IN THE MATTER **of the Resource Management Act 1991(RMA)**

AND

IN THE MATTER **of Private Plan Change 100 – Riverhead to the Auckland Unitary Plan**

JOINT WITNESS STATEMENT (JWS) IN RELATION TO:

Topic: Stormwater and Flooding (2)

Date 5 August 2025

Expert Conferencing Held on: 5 August 2025

Venue: Auckland Town Hall and Online

Independent Facilitator: Marlene Oliver

Admin Support: Rebecca Sanders

1 Attendance:

1.1 The list of participants is included in the schedule at the end of this Statement.

1.2 Declarations – the participants expertise and roles are set out in the schedule. This JWS should be read having regard to those relationships.

2 Basis of Attendance and Environment Court Practice Note 2023

2.1 All participants agree to the following:

(a) The Environment Court Practice Note 2023 provides relevant guidance and protocols for the expert conferencing session;
(b) They will comply with the relevant provisions of the Environment Court Practice Note 2023;
(c) They will make themselves available to appear before the Panel;
(d) This statement is to be filed with the Panel and posted on the Council's website.

3 Matters considered at Conferencing – Agenda and Outcomes

3.1 Additional Modelling

3.1.1 Further to JWS Stormwater and Flooding 1 dated 25 June 2025 the experts for the applicant provided additional modelling as set out in Attachment A (Further Assessment FRA PC100 Volume 2 – dated 29 July 2025).

3.1.2 With reference to JWS stormwater and flooding (1) section 3.1.1, additional Scenario 19 was discussed but the position of the experts remains as set out in JWS stormwater and flooding (1).

3.2 HP24 Is the Applicant's stormwater model fit for purpose to assess the impact of development from PC100 on flooding downstream of the PC100 area?

3.2.1 All stormwater experts consider that the SW model is fit for purpose to assess the impact of development from PC100 on flooding downstream of the PC100 area.

3.3 HP25 Is the Applicant's stormwater model of a sufficient level of detail and granularity that it can show that the requirements of Schedule 2 and 4 of the NDC can be met in full, or alternatively that a Best Practicable Option in relation to flood management can be achieved?

3.3.1 BR, PW, ZW, RP, MI and JI consider that the stormwater model is of a sufficient level of detail and granularity to confirm that it can meet the requirements of Schedule 2 and 4 of the NDC.

3.3.2 All stormwater experts consider that at subsequent resource consent stage further details will need to be included to confirm all requirements of Schedule 4 of the NDC are met.

3.3.3 All stormwater experts consider that the stormwater model is of a sufficient level of detail and granularity to confirm that a Best Practicable Option in relation to flood management can be achieved.

3.4 HP26 If the answer is "no" to either questions 1 [HP24] or 2 [HP25] above, what additional modelling is required to be undertaken? How long will this work take?

3.4.1 N/A

3.5 HP27 Will PC100 result in an increase in flooding on downstream (or upstream) properties over and above the existing situation?

3.5.1 ZW and BR consider that in the primary flooding scenarios used for assessing flood risk under Auckland Council's guidelines (i.e. the 100yr ARI 3.8°C Climate Change with both Existing and Maximum Probable Development) the modelling demonstrates no increase in flooding on downstream or upstream properties as a result of PC100 as proposed.

3.5.2 DS, KL and SF consider that the Auckland Council guidelines referred to in 3.5.1 identify a floodplain/hazard and there is a wider basis on which an increase in flooding should be considered. Flood risk assessment should consider a wider range of storm events including assessing effects on flood extent, frequency, duration, depth and velocity.

3.5.3 All stormwater experts consider that the additional modelling results (attached as Attachment A) show that in some scenarios there are localised increases. However, in the scenarios where this occurs, the increases are generally contained within the existing stream corridors. In all scenarios, with and without climate change, there are areas of decrease in flooding, particularly along Cambridge Road and upstream of Riverhead Road.

3.5.4 SF also notes that 22 Duke Street has been modelled (scenario 12-13) to be subject to more flooding of up to 115mm in the two year storm event with 2.1 degrees Celsius climate change and up to 70mm in the ten year with 2.1 degrees Celsius climate change (noting this is based on ED for all catchment areas outside of PPC100 and no primary network).

3.5.5 BR and SF note that once the primary network is included to convey 10 year plus climate change flows (as per the SWCOP v4) downstream of 22 Duke Street the flood modelling should show an improvement. This is subject to detailed modelling to be undertaken at resource consent stage.

3.6 **Direction 4: The Hearing Panel directs that the expert conferencing session for stormwater/ flooding, the experts conference on the following further questions / actions (HP40A-C) in relation to whether the Applicant's flood model is fit for purpose:**

3.7 **HP40A Determine the extent, depth and velocity of 1% AEP flooding on land adjoining and within the northern part of the PC100 area.**

3.7.1 All Stormwater Experts consider that the modelling undertaken appropriately confirms the depth and velocity of the 1% AEP extent on land adjoining and within the northern part of the PC100 area, for the purpose of the plan change assessment of effects. Refer to Attachment A for the modelling results.

3.8 **HP40B Determine any increase in flooding (depth, duration and velocity) for flood prone land adjacent to the Riverhead Forest Stream land downstream of PC100 arising from maximum probable development (MPD) within the PC100 area and MPD within the balance contributing catchment.**

3.8.1 All stormwater experts agree that the fit for purpose model is sufficient to determine any increase in flooding for flood prone land adjacent to the Riverhead Forest Stream and downstream of PC100. Scenario 14 covered MPD within the PC100 area and existing development (ED) within the balance contributing catchment. This is expected to show worse relative increases compared to the MPD (PC100)/MPD (balance contributing catchment) scenario, as shown in Attachment A.

3.9 **HP40C With respect to the two items above [HP40A and HP40B], are the following parameters/input data sufficiently accurate for robust modelling of areas inundated in a 1% AEP flood?**

- **Existing ground topography, noting whether it is sourced from LIDAR or topographical survey;**
- **Assumptions on future ground topography; and**
- **Roughness of the floodplain including adequate account of vegetation type, density and height, presence of trees, fences, ditches and other obstructions both for the current and MPD scenarios.**

3.9.1 BR and ZW note that the existing ground topography has been sourced from LIDAR and topographical survey. All stormwater experts accept that this is appropriate.

3.9.2 All stormwater experts consider that assumptions on future ground topographies for north of Riverhead Road are not appropriate at Plan Change stage due to the variable nature of outcomes possible. SF's agreement is subject to his further statements at HP31 and HP32 with respect to 22 Duke Street.

3.9.3 All stormwater experts consider the updated roughness (Manning's n values) applied to the ground model (Terrain) are appropriate. This has been confirmed by Healthy Waters during the review stage of the model and suggested refinements.

3.10 **HP30 Is any part of the property at 22 Duke Street required for the integrated stormwater management approach being proposed?**

3.10.1 BR and SF agree that 22 Duke Street has an existing overland flow path present.

3.10.2 BR considers that the overland flow path will be retained as part of the stormwater management approach for PC100. This is confirmed in the framework outlined in the SMP, which does not rely on any stormwater mitigation in 22 Duke Street to be implemented.

3.10.3 SF considers that the existing overland flow path could be subject to increased overland flows as a result of PC100 development. This will be checked at resource consent stage.

3.10.4 BR considers that as per the stormwater management framework the conveyance of stormwater will be designed at resource consent stage which will include optioneering of alignments, which may not rely on 22 Duke Street.

3.11 **HP31 Is the flood plain line, based on not more than 200mm depth of water in a 1 per cent AEP flood event, the most appropriate location for an urban zoning boundary?**

3.11.1 BR, ZW, PW, KL, SF and RP considers that the terminology "flood plain line" used in this question should read "200mm flood depth contour".

3.11.2 BR, ZW, PW and RP consider that the 200mm flood depth contour, based on the modelling completed, is an appropriate location for an urban zone boundary.

3.11.3 SF considers that the urban zoning boundary could be defined on an alternative approach where by sufficient information should be provided to show how the land is to be earth worked, shifting overland flowpaths and floodplains so as to address potential upstream and downstream effects and achieve other benefits, such as improved development potential, green corridors and amenity. If the scale of proposed earthworks is large, relative to the development area, or there are significant potential effects, sufficient information should be provided at the Plan Change stage to support such changes; otherwise, it may be provided post-plan change.

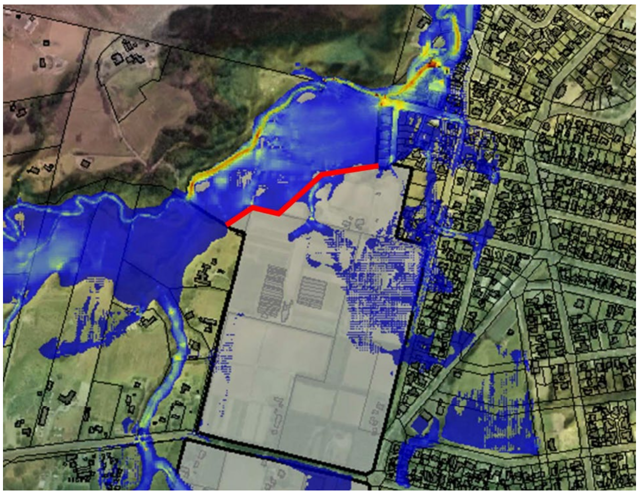
3.11.4 DS does not agree that the 200mm flood depth contour is an appropriate location for the urban boundary and notes that due to the complexity of the Riverhead Forrest Stream catchment and floodplain, and the sensitivity of the receiving environment, urban zoning should avoid the floodplain. DS considers that flood risk avoidance and reduction approach is most appropriate to be applied for greenfield land which includes PC100.

3.11.5 BR and RP note that the plan change adopted a 200mm flood depth contour to identify the RUB/zone boundary, which represents less significant flooding. A specific assessment of how depth and velocity of flood waters can be managed through subdivision design can be completed during resource consent design and application. This will consider all flood depths and displacement and any exacerbation of hazards in the normal manner through the resource consent process. (refer to AUP chapters E36 and E38).

3.11.6 KL notes in the context of the PC100 model that the 200mm flood depth contour aligns closely with other key flood hazard indicators from the Applicant's model, such as flow concentration and flood extent, providing a consistent representation of the wider flood hazard footprint.

3.11.7 KL considers it would be appropriate for the urban zoning boundary to better reflect the full extent of flood risk and support a more resilient and integrated stormwater management outcome. In the modelling outputs provided by the Applicant, areas highlighted in dark blue indicate predicted flood depths exceeding 200 mm in a 1% AEP event, which is greater than 6ha in contiguous area (i.e. the proposed area for rural zoning).

3.11.8 KL and DS consider that the zoning boundary should be extended further south within the catchment, beyond the current floodplain line, to provide an appropriate buffer from downstream-sensitive receiving environments as shown in this diagram (Scenario 9) 1% AEP + climate change 3.8 degrees Celsius, MPD imperviousness within the site and outside the site).



3.11.9 KL and DS consider that it is important that the floodplain is protected and retained to ensure it continues to function effectively in flood attenuation and conveyance, and to avoid exposing future residents or infrastructure to existing flood hazards—particularly in areas where development could compromise natural flood pathways or increase residual risk to vulnerable activities.

3.11.10 RP notes that the topography at 30 Cambridge Road as of May 2025 is different to the LiDAR used in the model therefore localised depressions shown in the model may not be realistic to base the RUB boundary on. He considers the urban boundary should be further north as per the notified PC100 map.

3.12 HP32 Given the sensitivity to flooding downstream, is there a more appropriate location for this boundary?

3.12.1 BR considers that the sensitivity to flooding downstream is not affected by the location of the urban zone boundary line. Another location may be appropriate for the urban zoning boundary which is an alternative to the 200mm flood depth contour if supported by specifically identified flood mitigation measures and assessment of risk, but that any changes to the boundary of the urban zoning will likely have no effect on the flooding downstream.

3.12.2 SF considers that including 22 Duke St within the PC100 urban area will result in improved outcomes for PC100 overall in relation to drainage, flooding and amenity.

3.13 HP38 Have the necessary precinct provisions required to integrate stormwater management into the development been incorporated within the proposed precinct provisions?

3.13.1 BR considers that the precinct provisions, particularly Objectives 5, 5A, 6, Policies 13, and 17 and Standards IX.6.4 and IX.6.16, appropriately reflect the stormwater management approach within the proposed SMP.

3.13.2 KC and MT consider that the proposed precinct provisions (KC rebuttal evidence version, dated 12 May 2025) appropriately require the integration of stormwater management in future development within the PC100 area.

3.13.3 RD agrees with 3.13.2 above subject to the amendments as outlined in paragraph 3.13.4. below.

3.13.4 DS considers that precinct provisions should incorporate an additional standard addressing the development dependencies relating to flood management works (i.e. Riverhead Road culvert upgrade and diversion of approximately 8ha catchment - refer DS evidence in chief Paragraph 9.8.) DS also considers that incorporation of amendments to the proposed water quality standard (IX6.4) are required as per his evidence in chief Paragraph 9.6.

3.13.5 AT considers that two new Special Information Requirements are needed and should be included in the proposed precinct provisions; one to address the requirement of flood modelling and assessment at the resource consent stage, the other to address the requirement of stream erosion assessment. The need for both was outlined in AT and KL s42A Addendum Memorandum, dated 11 April 2025. The proposed wording is outlined below with the latest recommended amendments highlighted in bold which are to reflect discussion as per the JWS Stormwater and Flooding (1) paragraphs 3.2.2.5 and 3.2.2.6.

IX.9 Special information requirements

(NEW) Flood modelling and Assessment

At each stage of subdivision and/or development of any site within the Precinct, a detailed flood modelling and assessment must be undertaken and provided. Modelling limitation must include but is not limited to:

- Detail of stormwater infrastructure at each stage of development.
- Terrain detail for proposed development.
- All downstream public infrastructure from any discharge point of proposed development, including the pipe network serving Duke Street, Riverhead Point Drive and culverts.
- Building footprints and finished floor levels downstream of proposed development.
- **Effects on third party land within the Riverhead Precinct.**

(NEW) Watercourse Assessment

The first application for any land modification, subdivision and/or development which:

- Adjoins a permanent or intermittent stream; or
- Discharges stormwater to the Southern Stream and the unnamed stream to the west of the Riverhead Precinct and identified in Figure (NEW) below.

Must be accompanied by a Site Specific Watercourse Assessment prepared by a suitably qualified person. The assessment must include:

- A stream reach assessment identifying any erosion hotspots and stream bank erosion;
- **Assessment of pre and post development hydrology flows of the overall catchment and associated effects; and**
- **Identification of appropriate erosion mitigation measures and implementation plan. Mitigation measures might include hydrology mitigation and/or physical in-stream mitigation.**

3.13.6 AT considers that as an alternative to 3.13.5, the guidance recommended as part of the new flood modelling assessment Special Information Requirement can be combined into the relevant assessment criteria which is IX.8.2.(2)(o). DW prefers this approach subject to wording amendments to clarify that a matter should only be considered where relevant.

3.13.7 DW, RD, MT and KC consider that the watercourse assessment special information requirement is not necessary as the matters will be addressed within the SMP, noting that the approved SMP is already referred to in the assessment criteria. RD notes this is subject to the watercourse assessment being carried out in JWS Stormwater and Flooding (1) paragraph 3.2.2.5.

3.13.8 All experts agree that the exact wording of any provisions will be addressed in the future planning expert conferencing session.

3.14 HP39 Are the proposed precinct provisions consistent with the proposed SMP?

3.14.1 Addressed in HP38 noting that the precinct provisions now refer to the approved SMP.

4 PARTICIPANTS TO JOINT WITNESS STATEMENT

4.1 The participants to this Joint Witness Statement, as listed below, confirm that:

(a) They agree that the basis of their participation and the outcome(s) of the expert conferencing are as recorded in this Joint Witness Statement; and
(b) They agree to the introduction of the attached information – Refer to paragraph 3.1.1 above; and
(c) They have read the Environment Court's Practice Note 2023 and agree to comply with it; and
(d) The matters addressed in this statement are within their area of expertise; and
(e) As this session was held both in-person and online, in the interests of efficiency, it was agreed that each expert would verbally confirm their position in relation to this

para 4.1 to the Independent Facilitator and the other experts and this is recorded in the schedule below.

Confirmed: 5 August 2025

EXPERT'S NAME & EXPERTISE	PARTY	EXPERT'S CONFIRMATION REFER PARA 4.1
Bronwyn Rhynd (BR), Environmental Engineer (Stormwater Expert)	RLG (Applicant) Consultant	Yes
Zeb Worth (ZW), Environmental Engineer (Stormwater Expert)	RLG (Applicant) Consultant	Yes
Pranil Wadan (PW), Stormwater Engineer (Stormwater Expert)	RLG (Applicant) Consultant	Yes
Karl Cook (KC), Planning	RLG (Applicant) Consultant	Yes
Kelsey Bergin (KB), Planning	Fletcher Residential Limited (with the applicant) Employee – Development Manager	Yes
Anthony Smith (AS), Surveying	Fletcher Residential Limited (with the applicant) Employee – Head of Development	Yes
Dali Suljic (DS), Engineer (Stormwater Expert)	Auckland Council (submitter) Consultant	Yes
Rachel Dimery (RD), Planning	Auckland Council (submitter) Consultant	Yes
David Wren (DW), Planning	Auckland Council (s42A team) Consultant	Online Yes
Kedan Li (KL), Stormwater Engineer (Stormwater Expert)	Auckland Council (s42A team) Employee – Auckland Council, Healthy Waters	Yes

Danny Curtis (DC), Stormwater Management / Engineer (Stormwater Expert)	Auckland Council (s42A team) Consultant	Yes
Amber Tsang (AT), Planning	Auckland Council (s42A team) Consultant	Yes
Mark Iszard (MI), Stormwater Engineer (Stormwater Expert)	Auckland Council (Network Discharge Consent holder) Employee - Auckland Council, Healthy Waters	Yes (Online for HP38 and HP39)
Jahangir Islam (JI), Stormwater Engineer (Stormwater Expert)	Auckland Council (Network Discharge Consent holder) Consultant	Yes
Sean Finnigan (SF), Stormwater Engineer (Stormwater Expert)	Aberdeen Adventures Ltd Consultant	Yes
Ryan Pitkethley (RP), Engineer (Stormwater Expert)	Good Planet Landholder Submitter Group Consultant	Yes Online
Mark Tollemache (MT), Planning	Good Planet Landholder Submitter Group Consultant	Yes Online

Planning | Surveying | Engineering | Environmental

FURTHER ASSESSMENT FRA PC100

Volume 2

Riverhead Landowner Group

Document Information

Client	**Riverhead Landowner Group**
Site Location	**Riverhead**
Legal Description	Lot 2 DP 164978, Lot 1 DP 164978, Lot 1 DP 64605, Pt Lot 2 DP 37432, Lot 2 DP 64605Pt, Lot 2 DP 4818, Lot 1 DP 61985, Lot 1 DP 77992, Lot 2 DP 77992, Lot 3 DP 63577, Lot 2 DP 63577, Lot 1 DP 113506, Lot 1 DP 66488, Lot 1 DP 109763, Lot 1 DP 164590, Lot 2 DP 164590, LOT 1 DP 499822, LOT 20 DP 499876
CKL Reference	A20405
Office of Origin	Auckland

Author	Sarala Karunarathna/Zeb Worth		
Signed		**Date**	29/07/2025

Author	Bronwyn Rhynd		
Signed		**Date**	29/07/2025

Reviewed & Authorised By	Bronwyn Rhynd		
Signed		**Date**	29/07/2025

Revision	Status	Date	Author	Reviewed By	Authorised By

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1 Introduction

This report summarises the outcomes of further assessment of potential effects during different storm events that have been requested through the Riverhead Private Plan Change 100 (RPPC100) hearing and caucusing of experts associated with the commissioner's directive associated with the hearing. Specifically, this report outlines the results of scenarios 12-18 as confirmed in the Joint Witness Statement (JWS) dated 25 June 2025.

This report provides details of the additional hydrological and hydraulic modelling undertaken and the results of the additional analysis.

1.1 Background

The previous modelling provided in the RPPC100 SMP, and subsequent addendum reporting concluded that the change in land use arising from the RPPC100 would result in less than minor effects in relation to flooding in the 2yr and 10yr ARI with allowance for 2.1°C climate change (2yrARI+2.1CC and 10yrARI+2.1CC) and the 100yr ARI event with allowance for 3.8°C climate change (100yrARI+3.8CC). This was based on refinement of the upgrading to the existing DN750 Riverhead Road culvert, as recommended in the RPPC100 SMP, diversion of part of the southern RPPC100 area to the south, and the provision of peak flow attenuation for discharges to the south. However, to test the sensitivity of the overall flood mitigation strategy, additional scenarios were agreed combining various rainfall and land uses within the surrounding catchment, as well as refinements to hydrological parameters within the model.

1.2 Objectives

The objectives of the current study can be summarised as follows:

1. Update hydrological parameters in line with model refinement recommendations suggested by Auckland Council's Healthy Waters catchment modelling team (AC Modelling Team), including:
   a) Updating Curve Numbers (CN) based on more detailed analysis of existing soil types and land use.
   b) Updating percentage impervious to reflect actual existing development (ED) – previous modelling assumed MPD for all sub-catchments external to RPPC100 area.
   c) Updating channelisation factors to reflect actual ED.
   d) Re-calibrating catchment SCS Lag times to better reflect Auckland Council GeoMaps Overland Flow path layer times of concentration.
2. Update hydraulic model parameters based on updated information and suggested model refinements, including:
   a) refinement of Manning's roughness layers to reflect ED and inclusion of buildings and streams.
   b) updating existing culvert configuration at 22 Duke Street from 2.5m diameter to 2 x 1.5m diameter on the Riverhead Forest Stream, reflecting culvert replacements completed in 2021.
3. Test sensitivity of the updated model to combinations of storm events and climate change including:
   a) 2yr, 10yr and 100yr ARIs **with** climate change.
   b) 2yr, 10yr and 100yr ARIs **without** climate change.
   c) 2yr ARI rainfall in upper catchment with 100yr ARI rainfall in lower catchment (without climate change).
4. Identify areas for refinement of modelling for future development stages.

2 Site Features

As per previous reporting, and included for clarity in this report, a number of key features and areas of interest are referred to in this report. To provide clarity, these are listed below and shown graphically in Figure 1.

22 Duke Street	Low-lying region in northern part of RPPC100 area that sits within the main floodplain
Forest Stream	Main stream from upper catchment to the north of Riverhead Plan Change area. Northern Plan Change area discharges directly to this stream.
Riverhead Rd Culvert	Existing DN750 culvert to be upgraded as part of RPPC100.
Southern Stream	Minor stream at southern extent of Riverhead Plan Change area. Southern Plan Change area discharges to this stream. Includes Coatesville-Riverhead Highway Culvert.
Western Tributary	Minor tributary of Forest Stream running south to north, immediate west of Riverhead Plan Change Area. Northwestern part of Southern Plan Change Area discharges directly to this tributary. Includes Riverhead Road Culvert.

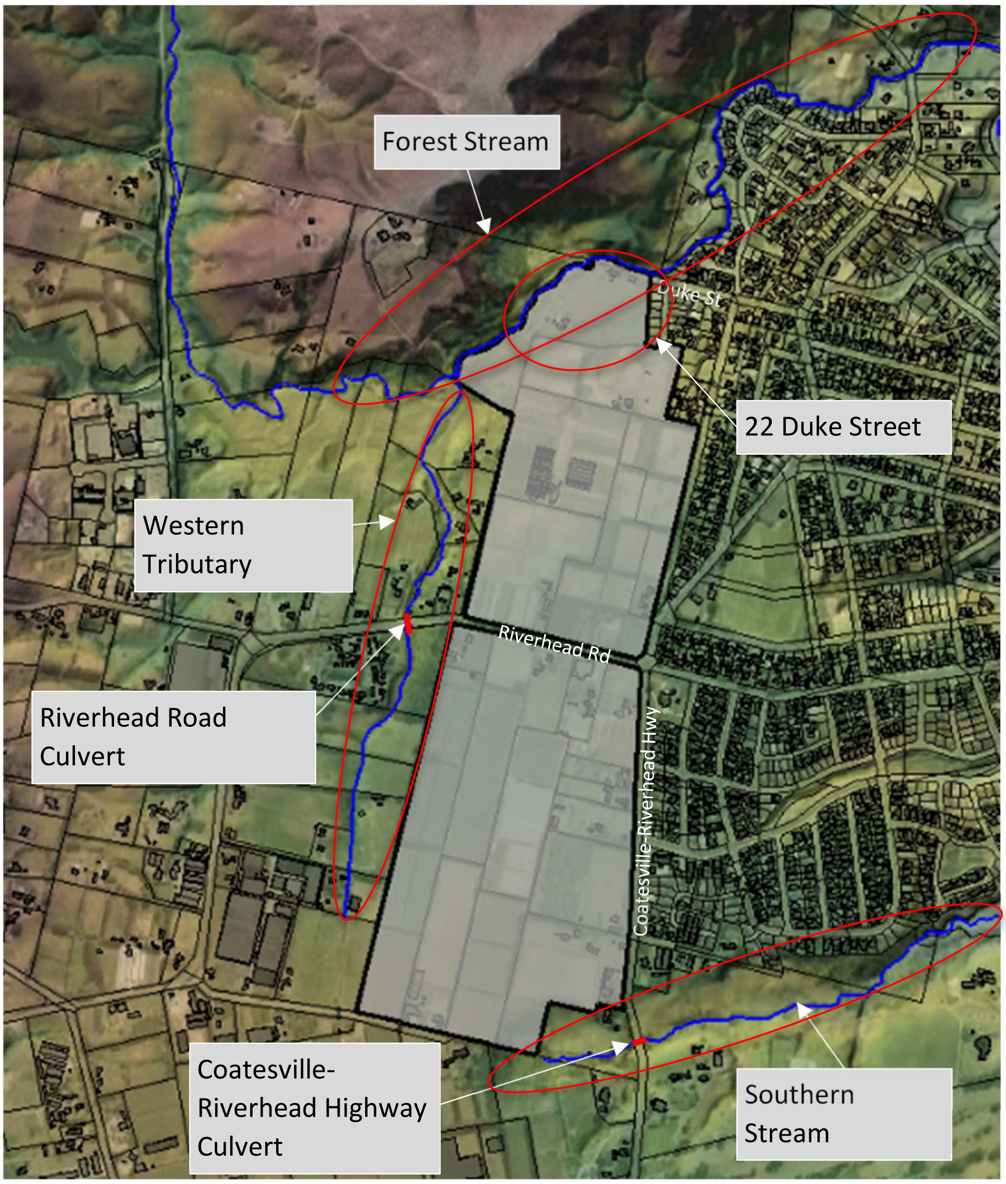

Figure 1: Key site features and areas of interest

3 HEC HMS model updates

The following updates have been made to the HEC-HMS hydrological model. All other hydrological data remains the same as previously reported.

3.1 SMAF 1 Hydrological Mitigation

SMAF 1 hydrological mitigation has been included in the current assessment to assess the effects of SMAF detention on top water levels during frequent events. This has been included as the provision of SMAF mitigation may delay the peak of the hydrographs discharging from the RPPC100 area. Previous modelling demonstrated that delaying the peak from the RPPC100 area via peak flow attenuation resulted in the peak coinciding with that of the larger upstream Forest Stream catchment during extreme events (i.e. 100yr +3.8CC), resulting in an increase of top water levels downstream of the RPPC100 area. While not the same as peak flow attenuation, SMAF 1 detention may result in overlapping hydrographs. Hence, it was decided to include this in the assessment for completeness as SMAF 1 hydrological mitigation is proposed for all sub-catchments discharging to the Forest Stream and Southern Stream.

3.2 Hydrological Parameter Updates

The following updates have been made to the hydrological parameters. The updated hydrological calculations are provided in Appendix 2.

3.2.1 SCS Curve Numbers (CN)

CN values for all the sub catchments outside RPPC100 area have been updated based on the corresponding land use and hydrological soil group as shown in Table 1.

Table 1: Updated SCS Curve Numbers based on land use and hydrological soil group

Soil Group	Land Use	Curve Number (CN)
B	Impervious	98
	Bush	55
	Pasture	61
	Urban Lawn	61/74*
	Straight Row Crops	81
C	Impervious	98
	Bush	70
	Pasture	74
	Urban Lawn	74
	Straight Row Crops	88

*urban lawns within HSG B soils are assumed to have a higher CN post development due to the effects of earth working.

3.2.2 Percent Impervious to reflect Existing Development

The percentage of impervious coverage within each sub-catchment has been updated through analysis of the latest available aerial photography to represent actual existing development conditions.

3.2.3 Channelisation (C) factors

Channelisation factors for of all the sub catchments outside[1] RPPC100 area have been updated based on existing conditions within each sub-catchment to test the sensitivity of the results to changes in channelisation factors. Previous modelling had used lower channelisation factors (0.8 and 0.6) on the basis that external sub-catchments were to be considered as Maximum Probable Development (MPD) as agreed with Auckland Council during early model reviews in order to provide a 'worst case' in terms of timing and magnitude of peak flows in the downstream floodplain. The updated channelisation factors adopted are as shown in Table 2.

Table 2: Updated channelisation factors

Criteria	Channelisation factor C
Natural Streams	1
Engineered Channels	0.8

3.2.4 SCS Lag Times

The catchment lengths and slopes for the following catchments (please refer Table 3) have been updated to align with the overland flow path extents shown in Auckland Council's GeoMaps. Please refer Figure 2 for the catchments with updated lag time.

Table 3: Updated lag times based on updated catchment lengths and slopes to match council GeoMaps.

Sub catchments	Length from AKL Council GeoMaps (km)	Slope from AKL Council GeoMaps	Updated length (km)	Updated slope (m/m)	Updated lag time (hr)
C11	5.5	0.013	4.7	0.012	1.6
C12-2	0.5	0.057	0.7	0.045	0.4
C21	1.2	0.037	1.1	0.041	0.5
C42_1	1.3	0.023	1.4	0.015	0.8

[1] Channelization factor inside PC100 area already follows the criteria in Table 2.

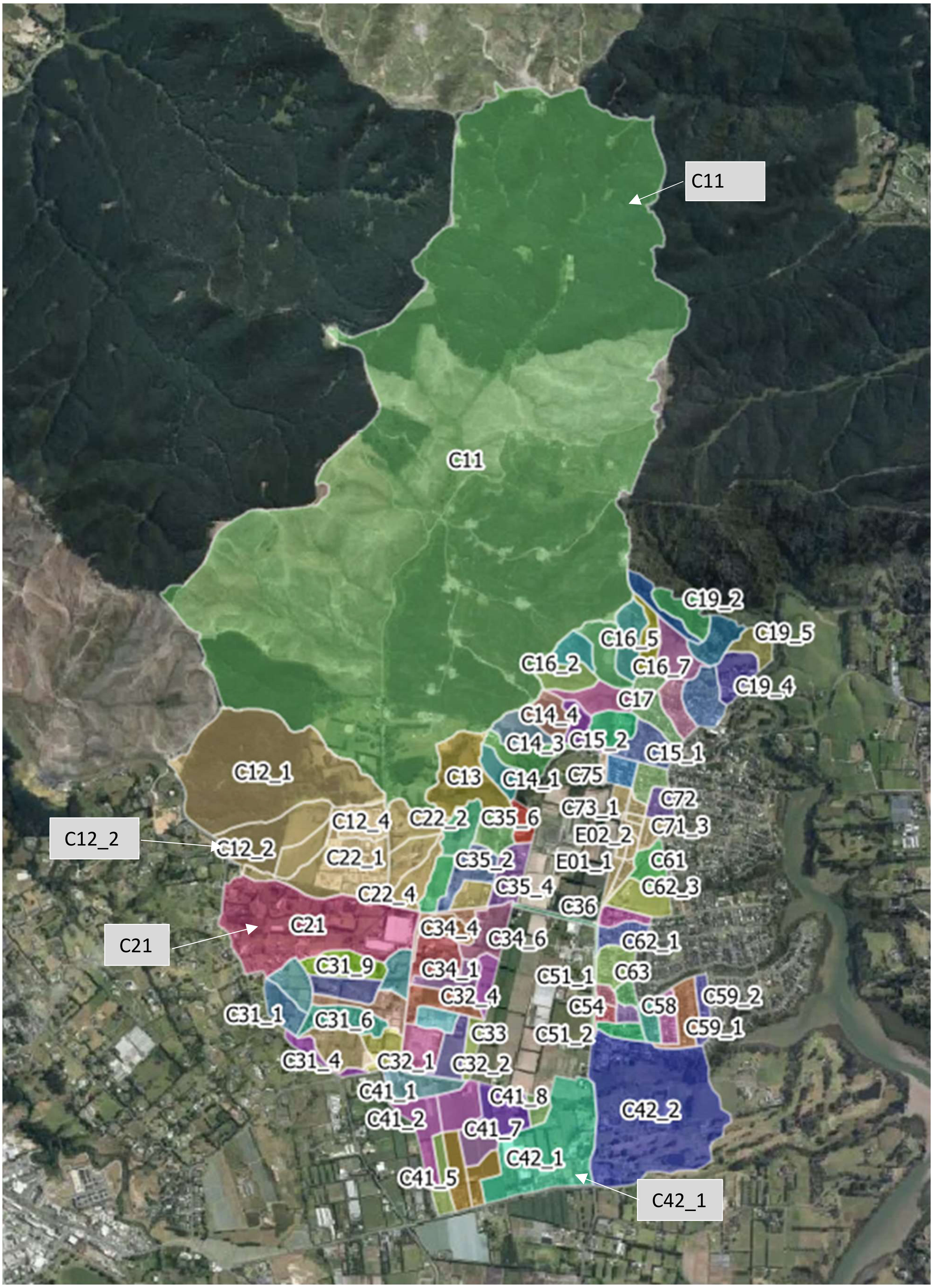

Figure 2:Catchments with updated lag times

3.3 Rainfall Events Considered

Three rainfall events and eight scenarios have been modelled. Please refer Appendix 1 model build summary for the table containing the information on corresponding model runs.

Each scenario has been run under both pre and post development conditions and a top water level difference map between post development and predevelopment conditions have been plotted to assess any potential effects.

Pre-development conditions assume existing land use across all sub-catchments both within and outside the RRPC100 area. Post-development conditions consider maximum probable development within the RRPC100 area, while retaining existing development outside the RRPC100 area.

Table 4 below summarizes the scenarios considered.

Table 4: Different rainfall events and Scenarios

Rainfall Event (ARI)	Scenarios	Description
10Yr	10yrCC2.1	10yr rainfall event considering climate change adjustments corresponding 2.1˚C
	10YrWoCC	10yr rainfall event without considering climate change adjustments
2Yr	2yrCC2.1	2yr rainfall event considering climate change adjustments corresponding 2.1˚C
	2YrWoCC	2yr rainfall event without considering climate change adjustments
100YR	100yrCC3.8	100yr rainfall event considering climate change adjustments corresponding 3.8˚C
	100YrWoCC	100yr rainfall event without considering climate change adjustments
	2YRUp100YrRest	2yr rainfall without climate change has been considered for inflows C11, C12_4 and SumC12[2] upstream catchments whereas 100yr rainfall without climate change has been considered for the rest

[2] SumC12 refers to sub-catchments C12_1, C12_2 and C12_3 which are grouped as a single inflow boundary (as per original FRA model previously reviewed by Auckland Council). This terminology has been retained for consistency

Catchments C11, Sum C12, and C12_4 were modelled using the 2-year ARI rainfall depths without climate change allowance for the final scenario outlined in Table 4. This is as per the original Scenario 4 (refer Appendix 4) provided in the as-notified Flood Risk Assessment report provided to support the RPPC100 application, and as agreed in paragraph 3.1.1.2 of the JWS. The corresponding upstream sub-catchments are shown in Figure 3 below.

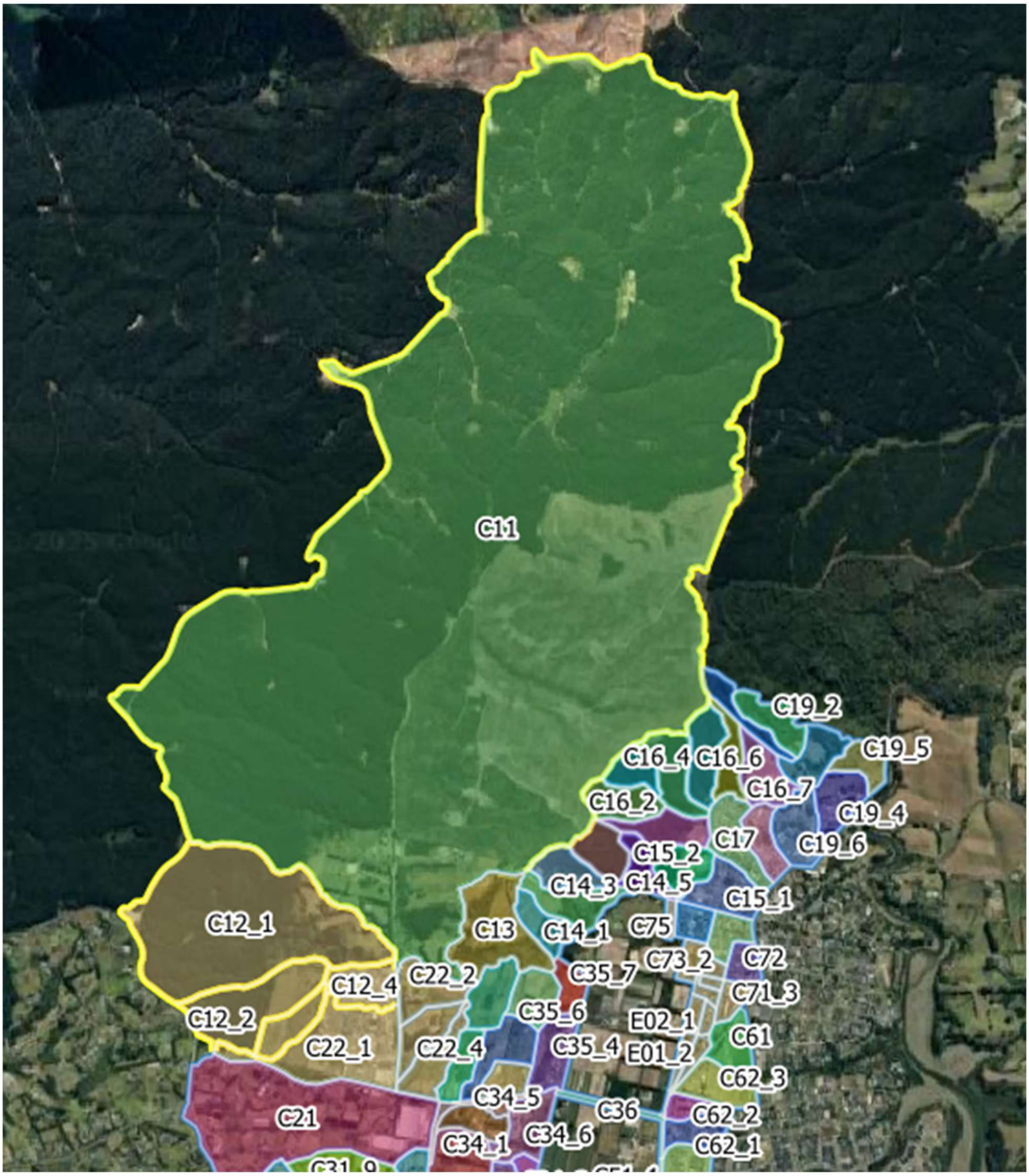

Figure 3: Upstream catchments C11, Sum C12 (C12_1, C12_2 and C12_3) and C12_4 highlighted in yellow colour line

4 HEC-RAS Model Updates

To analyse the hydraulic effects of the updated hydrology and the addition of the updates the following were included in the HEC RAS model:

- Updated flow hydrographs from HEC-HMS for all internal catchments to include the effects of SMAF detention, updated hydrological parameters and different rainfall events and scenarios (see Section 3 above).
- Refinement of Manning's Roughness (see Section 4.1 below).
- The previously modelled 2.5m diameter culvert on the Forest Stream has been updated to two 1.5 m diameter culverts, reflecting the culvert replacements completed in 2021.

All other aspects of the model remain as previously reported.

4.1 Manning's Roughness

The Manning's roughness layer has been updated by digitising building platforms and the stream network, with corresponding Manning's *n* values assigned to reflect surface characteristics as shown in Figure 4.

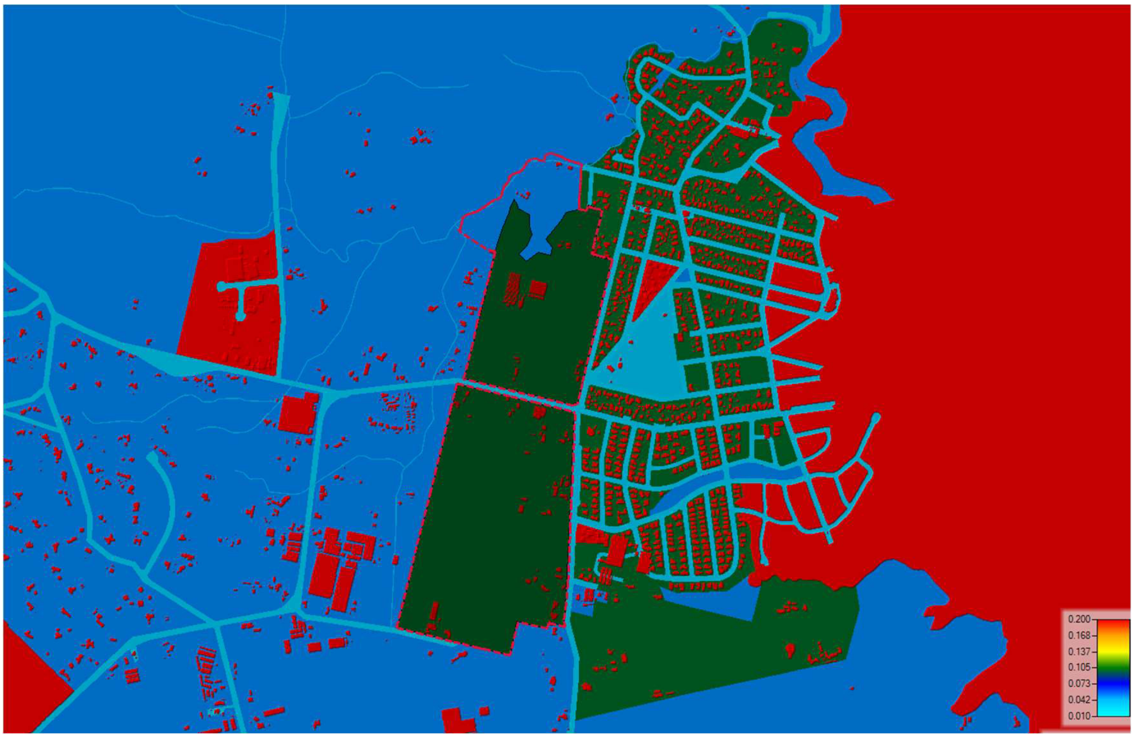

Figure 4: Manning's Roughness Layer (Post Development) – ED outside MPD inside

The final Manning's n values adopted for the updated model are shown in Table 5.

