REPORT

Tonkin+Taylor

# Okawa Stream Hydraulic Model Build

**Prepared for**
Hawkes Bay Regional Council

**Prepared by**
Tonkin & Taylor Ltd

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## Document control

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| **Date** | **Version** | **Description** | **Prepared by:** | **Reviewed by:** | **Authorised by:** |
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| 30/07/24 | 2 | Changed climate change allowance.<br>More information around effects on bridge.<br>Added Option 4. | KTHA | RIBR | TGM |
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# 1 Introduction

Hawkes Bay Regional Council (HBRC) engaged Tonkin & Taylor Ltd (T+T) on 19th February 2024 to undertake a hydrological study of the Okawa/Ohiwa Stream catchment as part of the land categorisation review process.

During Cyclone Gabrielle, severe flooding occurred within the Omahu area along the Okawa/Ohiwa Stream. Floodwaters flowed over Taihape Road and inundated the residential subdivision on Ohiti Road (Figure 2.1). There were also reports of floodwaters breaking out of the left bank of the Ohiwa Stream into the Omahu township. As a result, HBRC categorised the Ohiti Road area as Category 2P, implying property level interventions were to be investigated. HBRC are revising the area to a Category 2A, meaning that a community-based solution may be appropriate.

This report presents a hydrological study of the Okawa/Ohiwa Stream catchment including a review of stream flows and the development of a 2-dimensional (2D) hydraulic model used to assess potential flood mitigation options.

Version 2 of this report has the following differences from Version 1:

- Added commentary on the effects of the flood protection stopbank on the Taihape Road bridge (Section 4.1.3).
- Updated climate change allowance in modelling from RCP4.5 2130 to RCP8.5 2075.
- Added another stopbank option (Option 4) that involves raising Taihape Road. This was raised as a potential option when discussing the flood protection work with Hastings District Council.

This assessment follows an initial assessment of flood mitigation options undertaken by Tonkin & Taylor[1] in 2023.

[1] Tonkin & Taylor. 2023. *Omahu Stopbank Concept Design Review*. T+T ref 1017353.2301

# 2 Hydraulic flood model

## 2.1 Model purpose

The primary purpose of the hydraulic flood model was to estimate flood flows and levels to inform concept design of several flood mitigation options for the Omahu area.

The flood mitigation options were tested in the model for the estimated 100-year Average Recurrence Interval (ARI) flood event with climate change allowance (RCP8.5 2075). The performance of the flood mitigation options in an event similar to Cyclone Gabrielle was also modelled. The model was also used to assess the effects of the flood mitigation options on the Taihape Road bridge. The effects were assessed for the 5-year ARI and 20-year ARI flood events with climate change allowance.

The following sections outline the model inputs, assumptions, results and recommendations.

## 2.2 Model solver and model domain

The model was built using the 2D 2023 TUFLOW HPC solver.

The hydraulic model domain encompasses an area from north of Lake Runanga to south of the Ngaruroro River as shown in Figure 2.1.

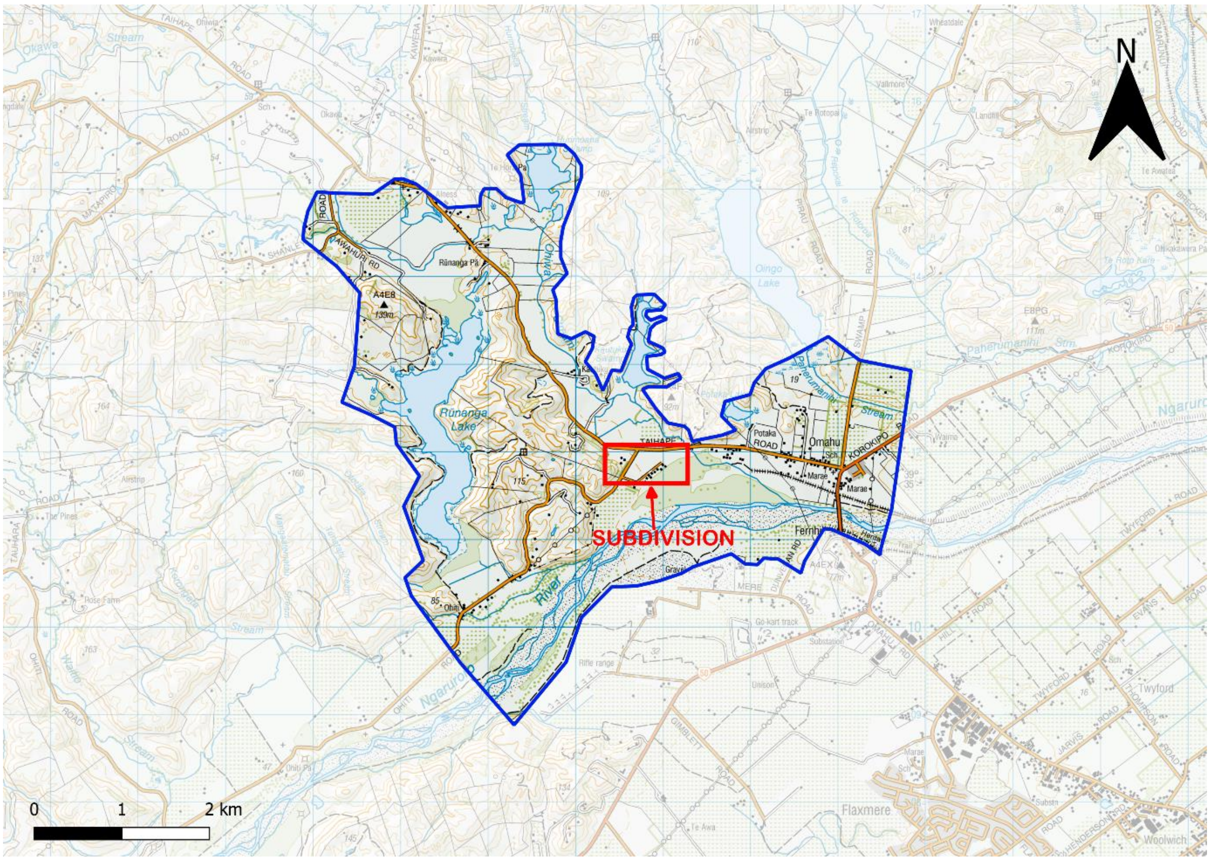


*Figure 2.1: Domain of TUFLOW hydraulic model.*

## 2.3 Model extents and geometry

### 2.3.1 Digital elevation model

A 1 m x 1 m gridded bare earth DEM formed from LiDAR captured in 2021[2] sourced from Land Information New Zealand (LINZ) was used to represent the ground level across the model domain. This DEM represents a pre-Cyclone Gabrielle topographic condition.

A DTM of three areas within the model domain was undertaken via a UAV survey in April 2024. Details of the survey are provided in Appendix B. The following areas were captured in the survey:

- Along Okawa/Ohiwa Stream from the upstream Taihape Road crossing to downstream Taihape Road crossing, with an approximate 100 m width.
- The area between Okawa/Ohiwa Stream and Runanga Lake.
- The Runanga Stream downstream of Runanga Lake.

Figure 2.2 shows the DEM used for the model, and the extents of the UAV survey. The vertical datum for all DEM grids is NZVD2016. The UAV survey represents a bare earth terrain with buildings removed, bridges were not removed from the DEM supplied to T+T.

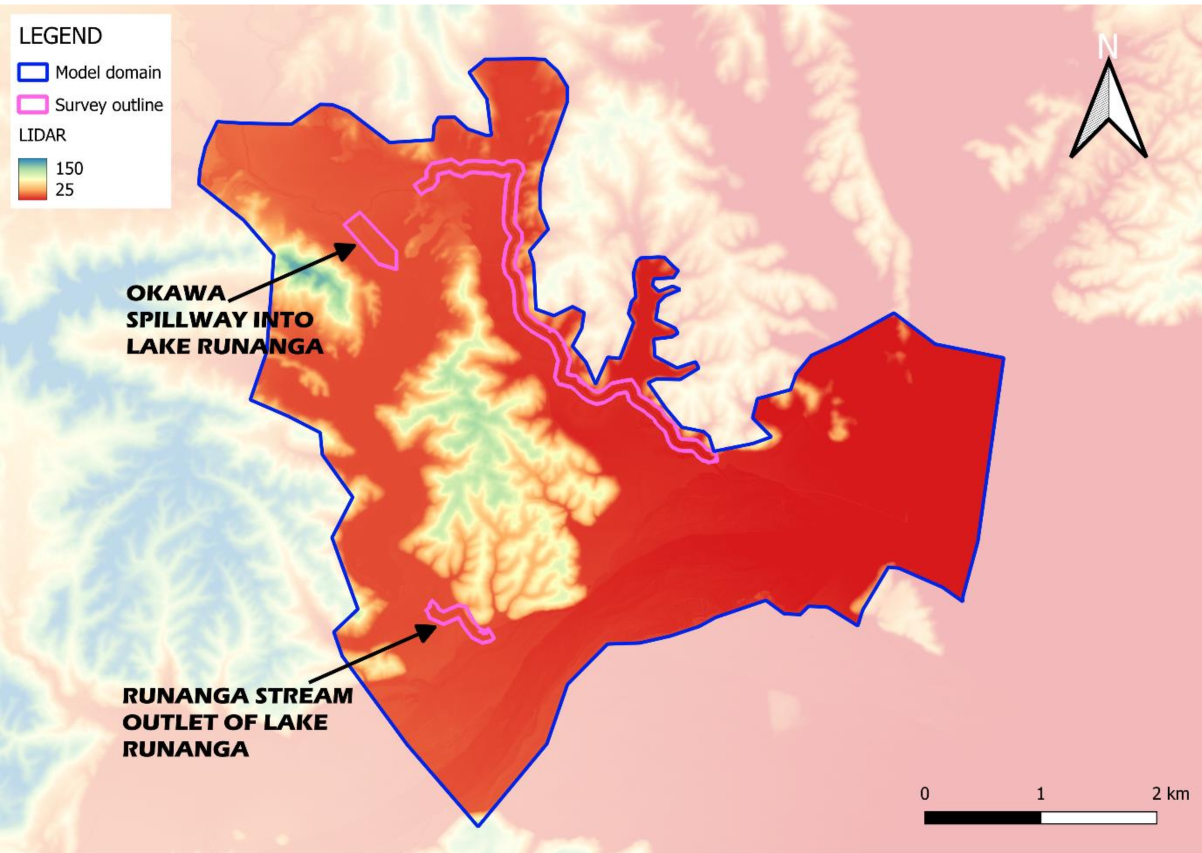


*Figure 2.2: LIDAR with detailed survey extent*

Historical flood observations show that at high flows, the Okawa/Ohiwa Stream overtops and spills into Lake Runanga. Any spill into the lake reduces the peak flow rate within the Okawa/Ohiwa Stream. The model grid size was refined (refer Section 2.3.3) at the spill location to improve the hydraulic representation of conveyance into the lake.

[2] Hawkes Bay LiDAR (2021-2021) sourced from LINZ 9 March 2024

### 2.3.2 Terrain modification

The bridges along Okawa/Ohiwa Stream were removed from the DEM by T+T using TUFLOW's 2d_zsh terrain modification.

The DEM was modified to represent identified buildings within the model domain using TUFLOW's 2d_zsh terrain modification.

The 2d_zsh feature was used to enforce the Ngaruroro stopbank and Taihape Road crest levels into the model.

### 2.3.3 Computational grid size

The DEM has been applied to the model across a range of grid sizes using TUFLOW's quadtree nesting and sub-grid sampling. Quadtree nesting allows the user to refine the computation grid size in areas of interest and makes the computation grid size coarser in areas of lesser significance.

Figure 2.3 shows the different Quadtree nesting levels applied to the model domain and how this has been spatially varied. The finest computation grid resolution applied to the model is 1.25 m and the coarsest resolution is 10 m. The following resolutions have been used for the various model area elements:

- Omahu town: 2.5 m.
- Area surrounding Omahu town: 5 m.
- Okawa/Ohiwa Stream Channel: 5 m.
- Okawa/Ohiwa Stream spill to Lake Runanga: 2.5 m.
- Runanga Stream: 1.25 m.
- Rest of model domain: 10 m.

The model applies sub-grid sampling to the computational grid which facilitates improved conveyance and storage by sampling the underlying DEM at its original resolution (for the LINZ LiDAR is a resolution of 1 m x 1 m and the UAV survey is a resolution of 150 mm x 150 mm).

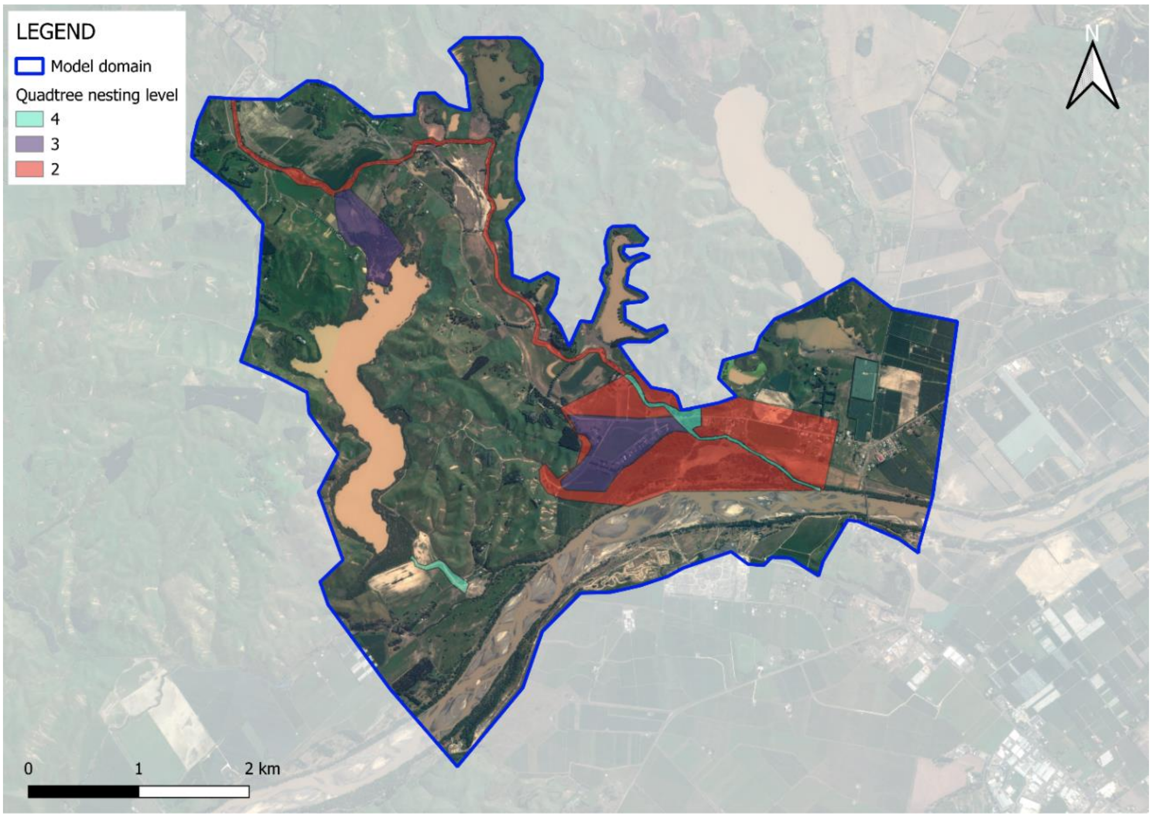


*Figure 2.3: Quadtree nesting levels*

### 2.3.4 Roughness

Manning's 'n' roughness coefficients were applied to different land uses within the model domain to represent the hydraulic roughness of the area.

The roughness in the Ngaruroro River margins was adopted from a separate hydraulic model being developed for the Ngaruroro River (roughness values provided by HBRC).

The Manning's roughness used in the remaining area of the model domain is based on land use. The land use adopted in the model is based on the LCDB, created by Landcare Research New Zealand. This database was released in January 2020 and considers land use classification up until the end of 2018. LCDB does not provide specific detail over areas such as roads, buildings, and small waterbodies. Within the model domain, no such features have been identified that have a significant effect on flooding; therefore, no further refinements to the land use have been made.

Mannings 'n' values were adjusted during the model calibration as described in Section 3.

The Manning's 'n' values used within the hydraulic model are shown in Figure 2.4.

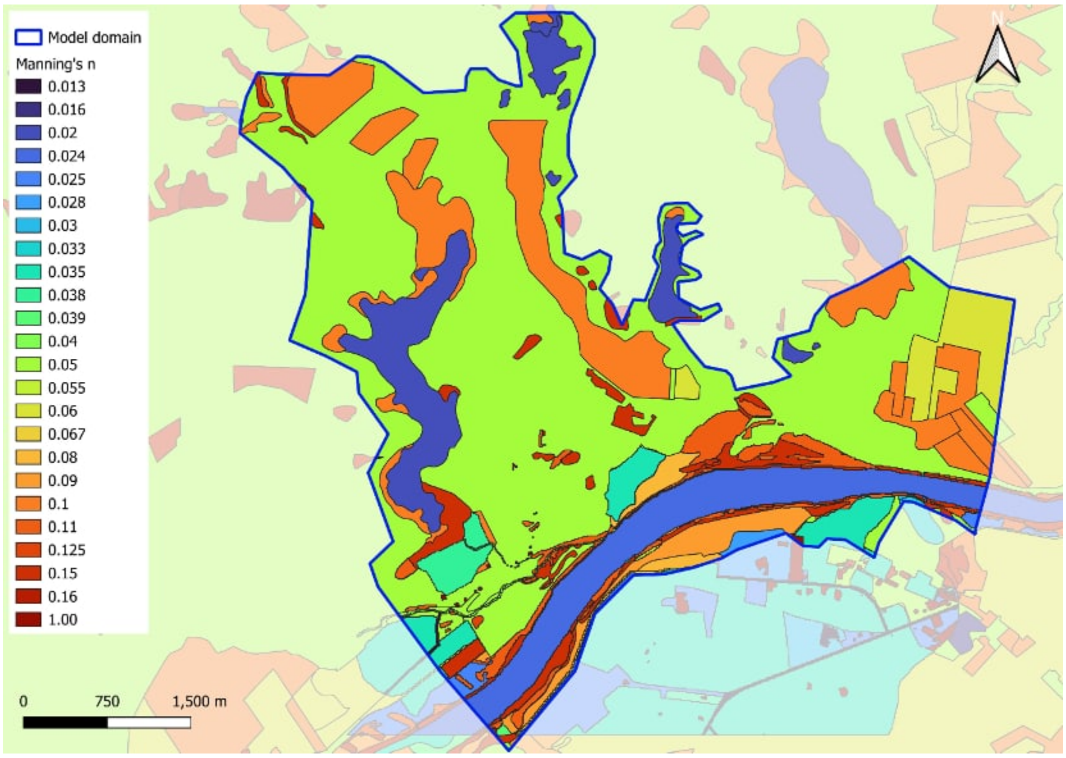


*Figure 2.4: Manning's 'n' roughness.*

### 2.3.5 Bridges

The Taihape Road bridge over the Okawa/Ohiwa Stream adjacent to the Omahu township (refer Figure 2.5) was modelled using a 2d_bg file in TUFLOW. The 2d_bg uses the inputs shown in Table 2.1 to create a single loss Form Loss Coefficient (FLC) for the bridge. There is some uncertainty in this parameter as the values for the inputs were estimated from site visit photographs and aerial photography.

*Figure 2.5: Taihape Road bridge*

The bridge was modelled with 50% blockage of the piers in the 100-year ARI RCP8.5 2075 and approximated Cyclone Gabrielle flood events. It is understood that during Cyclone Gabrielle, a large amount of sediment was deposited at the bridge, almost reaching the bridge soffit. The bridge was modelled with no blockage of the piers in the 5-year ARI and 20-year ARI with climate change allowance flood events as less sediment would be expected during these smaller events.

**Table 2.1: Bridge modelling inputs**

| GIS attribute name | Description | Value |
|---|---|---|
| Pier_pBloc | Percentage of blockage in pier layer. | 50[1] |
| Pier_FLC | Pier layer form loss coefficient | 0.07 |
| Deck_Soffit | The elevation of the bridge soffit (m). | 29 |
| Deck_Depth | The thickness of the bridge deck (m). | 1.5 |
| Deck_Width | The bridge width in the predominant direction of flow (m). | 8.5 |
| Deck_pBloc | The percentage blockage of the deck layer. | 100 |
| Rail_Depth | The depth of the rail layer (m). | 1.5 |
| Rail_pBloc | The percentage blockage of the rail layer. | 80 |
| SuperS_FLC | The combined form loss coefficient for the deck and rail layers. Two layers are treated as a single "super structure" layer. | N/A[2] |
| SuperS_IPf | A factor to set the elevation of the inflection point at which the transition from pressure flow to drowned flow commences. (Default from research = 1.6[3]) | 1.6 |

Notes:

1. 50% blockage for the 100-year ARI RCP8.5 2075 and Cyclone Gabrielle events, 0% blockage for the 5-year ARI and 20-year ARI with climate change events.

2. "Method A" approach used to determine the combined form loss coefficient (SuperS_FLC). Refer below for details.

The pier form loss coefficient, $\Delta K$ was derived from Figure 2.6 taken from the Hydraulics of Bridge Waterways[4]. The form loss coefficient was estimated using J which is the ratio of the water area occupied by piers, $A_p$ to the gross water area $A_{n2}$.

$$J = \frac{A_p}{A_{n2}}$$

[3] Collecutt et al, 2022. https://wiki.tuflow.com/TUFLOW_2D_Hydraulic_Structures

[4] J. N. Bradly, 1978. *Hydraulics of Bridge Waterways.* U.S. Department of Commerce, Bureau of Public Roads

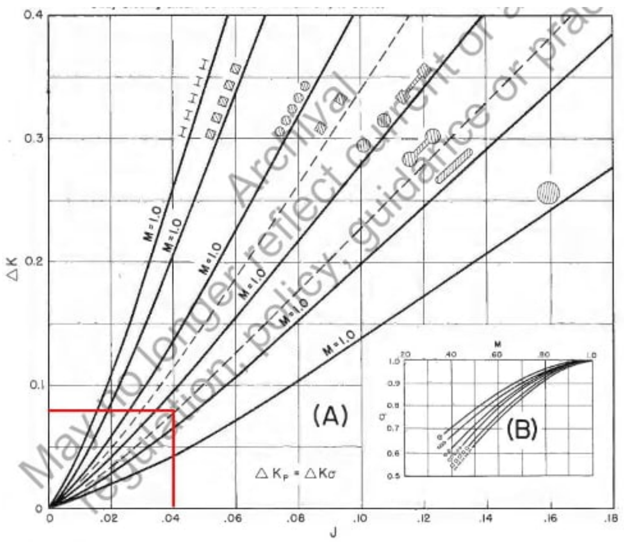


*Figure 2.6: Pier form loss coefficient derivation.*

The combined form loss coefficient for the deck and rail layers (SuperS_FLC) was calculated automatically by the TUFLOW software. The “Method A”[5] approach was used to determine the form loss coefficient. It is based on the ratio of the depth of the pier layer and the thickness of the deck and rails.

The other bridges within the model were removed from the DEM as outlined in Section 2.3.2 and the effects from the bridge were not modelled. It was assumed that the effect of the other bridges over Okawa/Ohiwa Stream were sufficiently far upstream that they would have minimal impact on flood characteristics at Omahu.

## 2.4 Boundary conditions

### 2.4.1 Lumped catchment model

Estimated hydrological inflow boundaries representing flow from the Okawa/Ohiwa Stream, Kautuku Swamp and Hurimoana Swamp were applied to the upstream boundary of the hydraulic model domain. Estimated inflow boundaries were generated for the 100-year ARI with climate change allowance RCP8.5 2075 and Cyclone Gabrielle event. The rainfall data used to estimate flows for the 100-year ARI RCP8.5 2075 event is based on the High Intensity Rainfall Design System (HIRDS)[6] information which does not include the Cyclone Gabrielle event in the estimates for rainfall. Figure 2.7 shows the location of the hydrological boundaries applied to the hydraulic model.

[5] Collecutt et al, 2022. https://wiki.tuflow.com/TUFLOW_2D_Hydraulic_Structures
[6] National Institute of Water and Atmospheric Research (NIWA), *High Intensity Rainfall Design System (HIRDS).* https://hirds.niwa.co.nz/

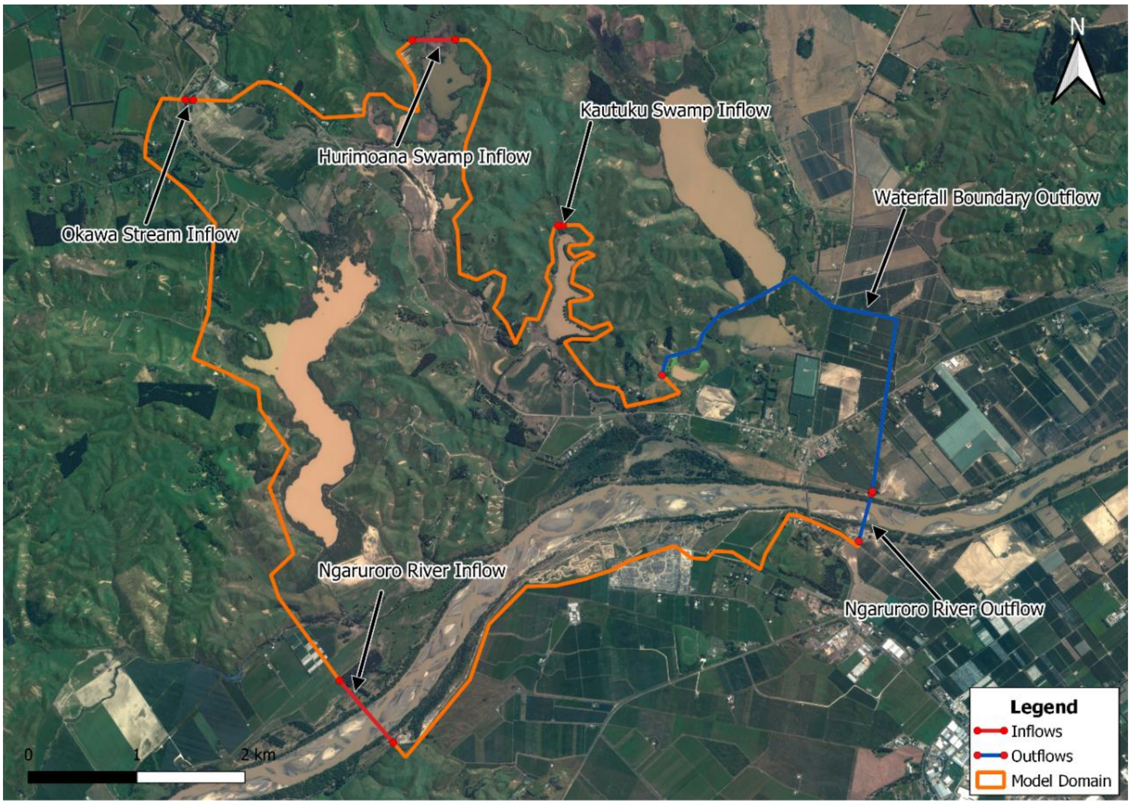


*Figure 2.7: Location of boundary conditions applied to the hydraulic model.*

Information on the estimation of the Okawa/Ohiwa Stream, Hurimoana Swamp and Kautuku Swamp hydrographs is provided in Appendix A.

The peak flow assessments for the three inflow boundaries are shown in Table 2.2 and the estimated boundary hydrographs are shown in Figure 2.8. The 12-hour duration event was chosen as it resulted in the highest flow estimates in Okawa/Ohiwa Stream.

It is noted that the estimated flows for the Hurimoana and Kautuku catchments in the 100-year ARI RCP8.5 2075 event are larger than the Cyclone Gabrielle flows. This is because in Cyclone Gabrielle, the rainfall gauges in these catchments measured less rainfall than the Okawa/Ohiwa catchment.

**Table 2.2: Inflow boundary peak flows**

| Insert heading | Okawa/Ohiwa Stream | Kautuku Swamp | Hurimoana Swamp |
|---|---|---|---|
| Cyclone Gabrielle | 580 $m^3/s$ | 2.4 $m^3/s$ | 5.0 $m^3/s$ |
| 100-year ARI RCP8.5 2075 | 336 $m^3/s$ | 6.2 $m^3/s$ | 9.1 $m^3/s$ |

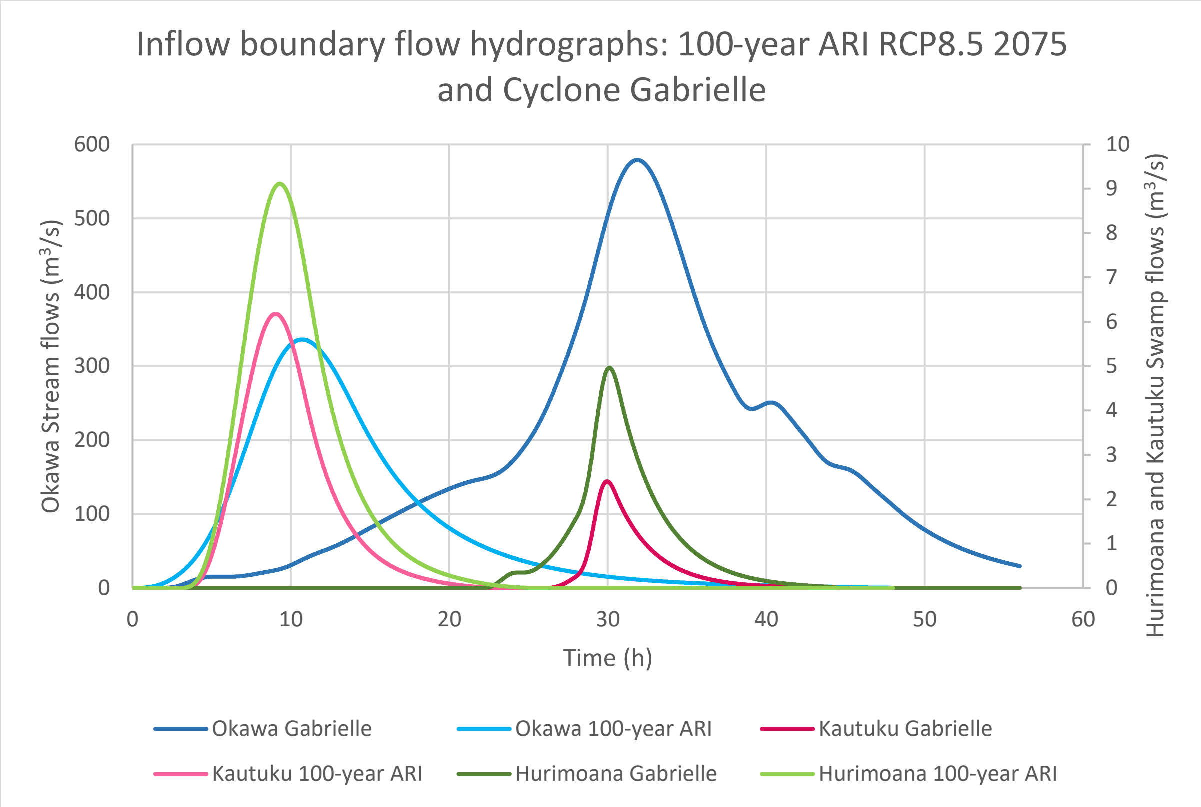


*Figure 2.8: Modelled event hydrographs. Note the Okawa Stream is plotted on the primary axis, with Hurimoana and Kautuku Swamp plotted on the secondary axis.*

An additional hydrology assessment was undertaken to estimate 5-year ARI and 20-year ARI RCP8.5 2075 flows. These were used to assess the effects of the flood mitigation options on the Taihape Road bridge. The hydrology was estimated using the same model outlined in Appendix A. The hydrological model was primarily developed to estimate larger flood events (i.e. 100-year ARI). As such, the estimates of the 5-year and 20-year ARI are indicative only. It is likely that the flows are conservative for the more-frequent events based on the assumed hydrological parameters.

Figure 2.9 shows the inflow boundary hydrographs for the 5-year ARI and 20-year ARI RCP8.5 2075 events.

