District of Ucluelet Coastal Flood Mapping
Appendix C: Coastal Flood Hazard Map Atlas
Map Series 3/4: Tsunami Flood Hazard

Cover Photo: Ucluelet. © Photo by Ebbwater Consulting

26 June 2020

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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

Notes for Map User

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2. Flood water levels were determined based on a simulation of the tsunami wave generated by a modelled rupture (splay faulting rupture A from Gao et al., (2018) and buried rupture from Wang et al., (2003)).

3. Water levels conservatively assume a tide equal to higher high water large tide (HHWLT, equal to 2 m at Ucluelet), 2 m subsidence, and 0 m, 1 m, and 2 m of relative sea level rise (RSLR), to provide results for a potential present-day and future flood event.

4. Based on guidelines for the management of coastal flood hazard land use (Ausenco Sandwell 2011) 0 m, 1 m, and 2 m sea level rise approximately correspond to the years 2000, 2100, and 2200.

5. Water depths DO NOT include a freeboard allowance.

Limitations

1. The accuracy of the presented flood depths 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 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 in 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. It provides an indication of potential flood extents and depths, however flooding may still occur outside the defined flood hazard boundary. 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 water depths 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.

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. Flood depths 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).

References

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2. Ausenco Sandwell (2011). Climate Change Adaptation 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. Gao *et al.* (2018). Nat. Haz. (2018) 94:445–469.

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

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3. Water levels conservatively assume a tide equal to higher high water large tide (HHWLT, equal to 2 m at Ucluelet), 2 m subsidence, and 0 m of relative sea level rise (RSLR), to provide results for a potential present-day flood event.
4. Based on guidelines for the management of coastal flood hazard land use (Ausenco Sandwell 2011) 0 m sea level rise approximately corresponds to the year 2000.
5. Water depths DO NOT include a freeboard allowance.

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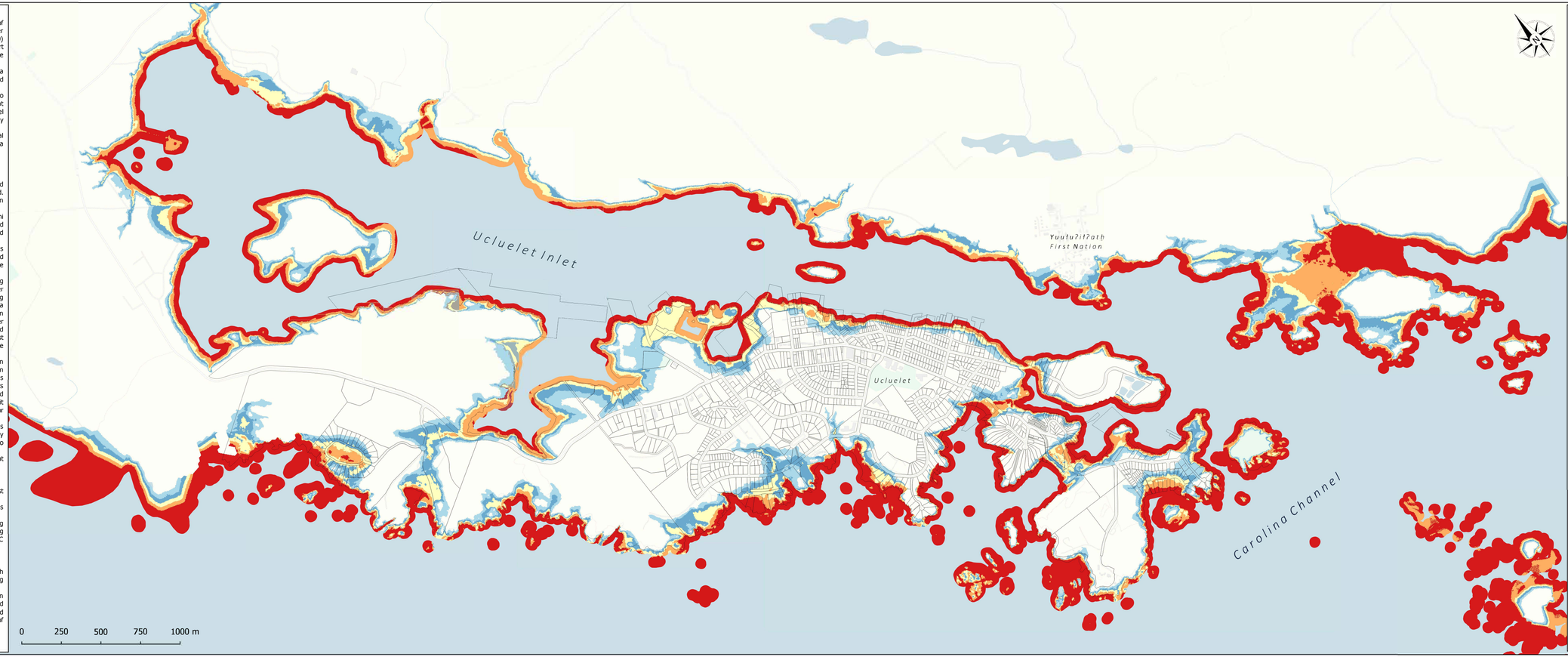
3. Gao et al., (2018). Nat. Haz. (2018) 94:445–469.



