Hurunui District Coastline Hazard and Risk Assessment

Appendix Booklet

IZ128300-NC-RPT-0001 | A

March 5, 2020

Hurunui District Council

Document history and status

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A	06/05/2020	Draft Report	K. MacDonald		D.Todd	C. Redmond

Hurunui District Coastline Hazard and Risk Assessment

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The sole purpose of this report and the associated services performed by Jacobs is to undertake a coastal and groundwater hazard assessment of six coastal settlements in the Hurunui District in accordance with the scope of services set out in the contract between Jacobs and the Hurunui District Council ('the Client'). That scope of services, as described in this report, was developed with the Client.

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Contents

Appendix A. Reviewed Literature

The following literature from HDC council records and previous consulting reports undertaken by Environment Canterbury and DTec Consulting were reviewed for relevant information regarding historical erosion and flooding events, both inland and coastal, to inform further understanding of coastal hazards within the local area and provide information to 'ground-truth' predictive mapping.

- Environment Canterbury (2014). Kowai River, Leithfield Beach and Amberley Beach flood investigation. Report No. R14/99
- Environment Canterbury (2014). Flood hazard mapping for Hurunui District Plan Review. Report No. R14/42.
- Environment Canterbury (2011). Aerial photo analysis of the Gore Bay coastline, 1955-2004.Report No. R11/119.
- Environment Canterbury (2010). A summary of Environment Canterbury's coastal environment monitoring programme for the Hurunui coastline, 1990-2010. Report No. R10/51.
- DTec Consulting (2009). Coastal Hazards Assessment for a Proposed Residential Dwelling: Section V, Block V, Conway Village (Conway Flats), North Canterbury.
- PDP (2008). Flood Management for Amberley and Amberley Beach.
- DTec Consulting (2004). Coastal Hazards Assessment: Proposed Residential Subdivision; Claverley, North Canterbury.
- Bennett, G (2004). Amberley Beach Erosion and Renourishment.
- DTec Consulting (2003). Investigation into surface water flooding at Leithfield Beach: Issues and options report.
- DTec Consulting (2002). Resource Consent Application and AEE for Beach Renourishment at Amberley Beach. Prepared for Hurunui District Council.
- Geotech Consulting Ltd (2000). Natural Hazard Assessment Part 1: Literature Review & Hazard Scenarios. Prepared for Environment Canterbury. Report No. U00/73(Part 1).
- Wilson, K (1992). The Hurunui District: Natural Hazards.
- Canterbury Regional Council (1990). Analysis of Natural Hazards in the Canterbury Civil Defence Region.
- Yetton M & Garland M (1988). Cheviot County Coastal Environment Planning.

The following national and international guidance and case study documents pertaining to managing coastal hazards were reviewed for relevance and consideration for this assessment. These documents included:

- New Zealand Coastal Policy Statement (2010)
- Ramsay, D. L. et al., (2012) Defining coastal hazard zones and setback lines. A guide to good practice.
- Wright, J. (2015). Preparing New Zealand for rising seas: Certainty and Uncertainty.
- Ministry for the Environment (2017) Coastal Hazards and Climate change: Guidance for Local Government.

Appendix B. Historical Shoreline Positions and DSAS Results

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Erosion Rate (m/yr)

- <-0.5
- -0.49 - -0.25
- -0.24 - -0.10
- -0.09 - 0.10
- 0.10 - 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.25
- >1.25

Shorelines

- 1956
- 1974
- 2000
- 2018

Date: 10/25/2019

DSAS Historical Shoreline Analysis

Leithfield

0 100 200 m

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Erosion Rate (m/yr)

- <-0.5
- -0.49 - -0.25
- -0.24 - -0.10
- -0.09 - 0.10
- 0.10 - 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.25
- >1.25

Shorelines

- 1959
- 1967
- 1986
- 2004
- 2018

Date: 10/25/2019

DSAS Historical Shoreline Analysis

Amberley Beach

0 100 200 m

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Erosion Rate (m/yr)

- <-0.5
- -0.49 - -0.25
- -0.24 - -0.10
- -0.09 - 0.10
- 0.10 - 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.25
- >1.25

Shorelines

- 1950
- 1968
- 1986
- 2004
- 2018

DSAS Historical Shoreline Analysis

Motunau

0 50 100 m

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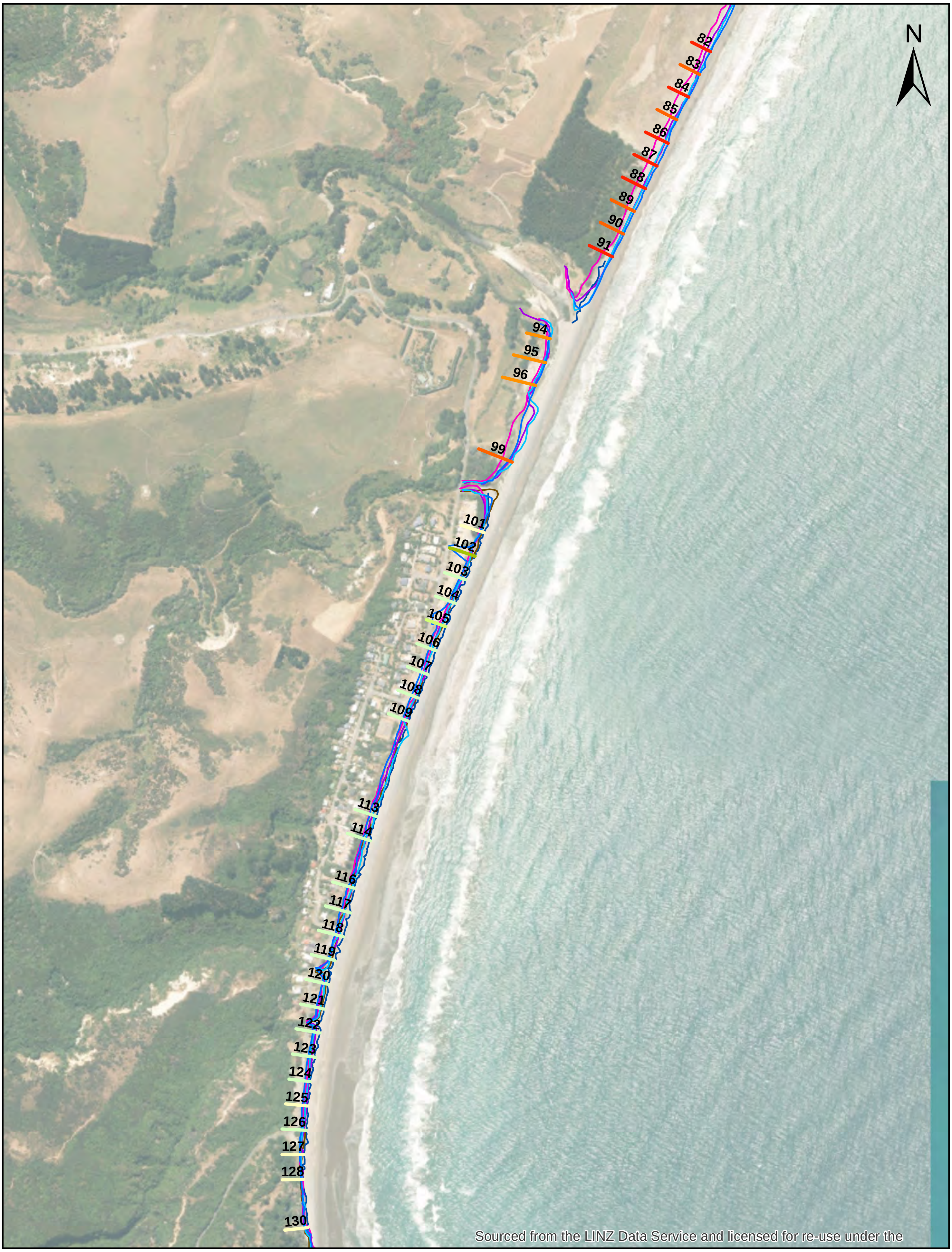
Date: 11/26/2019



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Erosion Rate (m/yr)

- <-0.5
- -0.49 - -0.25
- -0.24 - -0.10
- -0.09 - 0.10
- 0.10 - 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.25
- >1.25

Date: 10/25/2019

Shorelines

- 1955
- 1965
- 1979
- 1985
- 2004
- 2015

DSAS Historical Shoreline Analysis

Gore Bay

0 100 200 m

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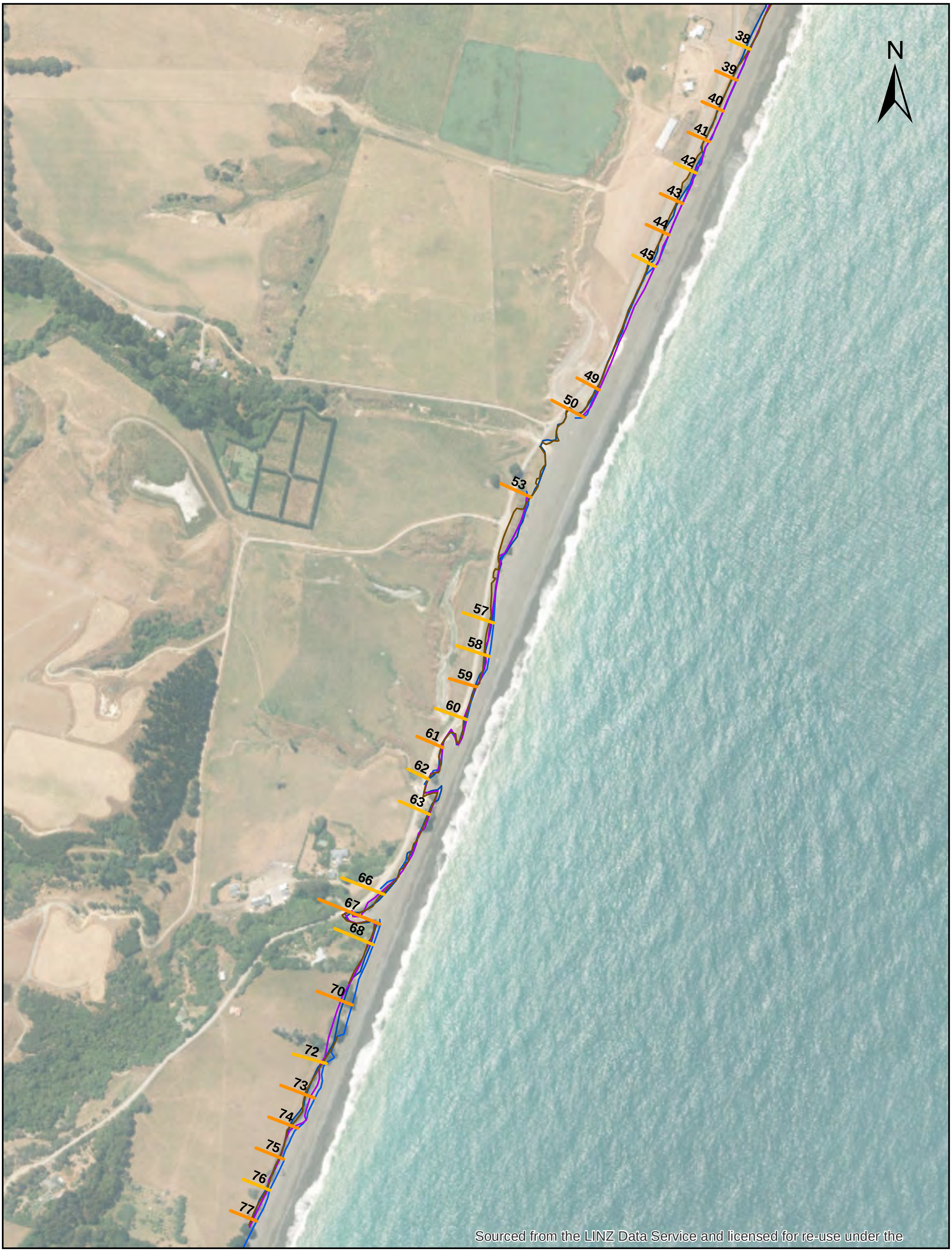

Erosion Rate (m/yr)

- <-0.5
- -0.49 - -0.25
- -0.24 - -0.10
- -0.09 - 0.10
- 0.10 - 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.25
- >1.25

Shorelines

- 1950
- 1975
- 2004
- 2015

DSAS Historical Shoreline Analysis

Conway Flat

0 75 150 m

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Date: 12/2/2019

Shorelines

- 1950
- 1966
- 1985
- 2004
- 2019

Erosion Rate (m/yr)

- < -0.50
- -0.49 - -0.25
- -0.24 - -0.05
- -0.04 - 0.05
- 0.05 - 0.25
- 0.25 - 0.50
- 0.51 - 0.75
- 0.76 - 1.00
- 1.01 - 1.25
- 1.26 - 1.60

DSAS Historical Shoreline Analysis

Claverley

0 40 80 m

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Date: 10/25/2019

Appendix C. Validation of DSAS analysis using historical profile data

Validation of the DSAS analysis was undertaken by comparing the DSAS shoreline change result from the two latest aerial images, with the change in the corresponding shoreline reference position from the Environment Canterbury (ECan) survey profiles between similar dates as to when the aerial photography was captured. For the sake of the validation, the changes from the profile surveys were deemed to be the more accurate and a tolerance of ±5m difference in position change between the two methods was considered to be acceptable. The following discussion outlines the results of this validation for each settlement.

C.1 Leithfield Beach

The ECan profile used in Leithfield is PCC4200, and its location in relation to the settlement can be seen in Figure **C.1**.

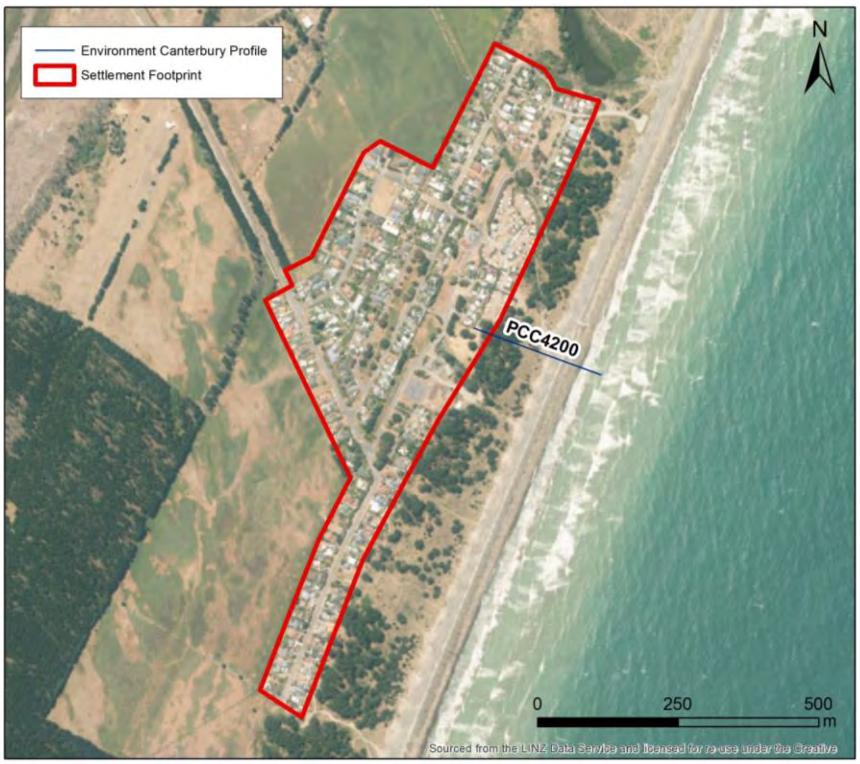

Figure C.1: ECan Profile at Leithfield

The vegetation line, which was recorded in the 2000 profile survey, was located around the 4m contour, therefore a comparison of the surveyed 4m contour and the vegetation line on the aerial images was undertaken at this profile. The results of the validation are shown in Table . Both methods produced an accretionary trend over the 18-year period, with the DSAS under-estimating the magnitude of accretion by 2.6m. This may have been due to the survey record being 10 months longer and including an additional winter (2018) at the end of the survey period that included four storm events on the ECan storm database[1]. As per the acceptable tolerance level, it is considered that the DSAS results are a good estimate of the overall historical shoreline changes.

[1] ECan storm database: List of storm events when significant wave height at the ECan Steep Head wave recorder (off Banks Peninsula) exceeded 4 m. Includes 81 events in 10 years from May 1999 to July 2019.

Table C.1: Leithfield DSAS analysis data validation using ECan beach profiles.

Profile	Aerial Imagery Dates	Survey Dates	Survey change (Net Movement)	DSAS change (Net Movement)	Absolute Difference
Leithfield	5/12/2000 1/1/2018	18/11/2000 7/11/2018	+7.7m	+5.1m	2.6m

C.2 Amberley Beach

Four ECan beach profiles from 2004 and 2018 were analysed (Figure C.**2**) to validate the shoreline change detected using DSAS.

Figure C.2: ECan beach profiles at Amberley.

The results from the DSAS and beach profile comparison are presented below Table C.2. The results from both methods was that there has been an erosional trend over the 14-year period. However, over the four profiles there was no common over or under estimation by the DSAS methods. The range of differences in shoreline change was -4.7m to +2.6 m, with an absolute average across the four profiles of 2.75m.

Part of the difference between the two methods could be explained by the nine month difference in start date for the analysis March 2004 (aerial photography) and November 2004 (Survey) during which there were seven storms recorded on the ECan storm database, and the 10 months longer at the end of the survey period that included four storm events on the ECan storm database.

However, given that all the differences are under the acceptable tolerance level, it is considered that the DSAS results are a good estimate of the overall historical shoreline changes at Amberley.

Table C.2: Amberley DSAS analysis data validation using ECan beach profiles.

Profile	Aerial Imagery Dates	Survey Dates	Survey change (Net Movement)	DSAS change (Net Movement)	Absolute Difference
PCC4682	4/3/2004 1/1/2018	18/11/2004 7/11/2018	-12.6m	-7.9m	4.7m
PCC4694			-9.6m	-11.1m	1.5m
PCC4722			-11.9m	-9.9m	2m
PCC4782			-11.9m	-14.5m	2.6m
				Average	2.7m

C.3 Motunau

Four ECan beach profiles from 2004 and 2018 were analysed (Figure Figure **C.3**) to validate the shoreline change detected using DSAS.

Figure C.3: ECan beach profiles at Motunau.

The results of the validation, as shown in Table , the results of both methods show that there has been an erosional trend occurring the 14-year period (although the surveys showed no change at profile HCH2458). For three of the four profiles, the changes measured by the DSAS method largely matched those recorded by the beach profile surveys, with a general over-estimation of 0.4 m to 2.3 m. Part of this over-estimation could be explained by the nine-month difference in start date for the analysis March 2004 (aerial photography) and December 2004 (Survey) during which there were seven storms recorded on the ECan storm database. However, profile HCH2549 located on the low-lying hinterland inside the Motunau River Mouth, had a large 6.2 m under-estimation, therefore additional caution is required in interpreting the DSAS results from this site.

Over the four profiles the average absolute difference in shoreline change between the methods was 2.5 m, which is below the acceptable tolerance level. It is therefore considered that the DSAS results are a good estimate of the overall historical shoreline changes at Motunau.

Table C.3: Motunau DSAS analysis data validation using ECan beach profiles.

Profile	Aerial Imagery Dates	Survey Dates	Survey change (Net Movement)	DSAS change (Net Movement)	Absolute Difference
HCH2549	4/3/2004 1/1/2018	14/12/2004 2/5/2018	-7.6m	-1.4m	6.2
HCH2487			-5.6m	-6.8m	1.2
HCH2477			-4.7m	-5.1m	0.4
HCH2458			0m	-2.3m	2.3
				Average	2.5

C.4 Gore Bay

Nine ECan beach profiles from 2004 and 2018 were analysed (Figure **C.4**) to validate the shoreline change detected using DSAS.

Figure C.4: ECan beach profiles at Gore Bay.

The results from the data validation are shown below in Table . For all profiles except one, both methods showed an accretionary trend over the eleven-year period, with the exception being HCH5782, for which the profile survey showed very minimal erosion (-0.1 m). For all sites the DSAS over-estimated the accretion with the range of differences in shoreline change between methods being 0.2 m to 9.4 m, with 2 sites (HCH5736 & HCH5700) having difference greater than the 5 m tolerance level. Part of this over-estimation could be explained by the nine-month difference in start date for the analysis March 2004 (aerial photography) and December 2004 (Survey) during which there were seven storms recorded on the ECan storm database.

The reason for the poor validation at profiles HCH5736 & HCH5700 is uncertain, but may be due to the vegetation line not being recorded in later surveys, hence the 3 m contour survey having to be used as a proxy in the 2015 survey.

However, the average difference between methods across all nine sites was 3.16 m, being below the tolerance level for accepting the DSAS results as being a good estimate of the overall historical shoreline changes at Gore Bay.

Table C.4: Gore Bay DSAS analysis data validation using ECan beach profiles .

Profile	Aerial Imagery Dates	Survey Dates	Survey change (Net Movement)	DSAS change (Net Movement)	Absolute Difference
HCH5747	4/03/2004 9/01/2015	13/12/2004 22/05/2015	+1.5m	+1.7m	0.2
HCH5667			+3.3m	+3.5m	0.2
HCH5658			+3.7m	+4.7m	1
HCH5782			-0.1m	+3m	3.1
HCH5765			+3.0m	+7.4m	4.4
HCH5736			+3.1m	+8.3m	5.2
HCH5722			+2.9m	+7m	4.1
HCH5700			+1.3m	+10.7m	9.4
HCH5711			+4.5m	+5.5m	1
				Average	3.16

C.5 Conway Flat

As shown in Figure C.5, there is being one historical profile located within the Conway Flat study area, therefore the validation is limited to one transect. The results presented in Table show that the profile surveys indicated cliff retreat, but the DSAS indicated cliff advance over the eleven-year period. But, from a coastal process perceptive, cliff advance is not possible, and can only be as a result of error in digitized shoreline position in one of aerial images. However, over the total aerial period, the DSAS assessed shoreline erosion to be occurring at an average rate of -0.1 m/yr.

Since the difference in shoreline change results between the methods are within the accepted error (less than 5m), and the overall erosion trends from the DSAS method, it is considered that the DSAS can be accepted as being a good estimate of the overall historical shoreline changes at Conway Flat.

Figure C.5: ECan beach profile at Conway Flat.

Table C.5: Conway Flat DSAS analysis data validation using ECan beach profiles .

Profile	Aerial Imagery Dates	Survey Dates	Survey change (Net Movement)	DSAS change (Net Movement)	Absolute Difference
HCK8510	4/3/2004 9/1/2015	24/02/2004 7/12/2015	-1.8m (Cliff top)	+1.1m	2.9

C.6 Claverley

The validation of the DSAS outputs against profile change at Claverley could not be completed due to the ECan Profile being located significantly further north than the study area (Figure C.6). The profile analysis showed that there was a 0m change at profile HCK9150 across the same period as covered by the aerial imagery. This result is not comparable to the DSAS results, but gives an indication that across a similar time period there were no strong erosion or accretion trends occurring at a nearby area.

Figure C.6: beach profile north of Claverley settlement

Appendix D. Methodology for Sea Level Rise Erosion Effects Assessment

D.1 Sea Level Rise Scenarios

IPCC AR5 (2014) developed four climate change and sea level rise (SLR) projections, termed RCPs (Representative Concentration Pathways), based on the following global emissions scenarios.

- RCP2.6 – low emission
- RCP4.5 – moderate then declining emissions
- RCP 6.0 – moderate emissions
- RCP8.5 – continuing status quo high emissions

Within each RCP, percentiles are used to quantify the distribution of the sea level rise projection with the median (50^{th} percentile) plotted as the main curve.

MfE (2017) *Coastal Hazards and Climate Change: Guidance for Local Government* presents four sea level rise scenarios are developed based on three of the IPCC RCP scenarios (RCP2.6, RCP4.5, RCP8.5) and a higher RCP8.5+ scenario taking into account possible instabilities in the polar ice sheets. The resulting SLR projections from these scenarios extended out to 2150 and including a small additional sea level rise above the global projections to account for NZ wide regional offset in rates of historical rise, are presented in Figure D.7. The use of the RCP8.5+ projection to 2150 corresponds to the recommended minimum transitional SLR allowance in MfE (2017) to avoid hazard risk for coastal subdivisions, greenfield developments and new major infrastructure (MfE 2017, Table 12).

For this assessment, the RCP8.5 and RCP8.5+ SLR projections were used.

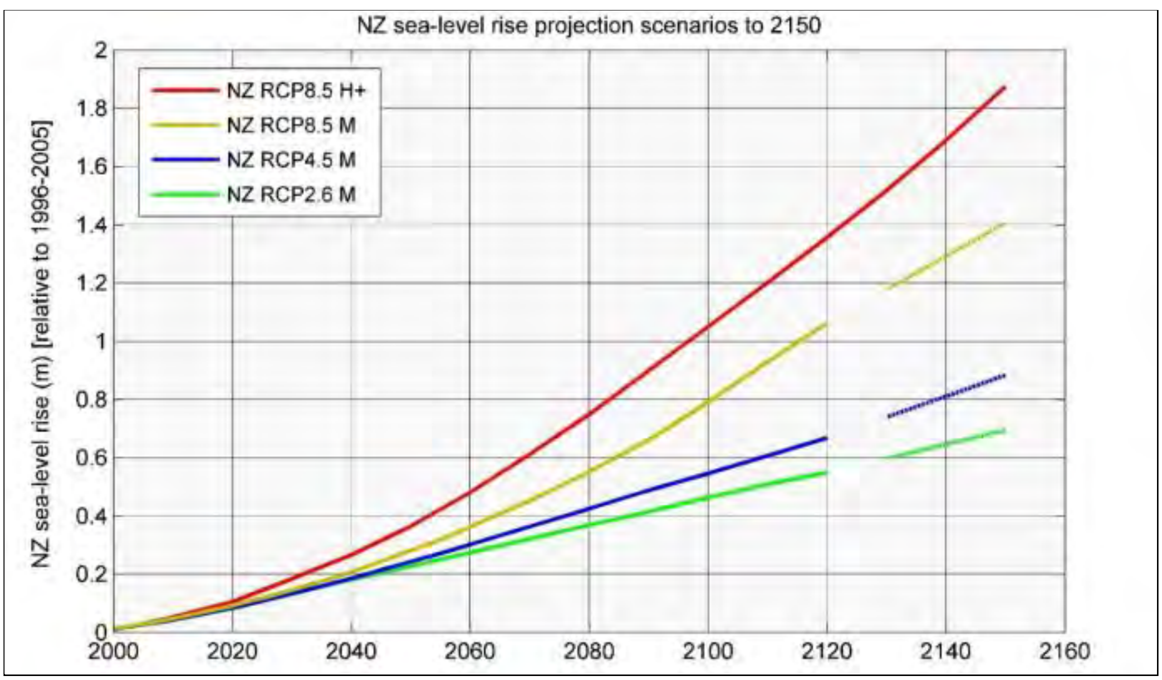

Figure D.7: MfE (2017, Figure 27) Four scenarios of New Zealand-wide regional sea-level rise projections based on IPCC (2014).

For this assessment the following adjustments have been made to these projections to make them more appropriate for the assessment of effects of accelerated sea level rise:

1. Since the MfE (2017) projections are based on rise above a 1986-2005 baseline, the projections have been offset by -0.05 m to account for SLR that has occurred since 1995 (e.g. mid date of above baseline) to current (e.g. 2020) at an average rate of 2 mm/yr (e.g. NZ average rate of SLR rise over at least the last 50 years).
2. Since the extrapolation of historical shoreline change already includes the effects of the current rate of SLR, the projected SLR scenarios need to also be offset by the current rate of rise (e.g. 2 mm/yr), for the calculation of the effect of future accelerated rise.

The resulting SLR projections used in this assessment from a 2020 baseline are presented in Table D.1.

Table D.1: SLR scenarios used in this assessment

Year	RCP8.5 SLR Scenario			RCP8.5+ SLR Scenario		
	MfE (2017) projection	Offset projection from 2020[1]	Rate of accelerated rise[2]	MfE (2017) projection	Offset projection from 2020	Rate of accelerated rise
2050 (30 Year)	+0.28 m	+0.23 m	5.7 mm/yr	+0.37 m	+0.32 m	8.7 mm/yr
2070 (50 Year)	+0.45 m	+0.40 m	6.0 mm/yr	+0.61 m	+0.56 m	9.2 mm/yr
2120 (100 Year)	+1.06 m	+1.01 m	8.1 mm/yr	+1.36 m	+1.31 m	13.1 mm/yr
Notes	1 Offset of -0.05 m from MfE (2017) to bring base date to 2020 2 Rate of accelerated SLR above current rate of 2 mm/yr					

D.2 Review of Geometric Beach Retreat Models

Geometric shoreline retreat models have been used for a number of years to provide order of magnitude estimates of predication of shoreline retreat with SLR. This is particularly the case for sand beach environments (e.g. The Bruun Rule), but there has been less development of shoreline retreat models for mixed sand and gravel and composite beach types such as found within the Hurunui District. However, it is generally accepted in the international literature that beaches containing gravel components will erode less that sand beaches under sea level rise as the coarser sediment is moved landward and upwards on the beach ridge rather than large volumes loss to the offshore.

All of the geometric prediction models have limitations around the assumptions applied and the uncertainty of the data required to be inputted into the models. However, their benefits are that they provide a practical method for obtaining a rapid semi-quantitative assessment of the likely order of magnitude of shoreline response to sea level rise.

Geometric models from literature which are relevant to this assessment and their limitations are summarised below:

D.2.1 Bruun Rule (1962)[2]:

This method is widely used in the international literature to provide order of magnitude estimates of shoreline retreat due to sea level rise for sand beach with dune elevation above run-up level. The model involves the assumptions of conservation of an equilibrium profile shape with the volume eroded seaward from the beach being that required to raise the nearshore profile out to the closure depth for cross-shore sediment transport by the same vertical magnitude as the magnitude of sea level rise. Therefore, the resulting horizontal shoreline retreat is dependent on the beach-nearshore slope from dune crest to the closure depth and is expressed by the following equation.

[2] Bruun, P. (1962). Sea level rise as a cause of shore erosion. *Journal of the Waterways and Harbours division, 88*(1), 117-132.

$$\boldsymbol{shoreline\ Retreat}\ (\Delta \boldsymbol{x})\ =\ \frac{\boldsymbol{s\ \ L}}{(\boldsymbol{h}+\boldsymbol{d})}$$

Where:

L = Horizontal distance to closure depth from dune crest

s = sea level rise over the planning timeframe

h = height of beach crest above MSL

d = Average closure depth below MSL

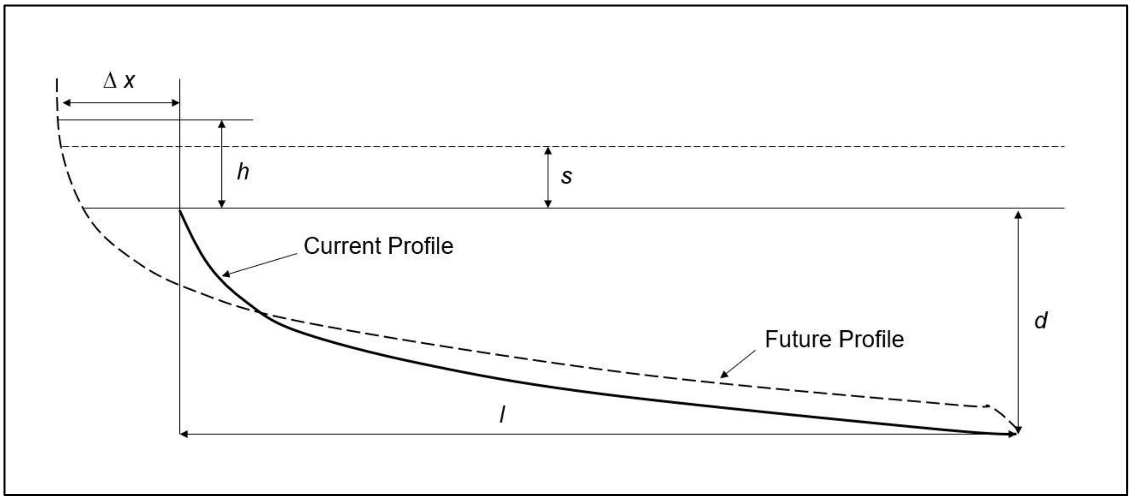

Figure D.2: Schematic of Bruun Rule components

For this study the beach height and slope were obtained from the ECan profile survey database, closure depth was calculated from local annual exceedance significant wave height at the 10 m water depth given in the NIWA coastal calculator (Stephens et al,2015), and nearshore slope from LINZ bathymetric charts.

Limitations of the Bruun Rule are well documented, including:

- Assumes only two dimensional cross-shore sediment movements hence does not include consideration of longshore sediment transport inputs/losses or plan shape controls (e.g. headlands, reefs etc),
- Is only applicable to equilibrium beach profiles,
- Difficulty in determining a closure depth for offshore sediment transport,
- Does not cater for cross-shore variations in sediment size as found on both composite and MSG beaches in the Hurunui District, and
- Does allow for landward sediment movements (e.g. dune rollover from overtopping).

This final point has been addressed by the following modification from Rosati et al (2013)[3] to the original Bruun Rule to deal with landward sediment losses due to dune or beach ridge overtopping.

$$\boldsymbol{shoreline\ Retreat}\ (\Delta \boldsymbol{x})\ =\ \frac{\boldsymbol{s}\ \ (\boldsymbol{L}\ +\frac{\boldsymbol{V}}{\boldsymbol{s}})}{(\boldsymbol{h}+\boldsymbol{d})}$$

[3] Rosati J.D. et al (2013) The modified Bruun rule extended for landward transport

Where:

V = Sediment rollover volume in units of m^3/m length of beach

D.2.2 Measures et al (2014)[4]:

This model was developed for the MSG barriers on the Kaitorete Spit where roll-over from wave overtopping is the dominant erosion process and where large back slope elevations extend into Te Waihora Lagoon behind the barrier. The model assumes that crest building from waves just overtopping the barrier crest will keep pace with SLR and that the volume required to lift the barrier crest to match SLR is supplied from a slice of equal volume from the beachface, hence causing the beachface to retreat.

The retreat equation is given as follows with a schematic of the components shown in Figure D.3.

$$\boldsymbol{R_{Measures}} = \Delta \boldsymbol{S} \left(\frac{\Delta \boldsymbol{S}}{\mathbf{2}} + \boldsymbol{H_{bs}}\right) \times \frac{\left(\frac{\mathbf{1}}{\tan \boldsymbol{\alpha}} + \frac{\mathbf{1}}{\tan \boldsymbol{\beta}}\right)}{\boldsymbol{H_{fs}}}$$

Where

$R_{Measures}$ is the retreat distance ($\Delta \boldsymbol{y}$)

ΔS is the expected sea-level rise over the planning timeframe,

H_{bs} is the height of the backshore,

α is the corresponding backshore slope,

H_{fs} is the height of the foreshore using the toe of the nearshore step as the base,

and β is the corresponding foreshore slope

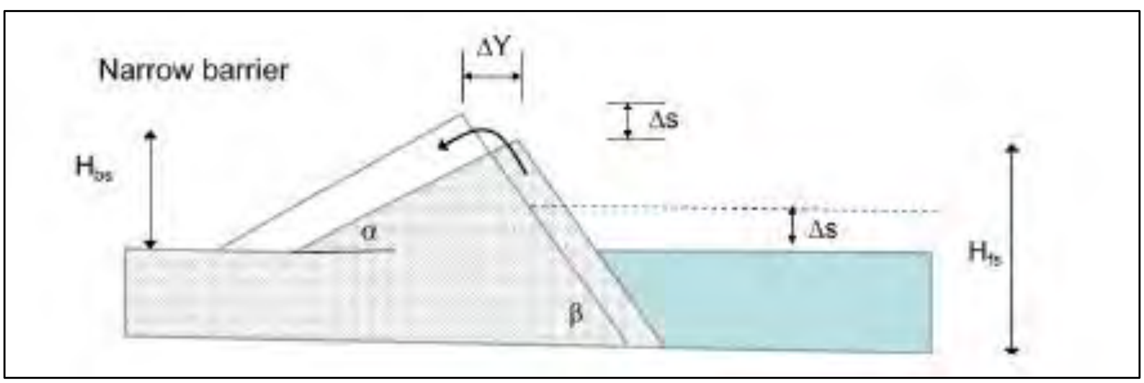

Figure D.3: Schematic of Measures et al (2014) Gravel Barrier retreat model

A limitation of the method is the requirement for total barrier foreshore elevation and slope from the base of the nearshore face. This information is not known for the mixed sand and gravel beaches in the Hurunui District, so a standard nearshore step elevation of 5 m (e.g. base is -.5 m MSL) and 1:10 slope was applied based on 1987 nearshore surveys at Washdyke (Timaru, Canterbury). Similar nearshore step elevations are recorded in Measures et al (2014) for Kaitorete Spit in the vicinity of Taumutu.

[4] Measures, R., et al. (2014). Analysis of Te Waihora lake level control options. NIWA client report prepared for Ngai Tahu and Environment Canterbury.

A further limitation for Hurunui District MSG beaches is that they are backed by land rather than water bodies, hence backshore elevations are small resulting in what appears to be an under-prediction of SLR induced erosion (see sensitivity testing below).

D.2.3 Orford et al (1995)[5]:

Studied three swash aligned gravel barriers to develop a correlation between mesoscale (e.g.1-10-year timeframe) rates of barrier retreat and the 5-yearly average rate of sea level change. The principle of the relationship was that movement of the barrier was the result of two interacting factors of wave forces driving the barrier onshore and barrier resistant, termed "barrier inertia" to onshore transport by waves. The assumptions of the relationship were that wave climates do not change, that the only source of material to the barrier was that exhumed from barrier retreat (e.g. barriers received zero or negligible net sediment supply from longshore or cross-shore from the nearshore sea bed).

The findings of the study were that the rate of retreat depended inversely on "barrier inertia" (I), defined as the product of barrier volume (per unit shore length) and barrier height (between foreshore toe and crest), according to the relationship:

$$R = 0.9575 - 0.000281\ (I)$$

Where

R is the rate of SLR in mm/yr,

I is the barrier inertia, being the barrier vol v barrier height and in the range 400-2800 m^3.

Limitation for using this relationship to predict shoreline retreat for MSG beaches in the Hurunui District include:

- The linear relationship between "barrier inertia" and SLR response is only based three sites, and therefore may not be representative of the relationship found on Hurunui beaches.
- The barrier volume required for the calculation of "barrier inertia" relies on an assumed barrier substrata profile as the basement for the volume calculation. Two assumed substrata profiles were used to calculate volume in the sensitivity testing:
  1) volume above MSL substrata profile, and
  2) volume above MSL + triangle wedge below MSL across width of barrier to toe of nearshore step. This second method used the assumed nearshore step profile from the Washdyke MSG beach profiles. Including the whole substrata above the nearshore face toe in the barrier volume was not option as it resulted in the barrier inertia exceeding the criteria of the prediction equation.

D.2.4 Sensitivity testing for MSG and composite beaches

Sensitivity testing of the results from the Bruun, modified Bruun, Measures and Orford methods for composite and MSG beaches at Leithfield, Amberley, Gore Bay and Claverley were undertaken to test the range of outcomes for contemporary SLR produced from these different methods, and whether they are appropriate in relation to the rates of measured shoreline movements. The sensitivity testing was also carried out for the MSG beaches fronting the alluvial cliffs at Conway Flat to compare theoretical contemporary beach retreat due to SLR with measured cliff retreat. The results from the sensitivity testing are presented in the following Table (D.2).