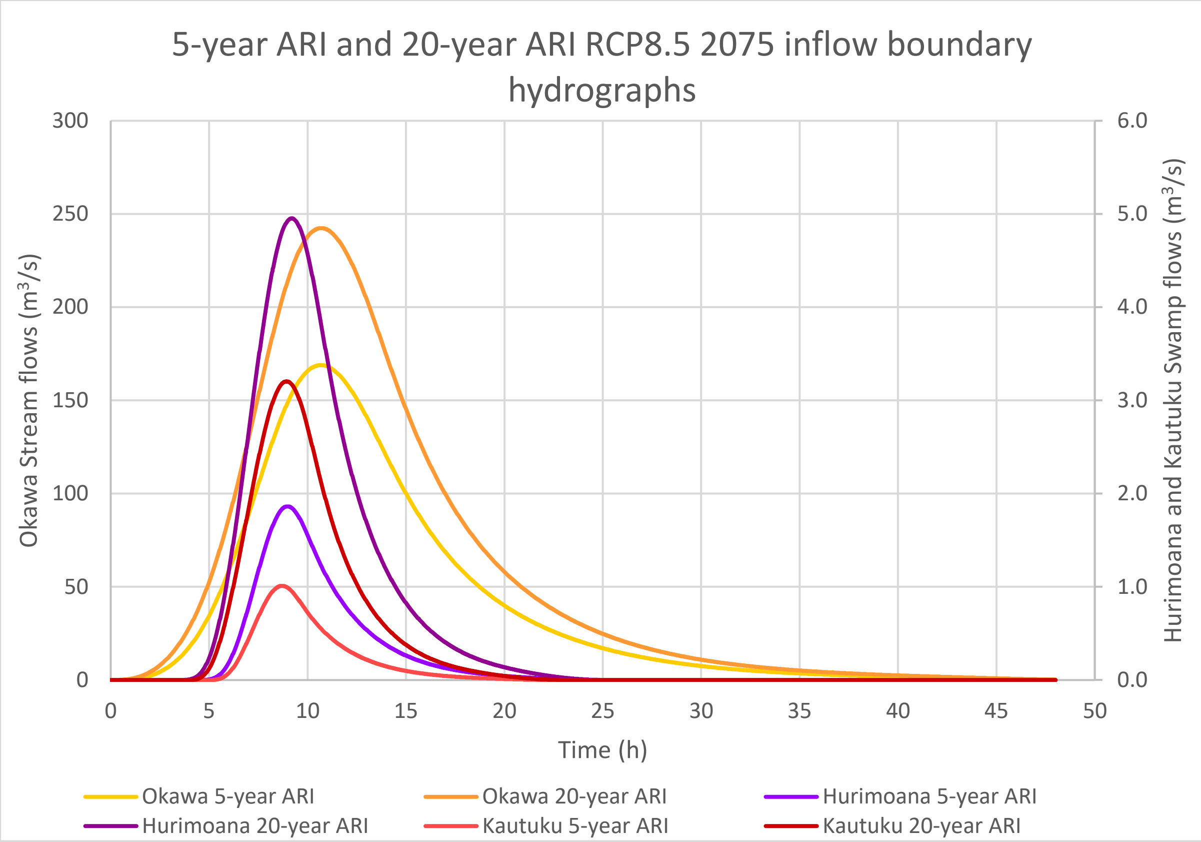


*Figure 2.9: Modelled 5-year ARI and 20-year ARI RCP8.5 2075 event hydrographs. Note the Okawa Stream is plotted on the primary axis, with Hurimoana and Kautuku Swamp plotted on the secondary axis.*

### 2.4.2 Ngaruroro River

The Ngaruroro River at the downstream boundary of the model was modelled using an inflow hydrograph and a water level-flow outflow boundary. Figure 2.7 shows the locations where the boundary conditions were applied.

The hydrograph for the Ngaruroro inflow boundary for the Cyclone Gabrielle event was sourced from the flow recorder on the Ngaruroro River located at Fernhill. This is located approximately 8 km downstream from where the flow was applied in the model. The estimated flow hydrograph for the 100-year ARI event was sourced from the separate model of the Ngaruroro River[7] current at the time of writing. The assumed hydrographs are shown in Figure 2.10.

[7] Peak flow at Fernhill of 3,925 $m^3/s$ derived from NIWA flood estimates using GEV distribution and provided to T+T by HBRC (March 2024).

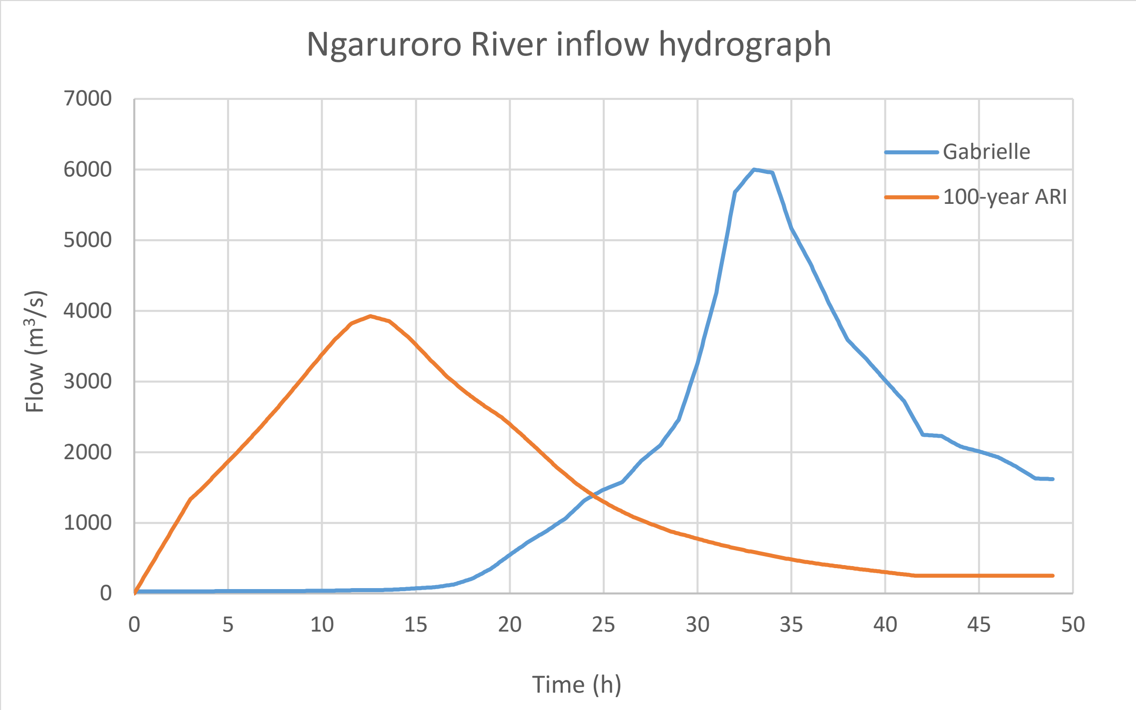


*Figure 2.10: Ngaruroro River inflow hydrograph.*

### 2.4.3 Waterfall boundary

A free outlet was assumed for the eastern model boundary on the Heretaunga Plains. The free outlet allows water levels upstream to stabilise to normal flow conditions and avoid build up of water along the model boundary.

### 2.4.4 Direct rainfall

Direct rainfall was also applied to the model as the model domain represented a relatively large area in the total catchment (approximately 20 $km^2$ of 120 $km^2$). Rainfall was not applied to the Omahu township south of Taihape Road, or the eastern portion of the model domain.

Infiltration parameters of the soil within the model domain are unknown and so a very low infiltration rate was assumed to be conservative. This skewed the flood results within Omahu as all rainfall landing within the Omahu township turned into runoff and flooding behind the stopbanks. The purpose of this model was to evaluate flood mitigation options from the Okawa/Ohiwa Stream, which remains valid despite this.

The 100-year ARI RCP8.5 2075 rainfall was taken from HIRDS. The Cyclone Gabrielle rainfall hyetograph was estimated using a combination of private gauges and the Moteo rainfall station.

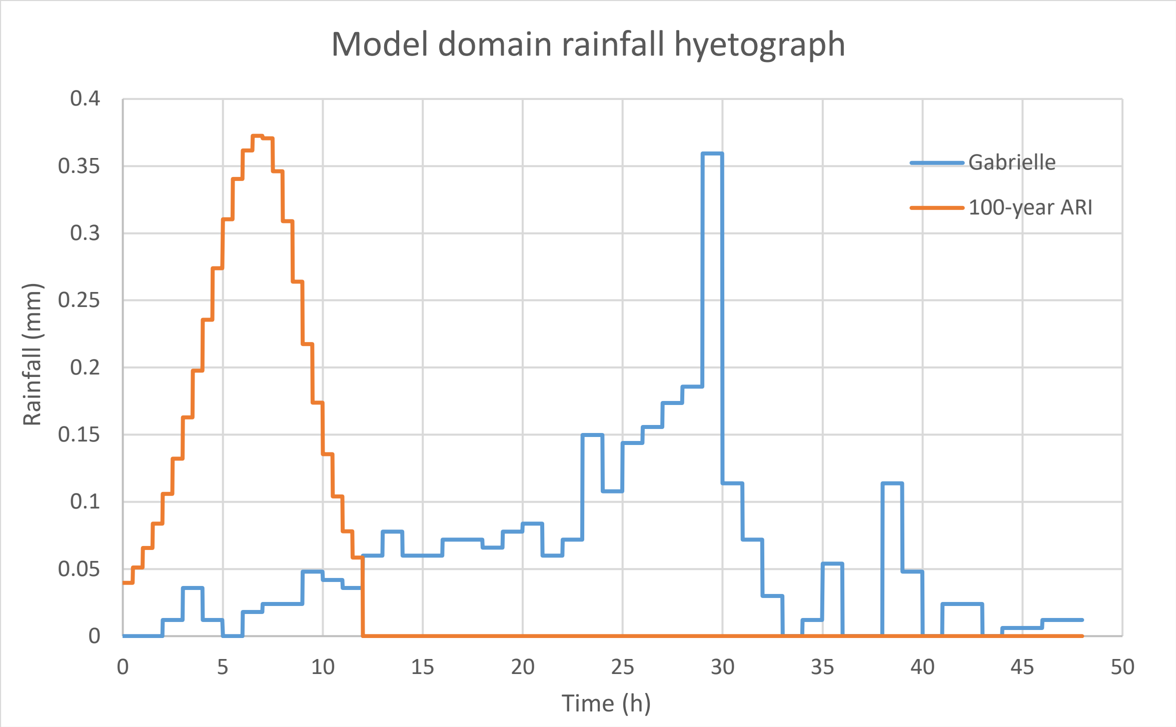


*Figure 2.11: Model rainfall hyetograph*

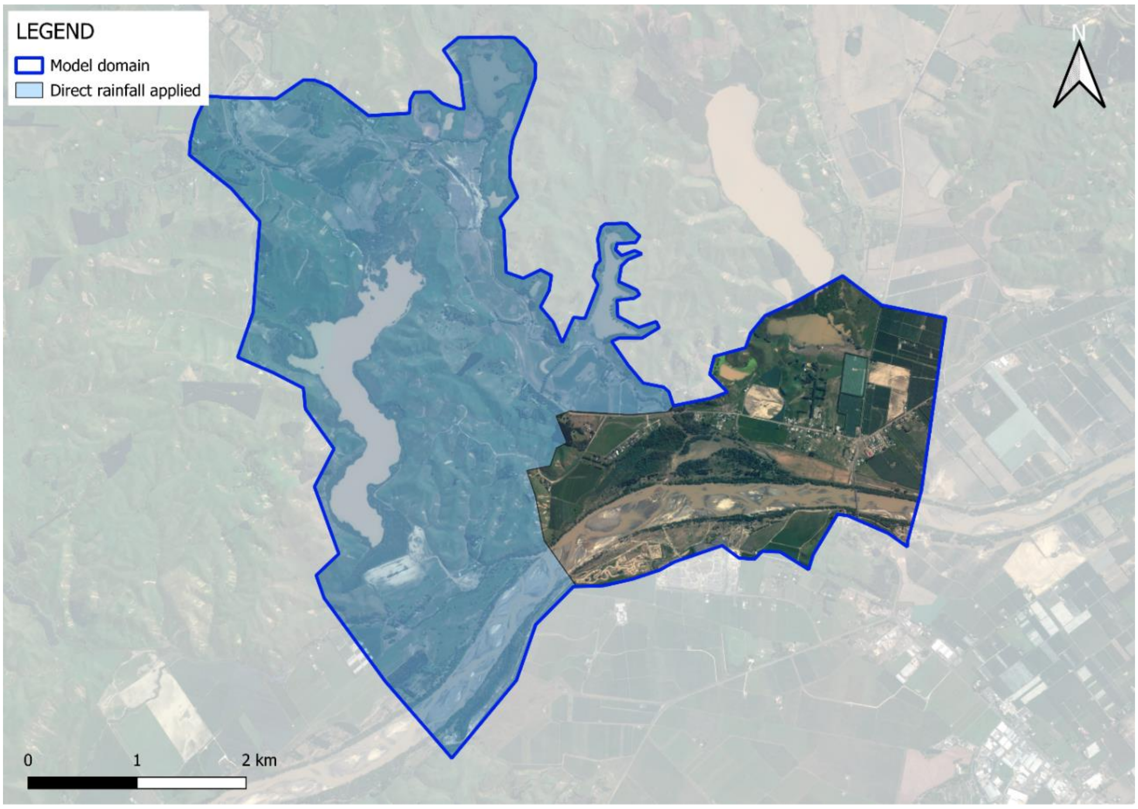


*Figure 2.12: Direct rainfall application extent*

### 2.4.5 Inflow peak coincidence

For the Cyclone Gabrielle event, the model used real-time inputs from the rainfall gauges and the Ngaruroro River modelling. Consequently, the timing of the peak values for each input aligned with real-time conditions.

For the hypothetical 100-year ARI event, the exact timing of peak flows in the Okawa/Ohiwa Stream, Hurimoana Swamp, Kautuku Swamp, Ngaruroro River and rainfall is unknown. To be conservative, the peaks were aligned to be coincidental at the Omahu township across all inputs.

# 3 Model calibration

Calibration of the hydraulic model was undertaken by adjusting key model input parameters until the hydraulic model results aligned with historical flood event observations.

The model parameters considered for adjustment in the calibration were peak inflow of the Okawa/Ohiwa Stream and roughness, as they are considered to have the most uncertainty and influence on the model results.

The Cyclone Gabrielle event was used for model calibration as this event had the most recorded flood observations available, including:

- Aerial imagery post Cyclone Gabrielle showing silt deposition or erosion extents.
- Personal accounts of flood depths, velocities and timing of flooding.
- Water and debris marks on buildings.
- Photos in Omahu during Cyclone Gabrielle.

The observational information available above is primarily water level/depths at various times during Cyclone Gabrielle.

Appendix C shows the calibration information used to validate the model for the Cyclone Gabrielle event.

The model shows a reasonable alignment to the flood observations recorded during Cyclone Gabrielle. There are some differences between the model and observed levels and depths, but it is generally within 200 mm – 300 mm. There is some uncertainty in the calibration data, our interpretation of the water levels and depths from the photos and anecdotal evidence of flood conditions. This uncertainty should be factored into freeboard provisions for flood mitigation.

There was no information available for calibrating the smaller events (i.e. the 5-year ARI and 20-year ARI). The model was used primarily for assessing the effects of the flood mitigation options on the bridge, looking at relative differences against the base case. Therefore, calibration of the model at smaller events was not necessary for this purpose.

# 4 Flood mitigation options

Four flood mitigation options were modelled using TUFLOW's zsh terrain modification feature. The four options comprise primarily of a new stopbank, indicatively shown on Figure 4.1 to protect the Category 2 residential properties off Ohiti Road.

Two smaller stopbanks in addition to the primary stopbank were also considered. These are detailed in Section 4.1.

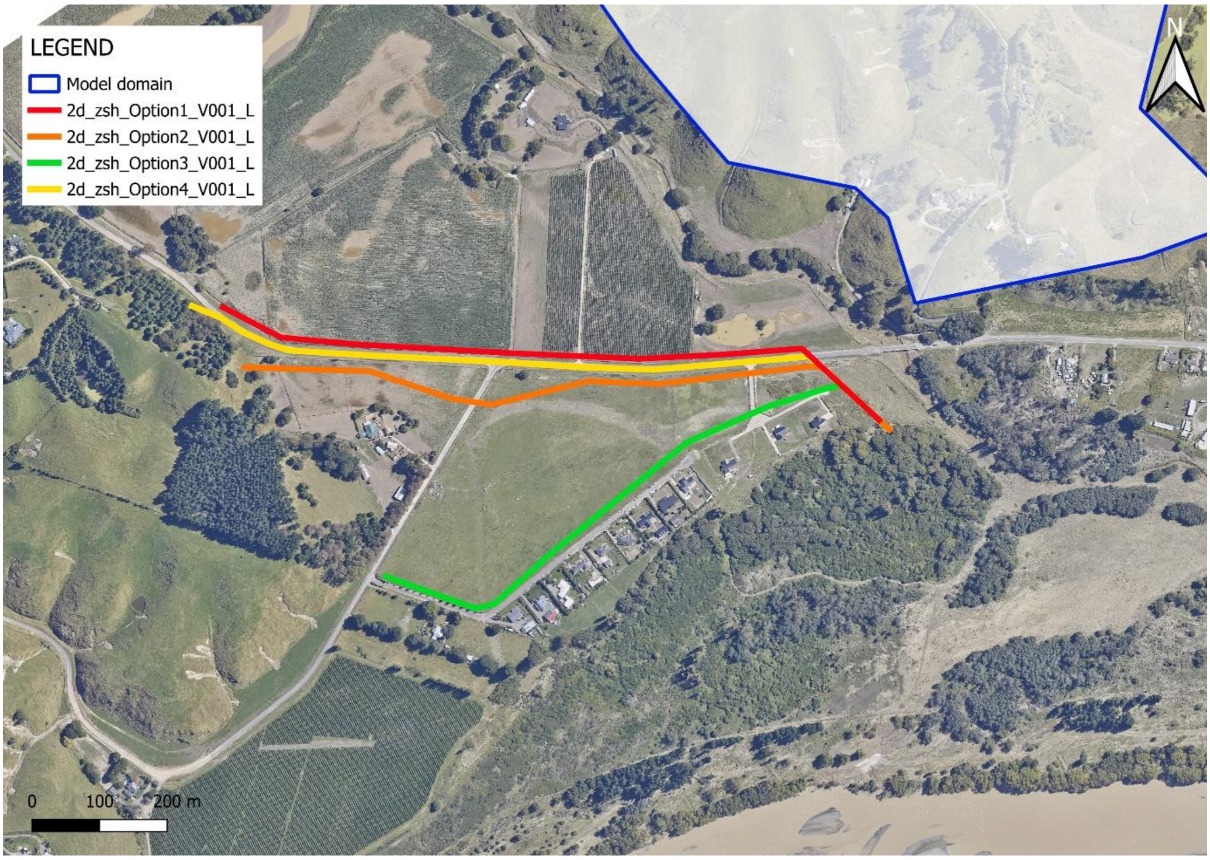


*Figure 4.1: Modelled primary stopbank alignments.*

The flood mitigation options were modelled with the 100-year ARI RCP8.5 2075 flood event hydrology.

Estimated maximum water depth maps from the model for each of the stopbank alignments and a base case (without stopbank) are provided in Appendix D. Mapping of velocity estimates for the preferred alignment (refer Section 6) and the base case are also provided in Appendix D.

Table 2.1 provides a summary of the four stopbank options modelled along with approximate stopbank length and typical water depth.

**Table 4.1: Stopbank alignment description**

| Option | Description | Length | Typical estimated 100-year water depth along stopbank |
|---|---|---|---|
| 1 | Option 1 stopbank alignment runs along the north of Taihape Road. The stopbank crosses Taihape Road at the eastern end before the bridge and diverts water past 203 Taihape Road.<br>The western end of the stopbank allows water to flow around the end of the stopbank and over the road, flooding the houses within Omahu township. This could be mitigated by crossing the stopbank over the road to tie into the high ground, but this option was not explored further as it was not believed to be the preferred option.<br>The stopbank on this alignment increases flows breaking out of the left bank of the Okawa/Ohiwa Stream near the bridge and increases the flooding of the properties east of Okawa/Ohiwa Stream.<br>This alignment was also modelled with a smaller stopbank east of the Okawa Stream to mitigate flooding of houses east of Okawa Stream (refer Section 4.1.1). | 1,025 m | 1.6 m |
| 2 | Option 2 stopbank alignment runs along the south of Taihape Road, crossing Ohiti Road near the intersection of the two roads. The western end of the stopbank was tied into the high ground at the hill. The eastern end continues past the houses and diverts water around 203 Taihape Road.<br>This alignment is effective at protecting all houses from Okawa/Ohiwa Stream flows. The modelling highlighted other flow paths that could cause flooding of the houses behind the stopbank. The stopbank on this alignment worsens the effects of this flooding as it traps water from draining back to the stream. This is explored further in Section 4.1.<br>The stopbank on this alignment increases flows breaking out of the left bank of the Okawa/Ohiwa Stream near the bridge and increases the flooding of the properties east of Okawa/Ohiwa Stream.<br>Two other variations of this option were modelled:<br>• Option 2B: the main alignment with a smaller stopbank east of the Okawa Stream to mitigate flooding of houses east of Okawa Stream (refer Section 4.1.1).<br>• Option 2C: the main alignment and the smaller eastern stopbank with another stopbank further south crossing Ohiti Road to mitigate overland flow path flooding (refer Section 4.1.2). | 1,002 m | 1.4 m |

| | | | |
|---|---|---|---|
| 3 | Option 3 stopbank alignment begins at the start of the access road to 23-37a Ohiti Road and runs along the north of the access road and houses to divert water around 203 Taihape Road.<br>The modelling showed that this alignment protected the houses from 23 Ohiti Road to 203 Taihape Road from Okawa/Ohiwa Stream flows and the other identified overland flow paths. This option does not protect 18/20 Ohiti Road from Okawa/Ohiwa Stream flows.<br>The stopbank on this alignment increases flows breaking out of the left bank of the Okawa/Ohiwa Stream near the bridge and increases the flooding of the properties east of Okawa/Ohiwa Stream.<br>This alignment was also modelled with a smaller stopbank east of the Okawa Stream to mitigate flooding of houses east of Okawa Stream (refer Section 4.1.1). | 871 m | 1.0 m |
| 4 | Option 4 stopbank alignment runs along Taihape Road. It ties into the hill at the western end and diverts water around 203 Taihape Road. This alignment would require raising Taihape Road. An assessment of the road geometrics of this alignment is provided in Appendix E.<br>This alignment is effective at protecting all houses from Okawa/Ohiwa Stream flows. The modelling showed other flow paths that cause flooding of the houses behind the stopbank. The stopbank on this alignment worsens the effects of this flooding as it traps water from draining back to the stream. This is explored further in Section 4.1.<br>This alignment was also modelled with a smaller stopbank east of the Okawa Stream to mitigate flooding of houses east of Okawa Stream (refer Section 4.1.1) and the stopbank south of the subdivision crossing Ohiti Road to mitigate overland flow path flooding (refer Section 4.1.2). | 1,090 m | 1.0 m |

## 4.1 Effects on surrounding flood levels

### 4.1.1 East of Okawa Stream

The model results indicate that all stopbank alignments modelled increase flows breaking out of the left bank of the Okawa/Ohiwa Stream near the bridge and increase flooding to properties east of Okawa/Ohiwa Stream. To mitigate this, a stopbank was modelled crossing Taihape Road on the east of the Okawa/Ohiwa Stream, as shown in Figure 4.2. This was modelled to tie in with the higher ground near the driveway access to 164 – 168 Taihape Road. The other end tied in with the natural terrace and diverted water back into the channel. The model indicates that this alignment could be effective at reducing the flooding of the properties.

The feasibility of raising Taihape Road will need to be discussed with HDC as the asset owner.

The stopbank alignment may be moved along Taihape Road but will have to tie in with the higher ground and terrace.

The modelling indicates that 100-year ARI flood depths are approximately 1.0 m deep at the deepest point along the proposed stopbank, and 0.5 m deep at the crest of Taihape Road at the proposed stopbank location.

### 4.1.2 Overland flow paths

The hydraulic model identified two significant overland flow paths coming from the hills on the west of Omahu as shown on Figure 4.2. The construction of Option 1, Option 2 and Option 4 stopbanks may exacerbate flooding from these flow paths as water is trapped and unable to get past the stopbank to drain back to the stream.

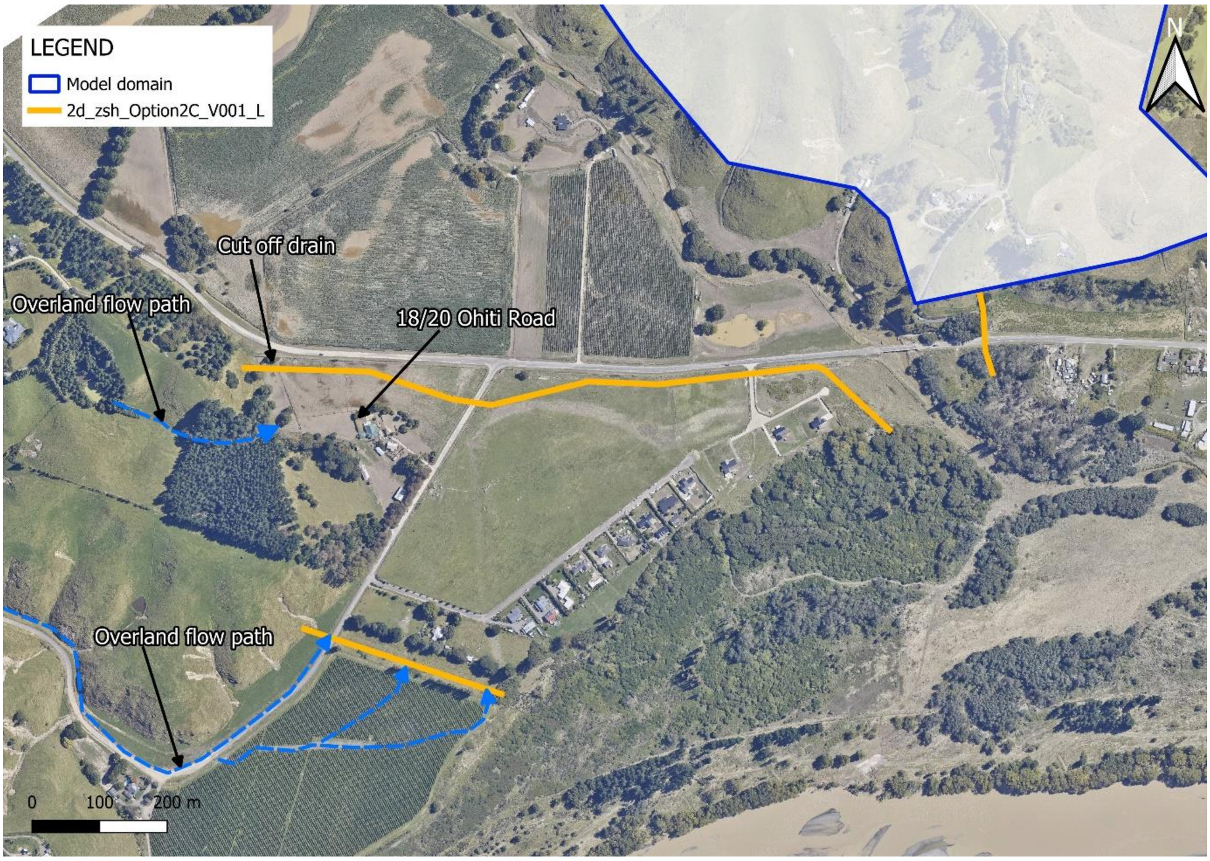


*Figure 4.2: Option 2 stopbank alignment with southern stopbank across Ohiti Road and stopbank east of Okawa/Ohiwa Stream.*

If the stopbank is constructed along these alignments, it is recommended that measures are put in place to mitigate flooding from the south-west flow path. This could include a stopbank crossing Ohiti Road south of 39 Ohiti Road or other options such as a culvert under Ohiti Road and a cut off drain. It is recommended that this is further explored if the primary stopbank option along the proposed alignment is constructed.

The stopbank alignments also intercept a cut off drain along the west of 18/20 Ohiti Road which may prevent water from draining to the north during certain flood conditions. Ground investigations indicate that the soil in this area is typically clayey, so infiltration will be low. This may cause nuisance flooding on the property in more frequent rainfall events, and some more significant flooding in more severe rainfall events. The flooding could be mitigated in smaller events by installing a flap gated culvert within the cut off drain through the stopbank. The efficiency of this in larger storm events with breakouts of the Okawa/Ohiwa Stream may vary. If there are high flood levels in the Okawa/Ohiwa Stream, water may be unable to drain through the stopbank culvert. However, the efficiency will depend on the timing of flows from the small catchment relative to the timing of flows from the Okawa/Ohiwa Stream. Another option may be to direct flow around the boundary of the property and install a culvert under Ohiti Road. This flow could then be infiltrated into the ground via a constructed basin.

### 4.1.3 Effects on the Taihape Road bridge

The effects on the bridge from the construction of Option 2C stopbanks were explored for the estimated 20-year ARI and 5-year ARI RCP8.5 2075 events. Figure 4.3 shows the water level and velocity on the upstream side of the bridge for the base case and Option 2C.

These were used to compare the water level and velocities at the bridge with and without a stopbank for flood protection. Option 2C was used as it is the preferred option, and includes the stopbank east of Okawa Stream, which will increase the flow through the bridge.

There is some uncertainty in the level of bridge soffit, and the flows corresponding to the smaller ARI flood events. As such, the plots in Figure 4.3 should be considered indicative. Further investigation into the bridge levels and flood flows/levels for more frequent events is recommended.

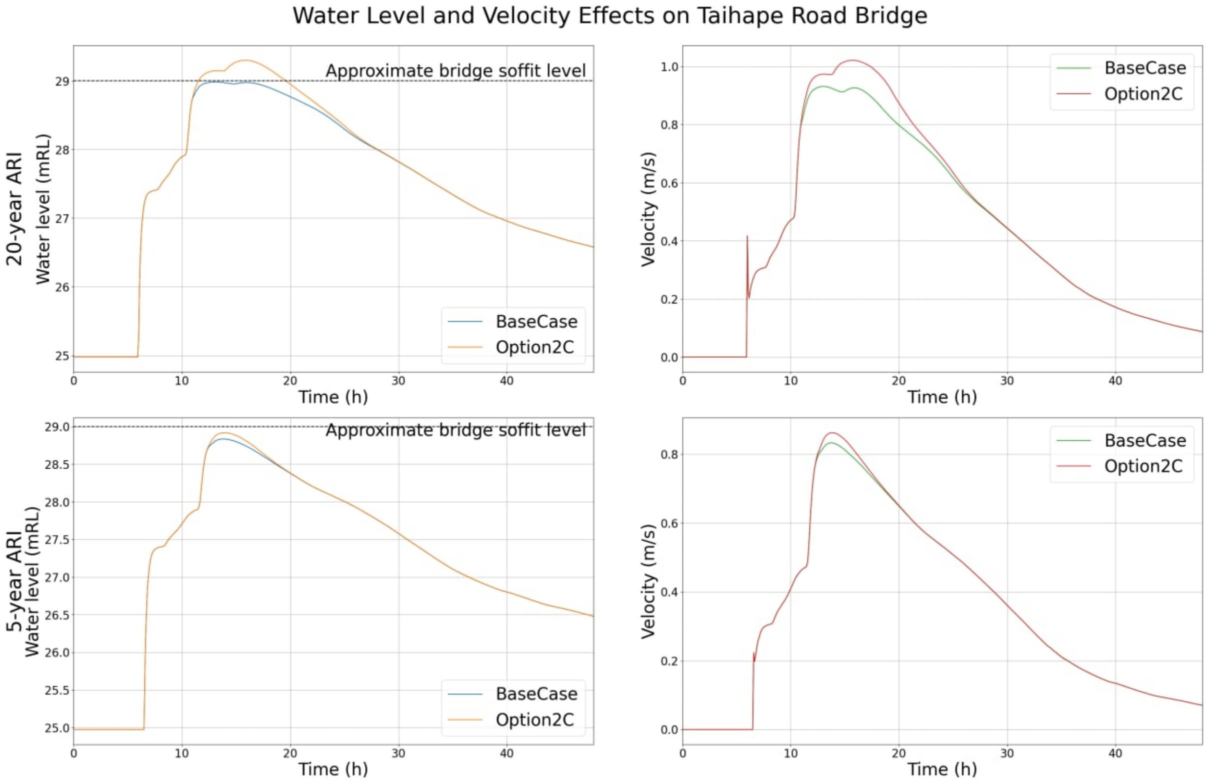


*Figure 4.3: Water level and velocity at Taihape Road bridge. Note that the bridge soffit level was estimated from photos of the bridge as outlined in Section 2.3.5.*

The model shows that the stopbanks concentrate the flow within the stream, and therefore, increase flows through the bridge. There is a slight increase in the peak water level and velocity in both the modelled 20-year and 5-year ARI RCP8.5 2075 events. In the modelled 20-year ARI RCP8.5 2075 event the water level at the bridge is estimated to increase 0.3 m and the velocity is estimated to increase 0.1 m/s. This small increase shows that the stopbanks will have minimal effects on the bridge in more frequent flood events.

