Sensitivity: General

REPORT

Blue Green Networks - Harania (Tennessee Bridge)

Flood hazard and risk assessment

Prepared for
Auckland Council
Prepared by
Tonkin & Taylor Ltd
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1 Introduction

1.1 Background

The January 2023 floods, followed closely by Cyclone Gabrielle, marked a period of unprecedented weather challenges for Auckland. Auckland Council is carrying out flood resilience projects with the aim of mitigating flood risk to property through a series of blue-green networks, addressing critical flood-prone areas with sustainable stormwater solutions. The Harania catchment was one of the worst affect areas of Auckland following the January 2023 floods. Healthy Waters identified significant flooding, causing risk to life, and widespread flood damage to homes. This occurred due to poor flood conveyance at the location of the current Tennessee Avenue embankment dam.

1.2 Project Description

The Tennessee Bridge project (the Project) involves removing the current embankment which carries the existing Eastern Interceptor (EI), an approximately 2.6 m diameter reinforced concrete trunk sewer. The replacement will comprise a new pipe and pipe bridge in the coastal marine area (CMA) to open up the waterway capacity to allow increased flood conveyance. Diversion chambers are required at either end of the new pipe, connecting it to the existing pipe to facilitate the change over from the old pipe to the new pipe bridge diversion.

A detailed description of the full project works can be found in the Assessment of Effects on the Environment (AEE) report[1].

1.3 Scope of Works

Tonkin & Taylor Ltd (T+T) has been engaged by Auckland Council's Healthy Waters to undertake a flood hazard risk assessment study related to the Project and this has been prepared to accompany a resource consent application for the Tennessee Bridge project under the Severe Weather Emergency Recovery (Auckland Flood Resilience Works) Order 2024.

The purpose of this report is to present flood hazard information and a hazard risk assessment the Project to support the resource consent application. This assessment has been prepared to assess the specific matters of control set out in the Severe Weather Emergency Recovery (Auckland Flood Resilience Works) Order 2024, being:

> *(a) The risks from natural hazards to people, property, infrastructure, and the environment, and measures to avoid or mitigate those risks.*
>
> *(b) The risk of flood resilience works increasing risks from existing natural hazards or creating new natural hazards, and measures to avoid or mitigate that risk.*

Responses to the matters of control are covered in Section 3.

[1] *Harania Flood Resilience Works – Tennessee Bridge Assessment of Effects on the Environment*, Beca Limited, November 2024.

2 Flood assessment

This section presents the changes in flood hazard and flood risk as a result of the Project. Information in this section is used to inform the natural hazard risk assessment (Section 3).

The flood hazard and risk assessment has been carried out using a design storm approach in accordance with Auckland Regional guidance (TP108). This is a common approach for carrying out flood hazard and flood risk assessments, although importantly, it does not relate to actual flood events (e.g. January 2023 floods in Auckland). Therefore, there are different (but similar) numbers of reported homes that experienced significant flooding, risk to life and flood damage in the Project Description in the AEE, compared to those reported in this report.

2.1 Overview and scenarios

A flood hazard assessment for the project area was carried out using an updated hydraulic model. The updated model supersedes Auckland Council's previous model and a model of the area that is being developed by LEAD Alliance for Kainga Ora. Appendix B provides a summary of the model updates and additional model details.

The flood model was used to compare flood extents, levels and depths for the current landform (i.e. with Tennessee culvert and embankment in its current form) and with the proposed Tennessee Bridge (i.e. culvert and embankment removed). These are referred to as pre-development and post-development respectively. Model results were also used to provide the design teams and other specialist reports with further information (e.g. velocity, shear stress etc).

The modelled pipe bridge is based on ACH drawing S110 and reproduced in Figure 2.1[2]. The reader is referred to the full drawing set for further information.

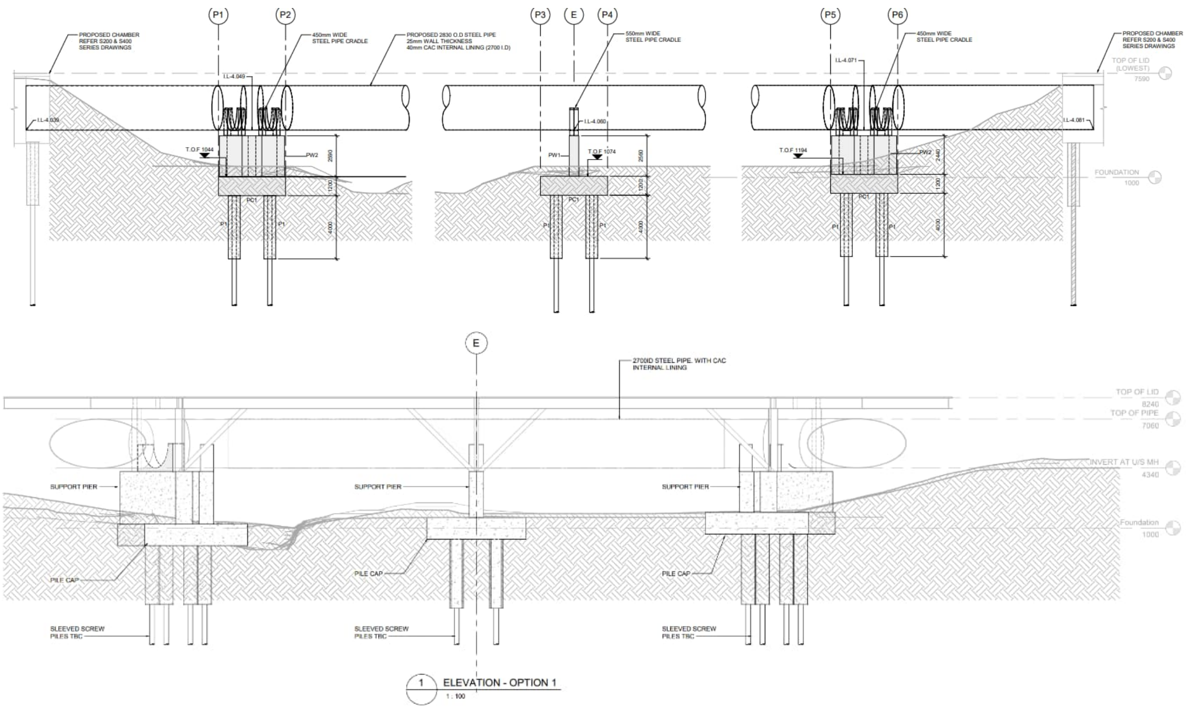


Figure 2.1 Pipe bridge cross section (extracted from ACH drawing S110, Project NO. 240345, Revision A)

[2] Refer ACH drawing set - drawing S110, Project NO. 240345

The invert level of the pipe bridge varies between RL 4.04 m and RL 4.06 m (NZVD2016) which equates to RL 4.32- 4.34 m (AVD-46)[3].

All model runs assumed maximum probable development (MPD) land use. Figure 2.2 presents 6 scenarios referred to in this assessment of effects; which include two sensitivity scenarios for the upstream assessment. Scenarios 1-4 adopt rainfall depths that are broadly representative of 24-hour 1% AEP rainfall depths, suitable for the effects assessment. A description of the adopted rainfall depths and tailwater levels for the scenarios are presented in Table 2.1.

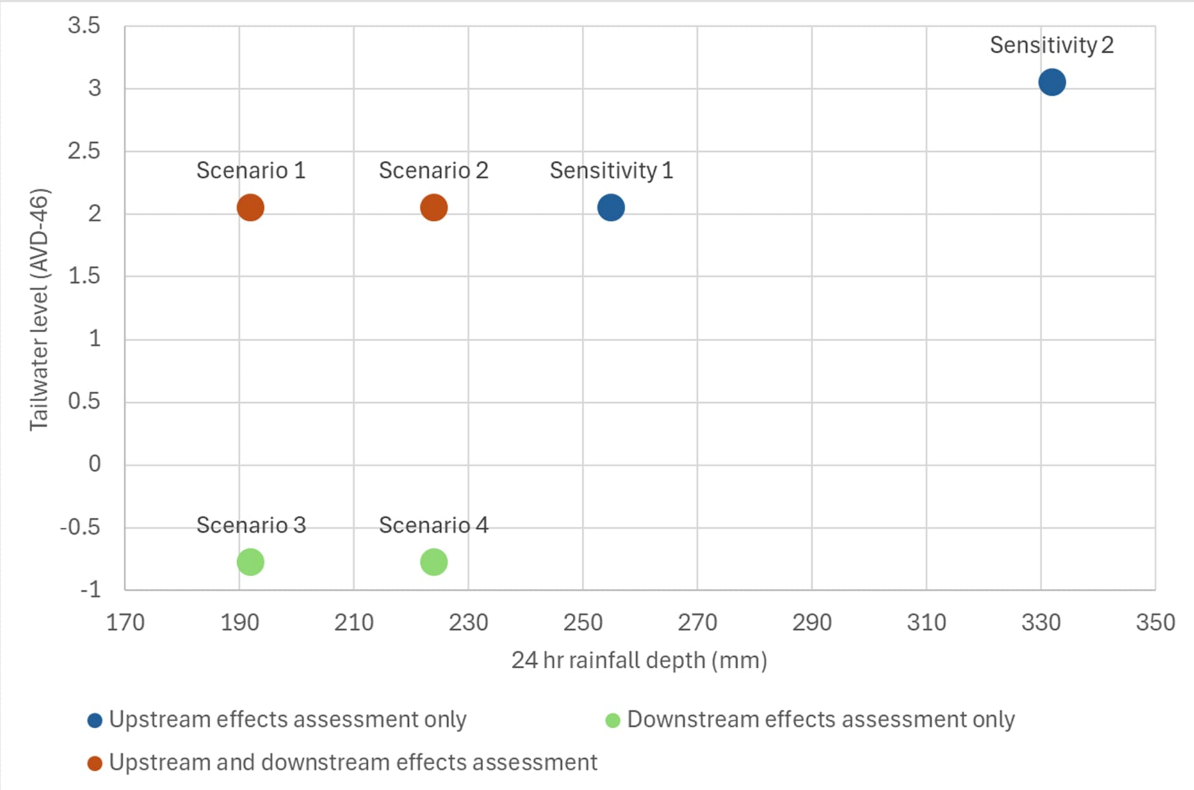


Figure 2.2 Flood hazard scenarios

[3] Levels are provided in both datums here because the design uses NZVD2016 and the model uses Auckland Vertical Datum 1946.

Table 2.1: Flood hazard assessment – rainfall depths and tailwater levels

24 hr Rainfall depth (mm)	Rainfall explanation	Tailwater level (RL AVD-46)	Tailwater explanation
192	"Existing" Rainfall depth adopted by the Mangere Inlet FHM. 1% AEP design rainfall depth prior to January 2023 event.	-0.78	Low tailwater condition used to assess flood hazard when coastal water level has less influence on water level (e.g. low tide).[4].
224	17% increase on "Existing" rainfall. (Represented the 2.1 degrees climate change scenario in the Mangere Inlet FHM)	2.05	Mean High Water Springs – 10 i.e. the level equalled or exceeded by the largest 10% of all high tides. Referred to as MHWS in this report.
255	33% increase on "Existing" rainfall. A 250 mm rainfall (i.e. very similar) has also been used by Auckland Council to support categorisation decision-making[5]	3.05	MHWS + 1 m
332	Used for sensitivity assessment. It is based on 33% increase on 250 mm (refer cell above). It has also been used to support resilience based design decisions for the pipe bridge, and to support categorisation decisions upstream of Tennessee Culvert (outside of scope for this assessment).		

2.2 Flood hazard and flood risk results

The flood hazard and flood risk results are presented in the following two sections, and they relate to locations upstream and downstream of Tennessee Bridge respectively.

2.2.1 Upstream flood hazard and risk

This sub-section presented the flood hazard and risk upstream from the Tennessee Bridge. It comprises the area where the most significant number of affected buildings and risk to life was identified from the January 2023 flood event.

The changes in the upstream flood plain (showing depth) are presented in Appendix A for Scenarios 1 and 2 and the two sensitivity assessments. Scenarios 3 and 4 are not presented in relation to the upstream flood hazard and risk because the lower tailwater level does not affect the upstream floodplain.

The results of the upstream flood hazard analysis are presented in the following subsections.

[4] -0.78 is the existing mean low water spring level, although the results can also be used for future scenarios despite sea level rise. The results would be the same in our areas of interest if the tailwater level was 0.22 m (i.e. -0.78 m + 1 m sea level rise).
[5] Auckland Council analysis and reporting for the 250 mm rainfall is unavailable.

2.2.1.1 Scenario 1

Figure 2.3 identifies the flooded properties for Scenario 1 (and Scenario 2). Figure Appendix A.1 in Appendix A shows the floodplains without the properties.

Analysis of the modelled results show:

- There are no increases in flood levels on properties upstream of the Tennessee Bridge as a result of the project.
- There are currently (i.e. pre-development) 50 flood affected properties for Scenario 1
- As a result of the proposed project, flooding will be removed from 40 properties.
- 10 properties remain flood affected (refer 2.2.1.5 for further information and discussion)

2.2.1.2 Scenario 2

Figure 2.3 identifies the flooded properties for Scenario 2. Scenario 2 properties include all of the properties which flood in Scenario 1. Figure Appendix A.1 in Appendix A shows the floodplains without the properties.

Analysis of the modelled results show:

- There are no increases in flood levels on properties upstream of the Tennessee Bridge as a result of the project.
- There are currently (i.e. pre-development) 55 flood affected properties for Scenario 2
- As a result of the proposed project, flooding will be removed from 45 properties.
- 10 properties remain flood affected (refer 2.2.1.5 for further information and discussion)

2.2.1.3 Sensitivity scenario 1

Figure 2.4 identifies the flooded properties for Sensitivity scenario 1. The properties flooded in sensitivity scenario 1 include all the properties flooded in Scenario 1 and 2. Figure Appendix A.2 presents the changes in floodplain for the sensitivity scenario

- There are no increases in flood levels on properties upstream of the Tennessee Bridge as a result of the project.
- There are currently 81 flood affected properties for Sensitivity Scenario 1.
- As a result of the proposed project, flooding will be removed from 71 properties.
- 10 properties remain flood affected (refer 2.2.1.5 for further information and discussion)

2.2.1.4 Sensitivity scenario 2

Figure 2.4 identifies the flooded properties for Sensitivity scenario 2. The properties flooded in sensitivity scenario 2 include all the properties flooded in the other scenarios. Figure Appendix A.2 presents the changes in floodplain for the sensitivity scenario

- There are no increases in flood levels on properties upstream of the Tennessee Bridge as a result of the project.
- There are currently 106 flood affected properties for Sensitivity Scenario 2.
- As a result of the proposed project, flooding will be removed from 93-96 properties. There is a range of 93-96 because there are 4 locations which show flooding on the property and there may be flooding of the residential building (flood depth less than 200 mm for all buildings), which requires further validation. The flood levels reduce for all four of these properties.

- 10 -14 properties remain flood affected (refer 2.2.1.5 for further information and discussion on the 10 properties). The additional 4 properties (of the 14) may flood in this scenario (refer post-development component of Figure 2.4).
- The peak water level at the Tennessee Bridge under the sensitivity scenario is ~RL3.9 m (AVD-46)[6], which is ~400 mm below the underside of the proposed pipe bridge.

