District of Ucluelet Coastal Flood Mapping
Appendix C: Coastal Flood Hazard Map Atlas
Map Series 4/4: Tsunami Flood Planning Support

Cover Photo: Ucluelet. © Photo by Ebbwater Consulting

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Index

Introduction

This Coastal Flood Hazard Map Atlas (map atlas) is Appendix D of the District of Ucluelet (DOU) Coastal Flood Mapping report (Ebbwater Consulting Inc. and Cascadia Coast Research Ltd., 2020). It contains a collection of maps which show coastal flood hazards affecting the DOU. This information will in turn be used to inform and update policy and planning instruments, such as flood construction levels (FCLs) and the Official Community Plan (OCP) with the goal of reducing community risk to flooding. This work generally followed the approach set out in the professional practice guidelines in BC (EGBC 2017, 2018).

Overview of Maps

For coastal storm flood hazard, modelling results were produced for 20 scenarios. Flood maps were produced to show water depths and extents for selected scenarios. We assessed and mapped the coastal flood hazard for 6.67% and 0.5% Annual Exceedance Probability (AEP) floods (15- and 200- year indicative return period, respectively). We considered these two AEP floods for three relative sea level rise scenarios (0 m, 1 m, and 2 m RSLR). Based on the 0.5% AEP flood (plus 0.6 m freeboard), we also produced Sea Level Rise Planning Areas and FCLs for the near future and future (i.e., 0.5 m and 1 m RSLR) scenarios to support policy and planning.

For tsunami flood hazard, modelling results were produced for 24 scenarios based on the Cascadia Subduction Zone (CSZ) fault. Flood maps were produced to focus on the splay faulting rupture A and buried rupture earthquake rupture models. RSLR scenarios of 0 m, 1 m, and 2 m were also included. Based on the tsunami flood hazard maps, we also produced a range of tsunami flood planning level maps, with and without a safety factor. A tsunami flood hazard vulnerability zones map was also produced to support planning. The tsunami flood planning support maps were completed for the future (1 m RSLR) scenario.

Table 1 summarizes the 4 map series that comprise this map atlas. The map series in this file is highlighted.

Table 1: Summary of Atlas Maps.

Map Type	Map Series	Map No.	Map Title	Scenarios Details
Coastal Storm	1	1	Flood Depth – Frequent Event (Present-Day)	6.67% AEP, 0 m RSLR, no freeboard
		2	Flood Depth – Frequent Event (Future)	6.67% AEP, 1 m RSLR, no freeboard
		3	Flood Depth – Frequent Event (Far Future)	6.67% AEP, 2 m RSLR, no freeboard
		4	Flood Depth – Rare Event (Present-Day)	0.5% AEP, 0 m RSLR, no freeboard
		5	Flood Depth – Rare Event (Future)	0.5% AEP, 1 m RSLR, no freeboard
		6	Flood Depth – Rare Event (Far Future)	0.5% AEP, 2 m RSLR, no freeboard
		7	Flood Extent – Frequent Event (Present-Day, Future, Far Future)	6.67% AEP, for 0 m, 1 m, and 2 m RSLR, no freeboard

Map Type	Map Series	Map No.	Map Title	Scenarios Details
		8	Flood Extent – Rare Event (Present-Day, Future, Far Future)	0.5% AEP, for 0 m, 1 m, and 2 m RSLR, no freeboard
Coastal Storm Flood Planning Support	2	1	Sea Level Rise Planning Areas – Rare Event (Near Future and Future)	0.5% AEP, 0.5 m and 1 m RSLR, with 0.6 m freeboard
		2	Flood Construction Level – Zones for Rare Event (Near Future)	0.5% AEP, 0.5 m RSLR, with 0.6 m freeboard
		3	Flood Construction Level – Zones for Rare Event (Future)	0.5% AEP, 1 m RSLR, with 0.6 m freeboard
		4	Flood Construction Level – Zones with Contours for Rare Event (Near Future)	0.5% AEP, 0.5 m RSLR, with 0.6 m freeboard
		5	Flood Construction Level – Zones with Contours for Rare Event (Future)	0.5% AEP, 1 m RSLR, with 0.6 m freeboard
Tsunami Flood Hazard	3	1	Flood Depth – Splay Faulting Rupture (Present-Day)	G2018-S-A model, 0 m RSLR
		2	Flood Depth – Splay Faulting Rupture (Future)	G2018-S-A model, 1 m RSLR
		3	Flood Depth – Splay Faulting Rupture (Far Future)	G2018-S-A model, 2 m RSLR
		4	Flood Depth – Buried Rupture (Future)	W2003 model, 1 m RSLR
		5	Flood Extent – Splay Faulting Rupture (Present-Day, Future, Far Future)	G2018-S-A model, for 0 m, 1 m, and 2 m RSLR
		6	Flood Extent – Splay Faulting and Buried Ruptures (Present-Day)	G2018-S-A and W2003 models, 0 m RSLR
		7	Flood Extent – Splay Faulting and Buried Ruptures (Future)	G2018-S-A and W2003 models, 1 m RSLR
		8	Flood Extent – Splay Faulting and Buried Ruptures (Far Future)	G2018-S-A and W2003 models, 2 m RSLR
Tsunami Flood Planning Support	4	1	Tsunami Flood Planning Level – Buried Rupture (No Safety Factor)	W2003 model, 1 m RSLR
		2	Tsunami Flood Planning Level – Splay Faulting Rupture (No Safety Factor)	G2018-S-A model, 1 m RSLR
		3	Tsunami Flood Planning Level – Buried Rupture (Safety Factor)	W2003 model, 50% safety factor, 1 m RSLR
		4	Tsunami Flood Planning Level – Splay Faulting Rupture (Safety Factor)	G2018-S-A model, 50% safety factor, 1 m RSLR.
		5	Tsunami Flood Planning Level – Scenario Comparisons	W2003 and G2018-S-A with and without safety factor, 1 m RSLR
		6	Tsunami Flood Hazard Vulnerability Zones – Splay Faulting Rupture (Future)	G2018-S-A model, 1 m RSLR