Ensuring that the bridge is clear of silt and debris in flood events will have a greater impact on the bridge than the minor increases from the stopbanks.

## 4.2 Effects on velocities

Estimated maximum velocity maps for the 100-year ARI RCP8.5 2075 event for the base case and Option 2C (with the two extra stopbanks) are shown in Appendix D.

The modelling indicates that the velocities near the stopbank are affected by the stopbank. There are some areas where the stopbank interrupts flow and the velocity decreases. The velocities generally increase in the Okawa Stream channel east and north-east of the stopbank. Model estimates indicate that velocities increase by up to 1 m/s in some areas.

The velocities generally remain below 2 m/s. The maximum velocity in the Option 2 scenario is 2.5 m/s (excluding the Ngaruroro River flows). The higher velocities occur in the Okawa Stream channel and at the termination of the stopbank at the south-east end. In large flood events, some erosion of the channel is to be expected, but the model indicates the stopbank is unlikely to significantly increase this.

Estimated velocities along the stopbank are low enough that erosion is unlikely to be an issue if the stopbank has good grass cover.

## 4.3 Increase Lake Runanga flows

A potential option raised by community stakeholders during a site walkover was to divert more flow through Lake Runanga. This was noted as a preferred option by the community to increase the lake flow and improve water quality. The modelling indicates that during the 100-year ARI RCP8.5 2075 event, the majority of flow breaks out of the left bank of the Okawa/Ohiwa Stream and flows to the east.

Figure 4.4 shows the locations of Plot Output (PO) lines that were included in the model to measure the flows in the stream and the breakout. Figure 4.5 shows the hydrograph from the PO lines of the flows that breakout of the Okawa Stream compared to the flows through the Okawa/Ohiwa Stream. This shows that the flows through the breakout are significantly more than the flows going through Okawa/Ohiwa Stream.

This option has not been explored in detail. To increase flows through Lake Runanga, the flow breaking out of the stream before reaching the Okawa Spillway would need to be reduced. This may be possible with some modifications of existing levels such as the excavation of the Okawa Spillway channel, and filling the ground where the Okawa Stream breaks out, or stopbanking along the Okawa Stream. This would require a complex investigation of the hydraulic conditions in this area.

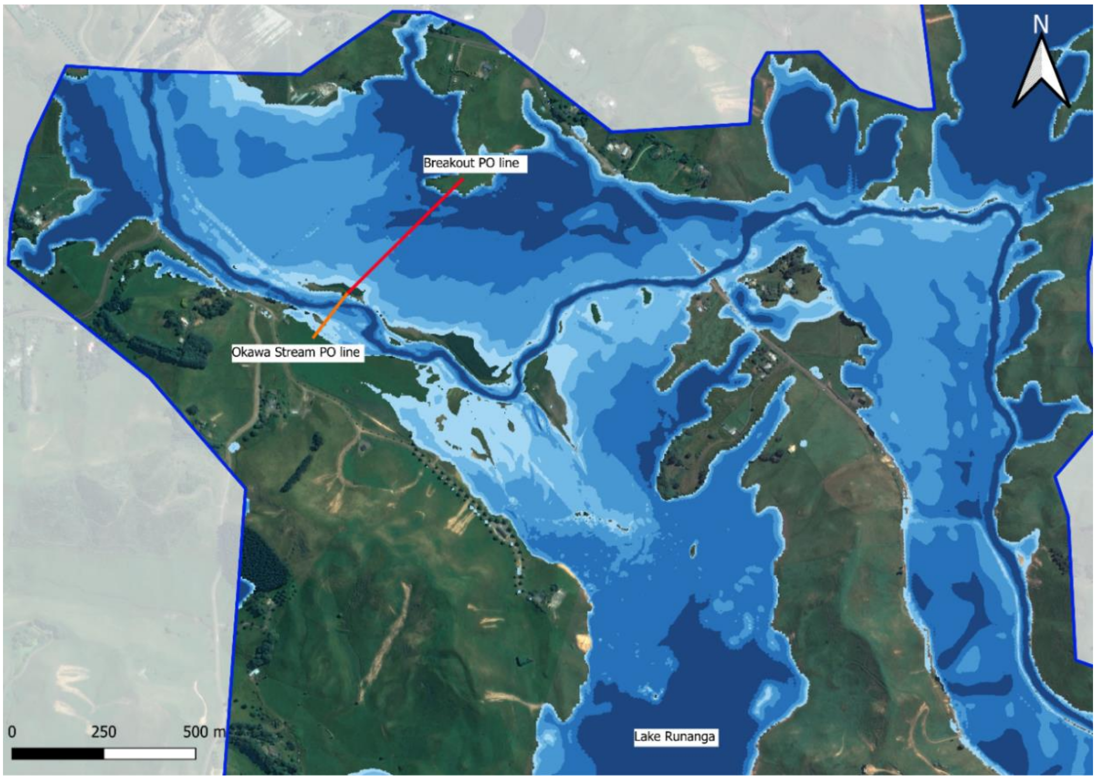


*Figure 4.4: PO lines upstream of Lake Runanga locations.*

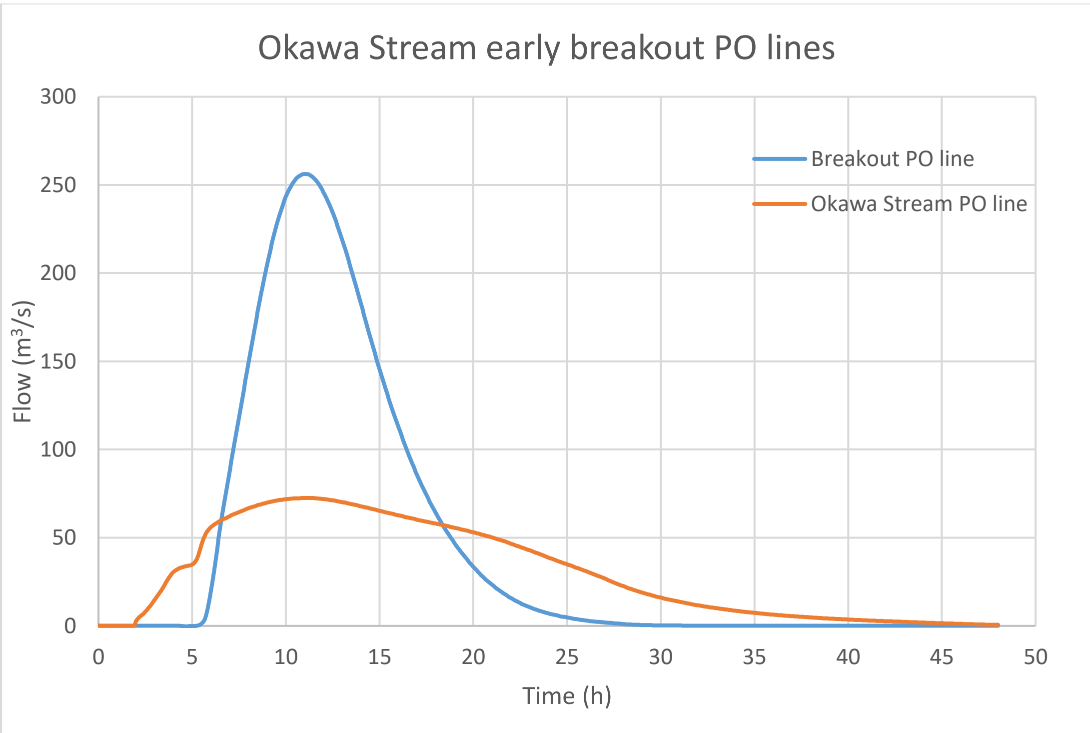


*Figure 4.5: Early breakout PO line hydrograph plot for 100-year ARI RCP8.5 2075 event.*

# 5 Model sensitivity

Sensitivity runs were undertaken for Option 2C (Option 2 with the two extra stopbanks), the option preferred by HBRC (refer Section 6). The following sensitivity scenarios were investigated:

- 100-year RCP8.5 2075 + 20% Mannings ‘n’ roughness.
- 100-year RCP8.5 2075 + 20% peak inflow.

The flood depth estimates for the sensitivity runs are provided in Appendix D.

# 6 Summary

Option 2 is the preferred option by HBRC and the landowner. It is preferred over Option 1 because of the reduced impacts on the highly productive land north of Taihape Road, and the requirement to cross Taihape Road. Option 3 is not preferred because it does not protect 18/20 Ohiti Road from Okawa/Ohiwa Stream flows. Option 4 is an alternative option raised during discussion with HDC. It would require raising a significant length of Taihape Road. Appendix E discusses the road geometrics and associated transport safety matters which can be used to inform discussions with HDC.

There are several other flooding effects to consider if this stopbank option is pursued which are outlined in Section 4.1. Two additional stopbanks and/or drainage works may also be required to manage these effects.

The proposed stopbank crest freeboard above the 100-year ARI RCP8.5 2075 water level is between 0.5 m and 1.0 m. 0.5 m of freeboard would be sufficient to prevent the stopbank overtopping in the modelled sensitivity runs with increased roughness and inflows. Approximately 0.7 m of freeboard would be required to prevent the stopbank overtopping in the modelled Cyclone Gabrielle event. However, flooding from the Ngaruroro River may still occur. We recommend that HBRC confirms its preference for freeboard requirements on each area of the proposed scheme.

It is recommended that the model is re-run with a 3D model alignment of the selected stopbank alignment once it is designed.

# 7 Model limitations

The model is a numerical representation of the physical reality and there includes uncertainty. A number of limitations to the accuracy of input data of the model exist, including:

- The modelling undertaken has been based on remotely sensed ground levels (LiDAR survey) and an UAV survey, which have accuracy limitations and represent conditions at the time the data was recorded. The LiDAR survey was captured before the Cyclone Gabrielle event which may have resulted in significant changes to the land form from erosion and silt deposition.
- There is no flow calibration data on the Okawa/Ohiwa Stream.
- The hydrology does not include Cyclone Gabrielle in the HIRDS statistics.
- The model results have generally been presented only to show flooding where maximum depth in excess of 100 mm has been predicted.
- Model calibration has been based on surveyed water levels, photos taken during the Cyclone Gabrielle event and aerial imagery post Cyclone Gabrielle.
- The model uses two DEM datasets created in 2016 and 2018. No modifications other than those stated in this report were made to the DEM.
- Recommended bund crest levels are based on the modelled bund alignment. Changes to the modelled alignment may alter the recommended crest levels.

# 8 Applicability

This report has been prepared for the exclusive use of our client Hawkes Bay Regional Council, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

Tonkin & Taylor Ltd
Environmental and Engineering Consultants

| Report prepared by: | Authorised for Tonkin & Taylor Ltd by: |
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| ........................................................... | ........................................................ |
| Kate Hand<br>Water Resources Engineer | Tim Morris<br>Project Director |

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# Appendix A Lumped catchment hydrology memo

# Memo

| | | | |
|---|---|---|---|
| **To:** | Richard Brunton | **Job No:** | 1017353.2402 |
| **From:** | John Hansford | **Date:** | 24 April 2024 |
| **cc:** | | | |
| **Subject:** | Okawa Stream hydrology | | |

## 1 Introduction

This memo presents the hydrological analyses carried out to prepare flood hydrographs for a 100 year ARI event with allowance for climate change and to replicate Cyclone Gabrielle for input to a hydraulic model at the three locations shown in Figure 1.1.

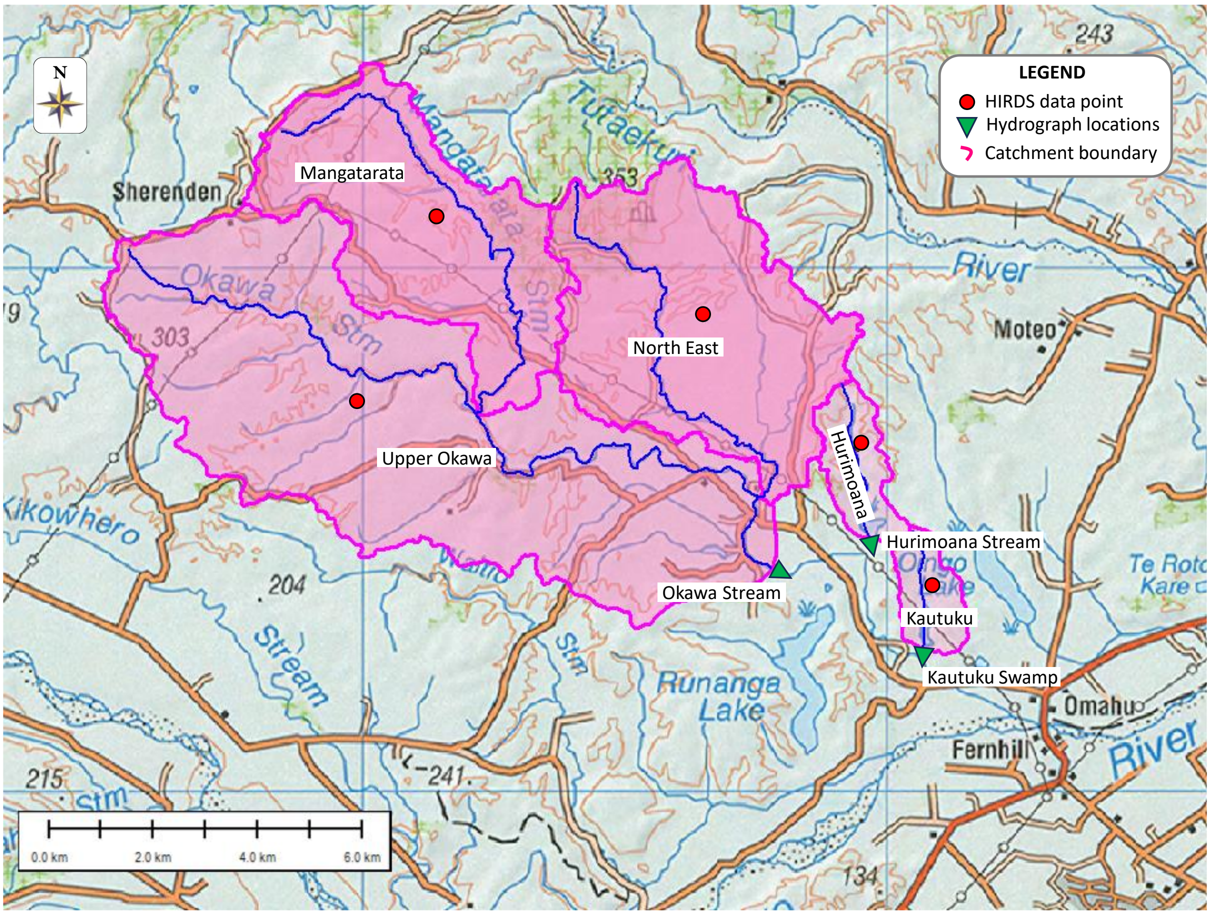



*Figure 1.1: Location plan*

# 2 Hydrometeorological data

There are no streamflow gauges that could be used to calibrate a rainfall-runoff model for the three catchments. The Henderson-Collins flood information from New Zealand River Flood Statistics does not always agree reasonably with streamflow gauge statistics, however, it is the only information available for the study catchments and were used to calibrate the rainfall-runoff model. These data are listed in Table 2.1.

**Table 2.1: Henderson-Collins flood peaks**

| ARI (years) | Peak discharge ($m^3$/s) | | |
|---|---|---|---|
| | Okawa Stream NZREACH 8024375 | Hurimoana Stream NZREACH 8024332 | Kautuku Swamp NZREACH 8024604 |
| 5 | 134 | 3.36 | 3.03 |
| 10 | 169 | 4.27 | 3.84 |
| 20 | 203 | 5.14 | 4.63 |
| 50 | 247 | 6.26 | 5.64 |
| 100 | 280 | 7.10 | 6.40 |

HIRDS rainfall data were downloaded for the five locations shown in Figure 1.1. Areal reduction was applied using the formula in the HIRDS document that takes area, ARI and storm duration into consideration.

HIRDS rainfall data were downloaded for locations within each of the five catchments shown in Figure 1.1 with the downloaded data included as Appendix A.

Three automatic HBRC rainfall stations and nine citizen rainfall stations that recorded rainfall during Cyclone Gabrielle were identified. The location of these gauges together with the total rainfall recorded during cyclone Gabrielle and the gauge name are shown in Figure 2.2. Recorded rainfall for the three rainfall stations from 12 February 2023 at 00:00 to 15 February 2023 at 08:00 are listed in Appendix B and the hourly rainfall shown in Figure 2.1. These rainfall data were used to prepare sub-catchment rainfall for Cyclone Gabrielle.

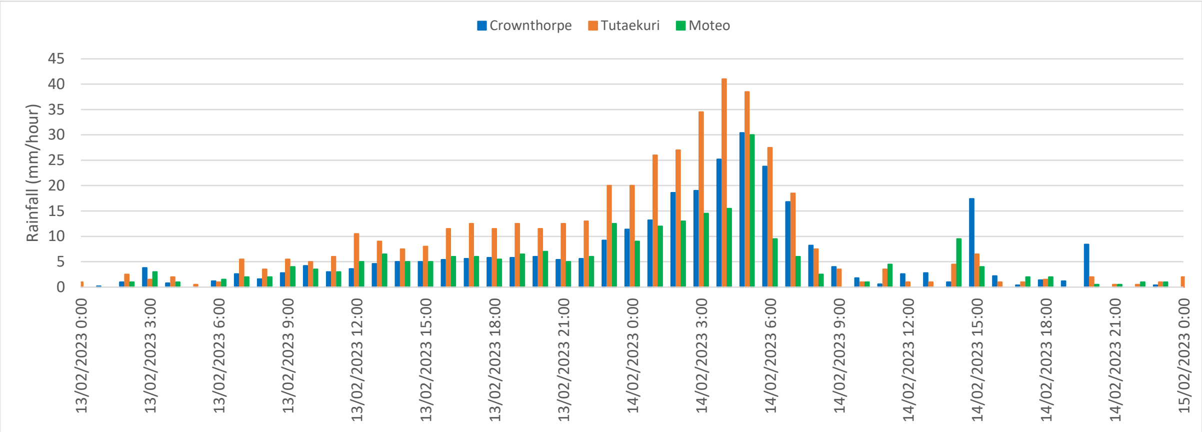



*Figure 2.1: Observed rainfall during Cyclone Gabrielle*

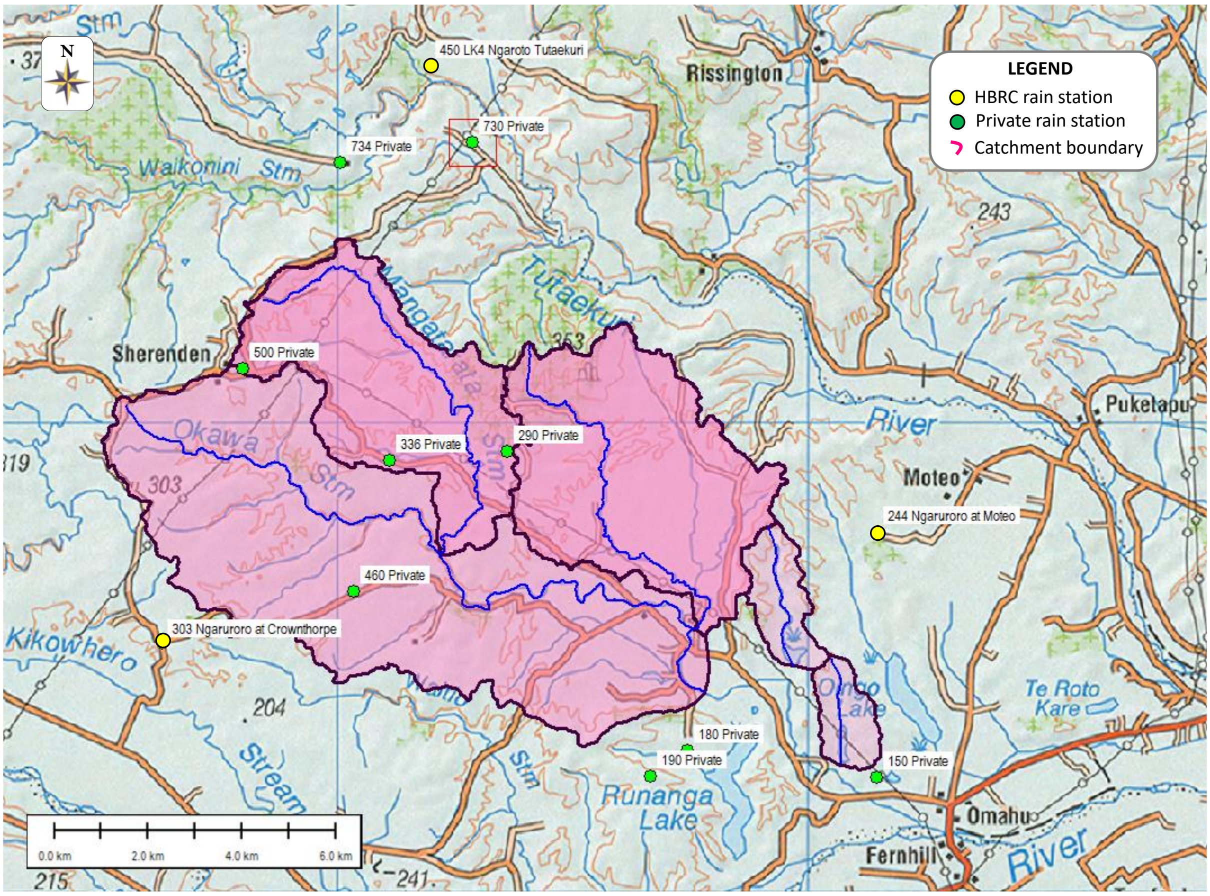



*Figure 2.2: Location of rain stations*

## 3 Rainfall-runoff model

A rainfall-runoff model was set up in HEC-HMS to simulate runoff from the Okawa Stream and the Hurimoana and Kautuku catchments.

### 3.1 Catchment characteristics

Catchment characteristics are summarised in Table 3.1.

**Table 3.1: Catchment characteristics**

| Characteristic | Upper Okawa | NE Stream | Mangatarata | Hurimoana | Kautuku |
|---|---|---|---|---|---|
| Catchment area ($km^2$) | 48.7 | 23.4 | 19.5 | 3.2 | 2.4 |
| Longest water course (km) | 19.3 | 10.1 | 11.6 | 3.2 | 2.3 |
| Equal area slope (m/m) | 0.006 | 0.008 | 0.016 | 0.008 | 0.008 |
| USBR Tc (hours) | 4.5 | 2.5 | 2.2 | 1.8 | 1.5 |
| Storage coefficient (hours) | 7.0 | 4.0 | 3.2 | 2.8 | 2.5 |

### 3.2 HIRDS rainfall data

The HIRDS rainfall totals used to calibrate the HEC-HMS model were adjusted for areal reduction using an area of 92 $km^2$ for the Upper Okawa, NE Stream and Mangatarata Stream (three catchments contributing to runoff from the Okawa Stream at the hydraulic model boundary) and

3.2 km$^2$ and 2.4 km$^2$ respectively for the Hurimoana and Kautuku catchments. These data are summarised in Table 3.2.

**Table 3.2: Rainfall depths used to calibrate the HEC-HMS model**

| ARI | 1 hour | 2 hour | 3 hour | 6 hour | 12 hour | 24 hour |
|---|---|---|---|---|---|---|
| **Okawa** | **92 km$^2$** | | | | | |
| 5 | 17.3 | 27.3 | 34.8 | 50.9 | 71.5 | 97.1 |
| 10 | 20.6 | 32.5 | 41.4 | 60.4 | 84.7 | 114.4 |
| 20 | 24.1 | 38.1 | 48.4 | 70.4 | 98.4 | 132.4 |
| 50 | 29.1 | 45.9 | 58.4 | 84.5 | 117.4 | 157.2 |
| 100 | 33.2 | 52.3 | 66.3 | 95.7 | 132.5 | 176.5 |
| **NE** | **92 km$^2$** | | | | | |
| 5 | 18.7 | 28.0 | 34.8 | 49.1 | 67.3 | 89.9 |
| 10 | 22.3 | 33.4 | 41.5 | 58.3 | 79.7 | 106.0 |
| 20 | 26.1 | 39.1 | 48.5 | 68.1 | 92.6 | 122.7 |
| 50 | 31.6 | 47.3 | 58.5 | 81.8 | 110.7 | 145.8 |
| 100 | 36.1 | 53.9 | 66.6 | 92.7 | 124.9 | 163.8 |
| **Mangatarata** | **92 km$^2$** | | | | | |
| 5 | 18.2 | 28.7 | 36.7 | 54.0 | 76.9 | 106.0 |
| 10 | 21.6 | 34.2 | 43.7 | 64.3 | 91.2 | 125.3 |
| 20 | 25.3 | 40.0 | 51.1 | 75.0 | 106.2 | 145.2 |
| 50 | 30.6 | 48.3 | 61.6 | 90.1 | 126.9 | 172.7 |
| 100 | 34.8 | 54.9 | 69.9 | 102.0 | 143.1 | 194.0 |
| **Hurimoana** | **3.2 km$^2$** | | | | | |
| 5 | 22.3 | 31.8 | 38.8 | 53.8 | 73.3 | 97.9 |
| 10 | 26.9 | 38.2 | 46.5 | 64.3 | 87.1 | 115.7 |
| 20 | 31.9 | 45.1 | 54.8 | 75.3 | 101.6 | 134.3 |
| 50 | 39.1 | 55.0 | 66.6 | 90.9 | 121.8 | 159.9 |
| 100 | 45.0 | 63.0 | 76.0 | 103.3 | 137.8 | 180.0 |
| **Kautuku** | **2.4 km$^2$** | | | | | |
| 5 | 21.8 | 30.7 | 37.1 | 50.4 | 67.0 | 87.4 |
| 10 | 26.4 | 37.0 | 44.5 | 60.1 | 79.6 | 103.2 |
| 20 | 31.4 | 43.7 | 52.5 | 70.5 | 92.7 | 119.6 |
| 50 | 38.5 | 53.3 | 63.7 | 85.0 | 111.1 | 142.3 |
| 100 | 44.4 | 61.0 | 72.8 | 96.6 | 125.5 | 159.9 |

The rainfall data used in the HEC-HMS model to generate 5 year, 20 year and 100 year ARI flood hydrographs for input to the hydraulic model were estimated using a catchment area of 104 km$^2$, corresponding to the three catchments and the hydraulic model area. These data RCP 4.5 2130 recommended by T+T as the climate change scenario and RCP 8.5 2075 preferred by HBRC as the climate change scenario are listed in Table 3.3 and Table 3.4.

**Table 3.3: Rainfall depths used to generate inputs to hydraulic model (RCP 4.5 2130)**

| Catchment | 1 hour | 2 hour | 3 hour | 6 hour | 12 hour | 24 hour |
|---|---|---|---|---|---|---|
| **5 year ARI RCP 4.5 2130** | | | | | | |
| Hurimoana | 22.8 | 34.1 | 42.3 | 59.3 | 80.8 | 107.2 |
| Kautuku | 22.2 | 32.8 | 40.3 | 55.4 | 73.8 | 95.6 |
| Mangatarata | 21.7 | 34.1 | 43.4 | 63.0 | 88.2 | 119.3 |
| Model area | 22.2 | 32.9 | 40.5 | 55.7 | 74.4 | 96.4 |
| NE Stream | 22.4 | 33.4 | 41.2 | 57.3 | 77.1 | 101.1 |
| Upper Okawa | 20.7 | 32.5 | 41.2 | 59.3 | 82.0 | 109.2 |
| **20 year ARI RCP 4.5 2130** | | | | | | |
| Hurimoana | 32.0 | 47.9 | 59.4 | 83.0 | 112.2 | 147.4 |
| Kautuku | 31.2 | 46.2 | 56.7 | 77.5 | 102.3 | 131.2 |
| Mangatarata | 30.4 | 48.0 | 61.0 | 88.3 | 122.7 | 164.5 |
| Model area | 31.1 | 46.2 | 56.8 | 77.8 | 102.9 | 132.1 |
| NE Stream | 31.4 | 46.9 | 57.9 | 80.1 | 107.0 | 138.9 |
| Upper Okawa | 28.9 | 45.6 | 57.8 | 82.9 | 113.7 | 149.9 |
| **100 year ARI RCP 4.5 2130** | | | | | | |
| Hurimoana | 44.1 | 66.1 | 81.7 | 113.4 | 152.1 | 197.7 |
| Katuku | 43.2 | 63.7 | 77.9 | 105.7 | 138.3 | 175.4 |
| Mangatarata | 41.8 | 65.9 | 83.7 | 120.4 | 166.0 | 220.5 |
| Model area | 42.9 | 63.6 | 78.0 | 106.1 | 139.0 | 176.5 |
| NE Stream | 43.3 | 64.7 | 79.7 | 109.4 | 144.9 | 186.3 |
| Upper Okawa | 39.9 | 62.8 | 79.4 | 113.0 | 153.7 | 200.7 |

**Table 3.4: Rainfall depths used to generate inputs to hydraulic model (RCP 8.5 2075)**

| Catchment | 1 hour | 2 hour | 3 hour | 6 hour | 12 hour | 24 hour |
|---|---|---|---|---|---|---|
| **5 year ARI RCP 8.5 2075** | | | | | | |
| Hurimoana | 23.7 | 35.5 | 44.0 | 61.4 | 73.8 | 83.4 |
| Kautuku | 23.2 | 34.2 | 41.9 | 57.3 | 68.0 | 76.1 |
| Mangatarata | 22.6 | 35.5 | 45.1 | 65.2 | 79.7 | 91.0 |
| Model area | 23.1 | 34.2 | 42.1 | 57.7 | 68.5 | 76.7 |
| NE Stream | 23.3 | 34.7 | 42.9 | 59.3 | 70.8 | 79.6 |
| Upper Okawa | 21.5 | 33.8 | 42.8 | 61.4 | 74.6 | 84.6 |
| **20 year ARI RCP 8.5 2075** | | | | | | |
| Hurimoana | 33.3 | 49.9 | 61.7 | 86.0 | 102.9 | 115.8 |
| Kautuku | 32.6 | 48.1 | 58.9 | 80.2 | 94.7 | 105.5 |
| Mangatarata | 31.7 | 49.9 | 63.4 | 91.5 | 111.3 | 126.6 |
| Model area | 32.4 | 48.1 | 59.0 | 80.6 | 95.3 | 106.2 |
| NE Stream | 32.7 | 48.8 | 60.2 | 83.0 | 98.6 | 110.4 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Upper Okawa | 30.2 | 47.5 | 60.1 | 85.8 | 103.7 | 117.3 |
| **100 year ARI RCP 8.5 2075** | | | | | | |
| Hurimoana | 46.1 | 68.9 | 85.2 | 117.8 | 140.3 | 157.3 |
| Katuku | 45.1 | 66.4 | 81.2 | 109.8 | 128.9 | 143.0 |
| Mangatarata | 43.6 | 68.7 | 87.2 | 125.0 | 151.5 | 171.7 |
| Model area | 44.8 | 66.3 | 81.2 | 110.1 | 129.4 | 143.7 |
| NE Stream | 45.2 | 67.4 | 83.0 | 113.6 | 134.4 | 149.9 |
| Upper Okawa | 41.6 | 65.4 | 82.7 | 117.4 | 141.1 | 158.9 |

## 3.3 Model calibration

The HEC-HMS model was calibrated against the Henderson-Collins (H-C) floods for the catchments because there is no other data available. The comparison simulated and H-C flood peaks for the Okawa Catchment are shown in Figure 3.1. The plot shows very good comparison in the flood peaks. However, the constant loss (CL) used in the simulations is only 1 mm/hr, which is much lower than initial estimates based on soil permeability of between 3 and 4 mm/hr. Accordingly the simulated flood peaks are considered conservative from a flooding point of view.