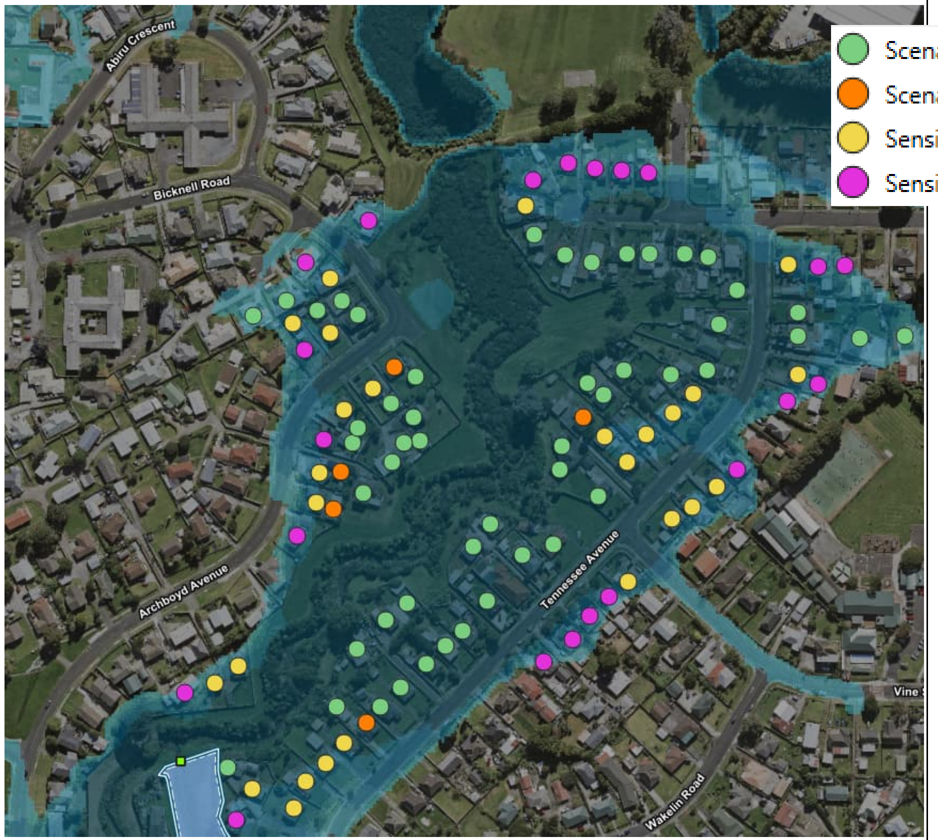
2.2.1.5 10 flood affected properties (post-development)

There are 10 properties that are likely to continue to be flood affected after the Tennessee Bridge is constructed. They are the same 10 properties in each of the scenarios (including sensitivity scenarios). Flooding is reduced at six of the properties for each scenario as a result of the project and there are four properties where flood levels are similar. This is due to their position on overland flowpaths draining to the main watercourse; their location is shown in the post-development part of Figure 2.3. The remaining four properties have insignificant reductions in flood level (~0.05 m).

[6] 3.616 m - NZVD2016

Pre-development	Post-development
	

Figure 2.3 Flooded properties pre-development and post-development (Scenarios 2 floodplain shown)

Pre-development 106 properties flooded	Post-development 10 properties flooded, four (pink) potentially flooded
	

Note that floodplains for both scenarios are included in the background

Figure 2.4 Flooded properties pre-development and post-development (Sensitivity scenario 2 in background)

2.2.2 Downstream flood hazard and risk

This sub-section presented the flood hazard and risk downstream from the Tennessee Bridge, including the estuarine embayment and outlet underneath Favona Road.

For reporting reasons, the downstream flood effects have been reported for two areas, as shown in Figure 2.5:

- The "channelised" area from Tennessee Bridge to the estuarine embayment
- The "Estuarine embayment."

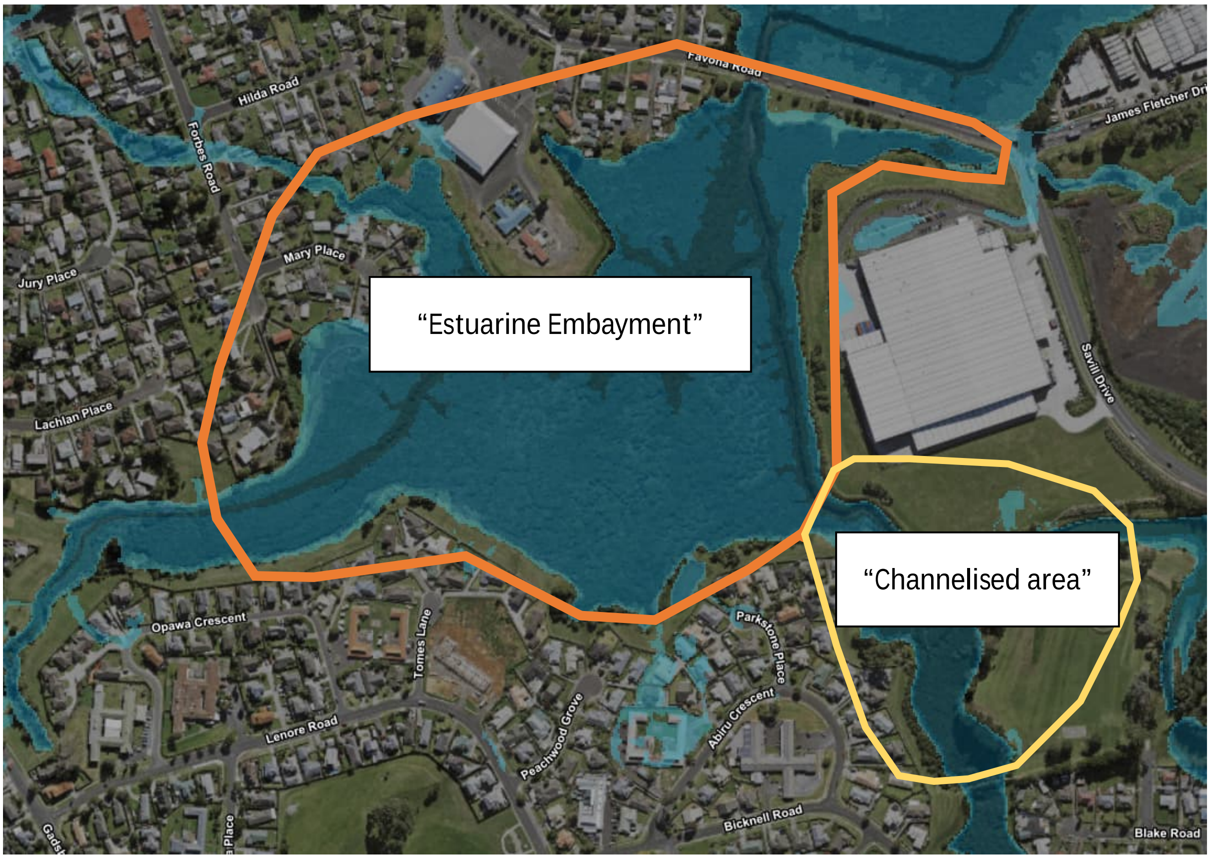


Figure 2.5 Reporting areas for downstream of Tennessee Bridge

Due to the coastal influence on water levels downstream of Tennessee Bridge, results are presented and discussed together for Scenario 1 and 3, and then for Scenario 2 and 4. This is to help determine whether the effects of the project are sensitive to tidal state[7].

The results of the downstream flood hazard analysis are presented in the following subsections.

2.2.2.1 Scenarios 1 & 3

Figure Appendix A.3 and Figure Appendix A.5 (Appendix A) shows a comparison of the "Channelised area" and "Estuarine Area" respectively. Each figure shows the pre-development floodplain, the post-development floodplain and a water level difference comparison for Scenarios 1 and 3.

Analysis of the modelled results show:

[7] Scenarios 1 and 2 assume high tide, Scenario 2 and 4 assume low tide

- The removal of the Tennessee embankment increases downstream water levels in the "Channelised area" by 300-350 mm[8] in the area immediately downstream of the existing culvert, reducing as distance from the existing dam embankment increases. At the discharge point to the embayment, the water level increases are the same as the resulting water level increases in the wider embayment area (refer later discussion).
- The increases in flood level do no not encroach on the private property within the "Channelised area" under these scenarios. The flood level increases occur within Lenore Foreshore Reserve and due to the relatively steep topography, the increased flood levels generally do not result in increases to the floodplain extents. However, there are notable increases in the floodplain within the reserve area adjacent to 24 Parkstone Place. Refer Section ▯ for further discussion on flooding within Lenore Foreshore Reserve.
- Water level increases across the "Estuarine embayment" are uniform and increase by approximately 170 mm to 210 mm for the two scenarios[9] as a result of the increased flows and volume passing downstream caused by removing the culvert and dam embankment.
- There are extensive reserve areas around the estuarine embayment and generally the increases in flood level are located within the reserve areas. However existing flooding on a number of properties on Mary Place is increased as a result of the project, particularly for high tide scenarios. The flooding at Mary Place, which is located on the western side of the embayment is discussed separately in Section 0.

2.2.2.2 Scenarios 2 & 4

Figure Appendix A.4 and Figure Appendix A.6 (Appendix A) shows a comparison of the "Channelised area" and "Estuarine Area" respectively. Each figure shows the pre-development floodplain, the post-development floodplain and a water level difference comparison for Scenarios 2 and 4.

Analysis of the modelled results show:

- The removal of the Tennessee embankment increases downstream water levels in the "Channelised area" by 370-400 mm[10] in the area immediately downstream of the existing culvert, reducing as distance from the existing dam embankment increases. At the discharge point to the embayment, the water level increases are the same as the wider embayment area (refer later discussion).
- Flood level increases occur within Lenore Foreshore Reserve and due to the relatively steep topography, the increased flood levels generally do not result in increases to the floodplain extents. However, there are notable increases in the floodplain within the reserve area adjacent to 24 Parkstone Place. At this location, the floodplain increase extends to the property boundary and may cross the private property boundary into their garden by 1-2 m in both scenario 2 and 4[11] (model resolution and accuracy is uncertain at this scale). The floodplain at 24 Parkstone Place can be seen in Figure 2.6.
- Water level increases across the "Estuarine embayment" are uniform and increase by approximately 220 mm to 270 mm for the two scenarios[12] as a result of the increased flows and volume passing downstream caused by removing the culvert and dam embankment.
- There are extensive reserve areas around the estuarine embayment and generally the increases in flood level are located within the reserve areas. However, existing flooding on a number of properties on Mary Place is increased as a result of the project, particularly for high

[8] 350 mm in Scenario 3, 300 mm in Scenario 1.
[9] 170 mm increase in Scenario 1 and 210 mm increase in Scenario 3
[10] 370 mm in Scenario 2, 400 mm in Scenario 4.
[11] The flood level is approximately 0.06 m lower in Scenario 2
[12] 220 mm increase in Scenario 2 and 270 mm increase in Scenario 4

tide scenarios. The flooding at Mary Place, which is located on the western side of the embayment is discussed separately in Section 0.

2.2.2.3 Flood risk at Lenore Foreshore Reserve

The floodplain changes in Lenore Foreshore Reserve as a result of the project can be seen in Figure Appendix A.3 to Figure Appendix A.6 in Appendix A for the four scenarios assessed. The floodplain in this area is not significantly influenced by tidal state (~0.06 m) for the scenarios considered.

As noted in the previous section, the flood level increases do not generally cause an increase in the floodplain extents due to the topography; however, at the eastern end of Parkstone Place, there is a localised area (<800 m^2) where the floodplain extents noticeably increase. The floodplain increase is largely on reserve land; although for the two scenarios assessed with higher rainfall (Scenario 2 and 4), the floodplain encroaches onto private property (24 Parkstone Place) that did not previously experience flooding.

The floodplain at 24 Parkstone Place can be seen in Figure 2.6.

The flood model predicts approximately 10 m^2 of flooding along the south-east facing boundary. The flooding does not impact the residential dwelling or access to and from the house. An outbuilding (~20 m^2) located at the eastern side of the property is partially located on the floodplain (by approximately 3 m^2) and the flood effect is therefore considered low. It is also highly likely that the building does not flood although this would require floor level survey to confirm. The impact of flooding on the property to the extents shown by the Scenario 2 and Scenario 4 floodplain are low and therefore the risk is also considered low.

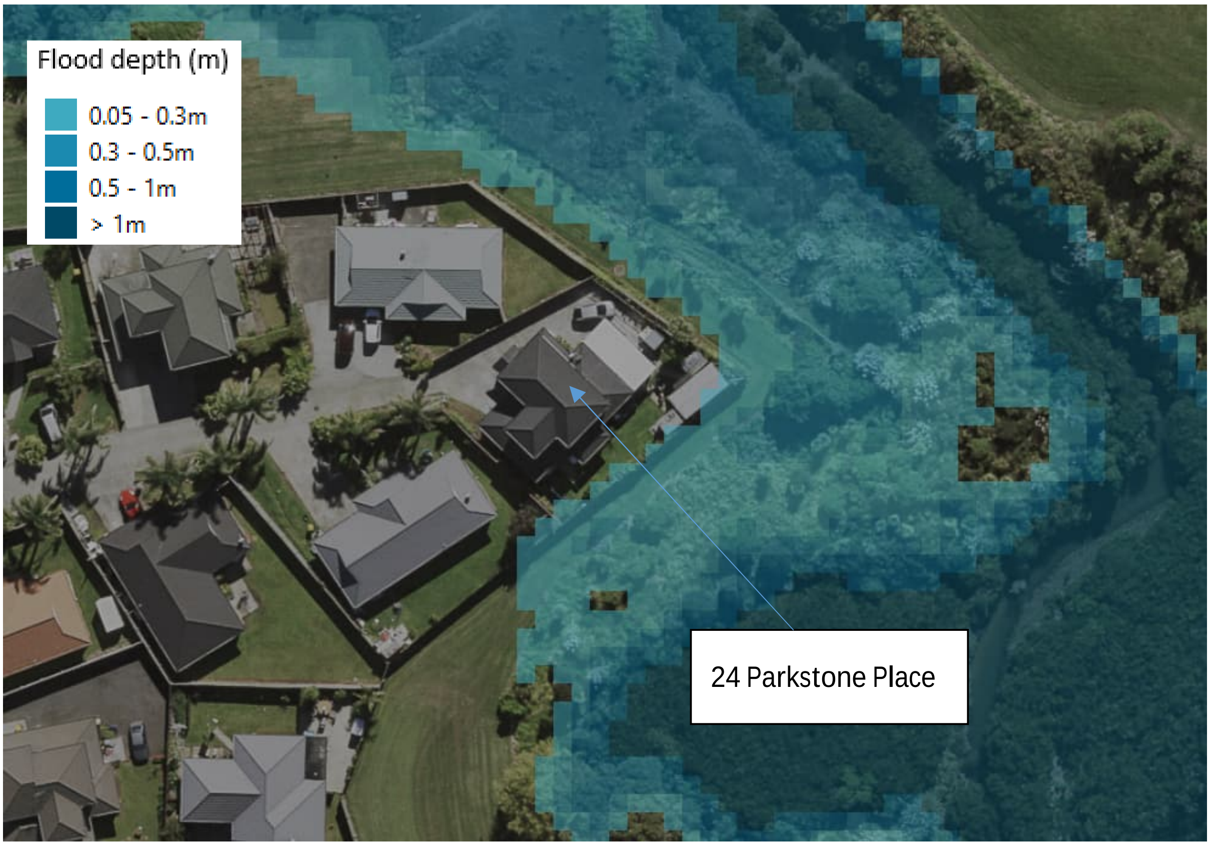


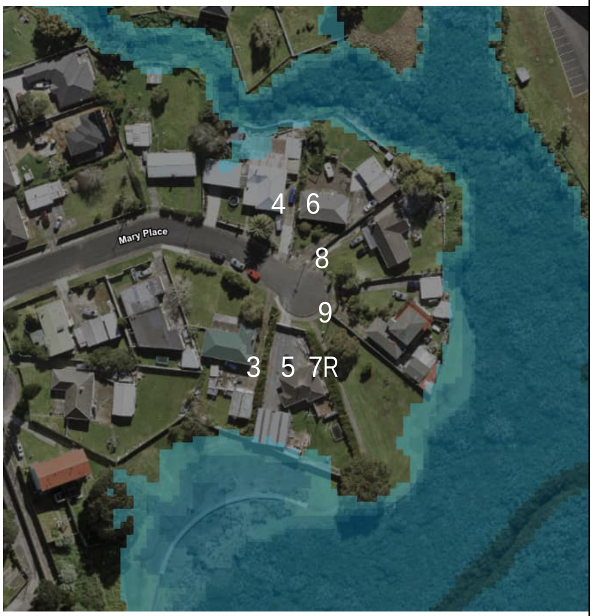
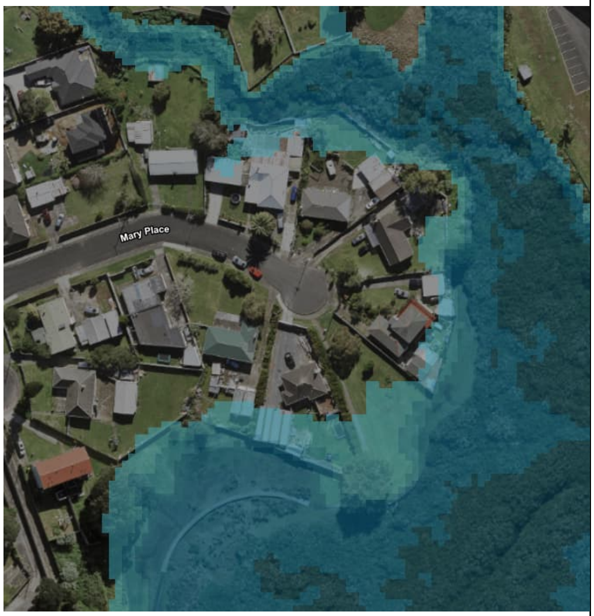
Figure 2.6 Scenario 2 floodplain at 24 Parkstone Place

2.2.2.4 Flood risk at Mary Place

There are 6 private properties located between 3 and 9 Mary Place[13], where the existing floodplain is predicted to encroach further onto their property as a result of the project. Table 2.2 provides a comparison of pre-development and post-development floodplains for each of the four scenarios. Subsequently the effect of the increase floodplain is considered in terms of its impact on habitable building flooding, access and egress, non-habitable building flooding and wider property effects. This information is then used to support the risk assessment.