DISTRICT OF
UCLUELET

Tsunami

Coastal Flood Mapping

Tsunami Flood Hazard Map 1/8

Flood Depth – Splay Faulting Rupture (Present-Day)

G2018-S-A model, 0 m RSLR

Land Parcels

Water Depth (m) :

- 0.0 to 2.0
- 2.0 to 4.0
- 4.0 to 6.0
- 6.0 to 8.0
- Over 8.0

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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2. Flood water levels were determined based on a simulation of the 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), 2 m subsidence, 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 sea level rise approximately corresponds to the year 2100. However, this time period is subject to changes in climate projections and the response of the earth system and is likely to require reassessment in the future.
5. Water depths DO NOT include a freeboard allowance.

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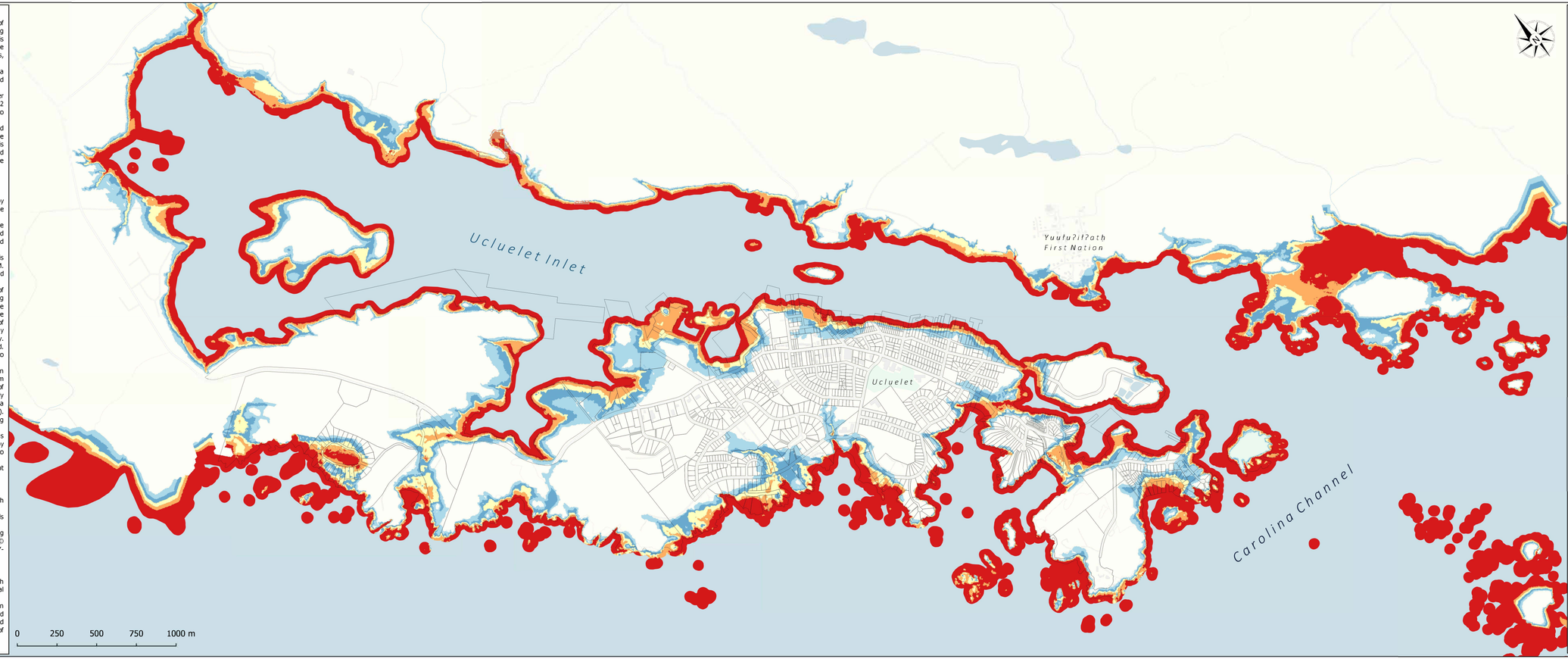