Maps 1 to 5 – Notes for Map User

1. This map is designed to accompany the District of Ucluelet Coastal Flood Mapping report (Ebbwater Consulting Inc. and Cascadia Coast Research Ltd, 2020) and is intended for the purposes set out in that report only. See the report for further details on the methodology, results and limitations.

2. The tsunami runup elevation was developed based on the highest values of the simulated tsunami (runup) elevations (Splay faulting rupture from Gao et al., (2018) and buried rupture from Wang et al., (2003)) for 1 m relative sea level rise (RSLR). A set of four values for no safety factor and a 50% safety factor for each rupture were applied to the tsunami runup (elevation).

3. Water levels conservatively assume a 2 m subsidence, a tide equal to higher high water large tide (HHWLT, equal to 2 m at Ucluelet), and 1 m of relative sea level rise (RSLR), to provide results for a potential future flood event.

4. Based on guidelines for the management of coastal flood hazard land use (Ausenco Sandwell 2011), 1 m of sea level rise approximately corresponds to the year 2100. However, this time period is subject to changes in climate projections and is likely to require reassessment in the future.

Limitations

1. The accuracy of the presented tsunami flood planning level is limited by available data and the modelling approaches used. Please refer to the report for detailed discussion on limitations.

2. This map provides results for one possible tsunami wave (based on one rupture type and source). Flood characteristics and associated responses could vary based on different tsunamis.

3. The accuracy of the tsunami flood planning level extent is limited by the accuracy of the base mapping data and DEM. The flood hazard limits were not established on the ground by legal survey.

4. No formal guidelines exist for the province for mapping of tsunamis. This map was produced by Ebbwater Consulting Inc. and Cascadia Coast Research Ltd. using guidance documents and approaches identified from a literature review of other similar studies.

5. The tsunami flood planning level extents shown on this map are to help inform decisions on future land use policy. Under the provisions of the Local Government Act [2004], these extents only take effect when adopted by bylaw or implemented via another planning tool (such as a development permit area). They therefore do not currently have any legal or planning standing.

5. Flood depths and extents are presented for all areas landward of the cadastral shoreline layer (as provided by the District of Ucluelet (DOU)), including a small buffer to ensure all exposed areas are captured.

6. Base map and parcel layers were provided by different data owners and are subject to differences.

Data Sources

1. Tsunami flood extents were provided by Cascadia Coast Research Ltd.

2. Mapping Templates, Shoreline layer, and Land Parcels were received from the DOU.

3. Base layer is based on CARTO's Positron, created using derivatives of OpenStreetMap data - openstreetmap.org (© OpenStreetMap contributors; cartography license CC BY-SA).

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3. Wang *et al.* (2003). J. Geophys. Res. 108 (B1).