[5] Orford, J.D., Carter, R. W. G., McKenna, J., & Jennings, S. C. (1995). The relationship between the rate of mesoscale sea-level rise and the rate of retreat of swash-aligned gravel-dominated barriers. *Marine Geology* (124) 17-186.

Table D.2: Sensitivity Testing for MSG and Composite Beaches

	Settlements and Profile Sites				
Erosion Rates (m/yr)	**Leithfield (PC4200)**	**North Amberley (PC4782)**	**North Gore Bay (HCH5782)**	**Conway Flats (HCK8510)**	**Claverley (HCK9150)**
Contemporary rates of shoreline change (m/yr)	+0.1	-0.91	+0.13	-0.16 (Cliff retreat)	+0.13
Theoretical Rates of Shoreline Change (m/yr) due to Contemporary Rate of SLR (2 mm/yr)					
With Bruun Method	-0.28	-0.22	-0.36	-0.36	-0.31
With Modified Bruun for landward sediment movement	-0.35 (over foreshore berm, not high crest)	Not applicable: No overtop sediment	-0.36	Not applicable: No overtop sediment	Not applicable: Not overtop
With Measures Method	Not applicable: Not MSG beach	Not applicable; not MSG beach	Not applicable; Not MSG beach	-0.01	-0.01
With Orford Method (Barrier vol > MSL)	-0.46	-1.00	-1.57	Out of calculation range	Out of calculation range
With Orford Method (Barrier vol include wedge < MSL))	Out of calculation range	-0.51	-0.99	-0.76	Out of calculation range

Although it is recognised that the actual measured shoreline movements are spatially variable due to different morphologies and rates of sediment supply, the following conclusion were reached from the results of the sensitivity testing:

- Bruun Rule: Generally accepted that the Bruun Rule will over predict shoreline retreat due to shallower sediment transport closure depths for the coarser sediment size, therefore, the estimated retreat from the other methods should be less. This over-prediction of erosion is best shown at Conway Flat, where the theoretical barrier retreat due to SLR from the Bruun rule is over two times the actual measured cliff retreat.
- Modified Bruun for landward sediment movement: Limited applicably due to lack of overtop volume recorded on profiles, or not overtop at a number of sites, but actually increased retreat relative to original Bruun due to additional of landward losses as well as seaward losses.
- Measures et al (2014) method: Applicability limited to northern MSG sites as composite beaches in the south of the district do not have a nearshore step. As indicated above, appears to give unacceptability small SLR contribution to the shoreline movement generated by small backshore elevations from the beaches not be backed by a water body, and as with the modified Bruun method, there was a lack of over-topping volume at these sites.
- Both versions of the Orford et al (1995) method give unacceptable large erosion rates, being larger that the Bruun rule results. There is also the issue that a number of the sites are out of the given calculation range hence this method cannot be applied.

Therefore, although the Measures and Orford methods are for gravel beaches, they are discarded for this study, and we looked at the following ways to modify the Bruun rule to account for the presence of gravel in the sediment composition of composite beaches and the steep nearshore step in mixed sand and gravel profiles.

D.3 Further Modifications to The Bruun Rule Applied for This Study

Due to the above issues with gravel beach and rollover volume methods, the following two modifications to the original Rule were also trialed for use on the composite and MSG beaches.

D.3.1 For composite beach erosion

A modification to the original Bruun Rule was undertaken for composite beach types (e.g. Leithfield, Amberley, Gore Bay) to account for the beach profile containing gravel, which is considered to reduce the effects of SLR on beach retreat. The modification involves multiplying the Bruun rule result by the average percentage of sand on the beach obtained from past sampling by Environment Canterbury at multiple sites across the survey profiles (e.g. averaged from samples at the upper berm, mid foreshore and swash zone)so that the rate of future retreat is slowed based on the proportion of sand in the onshore profile.

The resulting modified retreat formula for Composite Beaches is:

$$\boldsymbol{Bruun_{Composite}} = \frac{\boldsymbol{L \times a}}{\boldsymbol{(h+d)}} \times \% \; \boldsymbol{of\ Sand}$$

Where:

L = Horizontal distance to closure depth from dune crest

s = sea level rise over the planning timeframe

h = height of beach crest above MSL

d = Average closure depth below MSL

Due to the assumption that the nearshore profile is similar to an equilibrium sand profile, the closure depth remains as per the original Bruun calculations (e.g. calculated from local annual exceedance significant wave height at the 10 m water depth from Stephens et al, 2015).

It is recognised that this method raises a contradiction in the offshore transport processes represented by the Bruun rule, as the gravel component in the upper berm/crest region will not be transported as far offshore, and the nearshore profile elevation adjustments in response to SLR will need to be provided by only the sand component of the beach, hence accelerating erosion rates. However, in the long-term, this differential rate of loss of sand and gravel components would result in the beach converting to a more MSG form, in which erosion rates are reduced.

D.3.2 For Mixed Sand and Gravel (MSG) beach erosion

A second modification was applied to MSG beaches (e.g. Conway Flat and Claverley) to reduce the closure depth from the original Bruun rule. For these beaches the sediment transport processes indicate that the closure depth will be in the vicinity of the toe of the steep nearshore face rather than in relation to the storm wave height. Therefore, the modification involved applying a standard closure depth of 5 m below MSL, and nearshore slope of 1:10 to the Bruun rule calculations based on the results of the 1987 nearshore surveys at Washdyke, Timaru.

The assumption from the modification is that sediment will still be lost offshore due to profile adjusts with SLR, but as a result of applying a shallower closure depth, there is a corresponding steepening of the closure slope, and hence a reduction in the estimated erosion distances with SLR from these predicted by the original Bruun Rule using the storm wave determination of closure depth.

The modified retreat formula for MSG Beaches is:

$$Bruun_{MSG} = \frac{L \times a}{(h + dt)}$$

Where:

L = Horizontal distance to closure depth from dune crest

s = sea level rise over the planning timeframe

h = height of beach crest above MSL

dt = Closure depth below MSL defined as the toe of the steep nearshore face

D.3.3 Sensitivity testing for Modified Bruun Rule for MSG and composite beaches

The results of sensitivity testing of the above modifications to the original Bruun Rule for contemporary SLR are presented in Table D.3.

Table D.3: Sensitivity Testing of Modified Bruun Rule for MSG and Composite Beaches

	Settlements and Profile Sites				
Erosion Rates (m/yr)	**Leithfield (PC4200)**	**North Amberley (PC4782)**	**North Gore Bay (HCH5782)**	**Conway Flats (HCK8510)**	**Claverley (HCK9150)**
Contemporary rates of shoreline change (m/yr)	+0.1	-0.91	+0.13	-0.16 (Cliff retreat)	+0.13
Theoretical Rates of Shoreline Change (m/yr) due to Contemporary Rate of SLR (2 mm/yr)					
With original Bruun Method	-0.28	-0.22	-0.36	-0.36	-0.31
With sediment modified Bruun for composite beaches	-0.24 (sand= 84.5%)	-0.06 (sand= 29.2%)	-0.21 (sand= 59.2%)	-0.09 (sand= 25%)[1]	-0.08 (sand= 25%)[1]
With closure depth modified Bruun for MSG beaches	Not applicable	Not applicable	Not applicable	-0.02	-0.02
	Note (1) No sediment sampling available at Conway Flat and Claverley, so 25% Sand in profile is assumed				

It is considered that the results from the modifications are more realistic and applicable for the composite and MSG beaches than the original Bruun Rule and are therefore used in the assessment of erosion impacts of SLR on the relevant beaches of the Hurunui District.

D.4 Review of Soft Rock Cliff Retreat Models

D.4.1 Bray and Hookes (1997)6 Modified Bruun Relationship

Bray and Hookes (1997) proposed modifications to the Bruun rule for soft rock cliffs, based on increase in the rate of retreat being proportional to the percentage of cliff sediment too fine gained to remain in the equilibrium shore profile (e.g. silts and clays).

[6] Bray M.J. and Hookes J.M., (1997) Prediction of soft-cliff retreat with accelerating sea level rise. Journal of Coastal Research 13(2), 453-467.

The resulting retreat equation was:

$$\boldsymbol{Bruun_{Cliff}} = \frac{\boldsymbol{L \times a}}{\boldsymbol{P(h+d)}}$$

Where:

L = Horizontal distance to closure depth from dune crest

s = sea level rise over the planning timeframe

h = height of beach crest above MSL

d = Average closure depth below MSL

P = proportion of cliff sediment of sufficient size to be retained in the beach profile (e.g. sand sized or coarser).

However, more recent literature has deemed that there is little reason to expect rocky or cohesive cliff coasts to attain an equilibrium geometry independent of SLR and that the relationship of recession to SLR will be based on the magnitude of rise rather than the rate of rise.

D.4.2 Process-response numerical modelling approach: Walkden and Dickson (2008)7

Based on the SCAPE (Soft Cliff And Platform Erosion) model developed by Hall & Walkden (2005)[8] for retreat of soft cliffs (e.g. soft mudstone to soft clay) under strongly episodic mass movement driven by cliff base erosion. Under this model the rate of cliff retreat is driven by the development of an equilibrium cliff-beach/shore platform profile driven by the relationship and feedback mechanisms between the erosive forces of waves and water levels, the volume of the beach and the strength of the cliff material.

Walkden and Dickson (2008) used sensitivity testing of this model to examine the influence of different beach volumes, erosive forces, sea level rises on the development of equilibrium cliff retreat rates over long time periods (e.g. decadal to centuries). The results of this analysis were that for beach volumes below 30 m^3/m (e.g. the cliff retreat does not contribute significant sediment to the beach) there was a relationship between increase in cliff retreat rates and the ratio of rate of future SLR to the current rate of rise.

The Walkden and Dickson (2008) relationship is expressed by the following equation:

$$\boldsymbol{LT_F = LT_H \times \left(\frac{S_F}{S_H}\right)^m}$$

Where:

LT_F = Future cliff retreat rate

LT_H = Long term historical cliff retreat rate

S_F = Future rate of SLR

S_H = Historical rate of SLR (taken as 0.002 m/yr)

m = negative/damped feedback system for influence of beach/platform in front of the cliff face. Based on their sensitivity testing of the SCAPE model, Walkden and Dickson (2008) proposed that a value of m = 0.5 should be applied.

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[7] Walkden M.J.A. & Dickson M. (2008) Equilibrium erosion of soft rock shores with shallow or absent beach under increased sea level rise. Marine Geology 251(2008) 75-84.

[8] Walkden M.J.A. & Hall J.W (2005) A predictive Mesoscale model of the erosion and profile development of soft rock shores. *Coastal Engineering* 52 (2005) 535-563

By reorganizing this equation, the increase in erosion rate due to SLR can be expressed as

$$\boldsymbol{LT_{F(SLR)} = LT_H \times \left(\frac{S_F}{S_H}\right)^m - LT_H}$$

An important difference of this recession model to the ‘Bruun’ type geometric models was that the development of equilibrium retreat rates was dependent on the rate of SLR rather than the total magnitude of rise, the equilibrium slope is unrelated to the upland geometry, and the rate of cliff retreat response to accelerated SLR rates is a power relationship rather than a linear relationship.

Ashton et al (2011)[9] expanded the analysis of Walkden and Dickson (2008) looking at generic changes in the feedback power relationship (i.e. *m value*) for other types of cliff geology and strength (e.g. rock, alluvial glacial outwash terrace), but still with the assumption of low beach volumes which does not affect the evolution of the cliff-beach/platform profile and the cliff does not contribute significant beach building sediment. The paper concluded that the most common behaviour of cliffed coasts is likely to be that of a ‘negative feedback’, such as the power relationship found by Walkden and Dickson (2008), with *m values* in the range $0<m>1$. The paper further concluded that the general type of response to SLR changes will be determined by the coast type, environmental drivers and dominant processes, but unfortunately did not quantify appropriate *m* values for the different cliff types.

Limitation in applying the above relationships to the cliffed coast in the Hurunui District (e.g. Motunau and Conway Flat) include:

- The relationship is limited for use on cliffs with fronting beaches having volumes less than $30m^3/m$, therefore is not applicable to Conway Flat
- There is uncertainty in the *m* value of the power relationship for the alluvial cliffs such as at Conway Flat.
- The resulting erosion rates are after adequate time for the equilibrium profiles to fully develop, which may be centuries. Therefore, as noted by Ashton et al (2011), “*care should be taken with direct application of the formulations presented, particularly over shorten temporal scales*".

D.4.3 Sensitivity testing of the Walkden and Dickson (2008) future cliff retreat with SLR equation for Canterbury cliffs

To address the first two of the above limitations and to provide a consistent approach across the whole Canterbury region for the assessment of the effects of SLR on cliff retreat rates the following sensitivity testing was carried out for all cliffed sections of the Canterbury coast. The start point for this sensitivity analysis was the results from a similar SLR assessment being undertaken at the same time for the Timaru District, in which geomorphic plan shape considerations for the transition of MSG beaches to cliffs indicted that an *m value = 0.5* for alluvial and loess cliffs was too high.

The sensitivity testing started with analysis of the relationship between cliff retreat rates and beach volumes from 37 ECan profile sites across alluvial (27 sites), loess (6 sites) and mudstone (4 sites) cliff types throughout Canterbury. The data used were retreat rates and mean beach volumes over the 30-40 years of profile surveys. The results compared with those presented by Walkden and Dickson (2008) from their sensitivity testing of effect of beach volume on equilibrium retreat rate is presented in Figure D.4. An assumption from this comparison is that the current retreat rates are in equilibrium with the environment factors and cliff properties

[9] Ashton, A. D, Walkden, M. J., & Dickson, M. E. (2011). Equilibrium Responses of cliffed coasts to changes in the rate of sea level rise. *Marine Geology, 284*(1-4), 217-229.

for contemporary rates of SLR. To assist with the analysis, the Canterbury cliff sites are coded for location and type.

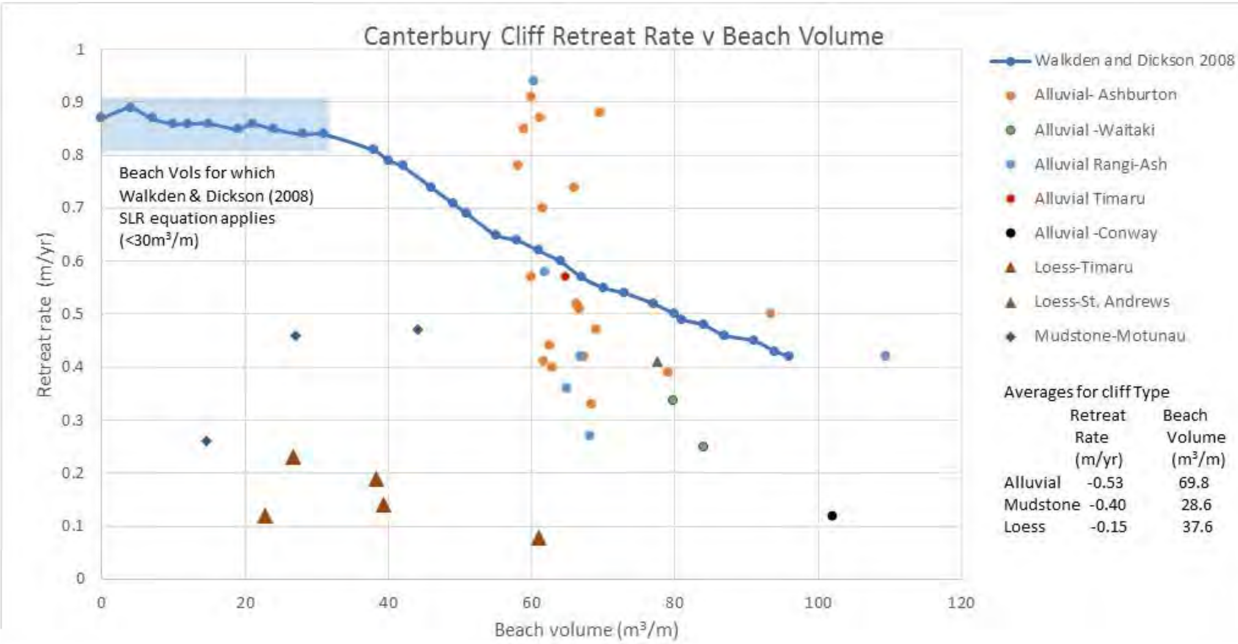


Figure D.4: Relationship between Canterbury cliff retreat rate and beach volumes from 37 ECan profile sites.

The results of the analysis show a large variably in cliff retreat and beach volume across individual sites, but when grouped together in the three cliff types (alluvial, mudstone and loess) the following general patterns emerge:

Mudstone cliffs (Motunau)

- Are the only cliff type to have average volumes (28.6 m^3/m with SD of 12.1 m^3/m) below the threshold (30 m^3/m) for the Walkden & Dickson (2008) relationship for SLR effects, with the erosion products being too fine to remain as a beach at the base of the cliff.
- It is therefore considered appropriate to apply an *m value of* 0.5 for these cliffs.
- The lower average cliff retreat rates (-0.4 m/yr with SD of 0.1 m/yr) at Motunau compared to those found by Walkden & Dickson (2008) reflects differences between the two locations in the erosive forces (e.g. waves, tides), landslide vulnerability, and/or strength of the cliff material to resist these forces.

Loess cliffs (Timaru and St. Andrews)

- Although the erosion of loess cliffs also releases sediment too fine to survive as a beach deposit, the beaches found at the base of these cliffs are of the MSG type from the longshore transport of sediment from rivers and alluvial cliff erosion to the south. These beaches have a greater ability to withstand the erosive forces of waves and water levels, resulting in greater beach volumes at the base of the cliffs (average 37.6 m^3/m with SD = 13.3 m^3/m), which in turn provides greater protection against cliff retreat.
- Since the beach volumes are marginally above the threshold (30 m^3/m) for the Walkden & Dickson (2008) relationship for SLR effects, there is some uncertainty of applying an *m value = 0.5* for the determination for SLR effects on erosion rates for this cliff type.
- As per the finding of the Walkden & Dickson (2008), the greater beach protection is considered to contribute to the lower average cliff retreat rates (-0.15 m/yr with SD of 0.05 m/yr) for the Timaru

loess cliffs compared to the Mudstone cliffs at Motunau, with other factors including differences in landslide vulnerability, and strength of the cliff material.

- As per the Mudstone cliffs, the retreat rates for the Timaru loess cliffs are much lower than those predicted by Walkden & Dickson (2008) for those beach volumes, with the differences again likely to be due to differences between the two locations in the erosive forces (e.g. waves, tides), landslide vulnerability, and/or strength of the cliff material to resist these forces.

Alluvial Cliffs (Canterbury Wide)

- Beach volumes at the base of alluvial cliffs are higher than both Mudstone and loess cliffs, with the average volume being 69.8 m^3/m (SD = 12.8 m^3/m). For these sites, the majority of the sediment eroded from the cliffs (e.g. gravel and sand) is of sufficient size to survive on the beach and clearly contributes to the beach volume, providing an episodic supply to supplement longshore transport supply.
- Since these beach volumes are well above the above the threshold (30 m^3/m) for the Walkden & Dickson (2008) relationship for SLR effects, there is large uncertainty of applying an *m value = 0.5* for the determination for SLR effects on erosion rates for this cliff type.
- Although there is a relatively narrow range of beach volumes, there is a large scatter of retreat rates for alluvial cliffs, with a mean rate of -0.53 m/yr and a standard derivation of 0.22 m/yr. This is considered to be due to local site characteristics, with there being no relationship between beach volume and cliff retreat rate, and only weak relationship between beach volume and distance from river sediment source.
- The greater cliff retreat rates for alluvial cliffs than mudstone and loess cliffs, despite the larger beach volume providing greater protection to the base of the cliff, is due to the less resistance of the alluvial cliff material to the erosive forces of waves and water levels compared to cohesive properties of mudstone and loess material.
- Despite the scatter in the cliff retreat rates, the relationship between the mean rate and the mean beach volume is very similar to found by Walkden & Dickson (2008) for that volume.

The above analysis was used as a basis for further sensitivity testing to quantify the effect of cliff type and beach volumes on cliff retreat due to SLR along the Canterbury coast. The assumptions applied to this sensitivity testing were:

- An *m value =0.5* is appropriate for mudstone cliffs.
- Greater beach volumes on loess and alluvial cliffs reduce the effects of SLR on erosion rates (e.g. greater negative feedback), therefore should have a lower *m value* than mudstone cliffs, with the *m value* being the lowest for alluvial cliffs due the greater volumes.

The sensitivities considered were:

1. The effects of reducing the *m value* of the Walkden & Dickson (2008) power relationship for loess and alluvial cliffs due to greater beach volume. Based on geomorphic plan shape considerations for the transition of MSG beaches to cliffs in the Timaru District, the combinations of *m values* tested were:
   Test 1a: *m = 0.3* for loess cliffs, and *m= 0.2* for alluvial cliffs.
   Test 1b: *m = 0.4* for loess cliffs, and *m= 0.3* for alluvial cliffs
2. The direct effect of the beach volume on the retreat rate, determined by applying a volume effect (Vol_{effect}) factor to the Walkden & Dickson (2008) future cliff retreat equation. The Vol_{effect} factor was calculated for each cliff type from the relationship of retreat rate to beach volume given by Walkden & Dickson (as shown in Figure D.4), being expressed as the following equation:

$$\boldsymbol{Vol_{effect}} = \left(\frac{\boldsymbol{Retreat\ rate\ for\ mean\ \ beach\ volume\ \ per\ beach\ type}}{\boldsymbol{Retreat\ rate\ for\ 30\ m3/m\ \ beach\ volume\ (e.g\ 0.85m/yr}}\right)$$

The resulting Vol_{effect} factors applied to each cliff type are presented in Table D.4.

Table D.4: Mean cliff retreat rates, beach volumes, and Vol_{effect} factors for Canterbury cliffs

Cliff Type	Mean Retreat Rate (m/yr)	Mean Beach Volume (m^3/m)	Vol_{effect} Factor
Mudstone	-0.40	28.6	1.00
Loess	-0.15	37.6	0.95
Alluvial	-0.53	69.8	0.65

The sensitivity testing involved ranking all 37 sites in terms of their current retreat rate, and comparing these ranking for both the total retreat rate and the retreat rate due to SLR from applying the different *m values* for cliff type and the Vol_{effect} factor for the rate of SLR to 2050 and 2120 under the RCP8.5 scenario.

The best results were interpreted as the methodology that best achieved the combination of the following:

- Relative ranking of SLR effects (e.g. separated from extrapolation of historical rates) – highest for mudstone sites, followed by loess sites then alluvial sites.
- Maintained relative ranking of total future erosion over both time periods – highest being alluvial cliff sites, followed by mudstone sites then loess sites
- Maintained geomorphic plan shape requirements for transition from MSG beaches to cliffs as determined by Timaru District sites.

Based on these criteria, the best results were obtained by the addition of the Vol_{effect} factor to the Walkden & Dickson (2008) future cliff retreat equation, followed by the adjustment of the *m values* for loess cliffs to *m=0.4*, and alluvial cliffs *m=0.3*.

D.4.3 Modification of the Walkden and Dickson (2008) future cliff retreat with SLR equation for Canterbury cliffs

Based on the above sensitivity analysis results the following modifications to the Walkden and Dickson (2008) future cliff retreat with SLR equation are made for use on cliff DSAS transects at Motunau and Conway Flat in this study.

$$\boldsymbol{LT_F = LT_H \times Vol_{effect} \times \left(\frac{S_F}{S_H}\right)^{0.5}}$$

Where:

LT_F = Future cliff retreat rate

LT_H = Long term historical cliff retreat rate (e.g. DSAS results)

Vol_{effect} = 1 for mudstone cliffs (e.g. Motunau), 0.95 for loess cliffs, and 0.65 for alluvial cliffs (e.g. Conway Flat)

S_F = Future rate of SLR

S_H = Historical rate of SLR rate (taken as 0.002 m/yr)

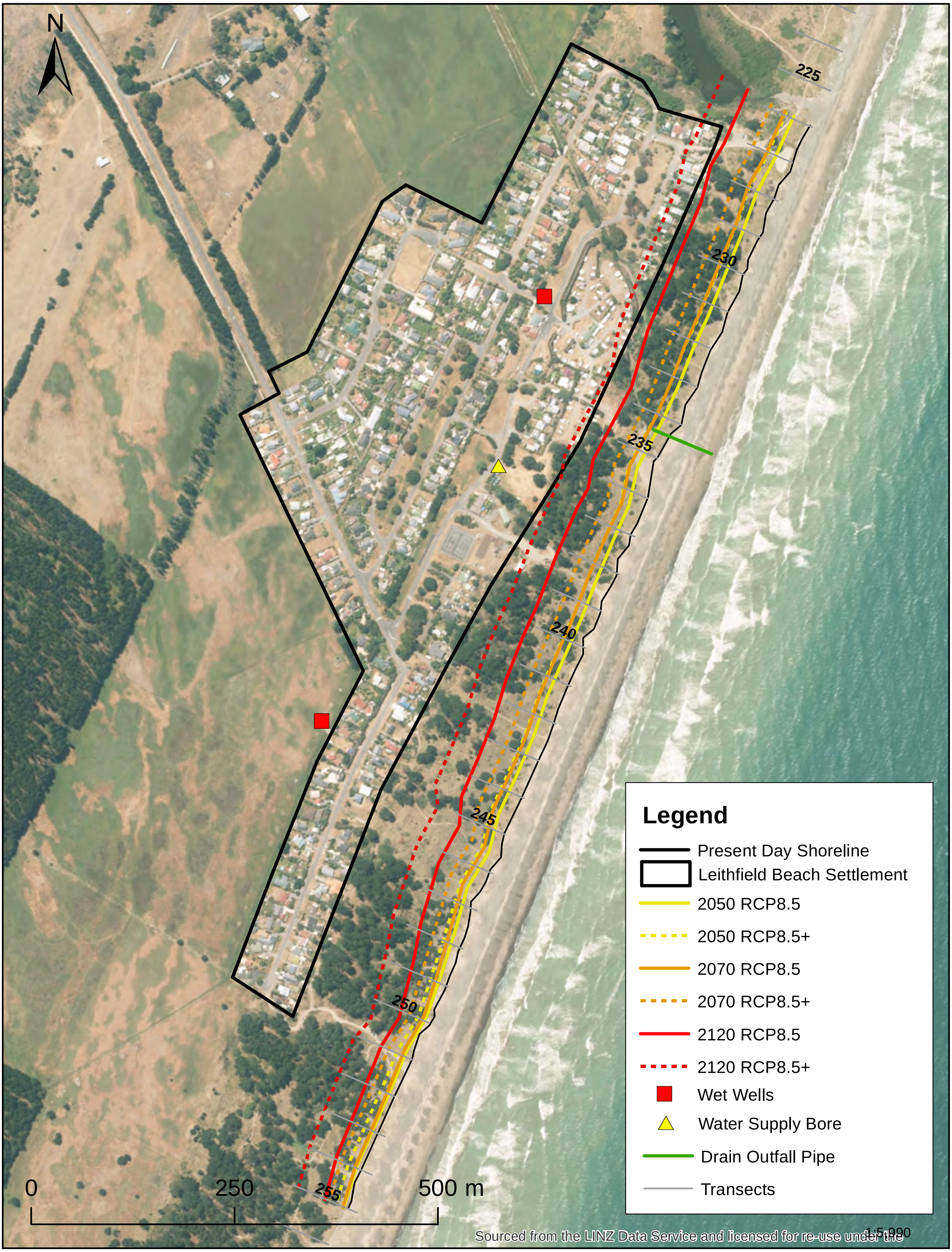
By reorganizing this equation, the increase in erosion rate due to SLR can be expressed as

$$\boldsymbol{LT_{F(SLR)} = LT_H \times Vol_{effect} \times \left(\frac{S_F}{S_H}\right)^m - LT_H}$$

Appendix E. Environment Canterbury beach profiles used for short term storm analysis

Settlement	Profile	Record
Leithfield	PCC4200	November 1991 – November 2018
Amberley	PCC4782	August 2002 – November 2018
	PCC4722	August 2002 – November 2018
	PCC4694	August 2002 – November 2018
	PCC4682	November 1991 – November 2018
Motunau	HCH2458	June 1990 – February 2019
	HCH2477	June 1990 – February 2019
	HCH2487	June 1990 – February 2019
	HCH2549	June 1990 – February 2019
Gore Bay	HCH5747	April 1993 – February 2019
	HCH5667	April 1993 – May 2018
	HCH5658	April 1993 – February 2019
	HCH5867	April 1993 – February 2019
	HCH5782	April 1993 – February 2019
	HCH5765	April 1993 – February 2019
	HCH5736	April 1993 – February 2019
	HCH5722	April 1993 – February 2019
	HCH5700	April 1993 – February 2019
	HCH5711	April 1993 – February 2019
	HCH5675	April 1993 – May 2019
Conway Flat	HCK8510	July 1997 – December 2015
Claverley	HCK9150	July 1997 – December 2015

Appendix F. Projected Future Shoreline Position (PFSP) Maps



Leithfield Beach Projected Future Shoreline Positions
RCP8.5 and RCP8.5+ 30, 50 and 100 years

Date: 04/17/2020

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JACOBS
SPATIAL
Level 2, Wynn Williams Building
47 Hereford St
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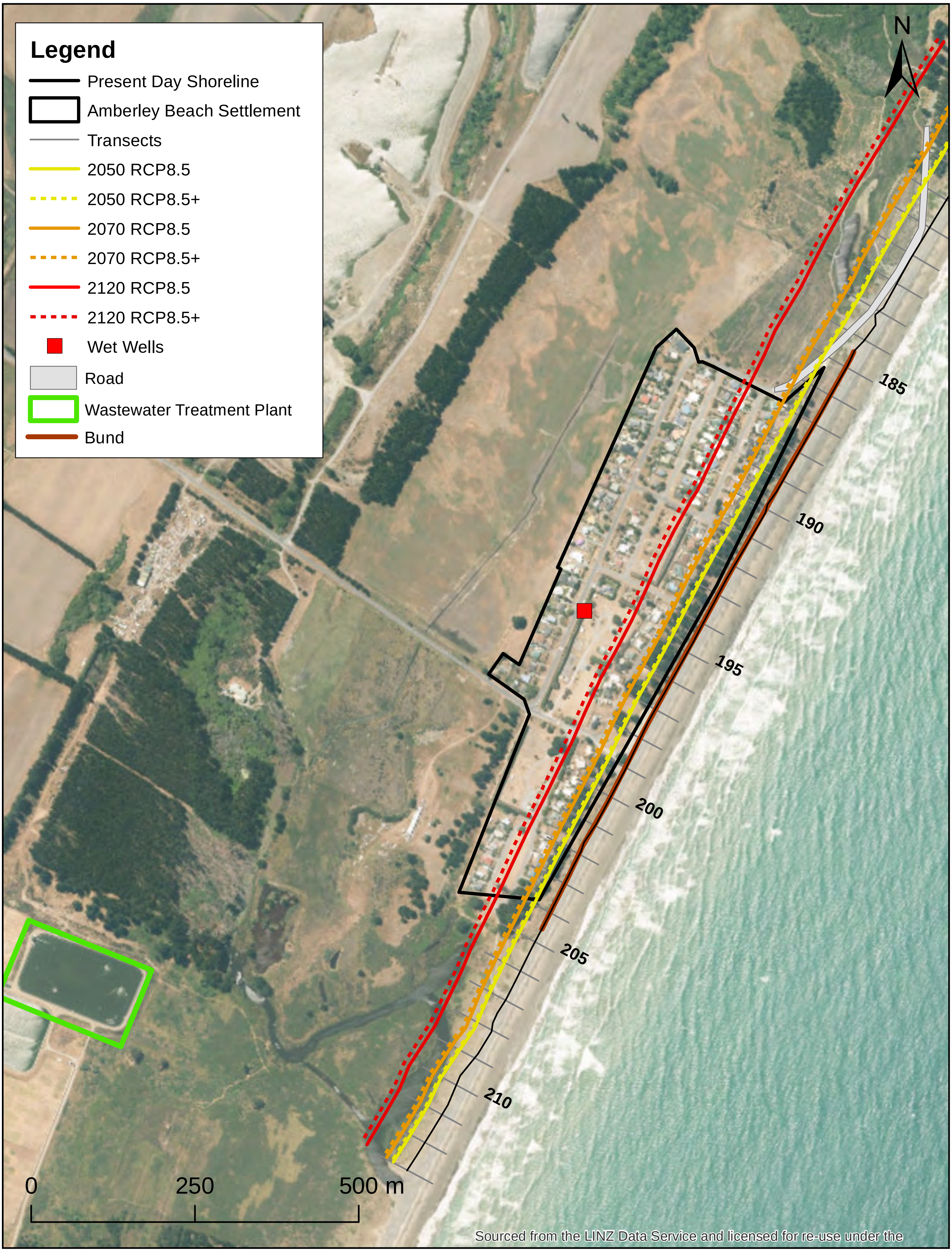
T +64 3 940 4900
F +64 3 940 4901



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Amberley Beach Projected Future Shoreline Positions
RCP8.5 and RCP8.5+ 30, 50 and 100 years

Date: 04/17/2020

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New Zealand
T +64 3 940 4900
F +64 3 940 4901

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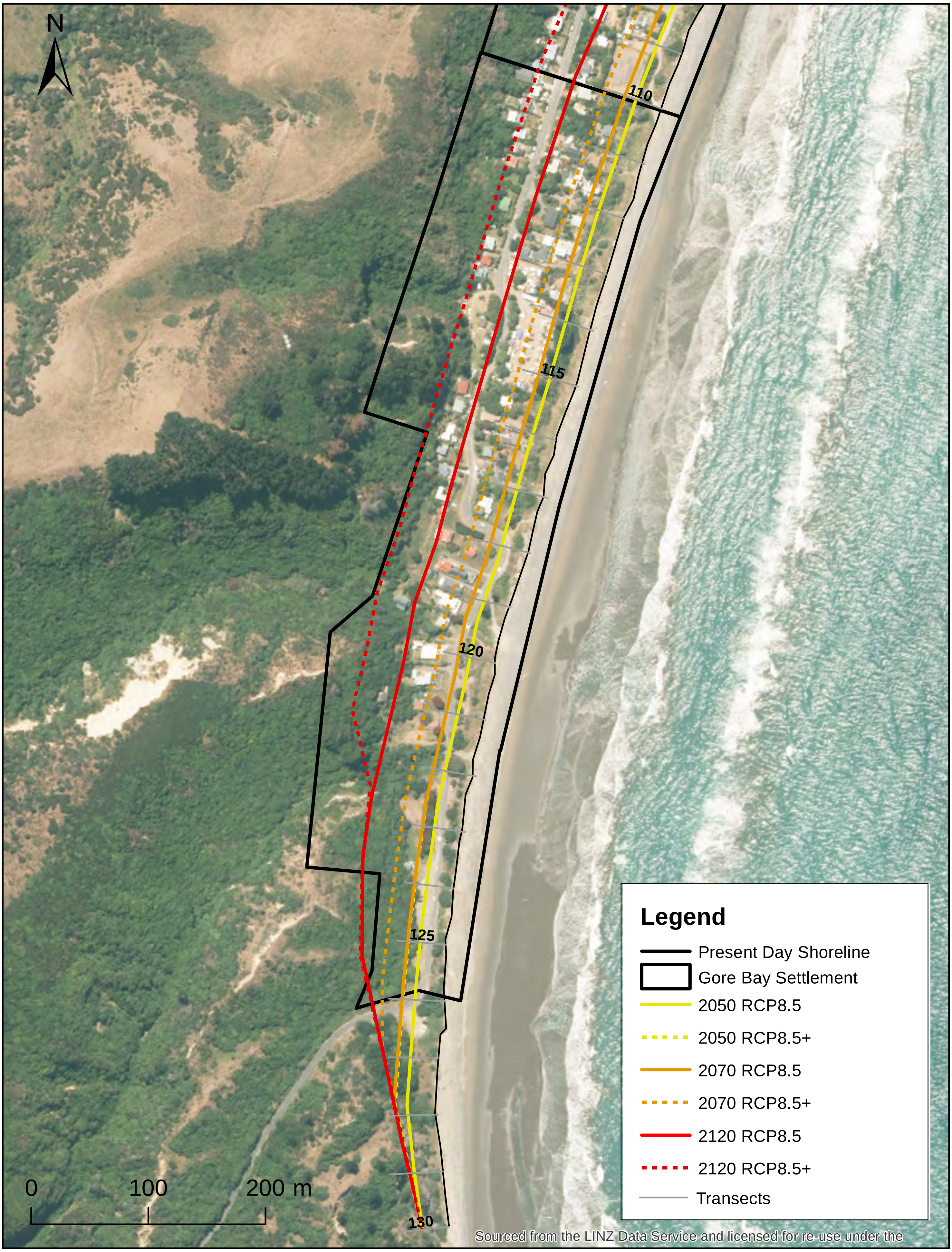
Motunau Projected Future Shoreline Positions
RCP8.5 and RCP8.5+ 30, 50 and 100 years

Date: 04/16/2020

JACOBS SPATIAL
Level 2, Wynn Williams Building
47 Hereford St
Christchurch Central 8013
New Zealand
T +64 3 940 4900
F +64 3 940 4901



C:\Users\macdonke\Desktop\Hurunui\GoreBay_PSFPLines.mxd

Gore Bay South Projected Future Shoreline Positions
RCP8.5 and RCP8.5+ 30, 50 and 100 years

Note: Hazard Lines are confined to the topography of the cliff behind the settlement

Date: 04/29/2020

JACOBS
SPATIAL
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Gore Bay North Projected Future Shoreline Positions
RCP8.5 and RCP8.5+ 30, 50 and 100 years

Note: Hazard Lines are confined to the topography of the cliff behind the settlement

