MITCHELL DAYSH

HAWKE'S BAY REGIONAL COUNCIL

WHIRINAKI RESILIENCE PROJECT - STAGE 1

Report to Inform Category 2A Decision

29 October 2023

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REPORT INFORMATION

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The information contained within this report has been informed by the most up-to-date information that has been provided by consultants and technical experts that make up the Project Team and where applicable the Technical Focus Group ("TFG"). It is however subject to change.

LIST OF KEY TERMS

Whirinaki Resilience Project ("WRP")

A project started in March 2023 by Pan Pac Forest Products Limited ("**Pan Pac**"), Transpower and Contact Energy Limited with the following purpose:

> *"To improve resilience for the Pan Pac Forest Products Limited, Contact Energy Limited and Transpower sites and the immediate established neighbouring community [of lower North Shore Road and Pohutukawa Drive], and ensure personal safety, business continuity, insurability, and community morale".*

Whirinaki Industrial Area

The industrial area located at Whirinaki comprising the Pan Pac pulp and saw mills, the Transpower 220kV substation and the Contact Energy power station.

Stage 1 Report

This Report commissioned by Hawke's Bay Regional ("**HBRC**") in July 2023 to provide considered advice on whether or not there is a proposed engineering solution whereby the 41 residential properties on Lower North Shore Road and Pohutukawa Drive which have an interim 2A categorisation can be moved to the 2C category, allowing those residents to return to their home. The three criteria to determine this as set by HBRC are that the proposed engineering solution:

1. Meets the 1 in 100-year[1] flood protection level (with an appropriate freeboard allowance).
2. Agreement has been reached, in principle, for any land access required for delivery.
3. Access to required funding is identified.

Stage 2 Report

A follow-up report to be commissioned by Pan Pac, Transpower and Contact Energy to ascertain what additional resilience works from the Long List of Options (over and above the Stage 1 Proposed Engineering Solution) are required to protect the Whirinaki Industrial area from a 1 in 500-year return period flood event.

[1] Equivalent to the term 1% AEP which is sometimes used in engineering literature.

Long List of Resilience Options

A list of discrete engineering works options developed by the WRP project team that could be employed to provide future flood resilience for the Lower Esk Valley (east of State Highway 2), and the communities of Whirinaki, and Bayview.

Base Case Concept

A group of four engineering elements taken from the Long List of Resilience Options, which have been developed to a concept design level and tested through the October 2023 Pattle Delamore Partners ("**PDP**") hydrological model to ascertain whether this engineering solution effectively meets the the 1 in 100-year flood protection level (with an appropriate freeboard allowance).

Base Case+ Concept

The four Base Case engineering elements **plus** an additional stopbank element to the south of the Esk River at Bayview tested through the October 2023 Pattle Delamore Partners hydrological model to ascertain whether this engineering solution effectively meets the the 1 in 100-year flood protection level (with an appropriate freeboard allowance).

Proposed Engineering Solution

The WRP Project teams proposed engineering solution (being the Base Case+ group of five engineering elements), recommended to HBRC, which we consider meets the three criteria to enable the 41 Category 2A residences at Lower North Shore Road and Pohutukawa Drive to be moved to Category 2C.

Final Future Whirinaki and Lower Esk Flood Protection Scheme

The final form of the flood protection scheme for the Whirinaki and Lower Esk area which includes the five Base Case+ engineering elements (designed to meet the three HBRC criteria for moving residences from Category 2A to 2C), **plus** any additional engineering elements identified in the Long List of Resilience Options which are required to provide the necessary protection for the Whirinaki Industrial Area from a 1 in 500-year return period future flood event.

1. EXECUTIVE SUMMARY

The purpose of this **Stage 1 Report** is to outline and assess a proposed engineering solution concept package of flood mitigation interventions, set at a predicted 1 in 100-year flood protection level[2] using a number of scenarios based on past flooding events in the catchment.

This assessment is required to advise whether the community of Lower North Shore Road and Pohutukawa Drive can be considered for transitioning from category 2A to 2C, which would allow these residents to move back into their homes.

The Hawke's Bay Regional Council ("**HBRC**") has established three key criteria to inform decision making associated with the design and implementation of Whirinaki flood resilience interventions which are consistent with how the HBRC is making decisions throughout the region. In any situation, a flood mitigation solution will be designed and built if it meets the following criteria:

- It meets the 1 in 100-year flood protection level (with an appropriate freeboard allowance).
- Agreement has been reached, in principle, for any land access required for delivery.
- Access to required funding is identified.

The Whirinaki Resilience Project ("**WRP**") Project Team including Mitchell Daysh Limited, Tonkin and Taylor ("**T+T**") and Pattle Delamore Partners ("**PDP**") have developed a proposed Base Case concept package of resilience interventions that meets the decision-making thresholds set by HBRC. The proposed Base Case and Base Case+ concepts have been informed by up-to-date hydrological modelling, with inputs from technical experts proficient in river and coastal processes. The proposed engineering solution consists of the following flood mitigation interventions being:

- **A5** - Esk River Mouth maintenance (Base Case)
- **B1** - Existing Whirinaki stopbank - pre cyclone, no change to level of service (Base Case)
- **B3** - New stopbank from SH2 to Coast - Pohutukawa Drive across Evans Land (Base Case)
- **C1** - Whirinaki Stream SH2 culvert improvements + Increase capacity of Whirinaki Stream - Downstream of SH2 (Base Case)

[2] 1% AEP is equivalent to a 1 in 100 year flood protection level

- **B5** - stopbank on the south side of the Esk River (Base Case+). *A supplementary stop bank designed to protect Bayview from potential flooding (extent of this is dependent on the final detailed design).*

The technical assessment summarised in this report demonstrates that the Base Case+ Concept is the most appropriate engineering solution to provide the appropriate flood protection for the category 2A land at Pohutukawa Drive and North Shore Road.

Cost estimate for the proposed Base Case+ concept package is **$14.06M**. Annual maintenance and monitoring costs will be additional to these cost estimates. Asset renewal costs are not included.

This includes a cost estimate associated with the lifting of State Highway 2 which is calculated to be in the order of $3 to $3.5M. Discussion with Waka Kotahi regarding funding / cost sharing of this portion will be required.

As recommended by PDP, the existing Whirinaki stopbank height should also be assessed in the detailed design phase. Any additional cost for the improvements related to option B2 (Existing Whirinaki stopbank to SH2 - increase height) have also been provided for consideration in the package (total of $2.7M). Funding of this option will need to be considered further by the HBRC.

This **proposed engineering solution** (the Base Case+ Concept) is an interconnected package where all aspects are required to provide this protection to the 2A land.

The concept presented in this report may be refined through detailed design in consultation with landowners and stakeholders.

Additional opportunities for a higher level of protection for the power station and substation utilities and Pan Pac site based on the long list of options identified by the project Technical Team will be progressed by those agencies as part of a **Stage 2 Report** of the Whirinaki Resilience Project[3]

It is noted that the Whirinaki Industrial Area landowners support for the Category 2A proposed engineering solution proposal was heavily reliant on the understanding that improvements to the existing stopbank (option B2) were part of the proposed engineering solution. This is not part of the proposed engineering solution in this Stage 1 Report and these works will need to be assessed as an additional resilience element in the Stage 2 Report process following immediately after the completion of this report.

Given the fact that the Whirinaki Industrial Area landowners were relying on an existing (pre-Cyclone Gabrielle) HBRC flood control scheme with a design standard of 1 in 500 it is presumed that all the five engineering elements in the proposed engineering solution set

[3] Project to be commissioned by the industrial landowners, following agreement on the recommendation for Stage 1.

out in this Stage 1 Report (Base Case+) will be funded by the public agencies (HBRC and Cyclone Gabrielle Crown contribution).

It needs to be emphasised that after the completion of the WRP Stage 2 Report, which will identify and assess additional engineering elements from the Long List of Resilience Options to provide the necessary 1 in 500-year level of protection for the Whirinaki Industrial Area, the final form of the **Final Future Whirinaki and Lower Esk Flood Protection Scheme** may have additional elements over and above the proposed engineering solution (five Base Case+ elements) identified in this Stage 1 Report.

The ultimate cost sharing split between the public agencies and the Whirinaki Industrial Area landowners for the Final Future Whirinaki and Lower Esk Flood Protection Scheme will require further discussions after this is identified with the completion of the Stage 2 Report.

2. BACKGROUND

2.1 CYCLONE GABRIELLE

The following summary of the Cyclone Gabrielle event has been taken from the HBRC Cyclone Gabrielle Impacts[4] web page.

- In February 2023, Te Matau a Māui Hawke's Bay faced devastation and loss from Cyclone Gabrielle – one of the biggest natural disasters in the history of Aotearoa New Zealand.
- HBRC rainfall figures show that Cyclone Gabrielle was one of the most significant weather events to impact the region on record. The cyclone delivered staggering amounts of rain over a relatively short period of time, and data indicates this was the largest rainfall event at a number of sites ever recorded in the region.
- The impacts of Cyclone Gabrielle have been significant and widespread, and they will be felt across our region and communities for a long time to come. The amount of rainfall coming through the region's rivers was much larger than the system was designed and constructed for, this has left Hawke's Bay with some long-term impacts on lives, livelihoods, whānau, homes, farms, orchards, vineyards and neighbourhoods.
- Extensive flooding due to rapidly rising rivers lead to extensive and widespread flooding across the region. Loss of human life as well as the loss of many animals caught up in the swift flowing flood waters. Many other people were trapped on their rooftops or cars and needed rescue by helicopter or boat during the event.
- Houses and buildings were flooded and people's possessions lost, this event placed a huge pressure on our communities. A state of emergency was declared, with Civil Defence activation following immediately after. Communities have also banded together to provide each other shelter and necessities as people start the recovery process.
- Many farmers and growers have had silt deposited across their land destroying crops, infrastructure and arable land, others have experienced a significant number of slips on their property reducing the availability of grazing land and stock feed.
- Small and large businesses across the region are feeling the impacts of the cyclone. They have either been directly impacted, due to reasons such as flooding, or indirectly, for example a loss of, or reduction in business or a lack of tourists or visitors.

[4] As at 28 August 2023

- It is estimated 5.4km of river stopbanks across Hawke's Bay were breached and 28km weakened, leaving 190km intact. Permanent repairs will take months to complete, but temporary fixes have been put in place to ensure that the flood network protection network is restored.
- Drains across the region were blocked with a combination of woody debris, leaf litter and silt. Drain clearage will need to be repeated as new rainfall continues to wash silt back into drains.
- The most significant infrastructural damage has been to the region's bridges and roading network, cutting off communities from main centres and causing ongoing traffic issues. Roads were impacted by multiple large slips and silt build up.
- During the event, two power substations were flooded, and a lot of the lines network was damaged. This cut off power and internet to 1000's of households, with connection to some rural areas taking extended periods of time to be reconnected.
- Numerous pump stations along drainage systems were impacted and instruments used for rainfall and river monitoring damaged or lost.
- Close to 30% of the Hawke's Bay Trail network was damaged and unable to be used due to stopbank damage, roading/trail slips or destroyed bridges. Trees, debris and access issues meant HBRC needed to close our parks until such time as they are able to be cleared and made safe for the public.
- Widespread flooding deposited silt throughout the region, in some places up to 2 metres in depth. Covering arable land, roads and tracks, spreading throughout houses, buildings and vehicles and infiltrating drains, it has left behind a huge volume to be dealt with.
- With silt coming from mixed origins, as well as it's fine-particled nature meaning it's easily aerated when it dries, it poses a health and safety hazard to people. PPE is necessary when dealing with silt removal.
- The flood event collected vast amounts of wood debris and channelled it through the extensive river network and eventually out to sea. The result of this has seen huge amounts of wood deposited on coastlines, river sides, piled up at bridges and washed onto flooded, low lying areas.
- The aftermath of Cyclone Gabrielle has resulted in large volumes of waste. Flooded household items, destroyed infrastructure, posts and wire from cropping lands, vehicles as well as woody debris and silt – the list is long.

2.2 LOWER ESK RIVER AND WHIRINAKI STREAM CATCHMENT[5]

Prior to Cyclone Gabrielle, the lower Esk River catchment was known for its vineyards, orchards, and farmland, with associated housing. The lower Esk River area has had a history of significant flood events, including those in 1938, 1986, 1988 (Cyclone Bola), 2018 and now February 2023.

The current Esk and Whirinaki flood control scheme (the Scheme) was established by HBRC in 1996 with the purpose of reducing overland flow or ponding in times of flood, reducing loss of land from bank erosion, and ensuring channels remain clear and free flowing.

Due to the nature of the catchment and terrain, the Esk River upstream itself does not have any structural flood protection (stopbanks) - the channel conveys flood events up to an estimated two-year return period flood (215 m^3/s) within the confines of the active river channel.

A drainage scheme for Whirinaki was designed in 1972 to provide flood protection to a five-year return period design standard. The work consisted of the construction of 4.7 km of new drains and 1.7 km of new stopbanks and forms the basis of the scheme that exists today (Figure 1 below).

The HBRC Asset Management Plan for the Whirinaki Scheme[6] defines the level of services for the scheme as a 1 in 100-year Return Period, and a 1 in 500-year return period of the Industrial sites. There has been a proposal to increase this by either upgrading the culvert under SH 2 or increasing the freeboard of the stopbank. At the time of writing this report, neither of these projects had been completed.

It is noted that the lower Whirinaki Stream in its current state is considered a modified watercourse as set out in the HBRC Environmental Code of Practice[7]. The upstream catchment consists of smaller natural watercourses that flow into the modified channel at the lower end of the catchment before it discharges into the Esk River at the mouth. It is however noted that the HBRC Asset Management Plan refers to this area as the "Whirinaki Drain".

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[5] Paragraphs 1 to 5 have been sourced from PDP memo titled "Esk/Whirinaki Resilience Project - Summary of Background Knowledge (Draft)" – 29 June 2023

[6] Esk River and Whirinaki Drainage Flood Control Scheme Asset Management Plan 20 July 2021 Hawke's Bay Regional Council Publication No. 5547_7

[7] HBRC Environmental Code of Practice for River and Drainage Works June 2003 Hawke's Bay Regional Council Publication No. 5547_7

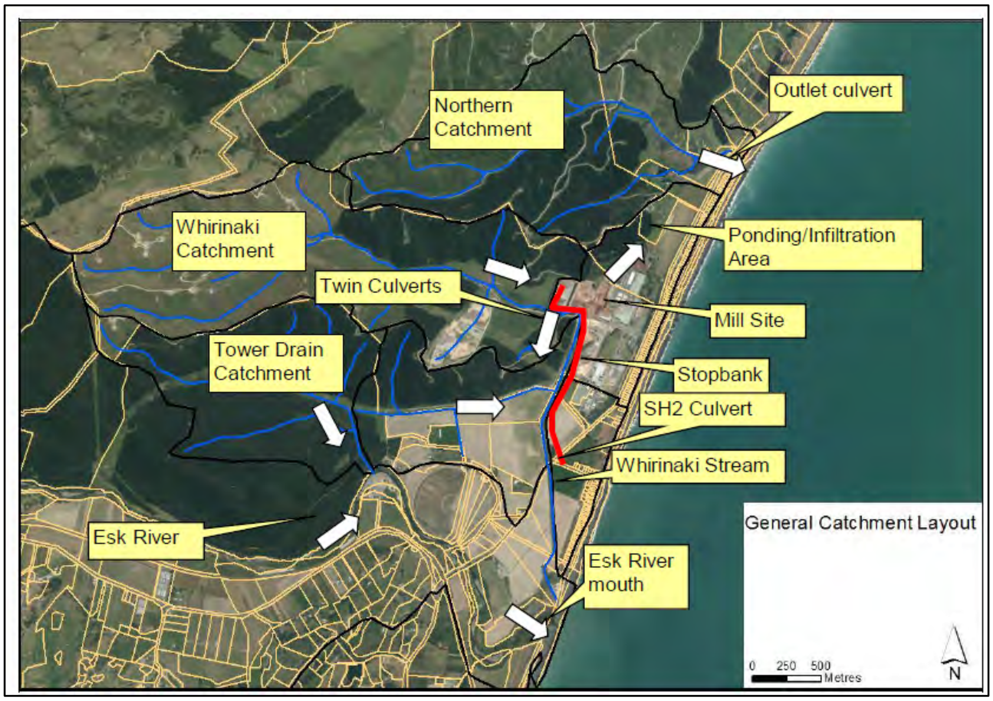

Figure 1: Existing Whirinaki flood control scheme

2.3 LOWER ESK / WHIRINAKI CYCLONE IMPACTS AND RESPONSE

Residential, lifestyle, agricultural and horticultural properties were severely impacted throughout the Esk Valley and at the coast in Whirinaki, with the majority of these properties being provisionally categorised as 3[8]. 41 residential properties fronting North Shore Road and Pohutukawa Drive were categorised as 2A.

Cyclone Gabrielle also severely impacted the Pan Pac Forest Products Limited site, the Contact Energy power station site and the Transpower substation site and theses agencies operations located at Whirinaki in the Lower Esk River catchment. Across the three businesses, there is approximately $2 billion worth of critical industrial and infrastructure assets in this area.

The existing stopbanks that were installed in the 1970's, and progressively upgraded following flood events in the mid/late 1980's, had proven to be an effective solution to flooding of the Whirinaki area from the Esk River, including during Cyclone Bola.

The unique nature of the Cyclone Gabrielle event meant that the large swells along the Hawke's Bay coastline, coupled with a near closed gravel barrier at the mouth of the Esk

[8] Cat 3 - Future severe weather event risk cannot be sufficiently mitigated. In some cases some current land uses may remain acceptable, while for others there is intolerable risk of injury or death. Cat 2A - Potential to fall within but significant further assessment required.

River, are likely to have compromised the ability of the Esk River to drain into the sea. This is likely to have been an influencing factor in the flooding that occurred upstream[9].

As part of the recovery phase, in March 2023 the three businesses initiated the WRP to investigate opportunities to provide better resilience for the three regionally significant facilities and for the nearby community, through an improved level of protection from future significant weather events.

The WRP was designed to work in an inclusive "team way" with Councils, other utility providers, landowners and residents, as a successful long term resilience solution must closely consider and factor in the interests and wellbeing of all stakeholders in the area.

2.4 THE LAND CATEGORISATION PROCESS[10]

The HBRC, and the Government's Cyclone Recovery Taskforce have been assessing future severe weather risk in areas across the region. This process has involved looking at information from a range of sources, including data from the HBRC and the district and city councils, the Ministry for the Environment, and claims data from insurance companies.

The risk assessment and land categorisation process has been completed in phases:

- On 1 June, Councils made direct contact with property owners in areas which had been provisionally categorised as Category 2 or Category 3, advising these property owners that more work was underway to finalise the land categorisation for their area.
- A more detailed review of the initial assessment data, including an independent review, was completed on Wednesday, 14 June. There were minor changes to the provisional categorisations of some areas following the review, and Councils have been in touch with those property owners directly to advise them of the change in provisional categorisation.
- From mid-June, Councils commenced a community engagement process, which included gathering further information from a variety of sources, including property owners and impacted residents, before final categorisation decisions.

Properties were provisionally categorised[4] as either a 2 (2A, 2C*, 2C or 2P) or a 3.

[9] Sourced from Tonkin and Taylor Presentation to the Technical Reference Group 2023.

[10] Land Categorisation Hawkes Bay website.

Table 1: Property Categories and Definitions

Category	Definitions[2]
1	Repair to previous state is all that is required to manage future severe weather risk event.
2C*	The outcome of quality assurance of existing stop bank rebuilds may see the categorisation change to a 1, which has the following definition: 'Repair [dwelling] to previous state is all that is required to manage future severe weather risk event.'
2C	Community level interventions are effective in managing future severe weather risk event.
2P	Property level interventions are needed to manage future severe weather event risk, including in tandem with community level interventions.
2A	Potential to fall within 2C/2P but significant further assessment required.
3	Future severe weather event risk cannot be sufficiently mitigated. In some cases some current land uses may remain acceptable, while for others there is intolerable risk of injury or death.

For the community of Whirinaki and the Lower Esk River, properties were provisionally categorised into either 3, 2A (Potential to fall within 2C/2P but significant further assessment required), or 1 (refer to Esk Valley Land Categorisation Map - Updated 18 August 2023).

Figure 2: **Close up of Whirinaki / Lower Esk River Catchment – Provisional Land Categories**

3. WHIRINAKI RESILIENCE PROJECT FUNDAMENTALS

3.1 PROJECT ESTABLISHMENT

The WRP was established by Pan Pac Forest Products Limited, Contact Energy Limited and Transpower in March 2023 under urgency following Cyclone Gabrielle to progress work towards finding a solution that would provide flood resilience for their sites at Whirinaki. The three organisations saw that there would also be benefits of a solution on the nearby residential community that was severely impacted in the Cyclone. The project fundamentals are set out below.

3.2 PURPOSE

The purpose of the project (defined in March 2023 and refined since) was "to improve resilience for the Pan Pac Forest Products Limited, Contact Energy Limited and Transpower sites and the immediate established neighbouring community [of lower North Shore Road and Pohutukawa Drive], and ensure personal safety, business continuity, insurability, and community morale".

3.3 OBJECTIVE

The project objective was established in March 2023 in order to provide a feasible option for long term protection of the industrial sites and community in the project area as follows:

> *To review and consider the event and outcome of Cyclone Gabrielle in order to rapidly assess options and decide the best overall option to provide a long-term level of protection for the Pan Pac Forest Products Limited, Contact Energy Limited and Transpower substation sites and the immediate established neighbouring community and design, consent and install the preferred solution before the end of 2023.*

The Project Team was engaged by the HBRC in August 2023 to consider the land categorisation and options for community level flood protection initiatives of the Category 2A properties within the project area. As such a revised project objective was developed as detailed below:

> *To review and consider the event and outcome of Cyclone Gabrielle in order to rapidly assess options and decide the best overall option to provide a long-term level of protection for the Pan Pac Forest Products Limited, Contact Energy Limited and Transpower substation sites and the immediate established neighbouring community of Category 2A properties fronting Pohutukawa Drive and parts of North Shore Road providing a preferred solution that transitions category 2A properties to category 2C as a matter of priority by October 2023 for consideration.*

3.4 WHIRINAKI RESILIENCE PROJECT STAGES

Following the change to the initial project objective being led by the industrial landowners, the WRP was broken into two broad project stages being:

Stage 1 – Proposed solution to inform land categorisation decision of Category 2A properties & continue to protect critical industry & infrastructure.

- Confirm project scope and setting up project structures.
- Initial Option / Package identification.
- Assess technical matters for each Option / Package, including hydrological modelling, cultural, landscape, engineering implications & consenting pathway.
- Engage with the critical industry, community and key stakeholders.
- Identify the "Base Case" Package that enables the transition from category 2A to 2C, is consentable, fundable and can be delivered at pace.
- Present Stage 1 Report to HBRC.
- Base Case regulatory and physical works processes commence.

Stage 2 – Evaluation of additional resilience measures for critical infrastructure and industrial landowners.

Additional opportunities for further resilience measures to provide a higher level of protection (1 in 500-year flood event design level) for the Whirinaki Industrial Area, based on the long list of options identified by the project Technical Team in July 2023 will be progressed following agreement on the recommendation for Stage 1. This work would be commissioned by the industrial landowners and will include the following steps.

- Conduct Multi Criteria Analysis (MCA) on additional resilience Options / Packages.
- Engage with community and key stakeholders.
- Identify additional feasible and viable resilience packages for the Whirinaki industrial area.
- Apply for additional Stage 2 resource consents for any identified feasible and viable additional resilience measures.
- Undertake physical works.

3.5 PROJECT STRUCTURES

The initial phase of the WRP project involving the industrial landowners was developed to ensure governance, technical and stakeholder input and involvement on a continual and key milestone basis. These are outlined below.

- Governance Group - The Governance Group was established in March 2023 and included senior representatives from the three industrial sponsors, Councils and Mana Whenua being led by an Independent Chair.

- Technical Focus Group ("**TFG**") - The project stakeholders were considered in the development of the TFG and include Councils, mana whenua, transport utilities and landowners / residents. The TFG is made up of representatives from these key stakeholder groups to enable engagement with the Project Team and provide focused and coordinated advice and input as part of a two-way information sharing process in the development of the resilience options being considered and the assessment studies for the preparation of any resource consent application(s).

Ongoing involvement of the stakeholders in the project is essential to its success through all stages, whether by the HBRC or the industrial landowners. The established relationships with the members of the TFG will provide ongoing benefits to the project through any necessary landowner negotiations, consenting and delivery phases for any proposed solution.

3.6 FUNDING

On 2 August 2023 HBRC accepted the Crown's offer of $203.5 million towards flood mitigation across the Hawke's Bay Region. An additional $44.15 million is being contributed from HBRC debt funding, making a combined total of $247.6 million for flood mitigation[11]. Further detail of the costs associated with the proposed solution are outlined in Section 5 of this report.

[11] HBRC Factsheet - Negotiated funding outcomes for Hawke's Bay Regional Council

4. OPTION DEVELOPMENT

4.1 PRELIMINARY CONCEPTS - LONG LIST OF RESILIENCE OPTIONS

A series of unconstrained preliminary concepts for the lower Esk River and Whirinaki Stream were developed by the Project Team and some members of the TFG on Wednesday 12 July 2023. These were subsequently refined by the Technical Team on 4 August 2023 (Figure 3 and Table 2).

These options have been informed by the overall objective of the project as well as HBRC's decision making thresholds.

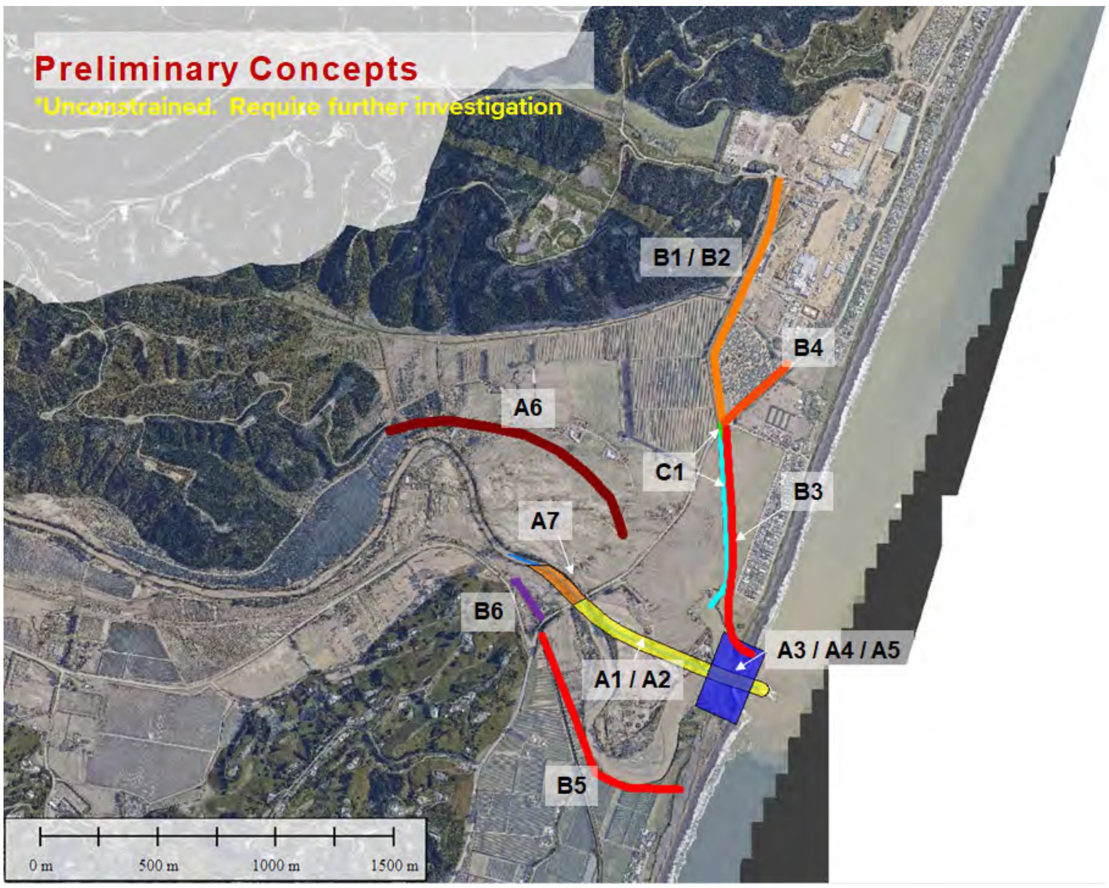

Figure 3: Preliminary Concepts Map

Table 2: Preliminary Concepts – Esk River and Whirinaki Stream

Option	Detail
A1	Esk River channel realignment - Downstream of SH2
A2	Esk River high flow bypass channel - Downstream of SH2
A3	Esk River Mouth and Coastal Works – groyne structure North side ties into B3 stopbank
A4	Esk River Mouth and Coastal Works extending landward to protect Urupa site (Pohutukawa Drive)
A5	Esk River Mouth maintenance
A6	Debris Fences - Upstream of SH2
A7	Esk River channel realignment - Upstream of SH2
B1	Existing Whirinaki stopbank - pre cyclone, no change to level of service[12]
B2[13]	Existing Whirinaki stopbank to SH2 - increase height
B3	New stopbank from SH2 to Coast - Pohutukawa Drive across Evans Land
B4	Improvements to and extension of existing Whirinaki stopbank around Lifeline Utility / Industrial properties - Upstream of SH2
B5	New stopbank Bayview side of Esk - SH2 bridge to Coast
B6	Bayview Stopbank revetment and small section above railway overbridge.
C1	Whirinaki Stream SH2 culvert improvements + Increase capacity of Whirinaki Stream - Downstream of SH2

Having identified a number of concepts that could provide specific flood protection and potential community solutions to the Category 2A properties in Pohutukawa Drive and lower North Shore Road, the Project Team has developed the relevant concepts into a

[12] 11 Sept 2023 Site visit with HBRC noted various one off and ongoing maintenance actions to address the impacts on the scheme from Cyclone Gabrielle and the historical maintenance schedule.

[13] There is a current scheme in place to protect those businesses that was to have a documented performance of protection from a 1:500 year event (Esk River and Whirinaki Drainage Flood Control Scheme Asset Management Plan 20 July 2021 Hawke's Bay Regional Council Publication No. 5547_7)

package outlined below for further technical assessment and modelling (as outlined in section 5 below) and ultimately consideration by the HBRC in their land categorisation decisions for these properties.

4.2 HBRC EXPECTATIONS

As noted previously, following Cyclone Gabrielle, Pan Pac Forest Products Limited, Contact Energy Limited and Transpower engaged Mitchell Daysh Limited to look at potential improvements to flood mitigations and also protect the Whirinaki community. Hawkes Bay Regional Council (HBRC) supported this approach.

HBRC created a number professional services teams to work through the options for flood mitigation for all Category 2A and 2C areas. To ensure a consistent approach Mitchell Daysh were engaged by HBRC to continue the work for the Whirinaki 2A area.

HBRC have identified three decision-making thresholds that any mitigation option or package of options must meet to enable the category to transition from 2A to 2C and ultimately Category 1.

These HBRC decision-making thresholds are:

- It meets the 1 in 100-year flood protection level (with an appropriate freeboard allowance).
- Agreement has been reached, in principle, for any land access required for delivery.
- Access to required funding is identified.

4.3 BASE CASE AND BASE CASE+ CONCEPTS

Further discussions with the Project Team and Technical Team on 21 August 2023 resulted in the identification of “Base Case” & “Base Case+” concept work packages for further technical assessment that meet the three decision-making thresholds set by HBRC set out above (Figure 4).

In addition to these thresholds, consideration has also been given to a set of evaluation criteria that has been established for the wider resilience project as follows:

- Community Safety & Social Wellbeing, Critical Industry & Infrastructure Continuity
- Mana Whenua / Cultural Wellbeing
- Ecology
- Landscape
- Regulatory framework, consenting and policy risks

A further three additional resilience packages have also been identified as opportunities to provide further resilience over and above the Base Case or Base Case+ and these will be developed in a separate Stage 2 Report following agreement on the recommendation for Stage 1[14].

This Stage 1 Report therefore does not make any recommendations on these additional resilience packages.

4.3.1 Base Case Concept

The Base Case concept is based on a "structural" set of responses that utilise the existing assets within the Whirinaki Drainage scheme - being the existing HBRC stopbank (reinstated to pre-cyclone levels) behind the industrial sites, SH2 culvert owned by Waka Kotahi and the downstream Whirinaki Stream. In developing the Base Case, consideration has been given to the current state and level of service of these assets following Cyclone Gabrielle and the recommendations for improvements in previous HBRC hydraulic modelling reports.

The Base Case concept therefore consists of four primary flood mitigation interventions being:

A5 - Esk River Mouth maintenance.

B1 - Existing Whirinaki stopbank - pre cyclone, no change to level of service.

B3 - The installation of a new stopbank from SH2 to Coast - Pohutukawa Drive across Evans Land.

C1 - Whirinaki Stream SH2 culvert improvements + increase capacity of Whirinaki Stream - Downstream of SH2.

4.3.2 Base Case+ Concept

The only difference between the Base Case and Base Case+ concepts is the inclusion of the new **B5** stopbank on the southern side of the Esk River. The Base Case+ concept therefore consists of five primary flood mitigation interventions being:

A5 - Esk River Mouth maintenance.

B1 - Existing Whirinaki stopbank - pre cyclone, no change to level of service.

B3 - The installation of a new stopbank from SH2 to Coast - Pohutukawa Drive across Evans Land.

[14] This further work will be commissioned by the industrial landowners.

C1 - Whirinaki Stream SH2 culvert improvements + increase capacity of Whirinaki Stream - Downstream of SH2.

<u>**PLUS**</u>

B5 - New stopbank Bayview side of Esk - SH2 bridge to Coast.

