Appendix 29

Coastal Processes Effects Assessment

Eastern Busway

EB3 Commercial and EB4 Link Road

Coastal Process Effects Assessment

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Eastern Busway

Quality Information

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List of Abbreviations and Definitions

Abbreviation and Definitions	Description
AEE	Assessment of Effects on the Environment
ARI	Annual Recurrence Interval
AUP(OP)	Auckland Unitary Plan (Operative in part)
BPO	Best Practicable Option
EB1	Eastern Busway 1 (Panmure to Pakuranga)
EB2	Eastern Busway 2 (Pakuranga Town Centre)
EB3C	Eastern Busway 3 Commercial (Pakuranga Creek to Botany)
EB3R	Eastern Busway 3 Residential (SEART to Pakuranga Creek)
EB4L	Eastern Busway 4 Link Road (link between Tī Rākau Drive and Te Irirangi Drive, Botany Town Centre)
EBA	Eastern Busway Alliance
HAT	Highest Astronomical Tide
IPCC	Intergovernmental Panel for Climate Change
km	Kilometre(s)
m	Metre(s)
MHWS	Mean High Water Spring. Calculated from tidal constituents M2 + S2 (Stephens et al, 2016)
MLWS	Mean Low Water Spring
MSE	Mechanically Stabilized Earth Walls
MSL	Mean Sea Level
Mw	Moment magnitude – a scale for ranking earthquakes by size
NoR	Notice of Requirement
NZCPS	New Zealand Coastal Policy Statement 2010
NZVD2016	New Zealand Vertical Datum 2016
RCP	Representative Concentration Pathway
RL	Relative Level
RTN	Rapid Transit Network
RMA	Resource Management Act 1991
SLR	Sea Level Rise
SSESCP	Site Specific Erosion and Sediment Control Plan
SSP	Shared Socioeconomic Pathways
VLM	Vertical Land Movement

Executive Summary

The purpose of this assessment of coastal process effects is to inform the AEE relating to the NoRs, and required regional consents and consents required under National Environmental Standards for EB3C and EB4L stages of the Eastern Busway Project (the Project) and identify the ways in which any adverse effects will be mitigated.

The Project is a package of works focusing on promoting an integrated, multi-modal transport system to support population and economic growth in southeast Auckland. This involves the provision of a greater number of improved public transport choices and aims to enhance the safety, quality and attractiveness of public transport and walking and cycling environments. The Project will be delivered in several stages.

This assessment is limited to works that are in or adjacent to the Coastal Marine Area (CMA) which extends across part of the Eastern Busway 3 Commercial (EB3C) project area in Pakuranga Creek. Within EB3C these works include: construction of two new Bridges (Bridge A and Bridge B) and scour protection (as necessary); a reinforced embankment at the northern end of Bridge B which includes a 549m^2 coastal reclamation in the CMA of imported fill, rip rap and permanent wick drains; a small retaining wall (RW304) between Bridge A and B which supports a 4m^2 reclamation in the CMA, two new stormwater outfalls (including scour protection) and two upgraded outfalls into the CMA. There are no works in Eastern Busway 4 Link Road (EB4L) that are in or adjacent to the CMA.

EB3C will cross Pakuranga Creek at Tī Rākau Drive, where the creek is a shallow tidal channel approximately 180 m wide with about half of the channel in mangrove vegetation. The spring tidal range is 2.96 m. To the east of the main channel is a small tidal estuary predominantly covered in mangrove vegetation, which will be crossed by EB3C (Bridge B).

Pakuranga Creek is a low energy environment, being exposed to limited wave heights of 0.5 m in 100-year wind events and maximum current velocities of <4 m/s in 100-year return period flows.

The 100-year return period storm tide level is 0.72 m above Mean Highwater Springs (MHWS) and is contained within the creek banks. However, projected maximum sea level rise (SLR) due to climate change and vertical land movement under the SSP8.5+ scenario over the next 80 years could result in these extreme levels overtopping the western bank, and the MHWS contour being at the top of bank in 100 years.

The risk of potential effects of construction and operation of the EB3C works on coastal processes range from low to indiscernible. Although the risk of bank and bed scour from the temporary removal of mangrove vegetation within the CMA for construction is low, it is recommended that re-planting of these areas (approximately 100 m^2 for bridges and retaining wall, and 300 m^2 for the stormwater outfalls), occurs following construction as this will reduce the potential for scour to occur over a longer period.

For potential effects of permanent occupancy, the current Bridge A design includes the placement of riprap for scour protection around the eastern abutment piles, however no scour protection is currently shown for the Bridge A piles located in the main Pakuranga Creek channel. The Structure Design Report notes that further scour modelling is required to confirm that this will not result in pile instability or failure. This modelling will be provided at detailed design. If modelling shows that scour protection is required that must be implemented as required in the conditions. If that occurs, the effects associated with the scour protection will only result in potential small, localised effects on coastal processes.

There are no effects on water levels, flow and scour from the piles and abutment of Bridge B, and very low potential effects on these processes from the placement in the estuary of the embankment north of Bridge B.

While the carriage and bridge decks of the EB3C works are well above the projected future sea level in 100 years under the highest SLR scenario (SSP8.5+), there are risks of future coastal inundation on the west bank of the Pakuranga Creek and up to 30 m erosion around the edges of the creek. However, these risks are unlikely to occur for the next 70 years and can be mitigated by appropriate engineering design of the EB3C embankments and bridge abutments in the future by engineered methods should they be required.

There is no tsunami inundation risk to the EB3C works.

1 Introduction

1.1 Overview of the Eastern Busway Project

The Eastern Busway Project (the Project) is a package of works focusing on promoting an integrated, multi-modal transport system to support population and economic growth in southeast Auckland. This involves the provision of a greater number of improved public transport choices and aims to enhance the safety, quality and attractiveness of public transport and walking and cycling environments. The Project includes:

- 5 km of two-lane busway
- Two new bridges for buses across Pakuranga Creek (Bridges A and B)
- A new bridge for buses crossing Guys Reserve and Whaka Maumahara Reserve (Bridge C)
- Improved active mode infrastructure (walking and cycling) along the length of the busway
- Three intermediate bus stations
- Two major interchange bus stations.

The project forms part of the previous Auckland Manukau Eastern Transport Initiative (AMETI) programme (the programme) which includes a dedicated busway and bus stations between Panmure, Pakuranga and Botany town centres. The dedicated busway will provide an efficient rapid transit network (RTN) service between the town centres, while local bus networks will continue to provide more direct local connections within the town centre areas. The project also includes new walking and cycling facilities, as well as modifications and improvements to the road network.

The programme includes the following works which do not form part of the Eastern Busway Project:

- Panmure Bus and Rail Station and construction of Te Horeta Road (completed)
- Eastern Busway 1 (EB1) – Panmure to Pakuranga (completed).

The Eastern Busway project consists of the following packages:

- Early Works Consents – William Roberts Road (WRR) extension from Reeves Road to Tī Rākau Drive (LUC60401706); and Project Construction Yard at 169 – 173 Pakuranga Road (LUC60403744).
- Eastern Busway 2 (EB2) – Pakuranga Town Centre, including the Reeves Road Flyover (RRF) and Pakuranga Bus Station
- Eastern Busway 3 Residential (EB3R) – Tī Rākau Drive from the South-Eastern Arterial (SEART) to Pakuranga Creek, including Edgewater and Gossamer Intermediate Bus Stations
- Eastern Busway 3 Commercial (EB3C)– which commences from Riverhills Park along Tī Rākau Drive to Botany, including two new bridges, and an offline bus route through Burswood (**this Assessment**)
- Eastern Busway 4 Link Road (EB4L) – Guys Reserve to the Botany Town Centre, including a link road through Guys Reserve and Whaka Maumahara Reserve to Te Irirangi Drive/Town Centre Drive intersection (**there are no works in or adjacent to the CMA, therefore EB4L is not directly relevant to this coastal process effects assessment**).

The overall Project is shown in Figure 1-1 below.

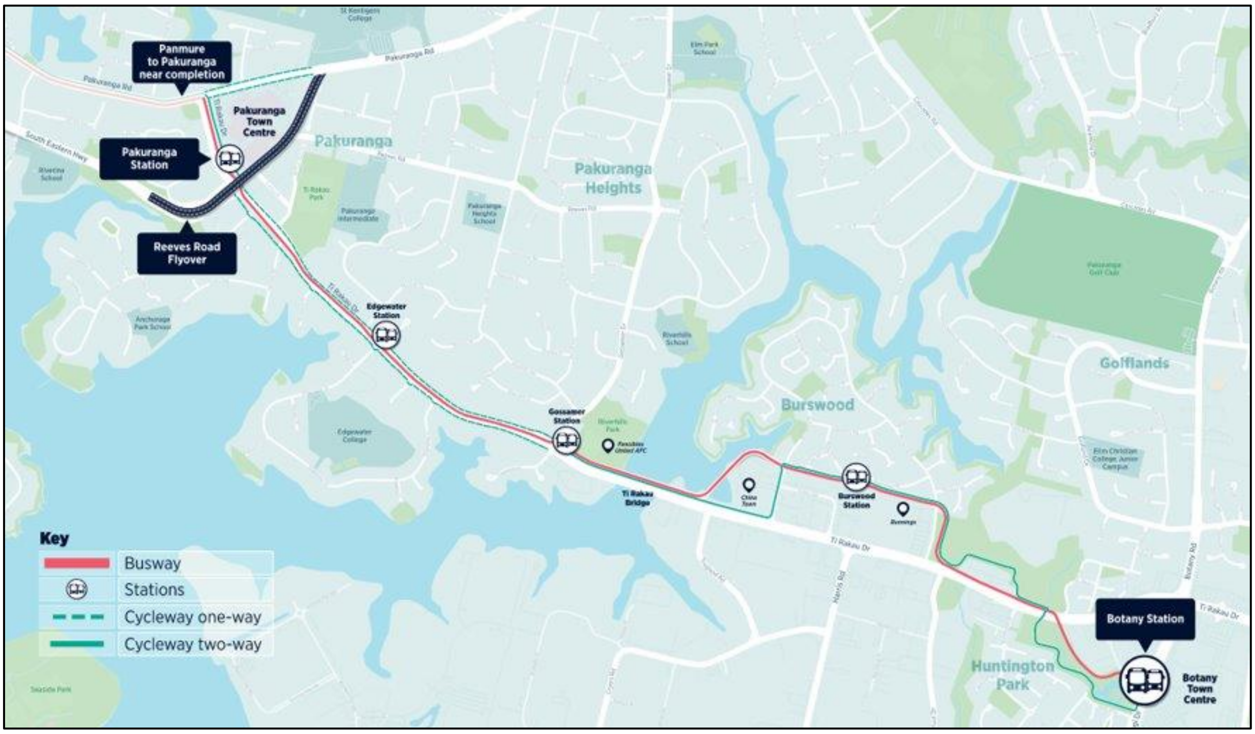

Figure 1-1 Eastern Busway Project alignment

1.2 Project Objectives

The Project objectives are:

1. Provide a multimodal transport corridor that connects Pakuranga and Botany to the wider network and increases choice of transport options.
2. Provide transport infrastructure that integrates with existing land use and supports a quality, compact urban form.
3. Contribute to accessibility and place shaping by providing better transport connections between, within, and to the town centres.
4. Provide transport infrastructure that improves linkages, journey time and reliability of the public transport network.
5. Provide transport infrastructure that is safe for everyone.
6. “Provide or Safeguard future” transport infrastructure at (or in the vicinity of) Botany Town Centre to support the development of strategic public transport connection to Auckland Airport.

