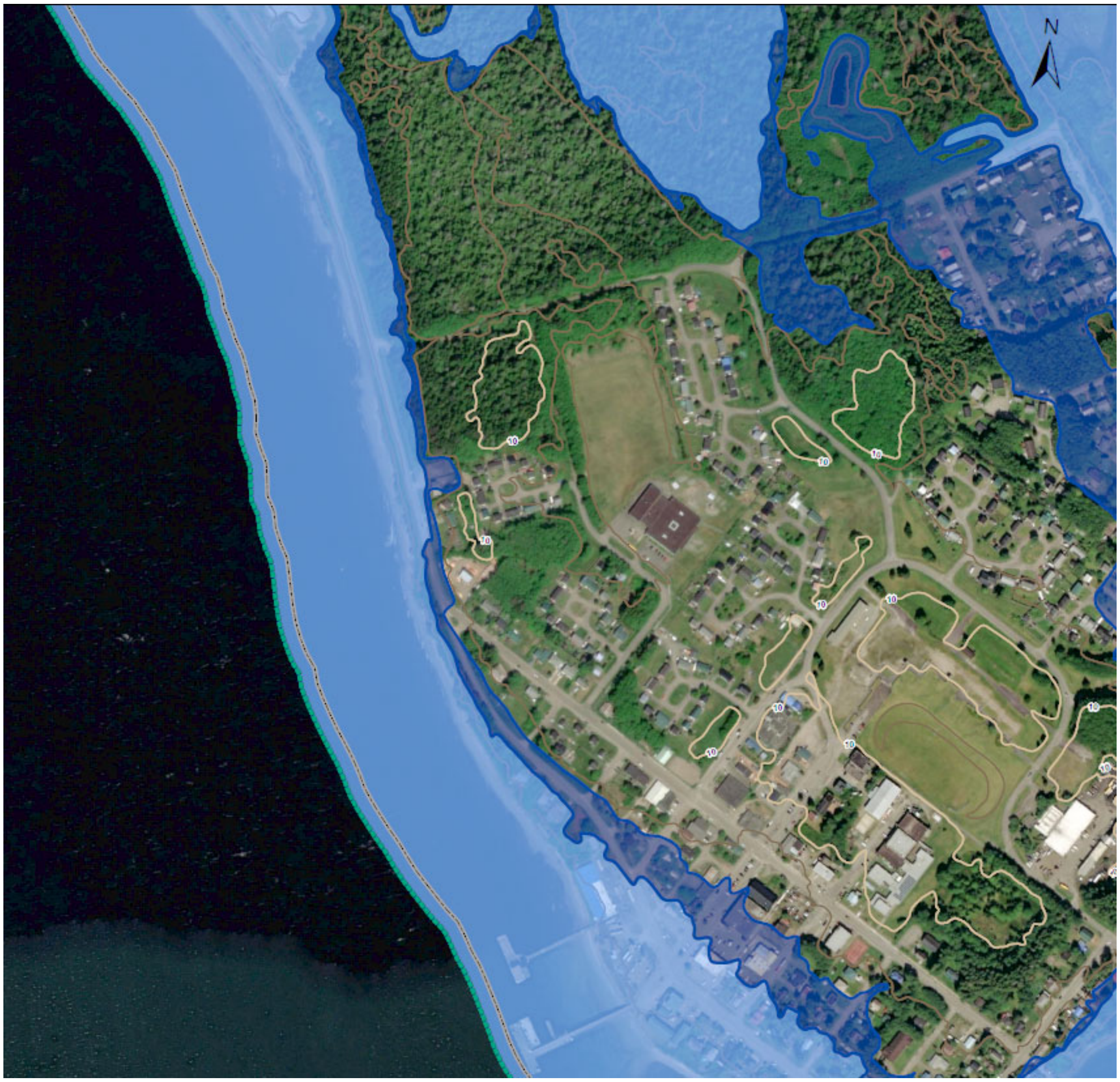

Figure 4-2. Tsunami inundation predicted in Masset on the eastern shore of Masset Sound with 1 m (light blue) and 2 m (dark blue) of SLR. North direction pointing upward. Note at the top of the image the hospital is within the tsunami hazard zone.