Table 5: Manning's N Value Refinements

Land Use	Manning's n Value
Roads	0.03
Open Fields	0.05
Streams	0.04
Buildings	1

5 Modelled Scenarios

In addition to the updates and refinements to the hydrological and hydraulic models described above, a number of scenarios were agreed as part of the RPPC100 Expert Conference – Stormwater and Flooding held on 25 June 2025 as referenced in the subsequent JWS. The additional scenarios agreed are summarised in Table 6. All scenarios were modelled with the hydrological and hydraulic model updates described in Sections 3 and 4 above. Relevant details for each scenario are provided in the Hydraulic Model Summary included in Appendix 1. A full list of scenarios modelled to date is provided in Appendix 4 for reference.

Table 6: Model Scenarios

<table>
<tr><th>Scenario Number</th><th>Rainfall Event</th><th>Model Updates</th><th>JWS reference</th></tr>
<tr><td>12</td><td>2yr ARI + 2.1°C Climate Change</td><td rowspan="7">Pre development: actual ED for all sub-catchments
Post Development: ED for sub-catchments external to RPPC100 area with MPD for sub-catchments within RPPC100
Both: Hydrological parameters and hydraulic model updated as per Sections 3 and 4 above</td><td>3.1.1.1</td></tr>
<tr><td>13</td><td>10yr ARI + 2.1°C Climate Change</td><td>3.1.1.1</td></tr>
<tr><td>14</td><td>100yr ARI + 3.8°C Climate Change</td><td>3.1.1.1</td></tr>
<tr><td>15</td><td>2yr ARI without climate change</td><td>3.1.1.1</td></tr>
<tr><td>16</td><td>10yr ARI without climate change</td><td>3.1.1.1</td></tr>
<tr><td>17</td><td>100yr ARI without climate change</td><td>3.1.1.1</td></tr>
<tr><td>18</td><td>2yr in upper catchment with 100yr in lower catchment</td><td>3.1.1.2</td></tr>
</table>

6 Results

Water surface level difference maps have been generated for each pair of modelled scenarios to compare post-development and pre-development conditions and assess any potential effects on existing flood hazards with the RPCC area and surrounding environment. The **pre-development** scenario reflects existing development conditions both within and outside the RPPC100 area, while the **post-development** scenario represents the maximum probable development within the RPPC100 area, with existing conditions maintained outside the PC100 boundary. Results for each modelled scenario are provided in the following subsections. Full results maps are provided in Appendix 3.

6.1 Scenario 12 - 2yr ARI + 2.1°C Climate Change

Under the 2yr ARI+2.1°C scenario, noticeable increases (more than 10mm) are observed within RPPC100 area and within the Western Tributary downstream of Riverhead Road culvert as shown in Figure 5 below.

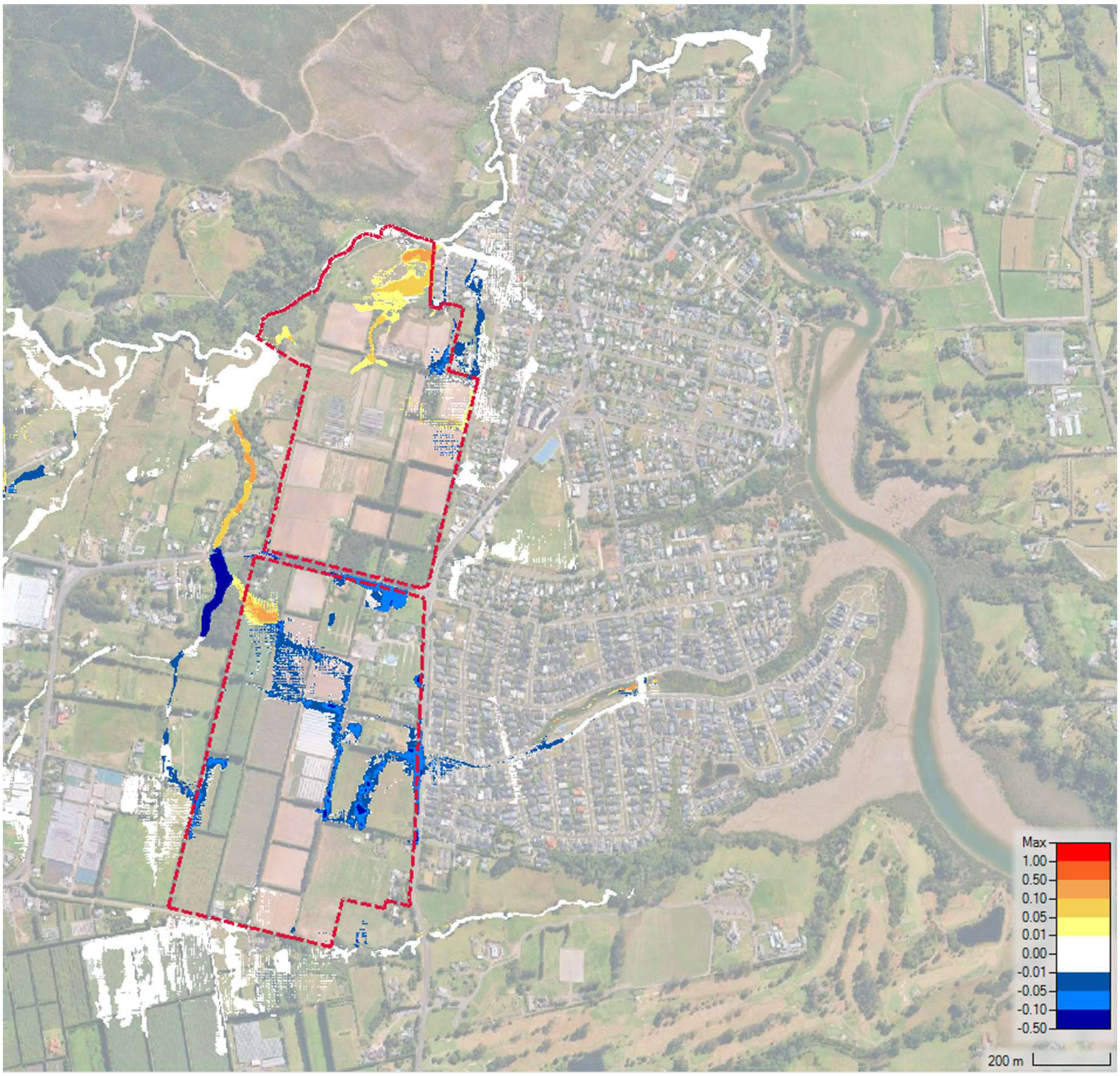

Figure 5: Water surface elevation difference map (post-Pre) – 2YrCC2.1

The maximum top water level differences within the major tributaries are shown in Table 7 below.

Table 7: Top water level difference along major tributaries -2YrCC2.1

Location	Top water level difference between proposed and existing conditions 2YrCC2.1	
22 Duke Street	Northern depression area	Increase up to 115mm
	Southern low-lying area	Increase up to 65mm
Forest Stream	Upstream of Duke Street	0mm to max 6mm increase
	Downstream of Duke Street	0mm to max 7mm increase
Southern Stream	Upstream Coatesville-Riverhead Hwy Culvert	0mm to max 3mm
	Downstream Coatesville-Riverhead Hwy Culvert	No increase
Western Tributary	Upstream Riverhead Road Culvert	Decrease up to 1200mm
	Downstream Riverhead Road Culvert	Increase up to 150mm (contained in stream channel)

The modelled change in top water levels within the Forest Stream and Southern Stream are considered to be less than minor and are contained within the banks of the stream.

The maximum observed increase in top water levels (up to 115 mm) within the RPPC100 area at 22 Duke Street is generally contained within the existing low-lying areas with minimal change to the horizontal extent, as shown in Figure 6 (with the pre-development 100yr+3.8 CC top water level shown for context). The observed increases are considered to be largely due to the fact that the flood model does not contain a primary stormwater system and, as such, all discharges are loaded directly as surface flow. It is common practice, at a plan change level, for a primary stormwater system not to be modelled because it (the stormwater conveyance system) will be subject to detailed engineering that appropriately occurs at resource consent stage.

In reality, once development occurs, the primary stormwater system within the RPPC100 area (including the existing public conveyance channel along the eastern boundary of 22 Duke Street) will be designed/upgraded to collect and convey flows from more frequent events, up to and including the 10yr ARI with climate change allowance, directly to the Forest Stream as required under the Auckland Council Stormwater Code of Practice. This is expected to eliminate the observed top water level increases in this (and other) locations with the RPPC100 area in both the 2yr and 10yr ARI events (including climate change).

The above also applies more generally to the localised increases observable at the hydrograph loading points within the model (e.g. near 280 Riverhead Road along the western boundary of the southern RPPC100 area) where previously separate subcatchment flows are grouped as a single discharge to the surface in the post development case. These are considered to be an artifact of the model schematisation and, in reality, when the primary stormwater networks are designed, the subcatchment flows will be more evenly distributed via pipe networks and separate outfalls. Once these primary systems are incorporated into the model, these localised changes are likely to no longer be observable.

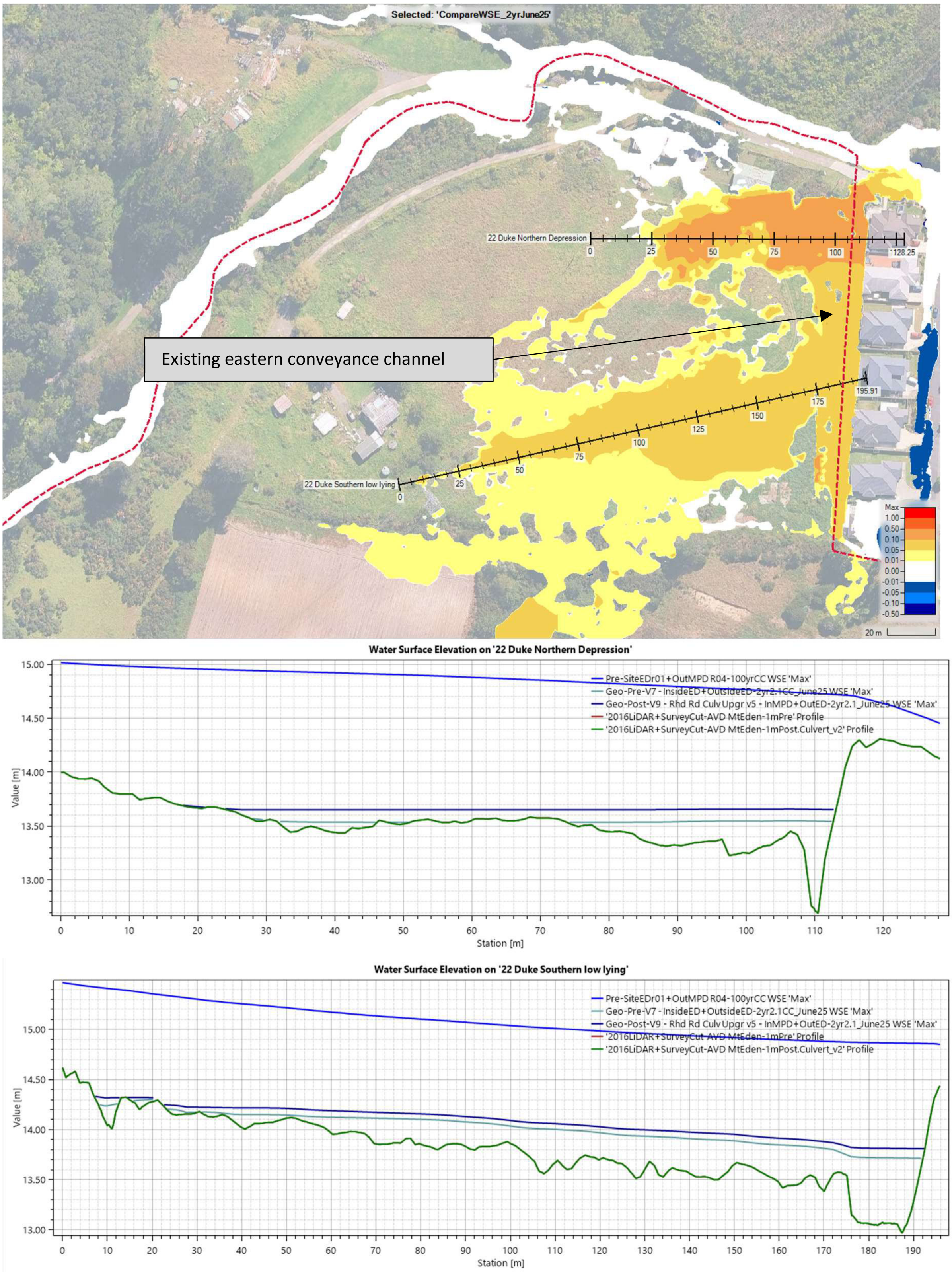

Figure 6: Top water level increases within 22 Duke Street - 2yrCC2.1

The modelling predicts a significant decrease in top water levels within the Western Tributary upstream of Riverhead Road due to the modelled Riverhead Road culvert upgrade. The maximum modelled increase in top water levels within the Western Tributary downstream of Riverhead Road is up to 150mm under post development conditions when compared to predevelopment. However, when examining a cross section of the Western Tributary at the location of the maximum water level increase, the increase is seen to be contained well within the stream channel as shown in Figure 7 below with the pre-development 100yr+3.8 CC top water level shown for context. It is, therefore, considered that the effect on the properties adjacent to this stream at 289, 301, 301A and 305 Riverhead Road is less than minor. In addition, it is considered that these effects are likely to be further reduced through refinements to the design of the Riverhead Road Culvert and primary stormwater systems at subsequent design stages.

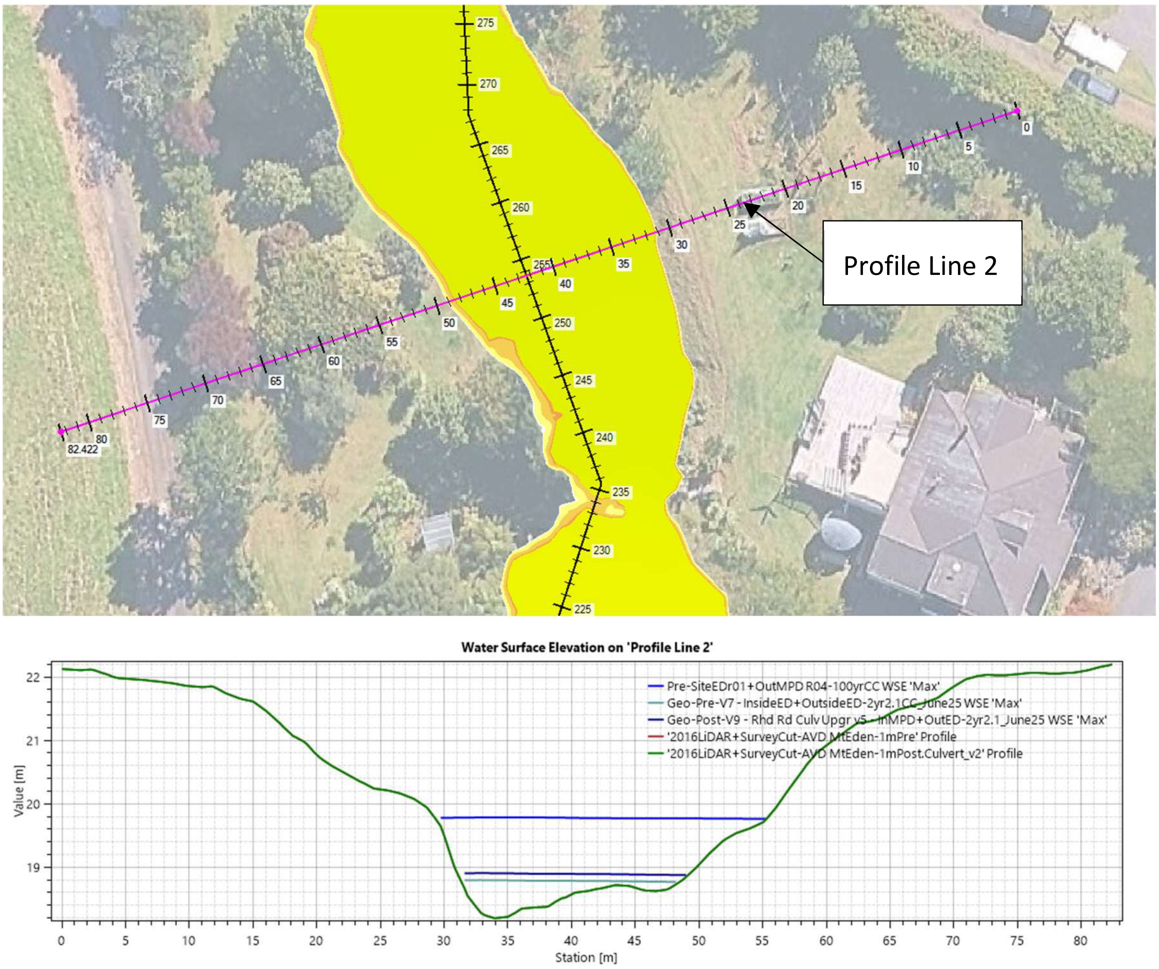

Figure 7: Cross section across the Western Tributary where the increase in top water level is maximum-2YrCC2.1

6.2 Scenario 13 - 10yr ARI + 2.1°C Climate Change

Under the 10yr ARI+2.1°C scenario, noticeable increases (of more than 10mm) are only observed within the RPPC100 area as shown in Figure 8 below. However, there are several areas outside the RPPC100 area where top water levels show a noticeable decrease.

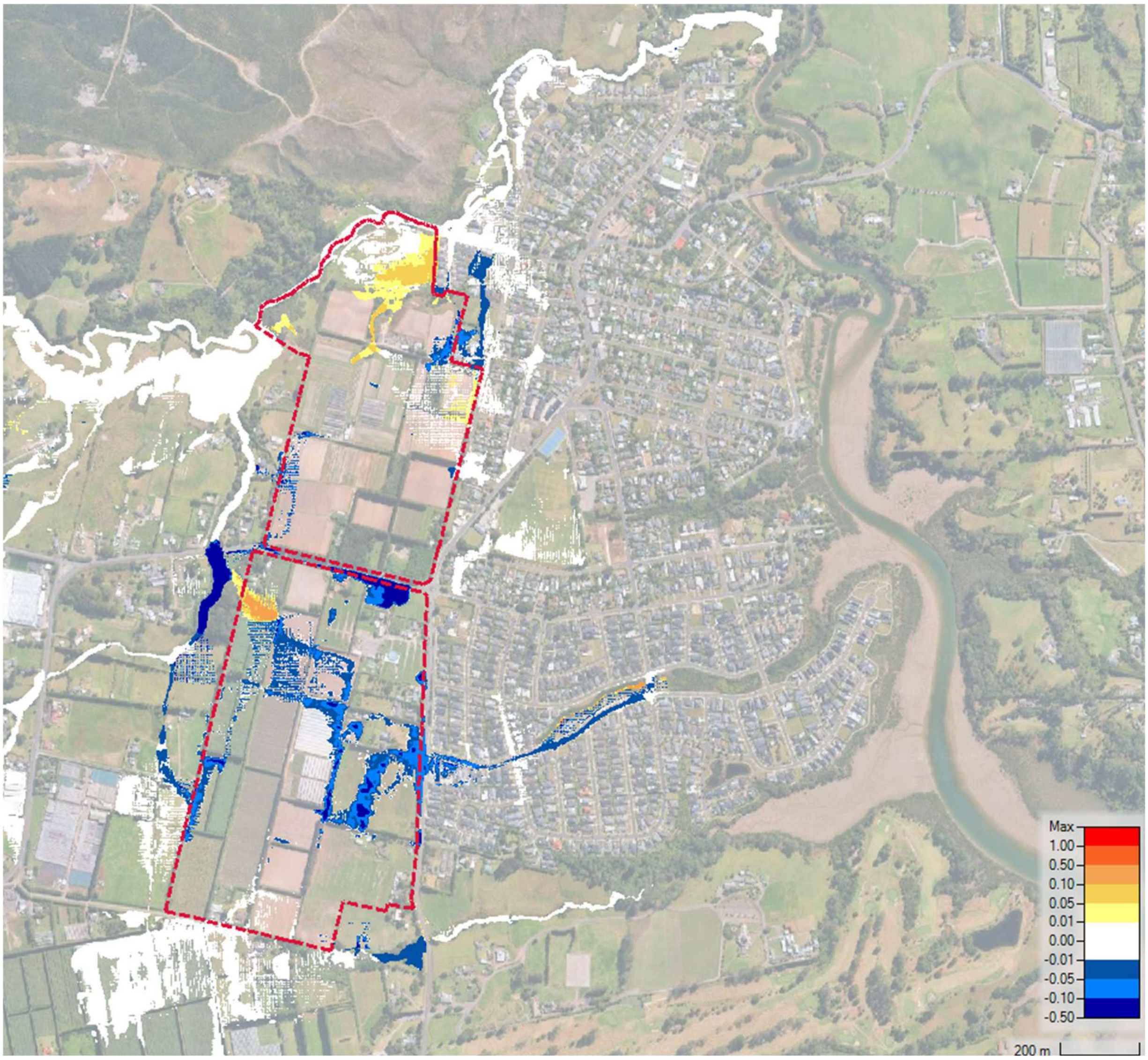

Figure 8: Water surface elevation difference map (post-Pre) – 10YrCC2.1

The maximum top water level differences within the major tributaries are shown in Table 8.

Table 8: Top water level difference along major tributaries -10YrCC2.1

Location	Top water level difference between proposed and existing conditions 10YrCC2.1	
22 Duke Street	Northern depression area	Increase up to 30mm
	Southern low-lying area	Increase up to 70mm
Forest Stream	Upstream of Duke Street	0mm to max 2mm increase
	Downstream of Duke Street	No increase
Southern Stream	Upstream Coatesville-Riverhead Hwy Culvert	Decrease up to 30mm
	Downstream Coatesville-Riverhead Hwy Culvert	No increase
Western Tributary	Upstream Riverhead Road Culvert	Decrease up to 800mm
	Downstream Riverhead Road Culvert	No increase

While there are noticeable increases in top water level observed within the RPPC100 area at 22 Duke Street, these are generally contained within the existing ponding areas, with no significant change in extent as shown in Figure 9 with pre-development 100yr+3.8CC shown for context. Additionally, as noted in Section 6.1 above, the observed increases are considered to be largely due to the fact that the flood model does not contain a primary stormwater system, as is appropriate at a Plan Change level of assessment. Once the design of the primary system is undertaken at future design and resource consent stages and included in future modelling, it is expected that the observed top water level increases within 22 Duke Street in frequent events will be resolved.

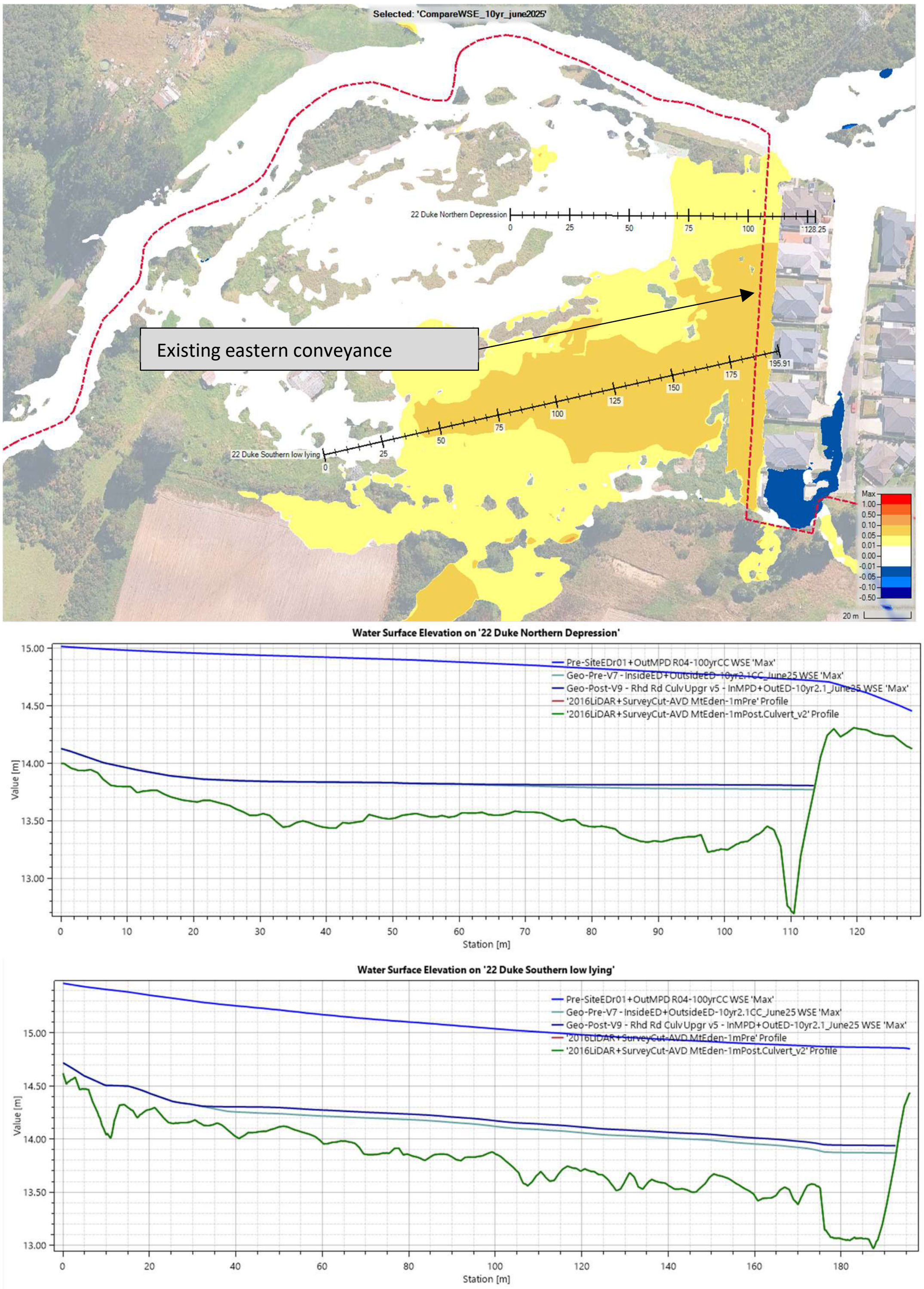

Figure 9: Top water level increases within 22 Duke Street - 10yrCC2.1

6.3 Scenario 14 - 100yr ARI + 3.8°C Climate Change

Under the 100yr ARI+3.8°C scenario, noticeable increases in top water level (of more than 10mm) are only observed within the RPPC100 area as shown in Figure 10 below. However, there are several areas outside the RPPC100 area where top water levels show a noticeable decrease, particularly along Cambridge Road.

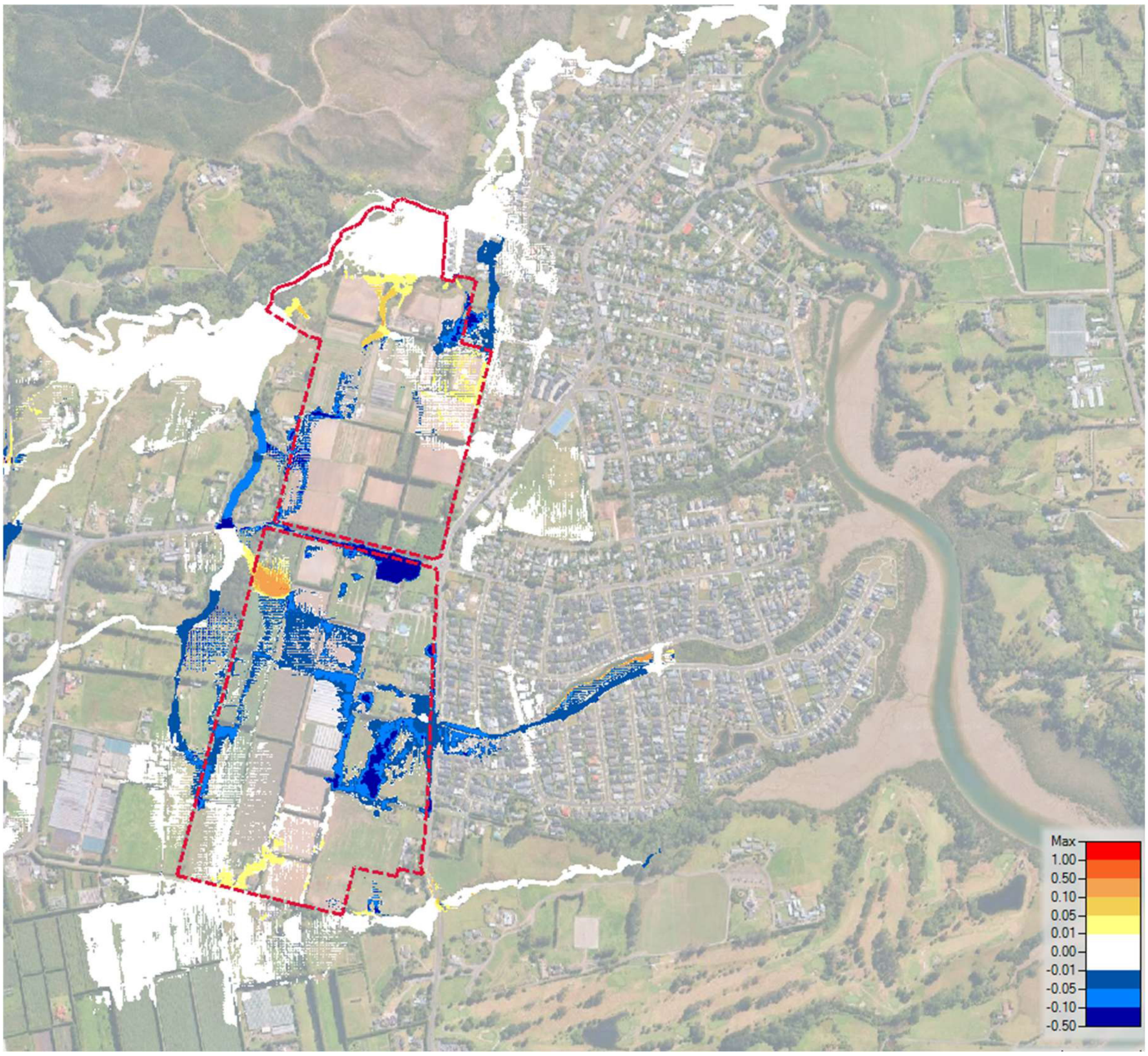

Figure 10: Water surface elevation difference map (post-Pre) – 100YrCC3.8

The maximum top water level differences within the major tributaries are shown in Table 9.

Table 9: Top water level difference along major tributaries -100YrCC3.8

Location	Top water level difference between proposed and existing conditions 100YrCC3.8	
22 Duke Street	Northern depression area	0mm to max 4mm increase
	Southern low-lying area	0mm to max 4mm increase
Forest Stream	Upstream of Duke Street	0mm to max 2mm increase
	Downstream of Duke Street	0mm to max 8mm increase
Southern Stream	Upstream Coatesville-Riverhead Hwy Culvert	0mm to max 7mm increase
	Downstream Coatesville-Riverhead Hwy Culvert	0mm to max 7mm increase
Western Tributary	Upstream Riverhead Road Culvert	0mm to max 2mm increase
	Downstream Riverhead Road Culvert	Decrease up to 70mm

6.4 Scenario 15 - 2yr ARI without Climate Change

Under the 2yr ARI without climate change scenario, noticeable increases (of more than 10mm) are observed within the RPPC100 area at 22 Duke Street, downstream of Riverhead Road culvert and in Forest Stream downstream of Duke Street as shown in Figure 11 below.

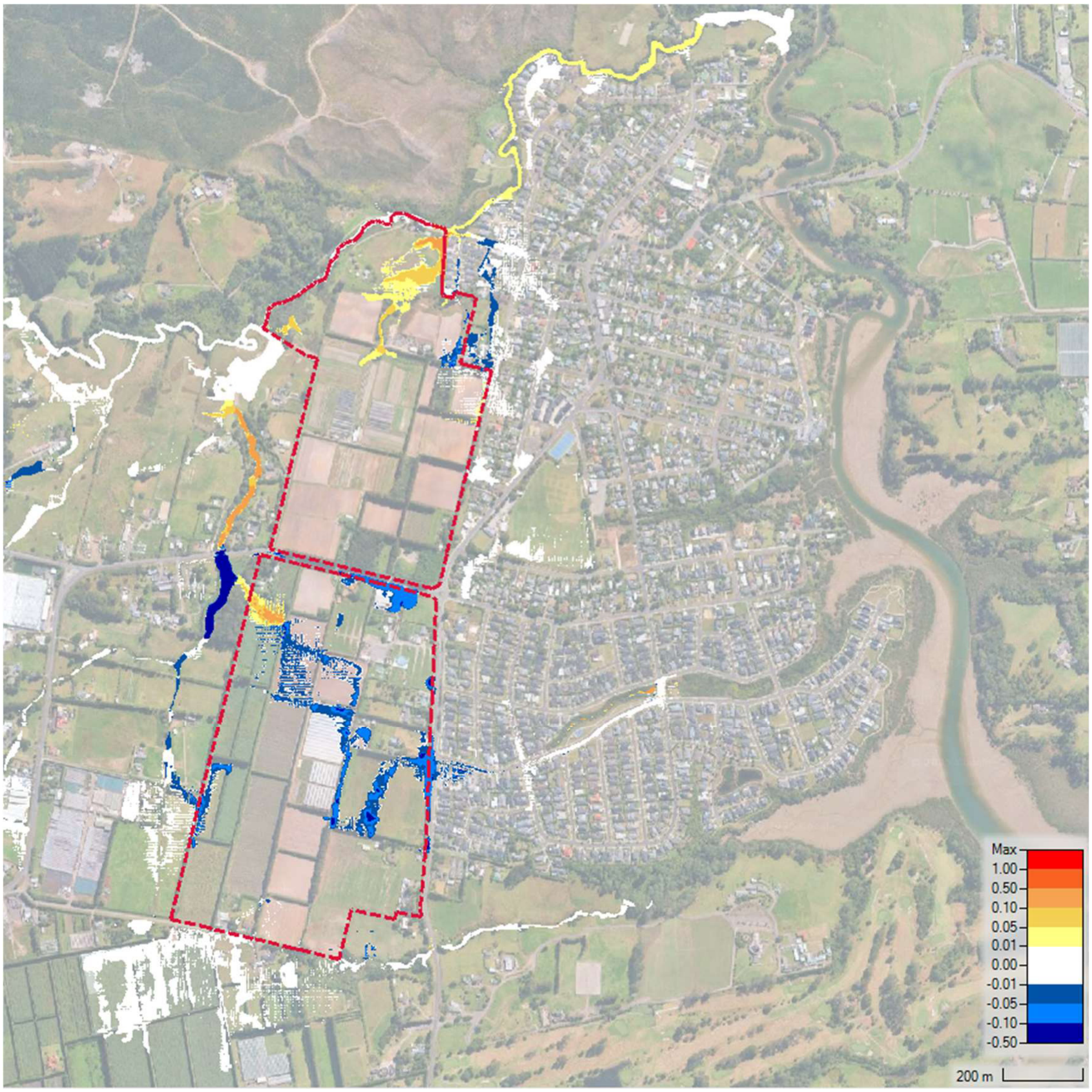

Figure 11 Water surface elevation difference map (post-Pre) – 2YrWOCC

The maximum top water level differences within the major tributaries are shown in Table 10.

Table 10: Top water level difference along major tributaries -2YrWOCC

Location	Top water level difference between proposed and existing conditions 2YrWOCC	
22 Duke Street	Northern depression area	Increase up to 220mm
	Southern low-lying area	Increase up to 100mm
Forest Stream	Upstream of Duke Street	0mm to max 7mm increase
	Downstream of Duke Street	0mm to 20mm increase (contained in channel)
Southern Stream	Upstream Coatesville-Riverhead Hwy Culvert	0mm to max 4mm increase
	Downstream Coatesville-Riverhead Hwy Culvert	0mm to max 6mm increase
Western Tributary	Upstream Riverhead Road Culvert	Decrease up to 1000mm
	Downstream Riverhead Road Culvert	Increase up to 250mm (contained in channel)

Similar to the results for the 2yrCC2.1 scenario (Scenario 12), the maximum observed increase in top water levels (up to 220 mm) within the RPPC100 area at 22 Duke Street is generally contained within the existing low-lying areas with minimal change to the horizontal extent, as shown in Figure 12 with the pre-development 100yr+3.8 CC top water level shown for context. The increase just beyond the eastern boundary of 22 Duke Street is contained within a channel protected by an easement noted on these properties for surface flow of overland flow. As discussed in previous sections, the observed increases are considered to be largely due to the fact that the flood model does not contain a primary network, and it is expected that these will be resolved through appropriate design of the primary system as the development within the RPPC100 area progresses through consenting phases.

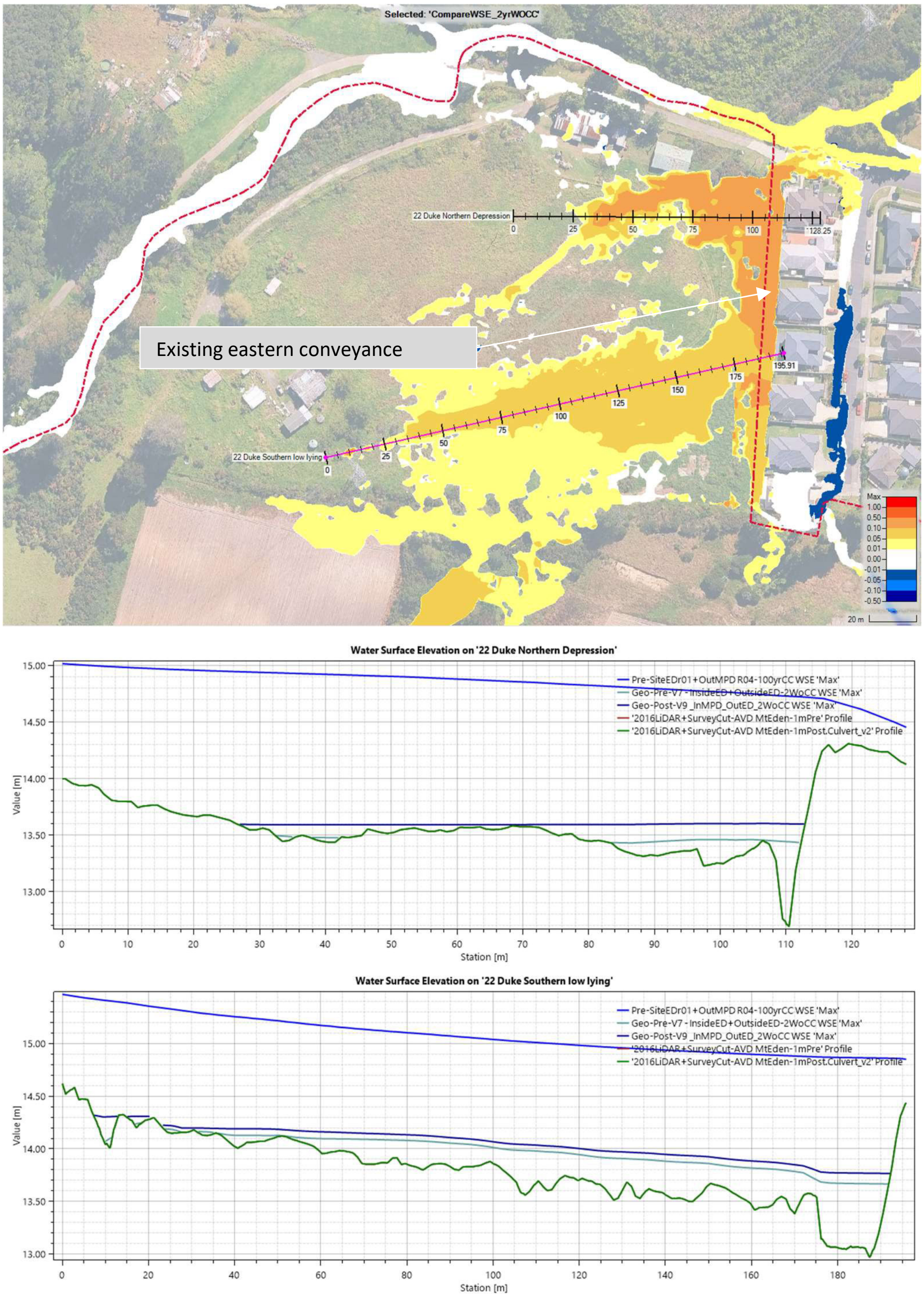

Figure 12: Top water level increases within 22 Duke Street - 2yrCCWOCC

Although there is an increase of top water levels (approximately 250mm max) observed within the Western Tributary downstream of Riverhead Road the increase is (easily) contained within the stream channel, as shown in Figure 13 with pre-development 100yr+3.8CC top water level shown for context, and is considered less than minor. This also applies for the minor (up to 20mm) increase downstream of Duke Street – see Figure 14.