2 Proposal Description

The following sections provide a brief description of both EB3C and EB4L. As previously indicated, works associated with EB4L will not generate effects on the CMA however for completeness, a description of that stage of the Project is included below.

These descriptions consist of the construction and operation of both EB3C and EB4L packages, with further details provided in the AEE and NoRs. A full set of proposed plans is attached to the AEE.

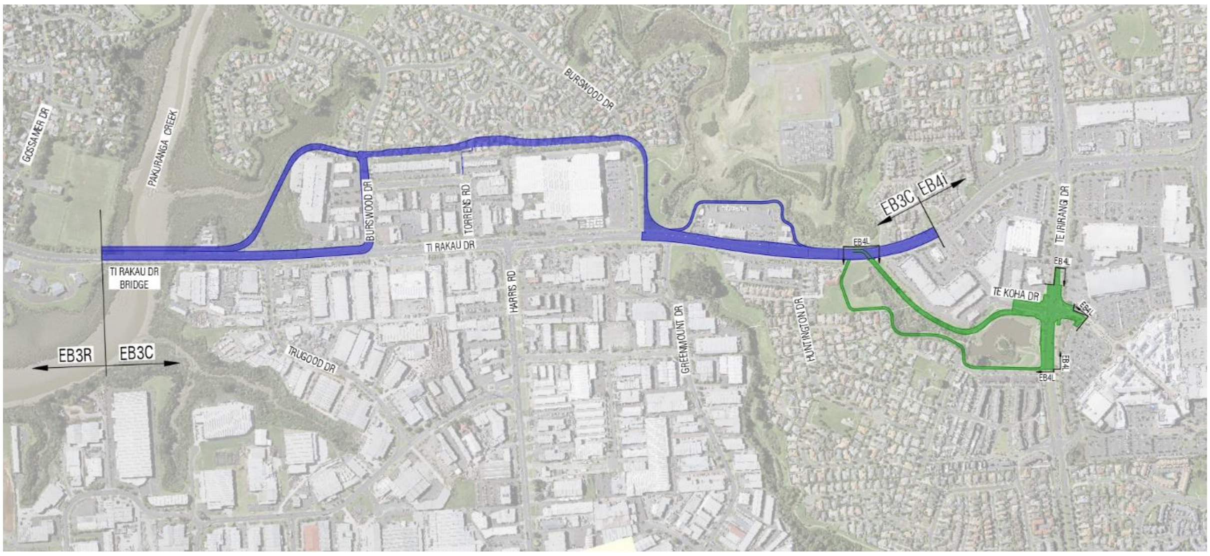

Figure 2-1 Eastern Busway 3 Commercial and 4 Link Road Project Extent

2.1 Eastern Busway 3 Commercial

The proposed EB3C works will involve the establishment of an 'off-line' busway, cycleway, and associated stormwater upgrades. These works will take place within existing road reserves, Council reserves[1] and privately held land within the proposed works footprint (refer Figure 2-2). The extent of works for EB3C runs between Riverhills Park (i.e., adjacent to the terminus of the EB3R package) in the west to Guys Reserve in the east, through the suburbs of Burswood and East Tāmaki.

The busway will be largely off-line (i.e., outside the current Tī Rākau Drive corridor), first crossing Pakuranga Creek by way of a new two-lane bridge (Bridge A) including abutments[2] and scour protection. It will then cross a coastal headland at 242 Tī Rākau Drive (a Mobil branded service station), and then an embayment within which a retaining wall, and a 4m^2 coastal reclamation will be constructed. The busway will cross a second headland at 254 Tī Rākau Drive (currently occupied by a pet store), before crossing a mangrove filled bay to the west of 262 Tī Rākau Drive (the 'Chinatown' retail business) via a second bridge (Bridge B). Bridge B will include two abutments with scour protection and will require construction of a reinforced embankment at its northern end involving imported fill, rip rap and permanent wick drains and 549m^2 of CMA reclamation. In parallel, a retaining wall will be constructed to the eastern side of the embankment. Following this, the busway runs between the commercial area and residential area north

[1] Including Burswood Esplanade Reserve and Bard Place Reserve
[2] The western abutment and associated scour protection was included in the EB3R consenting package

of Tī Rākau Drive, crossing several residential sites. The busway also crosses Burswood Drive twice, with raised signaled crossings established to control both the busway and road traffic.

A new 'intermediate' style bus station will be established at Burswood, before the busway then crosses over Burswood Esplanade Reserve and onto a widened Tī Rākau Drive (by the Howick and Eastern bus depot). The busway will then run beside the eastbound lanes of Tī Rākau Drive, before crossing over Tī Rākau Drive to connect with EB4L at Guys Reserve.

The busway will include a new cycleway, which will largely run parallel to the busway for most of this section of the Project. The exceptions to this include Bridge B, between 254 Tī Rākau Drive and Burswood Esplanade (west) – for this section the cycleway will continue along Tī Rākau Drive before turning into Burswood Drive West, as well as where the cycleway runs behind the Howick and Eastern bus depot.

Other works included in EB3C are the relocation of existing utility services, the provision of new or upgraded stormwater infrastructure and open space upgrades. Stormwater works will involve new outfalls discharging to Pakuranga Creek (and its tributaries) and rain gardens.

Lastly, EB3C involves the establishment of two laydown areas, one at 242 Tī Rākau Drive and the other within the boundaries of Burswood Esplanade Reserve. Both laydown areas are located on land that will be occupied by the Project upon its completion.

Figure 2-2 EB3 Commercial Extent of Works.

2.2 Eastern Busway 4 Link Road

The EB4L works will involve the establishment of an 'off-line' dedicated two-way busway, shared pathway, and stormwater upgrades. These works will take place in Guys Reserve, Whaka Maumahara Reserve, existing road reserve and Botany Town Centre land for the intersection improvements on Town Centre Drive.

EB4L commences south of Tī Rākau Drive, crossing through Guys Reserve, Whaka Maumahara Reserve and ending at the intersection of Te Irirangi Drive/Town Centre Drive.

The works will primarily involve the construction of a new two-way busway corridor which will run along the eastern side of Guys Reserve and Whaka Maumahara Reserve to provide access for bus services between Pakuranga and Botany. The two-way busway is designed to integrate with EB3C and be a continuation of the EB3C busway.

This section of the busway will feature a bridge (Bridge C) approximately 350m long. This bridge is needed due to the sloping topography of the Reserves.

The busway will then connect to Te Irirangi Drive, following alterations to the existing Te Irirangi Drive/Town Centre Drive intersection.

A shared pathway and minor retaining walls will also be constructed along the southern and western boundaries of Guys Reserve and Whaka Maumahara Reserve. The shared pathway will connect to existing walkways and will terminate at Te Irirangi Drive.

A new shared pathway and retaining wall will also be constructed along the western boundary of Te Irirangi Drive and is partially located within the Whaka Maumahara Reserve.

A new stormwater outfall (including riprap) will be constructed within Guys Reserve. The outfall will discharge stormwater over scour protection prior to its entry into a tributary of Pakuranga Creek. Additionally, a new stormwater connection will be constructed in Whaka Maumahara Reserve, adjacent to Te Irirangi Drive. This new connection will discharge via an existing outfall into the existing stormwater pond within the Reserve.

A construction laydown area will also be established within Guys Reserve, adjacent to Tī Rākau Drive and 47C Huntington Drive. A second laydown area will be established in Whaka Maumahara Reserve, between the existing stormwater pond and Te Irirangi Drive. Construction access will also be gained from Te Koha Road beside VTNZ's vehicle inspection premise located at 451 Tī Rākau Drive.

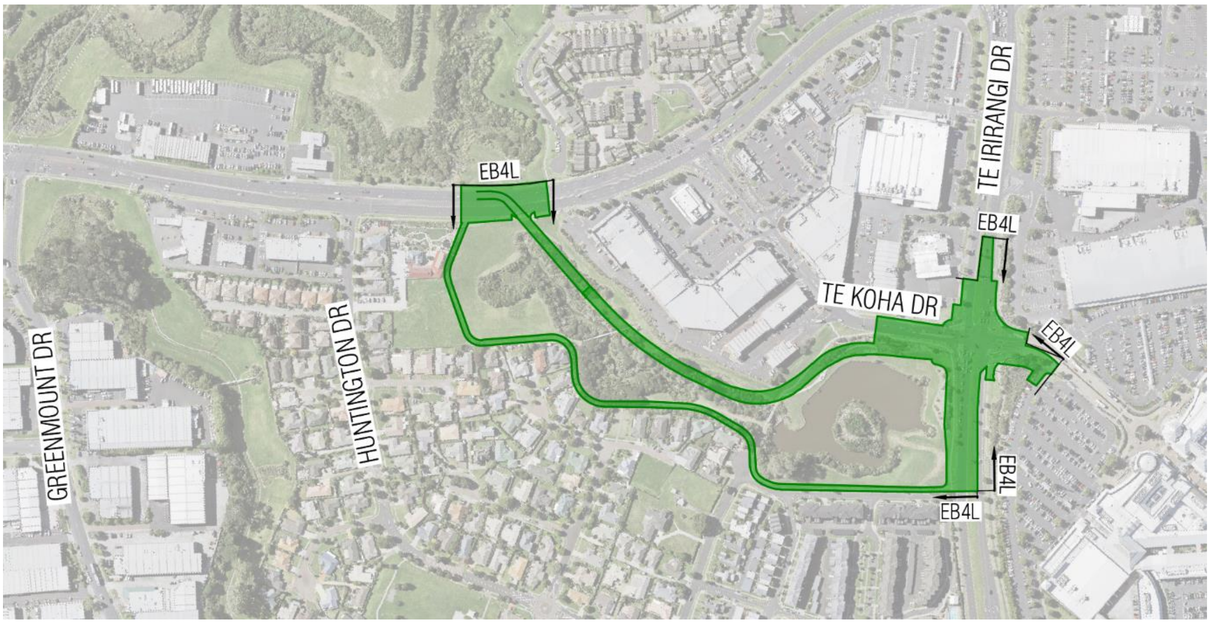

Figure 2-3 Eastern Busway 4 Link Road Project Area

3 Specialist Assessment

Chapter Summary

The potential effects on coastal processes from the construction and operation of the EB3C works in the CMA relate primarily to Bridge A and Bridge B, new and upgraded stormwater outfalls and retaining wall RW304 that are located in or near to the main channel of Pakuranga Creek and a small tributary estuary near the Chinatown site.

3.1 Assessment Content

This report describes the assessment of coastal process effects associated with the operation and construction of EB3C section of the Project. As previously indicated, the scope of this assessment also covers EB4L. However, there are no works in EB4L that are in or adjacent to the CMA, and therefore works associated with EB4L will not generate effects on the CMA and have not been further considered by this assessment.

Its purpose is to assess the coastal process effects of the proposal and inform the AEE relating to the NoRs and regional consents required under the AUP(OP), and consents required under National Environmental Standards and identify the ways in which any adverse effects will be appropriately minimised and managed.