4. Gao *et al.* (2018). Nat. Haz. (2018) 94:445–469.

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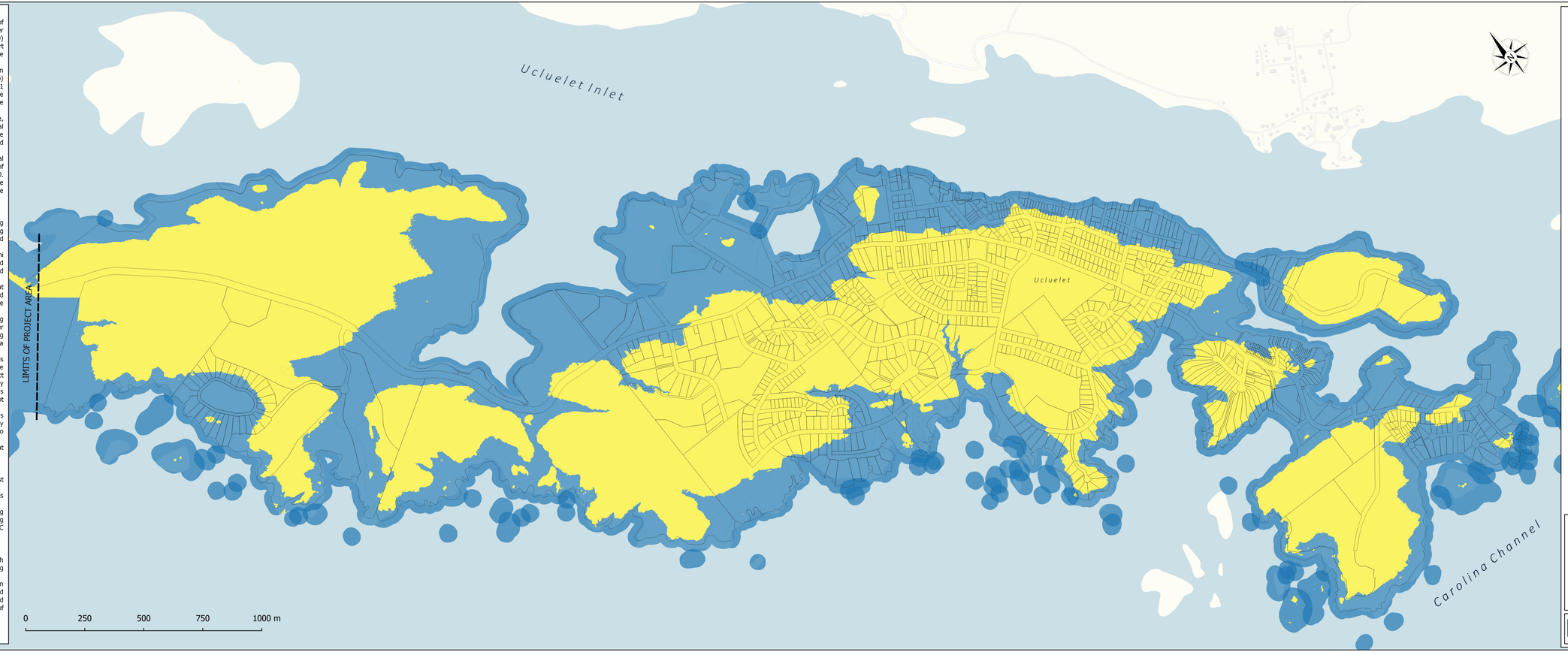

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Coastal Flood Mapping

Tsunami

Tsunami Flood Planning Support Map 1/6

Tsunami Flood Planning Level – Buried Rupture (No safety factor)
W2003 model, 1 m RSLR

Land Parcels

Tsunami Flood Planning Level:

Areas below 15 m CGVD 2013

Areas at or above 15 m CGVD 2013

Stamp provided in original version

Date Created:	June 26, 2020
Map Scale:	1:10,000
Coordinate System:	NAD83, UTM 10N
Vertical Datum:	CGVD 2013