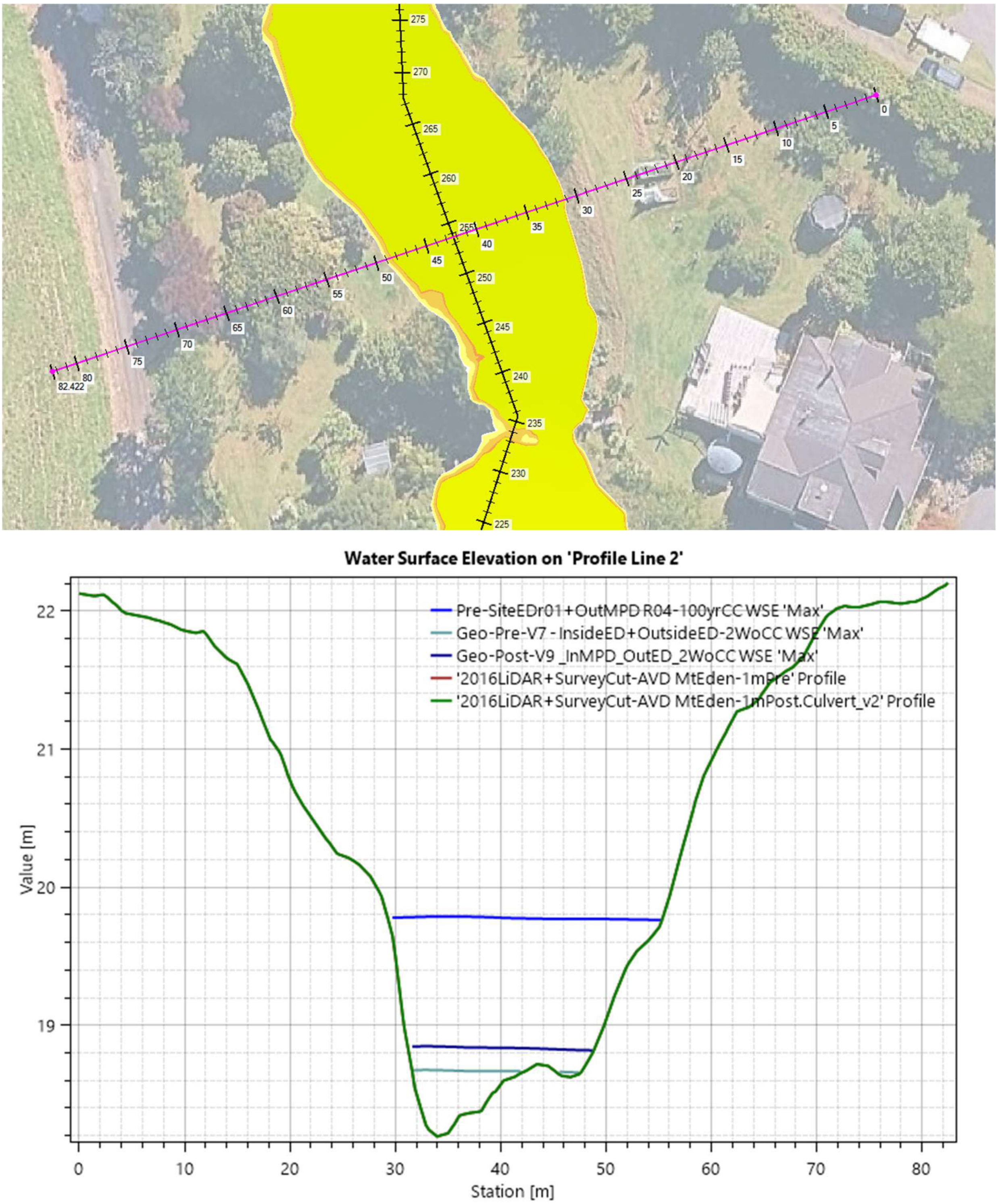

Figure 13: Cross section across the Western Tributary where the increase in top water level is maximum-2YrWOCC

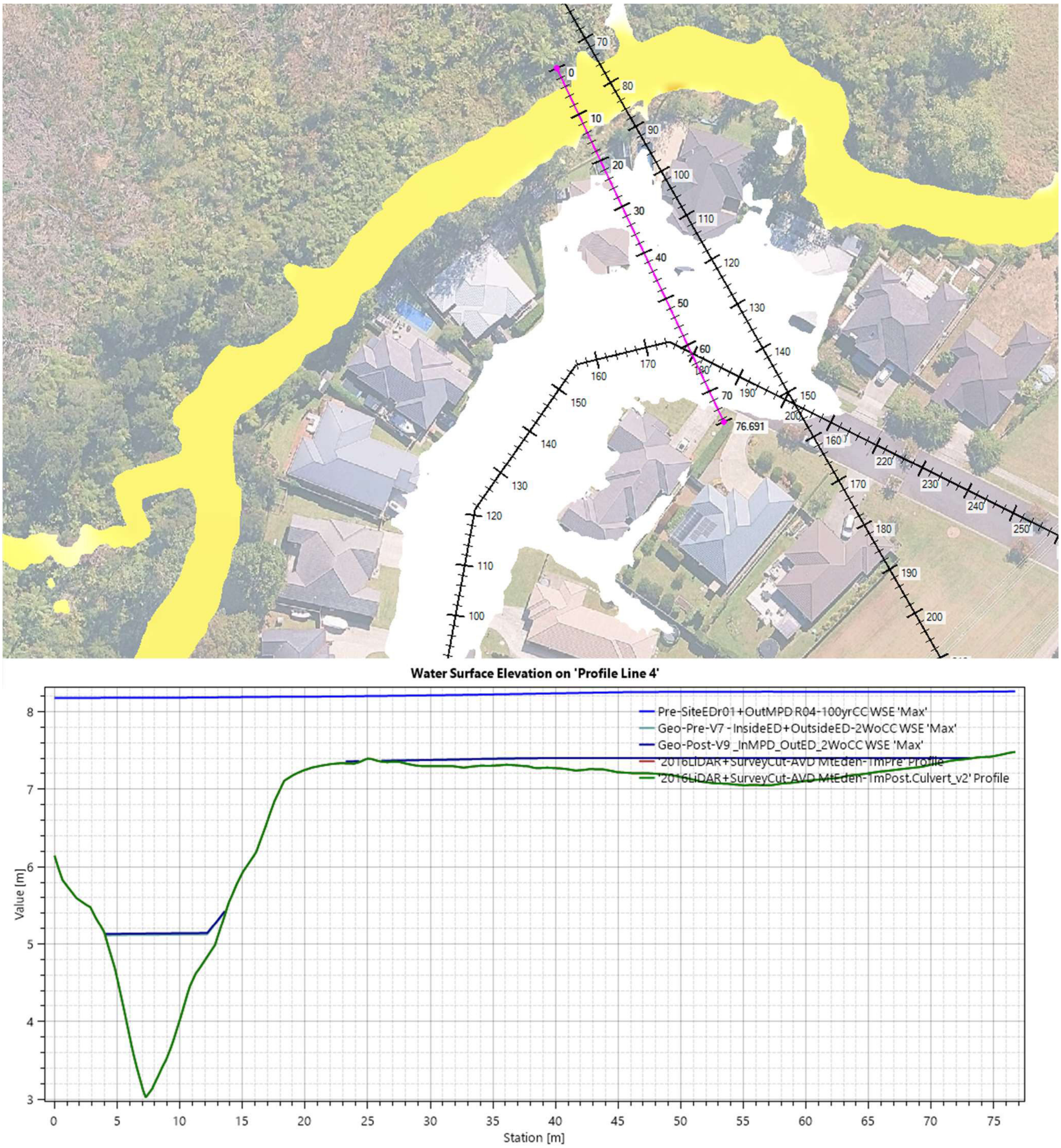

Figure 14: Cross section across the Riverhead Forest stream where the increase in top water level is maximum-2YrWOCC

6.5 Scenario 16 - 10yr ARI without Climate Change

Under the 10yr ARI without climate change scenario, noticeable increases (of more than 10mm) are not observed outside the RPPC100 area except for the Western Tributary downstream of Riverhead Road culvert as shown in Figure 15. However, in some locations, particularly Cambridge Road, there is a noticeable decrease in top water level.

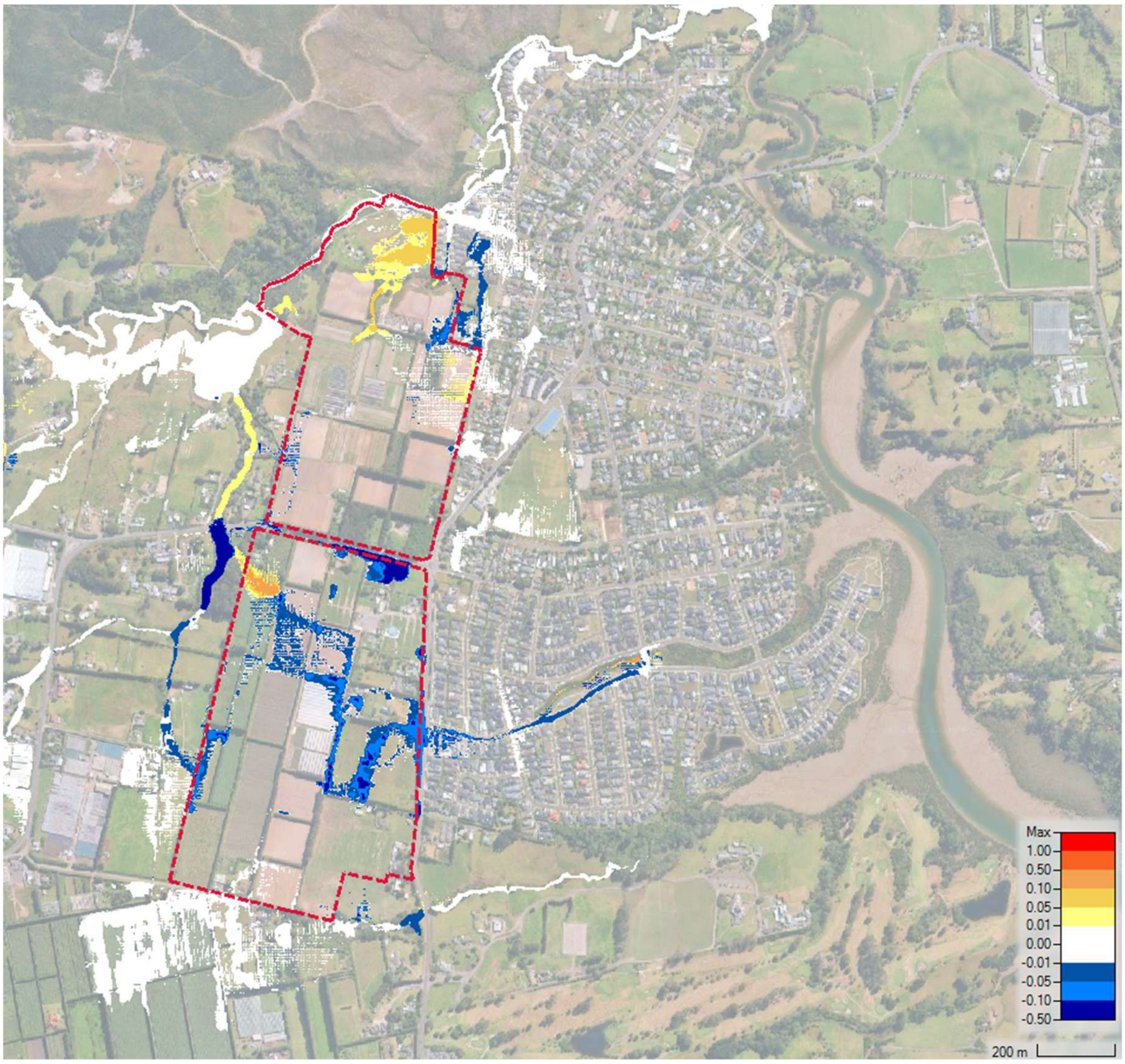

Figure 15 Water surface elevation difference map (post-Pre) – 10YrWOCC

The maximum top water level differences within the major tributaries are shown in Table 11.

Table 11: Top water level difference along major tributaries -10YrWOCC

Location	Top water level difference between proposed and existing conditions 10YrWOCC	
22 Duke Street	Northern depression area	Increase up to 80mm
	Southern low-lying area	Increase up to 80mm
Forest Stream	Upstream of Duke Street	0mm to max 3mm increase
	Downstream of Duke Street	No increase
Southern Stream	Upstream Coatesville-Riverhead Hwy Culvert	Decrease up to 25mm
	Downstream Coatesville-Riverhead Hwy Culvert	No increase
Western Tributary	Upstream Riverhead Road Culvert	Decrease up to 1000mm
	Downstream Riverhead Road Culvert	Increase up to 20mm (contained in channel)

As observed in the 10yrCC2.1 scenario (Scenario 13), while there are noticeable increases in top water level observed within the RPPC100 area at 22 Duke Street in the 10yrWOCC scenario, these are generally contained within the existing ponding areas or the flood management easement along the eastern boundary, with no significant change in extent as shown in Figure 16 with pre-development 100yr+3.8CC top water level shown for context. As discussed already, the observed increases are considered to be largely due to the fact that the flood model does not contain a primary network, and it is expected that these can be resolved during detailed design of the primary stormwater system.

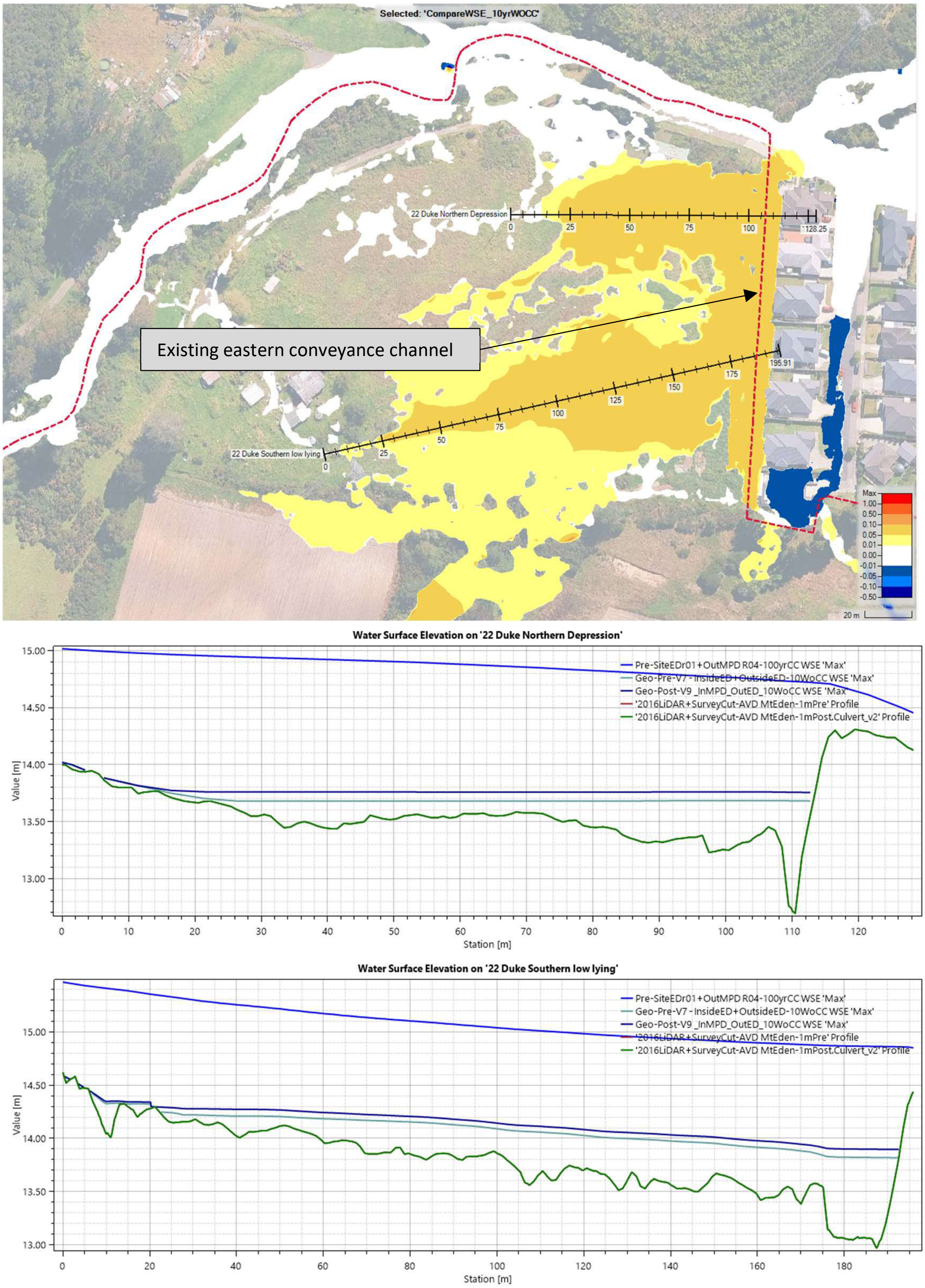

Figure 16: Top water level increases within 22 Duke Street - 10yrCCWOCC

Although there is a slight increase of top water levels (up to 20mm) within the Western Tributary downstream of Riverhead Road the increase is contained within the stream channel, as shown in Figure 17 with pre-development 100yr+3.8CC top water level shown for context, and is considered less than minor. Therefore, there are expected to be no increases in effects to the neighbouring properties.

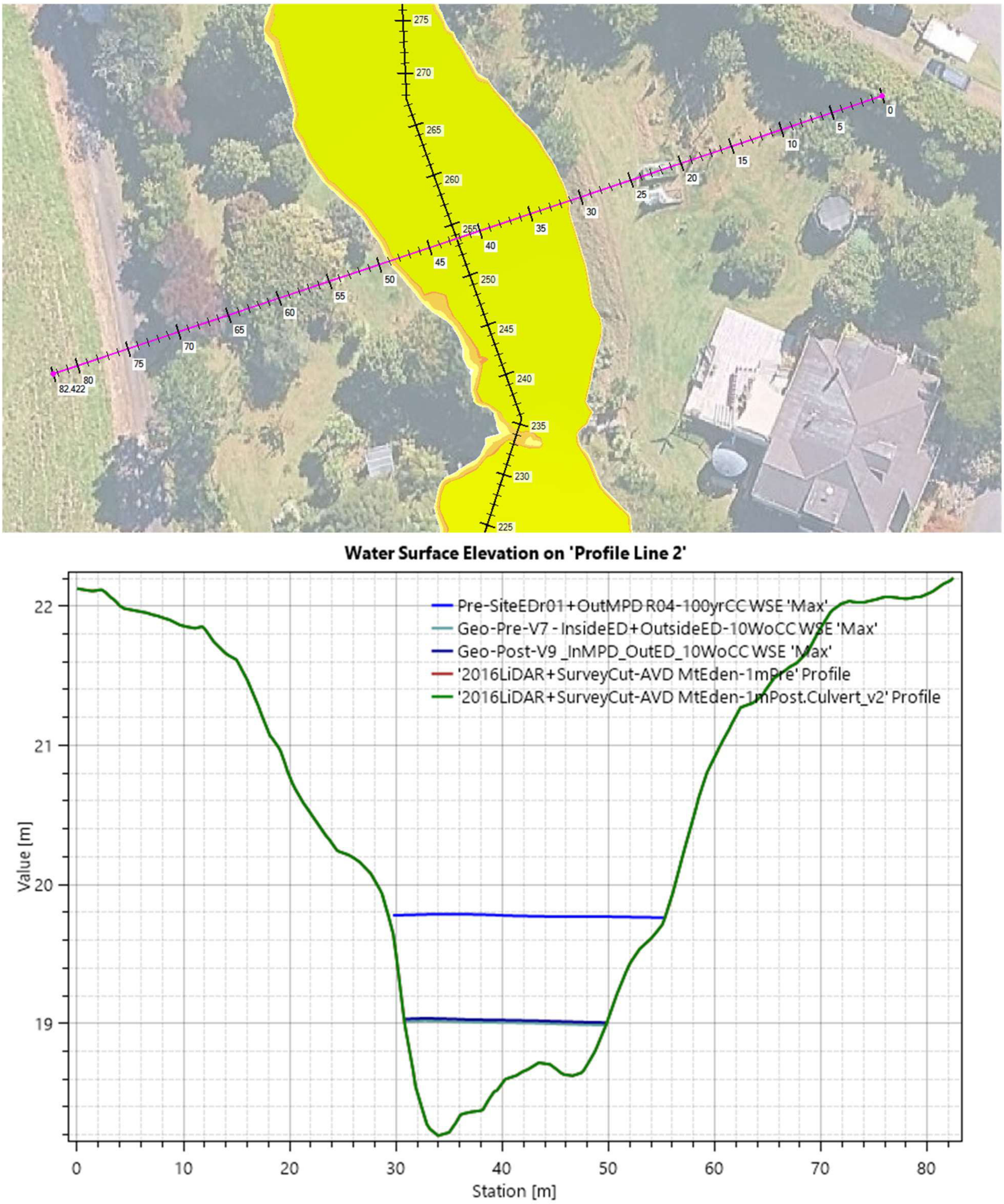

Figure 17: Cross section across the Western Tributary where the increase in top water level is maximum-10YrWOCC

6.6 Scenario 17 - 100yr ARI without Climate Change

Under the 100yr ARI without climate change scenario, noticeable increases (of more than 10mm) are not observed outside the RPPC100 as shown in Figure 18. However, there are noticeable decreases in several locations outside of the RPPC100 area.

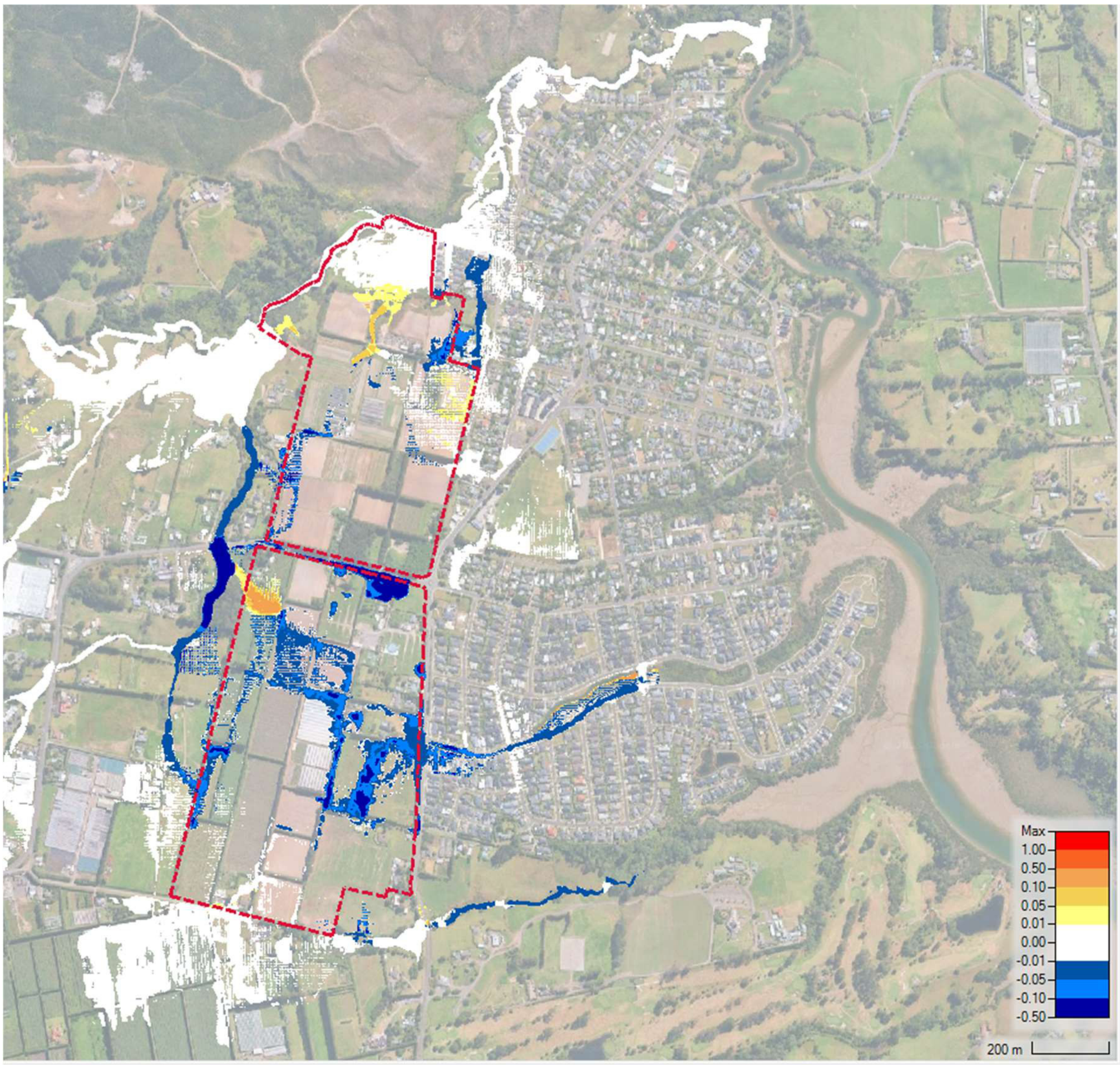

Figure 18: Water surface elevation difference map (post-Pre) – 100YrWOCC

The maximum top water level differences within the major tributaries are shown in Table 12.

Table 12: Top water level difference along major tributaries – 100YrWOCC

Location	Top water level difference between proposed and existing conditions 100YrWOCC	
22 Duke Street	Northern depression area	No increase
	Southern low-lying area	No increase
Forest Stream	Upstream of Duke Street	0mm to max 2mm increase
	Downstream of Duke Street	No increase
Southern Stream	Upstream Coatesville-Riverhead Hwy Culvert	No increase
	Downstream Coatesville-Riverhead Hwy Culvert	Decrease up to 20mm
Western Tributary	Upstream Riverhead Road Culvert	Decrease up to 500mm
	Downstream Riverhead Road Culvert	Decrease up to 30mm

6.7 Scenario 18 – 2yr upstream with 100yr downstream (without climate change)

Under the 2yr upstream/100yr downstream without climate change scenario, there are no noticeable increases (of more than 10mm) observed outside the RPPC100 as shown in Figure 19. However, there are several locations where there is a noticeable decrease in top water levels.

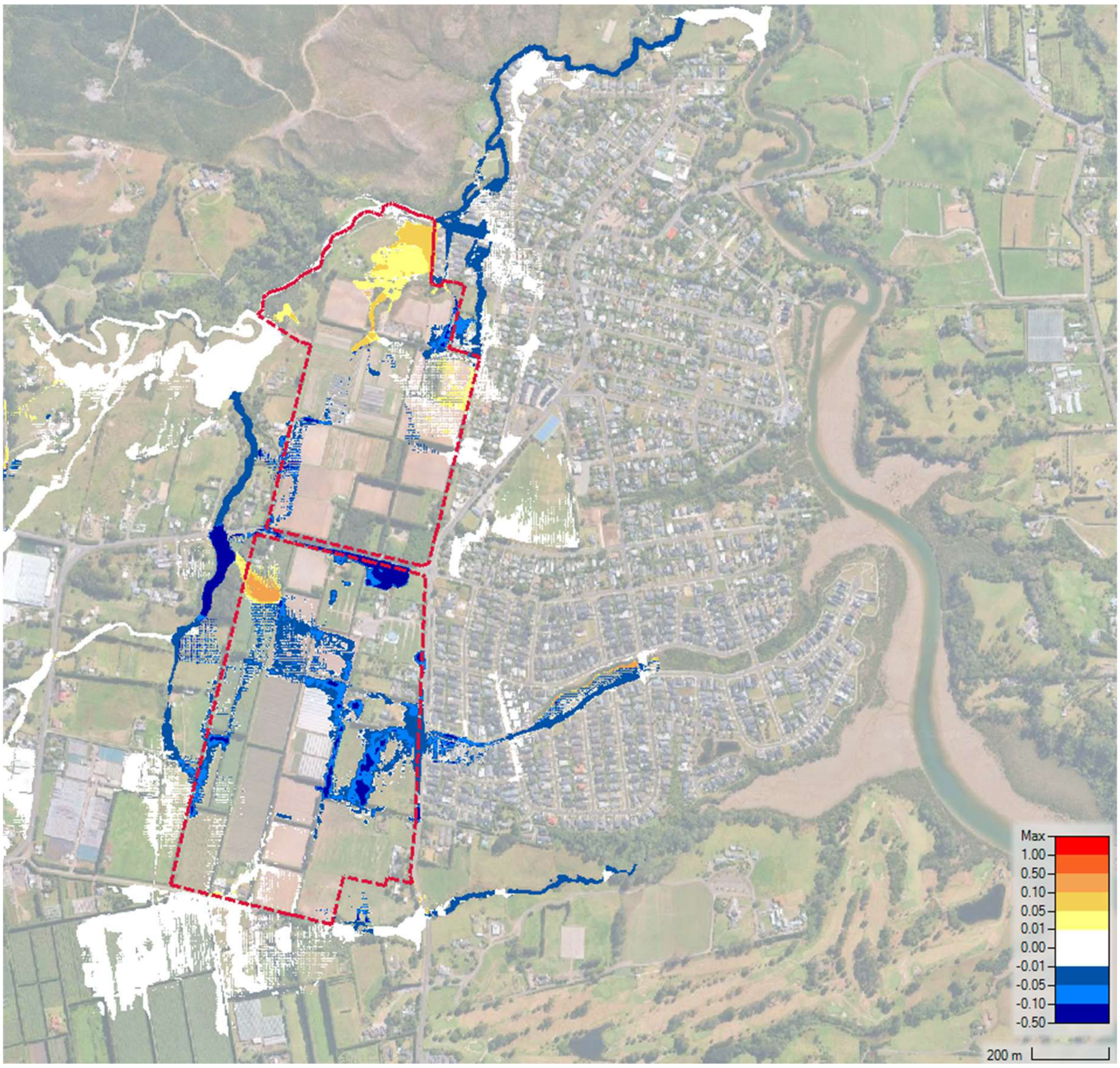

Figure 19: Water surface elevation difference map (post-Pre) – 2yr Upstream/100Yr downstream WOCC

The maximum top water level differences within the major tributaries are showing Table 13.

Table 13: Top water level difference along major tributaries -2yr upstream/100Yr downstream WOCC

Location	Top water level difference between proposed and existing conditions 2yr/100yr WOCC	
22 Duke Street	Northern depression area	Increase up to 70mm
	Southern low-lying area	Increase up to 60mm
Forest Stream	Upstream of Duke Street	0mm to max 2mm increase
	Downstream of Duke Street	No increase
Southern Stream	Upstream Coatesville-Riverhead Hwy Culvert	No increase
	Downstream Coatesville-Riverhead Hwy Culvert	Decrease up to 20mm
Western Tributary	Upstream Riverhead Road Culvert	Decrease up to 500mm
	Downstream Riverhead Road Culvert	Decrease up to 30mm

As observed in the previous scenarios, while there are noticeable increases in top water level observed within the RPPC100 area at 22 Duke Street, these are generally contained within the existing ponding areas, with no significant change in extent as shown in Figure 20 with pre-development 100yr+3.8CC top water level shown for context. As discussed already, the observed increases are considered to be largely due to the fact that the flood model does not contain a primary network, and it is expected that these can be resolved during detailed design of the primary stormwater system.

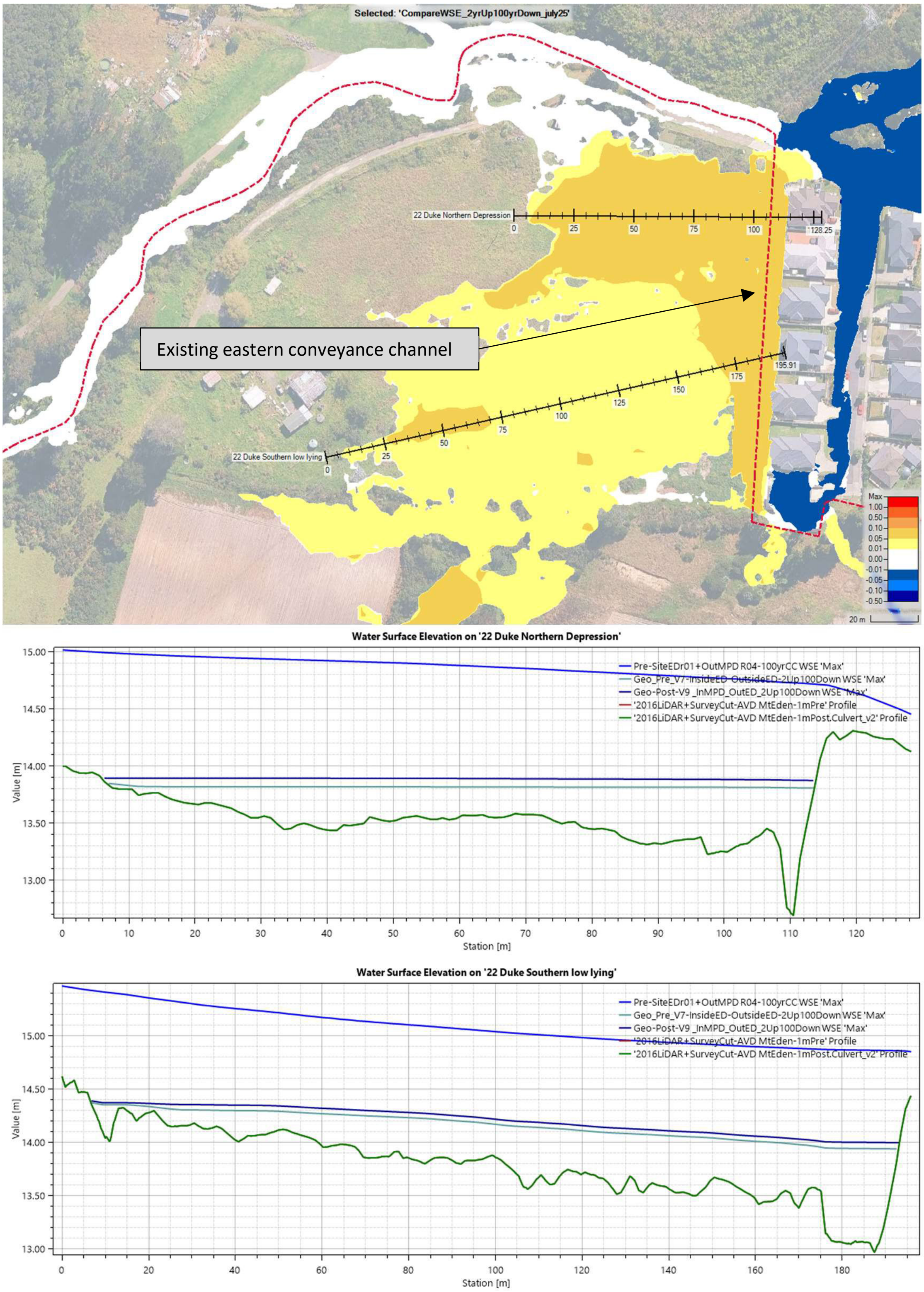

Figure 20: Top water level increases within 22 Duke Street – 2yrUp/100yrDown WOCC

7 Future refinements

The refinements identified below are intended to guide future analysis as design develops and are not possible at this stage as they rely on specific development layouts and more detailed engineering design than is possible at a Plan Change level of assessment. While these refinements are expected to improve the level of detail within the modelling at specific locations, they are not anticipated to alter the overall finding that the effects of the RPPC100 with respect to flooding can be managed via the management and mitigation strategies proposed within the RPPC100 SMP.

7.1 Riverhead Road Culvert refinement

The currently modelled design of the Riverhead Road culvert upgrade is based on managing peak flows under the 2yr, 10yr and 100yr climate change adjusted events under MPD conditions both inside and outside the RPPC100 area. As noted in the previous sections, under some events (predominantly in the more frequent 2yr and 10yr events), some increases in top water level are observed downstream of Riverhead Road when considering existing development (ED) outside of the RPPC100 area. However, these increases are all contained within the existing stream channel and do not increase the risk to the neighbouring properties.

Further engineering design refinement of the Riverhead Road Culvert upgrade will allow for optimisation of sizing, layout and road levels to meet Auckland Transport requirements while reducing the effects of increasing flows downstream in more frequent rainfall events. The refinement of this design, during resource consent and engineering plan approval (EPA) stages, will not noticeably alter the outcomes of the modelling shown in this report.

7.2 Attenuation refinement

The current dummy attenuation associated with the southern stream catchment S01_P is focussed on avoiding downstream effects during 100yrCC +3.8°C storm event. The attenuation volume and depths can be optimised through further refinement of the attenuation basin once more detailed information is available at Resource Consent stage.

Refinement and optimisation of the S01_P attenuation system will also enable effects during the smaller storm events (2yr and 10yr ARI with 2.1°C climate change) to be managed via more detailed design of the outlet structures to ensure peak flows arriving at the Coatesville Riverhead Highway culvert are less than or equal to predevelopment.

7.3 Primary Systems

While for major flood events, the overall flood mitigation strategy appears to be effective, showing negligible or no increases in major flood events (i.e. 100yr ARI), the modelling shows some minor increases in flood levels within the RPCC100 area and at hydrograph loading points within the model during more frequent rainfall events (assessed as 2yr and 10yr ARI). These increases are considered to primarily be a function of the model's current simplification, specifically its omission of primary stormwater systems arising from the lack of detail inherent at the Plan Change stage.

When the primary system is accounted for in future design stages, the observed increases are expected to be resolved as development will need to comply with the levels of service requirements of the Auckland Council Stormwater Code of Practice and appropriate outfall design will need to be incorporated.

Inclusion of primary stormwater systems in future modelling at resource consent stage will help to further refine the model results for more frequent events (e.g. 2yr and 10yr) to mitigate changes in off-site top water levels. It is standard practice for this detail to be provided at resource consent stage, rather than at a plan change level, and the modelling completed to date is appropriate to determine the extent of effects resulting from RPPC100.

8 Summary and Conclusions

Previous modelling for the Riverhead Private Plan Change (RPPC) had concluded that the proposed change in land use would result in **less than minor effects concerning flooding** for 2-year and 10-year Average Recurrence Interval (ARI) events with 2.1°C climate change, and for the 100-year ARI event with 3.8°C climate change. This conclusion was contingent on proposed mitigation measures, including an upgrade to the existing DN750 Riverhead Road culvert, the diversion of a portion of the southern RPPC100 area, and the provision of peak flow attenuation. These proposed mitigation measures are detailed in the SMP (Revision 4 as notified) and addendum SMP (dated 31 March 2025) supplied as part of RPPC100 to date.

The current study was undertaken to **test the sensitivity of the overall flood mitigation strategy** through several key objectives:

- **Updating hydrological parameters** in the HEC-HMS model, in line with recommendations from Auckland Council's Healthy Waters catchment modelling team. This involved:
    - refining **SCS Curve Numbers (CN)** based on detailed soil and land use analysis,
    - updating **percentage impervious** to accurately reflect existing development (ED) conditions,
    - adjusting **channelisation (C) factors** based on actual ED conditions, and
    - recalibrating **SCS Lag times** to align with Auckland Council GeoMaps overland flow path layer times of concentration.
    - SMAF 1 hydrological mitigation was also incorporated into this assessment to evaluate potential impacts on downstream top water levels due to delayed hydrograph peaks.
- **Updating hydraulic model parameters** in the HEC-RAS model. This included:
    - refining **Manning's roughness layers** to accurately represent ED, buildings, and streams, and
    - updating the Riverhead Forest Stream culvert at 22 Duke Street from a single 2.5m diameter culvert to **two 1.5-meter diameter culverts**, reflecting actual replacements completed in 2021.
- **Testing model sensitivity** to various combinations of storm events and climate change. This encompassed
    - 2yr, 10yr, and 100yr ARIs both with and without climate change, and
    - a sensitivity scenario combining different rainfall depths in upper and lower catchments (2yr upstream with 100yr downstream).

Seven additional scenarios were agreed upon during the RPPC100 Expert Conference – Stormwater and Flooding and subsequently modelled. For each scenario, **pre-development conditions** (assuming existing land use across all sub-catchments) were compared against **post-development conditions** (maximum probable development within the RPPC100 area, with existing development outside) to assess potential flood effects.

The updated water surface level difference maps were developed to compare pre- and post-development conditions, evaluating impacts on existing flood hazards both within the RPPC100 area and its surrounding environment. The findings **reinforce the previous conclusions that changes in top water levels and corresponding flood hazard are considered less than minor**. The findings also confirm that, in all modelled scenarios, the flood management approach proposed for RPPC100 is appropriate for adequately managing the effects on flooding of the change in land use arising from RPPC100.

Specific findings for the areas of interest include:

- **Within RPPC100 area at 22 Duke Street:** while the modelling for more frequent storm events (2-year and 10-year ARI, and 2yr/100yr) indicates increases in flood levels at 22 Duke Street and along the eastern boundary, these are considered a direct consequence of the flood model's current simplification in not fully representing the primary stormwater drainage system. These increases are **expected to be resolved as part of the detailed design process**, which will include the primary stormwater system and its conveyance capacity. Conversely, for the rarer and more extreme 100-year ARI flood events, the modelling shows **negligible or no increases** at 22 Duke Street, suggesting the broader flood mitigation strategy effectively manages these larger events at this location.
- **Forest Stream**: Minor increases were noted in some scenarios, for example, up to 20mm downstream of Duke Street for the 2yr ARI without Climate Change event. This increase was also considered **less than minor** and contained within the channel. Other scenarios generally showed negligible (e.g., up to 2mm or 8mm) or no increases downstream of Duke Street.
- **Southern Stream**: This tributary generally showed no increase or even decreases in top water levels across the modelled scenarios.
- **Western Tributary (Riverhead Road Culvert)**:
  - **Upstream of Riverhead Road Culvert**: A significant decrease in top water levels was consistently observed across most scenarios, ranging from 500mm to 1200mm. This positive effect is attributed to the proposed culvert upgrade.
  - **Downstream of Riverhead Road Culvert**: Some scenarios showed increases, such as up to 150mm for the 2yr ARI + 2.1°C Climate Change scenario and up to 250mm for the 2yr ARI without Climate Change scenario. However, these increases were consistently deemed easily contained within the stream channel and, therefore, considered less than minor. Most other scenarios showed no increase or even decreases downstream.
- For many scenarios, particularly those with higher ARI events (e.g. 10yr ARI + 2.1°C Climate Change, 100yr ARI + 3.8°C Climate Change, and various 100yr ARI without climate change scenarios), there are no noticeable increases in top water levels (more than 10mm) observed outside of the RPPC100 Area.

In conclusion, this detailed assessment, incorporating updated hydrological and hydraulic parameters and testing various storm event scenarios, confirms that the proposed Riverhead Private Plan Change, along with its planned mitigation measures (notably the Riverhead Road culvert upgrade), is expected to result in **less than minor flooding effects outside of the Plan Change area**. The model demonstrates that the overall mitigation strategies proposed are effective for managing flood effects outside of the RPPC100 area

9 Limitations

This report has been prepared solely for the benefit of our client with respect to the particular brief and it may not be relied upon in other contexts for any other purpose without the express approval by CKL. Neither CKL nor any employee or sub-consultant accepts any responsibility with respect to its use, either in full or in part, by any other person or entity. This disclaimer shall apply notwithstanding that the memo/report may be made available to other persons including Council for an application for consent, approval or to fulfil a legal requirement.

Appendix 1 Model build summary

Job number: A20405

Job description: Hydrology and Hydraulic flood modelling for Riverhead Development-Structure plan change stage

Calculations by: SK **Date:** 21.07.25

Checked by: ZW **Date:** 21.07.25

1 Aim

- To assess the hydrological and hydraulic impacts resulting from the proposed RRPC100 area across a broader range of events and scenarios than previously evaluated, in order to identify the potential effects.

2 Methodology – Key Changes to Initial Model

- Incorporated the proposed SMAF1 detention component into discharges from the proposed RPPC area during 100yr ARI (including the effects of +3.8°C Climate Change) 2yr and 10yr ARI (including the effects of +2.1°C Climate Change) Catchment flow hydrographs from HEC HMS model result are loaded as boundary conditions
- upgrade of the existing DN2500 22 Duke Street culvert to 12 x 1.5m diameter culvert
- Refinement to existing hydrology and hydraulic parameters
- Assess broader range of rainfall events and scenarios

3 Model Build - Hydrology

3.1 Software

Hydrologic Engineering Center - Hydrologic Modelling System (HEC-HMS) developed by the U.S. Army Corps of Engineers (version 4.11) has been used for hydrology modelling.

The link to the model project is below:

Synergy12d://CKL-AZU-SYN-1/Projects/A20405/CI 1 - Environmental/01 Environmental/Modelling and Calculations/FRA/HEC HMS/

3.2 Pre Development and Post Development Hydrology

The sub-catchment hydrology has been assessed separately for areas located inside and outside the RRPC100 boundary. Accordingly, three basin models were developed in HEC-HMS to represent the following development conditions:

TABLE 1: BASIN MODELS

Basin model	Development Conditions
Outside-ActualED_R04_June25	Existing Development Conditions for the sub catchments outside PC100 area
Site-Sub-ED--R01-0.8	Existing Development Conditions for the sub catchments inside PC100 area
Site-Sub-Post-R06	Maximum probable development conditions with SMAF attenuation for the sub catchments inside PC100 area

Accordingly, the following basin models have been used combinedly to define the pre-development and post development hydrology.

