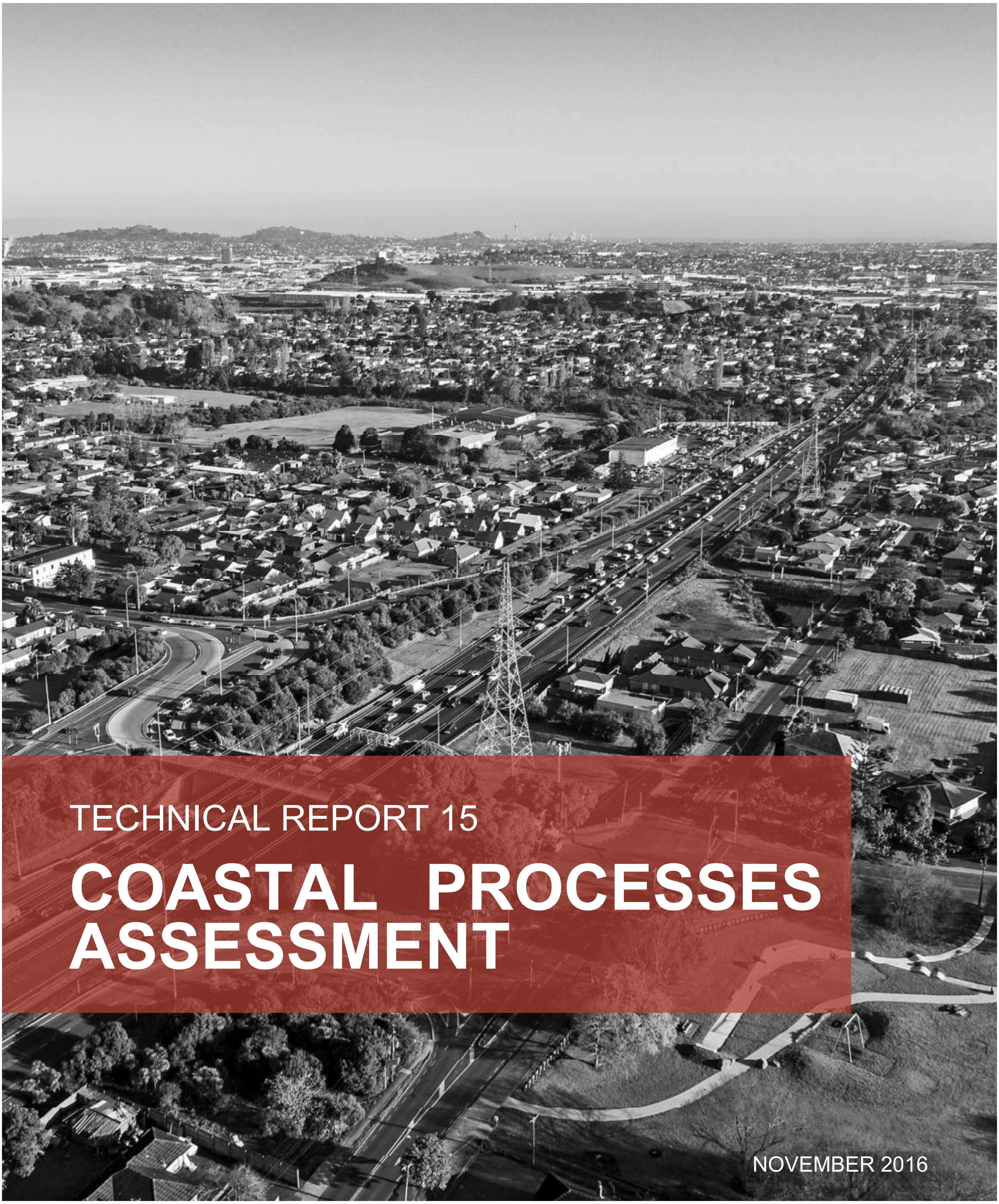

TECHNICAL REPORT 15

COASTAL PROCESSES ASSESSMENT

NOVEMBER 2016

Quality Assurance Statement	
Prepared by	Stephen Priestley
Reviewed by	Connon Andrews
Approved for release	Patrick Kelly (EWL Alliance Manager)

Revision schedule					
Rev. N°	Date	Description	Prepared by	Reviewed by	Approved by
0	November 2016	Final for Lodgement	Stephen Priestley	Connon Andrews	Patrick Kelly

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EXECUTIVE SUMMARY

A: Foreshore Works

1. The Foreshore Works involves creating reclamation of some 18.3ha along the northern coastline of the Inlet. It also includes a recreated coastline, dredging and CMA discharges. Issues related to dredging and discharges are covered separately.