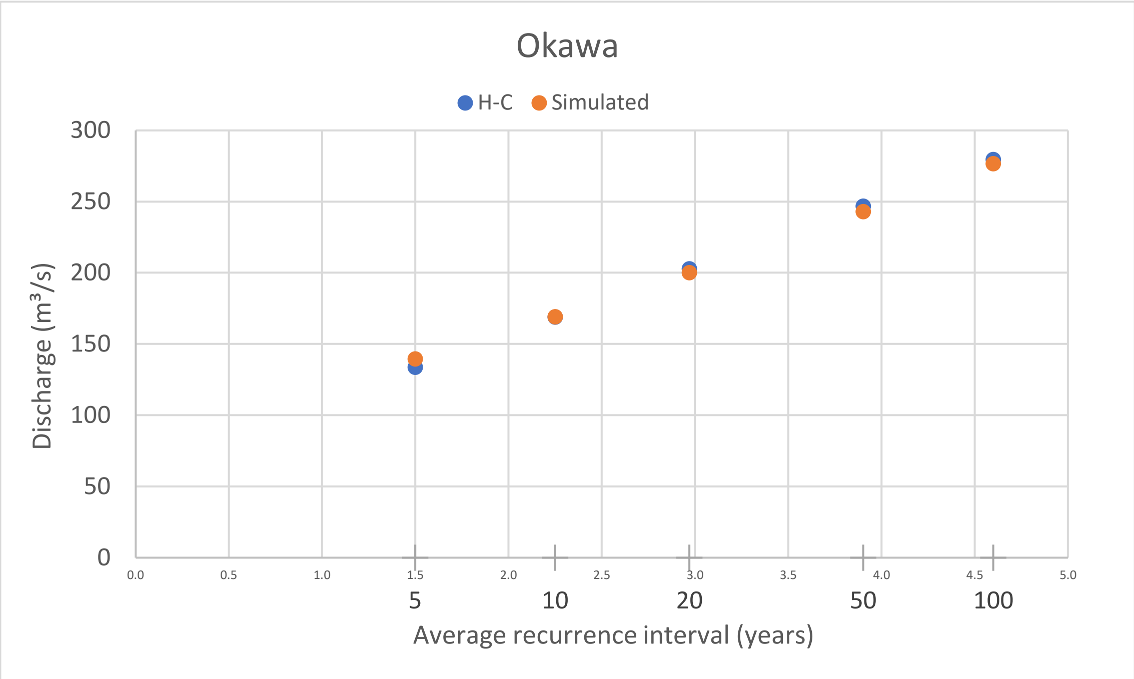



*Figure 3.1: Comparison of H-C and simulated flood peaks in the Okawa Stream*

For the Hurimoana and Kautuku catchments CL was increased to 9 mm/hr to get a reasonable match to the more frequent H-C floods. The distributions are shown in Figure 3.2 and Figure 3.3 for the Hurimoana and Kautuku catchments respectively.

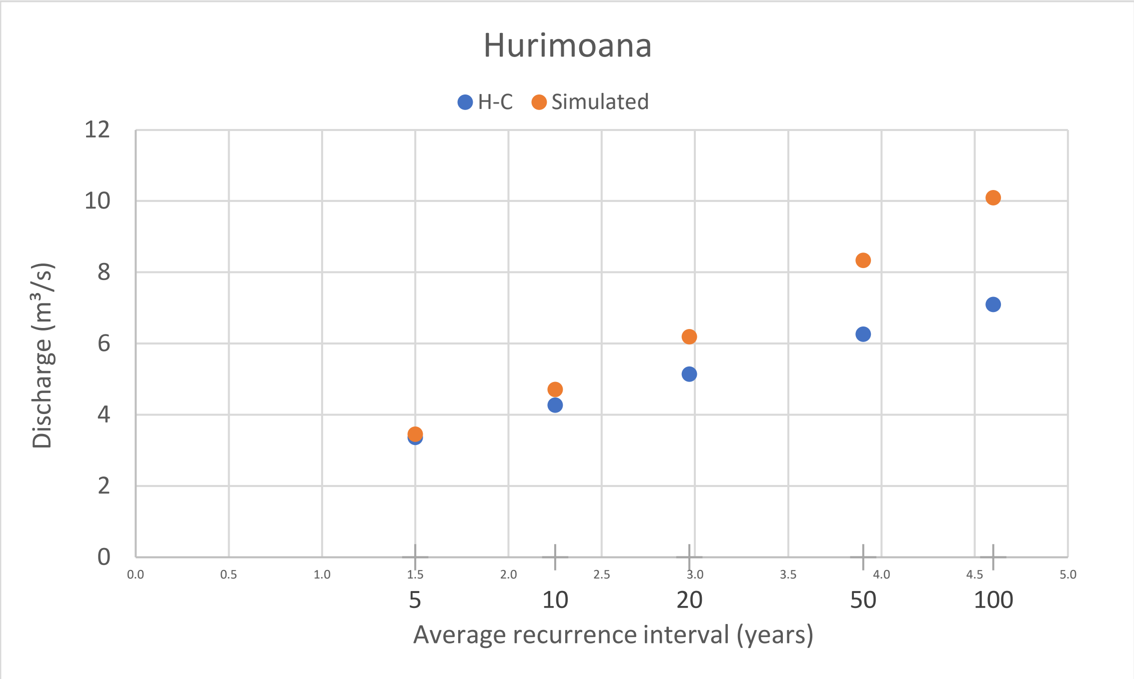



*Figure 3.2: Comparison of H-C and simulated flood peaks in the Hurimoana Catchment*

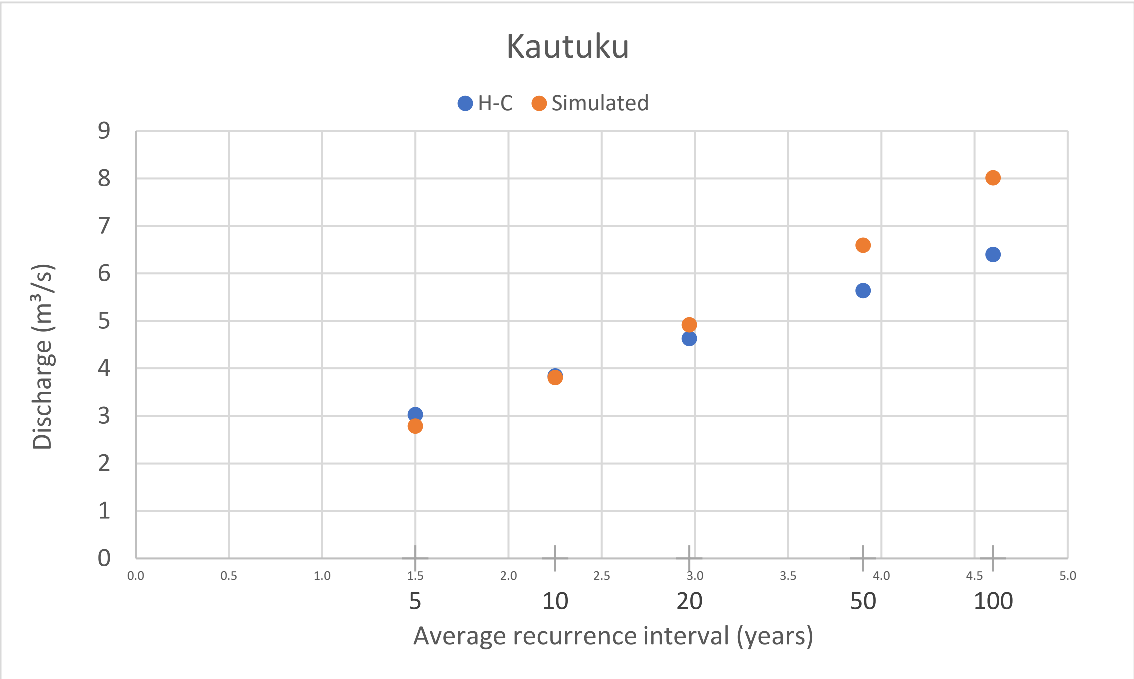



*Figure 3.3: Comparison of H-C and simulated flood peaks in the Kautuku Catchment*

While the difference in flood estimates for the two catchments for less frequent events is individually significant, their contribution to flooding in the hydraulic model area will be small relative to floods from the Okawa Stream so no further work was done to try and improve the comparisons.

## 3.4 Simulated design hydrographs

Design hydrographs were simulated using the calibrated HEC-HMS model with 5 year, 20 year and 100 year ARI RCP 4.5 2130 and RCP 8.5 2075 rainfall listed in Table 3.3 and Table 3.4 respectively.

### 3.4.1 RCP 4.5 2130 climate change scenario results

The 1, 3, 6, 12 and 24 hour hydrographs from the three catchments are shown in Figure 3.10 to Figure 3.12 for the Hurimoana, Kautuku and Okawa Stream respectively and the flood peaks are listed in Table 3.5 with the maxima for each ARI in bold.

**Table 3.5: RCP 4.5 2130 simulated hydrograph peak discharges**

| Storm duration | Peak discharge (m3/s) | | |
|---|---|---|---|
| | **Hurimoana** | **Kautuku** | **Okawa Stream** |
| **5 year ARI RCP 4.5 2130** | | | |
| 1 hour | 3 | 3 | 68 |
| 3 hour | **4** | **3** | 123 |
| 6 hour | 3 | 2 | 154 |
| 12 hour | 2 | 1 | **163** |
| 24 hour | 0 | 0 | 147 |
| **20 year ARI RCP 4.5 2130** | | | |
| 1 hour | 5 | 4 | 96 |
| 3 hour | **7** | **6** | 176 |
| 6 hour | 7 | 5 | 222 |
| 12 hour | 5 | 3 | **234** |
| 24 hour | 2 | 1 | 211 |
| **100 year ARI RCP 4.5 2130** | | | |
| 1 hour | 8 | 7 | 134 |
| 3 hour | **11** | **9** | 245 |
| 6 hour | 11 | 8 | 309 |
| 12 hour | 9 | 6 | **324** |
| 24 hour | 5 | 3 | 291 |

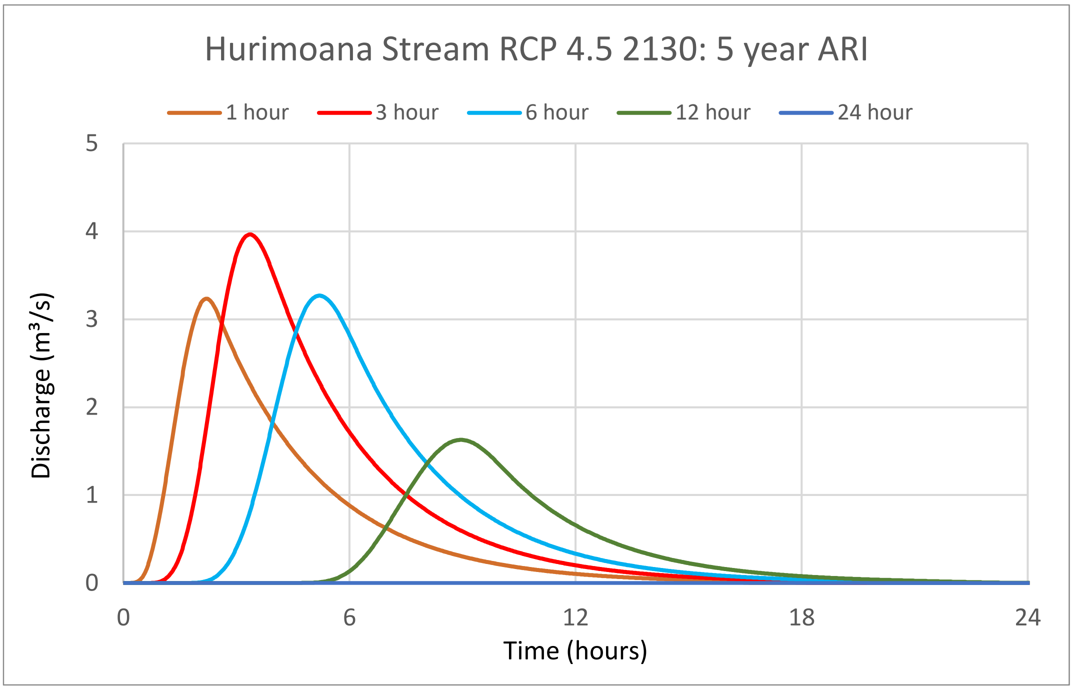



*Figure 3.4: Hurimoana Stream: RCP 4.5 2130 5 year ARI hydrographs*

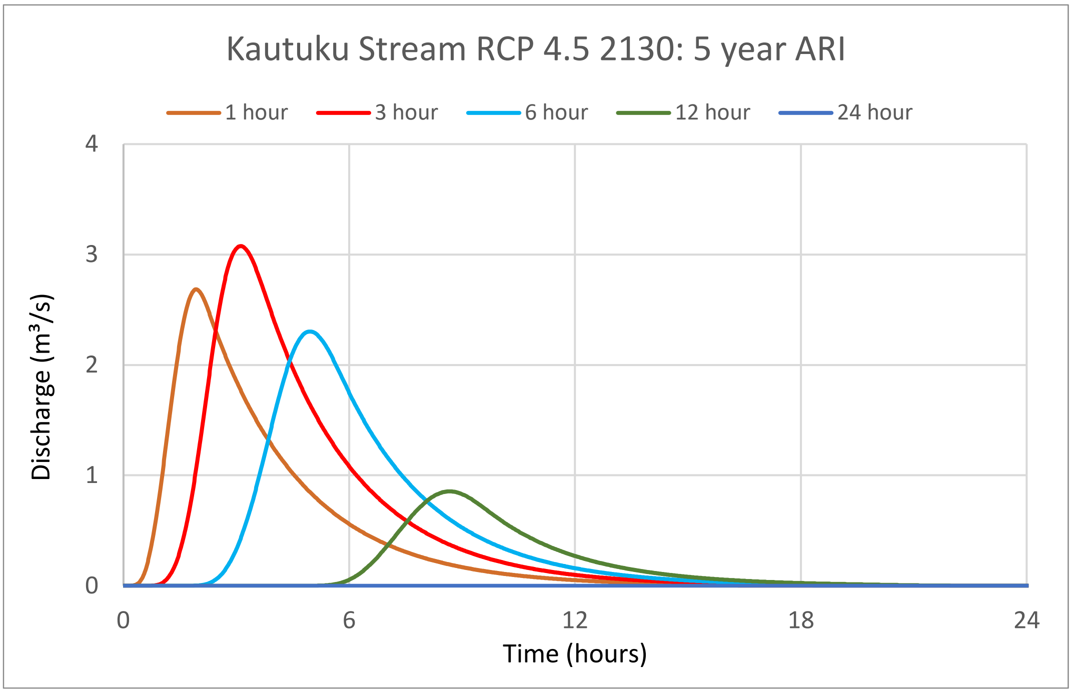



*Figure 3.5: Kautuku Stream: RCP 4.5 2130 5 year ARI hydrographs*

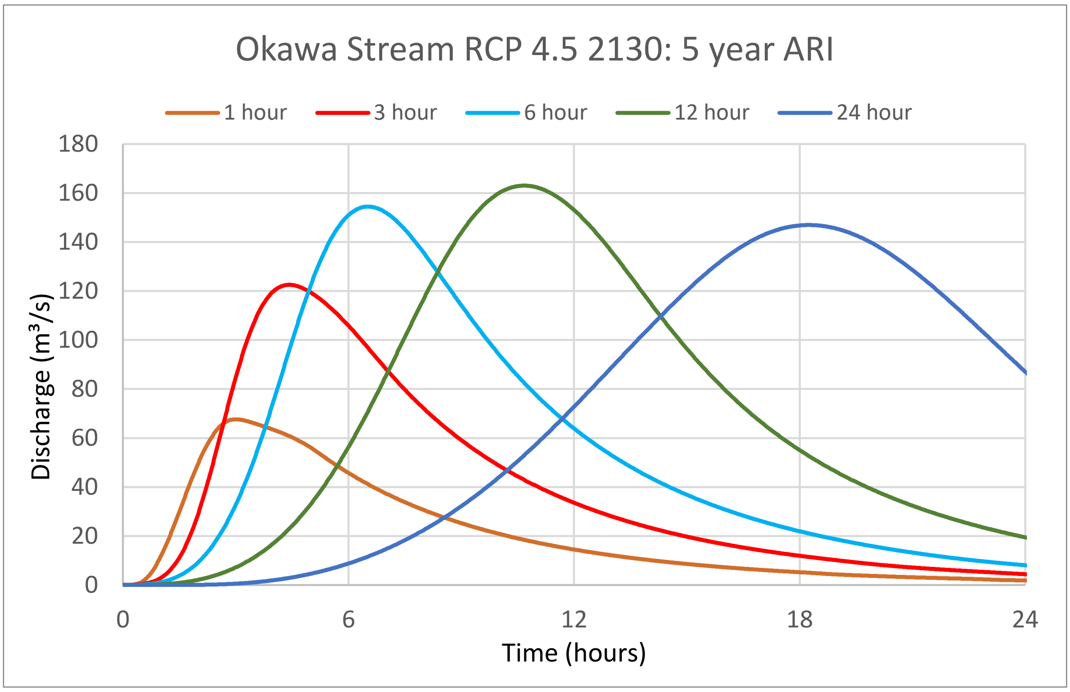



*Figure 3.6: Okawa Stream: RCP 4.5 2130  5 year ARI hydrographs*

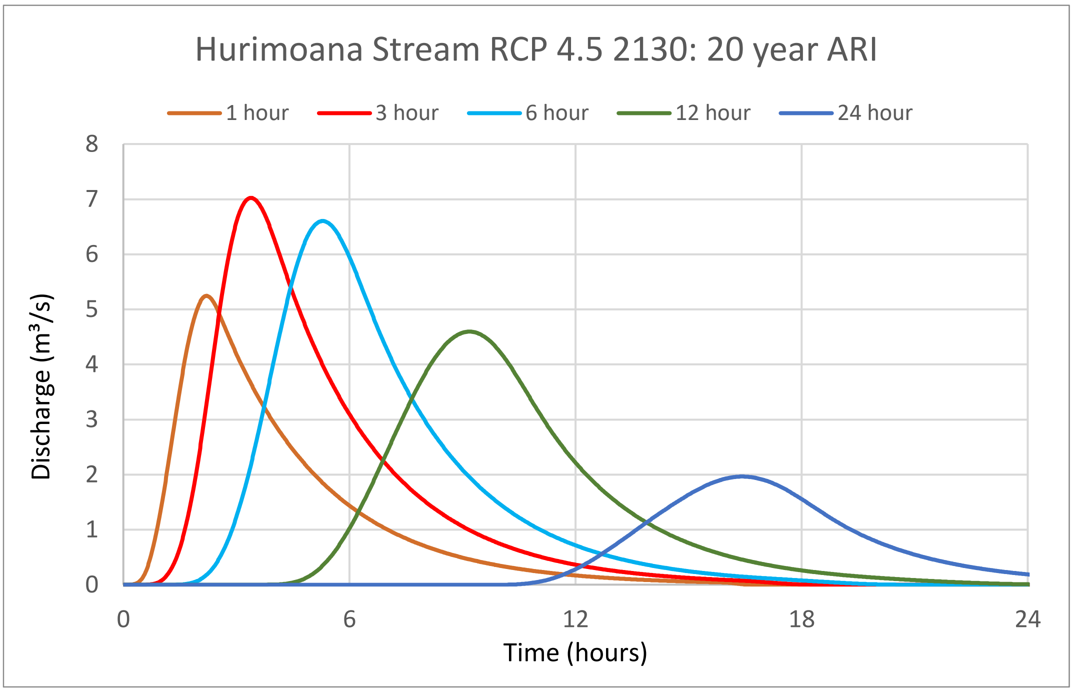



*Figure 3.7: Hurimoana Stream: RCP 4.5 2130 20 year ARI hydrographs*

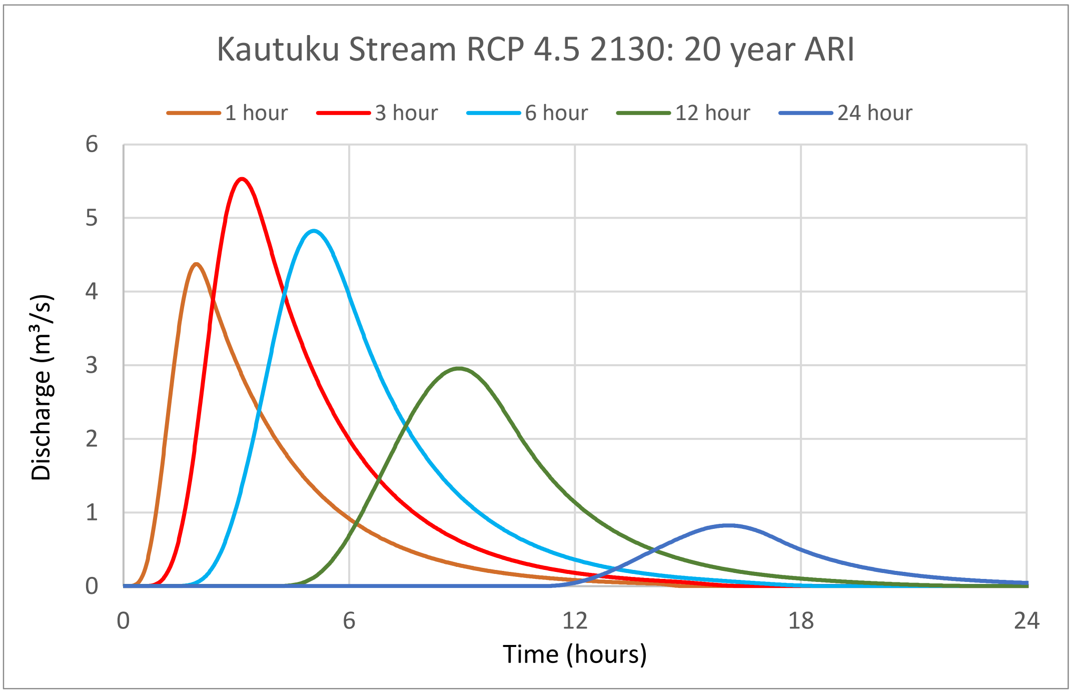



*Figure 3.8: Kautuku Stream: RCP 4.5 2130 20 year ARI hydrographs*

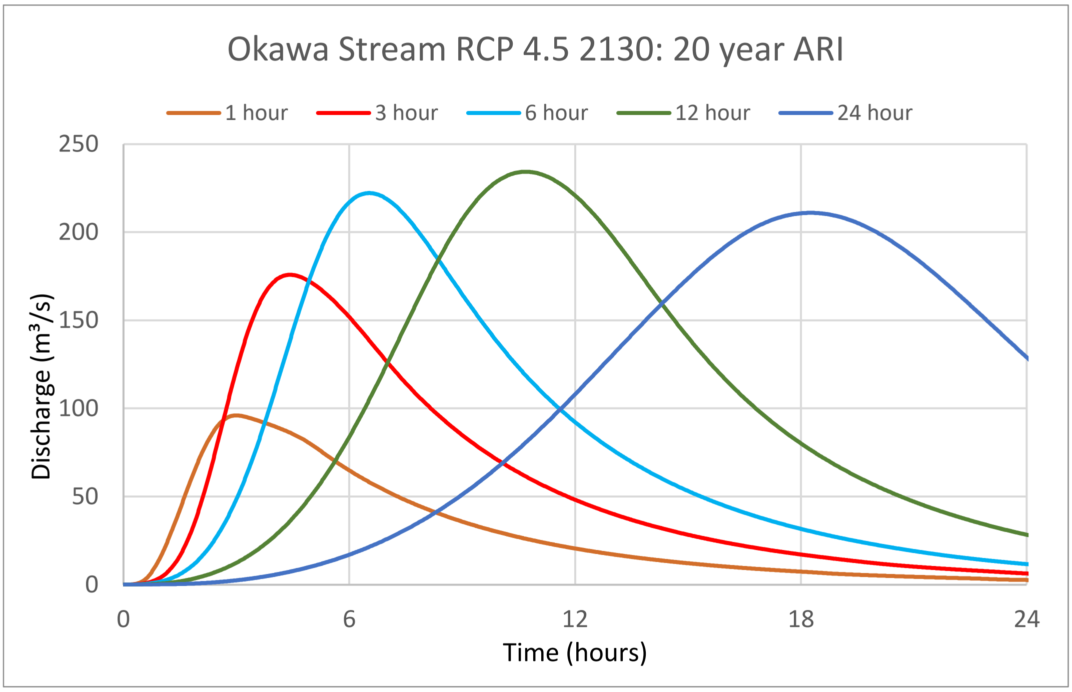



*Figure 3.9: Okawa Stream: RCP 4.5 2130 20 year ARI hydrographs*

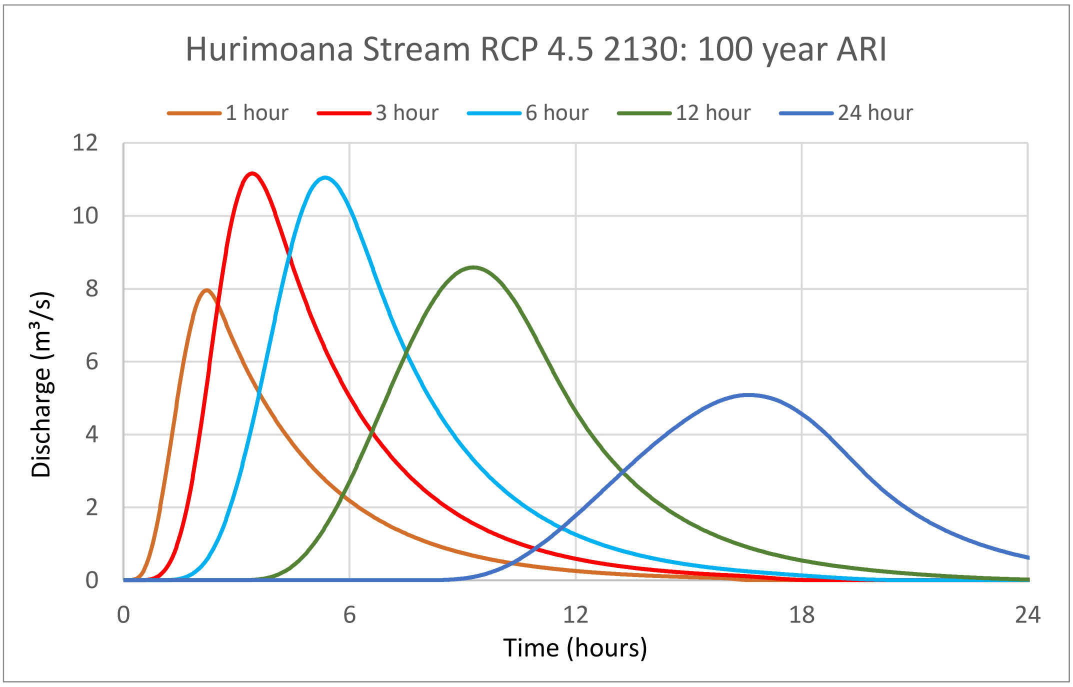



*Figure 3.10: Hurimoana Stream: RCP 4.5 2130 100 year ARI hydrographs*

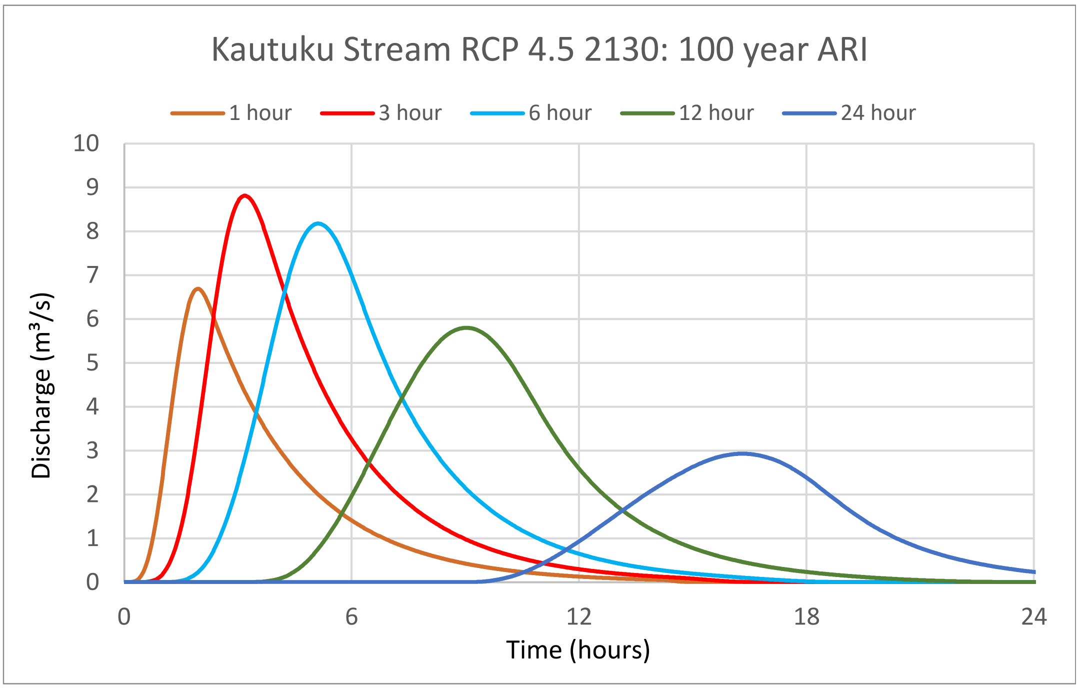



*Figure 3.11: Kautuku Stream: RCP 4.5 2130 100 year ARI hydrographs*

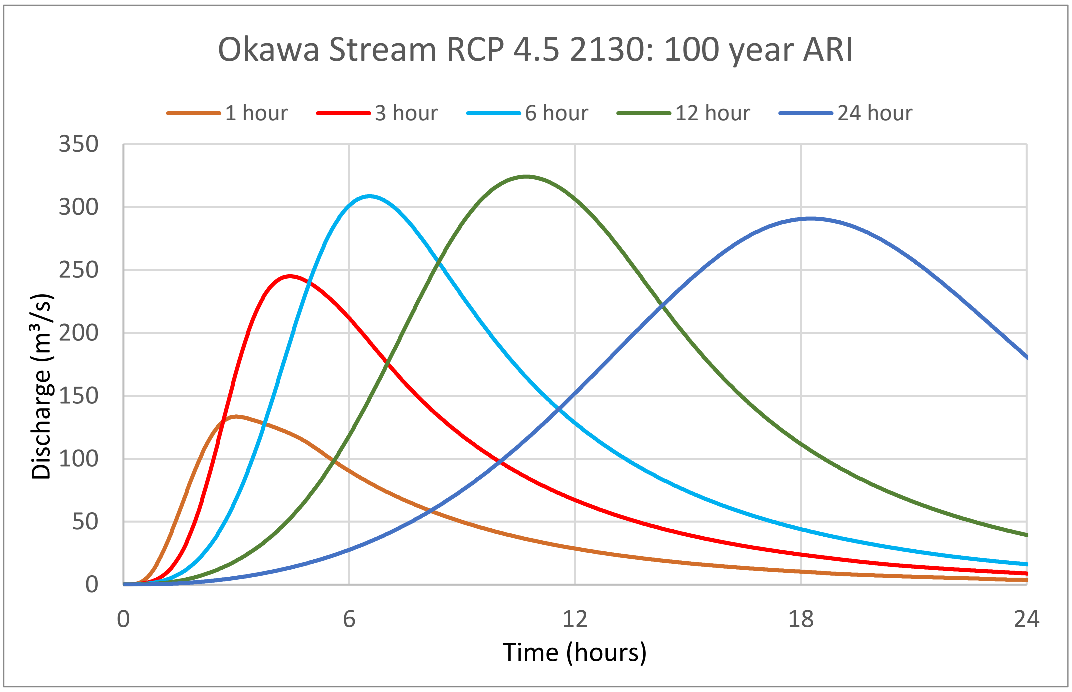



*Figure 3.12: Okawa Stream: RCP 4.5 2130 100 year ARI hydrographs*

### 3.4.2 RCP 8.5 2075 climate change scenario results

The 1, 3, 6, 12 and 24 hour hydrographs from the three catchments are shown in Figure 3.13 to Figure 3.21 for the Hurimoana, Kautuku and Okawa Stream respectively and the flood peaks are listed in Table 3.6 with the maxima for each ARI in bold.