TABLE 2: PRE AND POST DEVELOPMENT HYDROLOGY

Condition	Associated Basin Models	Description
Pre Development	Outside-ActualED_R04_June25 Site-Sub-ED--R01-0.8	Existing development conditions considered for all sub catchments inside and outside of the RRPC100 area
Post Development	Outside-ActualED_R04_June25 Site-Sub-Post-R06	Existing development conditions considered for all sub catchments outside of the RRPC100 area and maximum probable development conditions with SMAF attenuation for all sub catchments inside of the RRPC100 area

The hydrological parameters from previous model runs have been retained for this assessment, with the exception of the following key changes.

- Curve no of all the sub catchments outside PC100 area have been updated based on the corresponding land use and hydrological soil group.

TABLE 3: UPDATED CURVE NO'S BASED ON LAND USE AND HYDROLOGICAL SOIL GROUP _ OUTSIDE PC100 AREA

Soil Group	Land Use	Curve Number (CN)
B	Bush	55
	Pasture	61
	Urban Lawn	61
	Crops	81
C	Bush	70
	Pasture	74
	Urban Lawn	74
	Crops	88

- Pre development Curve Numbers of all the sub catchments inside PC100 area have been updated based on the corresponding land use and hydrological soil group.

TABLE 4: UPDATED PRE DEVELOPMENT CURVE NO'S BASED ON LAND USE AND HYDROLOGICAL SOIL GROUP _ INSIDE PC100 AREA

Soil Group	Land Use	Curve Number (CN)
B	Good Crops	81
	Pasture	61

- Post development Curve numbers of all sub catchments inside PC100 area remain as per previous modelling
- Channelization factors for all the sub catchments outside PC100 area have been updated based on the values in Table 5.

TABLE 5: UPDATED CHANNELIZATION FACTORS -OUTSIDE PC100 AREA

Criteria	Channelization factor
Natural Streams	1
Engineered Channels	0.8

3.3 Rainfall Events

Following rainfall events and scenarios have been considered.

TABLE 6: DIFFERENT RAINFALL EVENTS AND SCENARIOS

Rainfall Event	Name	Scenarios
100yr Event	100CC3.8	1. 100yr event with climate change adjustments for 3.8˚ C
	100WOCC	2. 100yr event without climate change adjustments
	2up100Down WOCC	3. 2yr event without climate change for C11, C12_4 and Sum C12 catchments and 100yr event without climate change adjustments for the rest
	40mmup 100Down WOCC	4. 40mm rainfall depths for C11, C12_4 and Sum C12 catchments and 100yr event without climate change adjustments for the rest
2yr Event	2CC2.1	5. 2yr event with climate change adjustments for 2.1˚ C
	2WOCC	6. 2yr event without climate change adjustments
10yr Event	10CC2.1	7. 10yr event with climate change adjustments for 2.1˚ C
	10WOCC	8. 10yr event without climate change adjustments

3.4 Resulting Peak Flows

The resulting peak flows for sub-catchments located inside and outside the PC100 area, under each development scenario and rainfall event, are summarized below.

TABLE 7: RESULTING PEAK FLOWS FOR EACH SCENARIO

Peak Flows (m^3/sec) Existing Development Conditions Outside the site - Outside-ActualED_R04_June25								
Location	100 CC3.8	100 WOCC	2up100 Down WOCC	40mmup 100Down WOCC	2CC2.1	2WOCC	10CC2.1	10WOCC
C11	72.34	49.20	12.24	3.35	15.73	12.24	34.09	26.61
C12_1	9.65	6.40	1.56	0.41	2.03	1.56	4.55	3.50
C12_2	2.92	1.94	0.48	0.13	0.62	0.48	1.38	1.06
C12_3	1.18	0.79	0.21	0.06	0.27	0.21	0.58	0.45
C12_4	1.93	1.36	0.44	0.15	0.55	0.44	1.05	0.84
C13	3.69	2.46	2.46	2.46	0.77	0.59	1.70	1.30
C14_1	1.23	0.82	0.82	0.82	0.25	0.19	0.55	0.42
C14_2	1.73	1.15	1.15	1.15	0.35	0.27	0.77	0.59
C14_3	1.38	0.92	0.92	0.92	0.28	0.21	0.61	0.47
C14_4	1.38	0.92	0.92	0.92	0.28	0.21	0.61	0.47
C14_5	1.08	0.72	0.72	0.72	0.22	0.16	0.48	0.37
C15_1	1.91	1.32	1.32	1.32	0.45	0.35	0.92	0.72
C15_2	1.36	0.91	0.91	0.91	0.28	0.21	0.61	0.47
C16_1	1.54	1.03	1.03	1.03	0.31	0.24	0.69	0.53
C16_2	1.48	0.99	0.99	0.99	0.30	0.23	0.66	0.51
C16_3	1.06	0.70	0.70	0.70	0.21	0.16	0.47	0.36
C16_4	1.67	1.11	1.11	1.11	0.33	0.25	0.74	0.57
C16_5	1.76	1.17	1.17	1.17	0.35	0.27	0.79	0.60
C16_6	1.16	0.77	0.77	0.77	0.23	0.18	0.52	0.40
C16_7	1.76	1.19	1.19	1.19	0.38	0.29	0.82	0.63
C17	1.82	1.25	1.25	1.25	0.43	0.33	0.87	0.69
C18	1.25	0.85	0.85	0.85	0.28	0.22	0.59	0.46
C19_1	1.09	0.76	0.76	0.76	0.27	0.21	0.54	0.42
C19_2	1.38	0.94	0.94	0.94	0.34	0.26	0.71	0.56
C19_3	1.39	0.93	0.93	0.93	0.33	0.25	0.70	0.54
C19_4	1.33	0.88	0.88	0.88	0.29	0.23	0.65	0.50
C19_5	0.85	0.55	0.55	0.55	0.18	0.14	0.41	0.31
C19_6	1.77	1.21	1.21	1.21	0.45	0.35	0.92	0.72
C21	8.38	5.73	5.73	5.73	2.09	1.63	4.35	3.42
C22_1	5.10	3.65	3.65	3.65	1.55	1.26	2.83	2.30
C22_2	1.10	0.72	0.72	0.72	0.21	0.16	0.48	0.36
C22_3	0.98	0.64	0.64	0.64	0.18	0.14	0.43	0.32

C22_4	0.91	0.59	0.59	0.59	0.17	0.13	0.40	0.30
C31_1	1.12	0.76	0.76	0.76	0.27	0.21	0.58	0.45
C31_10	0.82	0.53	0.53	0.53	0.17	0.13	0.39	0.30
C31_2	1.21	0.83	0.83	0.83	0.31	0.24	0.64	0.50
C31_3	0.57	0.39	0.39	0.39	0.13	0.10	0.29	0.22
C31_4	1.24	0.80	0.80	0.80	0.25	0.19	0.58	0.44
C31_5	1.20	0.85	0.85	0.85	0.35	0.28	0.67	0.54
C31_6	1.05	0.68	0.68	0.68	0.21	0.16	0.49	0.37
C31_7	1.05	0.69	0.69	0.69	0.23	0.18	0.51	0.39
C31_8	0.93	0.60	0.60	0.60	0.19	0.14	0.43	0.33
C31_9	1.25	0.80	0.80	0.80	0.23	0.17	0.54	0.40
C32_1	1.83	1.32	1.32	1.32	0.56	0.46	1.00	0.82
C32_2	1.32	0.92	0.92	0.92	0.33	0.26	0.67	0.53
C32_3	0.91	0.66	0.66	0.66	0.28	0.23	0.50	0.41
C32_4	1.40	0.98	0.98	0.98	0.36	0.28	0.71	0.57
C33	0.49	0.32	0.32	0.32	0.09	0.07	0.21	0.16
C34_1	1.74	1.21	1.21	1.21	0.44	0.34	0.88	0.70
C34_2	1.11	0.78	0.78	0.78	0.28	0.22	0.56	0.44
C34_3	0.84	0.58	0.58	0.58	0.21	0.16	0.42	0.33
C34_4	1.01	0.71	0.71	0.71	0.26	0.21	0.52	0.41
C34_5	0.60	0.44	0.44	0.44	0.21	0.17	0.34	0.29
C34_6	1.14	0.80	0.80	0.80	0.29	0.23	0.58	0.46
C35_1	0.79	0.51	0.51	0.51	0.15	0.11	0.34	0.26
C35_2	1.11	0.72	0.72	0.72	0.21	0.16	0.48	0.36
C35_3	0.70	0.45	0.45	0.45	0.13	0.10	0.31	0.23
C35_4	1.08	0.70	0.70	0.70	0.20	0.15	0.47	0.35
C35_5	1.00	0.64	0.64	0.64	0.18	0.14	0.43	0.32
C35_6	0.88	0.56	0.56	0.56	0.16	0.12	0.38	0.28
C35_7	0.63	0.41	0.41	0.41	0.11	0.08	0.26	0.19
C36	0.38	0.28	0.28	0.28	0.13	0.11	0.22	0.19
C41_1	1.16	0.82	0.82	0.82	0.32	0.26	0.62	0.50
C41_2	1.26	0.87	0.87	0.87	0.32	0.25	0.65	0.51
C41_3	1.21	0.84	0.84	0.84	0.31	0.24	0.63	0.50
C41_4	0.73	0.51	0.51	0.51	0.19	0.15	0.38	0.30
C41_5	1.02	0.71	0.71	0.71	0.26	0.20	0.53	0.42
C41_6	0.84	0.58	0.58	0.58	0.22	0.17	0.44	0.35
C41_7	1.12	0.78	0.78	0.78	0.28	0.22	0.56	0.44
C41_8	1.79	1.25	1.25	1.25	0.46	0.36	0.91	0.72
C41_9	0.60	0.42	0.42	0.42	0.15	0.12	0.30	0.24
C42_1	5.27	3.70	3.70	3.70	1.29	1.02	2.59	2.06
C42_2	9.26	6.05	6.05	6.05	1.63	1.24	3.78	2.87
C51_1	0.12	0.09	0.09	0.09	0.04	0.03	0.06	0.05
C51_2	0.09	0.07	0.07	0.07	0.03	0.03	0.05	0.04
C52	0.39	0.27	0.27	0.27	0.10	0.08	0.19	0.15
C53	0.51	0.35	0.35	0.35	0.12	0.10	0.24	0.19

C54	0.52	0.37	0.37	0.37	0.14	0.11	0.26	0.21
C55	0.47	0.33	0.33	0.33	0.11	0.09	0.23	0.18
C56	0.70	0.48	0.48	0.48	0.16	0.13	0.33	0.26
C57	0.88	0.62	0.62	0.62	0.22	0.18	0.43	0.34
C58	1.02	0.71	0.71	0.71	0.25	0.20	0.49	0.39
C59_1	1.57	1.10	1.10	1.10	0.39	0.31	0.76	0.61
C59_2	0.87	0.61	0.61	0.61	0.22	0.18	0.43	0.34
C61	1.26	0.85	0.85	0.85	0.26	0.20	0.56	0.43
C62_1	1.13	0.78	0.78	0.78	0.26	0.21	0.53	0.42
C62_2	0.80	0.56	0.56	0.56	0.19	0.15	0.38	0.30
C62_3	1.39	0.93	0.93	0.93	0.27	0.20	0.59	0.45
C63	1.53	1.07	1.07	1.07	0.38	0.30	0.74	0.59
C71_1	0.17	0.12	0.12	0.12	0.04	0.03	0.08	0.06
C71_2	0.27	0.19	0.19	0.19	0.07	0.05	0.13	0.10
C71_3	0.71	0.50	0.50	0.50	0.19	0.15	0.36	0.29
C72	0.81	0.57	0.57	0.57	0.20	0.16	0.40	0.31
C73_1	0.51	0.34	0.34	0.34	0.10	0.08	0.23	0.17
C73_2	0.33	0.23	0.23	0.23	0.08	0.07	0.16	0.13
C74	0.90	0.63	0.63	0.63	0.22	0.18	0.44	0.35
C75	0.26	0.19	0.19	0.19	0.08	0.06	0.14	0.11
C76	1.05	0.73	0.73	0.73	0.25	0.19	0.51	0.40
E01_1	0.43	0.31	0.31	0.31	0.11	0.09	0.22	0.17
E01_2	0.50	0.35	0.35	0.35	0.12	0.10	0.24	0.19
E02_1	0.35	0.25	0.25	0.25	0.09	0.07	0.17	0.14
E02_2	0.28	0.19	0.19	0.19	0.06	0.05	0.13	0.10
SumC12 [1]	14.19	9.47	2.38	0.65	3.09	2.38	6.78	5.24
Peak Flows (m³/sec) Existing Development Conditions Inside the site - Site-Sub-ED--R01-0.8								
Location	**100 CC3.8**	**100 WOCC**	**2up100 Down WOCC**	**40mmup 100Down WOCC**	**2CC2.1**	**2WOCC**	**10CC2.1**	**10WOCC**
CC [2]	2.27	1.48	1.48	1.48	0.41	0.31	0.94	0.71
N01_1	2.98	2.09	2.09	2.09	0.74	0.59	1.47	1.17
N01_2	4.01	2.81	2.81	2.81	1.00	0.79	1.99	1.58
N01_3	0.35	0.25	0.25	0.25	0.09	0.07	0.18	0.14
N01_4	1.11	0.78	0.78	0.78	0.28	0.23	0.56	0.44
N01_5	0.87	0.61	0.61	0.61	0.21	0.16	0.43	0.34
N02	0.21	0.15	0.15	0.15	0.05	0.04	0.11	0.09
N03	0.36	0.25	0.25	0.25	0.09	0.07	0.17	0.14

[1] Sum of C12_1, C12_2 and C12_3

[2] Coastville Road Culvert

N04	1.08	0.70	0.70	0.70	0.19	0.14	0.45	0.34
N05_1	0.32	0.21	0.21	0.21	0.06	0.04	0.13	0.10
N05_2	0.30	0.19	0.19	0.19	0.05	0.04	0.12	0.09
N06	0.33	0.23	0.23	0.23	0.08	0.06	0.16	0.13
RFS-D[3]	22.14	15.36	15.36	15.36	5.22	4.11	10.59	8.36
RPD-D[4]	1.75	1.16	1.16	1.16	0.33	0.25	0.74	0.57
RRD_C[5]	11.02	7.66	7.66	7.66	2.57	2.03	5.21	4.12
S01_1	0.80	0.51	0.51	0.51	0.14	0.10	0.32	0.24
S01_2	0.82	0.53	0.53	0.53	0.14	0.10	0.33	0.25
S02_1	1.54	1.07	1.07	1.07	0.36	0.28	0.73	0.57
S02_2	0.83	0.57	0.57	0.57	0.19	0.15	0.39	0.31
S02_3	7.20	5.04	5.04	5.04	1.74	1.38	3.46	2.75
S03_1	1.27	0.84	0.84	0.84	0.24	0.18	0.54	0.41
S03_2	0.46	0.30	0.30	0.30	0.09	0.07	0.19	0.15
S04_1	0.38	0.26	0.26	0.26	0.08	0.06	0.17	0.13
S04_2	0.28	0.19	0.19	0.19	0.06	0.04	0.12	0.09
S04_3	0.10	0.06	0.06	0.06	0.02	0.01	0.04	0.03
S05_1	0.85	0.57	0.57	0.57	0.17	0.13	0.37	0.29
S05_2	0.95	0.64	0.64	0.64	0.19	0.15	0.42	0.32
Peak Flows (m^3/sec) Maximum Probable Development Conditions and SMAF Attenuation Inside the site - Site-Sub-Post-R06								
Location	**100 CC3.8**	**100 WOCC**	**2up100 Down WOCC**	**40mmup 100Down WOCC**	**2CC2.1**	**2WOCC**	**10CC2.1**	**10WOCC**
CC	1.35	0.79	0.79	0.79	0.31	0.25	0.57	0.47
N01_P_1	5.51	3.96	3.96	3.96	1.61	1.31	2.92	2.37
N01_P_1_S	5.28	3.76	3.76	3.76	1.47	1.19	2.75	2.22
N01_P_2	4.00	2.88	2.88	2.88	1.17	0.95	2.12	1.72
N01_P_2_S	3.83	2.73	2.73	2.73	1.06	0.86	1.98	1.60
N01_P_3	0.61	0.44	0.44	0.44	0.18	0.15	0.32	0.26
N01_P_3_S	0.61	0.44	0.44	0.44	0.18	0.15	0.32	0.26
N01_P_4	0.81	0.58	0.58	0.58	0.24	0.19	0.43	0.35
N01_P_4_S	0.81	0.58	0.58	0.58	0.24	0.19	0.43	0.35
N02_P	0.24	0.17	0.17	0.17	0.07	0.06	0.13	0.10
N02_P_S	0.24	0.17	0.17	0.17	0.07	0.06	0.13	0.10
N03_P	0.43	0.31	0.31	0.31	0.12	0.10	0.23	0.18
N03_P_S	0.43	0.31	0.31	0.31	0.13	0.10	0.23	0.18

[3] Riverhead Forest Drive Discharge Point

[4] Riverhead Point Drive Discharge Point

[5] Riverhead Road Culvert

N04_P	1.80	1.30	1.30	1.30	0.53	0.43	0.96	0.78
N04_P_S	1.69	1.29	1.29	1.29	0.52	0.43	0.95	0.77
N05_P_1	0.72	0.52	0.52	0.52	0.21	0.17	0.38	0.31
N05_P_1_S	0.72	0.52	0.52	0.52	0.21	0.17	0.38	0.31
N05_P_2	0.29	0.20	0.20	0.20	0.06	0.05	0.14	0.10
RFS-D	21.20	15.17	15.17	15.17	5.81	4.66	10.89	8.78
RPD-D	2.51	1.80	1.80	1.80	0.71	0.58	1.29	1.05
RRD-C	8.41	6.16	6.16	6.16	2.34	1.89	4.36	3.53
S01_P	6.30	4.65	4.65	4.65	1.84	1.50	3.34	2.72
S01_P_D	1.14	0.45	0.45	0.45	0.10	0.09	0.14	0.12
S01_P_S	5.77	4.19	4.19	4.19	1.56	1.25	2.95	2.37
S02_P	9.06	6.72	6.72	6.72	2.71	2.22	4.84	3.96
S02_P_S	8.41	6.16	6.16	6.16	2.34	1.89	4.36	3.53
S03_P_1	1.78	1.28	1.28	1.28	0.51	0.41	0.92	0.75
S03_P_2	0.74	0.53	0.53	0.53	0.21	0.17	0.38	0.31
S04_P	1.09	0.78	0.78	0.78	0.31	0.25	0.56	0.46
S04_P_S	0.95	0.67	0.67	0.67	0.24	0.19	0.47	0.37

4 Model Build - Hydraulics

4.1 Software

The Hydrologic Engineering Center's River Analysis System (HEC-RAS) developed by the U.S. Army Corps of Engineers (version 6.5) has been used for hydraulic modeling.

The link to the model project is below:

Synergy12d://CKL-AZU-SYN-1/Projects/A20405/CI 1 - Environmental/01 Environmental/Modelling and Calculations/FRA/HEC RAS/

4.2 Geometry

The previous model geometry for pre and post development conditions retains except for the following refinements.

- Updated inflows for all internal and external sub catchments to include the effects of SMAF detention, updated hydrological parameters and different rainfall events and scenarios (see table 7).
- Refinement of Manning's Roughness.
- The previously modelled 2.5 m diameter culvert on the Wautaiti Stream has been updated to two 1.5 m diameter culverts, reflecting the culvert replacements completed in 2021.

Characteristics of the updated pre and post development geometries are shown below with the recent refinements highlighted in green colour letters.

4.2.1 Pre Development

- **Name:** Geo-Pre-V7
- **2D flow area:** 2D model extent (Please refer Figure 1) Cell size for 2D flow area is 5m x 5m.
- **Break lines:** Enforced with finer cell size (2m x 2m) refinement along roads, channels, OLFPs and site boundaries.

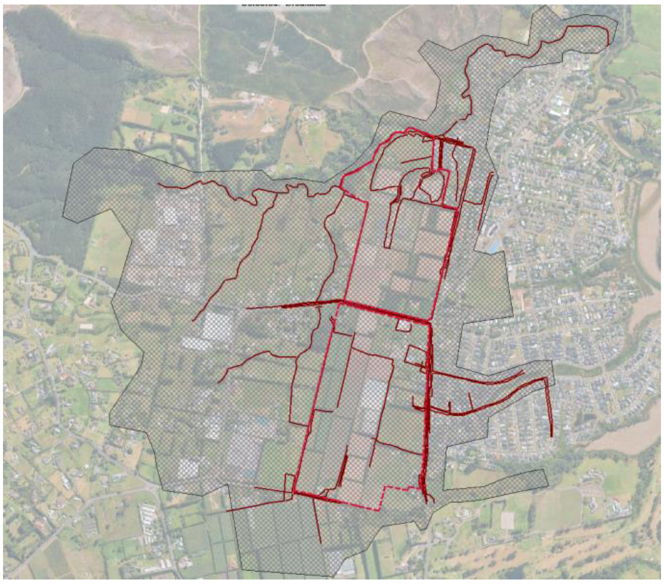

FIGURE 1: 2D AREA PERIMETER AND BREAK LINES IN MAROON COLOR

- **Flow boundary condition lines**: Flow hydrographs for external sub catchments (suffix C) and internal sub catchments (the rest) are loaded to 2D flow area.

TABLE 8: BASIN MODELS AND PEAK FLOWS ASSOCIATED WITH INTERNAL FLOW BOUNDARY CONDITIONS

Relevant Basin Models	Peak Flows
Outside-ActualED_R04_June25	Please refer table 7
Site-Sub-ED--R01-0.8	

- It is noted that boundary condition lines are located lower catchment. For the subject site, due to the lack of design surface, the flow boundary condition lines are located at the discharge outlet, i.e. channel and basin for each sub-catchment within the site.
- **Downstream boundary condition line**: Defined at locations where water leaves 2D flow area through downstream boundary conditions (suffix outlet).
  - *Coastal boundary*: the following coastal boundary condition obtained from the Coastal Marine Area Boundary for the Auckland Region provided by AC was set at the catchment outlet at the estuary:
    - MHWS+1m rise=1.83 +1=2.83 m

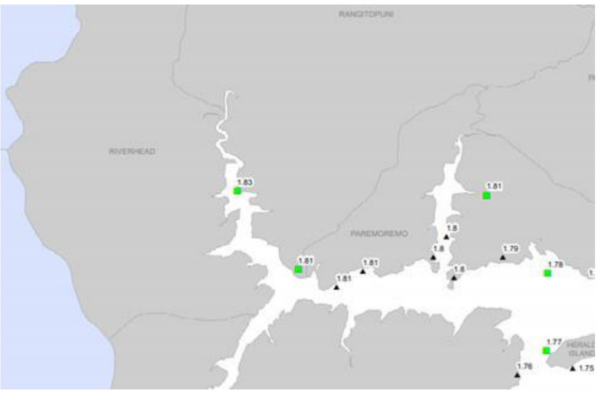

FIGURE 2: COASTAL BOUNDARY CONDITION _ REFERENCE MHWS

- *Other outlets*: Normal depth boundary condition (friction slope = 0.005) was set for all the other boundary lines where water will leave the 2D flow area.

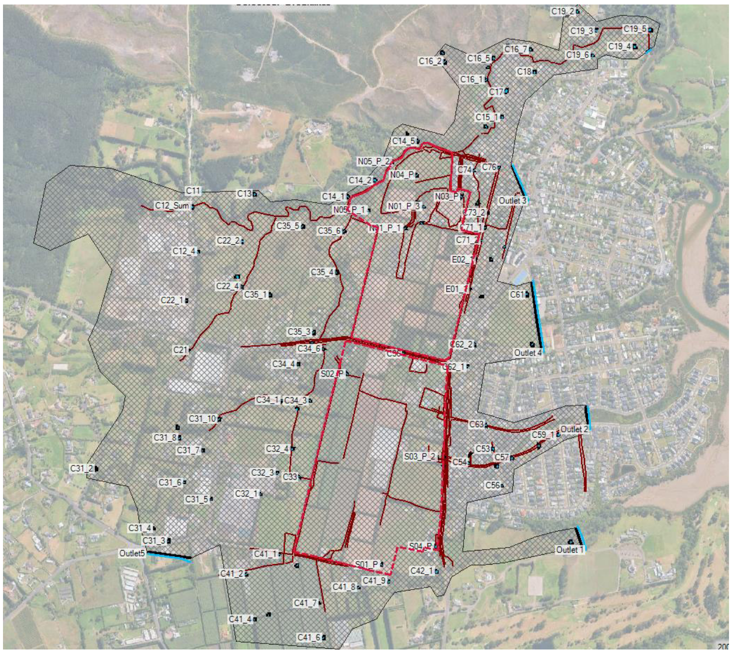

FIGURE 3: EXTERNAL AND INTERNAL BOUNDARY CONDITION LOCATIONS

- **Culverts:** Modelled as 2D connection in the model

TABLE 9: CULVERT SIZES

Culverts	Size(mm)	Sources
CV#1_1	800	Survey
CV#1_2	600	Survey
CV#1_3	1100	Survey
CV#1_4	600	Survey
CV#2_1	600	Survey
CV#2_2	Double 600	Survey
CV#3	1200	GeoMaps
CV#4	600	Survey
CV#5	600	Survey
CV#6_1	300	Survey
CV#6_2	400	Survey
CV#6_3	300	Survey
CV#9_6	600	Aerial photo
CV#_1	Double 1500	Updated reflecting the culvert replacements completed in 2021
CV#GIS_1	Double 1200	GIS Geomaps
CV#GIS_2	750	GIS Geomaps
CV#GIS_3	900	GIS Geomaps
CV#GIS_4	600	GIS Geomaps

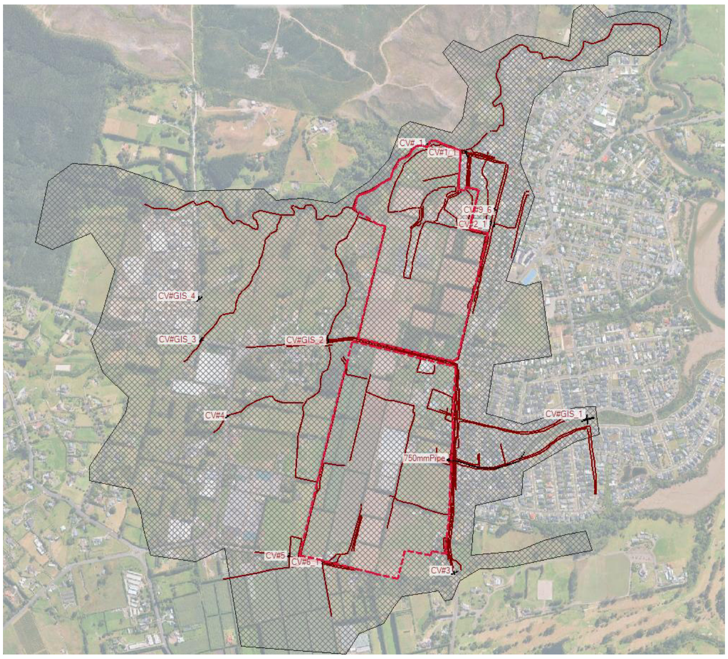

FIGURE 4: CULVERT LOCATIONS

- **Terrain model** : see section 4.3 for details.
- **Manning's Roughness** :

Manning's Roughness has been refined considering the following roughness for the corresponding land use. The resulting roughness layer is shown in figure 4.

TABLE 10: REFINEMENTS TO MANNING'S N VALUE

Land Use	Manning's N Value
Roads	0.03
Open Fields	0.05
Streams	0.04
Buildings	1

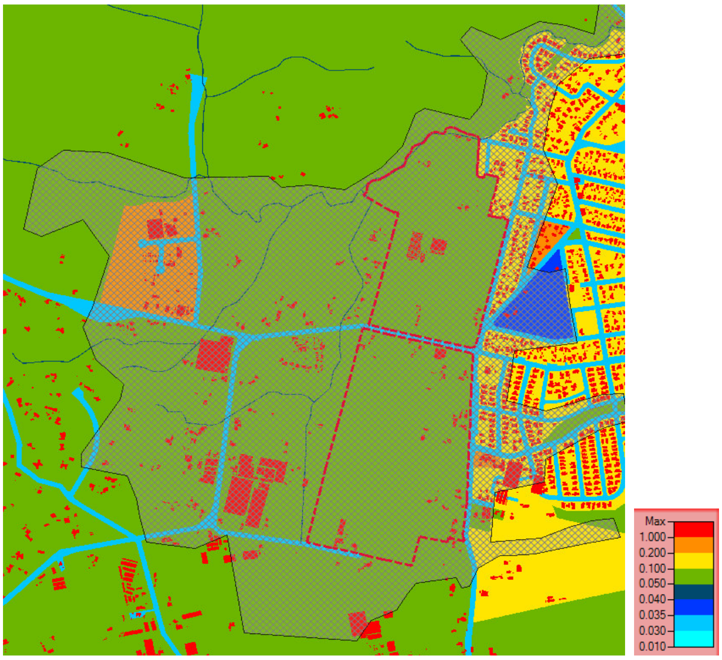

FIGURE 5: MANNING'S ROUGHNESS – PRE DEVELOPMENT

4.2.2 Post Development

Variations in post development geometry with compared to the predevelopment geometry are tabulated below.

TABLE 11: VARIATION OF COMPONENTS WITH COMPARED TO PREDEVELOPMENT

Component	Variation
Name	Geo-Post-V9 - Riverhead Rd Culvert Upgrade v5_remeshed
2D flow area	Same as predevelopment
Break lines	Same as predevelopment
Flow boundary condition line	Flow hydrographs from the basin models Outside-ActualED_R04_June25 and Site-Sub-Post-R06 (peak flow values are shown in table 7)
Downstream boundary condition line	Same as predevelopment
Culverts	All culverts remain as predevelopment except riverhead road culvert CV#GIS_2. It has been upgraded to 4.5m x1.5m box culvert. In addition, the 750mm outflow pipe from the site has been modelled as an SA-2D connection considering the limitations of HEC RAS.
Terrain model	See section 4.3 for details
Manning's Roughness	Same as predevelopment except for the inside of RRPC area which uses a Manning's roughness value of 0.1 in post development.

4.3 Terrain model

Terrain model was formed by merging the following resources:

- 2016 1m LiDAR DEM (AVD), and
- Topography survey TIN converted to AVD
- Terrain modifications have been done on culvert inlets and outlets with river head road being elevated to allow for the culvert upgrade during post development.

TABLE 12: TERRAIN NAMES ASSOCIATED WITH THE PRE AND POST DEVELOPMENT GEOMETRIES

Geometry	Associated Terrain Name
Pre Development	2016LiDAR+SurveyCut-AVD MtEden-1mPre
Post Development	2016LiDAR+SurveyCut-AVD MtEden-1mPost.Culvert_v2

4.4 Computation

- Adjustable time step base on courant
- Simulation periods:24 hrs

5 Model scenarios

5.1 Model scenarios

TABLE 13: HEC RAS MODEL SCENARIOS AND MODEL FILES

Rainfall event	Model Data	Pre Development	Post Development
10yr ARI + 2.1°C Climate Change	**Plan/result**	*Geo-Pre-V7 - InsideED+OutsideED-10yr2.1CC_June25*	*Geo-Post-V9 - Rhd Rd Culv Upgr v5 - InMPD+OutED-10yr2.1_June25*
	Geometry	*1. Geo-Pre-V7*	*i. Geo-Post-V9 - Riverhead Rd Culvert Upgrade v5_remeshed*
	Terrain	*2. 2016LiDAR+SurveyCut-AVD MtEden-1mPre*	*ii. 2016LiDAR+SurveyCut-AVD MtEden-1mPost.Culvert_v2*
	Manning's	*3. Mannings_june25-updated*	*Same as 3 (predevelopment) with refinement regions*
	Flow file	*InsideED+OutsideED-10yr2.1CC_June25*	*InsideMPD+OutsideED-10yr2.1CC_June25*
	Description	10yr 2.1°C Climate Change ED imperviousness within the site and ED impervious outside the site.	10yr 2.1°C Climate Change MPD imperviousness within the site and ED impervious outside the site. Dummy SMAF 1 detention

10yr ARI without Climate Change	**Plan/result**	*Geo-Pre-V7 - InsideED+OutsideED-10WoCC*	*Geo-Post-V9 _InMPD_OutED_10WoCC*
	Geometry	*Same as 1*	*Same as i*
	Terrain	*Same as 2*	*Same as ii*
	Manning's	*Same as 3*	*Same as 3 (predevelopment) with refinement regions*
	Flow file	*InsideED+OutsideED-10WoCC*	*InsideMPD+OutsideED-10WoCC*
	Description	10yr without Climate Change ED imperviousness within the site and ED impervious outside the site.	10yr without Climate Change MPD imperviousness within the site and ED impervious outside the site. Dummy SMAF 1 detention
2yr ARI + 2.1°C Climate Change	**Plan/result**	*Geo-Pre-V7 - InsideED+OutsideED-2yr2.1CC_June25*	Geo-Post-V9 - Rhd Rd Culv Upgr v5 - InMPD+OutED-2yr2.1_June25
	Geometry	Same as 1	*Same as i*
	Terrain	Same as 2	*Same as ii*
	Manning's	Same as 3	*Same as 3 (predevelopment) with refinement regions*
	Flow file	*InsideED+OutsideED-2yr2.1CC_June25*	*InsideMPD+OutsideED-2yr2.1CC_June25*
	Description	2 yr 2.1°C Climate Change ED imperviousness within the site and ED impervious outside the site.	2 yr 2.1°C Climate Change MPD imperviousness within the site and ED impervious outside the site. Dummy SMAF 1 detention
2yr ARI without Climate Change	**Plan/result**	*Geo-Pre-V7 - InsideED+OutsideED-2WoCC*	*Geo-Post-V9 _InMPD_OutED_2WoCC*
	Geometry	Same as 1	*Same as i*
	Terrain	Same as 2	*Same as ii*
	Manning's	Same as 3	*Same as 3 (predevelopment) with refinement regions*

	Flow file	*InsideED+OutsideED-2WoCC*	*InsideMPD+OutsideED-2WoCC*
	Description	2 yr without Climate Change ED imperviousness within the site and ED impervious outside the site.	2 yr without Climate Change MPD imperviousness within the site and ED impervious outside the site. Dummy SMAF 1 detention
100yr ARI + 3.8°C Climate Change	**Plan/result**	*Geo-Pre-V7 - InsideED+OutsideED-100yr3.8CC_June25*	*Geo-Post-V9 - Rhd Rd Culv Upgr v5 - InMPD+OutED-100yr3.8_June25*
	Geometry	Same as 1	*Same as i*
	Terrain	Same as 2	*Same as ii*
	Manning's	Same as 3	*Same as 3 (predevelopment) with refinement regions*
	Flow file	*InsideED+OutsideED-100yr3.8CC_June25*	*InsideMPD+OutsideED-100yr3.8CC*
	Description	100yr 3.8°C Climate Change ED imperviousness within the site and ED impervious outside the site.	100yr 3.8°C Climate Change MPD imperviousness within the site and ED impervious outside the site. Dummy SMAF 1 detention
100yr ARI without Climate Change	**Plan/result**	*Geo-Pre-V7 - InsideED+OutsideED-100WoCC_July25*	*Geo-Post-V9 - Rhd Rd Culv Upgr v5 - InMPD+OutED-100yrWoCC_July25*
	Geometry	Same as 1	*Same as i*
	Terrain	Same as 2	*Same as ii*
	Manning's	Same as 3	*Same as 3 (predevelopment) with refinement regions*
	Flow file	*InsideED+OutsideED-100WoCC*	*InsideMPD+OutsideED-100WoCC*
	Description	100 yr without Climate Change ED imperviousness within the site and ED impervious outside the site.	100 yr without Climate Change MPD imperviousness within the site and ED impervious outside the site. Dummy SMAF 1 detention

2yr without climate change for upstream catchme-nts and 100yr without climate change for the rest	**Plan/result**	*Geo-Pre-V7 - InsideED+OutsideED-2Up100Down*	Geo-Post-V9 _InMPD_OutED_2Up100Down
	Geometry	Same as 1	*Same as i*
	Terrain	Same as 2	*Same as ii*
	Manning's	Same as 3	*Same as 3 (predevelopment) with refinement regions*
	Flow file	*InsideED+OutsideED-2yrUp100yrDown_WOCC*	*InsideMPD+OutsideED-2yrUp100yrDown_WOCC*
	Description	2yr rainfall without climate change has been considered for C11, C12_4 and SumC12 upstream catchments whereas 100yr rainfall without climate change has been considered for the rest ED imperviousness within the site and ED impervious outside the site.	2yr rainfall without climate change has been considered for C11, C12_4 and SumC12 upstream catchments whereas 100yr rainfall without climate change has been considered for the rest MPD imperviousness within the site and ED impervious outside the site. Dummy SMAF 1 detention
40mm rainfall depth for upstream catchme-nts and 100yr without climate change for the rest	**Plan/result**		
	Geometry	Same as 1	*Same as i*
	Terrain	Same as 2	*Same as ii*
	Manning's	Same as 3	*Same as 3 (predevelopment) with refinement regions*
	Flow file		
	Description	40mm rainfall depth has been considered for C11, C12_4 and SumC12 upstream catchments whereas 100yr rainfall without climate change has been considered for the rest ED imperviousness within the site and ED impervious outside the site.	40mm rainfall depth has been considered for C11, C12_4 and SumC12 upstream catchments whereas 100yr rainfall without climate change has been considered for the rest MPD imperviousness within the site and ED impervious outside the site. Dummy SMAF 1 detention

5.2 Model Results

Resulting depths, water surface elevations, top water level difference maps and velocities for the eight scenarios will be appended to the main report.

5.2 Model Results

Resulting depths, water surface elevations, top water level difference maps and velocities for the eight scenarios will be appended to the main report.

Appendix 2 Hydrological calculations

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Job name	22 Duke St	File Name	A20405 -Hydrology analysis_v2.xlsx
Job No.	A20205	Sheet Name	Inside Site_ExR01PropR05_June25
Date	23/07/2025	Path	C:\ProgramData\12DSynergy\data\CKL-AZU-SYN-1\CI 1 - Environmental_18233\01 Environmental\Modelling and Calculations\FRA
By	ZW	Checked	

Internal post development subcatchments with ED CN and Lag

Site Subcatchment (Existing condition)

see GIS shapefile 'Site Existing SubCatchment-100yr-R01.shp' for detail.

Discharge Locations ID	Discharge Locations	Name	Catchment Area (ha)	100yr Rainfall depth-Ex	100yr Rainfall+CC (3.8°C)	Impervious for Existing (%)	Impervious area (ha)	CN for pervious area	Weighted CN	Weighted Ia	Length (km)	Slope (m/m)	ToC (hr) (C=0.8)	Lag (mins)
N01	Channel to wetland	N01_1	8.90	205	272	10%	0.89	81.0	82.7	4.5	0.611	0.014	0.3	14.0
		N01_2	11.20	205	272	10%	1.12	81.0	82.7	4.5	0.608	0.025	0.3	11.8
		N01_3	0.84	205	272	15%	0.13	81.0	83.6	4.3	0.142	0.005	0.2	7.3
		N01_4	2.63	205	272	15%	0.39	81.0	83.6	4.3	0.242	0.016	0.2	7.2
		N01_5	2.14	205	272	0%	0.00	81.0	81.0	5.0	0.309	0.027	0.2	7.5
N02	Wetland swale	N02	0.50	205	272	15%	0.08	81.0	83.6	4.3	0.091	0.043	0.1	6.7
N03	Te Roera Place	N03	0.85	205	272	0%	0.00	81.0	81.0	5.0	0.186	0.032	0.1	6.7
N04	Wetland	N04	4.49	205	272	3%	0.13	61.0	62.1	4.9	0.428	0.010	0.4	15.9
N05	Stream	N05_1	1.01	205	272	0%	0.00	61.0	61.0	5.0	0.178	0.023	0.2	7.0
		N05_2	0.94	205	272	0%	0.00	61.0	61.0	5.0	0.113	0.045	0.1	6.7
N06	Neighbour	N06	0.78	205	272	0%	0.00	81.0	81.0	5.0	0.139	0.031	0.1	6.7
S01	South channel	S01_1	2.40	210	279	0%	0.00	61.0	61.0	5.0	0.241	0.076	0.1	6.7
		S01_2	2.50	210	279	0%	0.00	61.0	61.0	5.0	0.202	0.029	0.2	7.1
S02	Stream south branch (Riverhead culvert)	S02_1	4.71	210	279	0%	0.00	81.0	81.0	5.0	0.480	0.007	0.4	15.2
		S02_2	2.09	210	279	0%	0.00	81.0	81.0	5.0	0.235	0.008	0.2	9.2
		S02_3	21.34	210	279	10%	2.13	81.0	82.7	4.5	0.656	0.014	0.4	14.7
S03	Riverhead Point Drive	S03_1	4.81	210	279	20%	0.96	61.0	68.4	4.0	0.331	0.003	0.4	17.5
		S03_2	1.48	210	279	20%	0.30	61.0	68.4	4.0	0.162	0.002	0.3	12.0
S04	Coatesville Highway	S04_1	0.98	210	279	30%	0.29	61.0	72.1	3.5	0.120	0.006	0.2	7.0
		S04_2	0.71	210	279	30%	0.21	61.0	72.1	3.5	0.120	0.074	0.1	6.7
	Coatesville Highway	S04_3	0.27	210	279	10%	0.03	61.0	64.7	4.5	0.044	0.004	0.1	6.7
S05	Riverhead Road	S05_1	2.20	210	279	30%	0.66	61.0	72.1	3.5	0.198	0.016	0.2	7.2
		S05_2	2.89	210	279	30%	0.87	61.0	72.1	3.5	0.306	0.009	0.3	11.7
		Total	80.7			10%	8.20							

Site Subcatchment (Proposed condition)

see GIS shapefile 'Catchment Area of the site R03_S02split.shp' for detail.