The coastal process effects assessment involves:

- Identifying the coastal processes of tides, extreme water levels, waves and sediment transport operating in and adjacent to the CMA of the lower Pakuranga Creek catchment that intersects with the footprint of EB3C
- Assessing the effects of the construction and operation of the infrastructure of EB3C located in or adjacent to the CMA on the existing environment including the typical flow of tidal water, extreme water levels including sea level rise and tsunami, the stability of the bed and banks of the creek, and the transport of sediment within the creek bed and environments.

3.2 Specific Project Elements

The specific Project elements in EB3C that are relevant to coastal process effects relate to:

- Bridge A - The proposed new Tī Rākau Drive Bridge across the main channel of Pakuranga Creek This includes the construction of the eastern abutment and the associated scour protection and scour protection around Bridge A piles (if required by modelling)
- Bridge B - The proposed new bridge across the estuary of a small tributary of Pakuranga Creek upstream of Tī Rākau Drive, including a reinforced embankment at its northern end involving reclamation of 549m^2 of the CMA
- Small retaining wall between the above two bridges which is located in the CMA. This involves 4m^2 of reclamation
- Two new outfalls and two upgraded stormwater outfalls located in the CMA
- Scour protection works located in the CMA associated with two new and two upgraded stormwater outfall that discharge into the CMA.

3.3 Permanent Structures

Figure 3-1 shows the proposed EB3C route in relation to the CMA boundary, which is defined by the MHWS contour. Structures on the creek banks and mangrove estuaries above the MHWS contour are included in this assessment as they have the potential to interact with coastal processes when water levels are higher than MHWS, which is approximately 12% of the time when accounting for extreme water level events or are likely to be affected by coastal processes with projected future sea level rise.

The structures included in this assessment include two new bridges – Bridge A on Tī Rākau Drive and Bridge B adjacent to China Town as shown in Figure 3-1, a small retaining wall (RW304) between these two bridges (which involves $4m^2$ of reclamation of the CMA), works associated with two new stormwater outfalls and the upgrade of two existing stormwater outfalls. A description of each of these structures in EB3C is included below.

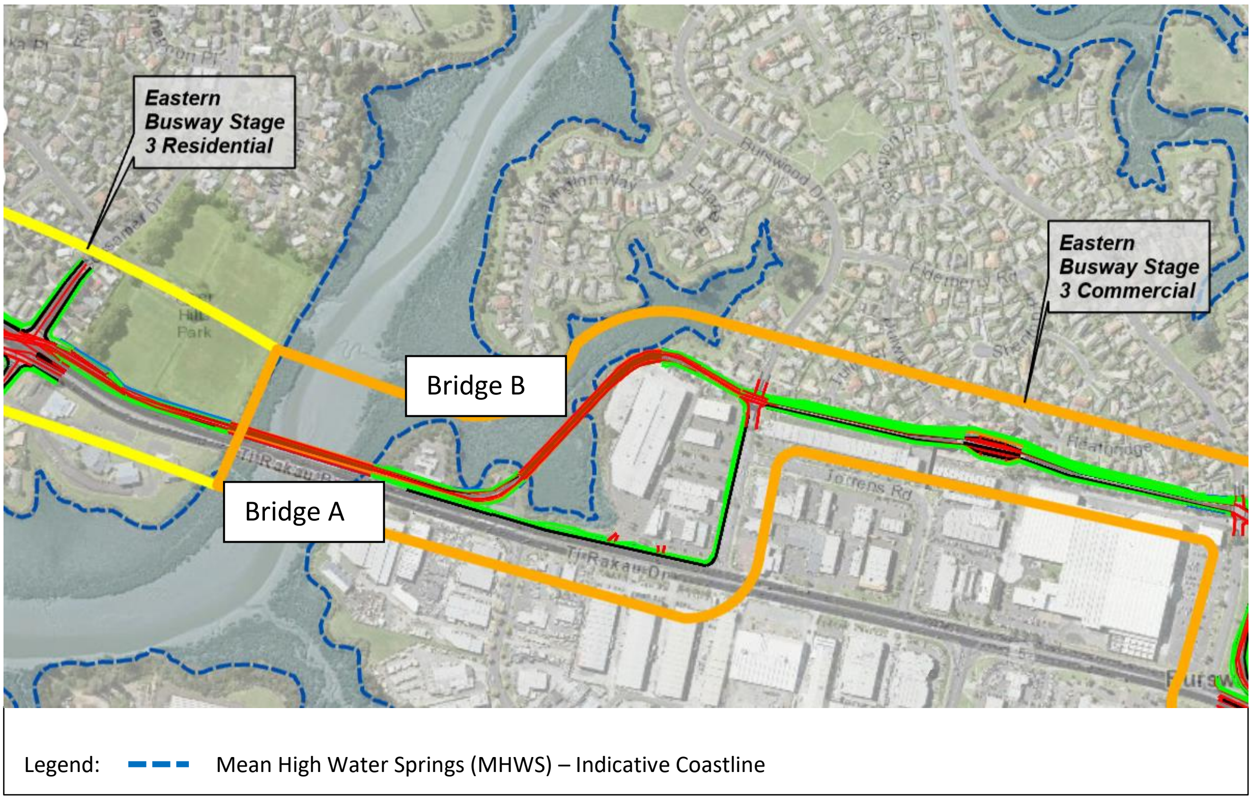

Figure 3-1 EB3C works which includes the indicative CMA boundary

3.3.1 Bridge A (Tī Rākau Drive)

The 183 m long new bridge over Pakuranga Creek at Tī Rākau Drive is proposed to be constructed from reinforced insitu and precast concrete components including 4 piers, each consisting of two 1.5 diameter concrete piles giving a total of 8 piles in the CMA (Construction Methodology Report), which the Structural Design Report (p15) states will be 19-21 m long. The Construction Methodology Report (Table 4) states that collectively these 8 piles will occupy 14 m^2 of the CMA, being a 50/50 mix of vegetated channel edge (4 piles) and unvegetated central tidal channel (4 piles).

No scour protection is currently proposed for the four Bridge A piles located in the unvegetated creek channel. However, the Structural Design Report notes that further scour modelling is required to confirm that this will not result in pile instability or failure. If this modelling indicates that scour protection around these piles is required, this could be added at the final design stages with rock riprap placed around each pile. Should this be required, the Construction Methodology Report (Table 4) states that this would involve an additional total footprint in the CMA of 147 m^2 across 4 piles, however does not involve any additional mangrove vegetation clearance.

The Structural Design Report (p15) states that the bridge abutments consist of reinforced concrete abutment beams supported by three 1.5 m diameter reinforced concrete piles, with the north side of the approach abutment being mechanically stabilized earth walls (MSE) comprising of layers of compacted fill with geogrid. The Structural Design Report (p20) states that scour protection will be provided on the eastern abutment to migrate potential scour issues in extreme flow events (i.e. 1000 year Annual Recurrence Interval (ARI) events), which will permanently occupy 30 m^2 of the CMA (Construction Methodology Report, Table 4). The design report states that scour protection is not required on the western abutment.

3.3.2 Bridge B (China Town Bridge)

The proposed 108 m long new bridge across the small tidal tributary of the Pakuranga Creek located adjacent to China Town is also proposed to be constructed from reinforced insitu and precast concrete components, including three single 1.8 m diameter insitu reinforced concrete bored piles. Collectively the three piles in the CMA will occupy an area of 8 m^2 (Construction Methodology Report, Table 4), all being located in intertidal areas currently occupied by mangroves as shown in Figure 3-2. The Bridge B abutments will be the same as for Bridge A, reinforced concrete beams resting on reinforced concrete piles. Some of the scour protection (i.e. rip rap) on the northern abutment of Bridge B also falls within the CMA, covering an area of 64 m^2 (Construction Methodology Report, Table 4).

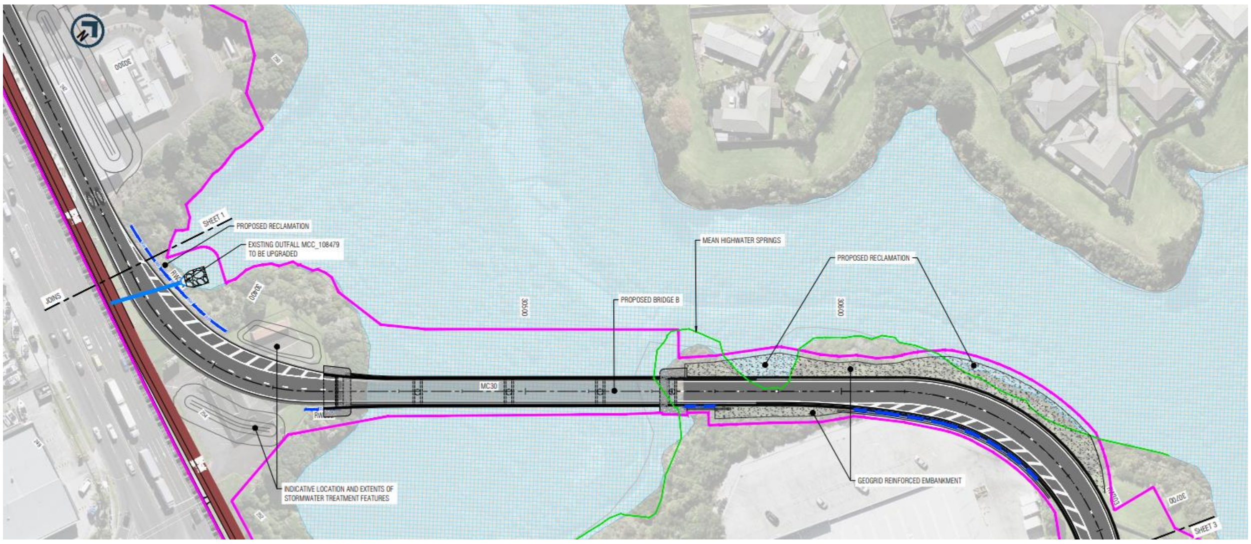

Figure 3-2 Bridge B and embankment in relation to MHWS position (green line).

The northern abutment of Bridge B will join a MSE embankment behind China Town, of which 549 m^2 will be a reclamation in the CMA over the two areas below MHWS as shown in Figure 3-2. Although there are only these two areas in the CMA, the majority of the rest of the embankment is located within the vegetated areas of the estuary above MHWS, therefore having a potential interaction with water levels in higher storm tides in the estuary. As shown in Figure 3-2, the embankment design includes rip rap toe protection along the full 125 m length of the estuary side, with a 20 m long retaining wall and a shorter 30 m length of rip rap along the China Town side. The design height of the embankment above the estuary bed varies from 6 m to 2 m along its length and has an elevation of over 7 m above MSL.

3.3.3 Permanent retaining wall (RW304)

The EB3C works include the construction of a permanent vertical concrete 2 m high retaining wall between Bridge A and Bridge B (between 242 and 254 Tī Rākau Drive). The section of the wall in the CMA is approximately 2 m long, and located 2 m from the CMA boundary, therefore would involve the permanent loss of approximately 4 m^2 of CMA.

3.3.4 Stormwater Outlets and Discharges

Figure 3-3 shows the location of the proposed stormwater outfalls. Two new outfalls (01A-1 and 09-1) will be constructed and existing outfalls MCC-108479 and MCC108409 will be upgraded. Permanent intertidal mangrove vegetation removal/occupation of the CMA will be approximately 25m^2 per outfall, which totals 100m^2. Temporary occupation and vegetation removal for the four outfalls will be 400m^2.