[13] 7 Mary Place is a Council Reserve

Table 2.2: Comparison of pre-development and post-development floodplains for Scenarios 1-4 – Mary Place

<table>
<tr><th>Pre-development</th><th>Post-development</th></tr>
<tr><td>Scenario 1

</td><td>
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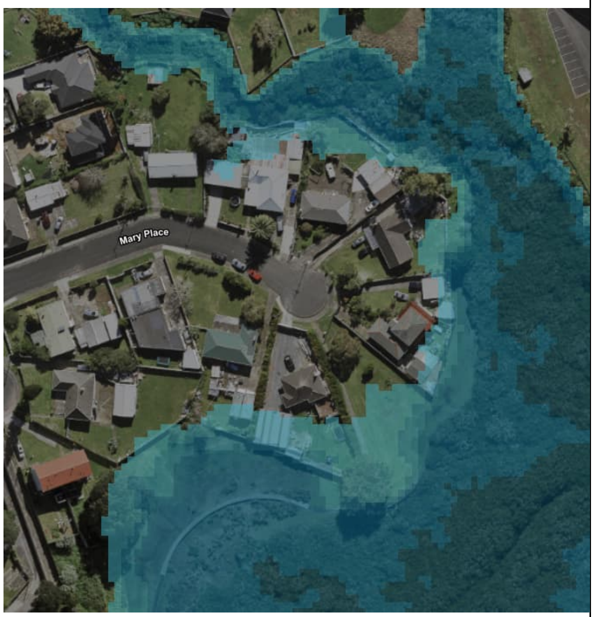
<tr><td>Scenario 2

</td><td>
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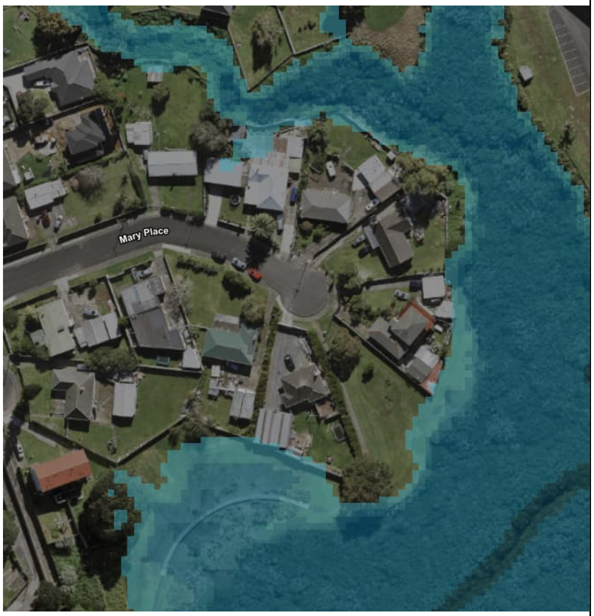
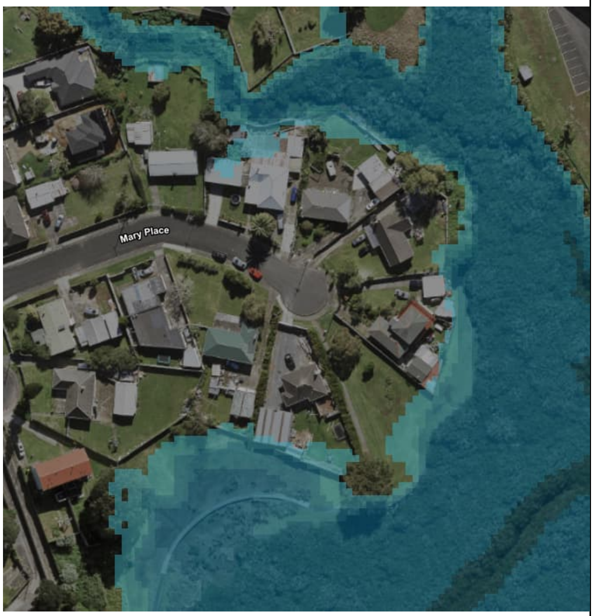
</table>

Pre-development	Post-development
Scenario 3  	
Scenario 4  	

The effect of the increases in floodplain as a result of the Tennessee Bridge project are considered in terms of its impact on habitable building flooding, access and egress, non-habitable building flooding and wider property effects. Further information is available in Appendix B to support the statements made below:

- There is no predicted habitable building flooding predicted for any of the scenarios considered in this assessment.
- There is no predicted flooding of non-habitable buildings predicted for any of the scenarios considered in this assessment.

- There is no adverse effect on safe access or egress for any of the scenarios considered in this assessment.
- There are increased floodplain extents on the coastal side of the properties as a result of increased flows into the estuarine embayment. The increases in the floodplain extents for each of the identified properties are summarised in Table 2.3. Where a range is provided, the lower number is indicative of the lower rainfall scenario (i.e. 1 and 3) and the upper number is indicative of the upper rainfall scenario (i.e. 2 and 4).

Table 2.3: Summary of likely increases in property flood extents

Property	Property area (m^2)	Floodplain increases (m^2)	
		"Low tide"*	High tide (2.05 m)
3 Mary Place	1032	<10	40-100
5 Mary Place	895	<10-100	200-300
9 Mary Place	817	<10-40	50-120
8 Mary Place	809	<10	40-110
6 Mary Place	819	<10-100	100-170
4 Mary Place	847	<10	<10-20
*Refer discussion on "Low tide" scenario beneath			

The results of the floodplain increase assessment shown in Table 2.3 identify the important role that the tidal state has on peak water levels at Mary Place. This suggests that the timings of the tide and the peak discharge from the Harania catchment flows may be an important factor in determining suitable scenarios for the effects assessment. However, it could be equally inappropriate to assume that the peak discharges would occur at low tide (scenario 3 and 4) as it would be at high tide (scenario 1 and 2).

In order to test sensitivity of whether increases in floodplain are likely closer to the "low tide" or "high tide" floodplain scenario, a range of tailwater levels were evaluated to determine at what point tailwater level impacts the flood increases on the private property. The conclusion was that tailwater levels below 1.6 m RL did not influence the floodplain at Mary Place (i.e. tailwater levels above 1.6 m RL do influence the floodplain at Mary Place), as demonstrated by the comparison of floodplains shown in Figure 2.7.

This suggests that the "Low tide" scenarios are more representative of effects under low probability events than the "High tide" scenarios. This is because water levels in the Manukau Harbour spend considerably more time below 1.6 m RL than above 1.6 m RL (e.g. mean sea level is 0.23 m RL). This is not to say that the "high tide" scenario can not occur, although due to the joint probabilities of the astronomical cycle (e.g. sping/neap), the daily tidal cycle (high tide/low tide) and the peak discharges needing to align, the likelihood is considerably less. A table of Onehunga Port water levels is provided in Appendix B (Table Appendix B.2) for information and comparative purposes.

Overall, it is considered that the "low tide" scenarios can be used to support the effects assessment component of the risk assessment (refer Conclusions in Section 3).

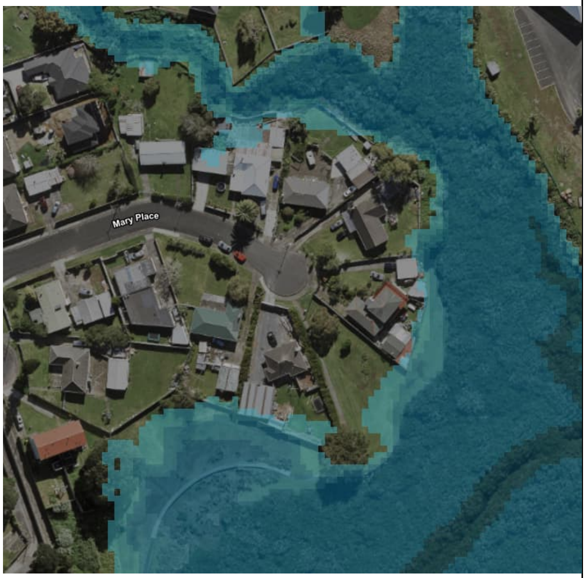
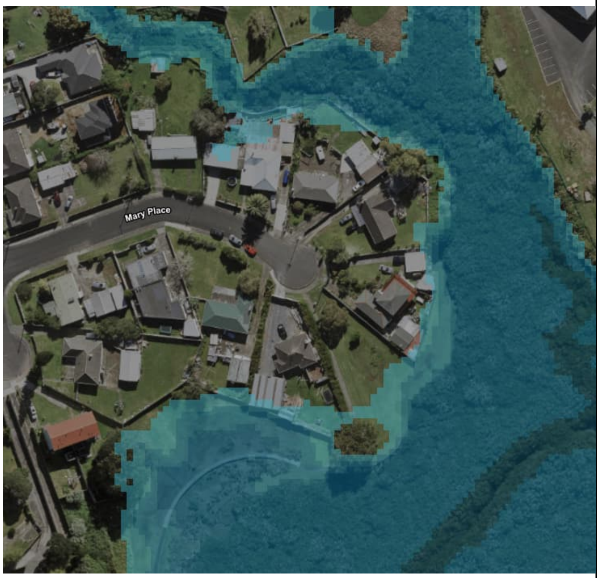
Scenario 4 – post development	1.6 m RL tailwater level, 224 mm rainfall
	

Figure 2.7 Comparison of floodplains for Scenario 4 with raised tailwater level (1.6 m RL)

3 Conclusion

The purpose of this report has been to present flood hazard information and a hazard risk assessment the Project to support the resource consent application. This assessment has been prepared to assess the specific matters of control set out in the Severe Weather Emergency Recovery (Auckland Flood Resilience Works) Order 2024, being:

(a) The risks from natural hazards to people, property, infrastructure, and the environment, and measures to avoid or mitigate those risks.

Pre-development there are between 50 and 55 properties which are identified as flood affected by scenarios considered in this report . Post-development flooding will be removed from 40 to 45 properties and reduced at a further six properties. The remaining four properties have insignificant reductions in flood level post development.

Two “sensitivity scenarios” have been assessed to improve the climate resilience of the new infrastructure. The pipe bridge is located approximately 400 mm above the most extreme scenario which used 332 mm rainfall and 3.05 m sea level, which was adopted at the request of Auckland Council. The sensitivity scenarios also identified that nearly 100 properties benefit from the project progressing. These additional ~45 properties are beneficiaries of the project because they are part of the residual risk that are exposed to flooding for over design-events (e.g. rainfall scenarios more extreme than the current 1% AEP scenario).

(b) The risk of flood resilience works increasing risks from existing natural hazards or creating new natural hazards, and measures to avoid or mitigate that risk.

An increase in flood level and flood extent under the low probability event has been identified at downstream properties at 24 Parkstone Place, and six properties located at 3-9 Mary Place.[14] This is as a result of passing more flows downstream by removing the culvert and embankment.

The potential impact on these properties is considered low for the following reasons:

- There is no habitable building flooding predicted for any of the scenarios considered in this assessment.
- There is no flooding of non-habitable buildings predicted for any of the scenarios considered in this assessment.
- There is no adverse effect on safe access or egress for any of the scenarios considered in this assessment.

In undertaking the assessment, consideration has been given to the changes of the floodplain within garden areas where small predicted increases in the floodplain extents occur for five of the seven properties (four with less than 10 m^2 of additional floodplain, and one with up to 40 m^2). For the remaining two properties, located at 5 & 6 Mary Place, there may be moderate increases in the floodplain extent of up to 100 m^2. For all seven properties, the increases reflect upper estimates based on the higher rainfall scenario (224 mm in 24 hours) although this is why a range in likely floodplain increases is provided. Under the lower rainfall (192 mm in 24 hours) there is between 0 m^2 and 10 m^2 floodplain extent increase for all properties.

Our assessment has identified scenarios where there are further increases in the floodplain extents on gardens (not buildings or access/egress), however the likelihood of these events occurring is significantly lower due to the combination of the solar/lunar cycle (i.e. spring/neap) and daily tidal cycle (e.g. high tide/low tide) and the peak catchment discharges that would need to align. Due to the highly unlikely nature of these scenarios they have not been considered further.

[14] 7 Mary Place is a Council Reserve and not included in the six properties.

4 Applicability

This report has been prepared for the exclusive use of our client Auckland 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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Report reviewed by:

....

Lisa Dowson
Principal Water Resources Consultant

JRRR
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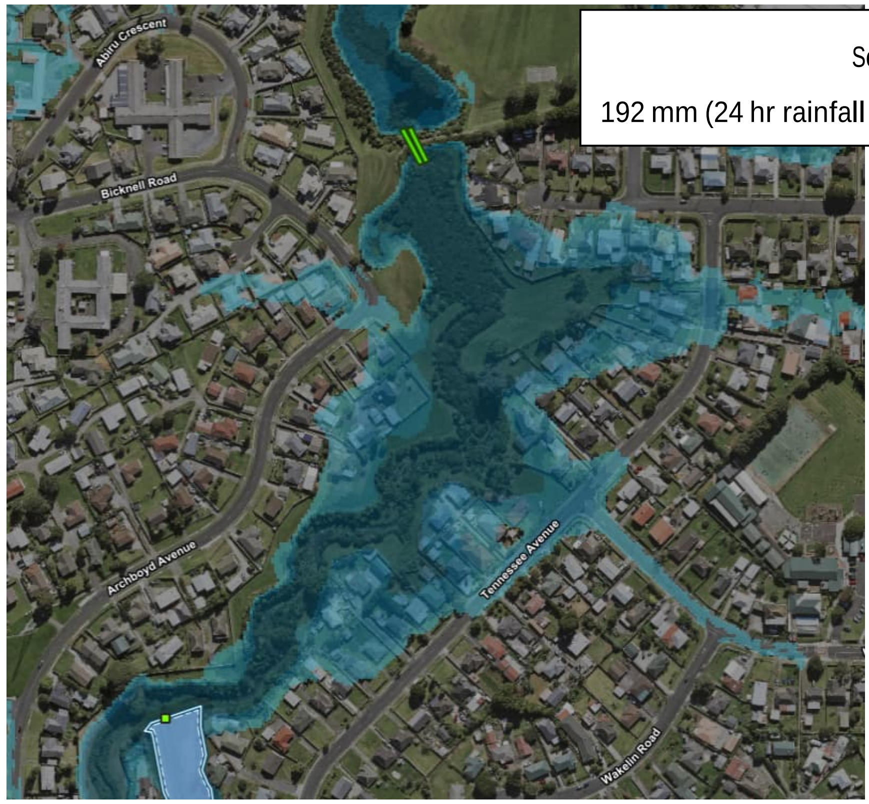
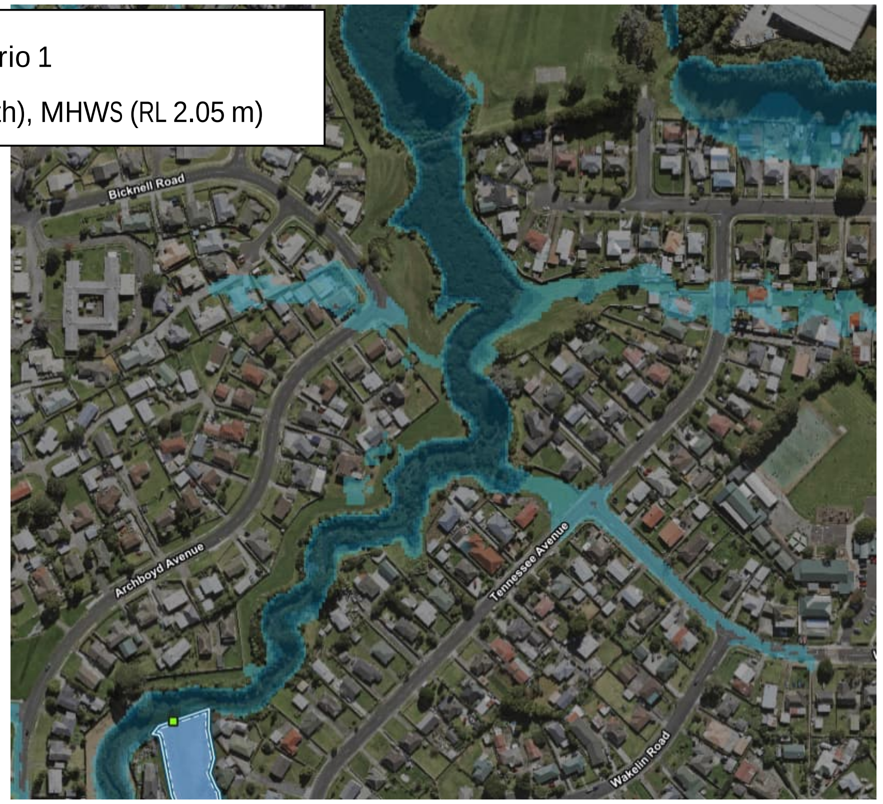
Appendix A Flood hazard maps