Discharge Locations ID	Discharge Locations	Name	Catchment Area (ha)	100yr Rainfall depth-Ex	100yr Rainfall+CC (3.8°C)	Impervious for Post (%)	Impervious area (ha)	CN for pervious area	Weighted CN	Weighted Ia	Length (km)	Slope (m/m)	ToC (hr) (C=0.6)	Lag (mins)
N01	Channel to Wetland	N01_P_1	13.16	205	272	65%	8.56	74.0	89.6	1.8	0.657	0.024	0.2	8.8
		N01_P_2	10.04	205	272	65%	6.52	74.0	89.6	1.8	0.739	0.018	0.3	10.2
		N01_P_3	1.36	205	272	65%	0.88	74.0	89.6	1.8	0.131	0.006	0.1	6.7
		N01_P_4	1.80	205	272	65%	1.17	74.0	89.6	1.8	0.204	0.008	0.1	6.7
N02	Wetland swale	N02_P	0.54	205	272	65%	0.35	74.0	89.6	1.8	0.091	0.043	0.0	6.7
N03	Te Roera Place	N03_P	0.95	205	272	65%	0.62	74.0	89.6	1.8	0.186	0.032	0.1	6.7
N04	Wetland	N04_P	4.07	205	272	65%	2.64	74.0	89.6	1.8	0.300	0.008	0.2	7.2
N05	Stream	N05_P_1	1.61	205	272	65%	1.05	74.0	89.6	1.8	0.17	0.010	0.2	6.7
		N05_P_2	0.76	205	272	0	0.00	74.0	74.0	5	0.09	0.045	0.1	6.7
S01	South Channel	S01_P	14.33	210	279	65%	9.31	74.0	89.6	1.8	0.366	0.058	0.1	6.7
S02	Stream South Branch (R	S02_P	23.67	210	279	70%	16.57	74.0	90.8	1.5	0.872	0.014	0.3	12.3
S03	Riverhead Point Drive	S03_P_1	4.35	210	279	65%	2.82	74.0	89.6	1.8	0.330	0.003	0.3	10.2
		S03_P_2	1.67	210	279	65%	1.08	74.0	89.6	1.8	0.216	0.003	0.2	7.9
S04	Coatesville Highway	S04_P	2.36	210	279	65%	1.54	74.0	89.6	1.8	0.363	0.020	0.2	6.7
		Total	80.6			66%	53.11							

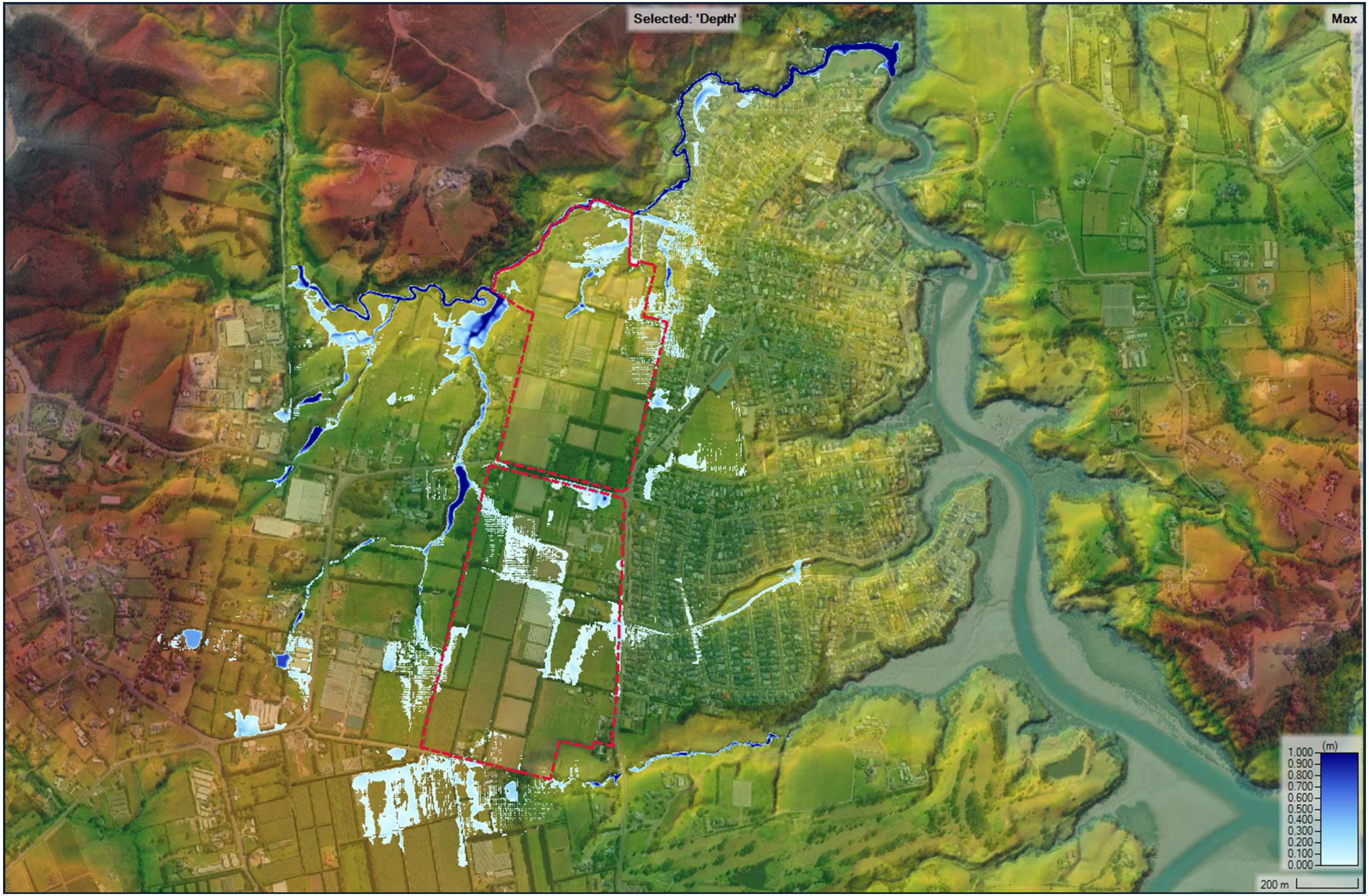
Job name	22 Duke St	File Name	A20405 -Hydrology analysis_v2.xlsx
Job No.	A20405	Sheet Name	Outside subcatch-June 2025
Date	23.07.25	Path	C:\ProgramData\12DSynergy\data\CKL-AZU-SYN-1\CI 1 - Environmental_18233\01 Environmental\Modelling and Calculations\FRA
By	SK	Checked	ZW

Sub-catchments outside the site (ED and MPD condition)-R04

Note: This version is for combined catchment-flow model input. The catchment flow for the sub-catchment 'ROG ' will not be used in HEC RAS model but extracted from CKL's RainOnGrid model result which is well ma approved by AC.

									ED condition				
Name	Catchment Area (ha)	100yr Rainfall depth-Ex	100yr Rainfall+CC (2.1°C)	100yr Rainfall+CC (3.8°C)	Channelization Factor	CN for pervious area	Length (km)	Slope (m/m)	Impervious for ED	Weighted CN for ED	Weighted Ia for ED	ToC (hr)	Lag (mins)
C11	515.9	200	234	265	0.8	74	4.699	0.0121	0.34%	74.1	5.0	1.6	62.7
C12_1	42.8	195	228	259	1	70	1.071	0.0425	0.52%	70.1	5.0	0.5	21.2
C12_2	11.1	195	228	259	1	70	0.660	0.0455	1.96%	70.6	4.9	0.4	15.0
C12_3	3.6	195	228	259	1	74	0.395	0.0533	0.76%	74.2	5.0	0.2	9.8
C12_4	4.7	195	228	259	1	81	0.298	0.0490	30.04%	86.1	3.5	0.2	7.3
C13	10.9	200	234	265	1	70	0.452	0.1613	0.91%	70.3	5.0	0.2	8.0
C14_1	3.4	205	239	272	1	70	0.271	0.2866	0.00%	70.0	5.0	0.1	6.7
C14_2	4.7	205	239	272	1	70	0.337	0.2365	0.86%	70.2	5.0	0.1	6.7
C14_3	3.8	205	239	272	1	70	0.364	0.1399	0.00%	70.0	5.0	0.2	7.3
C14_4	3.8	205	239	272	1	70	0.271	0.2325	0.00%	70.0	5.0	0.1	6.7
C14_5	3.0	205	239	272	1	70	0.336	0.1120	0.44%	70.1	5.0	0.2	7.4
C15_1	4.7	205	239	272	0.8	61	0.294	0.0444	45.30%	77.8	2.7	0.2	6.7
C15_2	3.7	205	239	272	1	70	0.256	0.0942	1.09%	70.3	4.9	0.2	6.7
C16_1	4.3	205	239	272	1	70	0.404	0.1757	1.11%	70.3	4.9	0.2	7.3
C16_2	4.0	205	239	272	1	70	0.342	0.1661	0.00%	70.0	5.0	0.2	6.7
C16_3	2.9	205	239	272	1	70	0.256	0.1962	0.00%	70.0	5.0	0.1	6.7
C16_4	4.9	205	239	272	1	70	0.457	0.1283	0.00%	70.0	5.0	0.2	8.7
C16_5	4.8	205	239	272	1	70	0.343	0.2252	0.00%	70.0	5.0	0.2	6.7
C16_6	3.2	205	239	272	1	70	0.393	0.2578	0.78%	70.2	5.0	0.2	6.7
C16_7	4.5	205	239	272	1	74	0.253	0.1147	2.70%	74.6	4.9	0.1	6.7
C17	4.9	205	239	272	0.8	61	0.401	0.0262	46.52%	78.2	2.7	0.2	9.3
C18	3.3	205	239	272	0.8	61	0.360	0.0367	41.56%	76.4	2.9	0.2	8.0
C19_1	2.7	205	239	272	1	70	0.541	0.1563	39.37%	81.0	3.0	0.2	8.0
C19_2	3.8	190	222	252	1	70	0.368	0.1540	20.50%	75.7	4.0	0.2	6.7
C19_3	4.0	190	222	252	1	70	0.270	0.1128	12.03%	73.4	4.4	0.2	6.7
C19_4	4.1	190	222	252	0.8	61	0.296	0.0486	21.78%	69.1	3.9	0.2	7.1
C19_5	2.8	190	222	252	1	55	0.202	0.0464	23.48%	65.1	3.8	0.2	7.3
C19_6	5.0	190	222	252	0.8	61	0.408	0.0429	44.75%	77.6	2.8	0.2	8.2
C21	33.3	190	222	252	1	74	1.066	0.0412	15.75%	77.8	4.2	0.5	19.5
C22_1	14.2	195	228	259	1	88	0.740	0.0616	17.67%	89.8	4.1	0.3	11.9
C22_2	4.6	200	234	265	1	61	0.381	0.0165	6.76%	63.5	4.7	0.4	15.4
C22_3	3.8	200	234	265	1	61	0.399	0.0292	8.13%	64.0	4.6	0.3	13.3
C22_4	4.0	200	234	265	1	61	0.481	0.0195	4.93%	62.8	4.8	0.4	17.3
C31_1	3.4	190	222	252	1	74	0.409	0.0634	10.11%	76.4	4.5	0.2	9.2
C31_10	2.9	190	222	252	1	61	0.183	0.0184	11.23%	65.2	4.4	0.2	9.0
C31_2	3.5	190	222	252	1	74	0.375	0.0607	18.11%	78.3	4.1	0.2	8.7
C31_3	1.9	190	222	252	0.8	61	0.503	0.0285	32.68%	73.1	3.4	0.3	11.2
C31_4	5.2	190	222	252	1	61	0.424	0.0325	7.77%	63.9	4.6	0.3	13.5
C31_5	3.4	190	222	252	0.8	81	0.394	0.0127	27.10%	85.6	3.6	0.3	10.5
C31_6	4.9	190	222	252	1	61	0.572	0.0322	4.10%	62.5	4.8	0.4	16.7
C31_7	3.9	190	222	252	1	61	0.465	0.0406	21.29%	68.9	3.9	0.3	12.6
C31_8	3.8	190	222	252	1	61	0.413	0.0479	3.63%	62.3	4.8	0.3	12.0
C31_9	5.0	200	234	265	1	61	0.473	0.0523	1.95%	61.7	4.9	0.3	12.9
C32_1	4.7	200	234	265	0.8	81	0.370	0.0103	57.91%	90.8	2.1	0.3	10.1
C32_2	3.7	200	234	265	1	81	0.360	0.0235	6.12%	82.0	4.7	0.3	10.7
C32_3	2.1	200	234	265	0.8	81	0.250	0.0123	60.69%	91.3	2.0	0.2	7.4
C32_4	4.5	200	234	265	1	81	0.524	0.0159	8.05%	82.4	4.6	0.4	15.4
C33	2.0	200	234	265	1	61	0.372	0.0190	4.09%	62.5	4.8	0.4	14.8
C34_1	5.1	200	234	265	1	81	0.363	0.0167	4.51%	81.8	4.8	0.3	12.0
C34_2	3.1	200	234	265	1	81	0.392	0.0333	2.42%	81.4	4.9	0.3	10.3
C34_3	2.3	200	234	265	1	81	0.334	0.0263	0.66%	81.1	5.0	0.2	10.0
C34_4	2.9	200	234	265	1	81	0.310	0.0142	9.76%	82.7	4.5	0.3	11.2
C34_5	1.5	200	234	265	0.8	98	0.624	0.0226	69.48%	98.0	1.5	0.3	10.5
C34_6	4.7	200	234	265	1	81	0.3553	0.0010	8.63%	82.5	4.6	0.7	27.3
C35_1	3.0	200	234	265	1	61	0.31752	0.0266	4.23%	62.6	4.8	0.3	12.0
C35_2	4.7	200	234	265	1	61	0.43646	0.0225	4.50%	62.7	4.8	0.4	15.6
C35_3	2.4	200	234	265	1	61	0.28347	0.0273	10.15%	64.8	4.5	0.3	10.8
C35_4	4.5	200	234	265	1	61	0.33823	0.0132	4.60%	62.7	4.8	0.4	15.4
C35_5	4.2	200	234	265	1	61	0.35041	0.0203	0.00%	61.0	5.0	0.4	14.2
C35_6	3.8	200	234	265	1	61	0.29453	0.0104	0.48%	61.2	5.0	0.4	15.4
C35_7	2.2	210	245	279	1	61	0.29527	0.0267	4.03%	62.5	4.8	0.3	11.5
C36	1.1	195	228	259	0.8	98	0.59825	0.0093	99.02%	98.0	0.0	0.3	13.3
C41_1	4.7	195	228	259	1	81	0.53835	0.0024	26.40%	85.5	3.7	0.7	26.6
C41_2	5.4	195	228	259	1	81	0.48823	0.0023	0.00%	81.0	5.0	0.7	26.6
C41_3	4.4	195	228	259	1	81	0.36971	0.0040	2.93%	81.5	4.9	0.5	18.8
C41_4	2.7	195	228	259	1	81	0.41877	0.0047	2.58%	81.4	4.9	0.5	19.4
C41_5	3.6	195	228	259	1	81	0.42085	0.0061	2.47%	81.4	4.9	0.4	18.0
C41_6	2.6	195	228	259	1	81	0.33095	0.0109	2.58%	81.4	4.9	0.3	12.9
C41_7	3.5	200	234	265	1	81	0.33779	0.0082	0.00%	81.0	5.0	0.4	14.3
C41_8	5.1	200	234	265	1	81	0.38527	0.0207	8.59%	82.5	4.6	0.3	11.6
C41_9	1.5	200	234	265	1	81	0.1647	0.0726	0.00%	81.0	5.0	0.1	6.7
C42_1	22.3	205	239	272	1	81	1.39897	0.0148	7.35%	82.2	4.6	0.8	30.1
C42_2	43.2	210	245	279	1	61	0.94783	0.0273	8.38%	64.1	4.6	0.6	24.1
C51_1	0.3	210	245	279	0.8	98	0.24068	0.0017	99.69%	98.0	0.0	0.3	12.1
C51_2	0.2	210	245	279	0.8	98	0.15963	0.0020	98.47%	98.0	0.1	0.2	8.8
C52	0.9	210	245	279	0.8	61	0.13188	0.0064	54.47%	81.2	2.3	0.2	6.7
C53	1.2	210	245	279	0.8	61	0.14063	0.0234	56.02%	81.7	2.2	0.1	6.7
C54	1.2	210	245	279	0.8	61	0.23439	0.0094	70.54%	87.1	1.5	0.2	8.0
C55	1.1	210	245	279	0.8	61	0.12836	0.0338	56.45%	81.9	2.2	0.1	6.7
C56	1.8	210	245	279	0.8	61	0.23906	0.0072	48.25%	78.9	2.6	0.2	9.7
C57	2.0	210	245	279	0.8	61	0.24466	0.0326	60.39%	83.3	2.0	0.1	6.7
C58	2.4	210	245	279	0.8	61	0.3376	0.0295	55.71%	81.6	2.2	0.2	7.7
C59_1	4.1	210	245	279	0.8	61	0.52029	0.0233	58.80%	82.8	2.1	0.3	10.9
C59_2	2.1	210	245	279	0.8	61	0.37044	0.0228	60.63%	83.4	2.0	0.2	8.7
C61	3.3	210	245	279	0.8	61	0.25776	0.0225	30.72%	72.4	3.5	0.2	7.8
C62_1	3.0	210	245	279	0.8	61	0.24097	0.0059	51.01%	79.9	2.4	0.3	10.2
C62_2	1.9	210	245	279	0.8	61	0.19466	0.0156	52.55%	80.4	2.4	0.2	6.7
C62_3	4.4	210	245	279	0.8	61	0.35693	0.0137	20.94%	68.7	4.0	0.3	11.7
C63	3.7	210	245	279	0.8	61	0.26276	0.0152	56.41%	81.9	2.2	0.2	8.0
C71_1	0.4	205	239	272	0.8	61	0.28313	0.0376	52.23%	80.3	2.4	0.2	6.7
C71_2	0.6	205	239	272	0.8	61			52.02%	80.2	2.4		6.7
C71_3	1.7	205	239	272	0.8	61			61.72%	83.8	1.9		6.7
C72	2.1	205	239	272	0.8	61	0.31562	0.0156	51.33%	80.0	2.4	0.2	9.1
C73_1	1.4	205	239	272	0.8	61	0.2408	0.0327	21.18%	68.8	3.9	0.2	7.0
C73_2	0.8	205	239	272	0.8	61			54.85%	81.3	2.3		6.7
C74	2.1	205	239	272	0.8	61	0.14384	0.0189	54.68%	81.2	2.3	0.1	6.7
C75	0.6	205	239	272	0.8	61	0.12785	0.0185	74.31%	88.5	1.3	0.1	6.7
C76	2.6	205	239	272	0.8	61	0.24062	0.0276	45.75%	77.9	2.7	0.2	6.7
E01_1	1.0	210	245	279	0.8	61	0.41842	0.0075	66.40%	85.6	1.7	0.3	6.7
E01_2	1.2	210	245	279	0.8	61			57.30%	82.2	2.1		6.7
E02_1	0.8	210	245	279	0.8	61	0.17598	0.0430	57.16%	82.2	2.1	0.1	6.7
E02_2	0.7	210	245	279	0.8	61			44.50%	77.5	2.8		6.7

Appendix 3 Results Maps



PROJECT:	RIVERHEAD PRIVATE PLAN CHANGE PC100	MAP TYPE:	FLOOD DEPTH (MAX)		
REF NUMBER:	A20405	SCENARIO:	12	EVENT:	2yr+2.1°C
DATE:	22/07/2025	LAND USE:	PRE-DEVELOPMENT – ED OUTSIDE + ED INSIDE		

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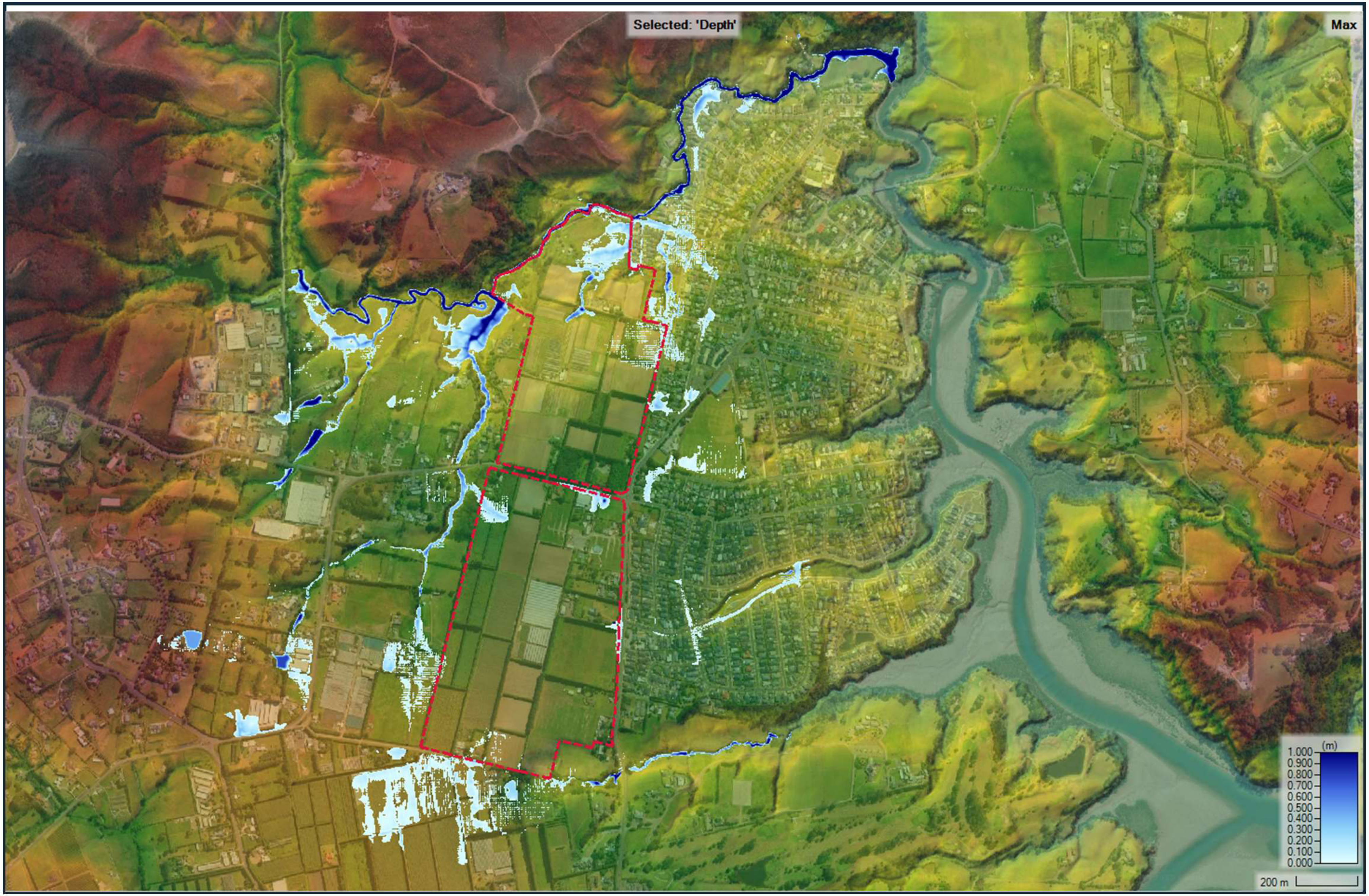

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DATE:	22/07/2025	LAND USE:	POST-DEVELOPMENT – ED OUTSIDE + MPD INSIDE		

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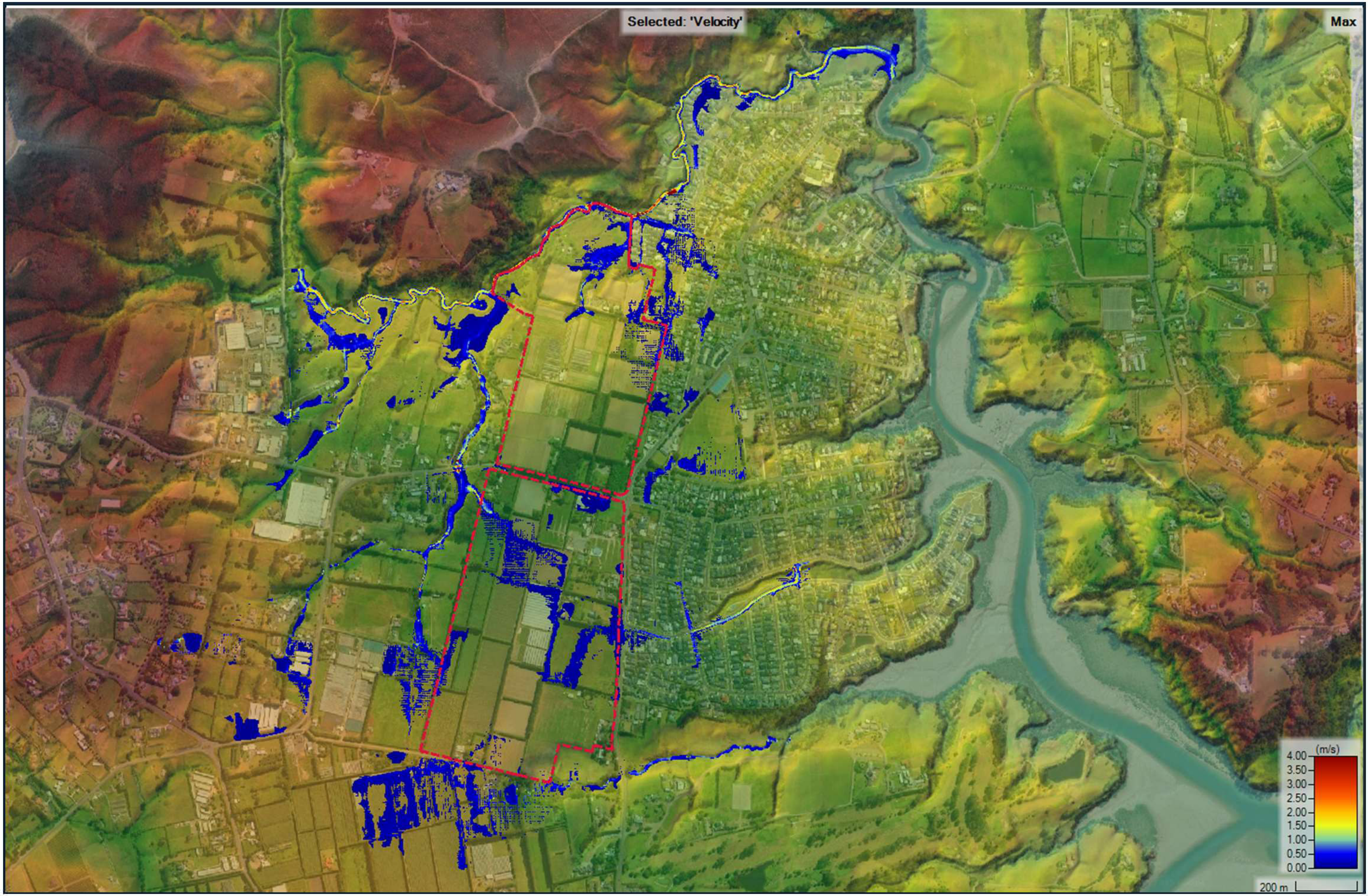

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DATE:	22/07/2025	LAND USE:	PRE-DEVELOPMENT – ED OUTSIDE + ED INSIDE		

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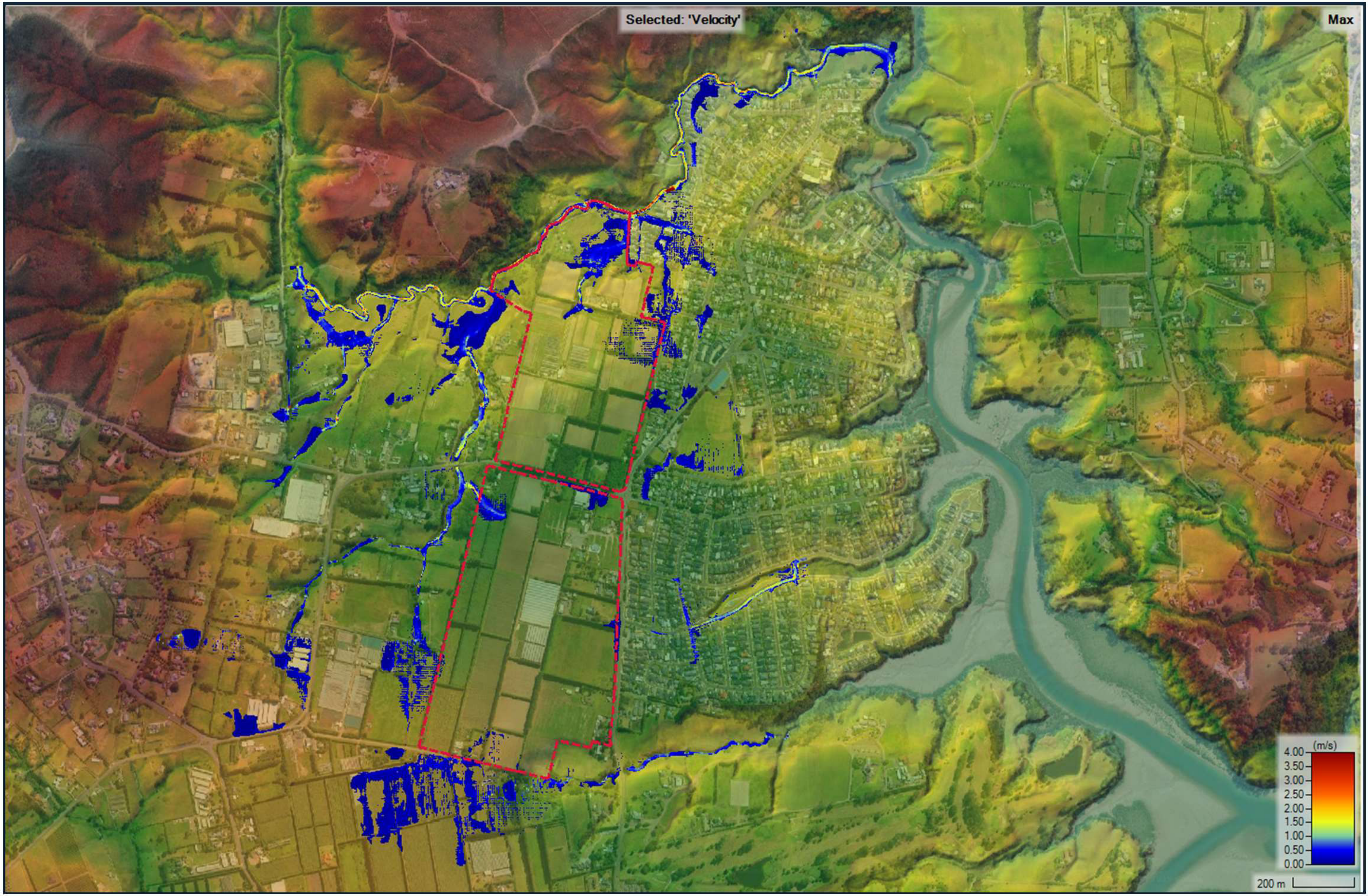

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DATE:	22/07/2025	LAND USE:	POST-DEVELOPMENT – ED OUTSIDE + MPD INSIDE		

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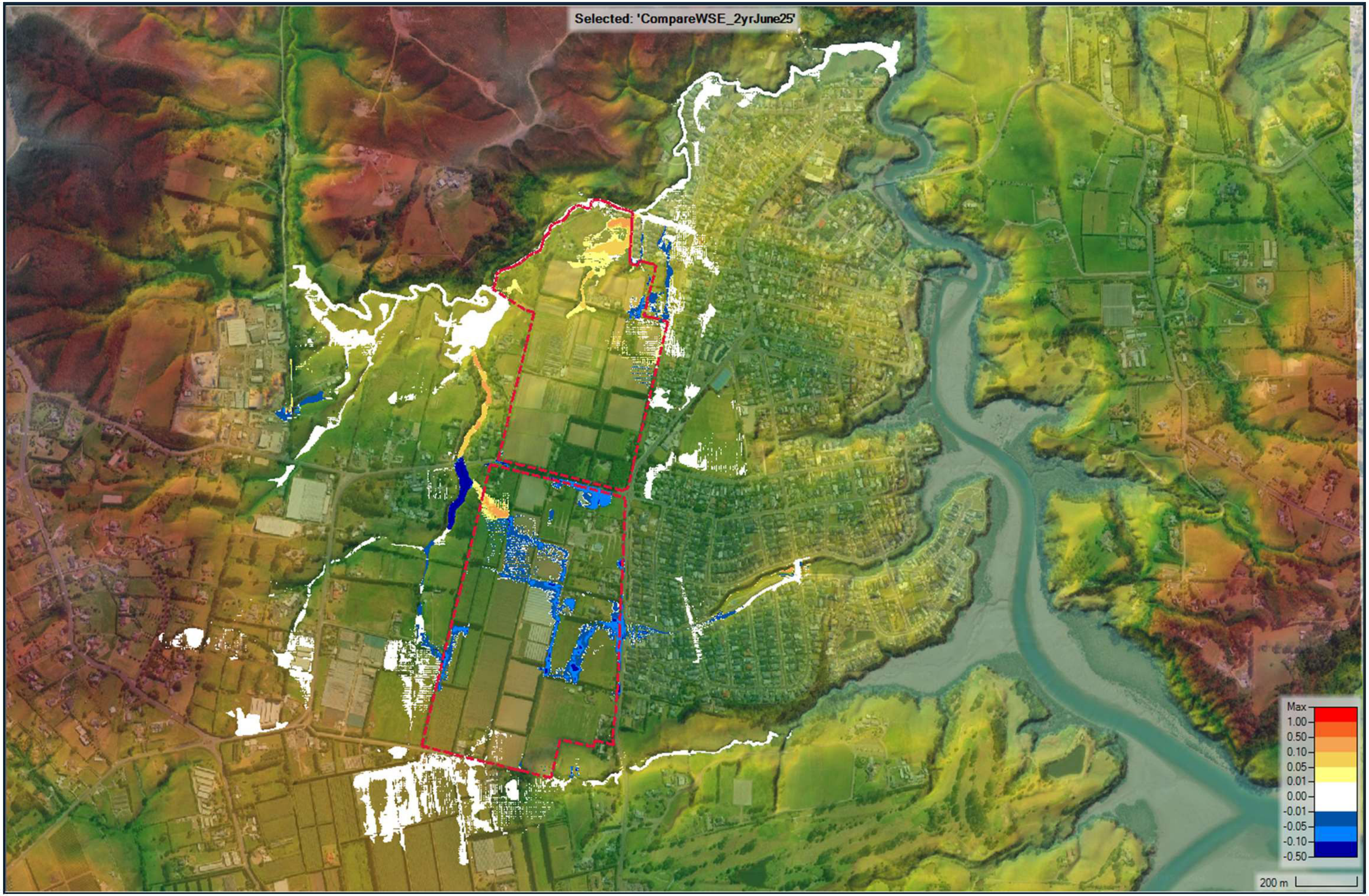

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DATE:	22/07/2025	LAND USE:	POST-DEVELOPMENT MINUS PRE-DEVELOPMENT		

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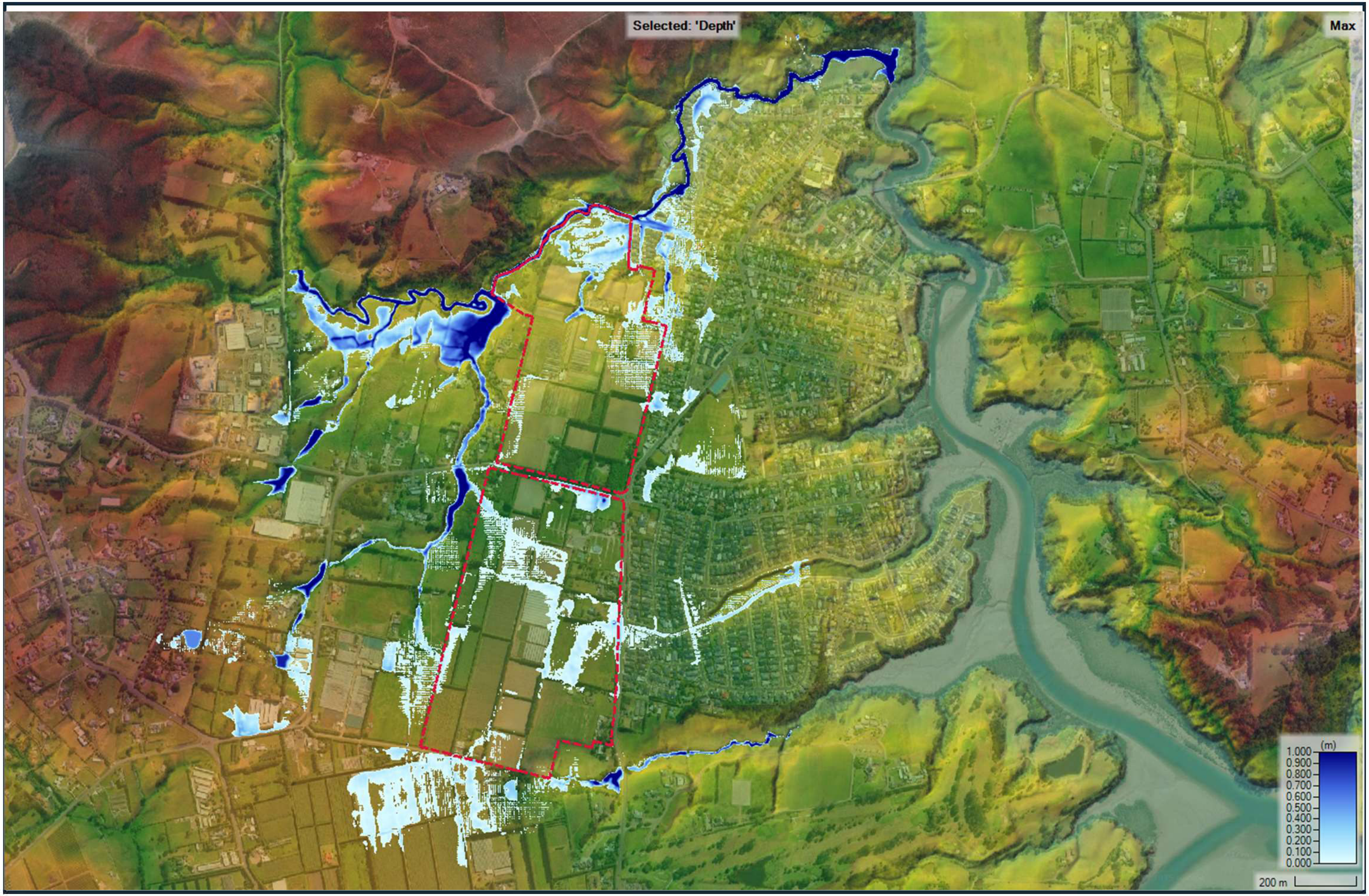

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DATE:	22/07/2025	LAND USE:	PRE-DEVELOPMENT – ED OUTSIDE + ED INSIDE		

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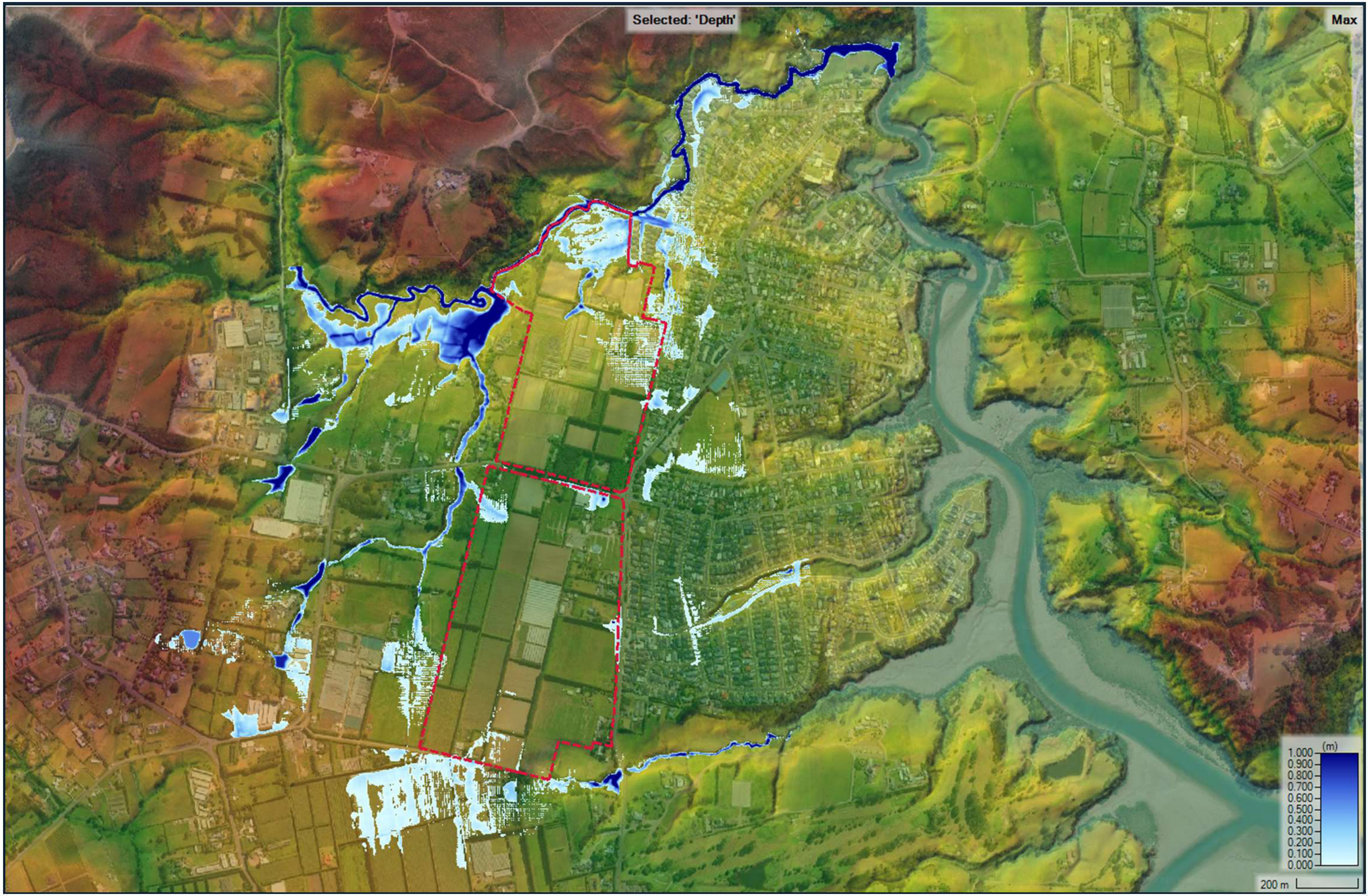

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DATE:	22/07/2025	LAND USE:	POST-DEVELOPMENT – ED OUTSIDE + MPD INSIDE		