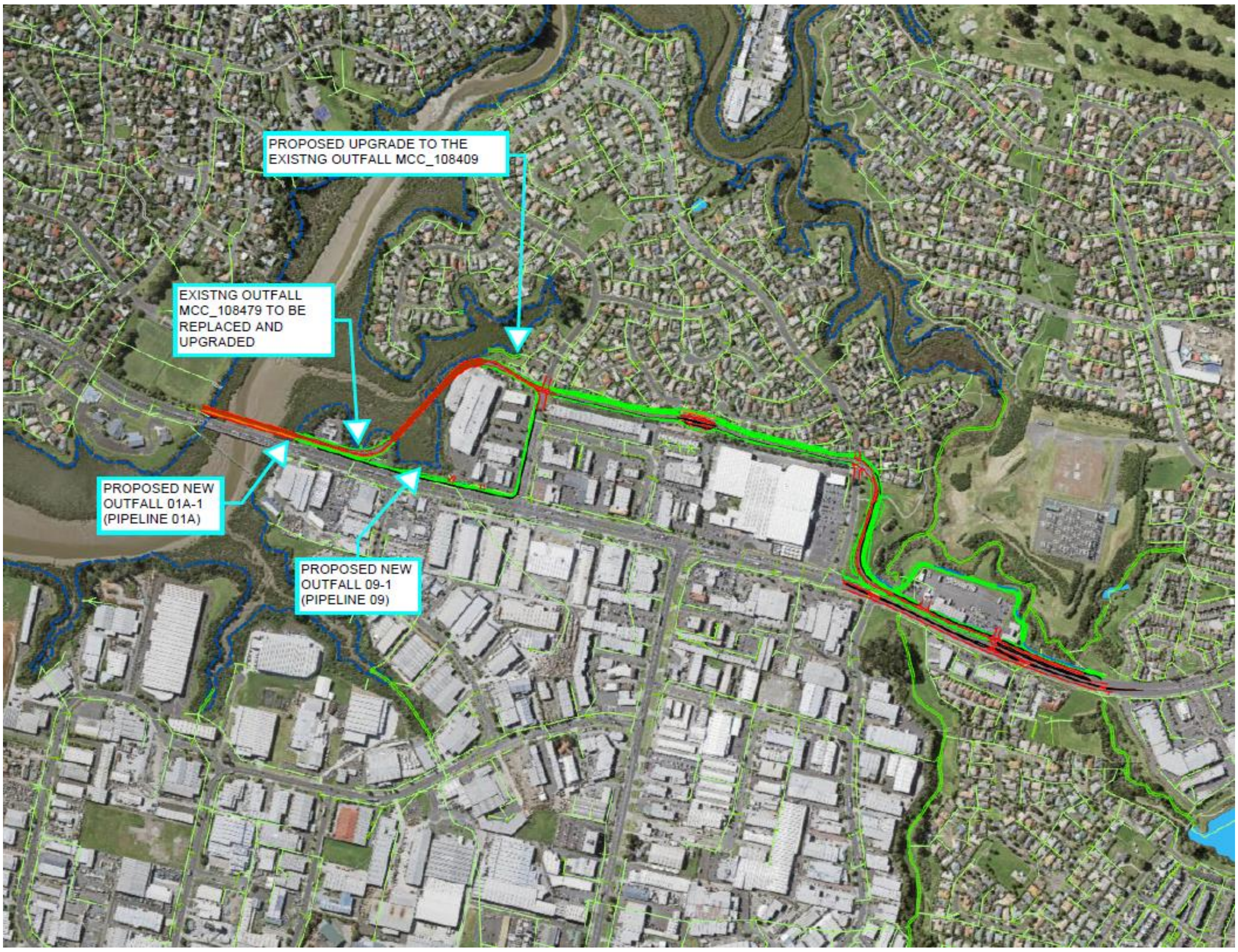

Figure 3-3 New Outfalls and Outfall Upgrades in the CMA

3.4 Proposed Construction Methodology

3.4.1 Bridge A (Tī Rākau Drive)

The Construction Methodology Report states that temporary staging will be required to undertake the bridge construction, that will involve the driving of approximately 60 piles of 0.7 m diameter of which 30 will be located within the CMA, which will temporarily disturb/occupy in the order of 23m2 of the CMA (Construction Methodology Report, Table 4), of which 10 m2 is existing mangrove vegetation. The Construction Methodology states that once the bridge is complete, every effort will be made to remove the temporary piles. If they cannot be removed, they will be cut off below ground/benthos level.

The construction of the eastern bridge abutment will disturb 50m2 of the CMA and (as indicated previously in relation to the bridge structures) permanently occupying 30m2 of the CMA.

3.4.2 Bridge B (China Town Bridge)

Temporary staging will also be required to undertake the construction of this bridge, which will involve the driving of approximately 30 piles of 0.7 m^2 diameter, temporarily disturbing/occupying 22 m^2 of CMA and existing mangrove vegetation (Construction Methodology Report, Table 4). As with Bridge A, the Construction Methodology Report states that once the bridge is complete, every effort will be made to remove the temporary piles. If they cannot be removed, they will be cut off below ground/benthos level.

The construction of the embankment from the northern abutment of Bridge B will include the installation of a series of permanent wick drains.

3.4.3 Construction of permanent retaining wall (RW304)

The Construction Methodology Report states that to allow construction of the retaining wall, it is proposed to drive sheet piles to a shallow depth to create a temporary wall and a dry area to build the base of the retaining wall. Once construction of the wall is complete, the sheet piles will be removed. The Construction Methodology Report (Table 4) estimates that approximately 70m^2 of mangrove vegetation will need to be removed/disturbed to enable construction of this wall.

3.4.4 Stormwater Outlets

The Construction Methodology Report (Table 4) indicates that the temporary occupation of and vegetation removal from the CMA for construction of the two new outfalls and two upgraded outfalls is estimated to be 100 m^2 per outfall, giving a total construction footprint in the CMA of 400 m^2.

3.4.5 Vegetation removal

Overall, permanent loss of marine vegetation from within the CMA will be:

- 100 m^2 for stormwater outfall structures (e.g. 25 m^2 each outfall)
- 678 m^2 for the permanent bridge piers, reclamation, and abutments [3]
- 4 m^2 permanent loss for the reclamation supported by the retaining wall (RW304).

There will be up to approximately 2000 m^2 of vegetation removal from the China Town estuary area above the CMA boundary (e.g. above MWHS) for the construction footprint of the Bridge B embankment and Bridge. Some of this area will be replanted, however what is of interest for coastal processes is the size of the footprint in relation to storm tide storage capacity.

Additional temporary loss of marine vegetation from the CMA during construction will include:

- 300 m^2 for stormwater outfall structures (e.g. Additional 75 m^2 each outfall)
- 32 m^2 for temporary bridge construction structures (temporary piles)
- 70 m^2 for the temporary works associated with the retaining wall (RW304) supporting the reclamation.

[3] This includes vegetation clearance for abutments, piles and scour protection and 549m^2 of reclamation for Bridge B.

The Construction Methodology Report (Table 5) states that temporary vegetation clearance of 3910 m^2 is required landward of the CMA boundary for the entire EB3C alignment. Some of this vegetation clearance area is in proximity to the Bridge B embankment and will be exposed to coastal waters in events above MHWS (e.g. above the CMA).

3.4.6 Erosion and Sediment Control

Erosion and sediment control practices in the CMA are covered in the Erosion and Sediment Control Effects Assessment. That assessment recommends preparation of Site-Specific Erosion and Sediment Control Plans (SSESCPs) that set out the use of coffer dams and casings to keep construction areas around bridge piers dry, and the use of coffer dams, silt fences and flow diversions around stormwater outfall construction areas. This recommendation has been included in the conditions.

4 Methodology and Analysis

Chapter Summary
The methodology employed in this assessment was a desktop assessment of the existing environment and potential effects on coastal processes from existing literature. A site visit to the area was undertaken in May 2021.

4.1 Assessment Methodology

The methodology for this assessment involved the following:

- Identify the coastal process environment of the lower Pakuranga Creek, covering the following factors:
  - Tidal levels and flows
  - Extreme water levels from:
    - storm tides
    - the effects of projected sea level rise over the next 100 years, and
    - tsunamis
  - Sediment transport operating in the CMA
  - Deposition and erosion processes generated by extreme water levels and flows, or the constrictions of flows.
- This coastal process environment was determined from the review of following reports:
  - Lane et al (2009) Auckland Regional Council Tsunami Inundation Study. Prepared by NIWA for Auckland Regional Council
  - Gillibrand et al (2010) Probabilistic Hazard Analysis and Modelling of Tsunami Inundation for the Auckland Region from Regional source Tsunami. Prepared by NIWA and GNS for Auckland Regional Council
  - Stephens et al (2016) Coastal Inundation by Storm-tides and Waves in the Auckland Region. Report prepared by NIWA for Auckland Council
  - Eastern Busway Alliance (2022) Tī Rākau Road Bridge Hydraulic Assessment. This is an update from a previous hydraulic assessment by AECOM (2018) and includes pile scour modelling results
  - Auckland Council (2020) Predicting Auckland's Exposure to Coastal Instability and Erosion. AC Technical report 2020/021
  - Ministry for the Environment (2022) Interim Guidance on the Use of New Sea Level Rise Projections.
- Understanding of the Eastern Busway construction methodology and design was determined from a review of the following Eastern Busway reports and plans:
  - Eastern Busway EB3 Commercial Construction Methodology
  - Eastern Busway Design Report 3ST-00 Tī Rākau Drive Bridge (Feb 2023)
  - Plan 00100-Road_EB3C_ General Arrangement Plans_20210820_Ref_Design
  - Plan 00300_Road_Plan & Long Sections_0210820_Ref_Design.
- To understand the local coastal environment a site visit to the lower Pakuranga Creek area in the vicinity of Tī Rākau Drive was undertaken on 13 May 2021
- A desktop assessment of the effects on the above coastal processes of the construction and operation of Bridge A and Bridge B and related infrastructure such as retaining walls and stormwater outfalls based on the information reviewed.

4.2 Statutory and Planning Framework

This assessment has been developed with consideration of the following relevant legislation, policy, plans and strategies:

1. Resource Management Act 1991
2. New Zealand Coastal Policy Statement 2010
3. Auckland Unitary Plan (Operative in Part) – Chapters B8, F2, F8
4. Hauraki Gulf Marine Park Act 2000 and the Hauraki Gulf Marine Spatial Plan 2017

5 Existing Environment

Chapter Summary

- *Pakuranga Creek at Tī Rākau Drive is a shallow tidal channel in the order of 180 m wide with approximately half of the channel covered in mangrove vegetation. The Spring tidal range is in the order of 2.9 m. To the east of the main channel is a small tidal estuary approximately 6.37 hectares in area, which is predominantly covered in mangrove vegetation except for narrow tributary channels*
- *The sheltered environment is exposed to limited wave heights (< 0.5 m), and maximum current velocities are < 4 m/s in 100-year return period flow events*
- *The 100-year return period storm tide level is 0.72 m above MHWS, and is contained within the creek banks. However, projected maximum SLR over the next 80 years could result in these extreme levels overtopping the western bank, and the MHWS contour being at the top of the bank in 100 years*
- *Up to 30 m of bank erosion is predicted to occur under maximum SLR scenarios over the next 100 years*
- *Risks from tsunami inundation and scour are low.*

5.1 Existing Coastal Environment

Note that EB4L does not include any works in the CMA, therefore this description is limited to EB3C.