Pre-development	Post-development	Flood depth (m)

Scenario 1

192 mm (24 hr rainfall depth), MHWS (RL 2.05 m)





Flood depth (m)

- 0.05 - 0.3m
- 0.3 - 0.5m
- 0.5 - 1m
- > 1m

Scenario 2

224 mm (24 hr rainfall depth), MHWS (RL 2.05 m)

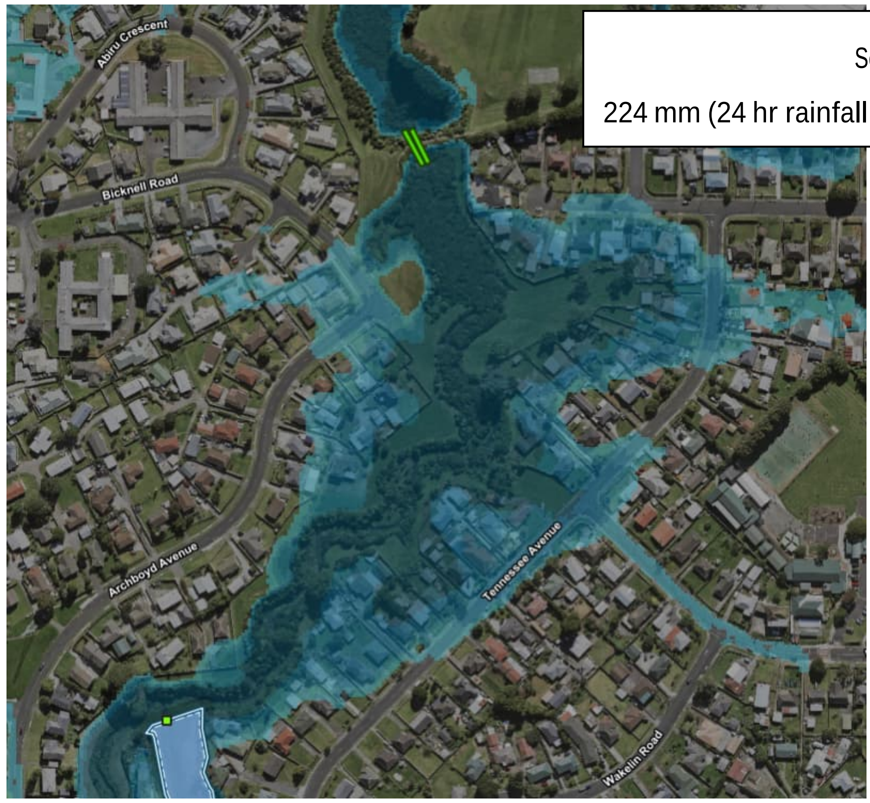


Figure Appendix A.1: Upstream flood extents – Scenario 1 & 2

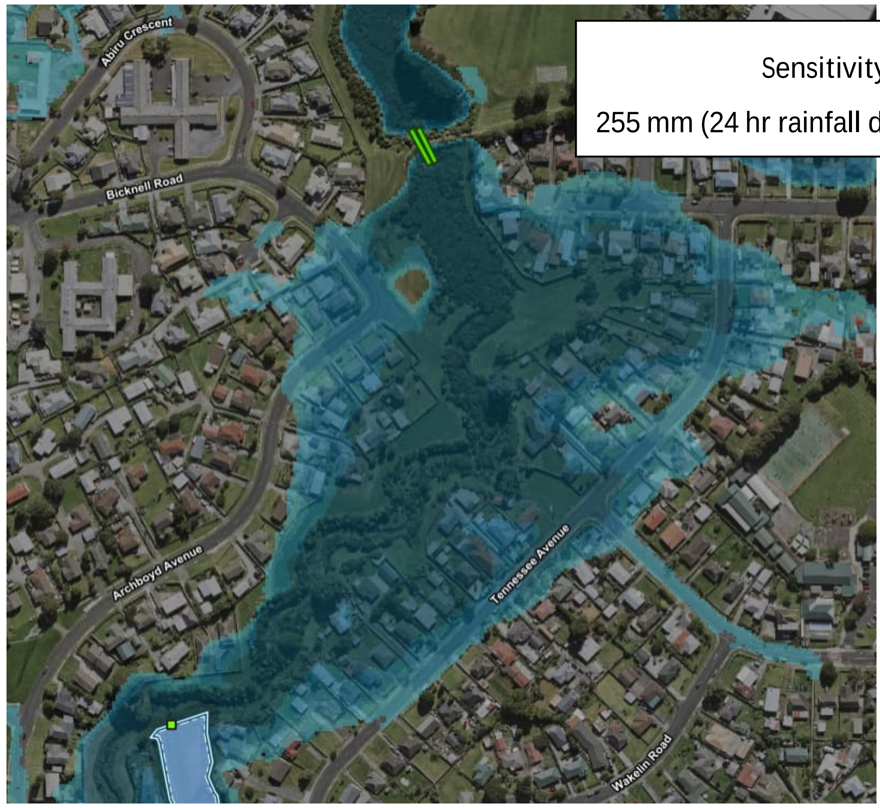
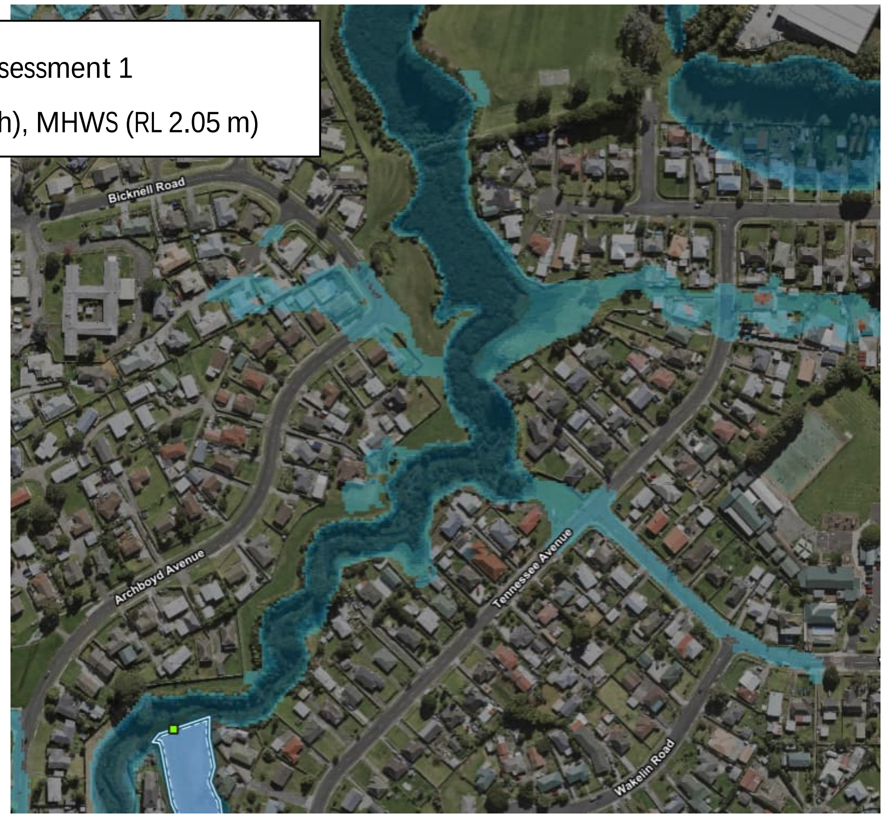
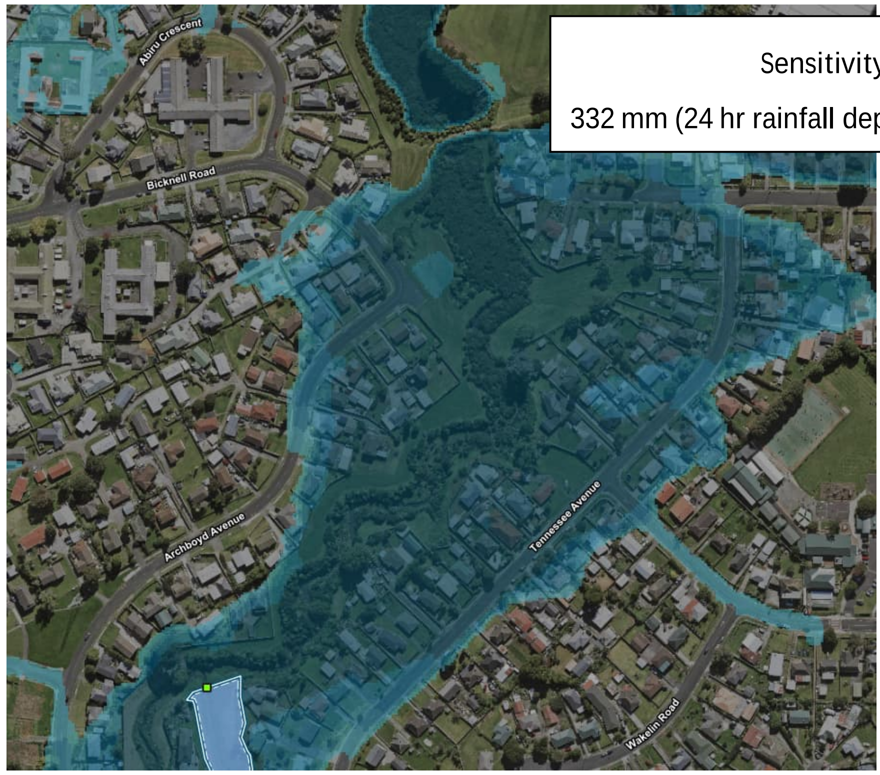
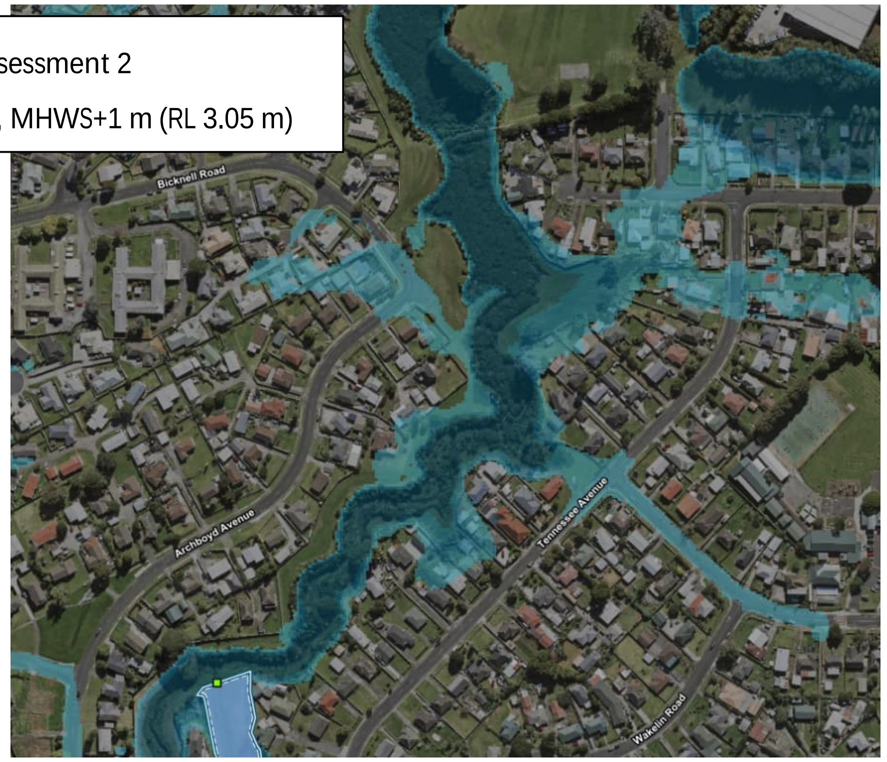
Pre-development	Post-development	Flood depth (m)
Sensitivity Assessment 1 255 mm (24 hr rainfall depth), MHWS (RL 2.05 m)		0.05 - 0.3m 0.3 - 0.5m 0.5 - 1m > 1m
		
Sensitivity Assessment 2 332 mm (24 hr rainfall depth), MHWS+1 m (RL 3.05 m)		
		