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Notes to Users

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2. The tsunami runup elevation was developed based on the highest value of the simulated tsunami (runup) elevations (splay faulting rupture from Gao et al., (2018)) for 1 m relative sea level rise (RSLR). The extents of the tsunami planning level of 18 m (without safety factor) are shown on this map.
3. Water levels conservatively assume a 2 m subsidence, a tide equal to higher high water large tide (HHWLT, equal to 2 m at Ucluelet), and 1 m of relative sea level rise (RSLR), to provide results for a potential future flood event.
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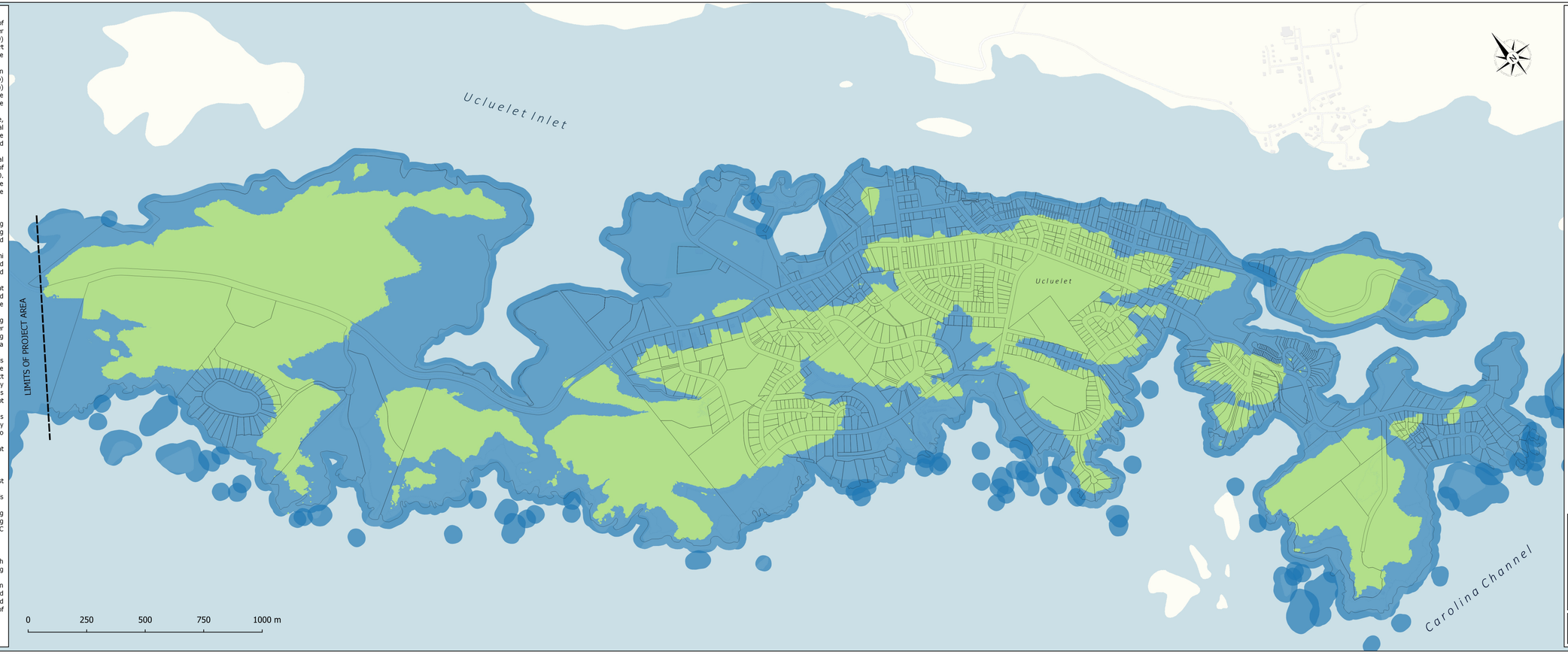

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Coastal Flood Mapping
Tsunami

Tsunami Flood Planning Support Map 2/6

Tsunami Flood Planning Level – Splay Faulting Rupture (No Safety Factor)
G2018-S-A model, 1 m RSLR

Land Parcels

Tsunami Flood Planning Level:

Areas below 18 m CGVD 2013

Areas at or above 18 m CGVD 2013

Stamp provided in original version

Date Created: June 26, 2020

Map Scale: 1:10,000

Coordinate System: NAD83, UTM 10N

Vertical Datum: CGVD 2013

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3. Water levels conservatively assume a 2 m subsidence, a tide equal to higher high water large tide (HHWLT, equal to 2 m at Ucluelet), and 1 m of relative sea level rise (RSLR), to provide results for a potential future flood event.
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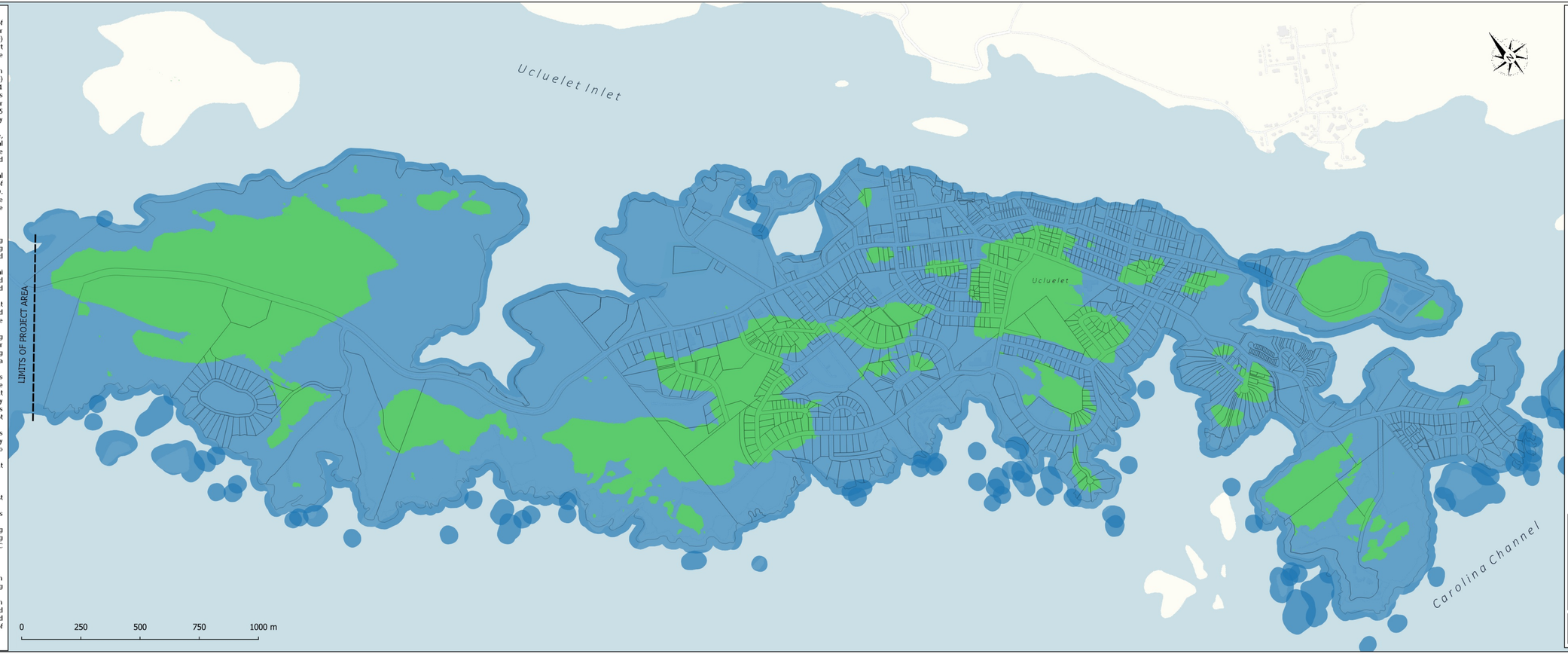