5.1.1 General Description

Pakuranga Creek is a meandering tidal tributary of the Tāmaki River, with the existing Tī Rākau Bridge located around 2.35 km north of the confluence with the main river channel, which itself flows into the Hauraki Gulf. As shown in Figure 3-1, the width of the CMA footprint of Pakuranga Creek at the Tī Rākau Drive Bridge is approximately 180m, with around 45m on the west bank and 35m on the east bank being covered in mangrove vegetation, and the central 100m being a clear flowing inter-tidal channel. The creek is also crossed by a Watercare water pipeline on the southern (downstream) side of the existing bridge.

As shown on Figure 3-1, approximately 135m upstream on Tī Rākau Drive on the east bank of the main Pakuranga Creek is a small tributary which drains an intertidal estuary area of 6.37 hectares (only includes area below MHWS) extending around 300 m east from the main Pakuranga Creek channel to the site known as 'China Town'. Around 60 m from the 'China Town' edge of the estuary, the tributary splits in two, with one branch draining from Tī Rākau Drive in the southeast corner of the estuary, and the other draining from Burswood Drive in the northeast. The whole of this estuary area is extensively covered in mangrove vegetation, except for the main tidal channels, which are in the order of 10 m wide above the tributary confluence and in the order of 15-20 m below.

The south-east estuary tributary towards Tī Rākau Drive includes the AUP (OP) Historic Heritage Extent known as the McCallum Wharf and Quarry or Donnelly's Quarry[4].

5.1.2 Current Hydraulic Conditions

The 2022 Tī Rākau Road Bridge Hydraulic Assessment (Eastern Busway Alliance) involved reviewing existing background information including past bathymetric survey and surface sediment sampling, developing a HEC-

[4] This historic heritage is discussed further in the archaeological assessment for EB3C EB4L.

RAS 2D current model (Hydraulic Engineering Centre – River Analysis System developed by the U.S. Army Corps of Engineers), and undertaking a wave assessment. The results of the assessment are summarised as follows.

Tide Levels

Applying the method outlined in Stephens et al (2016), Auckland Council have estimated a MHWS level of 1.71 m (Auckland 1946 datum) for Pakuranga Creek at the Tī Rākau Drive Bridge, which equates to a level of 1.43 m (NZVD2016). The full range of tide levels at this site are presented in Table 1. The spring tide range is given as 2.96 m.

Table 1: Tide levels for Pakuranga Creek at Tī Rākau Drive.

Tide Level	Auckland Council 1946 reduced levels (m)	Elevation in NZVD2016 (m)
Highest Astronomical Tide (HAT)	2.03	1.75
Mean High Water Spring (MHWS)	1.71	1.43
Mean High Water Neaps (MHWN)	1.17	0.89
Mean Sea Level (MSL)	0.22	-0.06
Mean Low Water Neap (MLWN)	-0.71	-0.99
Mean Low water Spring (MLWS)	-1.25	-1.53
Lowest Astronomical Tide (LAT)	-1.62	-1.90

Bathymetry

A hydrographic survey of the main creek channel of Pakuranga Creek in the vicinity of the Tī Rākau Bridge was conducted in 2018 and presented below as Figure 5-1. The surveyed levels are considered to still be relevant.

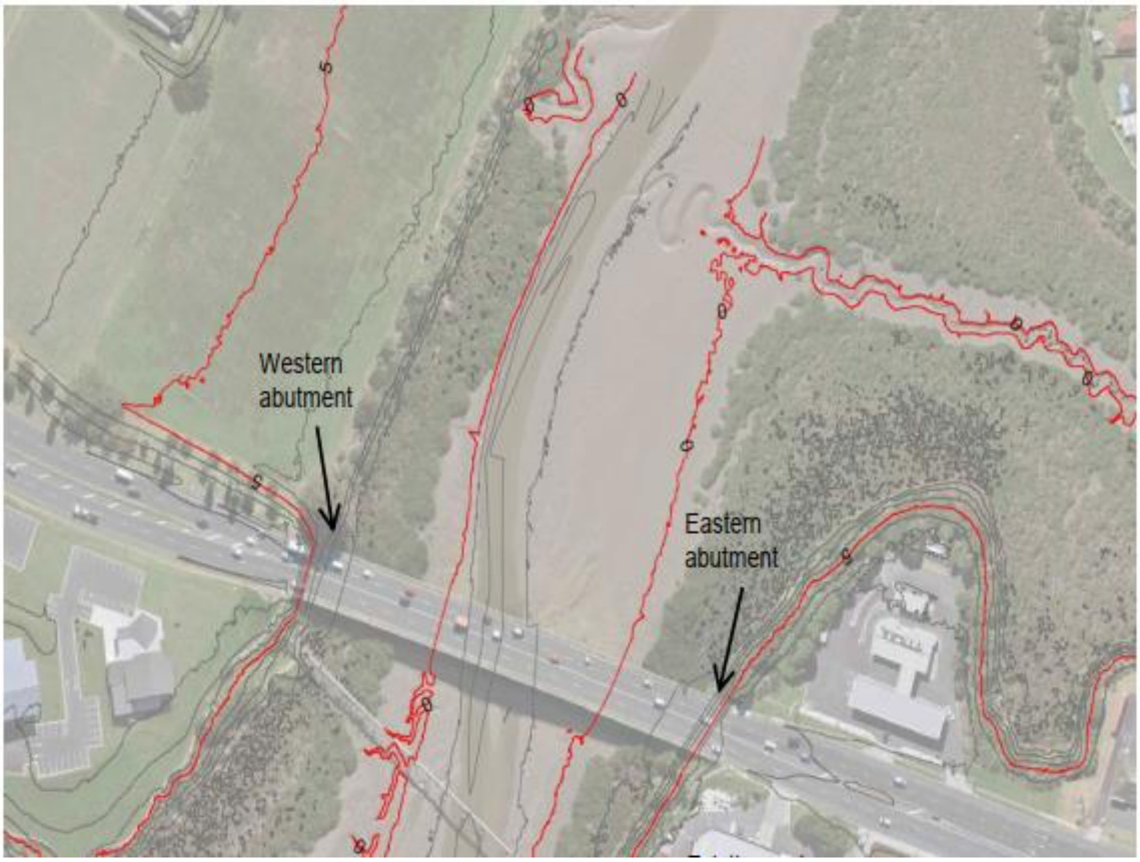

Figure 5-1 Pakuranga Creek bathymetry from 2018 hydrographic survey.

Source: Tī Rākau Road Bridge Hydraulic Assessment Figure 3, p13. (Eastern Busway Alliance, 2022)

Figure 5-1 indicates that the current top of west bank elevations in the vicinity of proposed Bridge A are less that 4m RL, and the east bank elevations being in the order of 7m RL. These elevations are important in the consideration of extreme water levels in the vicinity of the proposed Bridge A.

A more detailed cross section of the bathymetry at the location of proposed Bridge A is presented in Figure 5-2.

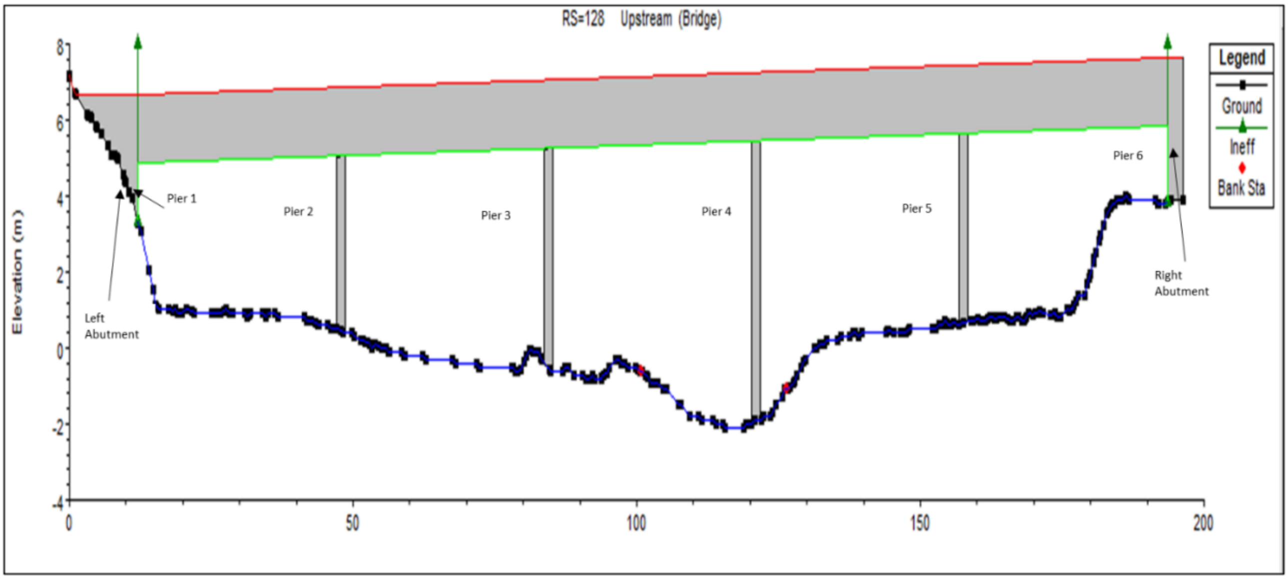

Figure 5-2 Bed levels across Pakuranga Creek at Tī Rākau Drive. (Elevations are in NZVD2016).

Source: Tī Rākau Road Bridge Hydraulic Assessment Figure 18, p36. (Eastern Busway Alliance, 2022)

As shown in Figure 5-2 the minimum bed level is in the order of -2 m RL (NZVD2016), with approximately 160m width of the creek cross-section being less than the MHWS contour (1.43 m RL), therefore being in the CMA. This figure also shows the proposed bridge/road elevations at the bridge abutments.

Although not shown in Figure 5-2, bed levels across the route of Bridge B in the small tributary estuary are shown on plan "*EB3C 00300_Road_Plan & Long Sections_20210820"* as being in the order of 0.935 to 1.083 m RL across the mangroves in the south-east tributary (e.g. all below the MHWS contour therefore in the CMA), around 0.886 m RL where the proposed bridge alignment crosses the tributary, and from around 1.1 m RL to 5.5 m RL for the north eastern tributary with only around 10 m length below the MHWS contour.

Extreme Sea Levels

Extreme sea levels were presented in the 2022 Tī Rākau Bridge Hydraulics Assessment that were derived by applying an amplification factor for harbours and streams to the maximum storm tides plus wave set-up from Stephens et al (2016) for harbour entrances. The amplification factor inside the harbours and up streams increased with distance from the harbour mouth. Tsunami or other meteorological and climate components that can increase sea levels at the coastline were not included. The resulting extreme sea levels in Pakuranga Creek relative to NZVD2016 are given in Table 2.

Table 2: Maximum storm tide plus wave set-up elevations in Pakuranga Creek.