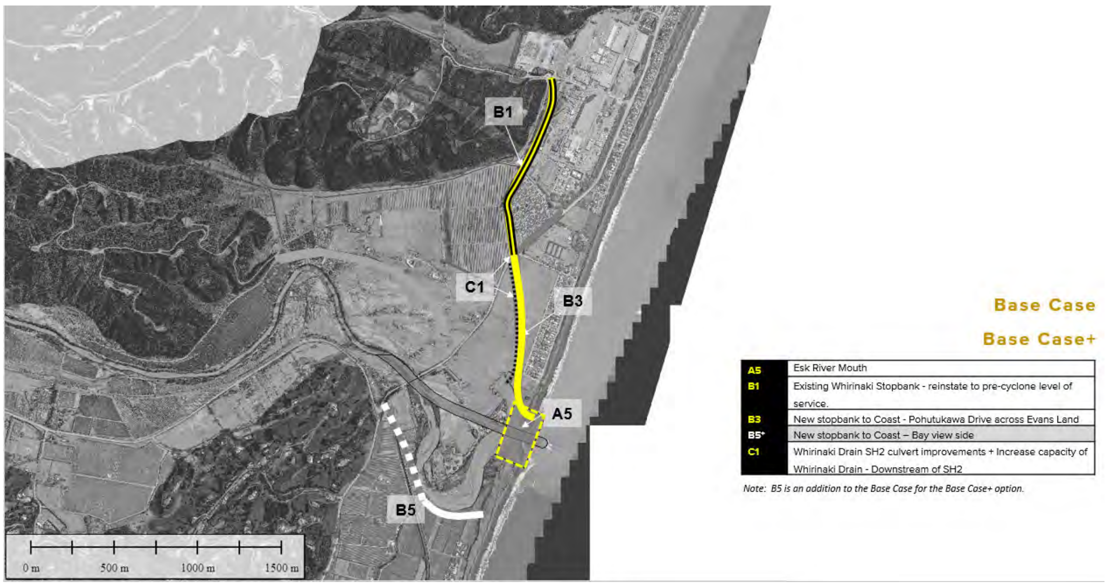

Figure 4: Base Case and Base Case+ Concept Resilience Scheme[15]

The technical assessment summarised in the following sections shows that the proposed **Base Case+ Concept** is the most appropriate engineering solution to provide the appropriate flood protection for the category 2A land at Pohutukawa Drive and North Shore Road.

This proposed engineering solution is an interconnected package where all aspects are required to provide this protection. In addition to this, and as shown by the PDP modelling without these interventions the impact on the wider Whirinaki community and industry is significant.

4.4 RATIONALE FOR BASE CASE AND BASE CASE+ CONCEPT

The options that make up the Base Case and Base Case+ concept address the decision-making thresholds set by HBRC to enable the transition of category 2A properties to 2C as follows:

[15] All stop bank, drain and improvement work alignments are indicative only and subject to detailed design and landowner negotiations.

- Pohutukawa Drive residential category 2A properties will be protected by a flood mitigation measure that meets the pre-Gabrielle 1 in 100-year level of protection.
- Pan Pac Forest Products Limited, Contact Energy Limited and Transpower critical infrastructure and assets surrounded by mitigation measures that meets the in 100-year level of protection. The proposal is to restore the stopbank to its pre cyclone scheme design level as a baseline for any improvements to the existing flood protection scheme to restore the higher level of the 1 in 500 additional engineering year protection required by the industrial sites that may have been reduced as a result of the cyclone[16].
- The landholdings required for the proposed works are predominantly within either Category 3, or on lands where landowners are being engaged with to ascertain whether they are willing to consider the divesting of part of their landholdings as part of this resilience project.
- The landholdings are generally large and contiguous, with a defined number of landowners. Discussions with the primary landowner that would be impacted by the C1, B3, and B5 interventions have been productive, with in principle support achieved for all of the land parcels.
- The detailed design of B3 and A5 near the Ararata Urupa and Nukurangi Pa site area will require consultation with, and the support of, mana whenua, and potentially a heritage order via Heritage New Zealand.
- We note that as part of this detailed design phase there could be land available that is protected by the proposed engineering solution for a new marae facility. This has been briefly discussed with the Petane Marae Chairperson who would be supportive of this opportunity, as the current marae sits within the Category 3 land, noting that any new site must be within the takiwā of the marae.
- Opportunities for property specific mitigation / protection (such as bunding) could also be considered for the Tait Road Urupa that would be “inside” the existing and new stopbanks.
- Engagement with mana whenua will need to be ongoing.
- Scheduled river mouth maintenance works will provide additional protection to the Ararata Urupa, Nukurangi pa, and Pohutukawa Drive area by mitigating the likelihood of erosion, scouring and inundation at the mouth of the Esk as a result of debris building up at the mouth.

[16] There is a current scheme in place to protect those businesses that was to have an agreed performance of protection from a 1:500 year event. The parties will need to consider how restoring this level of protection is to be funded.

5. TECHNICAL REVIEW

The following sections provide a technical assessment of the Base Case and Base Case+ concepts to inform HBRC land categorisation decisions and respond to typical technical "multi criteria analysis" considerations.

5.1 HYDROLOGICAL MODELLING PROCESS AND FINDINGS

PDP have completed detailed hydrological modelling of the Base Case and Base Case+ (see Appendix 1), these specific components being:

- Stopbanks along Whirinaki Drain;
- Stopbanks along south bank of the Esk River, from SH2 to the coast;
- Differing mouth conditions, including a closed mouth, engineered/open mouth and natural mouth;
- Improvements to the Whirinaki Drain culverts beneath SH2

PDP have modelled these components against a number of scenarios to show the maximum flood depths for the pre base case and post Base Case+ in 100-year events.

5.1.1 Flood Elevations

The flood maps presented in the PDP report (Appendix A Figures A1, A2 and A3) show that:

- *Without any additional flood control and/or mitigation such as stop banks, the industrial properties and Pohutukawa Drive will likely be inundated in the 1% AEP event*[17]*.*
- *Flooding can be contained by the stopbanks (Base Case and Base Case +), assuming they are built to a suitable height.*

The flood maps also show that with the proposed engineering solution in place (compared to the pre base case situation):

- *Flood levels will decrease behind the stopbanks, protecting Pohutukawa Drive, North Shore Road, the industrial sites and Bay View;*
- *Increases in flood levels, in excess of 100 mm are expected adjacent to proposed stopbanks and close to the river mouth;*
- *Upstream of the SH2, the increase in flooding is expected to be less than 100 mm; and,*

[17] 1% AEP is equivalent to a 1 in 100 year flood protection level

- *Further up the Esk Valley, the difference in flood elevation is expected to be less than 1 mm.*

5.1.2 Impacts on Road and Rail

PDP consider that the flood effects on the rail line (upstream of the SH2 bridge) and on SH5 would be less than minor with the flood levels being:

- *Generally less than 1 mm;*
- *Less than 20 mm closer to the intersection with SH2.*

The PDP flood modelling also showed that "*the proposed stopbank along the southern (true right) bank of the Esk River will provide protection from flooding and therefore the effect is considered positive".*

The Transport Rebuild East Coast Alliance ("**TREC**") [18] modelling team have undertaken a parallel review of the modelling and information provided with the draft version of this report, and provided general feedback in terms of the impacts on the road and rail networks and in particular on SH2[19]. Through subsequent discussions with the PDP modellers early indication is that the TREC and PDP modelling work has produced similar results although the TREC model considers the wider Esk catchment and is based on different assumptions and boundary conditions.

Following this preliminary feedback from the TREC team, PDP has undertaken additional modelling to more fully explore the predicted effects on SH2 (see section 8.2 of the PDP report in Appendix 1) and consider the length of closure of the road. The modelling showed that:

> *"For all modelled scenarios, the duration of inundation decreases with the base case scenario and therefore, we conclude that it the SH2 is set to a nominal elevation of 7.0 mRL, the base case scenario will not have an adverse effect on the serviceability of SH2. That is, the serviceability in terms of closures is predicted to be similar to the current serviceability of SH2."*

The PDP modelling concludes that:

> *"The modelling shows that if the stopbanks can be built to the design standard (1% AEP flood with climate change) then flooding will be contained*
> ....

[18] Engagement with KiwiRail and Waka Kotahi commenced in May 2023 through the TFG process and has subsequently been undertaken through TREC which represents both organisations.

[19] It is noted that the timeline and drivers behind the TREC work are quite different from the HBRC land categorisation.

This will provide protection to Pohutukawa Drive, North Shore Road and the Whirinaki industrial area for up to the 1% AEP flood event (with climate change).

… whilst the modelling shows that this will provide the desired protection, further work is recommended to determine the feasibility of the proposed stopbank heights. …

In conclusion, the proposed engineering solution (the base case+ scenario) consisting of the existing Whirinaki stopbank (with appropriate freeboard allowance), new stopbanks adjacent to Pohutukawa Drive and on the southern side of the Esk River at Bayview, along with the proposed river and coastal maintenance and culvert / drain improvements, and with the SH2 road surface set to 7.0 mRL, the effects on flooding are considered less than minor.

5.2 COASTAL ENGINEERING

Specialist environmental and engineering consultants T+T were engaged to provide specialist advice on the coastal processes associated with the Esk River Mouth and immediate surroundings. T+T also provided advice and input into the modelling undertaken by PDP, including in development of the river mouth morphology scenarios used in the model.

In order to manage flood flows in the Esk River and Whirinaki Drainage scheme T+T have recommended an improved river mouth management and maintenance regime which is detailed in section 3 of their memo attached in Appendix 2 of this report.

5.3 GEOTECHNICAL

Initial Geotechnical Specialists have completed an investigation of the ground conditions for the proposed new B3 stopbank (see Appendix 4 for site plan sowing investigation points). The ground conditions are described as follows:

- A layer of topsoil up to 0.3m.
- Underlain by loosely packed silty sand/sandy silt to depths of typically in the order of 1m and 2m.
- Which in turn is underlain by clayey silt, very stiff, high plastic, to depths of typically in the order of 2m and 6m.
- Dense Sand and Gravel was identified at depth beneath the site at depths ranging from 6m to 9m.

The geotechnical implications for the construction of the B3 stopbank are summarised in the table below.

Table 3: Ground conditions summary

Focus Area	Detail
Liquefaction and lateral spreading	• Calculated Liquefaction Severity numbers under ULS levels of shaking range between 0.5 and 10.5 (on average 5) which suggests expected damage is likely to be little to minor. • Given the thickness of the potentially liquefiable layers, vertical settlement is likely to be negligible. • The nearest free face (the Whirinaki Stream will be close to the stopbank), a detailed lateral spread assessment will need to be carried out.
Consolidation Settlement	• Given the potential size and height of the stopbank, detailed settlement analysis will need to be carried out to ensure that stopbank is not subjected to large settlements. The stopbank may have to be constructed in stages to allow for pore water pressures to dissipate before adding more material to the stopbank.
Slope stability	• If the stopbank is constructed close to the Whirinaki Stream that runs through this area, a global stability assessment will to be carried out to ensure that placing the stopbank close to the edge of the stream does not cause instability in the stream.

5.4 TRAFFIC

Specialist transportation and infrastructure advisors Urban Connection have developed a concept for the State Highway 2 - B1 and B3 stopbank interface. The concept drawing set is attached as Appendix 5.

The assumptions that have informed this concept are as follows:

- State Highway 2 to be lifted to RL8.00 (approximate 1.5m-2.0m lift at Whirinaki Stream).
- Design concept has been developed from 1m contours provided.
- Service impacts have not been considered (high level costs have been allowed for in estimate).

A topographical survey of the site would be recommended to further assess the land take requirements and confirm the road work extents.

The concept plans indicate that a suitable transportation solution is achievable.

Urban Connection has also reviewed the modelling work undertaken by PDP with respect to the impacts on SH2 (Appendix 6) and the wider network. The memo from Urban Connection states that based on the information provided their view is that there would be "*no discernible differences with the operation of SH2 between the existing conditions and those with the proposed stopbank*".

5.5 LANDSCAPE

Wayfinder Limited Landscape, Planning and Strategy consultants have been engaged to complete a preliminary review of the Base Case and Base Case+. The purpose of the assessment is to provide an overview of the potential landscape effects, as well as identify potential wider landscape opportunities. The details are summarised in Table 4 below and shown in Appendix 3.

Table 4: Potential landscape effects and opportunities of the proposed engineering solution (Base Case and Base Case+ Concepts)

Option	Potential Landscape Effects	Potential Landscape Opportunities
A5 – Esk River Mouth maintenance	It was noted in the site visit that the lagoon area that was created post-cyclone is already well inhabited by coastal birds – a sign of the landscape "healing itself". Dredging could be considered by some to be contrary to natural processes.	Widen this area and plant with native riparian vegetation to enhance the coastal habitat and coastal lagoon. Undertake planting to create a buffer between the semi-industrial activity and the coastal edge.
B1 – Existing Whirinaki stopbank	Limited landscape effects – stopbank is already in place, and is largely screened from public view, waterway is already a highly modified V-Channel.	Limited due to narrow land ownership and engineering requirements to protect stopbank. Potentially could consider some planting within the inner terrace (between stopbank and waterway) to create riparian habitat and shading of the waterway.
B3 - New stopbank from SH2 to Coast - Pohutukawa Drive across Evans Land	Introduction of a new modified landform that is incongruous to the wider, flat landscape – although consider this effect to be relatively low in significance. Greater separation of landscape, highlighting flood-prone side and "safe" side – could create false sense of security. May require rising of SH2, which may impact levels around the intersection with N Shore Road and potentially affect visibility of this intersection from neighbouring residents.	Planting within the inner terrace (between stopbank and waterway) to create riparian habitat and shading of the waterway. Relocation of the stopbank to directly adjacent to N Shore Drive and Pohutukawa Drive in order to reduce landscape effects of the channel. Naturalisation of the channel, minimising the V-Channel profile and introducing varied widths and slopes to provide habitat opportunities.

Option	Potential Landscape Effects	Potential Landscape Opportunities
B5 - New stopbank Bayview side of Esk	› Relatively limited, given that the effects from flooding have already resulted in widespread damage and landform change in this area. › Would result in the loss of some additional private land.	› Undertake riparian planting, ideally native, between the new stop bank and the river to provide ongoing stability and to establish an ecological corridor and habitat. › Install a limestone path on top of the stopbank to provide public access from SH2 to the coast (may require the construction of a car park area). › Undertake coastal native planting of the headland between the river and the coast, north of the stopbank, to provide habitat and amenity (potentially create this as public open space).
C1 - Whirinaki Stream SH2 culvert improvements + Increase capacity of Whirinaki Stream - Downstream of SH2	› Limited, if any.	› Limited, if any.

5.6 ECOLOGY

Ecological Solutions Limited ("**ESL**") have conducted a preliminary, high-level ecology assessment associated with Base Case and Base Case+ (Table 5). Any effects in terms of the ecology will be incorporated into any final design and location of a solution.

A brief partial site walkover of the true left bank of the Whirinaki Stream was undertaken by M. Roper (ESL) and M. Brady (Department of Conservation) on 8 September 2023. The purpose of this site visit was to inspect the condition of the known inanga spawning site within the Esk River Estuary / Whirinaki Stream and to discuss the need and methods for restoration work to be undertaken. An off-site discussion was also had between M. Roper (ESL) and H. Rook (local conservation expert who initially identified the inanga spawning site) on 15 August 2023 on the same topic. From this consultation, it is clear that a spawning site exists within/near the project site and that restoration work could be considered as part of the project.

Table 5: Ecological considerations of the proposed engineering solution (Base Case and Base Case+ Concepts)

Option	Preliminary Comments / Relevant Ecological Considerations
A5 – Esk River Mouth maintenance	› River mouth opening using excavators is common practice for New Zealand east coast regional council drainage works teams. This work will occur in a highly sensitive environment that supports a range of endangered bird and fish species at various times of the year and is in close proximity to the known whitebait spawning area at/near the confluence between the Whirinaki Stream and the Esk River. The potential effects of the river mouth opening include disturbance of rare bird species and bird feeding and nesting habitat and whitebait spawning habitat. A potentially positive effect of the river mouth opening is an increase to the extent of the year that fish are able migrate in and out of the river mouth. Depending on the frequency of the works the disturbance effects on birds and fish may be short lived. With careful consideration of the ecological sensitivities of the area and management of the timing and location of the works adverse effects will be able to be minimised.
B1 – Existing Whirinaki stopbank - pre cyclone, no change to level of service	› This work will occur in a highly modified environment and with appropriate controls effects on the terrestrial and aquatic ecological values will be minimal.

Option	Preliminary Comments / Relevant Ecological Considerations
B3 - New stopbank from SH2 to Coast - Pohutukawa Drive across Evans Land	- This work will occur in a highly modified environment and with appropriate location and controls effects on the terrestrial and aquatic ecological values will be minimal.
B5 - New stopbank Bayview side of Esk	- This work will occur on the outside bend in the lower Esk River. Prior to Cyclone Gabrielle the area of proposed works appears to have supported well established large stature vegetation with the potential to support terrestrial ecology values including birds, bats and lizards. With appropriate location and controls effects on the terrestrial and aquatic ecological values will be minimal.
C1 - Whirinaki Stream SH2 culvert improvements + Increase capacity of Whirinaki Stream - Downstream of SH2	- This work will occur in a highly modified section of an unnamed stream that is referred to as the Whirinaki Stream. The unnamed stream upstream of the Whirinaki site (i.e., upstream of B1), whilst highly modified does appear to provide more natural stream habitat. Close to the Esk River Estuary the stream is channelised and tidally influenced and at the tidal wedge (which is yet to be formally located) within the stream and the streams confluence with the Esk River there is a whitebait spawning site that is identified in the HBRC River Works Code of Practice. Given its close proximity to the sea (via the Esk River Estuary) the Whirinaki Stream has the potential to support a range of native fish particularly upstream of B1 and in the lower reaches close to the Esk River confluence. With appropriate controls the construction related effects of the culvert upgrade beneath SH2 and channel modifications to increase the stream's capacity will be minimal. The new culvert will need to be sized and installed in accordance with the national Native Fish Passage Guidelines to ensure it provides fish passage for any native fish species likely to occur in the stream.

5.7 LAND ACCESS, TENURE AND CONFIGURATION

Surveying the Bay have provided surveying and mapping services to this project including:

- Connection and verification of existing survey control marks and establishment of new survey control marks for use as the project progresses
- Topographical survey works of specific areas as required for more detailed design.

- Site inspections and plan works to investigate specific issues e.g., the hole created by the railway underpass.
- Source pre-Gabrielle lidar data and carry out "ground truthing" to ensure it matches survey datums utilised for the survey control network and generate contours across the study area.
- Source pre and post Gabrielle aerial photography.
- Investigate land ownership and boundary locations across the study area and plan preparation to summarise.
- Provide input to the design team on survey related issues as they arise.
- Review of archaeological reporting to assess damage to Nukurangi Pa.
- Surveying base levels (pond depths) of the scour hole at the Whirinaki Stream outlet.
- CAD works to plot possible mitigation works and refinement of locations to optimise engineering outcomes while minimising landowner impact, in particular with respect to Māori land parcels.

Mapping of these works has utilised the 12d and Autocad software packages. Coordinates are in terms of New Zealand Geodetic Datum 2000, Hawkes Bay ("**NZGD2000**") and heights are in terms of New Zealand Vertical Datum 2016 ("**NZVD2016**").

Boundaries have been sourced from the Digital Cadastral Database ("**DCDB**") via the Land Information New Zealand's "Landonline". Ownership schedules were compiled using "Grip" software, which sources this information from the official LINZ record.

Figure 5 and Table 6 below summarises that status of engagement with landowners affected by the Base Case and/or Base Case+ options.

Figure 5: Land parcels and Landowner Engagement Summary

Table 6: Land parcels and landowner engagement - proposed engineering solution (Base Case and Base Case+ Concepts)

ID	Status	Commentary
1	In Principle Agreement	In principle support conditional on final agreement on alignment details for stop bank and stream widening.
1A	In Principle Agreement	Design detail and final proposed configuration of interventions around the Ararata Urupa and Nukurangi Pa site will need to be worked through with mana whenua.
2	In Principle Agreement (with addition of B2 only)	Generally in support however considers that the proposed engineering solution should also include increased resilience to the industrial sites (B2).
3	In Principle Agreement	In support, pending confirmation of final stopbank alignment.
4	In Principle Agreement	In principle support. Land may not be required depending on detailed design
5	In Progress	Technical review being undertaken by Waka Kotahi (via TREC). Culvert improvement detailed design and final configuration under SH2 to be confirmed in collaboration with Waka Kotahi through a formal process.
6	In Progress	Technical review being undertaken by KiwiRail (via TREC). Stopbank design and alignment parallel to the Palmerston North to Gisborne rail line to be confirmed in collaboration with KiwiRail.

5.8 REGULATORY PATHWAYS

While the final detail of the proposed engineering solution is yet to be confirmed through detailed design, a preliminary assessment of the likely regulatory pathways and resource consent requirements has been undertaken and updated following advice from the HBRC[20].

5.8.1 Regional Council

The HBRC has special powers, functions and duties under the Soil Conservation and Rivers Control Act 1941, the Land Drainage Act 1908, or the Local Government Act 2002, in relation to flood control and drainage. This legislation gives a local authority, or anyone acting on behalf of a local authority, the ability to undertake various flood control and drainage activities as a Permitted Activity under the relevant provisions of the regional planning documents subject to compliance with conditions under the rules in the Hawke's Bay Regional Resource Management Plan ("**RRMP**") and the Hawke's Bay Coastal Environment Plan ("**RCEP**") or the National Environmental Standard for Freshwater Management ("**NES-FW**"). These permitted activities associated with the proposed engineering solution include:

- River mouth opening.
- Work in conjunction with the southern stop bank (B5) to construct river protection works in the Esk River.
- Wetland restoration works associated with any new stopbank (B3).
- Resource consents would be required for any works that could not be undertaken as a permitted activity. These activities include works at the Esk River mouth to maintain a lower beach profile (A5).
- The establishment of new stopbanks (B3 and B5)
- Activities in or affecting Whirinaki Stream (C1).

5.8.2 District Council

Any earthworks associated with the proposed engineering solution will require earthworks consents from the Hastings District Council (B3) and Napier City Council (B5).

5.8.3 Consent processing options

The HBRC has had preliminary discussions with respect to an Order in Council process that will incorporate all flood protection works for the region. It is likely that such a process across many different communities will take a considerable length of time and a simpler (notified) resource consent process would be more suitable for this lower Esk and Whirinaki flood protection solution particularly where there are previously engaged key

[20] M Miller, Manager Consents HBRC - email dated 11 Oct 2023

stakeholders and community members that have been involved during the Stage 1 TFG process.

5.9 MANA WHENUA ENGAGEMENT

In July 2023 the Project Team commenced engagement with various Petane Marae Trustees and Hapu members as well as representatives of the owners of nearby Māori land blocks (noting that this land is not necessary for the Base Case and Base Case+ concepts). As shown previously the Base Case B3 stopbank would be located on land near the Ararata Urupa and the former Nukurangi Pa site (as identified in a previous archaeological assessment).

It is understood that the Nukurangi Pa site has been significantly damaged, if not entirely destroyed by the land slumping following Cyclone Gabrielle. Surveying has been undertaken in this area and will be used to inform additional archaeological assessment and engagement with mana whenua, including those who whakapapa to both sites.

Careful consideration has been given in regard to the positioning of the proposed flood protection assets and the proposed stopbank can be aligned to avoid the culturally significant sites. Setbacks from these sites of significance will need to be agreed through further engagement with mana whenua ahead of the detailed design phase of the project.

Meetings between the Project Team and representatives of mana whenua and Petane Marae to discuss the proposed engineering solution have been productive. In these meetings the Project Team discussed the involvement of mana whenua in the next stage of work, including the requirements for further archaeological assessment work and a Cultural Impact / Cultural Values Assessment, and the input into the alignment of any stopbank in relation to the wāhi tapu sites.

5.10 COMMUNITY AND KEY STAKEHOLDER ENGAGEMENT

As noted previously the Project Team established the TFG and has convened four meetings with the representatives from key stakeholder groups (Table 7). This group has grown with each subsequent meeting with approximately 50 interested parties (including the Technical and Project Team) being invited to the last meeting held on 8 September 2023.

Table 7: Stakeholder organisations and groups invited to participate in the TFG

Group	Organisation
Landowner representatives	› Pohutukawa Drive › North Shore Road

Group	Organisation
	- Whirinaki - Bay View - Eskdale - Pan Pac Forest Products Limited - Contact Energy Limited - Transpower
Mana Whenua	- Mana Ahuriri - Petāne Marae - Maungaharuru Tangitū Trust - Ngāti Pāhauwera
Councils	- Hawke's Bay Regional Council - Hastings District Council - Napier City Council
Agencies	- Department of Conservation - Waka Kotahi - Kiwi Rail - Transport Rebuild East Coast Alliance - Hawke's Bay Recovery Agency

The four TFG meeting held to date are summarised in Table 8 below.

Table 8: TFG meeting summary

TFG Meeting and Date	Meeting Outline
Meeting 1 26 May 2023	- Introductory meeting - Project area downstream of the SH2 Bridge - No technical considerations on the table in terms of flood protection or long term resilience solutions.
Meeting 2 30 June 2023	- Presentation from the river and coastal experts (Ramon Strong, PDP; Eddie Betham and Richard Reinen-Hamill, T+T).

TFG Meeting and Date	Meeting Outline
	› Technical information about the causes and outcome of the Cyclone Gabrielle event. › High-level potential solutions.
Meeting 3 30 July 2023	› Presentation of "longlist" consent resilience concepts for the wider project area.
Meeting 4 8 September 2023	› Presentation of Base Case and Base Case+ concepts

Through this period, the Project Team have exchanged emails and phone calls and met face to face with many stakeholders, property owners and community members to discuss their experiences of Cyclone Gabrielle and their views of potential flood protection concepts among other things. This engagement is ongoing.

5.11 COST ESTIMATES[21]

In July 2023, PDP established rough order costs estimates of the preliminary concepts identified by the Project Team. The rough order costs estimates were provided to the HBRC on 13 July 2023 to inform their funding request to Central Government. At this time the total rough order cost estimate for this work was determined to be approximately $24.5 million with an uncertainty allowance of approximately $9 million.

Table 9 below provides the revised rough order costs provided by PDP for the upfront capital investment of the proposed Base Case and Base Case+ concepts (including ongoing maintenance costs associated with the Esk River Mouth maintenance (A5).

The total rough order cost estimate for all of the items within the proposed **Base Case +** concept is **$14.06 million**[22].

It is noted that the rough order costs to lift State Highway 2 as shown in Appendix 5 and included in the Base Case+ total have been calculated to be in the order of $3 to $3.5M[23].

[21] PDP rough order cost estimates for Esk / Whirinaki 13 July 2023

[22] This total does not include B2.

[23] Urban Connections – Concept Drawing Set + Costs 15 September 2023

Costs have also been included in the table below for B2 (Existing Whirinaki stopbank to SH2 - increase height) to recognise that the detailed design may need to consider additional height for this stopbank in order to meet the needs of the industrial landowners.

Table 9: Rough order costs for items that make up the proposed engineering solution (Base Case and Base Case+)

Option	Detail	Upfront Capital Investment Estimate	Professional Services	Land Acquisition	Uncertainty Allowance	Total Cost Estimate
A5	Esk River Mouth maintenance (4x per year)	$0.1M	0%	-	0%	**$0.12M**
B1[24]	Existing Whirinaki stopbank - pre cyclone, no change to level of service	$0.3M		-	15%	**$0.35M**
B3	New stopbank to Coast - Pohutukawa Drive across Evans (880m)	$3M	15%	$0.8M	15%	**$4.42M**
C1 - A	Whirinaki Stream SH2 culvert upgrade	$2.0M	15%	-	15%	**$2.61M**
C1 - B	Increase capacity of Whirinaki Stream - Downstream of SH2[25]	$0.27M	40%[26]	-	50%	**$0.50M**

[24] PDP has noted further work is required to confirm final stopbank heights. This will take place as part of the detailed design process. The costs for B1 are to reinstate the existing Whirinaki Stopbank to pre-cyclone level of service It is understood that the industrial landowners require a higher level of service and the detailed design of the connected aspects (roading etc) would need to account for this.

[25] C1 cost estimates are based on Option B disposed of excavated material off-site.

[26] 40% includes an allowance for professional services ($12K) and ecology assessment ($20K), total costs allowance $32K.

Option	Detail	Upfront Capital Investment Estimate	Professional Services	Land Acquisition	Uncertainty Allowance	Total Cost Estimate
B5[27]	New stopbank Bayview side of Esk railway culvert to coast (500m).	$1.5M	15%	$0.5M	15%	**$2.56M**
SH2	State Highway lifting as a result of B1, B3 + C1.	ROC	-		-	**$3.50M**
Total Costs	**Base Case**		*This includes the cost allowance for SH2.*			**$11.5M**
	Base Case+		*This includes the cost allowance for SH2.*			**$14.06M**
Additional costs for consideration						
B2	Existing Whirinaki stopbank to SH2 - increase height	$1.6M	15%	$0.5M	15%	**$2.7M**

For comparison purposes, the (pre-cyclone) capital values of the properties on Pohutukawa Drive and North Shore Road within the 2A area equate to a total of approx. $35million as below:

- Pohutukawa Drive = $ 23,670,000
- North Shore Road = $ 11,490,000

In the event that the HBRC allocated budgets are constrained, the additional costs over and above the WRP budget allowance for construction and ongoing maintenance of the proposed engineering solution (the Base Case+) could be recovered from the beneficiaries of scheme through a cost recovery mechanism[28]. As this proposed solution is an interconnected package where all aspects are required to provide this protection to the

[27] B5 cost estimates are based on a 0.5km stopbank that runs approximately from the existing culvert that runs under the Gisborne to Palmerston North Railway Line to the coast. Any stopbank longer than this will be an additional cost.

[28] In accordance with the Local Government (Rating) Act 2002.

2A land, the Bay View properties, and the industrial landowners, all of these parties would be considered beneficiaries. It is understood that there are mechanisms for this type of cost sharing arrangement that can be further explored by the HBRC.

6. RECOMMENDATIONS AND NEXT STEPS

6.1 RECOMMENDATION

Based on the information provided in the report and attached, the Project Team can confirm that the **proposed engineering solution** (the **Base Case +**) for the Lower Esk and Whirinaki Stream area will meet the following three key criteria for a flood mitigation solution.

- It meets the 1 in 100-year flood protection level (with an appropriate freeboard allowance).
- Agreement has been reached, in principle, for any land access required for delivery.
- Access to required funding is identified[29].

This proposed Base Case+ concept is the most appropriate engineering solution to provide flood protection for the category 2A land at Pohutukawa Drive and North Shore Road, while ensuring impacts on the Bayview area to the south are mitigated and the flooding effects on the SH2 are considered less than minor.

This proposed Base Case+ engineering solution is an interconnected package where all aspects are required to provide this protection to the 2A land.

A solution based on the concept presented in this report may be refined through detailed design in consultation with landowners and stakeholders.

6.2 NEXT STEPS[30]

The proposed next steps for the decision making, consenting and implementation for Stage 1 is proposed.

- HBRC to review this Stage 1 report and any amendments / refinements finally actioned.
- HBRC to make formal decision based on Stage 1 Report and recommendations.
- HBRC (via HDC) will communicate project delivery stages and associated timelines to community of North Shore Road and Pohutukawa Drive.

Milestone: HBRC have advised 2A residents that a decision regarding transition of Category 2A to 2C will be made in October 2023.

[29] Assumes that funding is available but requires confirmation by HBRC.

[30] All milestone dates are indicative only.

- The specialist consultant team will complete detailed design and resource consent drafting, collaborating closely with TREC, KiwiRail, Waka Kotahi, the Whirinaki Industrial Area landowners, mana whenua, applicable landowners and the TFG where appropriate. This stage of the process will include drafting a Cultural Impact Assessment (author and scope to be agreed with mana whenua).

The specialist consultant team and HBRC will discuss final scheme design and stopbank height. Note: This may facilitate restoring the 1 in 500-year level of service requirements of the industrial sites, that will be determined after the completion of the WRP Stage 2 Report.

- Ongoing engagement with landowners, stakeholders and other interested parties.
- Pre-application meeting(s) held ahead of formal resource consent submission.
- Resource consent submitted on behalf of HBRC.

Milestone: Resource Consent decision made by HBRC (target first half of 2024)

- Detailed design process complete and final design and funding approved by HBRC, Waka Kotahi, KiwiRail and supported by mana whenua, applicable landowners and the TFG.
- HBRC to initiate physical works procurement process.

Milestone: Physical works contractor appointed (target second half of 2024)

- Physical works commence.

1

APPENDIX 1

PDP Hydraulic Modelling Report and Cross Sections

Esk River Hydraulic Model

Prepared for

Hawke's Bay Regional Council

October 2023

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Quality Control Sheet

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DOCUMENT CONTRIBUTORS

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Limitations:

This report has been prepared by Pattle Delamore Partners Limited (PDP) on the basis of information provided by Hawkes Bay Regional Council [and] [others (not directly contracted by PDP for the work)], including [National Institute of Weather and Atmosphere, Land Information New Zealand and Landcare Research]. PDP has not independently verified the provided information and has relied upon it being accurate and sufficient for use by PDP in preparing the report. PDP accepts no responsibility for errors or omissions in, or the currency or sufficiency of, the provided information.

This report has been prepared by PDP on the specific instructions of Hawkes Bay Regional Council for the limited purposes described in the report. PDP accepts no liability if the report is used for a different purpose or if it is used or relied on by any other person. Any such use or reliance will be solely at their own risk.

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1.0 Purpose

Pattle Delamore Partners (PDP) has been engaged by Hawke's Bay Regional Council (HBRC) to prepare a hydraulic flood model for the purpose of determining the design height for a suite of proposed stopbanks which will be constructed to provide protection from flooding in the 1% Annual Exceedance Probability (AEP) event with the appropriate allowances for climate change.

The work has been commissioned as part of the response package to the 2023 Gabrielle weather event. A number of mitigation measures have been tabled although not all have been modelled for inclusion in this report. The mitigation measures that have been modelled have been identified as the "Base Case and Base Case+" for consideration by the HBRC in their land categorisation decision are shown in Bold text below:

- **Stopbanks along Whirinaki Drain (modelled)**;
- **Stopbanks along south bank of the Esk River, from SH2 to the coast (modelled);**
- **Differing mouth conditions, including a closed mouth, engineered/open mouth and natural mouth (modelled);**
- **Improvements to the Whirinaki Drain culverts beneath SH2 (not modelled)**
- Realignment of the Esk River from the SH2 Bridge to promote retention of an open mouth); and
- A debris fence upstream of the SH2 along the true right bank of the Esk River.