DISTRICT OF
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Coastal Flood Mapping

Tsunami

Tsunami Flood Planning Support Map 3/6

Tsunami Flood Planning Level – Buried Rupture (Safety Factor)

W2003 model, 50% safety factor, 1 m RSLR

Land Parcels

Tsunami Flood Planning Level:

Areas below 22.5 m CGVD 2013

Areas at or above 22.5 m CGVD 2013

Stamp provided in original version

Date Created: June 26, 2020

Map Scale: 1:10,000

Coordinate System: NAD83, UTM 10N

Vertical Datum: CGVD 2013

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3. Water levels conservatively assume a 2 m subsidence, a tide equal to higher high water large tide (HHWLT, equal to 2 m at Ucluelet), and 1 m of relative sea level rise (RSLR), to provide results for a potential future flood event.
4. Based on guidelines for the management of coastal flood hazard land use (Ausenco Sandwell 2011), 1 m of sea level rise approximately corresponds to the year 2100. However, this time period is subject to changes in climate projections and is likely to require reassessment in the future.

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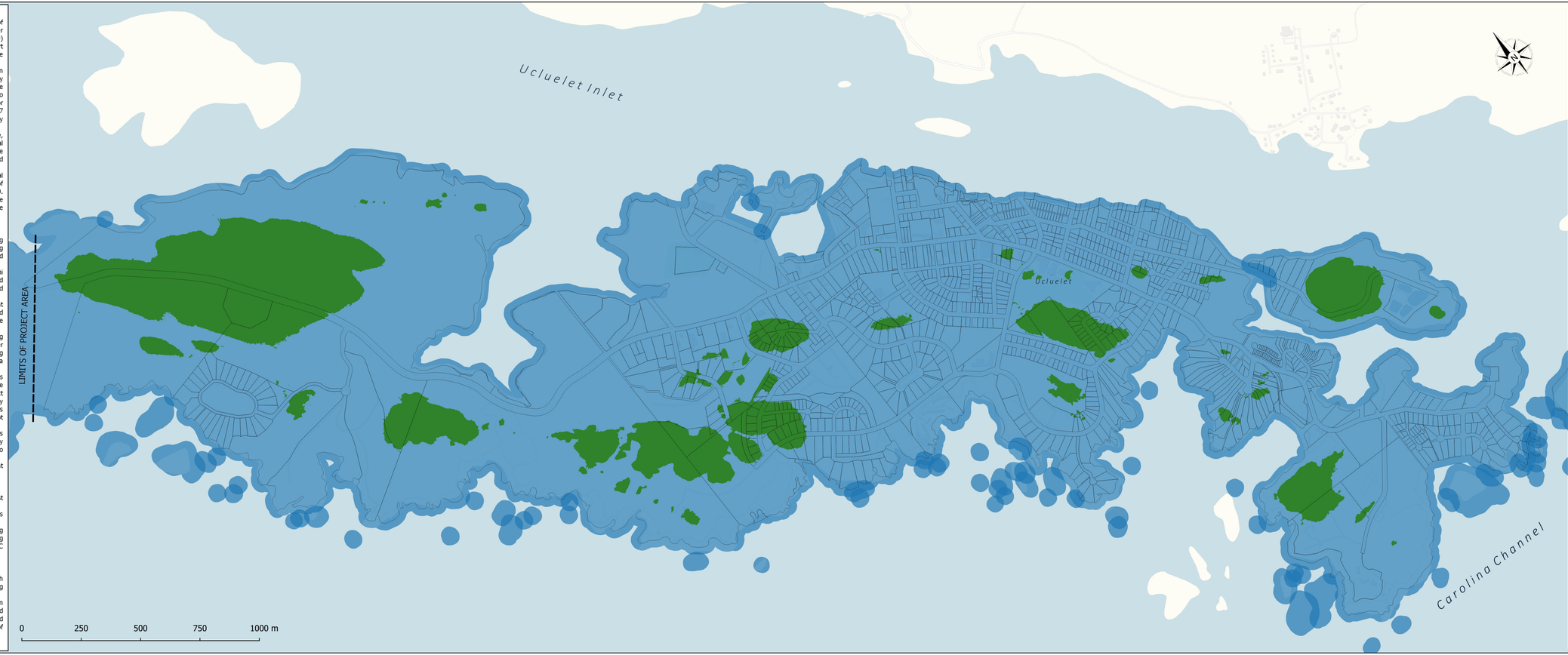