Source: Eastern Busway Alliance (2022)

Storm tide Return Period (years)	Auckland Council 1946 reduced levels (m)	Elevation in NZVD2016 (m)
10	2.29	2.01
20	2.34	2.06
50	2.40	2.12
100	2.43	2.15
200	2.46	2.18

These results show tha5t the current 10-year ARI storm tide level exceeds the MHWS elevation by 0.58 m and the HAT elevation by 0.26 m, hence the water surface extends beyond the CMA boundary. The 100-year ARI storm tide level exceeds these astronomical tidal levels by 0.72 m and 0.40 m respectively.

The 2022 hydraulics assessment notes that the extreme storm tide results indicate that coastal inundation is a greater threat to the proposed Bridge A overtopping than rainfall induced weather events. However, I would consider that under present day sea level, this threat is low, with the 200-year ARI water level being 1.77 m below the western bank elevation of Pakuranga Creek at Tī Rākau Drive.

Waveeffects

The existing Tī Rākau Bridge site is relatively protected with the greatest wind fetches for wave action created by wind from the Northeast and Southwest direction.

The 2022 hydraulic assessment presents the following results in Table 3 for wind generated waves calculated via the Young & Verhagen (1996) method for extreme conditions. The Hydraulic assessment concluded that "*these results show that the wind wave effect within the Pakuranga Creek is relatively gentle. Vessel wakes from transiting vessels in the Tāmaki River are unlikely to affect the site and are not expected to contribute to coastal processes*".

Table 3: Wave effects calculated at Tī Rākau Bridge.

Source: Eastern Busway Alliance (2022).

Return Period (year)	Design Wind Speed (m/s)	Wave Height H_s (m)	Peak Wave Period T_p (s)
1	28.5	0.40	2.43
10	32.3	0.45	2.58
20	35.1	0.49	2.67
50	37.0	0.51	2.74
100	38.9	0.54	2.80
200	40.8	0.56	2.86

Currents

The 2022 hydraulic assessment notes that no current velocity measurements have been carried out for Pakuranga Creek, but modelled results can be obtained from the HEC-RAS 2D current modelling undertaken for determining the effects of the bridge structures on flow and scour levels. The results of this modelling for the current bridge configuration are presented in Table 4.

Table 4: Summary of water levels, water depths, and peak approach flow velocities upstream of Tī Rākau Bridge with existing development from HEC-RAS modelling.

Source: Eastern Busway Alliance (2022)

Scenario			Water Level (m NZVD2016)	Flow Depth (m)	Approach Flow Velocity (m/s)
ID	Flood Flow - upstream (year ARI)	Tide boundary (m NZVD2016)			
S1	25	MHWS	1.44	3.52	1.23
S2		MSL	0.15	2.22	3.47
S3		MLWS	-0.14	1.94	4.62
S4	100	MHWS	1.45	3.52	1.46
S5		MSL	0.20	2.27	3.80
S6		MLWS	-0.03	2.04	4.85

The modelling results showed that as flow depth decreased the velocity increased, with the greatest flow velocity (4.85 m/s) occurring from a 100-year return period flow in conjunction with a Mean Low Water Spring tide (MLWS) level as the downstream boundary condition.

Sediments

The 2022 hydraulic assessment presents the results of geotechnical investigations carried out by Opus in 2003 that included two boreholes located immediately upstream of the existing Tī Rākau Bridge, and a 2019 investigation undertaken by AECOM that included three boreholes downstream of the bridge. The top 5 m of each borehole was dominated by soil textual classes of Silty clay, Peaty clay and Clayey sandy silt, all of which have high clay contents. No particle size analysis was carried out, with sediment size being estimated based on the ASTM Unified Classification (Coastal Engineering Manual, 2008). This classification has a representative grain size of 0.01 mm, which was adopted for the top 5m layer of the creek bed.

5.1.3 Projected Sea Level Rise

The AUP(OP) requires assessment of a 1m sea level rise over the next 100 years. The 2022 hydraulic assessment recommended that based on the projections in MfE (2017) *guidance on coastal hazards*, due to the importance and location of the proposed bridge infrastructure, a SLR of 1.34 m above existing levels to 2118 under the highest SLR scenario (RCP8.5+) should be applied. However, the SLR projections for New Zealand were updated in 2022 following the release of the 2021 IPCC Sixth Assessment Report (AR6) which moved from RCP (Representative Concentration Pathways) to SSP (Shared Socioeconomic Pathways) scenarios and incorporated new localised information on changes in land levels around the coast, known as vertical land movement (VLM).

Decadal increments of the "medium confidence" national scale SLR projections from climate change in the MfE (2022) "*Interim Guidelines on the Use of New Sea Level Projections*" are presented for five climate change scenarios from SSP1-2.6 (lowest) to SSP5-8.5+ (highest). Policy 24 of the New Zealand Coastal Policy Statement (2010) (NZCPS) states that coastal hazard assessments should be over a 100-year period, which the interim guidelines interpret to be to 2130, taking into account national guidance. The national scale SLR projections to this timeframe from a 2005 base date for each of the climate change scenarios are presented in Table 5.

Table 5: NZ national sea level rise projections due to climate change to 2130 from a 2005 base.
Source MfE (2022)

Year	SSP1-2.6 (median) (m)	SSP2-4.5 (median) (m)	SSP3-7.0 (median) (m)	SSP5-8.5 (median) (m)	SSP5-8.5H+ (83rd percentile of SSP5-8.5) (m)
2130	0.60	0.81	1.07	1.21	1.66

The NZ SeaRise Programme (https://searise.takiwa.co/map/6245144372b819001837b900) gives modelled VLM for coastal sites at 2 km spacing from a very short data set of 10 years of collected GPS data, and therefore has large uncertainties for long-term application. As shown in Figure 5-3, there are two relevant sites close to Tī Rākau Drive at Pakuranga Creek that have given VLM rates of -1.76 to -1.80 mm/yr. (subsidence). Therefore, over a 125-year period (i.e. 2005 to 2130), an additional 0.23 m needs to be added to the climate change induced sea level rise projections. The resulting relative SLR from combined climate change and VLM to 2130 is given in Table 6.

Table 6: Relative Sea level rise projections including VLM in the vicinity of Pakuranga Creek at Tī Rākau Drive to 2130 from a 2005 base.
Source NZ SeaRise programme (2022)

Year	SSP1-2.6 (median) (m)	SSP2-4.5 (median) (m)	SSP3-7.0 (median) (m)	SSP5-8.5 (median) (m)	SSP5-8.5H+ (83rd percentile of SSP5-8.5) (m)
2130	0.85	1.05	1.31	1.46	1.96

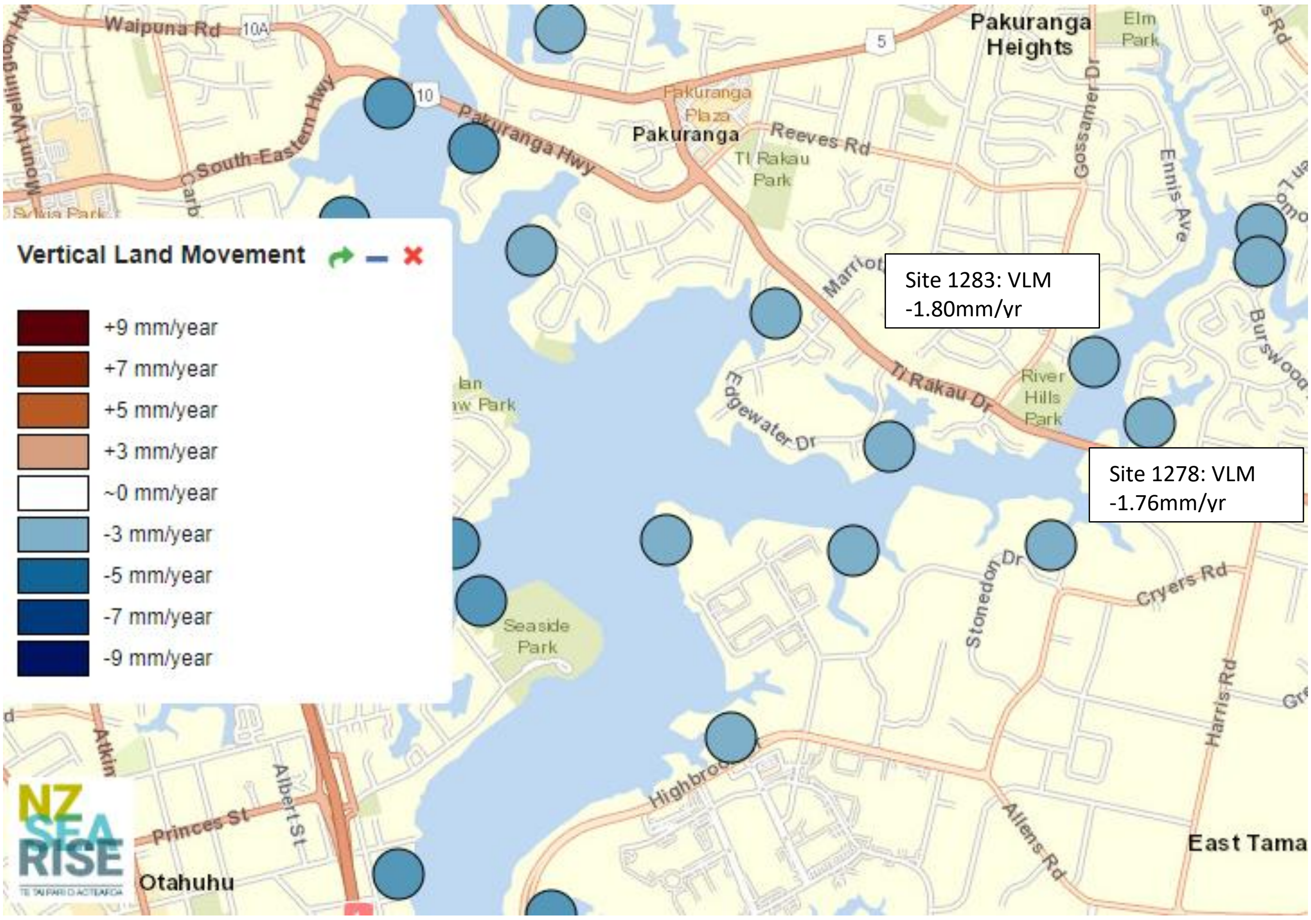

Figure 5-3 NZ SeaRise Vertical Land Movement Sites in the vicinity of Tī Rākau Drive at Pakuranga Creek.

Source NZ SeaRise https://searise.takiwa.co/map/6245144372b819001837b900

The MfE (2022) interim guidance recommends that for major new infrastructure, such as the Eastern Busway, the most extreme SSP5-8.5H+ scenario should be applied, which can be considered to be a precautionary approach as required by Policy 3 of the NZCPS. From Table 6 the corresponding relative SLR is of 1.96 m from a 2005 base, or in the vicinity of 1.86 m from current sea levels. Under this scenario, a 50 – year ARI storm tide would be above the bank levels on the western bank of Pakuranga Creek by 2130 and a 100-year ARI storm tide would cause inundation along this bank by 2095. However, the elevation of the EB3C corridor in this area is a minimum of 6.45 m RL, which is in the order of 2.45 m above the 2130 projected 100-year storm tide levels under the highest SSP5-8.5H+ SLR scenario.