2.0 Background and previous models

The lower Esk River catchment and Whirinaki area is known for its vineyards, orchards, and farmland. It has been a settlement largely of residential housing and lifestyle blocks.

The Esk River is one of Hawke's Bay's smaller rivers, with a catchment area of 252 km^2 (Figure 1). The Esk River flows south from Taraponui in the Maungaharuru Range before turning east to reach Hawke Bay 10 km north of SH5 (Hastings District).

Prior to the 1931 Hawke's Bay earthquake, the Esk River flowed south through Bay View into the northern end of Ahuriri Lagoon when the beach outlet was blocked - the earthquake raised the area blocking that flow path. That old southern branch of the river forms the northern boundary of urban development in Napier.

Pan Pac Forest Products Ltd (Pan Pac) timber and wood pulp mill (the Mill), one of Hawke's Bay's largest industrial plants, is located in Whirinaki. The Contact Energy diesel-powered Whirinaki Power Station opened next to the mill in 1978 and is operated as a backup "peaker plant" at times of low generation capacity on the national grid. The adjacent Transpower Whirinaki substation supplies power to Pan Pac and is the grid entry point for generation from the Whirinaki Power Station. The three sites comprise approximately $2 billion worth of critical industrial and infrastructural assets.

Cyclone Gabrielle has severely impacted all industries and residential properties in this area and more broadly, across Hawke's Bay.

It is important to note that while it is possible to increase protection from a river engineering perspective, the relatively high flood risk will remain due to the low-lying nature of the land and the dynamics of the river and upper catchment. Further, in the project phase, we will explore and define how to increase protection and manage residual risks (including events that exceed the design standard).

Figure 1: Esk Catchment area

2.1 Previous model reports

There are two previous hydraulic modelling studies that we are aware of:

1. The Esk River Flood Risk Assessment, completed in 2007 by HBRC for the purposes of obtaining flood level information to respond to flood level requests; and,

2. Pan Pac Forest Products Whirinaki Site Hydrologic and Hydrodynamic Analysis, completed by HBRC in 2013 for the purposes of understanding the risk associated with flooding for the Whirinaki Site.

2.2 Stopbank design standard

The design standard for the stopbanks in this analysis is the 1% AEP event with the appropriate allowance for climate change. The proposed stopbank locations are presented in Figure 2.

The climate change standard has been taken as RCP/SSP5 8.5 2120. This assumes a 100YR design horizon and a "business as usual" climate change scenario, i.e., minimum reduction to C02 emissions.

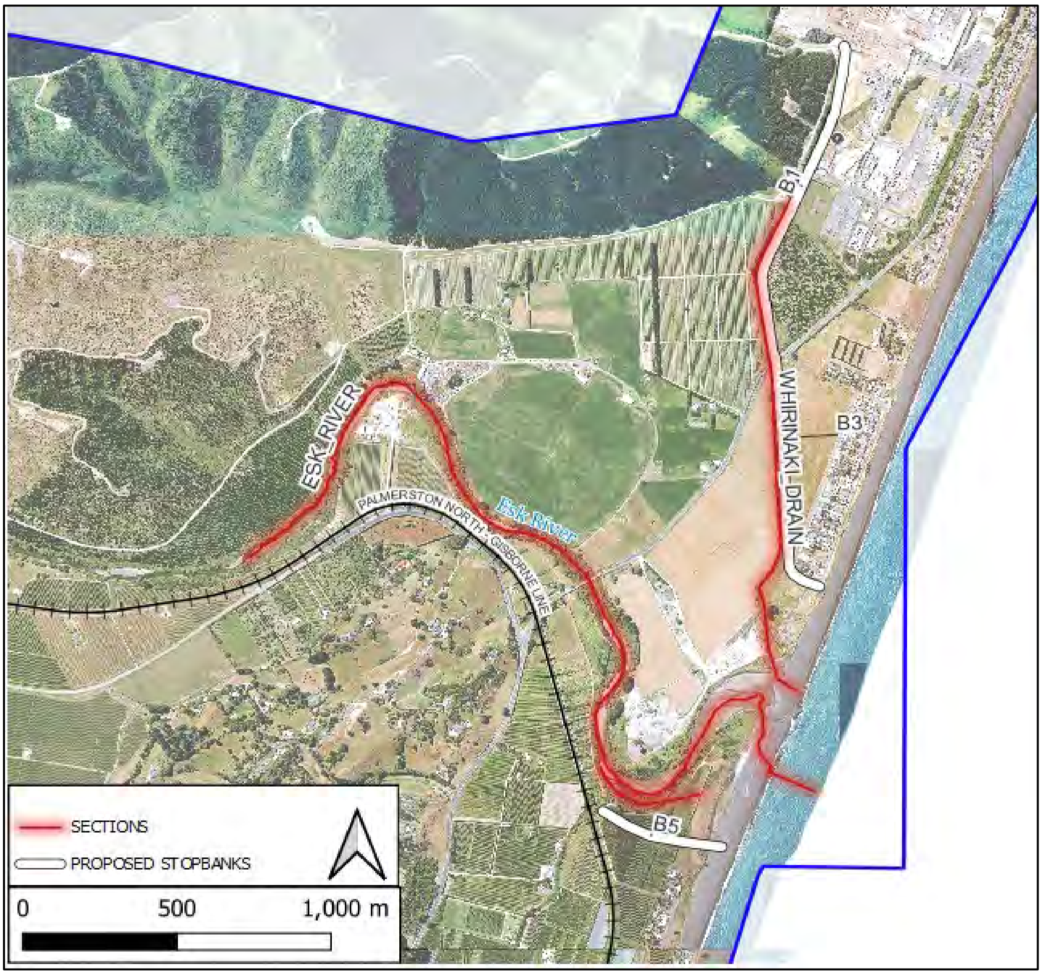

Figure 2: Proposed stopbank delineations and section lines used to extract results from the hydraulic model

3.0 Estimate of 1% AEP event

Estimating the design flow for a 1% AEP event is a critical component of this hydraulic analysis. The following is not an exhaustive study or review of all available data, and we recognise that work to derive design flood estimates is also being completed by NIWA, T+T and HBRC. Further collaboration and data sharing is recommended so that the selection of this critical parameter can be finalised. This critical piece of work should be completed prior to the detailed design of the stopbanks and any other proposed mitigation works.

Any estimate of the 1% AEP event will depend on what data is included/excluded from the assessment. Due to time constraints, we have selected two methodologies to estimate a design envelope which is likely to encompass the 100YR event. The methodologies are:

- A flood frequency assessment of the rated flow recorder, Esk River at Waipunga Bridge; and,
- A Bayesian Markov Chain Monte Carlo assessment which employs the rated flow record and uses interval data and perception thresholds to include historical and anecdotal flood data in the assessment.

3.1 Historic floods

Historic flood information has been obtained from local knowledge, HBRC and NIWA (historic weather catalogue).

June 1896[1]

The NIWA historic weather events catalogue reports that for Hawke's Bay:

- *"All the rivers were in high flood. The rivers continued to rise rapidly until noon on the 26th, when they began to fall rapidly."*

March 1924[2]

The NIWA historic weather events catalogue reports that:

- *"Esk River rose 4-5 ft (1.22-1.52 m) higher than previous records, and in one place soared 6 ft (1.83 m) on 15 minutes. Esk River rose 5 metres."*
- *"Eskdale recorded 419 mm (41.9 cm) of rain in nine hours."*
- *"The rainfall had a return period of over 100 years" and "A man was drowned in the Esk River at Kaiwaka".*

This rainfall depth is not dissimilar to those recorded in Gabrielle.

April 1938[3]

The NIWA historic weather events catalogue reports that:

- *"Esk River had a peak discharge flow of 1830 m^3/s above Mangakopikopiko Stream, catchment area of 200 km^2."*
- *"In the Upper Esk Valley the river rose 30 ft (9.14 m) above normal to reach a point 15 ft (4.57 m) higher than any previous flood."*

[1] https://hwe.niwa.co.nz/event/June_1896_New_Zealand_Flooding
[2] https://hwe.niwa.co.nz/event/March_1924_Hawkes_Bay_Flooding
[3] https://hwe.niwa.co.nz/event/April_1938_Gisborne_and_Hawkes_Bay_Flooding

March 1988 (Bola)[4]

The NIWA historic weather events catalogue reports that:

- *"The flood in the Esk River had a preliminary return period of 30 years".*
- HBRC report a peak flow of 841 m³/s for the Esk River at Waipunga Bridge.

March 2018

Intense rainfall in the Esk Valley (270 mm in 12 hours) caused the Esk River to breach its banks. HBRC report that the 2018 event had a peak flow of 1096 m³/s for the Esk River at Waipunga Bridge.

February 2023 (Gabrielle)

On 13-14 February, Cyclone Gabrielle caused an extreme weather event over much of the northern north island with particular devastation causes in the Hawke's Bay region. NIWA[5] summarise the event:

- The most significant damage occurred in Northland, Auckland, the Coromandel Peninsula, Gisborne, Hawke's Bay, and east-coastal Manawatū-Whanganui. The recovery from this storm is expected to take years and be very costly, particularly along the North Island's east coast;
- The highest 1-day rainfall was 316 mm, recorded at Tūtira (Hawke's Bay) on 13 February; and,
- In the morning (14 Feb), exceptional flooding was reported in Hawke's Bay, particularly Esk Valley, Hastings, where floodwater levels reached nearly to the roofs of homes and trapped at least 40 people.

3.2 Flood frequency assessment

HBRC maintain a rated flow recorded situated on the Esk River at Waipunga Bridge. This recorder is located downstream of the major tributaries and captures a catchment area[6] of 252.41 km², the majority of the Esk's 275 km² catchment area. The recorder has been operated from 1963 to the present day.

The major limitation of this recorder is that it did not capture the peak of the Gabrielle flood event as the recorder was damaged prior to the peak of the event. This gives two options for proceeding with a flood frequency assessment - exclude the Gabrielle event and the 2023 year from the assessment as the data is incomplete or include an estimate for the peak of this event.

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[4] https://hwe.niwa.co.nz/event/March_1988_North_Island_Ex-tropical_Cyclone_Bola
[5] https://niwa.co.nz/sites/niwa.co.nz/files/Climate_Summary_February_2023_NIWA-web.pdf
[6]https://niwa.maps.arcgis.com/apps/webappviewer/index.html?id=933e8f24fe9140f99dfb57173087f27d

Prior to the loss of the recorder, the largest flow for Gabrielle was reported[7] 1730.469 m^3/s. The next largest recorded flow occurred on 8 March 2018 and was rated at 1096 m^3/s. Even though the peak of the Gabrielle event was not captured, the flow is still significantly larger than any other recorded over the operating period and in our opinion, should be considered as part of any flood frequency assessment.

3.2.1 Additional data for missing years and events

Additional to the observed annual maxima that cover the period 1963 to 2020, a bandwidth is assumed for the major floods in 1938 and 2023. Additionally, an upper limit is assumed for the remaining missing years from 1867 to the present day. Table 1 lists the uncertainty estimates with an explanation.

Table 1: Uncertainty estimates for the missing years

Year or period	Estimate (m^3/s)	Explanation
1938	[1830, 2200]	The lower bound is based on the value of 1830 m^3/s as estimated by NIWA. This value was based on 200 km^2 of the catchment. Scaling this to the 25 km^2 gives an upper limit of 2200 m^3/s.
2023	[1850, 2500]	The lower bound is based on the peak flow estimated by HBRC. The upper bound was derived based on flow required to reach the observed sediment extent.
1867 – 1937	[0, 1830]	If a water level or discharge exceeding the 1830 m^3/s from 1938 would have been recorded/archived, an upper bound of 1830 for the period is assumed.
1939 – 1962 and 2019 – 2022	[0, 1000]	For the (more recent) missing years in between 1939 and 2022, we assume no discharges greater than 1000 m^3/s, which would be a flood of similar magnitude as the 1988 and 2018 events.

[7] Spreadsheet provided to Ben Throssell (PDP) by Craig Goodier (HBRC)

Adding estimates for the period without (significant) extremes is needed to assign proper return periods to the observed and estimated extremes (i.e., distribute the extremes over 156 years of data, rather than 56 years). The uncertainty estimates are added to the frequentist maximum likelihood estimate (see Section 3.2.2) as well as the Bayesian assessment (Section @). Figure 3 shows the recorded flows as well as the uncertainty estimates for the missing years.

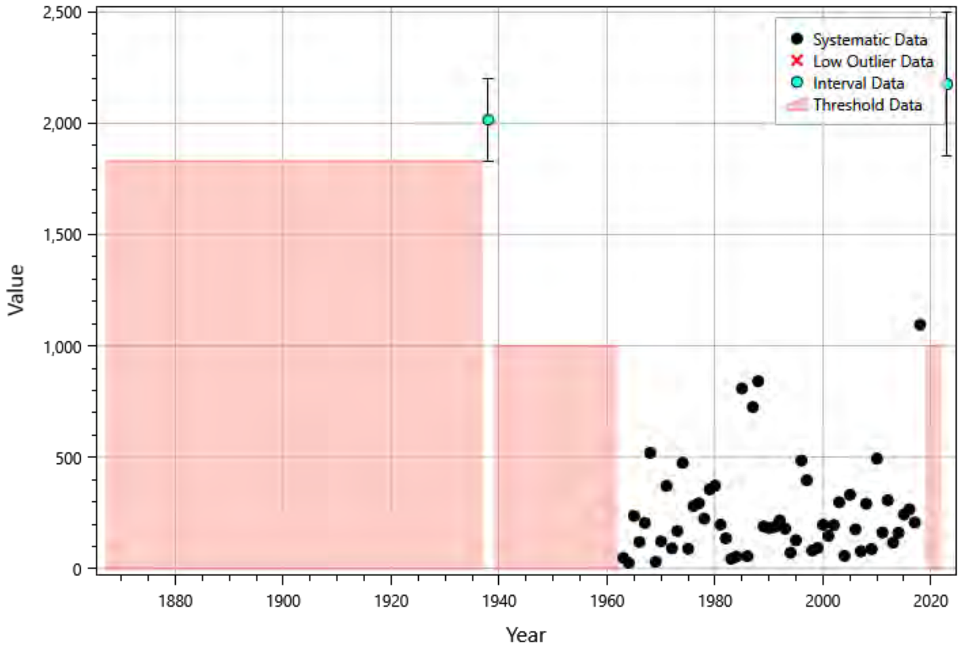

Figure 3: Observed annual maxima, including interval estimates and perceived maximum flows during the periods of missing data.

3.2.2 Frequentist assessment

RMC Best Fit was employed to complete the flood frequency assessment. This tool uses the maximum likelihood estimate (MLE) to fit extreme value distributions to the selected data set (annual maxima). Whilst other fitting methods are available, with some of the more popular methods being L-moments and probability weighted moments, in our experience there is minimal difference between the selected fitting methods when the available record is sufficiently long (as in our case) and selection of an appropriate extreme value distribution is the most important criterion.

Figure 4 shows the fitted Gumbel and GEV distributions to the annual maxima. Both distributions struggle to provide a good fit to the more extreme annual maxima, but the Gumbel distribution provides a particularly poor approximation which is perhaps not surprising due to the high tail and availability of only two fitting parameters. The 1% AEP event estimated by the GEV distribution is 1,650 m^3/s, slightly lower than the last recorded flow for the Gabrielle event.

Excluding the Gabrielle event, Figure 5 (and the other uncertainty estimates) gives an estimate for the 1% AEP event of 1350 m³/s and would rate the last recorded flow during the Gabrielle event around a 1 in 200-year event (0.5% AEP).

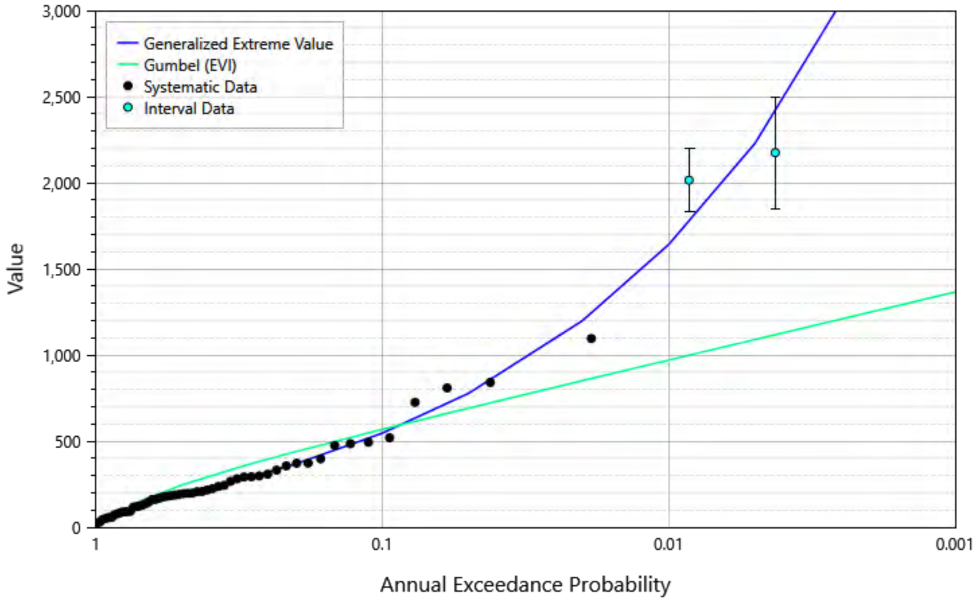

Figure 4: Flood frequency assessment including maximum recorded flow for 2023. Showing Gumbel and GEV distributions

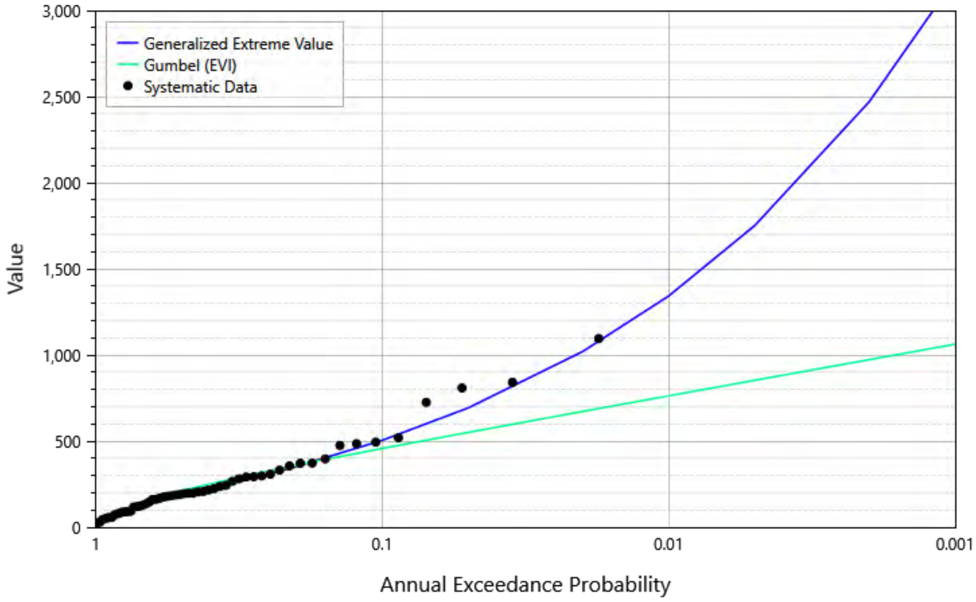

Figure 5: Flood frequency assessment excluding maximum recorded flow for 2023 and excluding other uncertainties. Showing Gumbel and GEV distributions

3.2.3 Bayesian assessment

A Bayesian Markov Chain Monte Carlo (MCMC) assessment was completed. MCMC is a method for determining a statistical models' parameters using Bayesian inference. The model in this case is an extreme value distribution. A regular maximum likelihood estimate (MLE) uses the likelihood (i.e., probability of the observations, given the model parameters) to determine the best fitting parameter combination. MCMC uses this as well, but in an iterative way. It walks the parameter-space to find the region of maximum likelihood and keeps track of all iterations on the way. Where a MLE would only move towards the highest likelihood, MCMC can move either way given by ratio of the probability of both directions (the Markov Chain). In this way, an uncertainty interval of model parameters, given the data, is derived for the specific model. The main advantage of an MCMC analysis with respect to a classical MLE is that the results naturally contain uncertainty intervals. An expected value of the 100-year ARI flow can however still be calculated, which is called the posterior predictive. The results are shown in Figure 6.

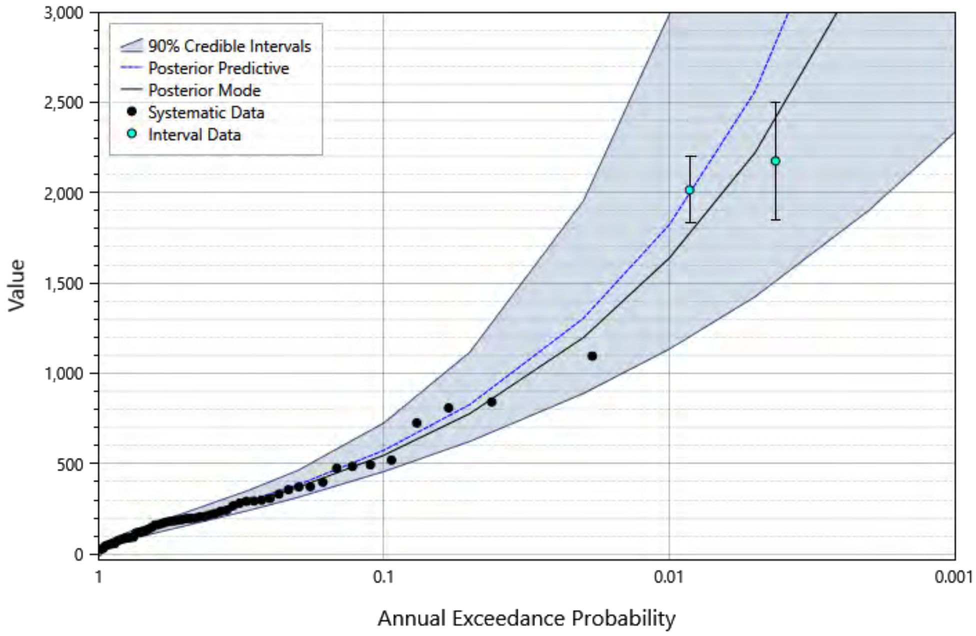

Figure 6: Bayesian flood frequency assessment for the GEV distribution, including estimates for missing events and years.

Based on the flood frequency assessment, the estimate for 1% AEP flow is 1,823 m^3/s. This is the posterior predictive, or the expected flow from the model given the uncertainty interval. The 90% credibility interval ranges from 1,135 to 2,986 m^3/s, with the mode at 1,638 m^3/s (similar to the MLE). Because the posterior predictive considered the uncertainty in the model prediction, this value, 1,823 m^3/s, should be used for the 1% AEP flow estimate. Note that the Gabrielle event and 1938 event both have at least the magnitude of the 1% AEP flow. This aligns with the 156 years of data, which would assign a plot position of approximately 1% to the second largest event.

3.3 Conclusion

The lower bound for the 1% AEP event is 1300 m^3/s, this estimate assumes that Gabrielle was an outlier and can be excluded from the record, or at least, should be excluded from the derivation of the flood frequency curves.

The upper bound for the 1% AEP event is 1800 m^3/s. This estimate is derived from an MCMC approach and includes both the 1938 flood and Gabrielle. We conclude that the MCMC approach is likely to give a more accurate estimation of the 1% AEP flow and whilst we have modelled the full range of flows, we recommend a flow of 1800 m^3/s is adopted for design purposes.

As noted, the above is one approach to deriving the 1% AEP flow and we recommend further collaboration with other parties to refine this critical estimate.

3.4 Climate change

All model design runs include allowances for climate change of 40%. A value of 40% was obtained by assuming 3.68°C of warming and an increase of 11.5% per degree of warming (which gives 42.32% which has been rounded to 40%). These values have been obtained from extrapolating data provided for the 100YR, six-hour duration event (approximately time of concentration, HBRC (2007)) from Table 6 of the HIRDS V4 report (NIWA (2018)) which is reproduced below.

We recognise that rainfall and flow response is non-linear and further investigation of this assumption is warranted.

Table 6: Percentage change factors to project rainfall depths derived from the current climate to a future climate that is 1 degree warmer.

DURATION/ARI	2 YR	5 YR	10 YR	20 YR	30 YR	40 YR	50 YR	60 YR	80 YR	100 YR
1 HOUR	12.2	12.8	13.1	13.3	13.4	13.4	13.5	13.5	13.6	13.6
2 HOURS	11.7	12.3	12.6	12.8	12.9	12.9	13.0	13.0	13.1	13.1
6 HOURS	9.8	10.5	10.8	11.1	11.2	11.3	11.3	11.4	11.4	11.5
12 HOURS	8.5	9.2	9.5	9.7	9.8	9.9	9.9	10.0	10.0	10.1
24 HOURS	7.2	7.8	8.1	8.2	8.3	8.4	8.4	8.5	8.5	8.6
48 HOURS	6.1	6.7	7.0	7.2	7.3	7.3	7.4	7.4	7.5	7.5
72 HOURS	5.5	6.2	6.5	6.6	6.7	6.8	6.8	6.9	6.9	6.9
96 HOURS	5.1	5.7	6.0	6.2	6.3	6.3	6.4	6.4	6.4	6.5
120 HOURS	4.8	5.4	5.7	5.8	5.9	6.0	6.0	6.0	6.1	6.1

4.0 Hydraulic Model

A hydrodynamic model was created to determine the flood levels for the Esk River and inform the stopbank design.

The hydraulic model was developed using Tuflow. Tuflow is a computational software which contains a 1D and 2D engine to numerically model free surface flows. The 2D depth averaged, momentum and continuity equations for free-surface flows are solved using a 2nd order semi-implicit solver. The model extent is shown in Figure 7.

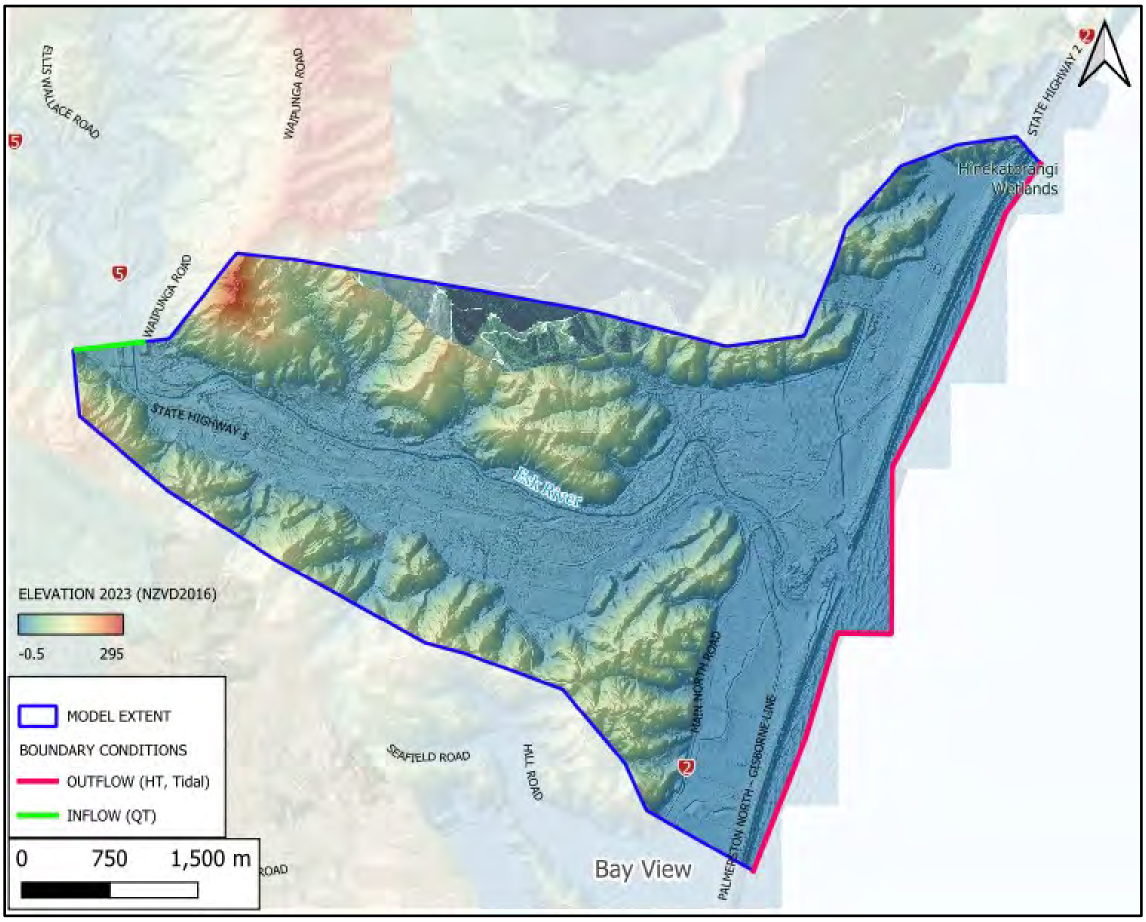

Figure 7: Model extent and terrain elevations derived from LiDAR

4.1 Model Boundary Conditions

Boundary conditions define how water enters and exits the model. The boundaries must be set suitably far from the study area to ensure boundary effects do not influence conclusions drawn from the model. For this model, two boundary conditions were required:

- An upstream boundary condition, flow vs time, representing the flow of water into the model (the design event); and,
- A downstream boundary condition, head vs stage, controlling how fast water can exit the model. This was set as tidal boundary condition for the 1% AEP storm surge and provided by T+T[8].

4.1.1 Modelled Inflow

The inflow boundary condition was flow vs time. Design flow rates were obtained using historical flow data from flow recorders and a frequency analysis to obtain the design flood events as outlined in Section 3.0. The 1% AEP is estimated at 1800 m^3/s with 40% added to this flow to account for climate change out to 2130 (SSP5-8.5).

The design flow was fitted to the Gabrielle hydrograph (Figure 8).

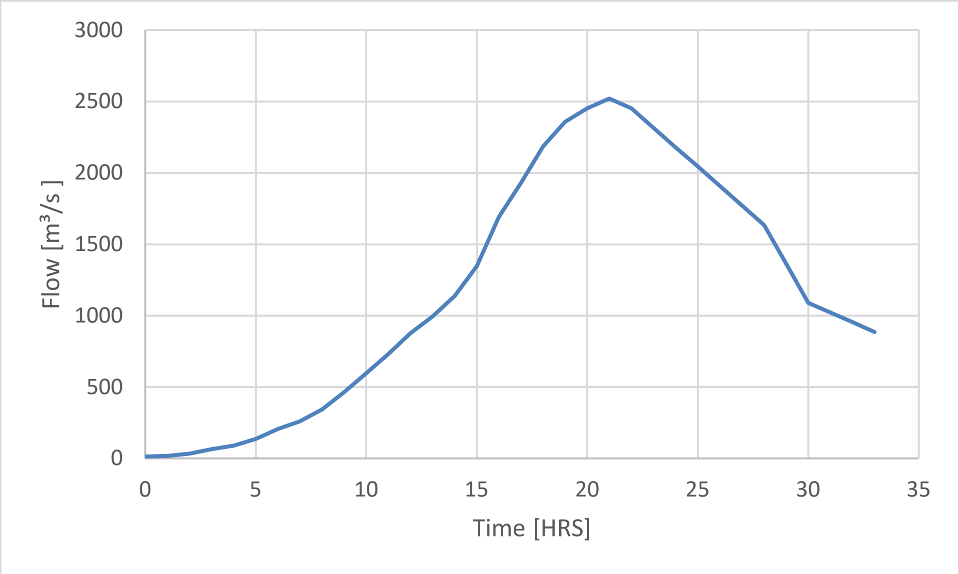

Figure 8: 1% AEP design flow with climate change. Model was run from 10 hours to 30 hours

4.1.2 Modelled Outflow

The outflow boundary condition was modelled as constant head with respect to water level. Table 2 shows the provided tail water boundary conditions scenarios that have been applied to the model. Further details on this boundary condition are provided in T+T's memo titled Coastal input on Category 2A draft report and dated 13 September 2023.

[8] Email from Eddie Beetham (T+T) to Ben Throssell (PDP) on 9 Sep 2023

Tidal amplitude was not modelled as the model was found to be insensitive to the assumed downstream boundary condition.

Table 2: Assumed tailwater scenario. Provided by Eddie Beetham (T+T)

Year	SSP	RSLR (m, inc. -3.68m VLM)	1% AEP storm tide (m NZVD)	Description
2020.00	n/a	0.00	1.28	Present day
2100.00	SSP5-8.5 p50	1.07	2.35	Consistent with recent inundation assessment for Clifton to Tangoio (Building Code)
2130.00	SSP5-8.5 p50	1.57	2.85	Category B from MfE interim guidance (2022). For land use planning controls for existing coastal development and asset planning.
2130.00	SSP5-8.5 p83	2.04	3.32	Category B from MfE interim guidance (2022). For changes in land use and redevelopment.

4.2 Model Geometry

4.2.1 Model Extent and Topographic Data

The model extent starts at the recorder site, Esk River at Waipunga Bridge, and terminates at the coast, see Figure 1 for the model extent. Two topographic LIDAR data sets were obtained, one flown in 2021, obtained from LINZ, and the other flown post Gabrielle and provided by HBRC. The LIDAR has a 1m resolution and was flow in 2023.

4.2.2 Model Roughness

Roughness represents the friction losses incurred by the water body as it traverses over the topography. The model roughness is determined by utilising multiple sources to define land cover. These include:

- LINZ Road Parcels;
- LINZ Building footprints;
- LRIS Land Cover Version 5.0; and,

- Aerial imagery and google street view.