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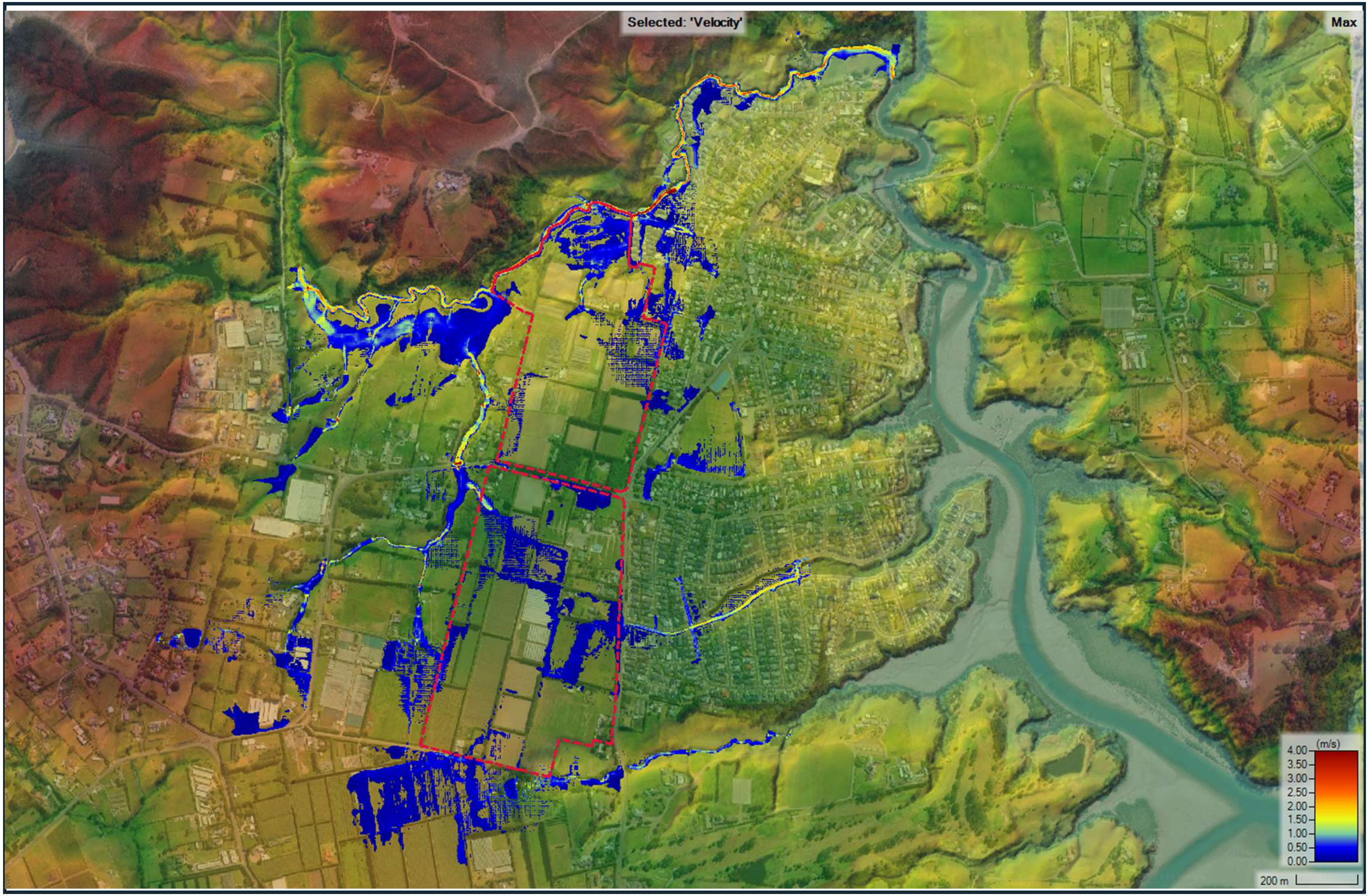

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REF NUMBER:	A20405	SCENARIO:	13	EVENT:	10yr+2.1°C
DATE:	22/07/2025	LAND USE:	PRE-DEVELOPMENT – ED OUTSIDE + ED INSIDE		

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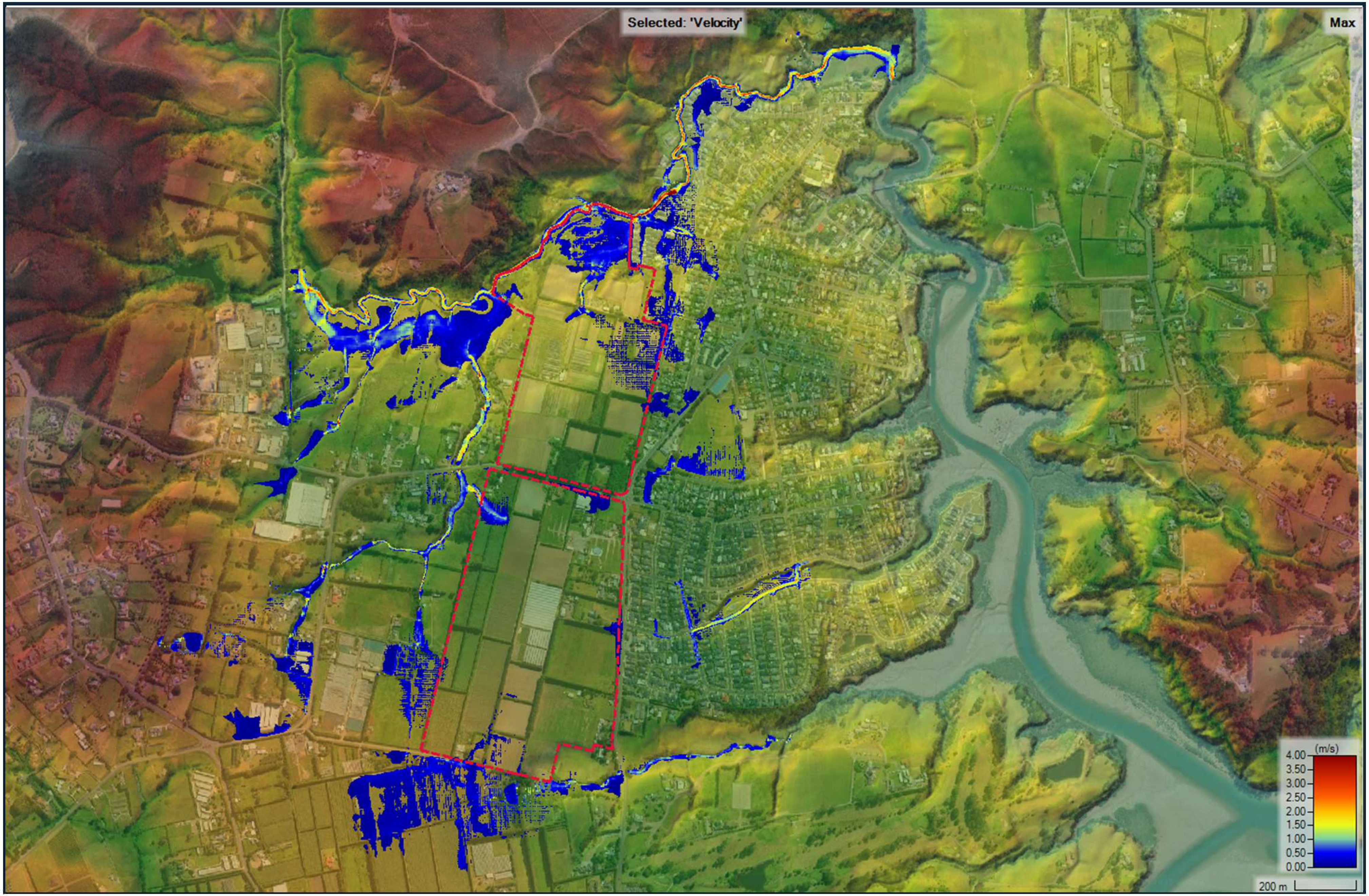

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DATE:	22/07/2025	LAND USE:	POST-DEVELOPMENT – ED OUTSIDE + MPD INSIDE		

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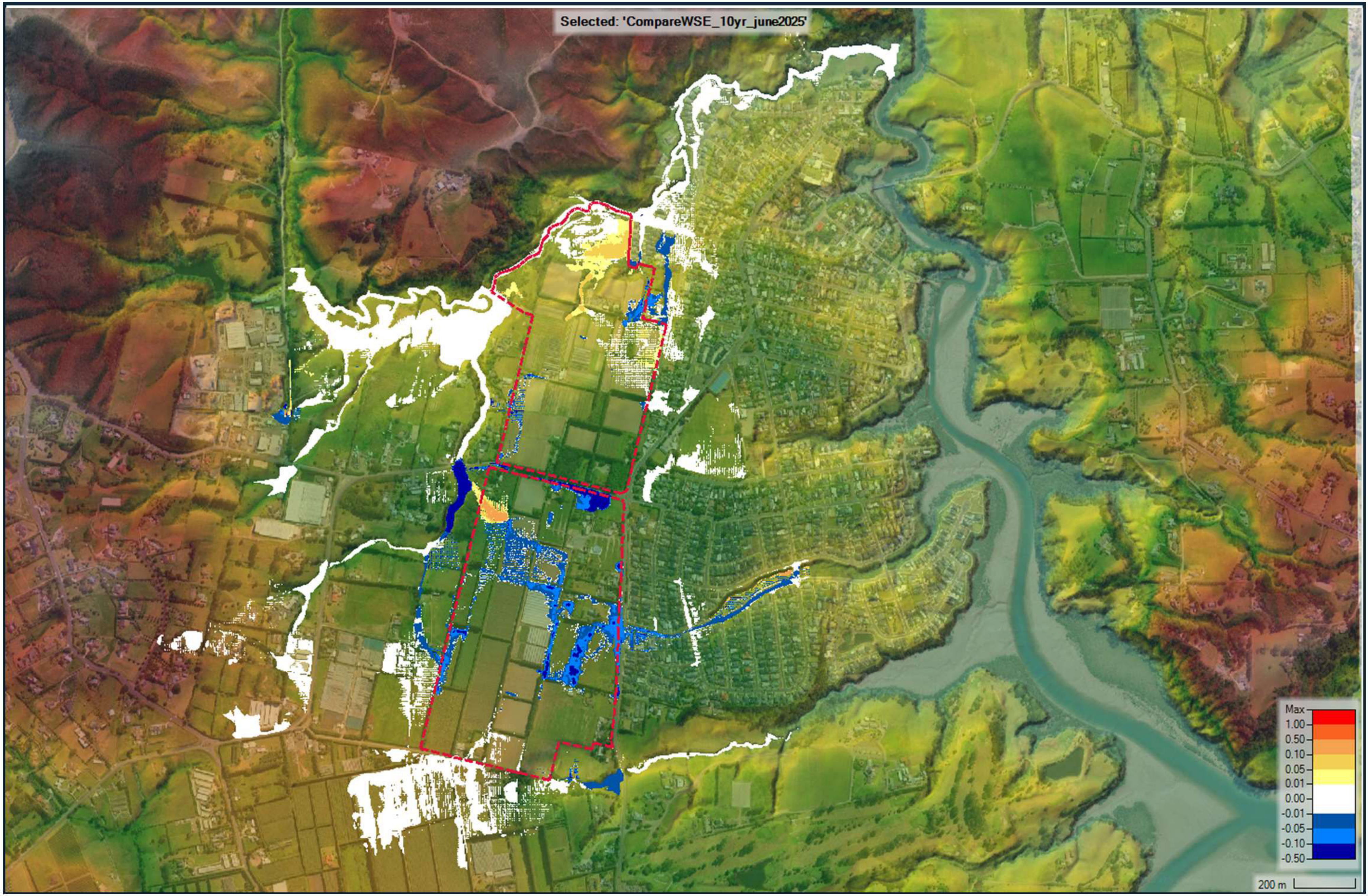

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DATE:	22/07/2025	LAND USE:	POST-DEVELOPMENT MINUS PRE-DEVELOPMENT		

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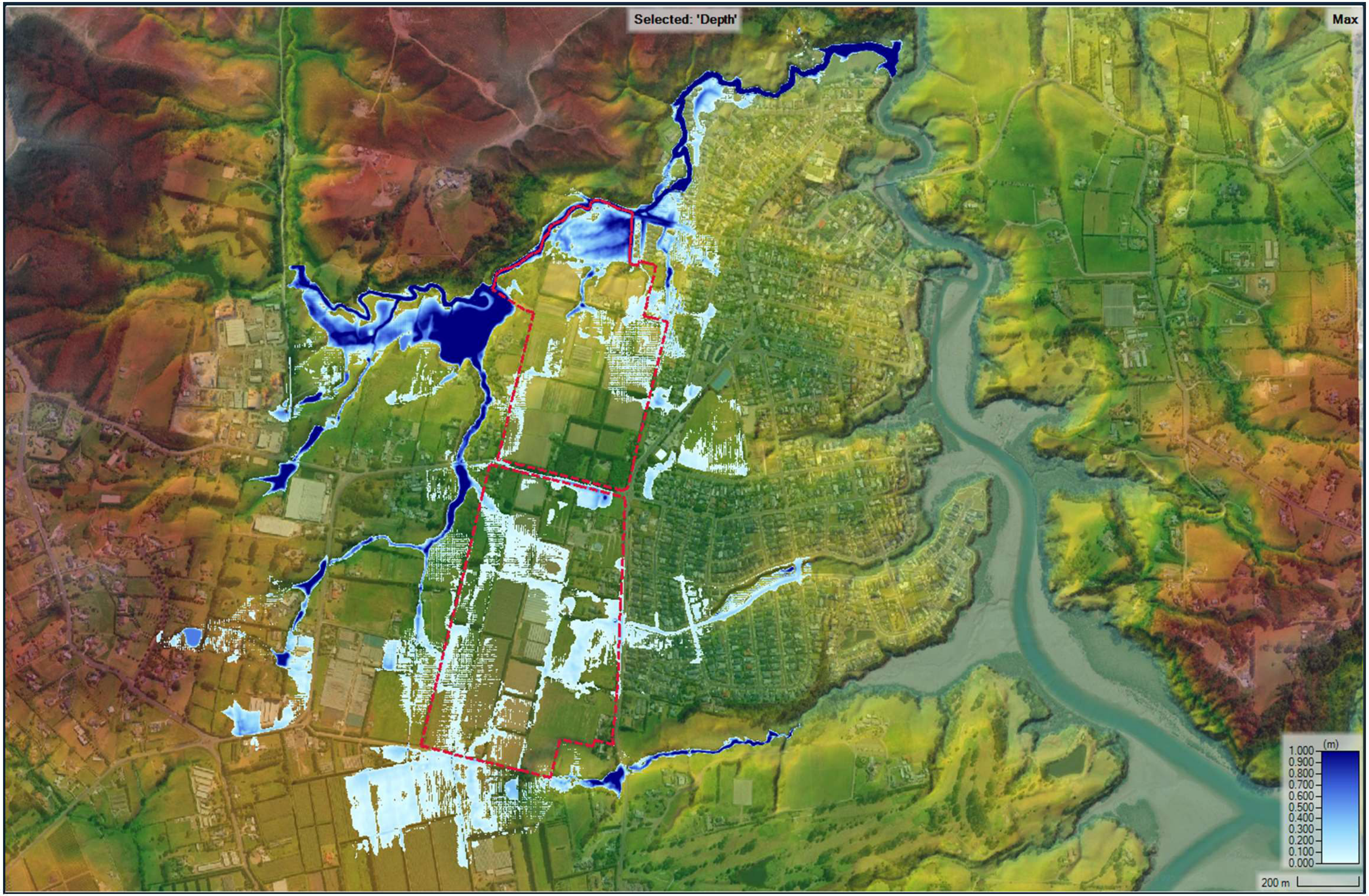

PROJECT:	RIVERHEAD PRIVATE PLAN CHANGE PC100	MAP TYPE:	FLOOD DEPTH (MAX)		
REF NUMBER:	A20405	SCENARIO:	14	EVENT:	100yr+3.8°C
DATE:	22/07/2025	LAND USE:	PRE-DEVELOPMENT – ED OUTSIDE + ED INSIDE		

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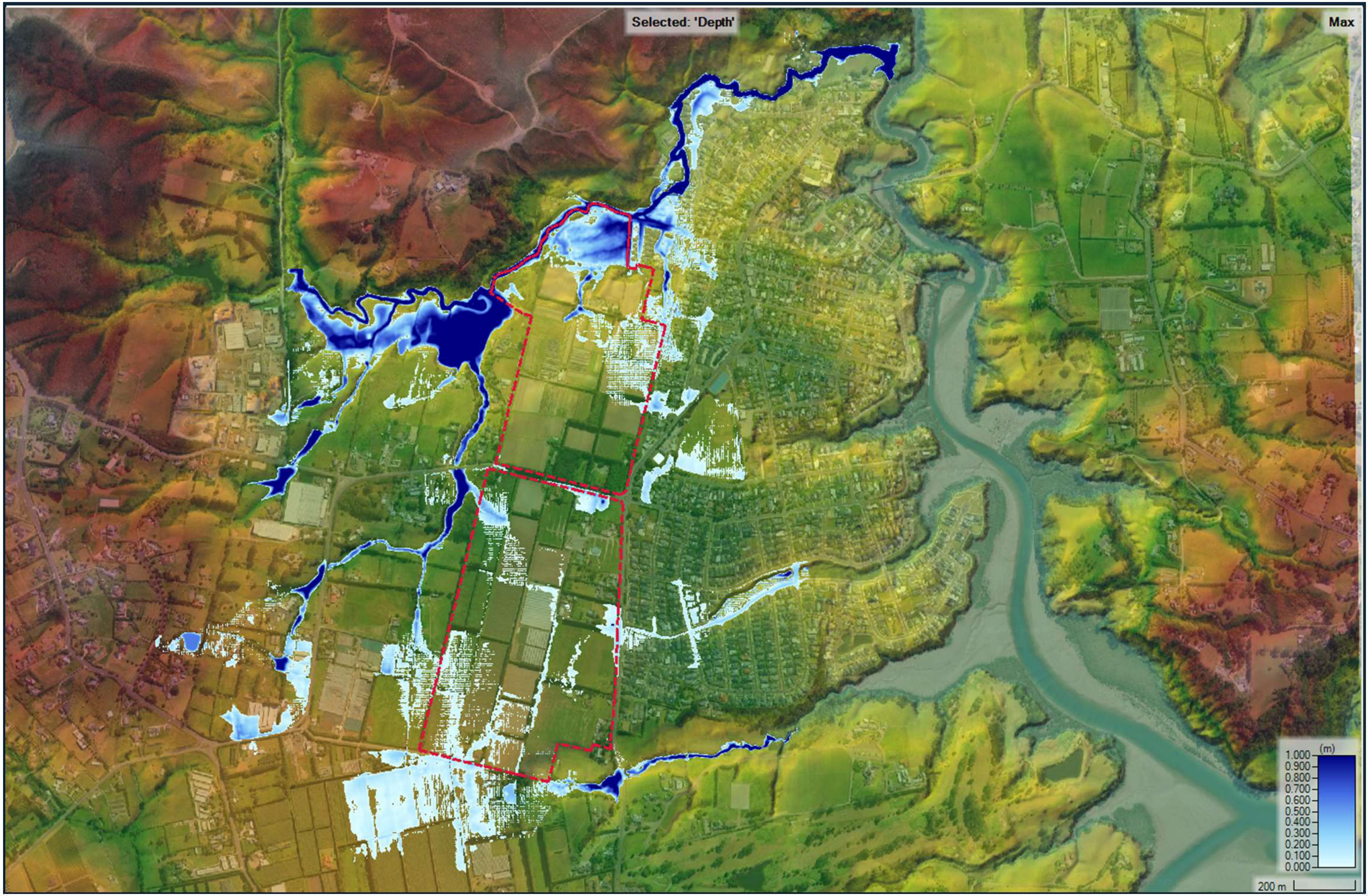

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DATE:	22/07/2025	LAND USE:	POST-DEVELOPMENT – ED OUTSIDE + MPD INSIDE		

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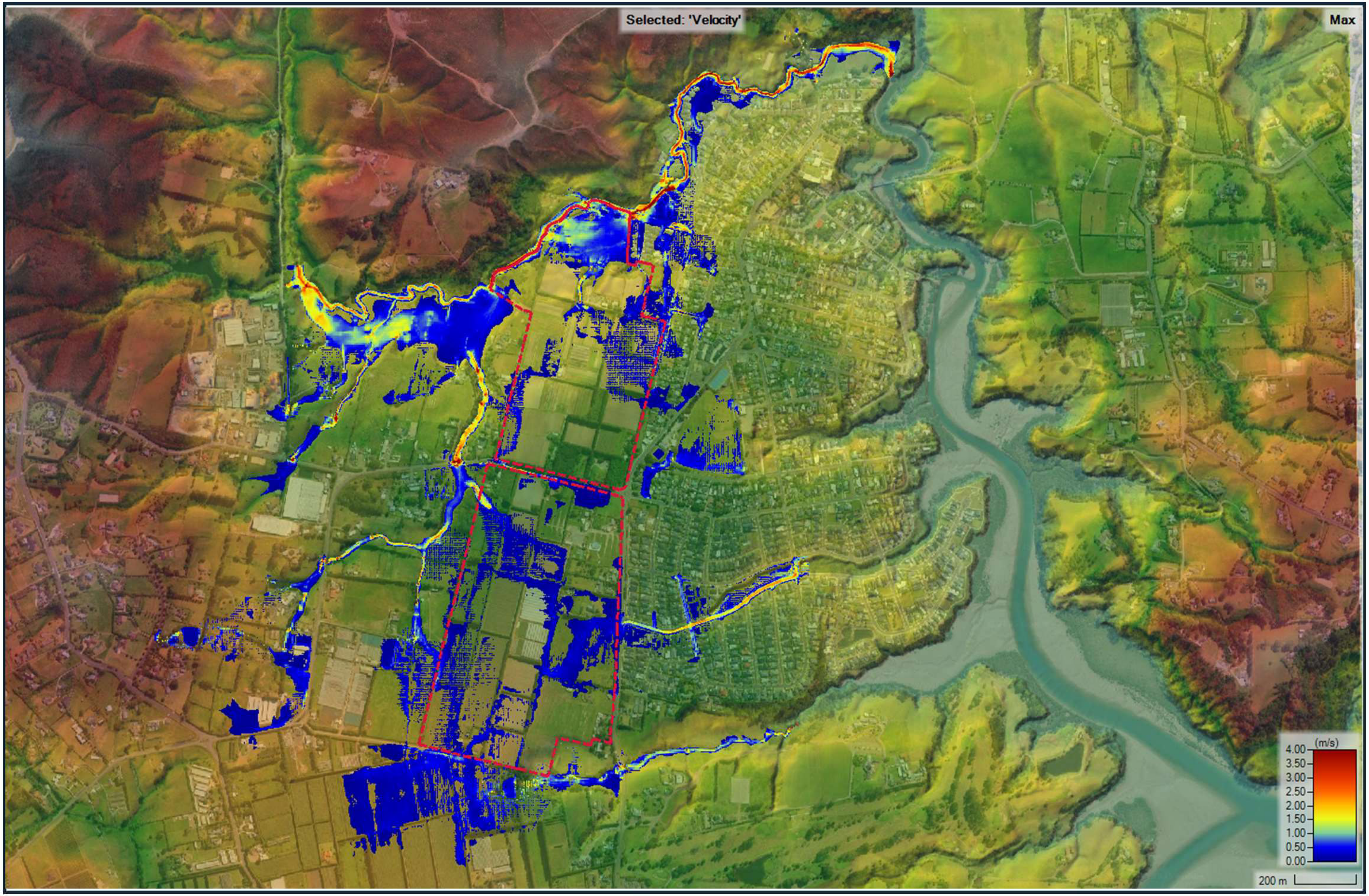

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DATE:	22/07/2025	LAND USE:	PRE-DEVELOPMENT – ED OUTSIDE + ED INSIDE		

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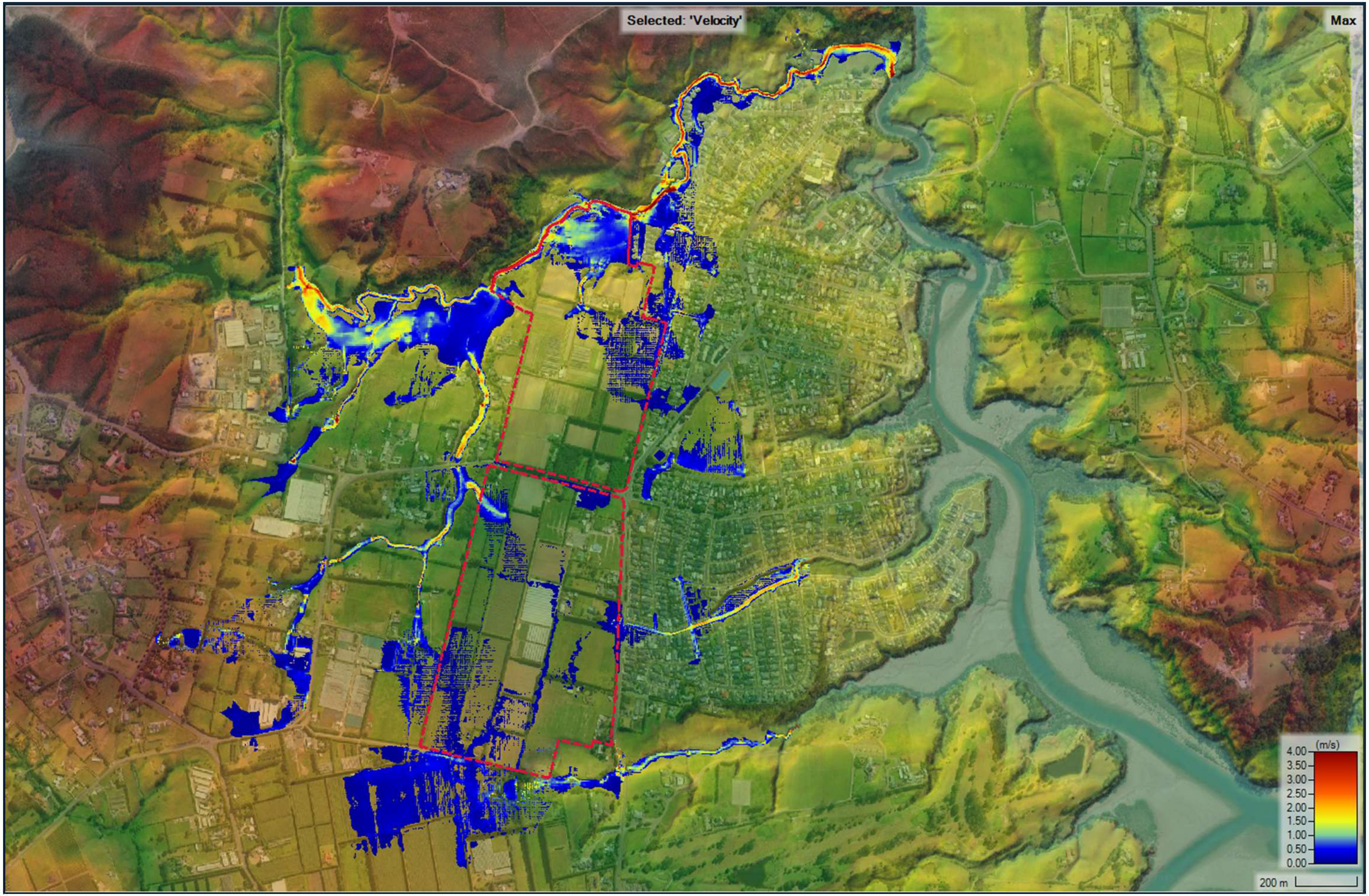

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DATE:	22/07/2025	LAND USE:	POST-DEVELOPMENT – ED OUTSIDE + MPD INSIDE		

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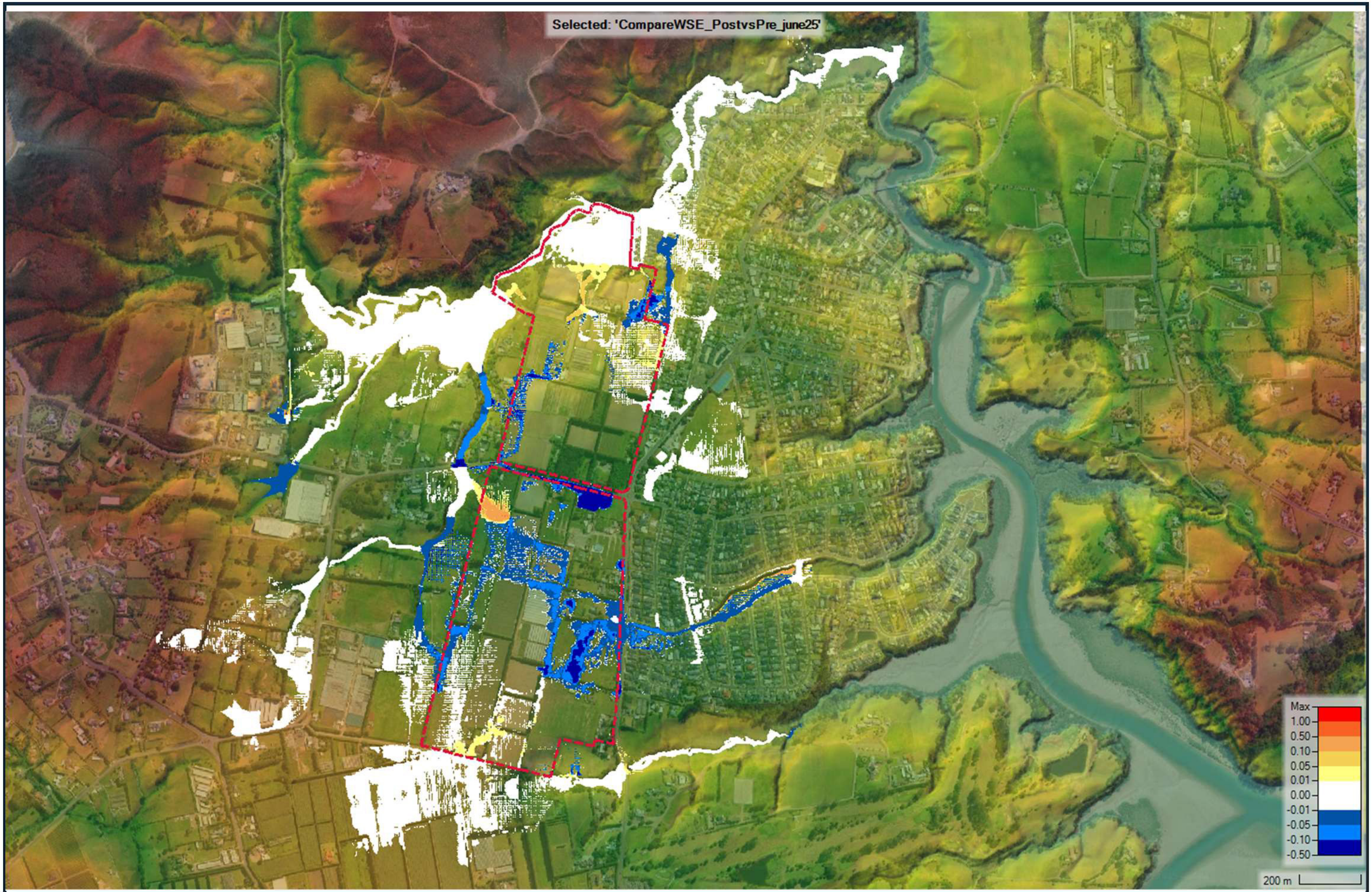

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DATE:	22/07/2025	LAND USE:	POST-DEVELOPMENT MINUS PRE-DEVELOPMENT		

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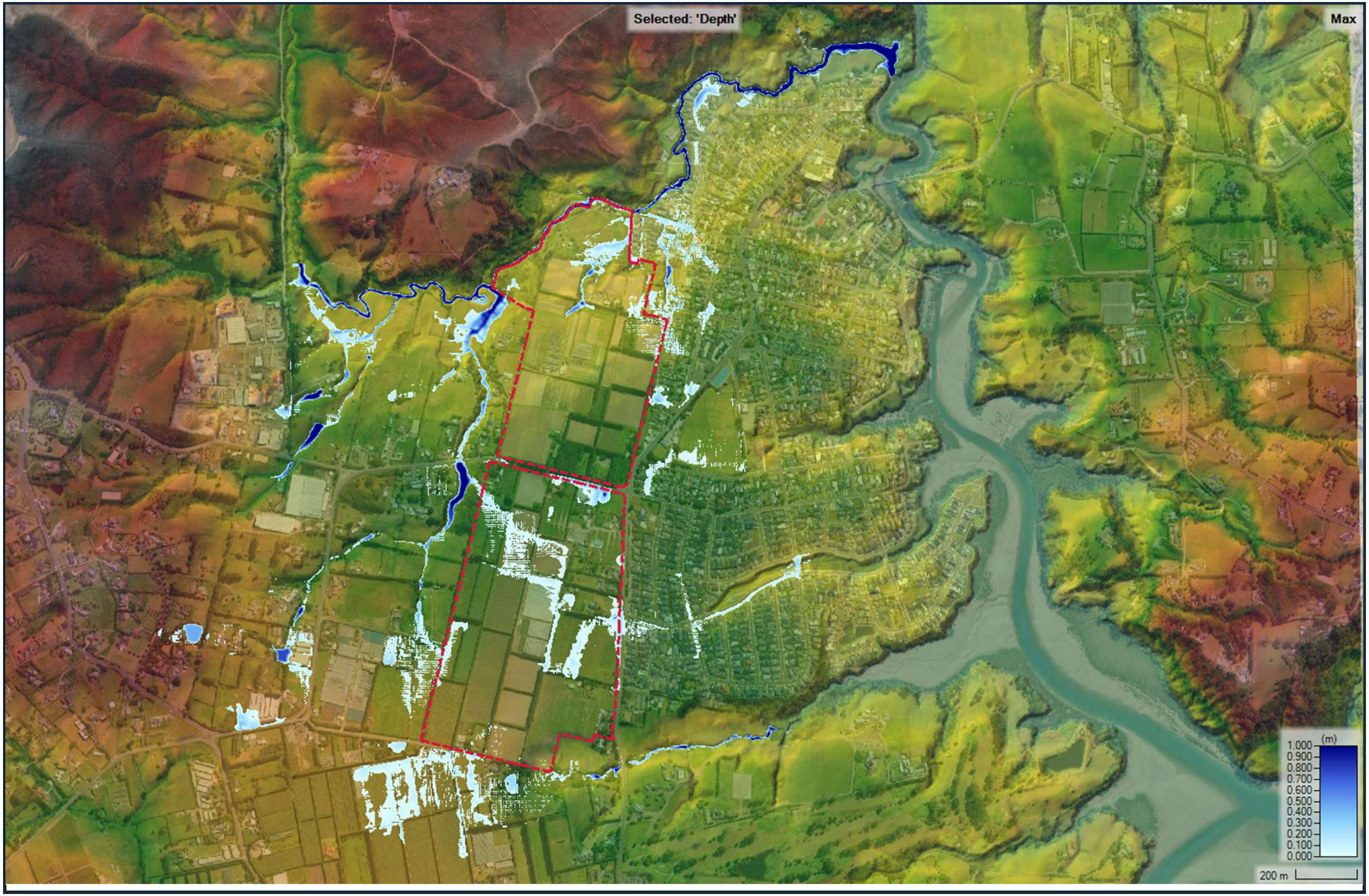

PROJECT:	RIVERHEAD PRIVATE PLAN CHANGE PC100	MAP TYPE:	FLOOD DEPTH (MAX)		
REF NUMBER:	A20405	SCENARIO:	15	EVENT:	2yr WITHOUT CLIMATE CHANGE
DATE:	22/07/2025	LAND USE:	PRE-DEVELOPMENT – ED OUTSIDE + ED INSIDE		

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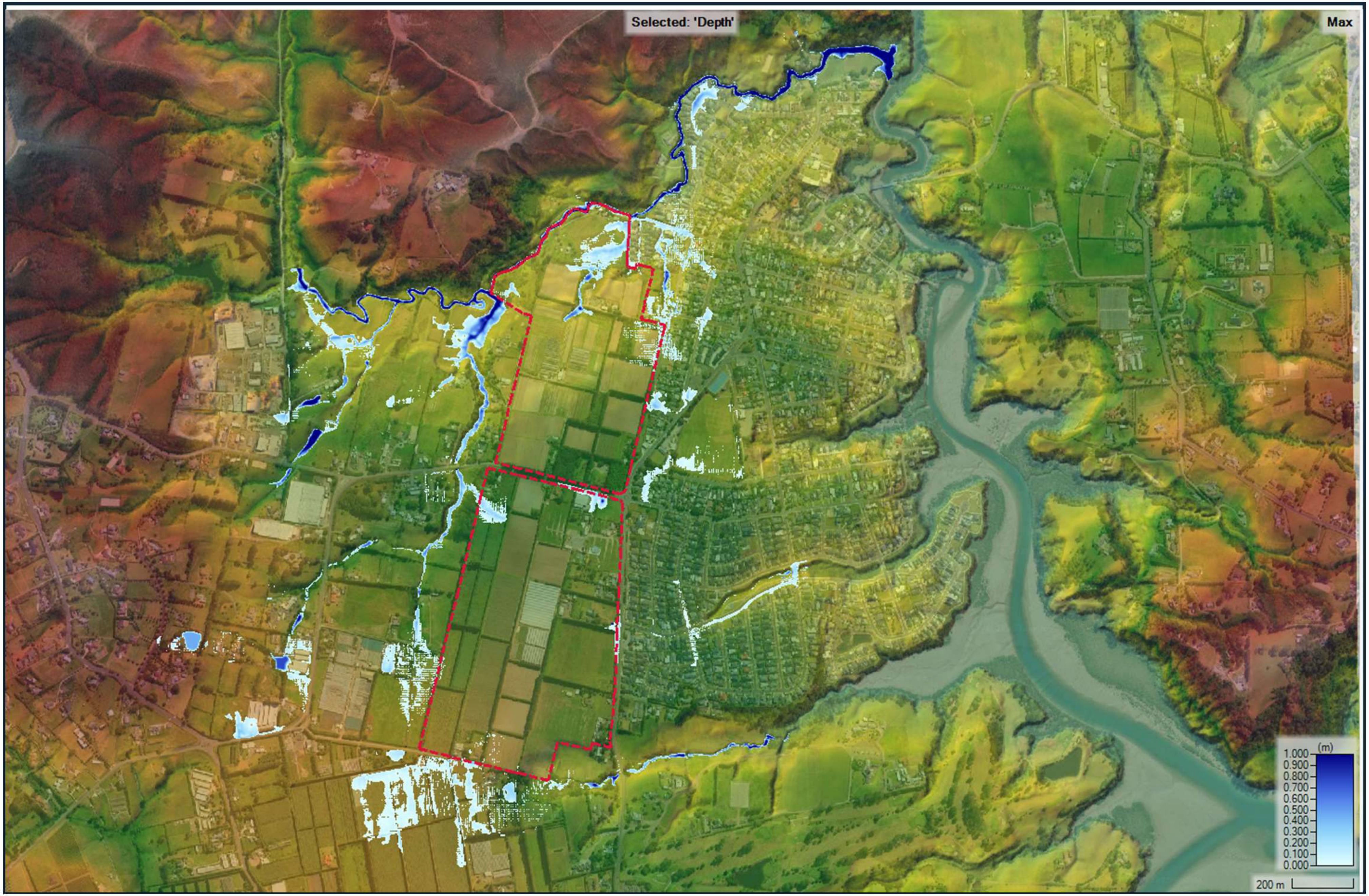

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DATE:	22/07/2025	LAND USE:	POST-DEVELOPMENT – ED OUTSIDE + MPD INSIDE		

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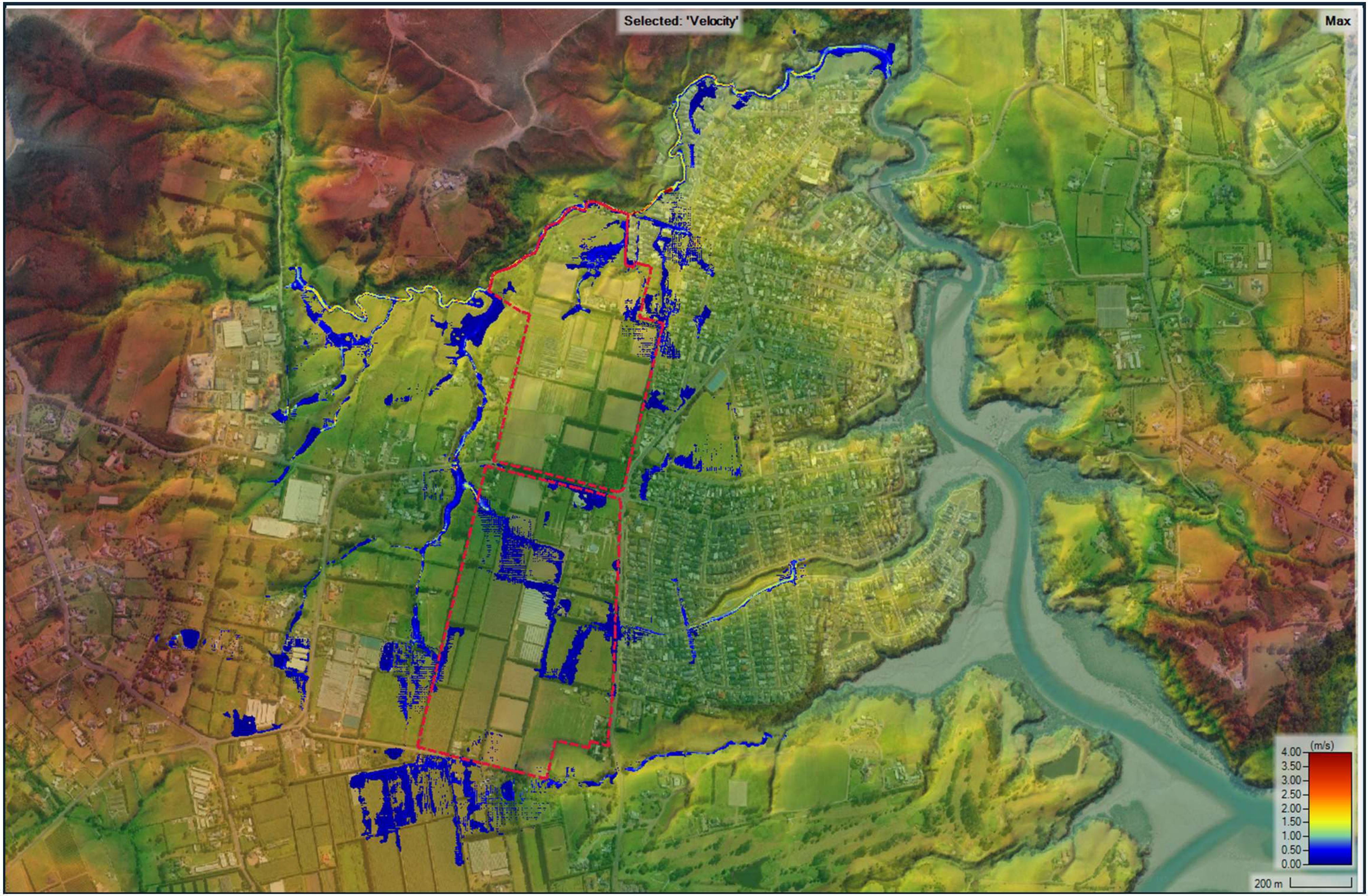