**Table 3.6: RCP 8.5 2075 simulated hydrograph peak discharges**

| Storm duration | Peak discharge (m3/s) | | |
|---|---|---|---|
| | **Hurimoana** | **Kautuku** | **Okawa Stream** |
| **5 year ARI RCP 8.5 2075** | | | |
| 1 hour | 3 | 3 | 70 |
| 3 hour | **4** | **3** | 128 |
| 6 hour | 4 | 3 | 160 |
| 12 hour | 2 | 1 | **169** |
| 24 hour | 0 | 0 | 152 |
| **20 year ARI RCP 8.5 2075** | | | |
| 1 hour | 6 | 5 | 100 |
| 3 hour | **7** | **6** | 183 |
| 6 hour | 7 | 5 | 231 |
| 12 hour | 5 | 3 | **242** |
| 24 hour | 2 | 1 | 217 |
| **100 year ARI RCP 8.5 2075** | | | |
| 1 hour | 8 | 7 | 139 |
| 3 hour | **12** | **9** | 256 |

| Storm duration | Peak discharge (m3/s) | | |
|---|---|---|---|
| | **Hurimoana** | **Kautuku** | **Okawa Stream** |
| 6 hour | 12 | 9 | 321 |
| 12 hour | 9 | 6 | **336** |
| 24 hour | 5 | 3 | 300 |

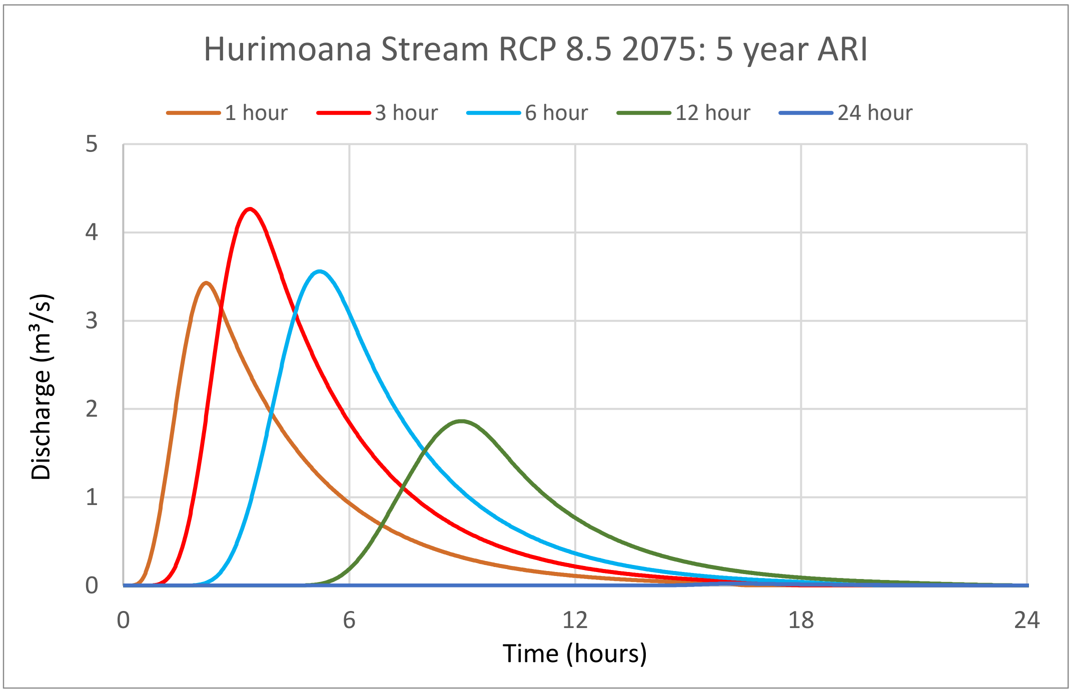



*Figure 3.13: Hurimoana Stream: RCP 8.5 2075 5 year ARI hydrographs*

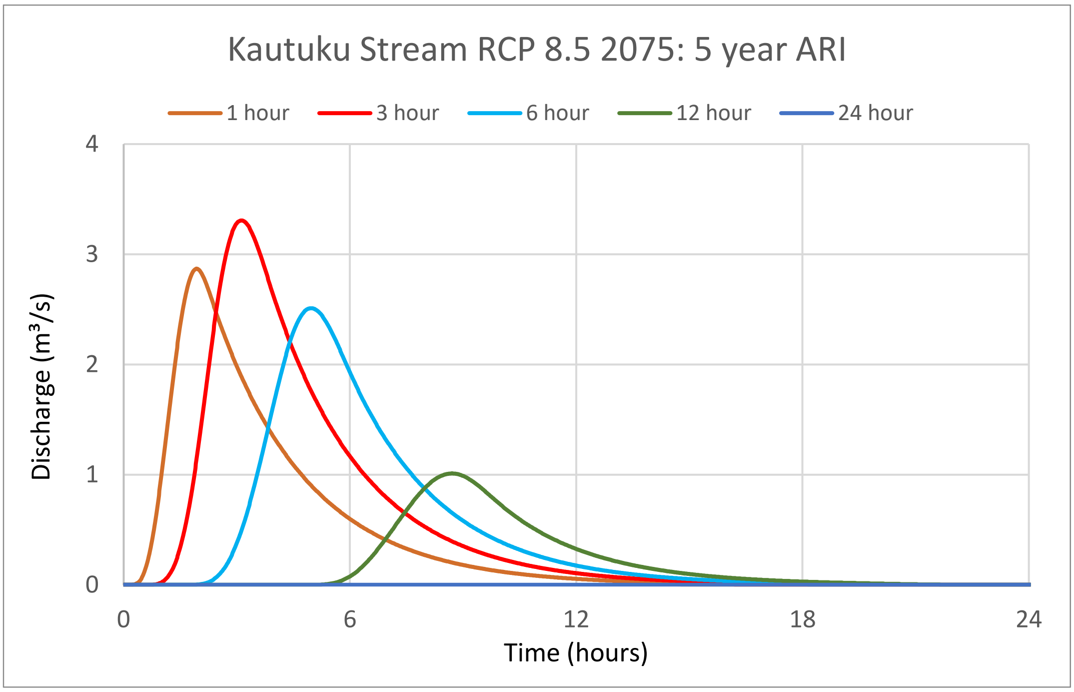



*Figure 3.14: Kautuku Stream: RCP 8.5 2075 5 year ARI hydrographs*

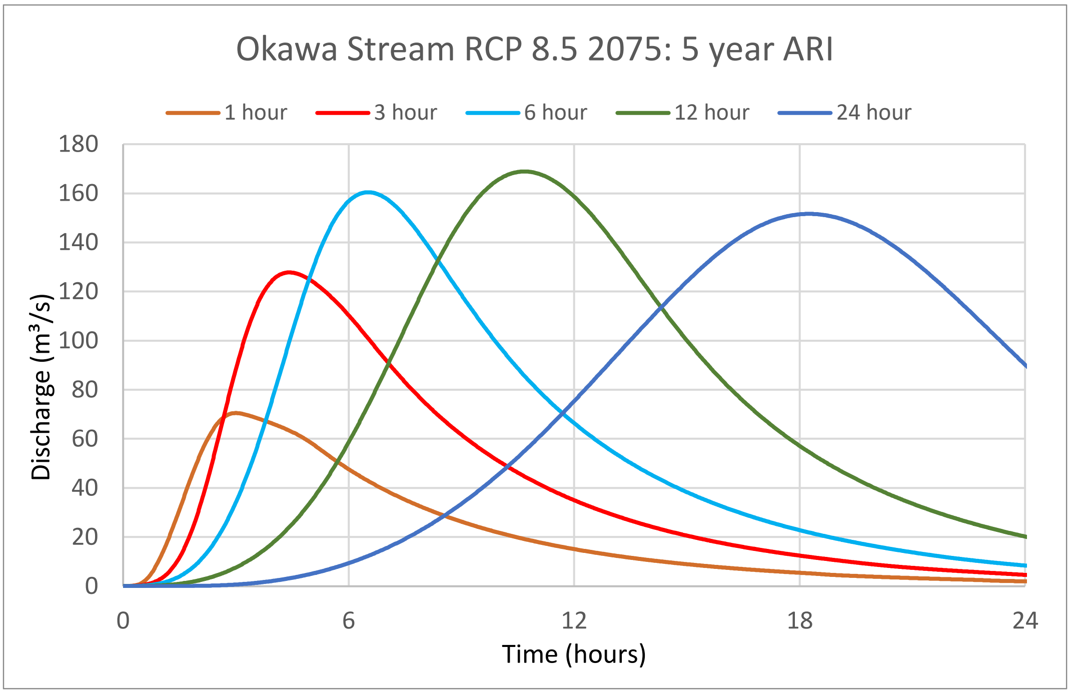



*Figure 3.15: Okawa Stream: RCP 8.5 2075 5 year ARI hydrographs*

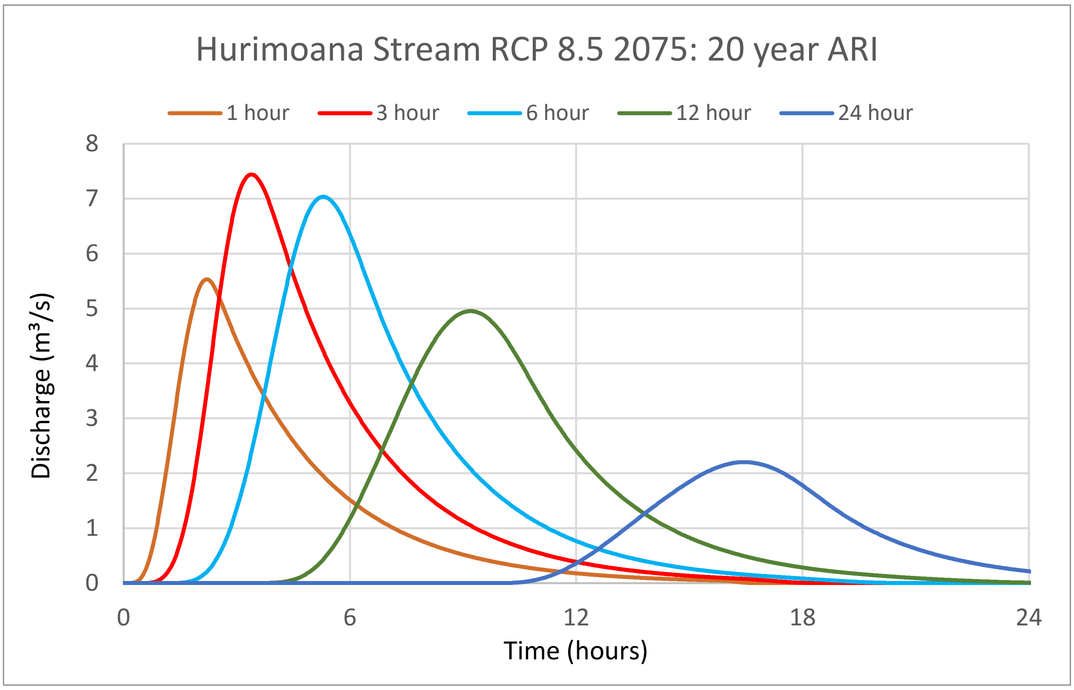



*Figure 3.16: Hurimoana Stream: RCP 8.5 2075 20 year ARI hydrographs*

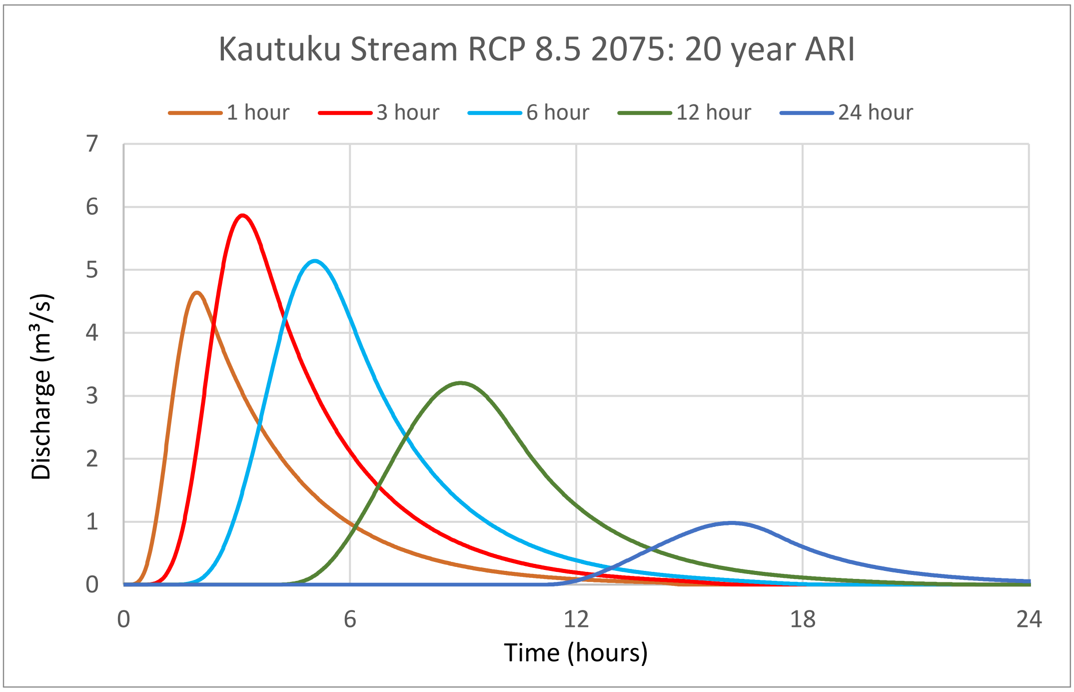



*Figure 3.17: Kautuku Stream: RCP 8.5 2075 20 year ARI hydrographs*

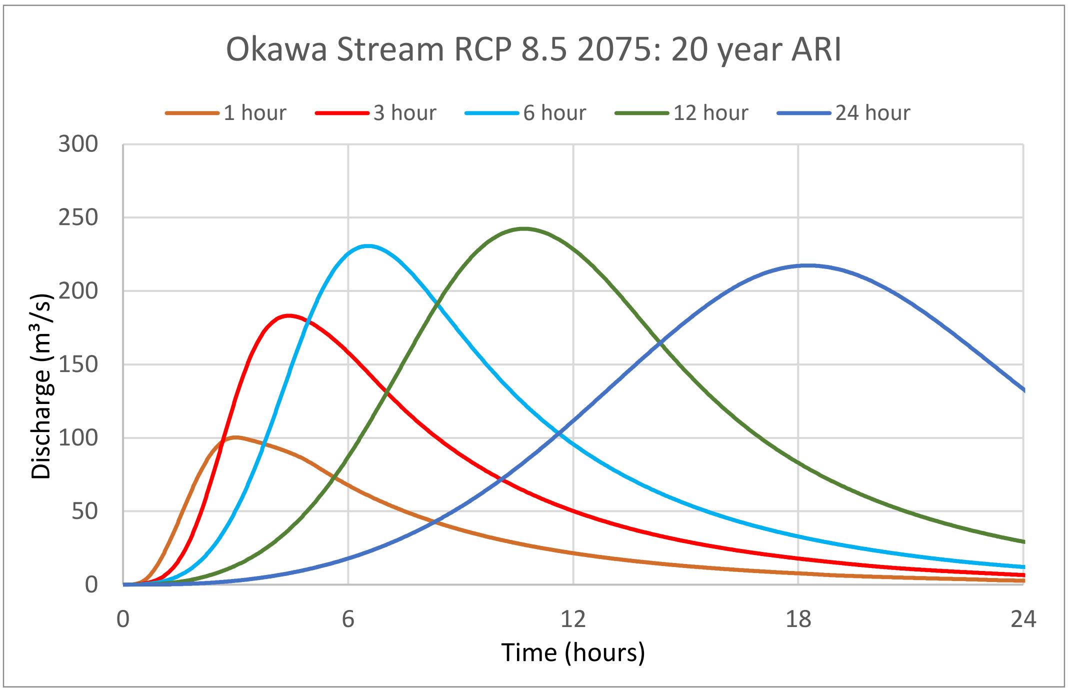



*Figure 3.18: Okawa Stream: RCP 8.5 2075 20 year ARI hydrographs*

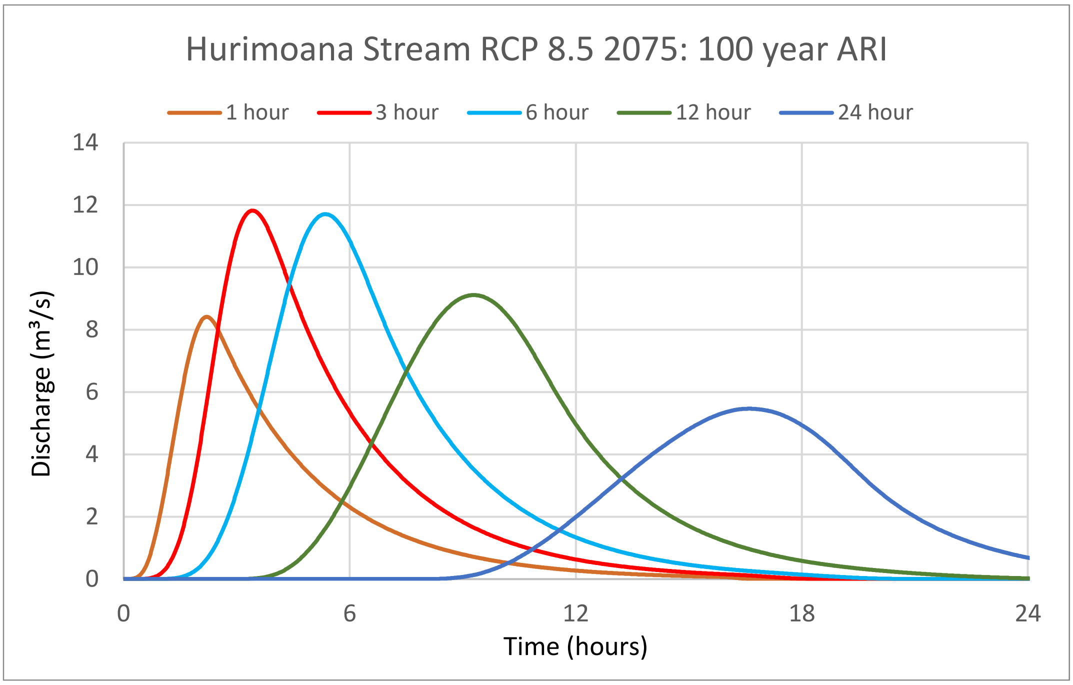



*Figure 3.19: Hurimoana Stream: RCP 8.5 2075 100 year ARI hydrographs*

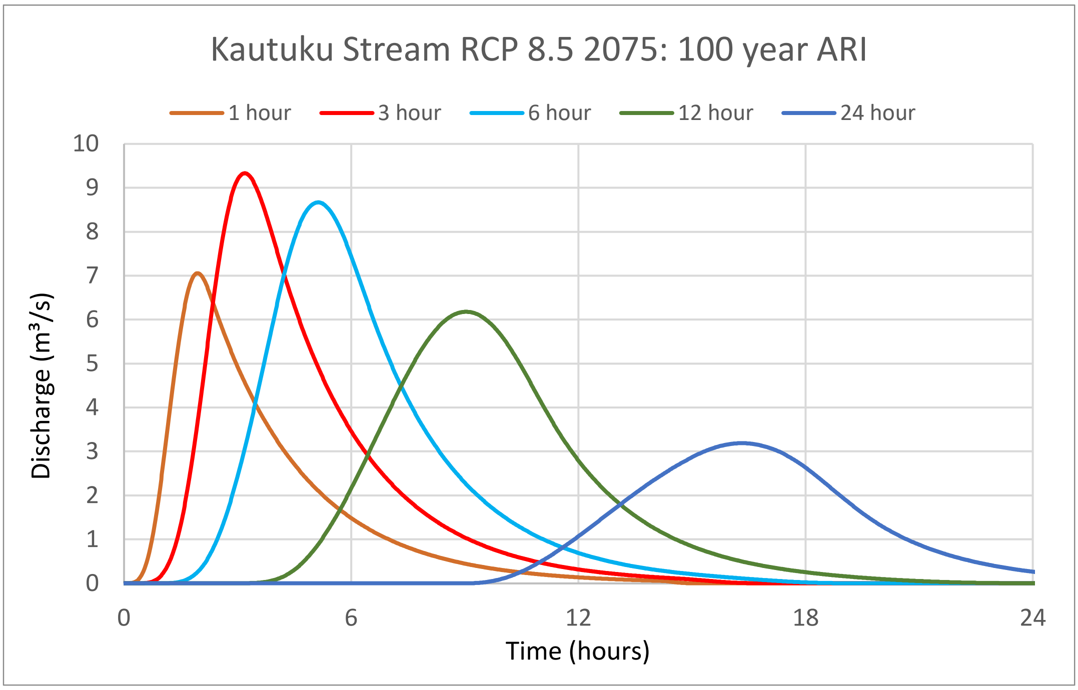



*Figure 3.20: Kautuku Stream: RCP 8.5 2075 100 year ARI hydrographs*

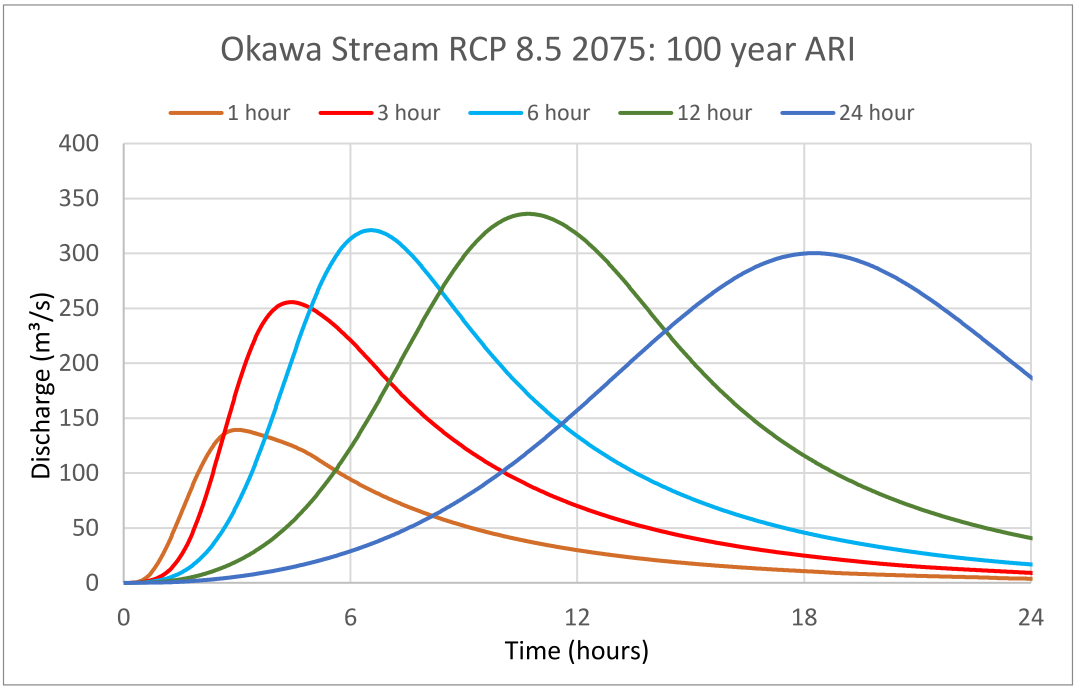



*Figure 3.21: Okawa Stream: RCP 8.5 2075 100 year ARI hydrographs*

The simulation results show that the critical storm duration for the Hurimoana and Kautuku catchments are 3 hours and 12 hours for the much larger Okawa Stream catchment. Simulations using the hydraulic model to estimate flood levels should address 12 hour storms.

## 3.5 Simulation of Cyclone Gabrielle

Hourly rainfall recorded during Cyclone Gabrielle was obtained from HBRC for three rainfall stations located outside the study catchments and for eight private rain gauges, four located in the study catchments. The location of these gauges together with the total depth of rainfall recorded during Cyclone Gabrielle are shown in Figure 3.22 together with the high rainfall area estimated by HBRC. This information was used to estimate sub-catchment rainfall for the study catchments during Cyclone Gabrielle.

Figure 2.1 shows that the pattern of hourly rainfall at the three rainfall stations is similar and that the rainfall intensity varies significantly. Average rainfall during Cyclone Gabrielle were estimated for the five study catchments based on the recorded data from the HBRC rainfall stations and the private rain gauges. The estimated average catchment rainfall during Cyclone Gabrielle, listed in Table 3.7, were disaggregated hourly using the data from the Crownthorpe gauge for the Upper Okawa and Mangatarata sub-catchments and the Moteo data for the NE, Hurimoana and Kautuku catchments.

**Table 3.7: Estimated average catchment rainfall during Cyclone Gabrielle**

| **Catchment** | **Upper Okawa** | **Mangatarata** | **NE** | **Hurimoana** | **Kautuku** |
|---|---|---|---|---|---|
| Average rain | 460 | 500 | 275 | 200 | 160 |
| Reference Gauge | Crownthorpe | | Moteo | | |

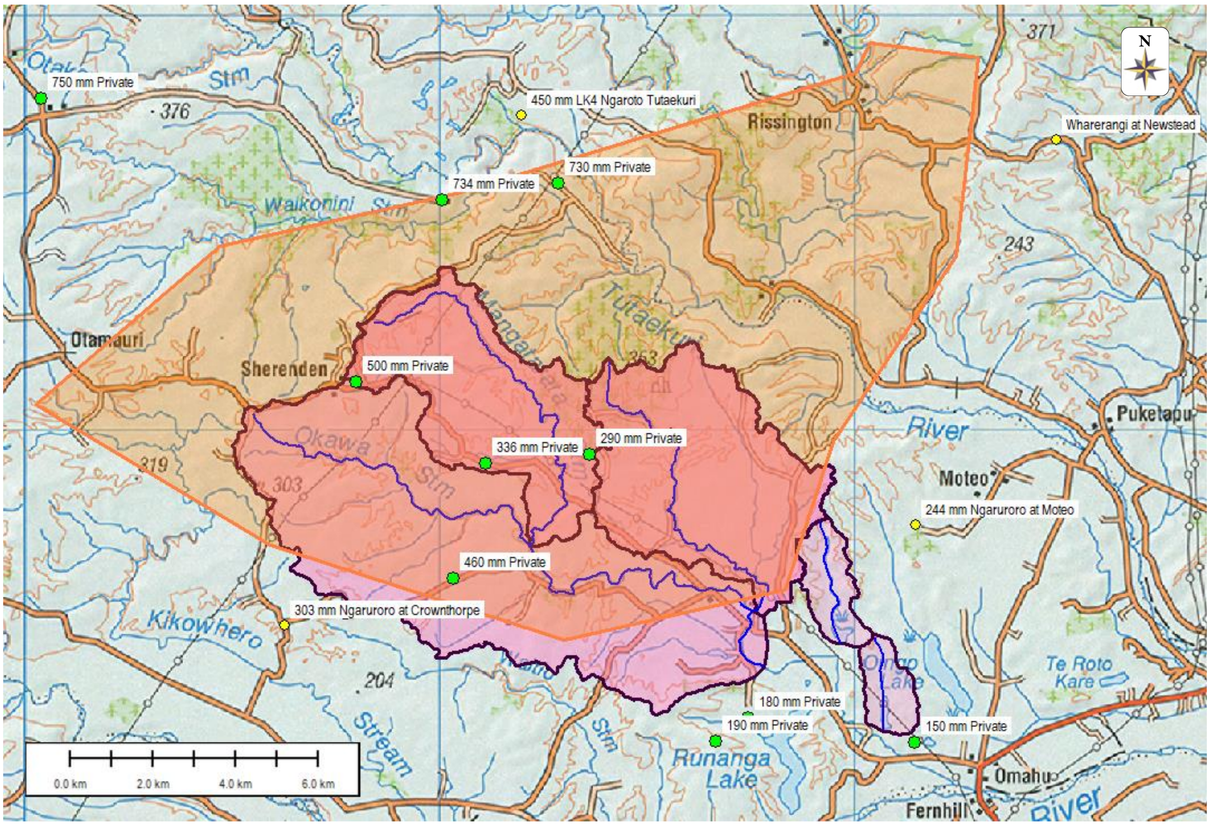



*Figure 3.22: Cyclone Gabrielle high rainfall area estimated by HBRC shown in orange*

The simulated hydrograph from the Okawa during Cyclone Gabrielle is shown in Figure 3.23 and for the Hurimoana and Kautuku catchments in Figure 3.24.

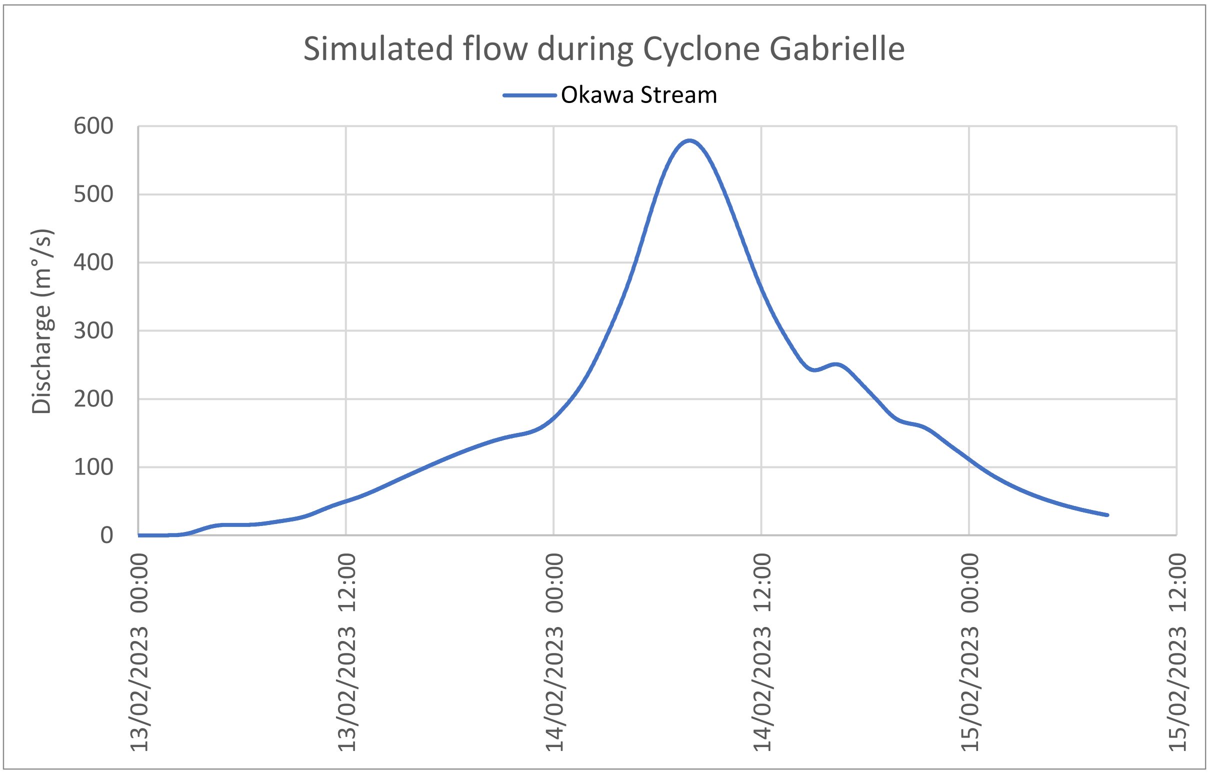



*Figure 3.23: Simulated flow from Okawa Stream during Cyclone Gabrielle*

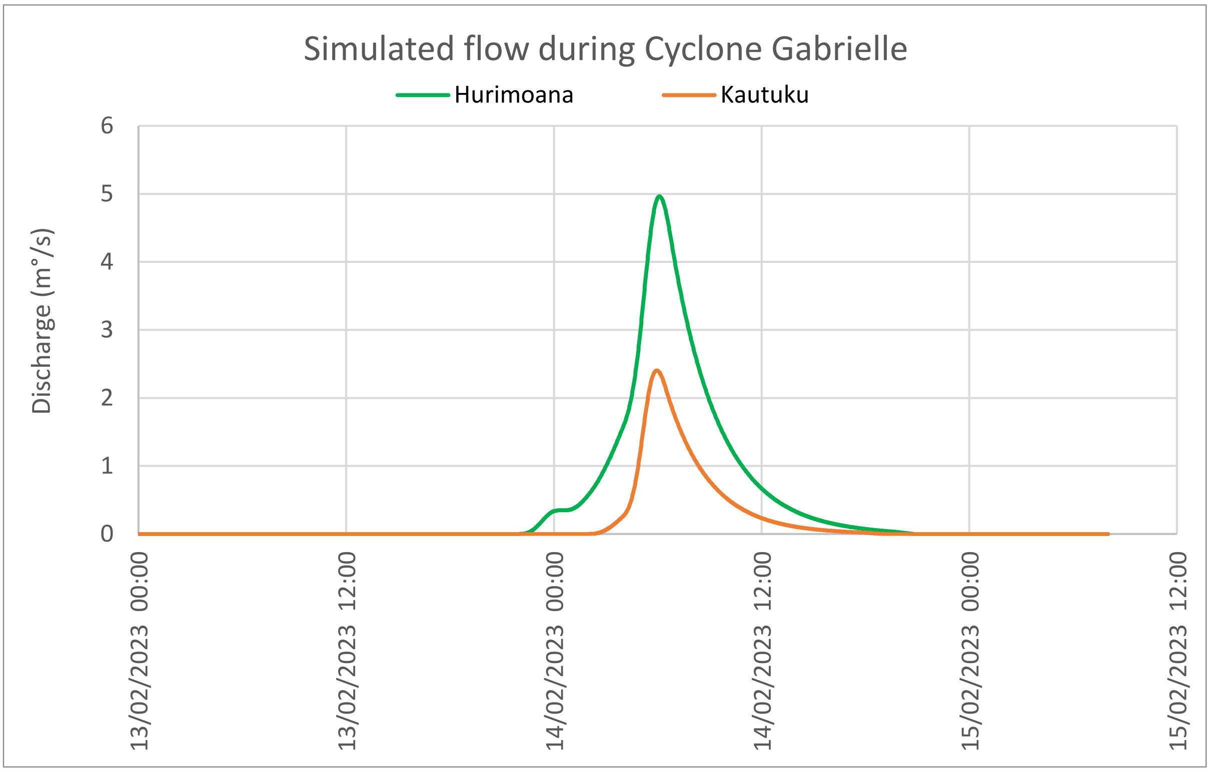



*Figure 3.24: Simulated flow from Okawa Stream during Cyclone Gabrielle*

The hydraulic model results will be used to compare simulated and observed flood levels during Cyclone Gabrielle. Confidence in both the constant loss estimates and the average catchment rainfall during Cyclone Gabrielle are low and these estimates should be adjusted as required to improve simulation of Cyclone Gabrielle flood levels.