Figure 3 shows the defined roughness for the development hydraulic model. Table 3 shows the Manning's roughness value associated with each land cover type. The Manning's roughness values are selected based on values typical for the respective land cover and to improve the fit to the historical extent in the calibration event.

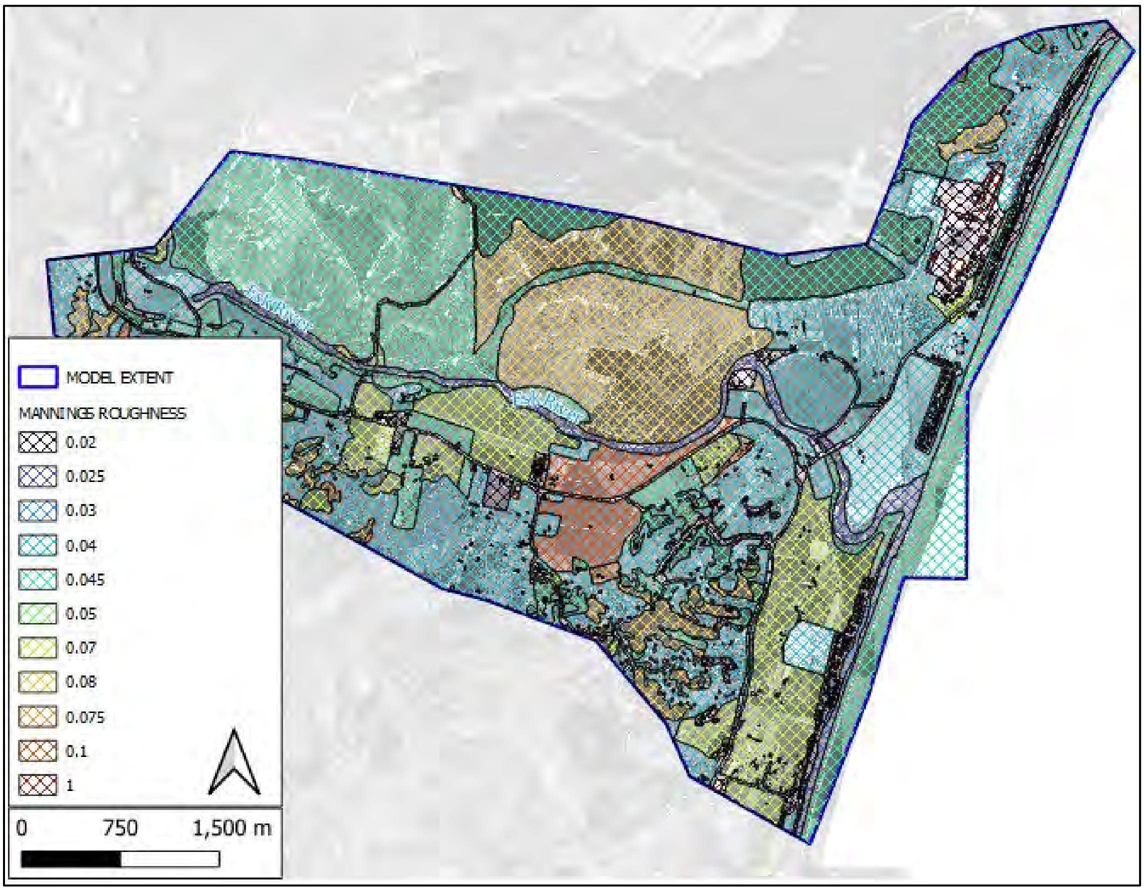

Figure 9: Employed model roughness values

Table 3: Model roughness		
Land Cover	**Manning's n**	**Typical Range[2][3]**
Building	1.000[1]	-
Roads and Hardstand Areas	0.020	0.020 - 0.030
Pasture (default)	0.03	0.020 - 0.080
High Density Trees	0.10	0.080 - 0.200

Table 3: Model roughness		
Medium Density Trees	0.08	0.045 - 0.160
Low Density Bush	0.04	0.035 - 0.080
Vineyard	0.07	-
Urban Parkland	0.035	0.030 – 0.050
Urban Areas	0.020	0.020 - 0.030
River	0.025	0.025 – 0.060

Notes:

1. *This high manning's rough value allows for floodplain storage within the building footprint but prevents any significant conveyance.*
2. *Sources: Cardno. (2021). Flood Hazard Modelling Standard. Wellington: Greater Wellington Regional Council.*
3. *Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors) Australian Rainfall and Runoff: A Guide to Flood Estimation, © Commonwealth of Australia (Geoscience Australia), 2019.*

4.3 Structures

Two structures have been included in the model, the SH2 bridge and the existing Whirinaki Drain SH2 culverts.

5.0 Selecting a model resolution

Whilst a high model resolution is often desirable, the trade of is always simulation time. The Australian Rainfall and Runoff guideline states that:

"The resolution of a 2D model grid/mesh determines the scale of physical features and flow behaviour that can be modelled for a given study area. Selection of an appropriate resolution is generally driven by a combination of the following factors:

- The scale of topographic and/or flow phenomena to be modelled;
- The desired level of detail to be achieved in the model outputs;
- The length of event time and consequent run time; and,
- The size of the area of interest."

Tuflow recommends testing cell size convergence to determine a suitable maximum resolution of the model. Figure 10 shows a long section of the Esk River for simulated scenarios at four model resolutions, from 50 m to 5 m (Table 4). Model convergence occurs at a resolution of 10 m and a value of 5 m has been adopted for this study. This resolution ensures model run times are reasonable (< 30 minutes) without comprising accuracy.

Table 4: Model runs to determine cell size convergance

	FLOW	SEA LEVEL	CELL SIZE	DEM	MOUTH	SB
S01_50M	2300	2020	50	2023-DEM	Natural-Mouth	SB-ALL
S02_20M	2300	2020	20	2023-DEM	Natural-Mouth	SB-ALL
S03_10M	2300	2020	10	2023-DEM	Natural-Mouth	SB-ALL
S04_05M	2300	2020	5	2023-DEM	Natural-Mouth	SB-ALL

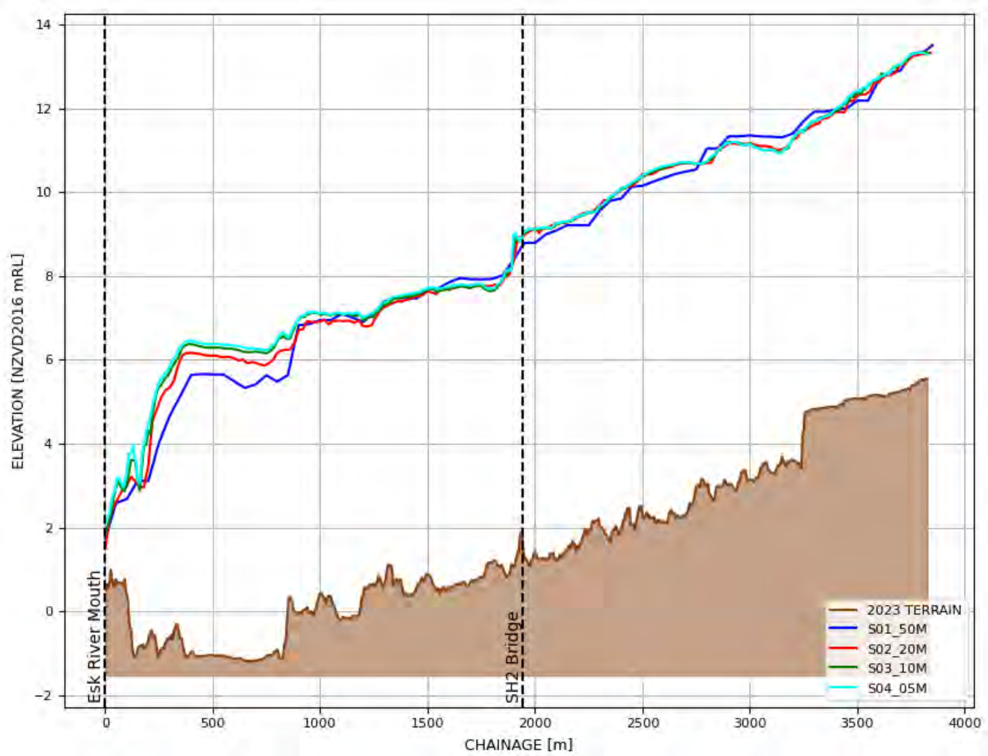

Figure 10: Cell size convergence for the Esk River Hydraulic model, see Figure 2 for location of section line.

6.0 Model sensitivity

Before selecting model design runs, a number of sensitivity assessments were completed. Given the uncertainty associated with the model inputs, where accuracy could not be achieved, a conservative approach has been taken.

For model simulations, the following model scenario tags are employed:

- Model resolution [50, 20, 10 and 5]. This represents the selected cell size and was used to test at what resolution the model converged;
- Upstream flow boundary for the Esk River, designated as the flow applied without climate change. This ranges from 1300 m^3/s to 1800 m^3/s. The range is informed by the estimate of the 1% AEP design event (section 3.0);
- Model DEM, [2023-DEM and 2021-DEM], the LIDAR employed for the model, 2023 was captured post Gabrielle;
- Mouth condition [Closed-Mouth, Open-Mouth and Natural-Mouth]. These were provided by T+T[9] and represent a closed mouth condition, an engineered open mouth condition and a natural mouth condition;
- Four tail water scenarios were investigated as described in Section 4.1.2:
  - 2020, 1% storm surge event with existing climate conditions;
  - 2100-p50, 1% storm surge event with 2100 climate conditions representing the 50th percentile of the SSP5-8.5 scenario, "business as usual";
  - 2130-p50, 1% storm surge event with 2130 climate conditions representing the 50th percentile of the SSP5-8.5 scenario, "business as usual"; and.
  - 2130-p83, 1% storm surge event with 2130 climate conditions representing the 83rd percentile of the SSP5-8.5 scenario, "business as usual";
- All models have been run with the stopbanks included (See Figure 2for delineation of stopbanks).

6.1 Sensitivity to coastal boundary assumption

The sensitivity of the 1% AEP model to the downstream coastal boundary was tested by using the four water level boundaries provided by T+T and holding other model parameters constant. The model runs are provided in Table 5, a flow of 1300 m^3/s was selected for the 1% AEP event which gives a modelled flow

[9] Eddie Beetham (T+T) to Ramon Strong (PDP) via email on 14 Aug 2023 and an update open mouth condition provided 29 Aug 2023

of 1820 m^3/s allowing for climate change. The lower bound flow estimate for the 1% AEP event was selected as a lower flow should be more sensitive to changes in the downstream boundary.

Figure 11 shows the effect of this change in model assumption. A localised effect at the boundary is observed, however, any differences have completely dissipated within 500 m of the coastal boundary.

Table 5: Model runs to determine sensitivity to coastal boundary condition

	FLOW	SEA LEVEL	CELL SIZE	DEM	MOUTH	SB
S05_2020	1300	2020	5	2023-DEM	Natural-Mouth	SB-ALL
S06_2100_P50	1300	2100-p50	5	2023-DEM	Natural-Mouth	SB-ALL
S07_2130_P50	1300	2130-p50	5	2023-DEM	Natural-Mouth	SB-ALL
S08_2130_P83	1300	2130-p83	5	2023-DEM	Natural-Mouth	SB-ALL

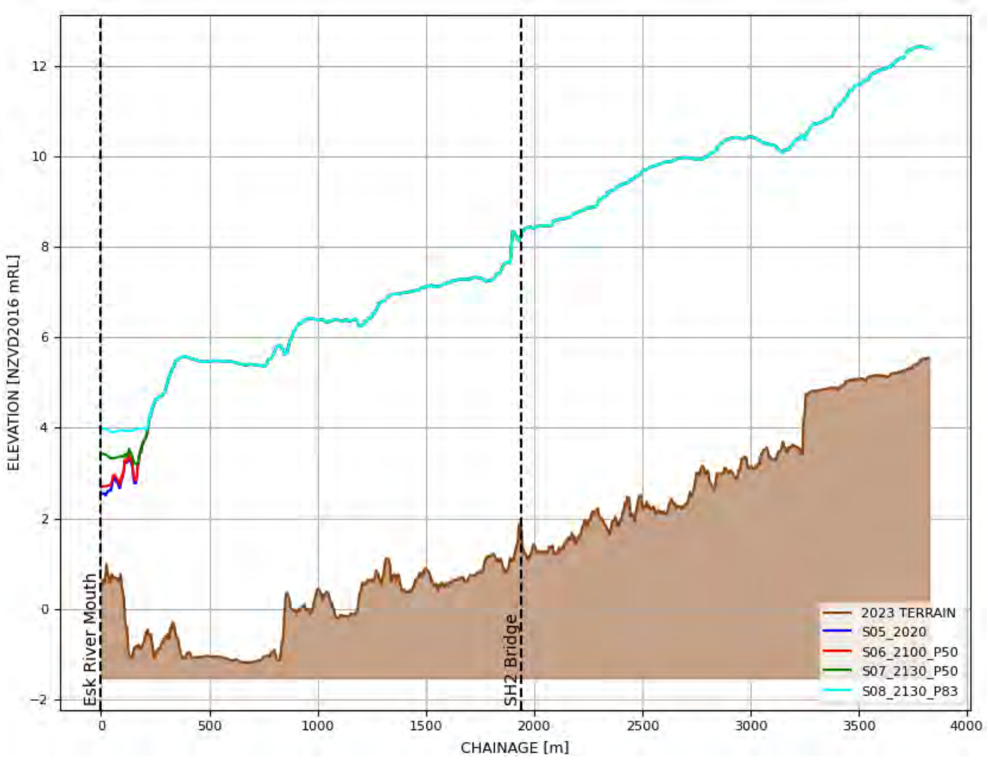

Figure 11: Sensitivity of the 1% AEP flood event to the coastal boundary condition

6.2 Sensitivity to Esk River mouth assumption

The sensitivity of the 1% AEP model to the assumed downstream mouth conditions was also tested using the files provided by T+T. For further details of the mouth scenario, refer to T+T 2023. Interrogation of the mouth scenarios show:

- The revised open mouth scenario (v2) is considerably smaller than the original open mouth (V1) scenario. The size of the opening has been decreased to reflect what could be realistically achieved with an excavator;
- The natural mouth scenario has the largest cross sectional area and the closed mouth scenario has the smallest, although it is not dissimilar to the open mouth V2 scenario.

The model runs are provided in Table 6 a flow of 1300 m³/s was selected for the 1% AEP event which gives a modelled flow of 1820 m³/s allowing for climate change. A low flow estimate for the 1% AEP event was selected as a lower flow should be more sensitive to changes in the downstream boundary.

Figure 12 shows the effect of this change in model assumption. A localised effect at the boundary is observed, however, any differences have largely dissipated within 1500 m of the coastal boundary. At around 500 m from the coastal boundary the decrease in water level for the:

- natural mouth scenario compared to the closed mouth scenario is 100 mm; and,
- open mouth (V2) scenario compared to the closed mouth scenario is 200 mm.

We note that this model does not account for geomorphic changes dues to erosion of the gravel embankment which could reasonably be expected to occur over a large flood event which would widen the opening and alleviate flooding. Further work should be considered to provide additional quantification of this mechanism although model results appear to be largely insensitive to this parameter.

Table 6: Model runs to determine sensitivity to Esk River mouth condition

	1% AEP FLOW	SEA LEVEL	CELL SIZE	DEM	MOUTH	SB
S09_Closed_Mouth	1300	2020	5	2023-DEM	Closed-Mouth	SB-ALL
S10_Open_Mouth	1300	2020	5	2023-DEM	Open-Mouth	SB-ALL
S11_Natural_Mouth	1300	2020	5	2023-DEM	Natural-Mouth	SB-ALL

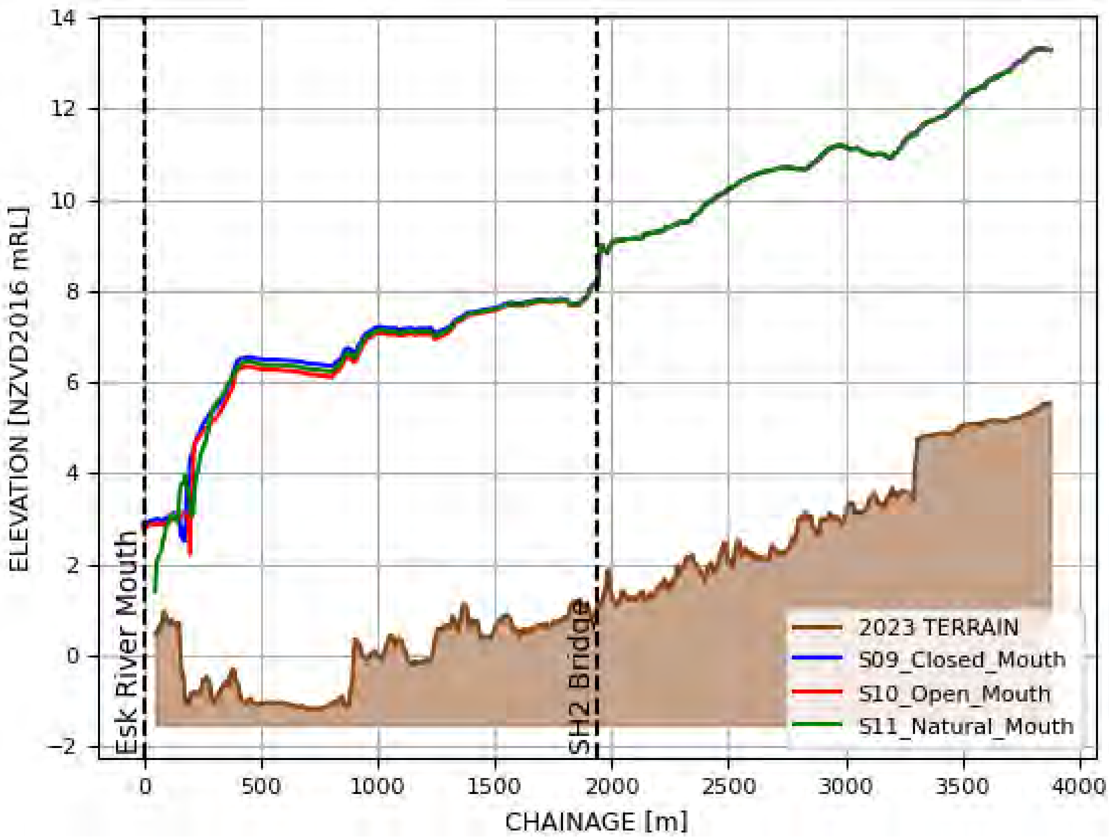

Figure 12: Sensitivity of the 1% AEP flood event to the Esk River mouth condition

6.3 Conclusion for sensitivity models

The model results show that for the 1% AEP flood event, the stopbank design is unlikely to be sensitive to sea level rise scenarios. Downstream of the bridge, the mouth scenario could affect the predicted water levels by around 200 mm.

For design runs, the 2130-p50 scenario was selected with a natural mouth condition.

7.0 Model design runs

Given the uncertainty associated with both the effects of climate change on the flow in the Esk River and the uncertainty associated with the 1% AEP design flood estimate, a suite of flows has been assessed to determine the impact it has on the design parameters (stopbank crest). Not all models are reported on. Note that the flows presented are the design flows from the flood frequency assessment and the actually modelled flow was increased by 40% to account for climate change out to 2130.

Table 7: Pre base case model runs

	1% AEP FLOW	SEA LEVEL	CELL SIZE	DEM	MOUTH	STOPBANKS
P01_1300_2130-p50	1300	2130-p50	5	2023-DEM	Natural-Mouth	SB-NO
P02_1800_2130-p50	1400	2130-p50	5	2023-DEM	Natural-Mouth	SB-NO
P03_1500_2130-p50	1500	2130-p50	5	2023-DEM	Natural-Mouth	SB-NO
P04_1600_2130-p50	1600	2130-p50	5	2023-DEM	Natural-Mouth	SB-NO
P05_1700_2130-p50	1700	2130-p50	5	2023-DEM	Natural-Mouth	SB-NO
P06_1800_2130-p50	1800	2130-p50	5	2023-DEM	Natural-Mouth	SB-NO

Table 8: Base case model runs

	1% AEP FLOW	SEA LEVEL	CELL SIZE	DEM	MOUTH	STOPBANKS
D01_1300_2130-p50	1300	2130-p50	5	2023-DEM	Natural-Mouth	SB-ALL
D02_1400_2130-p50	1400	2130-p50	5	2023-DEM	Natural-Mouth	SB-ALL
D03_1500_2130-p50	1500	2130-p50	5	2023-DEM	Natural-Mouth	SB-ALL
D04_1600_2130-p50	1600	2130-p50	5	2023-DEM	Natural-Mouth	SB-ALL
D05_1700_2130-p50	1700	2130-p50	5	2023-DEM	Natural-Mouth	SB-ALL
D06_1800_2130-p50	1800	2130-p50	5	2023-DEM	Natural-Mouth	SB-ALL

Figure A1 and Figure A2, appendix A shows the maximum flood depths for the pre base case and post base case 1% AEP events (P06_1800_2130-p50 and D06_1800_2130-p50 respectively). Figure A1 shows that without any additional flood control and/or mitigation such as stop banks, the industrial properties and Pohutukawa Drive will likely be inundated in the 1% AEP event.

Figure 13 shows a long section of the maximum flood levels for the same events.

Figure A2 shows that flooding can be contained by the stopbanks (Base Case and Base Case +), assuming they are built to a suitable height. Flood depths are over 2 m within the Esk River channel and typically less than this elsewhere. Figure 14 shows that there are two key hydraulic constraints to this model:

- At chainage 300 to 400, the hydraulic grade is relatively steep indicating a control point. This location is at the river/beach interface and shows the increase in hydraulic head required to push flow through the mouth and over the beach embankment; and,
- At the SH2 bridge, there is a second steep increase in hydraulic grade which is required to drive flow through the constricted aperture formed by the SH2 bridge.

Therefore, levels immediately upstream of the SH2 bridge will largely be controlled by the bridge itself and the elevation of the highway which acts as an embankment.

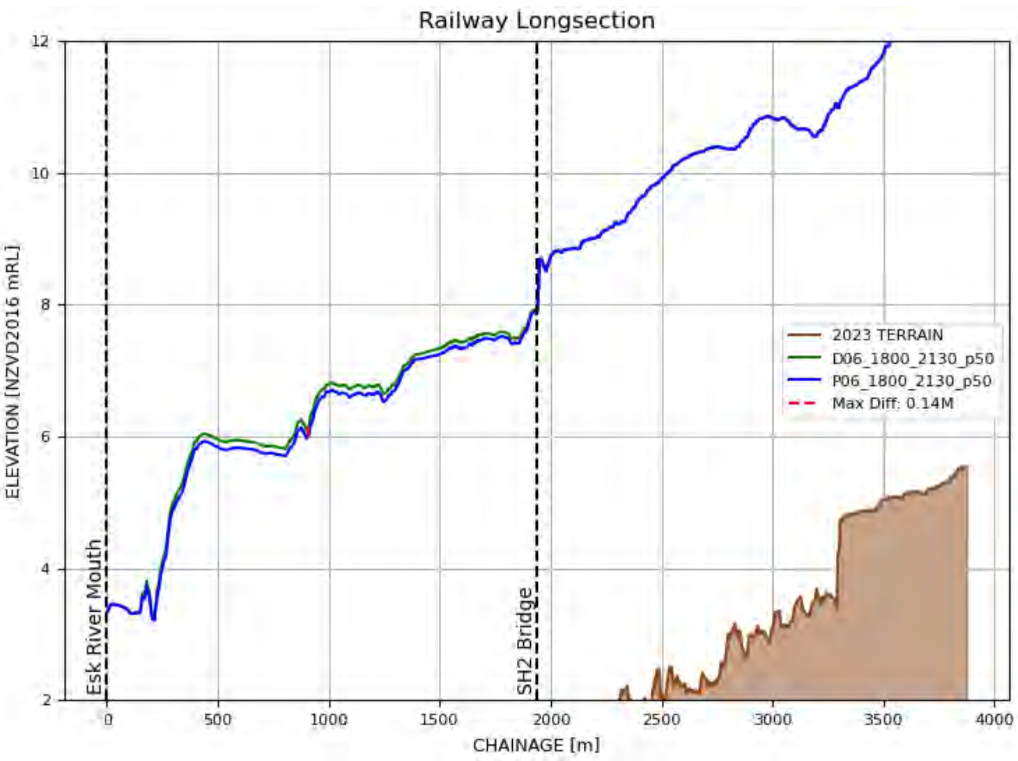

Figure 13: Maximum flood elevation within Esk River for the 1% AEP event with climate change for the pre and post base case scenarios. Maximum difference in flood elevations is 140 mm.

Figure 14 and Figure 15 show the maximum flood levels along the Whirinaki Drain and southern stopbanks for the 1% AEP design flood event with climate change. The full range of 1% AEP events is presented with the lower and upper flow estimate.

For the selected 1% AEP estimate, the maximum flood levels in Whirinaki Drain are:

- 8 mRL upstream of the SH2 to Pan Pac;
- Between 7 mRL and 8 mRL from Pohutukawa Drive to SH2; and,
- Between 6 mRL and 7 mRL from the coast to Pohutukawa Drive.

From the 2023 LIDAR series, the existing stopbank upstream of the SH2 appears to have an elevation of 8.0 mRL although we note that LIDAR often underestimates heights of features like embankments and therefore this should be confirmed via survey.

For the southern stopbank, the maximum flood levels are approximately 7.0 mRL. From the 2023 LIDAR series, the rail embankment appears to have an elevation of 7.4 mRL although we note that LIDAR often underestimates heights of features like embankments and therefore this should be confirmed via survey.

We also note that the southern stopbank (B5) may need to be extended all the way to SH2. The 2023 LIDAR shows the railway height from B5 to SH2 as at or just above the 1% AEP flood level, but LIDAR often underestimates crest heights and as noted above, a survey should be undertaken to confirm this critical height. In any case, the railway line is very unlikely to have 500 mm freeboard in the design flood event (1% AEP + climate change) and if this design standard needs to be achieved across the catchment then the stopbank will need to extend to the highway. If the rail just needs to be above the flood level then the truncated stopbank options shown in Figure 2 may suffice.

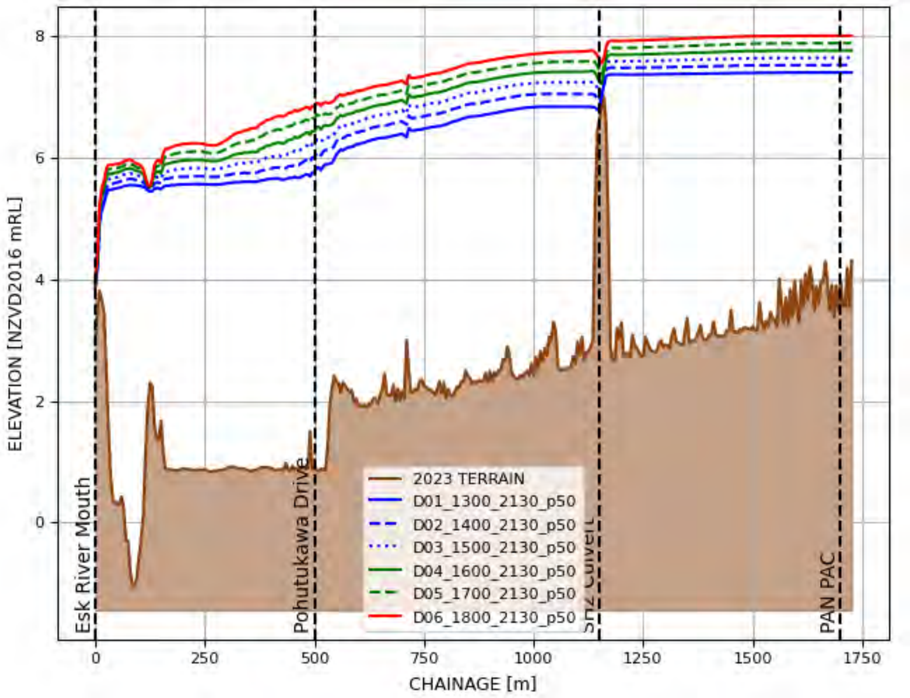

Figure 14: Maximum flood levels for the base case 1% AEP flood event with climate change for the Whirinaki Drain stopbanks

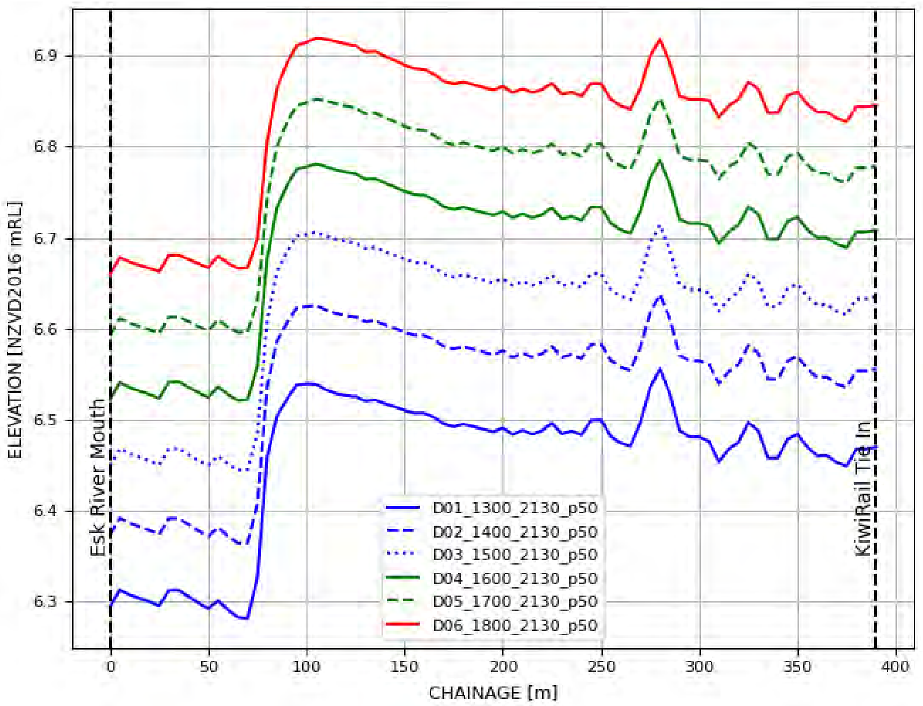

Figure 15: Maximum flood levels for the base case 1% AEP flood event with climate change for the southern stopbank

8.0 Effects on flooding for the proposed base case scenario

The effects on flooding for the proposed base case scenario is presented in Figure A3, Appendix A. This figure is created by subtracting the flood elevations from the pre base case scenario (P06_1800_2130-p50) from the post base case scenario (D06_1800_2130-p50). This gives the change in flood level for the 1% AEP event, with climate change. Note that differences in the flood elevation of less than 1 mm are not shown on the figure.

Figure A3 shows:

- Flood levels will decrease behind the stopbanks protecting Pohutukuawa Drive, North Shore Road, the industrial sites and Bay View;
- Increases in flood levels, in excess of 100 mm are expected adjacent to proposed stopbanks and close to the river mouth;
- Upstream of the SH2, the increase in flooding is expected to be less than 100 mm; and,
- Further up the Esk Valley, the difference in flood elevation is expected to be less than 1 mm.

8.1 Effects on rail and SH5

Figure A3, Appendix A shows that the flood effects on SH5 and the section of rail which is located upstream of the SH2 bridge will be:

- generally less than 1 mm; and,
- less than 20 mm closer to the intersection with SH2.

This effect is considered less than minor.

For the rail located between the SH2 bridge and the river mouth, the proposed stopbank along the southern (true right) bank of the Esk River will provide protection from flooding and therefore the effect is considered positive.

8.2 Effects on SH2

The effects of flooding on SH2 as a result of the proposed base case scenario are presented in Figure 16. This figure shows:

- the maximum flood levels along SH2 for both modelled scenarios (with and without the base case);
- flooding is constrained by the proposed stopbank along Whirinaki Drain and this constriction elevates flood levels over the remaining length of SH2 (between the Whirinaki Drain and the Esk River);

- The maximum flood depth on SH2 (without the base case scenario) is 950 mm and the maximum flood depth (with the base case scenario) is 1300 mm, an increase of 350 mm; and,
- The maximum increase in flood depth over SH2 is around 500 mm.

Preliminary conversations with representatives from TREC (Transport Rebuild East Coast) indicated that this level of effect was unlikely to be supported.

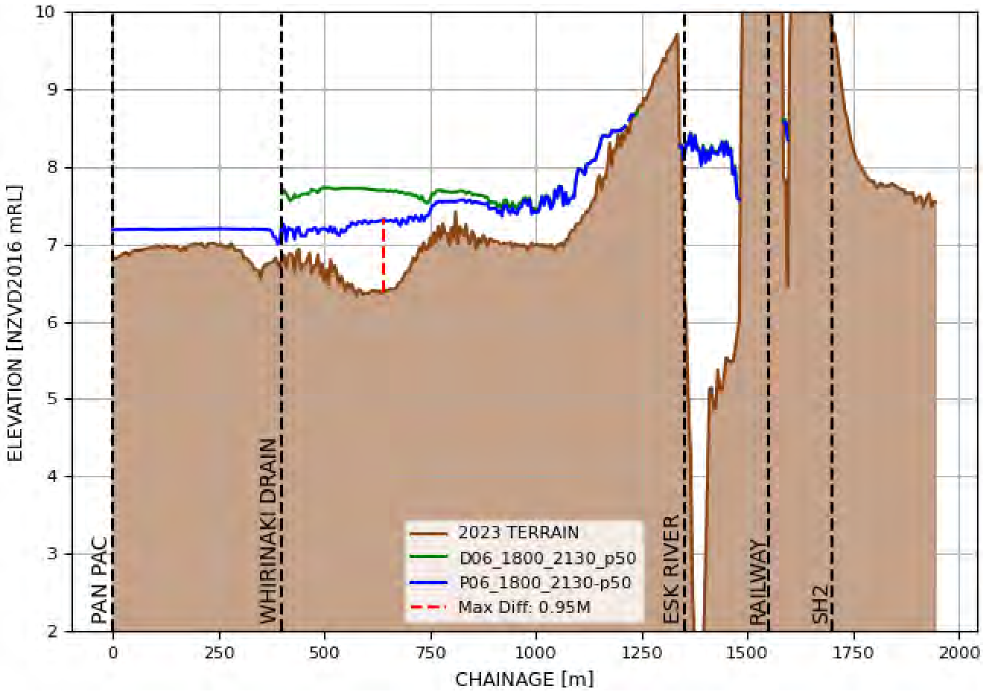

Figure 16: Maximum flood levels with (D06_1800_2130_p50) and without (P06_1800_2130_p50) the base case scenario for a 1% AEP flood event with climate change

Further modelling work has been undertaken to determine if the effects on SH2 can be reduced by reconfiguring the SH2 road surface. Figure 17 shows that if the SH2 road surface is set to a nominal height of 7.0 mRL (NZVD 2016) the maximum flood depth for the base case scenario will be 830 mm, less than the maximum flood depth for the existing (no base case) scenario which as shown in Figure 16, is 950 mm.