Figure Appendix A.2: Upstream flood extents – Sensitivity scenarios 1 & 2

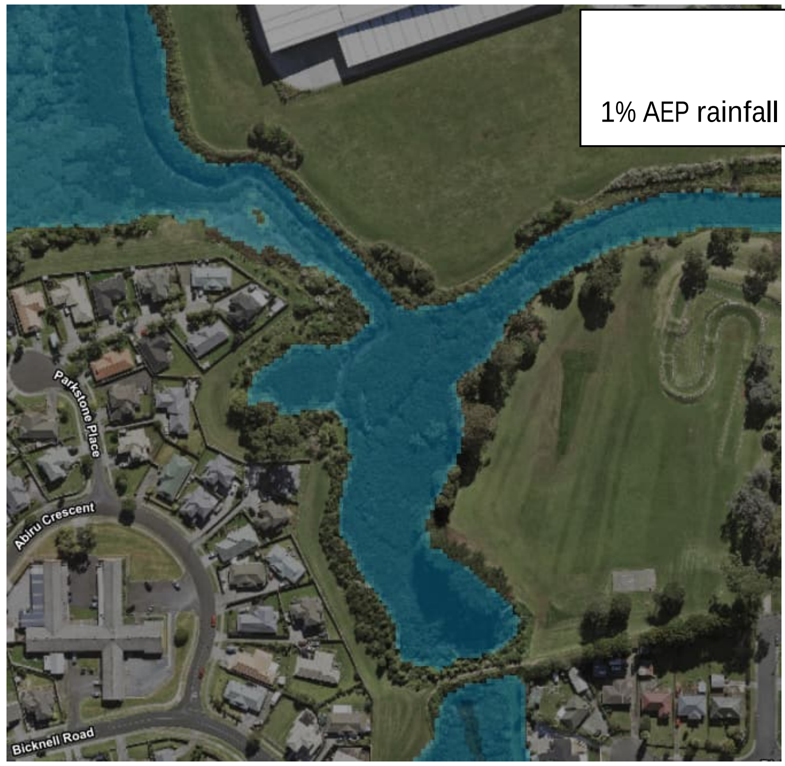
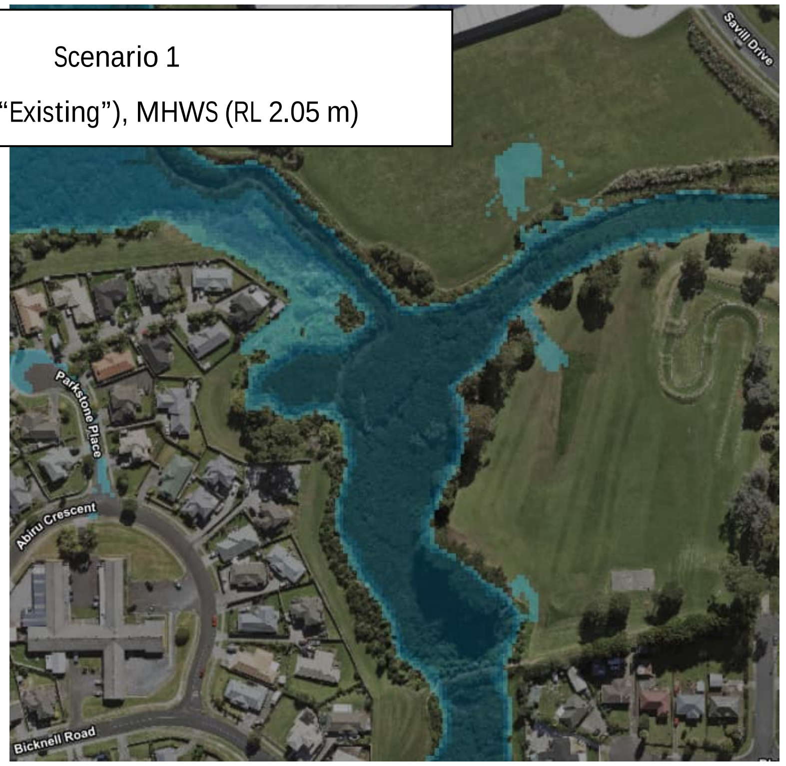
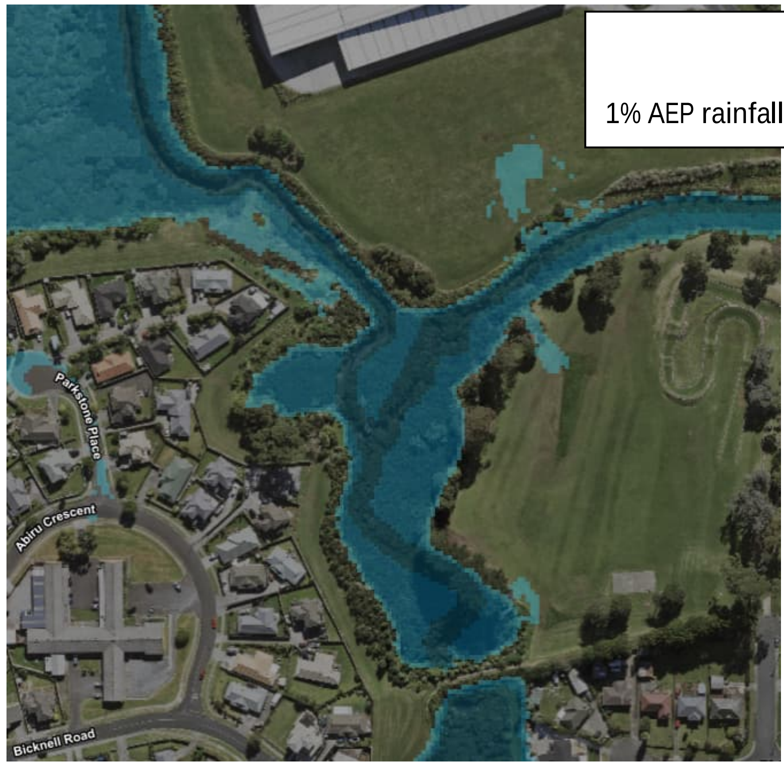
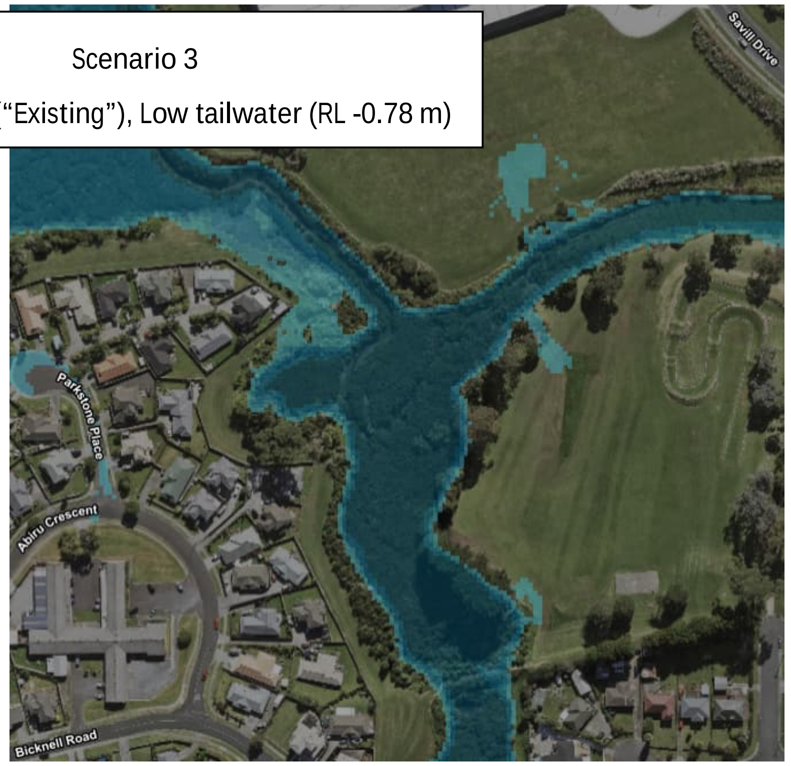
Pre-development	Post-development	Difference (dark red = new flood extent)	
	Scenario 1 1% AEP rainfall (“Existing”), MHWS (RL 2.05 m) 		Flood depth (m) 0.05 - 0.3m 0.3 - 0.5m 0.5 - 1m > 1m Difference (m) +ve number indicates increase in flood level < -0.50 -0.50 - -0.25 -0.25 - -0.10 -0.10 - -0.05 -0.05 - 0.05 ('No Difference') 0.05 - 0.10 0.10 - 0.25 0.25 - 0.50 Increase in flood extents
	Scenario 3 1% AEP rainfall (“Existing”), Low tailwater (RL -0.78 m) 		

Figure Appendix A.3: Downstream flood extents for Scenario 1 and 3 “Channelised area”

Figure Appendix A.4: Downstream flood extents for Scenario 2 and 4 "Channelised area"

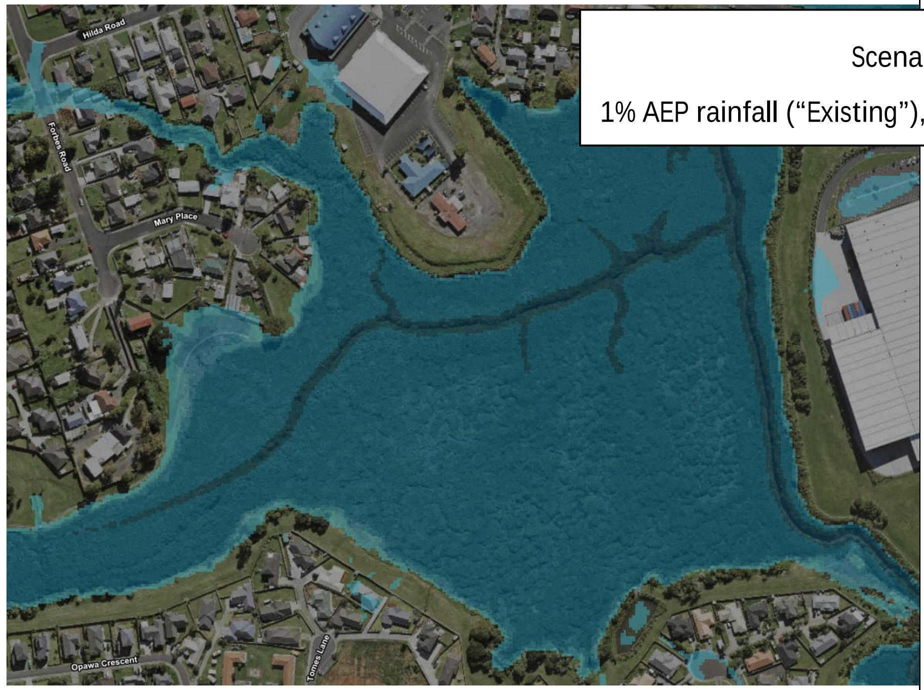
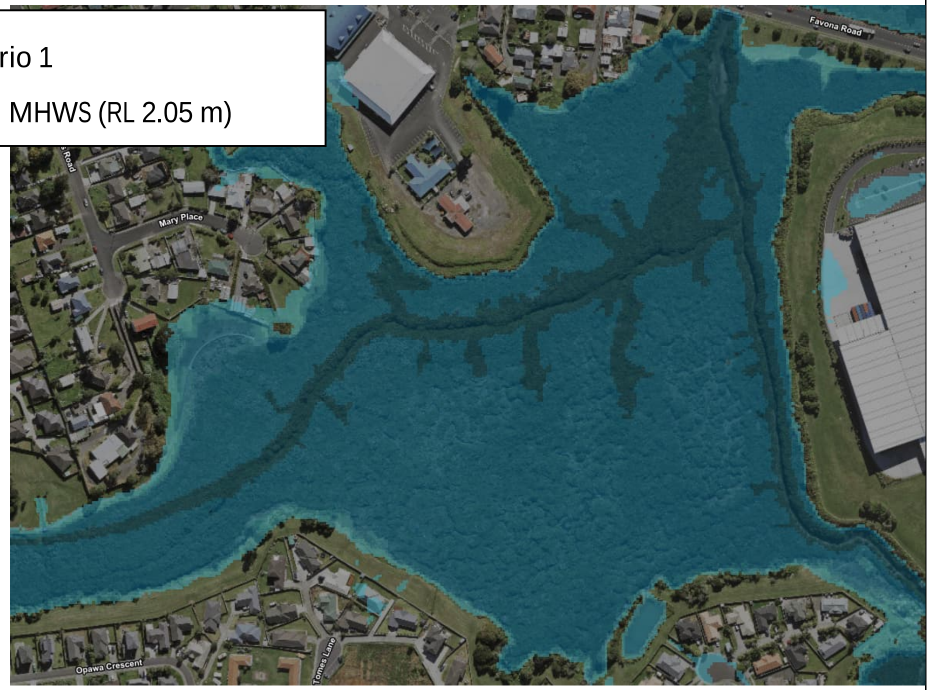
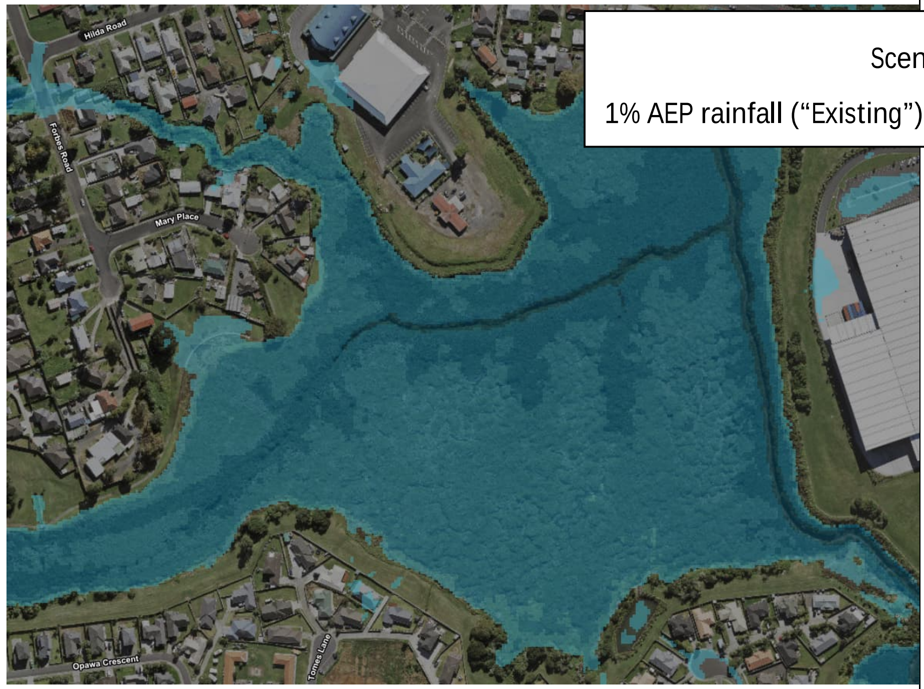
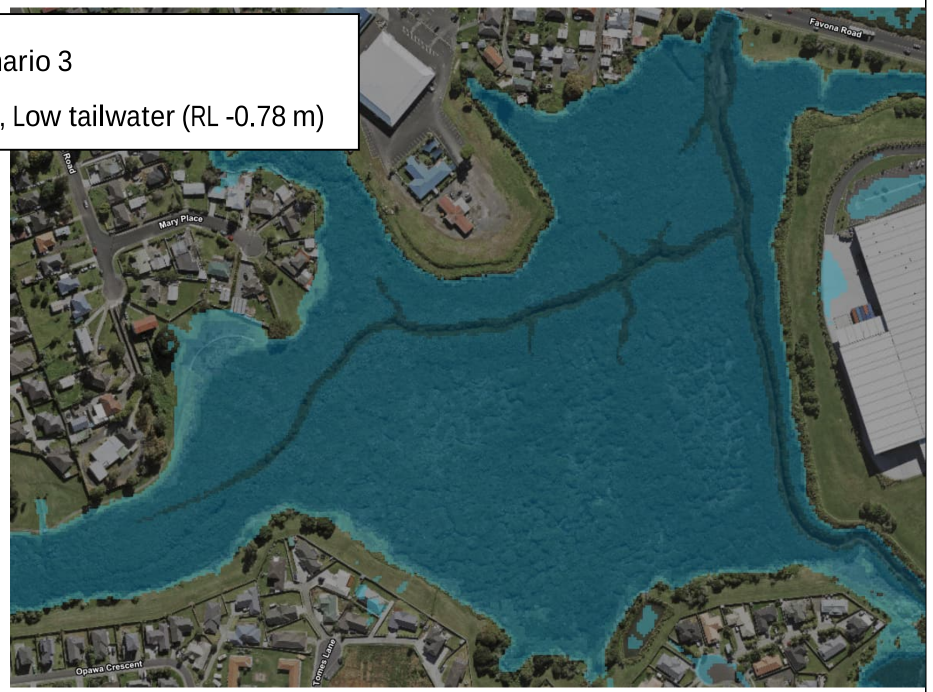
Pre-development	Post-development	Difference (dark red = new flood extent)
	Scenario 1 1% AEP rainfall (“Existing”), MHWS (RL 2.05 m) 	
	Scenario 3 1% AEP rainfall (“Existing”), Low tailwater (RL -0.78 m) 	
Refer Figure Appendix A.3and Figure Appendix A.4 for depth legend		New floodplain (Refer Figure Appendix A.3 and Figure Appendix A.4 for full water level legend)

Figure Appendix A.5: Downstream flood extents for Scenario 1 and 3 “Estuarine Embayment”