Existing Environment

2. Māngere Inlet (the Inlet) and Onehunga Bay have been subject to significant change since the mid 1800's and been the location of several large scale industrial developments that has resulted in reduction of the Inlet surface area and Inlet cross-sectional area. Ongoing development has resulted in reclamation of the foreshore along the northern embankment of the Inlet and to the west of Gloucester Park. Up to the old Māngere Bridge, the original Inlet had coastal marine area (CMA) of 7.5km^2 but this has been reduced to 5.7km^2 through reclamation, resulting in a loss of 1.8km^2 (24%) of the CMA.

3. The northern coastal edge of the Inlet is protected by a variety of coastal structures including tipped rock, rock revetments and vertical seawalls offering varying degrees of coastal erosion protection. There is no evidence of any significant erosion along the northern coastal edge.

4. Sediments within the Inlet consist of mud and fine grained sand. Core sampling indicated that sediment texture has been muddy since pre-human times. Measured mass fluxes of suspended sediment in Māngere Inlet were greater during the incoming flood than the outgoing ebb tide, indicating that the Inlet acts as a sediment and contaminant sink.

5. Māngere Inlet experiences a significant amount of sediment movement, particularly during windy conditions. Sediment is predominantly from redistribution around the harbour and Inlet rather than from catchment sources. Overall, it is assessed that the average present day sedimentation rate is 10mm/yr.

6. Historical changes over time have been analysed because the construction of a new reclamation has the potential to change the natural character and coastal processes within the Inlet. Observed historical changes have been more pronounced with narrowing of the tidal Inlet channel than with reclamation. Changes to the Inlet due to reclamation have tended to be relatively benign, as reclamation did not encroach into the main tidal channels. It has probably been masked by the effects of narrowing the tidal Inlet channel and the increase in mangrove coverage (now occupy 20% of the inlet over the past 60 years). Narrowing of the tidal Inlet channel has created a coastal inlet whereas it was originally part of the wider harbour environment. This has resulted in a deepening of the main tidal channel and a reduction of wave energy entering the Inlet.

Assessment Undertaken

7. From the assessment of the existing environment, an understanding of how the Inlet and harbour have responded to historical coastal developments was developed.

8. Numerical modelling the Project was undertaken to gain an understanding of the likely changes in the hydrodynamic and sedimentation processes.

9. Morphological changes that relate to any encroachment into the Inlet channel and other tidal channels were assessed.

10. Compared with the existing environment, changes from the results of the numerical model, the morphology study, and coastal enhancement programme were interpreted as either adverse or beneficial effects.

Potential Environmental Effects

11. Potential environmental effects are related to changes to the tidal regime, the sedimentation regime and the coastal morphology. Although changes will occur with the implementation of the foreshore works, the tidal current circulation and the sedimentation patterns are similar.

12. Adverse effects associated with coastal processes for the Foreshore Works alone are considered to be minor.

13. The Project design has allowed for sea level rise and tsunami for at least the next 100 years.

14. The recreated coastline which is part of the Foreshore Works has a beneficial effect in that the coastal processes are part of the overall processes to enhance natural character.

Recommendations

15. As the secondary tidal channel at the eastern end is covered over, a new channel should be created (with similar geometry) to minimise morphological changes.

16. The detailed design of the Project should be peer reviewed to confirm that the effects of climate change and tsunami have been adequately allowed for. Detailed design of the Foreshore Works needs to recognise that elements will be subject to seawater spray and corrosion.

17. Options for declamation in the Manukau Harbour should be investigated to evaluate whether the level of adverse effects of reclamation can be reduced.

B: Ōtāhuhu Creek Bridge

18. Although the existing culverts under SH1 at Ōtāhuhu Creek perform their hydraulic function, the Transport Agency has agreed to replace the culverts with a new bridge. The proposed bridge comprises five 22.5m spans to give a total bridge length of 112.5m and width of 50m.

Existing Environment

19. Ōtāhuhu Creek is a tidal creek which flows into the Tāmaki Estuary. Currently the approximate coastal marine area (CMA) of the creek to the west of SH1 is 5 ha, 95% of which is covered with mangroves. The mostly urbanised catchment has a contributing area of 144ha. The soils in this catchment are well drained, being of volcanic origin.