# Appendix A HIRDS data

- **Upper Okawa**
- **NE**
- **Mangatarata**
- **Hurimoana**
- **Kautuku**

HIRDS V4 Depth-Duration-Frequency Results
Sitename: Upper Okawa
Coordinate system: WGS84
Longitude: 176.6063
Latitude: -39.5374
DDF Model

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Parameters: | | c | d | e | f | g | h | i |
| | Values: | -0.01059 | 0.600791 | -0.0295 | 0.000 | 0.29914 | -0.0114 | 2.626516 |
| | Example: | Duration (hrs) | ARI (yrs) | x | y | Rainfall Depth (mm) | | |
| | | 24 | 100 | 3.178054 | 4.600149 | 184.5772 | | |

Rainfall depths (mm) :: Historical Data

| ARI | AEP | 10m | 20m | 30m | 1h | 2h | 6h | 12h | 24h | 48h |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.58 | 0.633 | 4.3 | 6.9 | 9.0 | 13.8 | 20.7 | 36.9 | 51.2 | 69.2 | 90.9 |
| 2 | 0.5 | 4.8 | 7.7 | 10.0 | 15.4 | 23.0 | 40.8 | 56.6 | 76.2 | 99.8 |
| 5 | 0.2 | 6.7 | 10.7 | 13.9 | 21.1 | 31.2 | 54.8 | 75.3 | 101.0 | 131.0 |
| 10 | 0.1 | 8.3 | 13.1 | 16.9 | 25.6 | 37.6 | 65.4 | 89.4 | 119.0 | 153.0 |
| 20 | 0.05 | 10.0 | 15.7 | 20.2 | 30.4 | 44.5 | 76.7 | 104.0 | 138.0 | 177.0 |
| 30 | 0.033 | 11.0 | 17.3 | 22.3 | 33.4 | 48.7 | 83.6 | 113.0 | 149.0 | 191.0 |
| 40 | 0.025 | 11.8 | 18.5 | 23.8 | 35.6 | 51.8 | 88.6 | 120.0 | 158.0 | 201.0 |
| 50 | 0.02 | 12.5 | 19.5 | 25.0 | 37.3 | 54.3 | 92.6 | 125.0 | 164.0 | 209.0 |
| 60 | 0.017 | 13.0 | 20.3 | 26.0 | 38.8 | 56.3 | 95.8 | 129.0 | 169.0 | 216.0 |
| 80 | 0.013 | 13.9 | 21.6 | 27.6 | 41.2 | 59.6 | 101.0 | 136.0 | 178.0 | 226.0 |
| 100 | 0.01 | 14.5 | 22.6 | 28.9 | 43.0 | 62.2 | 105.0 | 141.0 | 185.0 | 234.0 |
| 250 | 0.004 | 17.5 | 27.1 | 34.5 | 50.9 | 73.1 | 122.0 | 163.0 | 212.0 | 267.0 |

HIRDS V4 Depth-Duration-Frequency Results
Sitename: NE
Coordinate system: WGS84
Longitude: 176.6826
Latitude: -39.5198
DDF Model

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Parameters: | | c | d | e | f | g | h | i |
| | Values: | -0.01078 | 0.518041 | -0.01879 | 0.000 | 0.300244 | -0.01136 | 2.703522 |
| | Example: | Duration (hrs) | ARI (yrs) | x | y | Rainfall Depth (mm) | | |
| | | 24 | 100 | 3.178054 | 4.600149 | 171.3017 | | |

Rainfall depths (mm) :: Historical Data

| ARI | AEP | 10m | 20m | 30m | 1h | 2h | 6h | 12h | 24h | 48h |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.58 | 0.633 | 5.6 | 8.3 | 10.3 | 14.9 | 21.2 | 35.5 | 48.1 | 64.0 | 83.7 |
| 2 | 0.5 | 6.2 | 9.3 | 11.5 | 16.6 | 23.6 | 39.4 | 53.2 | 70.5 | 91.9 |
| 5 | 0.2 | 8.8 | 12.9 | 16.0 | 22.8 | 32.0 | 52.8 | 70.8 | 93.1 | 120.0 |
| 10 | 0.1 | 10.8 | 15.7 | 19.5 | 27.7 | 38.7 | 63.2 | 84.2 | 110.0 | 141.0 |
| 20 | 0.05 | 13.0 | 18.9 | 23.3 | 33.0 | 45.7 | 74.1 | 98.2 | 128.0 | 163.0 |
| 30 | 0.033 | 14.4 | 20.9 | 25.7 | 36.2 | 50.1 | 80.8 | 107.0 | 138.0 | 176.0 |
| 40 | 0.025 | 15.4 | 22.3 | 27.5 | 38.6 | 53.3 | 85.7 | 113.0 | 146.0 | 186.0 |
| 50 | 0.02 | 16.3 | 23.5 | 28.9 | 40.5 | 55.9 | 89.5 | 118.0 | 152.0 | 193.0 |
| 60 | 0.017 | 17.0 | 24.5 | 30.1 | 42.1 | 58.0 | 92.7 | 122.0 | 157.0 | 199.0 |
| 80 | 0.013 | 18.1 | 26.0 | 32.0 | 44.7 | 61.4 | 97.8 | 128.0 | 165.0 | 209.0 |
| 100 | 0.01 | 19.0 | 27.3 | 33.5 | 46.7 | 64.1 | 102.0 | 133.0 | 171.0 | 216.0 |
| 250 | 0.004 | 22.9 | 32.7 | 40.0 | 55.4 | 75.5 | 119.0 | 154.0 | 197.0 | 247.0 |

HIRDS V4 Depth-Duration-Frequency Results
Sitename: Mangatarata
Coordinate system: WGS84
Longitude: 176.6215
Latitude: -39.5
DDF Model

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Parameters: | | c | d | e | f | g | h | i |
| | | | | | | | - | |
| | Values: | -0.00984 | 0.596075 | -0.02305 | 0.000 | 0.30295 | 0.01208 | 2.670769 |
| | Example: | Duration (hrs) | ARI (yrs) | x | y | Rainfall Depth (mm) | | |
| | | 24 | 100 | 3.178054 | 4.600149 | 202.8433 | | |

Rainfall depths (mm) :: Historical Data

| ARI | AEP | 10m | 20m | 30m | 1h | 2h | 6h | 12h | 24h | 48h |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.58 | 0.633 | 4.6 | 7.3 | 9.5 | 14.4 | 21.6 | 38.9 | 54.7 | 75.0 | 100.0 |
| 2 | 0.5 | 5.2 | 8.2 | 10.6 | 16.1 | 24.0 | 43.2 | 60.5 | 82.8 | 110.0 |
| 5 | 0.2 | 7.3 | 11.4 | 14.6 | 22.2 | 32.8 | 58.2 | 80.9 | 110.0 | 145.0 |
| 10 | 0.1 | 9.0 | 13.9 | 17.9 | 26.9 | 39.6 | 69.6 | 96.4 | 130.0 | 171.0 |
| 20 | 0.05 | 10.8 | 16.7 | 21.3 | 31.9 | 46.8 | 81.7 | 113.0 | 151.0 | 198.0 |
| 30 | 0.033 | 11.9 | 18.4 | 23.5 | 35.1 | 51.2 | 89.1 | 122.0 | 164.0 | 214.0 |
| 40 | 0.025 | 12.8 | 19.7 | 25.1 | 37.4 | 54.5 | 94.4 | 129.0 | 173.0 | 225.0 |
| 50 | 0.02 | 13.4 | 20.7 | 26.3 | 39.2 | 57.1 | 98.7 | 135.0 | 180.0 | 234.0 |
| 60 | 0.017 | 14.0 | 21.5 | 27.4 | 40.7 | 59.2 | 102.0 | 140.0 | 186.0 | 242.0 |
| 80 | 0.013 | 14.9 | 22.9 | 29.1 | 43.2 | 62.6 | 108.0 | 147.0 | 196.0 | 253.0 |
| 100 | 0.01 | 15.6 | 24.0 | 30.4 | 45.1 | 65.3 | 112.0 | 153.0 | 203.0 | 263.0 |
| 250 | 0.004 | 18.8 | 28.6 | 36.2 | 53.2 | 76.6 | 130.0 | 176.0 | 233.0 | 299.0 |

HIRDS V4 Depth-Duration-Frequency Results
Sitename: Hurimoana
Coordinate system: WGS84
Longitude: 176.7178
Latitude: -39.5
DDF

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Model | Parameters: | c | d | e | f | g | h | i |
| | | | | | | | - | |
| | Values: | -0.01069 | 0.517578 | -0.01128 | -0.001 | 0.300602 | 0.01139 | 2.720763 |
| | Example: | Duration (hrs) | ARI (yrs) | x | y | Rainfall Depth (mm) | | |
| | | 24 | 100 | 3.178054 | 4.600149 | 181.8725 | | |

Rainfall depths (mm) :: Historical Data

| ARI | AEP | 10m | 20m | 30m | 1h | 2h | 6h | 12h | 24h | 48h |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.58 | 0.633 | 5.8 | 8.5 | 10.6 | 15.2 | 21.6 | 36.8 | 50.4 | 67.8 | 89.4 |
| 2 | 0.5 | 6.6 | 9.5 | 11.8 | 16.9 | 24.0 | 40.8 | 55.7 | 74.7 | 98.3 |
| 5 | 0.2 | 9.2 | 13.2 | 16.3 | 23.2 | 32.7 | 54.7 | 74.2 | 98.7 | 129.0 |
| 10 | 0.1 | 11.3 | 16.2 | 19.9 | 28.2 | 39.5 | 65.5 | 88.2 | 117.0 | 151.0 |
| 20 | 0.05 | 13.6 | 19.4 | 23.8 | 33.6 | 46.7 | 76.8 | 103.0 | 136.0 | 175.0 |
| 30 | 0.033 | 15.1 | 21.5 | 26.3 | 36.9 | 51.2 | 83.8 | 112.0 | 147.0 | 189.0 |
| 40 | 0.025 | 16.2 | 23.0 | 28.1 | 39.3 | 54.5 | 88.8 | 118.0 | 155.0 | 199.0 |
| 50 | 0.02 | 17.1 | 24.2 | 29.5 | 41.3 | 57.1 | 92.8 | 124.0 | 162.0 | 207.0 |
| 60 | 0.017 | 17.8 | 25.2 | 30.7 | 42.9 | 59.2 | 96.1 | 128.0 | 167.0 | 213.0 |
| 80 | 0.013 | 19.0 | 26.8 | 32.7 | 45.5 | 62.7 | 101.0 | 135.0 | 175.0 | 224.0 |
| 100 | 0.01 | 19.9 | 28.1 | 34.2 | 47.6 | 65.5 | 106.0 | 140.0 | 182.0 | 232.0 |
| 250 | 0.004 | 24.1 | 33.7 | 40.9 | 56.4 | 77.1 | 123.0 | 162.0 | 209.0 | 264.0 |

HIRDS V4 Depth-Duration-Frequency Results
Sitename: Kautuku
Coordinate system: WGS84
Longitude: 176.7352
Latitude: -39.5649
DDF Model

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Parameters: | | c | d | e | f | g | h | i |
| | Values: | -0.01146 | 0.504529 | -0.01915 | 0.000 | 0.302204 | -0.01153 | 2.694912 |
| | Example: | Duration (hrs) | ARI (yrs) | x | y | Rainfall Depth (mm) | | |
| | | 24 | 100 | 3.178054 | 4.600149 | 161.3542 | | |

Rainfall depths (mm) :: Historical Data

| ARI | AEP | 10m | 20m | 30m | 1h | 2h | 6h | 12h | 24h | 48h |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.58 | 0.633 | 5.6 | 8.3 | 10.3 | 14.8 | 20.8 | 34.4 | 46.1 | 60.6 | 78.3 |
| 2 | 0.5 | 6.3 | 9.3 | 11.6 | 16.5 | 23.1 | 38.1 | 50.9 | 66.7 | 86.0 |
| 5 | 0.2 | 8.9 | 13.0 | 16.0 | 22.7 | 31.5 | 51.1 | 67.7 | 88.0 | 112.0 |
| 10 | 0.1 | 11.0 | 15.9 | 19.6 | 27.6 | 38.1 | 61.1 | 80.5 | 104.0 | 132.0 |
| 20 | 0.05 | 13.3 | 19.1 | 23.5 | 32.8 | 45.0 | 71.7 | 93.8 | 121.0 | 152.0 |
| 30 | 0.033 | 14.7 | 21.1 | 25.9 | 36.1 | 49.4 | 78.2 | 102.0 | 131.0 | 164.0 |
| 40 | 0.025 | 15.8 | 22.6 | 27.7 | 38.5 | 52.5 | 82.9 | 108.0 | 138.0 | 173.0 |
| 50 | 0.02 | 16.7 | 23.8 | 29.1 | 40.4 | 55.0 | 86.6 | 112.0 | 144.0 | 180.0 |
| 60 | 0.017 | 17.4 | 24.8 | 30.3 | 42.0 | 57.1 | 89.6 | 116.0 | 148.0 | 185.0 |
| 80 | 0.013 | 18.6 | 26.4 | 32.2 | 44.5 | 60.5 | 94.6 | 122.0 | 156.0 | 194.0 |
| 100 | 0.01 | 19.5 | 27.7 | 33.7 | 46.6 | 63.1 | 98.4 | 127.0 | 161.0 | 201.0 |
| 250 | 0.004 | 23.6 | 33.2 | 40.3 | 55.2 | 74.3 | 115.0 | 147.0 | 185.0 | 229.0 |

# Appendix B Cyclone Gabrielle rainfall

- **Crownthorpe, Tutaekuri and Moteo**

| Date Time | Crownthorpe Climate | LK4 Ngaroto Tutaekuri | Ngaroto at Moteo |
|---|---|---|---|
| 12/02/2023 0:00 | 0.0 | 0.0 | 0.0 |
| 12/02/2023 1:00 | 0.0 | 0.0 | 0.0 |
| 12/02/2023 2:00 | 0.0 | 0.0 | 0.0 |
| 12/02/2023 3:00 | 0.0 | 0.5 | 0.5 |
| 12/02/2023 4:00 | 0.8 | 1.0 | 0.5 |
| 12/02/2023 5:00 | 0.2 | 0.0 | 3.5 |
| 12/02/2023 6:00 | 2.8 | 1.0 | 1.5 |
| 12/02/2023 7:00 | 0.0 | 0.0 | 0.0 |
| 12/02/2023 8:00 | 0.0 | 0.0 | 0.0 |
| 12/02/2023 9:00 | 0.0 | 0.0 | 0.0 |
| 12/02/2023 10:00 | 0.0 | 0.0 | 0.0 |
| 12/02/2023 11:00 | 0.0 | 0.0 | 0.0 |
| 12/02/2023 12:00 | 0.0 | 0.0 | 0.0 |
| 12/02/2023 13:00 | 0.0 | 0.0 | 1.5 |
| 12/02/2023 14:00 | 0.0 | 0.0 | 0.0 |
| 12/02/2023 15:00 | 0.0 | 0.0 | 0.0 |
| 12/02/2023 16:00 | 0.0 | 0.0 | 0.0 |
| 12/02/2023 17:00 | 0.0 | 0.0 | 0.0 |
| 12/02/2023 18:00 | 0.0 | 0.0 | 0.0 |
| 12/02/2023 19:00 | 0.0 | 0.0 | 0.0 |
| 12/02/2023 20:00 | 0.0 | 0.0 | 0.0 |
| 12/02/2023 21:00 | 0.0 | 0.0 | 0.0 |
| 12/02/2023 22:00 | 0.0 | 0.5 | 0.0 |
| 12/02/2023 23:00 | 0.6 | 0.5 | 0.0 |
| 13/02/2023 0:00 | 0.2 | 1.0 | 0.0 |
| 13/02/2023 1:00 | 0.2 | 0.0 | 0.0 |
| 13/02/2023 2:00 | 1.0 | 2.5 | 1.0 |
| 13/02/2023 3:00 | 3.8 | 1.5 | 3.0 |
| 13/02/2023 4:00 | 0.8 | 2.0 | 1.0 |
| 13/02/2023 5:00 | 0.0 | 0.5 | 0.0 |
| 13/02/2023 6:00 | 1.2 | 1.0 | 1.5 |
| 13/02/2023 7:00 | 2.6 | 5.5 | 2.0 |
| 13/02/2023 8:00 | 1.6 | 3.5 | 2.0 |
| 13/02/2023 9:00 | 2.8 | 5.5 | 4.0 |
| 13/02/2023 10:00 | 4.2 | 5.0 | 3.5 |
| 13/02/2023 11:00 | 3.0 | 6.0 | 3.0 |
| 13/02/2023 12:00 | 3.6 | 10.5 | 5.0 |
| 13/02/2023 13:00 | 4.6 | 9.0 | 6.5 |
| 13/02/2023 14:00 | 5.0 | 7.5 | 5.0 |
| 13/02/2023 15:00 | 5.0 | 8.0 | 5.0 |
| 13/02/2023 16:00 | 5.4 | 11.5 | 6.0 |

| Date Time | Crownthorpe Climate | LK4 Ngaroto Tutaekuri | Ngaroto at Moteo |
|---|---|---|---|
| 13/02/2023 17:00 | 5.6 | 12.5 | 6.0 |
| 13/02/2023 18:00 | 5.8 | 11.5 | 5.5 |
| 13/02/2023 19:00 | 5.8 | 12.5 | 6.5 |
| 13/02/2023 20:00 | 6.0 | 11.5 | 7.0 |
| 13/02/2023 21:00 | 5.4 | 12.5 | 5.0 |
| 13/02/2023 22:00 | 5.6 | 13.0 | 6.0 |
| 13/02/2023 23:00 | 9.2 | 20.0 | 12.5 |
| 14/02/2023 0:00 | 11.4 | 20.0 | 9.0 |
| 14/02/2023 1:00 | 13.2 | 26.0 | 12.0 |
| 14/02/2023 2:00 | 18.6 | 27.0 | 13.0 |
| 14/02/2023 3:00 | 19.0 | 34.5 | 14.5 |
| 14/02/2023 4:00 | 25.2 | 41.0 | 15.5 |
| 14/02/2023 5:00 | 30.4 | 38.5 | 30.0 |
| 14/02/2023 6:00 | 23.8 | 27.5 | 9.5 |
| 14/02/2023 7:00 | 16.8 | 18.5 | 6.0 |
| 14/02/2023 8:00 | 8.2 | 7.5 | 2.5 |
| 14/02/2023 9:00 | 4.0 | 3.5 | 0.0 |
| 14/02/2023 10:00 | 1.8 | 1.0 | 1.0 |
| 14/02/2023 11:00 | 0.6 | 3.5 | 4.5 |
| 14/02/2023 12:00 | 2.6 | 1.0 | 0.0 |
| 14/02/2023 13:00 | 2.8 | 1.0 | 0.0 |
| 14/02/2023 14:00 | 1.0 | 4.5 | 9.5 |
| 14/02/2023 15:00 | 17.4 | 6.5 | 4.0 |
| 14/02/2023 16:00 | 2.2 | 1.0 | 0.0 |
| 14/02/2023 17:00 | 0.4 | 1.0 | 2.0 |
| 14/02/2023 18:00 | 1.4 | 1.5 | 2.0 |
| 14/02/2023 19:00 | 1.2 | 0.0 | 0.0 |
| 14/02/2023 20:00 | 8.4 | 2.0 | 0.5 |
| 14/02/2023 21:00 | 0.0 | 0.5 | 0.5 |
| 14/02/2023 22:00 | 0.0 | 0.5 | 1.0 |
| 14/02/2023 23:00 | 0.4 | 1.0 | 1.0 |
| 15/02/2023 0:00 | 0.0 | 2.0 | 0.5 |
| 15/02/2023 1:00 | 0.0 | 1.0 | 0.5 |
| 15/02/2023 2:00 | 0.0 | 0.0 | 0.5 |
| 15/02/2023 3:00 | 0.0 | 0.0 | 0.0 |
| 15/02/2023 4:00 | 0.0 | 0.5 | 0.0 |
| 15/02/2023 5:00 | 0.0 | 0.0 | 0.0 |
| 15/02/2023 6:00 | 0.0 | 0.0 | 0.0 |
| 15/02/2023 7:00 | 0.0 | 0.0 | 0.0 |
| 15/02/2023 8:00 | 0.0 | 0.0 | 0.0 |

# Appendix B UAV survey report

Report Date: 30/04/2024

# UAV Survey Report

**Checklist is to be used for all UAV surveys**

| | | | |
|---|---|---|---|
| **Remote Pilot:** | Lochlan Kelso | | |
| **Job Number:** | 243601 | | |
| **Job Name:** | Okawa Stream | | |
| **Survey Date:** | 23/04/2024 | | |
| **UAV Used:** | DJI Matrice M300 | | |
| **Sensor(s) Used:** | Zenmuse L2 | | |
| **Coordinate Datum:** | NZTM 2000 | | |
| **Height Datum:** | NZVD 2016 | | |
| | | | |
| **Base Point Name:** | IT XXIV SP 4609 | | |
| **Geodetic Code:** | DFBC | | |
| **Coordinates:** | 5612047.063 mN | 1920362.072 mE | 28.15 mZ |
| **Source:** | LINZ Geodetic Database | | |
| **Horizontal Order:** | 5 | | |
| **Vertical Order:** | 3 | | |
| | | | |
| **Check Point Name:** | IS I SO 10515 | | |
| **Geodetic Code:** | EHWC | | |
| **Coordinates:** | 5614192.941 mN | 1918973.681 mE | 38.22 mZ |
| **Source:** | LINZ Geodetic Database | | |
| **Horizontal Order:** | 5 | | |
| **Vertical Order:** | 3 | | |
| | | | |
| **<u>Photogrammetry Survey</u>** | | | |
| **Number of control points:** | 4 | | |
| **Number of check points:** | 8 | | |
| **Control point RMSe:** | 0.006 mX | 0.014 mY | 0.006 mZ |
| **Check point RMSe:** | 0.031 mX | 0.023 mY | 0.043 mZ |
| **Control method:** | GCPs + PPK | | |
| **Imagery geotagged using:** | RTK | | |
| **Imagery processed using:** | Pix4D Matic | | |
| **GSD Achieved:** | 2 cm/px | | |
| | | | |
| **<u>LiDAR Survey</u>** | | | |
| **Number of check points:** | 15 | | |
| **Check point RMSe (Terra):** | | | 0.033 mZ |

Report Date: 30/04/2024

# UAV Survey Report

**Checklist is to be used for all UAV surveys**

| | | | |
|---|---|---|---|
| **Remote Pilot:** | Lochlan Kelso | | |
| **Job Number:** | 243601 | | |
| **Job Name:** | Okawa Spillway | | |
| **Survey Date:** | 22/04/2024 | | |
| **UAV Used:** | DJI Matrice M300 | | |
| **Sensor(s) Used:** | Zenmuse L2 | | |
| **Coordinate Datum:** | NZTM 2000 | | |
| **Height Datum:** | NZVD 2016 | | |
| | | | |
| **Base Point Name:** | IT XXIV SP 4609 | | |
| **Geodetic Code:** | DFBC | | |
| **Coordinates:** | 5612047.063 mN | 1920362.072 mE | 28.15 mZ |
| **Source:** | LINZ Geodetic Database | | |
| **Horizontal Order:** | 5 | | |
| **Vertical Order:** | 3 | | |
| | | | |
| **Check Point Name:** | IS I SO 10515 | | |
| **Geodetic Code:** | EHWC | | |
| **Coordinates:** | 5614192.941 mN | 1918973.681 mE | 38.22 mZ |
| **Source:** | LINZ Geodetic Database | | |
| **Horizontal Order:** | 5 | | |
| **Vertical Order:** | 3 | | |
| | | | |
| **<u>Photogrammetry Survey</u>** | | | |
| **Number of control points:** | 1 | | |
| **Number of check points:** | 2 | | |
| **Control point RMSe:** | 0.002 mX | 0.009 mY | 0.1 mZ |
| **Check point RMSe:** | 0.04 mX | 0.026 mY | 0.2 mZ |
| **Control method:** | GCPs + PPK | | |
| **Imagery geotagged using:** | RTK | | |
| **Imagery processed using:** | Pix4D Matic | | |
| **GSD Achieved:** | 2.3 cm/px | | |
| | | | |
| **<u>LiDAR Survey</u>** | | | |
| **Number of check points:** | 3 | | |
| **Check point RMSe (Terra):** | | | 0.014 mZ |

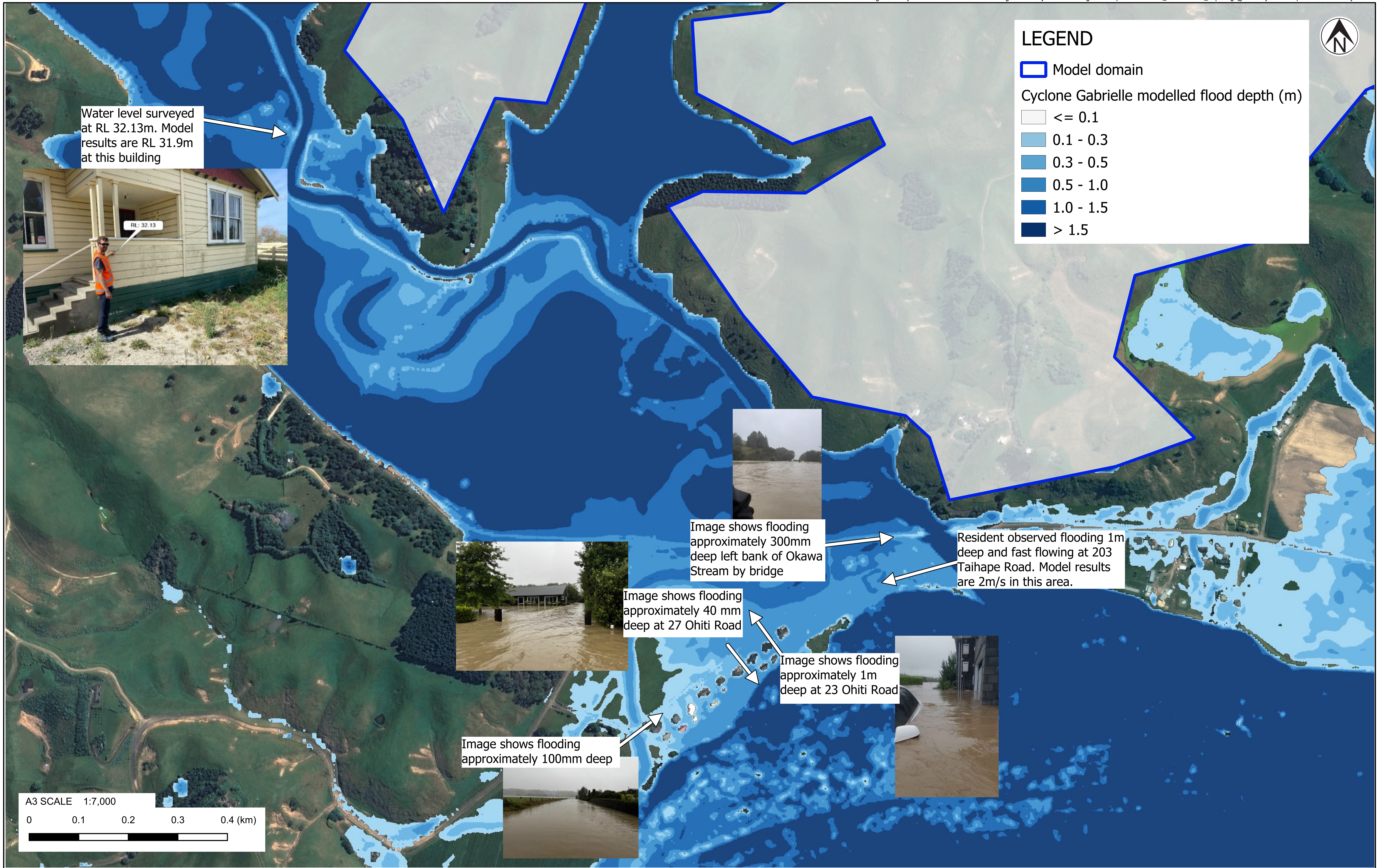
Report Date: 29/04/2024

# UAV Survey Report

**Checklist is to be used for all UAV surveys**

| | | | | | | |
|---|---|---|---|---|---|---|
| **Remote Pilot:** | Will Heesterman | | | | | |
| **Job Number:** | 243601 | | | | | |
| **Job Name:** | Rununga Outlet | | | | | |
| **Survey Date:** | 19/04/2024 | | | | | |
| **UAV Used:** | DJI Mavic 3 Enterprise | | | | | |
| **Sensor(s) Used:** | | | | | | |
| **Coordinate Datum:** | NZTM 2000 | | | | | |
| **Height Datum:** | NZVD 2016 | | | | | |
| | | | | | | |
| **Base Point Name:** | IT XXIV SO 4609 | | | | | |
| **Geodetic Code:** | DFBC | | | | | |
| **Coordinates:** | 5612047.063 | mN | 1920362.072 | mE | 28.15 | mZ |
| **Source:** | LINZ Geodetic Database | | | | | |
| **Horizontal Order:** | 5 | | | | | |
| **Vertical Order:** | 3 | | | | | |
| | | | | | | |
| **Check Point Name:** | IS I SO 10515 | | | | | |
| **Geodetic Code:** | EHWC | | | | | |
| **Coordinates:** | 5614192.941 | mN | 1918973.681 | mE | 38.22 | mZ |
| **Source:** | LINZ Geodetic Database | | | | | |
| **Horizontal Order:** | 5 | | | | | |
| **Vertical Order:** | 3 | | | | | |
| | | | | | | |
| **<u>Photogrammetry Survey</u>** | | | | | | |
| **Number of control points:** | 1 | | | | | |
| **Number of check points:** | 3 | | | | | |
| **Control point RMSe:** | 0.037 | mX | 0.012 | mY | 0 | mZ |
| **Check point RMSe:** | 0.033 | mX | 0.022 | mY | 0.028 | mZ |
| **Control method:** | GCPs + PPK | | | | | |
| **Imagery geotagged using:** | KlauPPK for DJI | | | | | |
| **Imagery processed using:** | Pix4D Matic | | | | | |
| **GSD Achieved:** | 1.9 | cm/px | | | | |
| | | | | | | |
| **~~LiDAR Survey~~** | | | | | | |
| **~~Number of check points:~~** | | | | | | |
| **~~Check point RMSe (Terra):~~** | | ~~mX~~ | | ~~mY~~ | | ~~mZ~~ |
| **~~Check point RMSe (GM):~~** | | | | | | ~~mZ~~ |