5 BACKGROUND AND DISCUSSION

This section presents a summary of the project background along with a discussion of the findings of the effects of sea-level rise on the Village of Masset. In addition, this section provides guidance on how to interpret the maps that have been developed for Masset from the data that has been gathered and developed as part of this assessment.

5.1 Sea-Level Rise

The hazards shown on the maps are influenced by sea-level rise and this hazard is expected to increase over time. The project's main report provides a discussion of the background science on sea-level rise and the uncertainty that presently exists in the scientific analysis and predictions. Following are the most important findings to consider during community planning discussions and decision-making:

- The sea level is expected to rise by 1 m during the next 80 to 150 years. Although the timing remains uncertain on when the 1 m of SLR will occur, the timing will ultimately depend on the actions of major emitting countries in the future (IPCC WGI, 2021).
- Up to 2 m of SLR may occur under worst-case emission scenarios as soon as year 2100 if rapid ice loss occurs in the Greenland and Antarctic ice sheets during the second half of this century, although the likelihood of this scenario is estimated to be low at this time (IPCC WGI, 2021).
- The BC government is recommending that communities plan for 1 m of SLR in year 2100 and 2 m of SLR by year 2200 (MFLNRORD, 2018). These planning levels remain consistent with the estimates developed in the latest scientific and climate change reports.

5.2 Interpreting the Maps

This section provides a discussion of the maps that have been developed for this project, which depict the coastal storm flood hazards, erosion susceptibility, and tsunami hazards. Guidance is also provided on how to interpret the map details to best understand the coastal flood, erosion, and tsunami hazards for the Village of Masset.

5.2.1 Coastal Storm Flood Hazards

The portion of map depicted in Figure 5-1 provides an overview of the horizontal extents of the hazard zones for the Village of Masset. The flood construction levels (or FCLs) are presented as red numbers on the maps and depict the elevations following the CGVD2013[4] reference datum. The schematic drawing shown in Figure 5-2 illustrates the components of the physical hazard that are considered in defining the FCL.

[4] Short for Canadian Geodetic Vertical Datum for 2013, CGVD2013 is the reference standard for heights across Canada. This height reference system replaced the Canadian Geodetic Vertical Datum of 1928 and is defined by a surface of equal gravitational potential, which represents, by convention, the coastal mean sea level for North America.