20. In the late 1950s triple culverts were installed under SH1. The culverts comprise three 2.1x2.1m box culverts, 33m long, with its invert at about 0.5m above mean sea level. The culverts have adequate capacity to accommodate extreme flood events, as well as storm surges and tsunami.

21. Upstream and downstream of the culverts, seabed levels in the main tidal channel of the culverts are lower. This indicates that the tidal flows are sufficient to maintain a formed channel rather than for it to be in filled. Aerial photography indicates that the total area covered by mangrove forest has increased since 1940 especially upstream of the bridge. This suggests that the culverts potentially limited the transportation of sediment out into the estuary promoting a better environment for mangrove growth.

22. Based on the as-built drawings it appears that the area was reclaimed with the construction of SH1. The reclamation area was in the order of 0.6ha or about 12% of the Ōtāhuhu Creek CMA.

Assessment Undertaken

23. From the assessment of the existing environment, an understanding of how the creek has responded to historical coastal developments was developed.

24. Compared with the existing environment, changes related to replacing the culverts with a new bridge were interpreted as either adverse or beneficial effects.

Potential Environmental Effects

25. The proposed bridge will span the original creek to effectively declaim the area. On the northern side, the abutment more-or-less follows the original landform. On the southern side the new landform will declaim about 0.55ha of land. Complete declamation was not feasible as it would interfere with private property. A new tidal channel will be formed to be located in a similar alignment to the original channel at a mid-span location.

26. Ōtāhuhu Creek will remain a depositional environment with minimal erosion risk to the coastline although the tidal channel will exhibit erosion from time to time.

27. The new bridge structure and landform will have a beneficial effect. This effect is mainly as a result of re-introducing the coastal processes that relate to natural character.

C: Dredging and Mudcrete Operation

Short Term Effects

28. It is proposed to use ‘mudcrete’ to build parts of the Foreshore Works. Mudcrete is a material made from mixing dredged material with ordinary Portland cement. The dredged area will be sub-tidal and occupy an area of 15ha within Māngere Inlet.

29. Dredging production rates will be a maximum of 750m^3/day. Required quantities of mudcrete include:
    - 36,000m^3 of in-situ material under the outer bunds to form a stable foundation;
    - 200,000m^3 which needs to be won externally, and of which some 120,000m^3 would form the outer bund to contain the wetlands. The remaining quantity of 80,000m^3 would be used on the internal bunds; and
    - Material won from within the wetland footprint can used to form the seal or liner for the wetlands and to create the main bund for the Project road, but that operation would not be exposed to the tide.

30. Sources of sediment from the dredging/placing operation that could cause a sediment plume which would be dispersed around the Inlet/harbour are:
    - From a dredger bucket (estimated at 19 tonnes per day) in the subtidal area;
    - Overflow from the receiving barge (estimated at 3 tonnes per day);
    - From a small dredger bucket (estimated at 2 tonnes per day) in the intertidal area; and
    - Placement of the mudcrete material (estimated at 2 tonnes per day) in the intertidal area.

31. Maximum sediment concentration away the Project area and from the dredging operation at 200m is estimated to be 31 g/m^3 for the dredging and mudcrete operations at the eastern end of the

Foreshore Works. For comparison the ambient median sediment concentration in the Manukau Harbour is 26g/m^3 with a wide variation (10 to 150g/m^3). Average sediment concentration in the Māngere Inlet is about 30g/m^3. These values are representative of median/average concentrations which would persist over the whole tidal cycle.

32. It is estimated that the average release of sediment (and mudcrete) will be 9 tonnes/tide. This compares to the average natural flux of sediment into and out of the Inlet of 700 tonne on a spring tide and 350 tonne on a neap tide. The sediment release is therefore some 1.5 to 2.5% of the natural sediment flux. The dredged material is the native material, not an introduced source, so the water quality associated with sediment release will be similar to the native material when re-suspended.

33. The fate of the sediment plumes will be predominantly into the Inlet as naturally occurs. The total release of sediment for the Project is about 6,300 tonne. It is estimated that the maximum deposition away from the mixing zones will be 6mm with an average of 4mm. This compares to an average deposition within the inlet of 10mm/year (i.e. 43,000 tonne/year) with 25mm/year at the northern coastline and 10mm in the Anns Creek area.