The results of the assessment of shoreline erosion due to SLR (Auckland Council, 2020) for Pakuranga Creek in the vicinity of Tī Rākau Drive is presented in Figure *Figure 5-4 Projected future shoreline positions with SLR.*

Source: Auckland Council (2020)
https://aucklandcouncil.maps.arcgis.com/apps/webappviewer/index.html?id=3ded5342789f4af48deb906a3c05cabe

5-4. The methodology for determining the erosion distances involved a bank instability factor based on the height and slope of the bank, and a factor for the potential increase in past long-term retreat of the toe of the bank based on the geology. For the estuary areas of the Tāmaki River, including Pakuranga Creek, this factor was taken as 0.3 – a medium value for Auckland cliff/bank geologies. Bank erosion distances along both banks of Pakuranga Creek in the vicinity of Tī Rākau Drive are projected to be in the order of -30 m by 2130 under the highest RCP8.5 and RCP8.5+ scenarios. These scenarios pre-date the IPCC AR6 assessment (2021) and the NZSeaRise inclusion of VLM, with slightly lower SLR of 1.18m under RCP8.5 scenario and 1.52 m under RCP8.5+ scenario. Therefore, bank instability issues and erosion distances under the more recent SSP projections including VLM given in Table 6 will be greater than shown in Figure 5-4.

Figure 5-4 Projected future shoreline positions with SLR.

Source: Auckland Council (2020)
https://aucklandcouncil.maps.arcgis.com/apps/webappviewer/index.html?id=3ded5342789f4af48deb906a3c05cabe

5.1.4 Tsunami Risk

There are existing reports on the modelled potential effects for the Auckland area from large magnitude tsunami from South American and Tonga-Kermadec sources.

Lane *et al* (2009) modelled the tsunami inundation risks from a large subduction zone earthquake off the coast of South America, similar in magnitude (9.5 Mw) to that which caused the 1960 Chilean tsunami, but with the source characteristics from the 1868 Peru tsunami. A tsunami from this source is considered to be the most probable tsunami risk facing the Auckland region in the next 100 years. The modelling involved assuming a sea level of MHWS at the time of arrival and increases in sea level by up to 0.5 m due to SLR.

Maximum water levels were modelled to be in the order of 2-3 m on the Auckland East coast, and up to 3.5 m in some bays. However, inundation was modelled to be mostly confined to narrow coastal strips. Although, Pakuranga Creek was included in the model extent, no information on tsunami levels was presented for the margins of the creek. However, inundation in the Panmure Basin approximately 4.5 km downstream on the Tāmaki River is shown as being in the range 0.1 -1 m for tsunami arrival at MHWS, and in the 1.1 -2 m range with 0.5 m of sea level rise. It can be assumed that the water level increases due to tsunami will be less in Pakuranga Creek. The mapped results indicate that maximum water velocity in the creek were in the lowest classification range of 0.1 – 1 m/s for both arrival at MHWS and with 0.5 m sea level rise.

Gillibrand *et al* (2010) modelled the inundation on the east coast of the Auckland region from a 2500-year return period tsunami generated by a large earthquake on the Tonga-Kermadec and Southern New Hebrides subduction Arcs, which are considered to be the source of worst-case tsunami for the region over timescales longer than 100 years. The study involved the modelling of the generation of a large number of possible tsunamis from these subduction arcs and the subsequent inundation modelling of the resulting 100 largest events to produce probabilistic maps of inundation depth and maximum current speed. Tsunami arrival was modelled to coincide with various tidal levels up to MHWS tide level but did not include SLR.

Maximum water levels were modelled to be in the order 4-5 m for parts of the East coast of the Auckland Region, and up to 10 m on Great Barrier Island. Again, although Pakuranga Creek was included in the model extent, no information on tsunami levels was presented for the margins of the creek. Velocities downstream of the Panmure Bridge on the Tāmaki River are mapped as being a maximum of 0.1 m/s, with very little inundation shown in Panmure Basin, with depths limited to 0.1 m. On this basis, it can be assumed that both water speeds and water level increases in Pakuranga Creek due to a large-scale magnitude tsunami from a Tonga-Kermadec and Southern New Hebrides subduction zone source will be negligible.

6 Assessment of Coastal Effects

Chapter Summary
Potential effects of operation are limited to: ¶ *No effect to minimal/negligible effects on water depth and velocity from the existing conditions with the addition of Bridge A across the main channel of Pakuranga Creek at Tī Rākau Drive* ¶ *No effect on tidal hydraulics from Bridge B, the northern embankment to Bridge B, or the reclamation retaining wall. The Bridge B embankment is also very unlikely to affect storm tide flood levels in the 'China Town' tributary estuary.* ¶ *Stormwater discharges are not expected to affect existing tidal hydraulics* ¶ *Projected maximum SLR would result in the MHWS contour being at the top of western Pakuranga Creek bank in 100 years, and 100-year storm tide could overtop the bank in 80 years. However, the elevation of the EB3C corridor in these areas is a minimum of 6.45 m RL, in the order of 2.45 m above the 2130 projected 100-year storm tide levels under the highest SLR scenario* ¶ *Bank erosion in Pakuranga Creek in the order of 30 m is projected to occur by 2130 under the highest SLR scenario without any protection interventions. However, any such erosion is not projected to start to around 2080, and later under slower SLR scenarios. Therefore, there is plenty of opportunity to address any adverse effects on the bridge abutments from any such erosion by engineered protection before it becomes an issue* ¶ *Total scour depths at the Bridge A piles are likely to be similar to the existing bridge, with modelled results of maximum local pier scour of 3.48 m and 3.67 m around the middle piers for 100 year and 1000-year ARI events respectively. Debris rafts were modelled to increase the local pier scour by 1.26 m and 1.42 m for these two ARI events respectively. All of this scour is into the soft sediments and well above the rock foundation level below the creek bed* ¶ *The eastern abutment of Bridge A was also modelled to be vulnerable to scour with a maximum modelled scour of 2.82 m under MHWS conditions in a 1000-year ARI event* ¶ *No effects on water levels, flow and scour from the piers of Bridge B* ¶ *The use of a 25 m^2 riprap apron overlaying a geotextile fabric layer at the stormwater outfalls will prevent any localised scour issues at these locations.* *Potential effects of construction are limited to:* ¶ *There is potential for bank and bed scour from temporary vegetation clearance in the main Pakuranga Creek if extreme storm tides or creek flows occur during construction of Bridge A. However, the likelihood of these events occurring during the construction timeframe is considered to be low* ¶ *Due to being located away from high tidal flows, risk of bank or bed scour associated with temporary vegetation clearance in the tributary estuary of construction of Bridge B, the stormwater outfalls, and the reclamation retaining wall are considered to be minimal* ¶ *The placement of temporary piles in the main channel of Pakuranga Creek are considered to have only a potential small, localised effects on water levels and flow velocities in the creek during extreme events, which have a very low likelihood of occurring within the construction time frame* ¶ *The placement of temporary piles in the tributary estuary will have no effect on water levels in this area.*

6.1 Operational Effects

6.1.1 Hydraulic Conditions

The results of the HEC-RAS 2D modelling in the 2022 Tī Rākau Road Bridge Hydraulic Assessment (Eastern Busway Alliance) included the effects of the proposed new Bridge A on water level, flow depth and flow velocity for a combination of upstream flow frequencies (25-, 100- and 1000-year ARI's) and downstream tide levels (MHWS, MSL, MLWS). Those results are presented below in Table 7. The hydraulic assessment noted that although flow patterns are changed due to the proposed Bridge A, the magnitude of the flow velocities upstream and downstream of the bridge only result in a small change. The assessment concluded that the modelling results showed minimal to no change from the existing hydraulic conditions. I concur with this conclusion.

Table 7: Comparison of hydraulic conditions upstream of Tī Rākau Bridge with the future bridge development

Source Hydraulic Assessment (Eastern Busway Alliance, 2022)

Scenario			Water Level (m NZVD2016)			Flow Depth (m)			Approach Flow Velocity (m/s)		
ID	Flood Flow - UB (year ARI)	Tide - DB (m NZVD2016)									
			Existing bridge	Proposed bridge	% Change	Existing bridge	Proposed bridge	% Change	Existing bridge	Proposed bridge	% Change
S1	25	MHWS	2.44	2.44	0.00	4.5	4.50	0.00	0.87	0.87	0.00
S2		MSL	0.98	0.98	0.00	3.05	3.05	0.00	1.9	1.87	-1.58
S3		MLWS	0.01	0.01	0.00	2.08	2.07	-0.48	4.47	4.44	-0.67
S4	100	MHWS	2.44	2.44	0.00	4.51	4.51	0.00	1.16	1.15	-0.86
S5		MSL	1.01	1.04	2.97	3.08	3.08	0.00	2.49	2.46	-1.20
S6		MLWS	0.19	0.18	-5.26	2.26	2.25	-0.44	4.97	4.93	-0.80
S7	1000	MHWS	2.45	2.45	0.00	4.51	4.51	0.00	1.56	1.54	-1.28
S8		MSL	1.06	1.06	0.00	3.13	3.12	-0.32	3.23	3.20	-0.93
S9		MLWS	0.4	0.40	0.00	2.47	2.46	-0.40	5.46	5.42	-0.73

The piles for Bridge B are not located in any of the active channels in the estuary area, so they will not affect the existing hydraulic tidal conditions present in this estuary area. The Bridge B embankment is located at least 10 m away from the Tī Rākau Drive Pakuranga Creek tributary channel and in the order of 20 m from the Burswood Drive Pakuranga Creek tributary channel, so similarly will not affect the existing hydraulic tidal conditions present in this estuary area. The embankment will remove in the order of 2500 m^2 of 'China Town' tributary estuary in the area that is impacted by coastal processes. This area is less is than 0.5% of the storm tide flood area available within this tributary estuary, and I therefore consider that the embankment is very unlikely to impact flood levels in the tributary estuary.

The permanent occupation of 4 m^2 of the CMA of the tributary estuary for the footprint of the small retaining wall between 242 & 254 Tī Rākau Drive will not have any effect on the tidal hydraulics of this estuary area.

The stormwater discharges from the new and upgraded stormwater outfalls are expected to have a negligible effect on the size and hydraulics of the tidal channels into which they discharge.

6.1.2 Sediment Transport

Since there is no to minimal/negligible effects of the bridge structures on tidal flows and velocities, there will be no effects on sediment transport within the channels.

6.1.3 Coastal Flood Risk

This assessment considers the potential flood risks to the operation of EB3C because of SLR and due to tsunamis.

The MHWS contour with the highest relative SLR scenario (i.e. SSP8.5+ combined with VLM) is projected to be around the elevation of the top of the western bank of Pakuranga Creek at Tī Rākau Drive by 2130. This suggests that very frequent inundation of Riverhills Park could occur from this time on or could occur before 2100 for 100-year return period storm tides and soon after 2100 for 10-year return period storm tides. While this may affect the land adjacent to the EB3C corridor, the elevation of the EB3C corridor in these areas is a minimum of 6.45 m RL, in the order of 2.45 m above the 2130 projected 100-year storm tide levels under the highest SLR. Any flood effects on the corridor embankment and western Bridge A abutments can be mitigated in the future by engineered methods should they be required.