Date: 04/29/2020

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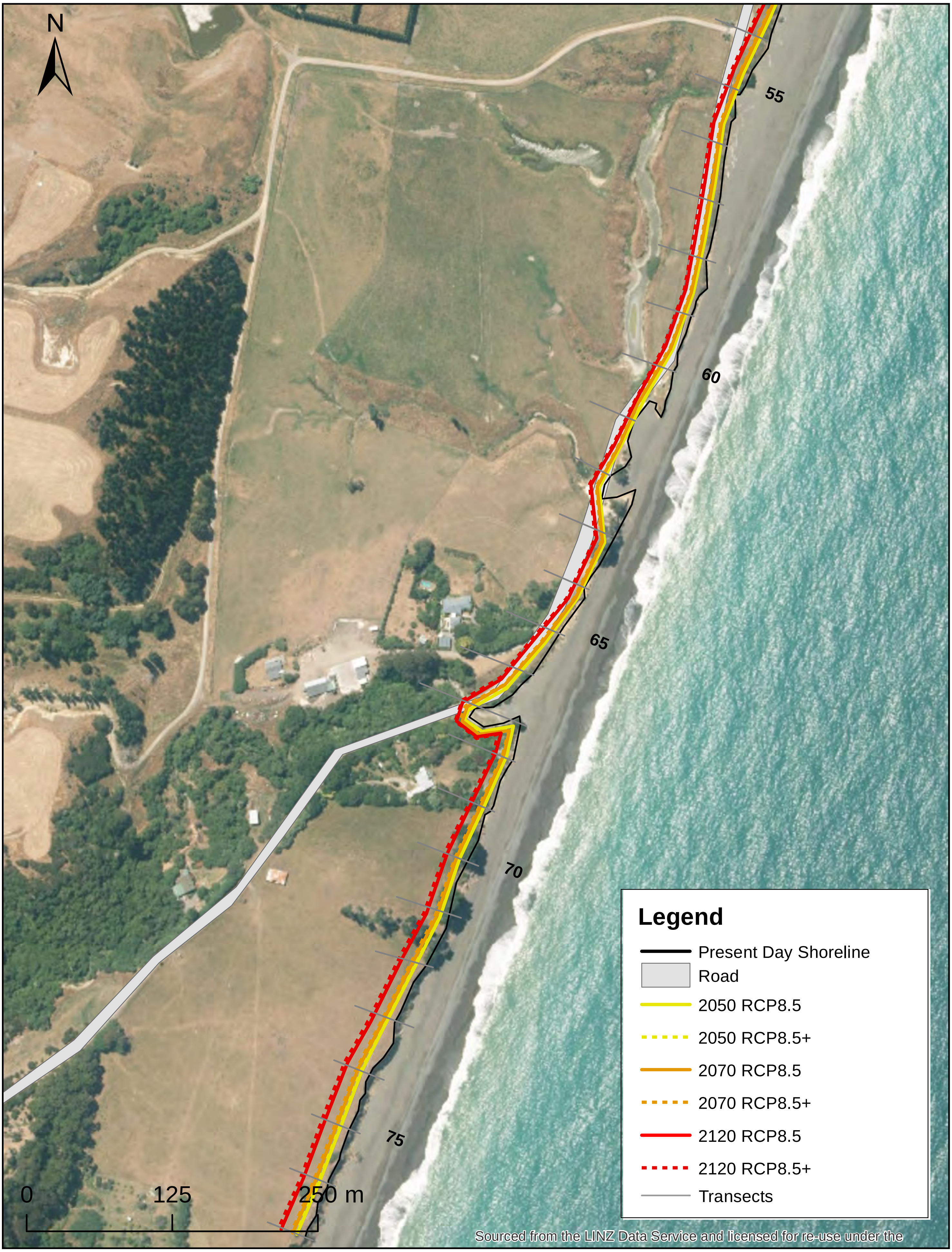

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Conway Flat South Projected Future Shoreline Positions
RCP8.5 and RCP8.5+ 30, 50 and 100 years

Date: 04/17/2020

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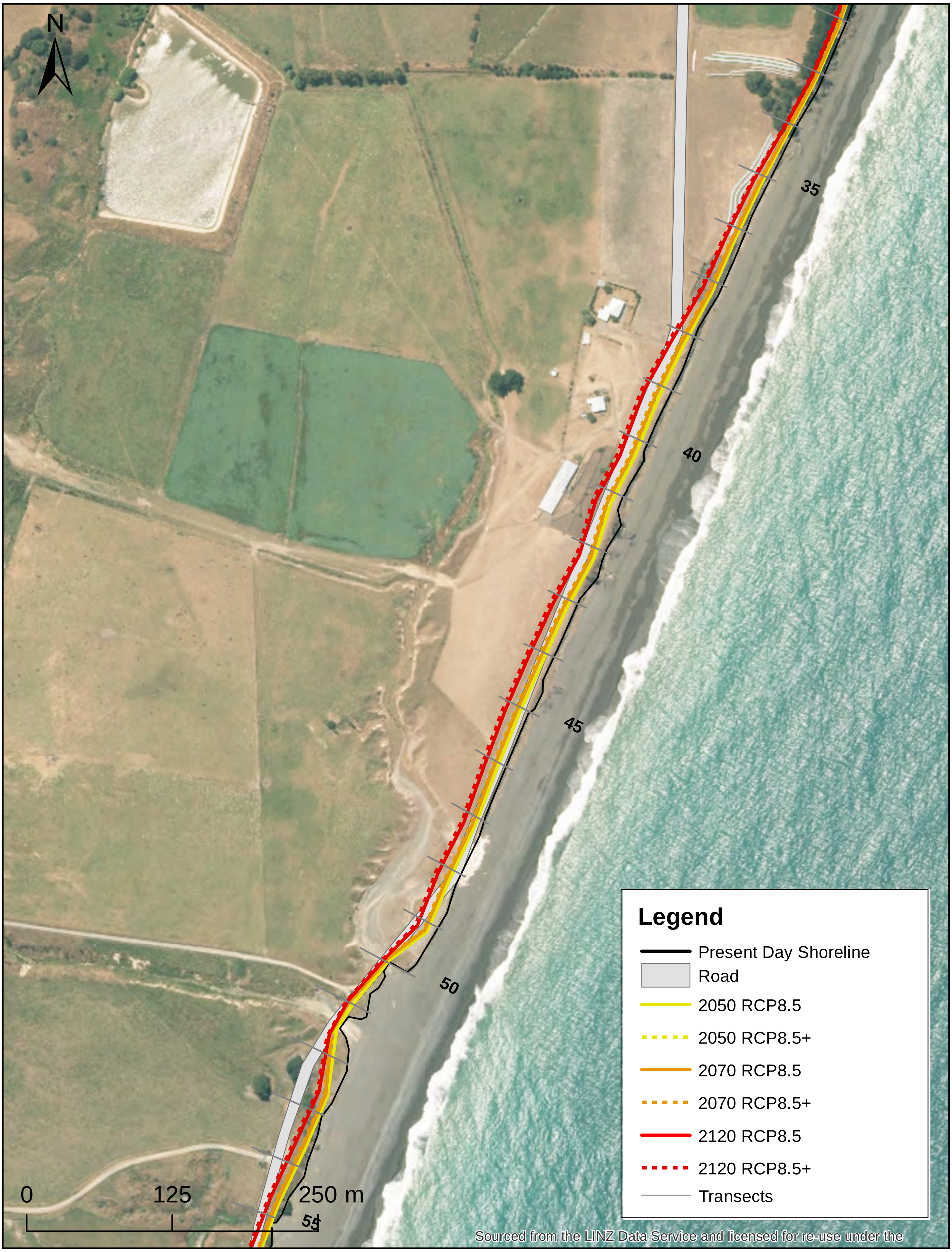

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Conway Flat North Projected Future Shoreline Positions
RCP8.5 and RCP8.5+ 30, 50 and 100 years

Date: 04/17/2020

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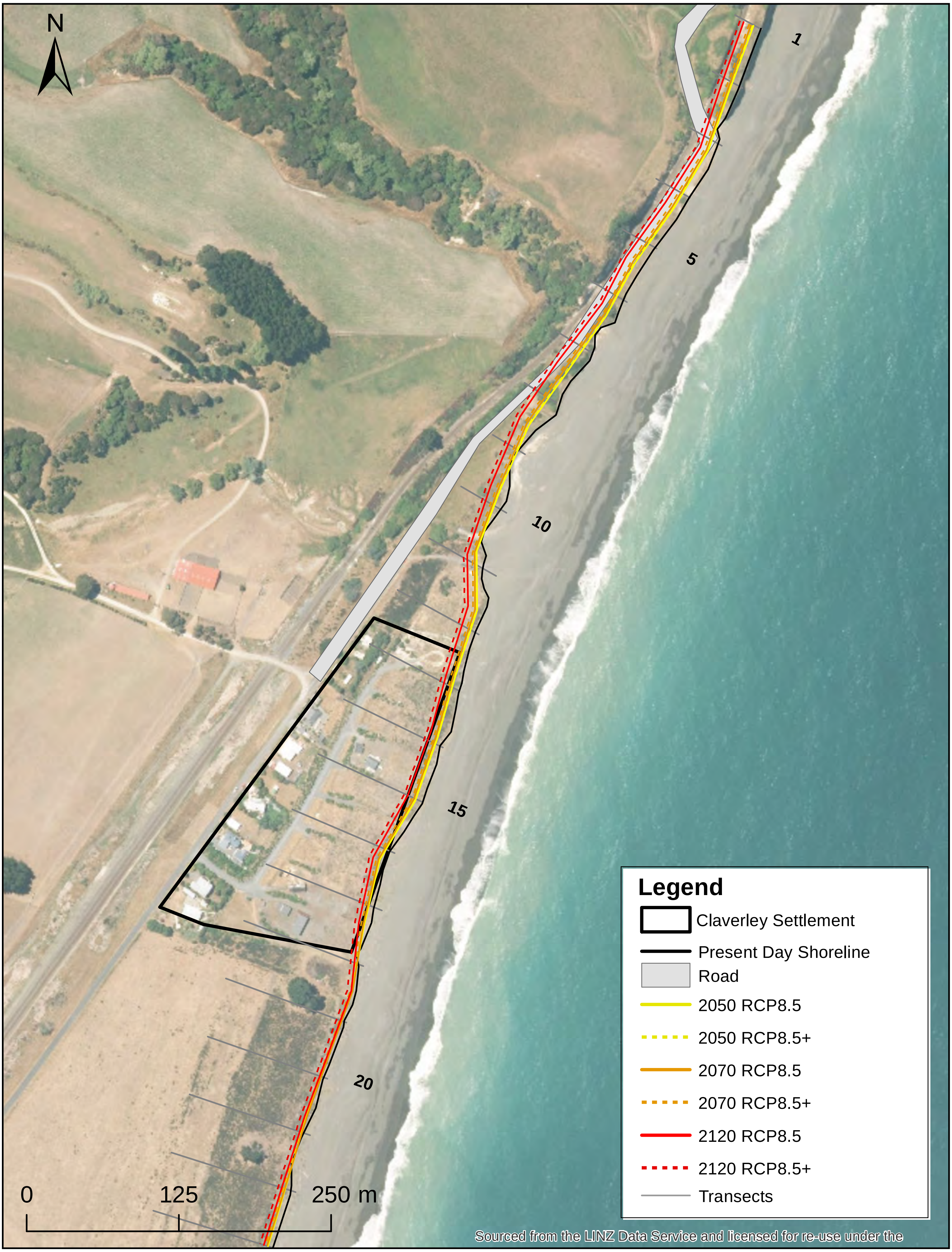

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Claverley Projected Future Shoreline Positions
RCP8.5 and RCP8.5+ 30, 50 and 100 years

Date: 05/03/2020

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Appendix G. PFSP components for coastline transects

					SLR						Total PFSP Distance					
Transect	Settlement	Profile	LT (m/yr)	ST (m)	2050 RCP 8.5	2050 RCP 8.5+	2070 RCP 8.5	2070 RCP 8.5+	2120 RCP 8.5	2120 RCP 8.5+	2050 RCP 8.5	2050 RCP 8.5+	2070 RCP 8.5	2070 RCP 8.5+	2120 RCP 8.5	2120 RCP 8.5+
1	Claverley	HCK9150	0.0	-4.0	-1.6	-2.6	-2.9	-4.6	-8.0	-11.2	-6.5	-7.5	-8.4	-10.1	-15.0	-18.2
2	Claverley	HCK9150	0.0	-4.0	-1.6	-2.6	-2.9	-4.6	-8.0	-11.2	-6.3	-7.3	-8.0	-9.7	-14.2	-17.4
3	Claverley	HCK9150	0.0	-4.0	-1.6	-2.6	-2.9	-4.6	-8.0	-11.2	-5.8	-6.8	-7.3	-9.0	-12.8	-16.0
4	Claverley	HCK9150	0.0	-4.0	-1.6	-2.6	-2.9	-4.6	-8.0	-11.2	-6.5	-7.5	-8.4	-10.1	-14.9	-18.1
5	Claverley	HCK9150	0.0	-4.0	-1.6	-2.6	-2.9	-4.6	-8.0	-11.2	-6.6	-7.6	-8.6	-10.3	-15.4	-18.6
6	Claverley	HCK9150	-0.1	-4.0	-1.6	-2.6	-2.9	-4.6	-8.0	-11.2	-7.6	-8.6	-10.2	-11.9	-18.7	-21.9
7	Claverley	HCK9150	-0.1	-4.0	-1.6	-2.6	-2.9	-4.6	-8.0	-11.2	-7.7	-8.7	-10.3	-12.0	-18.9	-22.1
8	Claverley	HCK9150	0.0	-4.0	-1.6	-2.6	-2.9	-4.6	-8.0	-11.2	-7.1	-8.1	-9.4	-11.1	-17.0	-20.2
9	Claverley	HCK9150	0.0	-4.0	-1.6	-2.6	-2.9	-4.6	-8.0	-11.2	-6.5	-7.5	-8.5	-10.2	-15.1	-18.3
10	Claverley	HCK9150	0.0	-4.0	-1.6	-2.6	-2.9	-4.6	-8.0	-11.2	-6.3	-7.3	-8.1	-9.8	-14.4	-17.6
11	Claverley	HCK9150	0.0	-4.0	-1.6	-2.6	-2.9	-4.6	-8.0	-11.2	-6.3	-7.3	-8.1	-9.8	-14.3	-17.5
12	Claverley	HCK9150	0.0	-4.0	-1.6	-2.6	-2.9	-4.6	-8.0	-11.2	-6.2	-7.2	-7.8	-9.5	-13.8	-17.0
13	Claverley	HCK9150	0.0	-4.0	-1.6	-2.6	-2.9	-4.6	-8.0	-11.2	-6.0	-7.0	-7.6	-9.3	-13.4	-16.6
14	Claverley	HCK9150	0.0	-4.0	-1.6	-2.6	-2.9	-4.6	-8.0	-11.2	-6.0	-7.0	-7.6	-9.3	-13.4	-16.6
15	Claverley	HCK9150	0.0	-4.0	-1.6	-2.6	-2.9	-4.6	-8.0	-11.2	-5.3	-6.3	-6.5	-8.2	-11.1	-14.3
16	Claverley	HCK9150	0.0	-4.0	-1.6	-2.6	-2.9	-4.6	-8.0	-11.2	-4.9	-5.9	-5.8	-7.5	-9.8	-13.0
17	Claverley	HCK9150	0.1	-4.0	-1.6	-2.6	-2.9	-4.6	-8.0	-11.2	-3.2	-4.2	-2.9	-4.6	-4.1	-7.3
18	Claverley	HCK9150	0.1	-4.0	-1.6	-2.6	-2.9	-4.6	-8.0	-11.2	-3.2	-4.2	-2.9	-4.6	-4.1	-7.3

					SLR						Total PFSP Distance					
Transect	Settlement	Profile	LT (m/yr)	ST (m)	2050 RCP 8.5	2050 RCP 8.5+	2070 RCP 8.5	2070 RCP 8.5+	2120 RCP 8.5	2120 RCP 8.5+	2050 RCP 8.5	2050 RCP 8.5+	2070 RCP 8.5	2070 RCP 8.5+	2120 RCP 8.5	2120 RCP 8.5+
19	Claverley	HCK9150	0.1	-4.0	-1.6	-2.6	-2.9	-4.6	-8.0	-11.2	-3.6	-4.6	-3.5	-5.2	-5.2	-8.4
20	Claverley	HCK9150	0.1	-4.0	-1.6	-2.6	-2.9	-4.6	-8.0	-11.2	-4.0	-5.0	-4.3	-6.0	-6.8	-10.0
21	Claverley	HCK9150	0.0	-4.0	-1.6	-2.6	-2.9	-4.6	-8.0	-11.2	-4.3	-5.3	-4.8	-6.5	-7.8	-11.0
25	Conway Flat	HCK8510	-0.1	-3.0	-4.0	-4.3	-6.8	-7.4	-14.6	-15.6	-10.1	-10.5	-15.1	-15.7	-28.1	-29.1
26	Conway Flat	HCK8510	-0.1	-3.0	-3.5	-3.8	-6.0	-6.6	-13.0	-13.8	-9.3	-9.6	-13.7	-14.2	-25.2	-26.1
27	Conway Flat	HCK8510	-0.1	-3.0	-2.9	-3.2	-5.0	-5.5	-10.8	-11.5	-8.3	-8.5	-11.9	-12.4	-21.6	-22.3
28	Conway Flat	HCK8510	-0.1	-3.0	-2.3	-2.5	-3.9	-4.2	-8.4	-8.9	-7.1	-7.3	-9.9	-10.2	-17.4	-17.9
29	Conway Flat	HCK8510	-0.1	-3.0	-2.3	-2.5	-3.9	-4.2	-8.4	-8.9	-7.1	-7.3	-9.9	-10.2	-17.4	-17.9
30	Conway Flat	HCK8510	-0.1	-3.0	-2.3	-2.5	-3.9	-4.2	-8.4	-8.9	-7.1	-7.3	-9.9	-10.2	-17.4	-17.9
31	Conway Flat	HCK8510	-0.1	-3.0	-1.9	-2.1	-3.3	-3.5	-7.0	-7.4	-6.4	-6.6	-8.8	-9.0	-15.0	-15.4
32	Conway Flat	HCK8510	0.0	-3.0	-1.6	-1.8	-2.8	-3.0	-6.0	-6.4	-5.9	-6.1	-7.9	-8.2	-13.3	-13.7
33	Conway Flat	HCK8510	0.0	-3.0	-1.6	-1.7	-2.7	-2.9	-5.7	-6.1	-5.8	-5.9	-7.7	-8.0	-12.8	-13.2
35	Conway Flat	HCK8510	-0.1	-3.0	-2.5	-2.7	-4.2	-4.6	-9.1	-9.7	-7.4	-7.6	-10.5	-10.8	-18.6	-19.2
36	Conway Flat	HCK8510	-0.1	-3.0	-2.9	-3.2	-5.0	-5.4	-10.7	-11.5	-8.2	-8.5	-11.9	-12.3	-21.4	-22.2
37	Conway Flat	HCK8510	-0.1	-3.0	-3.0	-3.3	-5.1	-5.6	-11.0	-11.8	-8.4	-8.6	-12.1	-12.5	-21.9	-22.7
38	Conway Flat	HCK8510	-0.1	-3.0	-3.9	-4.2	-6.6	-7.2	-14.2	-15.2	-9.9	-10.3	-14.7	-15.3	-27.4	-28.4
39	Conway Flat	HCK8510	-0.1	-3.0	-4.9	-5.3	-8.4	-9.1	-18.0	-19.2	-11.8	-12.2	-17.8	-18.6	-33.9	-35.1
40	Conway Flat	HCK8510	-0.1	-3.0	-4.8	-5.2	-8.2	-8.9	-17.5	-18.7	-11.5	-11.9	-17.4	-18.1	-33.0	-34.2
41	Conway Flat	HCK8510	-0.1	-3.0	-4.7	-5.1	-8.0	-8.7	-17.2	-18.4	-11.4	-11.8	-17.2	-17.9	-32.6	-33.8
42	Conway Flat	HCK8510	-0.1	-3.0	-4.6	-5.0	-7.8	-8.5	-16.7	-17.9	-11.2	-11.6	-16.8	-17.5	-31.7	-32.9

					SLR						Total PFSP Distance					
Transect	Settlement	Profile	LT (m/yr)	ST (m)	2050 RCP 8.5	2050 RCP 8.5+	2070 RCP 8.5	2070 RCP 8.5+	2120 RCP 8.5	2120 RCP 8.5+	2050 RCP 8.5	2050 RCP 8.5+	2070 RCP 8.5	2070 RCP 8.5+	2120 RCP 8.5	2120 RCP 8.5+
44	Conway Flat	HCK8510	-0.1	-3.0	-4.5	-4.8	-7.6	-8.3	-16.4	-17.5	-11.0	-11.4	-16.5	-17.2	-31.1	-32.2
45	Conway Flat	HCK8510	-0.1	-3.0	-4.4	-4.7	-7.5	-8.1	-16.0	-17.1	-10.8	-11.2	-16.2	-16.8	-30.4	-31.5
46	Conway Flat	HCK8510	-0.1	-3.0	-4.0	-4.3	-6.8	-7.4	-14.5	-15.5	-10.1	-10.4	-15.0	-15.6	-27.9	-28.9
47	Conway Flat	HCK8510	-0.1	-3.0	-3.6	-3.9	-6.1	-6.7	-13.2	-14.1	-9.4	-9.7	-13.9	-14.4	-25.6	-26.5
48	Conway Flat	HCK8510	-0.1	-3.0	-4.1	-4.5	-7.0	-7.6	-15.0	-16.0	-10.3	-10.7	-15.4	-16.0	-28.8	-29.8
49	Conway Flat	HCK8510	-0.1	-3.0	-3.6	-3.9	-6.1	-6.6	-13.0	-13.9	-9.4	-9.7	-13.7	-14.3	-25.4	-26.2
50	Conway Flat	HCK8510	-0.1	-3.0	-2.9	-3.2	-5.0	-5.4	-10.7	-11.4	-8.2	-8.5	-11.8	-12.3	-21.4	-22.1
51	Conway Flat	HCK8510	-0.1	-3.0	-2.7	-3.0	-4.7	-5.1	-10.1	-10.8	-7.9	-8.2	-11.3	-11.7	-20.3	-21.0
52	Conway Flat	HCK8510	-0.1	-3.0	-2.7	-3.0	-4.7	-5.1	-10.1	-10.8	-7.9	-8.2	-11.3	-11.7	-20.3	-21.0
53	Conway Flat	HCK8510	-0.1	-3.0	-3.0	-3.2	-5.1	-5.5	-10.9	-11.6	-8.3	-8.5	-11.9	-12.4	-21.6	-22.4
54	Conway Flat	HCK8510	-0.1	-3.0	-3.4	-3.7	-5.8	-6.3	-12.4	-13.2	-9.0	-9.3	-13.2	-13.7	-24.3	-25.1
55	Conway Flat	HCK8510	-0.1	-3.0	-3.1	-3.4	-5.3	-5.7	-11.3	-12.1	-8.5	-8.8	-12.3	-12.8	-22.4	-23.2
56	Conway Flat	HCK8510	-0.1	-3.0	-3.1	-3.4	-5.3	-5.7	-11.3	-12.1	-8.5	-8.8	-12.3	-12.8	-22.4	-23.2
57	Conway Flat	HCK8510	-0.1	-3.0	-3.1	-3.3	-5.3	-5.7	-11.3	-12.1	-8.5	-8.8	-12.3	-12.8	-22.4	-23.2
58	Conway Flat	HCK8510	-0.1	-3.0	-3.0	-3.3	-5.1	-5.6	-11.0	-11.8	-8.4	-8.6	-12.1	-12.6	-21.9	-22.7
59	Conway Flat	HCK8510	-0.1	-3.0	-2.6	-2.8	-4.4	-4.8	-9.4	-10.0	-7.6	-7.8	-10.7	-11.1	-19.1	-19.7
60	Conway Flat	HCK8510	-0.1	-3.0	-2.4	-2.6	-4.0	-4.4	-8.6	-9.2	-7.2	-7.4	-10.1	-10.5	-17.8	-18.4
61	Conway Flat	HCK8510	-0.1	-3.0	-2.3	-2.5	-3.9	-4.2	-8.4	-8.9	-7.1	-7.3	-9.9	-10.2	-17.4	-17.9
62	Conway Flat	HCK8510	-0.1	-3.0	-2.5	-2.7	-4.3	-4.7	-9.3	-9.9	-7.5	-7.7	-10.6	-11.0	-18.9	-19.5
63	Conway Flat	HCK8510	-0.1	-3.0	-2.6	-2.9	-4.5	-4.9	-9.6	-10.3	-7.7	-7.9	-10.9	-11.3	-19.5	-20.2

					SLR						Total PFSP Distance					
Transect	Settlement	Profile	LT (m/yr)	ST (m)	2050 RCP 8.5	2050 RCP 8.5+	2070 RCP 8.5	2070 RCP 8.5+	2120 RCP 8.5	2120 RCP 8.5+	2050 RCP 8.5	2050 RCP 8.5+	2070 RCP 8.5	2070 RCP 8.5+	2120 RCP 8.5	2120 RCP 8.5+
64	Conway Flat	HCK8510	-0.1	-3.0	-2.7	-2.9	-4.6	-5.0	-9.9	-10.6	-7.8	-8.1	-11.2	-11.6	-20.0	-20.6
65	Conway Flat	HCK8510	-0.1	-3.0	-2.9	-3.2	-5.0	-5.4	-10.7	-11.4	-8.2	-8.4	-11.8	-12.2	-21.3	-22.0
66	Conway Flat	HCK8510	-0.1	-3.0	-3.2	-3.5	-5.5	-6.0	-11.8	-12.6	-8.8	-9.0	-12.7	-13.2	-23.2	-24.0
67	Conway Flat	HCK8510	-0.1	-3.0	-2.9	-3.2	-5.0	-5.4	-10.7	-11.4	-8.2	-8.4	-11.8	-12.2	-21.3	-22.0
68	Conway Flat	HCK8510	-0.1	-3.0	-3.4	-3.7	-5.9	-6.4	-12.6	-13.4	-9.1	-9.4	-13.4	-13.9	-24.6	-25.4
69	Conway Flat	HCK8510	-0.1	-3.0	-3.9	-4.2	-6.6	-7.2	-14.2	-15.2	-9.9	-10.3	-14.7	-15.3	-27.4	-28.3
70	Conway Flat	HCK8510	-0.1	-3.0	-4.1	-4.5	-7.0	-7.7	-15.1	-16.1	-10.4	-10.7	-15.4	-16.1	-28.9	-29.9
71	Conway Flat	HCK8510	-0.1	-3.0	-4.3	-4.7	-7.4	-8.0	-15.9	-16.9	-10.7	-11.1	-16.1	-16.7	-30.2	-31.3
72	Conway Flat	HCK8510	-0.1	-3.0	-4.7	-5.1	-8.0	-8.7	-17.1	-18.3	-11.4	-11.8	-17.1	-17.8	-32.4	-33.5
73	Conway Flat	HCK8510	-0.1	-3.0	-4.7	-5.1	-8.0	-8.7	-17.2	-18.3	-11.4	-11.8	-17.2	-17.9	-32.5	-33.6
74	Conway Flat	HCK8510	-0.1	-3.0	-4.9	-5.3	-8.4	-9.1	-18.0	-19.2	-11.8	-12.2	-17.8	-18.6	-33.9	-35.1
75	Conway Flat	HCK8510	-0.1	-3.0	-5.1	-5.6	-8.8	-9.6	-18.8	-20.1	-12.2	-12.6	-18.5	-19.3	-35.3	-36.6
76	Conway Flat	HCK8510	-0.1	-3.0	-4.9	-5.3	-8.4	-9.1	-17.9	-19.1	-11.7	-12.2	-17.8	-18.5	-33.8	-35.0
77	Conway Flat	HCK8510	-0.1	-3.0	-4.9	-5.4	-8.5	-9.2	-18.1	-19.4	-11.8	-12.3	-18.0	-18.7	-34.1	-35.4
82	Gore Bay	HCH5867	-0.5	-10.0	-16.3	-25.8	-28.9	-45.8	-79.9	-111.7	-36.6	-46.1	-59.4	-76.3	-135.9	-167.7
83	Gore Bay	HCH5867	-0.5	-10.0	-16.3	-25.8	-28.9	-45.8	-79.9	-111.7	-36.9	-46.4	-59.9	-76.8	-136.9	-168.7
84	Gore Bay	HCH5867	-0.5	-10.0	-16.3	-25.8	-28.9	-45.8	-79.9	-111.7	-36.6	-46.2	-59.5	-76.4	-136.2	-167.9
85	Gore Bay	HCH5867	-0.5	-10.0	-16.3	-25.8	-28.9	-45.8	-79.9	-111.7	-36.0	-45.5	-58.4	-75.3	-133.9	-165.7
86	Gore Bay	HCH5867	-0.5	-10.0	-16.3	-25.8	-28.9	-45.8	-79.9	-111.7	-36.2	-45.8	-58.8	-75.7	-134.8	-166.6
87	Gore Bay	HCH5867	-0.5	-10.0	-16.3	-25.8	-28.9	-45.8	-79.9	-111.7	-35.3	-44.8	-57.3	-74.2	-131.8	-163.5

					SLR						Total PFSP Distance					
Transect	Settlement	Profile	LT (m/yr)	ST (m)	2050 RCP 8.5	2050 RCP 8.5+	2070 RCP 8.5	2070 RCP 8.5+	2120 RCP 8.5	2120 RCP 8.5+	2050 RCP 8.5	2050 RCP 8.5+	2070 RCP 8.5	2070 RCP 8.5+	2120 RCP 8.5	2120 RCP 8.5+
88	Gore Bay	HCH5867	-0.4	-10.0	-16.3	-25.8	-28.9	-45.8	-79.9	-111.7	-34.5	-44.1	-56.0	-72.9	-129.2	-160.9
89	Gore Bay	HCH5867	-0.4	-10.0	-16.3	-25.8	-28.9	-45.8	-79.9	-111.7	-33.9	-43.4	-54.9	-71.8	-126.9	-158.7
90	Gore Bay	HCH5867	-0.4	-10.0	-16.3	-25.8	-28.9	-45.8	-79.9	-111.7	-32.9	-42.4	-53.2	-70.2	-123.7	-155.4
91	Gore Bay	HCH5867	-0.4	-10.0	-16.3	-25.8	-28.9	-45.8	-79.9	-111.7	-32.3	-41.9	-52.3	-69.2	-121.8	-153.6
92	Gore Bay	HCH5867	-0.3	-10.0	-16.3	-25.8	-28.9	-45.8	-79.9	-111.7	-31.1	-40.7	-50.3	-67.2	-117.8	-149.6
93	Gore Bay	HCH5867	-0.3	-10.0	-16.3	-25.8	-28.9	-45.8	-79.9	-111.7	-31.0	-40.5	-50.1	-67.0	-117.4	-149.1
94	Gore Bay	HCH5867	-0.3	-10.0	-16.3	-25.8	-28.9	-45.8	-79.9	-111.7	-30.5	-40.0	-49.2	-66.1	-115.6	-147.3
95	Gore Bay	HCH5867	-0.3	-10.0	-16.3	-25.8	-28.9	-45.8	-79.9	-111.7	-29.1	-38.6	-46.9	-63.8	-110.9	-142.7
96	Gore Bay	HCH5867	-0.2	-10.0	-16.3	-25.8	-28.9	-45.8	-79.9	-111.7	-27.9	-37.5	-45.0	-61.9	-107.2	-138.9
97	Gore Bay	HCH5867	-0.1	-10.0	-16.3	-25.8	-28.9	-45.8	-79.9	-111.7	-24.6	-34.1	-39.4	-56.3	-96.0	-127.7
98	Gore Bay	HCH5867	-0.1	-10.0	-16.3	-25.8	-28.9	-45.8	-79.9	-111.7	-23.8	-33.3	-38.1	-55.0	-93.4	-125.1
99	Gore Bay	HCH5867	-0.1	-10.0	-16.3	-25.8	-28.9	-45.8	-79.9	-111.7	-22.8	-32.4	-36.5	-53.4	-90.2	-121.9
100	Gore Bay	HCH5782	0.0	-10.0	-16.4	-26.0	-29.1	-46.1	-80.5	-112.4	-21.6	-31.2	-34.5	-51.5	-86.3	-118.3
101	Gore Bay	HCH5782	0.0	-10.0	-16.4	-26.0	-29.1	-46.1	-80.5	-112.4	-20.8	-30.3	-33.0	-50.1	-83.4	-115.4
102	Gore Bay	HCH5782	0.1	-10.0	-16.4	-26.0	-29.1	-46.1	-80.5	-112.4	-19.7	-29.2	-31.2	-48.2	-79.8	-111.7
103	Gore Bay	HCH5782	0.1	-10.0	-16.4	-26.0	-29.1	-46.1	-80.5	-112.4	-18.7	-28.3	-29.6	-46.7	-76.6	-108.5
104	Gore Bay	HCH5765	0.2	-10.0	-16.7	-26.0	-29.1	-46.1	-82.2	-114.9	-17.2	-26.4	-26.5	-43.5	-72.1	-104.7
105	Gore Bay	HCH5765	0.2	-10.0	-16.7	-26.0	-29.1	-46.1	-82.2	-114.9	-16.2	-25.4	-24.8	-41.9	-68.8	-101.4
106	Gore Bay	HCH5765	0.2	-10.0	-16.7	-26.0	-29.1	-46.1	-82.2	-114.9	-16.0	-25.2	-24.4	-41.5	-68.0	-100.6
107	Gore Bay	HCH5747	0.2	-10.0	-16.4	-26.1	-29.2	-46.3	-80.8	-112.8	-15.7	-25.3	-24.5	-41.6	-66.5	-98.6

Transect	Settlement	Profile	LT (m/yr)	ST (m)	SLR 2050 RCP 8.5	SLR 2050 RCP 8.5+	SLR 2070 RCP 8.5	SLR 2070 RCP 8.5+	SLR 2120 RCP 8.5	SLR 2120 RCP 8.5+	Total PFSP Distance 2050 RCP 8.5	Total PFSP Distance 2050 RCP 8.5+	Total PFSP Distance 2070 RCP 8.5	Total PFSP Distance 2070 RCP 8.5+	Total PFSP Distance 2120 RCP 8.5	Total PFSP Distance 2120 RCP 8.5+
108	Gore Bay	HCH5747	0.1	-10.0	-16.4	-26.1	-29.2	-46.3	-80.8	-112.8	-17.0	-26.6	-26.8	-43.9	-71.1	-103.1
109	Gore Bay	HCH5747	0.2	-10.0	-16.4	-26.1	-29.2	-46.3	-80.8	-112.8	-16.9	-26.5	-26.6	-43.7	-70.7	-102.8
110	Gore Bay	HCH5736	0.2	-10.0	-16.5	-26.1	-29.3	-46.4	-81.1	-113.2	-17.0	-26.6	-26.7	-43.9	-71.0	-103.1
111	Gore Bay	HCH5736	0.1	-10.0	-16.5	-26.1	-29.3	-46.4	-81.1	-113.2	-17.5	-27.2	-27.6	-44.8	-72.8	-105.0
112	Gore Bay	HCH5736	0.1	-10.0	-16.5	-26.1	-29.3	-46.4	-81.1	-113.2	-17.3	-26.9	-27.3	-44.4	-72.1	-104.2
113	Gore Bay	HCH5722	0.1	-10.0	-16.5	-26.1	-29.3	-46.4	-81.1	-113.2	-17.3	-27.0	-27.3	-44.5	-72.2	-104.3
114	Gore Bay	HCH5722	0.1	-10.0	-16.5	-26.1	-29.3	-46.4	-81.1	-113.2	-17.3	-27.0	-27.3	-44.5	-72.2	-104.3
115	Gore Bay	HCH5722	0.1	-10.0	-16.5	-26.1	-29.3	-46.4	-81.1	-113.2	-17.4	-27.1	-27.5	-44.6	-72.4	-104.6
116	Gore Bay	HCH5711	0.2	-10.0	-17.0	-27.0	-30.2	-47.9	-83.7	-116.9	-17.3	-27.3	-27.4	-45.1	-73.1	-106.3
117	Gore Bay	HCH5711	0.2	-10.0	-17.0	-27.0	-30.2	-47.9	-83.7	-116.9	-17.2	-27.2	-27.2	-44.9	-72.6	-105.8
118	Gore Bay	HCH5700	0.2	-10.0	-17.1	-27.0	-30.2	-47.9	-83.7	-116.9	-17.0	-27.0	-26.8	-44.5	-71.9	-105.1
119	Gore Bay	HCH5700	0.2	-10.0	-17.1	-27.0	-30.2	-47.9	-83.7	-116.9	-17.1	-27.0	-26.9	-44.6	-72.1	-105.3
120	Gore Bay	HCH5700	0.2	-10.0	-17.1	-27.0	-30.2	-47.9	-83.7	-116.9	-17.3	-27.2	-27.2	-44.9	-72.7	-105.9
121	Gore Bay	HCH5700	0.2	-10.0	-17.1	-27.0	-30.2	-47.9	-83.7	-116.9	-17.2	-27.2	-27.2	-44.9	-72.6	-105.8
122	Gore Bay	HCH5675	0.2	-10.0	-17.0	-27.0	-30.2	-47.9	-83.7	-116.9	-17.3	-27.3	-27.3	-45.0	-72.9	-106.1
123	Gore Bay	HCH5675	0.1	-10.0	-17.0	-27.0	-30.2	-47.9	-83.7	-116.9	-17.8	-27.7	-28.1	-45.9	-74.5	-107.8
124	Gore Bay	HCH5667	0.1	-10.0	-17.0	-26.9	-30.2	-47.9	-83.6	-116.7	-18.0	-28.0	-28.5	-46.2	-75.3	-108.5
125	Gore Bay	HCH5667	0.1	-10.0	-17.0	-26.9	-30.2	-47.9	-83.6	-116.7	-18.3	-28.2	-29.0	-46.7	-76.2	-109.4
126	Gore Bay	HCH5658	0.1	-10.0	-17.4	-27.5	-30.8	-48.9	-85.4	-119.3	-18.7	-28.9	-29.7	-47.8	-78.2	-112.1
127	Gore Bay	HCH5658	0.1	-10.0	-17.4	-27.5	-30.8	-48.9	-85.4	-119.3	-19.0	-29.1	-30.2	-48.2	-79.0	-112.9

					SLR						Total PFSP Distance					
Transect	Settlement	Profile	LT (m/yr)	ST (m)	2050 RCP 8.5	2050 RCP 8.5+	2070 RCP 8.5	2070 RCP 8.5+	2120 RCP 8.5	2120 RCP 8.5+	2050 RCP 8.5	2050 RCP 8.5+	2070 RCP 8.5	2070 RCP 8.5+	2120 RCP 8.5	2120 RCP 8.5+
128	Gore Bay	HCH5658	0.1	-10.0	-17.4	-27.5	-30.8	-48.9	-85.4	-119.3	-19.3	-29.4	-30.6	-48.7	-80.0	-113.9
129	Gore Bay	HCH5658	0.1	-10.0	-17.4	-27.5	-30.8	-48.9	-85.4	-119.3	-19.6	-29.7	-31.2	-49.3	-81.1	-115.0
130	Gore Bay	HCH5658	0.1	-10.0	-17.4	-27.5	-30.8	-48.9	-85.4	-119.3	-19.8	-29.9	-31.5	-49.6	-81.7	-115.6
147	Motunau	HCH2487	-0.3	-5.0	-9.7	-10.5	-16.6	-18.0	-35.6	-38.0	-22.4	-23.2	-34.3	-35.8	-66.1	-68.5
148	Motunau	HCH2487	-0.3	-5.0	-9.7	-10.5	-16.6	-18.0	-35.6	-38.0	-22.4	-23.2	-34.3	-35.8	-66.1	-68.5
149	Motunau	HCH2487	-0.3	-5.0	-9.7	-10.5	-16.6	-18.0	-35.6	-38.0	-22.4	-23.2	-34.3	-35.8	-66.1	-68.5
150	Motunau	HCH2487	-0.3	-5.0	-9.7	-10.5	-16.6	-18.0	-35.6	-38.0	-22.4	-23.2	-34.3	-35.8	-66.1	-68.5
151	Motunau	HCH2487	-0.3	-5.0	-9.7	-10.5	-16.6	-18.0	-35.6	-38.0	-22.4	-23.2	-34.3	-35.8	-66.1	-68.5
152	Motunau	HCH2487	-0.3	-5.0	-9.7	-10.5	-16.6	-18.0	-35.6	-38.0	-22.4	-23.2	-34.3	-35.8	-66.1	-68.5
154	Motunau	HCH2477	-0.5	-6.0	-17.5	-19.0	-29.9	-32.5	-64.2	-68.5	-37.3	-38.8	-58.9	-61.5	-116.2	-120.5
155	Motunau	HCH2458	-0.5	-6.0	-17.7	-19.2	-30.3	-32.9	-65.0	-69.3	-37.7	-39.2	-59.6	-62.2	-117.5	-121.9
156	Motunau	HCH2458	-0.5	-6.0	-17.8	-19.4	-30.5	-33.2	-65.4	-69.8	-37.9	-39.4	-59.9	-62.6	-118.3	-122.7
157	Motunau	HCH2458	-0.5	-6.0	-17.9	-19.5	-30.6	-33.3	-65.7	-70.1	-38.1	-39.6	-60.2	-62.9	-118.8	-123.2
158	Motunau	HCH2458	-0.5	-6.0	-17.8	-19.3	-30.4	-33.1	-65.3	-69.7	-37.8	-39.4	-59.8	-62.5	-118.1	-122.5
159	Motunau	HCH2458	-0.5	-6.0	-17.7	-19.2	-30.2	-32.9	-64.8	-69.2	-37.6	-39.1	-59.4	-62.1	-117.3	-121.6
160	Motunau	HCH2458	-0.5	-6.0	-18.1	-19.6	-30.9	-33.6	-66.3	-70.8	-38.4	-39.9	-60.7	-63.4	-119.9	-124.3
161	Motunau	HCH2458	-0.5	-6.0	-18.3	-19.8	-31.2	-34.0	-67.0	-71.5	-38.7	-40.2	-61.2	-64.0	-121.0	-125.5
162	Motunau	HCH2458	-0.5	-6.0	-18.4	-19.9	-31.4	-34.2	-67.3	-71.9	-38.8	-40.4	-61.5	-64.3	-121.6	-126.1
163	Motunau	HCH2458	-0.5	-6.0	-18.4	-20.0	-31.5	-34.2	-67.5	-72.0	-38.9	-40.5	-61.6	-64.4	-121.8	-126.4
164	Motunau	HCH2458	-0.5	-6.0	-18.6	-20.2	-31.7	-34.5	-68.1	-72.6	-39.2	-40.8	-62.1	-64.9	-122.9	-127.4