DISTRICT OF
UCLUELET

Tsunami

Coastal Flood Mapping

Tsunami Flood Hazard Map 2/8

Flood Depth – Splay Faulting Rupture (Future)

G2018-S-A model, 1 m RSLR

Land Parcels

Water Depth (m) :

- 0.0 to 2.0
- 2.0 to 4.0
- 4.0 to 6.0
- 6.0 to 8.0
- Over 8.0

Stamp provided in original version

Date Created:	June 26, 2020
Map Scale:	1:15,000
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3. Water levels conservatively assume a tide equal to higher high water large tide (HHWLT, equal to 2 m at Ucluelet), 2 m subsidence, and 2 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) 2 m sea level rise approximately corresponds to the year 2200. However, this time period is subject to changes in climate projections and the response of the earth system and is likely to require reassessment in the future.
5. Water depths DO NOT include a freeboard allowance.

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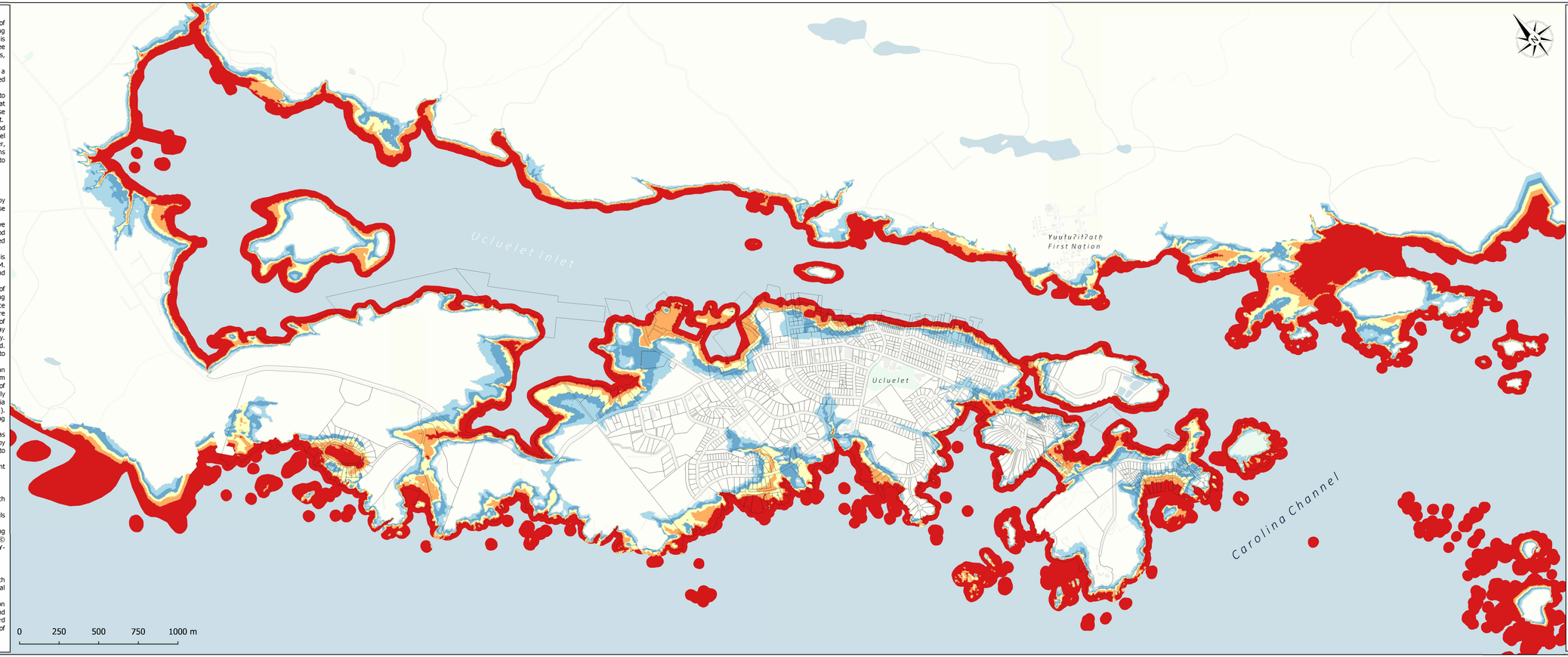