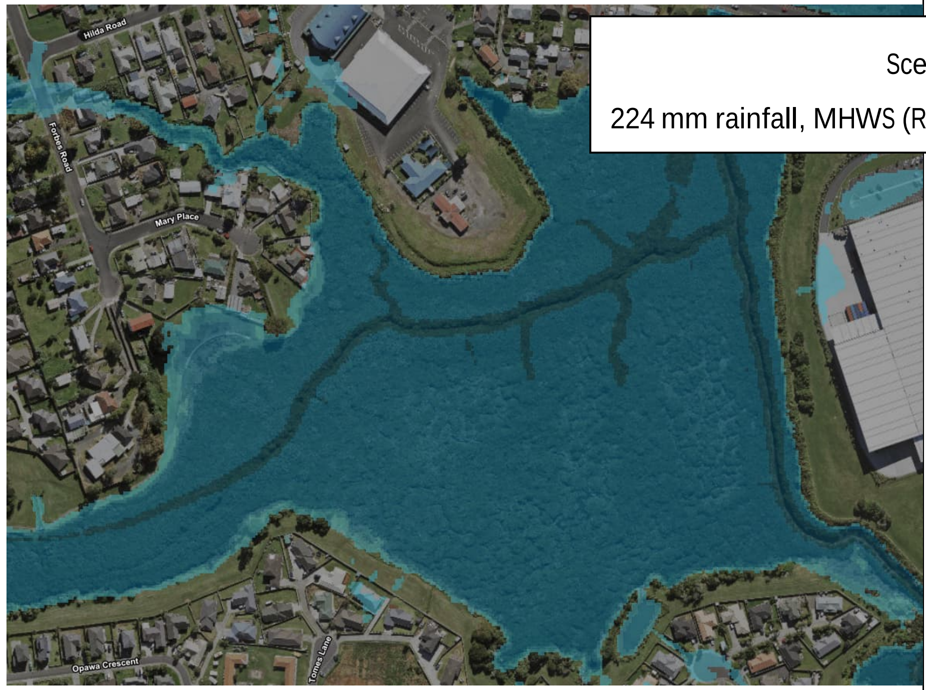
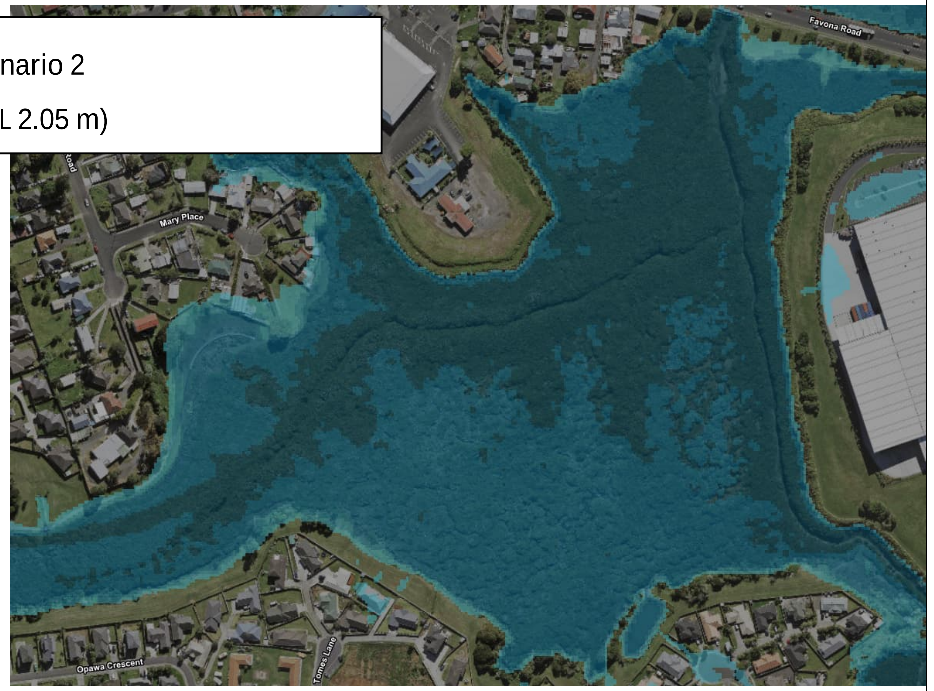
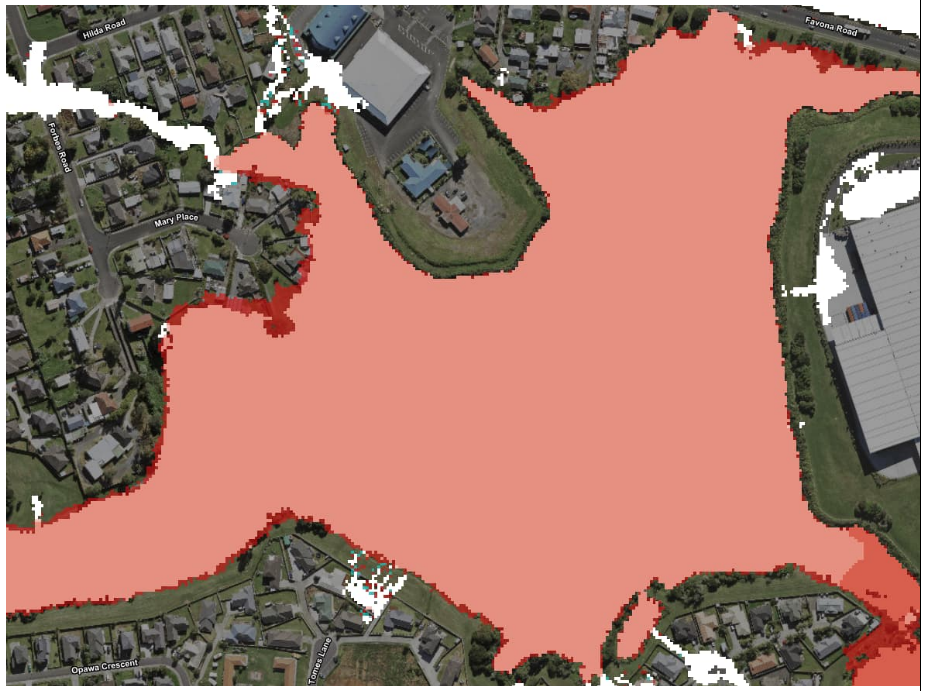
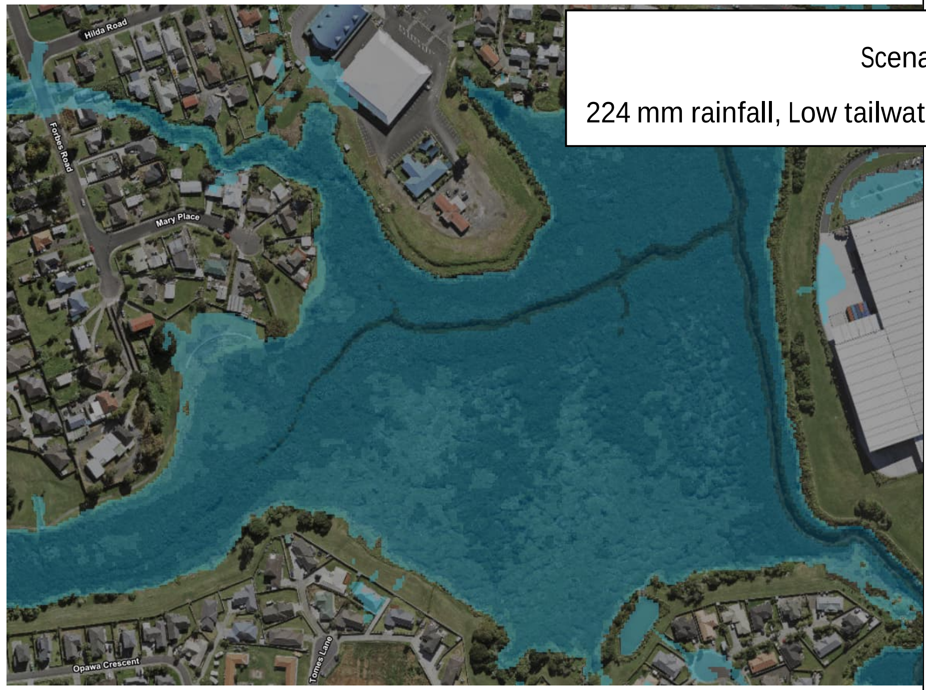
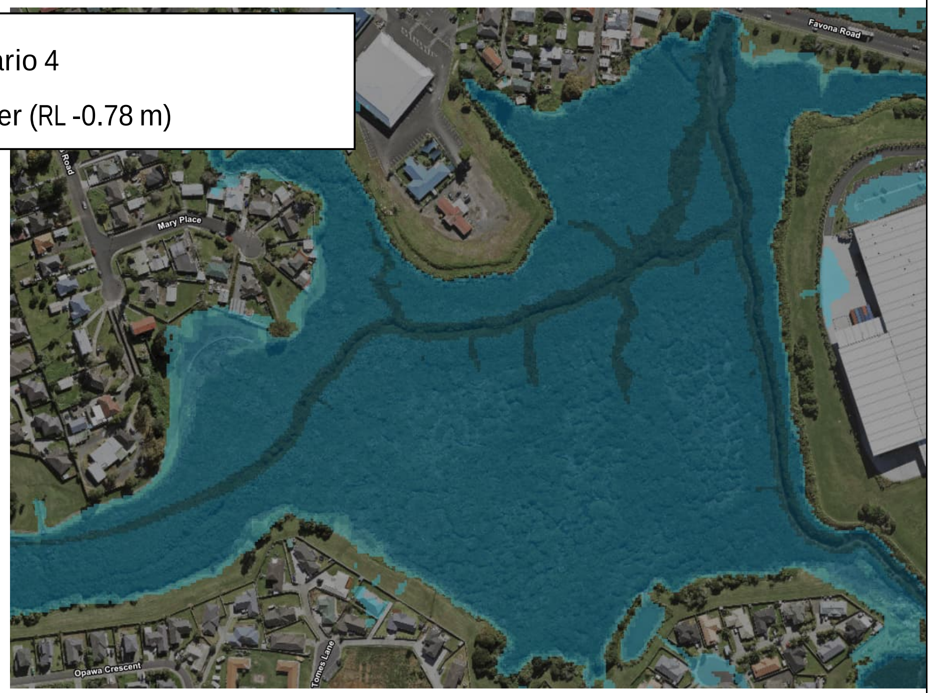
Pre-development	Post-development	Difference
 Scenario 2 224 mm rainfall, MHWS (RL 2.05 m)		
 Scenario 4 224 mm rainfall, Low tailwater (RL -0.78 m)		
Refer Figure Appendix A.3 and Figure Appendix A.4 for depth legend		New floodplain (Refer Figure Appendix A.3 and Figure Appendix A.4 for full water level legend)

Figure Appendix A.6: Downstream flood extents for Scenario 2 and 4 "Estuarine Embayment"

Appendix B Supporting information for flood effects assessment at Mary Place, Favona

- Building flooding at Mary Place, Favona

As part of the Mangere Inlet FHM study (T+T, 2019) floor level surveys (Woods, 2017) were carried out at the 6 identified properties with flood effects located at 3-9 Mary Place.

Figure Appendix B.1: identifies the building footprints and surveyed levels. Note that the floodplain should not be used for the purposes of this report because it adopts coastal water levels scenarios not included in this assessment.

A comparison of the floor levels and flood levels from Scenario 2 is provided in

Table Appendix B.1: . Scenario 2 was adopted because it provides the highest flood levels from the four scenarios evaluated for the purpose of this assessment.

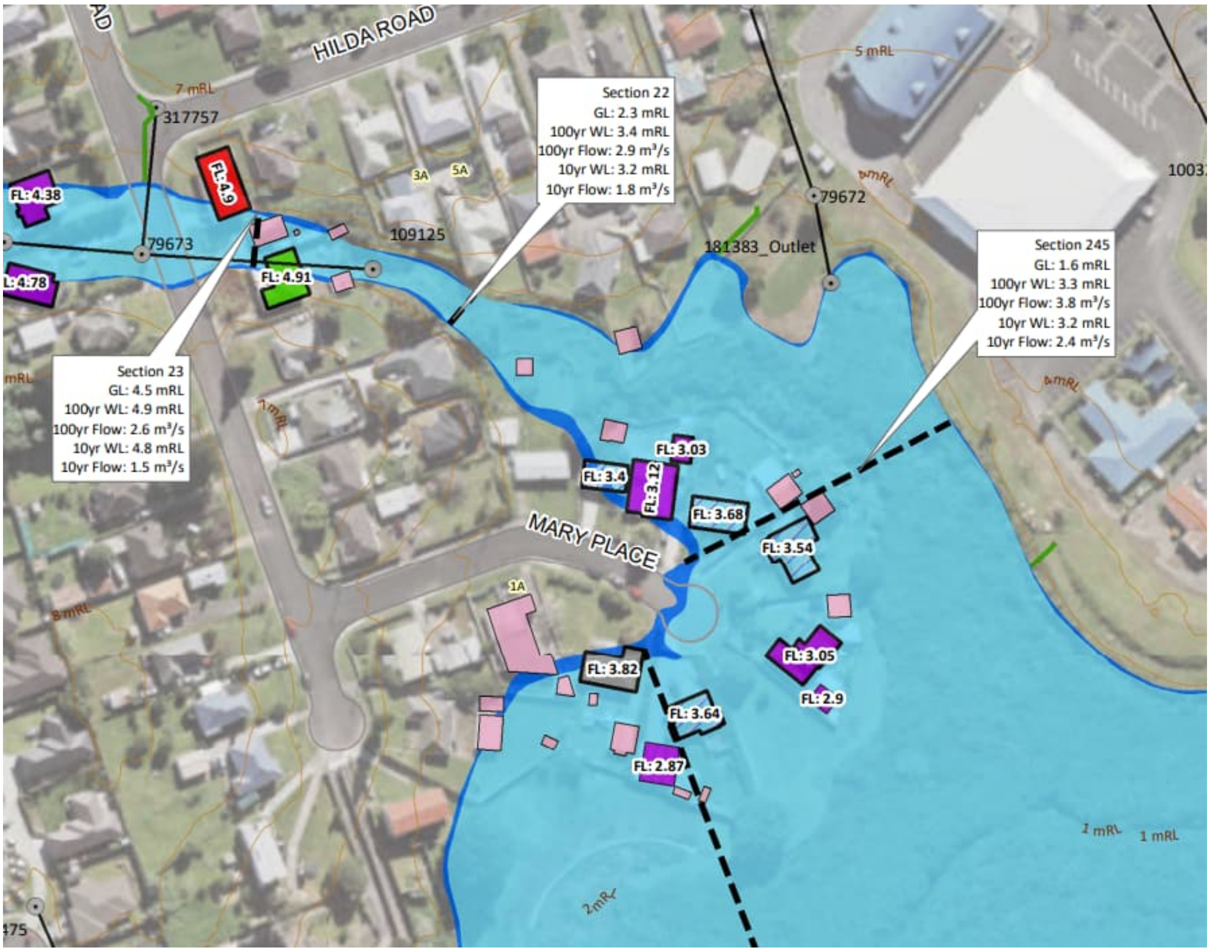


Figure Appendix B.1: Floor levels of Mary Place properties (Mangere Inlet FHM (T+T, 2019))

Table Appendix B.1: Comparison of building floor level and flood level at Mary Place properties

Address	Building Floor level (m RL AVD-46)		Flood level (mRL-AVD46) (Scenario 2)		Additional commentary
	Habitable	Outbuilding	Pre-dev	Post-dev	
3 Mary Place	3.82	Refer additional commentary	2.52	2.74	Habitable building located outside the predicted floodplain and above the predicted levels for all scenarios considered for this assessment. An outbuilding that is partially exposed to the Scenario 2 floodplain wasn't surveyed. The level of the outbuilding is likely above the level of the neighbours outbuilding[15] at 5 Mary Place (RL2.87 m) and therefore considered unlikely to flood.
5 Mary Place	3.64	2.87	2.52	2.74	Habitable building located outside the predicted floodplain and above the predicted levels for all scenarios considered for this assessment. Outbuilding partially exposed to flooding although floor level is above the predicted flood level for all scenarios considered for this assessment.
9 Mary Place	3.05	2.9 Refer additional commentary	2.52	2.74	Habitable building located outside the predicted floodplain and above the predicted levels for all scenarios considered for this assessment. Two outbuildings appear partially exposed to predicted floodplain. One outbuilding was surveyed and is above the predicted flood level for all scenarios considered for this assessment. An additional low-height small "building" (~30 m^2) (appears to be mobile) raised off ground on the north-western side of the property. Assessed as non-habitable and likely similar level to the lower surveyed building. Considered low risk building and unlikely to flood.
8 Mary Place	3.54	Refer additional commentary	2.52	2.74	Habitable building located outside the predicted floodplain and above the predicted levels for all scenarios considered for this assessment. Additional building (usage uncertain although unlikely habitable) located on the north corner of the property although it is not exposed to any of the floodplains considered for this assessment.
6 Mary Place	3.68	Refer additional commentary	2.52	2.74	Habitable building located outside the predicted floodplain and above the predicted levels for all scenarios considered for this assessment. An additional buildings (appears to be a garage) was not surveyed although it is not exposed to any of the floodplains considered for this assessment.

[15] Based on relative location, topography and local floodplain characteristics

Address	Building Floor level (m RL AVD-46)		Flood level (mRL-AVD46) (Scenario 2)		Additional commentary
	Habitable	Outbuilding	Pre-dev	Post-dev	
4 Mary Place	3.12 (primary) 3.4 (secondary)	3.03	2.56	2.76	There are potentially two habitable buildings located on this site. The larger building, referred to as primary is located outside the predicted floodplain and above the predicted levels for all scenarios considered for this assessment. The smaller building (secondary) is partially located within the predicted floodplain although the flood level is above all scenarios considered for this assessment. The outbuilding is a car port and has a surveyed floor level above all scenarios considered for this assessment.