# Appendix C Flood photos



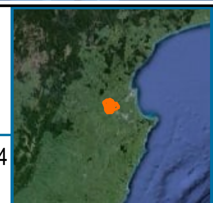

**Tonkin+Taylor**

*Exceptional thinking together* www.tonkintaylor.co.nz

**NOTES:**

Aerial imagery sourced from LINZ - Hawke's Bay 0.10m Cyclone Gabrielle Aerial Photos (2023)
This map should be read in conjunction with T+T report "Okawa Stream Hydraulic Model Build".

| REV | DESCRIPTION | GIS | CHK | DATE |
|---|---|---|---|---|
| 1 | First version | KTHA | RIBR | 10/06/24 |



LOCATION PLAN

| | | |
|---|---|---|
| PROJECT No. | 1017353.2402 | |
| DESIGNED | KTHA | JUN.24 |
| DRAWN | KTHA | JUN.24 |
| CHECKED | RIBR | JUN.24 |
| APPROVED | | DATE |

CLIENT **HAWKES BAY REGIONAL COUNCIL**

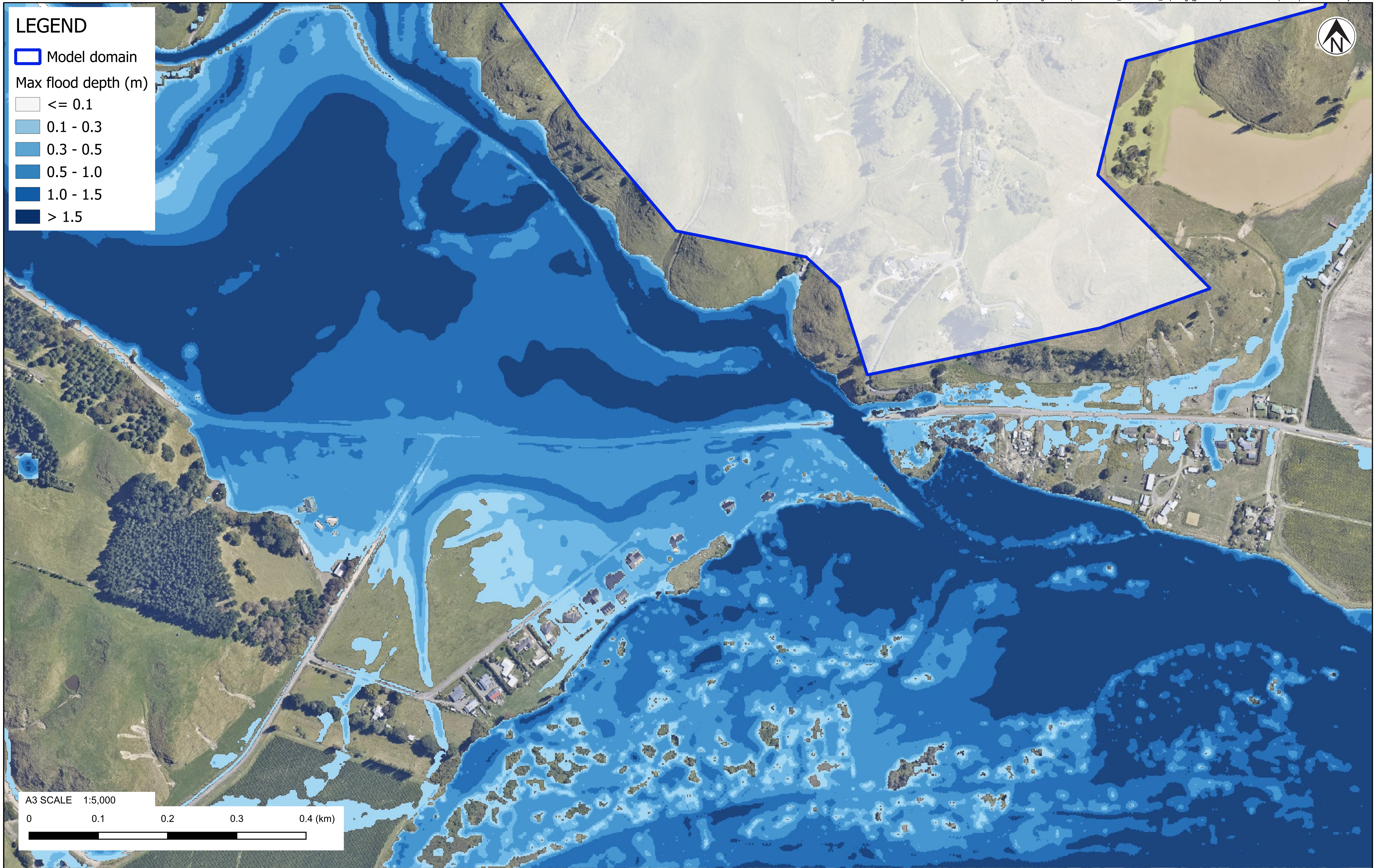
PROJECT **OKAWA STREAM HYDRAULIC MODEL**

TITLE FLOOD PHOTOS AND OBSERVATIONS

SCALE (A3) 1:7,000 FIG No. C1. REV 1

# Appendix D Flood modelling result maps

T:\Wellington\TT Projects\1017353\1017353.2402\WorkingMaterial\8 Hydraulic Modelling\QGIS\Maps\1017353.2402_OkawaStream_Reporting.qgz Layout: T+T A3 Landscape Template Drawn by KTHA

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**NOTES:**

Aerial imagery sourced from LINZ - Hawke's Bay 0.10m Cyclone Gabrielle Aerial Photos (2023).
This map should be read in conjunction with T+T report "Okawa Stream Hydraulic Model Build".

| REV | DESCRIPTION | GIS | CHK | DATE |
| --- | --- | --- | --- | --- |
| 1 | First version | KTHA | | 09/07/24 |
| 2 | Climate change allowance updated | KTHA | | 25/07/24 |

LOCATION PLAN

| | | |
| --- | --- | --- |
| PROJECT No. | 1017353.2402 | |
| DESIGNED | KTHA | JUL.24 |
| DRAWN | KTHA | JUL.24 |
| CHECKED | RIBR | JUL.24 |

APPROVED DATE

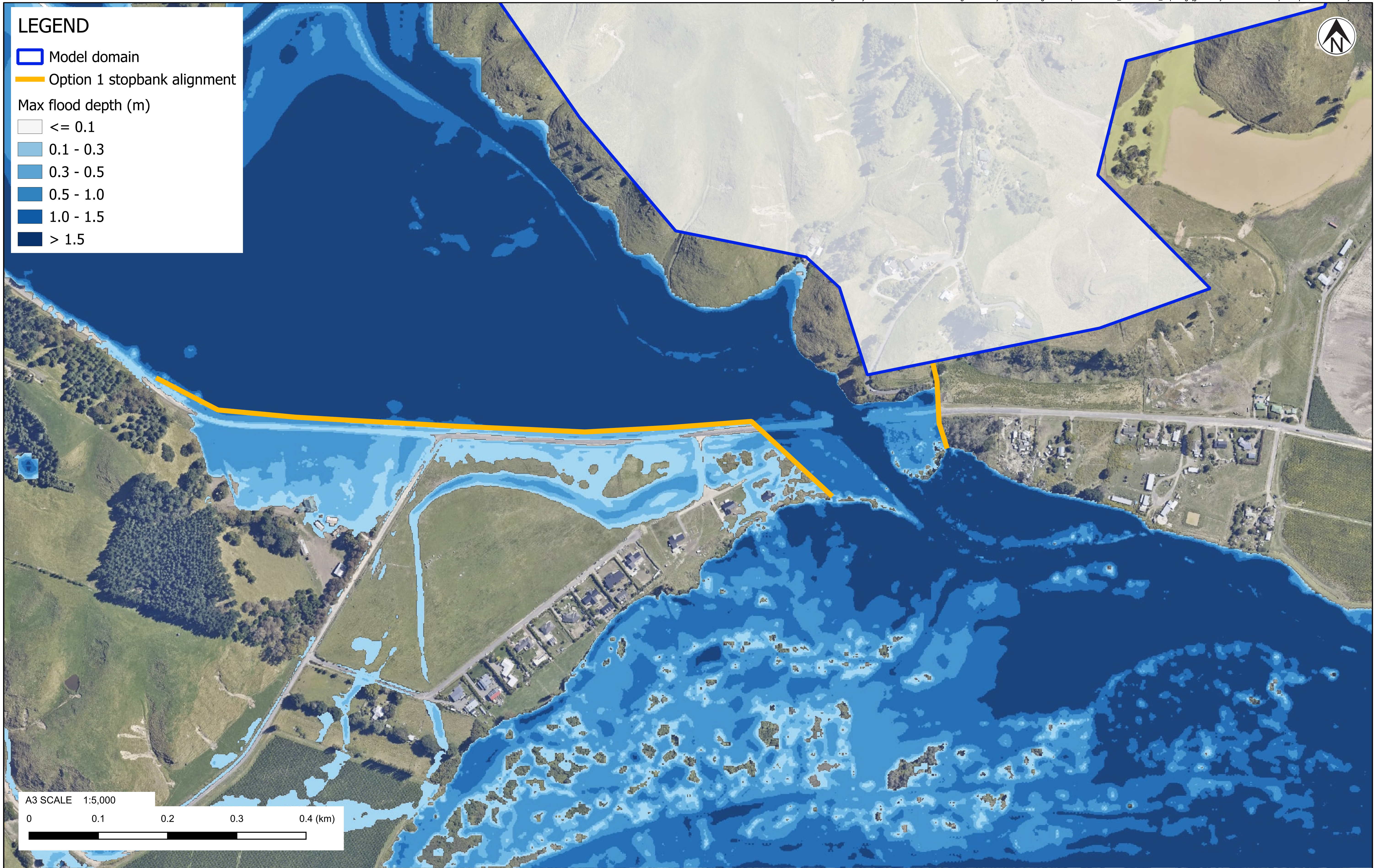
**CLIENT** HAWKES BAY REGIONAL COUNCIL

**PROJECT** OKAWA STREAM FLOOD MITIGATION

**TITLE** 100-YEAR RCP8.5 2075 FLOOD DEPTH BASE CASE

SCALE (A3) 1:5,000 FIG No. D1 REV 2

T:\Wellington\TT Projects\1017353\1017353.2402\WorkingMaterial\8 Hydraulic Modelling\QGIS\Maps\1017353.2402_OkawaStream_Reporting.qgz Layout: T+T A3 Landscape Template Drawn by KTHA

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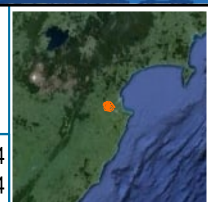
NOTES:
Aerial imagery sourced from LINZ - Hawke's Bay 0.10m Cyclone Gabrielle Aerial Photos (2023).
This map should be read in conjunction with T+T report "Okawa Stream Hydraulic Model Build".

| REV | DESCRIPTION | GIS | CHK | DATE |
|---|---|---|---|---|
| 1 | First version | KTHA | | 09/07/24 |
| 2 | Climate change allowance updated | KTHA | | 25/07/24 |

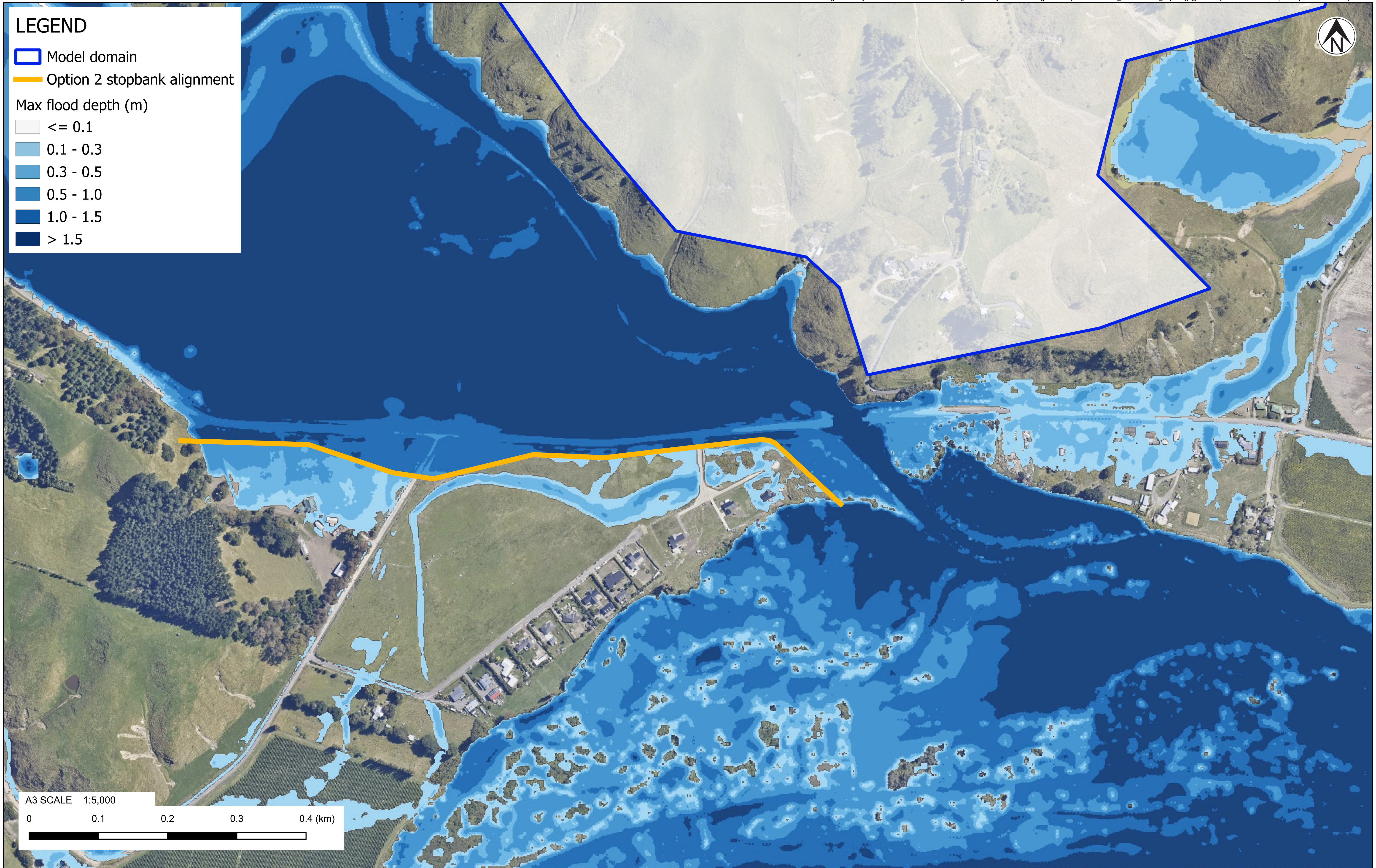


LOCATION PLAN

| PROJECT No. | 1017353.2402 | |
|---|---|---|
| DESIGNED | KTHA | JUL.24 |
| DRAWN | KTHA | JUL.24 |
| CHECKED | RIBR | JUL.24 |
| APPROVED | | DATE |

CLIENT HAWKES BAY REGIONAL COUNCIL
PROJECT OKAWA STREAM FLOOD MITIGATION
TITLE 100-YEAR RCP8.5 2075 FLOOD DEPTH OPTION 1
SCALE (A3) 1:5,000 FIG No. D2 REV 2

T:\Wellington\TT Projects\1017353\1017353.2402\WorkingMaterial\8 Hydraulic Modelling\QGIS\Maps\1017353.2402_OkawaStream_Reporting.qgz Layout: T+T A3 Landscape Template Drawn by KTHA

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**NOTES:**
Aerial imagery sourced from LINZ - Hawke's Bay 0.10m Cyclone Gabrielle Aerial Photos (2023).
This map should be read in conjunction with T+T report "Okawa Stream Hydraulic Model Build".

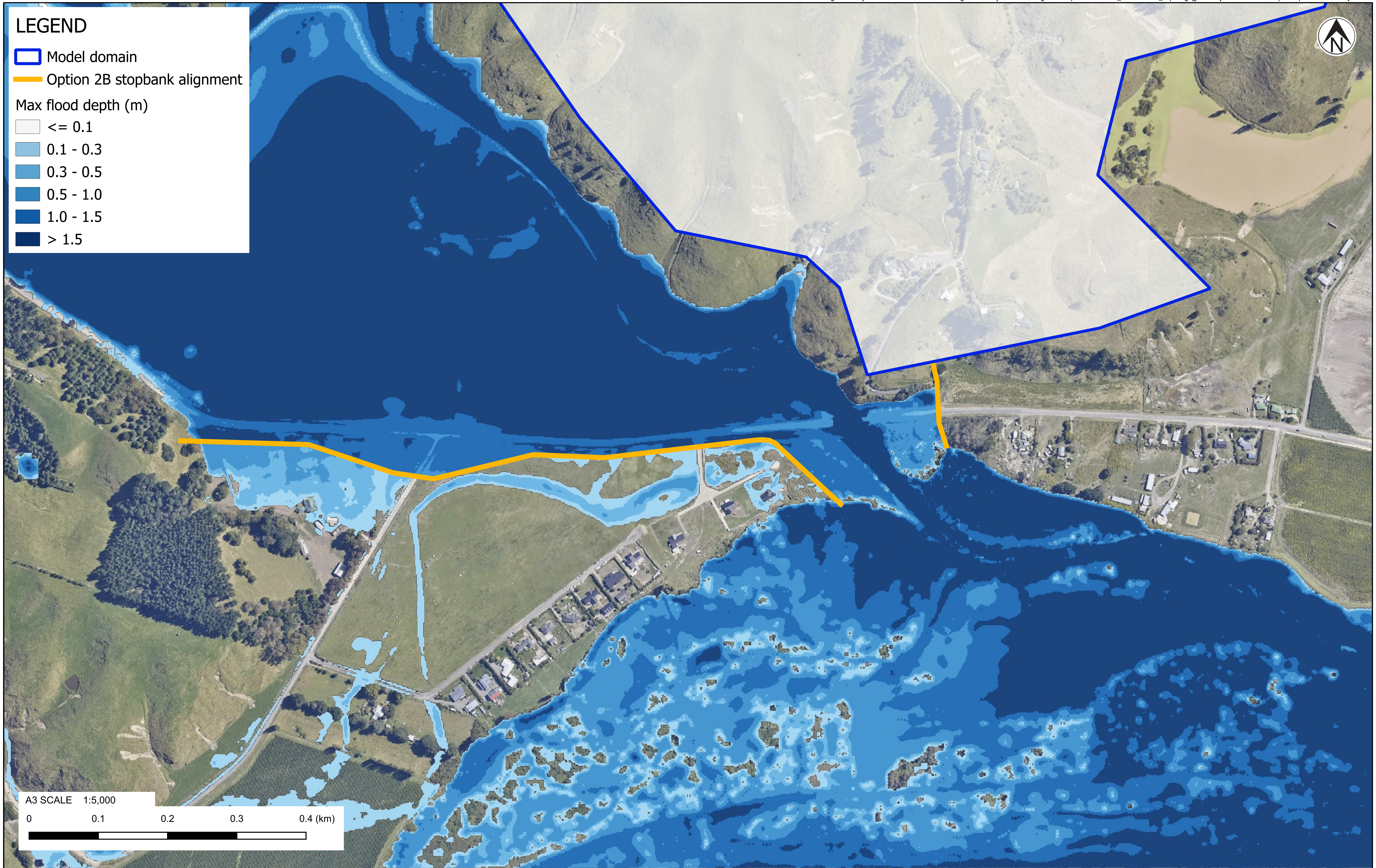
| REV | DESCRIPTION | GIS | CHK | DATE |
|---|---|---|---|---|
| 1 | First version | KTHA | | 09/07/24 |
| 2 | Climate change allowance updated | KTHA | | 25/07/24 |

LOCATION PLAN

| | | |
|---|---|---|
| PROJECT No. | 1017353.2402 | |
| DESIGNED | KTHA | JUL.24 |
| DRAWN | KTHA | JUL.24 |
| CHECKED | RIBR | JUL.24 |
| APPROVED | | DATE |

**CLIENT** HAWKES BAY REGIONAL COUNCIL
**PROJECT** OKAWA STREAM FLOOD MITIGATION
**TITLE** 100-YEAR RCP8.5 2075 FLOOD DEPTH OPTION 2
**SCALE (A3)** 1:5,000 **FIG No.** D3 **REV** 2

T:\Wellington\TT Projects\1017353\1017353.2402\WorkingMaterial\8 Hydraulic Modelling\QGIS\Maps\1017353.2402_OkawaStream_Reporting.qgz Layout: T+T A3 Landscape Template Drawn by KTHA

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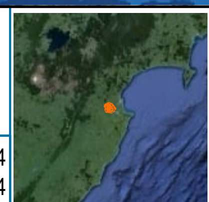
NOTES:
Aerial imagery sourced from LINZ - Hawke's Bay 0.10m Cyclone Gabrielle Aerial Photos (2023).
This map should be read in conjunction with T+T report "Okawa Stream Hydraulic Model Build".

| REV | DESCRIPTION | GIS | CHK | DATE |
|---|---|---|---|---|
| 1 | First version | KTHA | | 09/07/24 |
| 2 | Climate change allowance updated | KTHA | | 25/07/24 |

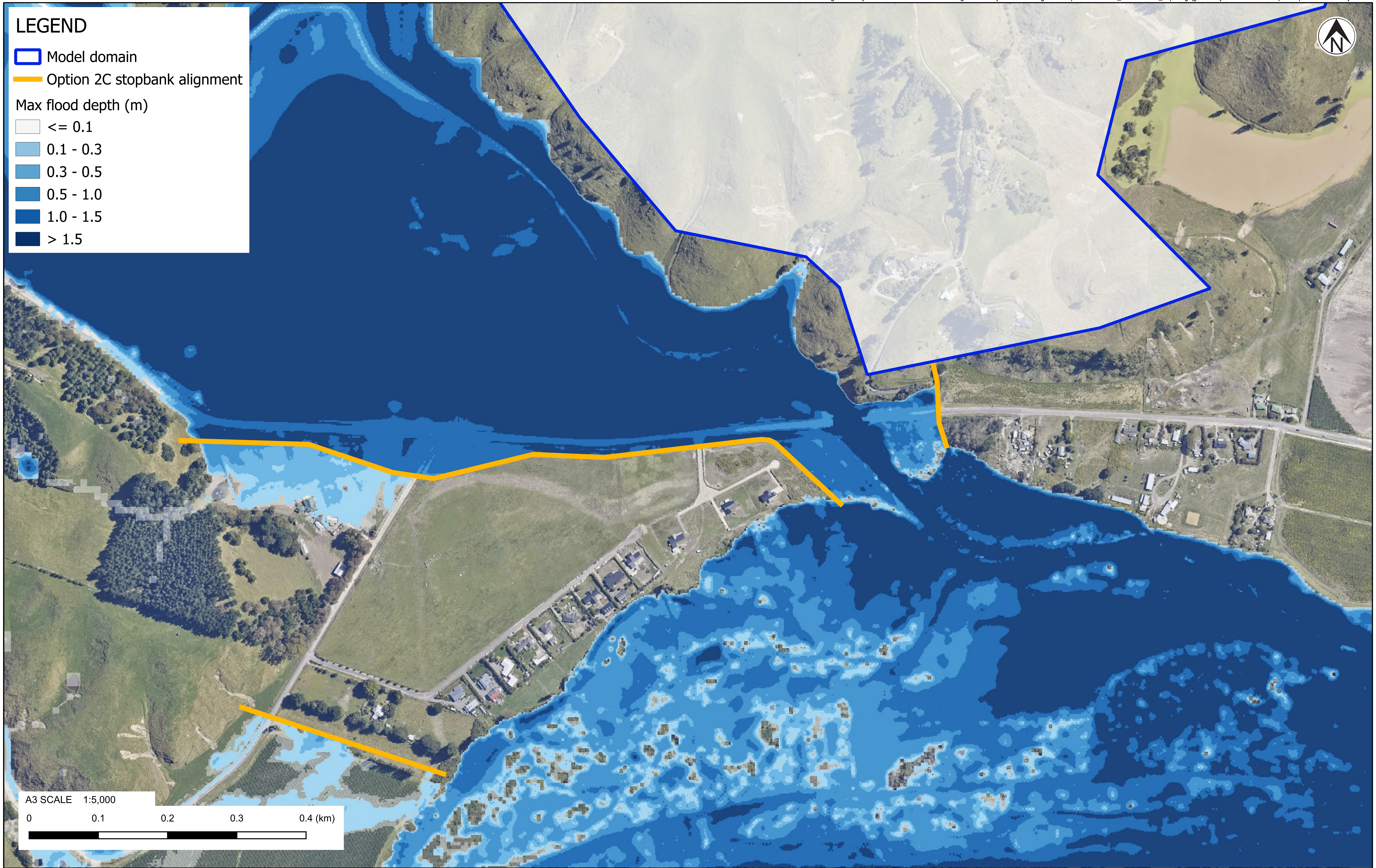
LOCATION PLAN



| PROJECT No. | 1017353.2402 | |
|---|---|---|
| DESIGNED | KTHA | JUL.24 |
| DRAWN | KTHA | JUL.24 |
| CHECKED | RIBR | JUL.24 |
| APPROVED | | DATE |

CLIENT HAWKES BAY REGIONAL COUNCIL
PROJECT OKAWA STREAM FLOOD MITIGATION
TITLE 100-YEAR RCP8.5 2075 FLOOD DEPTH OPTION 2B
SCALE (A3) 1:5,000 FIG No. D4 REV 2

COPYRIGHT ON THIS FIGURE IS RESERVED     DO NOT SCALE FROM THIS FIGURE     T:\Wellington\TT Projects\1017353\1017353.2402\WorkingMaterial\8 Hydraulic Modelling\QGIS\Maps\1017353.2402_OkawaStream_Reporting.qgz     Layout: T+T A3 Landscape Template     Drawn by KTHA

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NOTES:
Aerial imagery sourced from LINZ - Hawke's Bay 0.10m Cyclone Gabrielle Aerial Photos (2023).
This map should be read in conjunction with T+T report "Okawa Stream Hydraulic Model Build".

| REV | DESCRIPTION | GIS | CHK | DATE |
|---|---|---|---|---|
| 1 | First version | KTHA | | 09/07/24 |
| 2 | Climate change allowance updated | KTHA | | 25/07/24 |

LOCATION PLAN

| | | |
|---|---|---|
| PROJECT No. | 1017353.2402 | |
| DESIGNED | KTHA | JUL.24 |
| DRAWN | KTHA | JUL.24 |
| CHECKED | RIBR | JUL.24 |
| APPROVED | | DATE |

CLIENT **HAWKES BAY REGIONAL COUNCIL**
PROJECT **OKAWA STREAM FLOOD MITIGATION**
TITLE 100-YEAR RCP8.5 2075 FLOOD DEPTH OPTION 2C
SCALE (A3) 1:5,000     FIG No. D5     REV 2

COPYRIGHT ON THIS FIGURE IS RESERVED DO NOT SCALE FROM THIS FIGURE

T:\Wellington\TT Projects\1017353\1017353.2402\WorkingMaterial\8 Hydraulic Modelling\QGIS\Maps\1017353.2402_OkawaStream_Reporting.qgz Layout: T+T A3 Landscape Template Drawn by KTHA


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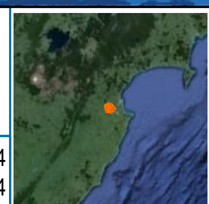
NOTES:
Aerial imagery sourced from LINZ - Hawke's Bay 0.10m Cyclone Gabrielle Aerial Photos (2023).
This map should be read in conjunction with T+T report "Okawa Stream Hydraulic Model Build".

| REV | DESCRIPTION | GIS | CHK | DATE |
|---|---|---|---|---|
| 1 | First version | KTHA | | 09/07/24 |
| 2 | Climate change allowance updated | KTHA | | 25/07/24 |



LOCATION PLAN

| | | |
|---|---|---|
| PROJECT No. | 1017353.2402 | |
| DESIGNED | KTHA | JUL.24 |
| DRAWN | KTHA | JUL.24 |
| CHECKED | RIBR | JUL.24 |
| APPROVED | | DATE |

CLIENT **HAWKES BAY REGIONAL COUNCIL**

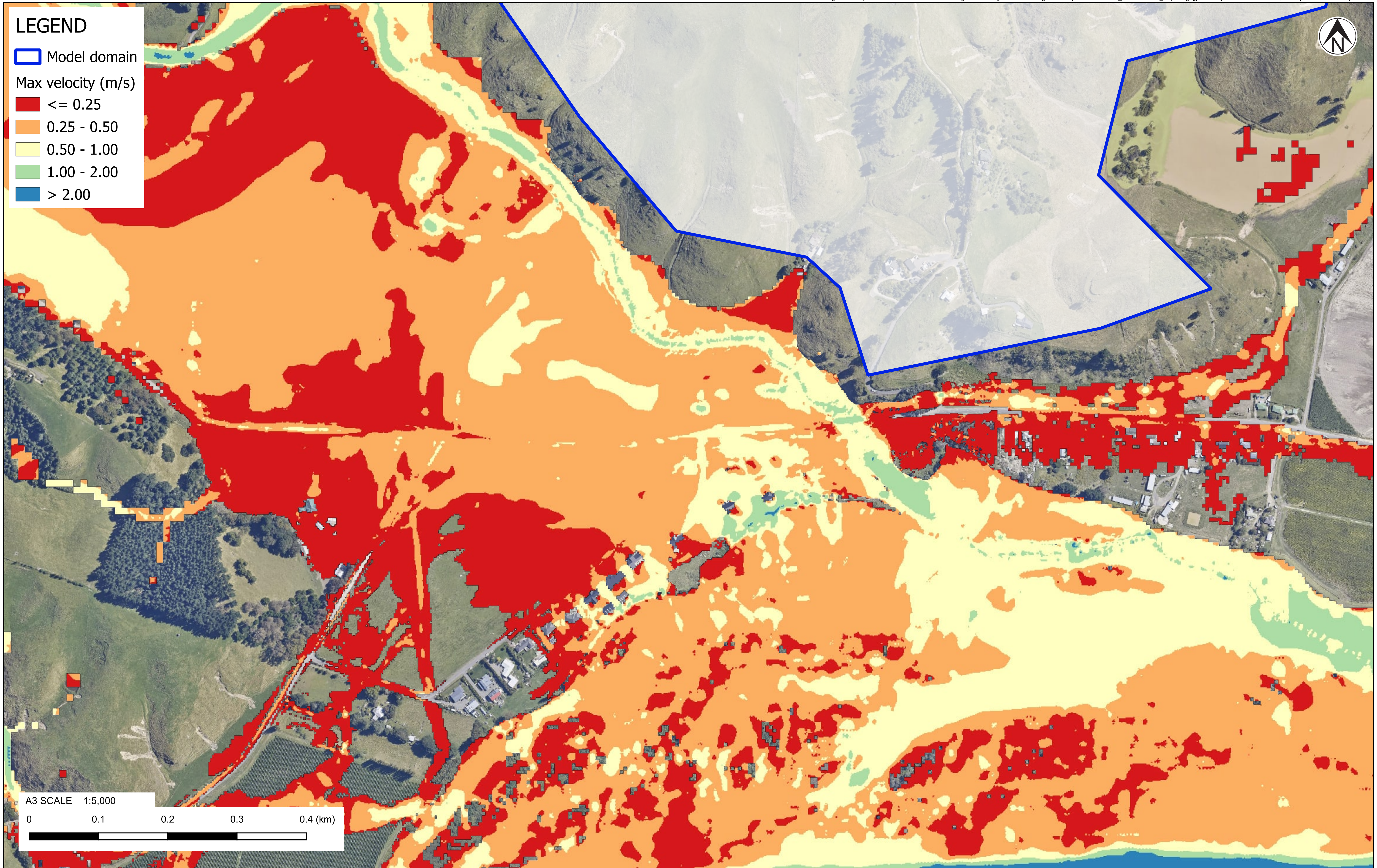
PROJECT **OKAWA STREAM FLOOD MITIGATION**