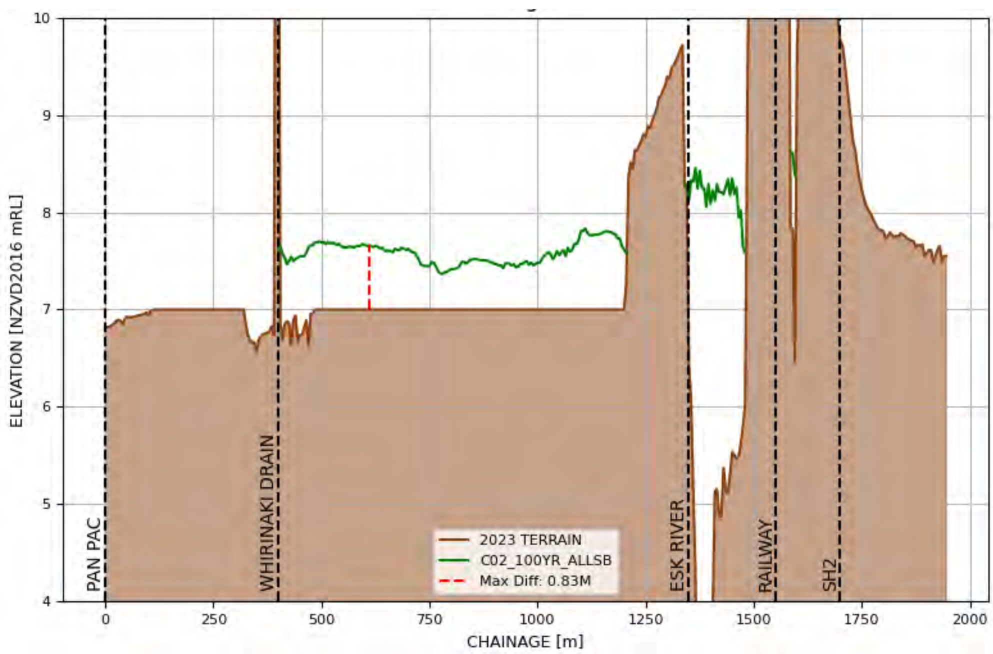

Figure 17: Maximum flood levels with SH2 set to an elevation of 7.0 mRL and the base case scenario.

To more fully explore the predicted effects on SH2, a number of additional model runs were completed. These included the 0.5% AEP, 1% AEP,2% AEP, 5% AEP and 10% AEP events both with and without the base case. The purpose of running these additional model scenarios was to determine the effects of the base case on SH2 by considering the length of closure which was determined by calculating the duration that a given flood depth was exceeded.

Three flood depths were selected for this assessment:

- 100 mm, the depth at which the AA recommends not driving through;
- 300 mm, the limiting still water depth for small passenger vehicles, from Austroads; and,
- 500 mm, the limiting still water depth for large vehicles, such as emergency vehicles (Austroads).

Table 9 shows the duration of inundation above a given depth with and without the base case. For all modelled scenarios, the duration of inundation decreases with the base case scenario and therefore, we conclude that if the SH2 is set to a nominal elevation of 7.0 mRL, the base case scenario will not have an adverse effect on the serviceability of SH2. That is, the serviceability in terms of closures is predicted to be similar to the current serviceability of SH2.

We note that the duration of flooding will be dependent on the shape of the hydrograph, for all model runs reported on, the design flows were scaled to a Gabrielle shape hydrograph. Furthermore, silt deposition in a large flood event, such as Gabrielle, may result in an extended closure of the highway.

Table 9: Duration (hours) that depth over SH2 is greater than…

	Depth > 500 mm		Depth > 300 mm		Depth > 100 mm	
	Existing	Base case	Existing	Base case	Existing	Base case
0.5% AEP	15.25 hrs	15 hrs	17	16.5 hrs	17.5	17.5 hrs
1% AEP	12.25 hrs	11.75 hrs	14.5	14.25 hrs	15.5	15.5 hrs
2% AEP	5.5 hrs	4.75 hrs	12	10.5 hrs	13.5	13.5 hrs
5% AEP	0 hrs	0 hrs	0	0 hrs	10.25	5.5 hrs
10% AEP	0 hrs	0 hrs	0	0 hrs	0	0 hrs
INCREASE	NO CHANGE	DECREASE				

Noting that the duration of flooding will be dependent on the shape of the hydrograph, for all model runs reported on, the design flows were scaled to a Gabrielle shape hydrograph.

9.0 Further design considerations for the stopbanks

The following is a list of considerations for the proposed stopbanks that will need to be addressed at or prior to the detailed design stage:

- The Whirinaki Drain stopbanks will need to tie in with SH2 to ensure a continuous crest height;
- There will need to be a nominal set back from the edge of the Whirinaki Drain. The Base Case and Base Case+ includes improvements to the Whirinaki Drain and downstream of the State Highway and larger culverts. This will be the subject of further modelling exercise;
- There is an old pa site and urupa off the end of Pohutakawa Drive and the earthworks will need to be well clear of that;
- A revetment may be required where the Whirinaki stopbank is adjacent to the large scour hole at the downstream end of the Whirinaki Drain (the last bend in alignment shown at toward the southern end of the stopbank).

10.0 Recommendations

This model still has some assumptions which have a high degree of uncertainty. The following work must be completed before the predictions made by this model are useful for detailed design of stopbanks:

- The estimation of the 1% AEP has a high degree of uncertainty, further work must be completed to refine this estimate;
- The 40% increase to allow for climate change should be further justified;
- We recommend that this model and its assumptions are independently peer reviewed prior to the detailed design stage;
- Further model sensitivity tests are recommended, including sensitivity to Mannings roughness;
- The railway line should be surveyed to confirm the extent of the southern stopbank (B5);
- The residual risk of stopbank failure should be considered and the effects on flood levels of building the stopbanks compared to the status quo;
- Optimisation of culverts beneath SH2 on Whirinaki Drain and associated changes to SH2 should be investigated; and,
- Other mitigation measures can also be considered, including the debris fence, Esk River realignment and improvement of hydraulic capacity for the SH2 bridge.

11.0 Conclusions

Whilst some further work is required to finalise the flood levels for the 1% AEP design event, the interim result indicate that the maximum flood levels in Whirinaki Drain are:

- 8 mRL upstream of the SH2 to Pan Pac;
- Between 7 mRL and 8 mRL from Pohutukawa Drive to SH2; and,
- Between 6 mRL and 7 mRL from the coast to Pohutukawa Drive.

From the 2023 LIDAR series, the existing stopbank upstream of the SH2 appears to have an elevation of 8.0 mRL although we note that LIDAR often underestimates heights of features like embankments and therefore this should be confirmed via survey.

For the southern stopbank, the maximum flood levels are approximately 7.0 mRL. From the 2023 LIDAR series, the rail embankment appears to have an elevation of 7.4 mRL although we note that LIDAR often underestimates heights of features like embankments and therefore this should be confirmed via survey.

A freeboard of 0.5m should be applied to these flood levels.

The modelling shows that if the stopbanks can be built to the design standard (1% AEP flood with climate change) then flooding will be contained as shown on Figure A1, Appendix A. This will provide protection to Pohutukawa Drive, North Shore Road and the Whirinaki industrial area for up to the 1% AEP flood event (with climate change). As noted in Section 9.0, whilst the modelling shows that this will provide the desired protection, further work is recommended to determine the feasibility of the proposed stopbank heights.

The effects on flooding for the proposed base case scenario (compared to the existing/no base case scenario) are:

- Flood levels will decrease behind the stopbanks, Pohutukuawa Drive, North Shore Road, the industrial sites, and Bay View;
- Increases in flood levels, in excess of 100 mm are expected adjacent to proposed stopbanks and close to the river mouth;
- Upstream of the SH2, the increase in flooding is expected to be less than 100 mm; and,
- Further up the Esk Valley, the difference in flood elevation is expected to be less than 1 mm;
- For rail and SH5, the effects are expected be minimal; and,
- For SH2, if the road surface is set to 7.0 mRL, then there is expected to be no change in the serviceability of this infrastructure with regard to closure times.

In conclusion, the proposed engineering solution (the base case+ scenario) consisting of the existing Whirinaki stopbank (with appropriate freeboard allowance), new stopbanks adjacent to Pohutukawa Drive and on the southern side of the Esk River at Bayview, along with the proposed river and coastal maintenance and culvert /drain improvements, and with the SH2 road surface set to 7.0 mRL, the effects on flooding are considered less than minor.

12.0 References

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Software (FOSS)

- Figures created in QGIS 3.22
- Python 3.9 including the numpy, pandas, matplotlib and scipy modules.

Appendix A: Flood Maps

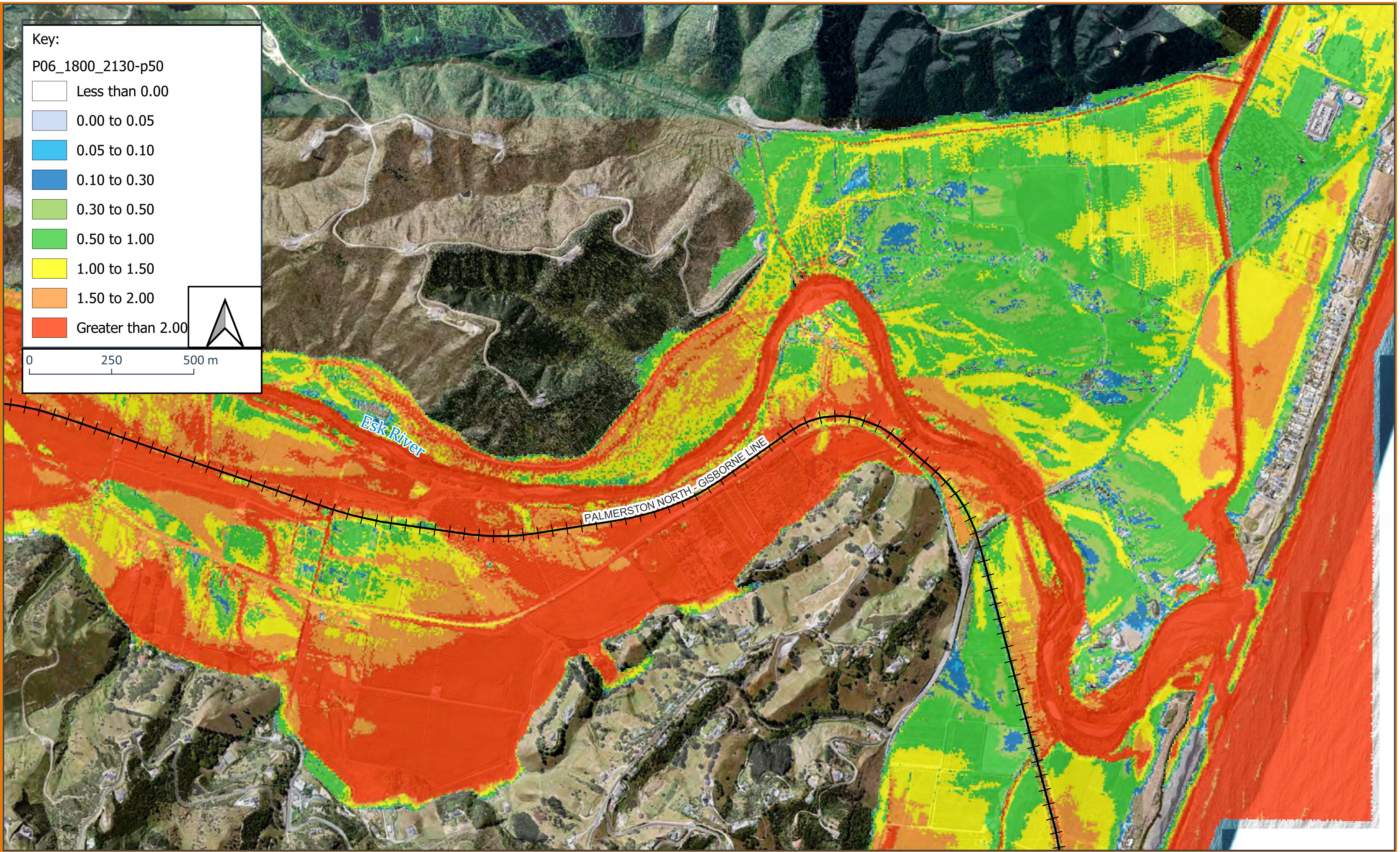

FIGURE A2: MAXIMUM FLOOD DEPTHS FOR PRE DEVELOPMENT 1% AEP FLOOD EVENT WITH CLIMATE CHANGE (P06_1800_2130-p50)

ESK RIVER HYDRAULIC MODEL

NOTES:
1. AERIAL IMAGERY SOURCED FROM THE LINZ DATA SERVICE [https://data.linz.govt.nz] AND LICENCED BY LINZ FOR RE-USE UNDER THE CREATIVE COMMONS ATTRIBUTION 4.0 INTERNATIONAL LICENCE.

KILOMETRES

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CLIENT: HBRC

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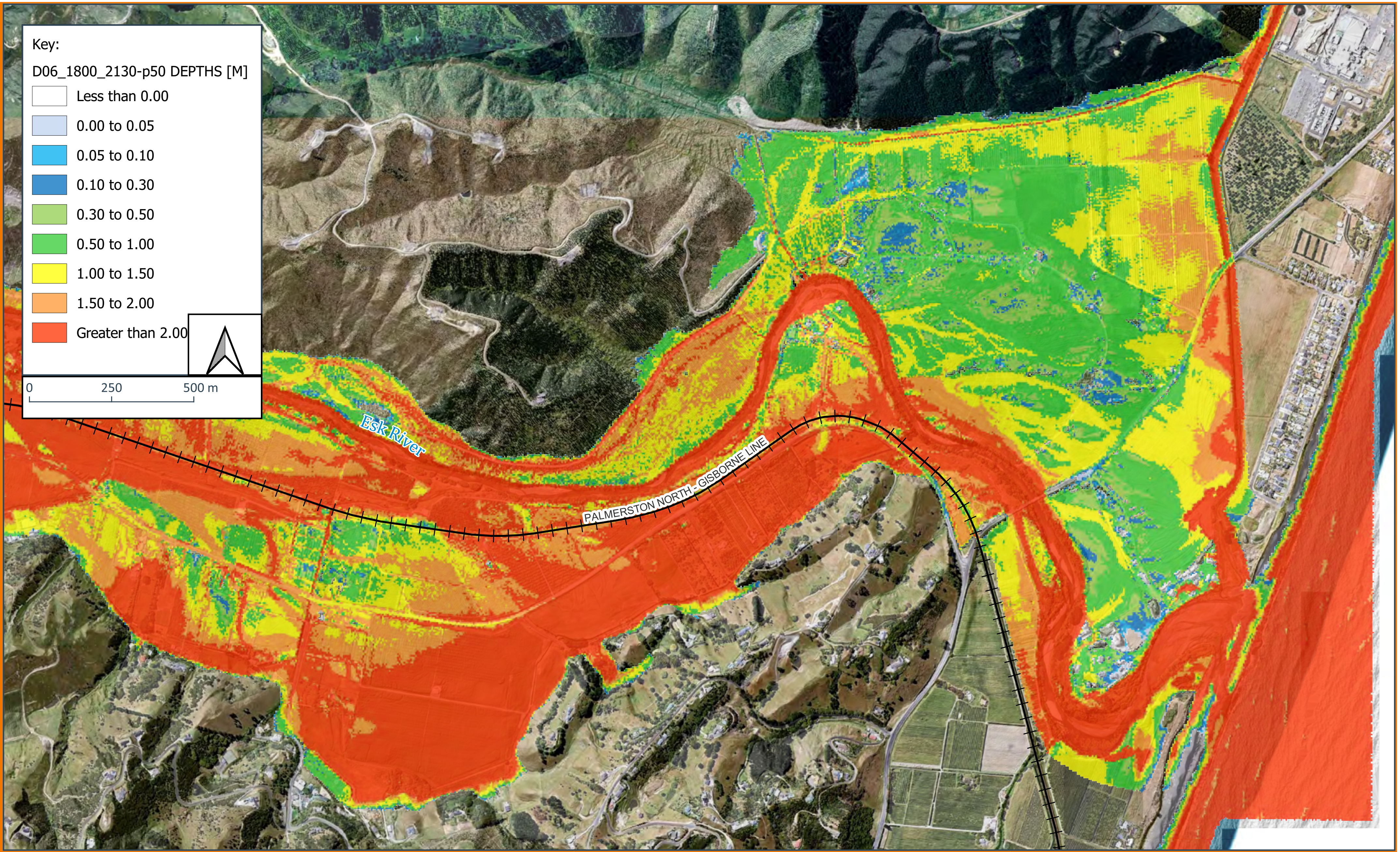

FIGURE A2: MAXIMUM FLOOD DEPTHS FOR POST DEVELOPMENT 1% AEP FLOOD EVENT WITH CLIMATE CHANGE (D06_1800_2130-p50)

ESK RIVER HYDRAULIC MODEL

NOTES:
1. AERIAL IMAGERY SOURCED FROM THE LINZ DATA SERVICE [https://data.linz.govt.nz] AND LICENCED BY LINZ FOR RE-USE UNDER THE CREATIVE COMMONS ATTRIBUTION 4.0 INTERNATIONAL LICENCE.

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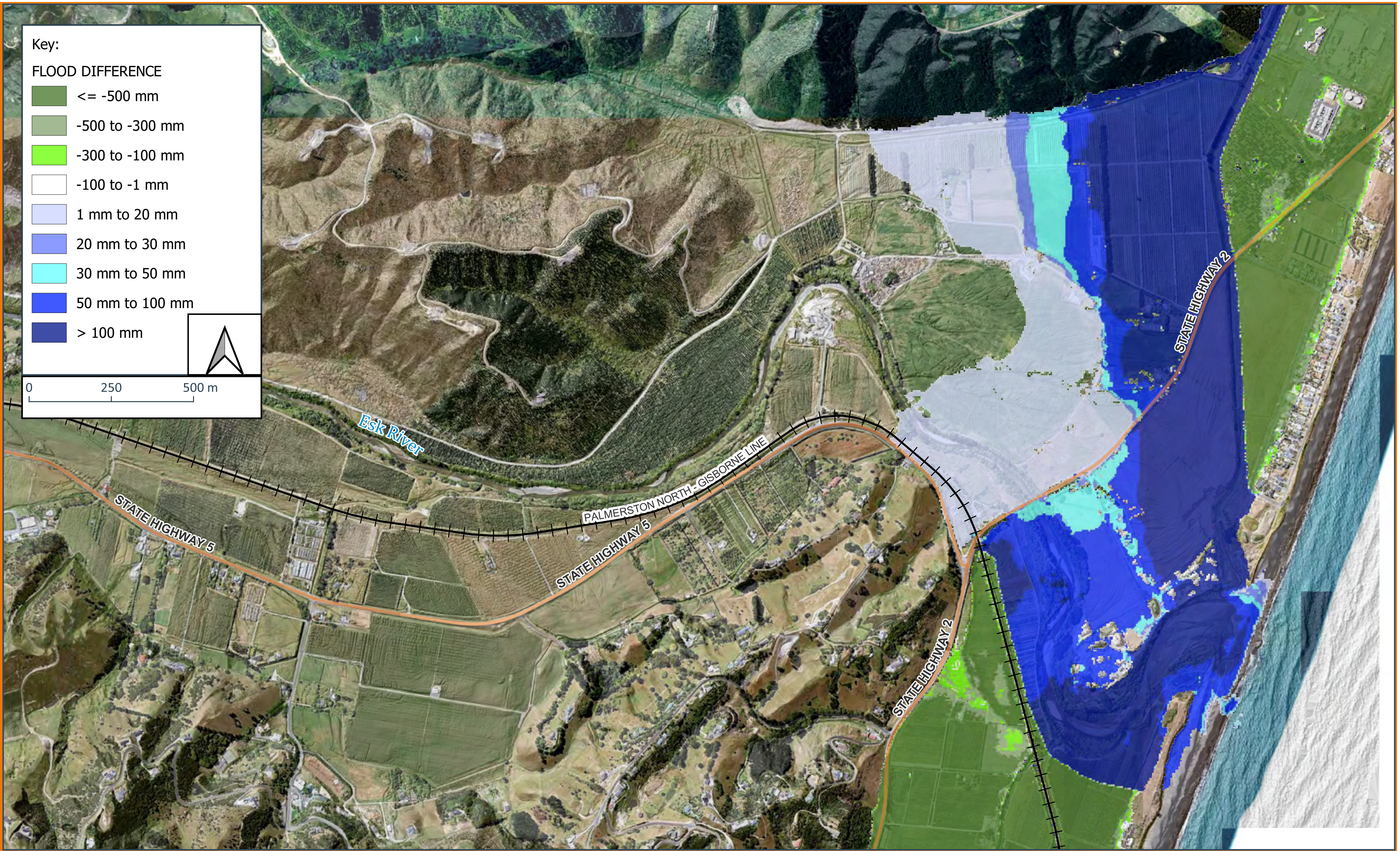

FIGURE A3: FLOOD DIFFERENCES BETWEEN THE BASE CASE AND PRE BASE CASE SCENARIO FOR THE 1% AEP FLOOD EVENT WITH CLIMATE CHANGE

ESK RIVER HYDRAULIC MODEL

NOTES:
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DO NOT SCALE DRAWING

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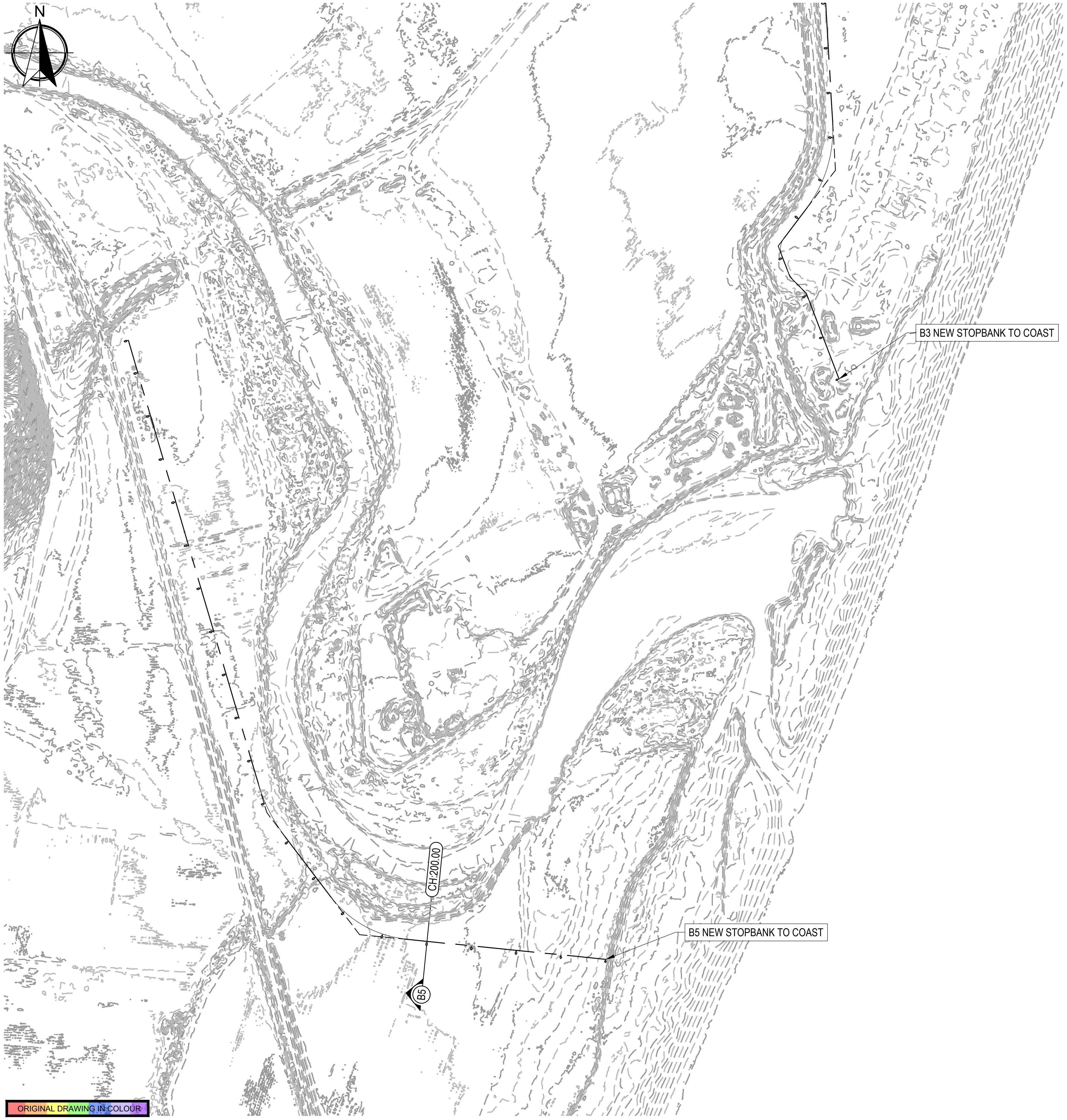

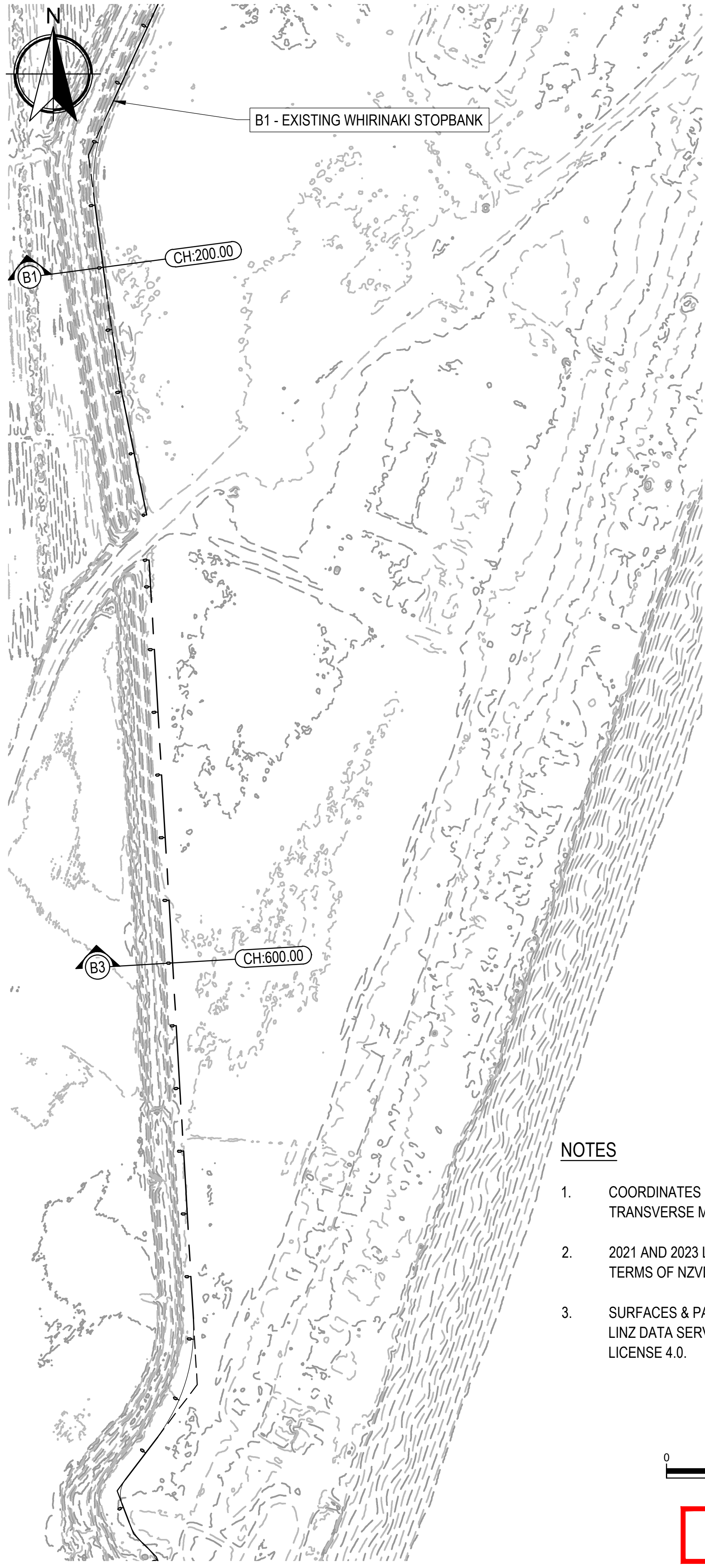

NOTES

1. COORDINATES IN TERMS OF NEW ZEALAND TRANSVERSE MERCATOR PROJECTION (NZTM).
2. 2021 AND 2023 LIDAR SURFACE DATA LEVELS ARE IN TERMS OF NZVD2016.
3. SURFACES & PARCEL BOUNDARIES SOURCED FROM LINZ DATA SERVICE UNDER CREATIVE COMMONS LICENSE 4.0.

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SCALE 1:5,000 (A3)

PRELIMINARY

NO.	REVISION	DATE	APP.
A	FOR INFORMATION	14.09.23	

HAWKES BAY REGIONAL COUNCIL
TE KAUNIHERA Ā-ROHE O TE MATAU-A-MĀUI

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BT				
DRAWN	DRAWING CHECK	DATE	THIS DRAWING IS NOT FOR CONSTRUCTION UNLESS SIGNED AS APPROVED	
BM		14.09.23		

ESK RIVER WHIRINAKI DRAIN STOPBANK
LAOUT PLAN

SCALE : AS SHOWN (A3)

DRAWING NO. : HB01037300-CI-001-CONCEPT-DE

REV :

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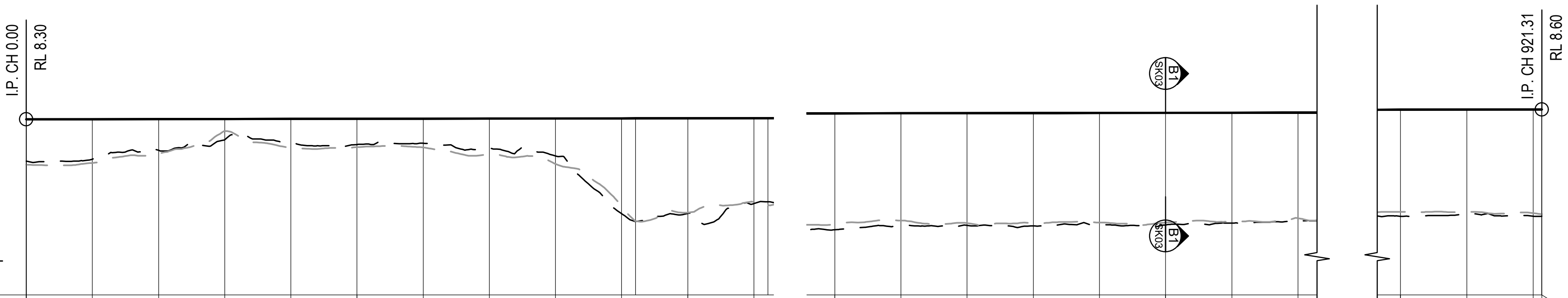
NOTES

1. 2021 AND 2023 LIDAR SURFACE DATA LEVELS IN TERMS OF NZVD2016.