DISTRICT OF
UCLUELET

Coastal Flood Mapping

Tsunami

Tsunami Flood Hazard Map 3/8

Flood Depth – Splay Faulting Rupture (Far Future)

G2018-S-A model, 2 m RSLR

Land Parcels

Water Depth (m) :

- 0.0 to 2.0
- 2.0 to 4.0
- 4.0 to 6.0
- 6.0 to 8.0
- Over 8.0

Stamp provided in original version

Date Created:	June 26, 2020
Map Scale:	1:15,000
Coordinate System:	NAD83, UTM 10N
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3. Water levels conservatively assume a tide equal to higher high water large tide (HHWLT, equal to 2 m at Ucluelet), 2 m subsidence, 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 sea level rise approximately corresponds to the year 2100. However, this time period is subject to changes in climate projections and the response of the earth system and is likely to require reassessment in the future.
5. Water depths DO NOT include a freeboard allowance.

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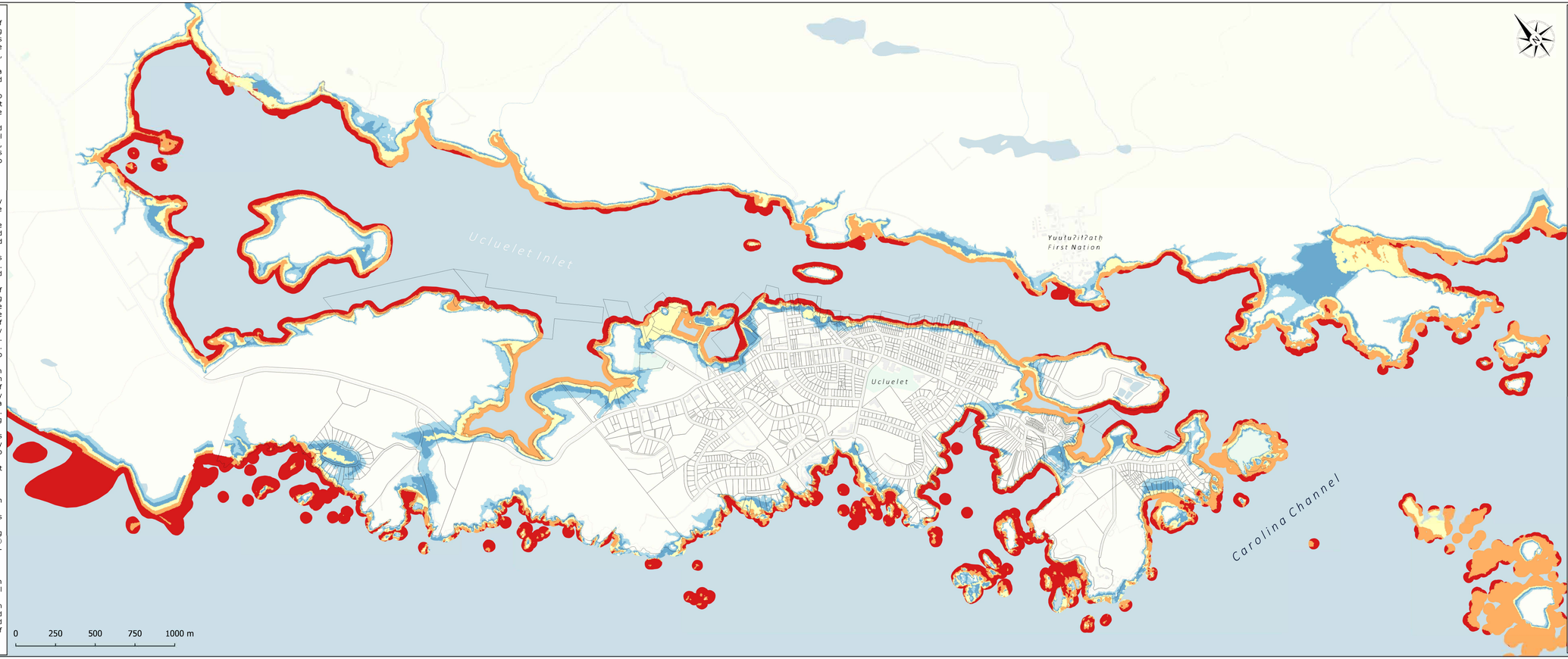