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DATE:	22/07/2025	LAND USE:	PRE-DEVELOPMENT – ED OUTSIDE + ED INSIDE		

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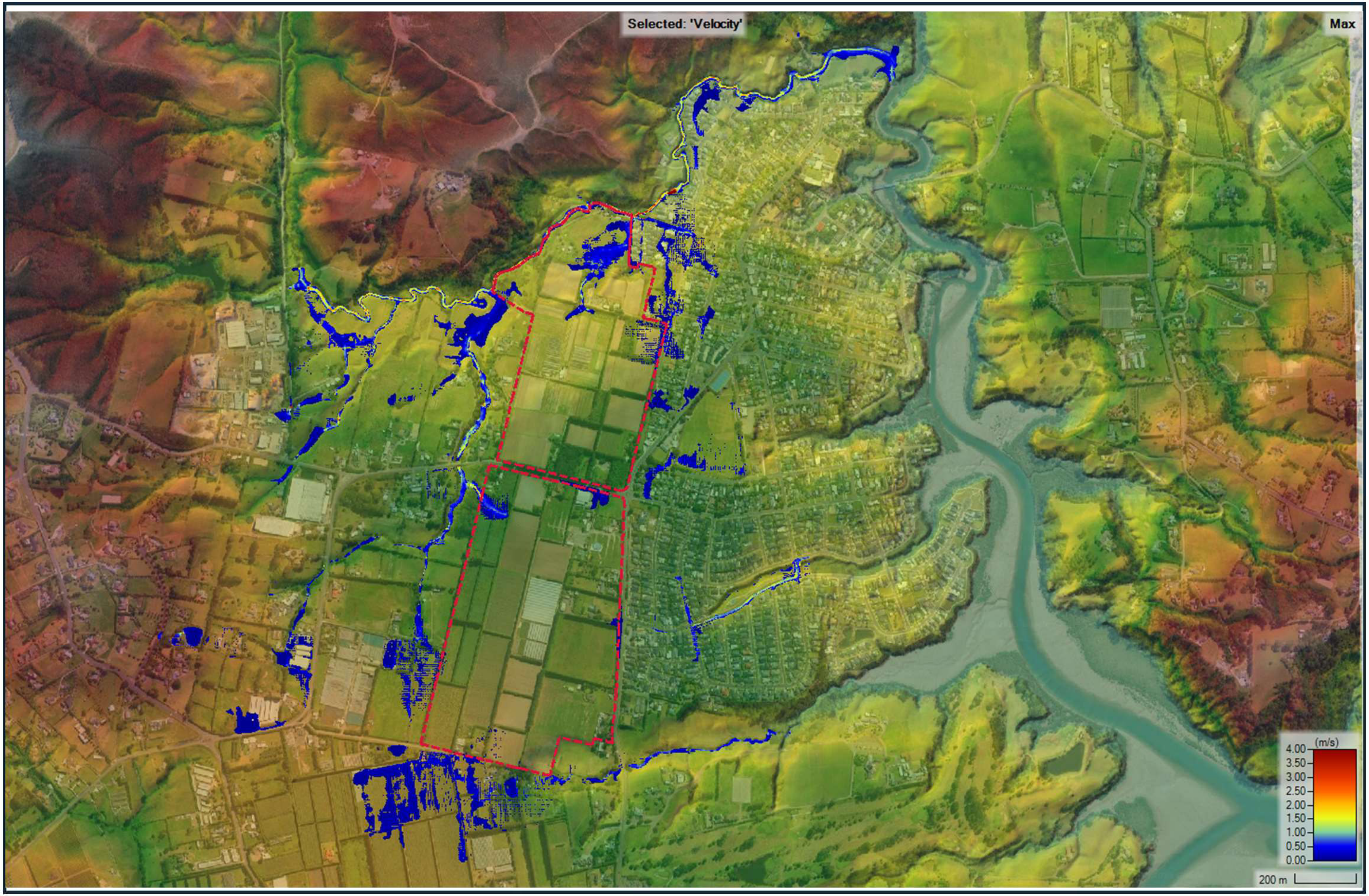

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DATE:	22/07/2025	LAND USE:	POST-DEVELOPMENT – ED OUTSIDE + MPD INSIDE		

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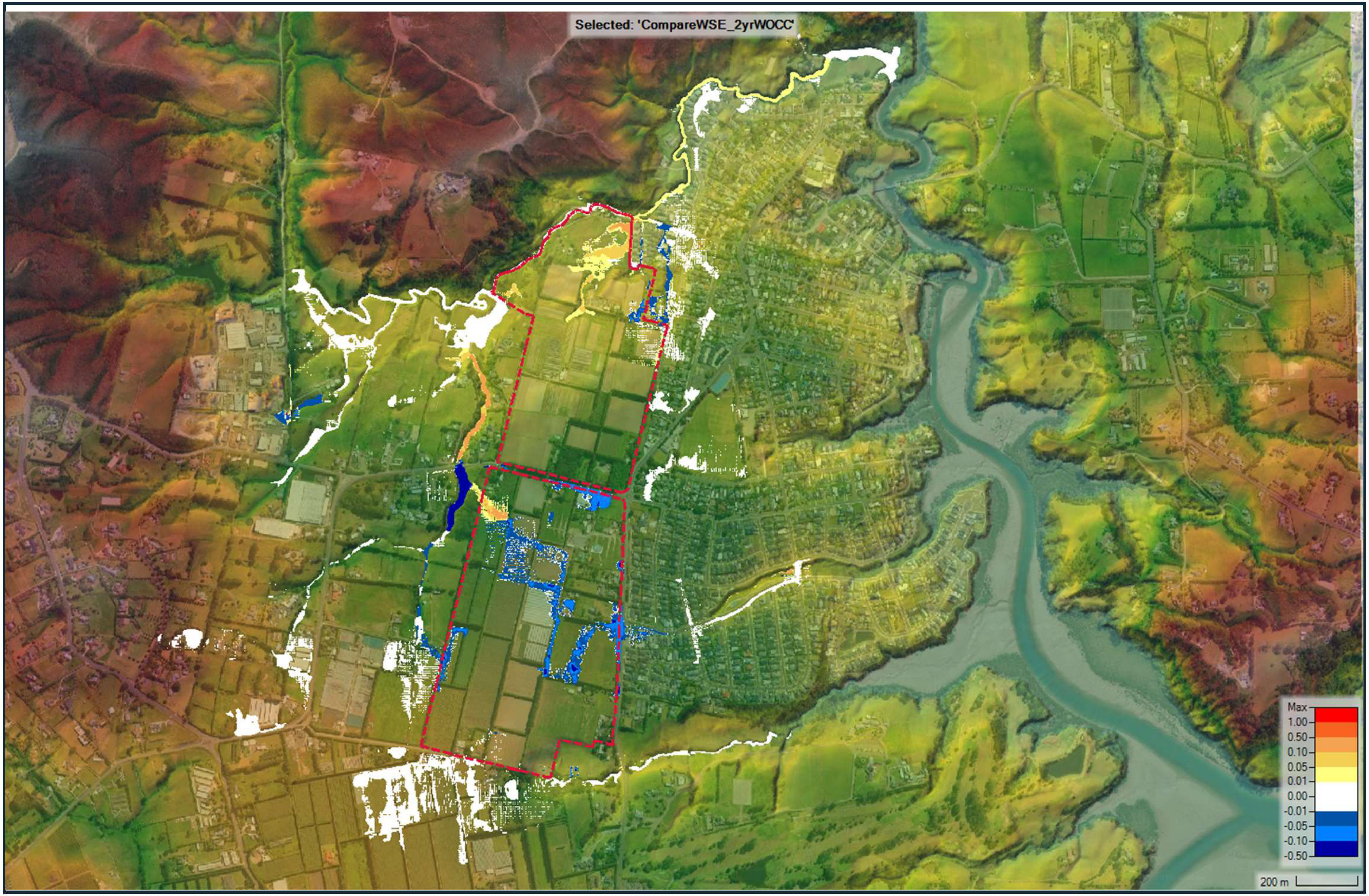

PROJECT:	RIVERHEAD PRIVATE PLAN CHANGE PC100	MAP TYPE:	WATER SURFACE ELEVATION DIFFERENCE (MAX)		
REF NUMBER:	A20405	SCENARIO:	15	EVENT:	2yr WITHOUT CLIMATE CHANGE
DATE:	22/07/2025	LAND USE:	POST-DEVELOPMENT MINUS PRE-DEVELOPMENT		

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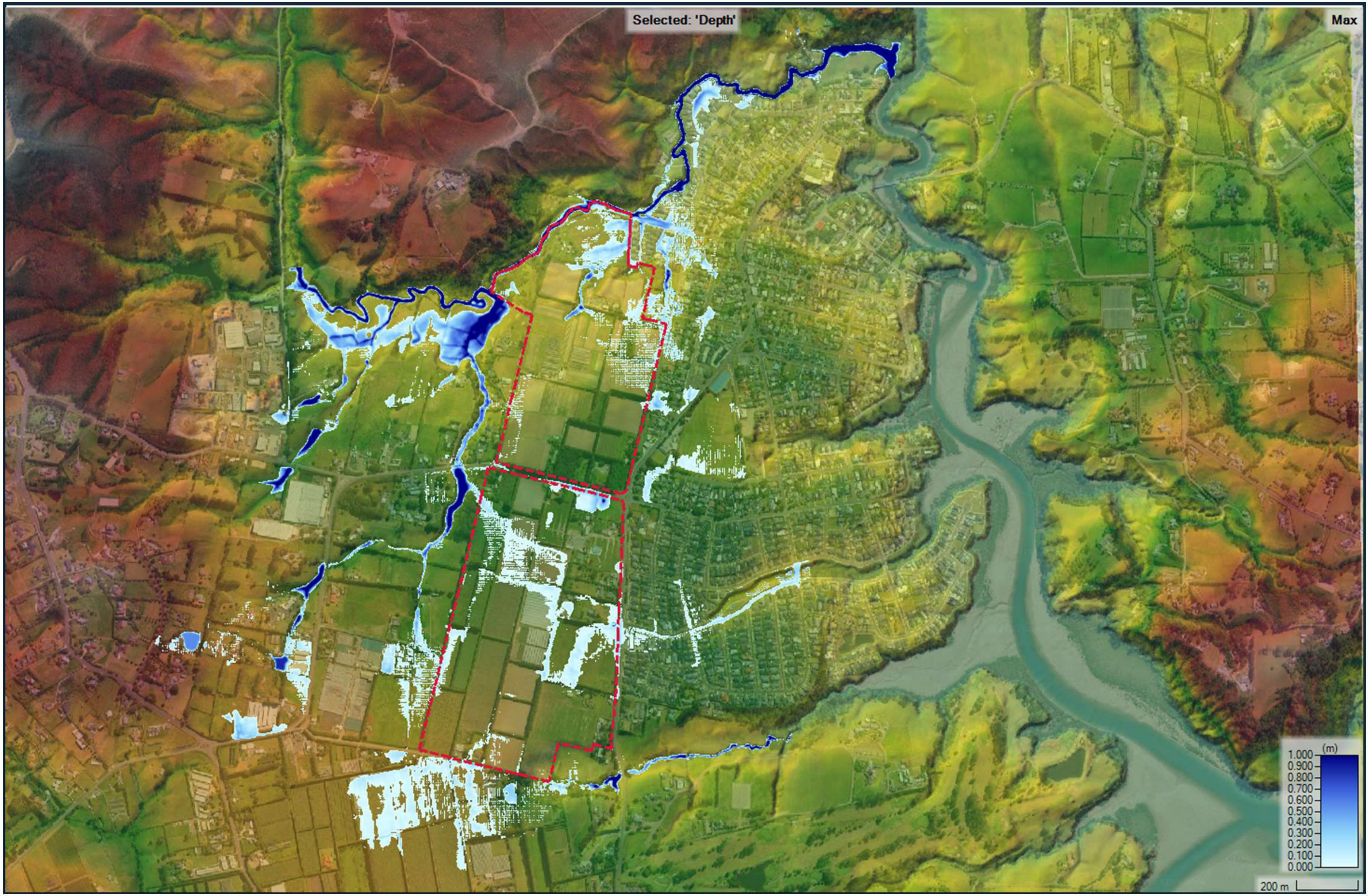

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REF NUMBER:	A20405	SCENARIO:	16	EVENT:	10yr WITHOUT CLIMATE CHANGE
DATE:	22/07/2025	LAND USE:	PRE-DEVELOPMENT – ED OUTSIDE + ED INSIDE		

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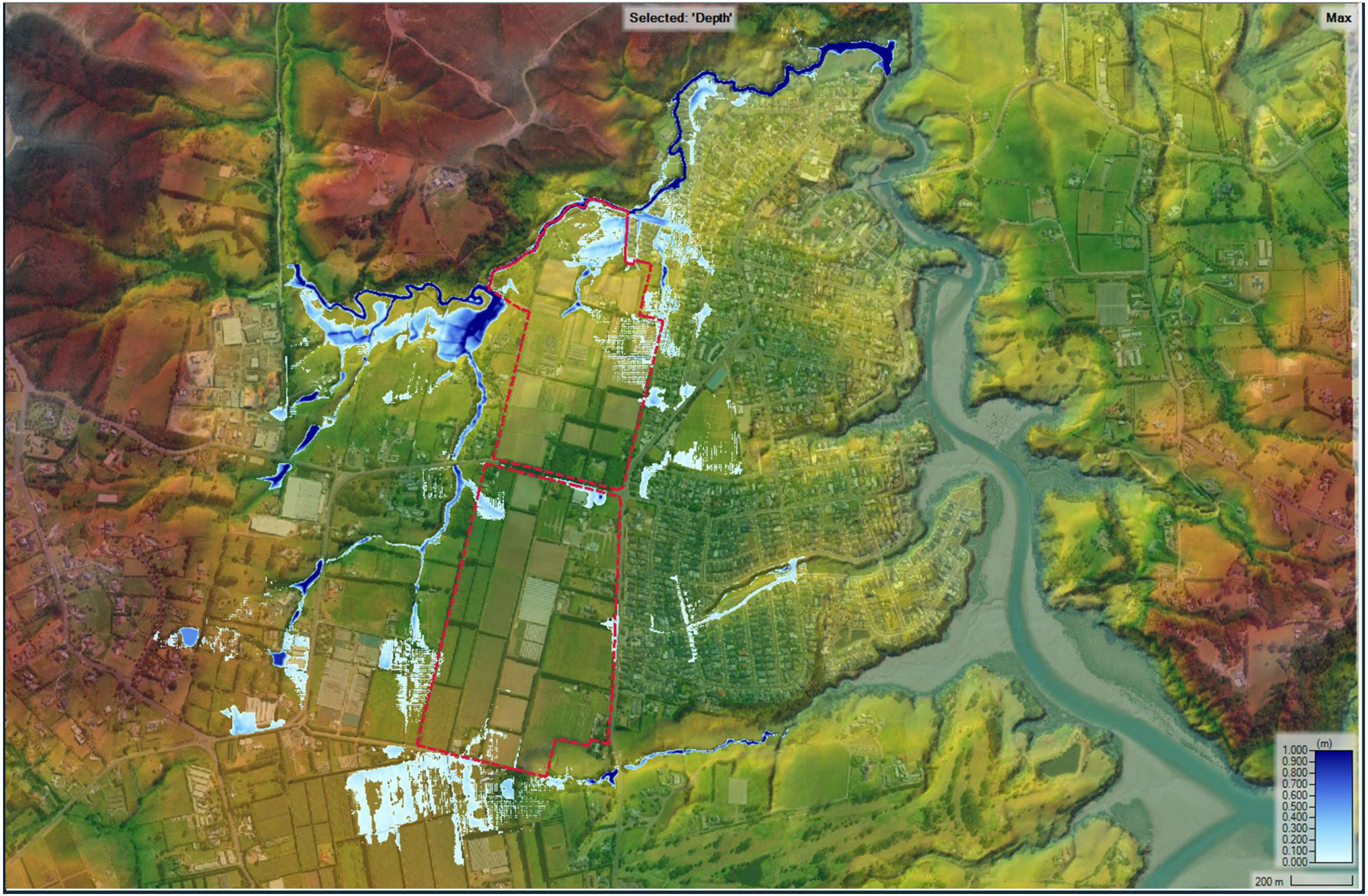

PROJECT:	RIVERHEAD PRIVATE PLAN CHANGE PC100	MAP TYPE:	FLOOD DEPTH (MAX)		
REF NUMBER:	A20405	SCENARIO:	16	EVENT:	10yr WITHOUT CLIMATE CHANGE
DATE:	22/07/2025	LAND USE:	POST-DEVELOPMENT – ED OUTSIDE + MPD INSIDE		

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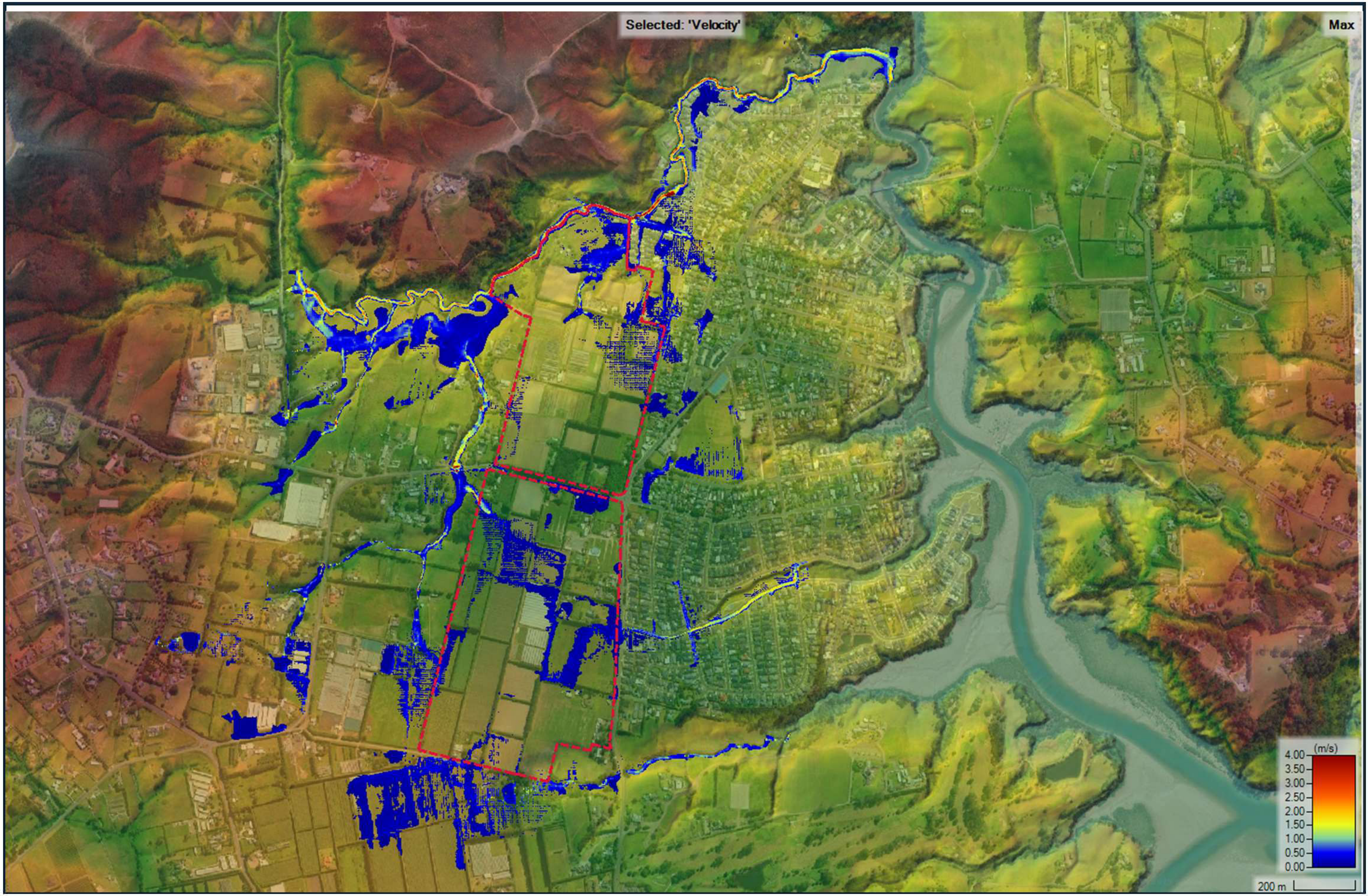

PROJECT:	RIVERHEAD PRIVATE PLAN CHANGE PC100	MAP TYPE:	VELOCITY (MAX)		
REF NUMBER:	A20405	SCENARIO:	16	EVENT:	10yr WITHOUT CLIMATE CHANGE
DATE:	22/07/2025	LAND USE:	PRE-DEVELOPMENT – ED OUTSIDE + ED INSIDE		

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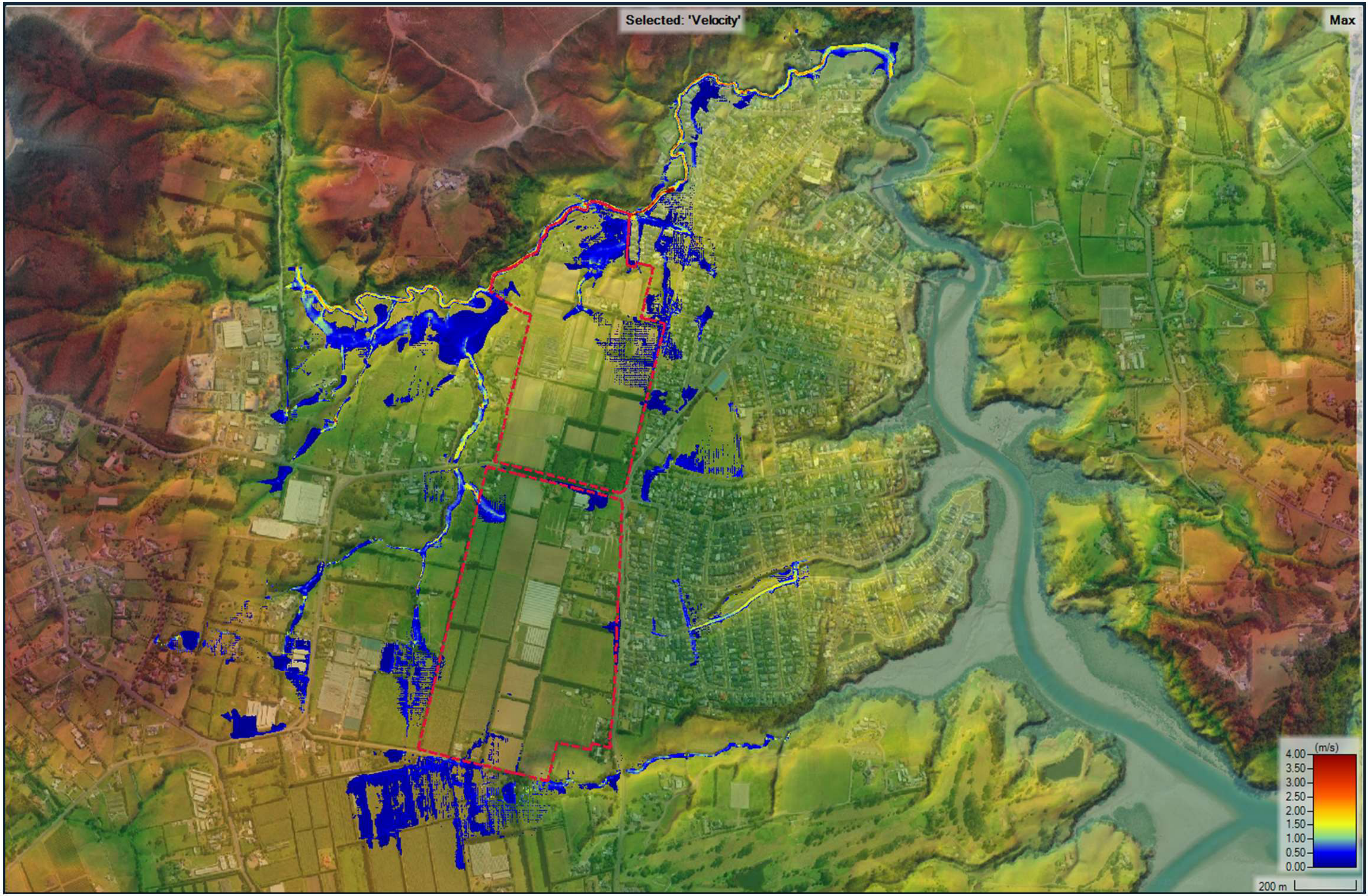

PROJECT:	RIVERHEAD PRIVATE PLAN CHANGE PC100	MAP TYPE:	VELOCITY (MAX)		
REF NUMBER:	A20405	SCENARIO:	16	EVENT:	10yr WITHOUT CLIMATE CHANGE
DATE:	22/07/2025	LAND USE:	POST-DEVELOPMENT – ED OUTSIDE + MPD INSIDE		

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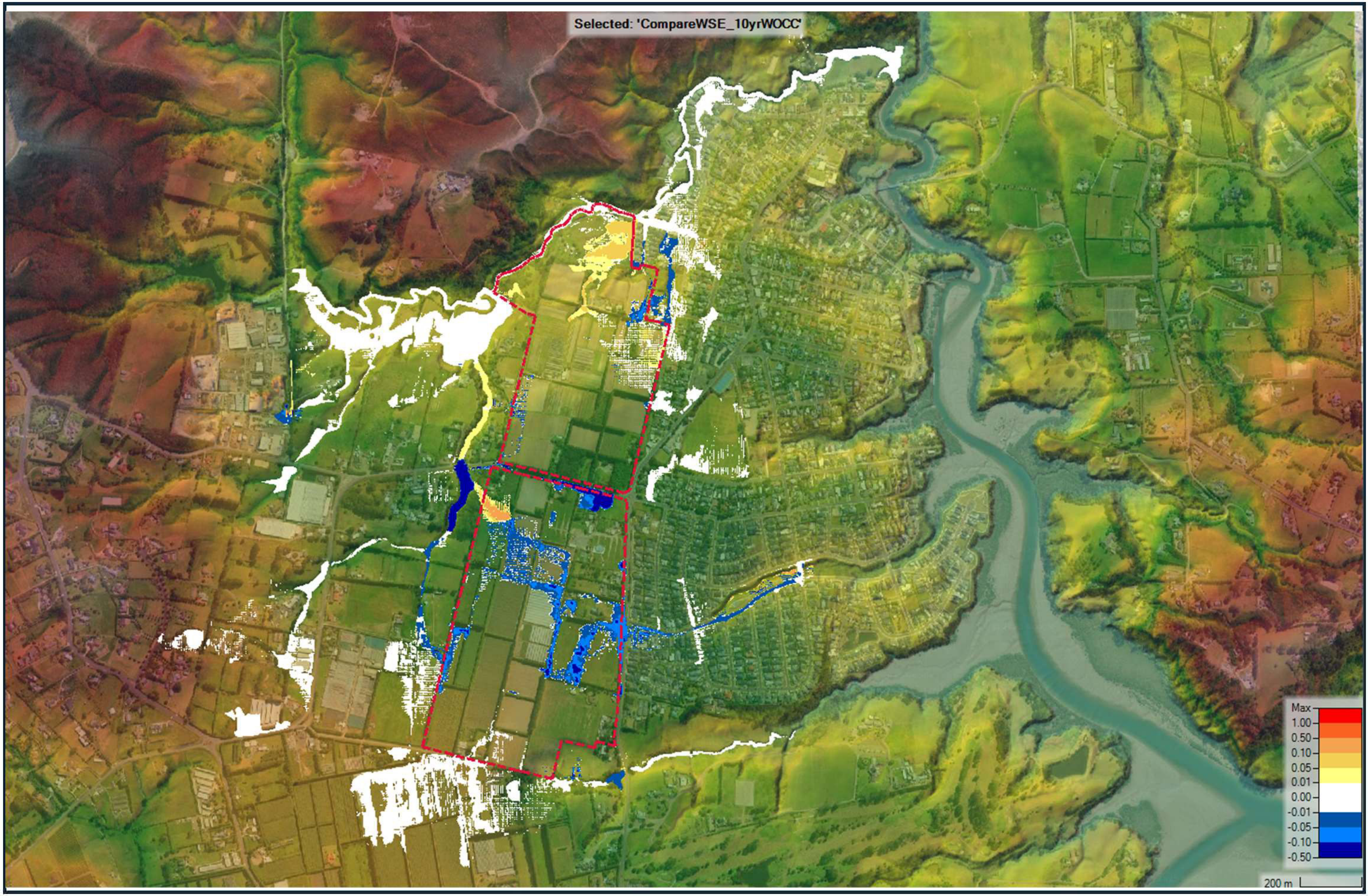

PROJECT:	RIVERHEAD PRIVATE PLAN CHANGE PC100	MAP TYPE:	WATER SURFACE ELEVATION DIFFERENCE (MAX)		
REF NUMBER:	A20405	SCENARIO:	16	EVENT:	10yr WITHOUT CLIMATE CHANGE
DATE:	22/07/2025	LAND USE:	POST-DEVELOPMENT MINUS PRE-DEVELOPMENT		

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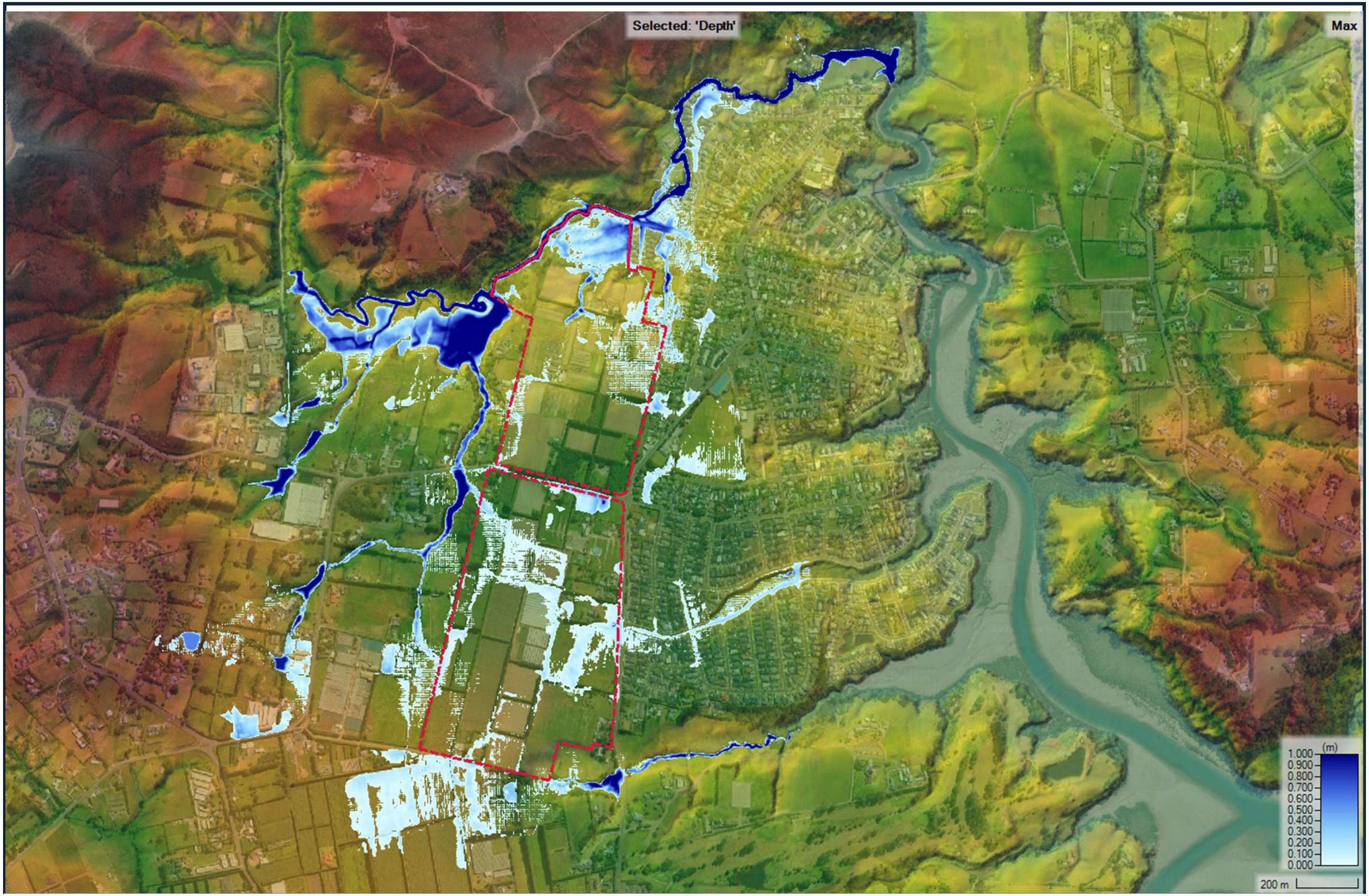

PROJECT:	RIVERHEAD PRIVATE PLAN CHANGE PC100	MAP TYPE:	FLOOD DEPTH (MAX)		
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DATE:	22/07/2025	LAND USE:	PRE-DEVELOPMENT – ED OUTSIDE + ED INSIDE		

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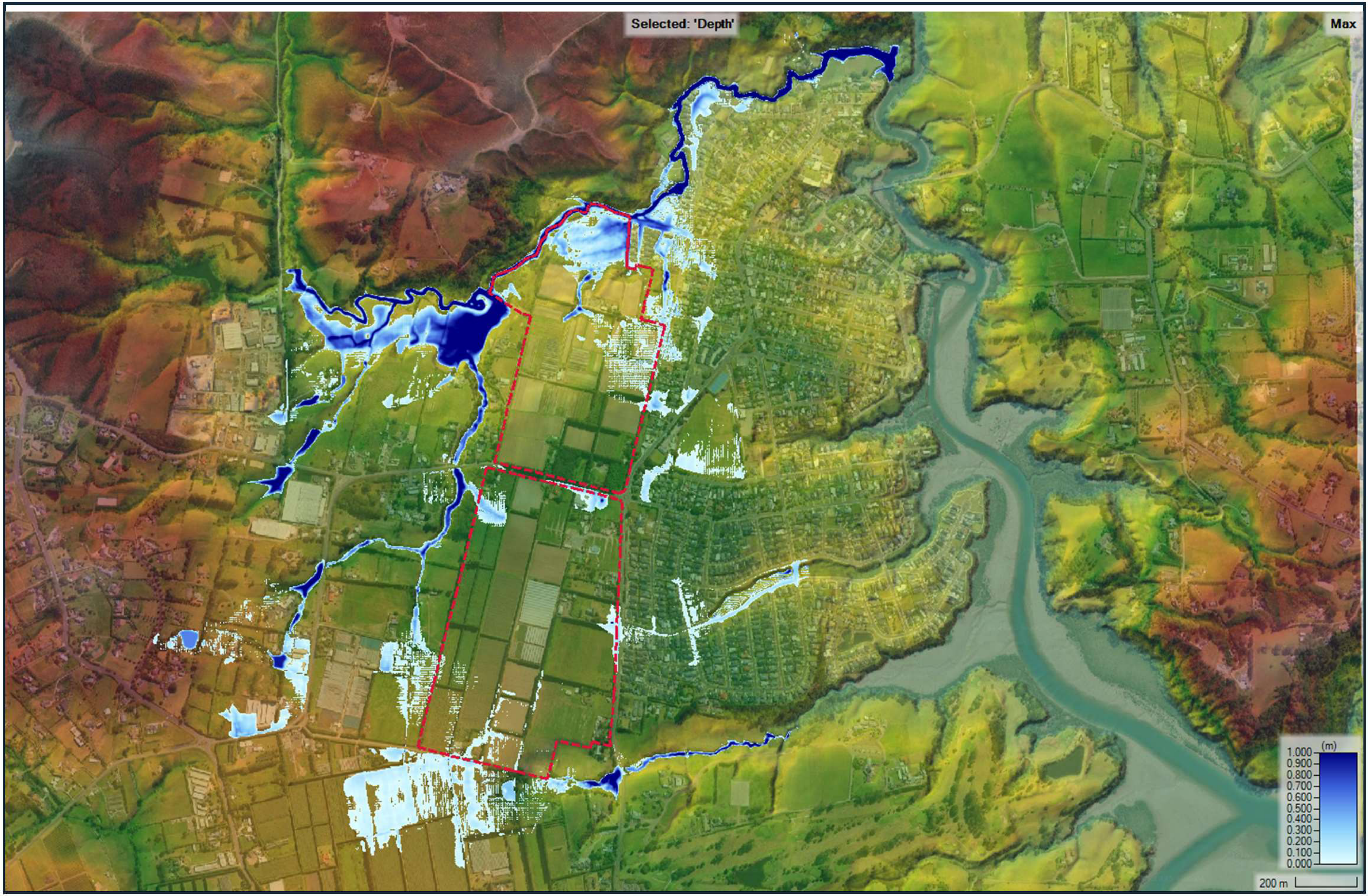

PROJECT:	RIVERHEAD PRIVATE PLAN CHANGE PC100	MAP TYPE:	FLOOD DEPTH (MAX)		
REF NUMBER:	A20405	SCENARIO:	17	EVENT:	100yr WITHOUT CLIMATE CHANGE
DATE:	22/07/2025	LAND USE:	POST-DEVELOPMENT – ED OUTSIDE + MPD INSIDE		

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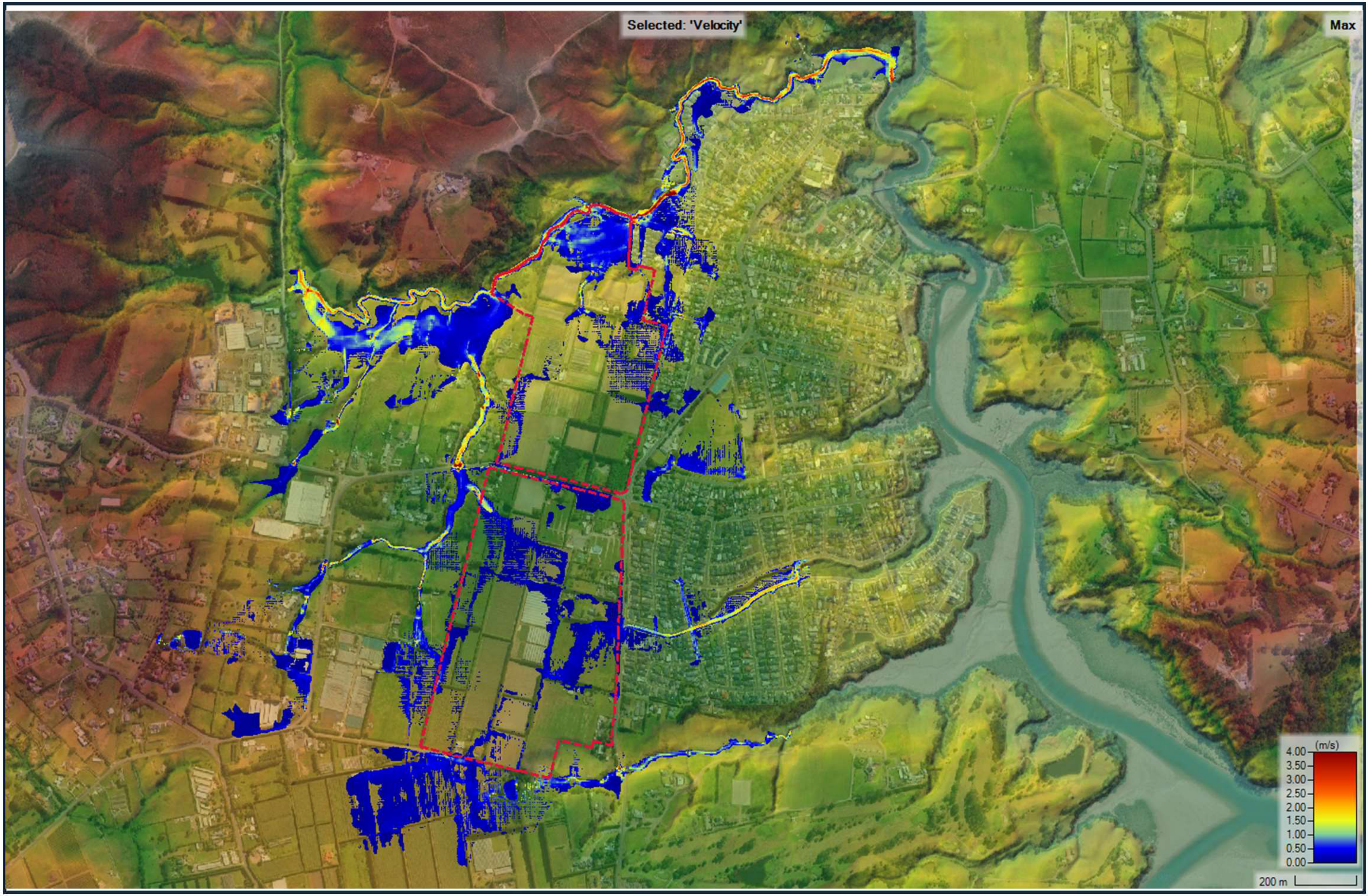