HA.DATUM 5m RL

CHAINAGE (m)	0.00	10.00	20.00	30.00	40.00	50.00	60.00	70.00	80.00	90.00	96.54	100.00	109.35	110.00	120.00	130.00	139.27	140.00	150.00	160.00	170.00	180.00	183.37	190.00	200.00	210.00	220.00	230.00	390.00	400.00	410.00	420.00	421.59
EXISTING GROUND LEVEL (m RL)	6.88	7.50	7.73	7.51	6.97	7.64	7.50	7.60	7.71	7.96	7.59	8.06	7.96	7.96	7.94	7.98	7.97	7.96	8.11	8.10	8.06	7.93	7.94	7.86	7.83	7.86	7.75	7.84	7.87	7.86	8.07	7.84	7.87
PROPOSED DESIGN LEVELS (m RL)	6.88	7.50	7.73	7.51	6.97	7.64	7.50	7.60	7.71	7.96	7.59	8.06	7.96	7.96	7.94	7.98	7.97	7.96	8.11	8.10	8.06	7.93	7.94	7.86	7.83	7.86	7.75	7.84	7.87	7.86	8.07	7.84	7.87
DEPTH (m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

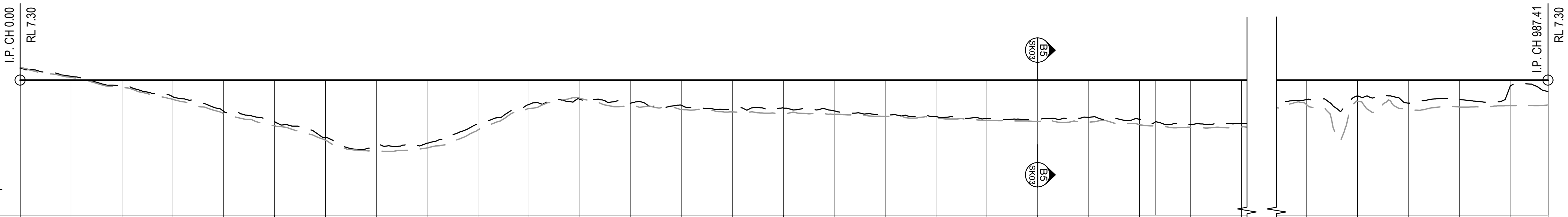
B1 LONG SECTION



H.A DATUM 3.0m RL
VERT EXAG 1:5

CHAINAGE (m)	0.00	10.00	20.00	30.00	40.00	50.00	60.00	70.00	80.00	90.00		100.00	110.00	[illegible]	550.00	560.00	570.00	580.00	590.00	600.00	610.00	620.00	900.00	910.00	920.00	921.31
EXISTING GROUND LEVEL (m RL)	6.93	6.99	7.28	7.94	7.44	7.46	7.45	7.24	6.95	5.68	5.23	5.49	5.81	5.71	5.13	5.24	5.17	5.16	5.19	5.18	5.22	5.31	5.50	5.51	5.47	5.44
PROPOSED DESIGN LEVELS (m RL)	8.30	8.30	8.31	8.31	8.31	8.32	8.32	8.32	8.33	8.33	8.33	8.33	8.34	8.34	8.48	8.48	8.49	8.49	8.49	8.50	8.50	8.50	8.59	8.60	8.60	8.60
DEPTH (m)	1.37	1.32	1.03	0.37	0.87	0.86	0.87	1.08	1.37	2.65	3.10	2.84	2.52	2.6[illegible]	3.35	3.24	3.32	3.33	3.31	3.31	3.28	3.19	3.09	3.09	3.13	3.16

CL-STOP-BANK-B3 LONG SECTION



H.A DATUM 2.0m RL
VERT EXAG 1:5

CHAINAGE (m)	0.00	10.00	20.00	30.00	40.00	50.00	60.00	70.00	80.00	90.00	100.00	110.00	120.00	130.00	140.00	150.00	160.00	170.00	180.00	190.00	200.00	210.00	220.00	230.00	240.00	940.00	950.00	960.00	970.00	980.00	987.41
EXISTING GROUND LEVEL (m RL)	7.78	7.41	7.01	6.55	5.98	5.51	4.94	4.52	4.64	5.35	6.18	6.59	6.31	6.14	6.06	5.99	5.96	5.88	5.79	5.72	5.68	5.66	5.55	5.45	5.46	6.34	6.47	6.13	6.25	6.30	6.32
PROPOSED DESIGN LEVELS (m RL)	7.30	7.30	7.30	7.30	7.30	7.30	7.30	7.30	7.30	7.30	7.30	7.30	7.30	7.30	7.30	7.30	7.30	7.30	7.30	7.30	7.30	7.30	7.30	7.30	7.30	7.30	7.30	7.30	7.30	7.30	7.30
DEPTH (m)	-0.48	-0.11	0.29	0.75	1.32	1.79	2.36	2.78	2.66	1.95	1.12	0.71	0.99	1.16	1.24	1.31	1.34	1.42	1.51	1.58	1.62	1.64	1.75	1.85	1.84	0.96	0.83	1.17	1.05	1.00	0.98

CL-STOP-BANK-B5 LONG SECTION

0 10 20m
SCALE 1:500 (A3)

ORIGINAL DRAWING IN COLOUR

NO.	REVISION	DATE	APP.

HAWKES BAY REGIONAL COUNCIL
TE KAUNIHERA Ā-ROHE O TE MATAU-A-MĀUI

PATTLE DELAMORE PARTNERS

ACE MEMBER

CLIENT: HAWKES BAY REGIONAL COUNCIL

PROJECT: ESK WHIRINAKI RESILIENCE PROJECT

ESK RIVER WHIRINAKI DRAIN STOPBANK LONG SECTIONS

DESIGNED	DESIGN REVIEW	DATE	APPROVED	DATE
DRAWN ----	DRAWING CHECK	DATE	THIS DRAWING IS NOT FOR CONSTRUCTION UNLESS SIGNED AS APPROVED	

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DRAWING NO. : HB01037300-SK-001
REV : ----

Plot: 14/09/2023 12:09:04 PM
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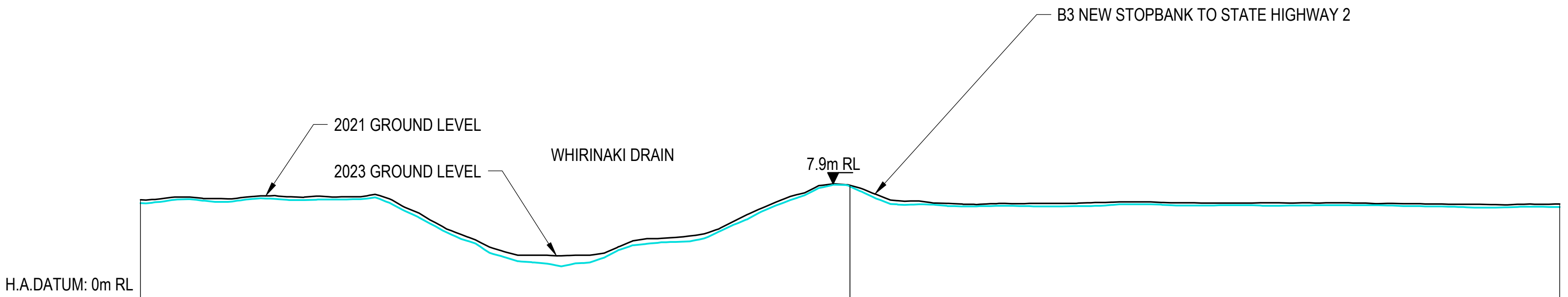

PROPOSED DESIGN LEVELS (m RL)			
EXISTING GROUND LEVELS (m RL)	6.88	7.90	6.59
LEVEL DIFFERENCE (m)	0.000	0.000	0.000
OFFSETS (m)	-50.00	0.00	50.00

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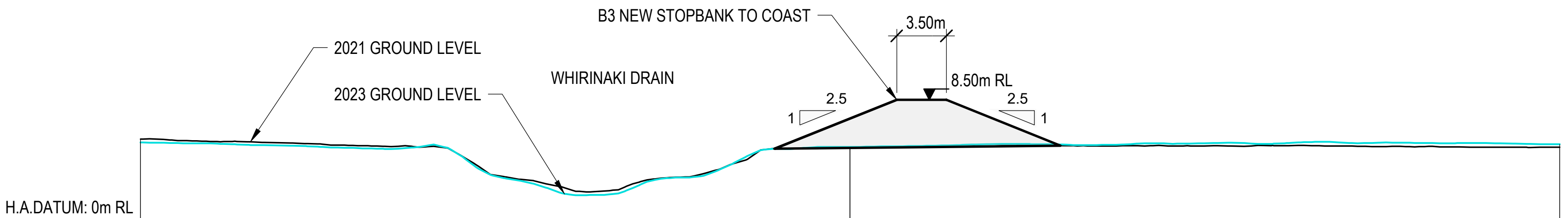
SCALE 1:500



PROPOSED DESIGN LEVELS (m RL)		5.18	
EXISTING GROUND LEVELS (m RL)	5.51	5.18	5.38
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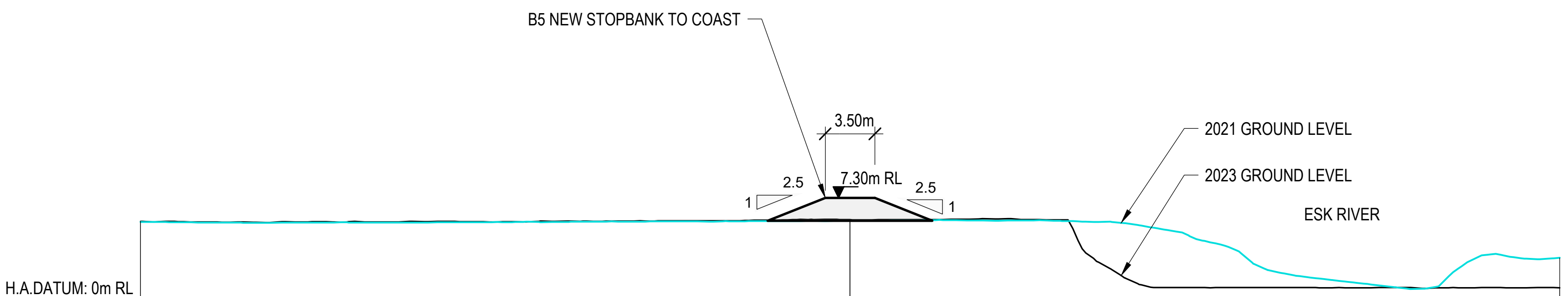
OFFSETS (m)	-50.00	0.00	50.00

XSEC B3 (CH:600)
SCALE 1:500



PROPOSED DESIGN LEVELS (m RL)	5.64	99	0.98
EXISTING GROUND LEVELS (m RL)	5.64	5.76	0.98
LEVEL DIFFERENCE (m)	0.000	0.000	0.000
OFFSETS (m)	-50.00	0.00	50.00

XSEC B5 (CH:200)
SCALE 1:500

NOTES

1. 2021 AND 2023 LIDAR SURFACE DATA LEVELS IN TERMS OF NZVD2016.

0 10 20m
SCALE 1:500 (A3)

PRELIMINARY

ORIGINAL DRAWING IN COLOUR

NO.	REVISION	DATE	APP.
A	FOR INFORMATION	14.09.23	

HAWKES BAY REGIONAL COUNCIL
TE KAUNIHERA Ā-ROHE O TE MATAU-A-MĀUI

PATTLE DELAMORE PARTNERS

ACE MEMBER

CLIENT: HAWKES BAY REGIONAL COUNCIL

PROJECT: ESK WHIRINAKI RESILIENCE PROJECT

DESIGNED	DESIGN REVIEW	DATE	APPROVED	DATE
BT				
DRAWN	DRAWING CHECK	DATE		
BM		14.09.23	THIS DRAWING IS NOT FOR CONSTRUCTION UNLESS SIGNED AS APPROVED	

ESK RIVER, WHIRINAKI DRAIN STOPBANK CROSS SECTIONS

SCALE :	DRAWING NO. :	REV :
AS SHOWN (A3)	HB01037300-SK-003	A

FILED: HB01037300-SK-003.dwg Plot: 14/09/2023 9:49:19 AM

2

APPENDIX 2

T+T Coastal Memo

Memo

To:	Whirinaki Resilience TFG team	Job No:	1090451.1000
From:	Eddie Beetham Richard Reinen-Hamill	Date:	13 September 2023
cc:	HBRC		
Subject:	Coastal input on Category 2A draft report		

1 Coastal and River mouth environment

1.1 Setting

The Esk River mouth is situated in the middle of the Bay View Littoral cell, which is a a coastal compartment that extends approximately 18 km from Bluff Hill (Scinde Island) in the city of Napier to the south to Tangoio Bluff to the north (Figure 1-1). The shoreline is characterised by a gravel barrier beache, with a mean grain size of 2-3 mm. A secondary component of sand is also present on the beaches, resulting in a mixed sand-gravel morphology. The only present-day natural source of additional gravel is the Esk River. Sediment supply from the Esk is believed to provide only small quantities of sands and fine gravels to the beach (Komar and Harris, 2014).

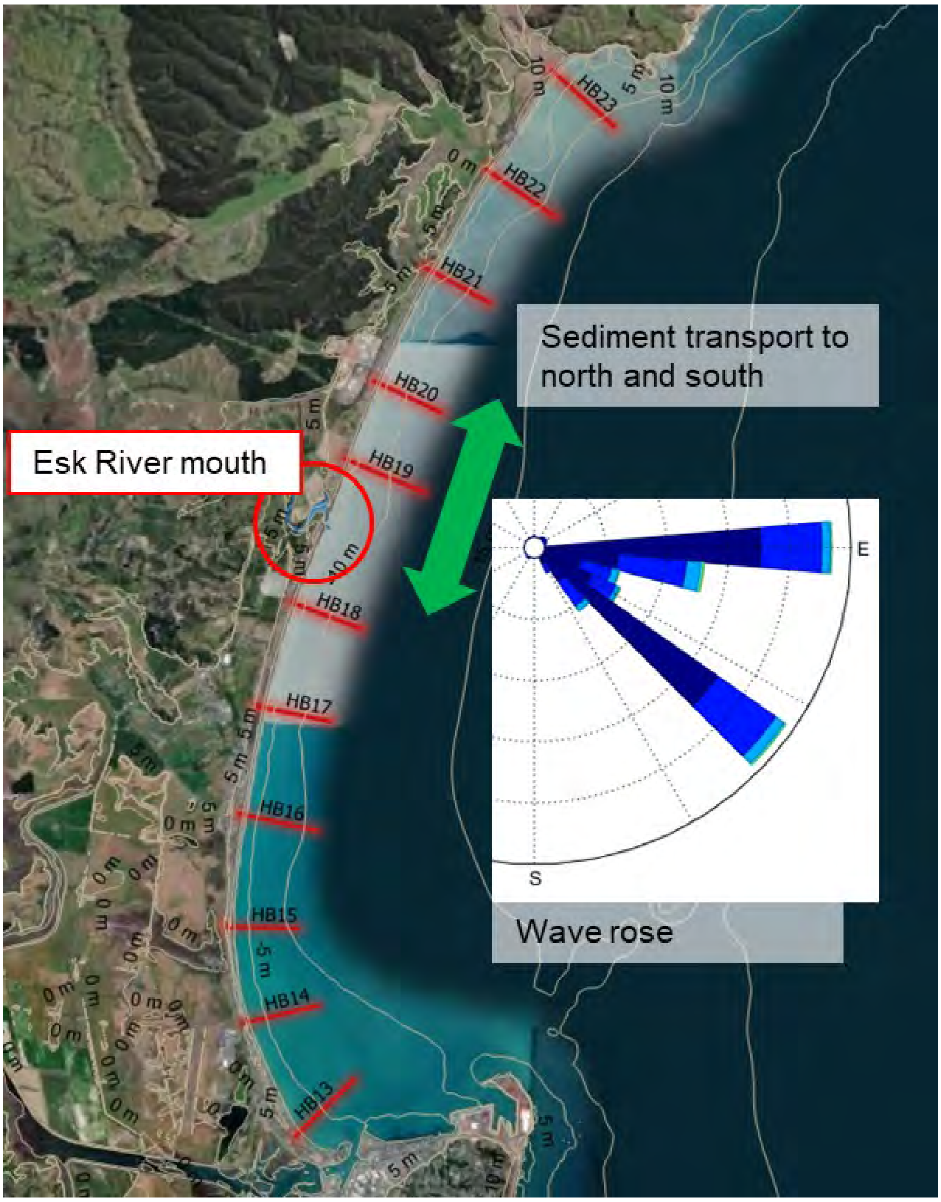


Figure 1-1: Location of Esk River mouth, location of beach profile monitoring within the Bay View Littoral Cell and key coastal features affecting present day shoreline change

This area was significantly affected by the 1931 earthquake with recorded uplift of around 2m along the coastal edge (refer Figure 1-2) based on observations along the railway lines, although analysis by Single (1985) suggest elevation increases on the beach ridge at Whirinaki could have increased by more than 4 m.

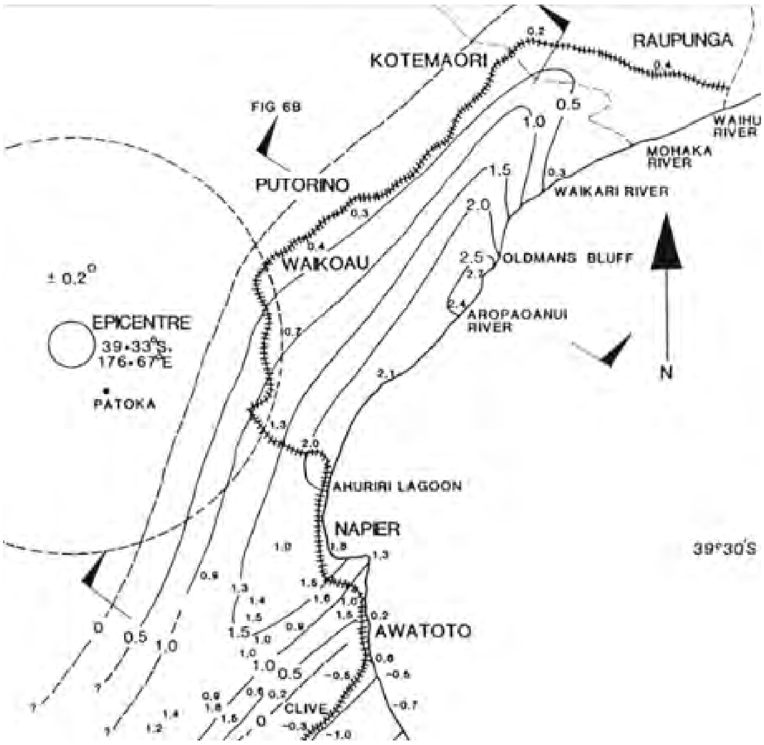


Figure 1-2: Land elevation changes produced by the 1931 Hawke's Bay earthquake. Negative values denote land subsidence (Source: Hull, 1990)

Figure 1-3 shows the typical beach profile in the vicinity on the Esk River mouth. This is taken from beach monitoring profile HB19 situating mid-way along North Shore Road based on LiDAR and bathymetry surveys from 2020. The beach profile shows the raised ridge, with an elevation of around 8 m and a relatively steep intertidal and subaerial beach, with a more gently sloping sub-tidal beach slope to deeper water.

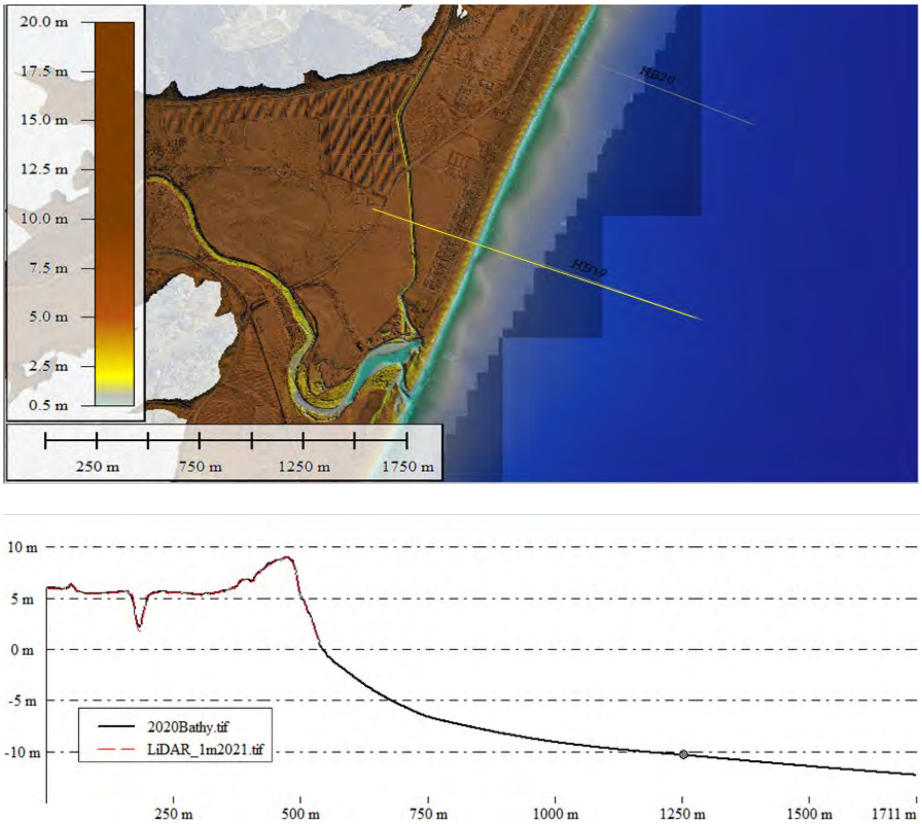


Figure 1-3: Location of beach profile monitoring station HB19 and typical profile in NZVD 2016 (RL)

1.2 Shoreline change

Beach profile monitoring has been carried out at the 11 beach profile locations shown in Figure 1-1. The trends of shoreline change at each of these locations are shown Figure 1-4 both based on the difference between the first and last survey at each location as well as the linear trend over the time period. The figure also shows the predicted shoreline change from a numerical shoreline evolution model undertaken by HBRC (from Beya and Asmat, 2021).

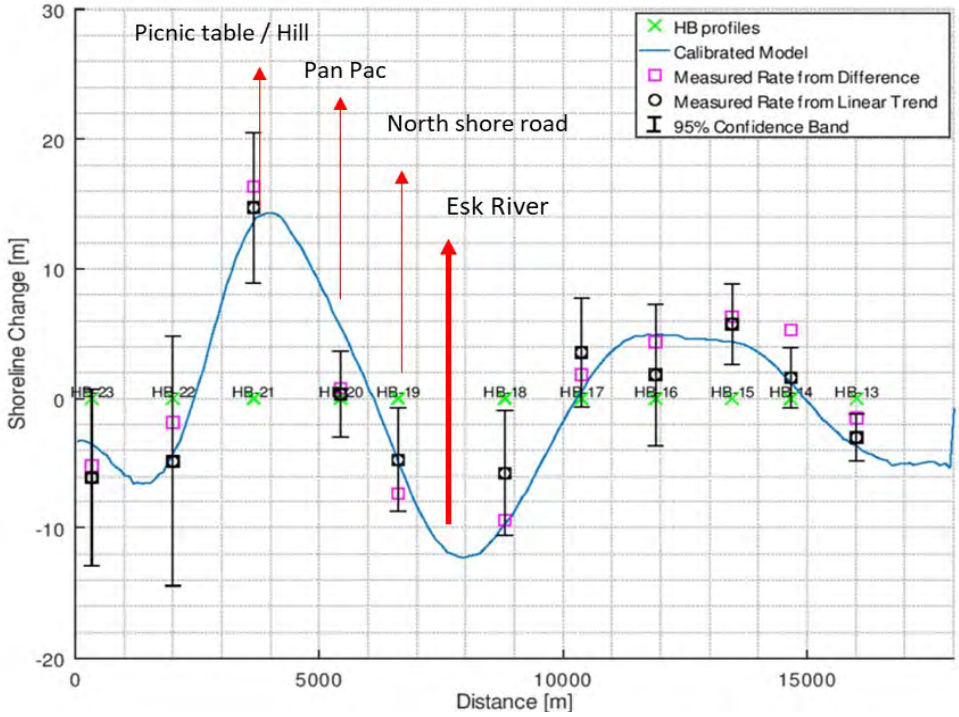


Figure 1-4: Observed shoreline change within Bay View Littoral Cell and modelled change (source: Beya and Asmat, 2021)

These results show that there are areas of accretion (positive shoreline change) and erosion (negative shoreline change) along the littoral cell, with erosion at HB13 (Westshore), accretion in the vicinity of Bayview (HB14 to HB17), erosion in the vicinity of the Esk River mouth HB18 and 19), accretion between the Pan Pac site and Tangoio (HB 20 and 21) and erosion around Tangoio, although the net changes indicate a dynamically varying shoreline, with periods of both north and south transport rather than strong trends.

Long term rates of erosion in the vicinity of the Esk River mouth and North Shore Road are in the order of 0.5m/year on the gravel beach face, with the short-term coastal erosion hazard zone extent being around 20 m. With increased relative sea level rise of 0.5 m, erosion rates are likely to increase to around 50 m and with 1m sea level rise this will increase to around 80 m (T+T, 2016). Figure 1-5 shows the hazard extents based on the 2016 coastal hazard assessment.

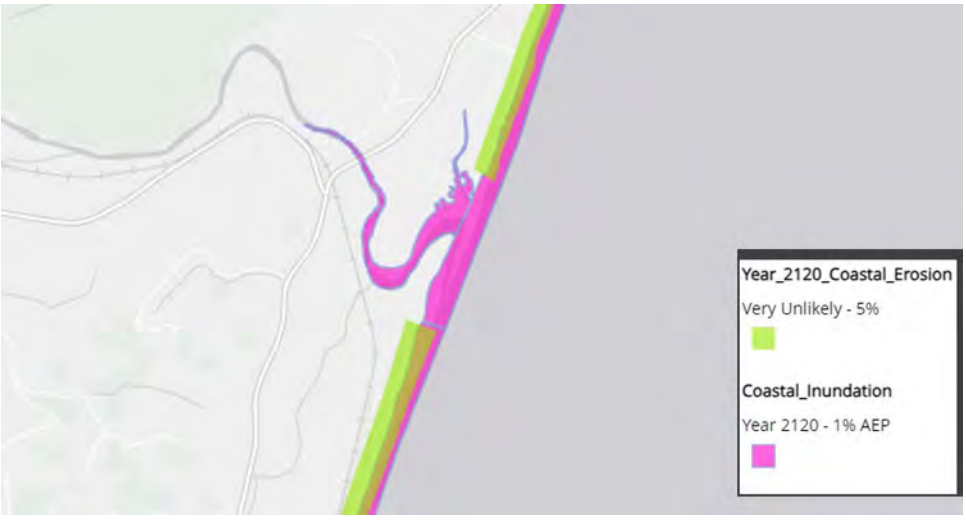


Figure 1-5: Hazard extents (Source: HBRC hazard viewer)

1.3 Present day Esk River mouth dynamics

The dynamics of the Esk River mouth has been analysed using multi-spectral satellite images from Sentinel 2, and aerial imagery from Google Earth, as shown in Figure 1-6. This figure shows that the outlet can migrate more than 1km along the coast, with the most northerly location close to the residential development at North Shore Road and southward towards Bayview. The river mouth is susceptible to partial or complete closure during periods of low river flows.

Figure 1-6: Locations of river mouth position based on nine satellite images from 2003 to 2023 (Source: Google Earth)

1.4 Wave climate

The Bay View Littoral cell is exposed to ocean swell energy from the east and southeast. Local storms, and sub-tropical ex-tropical cyclone activity can also create energetic sea states and swell conditions. Extreme wave heighs offshore of Whirinaki were assessed by T+T (2023) using an updated SWAN wave hindcast model undertaken by HBRC. The resulting 1% AEP wave height offshore of Whirinaki at a depth of 15m is 6.3 m, associated with a moderate wave period (10 – 12s).

1.5 Water levels

A summary of tidal water levels is presented in Table 1.1, which will be referenced in context of concept design work for assessing river mouth management options. Extreme value analysis of available tide gauge data at Napier Port was also undertaken by T+T (2023). The resulting 1% AEP storm tide event, as contributed by astronomical tide, low atmospheric pressure, and onshore wind is 1.28 m RL (NZVD 2016). There is only 5 cm difference between the 1% AEP storm tide and the 2% AEP storm tide and 13 cm difference between the from the 1% AEP storm tide and the 63% storm tide. This shows that high sea levels during onshore storm events can occur reasonably frequently.

Table 1.1: Tide levels and extreme water levels for Napier based on LINZ (2021)

	Chart Datum (m)	**NVD-62 (m)**	**NZVD 2016 (RL) (m)**
1% AEP storm tide	2.40	1.48	1.28
2% AEP storm tide	2.35	1.43	1.23
63% AEP storm tide	2.27	1.35	1.15
Highest astronomical tide	2.00	1.08	0.88
Mean high water spring	1.87	0.95	0.75
Mean high water neap	1.46	0.54	0.34
Mean sea level	0.97	0.05	-0.15
Mean low water neap	0.45	-0.47	-0.67
Mean low water spring	0.12	-0.80	-1.00
Lowest astronomic tide	-0.02	-0.94	-1.14
Tide levels based on LINZ Nautical Almanac 2021 Storm tide levels assessed by T+T (2022) relative to a 2020 baseline			

1.6 Sea level rise

Sea level rise is an important consideration for defining the tail water level used in the hydrodynamic simulations being undertaken for assessing flood protection options. Sea level rise was assessed for Whirinaki using the NZ Sea Rise dataset and accounts for locally assessed vertical land movement (VLM). Subsidence following the 1931 earthquake uplift dominates the VLM signal in the Hawkes Bay, with a rate -3.68 mm/yr identified for the site. This results in a relatively greater rate of sea level rise compared to locations with stable or rising land levels. Table 1.2 outlines the magnitude of relative sea level rise (RSLR is sea level rise plus VLM) for the site for different Shared Socioeconomic Pathways (SSPs). Values highlighted in yellow are the indicative design parameters for proposed works.

Table 1.2: Relative sea level rise predicted for Whirinaki by NZ SeaRise, including VLM adjusted to a 2020 baseline

Year	**SSP2-4.5 p50**	**SSP3-7.0 p50**	**SSP5-8.5 p50**	**SSP5-8.5 p83**
2020	0	0	0	0
2030	0.09	0.09	0.09	0.11
2040	0.17	0.18	0.19	0.23

Year	SSP2-4.5 p50	SSP3-7.0 p50	SSP5-8.5 p50	SSP5-8.5 p83
2050	0.27	0.29	0.31	0.37
2060	0.37	0.4	0.43	0.53
2070	0.48	0.52	0.57	0.7
2080	0.59	0.66	0.72	0.9
2090	0.7	0.81	0.89	1.11
2100	0.82	0.98	1.07	1.34
2110	0.94	1.11	1.23	1.58
2120	1.05	1.27	1.4	1.81
2130	1.17	1.43	1.57	2.04
2140	1.28	1.58	1.73	2.26
2150	1.39	1.73	1.89	2.47

1.7 Gabrielle event

1.7.1 Waves

The sea state during Cyclone Gabrielle was very energetic, with the largest recorded waves measured at the Napier Port Buoy. The last reading at the buoy exceeded 6m. It is likely that waves were occurring across a wide-ranging spectrum of sea and swell periods, with direction from the east. Wave data specific to Whirinaki is not available. Waves are not a specific boundary condition for the hydrodynamic modelling that is being undertaken to assessing flood protection options. However, wave conditions will be considered for any coastal engineering work or training structures.

1.7.2 Storm tide

High frequency water level sampling at the Napier Port tide gauge (LINZ data access) shows the storm surge lasted over two high tide cycles on 14 November as indicated by the agitated blue signal. The high frequency signal (blue) shows infragravity frequency wave surges with amplitudes of 0.5 – 0.8 m. When averaged over 30 minutes, the peak storm tide is more representative, with a peak (red line) at 2.35 m CD, which is 1.23 m RL. The Gabrielle storm was therefore consistent with a 2% AEP event from Table 1.1.

A tail water level of 1.23 m NZVD is recommended for the calibrating the catchment model to Cyclone Gabrielle flood observations.

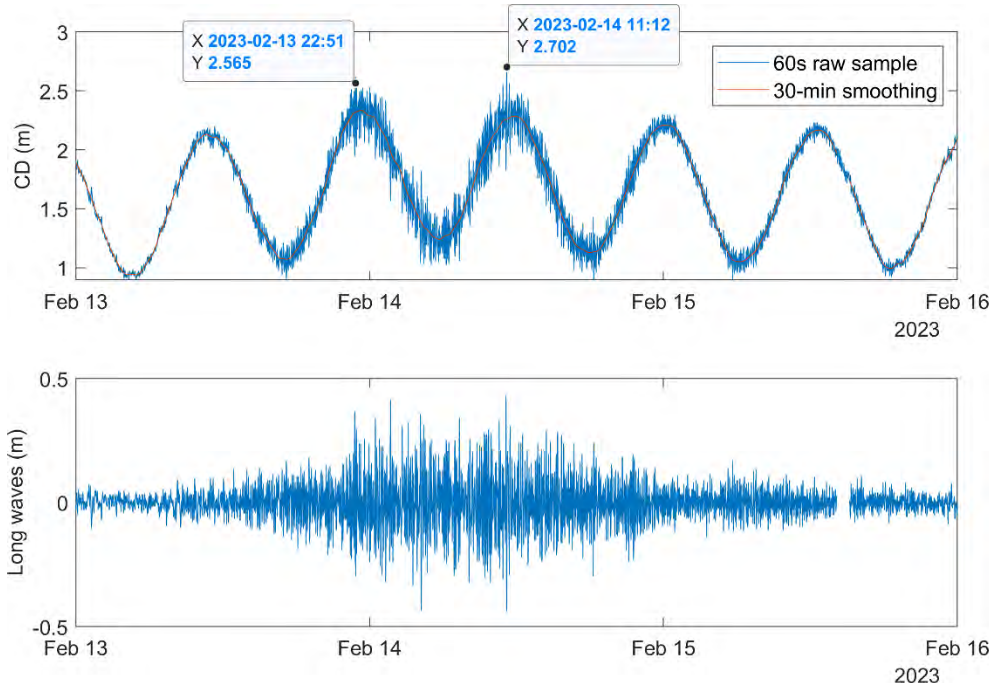


Figure 1-7: Napier port tide gauge levels during cyclone Gabrielle.

1.7.3 Mouth dynamics

Figure 1-8 shows the gravel berm position five days before and five days after Cyclone Gabrielle and also in June and July 2023 using multi-spectral images from the Sentinel 2 satellite. The river outlet position through the gravel was offset to the south 5 days before the flood event. The effects of the flooding, including significant changes to the river mouth and substantial siltation of the lower river reaches, are clear in the mouth configuration 5 days after Gabrielle (Figure 1-8). The river outlet channel which was significantly southwards prior to the Cyclone was moved some 600 m northwards. In June the river outlet can be seen to have returned to the south and gravel overwash is evident at the northern end of the estuary, with overwash moving beach sediments into the estuary.

The effect on sea level rise and shoreline erosion on the river mouth will be to translate the river mouth landward as increased wave heights at the coast will increase overtopping and roll over of the berm crest.