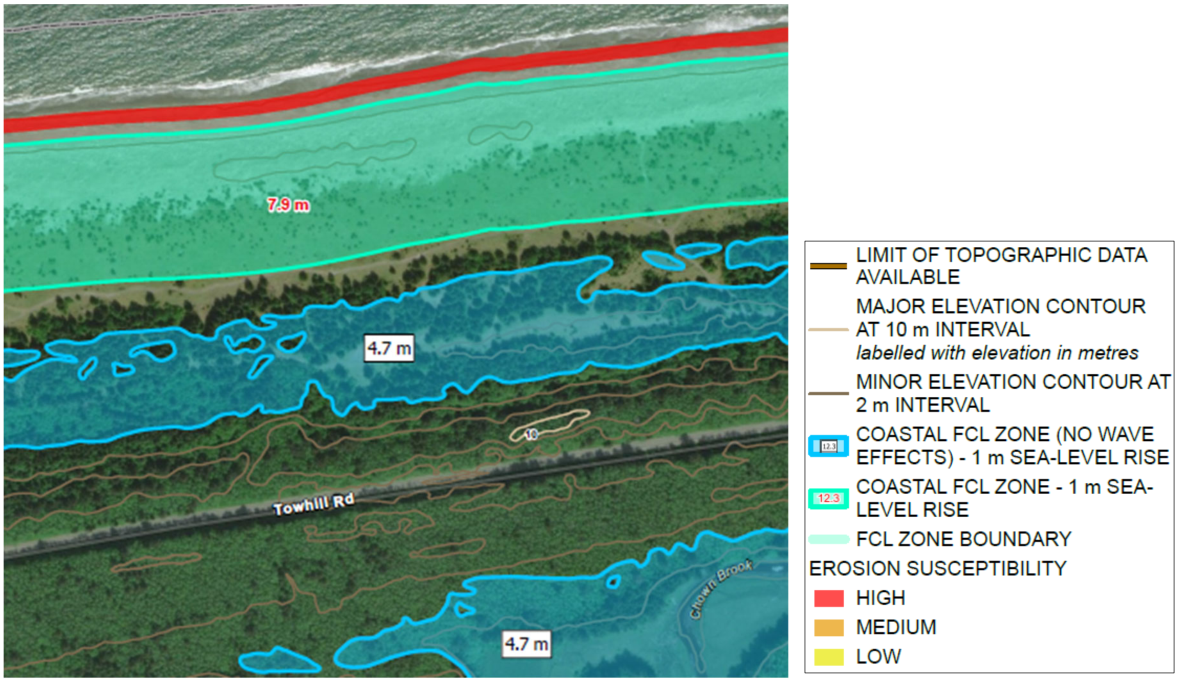

Figure 5-1. Example of a hazard zone on the map showing the FCL at the Village of Masset. The area outlined in blue shows the coast FCL zone with a 1 m SLR with no wave effects. The area outlined in green shows the coastal FCL zone with a 1 m SLR that includes wave effects. Erosion susceptibility is high, as shown by the thick red line that parallels the shoreline.

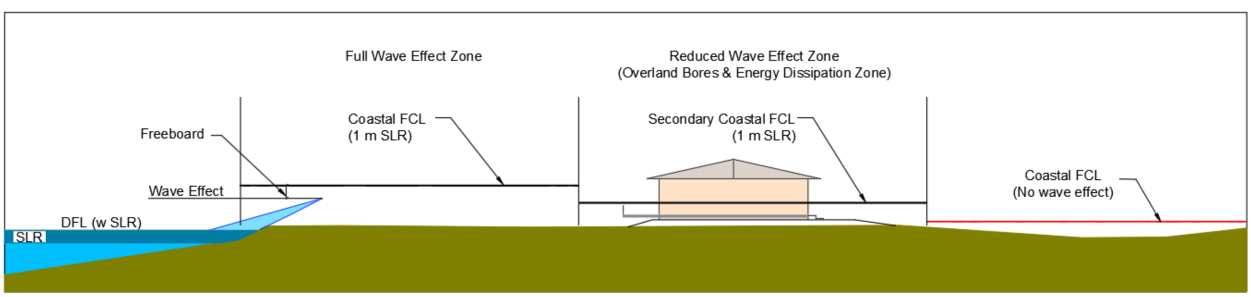

Figure 5-2. This schematic drawing shows the predicted FCL levels in profile view, which are depicted in the coastal storm hazard maps produced for the project. In some areas where the land is flat, two FCL zones are presented with wave effects of different elevations where wave overtopping rates at the shoreline are high enough to propagate in the form of overland bores[5] in low-lying areas. Further inland where wave energy has dissipated an FCL zone is shown with no wave effects.

[5] A hydraulic bore is a wave with a steep and turbulent front moving across standing waters or dry land. It can result from the breaking of ocean waves.

5.2.2 Erosion Susceptibility

The project study team developed a shoreline erosion susceptibility rating system to provide additional context for the coastal storm hazard maps, highlighting how the relative rate of shoreline retreat may intensify the flood hazard. The methods adopted for this classification system (Table 5-1) enable relatively rapid classification of extensive segments of the shoreline, so that similar shoreline types can be grouped into reaches, rather than having to sub-divide the shoreline to accommodate highly localized changes in conditions. The system is not intended to predict future conditions, but it must still consider the time scales associated with future sea-level changes. Large-scale geomorphic processes[6] will adjust to the gradual increase in sea level in the future, which in many cases will result in drastic alterations of the shoreline system. The study team took a conservative approach to classifying erosion susceptibility to avoid the potential of present-day erosion rates unduly influencing the assessment.