DISTRICT OF
UCLUELET

Tsunami

Coastal Flood Mapping

Tsunami Flood Hazard Map 4/8

Flood Depth – Buried Rupture (Future)

W2003 model, 1 m RSLR

Land Parcels

Water Depth (m) :

- 0.0 to 2.0
- 2.0 to 4.0
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- 6.0 to 8.0
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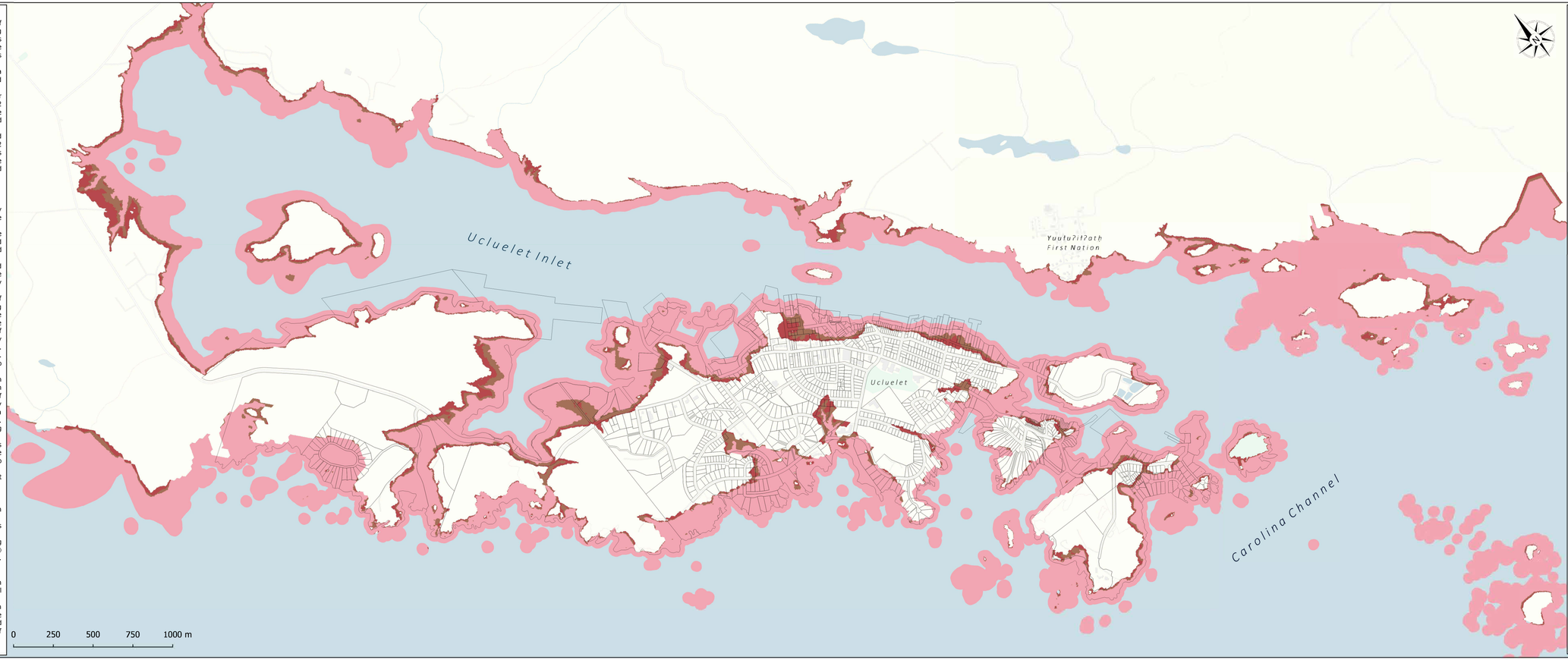

DISTRICT OF
UCLUELET

Tsunami

Coastal Flood Mapping

Tsunami Flood Extent
Map 5/8
Flood Extent – Splay Faulting Rupture (Present-Day, Future, Far Future)
G2018-S-A model, for 0 m, 1 m, and 2 m RSLR

Land Parcels

Flood Extents:

- 0 m RSLR
- 1 m RSLR
- 2 m RSLR

Stamp provided in original version

Date Created: June 26, 2020

Map Scale: 1:15,000

Coordinate System: NAD83, UTM 10N

Vertical Datum: CGVD 2013

CASCADIA COAST RESEARCH LTD. ebbwater CONSULTING

Notes to Users

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 water levels were determined based on a simulation of the tsunami wave generated by two modelled ruptures (splay faulting rupture A from Gao et al., (2018)) and (buried rupture from Wang et al., (2003)).
3. Water levels conservatively assume a tide equal to higher high water large tide (HHWLT, equal to 2 m at Ucluelet), 2 m subsidence, and 0 m of relative sea level rise (RSLR), to provide results for a potential present-day flood event.
4. Based on guidelines for the management of coastal flood hazard land use (Ausenco Sandwell 2011) 0 m of sea level rise approximately corresponds to the year 2000.
5. Water depths DO NOT include a freeboard allowance.

Limitations

1. The accuracy of the presented flood depths 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 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 in 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. It provides an indication of potential flood extents and depths, however flooding may still occur outside the defined flood hazard boundary. 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 water depths 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.
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. Flood depths 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).

References

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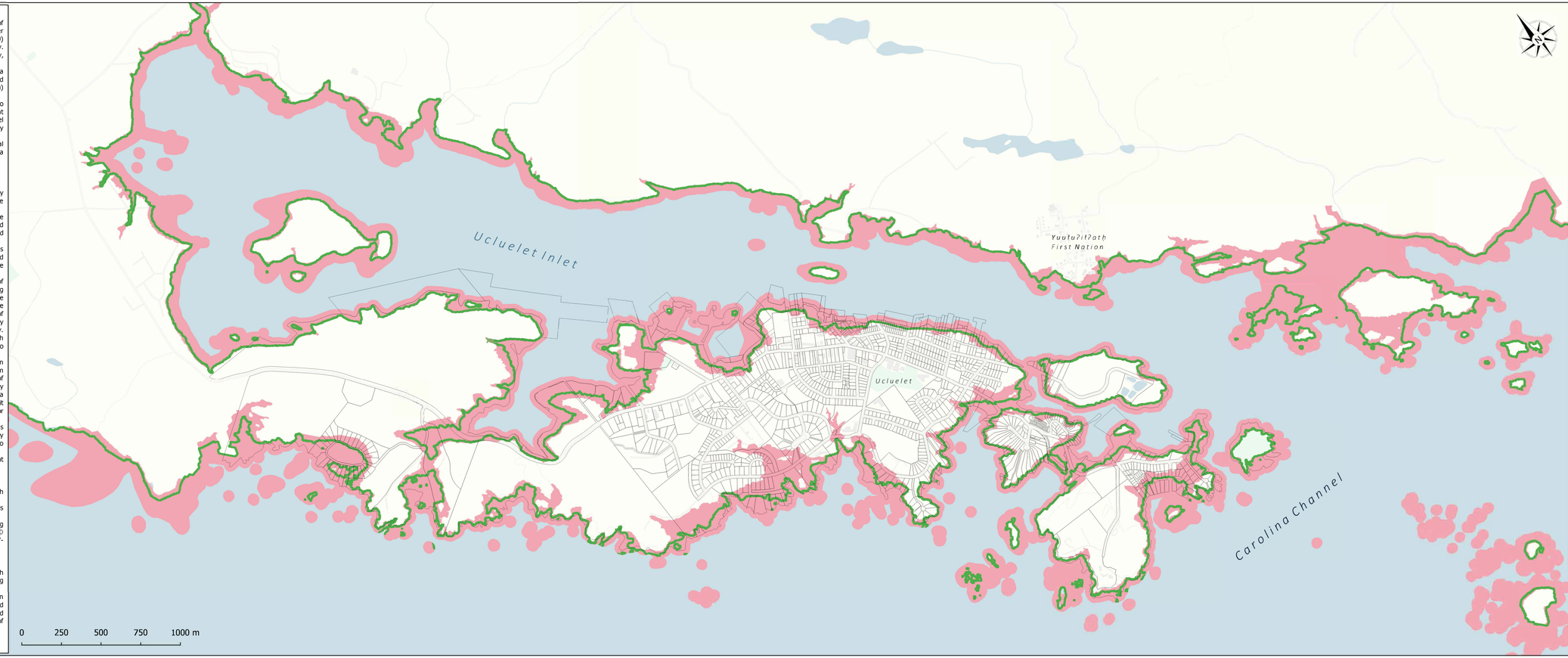