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Coastal Flood Mapping
Tsunami

Tsunami Flood Planning Support Map 4/6

Tsunami Flood Planning Level – Splay Faulting Rupture (Safety Factor)

G2018-S-A model, 50% safety factor, 1 m RSLR

Land Parcels

Tsunami Flood Planning Level:

Areas below 27 m CGVD 2013

Areas at or above 27 m CGVD 2013

Stamp provided in original version

Date Created: June 26, 2020

Map Scale: 1:10,000

Coordinate System: NAD83, UTM 10N

Vertical Datum: CGVD 2013

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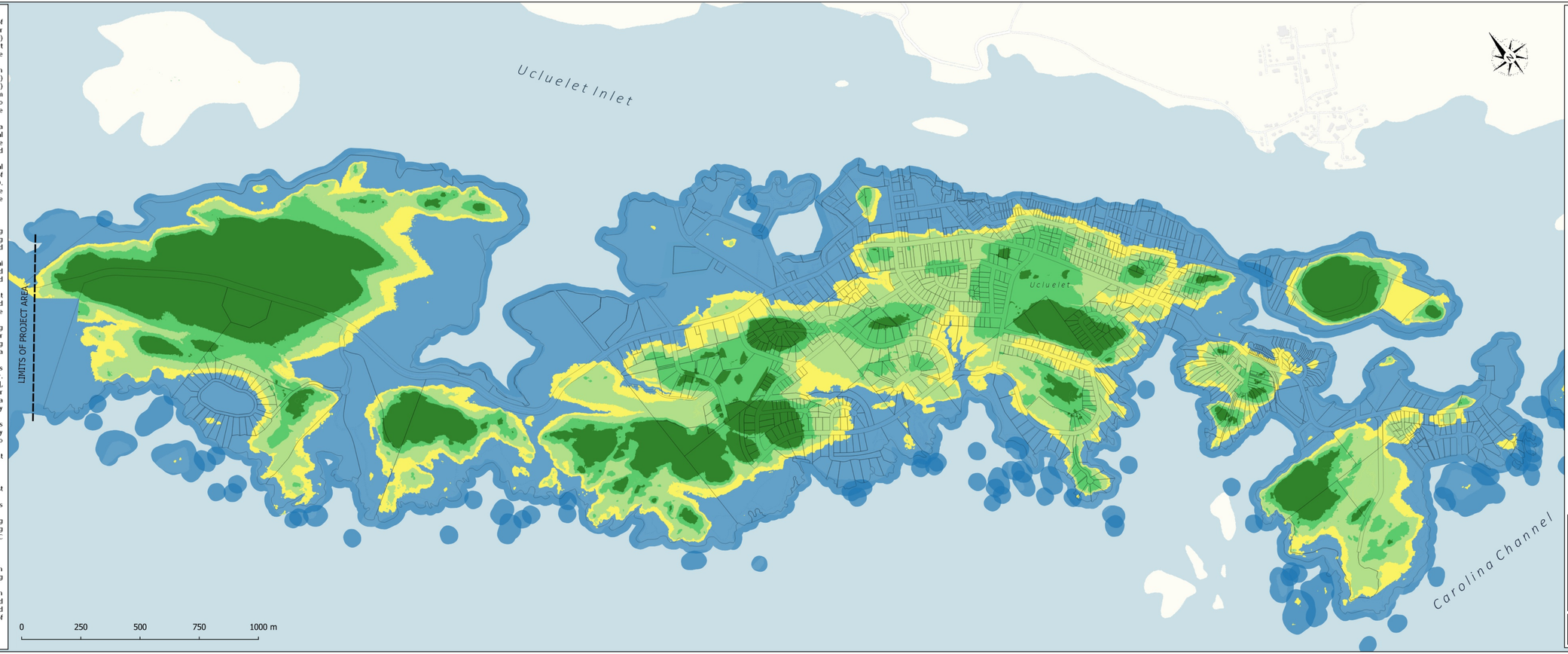