34. In the context of the Manukau Harbour which is noted for having high natural levels of total suspended solids and sediment deposition, the sediment plumes from the dredging and mudcrete operation will have a minor adverse effect. It will be temporary, persisting for a period of about 1 year.

Long Term Effects

35. On completion of the project the dredged will cover an area of about 15 ha, with the removal of about 200,000m^3 of sediment at an average depth below existing seabed levels of 1.5m. As part of the dredging operation the area of Asian date mussels will be removed.

36. Modelling has indicated that while sedimentation is likely on the flanks of the dredged area the central part of it will remain as a basin. This is likely to be a remnant feature long term but will be within the subtidal area of the Inlet. Overall the long term effect of the dredged area on coastal processes is considered to be minor.

37. The long term adverse effects from the use of mudcrete and potential leaching of contaminants are negligible.

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Glossary of Technical Terms/Abbreviations

Abbreviation	Term
AEE	Assessment of Effects on the Environment
ANZECC	Australia and New Zealand
ARI	Annual Recurrence Interval
AVD	Auckland Vertical Datum
CMA	Coastal Marine Area
EWL	East West Link
ha	Hectares
HAT	Highest Astronomical Tide
km	Kilometre
LAT	Lowest Astronomical Tide
LiDAR	Light Detection and Ranging
MCA	Multi Criteria Analysis
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
MSL	Mean sea level
m/s	Metres per second
mm/year	Millimetres per year
NIWA	National Institute of Water and Atmospheric Research
NZCPS	New Zealand Coastal Policy Statement
The NZ Transport Agency	New Zealand Transport Agency
RL	Relative level
SH(x)	State Highway (number)
TSS	Total suspended solids
UDLF	Urban Design Landscape Plans

1 Introduction

1.1 Purpose and Scope of this Report

This report forms part of a suite of technical reports prepared for the NZ Transport Agency's East West Link project (EWL or the Project). Its purpose is to inform the Assessment of Effects on the Environment (AEE) and to support the resource consent applications, new Notices of Requirement and alterations to existing designations required for the EWL.

This report assesses the coastal processes effects of the proposed alignment of the Project as shown on the Project Drawings in *Volume 2: Drawing Set*. The effects related to the foreshore works and the elevated structures in the coastal marine area are hereafter referred to as the “foreshore works” assessment (See Figure 1-1). The coastal processes effects related to the new bridge across Ōtāhuhu Creek in the coastal marine area are hereafter referred to as the “Ōtāhuhu Creek” assessment (See Figure 1-2).

The purpose of this report is to:

a) Identify and describe the existing coastal processes environment;

b) Describe the potential coastal processes effects of the Project;

c) Recommend measures as appropriate to avoid, remedy or mitigate potential adverse coastal processes effects (including any conditions/management plan required); and

d) Present an overall conclusion of the level of potential adverse coastal processes effects of the Project after recommended measures are implemented.

It is also noted that through the process of understanding the coastal processes, guidance was given on the design of the works to reduce or minimise adverse effects. That guidance is described in this report.

This report provides a complete description of the proposed dredging operation and its potential effects is given in Appendix F.

1.2 Project description

The EWL Project involves the construction, operation and maintenance of a new four lane arterial road from State Highway 20 (SH20) at the Neilson Street Interchange in Onehunga, connecting to State Highway 1 (SH1) at Mt Wellington as well as an upgrade to SH1 between the Mt Wellington Interchange and the Princes Street Interchange at Ōtāhuhu. New local road connections are provided at Galway Street, Captain Springs Road, the ports link road and Hugo Johnston Drive. Cycle and pedestrian facilities are provided along the alignment.

The primary objective of the Project is to address the current traffic congestion problems in the Onehunga, Penrose and Mt Wellington commercial areas which will improve freight efficiency and travel reliability for all road users. Improvements to public transport, cycling and walking facilities are also proposed.

For description purposes in this report, the Project has been divided into six sectors. These are:

- Sector 1 Neilson Street Interchange and Galway Street connections;
- Sector 2 Foreshore works along the Māngere Inlet foreshore including dredging;
- Sector 3 Anns Creek from the end of the reclamation to Great South Road;
- Sector 4 Great South Road to SH1 at Mt Wellington;

- Sector 5 SH1 at Mt Wellington to the Princes Street Interchange;
- Sector 6 Onehunga local road works.