Table 5-1. Definition of ratings for the shoreline erosion susceptibility classification system.

Rating	Description
Low	Shoreline types that are classified as having a *low* potential for erosion are typically dominated by highly resistant materials or have very low exposure to coastal processes such as wind-driven waves. The presence of shoreline protection structures does not generally place the shoreline in the low category. Often, such structures point to past erosion activity that required active intervention Similarly, the term *low* does not mean non erodible, nor does it mean that the shoreline will not be modified by large storms in the future.
Medium	The *medium* designation is applied to shorelines that display characteristics of either a *high* or a *low* susceptibility to erosion and feature one or more key characteristics that indicate the need to lower or raise the classification, depending on the characteristic.
High	Shoreline types that are classified as having a *high* potential for erosion are typically dominated by small-calibre or loose materials that are easily transported by coastal processes and exposed to highly energetic coastal processes. Typically, there are no mitigating features along the shoreline or backshore to slow the rate of shoreline erosion.

5.2.3 Tsunami Hazards

Tsunamis pose a risk anywhere near the shoreline as well as over water, whereas the overland tsunami hazard varies across the study area depending on local topography in conjunction with exposure to the incoming waves. The tsunami hazards mapped in this study include flood hazards (e.g., overland inundation) in localized areas, as well as overwater hazards, such as maximum tsunami wave amplitude and maximum tsunami-induced current velocity.

[6] Geomorphic processes are processes associated with the form of a landscape and its relationship with surrounding natural features.

5.2.3.1 Overland Tsunami Inundation Maps

An example of a tsunami inundation map is shown in Figure 5-3. The map shows inundation extents for both 1 m and 2 m of SLR as well as elevation contours for reference. These extents are for the purpose of emergency planning and a safety factor is included to account for the uncertainties in the analysis. However, neither a vertical freeboard or horizontal setback were applied to the tsunami inundation estimated as part of this study.

Figure 5-3. Example of tsunami inundation map at Masset. North direction pointing upward.

5.2.3.2 Overwater Tsunami Hazard Maps

Figure 5-4 and Figure 5-5 show examples of maximum tsunami wave amplitude and maximum tsunami-induced current velocity, respectively. Neither a safety factor or freeboard were applied to the results plotted on the overwater hazard maps. Any overland inundation or overland tsunami flow velocity visible on these maps corresponds to information as approximated by the numerical model without any adjustment and should not be relied upon without additional site-specific assessment. It should also be noted that the amplitudes reported on the maximum tsunami amplitude maps are reported according to a reference plane that corresponds to the water level considered for the tsunami simulations. For this study this water level corresponds to higher high-water, mean tide[7].