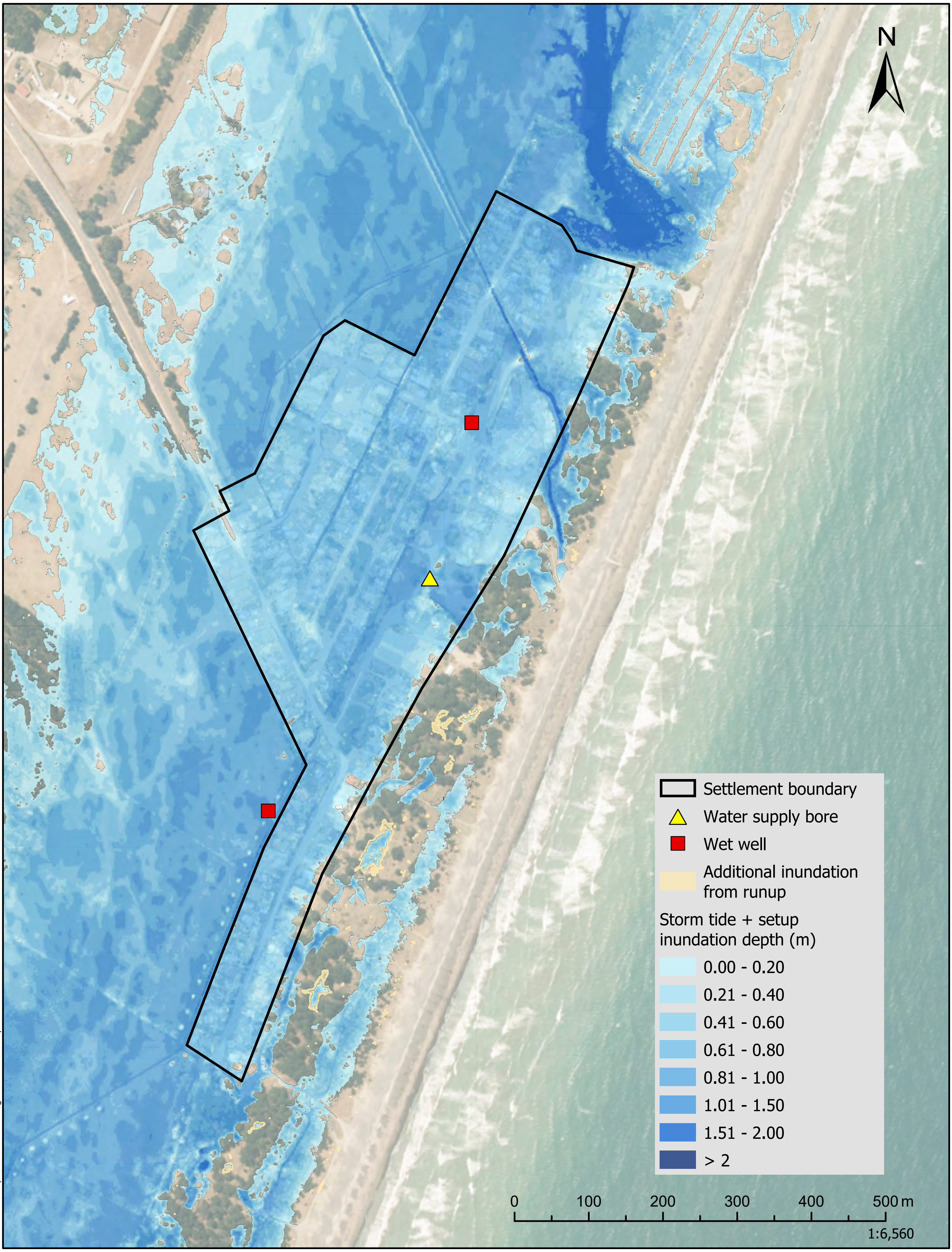
					SLR						Total PFSP Distance					
Transect	Settlement	Profile	LT (m/yr)	ST (m)	2050 RCP 8.5	2050 RCP 8.5+	2070 RCP 8.5	2070 RCP 8.5+	2120 RCP 8.5	2120 RCP 8.5+	2050 RCP 8.5	2050 RCP 8.5+	2070 RCP 8.5	2070 RCP 8.5+	2120 RCP 8.5	2120 RCP 8.5+
165	Motunau	HCH2458	-0.5	-6.0	-18.7	-20.3	-31.9	-34.7	-68.5	-73.1	-39.4	-41.0	-62.5	-65.3	-123.6	-128.2
166	Motunau	HCH2458	-0.5	-6.0	-18.6	-20.2	-31.9	-34.7	-68.4	-72.9	-39.3	-40.9	-62.4	-65.2	-123.4	-127.9
167	Motunau	HCH2458	-0.5	-6.0	-18.6	-20.2	-31.9	-34.7	-68.4	-72.9	-39.3	-40.9	-62.4	-65.2	-123.4	-127.9
168	Motunau	HCH2458	-0.5	-6.0	-18.6	-20.2	-31.9	-34.7	-68.4	-72.9	-39.3	-40.9	-62.4	-65.2	-123.4	-127.9
174	Amberley	PCC4782	-1.0	-7.0	-4.8	-7.7	-8.6	-13.6	-23.8	-33.3	-41.3	-44.2	-64.8	-69.8	-129.1	-138.6
175	Amberley	PCC4782	-1.0	-7.0	-4.8	-7.7	-8.6	-13.6	-23.8	-33.3	-41.8	-44.6	-65.5	-70.6	-130.7	-140.1
176	Amberley	PCC4782	-1.0	-7.0	-4.8	-7.7	-8.6	-13.6	-23.8	-33.3	-42.0	-44.8	-65.8	-70.9	-131.3	-140.8
177	Amberley	PCC4782	-1.0	-7.0	-4.8	-7.7	-8.6	-13.6	-23.8	-33.3	-41.7	-44.5	-65.3	-70.4	-130.3	-139.7
178	Amberley	PCC4782	-1.0	-7.0	-4.8	-7.7	-8.6	-13.6	-23.8	-33.3	-41.6	-44.4	-65.1	-70.2	-129.9	-139.4
179	Amberley	PCC4782	-1.0	-7.0	-4.8	-7.7	-8.6	-13.6	-23.8	-33.3	-41.5	-44.3	-65.0	-70.0	-129.5	-139.0
180	Amberley	PCC4782	-1.0	-7.0	-4.8	-7.7	-8.6	-13.6	-23.8	-33.3	-41.5	-44.3	-65.0	-70.0	-129.5	-139.0
181	Amberley	PCC4782	-1.0	-7.0	-4.8	-7.7	-8.6	-13.6	-23.8	-33.3	-41.1	-43.9	-64.3	-69.4	-128.3	-137.7
182	Amberley	PCC4782	-1.0	-7.0	-4.8	-7.7	-8.6	-13.6	-23.8	-33.3	-41.0	-43.8	-64.2	-69.2	-128.0	-137.4
183	Amberley	PCC4782	-1.0	-7.0	-4.8	-7.7	-8.6	-13.6	-23.8	-33.3	-40.8	-43.7	-63.9	-69.0	-127.4	-136.9
184	Amberley	PCC4782	-1.0	-7.0	-4.8	-7.7	-8.6	-13.6	-23.8	-33.3	-40.4	-43.2	-63.1	-68.2	-125.9	-135.4
185	Amberley	PCC4782	-0.9	-7.0	-4.8	-7.7	-8.6	-13.6	-23.8	-33.3	-39.5	-42.4	-61.7	-66.8	-123.1	-132.5
186	Amberley	PCC4782	-0.9	-7.0	-4.8	-7.7	-8.6	-13.6	-23.8	-33.3	-38.2	-41.1	-59.6	-64.6	-118.8	-128.3
187	Amberley	PCC4782	-0.9	-7.0	-4.8	-7.7	-8.6	-13.6	-23.8	-33.3	-37.5	-40.4	-58.4	-63.5	-116.4	-125.9
188	Amberley	PCC4782	-0.8	-7.0	-4.8	-7.7	-8.6	-13.6	-23.8	-33.3	-36.9	-39.7	-57.3	-62.4	-114.3	-123.7
189	Amberley	PCC4722	-0.8	-7.0	-4.6	-7.3	-8.2	-13.0	-22.7	-31.7	-36.2	-38.9	-56.1	-60.9	-111.5	-120.5

					SLR						Total PFSP Distance					
Transect	Settlement	Profile	LT (m/yr)	ST (m)	2050 RCP 8.5	2050 RCP 8.5+	2070 RCP 8.5	2070 RCP 8.5+	2120 RCP 8.5	2120 RCP 8.5+	2050 RCP 8.5	2050 RCP 8.5+	2070 RCP 8.5	2070 RCP 8.5+	2120 RCP 8.5	2120 RCP 8.5+
190	Amberley	PCC4722	-0.8	-7.0	-4.6	-7.3	-8.2	-13.0	-22.7	-31.7	-35.5	-38.2	-55.0	-59.8	-109.3	-118.3
191	Amberley	PCC4722	-0.8	-7.0	-4.6	-7.3	-8.2	-13.0	-22.7	-31.7	-35.0	-37.7	-54.2	-59.0	-107.8	-116.7
192	Amberley	PCC4722	-0.8	-7.0	-4.6	-7.3	-8.2	-13.0	-22.7	-31.7	-34.7	-37.4	-53.7	-58.5	-106.7	-115.7
193	Amberley	PCC4722	-0.7	-7.0	-4.6	-7.3	-8.2	-13.0	-22.7	-31.7	-34.1	-36.8	-52.6	-57.4	-104.5	-113.5
194	Amberley	PCC4722	-0.7	-7.0	-4.6	-7.3	-8.2	-13.0	-22.7	-31.7	-33.0	-35.7	-50.8	-55.6	-100.9	-109.9
195	Amberley	PCC4722	-0.7	-7.0	-4.6	-7.3	-8.2	-13.0	-22.7	-31.7	-32.1	-34.8	-49.3	-54.1	-97.9	-106.9
196	Amberley	PCC4722	-0.7	-7.0	-4.6	-7.3	-8.2	-13.0	-22.7	-31.7	-31.7	-34.4	-48.6	-53.4	-96.6	-105.6
197	Amberley	PCC4694	-0.7	-7.0	-4.6	-7.3	-8.1	-12.9	-22.5	-31.4	-31.5	-34.1	-48.3	-53.0	-95.8	-104.7
198	Amberley	PCC4694	-0.6	-7.0	-4.6	-7.3	-8.1	-12.9	-22.5	-31.4	-30.8	-33.5	-47.2	-51.9	-93.6	-102.5
199	Amberley	PCC4694	-0.6	-7.0	-4.6	-7.3	-8.1	-12.9	-22.5	-31.4	-30.4	-33.0	-46.4	-51.2	-92.1	-101.1
200	Amberley	PCC4694	-0.6	-7.0	-4.6	-7.3	-8.1	-12.9	-22.5	-31.4	-29.9	-32.6	-45.7	-50.4	-90.6	-99.5
201	Amberley	PCC4694	-0.6	-7.0	-4.6	-7.3	-8.1	-12.9	-22.5	-31.4	-29.6	-32.2	-45.1	-49.8	-89.4	-98.4
202	Amberley	PCC4694	-0.6	-7.0	-4.6	-7.3	-8.1	-12.9	-22.5	-31.4	-28.9	-31.6	-44.0	-48.8	-87.3	-96.3
203	Amberley	PCC4694	-0.6	-7.0	-4.6	-7.3	-8.1	-12.9	-22.5	-31.4	-28.4	-31.1	-43.2	-47.9	-85.6	-94.5
204	Amberley	PCC4694	-0.5	-7.0	-4.6	-7.3	-8.1	-12.9	-22.5	-31.4	-27.9	-30.6	-42.4	-47.1	-84.0	-92.9
205	Amberley	PCC4694	-0.5	-7.0	-4.6	-7.3	-8.1	-12.9	-22.5	-31.4	-27.7	-30.4	-42.0	-46.8	-83.2	-92.2
206	Amberley	PCC4694	-0.5	-7.0	-4.6	-7.3	-8.1	-12.9	-22.5	-31.4	-27.6	-30.3	-41.8	-46.6	-82.9	-91.8
207	Amberley	PCC4694	-0.5	-7.0	-4.6	-7.3	-8.1	-12.9	-22.5	-31.4	-26.8	-29.4	-40.4	-45.2	-80.1	-89.1
208	Amberley	PCC4694	-0.5	-7.0	-4.6	-7.3	-8.1	-12.9	-22.5	-31.4	-26.3	-29.0	-39.6	-44.4	-78.5	-87.4
209	Amberley	PCC4694	-0.5	-7.0	-4.6	-7.3	-8.1	-12.9	-22.5	-31.4	-26.1	-28.8	-39.3	-44.1	-77.9	-86.8

					SLR						Total PFSP Distance					
Transect	Settlement	Profile	LT (m/yr)	ST (m)	2050 RCP 8.5	2050 RCP 8.5+	2070 RCP 8.5	2070 RCP 8.5+	2120 RCP 8.5	2120 RCP 8.5+	2050 RCP 8.5	2050 RCP 8.5+	2070 RCP 8.5	2070 RCP 8.5+	2120 RCP 8.5	2120 RCP 8.5+
210	Amberley	PCC4694	-0.5	-7.0	-4.6	-7.3	-8.1	-12.9	-22.5	-31.4	-26.0	-28.7	-39.2	-43.9	-77.6	-86.6
211	Amberley	PCC4694	-0.5	-7.0	-4.6	-7.3	-8.1	-12.9	-22.5	-31.4	-25.5	-28.2	-38.4	-43.1	-76.0	-84.9
212	Amberley	PCC4694	-0.4	-7.0	-4.6	-7.3	-8.1	-12.9	-22.5	-31.4	-25.0	-27.7	-37.6	-42.3	-74.4	-83.3
213	Amberley	PCC4694	-0.4	-7.0	-4.6	-7.3	-8.1	-12.9	-22.5	-31.4	-24.6	-27.3	-36.8	-41.6	-72.8	-81.8
226	Leithfield	PCC4200	0.1	-7.0	-18.2	-28.8	-32.3	-51.2	-89.3	-124.8	-22.8	-33.4	-35.3	-54.2	-88.3	-123.8
227	Leithfield	PCC4200	0.1	-7.0	-18.2	-28.8	-32.3	-51.2	-89.3	-124.8	-22.7	-33.4	-35.2	-54.1	-88.2	-123.6
229	Leithfield	PCC4200	0.1	-7.0	-18.2	-28.8	-32.3	-51.2	-89.3	-124.8	-22.7	-33.3	-35.1	-54.0	-87.9	-123.4
230	Leithfield	PCC4200	0.1	-7.0	-18.2	-28.8	-32.3	-51.2	-89.3	-124.8	-21.5	-32.1	-33.1	-52.0	-84.0	-119.4
231	Leithfield	PCC4200	0.1	-7.0	-18.2	-28.8	-32.3	-51.2	-89.3	-124.8	-21.7	-32.3	-33.5	-52.4	-84.7	-120.2
232	Leithfield	PCC4200	0.1	-7.0	-18.2	-28.8	-32.3	-51.2	-89.3	-124.8	-21.5	-32.1	-33.1	-52.0	-84.0	-119.4
233	Leithfield	PCC4200	0.2	-7.0	-18.2	-28.8	-32.3	-51.2	-89.3	-124.8	-20.4	-31.1	-31.3	-50.3	-80.5	-116.0
234	Leithfield	PCC4200	0.2	-7.0	-18.2	-28.8	-32.3	-51.2	-89.3	-124.8	-19.8	-30.4	-30.3	-49.2	-78.4	-113.9
235	Leithfield	PCC4200	0.2	-7.0	-18.2	-28.8	-32.3	-51.2	-89.3	-124.8	-19.1	-29.7	-29.1	-48.0	-76.0	-111.5
236	Leithfield	PCC4200	0.2	-7.0	-18.2	-28.8	-32.3	-51.2	-89.3	-124.8	-18.5	-29.1	-28.1	-47.0	-74.0	-109.5
237	Leithfield	PCC4200	0.2	-7.0	-18.2	-28.8	-32.3	-51.2	-89.3	-124.8	-18.1	-28.7	-27.4	-46.3	-72.6	-108.0
238	Leithfield	PCC4200	0.2	-7.0	-18.2	-28.8	-32.3	-51.2	-89.3	-124.8	-19.8	-30.4	-30.3	-49.2	-78.4	-113.9
239	Leithfield	PCC4200	0.2	-7.0	-18.2	-28.8	-32.3	-51.2	-89.3	-124.8	-19.4	-30.0	-29.6	-48.5	-77.0	-112.5
240	Leithfield	PCC4200	0.2	-7.0	-18.2	-28.8	-32.3	-51.2	-89.3	-124.8	-19.0	-29.6	-28.9	-47.8	-75.7	-111.1
241	Leithfield	PCC4200	0.2	-7.0	-18.2	-28.8	-32.3	-51.2	-89.3	-124.8	-19.1	-29.8	-29.2	-48.1	-76.2	-111.7
242	Leithfield	PCC4200	0.2	-7.0	-18.2	-28.8	-32.3	-51.2	-89.3	-124.8	-18.3	-28.9	-27.8	-46.7	-73.3	-108.8

					SLR						Total PFSP Distance					
Transect	Settlement	Profile	LT (m/yr)	ST (m)	2050 RCP 8.5	2050 RCP 8.5+	2070 RCP 8.5	2070 RCP 8.5+	2120 RCP 8.5	2120 RCP 8.5+	2050 RCP 8.5	2050 RCP 8.5+	2070 RCP 8.5	2070 RCP 8.5+	2120 RCP 8.5	2120 RCP 8.5+
243	Leithfield	PCC4200	0.3	-7.0	-18.2	-28.8	-32.3	-51.2	-89.3	-124.8	-17.6	-28.2	-26.6	-45.5	-71.0	-106.5
244	Leithfield	PCC4200	0.3	-7.0	-18.2	-28.8	-32.3	-51.2	-89.3	-124.8	-16.9	-27.5	-25.5	-44.4	-68.8	-104.2
245	Leithfield	PCC4200	0.3	-7.0	-18.2	-28.8	-32.3	-51.2	-89.3	-124.8	-16.6	-27.2	-24.9	-43.8	-67.6	-103.0
246	Leithfield	PCC4200	0.3	-7.0	-18.2	-28.8	-32.3	-51.2	-89.3	-124.8	-15.6	-26.2	-23.3	-42.2	-64.4	-99.9
247	Leithfield	PCC4200	0.3	-7.0	-18.2	-28.8	-32.3	-51.2	-89.3	-124.8	-14.8	-25.4	-21.9	-40.8	-61.7	-97.1
248	Leithfield	PCC4200	0.4	-7.0	-18.2	-28.8	-32.3	-51.2	-89.3	-124.8	-13.2	-23.9	-19.3	-38.3	-56.5	-92.0
249	Leithfield	PCC4200	0.5	-7.0	-18.2	-28.8	-32.3	-51.2	-89.3	-124.8	-10.7	-21.3	-15.1	-34.0	-48.0	-83.5
250	Leithfield	PCC4200	0.5	-7.0	-18.2	-28.8	-32.3	-51.2	-89.3	-124.8	-9.3	-19.9	-12.8	-31.7	-43.3	-78.8
251	Leithfield	PCC4200	0.6	-7.0	-18.2	-28.8	-32.3	-51.2	-89.3	-124.8	-8.4	-19.1	-11.4	-30.3	-40.5	-76.0
252	Leithfield	PCC4200	0.6	-7.0	-18.2	-28.8	-32.3	-51.2	-89.3	-124.8	-7.8	-18.5	-10.4	-29.3	-38.5	-74.0
253	Leithfield	PCC4200	0.6	-7.0	-18.2	-28.8	-32.3	-51.2	-89.3	-124.8	-7.1	-17.7	-9.1	-28.0	-35.9	-71.4
254	Leithfield	PCC4200	0.6	-7.0	-18.2	-28.8	-32.3	-51.2	-89.3	-124.8	-6.4	-17.0	-8.0	-26.9	-33.7	-69.2
255	Leithfield	PCC4200	0.7	-7.0	-18.2	-28.8	-32.3	-51.2	-89.3	-124.8	-5.5	-16.2	-6.5	-25.4	-30.8	-66.3

Appendix H. Coastal Inundation Maps from Bathtub Modelling of 1% AEP water levels with sea level rise scenarios



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Leithfield Coastal Inundation 1% AEP Bathtub Model

Current day

Date: 09/01/2020

JACOBS SPATIAL
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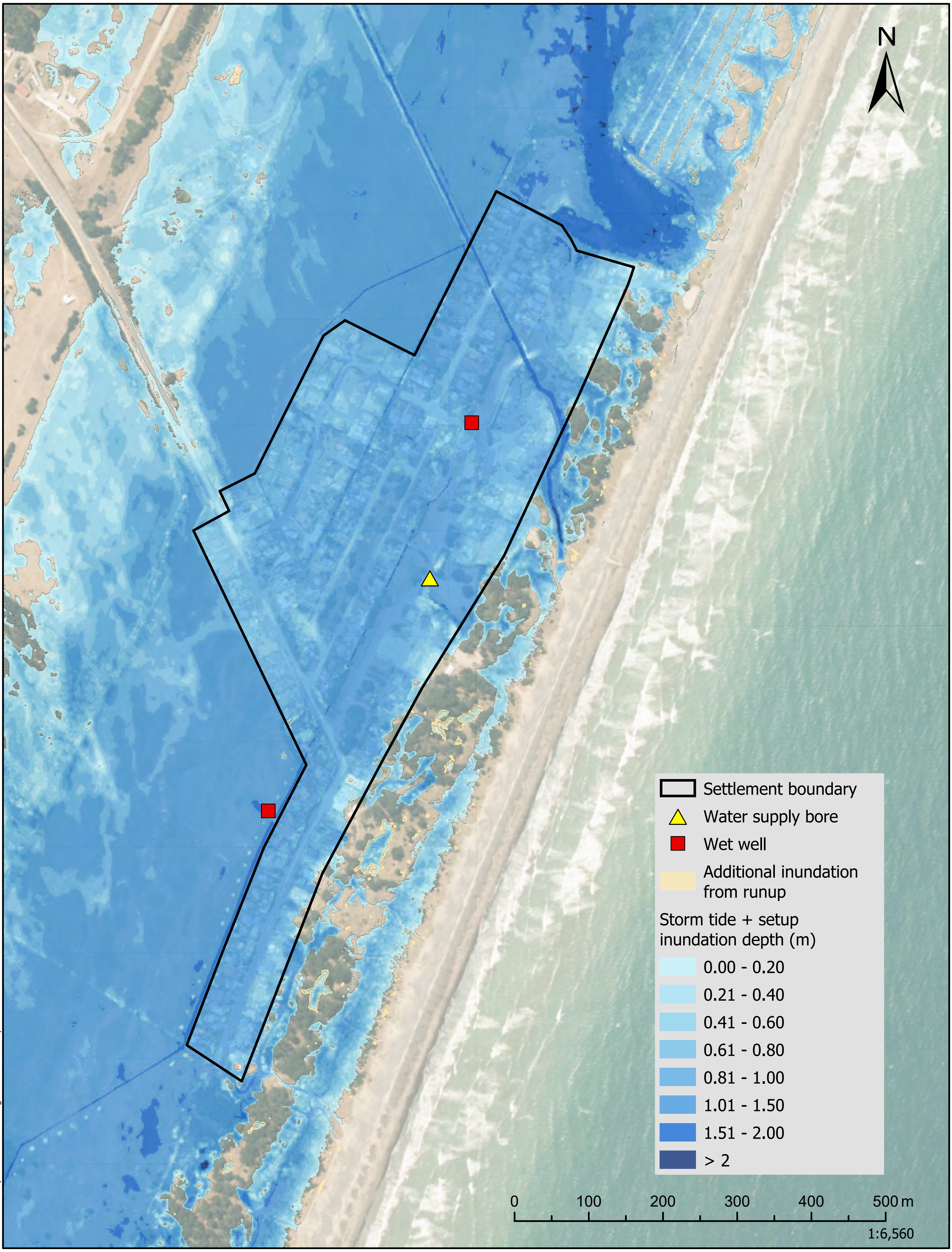
Parnell, Auckland
Tel +64 9 928 5500
Fax +64 9 928 5501



Leithfield Coastal Inundation 1% AEP Bathtub Model

30 year RCP 8.5

Date: 09/01/2020

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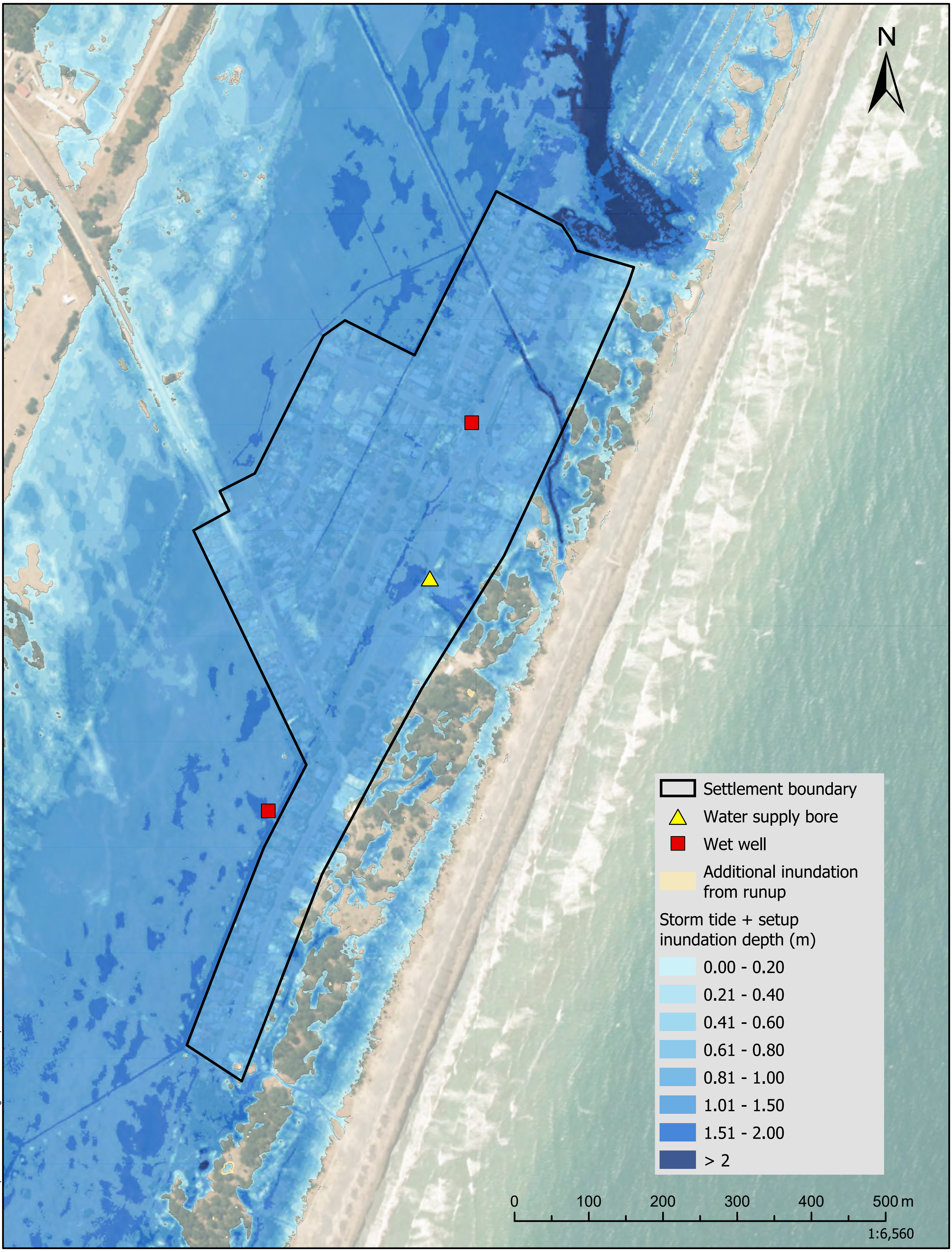

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Leithfield Coastal Inundation 1% AEP Bathtub Model

50 year RCP 8.5

Date: 09/01/2020

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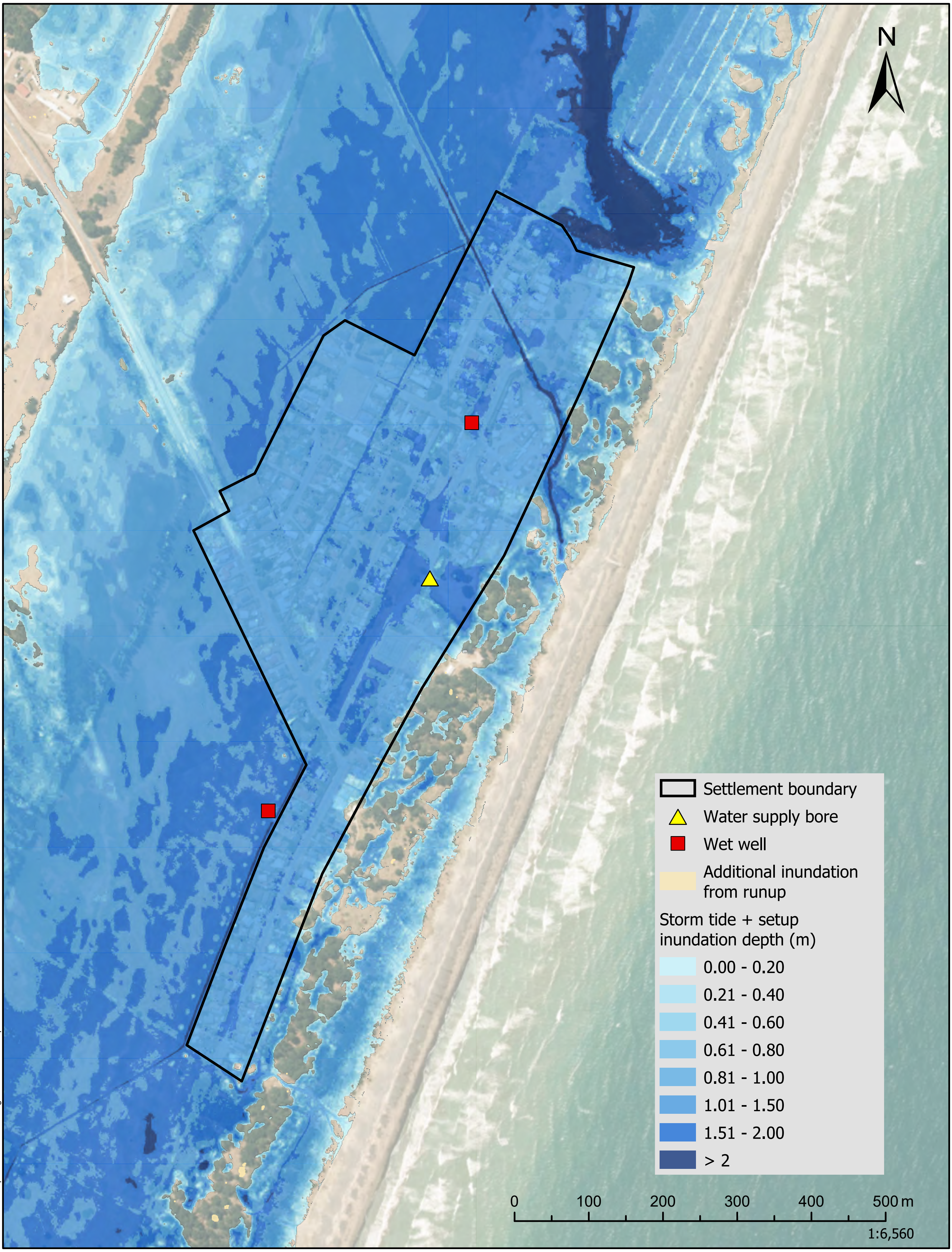

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Leithfield Coastal Inundation 1% AEP Bathtub Model

50 year RCP 8.5+

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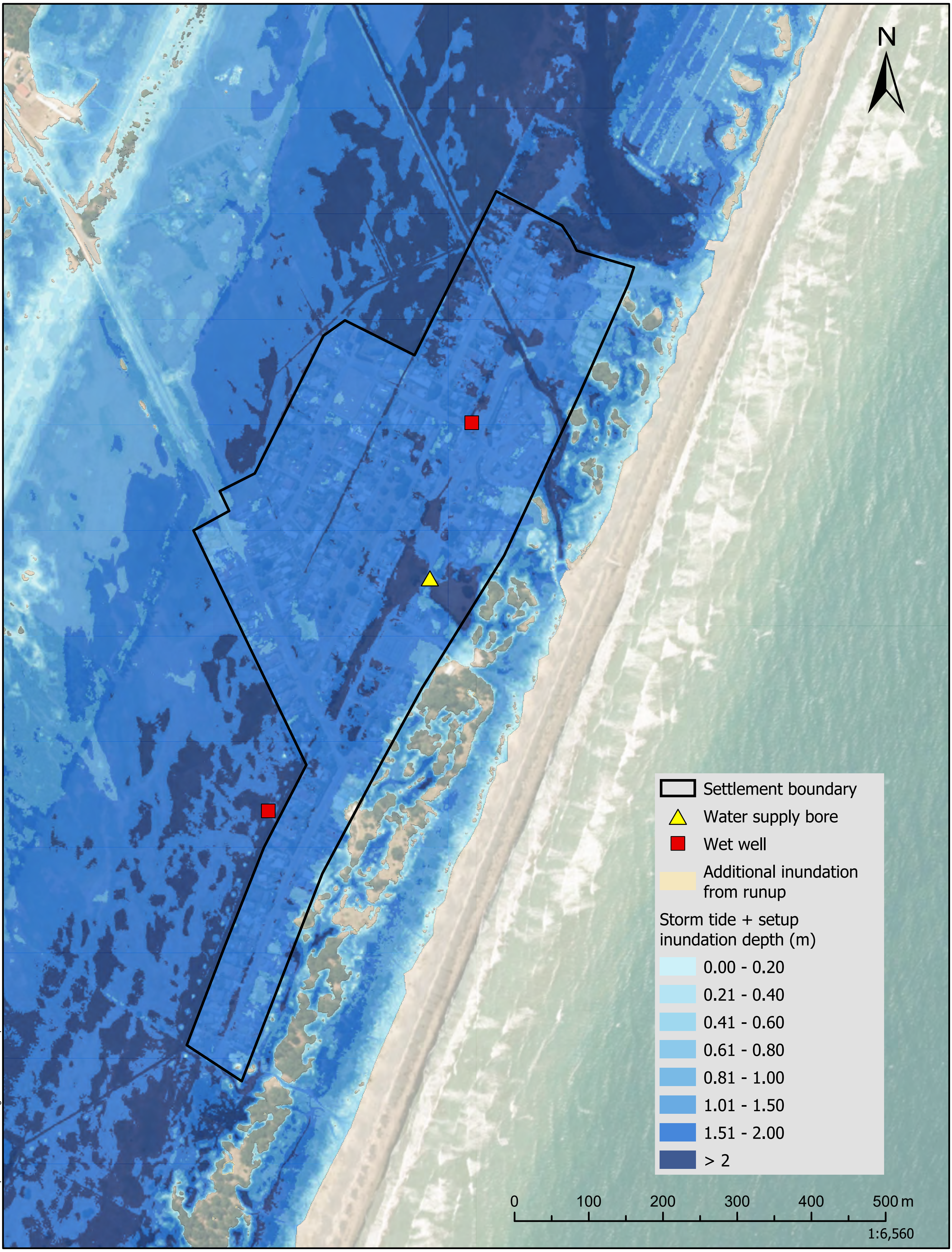

Leithfield Coastal Inundation 1% AEP Bathtub Model

100 year RCP 8.5

Date: 09/01/2020

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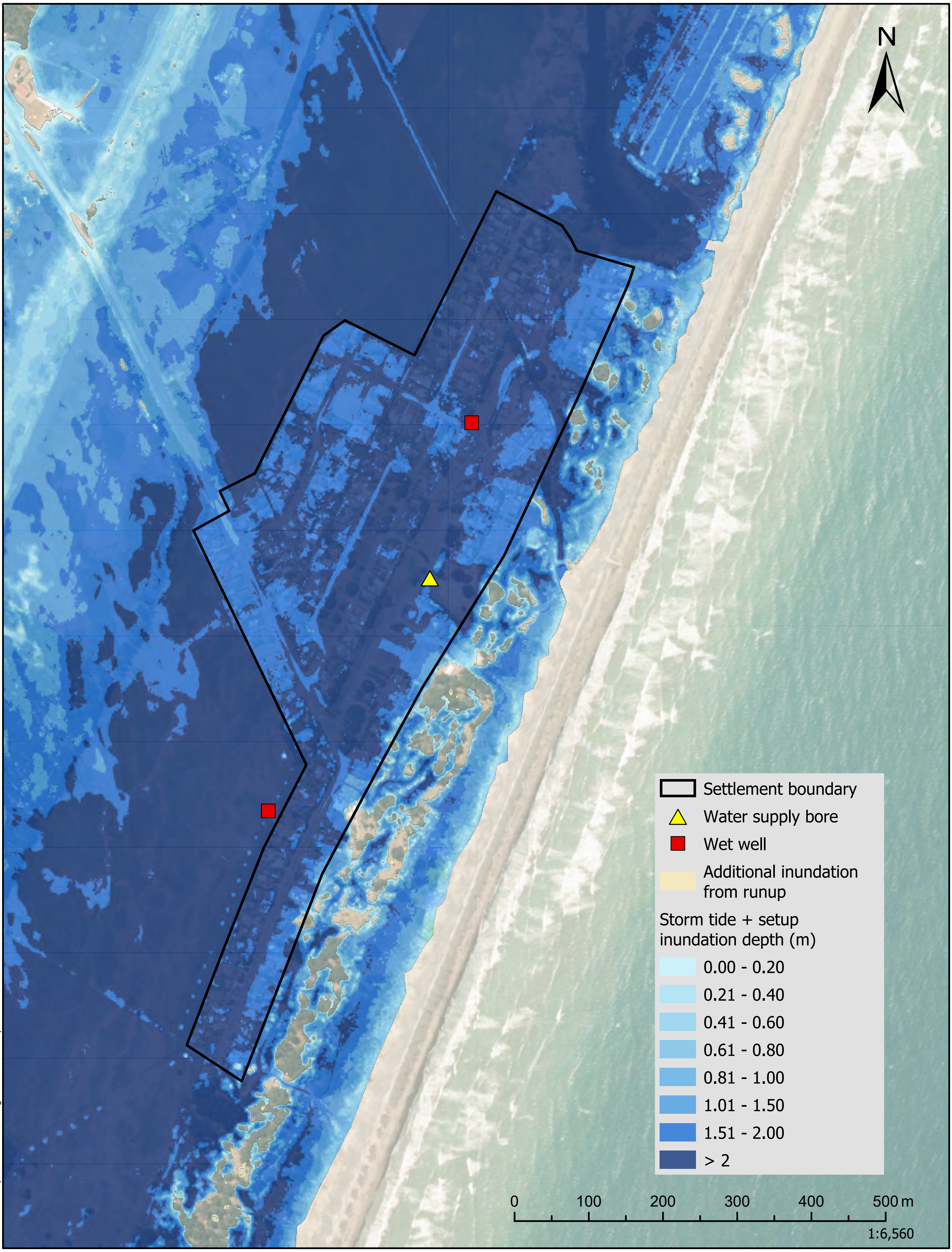