DISTRICT OF
UCLUELET

Coastal Flood Mapping

Tsunami

Tsunami Flood Planning Support Map 5/6

Tsunami Flood Planning Level – Scenario Comparisons
W2003 and G2018-S-A with and without safety factor, 1 m RSLR

Land Parcels

Tsunami Flood Planning Level:

- Areas below 15 m CGVD 2013
- Areas at or above 15 m CGVD 2013
  Buried Rupture without safety factor
- Areas at or above 18 m CGVD 2013
  Splay Faulting Rupture without safety factor
- Areas at or above 22.5 m CGVD 2013
  Buried Rupture with 50% safety factor
- Areas at or above 27 m CGVD 2013
  Splay Faulting Rupture with 50% safety factor

Stamp provided in original version

Date Created: June 26, 2020	
Map Scale: 1:10,000	
Coordinate System: NAD83, UTM 10N	
Vertical Datum: CGVD 2013	

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Map 6 – Notes for Map User

1. This map is designed to accompany the District of Ucluelet Coastal Flood Mapping report (Ebbwater Consulting Inc. and Cascadia Coast Research Ltd., 2020) and is intended for the purposes set out in that report only. See the report for further details on the methodology, results and limitations.

2. Flood depth and velocity layers were determined based on a simulation of a tsunami wave generated by a modelled rupture (Splay faulting rupture A from Gao et al., (2018)).

3. Water levels conservatively assume a tide equal to higher high water large tide (HHWLT, equal to 2 m at Ucluelet), and 1 m of relative sea level rise (RSLR), to provide results for a potential future flood event.

4. Based on guidelines for the management of coastal flood hazard land use (Ausenco Sandwell 2011), 1 m of sea level rise approximately corresponds to the year 2100. However, these time periods are subject to changes in climate projections and are likely to require reassessment in the future.

5. Flood depth colouring and thresholds are based on AIDR Guideline 7-3 Flood Hazard (2017).

Limitations

1. The accuracy of the presented tsunami flood hazard vulnerability zones is limited by available data and the modelling approaches used. Please refer to the report for detailed discussion on limitations.

2. This map provides results for one possible tsunami wave (based on one rupture type and source). Flood characteristics and associated responses could vary based on different tsunamis.

3. The accuracy of the tsunami flood hazard vulnerability zones is limited by the accuracy of the base mapping data and DEM. The flood hazard limits were not established on the ground by legal survey.

4. No formal guidelines exist for the province for mapping of tsunamis. This map was produced by Ebbwater Consulting Inc. and Cascadia Coast Research Ltd. using guidance documents and approaches identified from a literature review of other similar studies. Ebbwater Consulting Inc. and Cascadia Coast Research Ltd. do not assume any liability by reason of the failure to delineate flood hazard areas on this map.

5. The tsunami flood hazard vulnerability zones shown on this map are to provide an assessment of current and future flooding to help inform decisions on future land use policy. Under the provisions of the Local Government Act [2004], these flood extents only take effect when adopted by bylaw or implemented via another planning tool (such as a development permit area). They therefore do not currently have any legal or planning standing.

6. Flood depths and extents are presented for all areas landward of the cadastral shoreline layer (as provided by the District of Ucluelet (DOU)), including a small buffer to ensure all exposed areas are captured.

7. Base map and parcel layers were provided by different data owners and are subject to differences.

Data Sources

1. Tsunami flood depths and velocities were provided by Cascadia Coast Research Ltd.

2. Mapping Templates, Shoreline layer, and Land Parcels were received from the DOU.

3. Base layer is based on CARTO's Positron, created using derivatives of OpenStreetMap data - openstreetmap.org (© OpenStreetMap contributors; cartography license CC BY-SA).

Map 6 – References

1. Ebbwater Consulting Inc. and Cascadia Coast Research Ltd. (2020). District of Ucluelet Coastal Flood Mapping (Final Report).

2. Ausenco Sandwell (2011). Climate Change Adaption Guidelines for Sea Dikes and Coastal Flood Hazard Land Use - Guidelines for Management of Coastal Flood Hazard Land Use. Prepared for the British Columbia Ministry of Environment.

3. AIDR. 2017. "Australian Disaster Resilience Guideline 7-3:Flood Hazard." Australian Institute for Disaster Resilience, Australian Government Attorney-General's Department. https://doi.org/10.1038/ncomms14796.