DISTRICT OF
UCLUELET

Coastal Flood Mapping

Tsunami

Tsunami Flood Extent Map 6/8

Flood Extent – Splay Faulting and Buried Ruptures (Present-Day)

G2018-S-A and W2003 models, 0 m RSLR

Land Parcels

Flood Extents (0 m RSLR):

Buried Rupture (W2003 model)

Splay Faulting Rupture (G2018 model)

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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3. Water levels conservatively assume a tide equal to higher high water large tide (HHWLT, equal to 2 m at Ucluelet), 2 m subsidence, 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.
5. Water depths DO NOT include a freeboard allowance.

Limitations

1. The accuracy of the presented flood depths 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 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.
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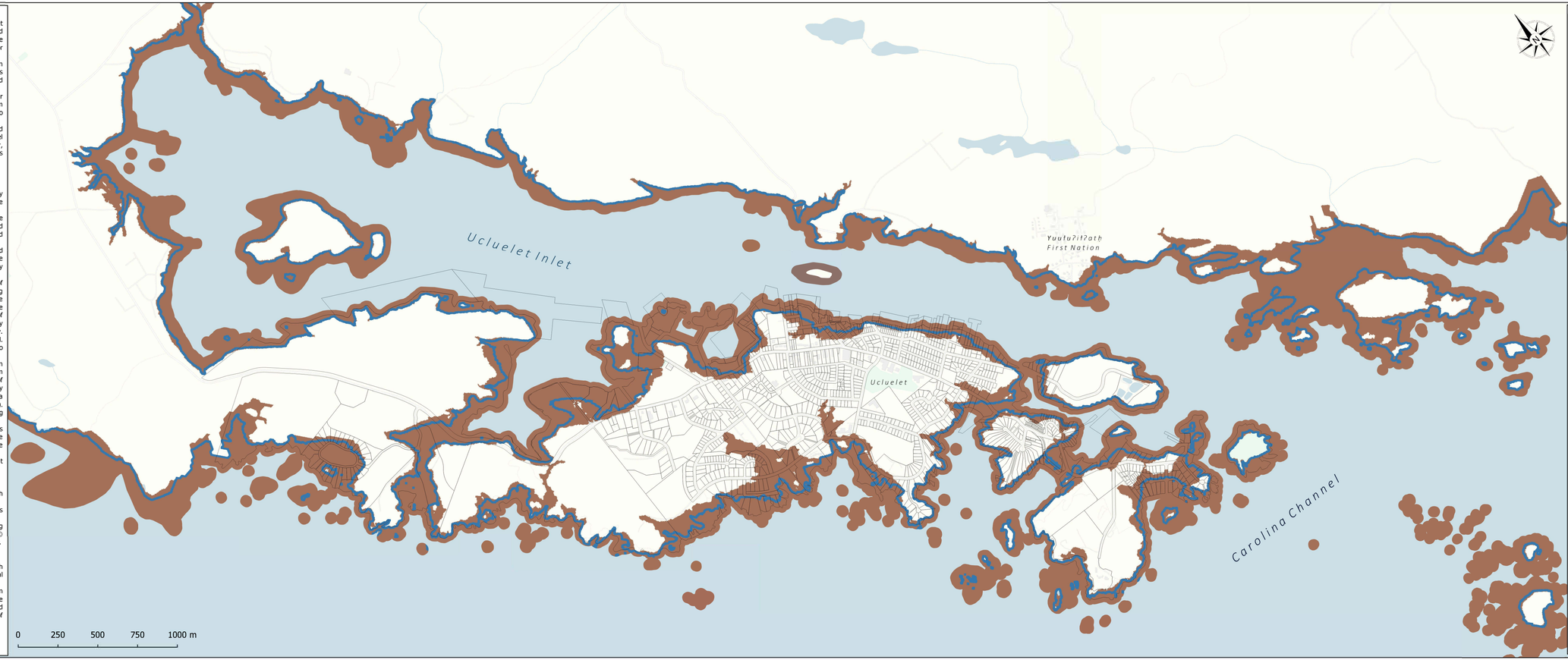

DISTRICT OF
UCLUELET

Tsunami

Coastal Flood Mapping

Tsunami Flood Extent Map 7/8

Flood Extent – Splay Faulting and Buried Ruptures (Future)

G2018-S-A and W2003 models, 1 m RSLR

Land Parcels

Flood Extents (1 m RSLR):

Buried Rupture (W2003 model)

Splay Faulting Rupture (G2018 model)

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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3. Water levels conservatively assume a tide equal to higher high water large tide (HHWLT, equal to 2 m at Ucluelet), 2 m subsidence, and 2 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) 2 m of sea level rise approximately corresponds to the year 2200. However, this time period is subject to changes in climate projections and is likely to require reassessment in the future.
5. Water depths DO NOT include a freeboard allowance.