Leithfield Coastal Inundation 1% AEP Bathtub Model

100 year RCP 8.5+

Date: 09/01/2020

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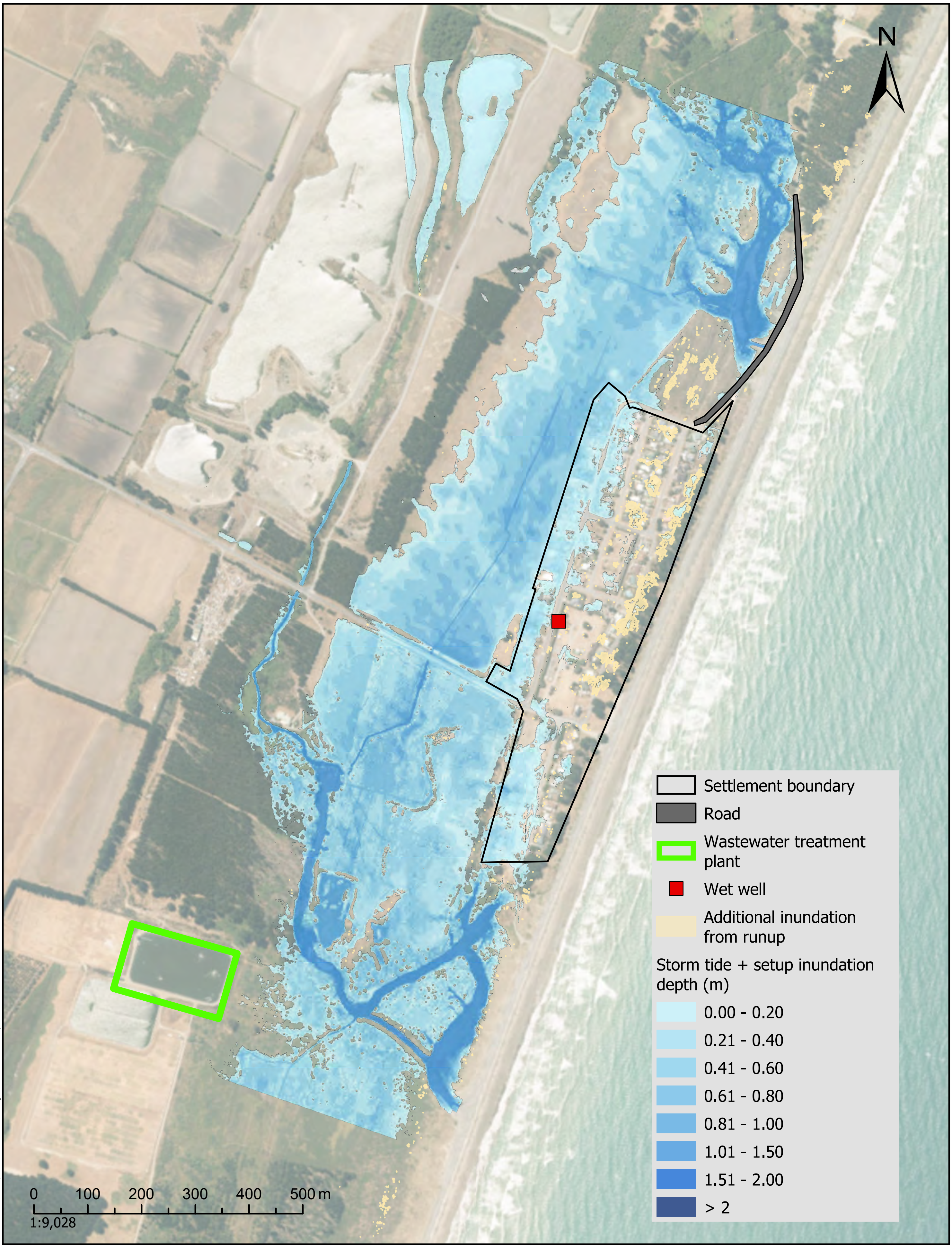

Amberley Coastal Inundation 1% AEP Bathtub Model

Current Day

Date: 09/01/2020

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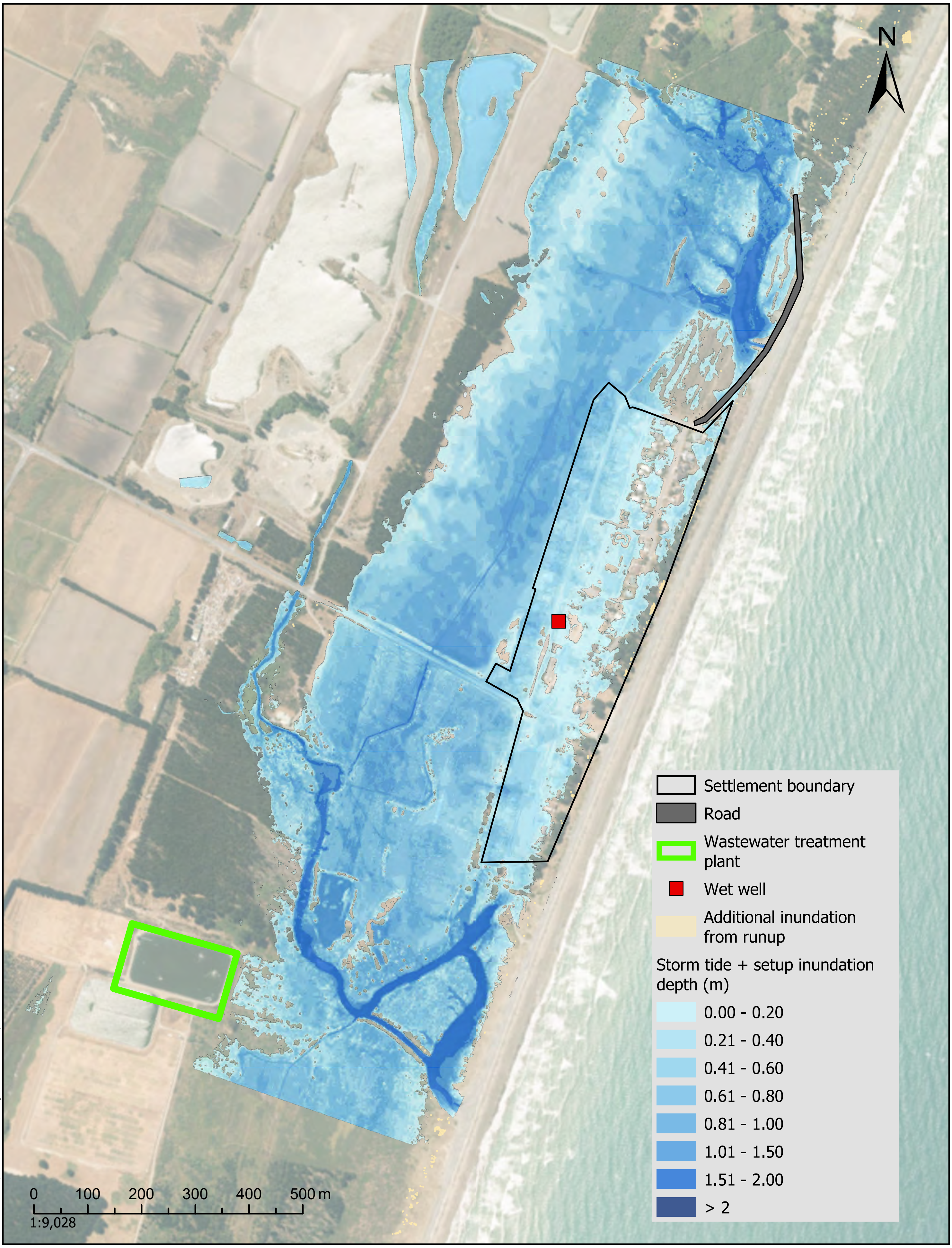

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Amberley Coastal Inundation 1% AEP Bathtub Model

30 year RCP 8.5

Date: 09/01/2020

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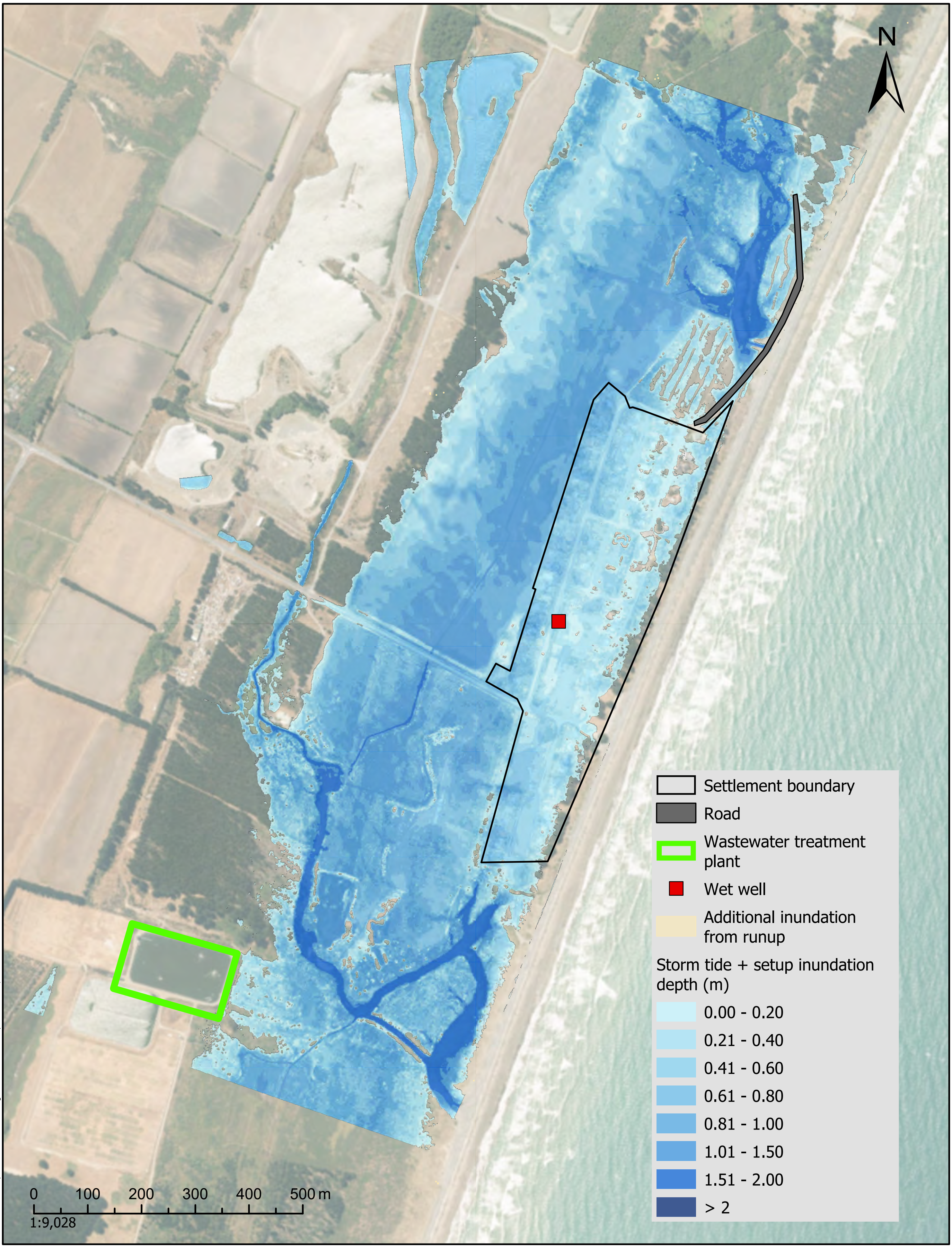

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Amberley Coastal Inundation 1% AEP Bathtub Model

50 year RCP 8.5

Date: 09/01/2020

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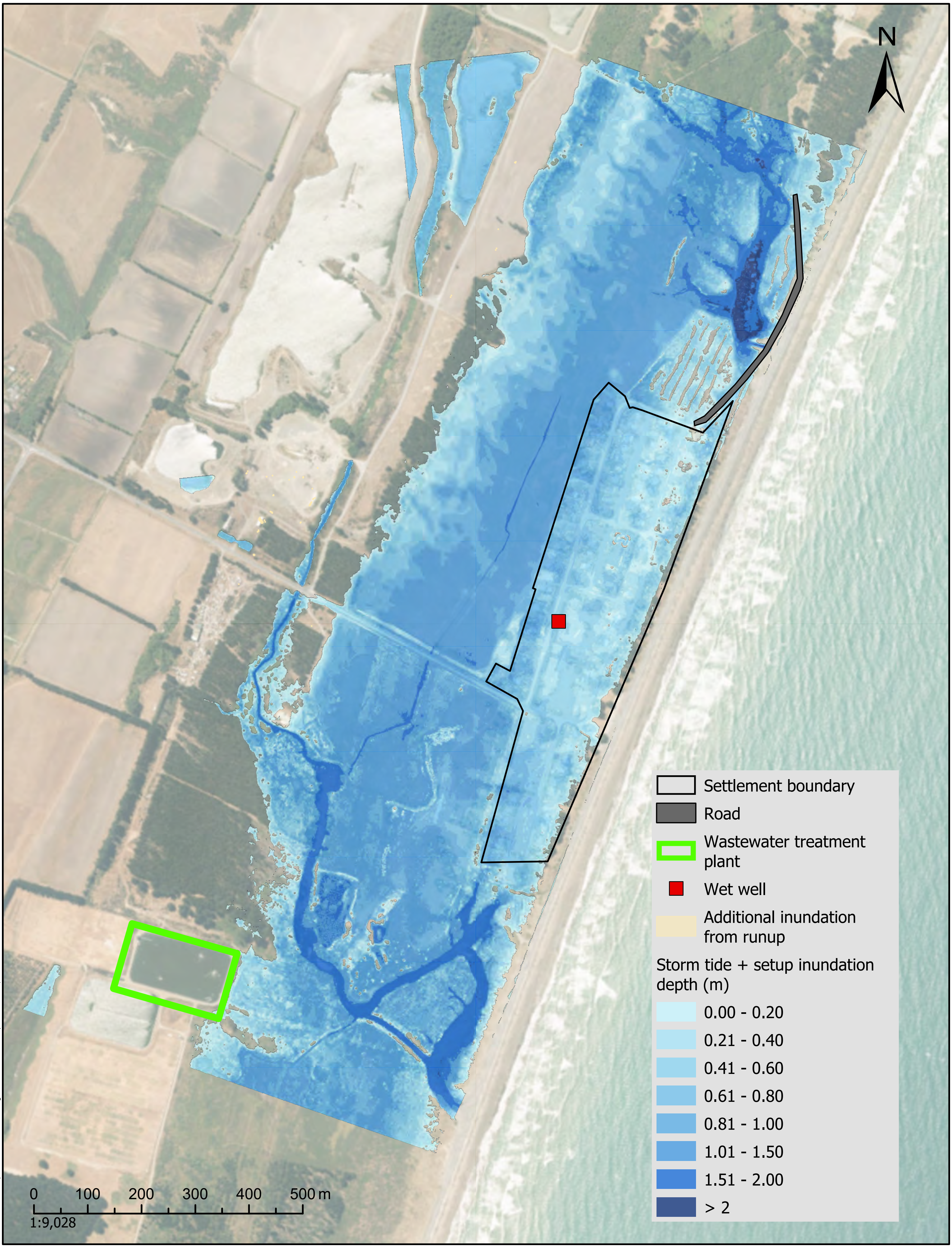

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Amberley Coastal Inundation 1% AEP Bathtub Model

50 year RCP 8.5+

Date: 09/01/2020

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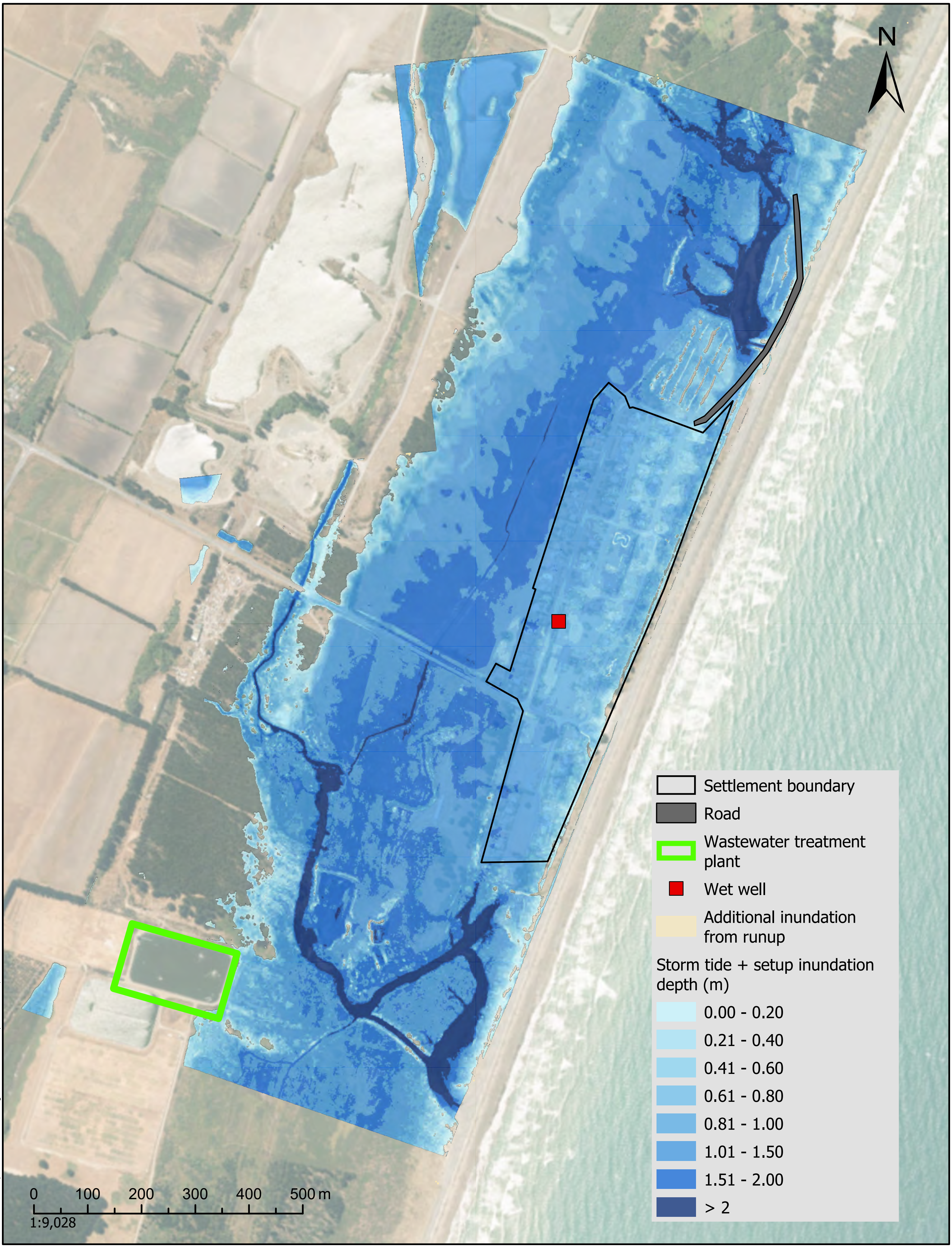

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Amberley Coastal Inundation 1% AEP Bathtub Model

100 year RCP 8.5

Date: 09/01/2020

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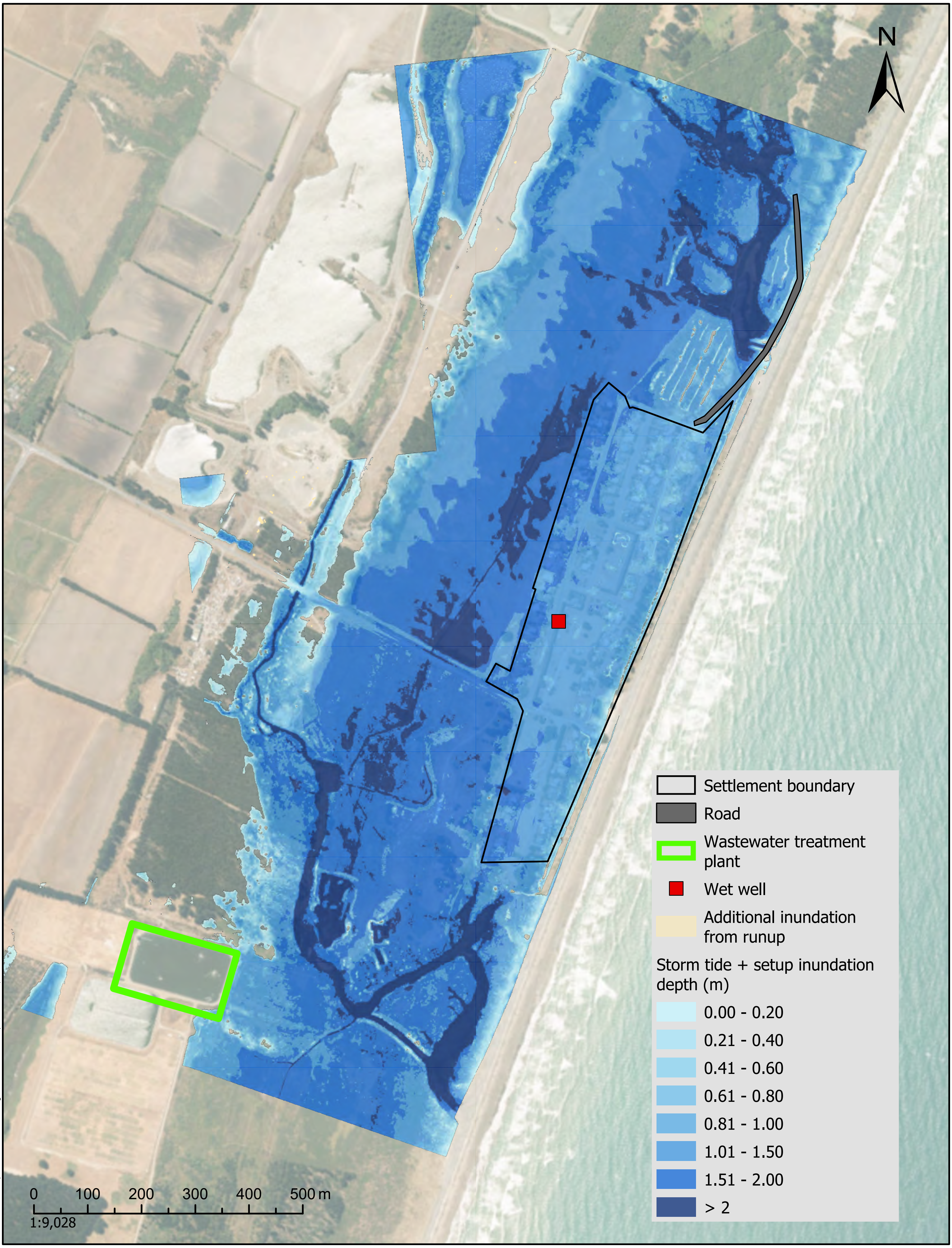

Amberley Coastal Inundation 1% AEP Bathtub Model

100 year RCP 8.5+

Date: 09/01/2020

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Spatial Reference : Name: NZGD 2000 New Zealand Transverse Mercator

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Spatial Reference : Name: NZGD 2000 New Zealand Transverse Mercator

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Motanau Coastal Inundation 1% AEP Bathtub Model

Current day

Date: 09/01/2020

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Motanau Coastal Inundation 1% AEP Bathtub Model

30 year RCP 8.5

Date: 09/01/2020

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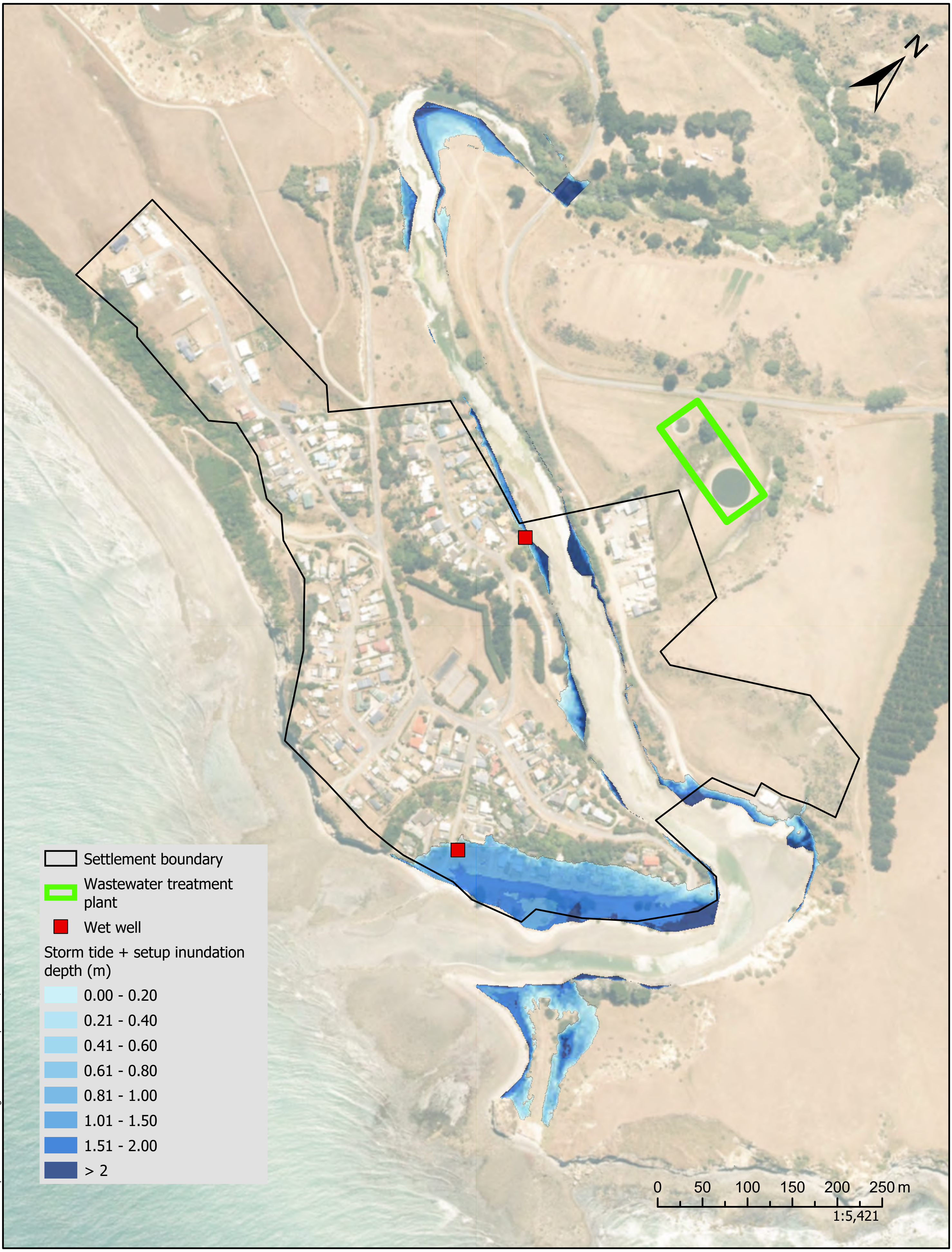

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Motanau Coastal Inundation 1% AEP Bathtub Model

50 year RCP 8.5

Date: 09/01/2020

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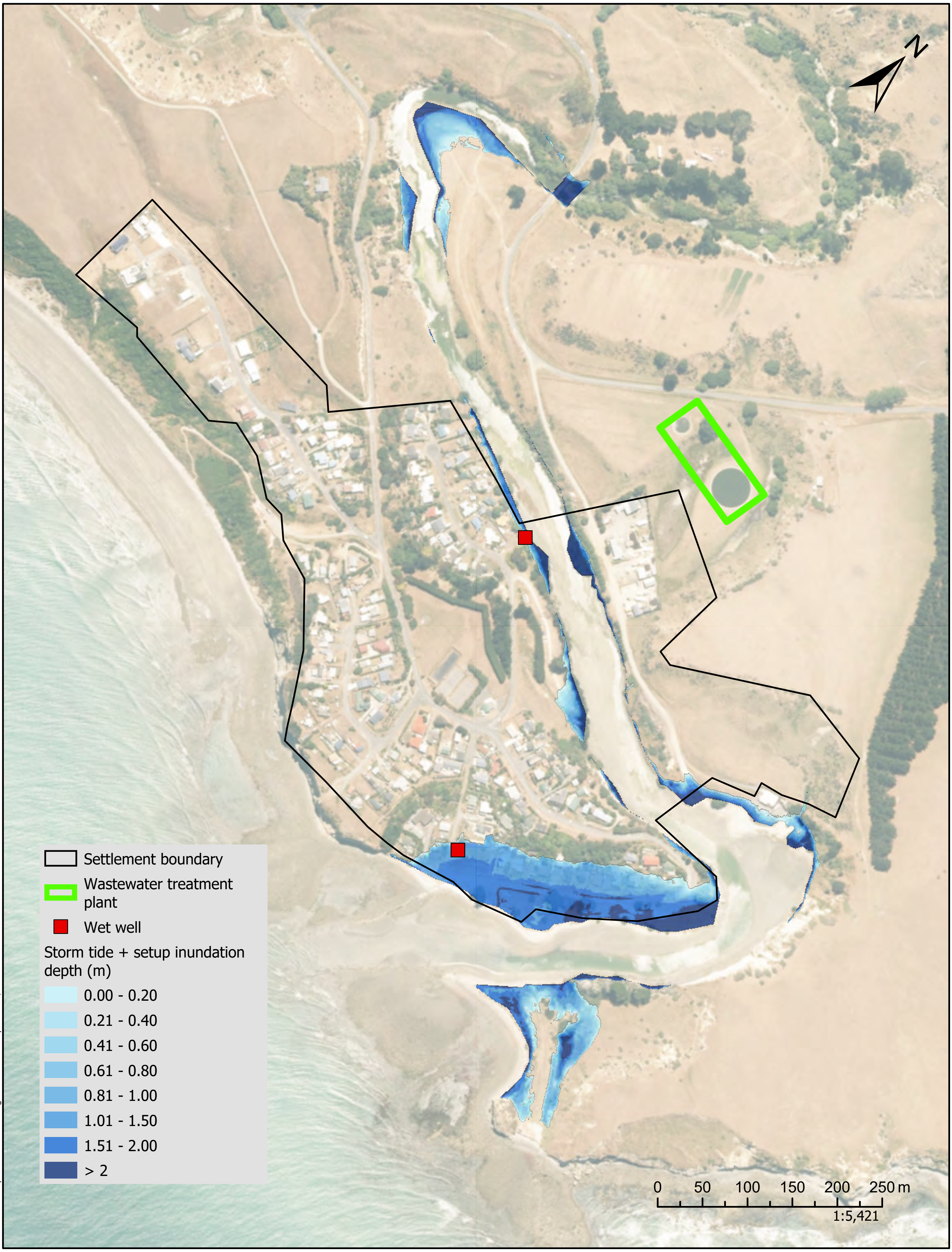

Motanau Coastal Inundation 1% AEP Bathtub Model

50 year RCP 8.5+

Date: 09/01/2020

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Spatial Reference : Name: NZGD 2000 New Zealand Transverse Mercator

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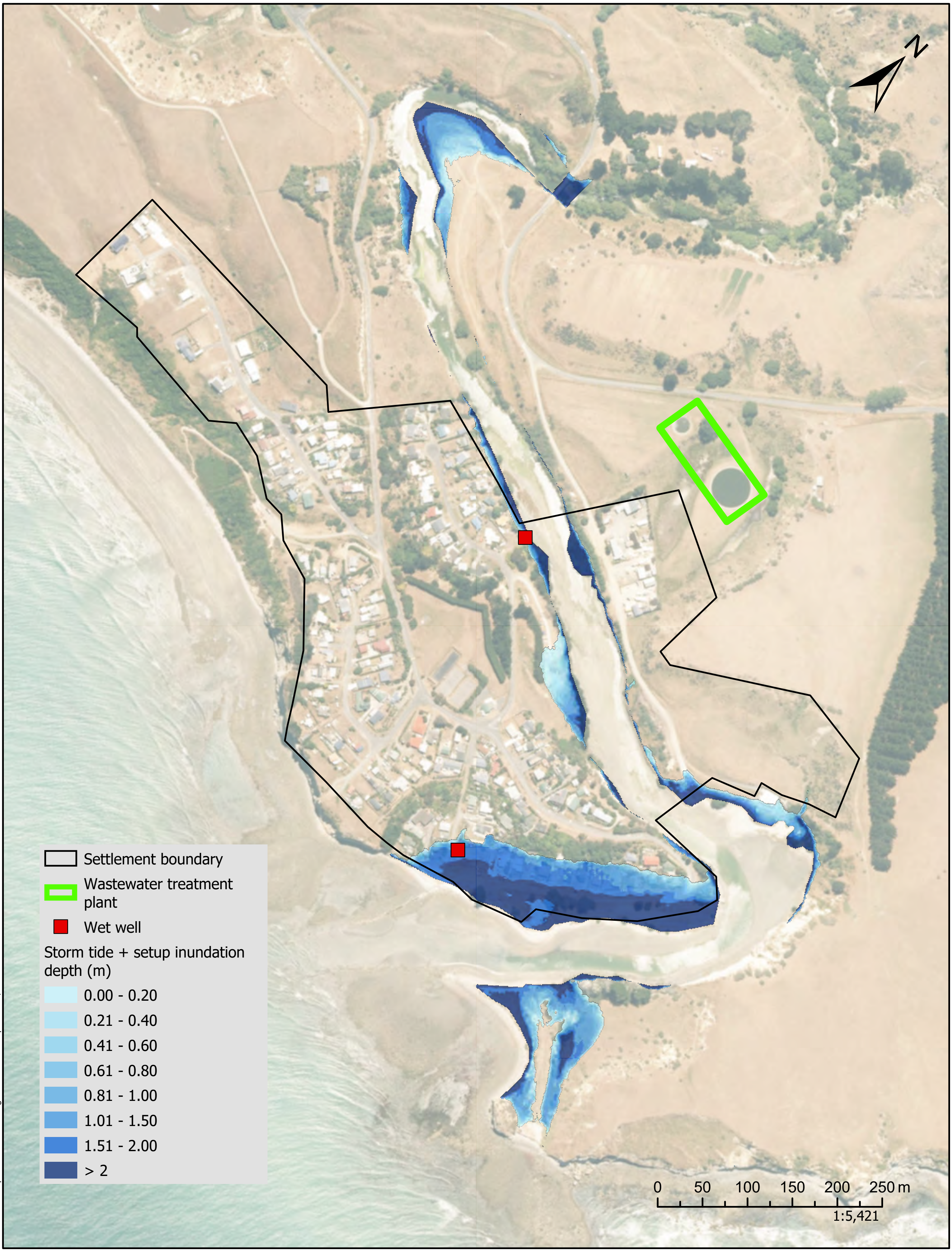

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Motanau Coastal Inundation 1% AEP Bathtub Model

100 year RCP 8.5

Date: 09/01/2020

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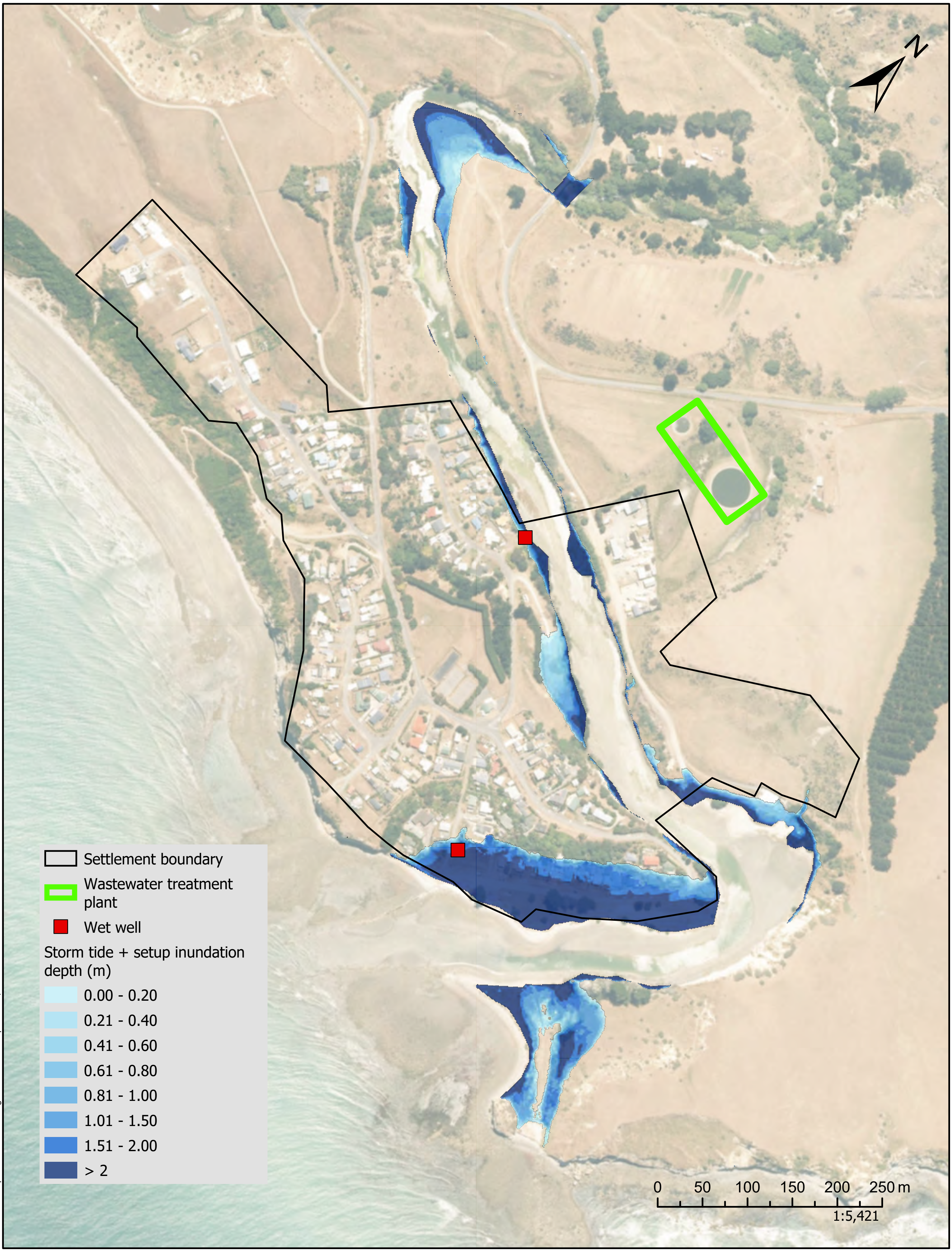