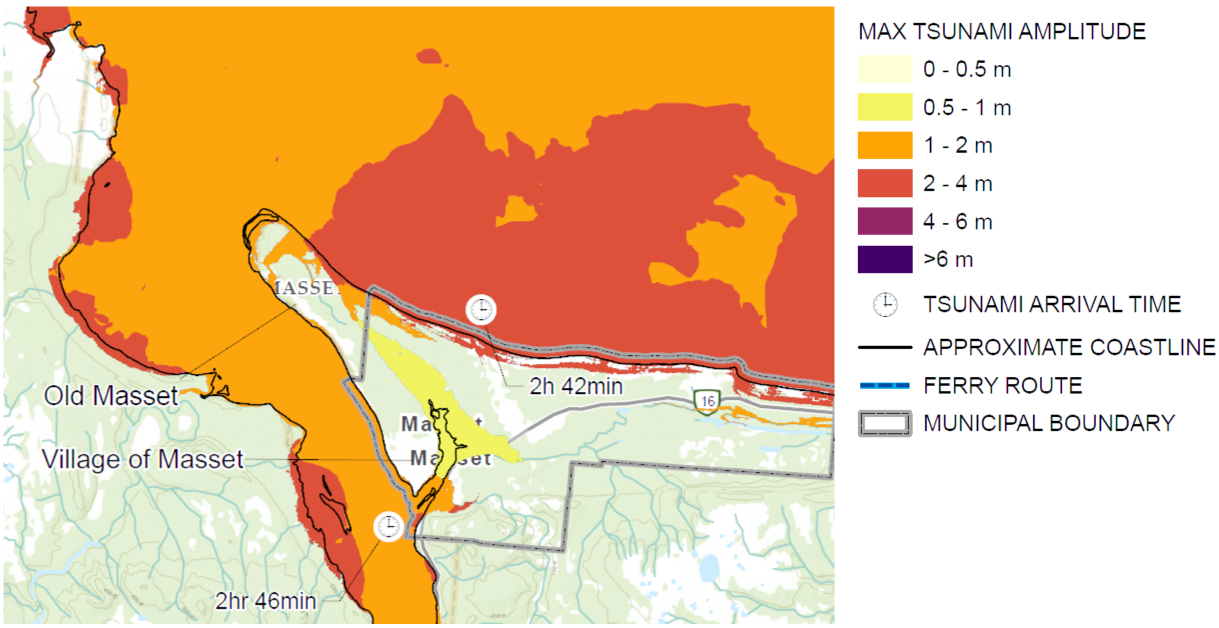

Figure 5-4. Example of maximum tsunami amplitude map offshore of Masset. North direction pointing upward.

[7] The average of the higher high-water height of each tidal day observed over a tidal epoch, as defined by the Canadian Hydrographic Service in Canada.

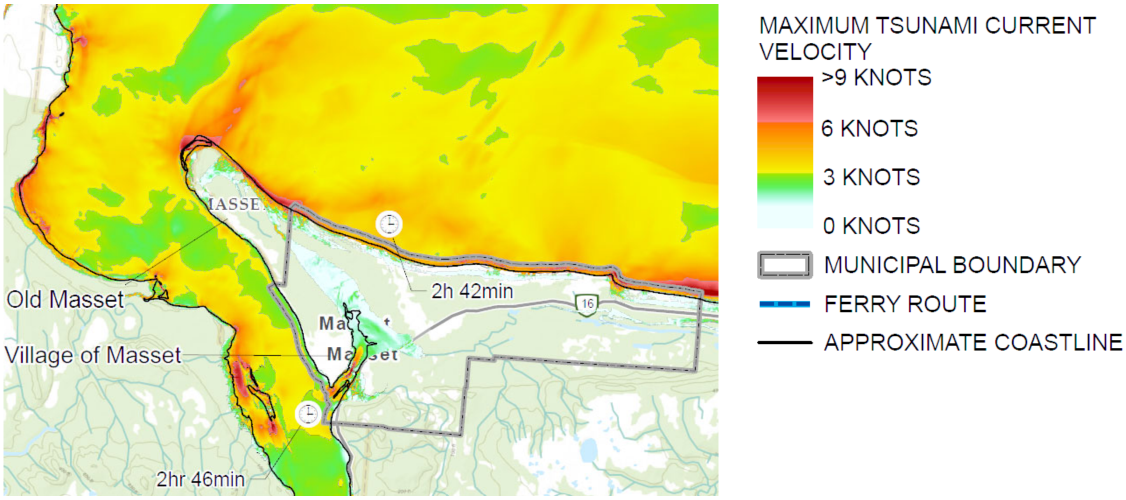

Figure 5-5. Example of maximum tsunami current velocity map offshore of Masset. North direction pointing upward.