The projected SLR till 2130 will not cause inundation issues for the land between Bridge A and Bridge B, or for the northern abutment of Bridge B. The elevation of the EB3C corridor in these areas is a minimum of 6.45 m RL, in the order of 2.45 m above the 2130 projected 100-year storm tide levels under the highest SLR scenario.

As pointed out in Section 5.1.4, there is very unlikely to be any inundation risk from tsunami with current sea levels or events occurring over the next 100 years even when taking into account the effects of SLR.

6.1.4 Erosion and Deposition

The 2022 hydraulic assessment assessed local scour effects on the piers of the proposed new Bridge A at Tī Rākau Drive using a 1D model developed using the HEC-RAS modelling software, of which the underlying calculations are consistent with the methods in the Melville and Coleman (2000) publication for scour analysis recommended in the Waka Kotahi Bridge Manual. The modelling involved calculating scour using both a maximum scour approach across a cross section located just upstream of the proposed Bridge A, and a local velocity-depth approach just upstream of each pier. The modelling also applied different downstream tidal conditions of MLWS, MSL, and MHWS combined with upstream flow at 25, 100 and 1000-year ARI's.

The results showed that the maximum scour depths occurred around the middle piers with a MLWS downstream boundary condition due to the higher flow velocity at this tidal level. However, this is countered by fewer piers being exposed to scouring than was the case with MSL and MHWS tidal elevations. Total scour depths (local pier scour plus flow contraction scour) for the proposed Bridge A was similar to the existing bridge, being 3.48 m and 3.67m for 100-year and 1000-year ARI flows respectively. Debris rafts around the piers, assumed to be rectangular in form with a width of 15 m and thickness of 2 m, were modelled to increase the local pier scour by 1.26 m and 1.42 m for 100-year and 1000-year ARI's respectively. These scour depths, which at a worst case are in the order of 4.7 m to 5.1 m for these extreme events need to be considered in the context of the greater than 20 m driven depth of the piles, which includes 12-14 m through soft sediments and greater than 6 m into rock (From Table 2 of Appendix 2 (Tī Rākau Drive Bridge Geotechnical Design Memorandum of the Tī Rākau Drive Bridge Design Report)). Although scour protection to counter these projected scour depths are not currently proposed, they will be the subject of further scour modelling in final design involving the modelling of flood flows with this degree of pre-existing scour. Should this additional modelling indicate that pile instability or failure from scour is a possibility, the final design will include rock riprap protection around the piles of Bridge A. Any such placement of rip rap will only result in small localised additional effects on coastal processes.

The scour modelling that has been undertaken to date showed that the western abutment of Bridge A is unlikely to suffer from scour for all boundary conditions (e.g. MHWS, MSL, and MLWS), but the eastern abutment could experience maximum scour of 2.82m under MHWS boundary conditions in combination with a 1000 yr. ARI flow conditions. This maximum potential scour is much less that the 21 m driven length of piles at both abutments and it is considered that this is a very low frequency event.

Since the Piles for Bridge B are not located in the tributary channel there will not be any scour effects from this bridge.

The use of a 25 m^2 riprap apron overlaying a geotextile fabric layer at the stormwater outfalls is likely to prevent any localised scour issues at these locations.

As shown in Figure 5-3, bank erosion in the order of 30 m is projected to occur by 2130 under the highest SLR scenario. Again, any effects of this future bank instability on the corridor embankment and Bridge A abutments can be mitigated in the future by appropriate engineering methods should they be required.

6.1 Construction Effects

6.1.1 Vegetation Clearance

In terms of potential effects on coastal processes, it is the temporary vegetation clearance during construction that is of interest for increasing the risk of bank scour, failure, and erosion. For the marine vegetation areas permanently removed and replaced by engineering structures, the effects are addressed above under operational effects.

Overall, the area of marine vegetation to be removed temporarily for construction purposes includes:

- 300 m^2 for stormwater outfall structures (e.g. Additional 75 m^2 each outfall)
- 32 m^2 for temporary bridge construction structures (temporary piles)
- 70 m^2 for the temporary works associated with the retaining wall (RW304) supporting the reclamation.
- A percentage of the 3,900 m^2 of temporary vegetation removal landward of the CMA boundary for the entire EB3C alignment.

The largest area of vegetation removal in the CMA is for the construction of bridge structures. While there is potential for bank scour in these clearance areas should the extreme storm tide levels or creek flows given in Tables 2 and 4 respectively (e.g. 1 in 50- or 100-year ARI events) occur while the banks are exposed, the likelihood of these magnitude events occurring during the construction timeframe are considered to be low. The replanting of these areas once construction is completed as noted in the Construction Methodology Report and LEAM plans will mitigate any longer-term bank stability effects from this clearance.

The areas of temporary vegetation removal associated with the construction of the abutments and embankment for Bridge B in the China Town Estuary are away from high tidal flow areas, there is minimal risk of any bank scour or bed erosion associated with this clearance.

For the same reasons, the small area (70 m^2) vegetation removal/disturbance for the construction of the retaining wall between 242 & 254 Tī Rākau Drive is extremely unlikely to result in bank scour or bed erosion associated with this clearance.

Similarly, the temporary removal of around 100 m^2 of mangrove vegetation at each of two proposed new and two upgraded stormwater outfalls (i.e. total 400 m^2) is considered very unlikely to result in bank or bed scour unless there are extreme stormwater flows during construction.

6.1.2 Temporary Structures for construction

The 2022 Hydraulic Assessment for Bridge A does not include an assessment of the effects of the temporary piles associated with the staging for construction of this bridge. Since the area of occupancy of the temporary piles (23 m^2) for the construction of Bridge A is approximately two times greater than the area of occupancy for the permanent piles (14 m^2), it is anticipated that the potential effect on water levels and flow velocities in extreme events is also higher. However, given that the effects on water levels and flow velocities from the permanent piles presented in Table 7 are negligible, any increases in these hydraulic parameters are considered to only have a small effect at worst. Also, any potential increase in levels and flows is counteracted by the very low likelihood of these extreme events occurring within the construction timeframe. The Construction Methodology Report (p37) indicates that these temporary piles will have a driven depth of approximately 20 m, the same as the permanent piles, so any local scour should extreme events occur, will not result in instability or failure of the temporary piles.

None of the temporary piles for the construction of Bridge B are required to be located in the tidal channels of the tributary estuary, there will not be any effect on water levels and flow velocities in these channels.

With appropriate erosion and sediment control, as set out in the Erosion and Sediment Control Assessment, there should not be any unexpected deposition in the CMA as a result of the proposed works.

7 Mitigation

Chapter Summary
¶ *Minimise the clearance of vegetation in construction areas and replant these areas following construction.* ¶ *The current Bridge A design includes the placement of riprap for scour protection around the eastern abutment piles* ¶ *No scour protection is proposed for the Bridge A piers located in the main Pakuranga Creek channel, however further scour modelling is required to confirm that this will not result in pile instability or failure. If this modelling indicated that scour protection around Bridge A piles is required, this could be added at the final design stage. The placement of rip rap for scour protection around the piles of Bridge A will only result in small localised additional effects on coastal processes.*

7.1 Proposed Mitigation

7.1.1 Construction Effects

Although the risk of potential bank or bed scour from the clearance of mangrove vegetation for construction activities is considered to be low, the removal of vegetation should be minimised as far as possible to mitigate the risk of temporary scour effects. It is recommended that the areas of mangrove removal are replanted on completion of construction to mitigate any potential long-term stability effects. If construction is undertaken in accordance with the recommended mitigation along with the actions set out in the Erosion and Sediment Control Assessment, there will be negligible temporary and permanent effects from vegetation clearance during construction.

Overall, the marine vegetation to be replaced to mitigate potential long term stability effects are:

¶ 300 m^2 for stormwater outfall structures (75 m^2 per each outfall)

¶ 32 m^2 for temporary bridge construction structures (temporary piles for Bridges A and B)

¶ 70 m^2 for the temporary works associated with the retaining wall (RW304) supporting the reclamation.

7.1.2 Operation effects

The design elevations of the bridge decks and road carriageways are sufficient to account for the highest scenario of relative SLR for the next 100 years and considerably longer. Any potential effects of future elevated water levels and associated bank instability on the bridge abutments and road embankment can be mitigated by appropriate engineering design in the future by engineered methods should they be required.

To mitigate scour around the Piers of Bridge A, the 2022 Tī Rākau Road Bridge Hydraulic Assessment (p38) proposed that rip rap be placed around the bridge piles and the eastern abutment piles as a countermeasure for local piers scour, with d_{50} rock size of 700 mm and thickness of 1.4 m being recommended as being required to prevent scour in 100-year ARI events. However, the more recent Tī Rākau Bridge Design Report (2023) (p20) does not support the placement of this scour protection at the Bridge A piers. Instead of scour protection, the design report states that *"the design will be checked for a case where the top 5 m of material at the creek bed is removed to allow for loss due to scour around piers during a flood event"*. However, scour protection is proposed to be provided at the eastern abutment of Bridge A to prevent stream bank erosion at this location.

The additional scour modelling for Bridge A of the above scenario (i.e. pile scour present prior to a flood event) has not been undertaken. I agree with the need to undertake this additional scour modelling and that should it show that scour protection is required to prevent pile instability or failure in flood events, then it is added at the final design stage.

The design report does not elaborate on what the potential impacts on the marine environment they were avoiding by not placing scour protection riprap around the Bridge A piles. However, in terms of coastal processes these effects would include greater areas of sediment disturbance in construction (no additional vegetation disturbance as scour only required for piles in the unvegetated channel), and small additional increases in water levels during extreme flows due to a greater displacement area. Both additional effects on coastal processes are considered to be small and localised.

The stormwater outfall design already includes scour protection by geotextiles and rock riprap which will sufficiently mitigate localised scour effects from stormwater discharge at these locations.

8 Recommendations and Conclusions

The potential effects of construction and operation of the EB3C and EB4L works on coastal processes range from low to non-existent. Although the risk of bank and bed scour from the removal of mangrove vegetation within the CMA for construction is low, the recommended re-planting of these areas following construction will reduce the potential for scour to occur over a longer period.

Overall, the marine vegetation to be replaced to mitigate potential long term stability effects are:

¶ 300 m^2 for stormwater outfall structures (75 m^2 per each coastal outfall)

¶ 32 m^2 for temporary bridge construction structures (temporary piles for Bridges A and B)

¶ 70 m^2 for the temporary works associated with the retaining wall (RW304) supporting the reclamation.

The current Bridge A design includes the placement of riprap for scour protection around the eastern abutment piles, however no scour protection is proposed for the Bridge A piles in the unvegetated section of the Pakuranga Creek channel. However, further scour modelling is required to confirm that this will not result in pile instability or failure. If this modelling indicates that scour protection around Bridge A piles is required, this could be added at the final design stage. Any such placement of rip rap for scour protection around the piles of Bridge A will only result in small localised additional effects on coastal processes.

While the carriage and bridge decks of the EB3C works are well above the projected future sea level in 100 years under the highest SLR scenario, there are risks of future coastal inundation on the west bank of the Pakuranga Creek and up to 30 m erosion around the edges of the creek. However, these risks are unlikely to occur for the next 70 years and can be mitigated by appropriate engineering design of the EB3C embankments and Bridge A abutments in the future by engineered methods should they be required.

There is no tsunami inundation risk to the EB3C and EB4Lworks.

9 References

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