Limitations

1. The accuracy of the presented flood depths 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.
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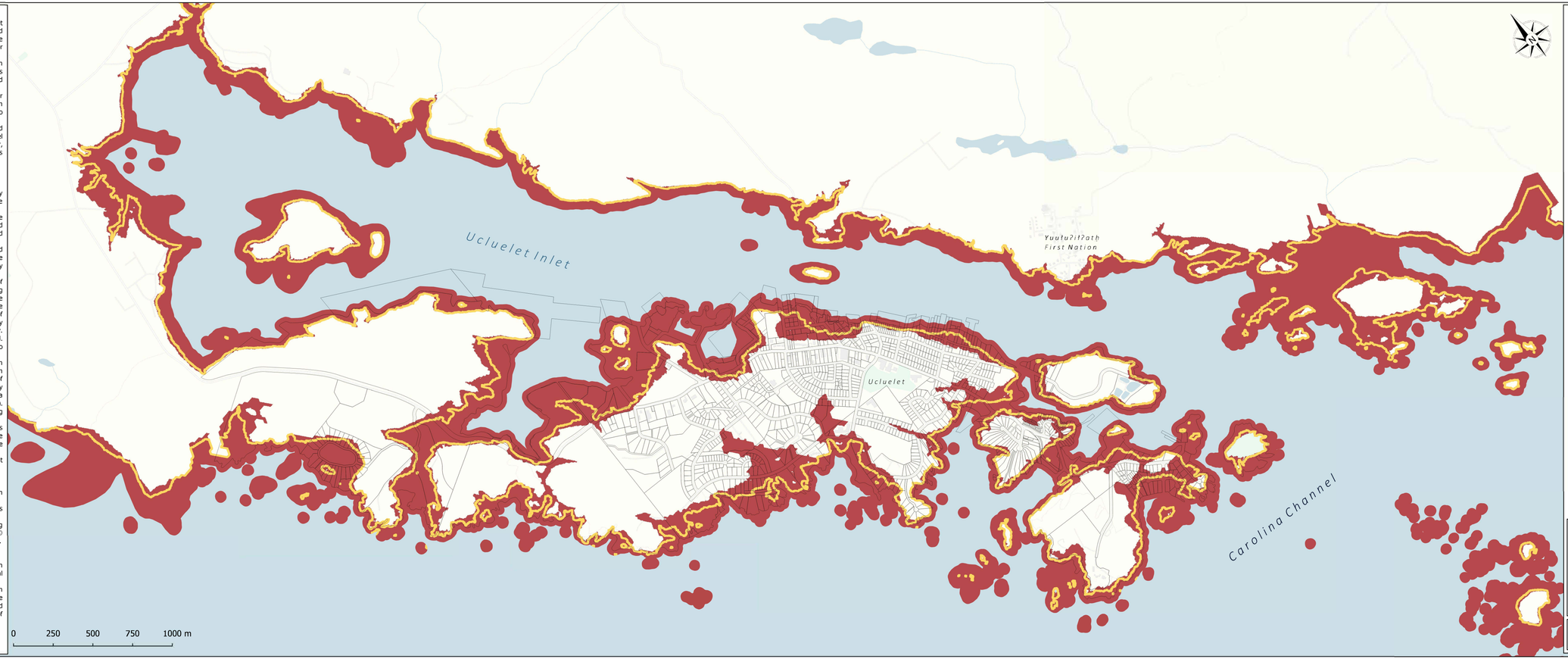

DISTRICT OF
UCLUELET

Tsunami

Coastal Flood Mapping

Tsunami Flood Hazard Map 8/8

Flood Extent – Splay Faulting and Buried Ruptures (Far Future)
G2018-S-A and W2003 models, 2 m RSLR

Land Parcels

Flood Extents (2 m RSLR):

Buried Rupture (W2003 model)

Splay Faulting Rupture (G2018 model)

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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