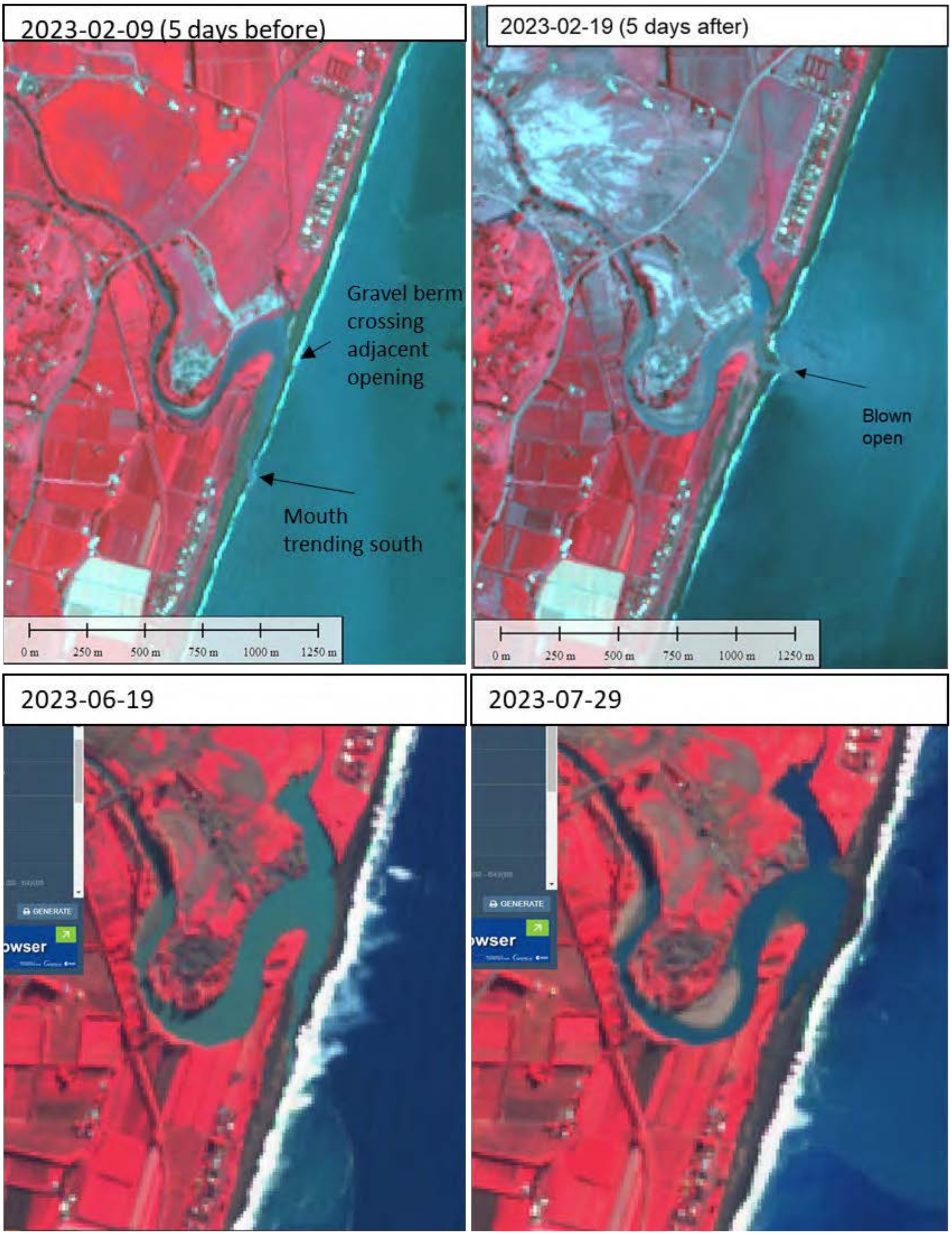


Figure 1-8: Satellite imagery prior and post Cyclone Gabrielle and in June and July 2023

The available aerial imagery and topographic information prior to Cyclone Gabrielle (2020 – 2022) shows that the gravel beach extends across the Esk River mouth in the form of a gravel berm. The 2020 LiDAR shows a narrow river outlet through the gravel berm, offset to the south. LiDAR levels are in NZVD-2016 (RL). The gravel berm in front of the river mouth was approximately 70 – 100 m wide at the zero contour (approx. MSL) and had a crest level of approximately 3.0 – 3.5 m RL, with variability across the width (Figure 1-9).

The post cyclone Gabrielle LiDAR survey (Draft processing from the University of Canterbury and NIWA dataset) shows a much smaller gravel berm, with a crest level of 2.5m RL and a wider outlet channel (Figure 1-9). A profile cross section of the berm and river mouth is presented in Figure 1-10.

Figure 1-9: Comparison of aerial images and contours (NZVD2016) from 2020 and from the post Gabrielle survey in 2023

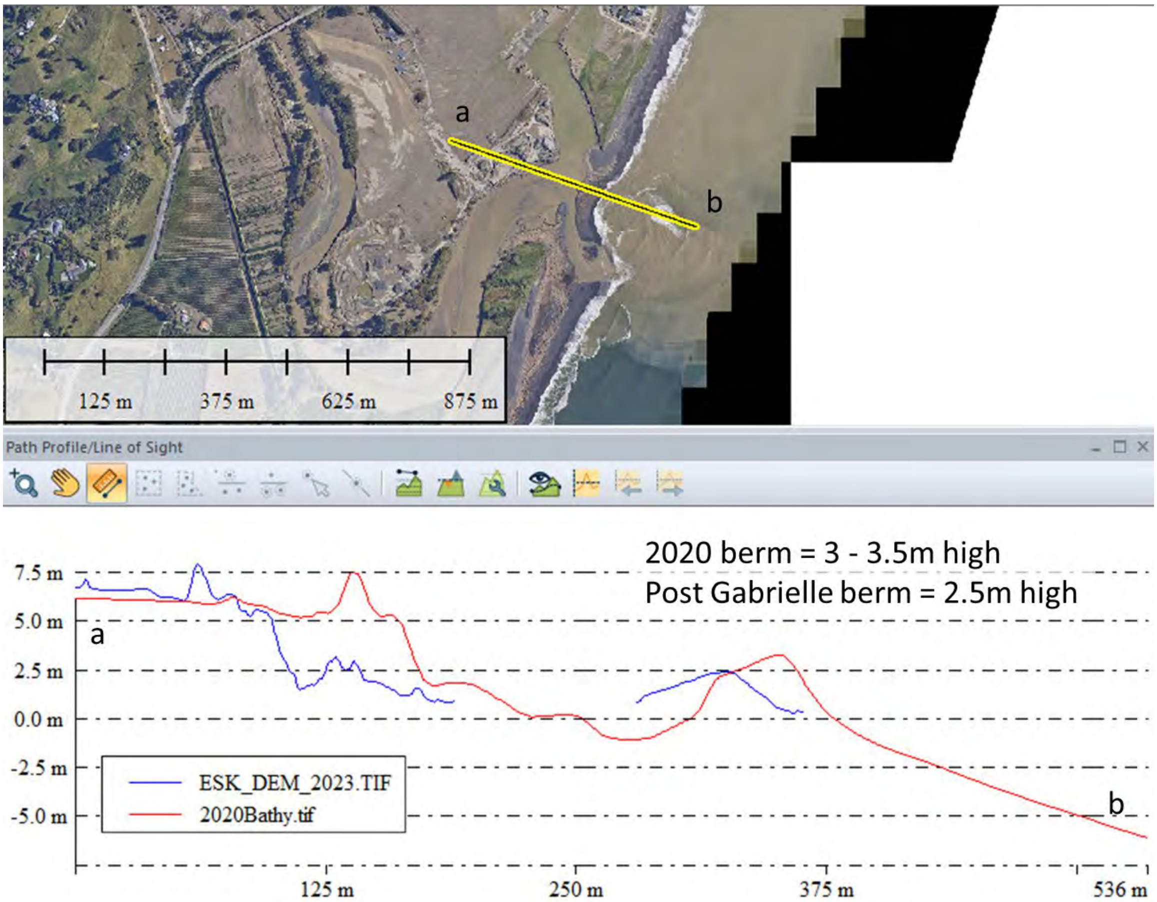


Figure 1-10: Profile cross section showing the 2020 and 2023 terrain at the river mouth and berm

1.8 Coastal parameters for concept design

1.8.1 Tail water conditions

This section sets out the parameters provided to PDP for including as tail water conditions in the hydrodynamic river model. These are based on the 1% AEP design criteria for a storm tide level and relative sea level rise based on recent local assessments and guidance from MfE (2022) regarding sea level rise and coastal development. If the land categorisation work is considered a 'change in land use' then category B from MfE (2022) would apply, meaning a sea level rise timeframe of 2130 and the SSP5-8.5 p83 scenario. If the proposed works are in the context of existing land use, then category C may be suitable for existing coastal developments and asset planning. This considers the 2130 timeframe and the SSP5-8.5 p50 scenario. All scenarios include local VLM as recommended by MfE (2022). Note that there is some uncertainty with the exact sea level rise scenario that should be used for informing this design. The stopbank options will not act as a sea barriers but as catchment flood barriers. The influence of sea level rise is to increase the tail water level, which may influence catchment drainage. Therefore, considering the effect of sea level rise and a 1% AEP storm tide level may be conservative for informing a stop bank crest level. Sensitivity of the flood level (and therefore stop bank level) to the tail water elevation is recommended, based on the values in Table 1-3.

Table 1-3: Relative sea level rise (RSLR*) scenarios with the 1% AEP event

Year	SSP	RSLR (m)	1% AEP storm tide and RSLR (m NZVD)	Description
2020	n/a	0	1.28	Present day
2100	SSP5-8.5 p50	1.07	2.35	Consistent with recent inundation assessment for Building Code assessments for Clifton to Tangoio (T+T 2022)
2130	SSP5-8.5 p50	1.57	2.85	Category C from MfE interim guidance (2022). For land use planning controls for existing coastal development and asset planning.
2130	SSP5-8.5 p83	2.04	3.32	Category B from MfE interim guidance (2022). For changes in land use and redevelopment.

*Includes local vertical land movement of -3.68 mm/yr.

1.8.2 River mouth morphology scenarios

The review of river mouth dynamics and preliminary options for managing an opening outlet were used to inform four different river mouth morphologies for consideration in hydrodynamic modelling, as visualised in Figure 1-11. The idea of representing different river mouth morphologies is to understand sensitivity of flood level to a closed, open or partially open mouth.

1 A closed mouth where coastal gravels completely block the river outlet. The gravel berm level was assumed to be at least 3.0 m RL based on levels in the 2021 LiDAR survey

2 A natural river mouth where the outlet through the gravel berm is small and offset to the south (based on 2021 LiDAR and river surveys by HBRC)

3 A partially open mouth, based on an excavated opening that is widened during a period of high flow

4 A very open mouth, which may occur towards the end of a catchment flood with significant breaching event, and initial opening work.

A long section across the river mouth is presented in Figure 1-12 to show the different channel geometries and positions. The four mouth configurations were provided to PDP for consideration and sensitivity testing of the hydrodynamic model. It is recommended that a stop bank crest level is designed to provide sufficient protection during a worst-case scenario where the river mouth is blocked. Note that all river mouth morphologies were based on a pre-Gabrielle base terrain and do not consider the potential damming effects of wooden debris. The morphologies are idealised terrain configurations, and the actual terrain will vary spatially and temporally. We have not attempted to understand how the river mouth, beach or berm may adjust morphologically to sea level rise over any design life.

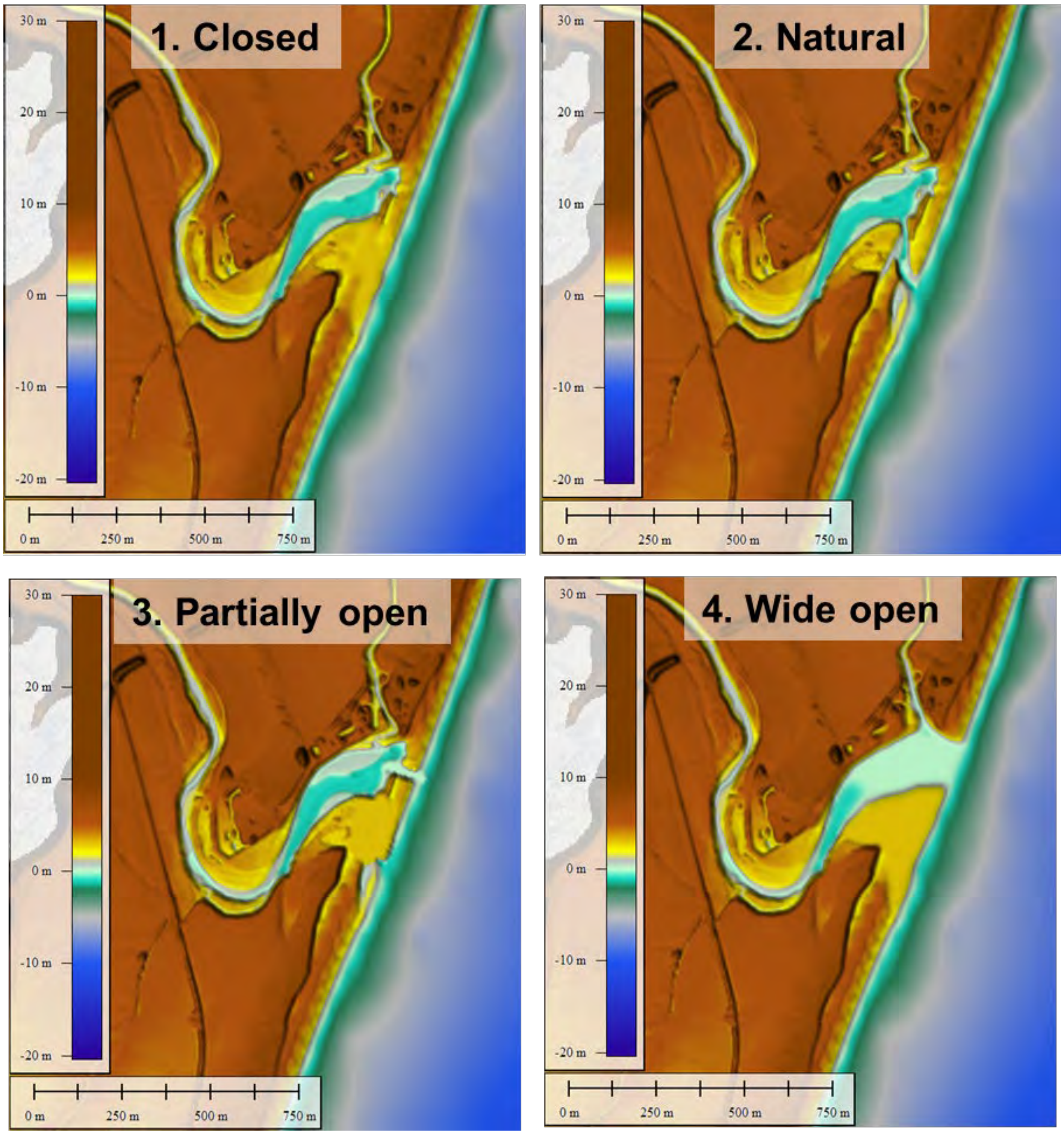


Figure 1-11: Four different river mouth morphologies for consideration in catchment flood modelling

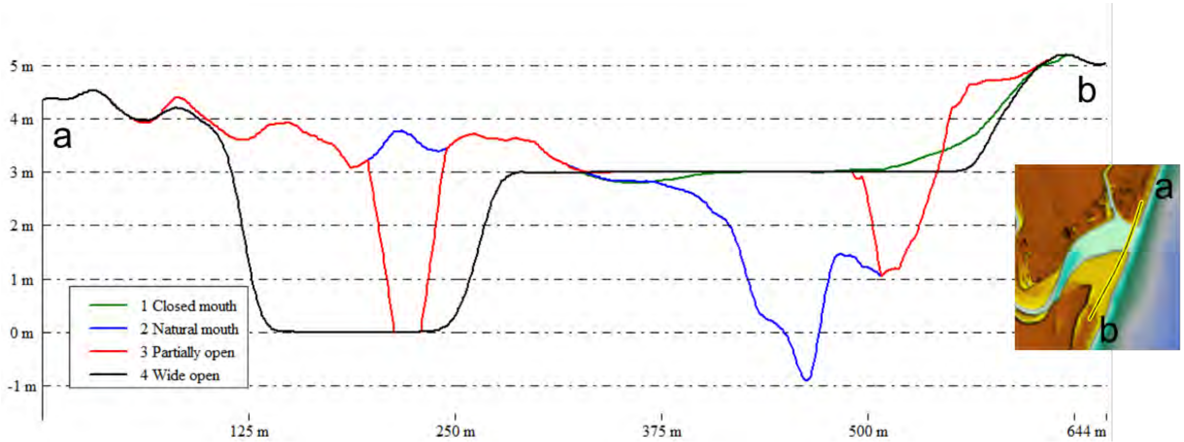


Figure 1-12: Long section across the gravel section of the river mouth showing the different configurations

2 Options assessment

An initial workshop was undertaken to identify a range of options to manage the river mouth with the objective of improving outflow during flood events. The long list included:

1. Continue the status quo maintenance opening program (managed by HBRC)
2. Establish and resource an improved maintenance opening plan
3. Consider the benefit of any upstream works on improving outflow (e.g., channel re-alignment or bank stabilisation)
4. River mouth control structures

A summary of the benefits and limitations of each option is presented in Table 2-1.

Table 2-1: Initial list of options identified for managing the river mouth to improve outflow.

Option	Benefits	Limitations	Indicative cost (excl. GST)
1 Status quo	Opening instructions already exists.	Local community and businesses indicate that the recent opening work has not been reliable.	The maintenance opening plan indicates \$500 – 2,000 per opening.
2 Improved opening scheme	Opportunity to incorporate opening management into a wider catchment scheme. Management could be improved with associated monitoring . Channel position can be flexible based on river flow and gravel berm level (as opposed to a structural option).	Requires additional monitoring and resourcing compared to status quo. Should not be relied on as a standalone solution for flood protection, as effectiveness is uncertain because of environmental dynamics and operational constraints. Reliance on manual intervention can be unreliable.	Setup costs to complete baseline surveys and establish monitoring equipment: approx. \$80,000. Operational costs of approx. \$116,000 per year. Assuming 4 openings per year and regular lowering of the berm level. Monitoring costs of approx. \$20,000 per year.

3 Benefit of upstream channel work	Re-alignment of the lower reach or bank stabilisation may result in improved focusing of flow at the outlet.	Uncertainty in performance regarding influence on outlet opening. No re-alignment options included in the base-case.	Not considered as feasible for Base Case to inform flood protection to Category 2a properties.
4 Control structure	Focuses a scour channel to form during flood conditions. Provides platform for operation long reach-excavator (with design constraints)	Feasibility constraints identified in concept design. Still requires maintenance opening and all limitations of option 2. Very expensive. Consenting challenges with sediment transport and potential occupation of CMA. Uncertain if performance is improved compared to a non-structural option. Consenting could be complex and a structure may influence coastal processes at Whirinaki and Bay View where coastal erosion is already an issue.	Indicative feasibility design work indicates a $5M to $6M cost per training structure. This includes some contingency but not professional design and consenting fees. Maintenance opening work would be additional per year. Structural maintenance would also be additional.

3 Base case option: Improved river opening scheme

The preferred option for including in the base case flood improvement scheme is the improved maintenance opening with a structural training.

This section sets out a draft river opening management plan and includes:

1. River mouth features
2. Objective
3. Operational and environmental considerations
4. Excavation design
5. Triggers for opening
6. Monitoring
7. Costs

3.1 River mouth features

The morphological features referred to in this section are identified in Figure 3-1. The key features are the gravel berm that extends across the river mouth, and the outlet channel that flows through the gravel berm.

The morphology of the gravel berm is variable. Based on the 2021 LiDAR the berm had a crest level approximately 3 – 3.5 m RL. The berm width (across-shore) is also variable across space and time, ranging between 50 – 100 m wide at the MSL contour.

Figure 3-1: Geomorphic features of the Esk River mouth

3.2 Objective

The Esk River flows out through a gravel berm that is very dynamic and influenced by a combination of catchment and coastal processes. Under typical low flow conditions, the outlet channel through the gravel berm can be offset laterally from the main river mouth, which slows down drainage. If river flow is not strong enough to breach the gravel and form an efficient pathway to the sea, flood levels on the lower reach may be elevated.

The objective of the river mouth opening excavation work is to improve outflow of the river water during flood conditions.

3.3 Environmental and operational considerations

An initial list of environmental and operational considerations is outlined below:

- Ecological considerations include temporarily changing the salinity of the estuary location (landward of the gravel barrier) by modifying sea water exchange with the lower river system and impact on ecology.
- Fish passage needs considering (e.g. inanga spawning).
- If outlet drainage is 'too efficient' the base river level could be lowered and cause an adverse effect on wetland area (existence of wetlands needs considering in baseline surveys).
- Salinity in the lower river system can cause issues to water use for industrial sites and this has been an issue in the past during low flow conditions.
- Excavator operations should be undertaken at low tide, limiting the working window to 3-4 hours.
- Performance of opening operation, and potential effects on the environment should be carefully monitored as part of the improved maintenance work.
- River mouth management should be considered as part of a larger catchment management scheme.

3.4 Opening channel design

Two maintenance opting strategies have been identified:

1 Maintain a low berm level across the width of the river mouth.

This option was identified at the TFG meeting on 8 September 2023 and is based on limiting the gravel level to a height that prevents wave overwash on typical high tide conditions but allows river flow to overtop the berm when river level rises, effectively widening the outlet in high flow. Maintaining a lower berm level would also make it easier to cut a new outlet (aligned with the main river flow path) if triggered by a rainfall forecast (see point 2 below). Maintaining a lower crest level could be undertaken on a quarterly basis.

Gravel material could either be redistributed along the berm (i.e., effectively widening the berm), or be placed on the beach crest (toe of grass bank) along North Shore Road to help manage coastal erosion, which would be consistent with the short term adaptation action for this cell.

Excavation levels:

- An indicative design height for the berm is 2.5 m above RL. This would be refined during the initial monitoring and establishment phase to understand any performance issues and environmental effects.
- It may not be feasible or necessary to manage the berm level across the full 200m wide mouth area. This would depend on the antecedent berm morphology (width, height, length) and the position of the outlet channel.

2 Excavate a channel thought the berm to direct river outlet directly to sea.

If environmental conditions are met (see diagram below) and a rainfall threshold is exceeded (to be determined) then an outlet channel needs to be excavated to allow direct outflow from the river mouth, through the gravel berm, to the sea.

Excavation design:

- Position the channel to be inside the 200m wide span that allows direct flow from the mouth to the sea. The exact channel location would need to be determined on the day based on the berm morphology and the existing outlet channel position.
- Channel opening work should be initiated around 2 hours before low tide. The channel excavation work should start at the landward end move seaward. Channel depth needs to achieve the most hydraulicly efficient flow path and will depend on the river level. Excavating to just above MHWS (1 m) should achieve a suitable flow path.
- Channel width may be limited by operation time (e.g., 4 hours around low tide). Aim for a channel width of 1 – 2 excavator buckets wide at the base. The channel should scour and grow wider and deeper during high flow.
- The excavated channel is expected to fill in as a result of coastal processes quickly after flood waters subside. Therefore, opening the channel during low flow conditions is unlikely to achieve anything.

3.5 Trigger for opening

The berm maintenance work could be scheduled regularly (e.g., quarterly) and adapted as monitoring is available to understand the performance and effects.

Opening the river outlet manually should be triggered by a 5-day rainfall forecast. The threshold will need to be refined by could be based on 99 percentile rainfall forecasted over 12 hours.

If the rainfall forecast is not reliable (e.g., an event was not predicted) then river level should be monitored to trigger emergency opening. This could be the existing threshold of water level in Whirinaki Drain reaching the bridge sofit level.

A conceptual management approach for monitoring and opening the river mouth outlet channel is presented in Figure 3-2. This is based on balancing operational logistics, the flood improvement objective, and environmental considerations. Note that this is for the outlet channel, not the berm level maintenance.

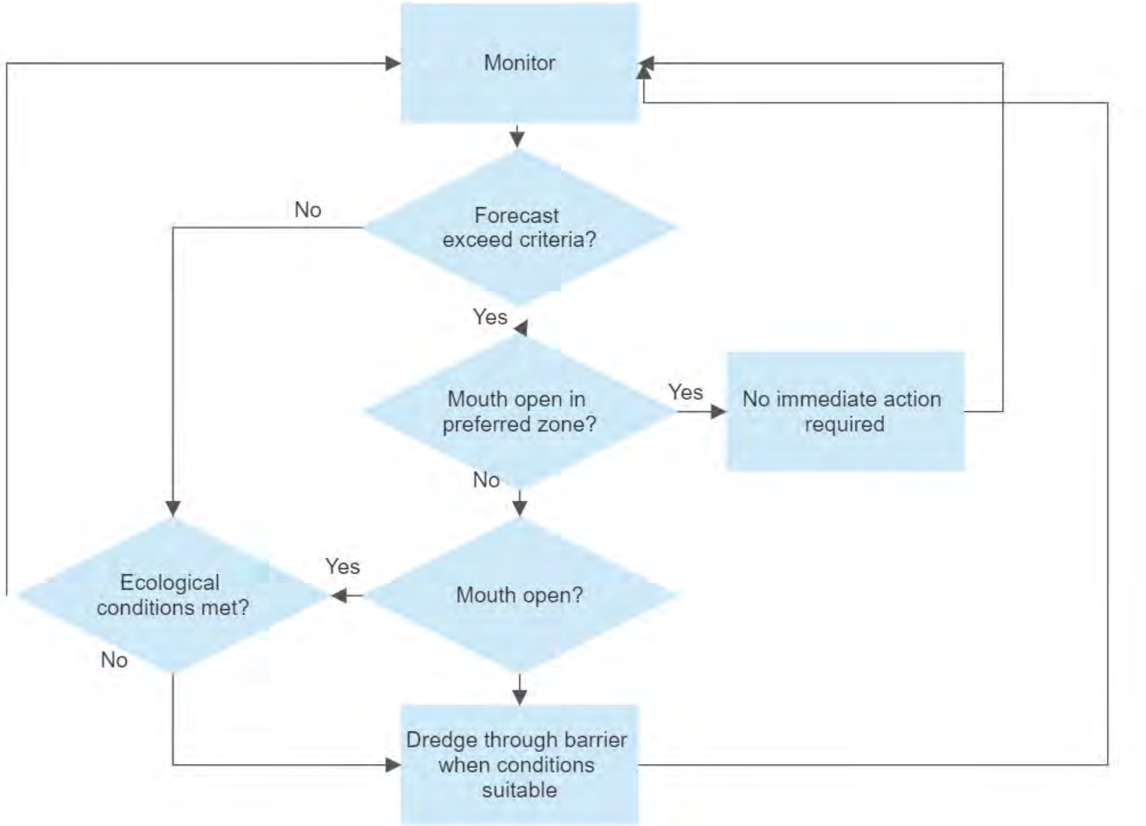


Figure 3-2: Conceptual diagram of the river outlet management plan.

3.6 Monitoring

Monitoring will be important for understanding the performance of the opening scheme and to identify any environmental effects. If performance is lacking, or effects are identified the scheme can be reviewed and improved adaptively. Monitoring could consider:

1. Baseline and regular ecological surveys (e.g., before and after the initial opening events)
2. Baseline and regular UAV surveys to provide aerial images and terrain mapping (e.g., before and after the initial opening activity)
3. A fixed camera taking time lapse still images of the river mouth and lower river. Note that a feasible location to mount the camera may not exist which may be a constraint
4. River level gauge in the lower reach, integrated with the wider catchment monitoring system.

3.7 Costs

Indicative cost estimates for excavation works are approximately $116,000 per year, assuming the berm level is managed four times, and the outlet channel is managed an additional 4 times (Table 3-1). Costs associated with the berm maintenance do not include depositing excavated material along North Shore Road which may require additional equipment or transport costs. Cost estimate for different environmental and performance monitoring are outlined in Table 3-2.

Table 3-1: Cost estimate for excavation works

Item	Base rate	Quantity (pear year)	Total (per year)
Berm levelling	$25,000	4	$100,000
Outlet opening	$4,000	4	$16,000
Total			$116,000

Table 3-2: Approximate cost estimate for environmental and performance monitoring

	Baseline / setup cost	Operational (per year)
Ecological surveys	$60,000	$5,000
UAV survey	$5,000	$5,000
Camera monitoring	$15,000	$5,000
River level	n/a	n/a
Analysis and reporting	n/a	$5,000
Total	$80,000	$20,000

4 References

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3

APPENDIX 3

Landscape Plan

Lower Esk Valley Resilience Project

Landscape Concept Plan

September 15, 2023

Revision 03

Drawn: B O'Donnell Checked: S Bray

Scale: 1:10,000

Print at A3

Sheet 1

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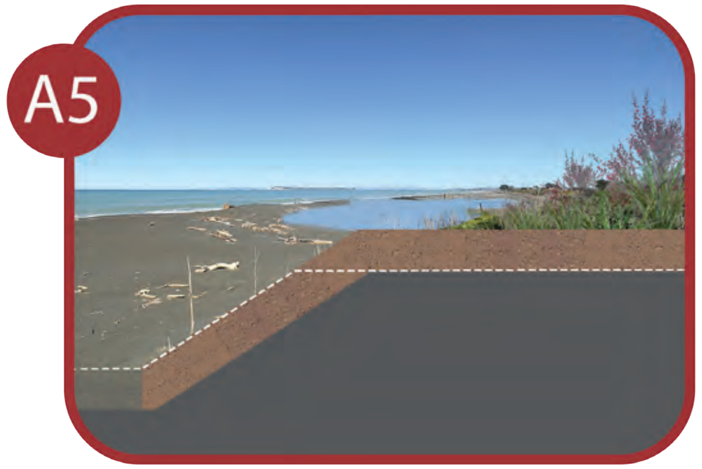
WAYFINDER

Landscape Planning & Strategy



A5: Esk River Mouth and Coastal Works – ties into B3 stopbank or Esk River Mouth and Coastal Works extending landward to protected Urupa site (Pohutukawa Drive) river mouth dredging/ maintenance option

B5: New stopbank to Coast – Bayview side

B1: Existing Whirinaki stopbank

C1: Whirinaki Drain SH2 culvert improvements + Increase capacity of Whirinaki Drain, Down-stream of SH2

B3: New stopbank to Coast – Pohutukawa Drive across Evans Land

Lower Esk Valley Resilience Project

Project Descriptions

September 15, 2023

Revision 03
Drawn: B O'Donnell Checked: S Bray

Not to Scale
Print at A3

Sheet 2

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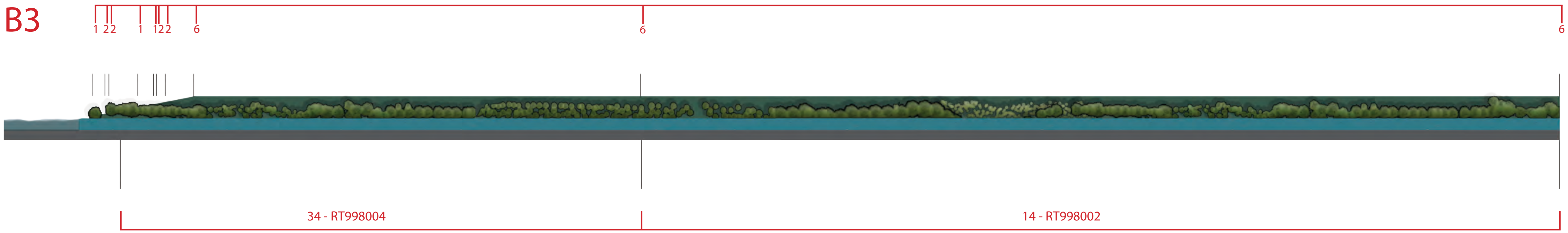
Site Contours 1m

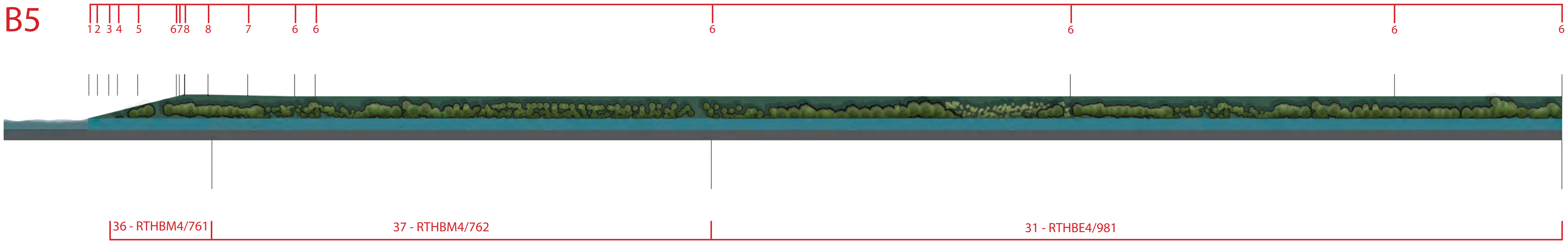
B3



Parcel Number - Title

Site Contours 1m

B5



Parcel Number - Title

B5 - Stopbank to Coast Bayview Side

B3 - Stopbank To Coast Pohutukawa Drive

Lower Esk Valley Resilience Project

Long Sections

September 15, 2023

Revision 03

Drawn: B O'Donnell Checked: S Bray

Scale, 1:3000

Print at A3

Sheet 3

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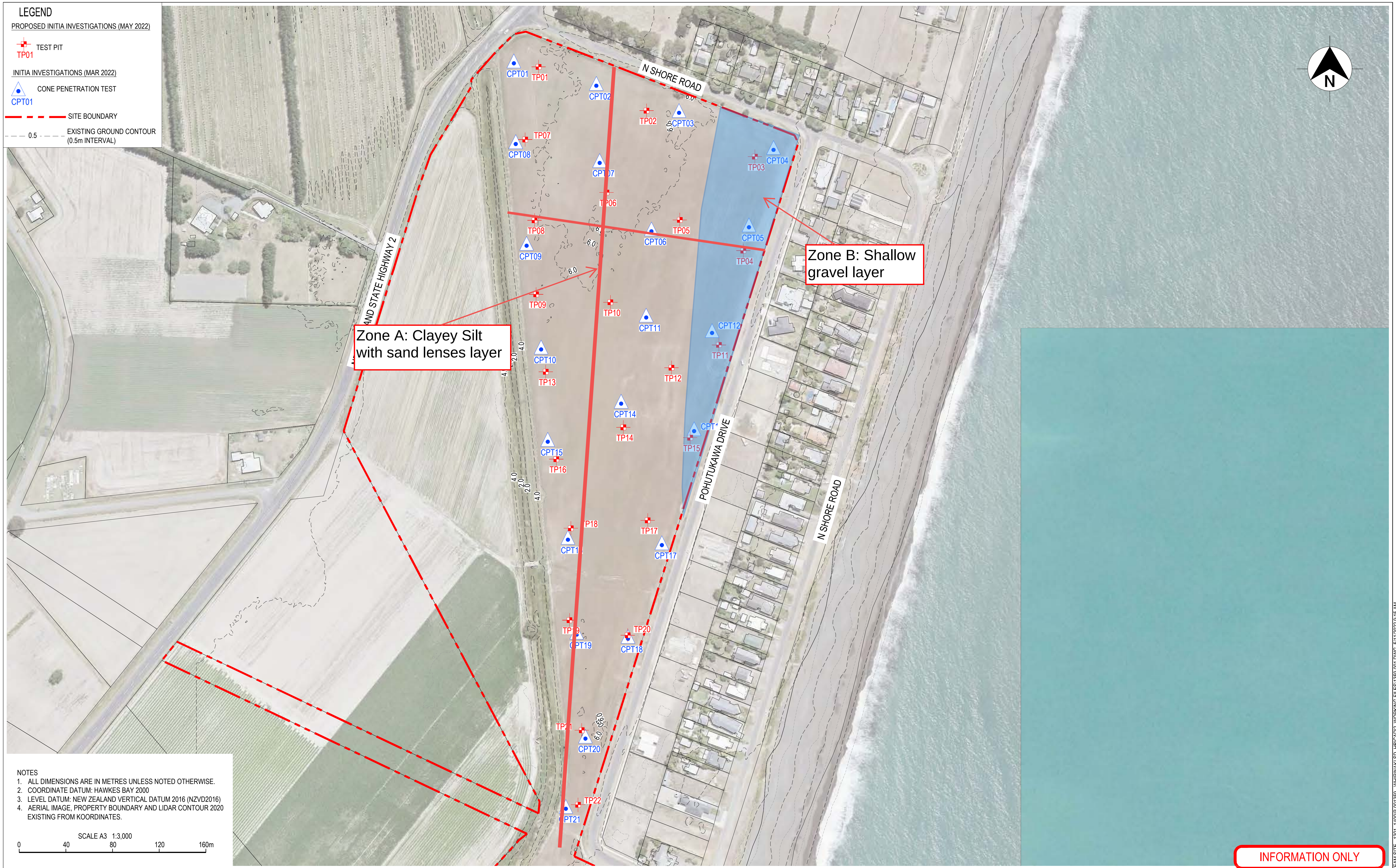
4

APPENDIX 4

Geotech Investigation Area Map



LEGEND

PROPOSED INITIA INVESTIGATIONS (MAY 2022)

- TP01 TEST PIT

INITIA INVESTIGATIONS (MAR 2022)

- CPT01 CONE PENETRATION TEST
- SITE BOUNDARY
- 0.5 EXISTING GROUND CONTOUR (0.5m INTERVAL)

NOTES

1. ALL DIMENSIONS ARE IN METRES UNLESS NOTED OTHERWISE.
2. COORDINATE DATUM: HAWKES BAY 2000
3. LEVEL DATUM: NEW ZEALAND VERTICAL DATUM 2016 (NZVD2016)
4. AERIAL IMAGE, PROPERTY BOUNDARY AND LIDAR CONTOUR 2020 EXISTING FROM KOORDINATES.