- Flood extent increases

	Floodplain increases (m^2)		Floodplain increases by scenario (m^2)			
	Low tide	High tide (2.05 m)	Scenario1	Scenario 2	Scenario 3	Scenario 4
3 Mary Place	<10	40-100 m^2	40 m^2	100 m^2	0-10	0-10
5 Mary Place	<10-100	200-300 m	200 m^2	300 m^2	0-10	100
9 Mary Place	<10-40	50-120	50 m^2	120	0-10	40
8 Mary Place	<10	40-110	40 m^2	110	0	0-10
6 Mary Place	<10-100	100-170	100 m^2	170	0-10	100
4 Mary Place	<10	<10-20	<10 m^2	20	0-10	0-10

- Port of Onehunga tidal levels

Table Appendix B.2 : Port of Onehunga tidal levels

Datum	MHWS	MHWN	MLWN	MLWS	MSL	HAT	LAT
CD	4.18	3.33	1.45	0.56	2.43	4.54	0.12
AVD-46	1.979	1.129	-0.751	-1.641	0.229	2.339	-2.081
NZVD2016	1.695	0.845	-1.035	-1.925	-0.055	2.055	-2.365

Appendix C Model build summary

Table of contents

1 Introduction

The Harania catchment was one of the worst affected areas of Auckland following the January 2023 floods. Healthy Waters identified significant flooding which caused risk to life and widespread flood damage to approximately 60 homes. This occurred due to poor flood conveyance at the Tennessee Avenue and Blake Road embankment dams.

Hydraulic modelling was undertaken to assess the effects resulting from the proposed pipe bridge near Tennessee Avenue in the Harania catchment. This report describes the methodology of the hydraulic modelling.

The proposed works fall under the Blue Green Networks (BGN), a collection of projects aimed to improve flood resilience in Māngere.

The works considered in this report involve removal of the existing culverts and embankment and replacing it with a pipe bridge. The embankment carries the existing Eastern Interceptor, which is a 2.3 m diameter reinforced concrete trunk sewer. Figure 1.1 shows the location of the proposed works and Auckland Council's existing flood hazard information[1].

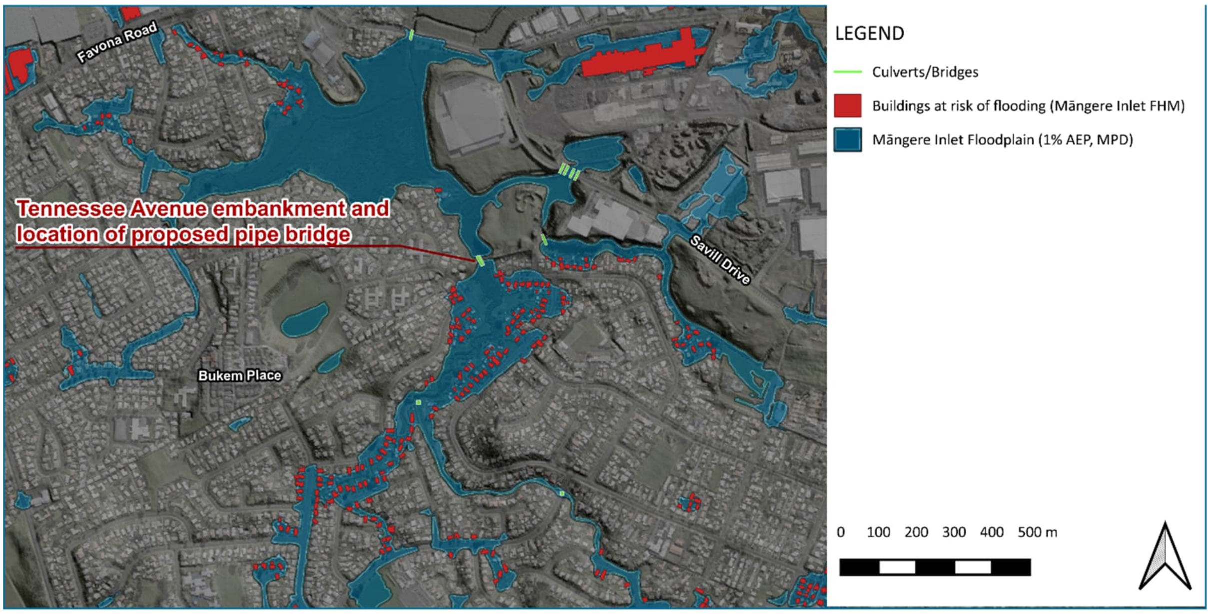


Figure 1.1: Location of proposed works and Auckland Council's existing flood hazard information

1.1 Model purpose

The purpose of the hydraulic model is to assess the relative effects of the proposed works on flooding in the Harania catchment.

2 Harania catchment and hydraulic model history

Harania creek is located within Auckland's Māngere area. Auckland Council have undertaken hydraulic modelling and flood hazard mapping (FHM) for the Māngere Inlet catchment[1].

The Māngere Inlet FHM model has been subsequently updated and used for large scale Kāinga Ora projects in Auckland. These projects and the associated hydraulic modelling have been undertaken by the LEAD Alliance. Hydraulic modelling of the Harania catchment by LEAD was ongoing at the time of writing this report. The Harania model is a cut-down version of the Māngere hydraulic model, as shown in Figure 2.1 below.

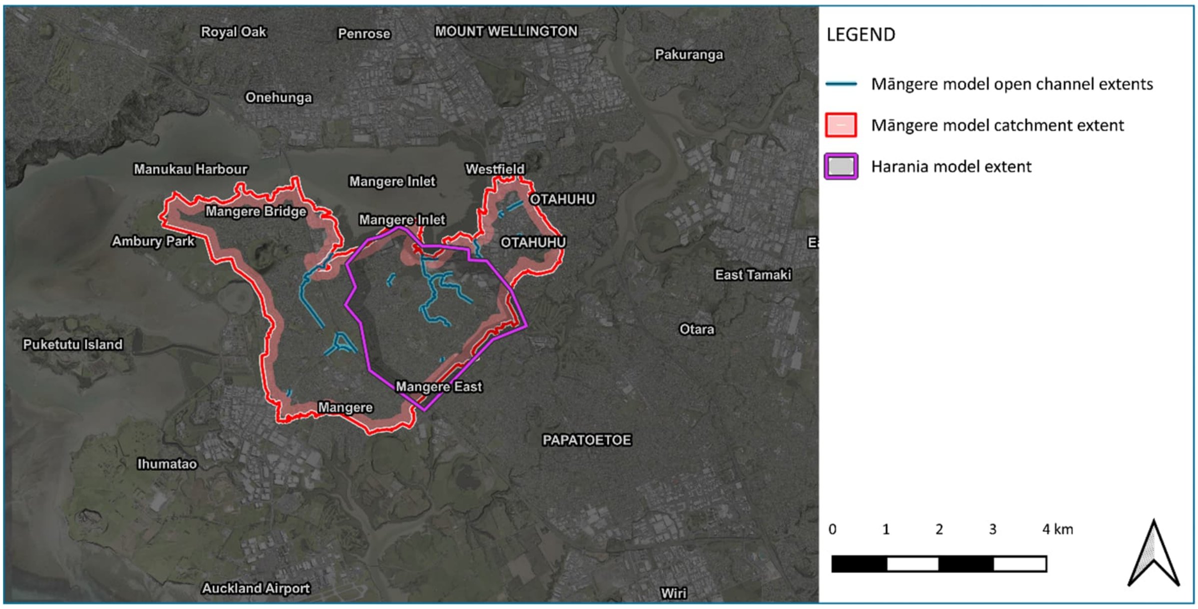


Figure 2.1: Māngere Inlet FHM and Harania model extents

LEAD's Harania model was not finalised at the time of writing this report. The model was provided to Tonkin & Taylor Ltd (T+T) in its draft form due to the programme constraints of this project. Parallel versions of the Harania model have therefore been developed.

Details of the Harania model provided by LEAD (the 'LEAD model') are as follows:

- Model folder: 00_DTOC40_R0XX-Base Model (D) - 100yr MPD
- Model couple file: *TEN_Base100yrMPD-C v8-1.couple*
- Source: Provided on 02/08/2024 via internal transfer link

End users should refer to LEAD's reporting for details of this hydraulic model. Updates made to this model by T+T are described in Section 3 below.

[1] *Māngere Inlet FHM Model Build and System Performance*, Tonkin & Taylor Ltd, June 2020.
Spatial data sourced from Tonkin + Taylor's 2017/2019 FHM mapping, project ref: 28456.1000.

3 Baseline hydraulic model

The Baseline Harania BGN model represents the existing or ‘pre-project’ scenario. For the purpose of assessing the relative effects of the project, a number of the waterways represented as 1D open channels in the received LEAD model were converted to 2D representation in the Harania BGN model. This is demonstrated in Figure 3.1 below.

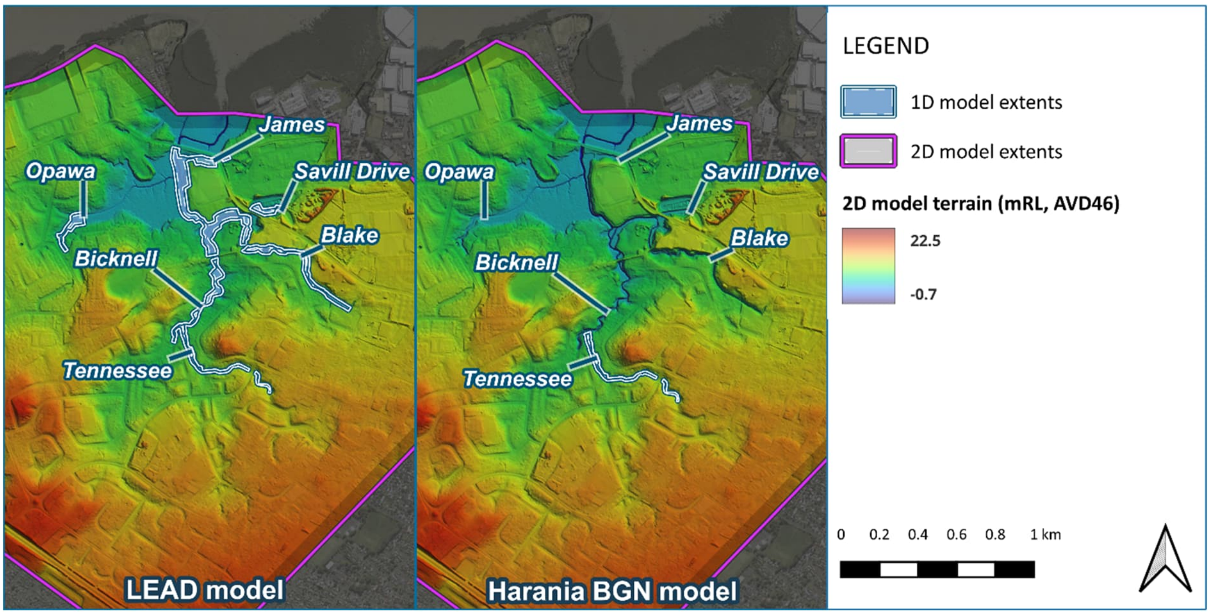


Figure 3.1: Harania BGN model - change in 1D extents from received LEAD model

Key features of the Baseline (‘BASE’) hydraulic model are summarised in Table 3.1 below. Details of the updates made to the LEAD model as part of the project are also provided.

Table 3.1: Harania BGN Baseline model summary and changes to LEAD model

Model element	Model summary	Update details (changes to LEAD model)
Model name	Harania Blue-Green Networks Baseline model, “HaraniaBGN_BASE”	• LEAD model name updated due to specific model purpose
Model version	*202408_v05*	• Model versioning initiated for quality assurance purposes
Software	MIKE by DHI, 2020 release	• Unchanged from LEAD model
Datums	Horizontal: New Zealand Transverse Mercator (NZTM) (NZGD2000). Vertical: Auckland Vertical Datum 1946 (AVD46).	• Unchanged from LEAD model
Extent	Cut-down version of the Māngere FHM model. Bordered by SH20 to the west, and Hospital Road to the right. Refer Figure 2.1 and Figure 3.2.	• Unchanged from LEAD model
Schema	Tennessee branch represented as 1D open channel. All other waterways represented in 2D flexible mesh. Refer Figure 3.2.	• Branches: – Bicknell – Blake – Opara – Savill are converted from 1D open channel in the LEAD model to 2D flexible mesh in HaraniaBGN model. Refer Figure 3.1.
Topography	Branches converted from 1D to 2D (Bicknell, Blake, Opara, Savill) have topographical data from the following sources: • 2013 cross section survey (BECA) • 2016 LiDAR	• Favona Bridge embankment manually adjusted using adjacent terrain levels. This was done to widen the road embankment which was not appropriately captured in the topographical data. • Savill Drive bridge embankment added to topography using adjacent terrain levels. This was done as the road embankment was not represented in the received topographical data. • Topography outside of Favona Bridge, Savill Drive Bridge and the newly schematised 2D extents is unchanged from LEAD model.
Roughness	Spatially varying roughness applied in model. This is based on land use. Newly schematised 2D waterways have roughness ranging from manning’s n = 0.035 to n = 0.15. Refer Figure 3.3.	• Branches converted from 1D to 2D (Bicknell, Blake, Opara, Savill) have roughness areas transposed from the open channel roughness defined in the 1D LEAD model. • Roughness outside of the newly schematised 2D extents is unchanged from LEAD model
Hydraulic structures	There are six culverts represented in the model: 1 Wickman Way culvert, located on Tennessee Branch (1D culvert) 2 Ten_Eng_10 culvert, located on Tennessee Branch (1D culvert) 3 East of Bicknell Road culvert, located at Tennessee Avenue embankment (2D culvert) 4 Blake Road Dam culvert, located at Blake Road embankment (2D culvert) 5 Savill Drive culvert, located at Savill Drive (2D culvert) 6 Favona Bridge, located at Favona Road (2D culvert) Culverts may be represented by multiple barrels. Refer Figure 3.2.	• Structures located at branches converted from 1D to 2D (Bicknell, Blake, Opara, Savill) have 1D culverts converted to 2D culverts. • Structures outside of the newly schematised 2D extents are unchanged from LEAD model.

Model element	Model summary	Update details (changes to LEAD model)
Urban network	The stormwater network is represented in the hydraulic model. Pipes greater than 300 mm are included, as well as smaller pipes where required for connectivity. Refer Figure 3.2.	• Unchanged from LEAD model
Hydrology	Lumped catchment inflows distributed through the urban model using TP108 methodology. Total rainfall depth (over 24 hours) for the 1% AEP[A] storm (current climate) is 192 mm. Maximum probable development ('MPD') land use scenario is represented. This considers an increased (maximum probable) impervious percentage for each land use, i.e. runoff is higher than for the existing development ('ED') scenario.	• Hydrology for *v05* model is unchanged from LEAD model. • 2024 rainfall: An additional scenario was assessed using rainfall statistics updated to include the January 2023 storms. Total rainfall depth (over 24 hours) for the 1% AEP storm (current climate, post-2023 floods) is 250 mm. This rainfall depth was provided by Auckland Council. The model version which utilises the updated rainfall depths is named *HaraniaBGN_202408_v11*.
Downstream boundary	Constant tidal tailwater boundary of 2.05 mRL (AVD46). The tidal boundary corresponds to mean high water spring tide exceeded 10 percent of the time (MHWS-10).	• Unchanged from LEAD model
Climate change	Rainfall: Total rainfall depths are increased, and hyetograph intensities adjusted to account for future climate scenarios. Two scenarios are considered: • 2.1°C temperature increase to year 2090: 1% AEP rainfall increased 16.8% • 3.8°C temperature increase to year 2110: 1% AEP rainfall increased 32.7% Sea level rise: Tidal boundary is increased by 1 m to account for sea level rise under future climate scenarios. Tidal boundary with climate change considered is 3.05 mRL (AVD46).	• Unchanged from LEAD model
Initial conditions	Initial conditions are set equal to the downstream tidal boundary condition.	• Unchanged from LEAD model
Model connections	Runoff: Rainfall converted to runoff is 'loaded' directly into the urban network model. Urban/river/floodplain: 3-way coupled model with connections between urban stormwater network, open channel 1D extents, and 2D floodplain.	• Standard link connection added where 1D Tennessee branch enters newly 2D waterway. • Urban-river ('MU-M11') connections updated to Urban-floodplain ('MU-M21') links in newly 2D areas. • Minor adjustments made to Tennessee branch river-floodplain connections (lateral links) for neatness and model stability. • No other changes to LEAD model connections.