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Motanau Coastal Inundation 1% AEP Bathtub Model

100 year RCP 8.5+

Date: 09/01/2020

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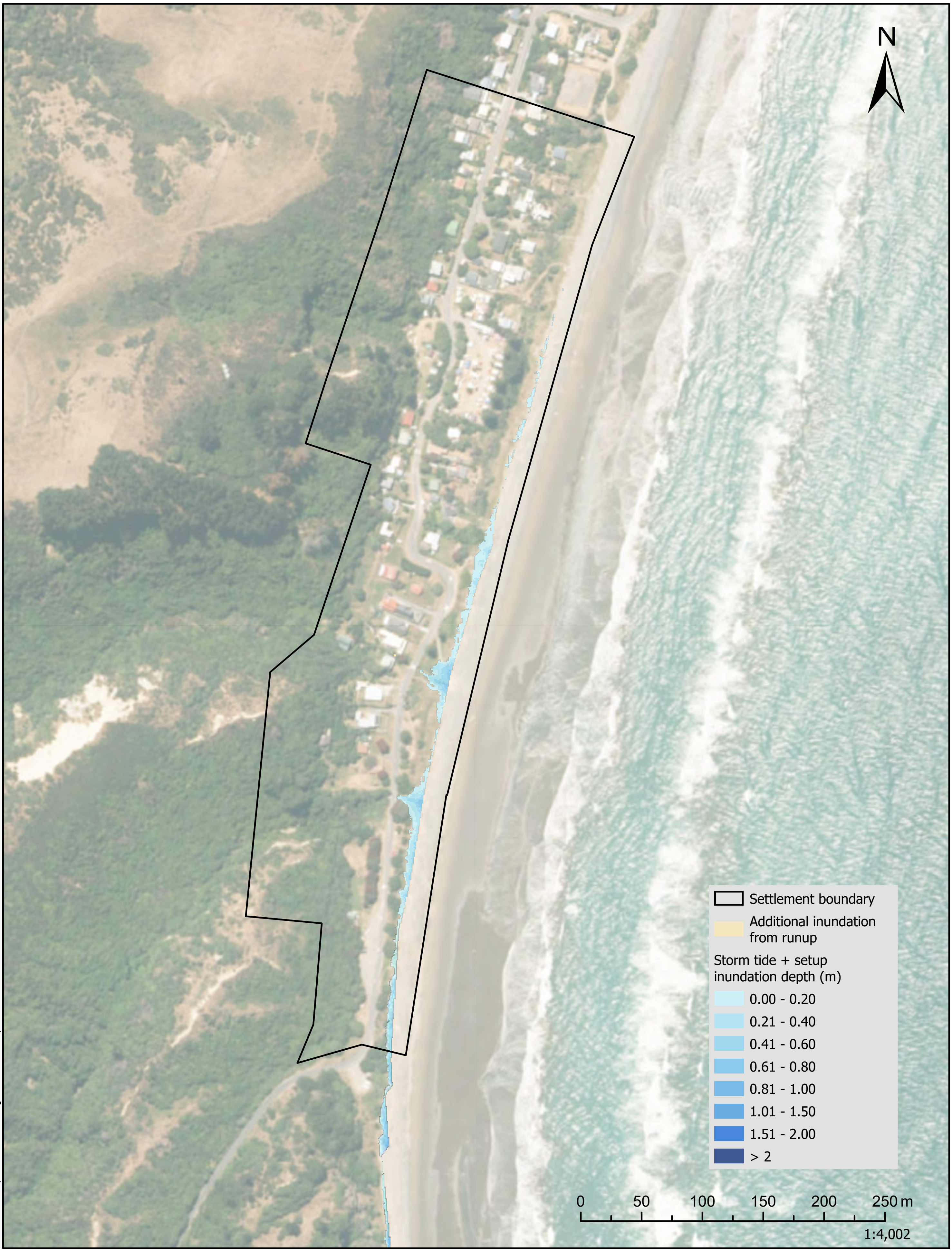
Fax +64 9 928 5501



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Gore Bay South Coastal Inundation 1% AEP Bathtub Model

Current day

Date: 09/01/2020

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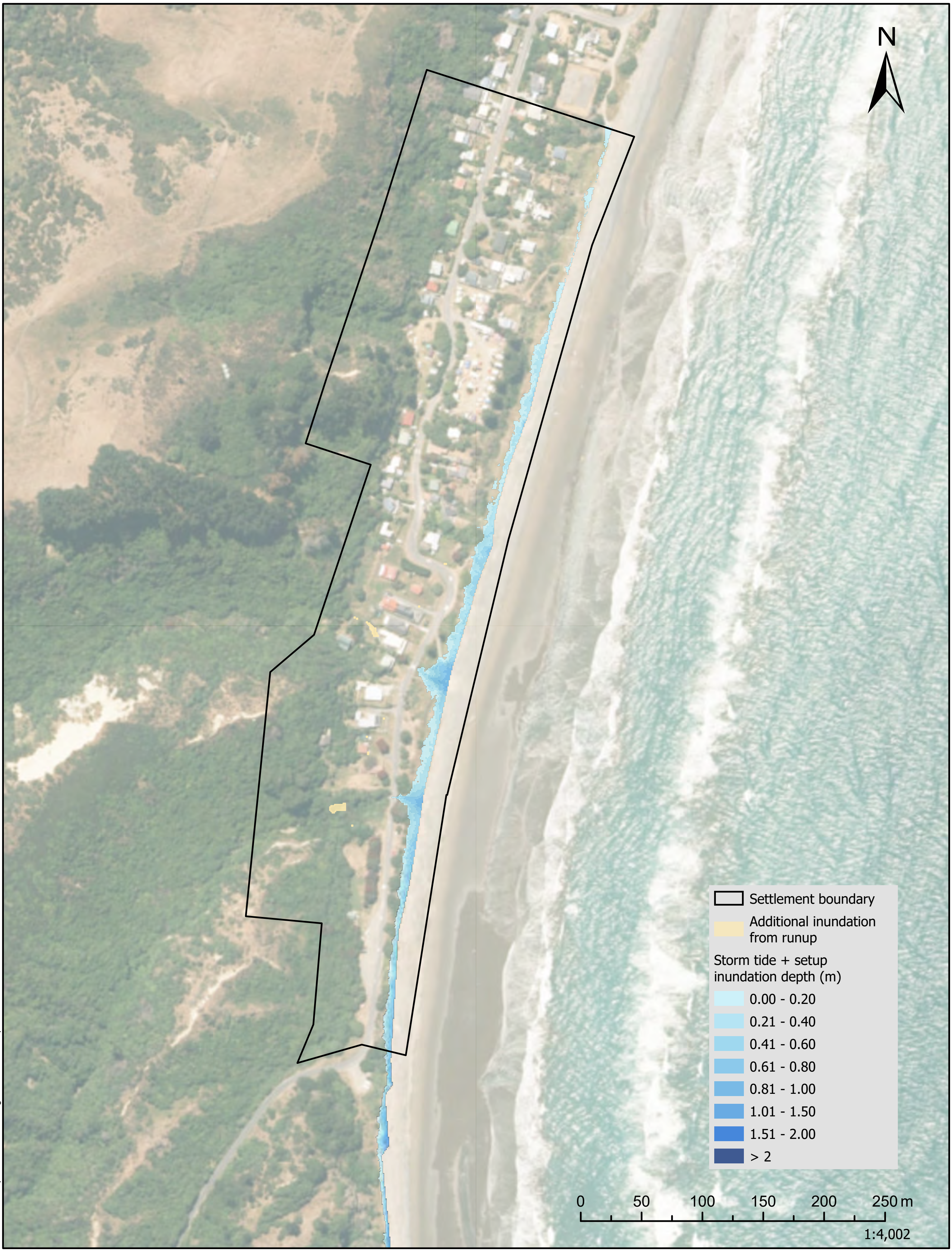
Parnell, Auckland
Tel +64 9 928 5500
Fax +64 9 928 5501



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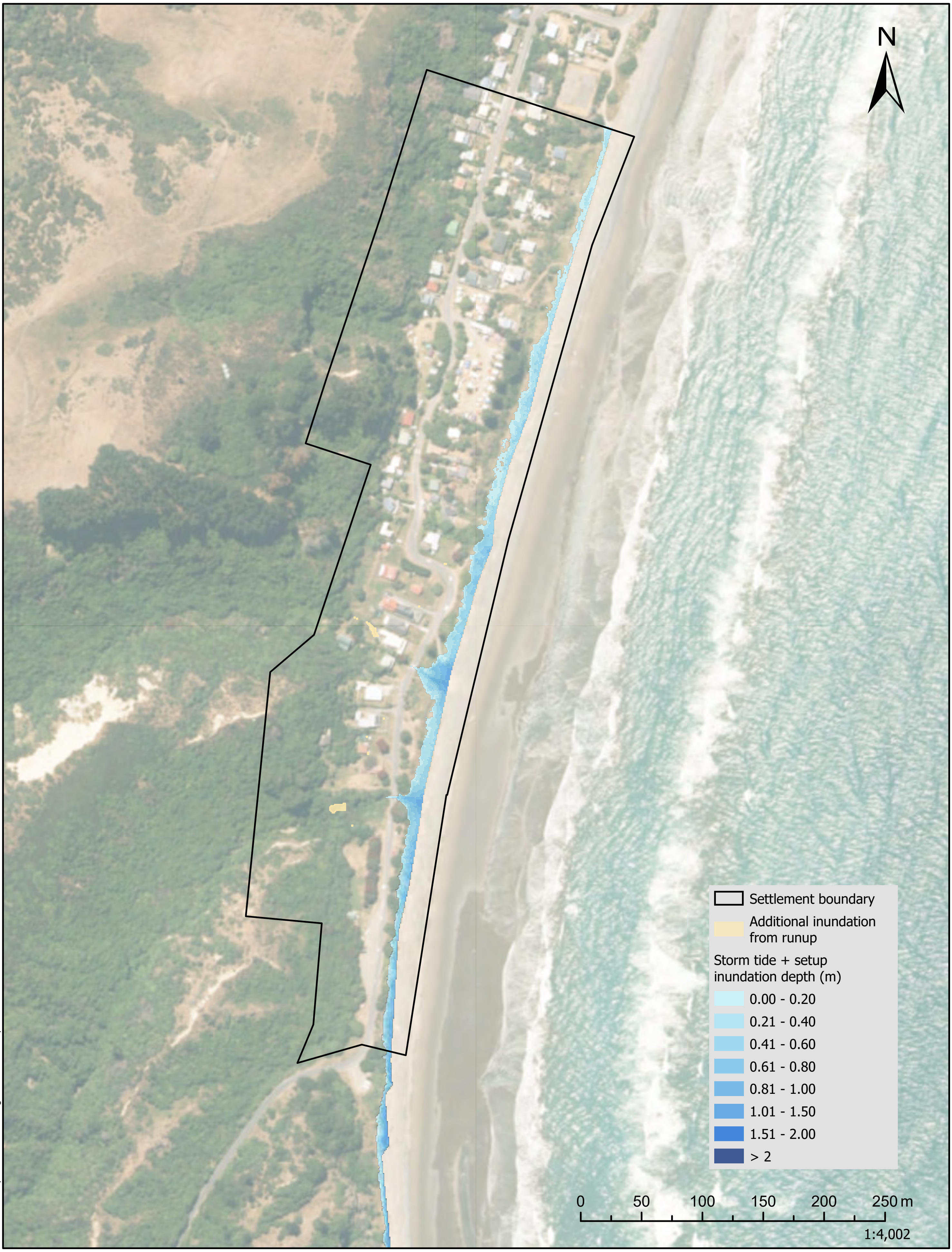
Gore Bay South Coastal Inundation 1% AEP Bathtub Model

30 year RCP 8.5

Date: 09/01/2020

JACOBS SPATIAL

Carlaw Park
12-16 Nicholls Lane
Parnell, Auckland
Tel +64 9 928 5500
Fax +64 9 928 5501



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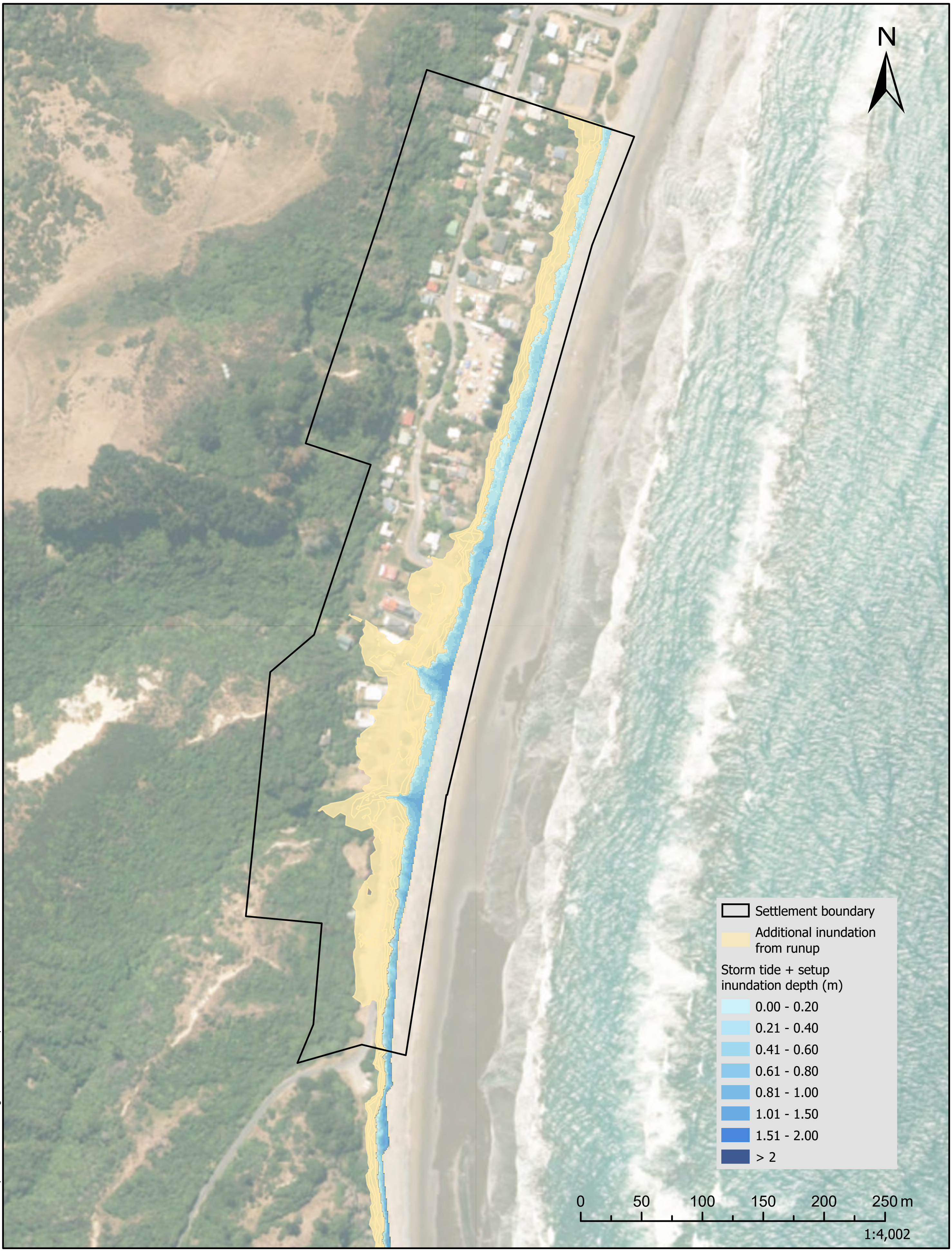
Gore Bay South Coastal Inundation 1% AEP Bathtub Model

50 year RCP 8.5

Date: 09/01/2020

JACOBS SPATIAL

Carlaw Park
12-16 Nicholls Lane
Parnell, Auckland
Tel +64 9 928 5500
Fax +64 9 928 5501



Gore Bay South Coastal Inundation 1% AEP Bathtub Model

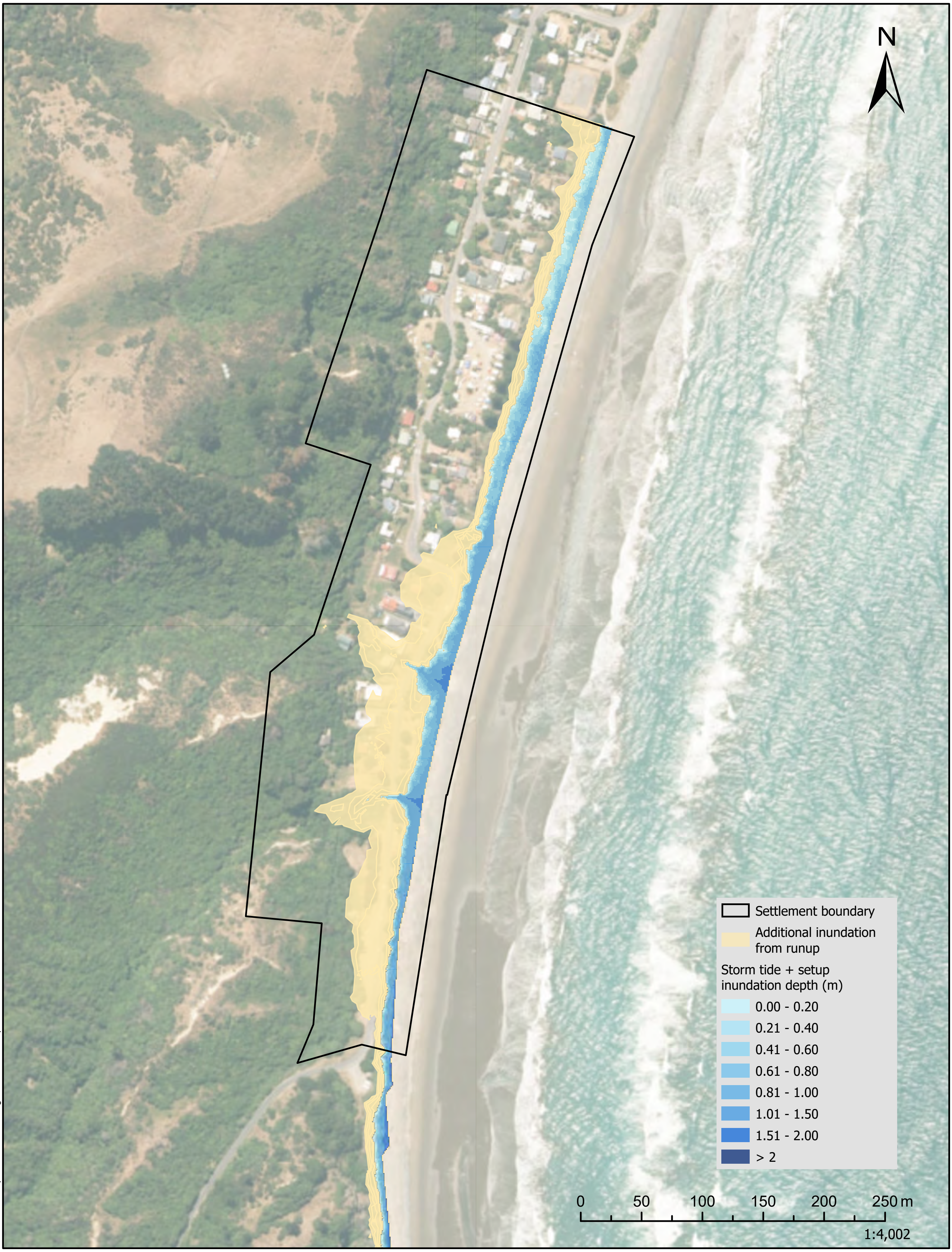
50 year RCP 8.5+

Date: 26/11/2019

JACOBS SPATIAL

Carlaw Park
12-16 Nicholls Lane
Parnell, Auckland
Tel +64 9 928 5500
Fax +64 9 928 5501

J:\IE\Projects\02_New Zealand\IZ128300\22 Technical\Spatial\Hurunui\Working\HurunuiBathtub.aprx



Gore Bay South Coastal Inundation 1% AEP Bathtub Model

100 year RCP 8.5

Date: 26/11/2019

JACOBS
SPATIAL

Carlaw Park
12-16 Nicholls Lane
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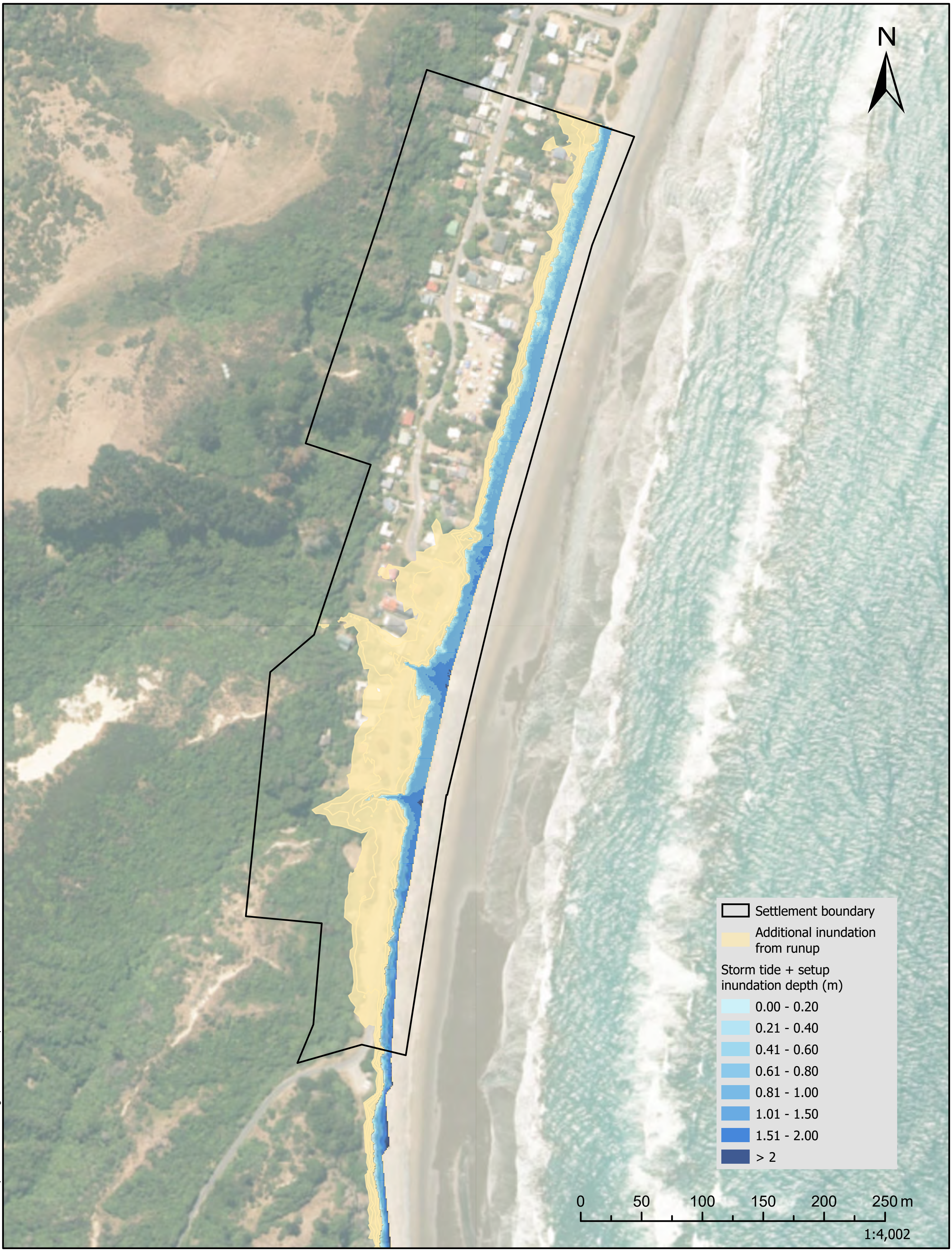
Tel +64 9 928 5500
Fax +64 9 928 5501

J:\IE\Projects\02_New Zealand\IZ128300\22 Technical\Spatial\Hurunui\Working\HurunuiBathtub.aprx



Gore Bay South Coastal Inundation 1% AEP Bathtub Model

100 year RCP 8.5+

Date: 26/11/2019

JACOBS SPATIAL

Carlaw Park
12-16 Nicholls Lane
Parnell, Auckland
Tel +64 9 928 5500
Fax +64 9 928 5501

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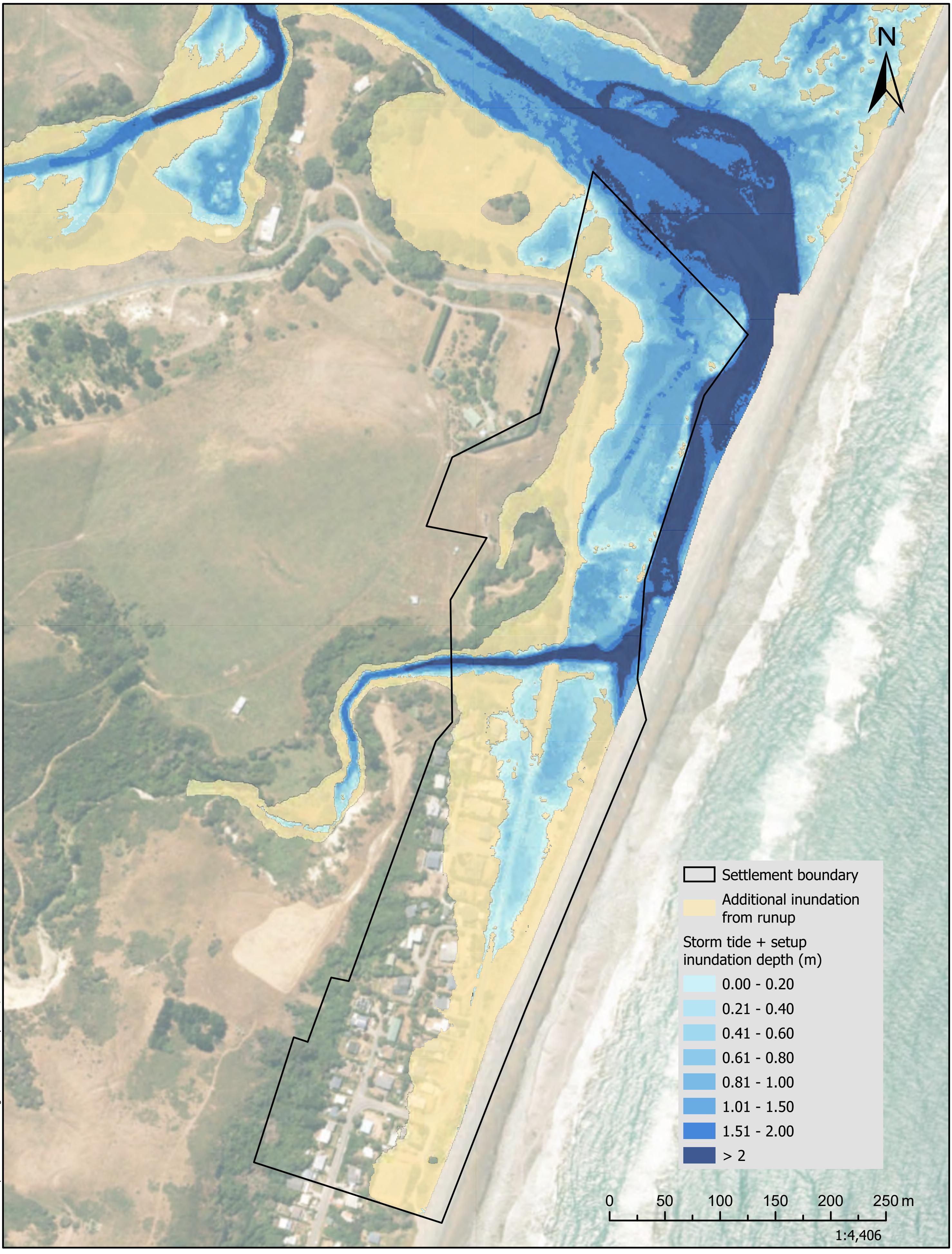

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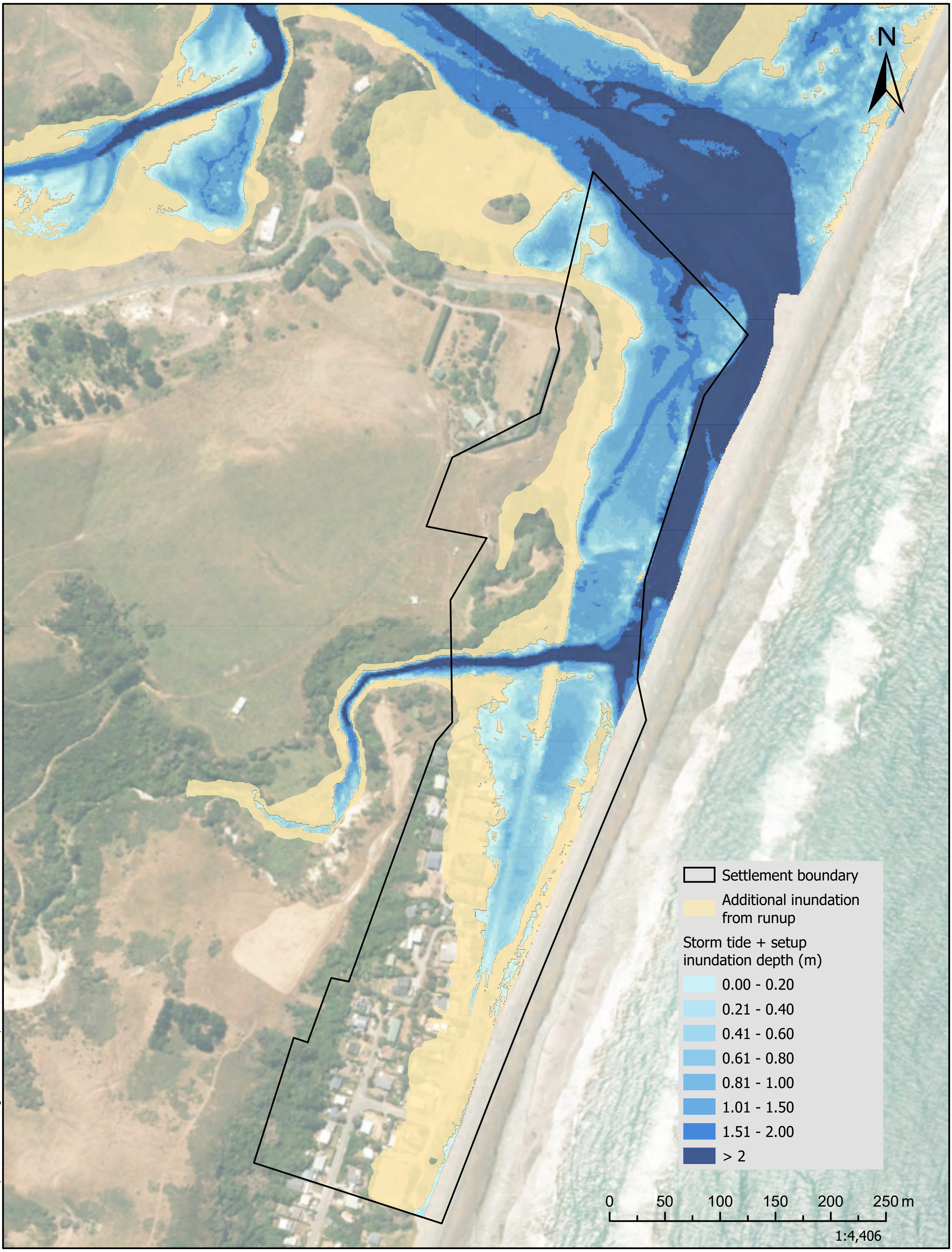
Gore Bay North Coastal Inundation 1% AEP Bathtub Model

Current day

Date: 26/11/2019

JACOBS SPATIAL
Carlaw Park
12-16 Nicholls Lane
Parnell, Auckland
Tel +64 9 928 5500
Fax +64 9 928 5501



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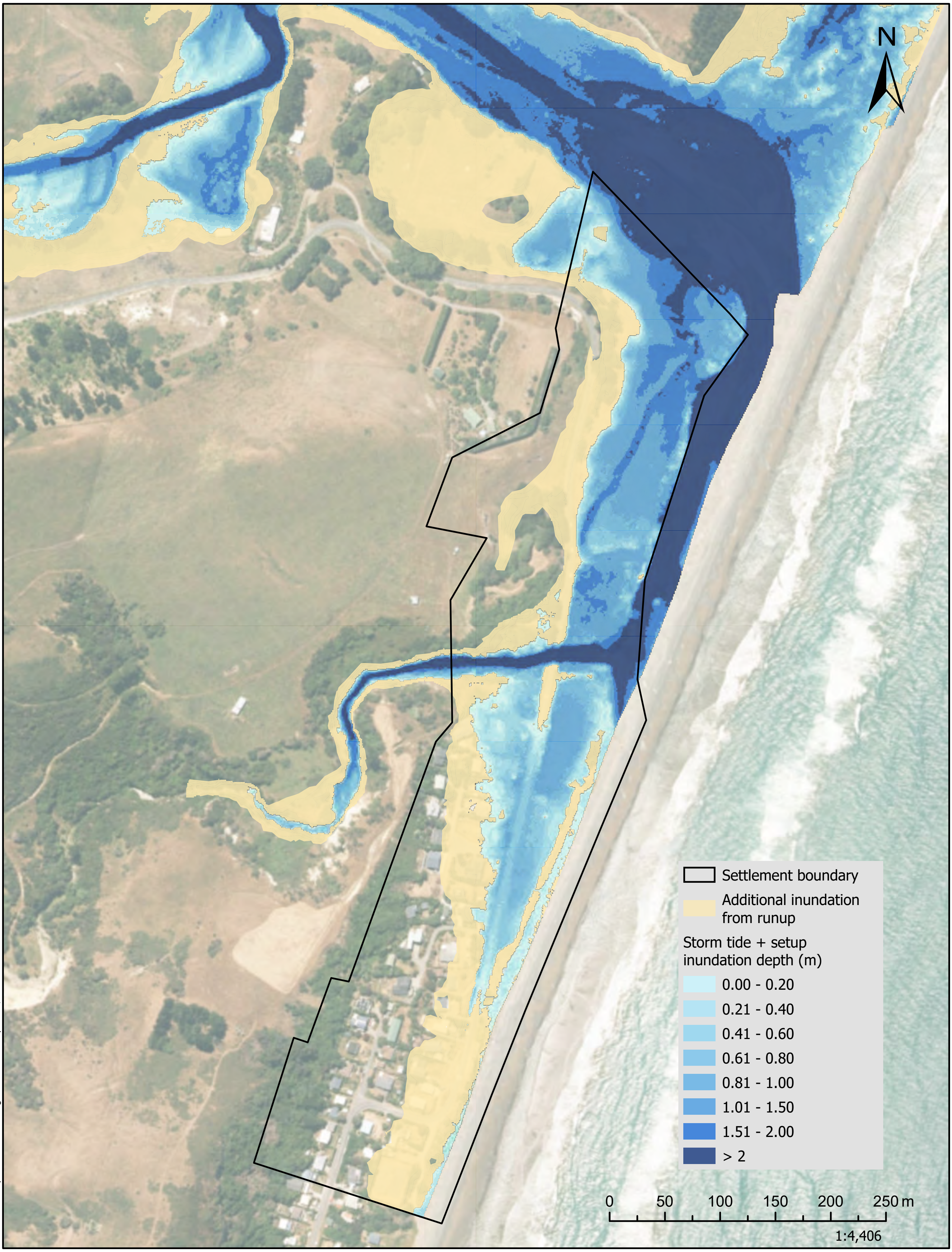
Gore Bay North Coastal Inundation 1% AEP Bathtub Model

30 year RCP 8.5

Date: 12/3/2019

JACOBS SPATIAL

Carlaw Park
12-16 Nicholls Lane
Parnell, Auckland
Tel +64 9 928 5500
Fax +64 9 928 5501



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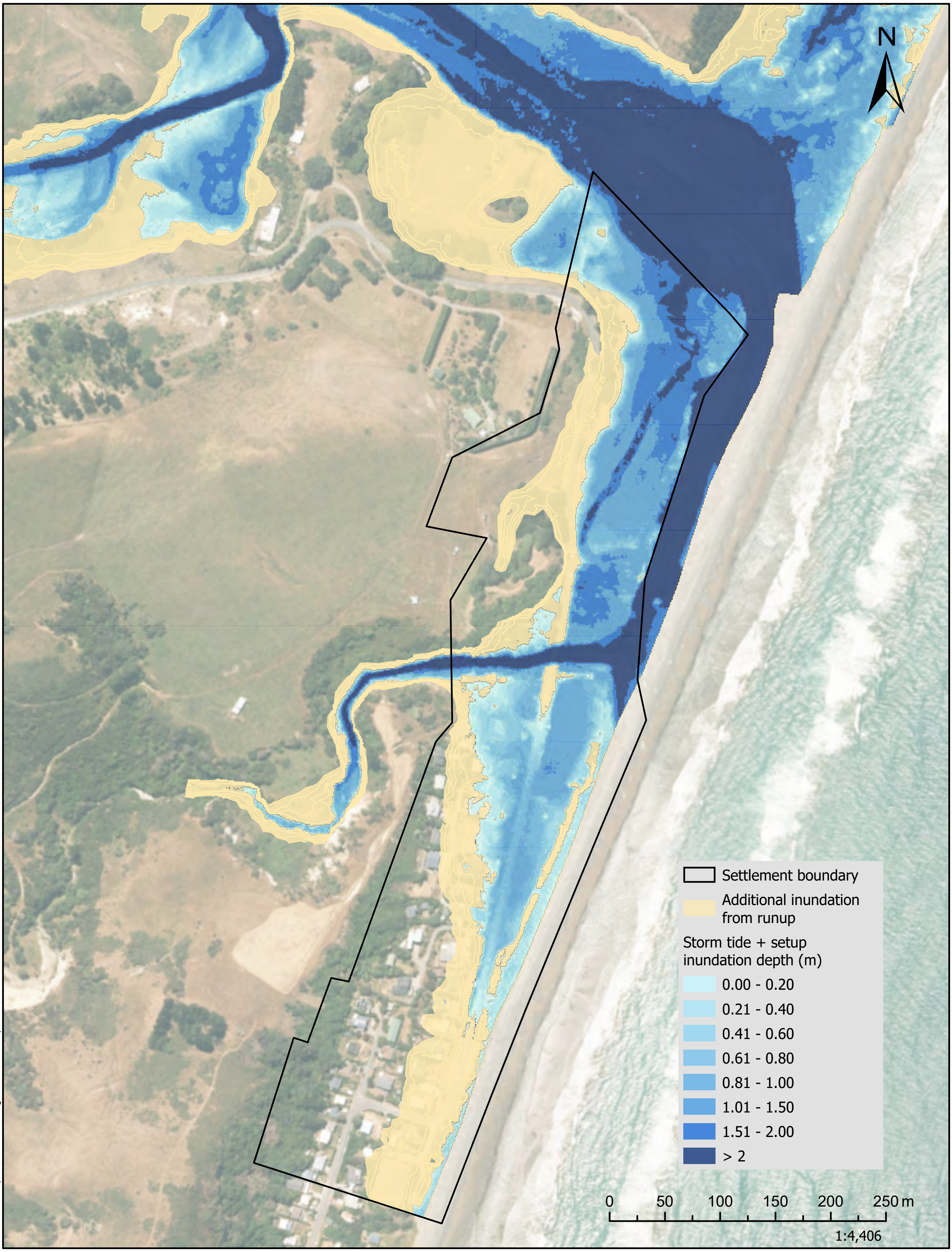
Gore Bay North Coastal Inundation 1% AEP Bathtub Model