6 FINDINGS AND RECOMMENDATIONS

6.1 Key Findings

Following is a summary of the key findings of the of coastal flood hazard and erosion study:

- All shoreline areas of the Village of Masset are exposed to coastal flood hazards and erosion.
- Storms in Dixon Entrance can generate large waves near the shoreline. With future SLR, this wave energy will produce more frequent flooding and erosion on the upper beaches.
- Many segments of the shoreline in Masset Sound are presently undergoing erosion or have been armoured in response to erosion in the past. As SLR occurs, erosion of the shoreline will intensify at numerous locations, presenting a large challenge in terms of shoreline management, regulatory approvals, and cost.
- Individual private properties on the shoreline are at risk from both erosion and coastal flooding.
- Tsunami hazards exist for low-lying areas of Masset and anywhere close to shorelines, including the airport and hospital, as well as key transportation corridors.

6.2 Recommendations

The project study team has developed the following recommendations for the Village of Masset residents and community planners to consider during future planning initiatives.

1. As SLR occurs, the frequency that waves large enough to mobilise sediments affecting the shoreline will increase, and it is expected that erosion will intensify, particularly at the upper shoreline. Shoreline protection that has been installed may mitigate this process but is unlikely to be fully effective, particularly during storm events that overtop the shoreline. It is

recommended that specific planning be focused on an overall strategy for management of the shoreline that considers the appropriate measures for responding to ongoing erosion as well as the ecological services inherent in the shoreline and backshore systems. At many locations it may be most appropriate to adopt the *retreat* strategy described below.

2. The coastal FCL zone impacts the main transportation and utility corridors at many locations. Disrupted communications and loss of electrical power to portions of the community could present serious additional challenges when responding to natural disasters relating to coastal hazards. Furthermore, inundation and damage to the main transportation route would hinder the response of emergency services and prevent many from accessing emergency health care. It is recommended that the community undertake a comprehensive review of this corridor and develop an adaptation plan.

3. The community has developed along the shoreline in many areas, and this exposes public and private properties, including homes, businesses, and public services, to coastal flood and erosion hazards. Options to manage the shoreline and mitigate the risks for flood hazard from coastal storms include the following:

    a. **Retreat:** A planned retreat option would include the eventual removal of public (and eventually private) buildings from selected areas that cannot be protected from coastal flooding and erosion at a reasonable cost. Similarly, segments of the transportation and utilities infrastructure should be relocated inland to areas not exposed to the hazard. Areas from which the community has retreated could continue to be used for public benefit, such as parks and recreation or naturalised areas offering ecological services. The retreat strategy could also be applied to portions of the shoreline that are deemed too expensive to protect with armouring or other infrastructure.

    b. **Accommodate**: Accept that large storm events will result in intermittent impacts to the community while adopting designs that reduce damage during such events. Improve the resilience of roadways and utilities to withstand wave effects and accept that temporary flooding will prevent the community from using this transportation corridor during large storm events. Upgrade existing buildings to withstand the effects of flooding and waves without excessive damage. As existing buildings reach the end of their service life, rebuild in place using resilient designs at higher elevations.

    c. **Protect:** Upgrade the existing shoreline protection structures to prevent further erosion, raising the crest of the shoreline to block incoming waves. Raise the roadway and utilities where necessary to a safe elevation along the present alignment. This mitigation option could pose challenges for adjacent properties that are much lower than the raised roadway and would need road access.

4. Building seawalls and rock armour revetments or stone facings could lead to accelerated coastal erosion in adjacent areas, since this construction could reduce the natural rate of sediment supply. These structures may also cause harm to intertidal habitats, thus affecting shellfish, and other species, as their presence would reduce the rate of natural sediments being added to the littoral or coastal shoreline systems. The potential benefits and consequences of building revetments and seawalls should be studied during the next 10 to 15 years to inform community planning decisions on this potential mitigation option.