TITLE 100-YEAR RCP8.5 2075 FLOOD DEPTH OPTION 3

SCALE (A3) 1:5,000 FIG No. D6 REV 2

COPYRIGHT ON THIS FIGURE IS RESERVED    DO NOT SCALE FROM THIS FIGURE

T:\Wellington\TT Projects\1017353\1017353.2402\WorkingMaterial\8 Hydraulic Modelling\QGIS\Maps\1017353.2402_OkawaStream_Reporting.qgz    Layout: T+T A3 Landscape Template    Drawn by KTHA

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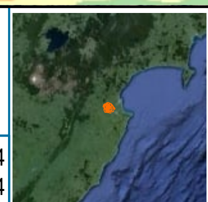
**NOTES:**
Aerial imagery sourced from LINZ - Hawke's Bay 0.10m Cyclone Gabrielle Aerial Photos (2023).
This map should be read in conjunction with T+T report "Okawa Stream Hydraulic Model Build".

| REV | DESCRIPTION | GIS | CHK | DATE |
|---|---|---|---|---|
| 1 | First version | KTHA | | 09/07/24 |
| 2 | Climate change allowance updated | KTHA | | 25/07/24 |



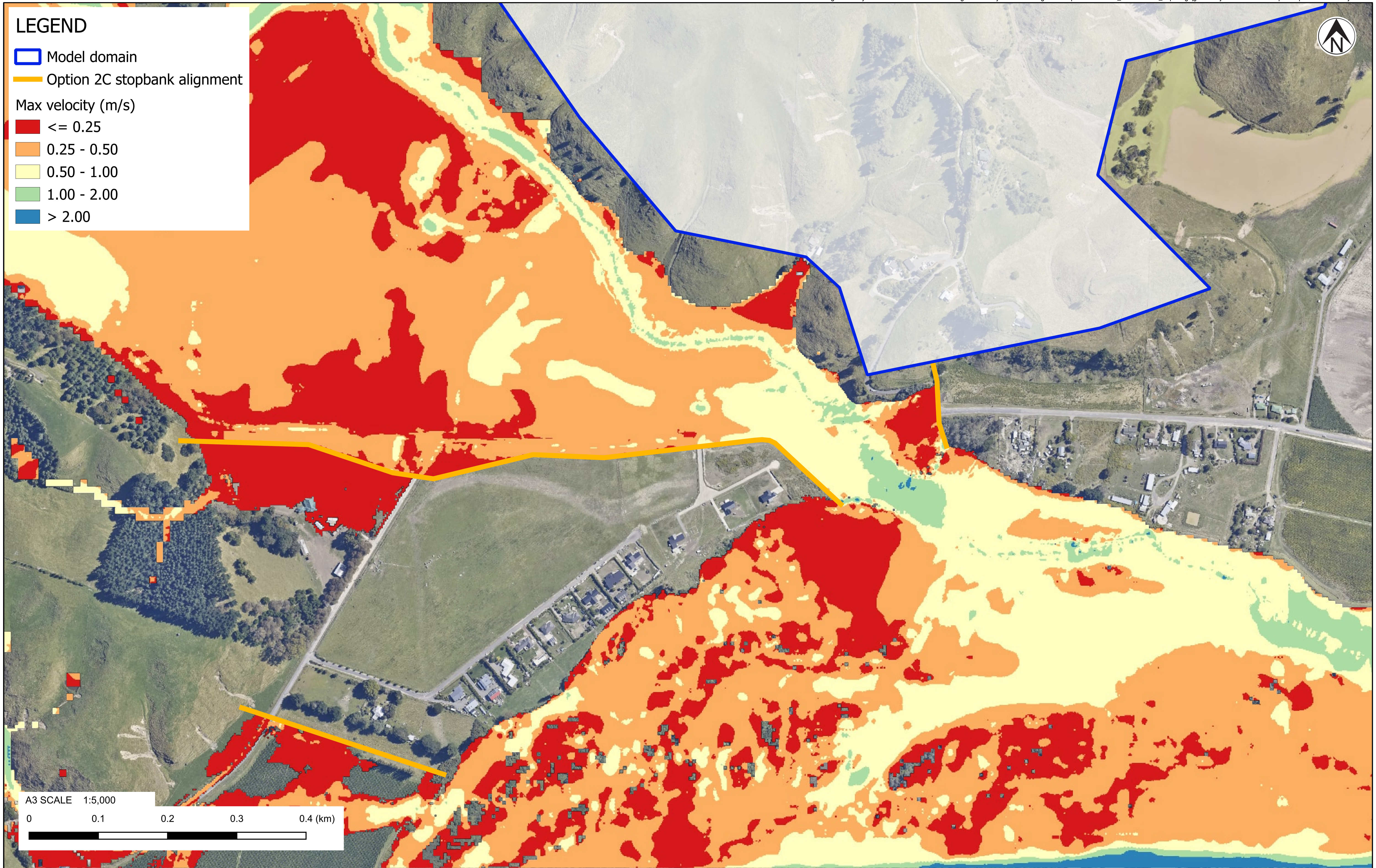
LOCATION PLAN

| | | |
|---|---|---|
| PROJECT No. | 1017353.2402 | |
| DESIGNED | KTHA | JUL.24 |
| DRAWN | KTHA | JUL.24 |
| CHECKED | RIBR | JUL.24 |
| APPROVED | | DATE |

CLIENT **HAWKES BAY REGIONAL COUNCIL**
PROJECT **OKAWA STREAM FLOOD MITIGATION**
TITLE 100-YEAR RCP8.5 2075 FLOOD VELOCITY BASE CASE

SCALE (A3) 1:5,000    FIG No. D7    REV 2

T:\Wellington\TT Projects\1017353\1017353.2402\WorkingMaterial\8 Hydraulic Modelling\QGIS\Maps\1017353.2402_OkawaStream_Reporting.qgz Layout: T+T A3 Landscape Template Drawn by KTHA

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NOTES:
Aerial imagery sourced from LINZ - Hawke's Bay 0.10m Cyclone Gabrielle Aerial Photos (2023).
This map should be read in conjunction with T+T report "Okawa Stream Hydraulic Model Build".

| REV | DESCRIPTION | GIS | CHK | DATE |
|---|---|---|---|---|
| 1 | First version | KTHA | | 09/07/24 |
| 2 | Climate change allowance updated | KTHA | | 25/07/24 |


LOCATION PLAN

| | | |
|---|---|---|
| PROJECT No. | 1017353.2402 | |
| DESIGNED | KTHA | JUL.24 |
| DRAWN | KTHA | JUL.24 |
| CHECKED | RIBR | JUL.24 |
| APPROVED | | DATE |

CLIENT HAWKES BAY REGIONAL COUNCIL
PROJECT OKAWA STREAM FLOOD MITIGATION
TITLE 100-YEAR RCP8.5 2075 FLOOD VELOCITY OPTION 2C

SCALE (A3) 1:5,000 FIG No. D8 REV 2

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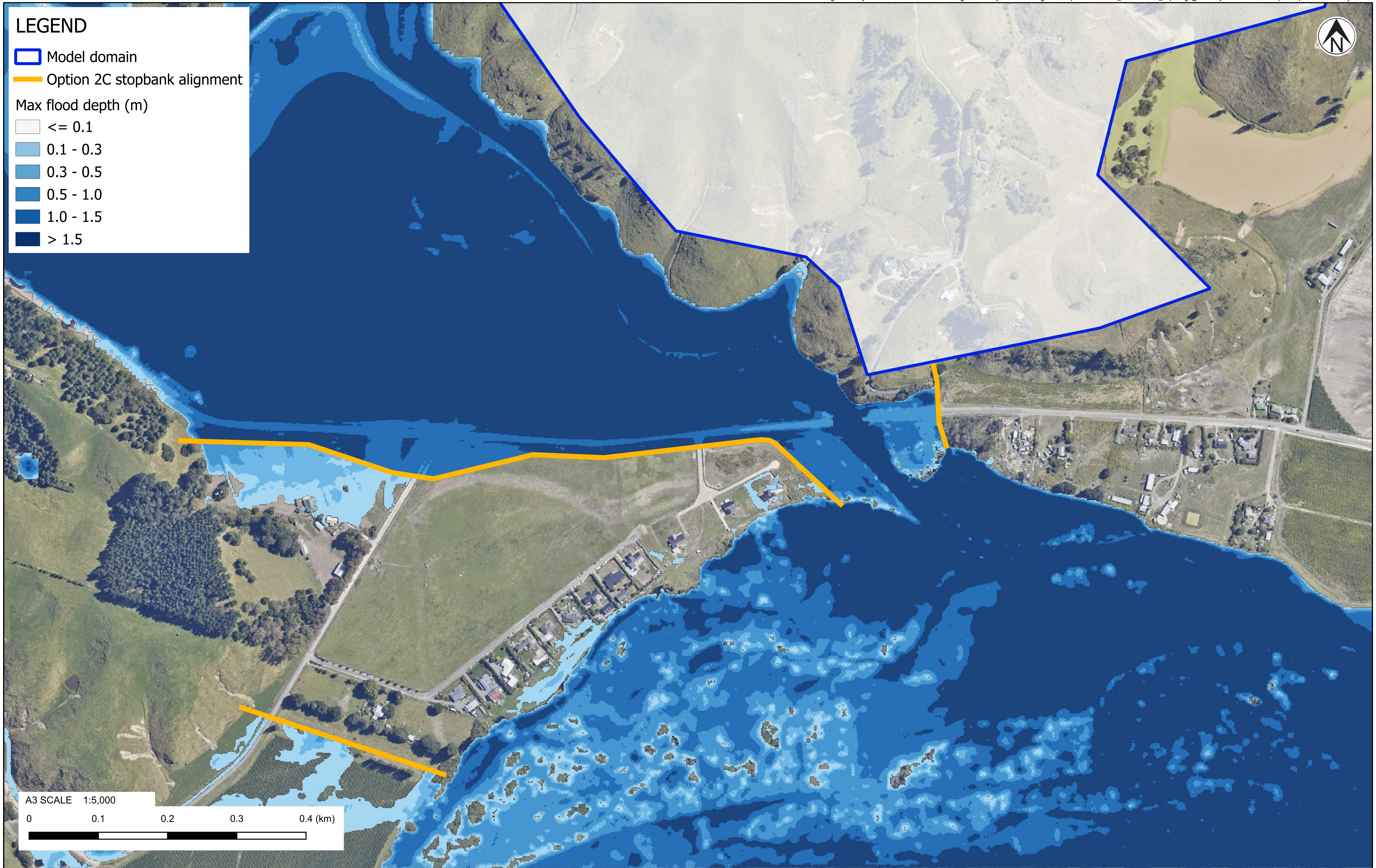
T:\Wellington\TT Projects\1017353\1017353.2402\WorkingMaterial\8 Hydraulic Modelling\QGIS\Maps\1017353.2402_OkawaStream_Reporting.qgz Layout: T+T A3 Landscape Template Drawn by KTHA

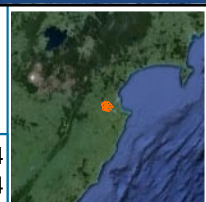



Tonkin+Taylor

*Exceptional thinking together* www.tonkintaylor.co.nz

**NOTES:**
Aerial imagery sourced from LINZ - Hawke's Bay 0.10m Cyclone Gabrielle Aerial Photos (2023).
This map should be read in conjunction with T+T report "Okawa Stream Hydraulic Model Build".

| REV | DESCRIPTION | GIS | CHK | DATE |
|---|---|---|---|---|
| 1 | First version | KTHA | | 09/07/24 |
| 2 | Climate change allowance updated | KTHA | | 25/07/24 |



LOCATION PLAN

| | | |
|---|---|---|
| PROJECT No. | 1017353.2402 | |
| DESIGNED | KTHA | JUL.24 |
| DRAWN | KTHA | JUL.24 |
| CHECKED | RIBR | JUL.24 |
| APPROVED | | DATE |

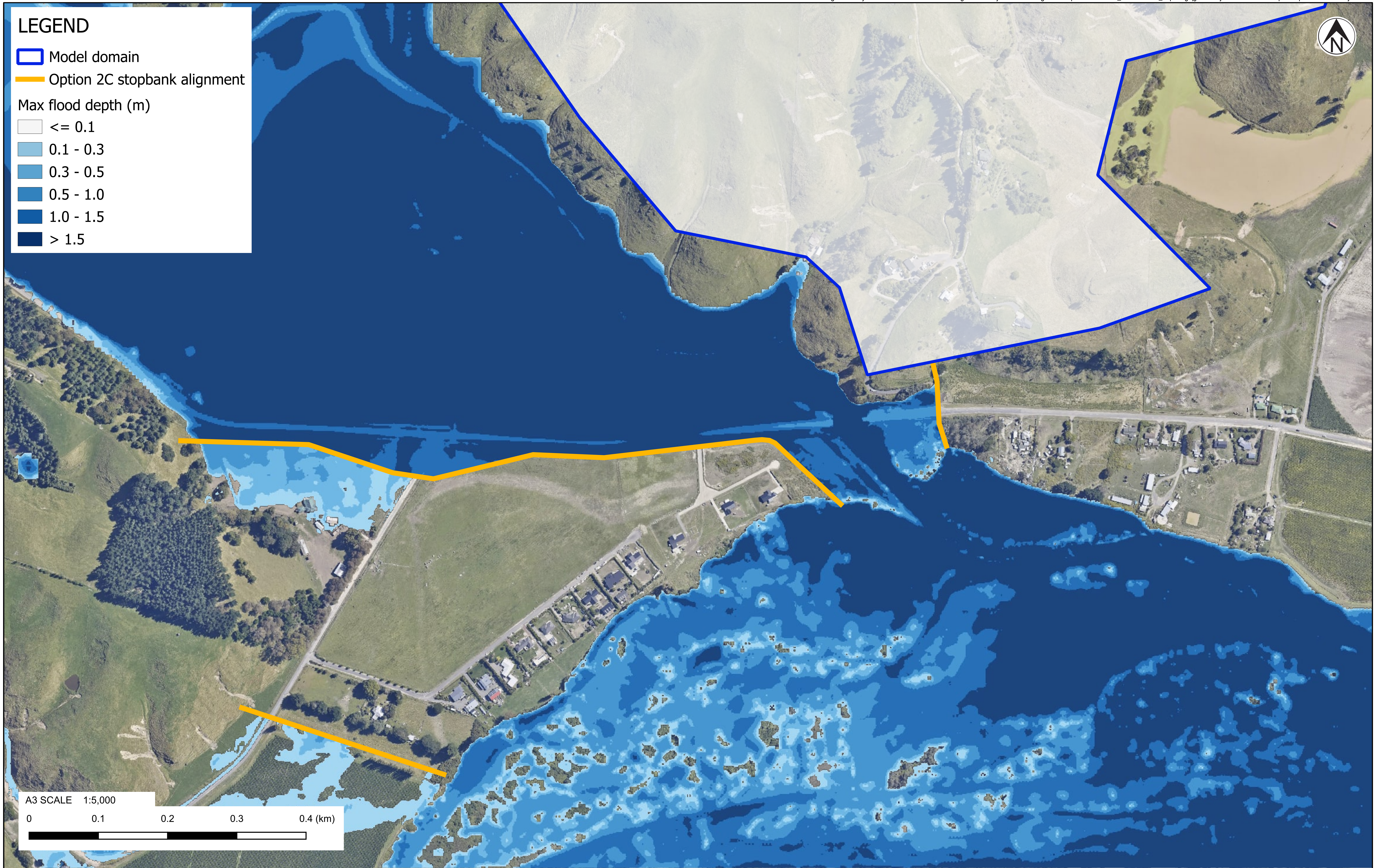
**CLIENT** HAWKES BAY REGIONAL COUNCIL

**PROJECT** OKAWA STREAM FLOOD MITIGATION

**TITLE** 100-YEAR RCP8.5 2075 FLOOD DEPTH
OPTION 2C, ROUGHNESS PLUS 20%

SCALE (A3) 1:5,000 FIG No. D9 REV 2

T:\Wellington\TT Projects\1017353\1017353.2402\WorkingMaterial\8 Hydraulic Modelling\QGIS\Maps\1017353.2402_OkawaStream_Reporting.qgz Layout: T+T A3 Landscape Template Drawn by KTHA

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**NOTES:**
Aerial imagery sourced from LINZ - Hawke's Bay 0.10m Cyclone Gabrielle Aerial Photos (2023).
This map should be read in conjunction with T+T report "Okawa Stream Hydraulic Model Build".

| REV | DESCRIPTION | GIS | CHK | DATE |
|---|---|---|---|---|
| 1 | First version | KTHA | | 09/07/24 |
| 2 | Climate change allowance updated | KTHA | | 25/07/24 |

LOCATION PLAN

PROJECT No. 1017353.2402

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| DESIGNED | KTHA | JUL.24 |
| DRAWN | KTHA | JUL.24 |
| CHECKED | RIBR | JUL.24 |

APPROVED DATE

CLIENT **HAWKES BAY REGIONAL COUNCIL**
PROJECT **OKAWA STREAM FLOOD MITIGATION**
TITLE 100-YEAR RCP8.5 2075 FLOOD DEPTH OPTION 2C, FLOWS PLUS 20%

SCALE (A3) 1:5,000 FIG No. D10 REV 2

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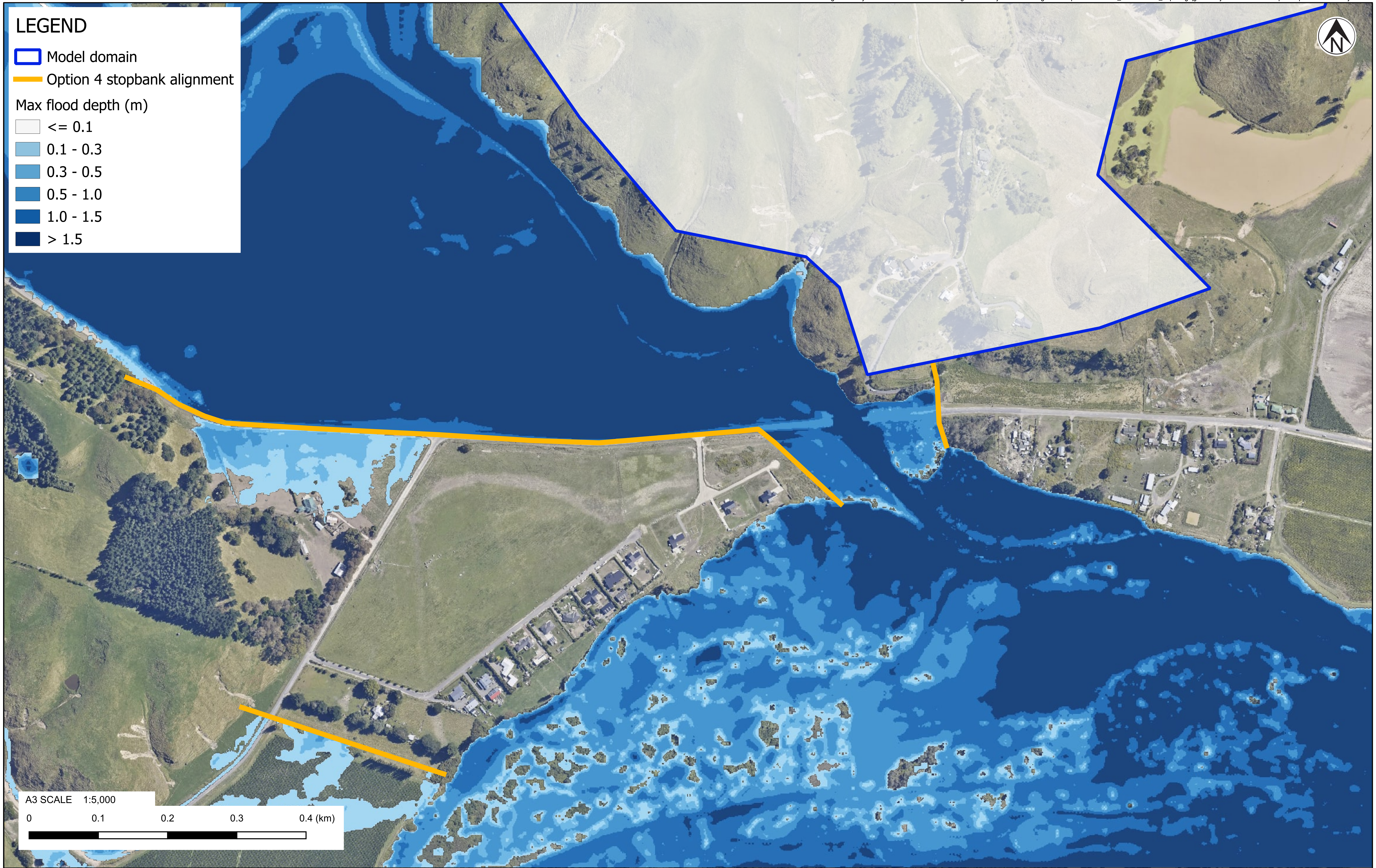


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NOTES:
Aerial imagery sourced from LINZ - Hawke's Bay 0.10m Cyclone Gabrielle Aerial Photos (2023).
This map should be read in conjunction with T+T report "Okawa Stream Hydraulic Model Build".

| REV | DESCRIPTION | GIS | CHK | DATE |
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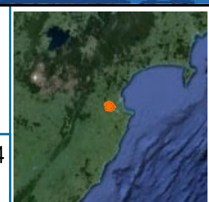

LOCATION PLAN

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| PROJECT No. | 1017353.2402 | |
| DESIGNED | KTHA | JUL.24 |
| DRAWN | KTHA | JUL.24 |
| CHECKED | RIBR | JUL.24 |
| APPROVED | | DATE |

CLIENT HAWKES BAY REGIONAL COUNCIL
PROJECT OKAWA STREAM FLOOD MITIGATION
TITLE 100-YEAR RCP8.5 2075 FLOOD DEPTH OPTION 4
SCALE (A3) 1:5,000 FIG No. D11 REV 1

# Appendix E Option 4 transport memo

Tonkin+Taylor

10 July 2024
Job No: 1017353.2402

HAWKES BAY REGIONAL COUNCIL
PRIVATE BAG 6006
NAPIER
Napier 4142

Attention: Mell Anderson

Dear Mell

**Ohiti Rd Flood Protection Scheme- Proposed Taihape Road Realignment and Stopbank**

**“Option 4” Geometrics**

## Introduction

Tonkin & Taylor Ltd (T+T) have been engaged by Hawkes Bay Regional Council (HBRC) to provide engineering and environmental services for a new flood scheme at Ohiti Rd, Omahu, Hastings. The flood scheme requires raising several local roads to provide protection for the local subdivision from flooding from the Okawa stream. Hastings District Council (HDC) manages these as the road controlling authority.

Following our recent meeting of Monday 1 July (HBRC/HDC/T+T), and as requested following that meeting, we have reviewed the feasibility of raising a section of Taihape Road to form part of the proposed flood protection scheme. This option is herein referred to as ‘Option 4’.

## ‘Option 4’ transport design summary

Taihape Road, Omahu, is a rural arterial road which carries approximately 2,700 vehicles per day including 18% heavy vehicles (source: mobileroad.org) and is a critical link between the Hawke’s Bay and the central North Island, as well as providing access from the surrounding rural areas to urban Hastings.

It is a two-lane crowned chip-sealed road with a marked centreline, edge lines and a 1m sealed shoulder either side with typical rural table drains either side. It has a current speed limit of 100km/h. The road alignment (driving towards Taihape) runs straight and level from the Okawa Stream Bridge for 350m where it bends gently to the right before continuing straight for 500m until past the intersection with Ohiti Road. Shortly beyond this point the road incorporates a sweeping right-left bend and rises gently.

The new raised stopbank alignment is proposed to begin at this western bend and extends the curve to the south, from where it runs roughly parallel with the existing Taihape Road alignment (at an RL of 31m, which is up to 2.4m above existing road level) at an offset of around 18m, until near the Okawa Stream Bridge, where it is proposed to curve back on to the existing alignment and drop down to the existing road level.



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At the eastern end of the stopbank, a perpendicular stopbank is proposed to branch off the main alignment and run parallel to the stream terminating at about 100m south of the bridge. This provides protection to the adjacent dwellings.

The realigned Taihape Road will run along the top of the proposed new stopbank and will comply with the HDC's standard rural road cross section, being 2 x3 .5m lanes with a 1m wide sealed shoulder either side. The side slopes of the stopbank will be at a maximum of 1:5 for traversability in case vehicles leave the road (note that these could be steepened to 1:3 but this would require continuous barriers either side).

*Figure 1 – Proposed Stopbank and raised road Alignment*

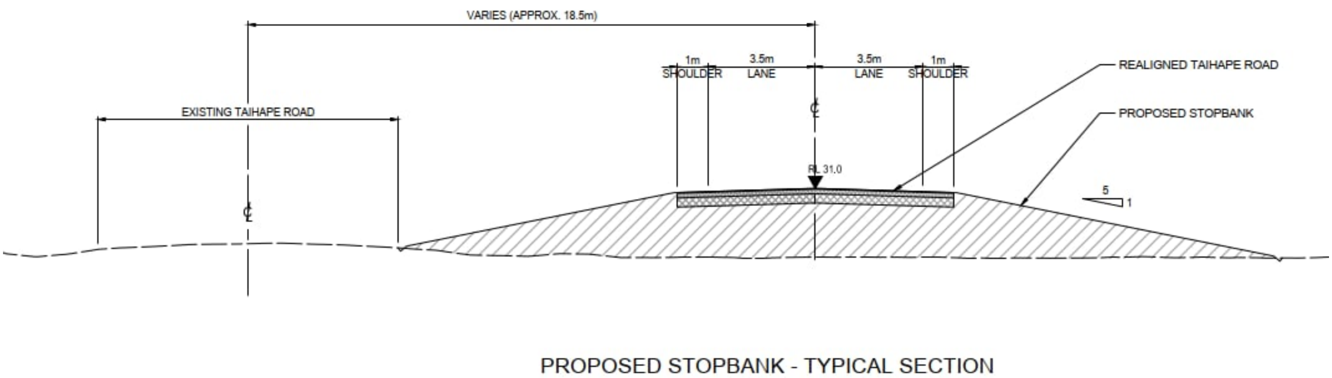


*Figure 2 – Typical Cross Section*

## Construction

Because of the importance of maintaining Taihape Road as an open connection, the offset alignment is a useful way of minimizing disruption during large portions of the new stopbank/road construction, as a large portion of the new works can be built offline. However, access will need to be maintained to Ohiti Road and the private driveway during construction, which will mean a workable construction staging plan will need to be developed. Details on a potential intersection with Ohiti Rd and the adjacent subdivision will be developed during the design stage. Tie in with the existing bridge approach will require working under traffic management.

The crest of the stopbank has been set at RL31m, which is 0.75m above the 1% AEP flood level. HBRC typically adopts freeboard levels between 0.7 and 1m. Final crest levels will be confirmed during the design stage. The volume of fill material required to form the new embankment is in the order of 53,000 $m^3$. We understand that a local borrow pit on private property could be used for construction material. Alternative options are avaliable to source from the local landfill, which has excess cut to waste from the new cell. The road formation works form part of the stopbank freeboard allowance.

## Road Safety

The realigned road will be designed in accordance with Austroads AGRD03-16 Guide to Geometric Road Design. It is proposed that the new curves will be superelevated in accordance with the design speed of 100km/h. Details will be confirmed during design. The maximum vertical offset at the transition is 1.8m and with the gradient at around 1.5% this gives a stopping sight distance of >180m for a car, which exceeds the minimum stipulated in Austroads using a reaction time ($R_T$) of 2 seconds.

The crest and sag curves will have a minimum k value of 40 in order to maintain comfort for vehicle users.

## Conclusions

Based on a high level review, development of a raised Taihape Road as part of the proposed flood scheme is feasible. Further design work is required to confirm details, including intersection and local access requirements.

## Applicability

This report has been prepared for the exclusive use of our client Hawkes Bay Regional Council, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

Yours Sincerely

Tim Morris

Project Director

Prepared by: Andrew Carline, Senior Civil Engineer (Transport)

30-Jul-24
t:\wellington\tt projects\1017353\1017353.2402\workingmaterial\6 transport\taihape road realignment and stopbank.docx

**Attachments:**

- **Road layout plan**
- **Long section**
- **Typical Cross section**

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PROJECT PHASE: PRELIMINARY DRAFT

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CLIENT: HAWKES BAY REGIONAL COUNCIL

PROJECT: OHITI ROAD FLOOD PROTECTION SCHEME

TITLE: TAIHAPE ROAD - PROPOSED ALIGNMENT PLAN VIEW

DRAFT

SCALE (A1) 1:2000    DWG No. 1017353.2402-100    REV 1

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| CHAINAGE | EXISTING LEVEL | PROPOSED LEVEL | CUT/FILL |
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| 50.00 | 31.17 | | |
| 100.00 | 30.83 | 31.00 | 0.17 |
| 150.00 | 30.39 | 31.00 | 0.61 |
| 200.00 | 30.16 | 31.00 | 0.84 |
| 250.00 | 29.93 | 31.00 | 1.07 |
| 300.00 | 30.01 | 31.00 | 0.99 |
| 350.00 | 29.70 | 31.00 | 1.30 |
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| 500.00 | 28.53 | 31.00 | 2.47 |
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| 600.00 | 28.66 | 31.00 | 2.34 |
| 650.00 | 28.66 | 31.00 | 2.34 |
| 700.00 | 28.65 | 31.00 | 2.35 |
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| 800.00 | 28.80 | 31.00 | 2.20 |
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| 1150.00 | 28.89 | 30.85 | 1.97 |
| 1200.00 | 29.15 | 30.29 | 1.14 |
| 1250.00 | 29.22 | 29.61 | 0.39 |
| 1300.00 | 29.31 | 29.32 | 0.00 |
| 1350.00 | 24.84 | 29.31 | 4.47 |
| 1400.00 | 29.26 | 29.32 | 0.05 |
| 1450.00 | 29.37 | 29.32 | -0.05 |
| 1500.00 | 29.18 | 29.16 | -0.03 |

## TAIHAPE ROAD - PROPOSED ALIGNMENT

SCALE 1:2000 (H) 1:200 (V)

0 50 100 m
1:2000 (A1)
1:4000 (A3)

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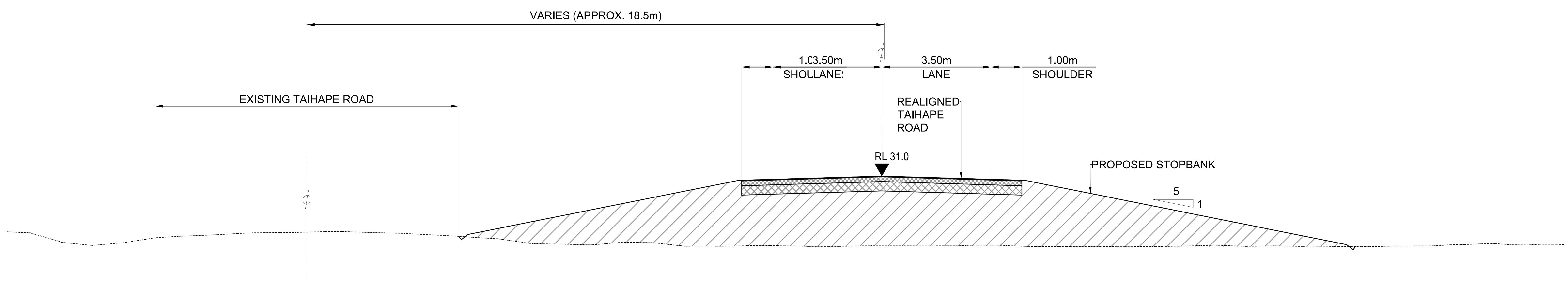
PROJECT PHASE: PRELIMINARY DRAFT

CLIENT: **HAWKES BAY REGIONAL COUNCIL**
PROJECT: **OHITI ROAD FLOOD PROTECTION SCHEME**
TITLE: TAIHAPE ROAD LONG SECTION

DRAFT

SCALE (A1) 1:2000    DWG No. 1017353.2402-200    REV 1

\\ttgroup.local\corporate\Wellington\TT Projects\1017353\1017353.2402\WorkingMaterial\6 Transport\1017353.2402-500-TYPICAL SECTION.dwg 2024-Jul-10 5:00:50 pm Plotted By: ANCA




**PROPOSED STOPBANK - TYPICAL SECTION**

SCALE 1:100

0 2.5 5 m
1:100 (A1)
1:200 (A3)

| REV | DESCRIPTION | CAD | CHK | DATE | APPROVED | DATE |
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PROJECT: OHITI ROAD FLOOD PROTECTION SCHEME

TITLE: PROPOSED STOPBANK TYPICAL SECTION

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