4. Gao et al., (2018). Nat. Haz. (2018) 94:445–469.

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References

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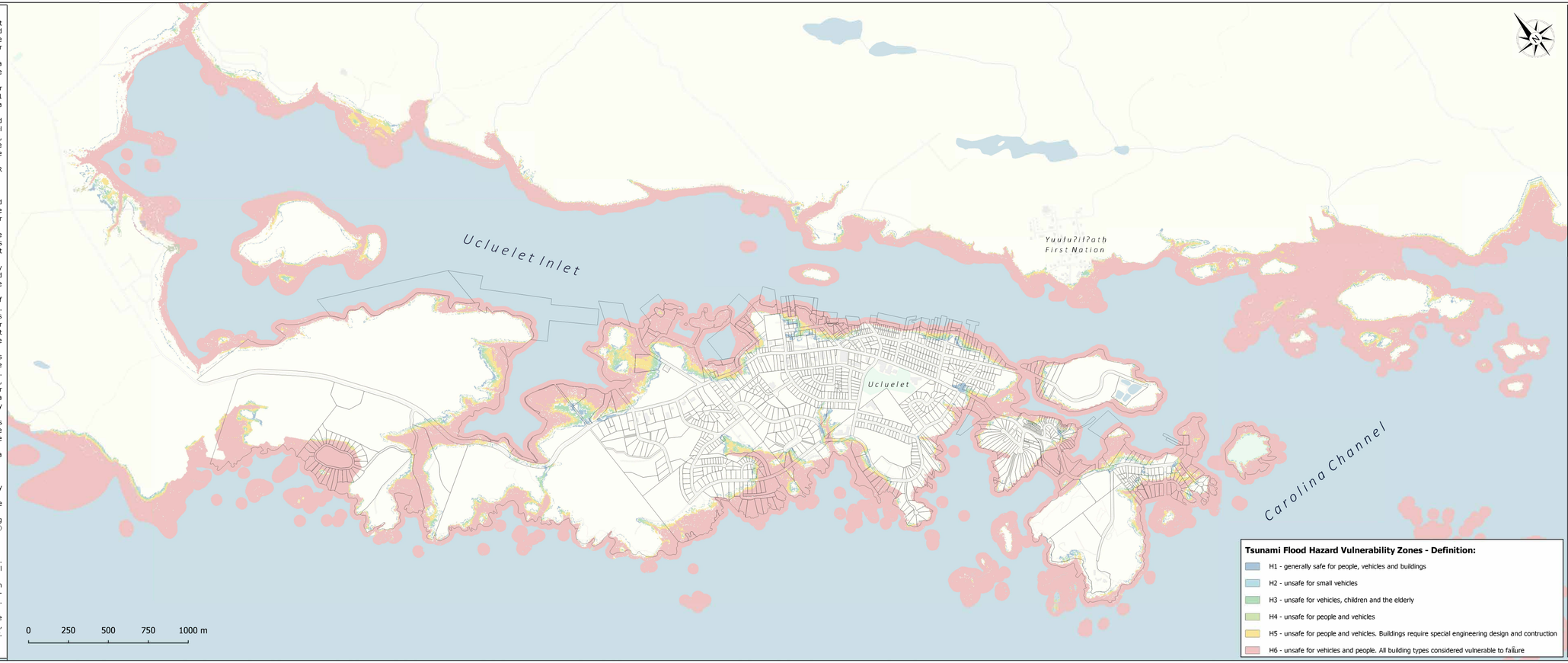
3. AIDR. 2017. "Australian Disaster Resilience Guideline 7-3:Flood Hazard." Australian Institute for Disaster Resilience, Australian Government Attorney-General's Department. https://doi.org/10.1038/ncomms14796.
4. Gao et al., (2018). Nat. Haz. (2018) 94:445–469.



Tsunami Flood Hazard Vulnerability Zones - Definition:

- H1 - generally safe for people, vehicles and buildings
- H2 - unsafe for small vehicles
- H3 - unsafe for vehicles, children and the elderly
- H4 - unsafe for people and vehicles
- H5 - unsafe for people and vehicles. Buildings require special engineering design and contruction
- H6 - unsafe for vehicles and people. All building types considered vulnerable to failure

DISTRICT OF
UCLUELET

Coastal Flood Mapping

Tsunami

Tsunami Flood Planning Support Map 6/6

Tsunami Flood Hazard Vulnerability Zones – Splay Faulting Rupture (Future)

G2018-S-A model, 1 m RSLR

Land Parcels

Tsunami Flood Hazard Vulnerability Zones

- H1
- H2
- H3
- H4
- H5
- H6

Stamp provided in original version

Date Created: June 26, 2020

Map Scale: 1:15,000

Coordinate System: NAD83, UTM 10N

Vertical Datum: CGVD 2013

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