5. New construction should adhere to FCL levels in any areas of exposed risk for coastal storm flooding. Critical community infrastructure, such as emergency service facilities and community centres should be built above the tsunami hazard zone, unless these structures are specifically designs to withstand tsunami loads and effects and are sufficiently tall to provide refuge from tsunami inundation.
6. The risk of tsunami propagation presents an immediate hazard, although this hazard is associated with a low probability of occurrence at any given time. The following important considerations apply to the community of Masset when considering and planning for this hazard:
    a. For a person caught in a tsunami the chance of survival is low, mainly due to the strong flow momentum and the floating debris that is often carried in the water during such an event. For planning purposes, NHC assumes that people exposed to tsunami hazards will experience an extreme risk to survival if they are unable to evacuate safely.
    b. Low-lying areas of the community are at direct risk of inundation from a tsunami. Emergency planning exercises should include evaluation of the inundation maps and arrival times so evacuation procedures can be refined for various parts of the community.
    c. The Hodges Avenue bridge crossing Delkatla Inlet is at risk of being inundated or damaged by the effects of a tsunami. This could affect access and egress of the village area located on the western shore of Delkatla Inlet. Residents in this area could be stranded for an extended period of time.
    d. The existing hospital and airport are both within the tsunami hazard zone. Potential affects of a tsunami on these facilities have not been assessed as part of this study.
    e. Marine facilities for small boats could be severely damaged in a tsunami, while tsunami conditions may be unsafe for mariners in shallow water areas near to the Masset area due to potential wave breaking and strong currents.
    f. The community should evaluate the potential consequences if infrastructure in neighbouring communities of Daajing Giids and Sandspit is damaged to the point that no ferry or airport services would be available for brief or extended periods to Haida Gwaii following a tsunami event, thus preventing delivery of supplies or access to emergency services. The bridge crossing the Kumdis River in Port Clements is also at risk of being inundated or damaged by the effects of a tsunami, which would limit access to Masset.

7 REFERENCES

BC MOE (2011). *Climate Change Adaption Guidelines for Sea Dikes and Coastal Flood Hazard Land Use - Draft Policy Discussion Paper*. Report prepared by Ausenco-Sandwell for BC Ministry of Environment (BC MOE). 75 pp. Available at https://www.env.gov.bc.ca/wsd/public_safety/flood/pdfs_word/draft_policy_rev.pdf.

IPCC WGI (2021). *AR6 Climate Change 2021: The Physical Science Basis, Prepared by the Intergovnmental Panel on Climate Change (IPCC) Working Group I (WGI)*. Available at https://www.ipcc.ch/report/ar6/wg1/.

MFLNRORD (2018). *Flood Hazard Area Land Use Management Guidelines.* Originally Ministry of Water, Land and Air Protection, Province of British Columbia. May 2004. Amended January 2018 by the Ministry of Forests, Lands, Natural Resource Operations and Rural Development. Available at https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/integrated-flood-hazard-mgmt/flood_hazard_area_land_use_guidelines_2017.pdf.

Report prepared by:

Philippe St-Germain, PEng
Coastal Engineer
Tsunami Hazards

Grant Lamont, PEng
Principal, Senior Coastal Engineer
Coastal Storm Hazards

Jan 12 2023

Report reviewed by:

JAN. 12, 2023

Derek Ray, PGeo
Principal, Senior Geomorphologist
Coastal Geomorphology

DISCLAIMER

This report has been prepared by Northwest Hydraulic Consultants Ltd. for the benefit of Village of Masset for specific application to the Haida Gwaii Coastal Flood and Erosion Study. The information and data contained herein represent Northwest Hydraulic Consultants Ltd.'s best professional judgement in light of the knowledge and information available to Northwest Hydraulic Consultants Ltd. at the time of preparation and was prepared in accordance with generally accepted engineering and geoscience practices.

Except as required by law, this report and the information and data contained herein ~~are to be treated as confidential and~~ may be used and relied upon only by Village of Masset, its officers, and employees. Northwest Hydraulic Consultants Ltd. denies any liability whatsoever to other parties who may obtain access to this report for any injury, loss, or damage suffered by such parties arising from their use of or reliance upon this report or any of its contents. GL