Note A: AEP = annual exceedance probability

Figure 3.2 below shows the key features of the Harania BASE model. The existing culvert at the Tennessee Avenue embankment (and location of proposed works) is named “East of Bicknell Rd”.

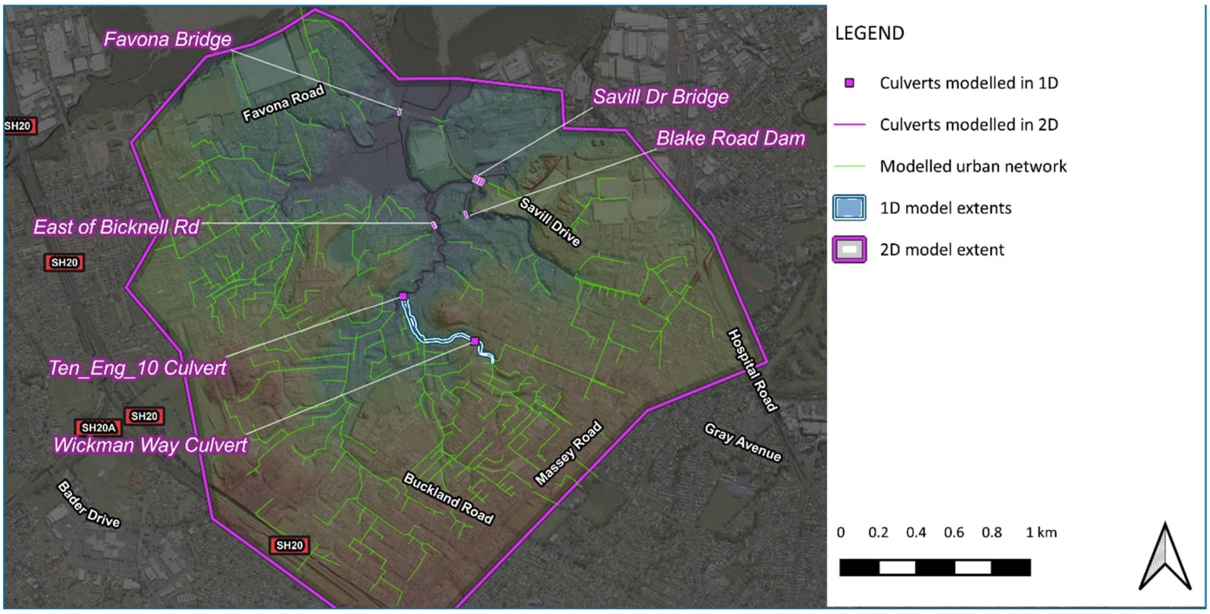


Figure 3.2: BASE model schema

The spatially varying roughness of the areas converted to 2D for the Harania BGN model are shown in Figure 3.3 below.

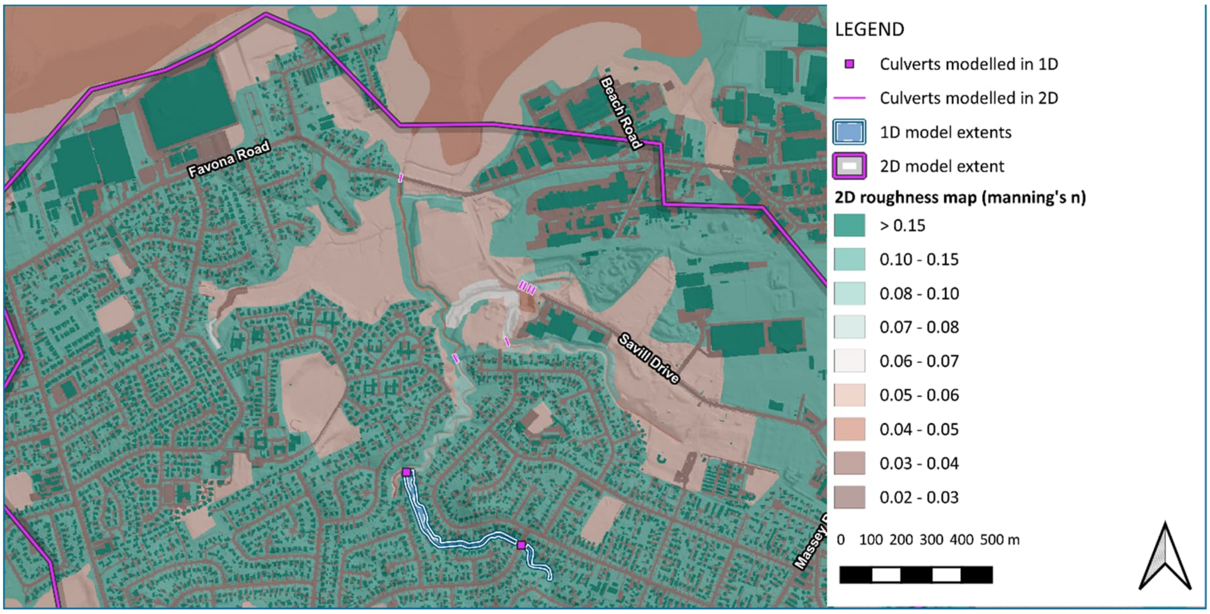


Figure 3.3: Spatially varying roughness in the Harania BGN model

4 Tennessee Bridge hydraulic model

The Tennessee pipe bridge is represented in the Harania BGN model for the 'post-project' scenario. The existing embankment is removed from the topography. A summary of the changes made to the baseline ('BASE') hydraulic model to establish the Tennessee Bridge ('TB01') hydraulic model are illustrated in Figure 4.1 and outlined in Table 4.1 below.

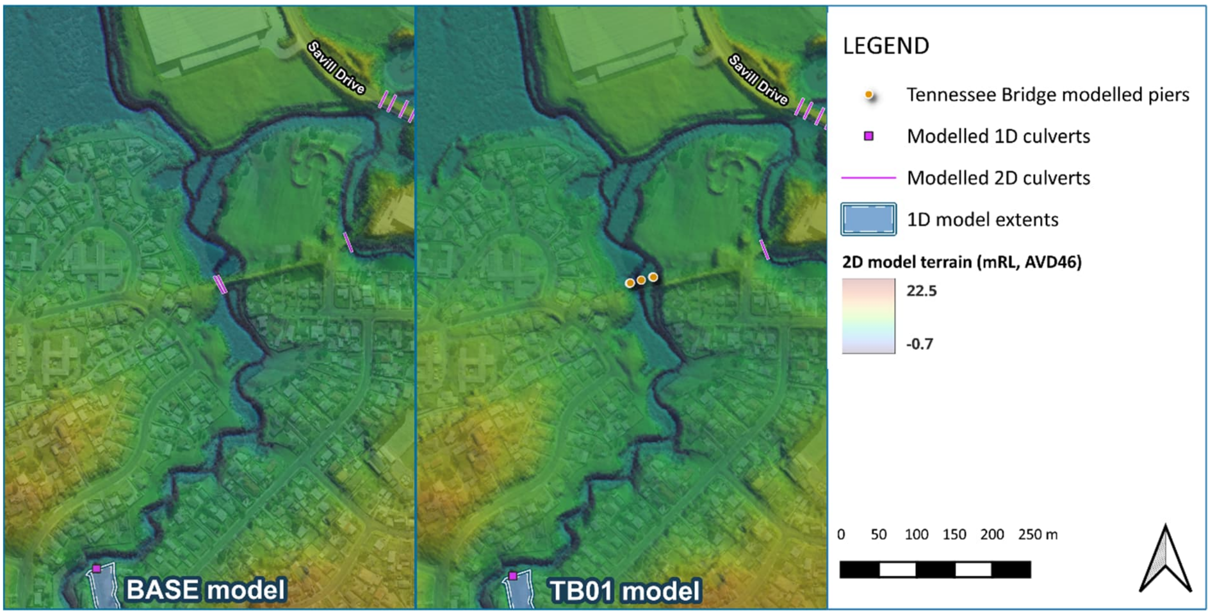


Figure 4.1: TB01 model differences from BASE model

Table 4.1: Harania BGN Tennessee Bridge model summary

Model element	Model summary	Changes from Baseline Model ('BASE')
Model name	• Harania Blue-Green Networks Tennessee Bridge model, "HaraniaBGN_TB01"	• Updated for post-project model
Model version	• *202408_v05*	• Updated for post-project model. • Note that model versioning is implemented independently between pre-/post-project (BASE/TB01) scenarios.
Software		• Unchanged from BASE
Datums		• Unchanged from BASE
Extent		• Unchanged from BASE
Schema		• Unchanged from BASE
Topography	Tennessee Avenue embankment removed and replaced with channel topography from proposed design surface provided by Blue-Green Networks project team ('*Tennessee Ave Design Triangles.dwg'*, August 2024*).* Refer Figure 4.1.	• Topography outside of Tennessee Bridge project extent is unchanged from BASE model.
Roughness		• Unchanged from BASE
Hydraulic structures	2D culvert through existing Tennessee Avenue embankment (*East of Bicknell Road* culvert) is removed. The piers of the proposed pipe bridge are represented using 2D pier structures in the model. The soffit of the proposed pipe bridge is not represented in the hydraulic model due to sufficient freeboard in the hydraulic model results, i.e. no hydraulic restriction occurs. Refer Figure 4.1.	• Structures outside of proposed Tennessee Bridge are unchanged from BASE model.
Urban network		• Unchanged from BASE
Hydrology		• Unchanged from BASE
Downstream boundary		• Unchanged from BASE
Climate change		• Unchanged from BASE
Initial conditions		• Unchanged from BASE
Model connections		• Unchanged from BASE.

5 Modelled scenarios

The scenario naming convention for the hydraulic model generally follows the Auckland Council 2023 Stormwater Modelling Specifications. Details of the naming convention are described below.

- Part 1 - Hydraulic model details:
  - Model name, project scenario, model version
  - E.g. *HaraniaBGN_BASE_202408_v05*
- Part 2 – Boundary condition details:
  - Table 5.1: Boundary condition ID's in hydraulic model scenario naming

Boundary condition	ID in model name	Details
Hydrological land use	ED	Existing development
	MPD	Maximum probable development
Rainfall climate change	HCLM	"Historic climate", i.e. existing climate or 0°C of warming
	21CC	2.1°C temperature increase from climate change
	38CC	3.8°C temperature increase from climate change
Storm event	001AEP	1% AEP[A] (24-hour duration) storm
Tailwater condition	TWA	MHWS-10[B] (2.05 mRL, AVD46)
	TWB	MHWS-10 + 1 m SLR[C] (3.05 mRL, AVD46)
	TWC	MLWS[D] (-0.78 mRL, AVD46)

Note A: AEP = annual exceedance probability

Note B: MHWS-10 = Mean high water spring tide exceeded 10 percent of the time.

Note C: SLR = sea level rise.

Note D: MLWS = mean low water spring tide.

  - E.g. *MPD21CC001AEPTWA*
- Example:
  - The proposed Tennessee Bridge model with a fully developed catchment, 1% AEP storm under current climate and a 'low' tide level would be denoted as:

HaraniaBGN_TB01_202408_v05_MPDHCLM001AEPTWC

Table 5.2 below details the modelled simulations that have been completed for this project. Table 5.3 details the modelled simulations that have been completed

Table 5.2: Harania BGN simulation matrix

No.	Project scenario	Land use[A]	Rainfall CC[B]	Rainfall depth (mm)	Storm event	Tailwater condition
1	Existing ('BASE')	MPD	Existing, 0°C	192	1% AEP[C]	MLWS[D]
2	Existing ('BASE')	MPD	Existing, 0°C	192	1% AEP	MHWS-10[E]
3	Existing ('BASE')	MPD	2.1°C	224	1% AEP	MLWS
4	Existing ('BASE')	MPD	2.1°C	224	1% AEP	MHWS-10
5	Existing ('BASE')	MPD	2.1°C	224	1% AEP	MHWS-10 + 1 m SLR[F]
6	Existing ('BASE')	MPD	3.8°C	255	1% AEP	MLWS[F]
7	Existing ('BASE')	MPD	3.8°C	255	1% AEP	MHWS-10
8	Existing ('BASE')	MPD	3.8°C	255	1% AEP	MHWS-10 + 1 m SLR
9	Tennessee Bridge ('TB01')	MPD	Existing, 0°C	192	1% AEP	MLWS
10	Tennessee Bridge ('TB01')	MPD	Existing, 0°C	192	1% AEP	MHWS-10
11	Tennessee Bridge ('TB01')	MPD	2.1°C	224	1% AEP	MLWS[F]
12	Tennessee Bridge ('TB01')	MPD	2.1°C	224	1% AEP	MHWS-10
13	Tennessee Bridge ('TB01')	MPD	2.1°C	224	1% AEP	MHWS-10 + 1 m SLR
14	Tennessee Bridge ('TB01')	MPD	3.8°C	255	1% AEP	MLWS
15	Tennessee Bridge ('TB01')	MPD	3.8°C	255	1% AEP	MHWS-10
16	Tennessee Bridge ('TB01')	MPD	3.8°C	255	1% AEP	MHWS-10 + 1 m SLR

Note: Model versions *HaraniaBGN_BASE_202408_v05* and *Harania_TB01_202408_v05.*

Note A: Hydrological land use, altered via percent impervious.

Note B: Rainfall CC = climate change scenario applied to rainfall, in terms of temperature increase.

Note C: AEP = annual exceedance probability. 24-hour duration as per TP108 methodology.

Note D: Mean low water spring tide.

Note E: Mean high water spring tide exceeded 10 percent of the time.

Note F: SLR = sea level rise.

Table 5.3: Harania BGN simulation matrix (2024 rainfall update)

No.	Project scenario	Land use	Rainfall CC	Rainfall depth (mm)	Storm event	Tailwater condition
1	Existing ('BASE')	MPD	3.8°C	332	1% AEP	MHWS-10 + 1 m SLR
2	Tennessee Bridge ('TB01')	MPD	3.8°C	332	1% AEP	MHWS-10 + 1m SLR

Note: Model versions *HaraniaBGN_BASE_202408_v11* and *Harania_TB01_202408_v11.*

Note: Post-2023 flood historic climate rainfall depth is 250 mm.

6 Model limitations and assumptions

The accuracy of model outputs is naturally limited to the quality and availability of data inputs to the model. The Harania BGN hydraulic model has been developed from a catchment-wide scale model for the purpose of assessing relative effects. A site-specific assessment is recommended for any use case that differs from the model purpose.

Listed below are a summary of limitations or assumptions that end users of the model will need to consider when interpreting and using the results.

- It is understood that LEAD Alliance and Auckland Council carried out quality assurance checks on the hydraulic models in development. Additional quality assurance checks were not carried out on the received LEAD model prior to commencing this project.
- For limitations and assumptions associated with the original Māngere Inlet FHM or LEAD models, end users should refer to the appropriate documentation for these projects.
- Manning's n roughness values in the areas changed from 1D to 2D in the Harania BGN model are transposed directly from the received model 1D cross sections. 1D roughness values are typically higher than those for the equivalent 2D model. In the absence of calibration or validation, this is considered appropriate for a relative assessment.
- Flow-level (Q-h) plots for the modelled 2D culverts at the Tennessee Avenue embankment were compared with equivalent plots from HY-8 software. The results show that the 2D culverts in MIKE by DHI software have lower capacity at the same water level, allowing less flow through the embankment in the pre-development scenario than what may be expected. There are no culverts at this location in the post-development scenario.
- The soffit of the proposed pipe bridge is not represented in the hydraulic model. This is on the assumption that the proposed bridge soffit (at 4.34 mRL NZVD2016 = 4.62 mRL AVD46) is higher than the most extreme modelled water level (~3.9 mRL AVD46 for the MPD post-2023 floods 1% AEP with 3.8°C climate change storm, MHWS-10 tailwater with 1 m sea level rise). Any changes to the soffit of the pipe bridge or additional model scenarios will require users to confirm that the soffit of the proposed bridge is not reached (and therefore does not affect hydraulic performance).
- The piers of the proposed bridge are represented in the post-project model as 2D pier structures. These calculate the drag imposed by each pier within the grid (mesh triangle). The geometry of each pier is not explicitly represented in the 2D mesh or topography. The results are therefore limited in the resolution that can be provided at the pier structures.

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