50 year RCP 8.5

Date: 26/11/2019

JACOBS SPATIAL
Carlaw Park
12-16 Nicholls Lane
Parnell, Auckland
Tel +64 9 928 5500
Fax +64 9 928 5501



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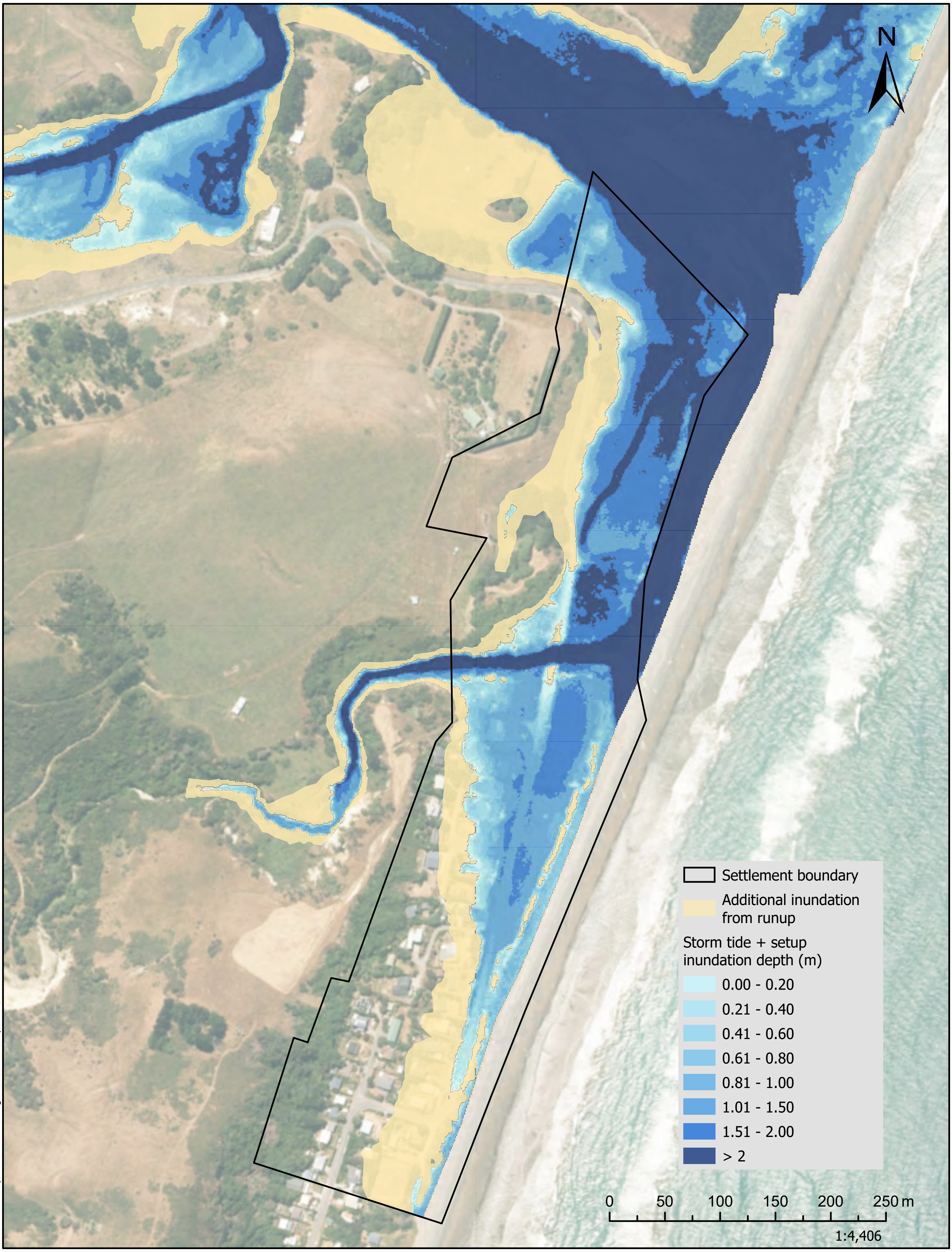
Gore Bay North Coastal Inundation 1% AEP Bathtub Model

50 year RCP 8.5+

Date: 26/11/2019

JACOBS
SPATIAL
Carlaw Park
12-16 Nicholls Lane
Parnell, Auckland
Tel +64 9 928 5500
Fax +64 9 928 5501



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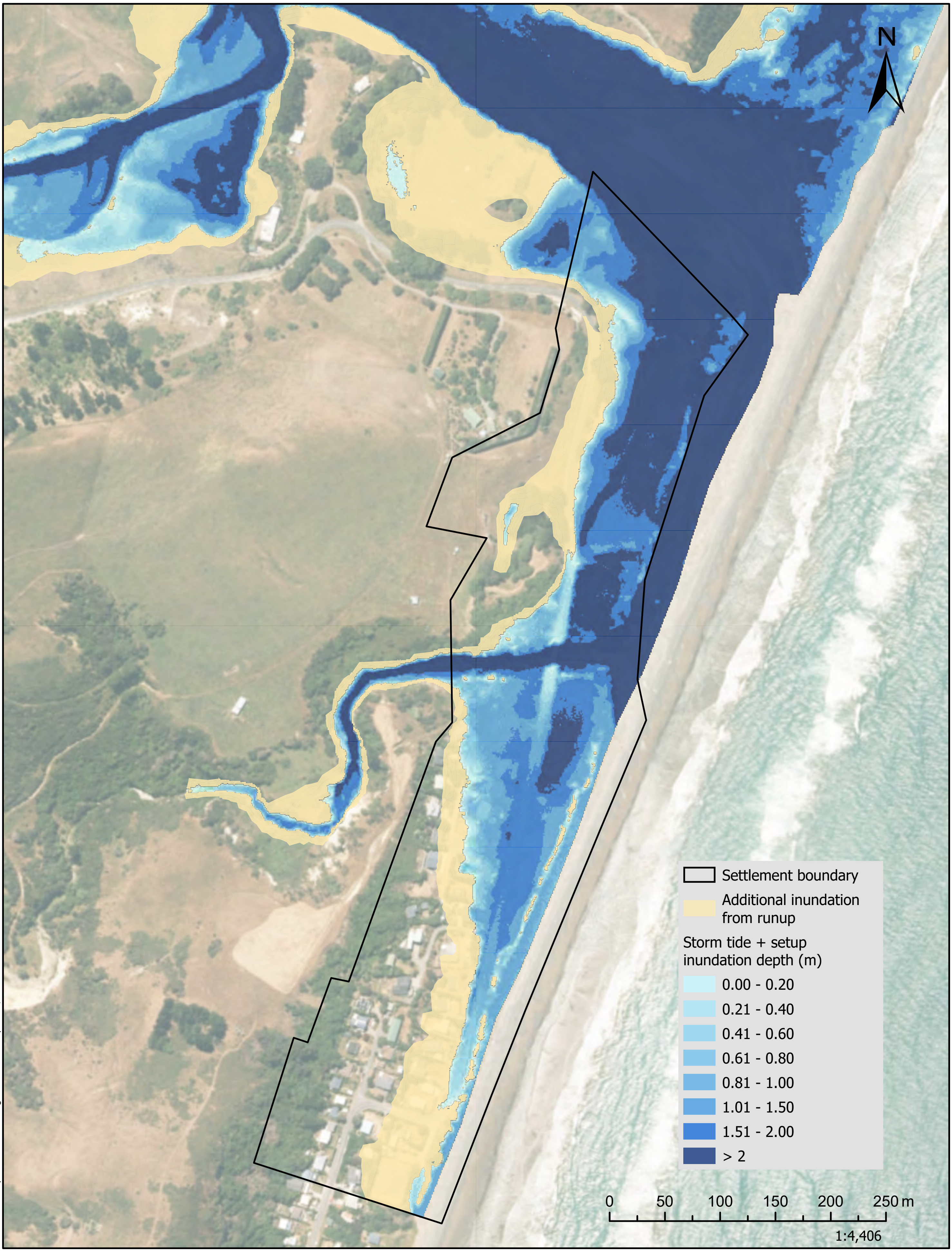
Gore Bay North Coastal Inundation 1% AEP Bathtub Model

100 year RCP 8.5

Date: 26/11/2019

JACOBS SPATIAL
Carlaw Park
12-16 Nicholls Lane
Parnell, Auckland
Tel +64 9 928 5500
Fax +64 9 928 5501



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Gore Bay North Coastal Inundation 1% AEP Bathtub Model

100 year RCP 8.5+

Date: 26/11/2019

JACOBS SPATIAL

Carlaw Park
12-16 Nicholls Lane
Parnell, Auckland
Tel +64 9 928 5500
Fax +64 9 928 5501

Spatial Reference : Name: NZGD 2000 New Zealand Transverse Mercator

J:\IE\Projects\02_New Zealand\IZ128300\22 Technical\Spatial\Hurunui\Working\HurunuiBathtub.aprx

Conway Flats Coastal Inundation 1% AEP Bathtub Model

Current day

Date: 26/11/2019

JACOBS SPATIAL
Carlaw Park
12-16 Nicholls Lane
Parnell, Auckland
Tel +64 9 928 5500
Fax +64 9 928 5501

Conway Flats Coastal Inundation 1% AEP Bathtub Model

30 year RCP 8.5

Date: 12/3/2019

JACOBS SPATIAL
Carlaw Park
12-16 Nicholls Lane
Parnell, Auckland
Tel +64 9 928 5500
Fax +64 9 928 5501

Spatial Reference : Name: NZGD 2000 New Zealand Transverse Mercator

J:\IE\Projects\02_New Zealand\IZ128300\22 Technical\Spatial\Hurunui\Working\HurunuiBathtub.aprx

Conway Flats Coastal Inundation 1% AEP Bathtub Model

50 year RCP 8.5

Date: 26/11/2019

JACOBS SPATIAL
Carlaw Park
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Parnell, Auckland
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Spatial Reference : Name: NZGD 2000 New Zealand Transverse Mercator

J:\IE\Projects\02_New Zealand\IZ128300\22 Technical\Spatial\Hurunui\Working\HurunuiBathtub.aprx

Conway Flats Coastal Inundation 1% AEP Bathtub Model

50 year RCP 8.5+

Date: 26/11/2019

JACOBS SPATIAL
Carlaw Park
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Spatial Reference : Name: NZGD 2000 New Zealand Transverse Mercator

J:\IE\Projects\02_New Zealand\IZ128300\22 Technical\Spatial\Hurunui\Working\HurunuiBathtub.aprx

Conway Flats Coastal Inundation 1% AEP Bathtub Model

100 year RCP 8.5

Date: 26/11/2019

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Spatial Reference : Name: NZGD 2000 New Zealand Transverse Mercator

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Conway Flats Coastal Inundation 1% AEP Bathtub Model

100 year RCP 8.5+

Date: 26/11/2019

JACOBS SPATIAL
Carlaw Park
12-16 Nicholls Lane
Parnell, Auckland
Tel +64 9 928 5500
Fax +64 9 928 5501

Claverley Coastal Inundation 1% AEP Bathtub Model

Current day

Date: 09/01/2020

JACOBS
SPATIAL
Carlaw Park
12-16 Nicholls Lane
Parnell, Auckland
Tel +64 9 928 5500
Fax +64 9 928 5501

Spatial Reference : Name: NZGD 2000 New Zealand Transverse Mercator

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Spatial Reference : Name: NZGD 2000 New Zealand Transverse Mercator

J:\IE\Projects\02_New Zealand\IZ128300\22 Technical\Spatial\Hurunui\Working\Hurunui\Bathtub.aprx

Claverley Coastal Inundation 1% AEP Bathtub Model

30 year RCP 8.5

Date: 09/01/2020

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Spatial Reference : Name: NZGD 2000 New Zealand Transverse Mercator

J:\IE\Projects\02_New Zealand\IZ128300\22 Technical\Spatial\Hurunui\Working\Hurunui\Bathtub.aprx

Claverley Coastal Inundation 1% AEP Bathtub Model

50 year RCP 8.5

Date: 09/01/2020

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Parnell, Auckland
Tel +64 9 928 5500
Fax +64 9 928 5501

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Spatial Reference : Name: NZGD 2000 New Zealand Transverse Mercator

Claverley Coastal Inundation 1% AEP Bathtub Model

50 Year RCP 8.5+

Date: 09/01/2020

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Claverley Coastal Inundation 1% AEP Bathtub Model

100 year RCP 8.5

Date: 09/01/2020

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Spatial Reference : Name: NZGD 2000 New Zealand Transverse Mercator

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Claverley Coastal Inundation 1% AEP Bathtub Model

100 Year RCP 8.5+

Date: 09/01/2020

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Carlaw Park
12-16 Nicholls Lane
Parnell, Auckland
Tel +64 9 928 5500
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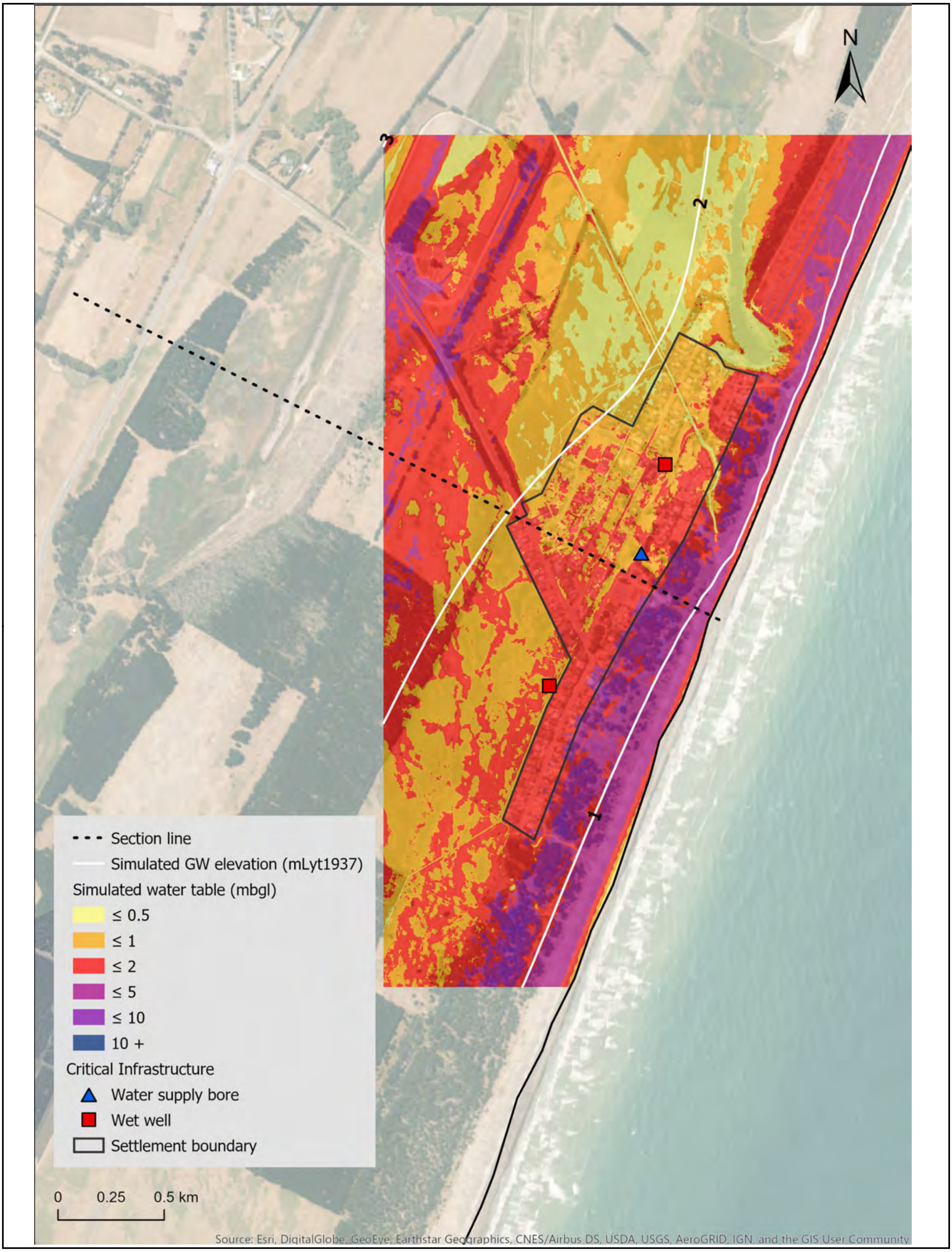
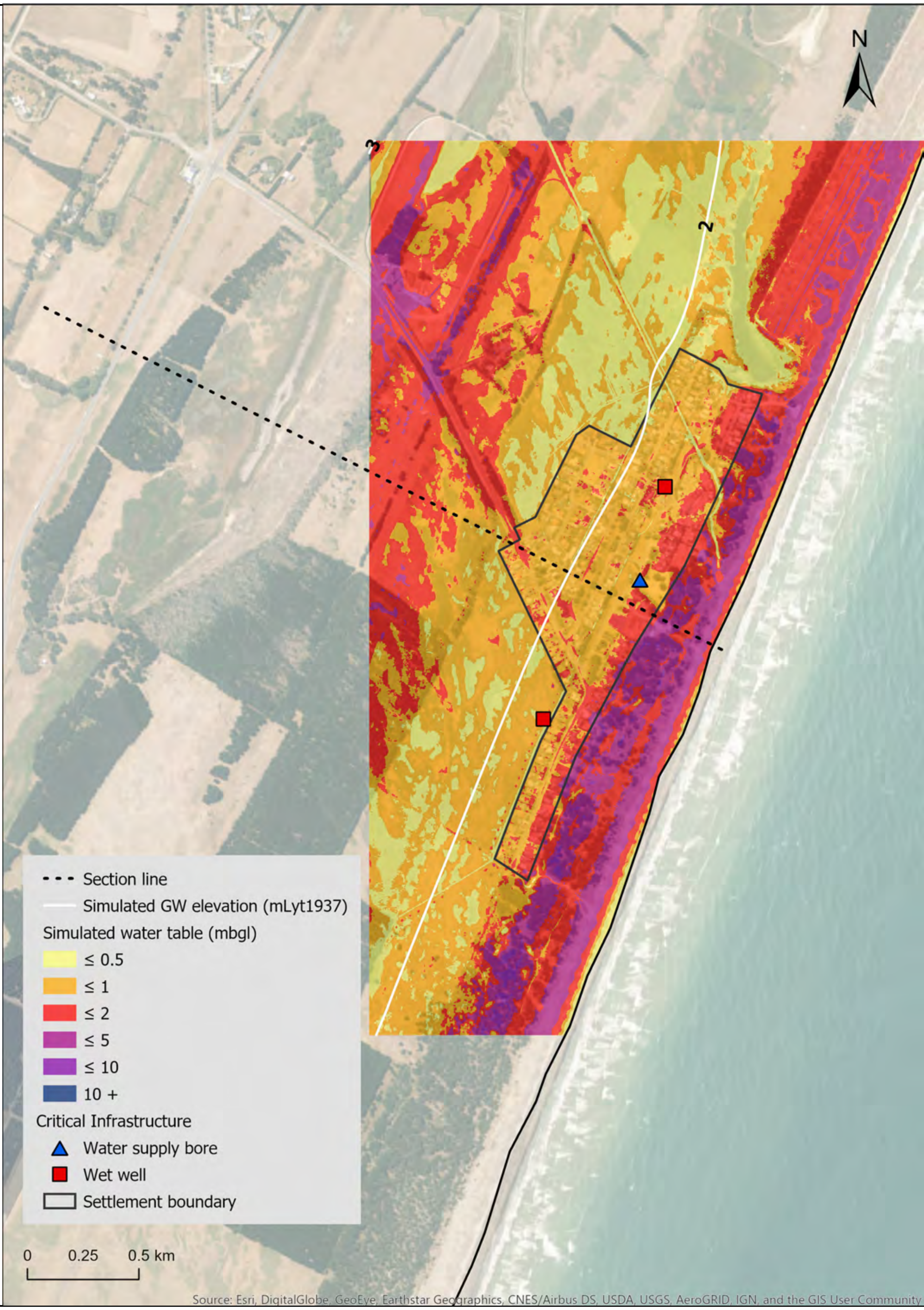
Appendix I. Shallow Groundwater Rise Hazard Maps



Leithfield Beach Shallow Groundwater Depths (Indicative Average)
Present Day (2020) Sea Level

Date: 04/20/2020

JACOBS SPATIAL
Level 2, Wynn Williams Building
47 Hereford St
Christchurch Central 8013
New Zealand
T +64 3 940 4900
F +64 3 940 4901



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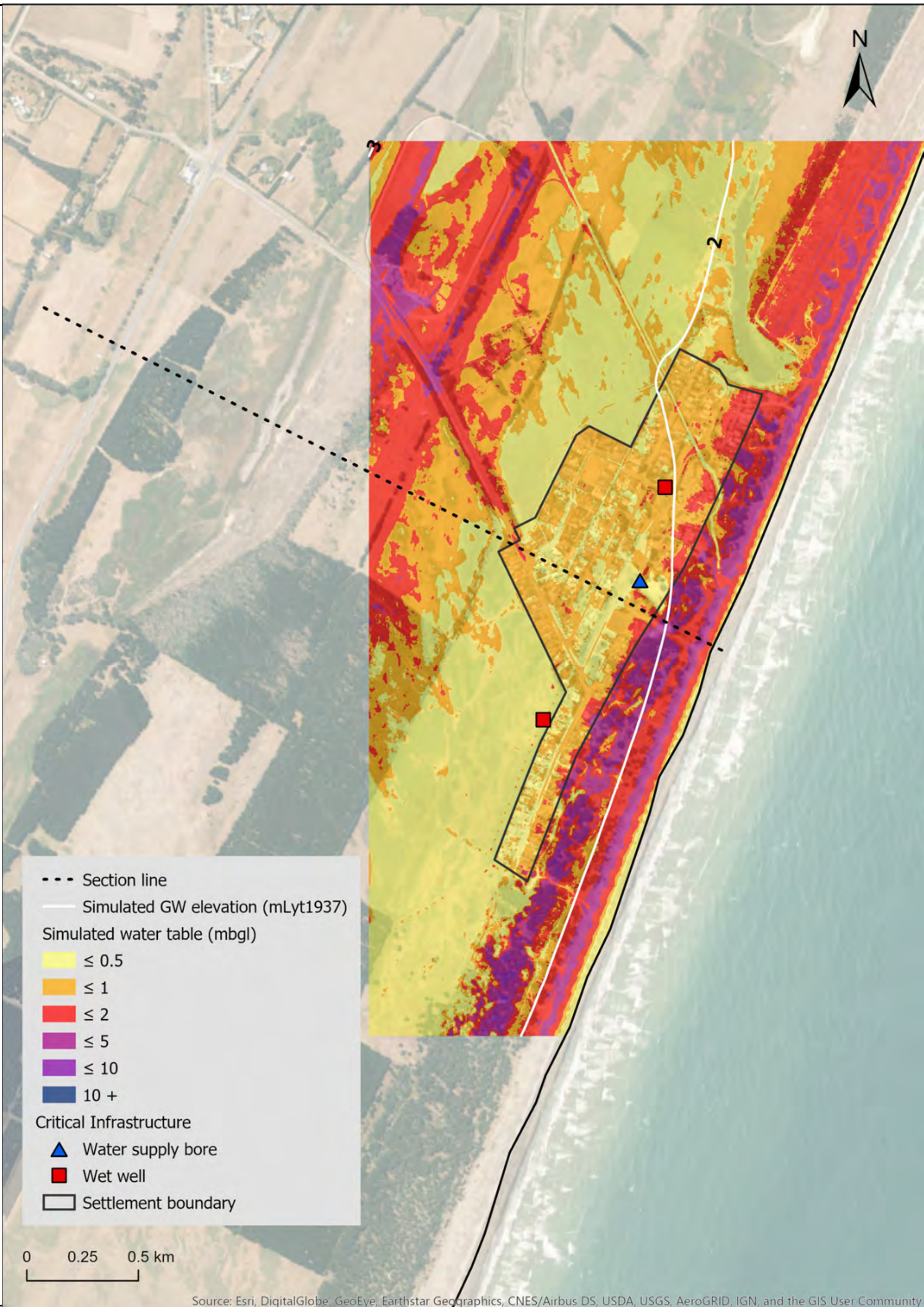
Leithfield Beach Shallow Groundwater Depths (Indicative Average)
RCP 8.5+ 50year Sea Level Rise Scenario

Date: 04/20/2020

JACOBS
SPATIAL
Level 2, Wynn Williams Building
47 Hereford St
Christchurch Central 8013
New Zealand
T +64 3 940 4900
F +64 3 940 4901



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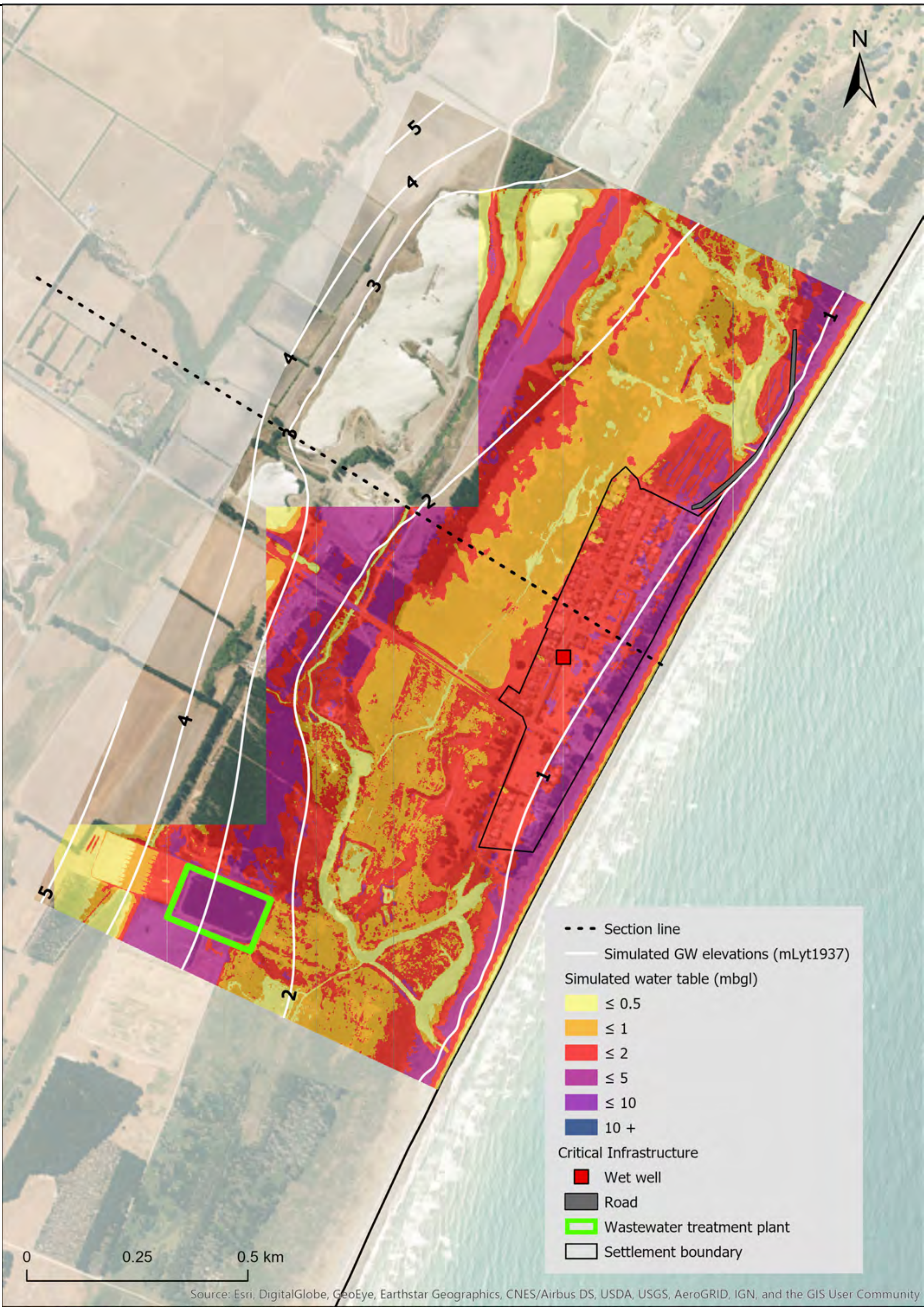
Leithfield Beach Shallow Groundwater Depths (Indicative Average)
RCP 8.5+ 100 year Sea Level Rise Scenario

Date: 04/20/2020

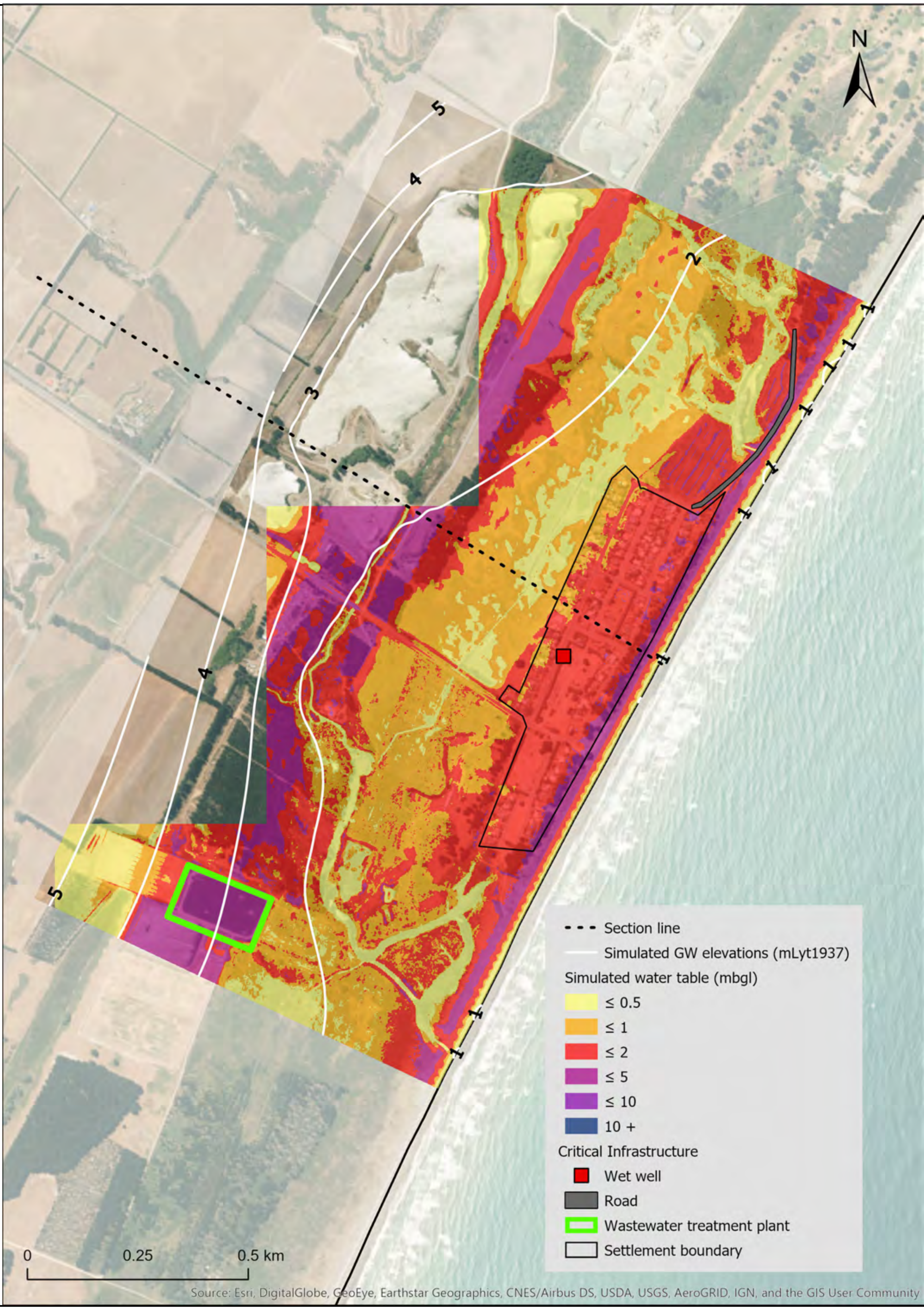
JACOBS
SPATIAL
Level 2, Wynn Williams Building
47 Hereford St
Christchurch Central 8013
New Zealand
T +64 3 940 4900
F +64 3 940 4901



**Amberley Beach Shallow Groundwater Depths (Indicative Average)
Present Day (2020) Sea Level**

Date: 04/20/2020

JACOBS
SPATIAL
Level 2, Wynn Williams Building
47 Hereford St
Christchurch Central 8013
New Zealand
T +64 3 940 4900
F +64 3 940 4901



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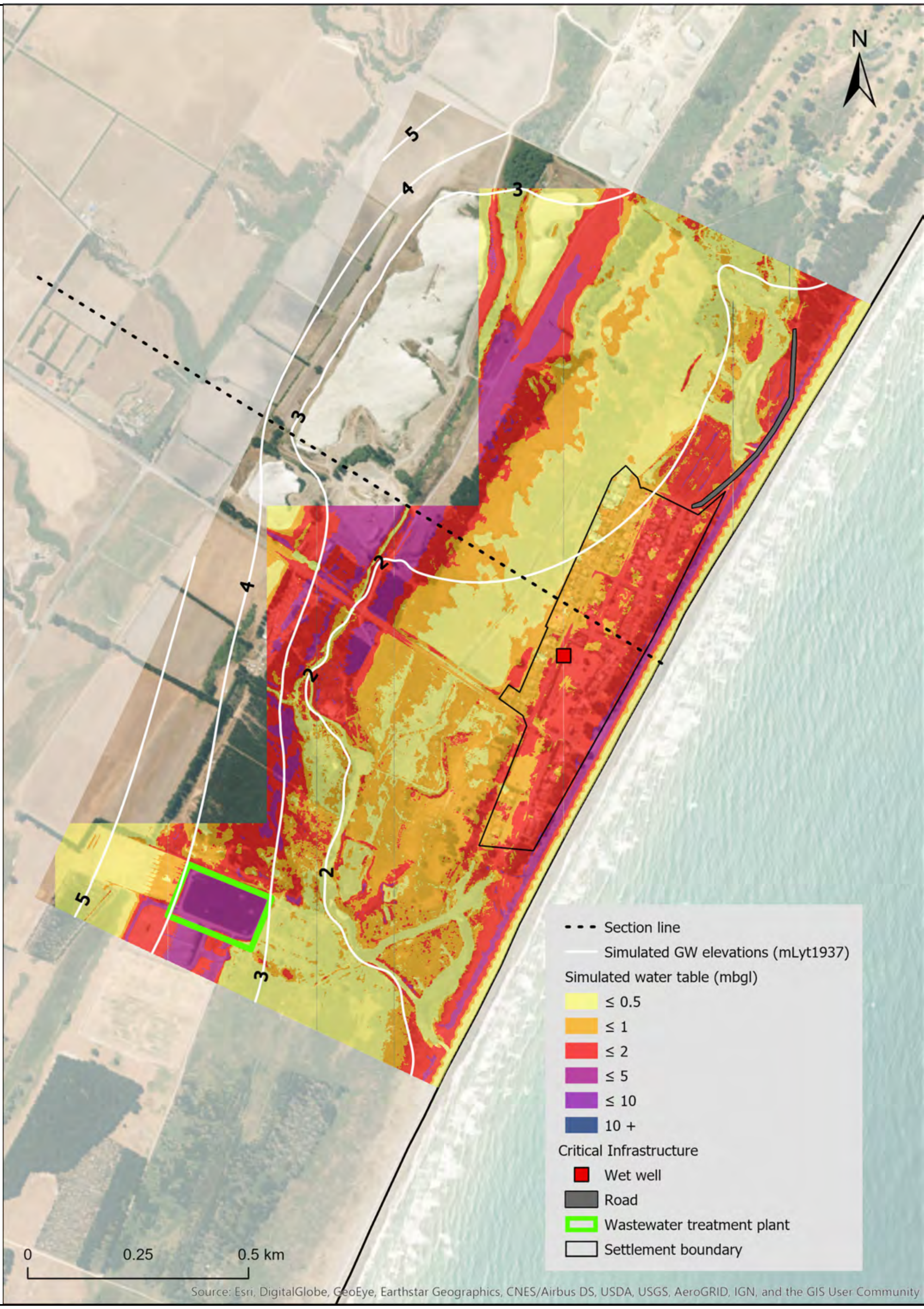
Amberley Beach Shallow Groundwater Depths (Indicative Average)
RCP 8.5+ 50 Year Sea Level Rise Scenario

Date: 04/20/2020

JACOBS
SPATIAL

Level 2, Wynn Williams Building
47 Hereford St
Christchurch Central 8013
New Zealand
T +64 3 940 4900
F +64 3 940 4901