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DATE:	22/07/2025	LAND USE:	PRE-DEVELOPMENT – ED OUTSIDE + ED INSIDE		

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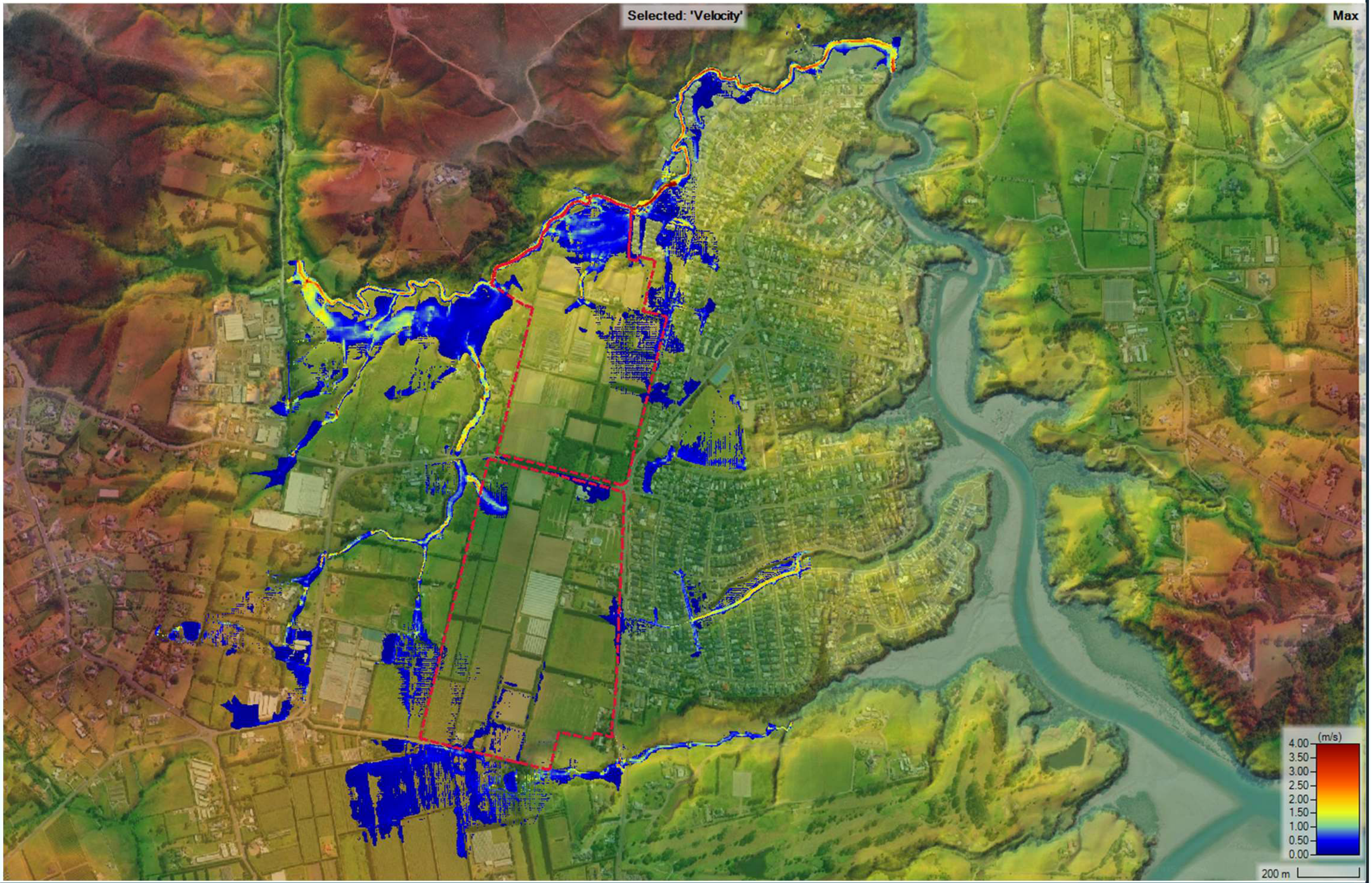
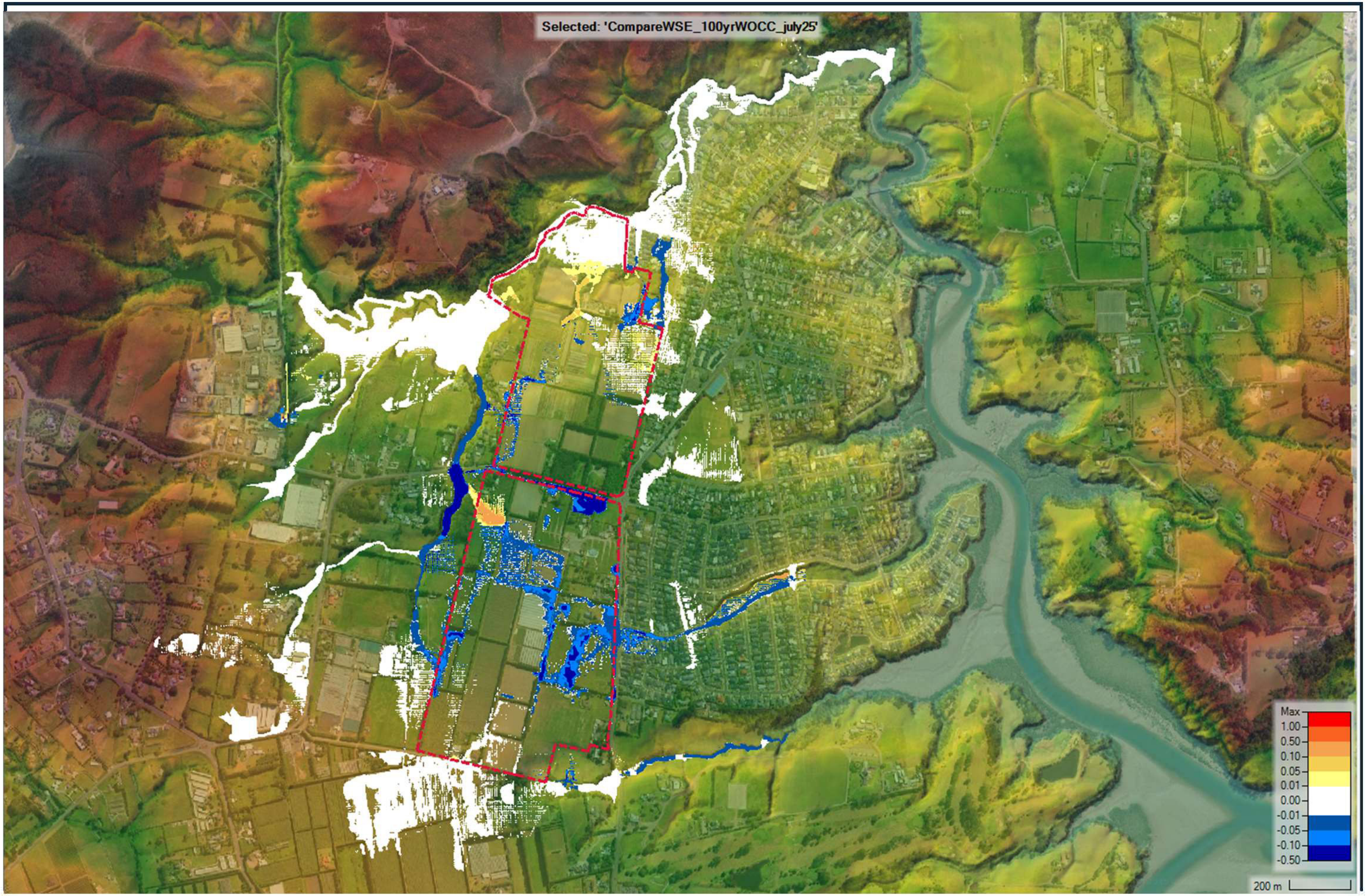


PROJECT:	RIVERHEAD PRIVATE PLAN CHANGE PC100	MAP TYPE:	VELOCITY (MAX)			CKL Planning | Surveying | Engineering | Environmental
REF NUMBER:	A20405	SCENARIO:	17	EVENT:	100yr WITHOUT CLIMATE CHANGE	
DATE:	22/07/2025	LAND USE:	POST-DEVELOPMENT – ED OUTSIDE + MPD INSIDE			



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REF NUMBER:	A20405	SCENARIO:	17	EVENT:	100yr WITHOUT CLIMATE CHANGE
DATE:	22/07/2025	LAND USE:	POST-DEVELOPMENT MINUS PRE-DEVELOPMENT		

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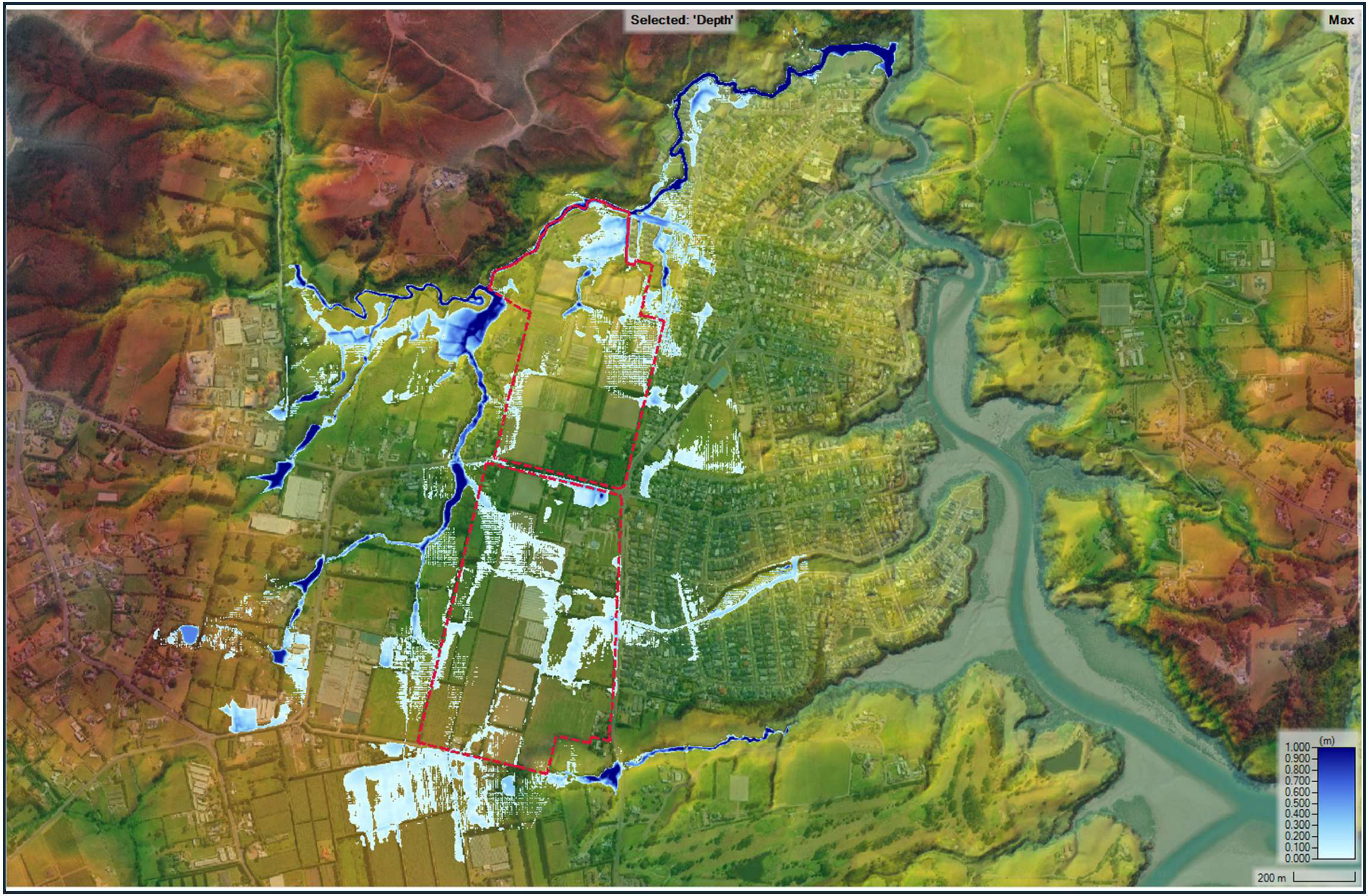

PROJECT:	RIVERHEAD PRIVATE PLAN CHANGE PC100	MAP TYPE:	FLOOD DEPTH (MAX)		
REF NUMBER:	A20405	SCENARIO:	18	EVENT:	2yr UP/100yr DOWN WITHOUT CC
DATE:	22/07/2025	LAND USE:	PRE-DEVELOPMENT – ED OUTSIDE + ED INSIDE		

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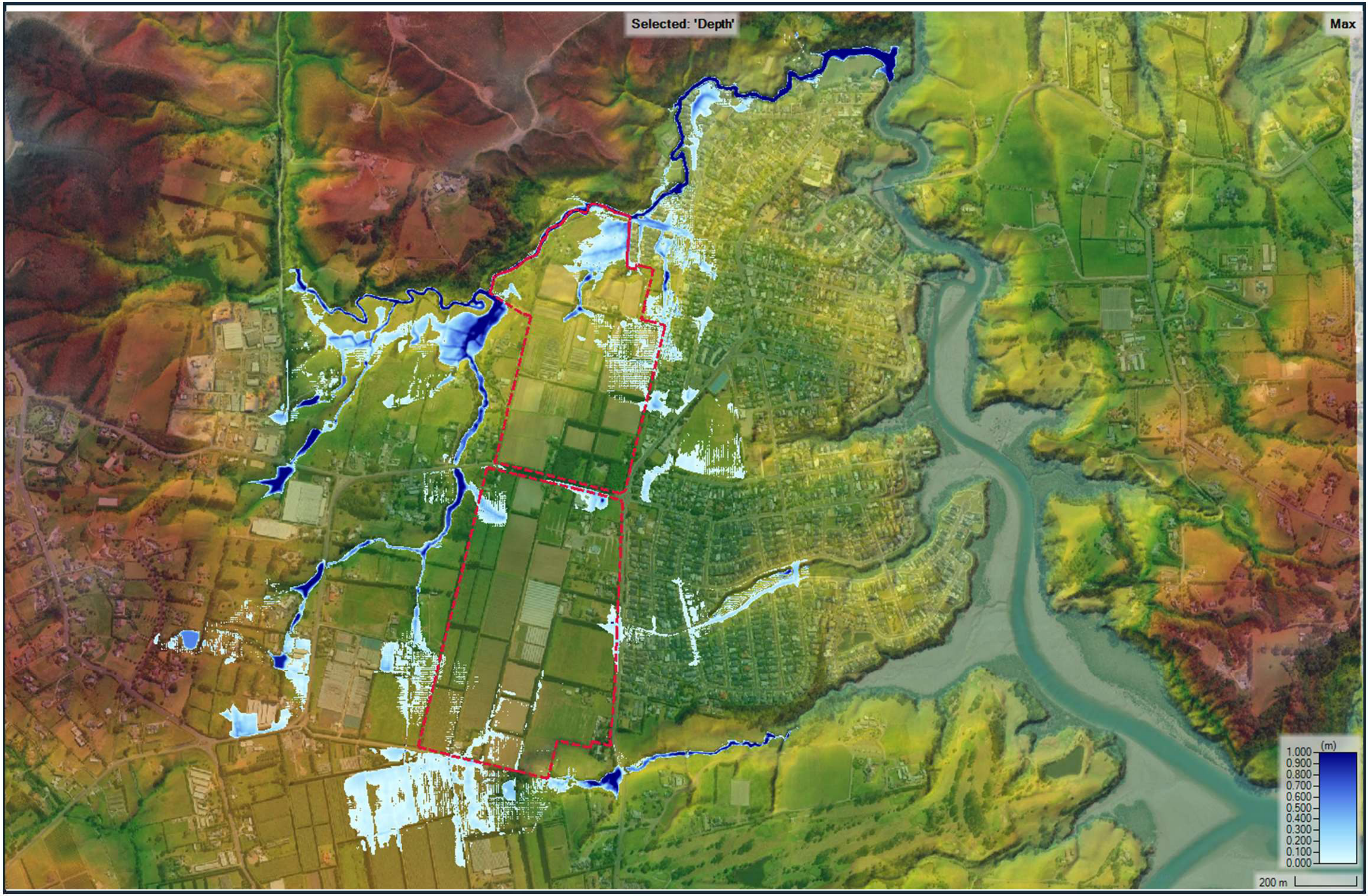

PROJECT:	RIVERHEAD PRIVATE PLAN CHANGE PC100	MAP TYPE:	FLOOD DEPTH (MAX)		
REF NUMBER:	A20405	SCENARIO:	18	EVENT:	2yr UP/100yr DOWN WITHOUT CC
DATE:	22/07/2025	LAND USE:	POST-DEVELOPMENT – ED OUTSIDE + MPD INSIDE		

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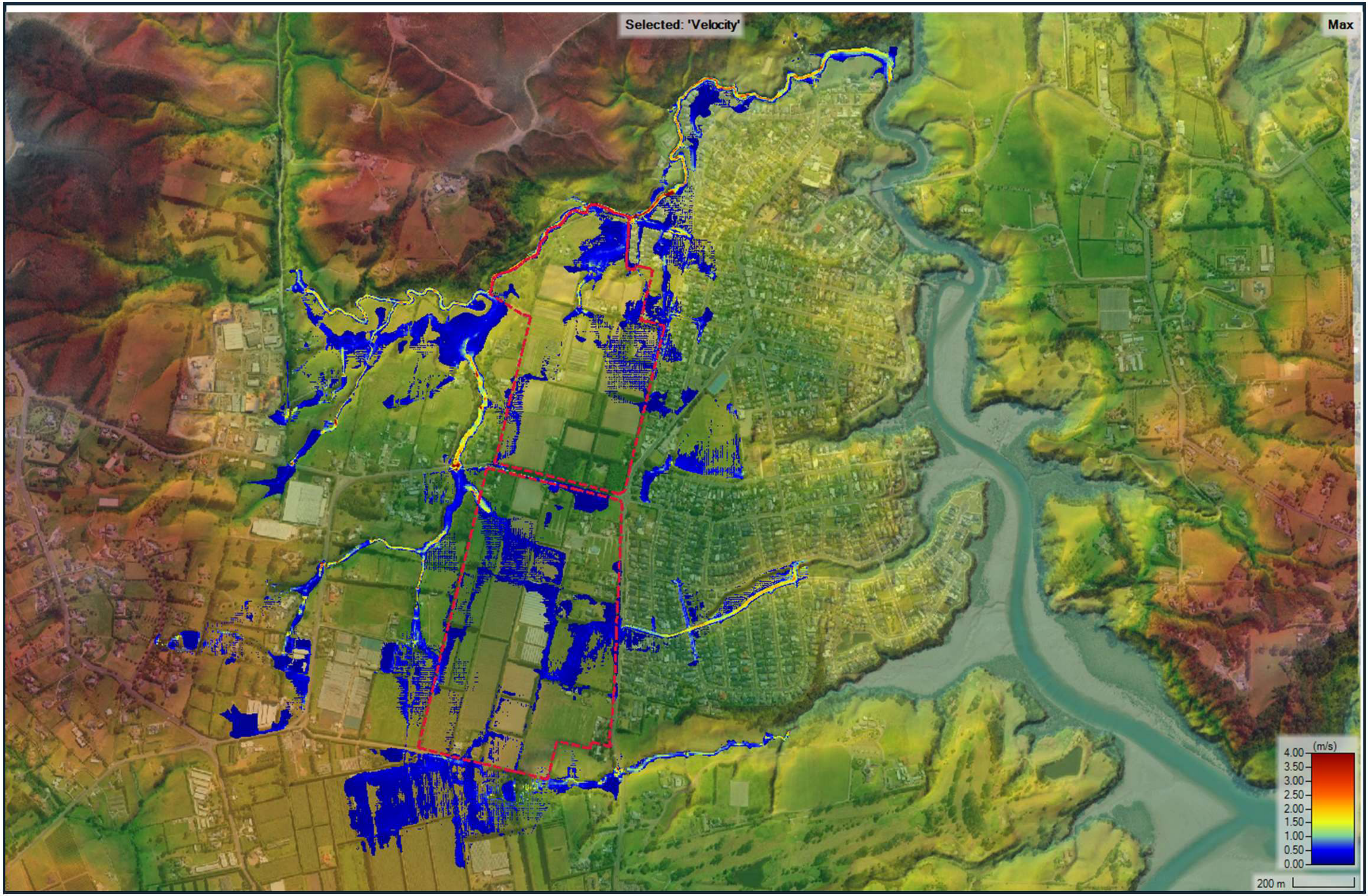

PROJECT:	RIVERHEAD PRIVATE PLAN CHANGE PC100	MAP TYPE:	VELOCITY (MAX)		
REF NUMBER:	A20405	SCENARIO:	18	EVENT:	2yr UP/100yr DOWN WITHOUT CC
DATE:	22/07/2025	LAND USE:	PRE-DEVELOPMENT – ED OUTSIDE + ED INSIDE		

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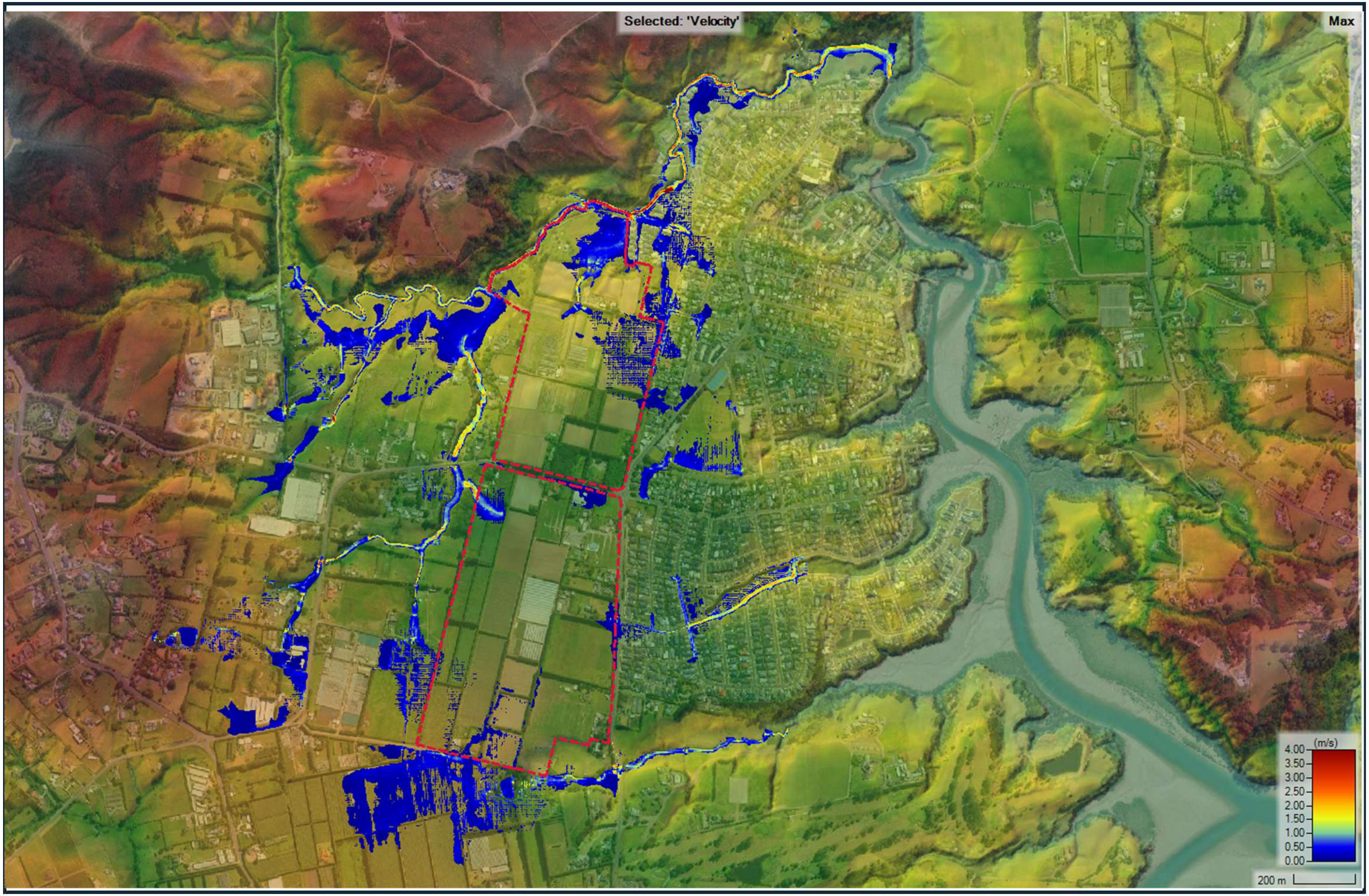

PROJECT:	RIVERHEAD PRIVATE PLAN CHANGE PC100	MAP TYPE:	VELOCITY (MAX)		
REF NUMBER:	A20405	SCENARIO:	18	EVENT:	2yr UP/100yr DOWN WITHOUT CC
DATE:	22/07/2025	LAND USE:	POST-DEVELOPMENT – ED OUTSIDE + MPD INSIDE		

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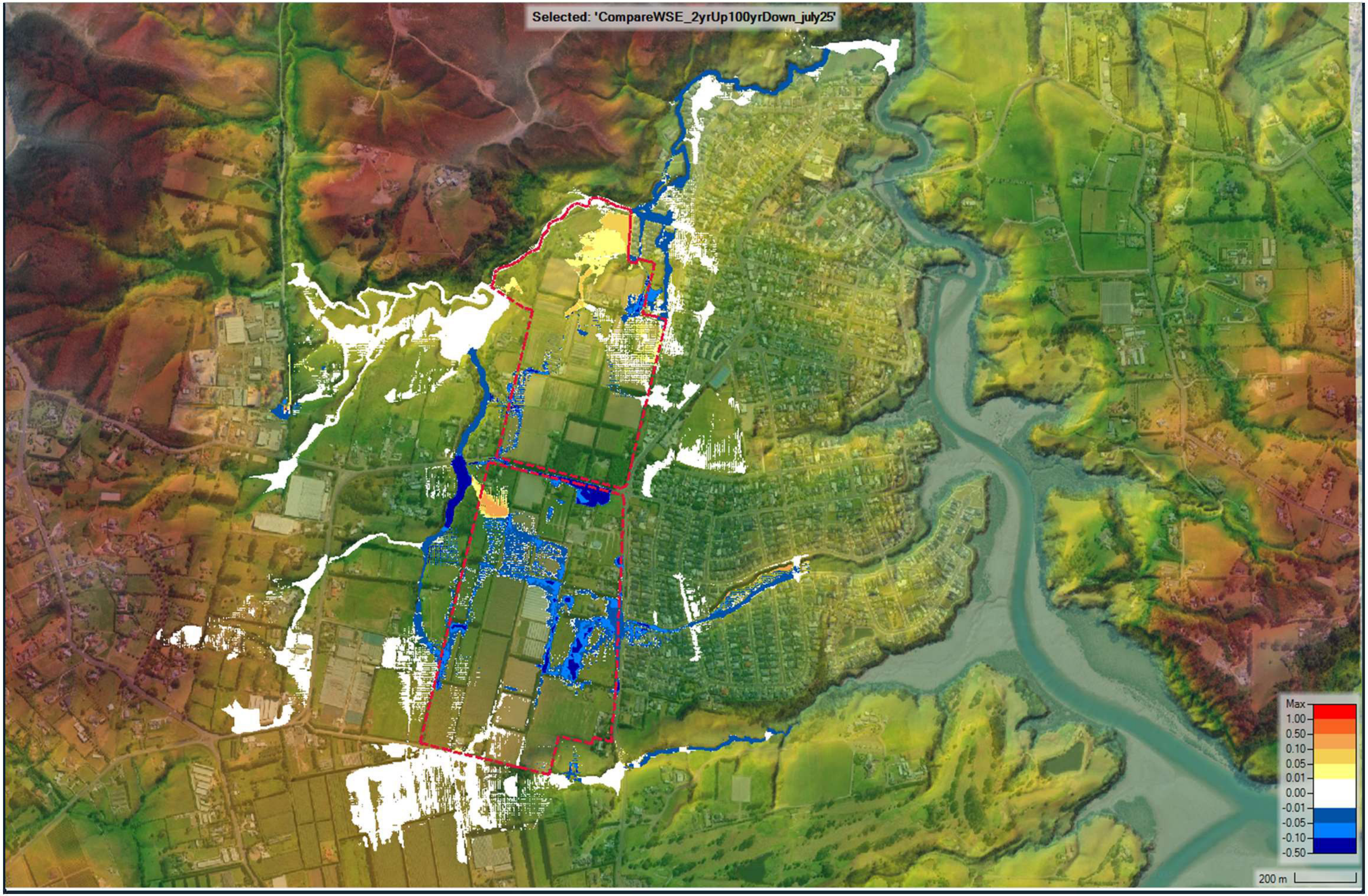

PROJECT:	RIVERHEAD PRIVATE PLAN CHANGE PC100	MAP TYPE:	WATER SURFACE ELEVATION DIFFERENCE (MAX)		
REF NUMBER:	A20405	SCENARIO:	18	EVENT:	2yr UP/100yr DOWN WITHOUT CC
DATE:	22/07/2025	LAND USE:	POST-DEVELOPMENT MINUS PRE-DEVELOPMENT		

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Appendix 4 Summary of modelled scenarios

Riverhead Private Plan Change - Hydrological and hydraulic model runs overview to support Riverhead PC100 application

Hydraulic Modelling Completed to date and in Public Record

Scenario	Rainfall event	Development	Model Files		Description	Document Reference	Document Date
1	50% AEP	Pre-development	Plan/result:	Pre-SiteEDR01+OutEDR04-2yrNoCC	50% AEP flood assessment scenario for pre-development.	Appendix 10: STORMWATER MANAGEMENT AND FLOOD RISK ASSESSMENT Revision 04 Appendix 3	29/09/2023
			Geometry:	Geo-Pre-V7	No climate change. ED imperviousness within the site and outside of the site.		
			Flow file:	SiteEDR01+OutEDR04-ED-2yrNoCC			
		Post-development	Plan/result:	Post-SitePostR03+OutEDR04-2yrNoCC	50% AEP flood assessment scenario for post-development.		
			Geometry:	Geo-Post-V7	No climate change. MPD imperviousness within the site and ED imperviousness outside of the site.		
			Flow file:	SitePostR03+OutEDR04-ED-2yrNoCC			
2	10% AEP	Pre-development	Plan/result:	Pre-SiteEDR01+OutEDR04-10yrNoCC	10% AEP flood assessment scenario for pre-development.		
			Geometry:	Geo-Pre-V7	No climate change. ED imperviousness within the site and outside of the site.		
			Flow file:	SiteEDR01+OutEDR04-ED-10yrNoCC			
		Post-development	Plan/result:	Post-SitePostR03+OutEDR04-10yrNoCC	10% AEP flood assessment scenario for post-development.		
			Geometry:	Geo-Post-V7	No climate change. MPD imperviousness within the site and ED imperviousness outside of the site.		
			Flow file:	SitePostR03+OutEDR04-ED-10yrNoCC			
3	1% AEP	Pre-development	Plan/result:	Pre-SiteEDR01+OutEDR04-100yrNoCC-V3	1% AEP flood assessment scenario for pre-development.		
			Geometry:	Geo-Pre-V7	No climate change. ED imperviousness within the site and outside of the site.		
			Flow file:	SiteEDR01+OutEDR04-ED-100yrNoCC			
		Post-development	Plan/result:	ProstSitePostR03+OutEDR04-100yr	1% AEP flood assessment scenario for post-development.		
			Geometry:	Geo-Post-V7	No climate change. MPD imperviousness within the site and ED imperviousness outside of the site.		
			Flow file:	SitePostR03+OutEDR04-100yrNoCC			
4	50% AEP without climate change for upstream and 1% without climate change for the rest	Pre-development	Plan/result:	Pre-SiteEDR01+OutEDR04-100yrNoCC+US2yr	Scenario to test localised impact for pre-development.		
			Geometry:	Geo-Pre-V7	No climate change. 50% AEP for upstream of 50 Forestry Road (C11,C12_4 and C12_sum) and 1% AEP for the rest of catchment.		
			Flow file:	US2yr+SiteEDR01+OutEDR04-ED-100yrNoCC	ED imperviousness within the site and outside of the site.		
		Post-development	Plan/result:	Post-SitePostR03+OutEDR04-100yr+US2yr	Scenario to test localised impact for post-development.		
			Geometry:	Geo-Post-V7	No climate change. 50% AEP for upstream of 50 Forestry Road (C11,C12_4 and C12_sum) and 1%AEP for the rest of catchment.		
			Flow file:	US2yr+SitePostR03+OutEDR04-100yrNoCC	MPD imperviousness within the site and ED imperviousness outside of the site.		
5	1% AEP -Attenuation	Post-development	Plan/result:	Attenuation-SitePostR03+OutEDR04-100yr	Attenuation scenario to test potential attenuation effect		
			Geometry:	Geo-Post-V7	No climate change. MPD imperviousness within the site and ED imperviousness outside of the site.		
			Flow file:	SitePostR03+OutEDR04-100yrNoCC-attenu	Dummy attenuated flow for three large sub-catchments within the site.		
6	10% AEP -Attenuation	Post-development	Plan/result:	Attenuation-SitePostR03+OutEDR04-10yr	Attenuation scenario to test potential attenuation effect		
			Geometry:	Geo-Post-V7	No climate change. MPD imperviousness within the site and ED imperviousness outside of the site.		
			Flow file:	SitePostR03+OutEDR04-10yrNoCC-attenu	Dummy attenuated flow for three large sub-catchments within the site.		
7	1% AEP + Climate Change 2.1°C	Pre-development	Plan/result:	Pre-SiteEDR01+OutMPD R04-100yrCC	Scenario for 2.1 °C climate change.		
			Geometry:	Geo-Pre-V7	Climate change for 2.1°C increase.		
			Flow file:	SiteEDR01+OutMPDR04-100yrCC	ED imperviousness within the site and MPD outside the site.		
		Post-development	Plan/result:	Post-SitePostR01+OutMPD R04-100yr	Scenario for 2.1 °C climate change (validation scenario)		
			Geometry:	Geo-Post-V7	Climate change for 2.1°C increase.		
			Flow file:	SitePostR03+OutMPDR04-100yrCC	MPD imperviousness within the site and MPD outside the site.		
8	1% AEP + Climate Change 3.8°C	Pre-development	Plan/result:	Pre-SiteEDR01+OutMPD R04-100yrCC3.8	Climate change for 3.8°C increase. .		
			Geometry:	Geo-Pre-V7	ED imperviousness within the site and MPD outside the site.		
			Flow file:	SiteEDR01+OutMPDR04-100yr3.8CC			
		Post-development	Plan/result:	Post-SiteMPDR03+OutMPD R04-100yrCC	Climate change for 3.8°C increase. .		
			Geometry:	Geo-Post-V7	MPD imperviousness within the site and MPD outside the site.		
			Flow file:	SitePostR03+OutMPDR04-100yr3.8CC			
9	1% AEP + Climate Change 3.8°C	Post-development	Plan/result:	Post-SiteMPDR04+OutMPDR04-100yr3.8CC	3.8°C Climate Change	STATEMENT OF EVIDENCE OF BRONWYN RHYND STORMWATER MANAGEMENT / FLOODING: Exhibit 1 ADDENDUM TO RIVERHEAD PLAN CHANGE AREA SMP	31/03/2025
			Geometry:	Geo-Post-V8 – Riverhead Rd Culvert Upgrade	MPD imperviousness within the site and MPD outside the site.		
			Flow file:	SiteMPDR04+OutMPDR04- 100yr3.8CC	Reduced S02_P Catchment		
					Dummy attenuation of increased S01_P		
					Upgrade Riverhead Road Culvert to 4.5mW x 1.5mH box culvert at same invert as existing		
10	10%AEP + Climate Change 2.1°C	Pre-development	Plan/result:	Pred-SiteEDR01+OutMPDR04-010yr2.1CC	10yr 2.1°C Climate Change	STATEMENT OF SUPPLEMENTARY REBUTTAL EVIDENCE OF BRONWYN RHYND: FURTHER ASSESSMENT FRA PC100	14/05/2025
			Geometry:	Geo-Pre-V7	ED imperviousness within the site and MPD outside the site.		
			Flow file:	SiteEDR01+OutMPDR04-10yr2.1CC			
		Post-development	Plan/result:	Post-InMPDR05+OutMPDR04-10yr2.1CC_CULv5	10yr 2.1°C Climate Change		
			Geometry:	Geo-Post-V9 - Riverhead Rd Culvert Upgrade v5	MPD imperviousness within the site and outside the site.		
			Flow file:	SiteMPDR05+OutMPDR04-10yr2.1CC	Dummy SMAF 1 detention		
					Refined Riverhead Rd culvert upgrade		
11	1% AEP + Climate Change 3.8°C	Pre-development	Plan/result:	Pre-SiteEDR01+OutMPD R04-100yrCC3.8	100yr 3.8°C Climate Change		
			Geometry:	Geo-Pre-V7	ED imperviousness within the site and MPD outside the site.		
			Flow file:	SiteEDR01+OutMPDR04-100yr3.8CC			
		Post-development	Plan/result:	Post-InMPDR05+OutMPDR04-100yr3.8CC_CULv5	100yr 3.8°C Climate Change		
			Geometry:	Geo-Post-V9 - Riverhead Rd CulvertUpgrade v5	MPD imperviousness within the site and outside the site.		
			Flow file:	SiteMPDR05+OutMPDR04-100yr3.8CC	Dummy SMAF 1 detention		
					Refined Riverhead Rd culvert upgrade		

Riverhead Private Plan Change - Hydrological and hydraulic model runs overview to support Riverhead PC100 application

Additional Modelling runs completed in response to submitter queries

Scenario	Rainfall event	Development	Model Files	Description	Document Reference	Document Date
12	50%AEP + Climate Change 2.1°C	Pre-development	**Plan/result:** Geo-Pre-V7 - InsideED+OutsideED-2yr2.1CC June25 **Geometry:** Geo-Pre-V7 **Flow file:** InsideED+OutsideED-2yr2.1CC_June25	2yr 2.1°C Climate Change ED imperviousness within the site and outside of the site. Updated pre development hydrology based on submission feedback (CN values, Lag times, Manning's roughness) Updated culvert layout at 22 Duke Street to reflect (2 x 1.5m diameter)	FURTHER ASSESSMENT FRA PC100 VOLUME 2	23/07/2025
12	50%AEP + Climate Change 2.1°C	Post-development	**Plan/result:** Geo-Post-V9 - Rhd Rd Culv Upgr v5 - InMPD+OutED-2yr2.1_June25 **Geometry:** Geo-Post-V9 - Riverhead Rd Culvert Upgrade v5_remeshed **Flow file:** InsideMPD+OutsideED-2yr2.1CC_June25	2yr 2.1°C Climate Change MPD imperviousness within the site and ED outside of the site. Updated Post development hydrology based on submission feedback (CN values, Lag times, Manning's roughness) Updated culvert layout at 22 Duke Street (2 x 1.5m diameter). Includes previous model refinements (Riverhead Rd Culvert Upgrade, S01_P attenuation, inclusion of dummy SMAF detention		
13	10%AEP + Climate Change 2.1°C	Pre-development	**Plan/result:** Geo-Pre-V7 - InsideED+OutsideED-10yr2.1CC_June25 **Geometry:** Geo-Pre-V7 **Flow file:** InsideED+OutsideED-10yr2.1CC_June25	10yr 2.1°C Climate Change ED imperviousness within the site and outside of the site. Updated pre development hydrology based on submission feedback (CN values, Lag times, Manning's roughness) Updated culvert layout at 22 Duke Street to reflect (2 x 1.5m diameter)		
13	10%AEP + Climate Change 2.1°C	Post-development	**Plan/result:** Geo-Post-V9 - Rhd Rd Culv Upgr v5 - InMPD+OutED-10yr2.1_June25 **Geometry:** Geo-Post-V9 - Riverhead Rd Culvert Upgrade v5_remeshed **Flow file:** InsideMPD+OutsideED-10yr2.1CC_June25	10yr 2.1°C Climate Change MPD imperviousness within the site and ED outside of the site. Updated Post development hydrology based on submission feedback (CN values, Lag times, Manning's roughness) Updated culvert layout at 22 Duke Street (2 x 1.5m diameter). Includes previous model refinements (Riverhead Rd Culvert Upgrade, S01_P attenuation, inclusion of dummy SMAF detention		
14	1% AEP + Climate Change 3.8°C	Pre-development	**Plan/result:** Geo-Pre-V7 - InsideED+OutsideED-100yr3.8CC_June25 **Geometry:** Geo-Pre-V7 **Flow file:** InsideED+OutsideED-100yr3.8CC_June25	100yr 3.8°C Climate Change ED imperviousness within the site and outside of the site. Updated pre development hydrology based on submission feedback (CN values, Lag times, Manning's roughness) Updated culvert layout at 22 Duke Street to reflect (2 x 1.5m diameter)		
14	1% AEP + Climate Change 3.8°C	Post-development	**Plan/result:** Geo-Post-V9 - Rhd Rd Culv Upgr v5 - InMPD+OutED-100yr3.8_June25 **Geometry:** Geo-Post-V9 - Riverhead Rd Culvert Upgrade v5_remeshed **Flow file:** InsideMPD+OutsideED-100yr3.8CC	100yr 3.8°C Climate Change MPD imperviousness within the site and ED outside of the site. Updated Post development hydrology based on submission feedback (CN values, Lag times, Manning's roughness) Updated culvert layout at 22 Duke Street (2 x 1.5m diameter). Includes previous model refinements (Riverhead Rd Culvert Upgrade, S01_P attenuation, inclusion of dummy SMAF detention		
15	50%AEP without Climate Change	Pre-development	**Plan/result:** Geo-Pre-V7 - InsideED+OutsideED-2WoCC **Geometry:** Geo-Pre-V7 **Flow file:** InsideED+OutsideED-2WoCC	2yr without climate change ED imperviousness within the site and outside of the site. Updated pre development hydrology based on submission feedback (CN values, Lag times, Manning's roughness) Updated culvert layout at 22 Duke Street to reflect (2 x 1.5m diameter)		
15	50%AEP without Climate Change	Post-development	**Plan/result:** Geo-Post-V9 _InMPD_OutED_2WoCC **Geometry:** Geo-Post-V9 - Riverhead Rd Culvert Upgrade v5_remeshed **Flow file:** InsideMPD+OutsideED-2WoCC	2yr without climate change MPD imperviousness within the site and ED outside of the site. Updated Post development hydrology based on submission feedback (CN values, Lag times, Manning's roughness) Updated culvert layout at 22 Duke Street (2 x 1.5m diameter). Includes previous model refinements (Riverhead Rd Culvert Upgrade, S01_P attenuation, inclusion of dummy SMAF detention		
16	10%AEP without Climate Change	Pre-development	**Plan/result:** Geo-Pre-V7 - InsideED+OutsideED-10WoCC **Geometry:** Geo-Pre-V7 **Flow file:** InsideED+OutsideED-10CC	10yr without climate change ED imperviousness within the site and outside of the site. Updated pre development hydrology based on submission feedback (CN values, Lag times, Manning's roughness) Updated culvert layout at 22 Duke Street to reflect (2 x 1.5m diameter)		
16	10%AEP without Climate Change	Post-development	**Plan/result:** Geo-Post-V9 _InMPD_OutED_10WoCC **Geometry:** Geo-Post-V9 - Riverhead Rd Culvert Upgrade v5_remeshed **Flow file:** InsideMPD+OutsideED-10WoCC	10yr without climate change MPD imperviousness within the site and ED outside of the site. Updated Post development hydrology based on submission feedback (CN values, Lag times, Manning's roughness) Updated culvert layout at 22 Duke Street (2 x 1.5m diameter). Includes previous model refinements (Riverhead Rd Culvert Upgrade, S01_P attenuation, inclusion of dummy SMAF detention		
17	1%AEP without Climate Change	Pre-development	**Plan/result:** Geo-Pre-V7 - InsideED+OutsideED-100WoCC_July25 **Geometry:** Geo-Pre-V7 **Flow file:** InsideED+OutsideED-100WoCC	100yr without climate change ED imperviousness within the site and outside of the site. Updated pre development hydrology based on submission feedback (CN values, Lag times, Manning's roughness) Updated culvert layout at 22 Duke Street to reflect (2 x 1.5m diameter)		
17	1%AEP without Climate Change	Post-development	**Plan/result:** Geo-Post-V9 - Rhd Rd Culv Upgr v5 - InMPD+OutED-100yrWoCC_July25 **Geometry:** Geo-Post-V9 - Riverhead Rd Culvert Upgrade v5_remeshed **Flow file:** InsideMPD+OutsideED-100WoCC	100yr without climate change MPD imperviousness within the site and ED outside of the site. Updated Post development hydrology based on submission feedback (CN values, Lag times, Manning's roughness) Updated culvert layout at 22 Duke Street (2 x 1.5m diameter). Includes previous model refinements (Riverhead Rd Culvert Upgrade, S01_P attenuation, inclusion of dummy SMAF detention		

Riverhead Private Plan Change - Hydrological and hydraulic model runs overview to support Riverhead PC100 application

Additional Modelling runs completed in response to submitter queries

Scenario	Rainfall event	Development	Model Files		Description	Document Reference	Document Date
18	50% AEP without climate change for upstream and 1% AEP without climate change for the rest	Pre-development	Plan/result:	Geo-Pre-V7 - InsideED+OutsideED-2Up100Down	2yr rainfall without climate change has been considered for C11, C12_4 and SumC12 upstream catchments whereas 100yr rainfall without climate change has been considered for the rest	FURTHER ASSESSMENT FRA PC100 VOLUME 2	23/07/2025
			Geometry:	Geo-Pre-V7	ED imperviousness within the site and outside of the site.		
			Flow file:	InsideED+OutsideED-2yrUp100yrDown_WOCC	Updated pre development hydrology based on submission feedback (CN values, Lag times, Manning's roughness) Updated culvert layout at 22 Duke Street to reflect 2 x 1.5m diameter culverts installed after previous culvert damaged		
		Post-development	Plan/result:	Geo-Post-V9 _InMPD_OutED_2Up100Down	2yr rainfall without climate change has been considered for C11, C12_4 and SumC12 upstream catchments whereas 100yr rainfall without climate change has been considered for the rest		
			Geometry:	Geo-Post-V9 - Riverhead Rd Culvert Upgrade v5_remeshed	MPD imperviousness within the site and ED outside of the site.		
			Flow file:	InsideMPD+OutsideED-2yrUp100yrDown_WOCC	Updated Post development hydrology based on submission feedback (CN values, Lag times, Manning's roughness) Updated culvert layout at 22 Duke Street to reflect 2 x 1.5m diameter culverts installed after previous culvert damaged Includes previous model refinements (Riverhead Rd Culvert Upgrade, S01_P attenuation, inclusion of dummy SMAF detention		