A full description of the Project including its design, construction and operation is provided in Part C: Description of the Project in the Assessment of Effects on the Environment Report contained in *Volume 1: AEE* and shown on the Drawings in *Volume 2: Drawing Set* in the following plan sets:

- Plan Set 4: Landscape
- Plan Set 5: Coastal Occupation
- Plan Set 6: Plan and Long Sections
- Plan Set 7: Typical Cross Sections
- Plan Set 8: Structural

1.3 Design Considerations for the Foreshore Works

Reclamation resulting in permanent loss of the coastal marine area (CMA) for construction of the foreshore has the potential to result in changes to the tidal regime, the sedimentation regime and coastal morphology.

The proposed reclamation includes occupation areas for the road embankment, stormwater treatment devices, and a naturalised coastal edge. The extent of the reclamation for the road embankment has been minimised to the greatest extent practicable for the given alignment along the northern coastline. Through the consultation process, there was support for incorporating stormwater treatment devices for the Onehunga/Penrose catchments but these would need to be located within the CMA. In addition it was considered by the Project Team that the Project should have a more naturalised coastal edge, representative of the historical land/coastal interface, with the aim of enhancing the natural character and providing amenity.

The design of the Project to date has given particular consideration to the potential effects on coastal processes with the purpose of avoiding or minimising effects by:

- Minimising intrusive reclamation in the area near the Inlet entrance (by Galway Street up to Albert Street) as past intrusion into the Inlet entrance has resulted in more noticeable effects;
- Avoiding reclaiming into the tidal channels as this would alter the morphology of the channels and result in a different distribution of tidal flows and sedimentation regime. The exception is at the eastern end of the reclamation where a secondary tidal channel that feeds into Anns Creek is located close to the northern coastline. In this location a new tidal channel has been included in the design with the same dimensions as the existing channel. The location of the new channel is shown on Figure F-1, Appendix F;
- Discharging stormwater from the proposed treatment wetlands through the headland structures into the tidal channels, thereby reducing scouring of the intertidal mudflats; and
- Incorporating coastal features such as headland structures and rocky foreshores into the recreated coastline.

Specific coastal engineering input into the design to date has included:

- Road levels and platform levels that provide long term resilience to extreme wave events, sea level rise and tsunami but also recognise the day-to-day functionality requirements;
- Beach shape in terms of alignment, berm level and slope;
- Headland lengths to contain pocket beaches;
- Rock armour protection for extreme waves, allowing for climate change; and

- Outfall locations for stormwater discharges.

Refer to the following drawings in *Volume 2: Drawing Set* for further details on the foreshore work

- Drawings referenced AEE-LA-103 to AEE-LA-107 and cross sections referenced AEE-LA-202 to AEE-LA-204 in Plan Set 4: Landscape;
- Drawings referenced AEE-CMA-101 to AEE-CMA-104 in Plan Set 5: Coastal Occupation; and
- Drawings referenced AEE-C-321, AEE-C-323 and AEE-C-324 in Plan Set 7: Typical Cross Sections.

Figure 1-1: Foreshore Works

1.4 Design Considerations for Otahuhu Creek

Existing box culverts are proposed to be replaced by a multi span bridge. This will also declaim an area of about 0.5 ha.

Specific coastal engineering input into the design to date has included:

- Realignment of the main tidal channel close to its 1940s historical alignment;
- Removal of fill material to create the declamation; and
- Slope protection to new areas adjoining existing properties and adjacent the new bridge abutments.

Refer to the following drawings in *Volume 2: Drawing Set* for further details on the works within Ōtahuhu Creek:

- Drawing referenced AEE-LA-112 and cross section referenced AEE-LA-207 in Plan Set 4: Landscape;
- Drawing referenced AEE-CMA-111 in Plan Set 5: Coastal Occupation; and

- Drawing referenced AEE-S-065 in Plan Set 8: Plans and Long Sections.

Figure 1-2: Ōtāhuhu Creek Bridge

2 Experience

2.1 Expertise

This report has been prepared by Stephen Priestley as lead of the coastal processes and coastal engineering. He has the qualifications of Bachelor of Engineering (1st class honours) and a Master of Engineering Science. He is a Fellow of the NZ Institution of Professional Engineers (IPENZ), a Chartered Professional Engineer, a member of the NZ Coastal Society, and a member of the NZ Hydrological Society.