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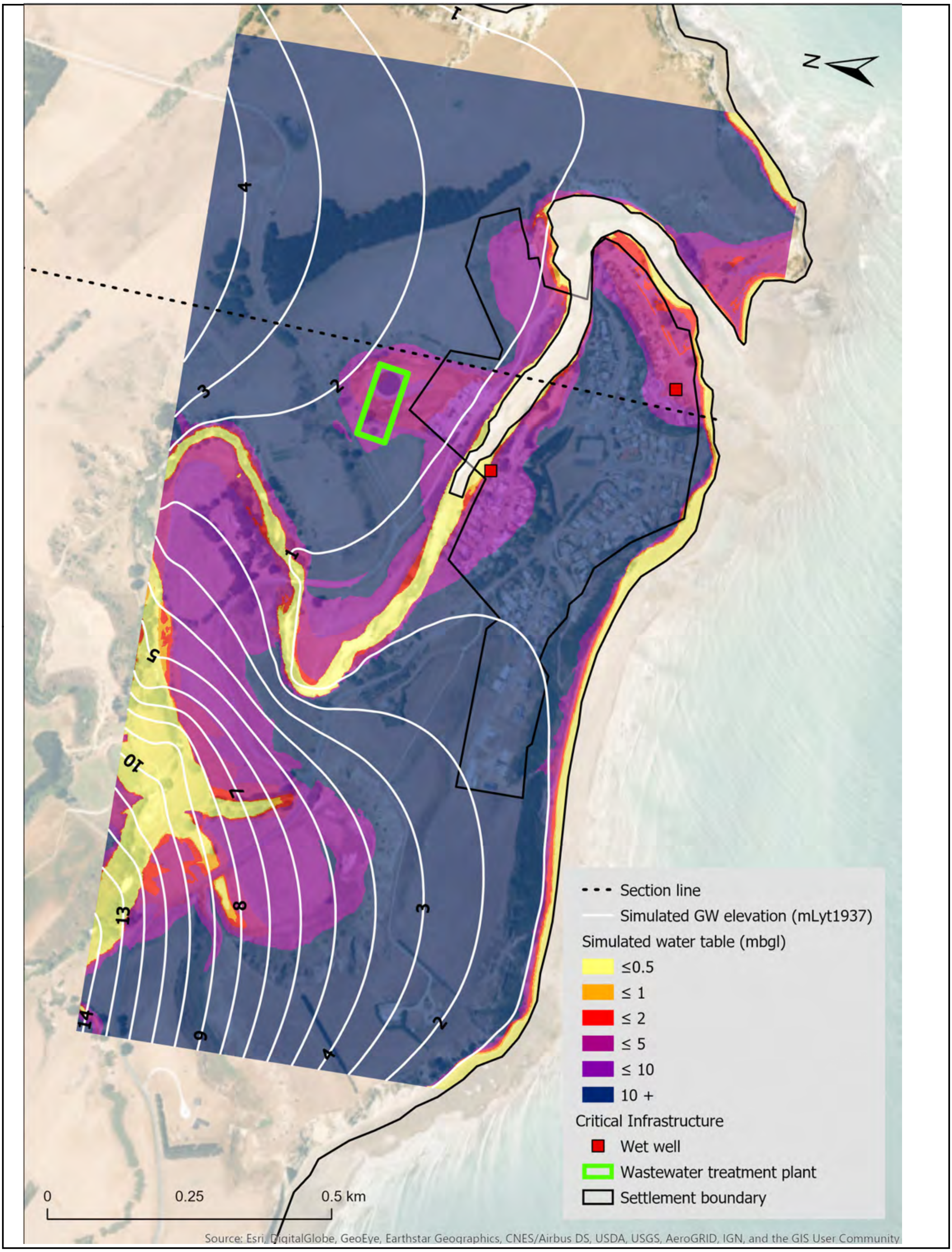
Amberley Beach Shallow Groundwater Depths (Indicative Average)
RCP 8.5+ 100 Year Sea Level Rise Scenario

Date: 04/20/2020

JACOBS SPATIAL
Level 2, Wynn Williams Building
47 Hereford St
Christchurch Central 8013
New Zealand
T +64 3 940 4900
F +64 3 940 4901



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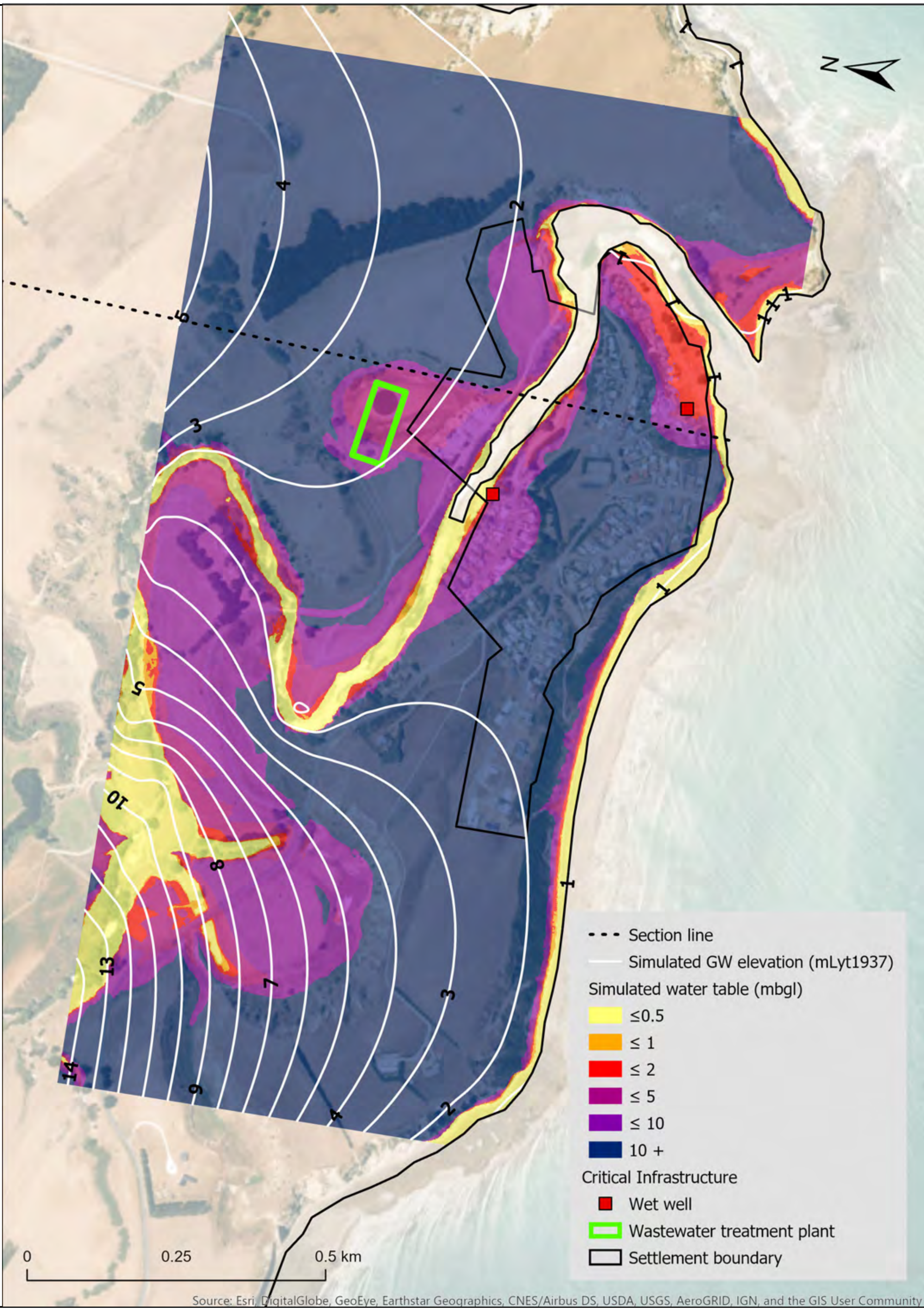
Motunau Shallow Groundwater Depths (Indicative Average)
Present Day (2020) Sea Level

Date: 04/20/2020

JACOBS SPATIAL
Level 2, Wynn Williams Building
47 Hereford St
Christchurch Central 8013
New Zealand
T +64 3 940 4900
F +64 3 940 4901



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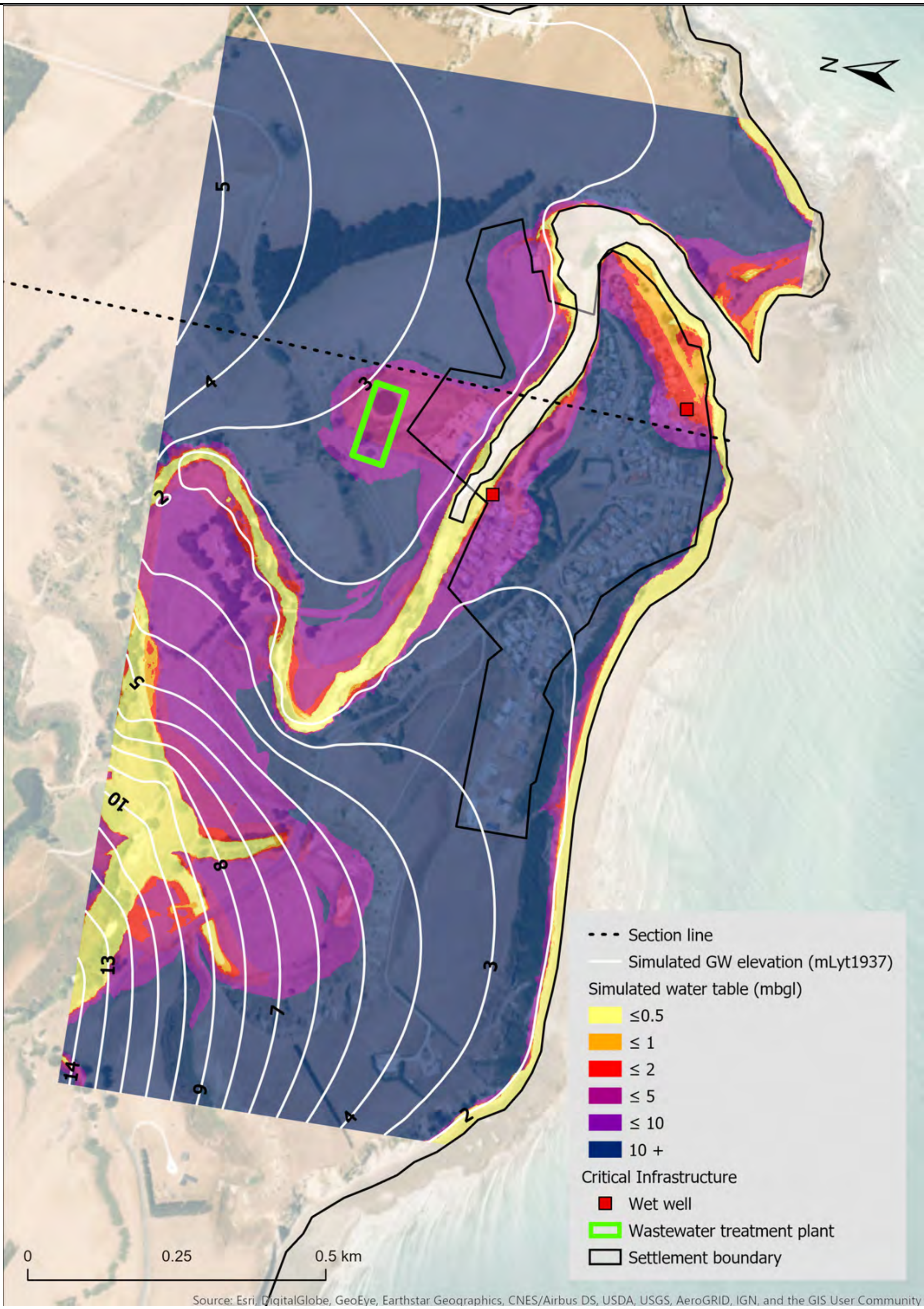
Motunau Shallow Groundwater Depths (Indicative Average)
RCP 8.5+ 50 Year Sea Level Rise Scenario

Date: 04/20/2020

JACOBS
SPATIAL
Level 2, Wynn Williams Building
47 Hereford St
Christchurch Central 8013
New Zealand
T +64 3 940 4900
F +64 3 940 4901



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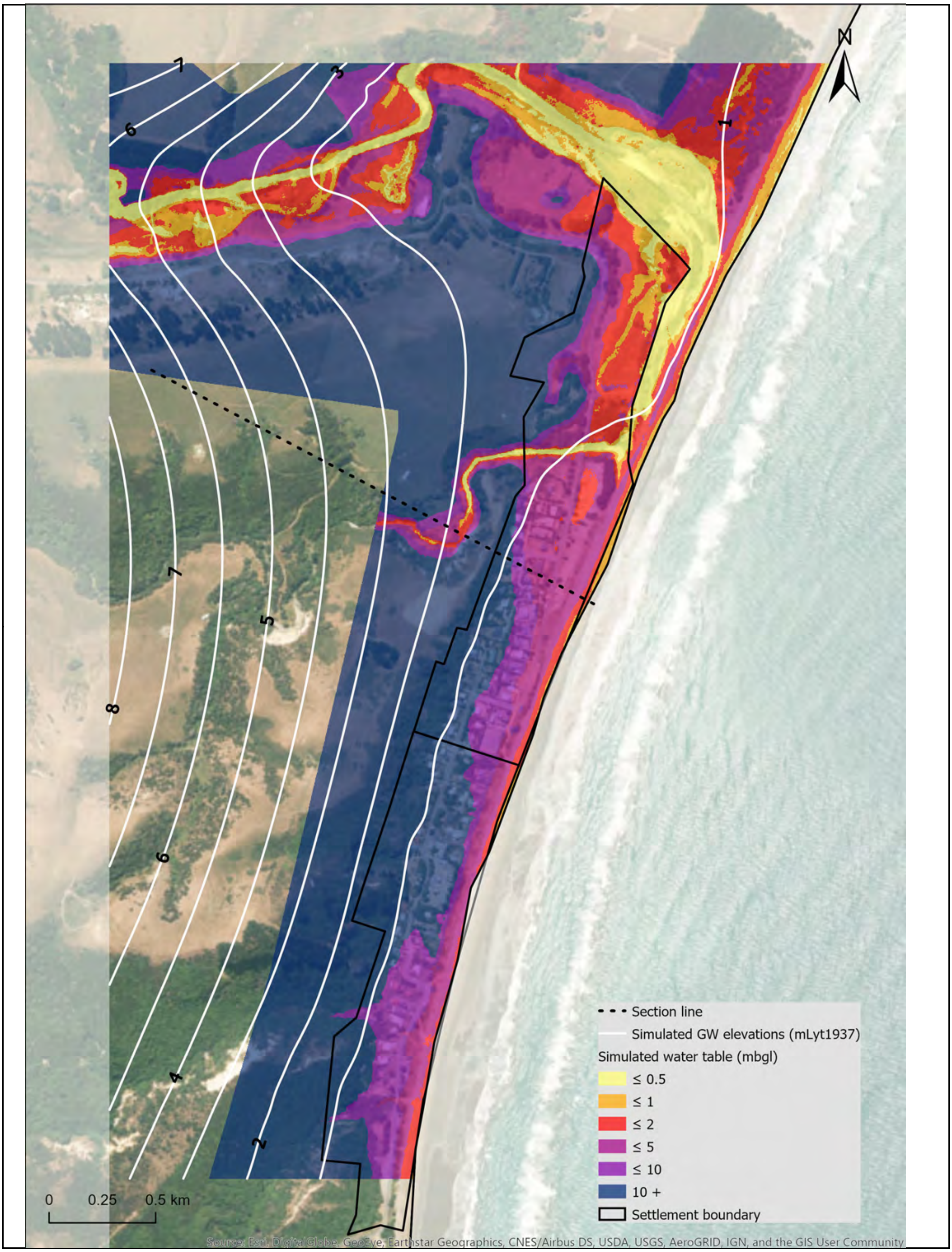
Motunau Shallow Groundwater Depths (Indicative Average)
RCP 8.5+ 100 Year Sea Level Rise Scenario

Date: 04/20/2020

JACOBS
SPATIAL
Level 2, Wynn Williams Building
47 Hereford St
Christchurch Central 8013
New Zealand
T +64 3 940 4900
F +64 3 940 4901



Gore Bay Shallow Groundwater Depths (Indicative Average)
Present Day (2020) Sea Level

Date: 04/20/2020

JACOBS SPATIAL
Level 2, Wynn Williams Building
47 Hereford St
Christchurch Central 8013
New Zealand
T +64 3 940 4900
F +64 3 940 4901

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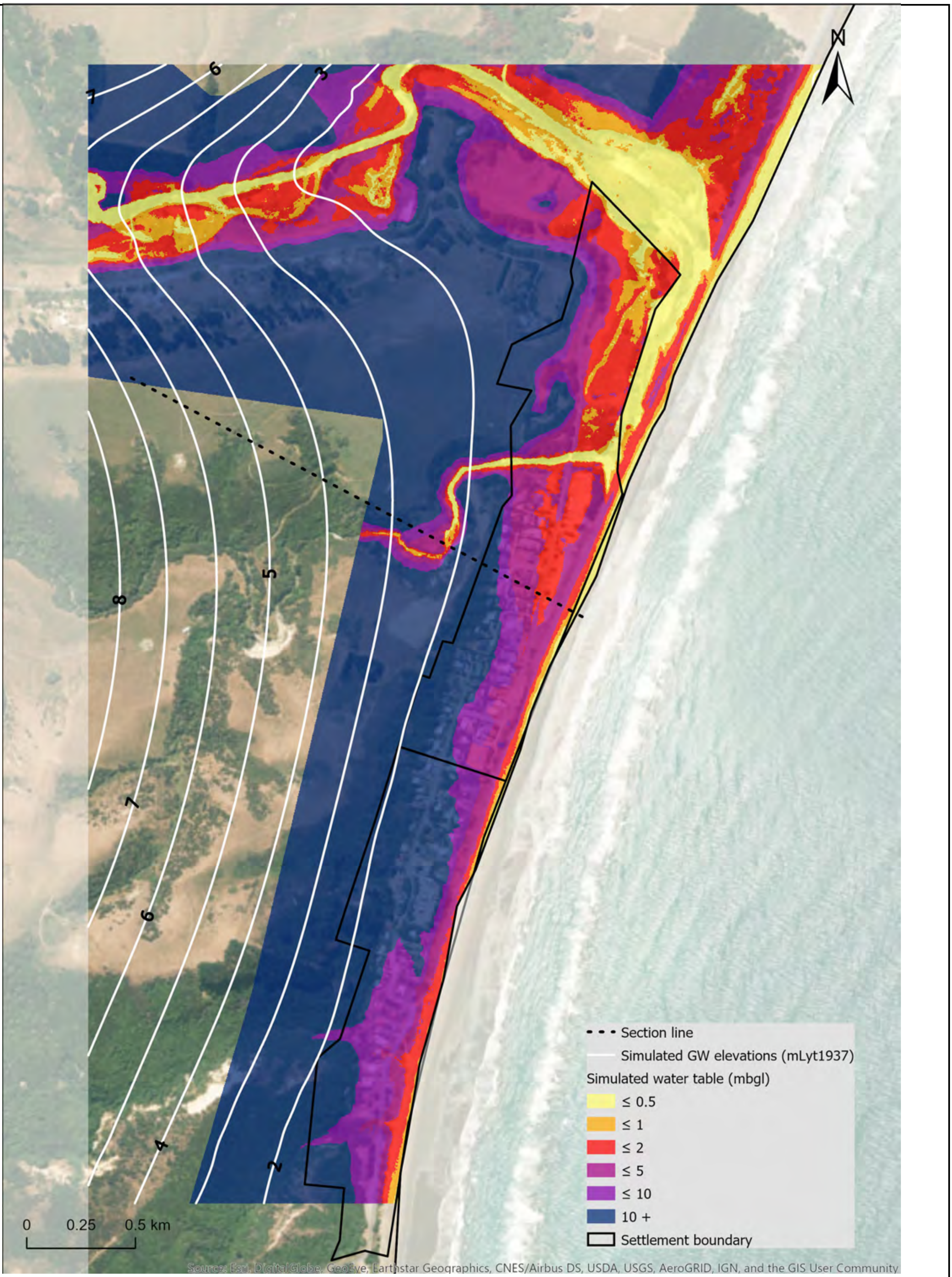

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Gore Bay Shallow Groundwater Depths (Indicative Average)
RCP 8.5+ 50 Year Sea Level Rise Scenario

Date: 04/20/2020

JACOBS
SPATIAL
Level 2, Wynn Williams Building
47 Hereford St
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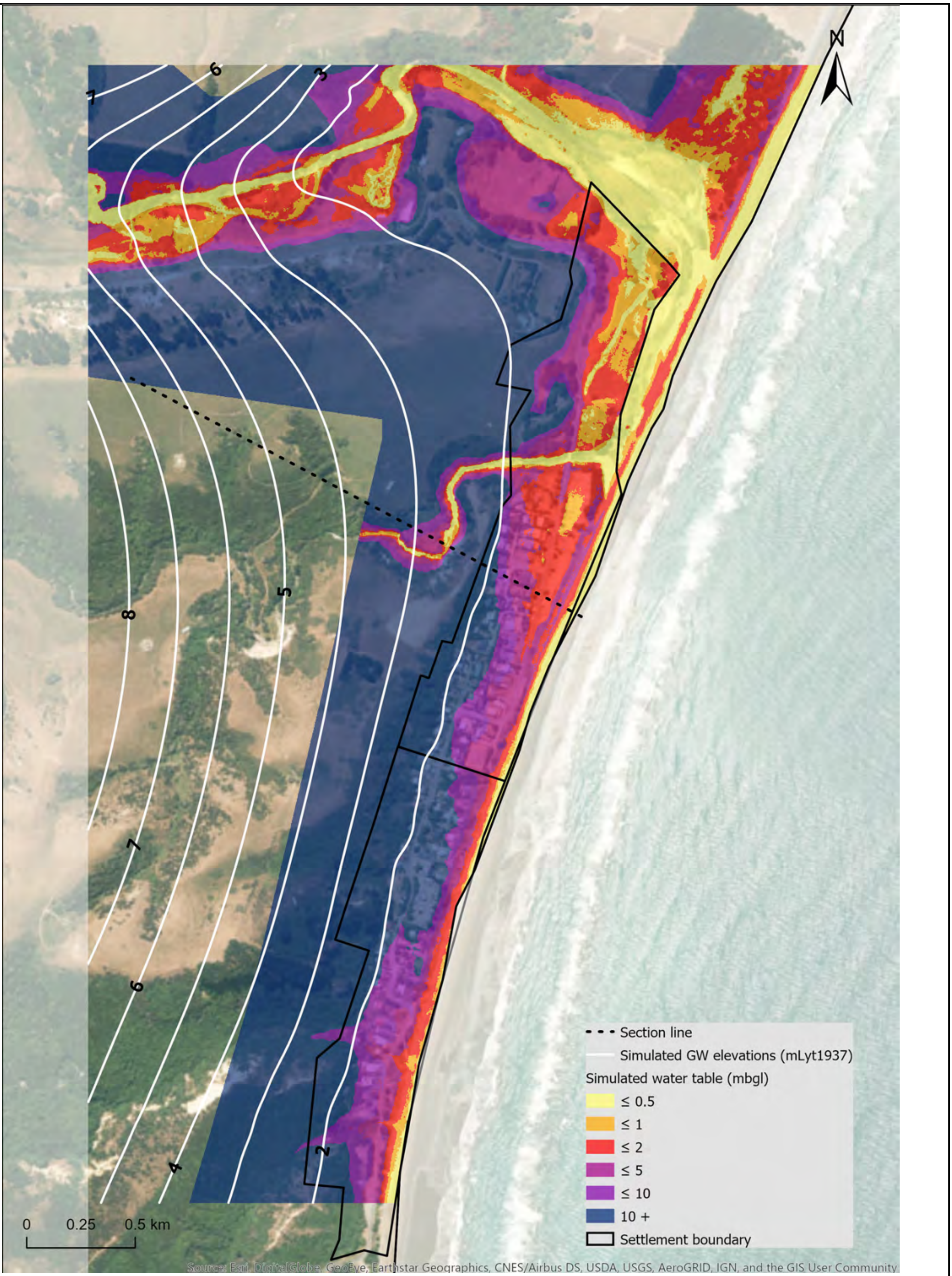

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Gore Bay Shallow Groundwater Depths (Indicative Average)
RCP 8.5+ 100 Year Sea Level Rise Scenario

Date: 04/20/2020

JACOBS SPATIAL
Level 2, Wynn Williams Building
47 Hereford St
Christchurch Central 8013
New Zealand
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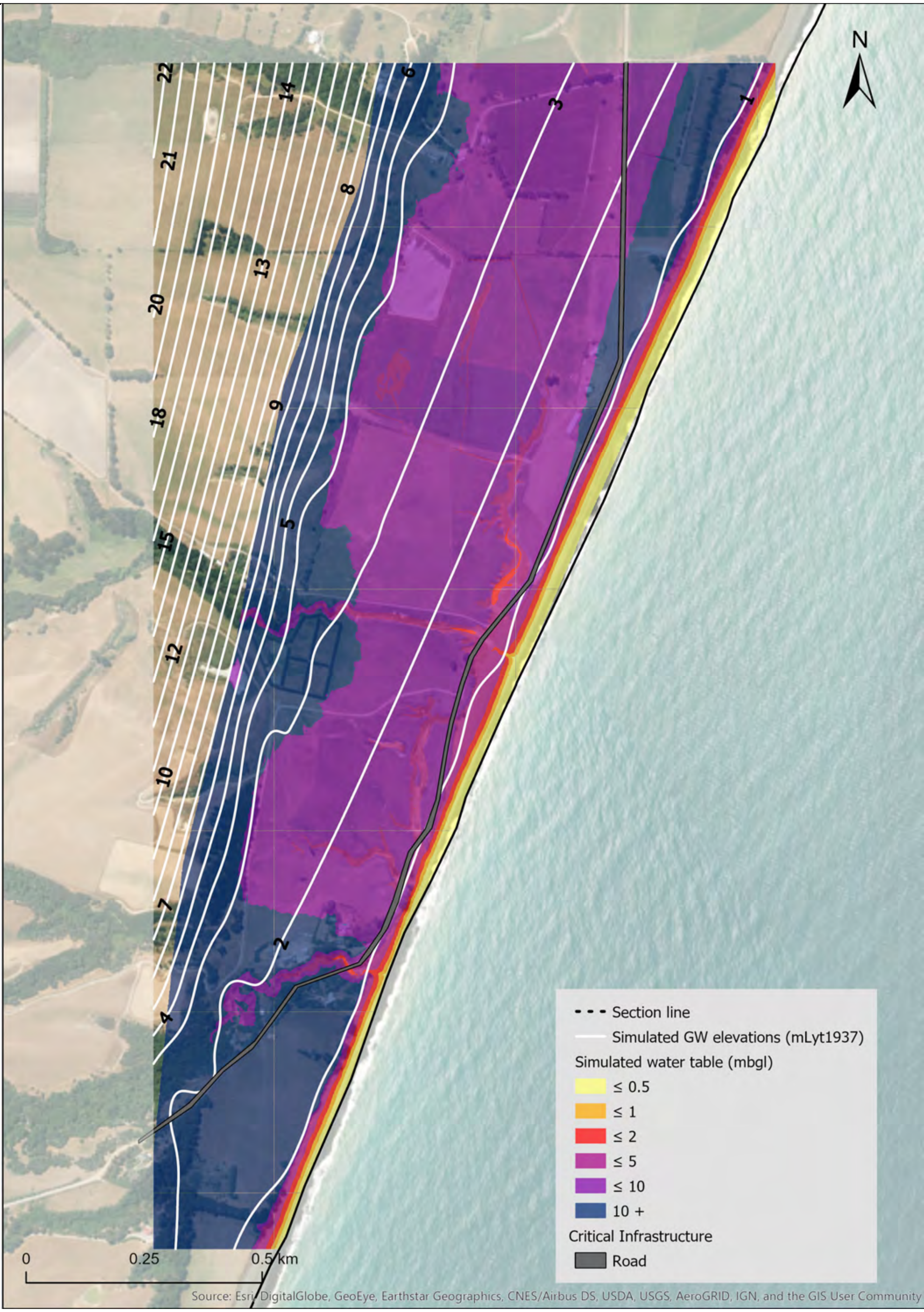
F +64 3 940 4901



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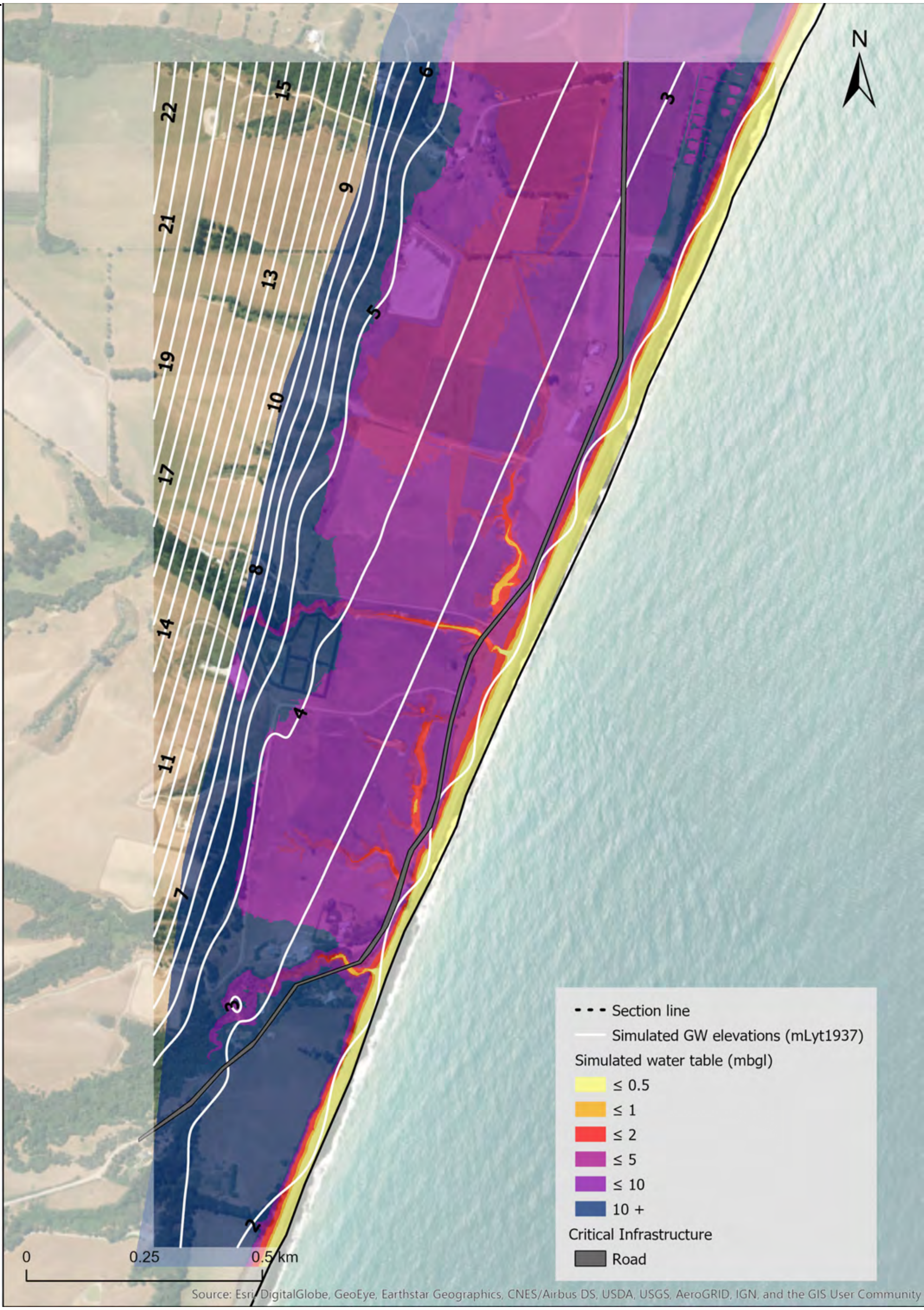
Conway Flat Shallow Groundwater Depths (Indicative Average)
Present Day (2020) Sea Level

JACOBS
SPATIAL
Level 2, Wynn Williams Building
47 Hereford St
Christchurch Central 8013
New Zealand
T +64 3 940 4900
F +64 3 940 4901

Date: 04/20/2020



Conway Flat Shallow Groundwater Depths (Indicative Average)
RCP 8.5+ 100 Year Sea Level Rise Scenario

Date: 04/20/2020

JACOBS
SPATIAL
Level 2, Wynn Williams Building
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New Zealand
T +64 3 940 4900
F +64 3 940 4901

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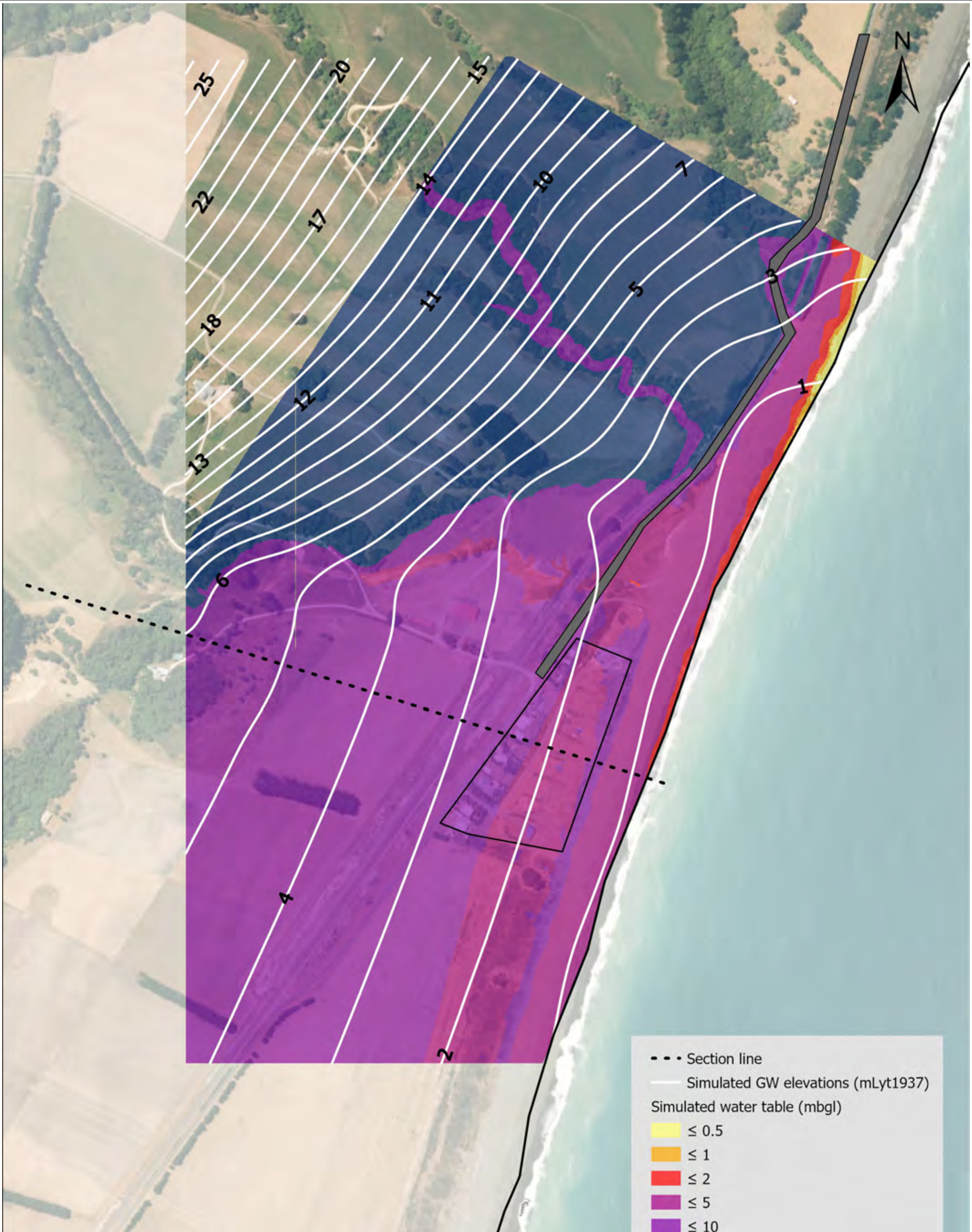

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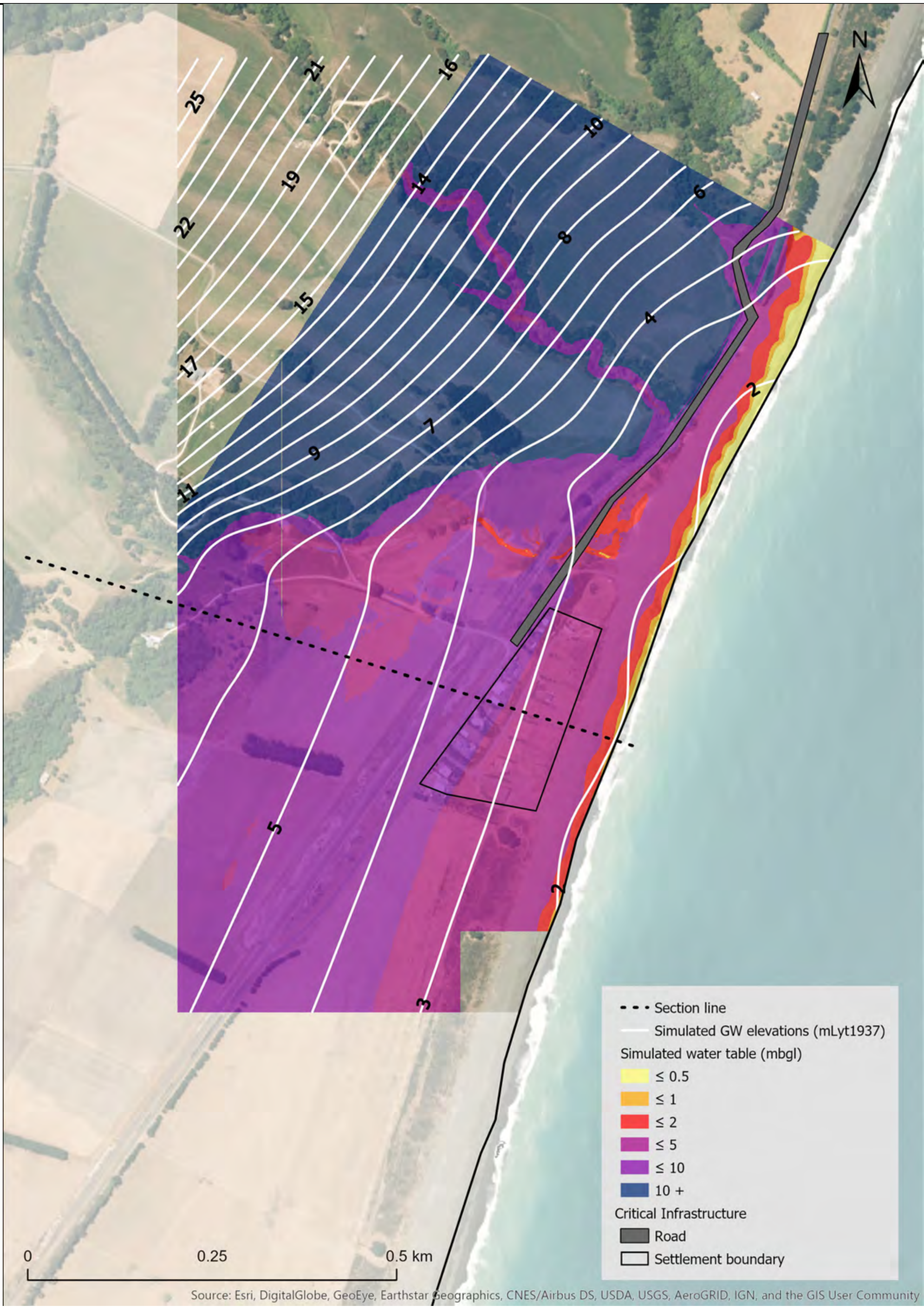
Claverley Shallow Groundwater Depths (Indicative Average)
Present Day (2020) Sea Level

Date: 04/20/2020

JACOBS
SPATIAL
Level 2, Wynn Williams Building
47 Hereford St
Christchurch Central 8013
New Zealand
T +64 3 940 4900
F +64 3 940 4901



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Claverley Shallow Groundwater Depths (Indicative Average)
RCP 8.5+ 100 Year Sea Level Rise Scenario

Date: 04/20/2020

JACOBS
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F +64 3 940 4901