SCALE A3 1:3,000

0 40 80 120 160m

Rev	Revision Description	Designed	Drawn	Checked
A	PROPOSED INVESTIGATION LOCATION (11/05/2022)	AP	GG	AP

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APPROVED:

DATE:

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INITIA GEOTECHNICAL SPECIALISTS

Unit 6, Level 1, 114 St Georges Bay Road Parnell, Auckland, 1052

Phone: +64 09 977 0460
Email: enquiries@initia.co.nz

EVANS FAMILY TRUST

996 STATE HIGHWAY 2, WHIRANAKI

GEOTECHNICAL INVESTIGATION LOCATION PLAN

Initia Project ref: P001359

Figure Number: 1359-001

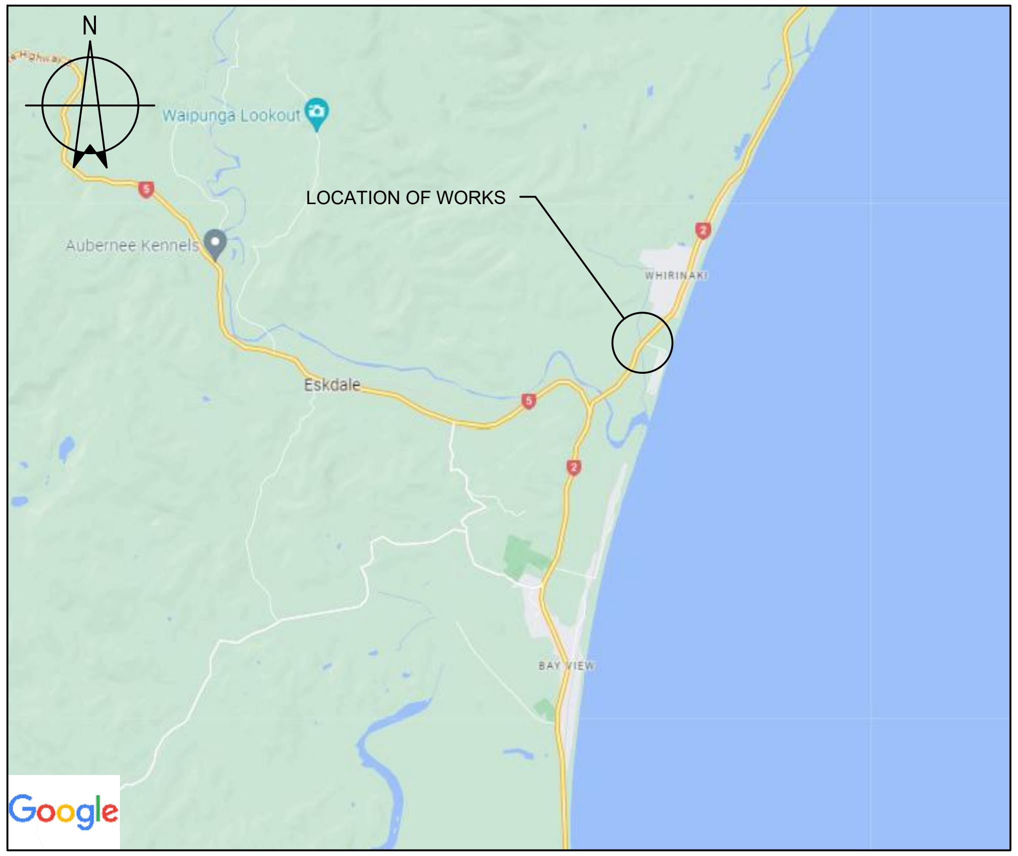
Revision: A

5

APPENDIX 5

State Highway 2 Lifting Concept Plans

PAN PAC FOREST PRODUCTS LIMITED
WHIRINAKI RESILIENCE PROJECT
STATE HIGHWAY 2 ROAD LIFT



LOCALITY PLAN
NTS

DRAWING LIST		Issued		
	Day	15		
	Month	9		
	Year	23		
Sheet Number	Sheet Title	Revision		
51-001-G001	COVER SHEET, DRAWING LIST & LOCALITY PLAN	A		
51-001-SK001	OVERALL LAYOUT PLAN	A		
51-001-SK002	TYPICAL CROSS SECTION	A		
51-001-SK101	STATE HIGHWAY 2 LONGITUDINAL SECTION AND PLAN - SHEET 1 OF 2	A		
51-001-SK102	STATE HIGHWAY 2 LONGITUDINAL SECTION AND PLAN - SHEET 2 OF 2	A		
51-001-SK201	NORTH SHORE ROAD LONGITUDINAL SECTION AND PLAN	A		

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Project: WHIRINAKI RESILIENCE PROJECT
Title: COVER SHEET, DRAWING REGISTER AND LOCALITY PLAN

Status	Date	Scale	Drawing No:	Rev:
DRAFT	15/09/2023	NTS	51-001-G001	A

PLAN
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Title	OVERALL LAYOUT PLAN

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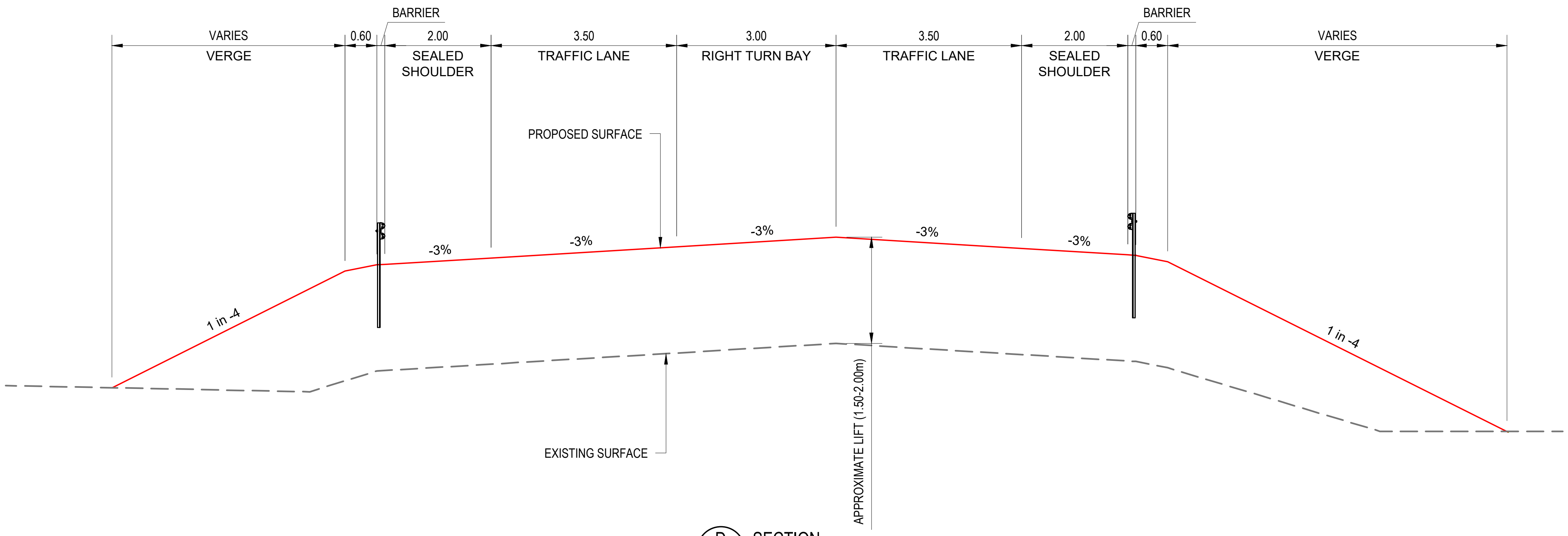

D SECTION
SK001 SCALE 1 : 100 H, 1 : 50 V

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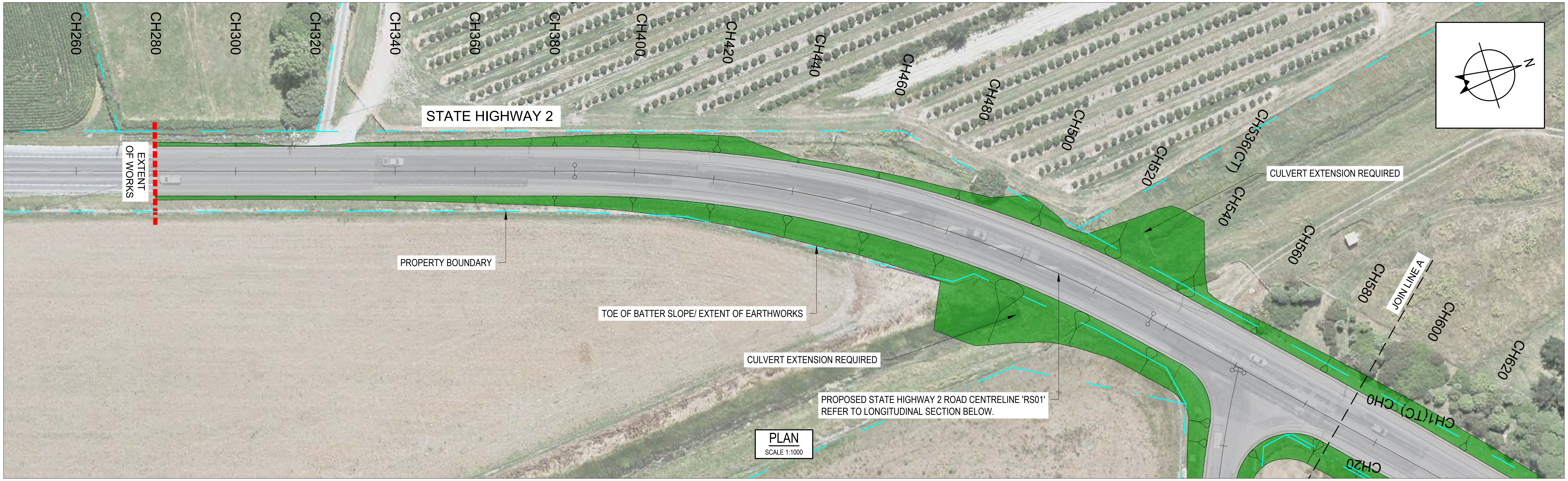

PLAN
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VERTICAL CREST CURVE MEETS AUSTROADS GUIDE TO ROAD DESIGN PART 3: GEOMETRIC DESIGN CRITERIA
- 'K VALUE' TO MEET HEADLIGHT SIGHT DISTANCE CRITERIA (TABLE 8.9)
- APPEARANCE CRITERIA (TABLE 8.10)

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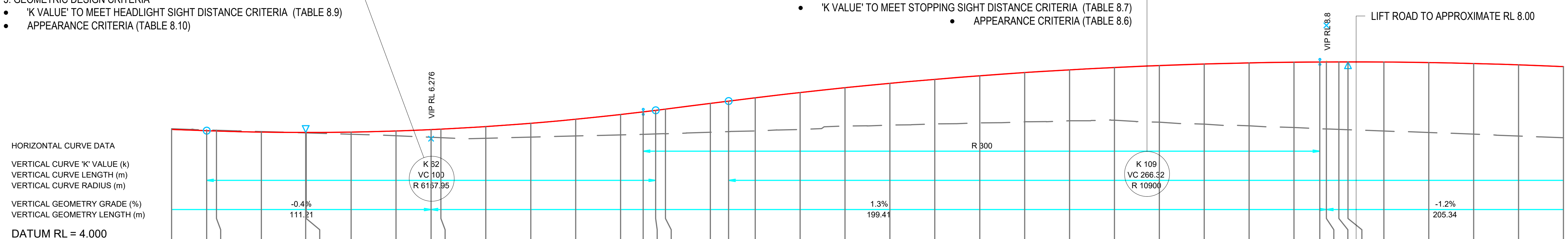

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FINISHED SURFACE LEVEL	6.484	6.456	6.448	6.424	6.416	6.416	6.424	6.449	6.479	6.490	6.547	6.620	6.710	6.815
EXISTING SURFACE LEVEL	6.497	6.472	6.466	6.435	6.405	6.405	6.377	6.343	6.309	6.300	6.287	6.312	6.339	6.361
CUT / FILL DEPTH	-0.014	-0.017	-0.018	-0.011	0.011	0.011	0.047	0.106	0.170	0.190	0.260	0.308	0.371	0.454
CHAINAGE	280	287.81	290	300	309.878	310	320	330	337.81	340	350	360	370	380

FINISHED SURFACE LEVEL	6.875	6.909	6.937	7.063	7.115	7.188	7.305	7.412	7.510	7.599	7.679	7.750	7.811	7.864
EXISTING SURFACE LEVEL	6.374	6.382	6.385	6.419	6.434	6.450	6.483	6.559	6.581	6.608	6.631	6.653	6.676	6.688
CUT / FILL DEPTH	0.500	0.527	0.551	0.645	0.681	0.738	0.822	0.853	0.929	0.991	1.048	1.096	1.135	1.176
CHAINAGE	385.038	387.81	390	400	404.061	410	420	430	440	450	460	470	480	490

FINISHED SURFACE LEVEL	7.907	7.941	7.965	7.981	7.986	7.987	7.988	7.988	7.985	7.973	7.952	7.921	7.882
EXISTING SURFACE LEVEL	6.645	6.601	6.565	6.525	6.500	6.493	6.483	6.475	6.447	6.415	6.378	6.336	6.298
CUT / FILL DEPTH	1.262	1.340	1.401	1.456	1.486	1.493	1.505	1.513	1.538	1.558	1.574	1.586	1.584
CHAINAGE	500	510	520	530	535.751	537.219	540	542.006	550	560	570	580	590

A1 SCALE: H 1:500, V 1:50

LONGITUDINAL SECTION RS01

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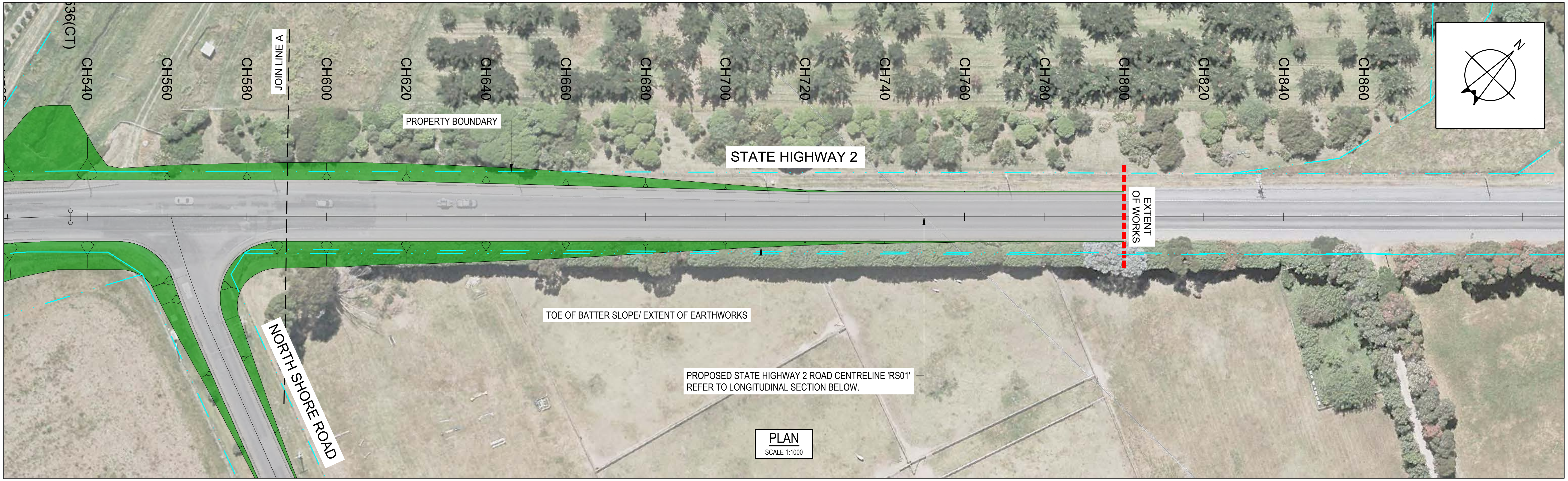

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- APPEARANCE CRITERIA (TABLE 8.6)

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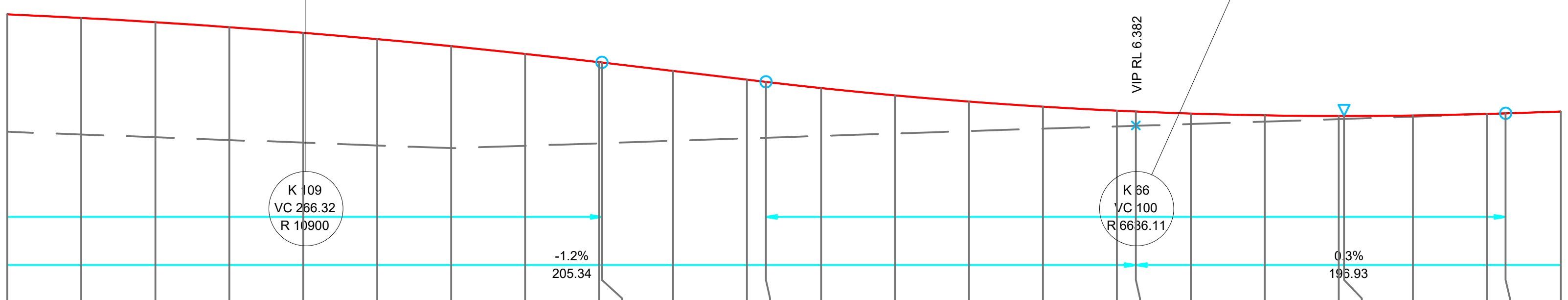
- APPEARANCE CRITERIA (TABLE 8.10)

HORIZONTAL CURVE DATA

VERTICAL CURVE 'K' VALUE (k)
VERTICAL CURVE LENGTH (m)
VERTICAL CURVE RADIUS (m)

VERTICAL GEOMETRY GRADE (%)
VERTICAL GEOMETRY LENGTH (m)



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EXISTING SURFACE LEVEL	6.298	6.260	6.223	6.185	6.151	6.111	6.076	6.109	6.142	6.143	6.175	6.209	6.217	6.242
CUT / FILL DEPTH	1.584	1.573	1.552	1.523	1.482	1.436	1.376	1.240	1.094	1.089	0.943	0.792	0.753	0.645
CHAINAGE	590	600	610	620	630	640	650	660	670	670.378	680	690	692.556	700

FINISHED SURFACE LEVEL	6.788	6.704	6.635	6.581	6.570	6.543	6.519	6.510	6.510	6.517	6.538	6.546	6.571
EXISTING SURFACE LEVEL	6.274	6.307	6.340	6.369	6.378	6.401	6.434	6.467	6.470	6.502	6.537	6.545	6.571
CUT / FILL DEPTH	0.514	0.397	0.296	0.213	0.193	0.141	0.085	0.043	0.041	0.015	0.002	0.001	-0.001
CHAINAGE	710	720	730	740	742.556	750	760	770	770.711	780	790	792.556	800

A1 SCALE: H 1:500, V 1:50

LONGITUDINAL SECTION RS01

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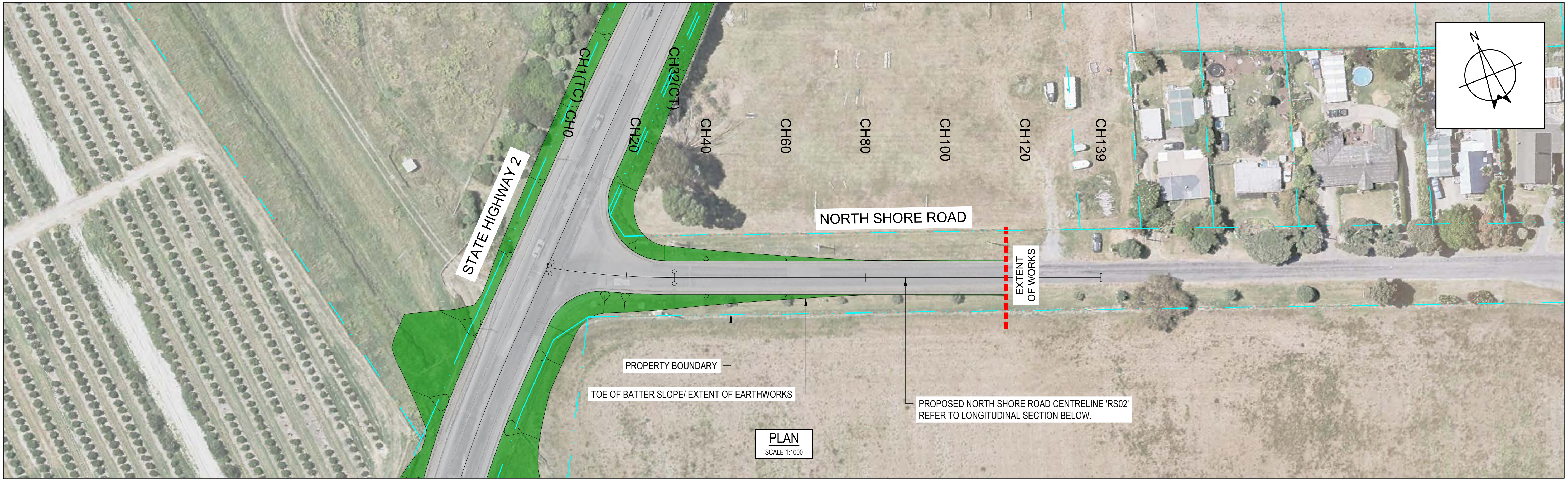

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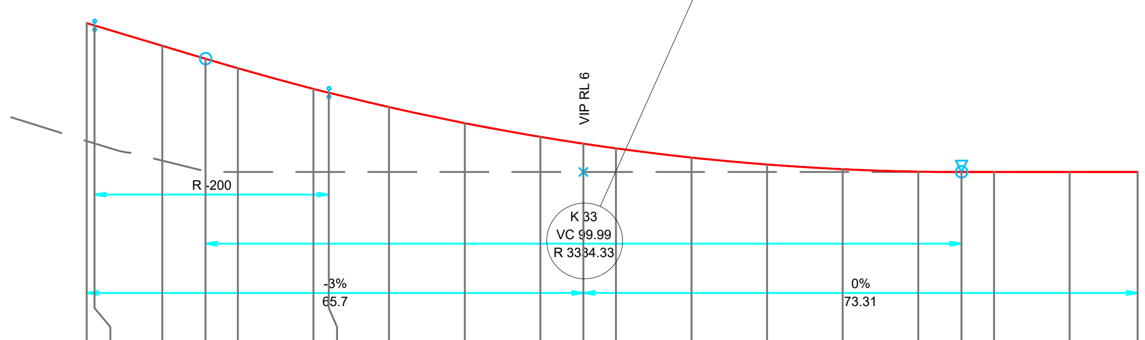
SCALE 1:1000

VERTICAL CREST CURVE MEETS AUSTROADS GUIDE TO ROAD DESIGN PART 3: GEOMETRIC DESIGN CRITERIA
- 'K VALUE' TO MEET HEADLIGHT SIGHT DISTANCE CRITERIA (TABLE 8.9)
- APPEARANCE CRITERIA (TABLE 8.10)



DATUM RL = 3.700

FINISHED SURFACE LEVEL	7.971	7.940	7.671	7.499	7.374	7.102	7.050	6.860	6.648	6.465	6.375	6.313	6.191	6.099	6.037	6.005	6.000	6.000	6.000	6.000
EXISTING SURFACE LEVEL	6.411	6.380	6.150	6.009	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
CUT / FILL DEPTH	1.560	1.561	1.521	1.490	1.374	1.102	1.050	0.860	0.648	0.465	0.375	0.313	0.191	0.099	0.037	0.005	0.000	0.000	0.000	0.000
CHAINAGE	0	1.028	10	15.723	20	30	32.031	40	50	60	65.704	70	80	90	100	110	115.708	120	130	139.011

A1 SCALE: H 1:500, V 1:50

LONGITUDINAL SECTION RS02

No	Revision	Designer	Checked	Approved
A	ISSUED FOR STAKEHOLDER FEEDBACK	SG	TH	TH

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DO NOT SCALE Original Sheet Size = A3

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	Name
Surveyor	-
Draftsman	S GREEN
Designer	S GREEN
Approved	T HARRISON

This drawing must not be used for construction unless signed as approved

Client: PAN PAC FOREST PRODUCTS LIMITED
Project: WHIRINAKI RESILIENCE PROJECT
Title: NORTH SHORE ROAD LONGITUDINAL SECTION AND PLAN

Status	Date	Scale	Drawing No:	Rev:
DRAFT	15/09/2023	1:1000	51-001-SK201	A

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APPENDIX 6

Urban Connection Memo

URBAN CONNECTION
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26 October 2023

Phil Duncan
Hawke's Bay Regional Council
PO Box 6006
Napier

Dear Phil

Whirinaki Stopbank – SH2 Resilience Effects

Further to our work undertaking the geometric concept design for changes to the vertical alignment required on SH2 in the vicinity of North Shore Road, we have reviewed the Esk River Hydraulic Model[1]report to understand the effects of the proposed stopbank and associated changes to the highway. We have specifically considered the effects relevant to the risk of road closures from flooding.

Context

SH2 from Napier to Wairoa is classified as a Regional Highway in the Waka Kotahi NZ Transport Agency's (Waka Kotahi) One Network Road Classification. This is the lowest level of State Highway and Waka Kotahi has a series of resilience planning tools which are considered the most appropriate to set the Target level of service that is sought when designing for any section on that State Highway.

These tools cover both high impact, low frequency events such as major earthquakes, tsunamis, cyclones etc, as well as low impact, high frequency events such as flood events, slips, snow, trees blocking the highway etc.

It is important when assessing the Target level of service at any one point on a section of highway that the wider resilience of that corridor is considered. Designing to a high target level in one location could be considered to be overdesigning if 5km up the highway is an existing site of very low resilience. Ideally a uniform level of resilience should be inherent along the corridor, which may not necessarily achieve the target, however is what can be realistically achieved and maintained at a corridor level.

The Transport Recovery East Coast (TREC) Alliance will likely be looking at the level of service across SH2 and ultimately any design outcomes applied at this site should be consistent with that programme of work and agreed design standards on this corridor.

Not disregarding the recent cyclone, but aligning with more typical event scenarios, further detailed analysis of the Traffic Road Event Information System (TREIS) would provide insight into the existing level of service on SH2 in terms of low impact, high frequency events. As the former professional services manager for the Hawke's Bay and Gisborne Network Outcome Contracts for Waka Kotahi I am aware that these events are relatively common with both over and underslips occurring and the Highway adjacent Lake Tutira being flooded.

[1] Pattle Delamore Partners Report prepared for the Hawke's Bay Regional Council

This location (SH2 Tutira Flooding) and the subsequent design response from TREC would potentially serve as a good comparison to determine the appropriate target levels of service that are being applied consistently to the corridor in regard to flooding.

Review of flood modelling report

Section 8 of the Pattle Delamore Partners report focuses on the effects on SH2 based on the existing situation and the proposed option (Base Case). The report states the following:

To more fully explore the predicted effects on SH2, a number of additional model runs were completed. These included the 0.5% AEP, 1% AEP,2% AEP, 5% AEP and 10% AEP events both with and without the base case. The purpose of running these additional model scenarios was to determine the effects of the base case on SH2 by considering the length of closure which was determined by calculating the duration that a given flood depth was exceeded.

Three flood depths were selected for this assessment:

- *100 mm, the depth at which the AA recommends not driving through;*
- *300 mm, the limiting still water depth for small passenger vehicles, from Austroads; and,*
- *500 mm, the limiting still water depth for large vehicles, such as emergency vehicles (Austroads).*

Table 9 shows the duration of inundation above a given depth with and without the base case. For all modelled scenarios, the duration of inundation decreases with the base case scenario and therefore, we conclude that if the SH2 is set to a nominal elevation of 7.0 mRL, the base case scenario will not have an adverse effect on the serviceability of SH2. That is, the serviceability in terms of closures is predicted to be similar to the current serviceability of SH2.

We note that the duration of flooding will be dependent on the shape of the hydrograph, for all model runs reported on, the design flows were scaled to a Gabrielle shape hydrograph. Furthermore, silt deposition in a large flood event, such as Gabrielle, may result in an extended closure of the highway.

Table 1 Table 9 from the PDP report

Table 9 Duration (hours) that depth over SH2 is greater than…						
	Depth > 500 mm		Depth > 300 mm		Depth > 100 mm	
	Existing	Base case	Existing	Base case	Existing	Base case
0.5% AEP	15.25 hrs	15 hrs	17	16.5 hrs	17.5	17.5 hrs
1% AEP	12.25 hrs	11.75 hrs	14.5	14.25 hrs	15.5	15.5 hrs
2% AEP	5.5 hrs	4.75 hrs	12	10.5 hrs	13.5	13.5 hrs
5% AEP	0 hrs	0 hrs	0	0 hrs	10.25	5.5 hrs
10% AEP	0 hrs	0 hrs	0	0 hrs	0	0 hrs
INCREASE	NO CHANGE	DECREASE				

If the maximum duration of 16.5 hours of depths of 300mm (impassable for light vehicles) occurs 2 times a year the Waka Kotahi Resilience Framework does not require a response (Refer Table 2).

Table 2 Waka Kotahi Resilience Level of Service Table

Regional/Arterial

Duration of outage	Frequency on corridor	Response
2 - 4 hrs	10 times a year	No response
5 - 12 hrs	2 times a year	No response
13 hrs - 2 days	2 times a year	No response
3 - 5 days	Once every 4 years	No response
6 - 14 days	Once every 10 years	No response
15 - 49 days	Once every 25 years	No response
50 - 120 days	Once every 50 years	No response
more than 120 days	Once every 50 years	No response

Conclusion

While any design response at the site should be consistent with that being applied elsewhere along the corridor, Table 9 from the report, outlines there are no increases to the duration of flooding over SH2 in any depth category as a result of the proposed stopbank. In all instances the modelling demonstrates that the effects are the same or improved.

Based on this we would consider there to be no discernible differences with the operation of SH2 between the existing conditions and those with the proposed stopbank.

The Pattle Delamore Partners Report does state that topographical surveys should be undertaken to confirm heights due to the limitations of the accuracy of LIDAR. They also recommend that their work is independently peer reviewed prior to detailed design commencing.

It should be noted that the proposed stopbank requires approximately 400m of SH2 to be raised in level which will be an improvement for that section in terms of resilience compared to the existing scenario.

Yours sincerely

Tony Harrison
Technical Director

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