Stephen has 37 years of experience in civil engineering with a focus on hydrological, hydraulic, coastal and port engineering. He has led and been responsible for projects such as the Fergusson Terminal expansion in the Waitematā Harbour, the Americas Cup Harbour Development in the Viaduct Basin, the development of Northport in Whangarei Harbour, dredging projects in the Manukau Harbour, and restoration of the coastline associated with the removal of the wastewater treatment ponds at Māngere Treatment Plant.

The report was reviewed by Connon Andrews. He has a Master of Science in coastal processes. He has over 20 years of experience and has worked in the areas of coastal processes, natural hazards, coastal engineering, master planning, marine facilities design and environmental assessment. He has had extensive international experience.

The hydrodynamic and sedimentation model studies were performed by Dr Mark Pritchard. He has a PhD in physical oceanography, has over 15 years of experience and is a coastal and estuarine physical process scientist with the National Institute of Water and Atmosphere (NIWA). He has completed studies into the coastal effects of the proposed runway extension of Wellington Airport, Kaipara Harbour sediment transport study and Firth of Thames sediment transport study.

3 Assessment Methodology

Coastal processes relate to the coastal hydrodynamics (the movement of fluid), sedimentation (the supply, transport, erosion and deposition of sediment) and morphology (the natural form) of the study areas. For the Foreshore Works Assessment, the study area is the Māngere Inlet (the "Inlet") and adjoining coastal marine areas (CMA) which is the area most likely to be affected by the Project. For the Ōtāhuhu Creek assessment, the study area is the upper part of the Tāmaki Estuary.

The overall aim of the report is to describe the coastal processes and to assess the environment effects of the Project on the study areas.

3.1 Foreshore Works Assessment

The initial phase of the study was to assess the existing environment. As there has been significant reclamation within the Inlet and encroachment into the Inlet channel, the effects of these human related activities will provide a gauge as to potential future effects. This part of the study included:

- Site visits;
- Condition assessment of existing coastal protection structures;
- Meeting with mana whenua to describe the Project and the coastal processes;
- Participation in the multi-criteria-assessments (MCAs) for the proposed foreshore works (Sector 2) and for the route over Anns Creek (Sector 3);
- Bathymetric survey of the Inlet;
- Literature search on hydrodynamics, sedimentation and morphology related issues in the study area. It also included information from historical reports, factual data, sounding charts and aerial photos;
- Assessing the historical coastal process changes (and effects) with the study area due to natural processes and human intervention. This provided an understanding of the cumulative effects; and
- Developing a numerical model to simulate the hydrodynamic and sedimentation processes (by NIWA).

The second phase of the study was to assess the effects of the Project on the existing environment. The Project will include reclamation, coastal enhancement and protection works, dredging and stormwater discharges to the CMA. This part of the study included:

- Working with the ecologists, landscape architects, urban designers, stormwater engineers and planners to develop an overall coastal enhancement programme, some of which was aimed at reducing historical adverse effects;
- Modelling the project to gain an understanding of the likely changes in the hydrodynamic and sedimentation processes, including any dredging operations;
- Assessing any morphological changes that relate to any encroachment into the Inlet channel and other tidal channels;
- Quantifying the extent of dredging and likely short and long term changes;
- Interpreting the changes from the numerical model, morphology study, dredging assessment, and coastal enhancement programme as either adverse or beneficial effects; and
- Preparing a coastal processes report (i.e. this report) which includes the existing environment, a description of coastal engineering works, the assessment of environmental effects and any mitigation.

3.2 Ōtāhuhu Creek Assessment

The initial phase of the study was to assess the existing environment. Due to installation of culverts, reclamation and encroachment into the estuarine channel, the effects of these human related activities provide a gauge as to potential future beneficial effects of building a new bridge. This part of the study included:

- A site visit;
- Participation in the multi-criteria-assessments (MCAs) for the proposed bridge (Sector 5);
- Topographic and bathymetric survey of the adjoining area;
- Literature search on hydrodynamics, sedimentation and morphology related issues in the study area. It also included information from historical reports, factual data, sounding charts and aerial photos;
- Assessing the historical coastal process changes (and effects) with the study area due to natural processes and human intervention. This provided an understanding of the historical adverse effects; and
- Assessing the stormwater inputs as well as tidal flows through the culverts.

The second phase of the study was to assess the effects of the Project on the existing environment. The Project will include removal of the culverts and declamation. This part of the study included:

- Working with the ecologists, landscape architects, urban designers, stormwater engineers and planners to develop a new landform adjacent to the new bridge structure;
- Assessing any morphological changes that relate to opening up of the tidal channel;
- Quantifying the need and extent of any dredging to create equilibrium within the new tidal channel; and
- Preparing a coastal processes report (i.e. this report) which includes the existing environment, a description of coastal engineering works, the assessment of environmental effects and any mitigation.

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4 Statutory Framework and Guidelines

The following documents have informed the assessment of coastal processes:

- The Resource Management Act (1991) and Amendments;
- New Zealand Coastal Policy Statement, particularly Policies 10, 24 and 25;
- Auckland Unitary Plan objectives, policies and rules;
- MFE, 2009: Preparing for Coastal Change – a guide for local government in New Zealand;
- NIWA, 2013: Coastal Inundation by Storm-Tides and waves in the Auckland Region. Prepared for Auckland Council; and
- GREIG, D, JAMES, 2014: Coastal Effects Assessment Guideline. For NZTA.

A key theme of these resource documents is the need to avoid reclamation where it cannot be justified. This aspect is described in detail in the AEE document. Evaluation of options and providing mitigation of adverse effects are key considerations.

5 Existing Environment: Foreshore Works

5.1 Physical Environment

5.1.1 Māngere Inlet

Māngere Inlet is a semi-enclosed basin comprising of shallow tidal creeks, mangroves and large expanses of intertidal mud flats. From the LiDAR data (2013) it is estimated that the estuary surface area is 5.7km^2 east of the old Māngere Bridge. The contributing catchment is mostly urbanised catchment with an area of about 34.5km^2. It is predominantly an intertidal estuary with low freshwater inflows.

Māngere Inlet is linked to Onehunga Bay by a narrow channel. The current width of the channel under the existing SH20 motorway bridge is around 300m and has a cross sectional area of 1524m^2 (ARC 2006). The original Māngere trestle bridge, however, incorporated causeways at both ends. That bridge was replaced in 1915 with the current ferro-cement bridge for which the design drawings show a channel width of about 250m (Felgate, 2016). With the construction of the impervious rock causeway at the south end of Māngere Bridge it is estimated to have a channel width of 240m at Mean Sea Level (MSL) and has a cross-section area of around 1420m^2 below MSL based on levels provided in NZ 4315 (ARC, 2006).

The northern coastline has undergone extensive urban development and reclamation since the 1940s as illustrated in Figure 5-1. It lies east of Onehunga Bay where it is sheltered from strong tidal currents and a moderate wave climate, making it a site for sediment deposition. Historic reclamation has led to the loss of three embayments and the loss of tidal inundation to the Hōpua volcanic crater.

Figure 5-1: Changes in the northern shorelines between 1853 (yellow outline) and 2010. Source LINZ.

Extensive reclamation along the eastern shore of Māngere Inlet was also carried out in the 1960s with the development of the Westfield rail yards (Matthews et al. 2005). Overall it has been estimated that 1.8km^2 (24% of the Inlet surface area) of land has been reclaimed within the bay since 1940.

Anns Creek remains in the northeast corner of the Inlet, although it is highly modified with only a short section of open stream remaining.

The southern shore is less modified, with inlets to Harania and Tararata Creeks still largely intact although the upper reaches of both creeks are dissected by high volume roads and, based on aerial photography, Harania creek lost area due to reclamation work done in the late 1900s. Tararata creek discharges into Māngere Inlet some 1km to the south east of the SH20 Māngere Bridge. Today, both creeks are heavily forested with mangroves.

The Inlet consists of muddy to fine grain sediment. The 1853 sounding chart described it as ‘soft black mud’ suggesting that sediments within the Inlet have always been muddy. The most widely distributed and abundant coastal plant is the mangrove Avicennia marina. They are most prevalent at the eastern end of the inlet. The total area covered by mangrove forest was approximately 1.1km^2 in 2001 but a 1959 aerial photo indicated that mangroves were absent (ARC 2006). There is a large central mudflat with a shelly shoal that extends southeast-northwest along its eastern edge. The mudflat and “white shelly bank” appears on the 1853 sounding chart (Figure 5-2) suggesting it has persisted more than 150 years. Also the small island of Ngarango Otainui is marked on the 1853 sounding chart.

Figure 5-2: 1853 Sounding Chart (Drury, 1853) with coastline highlighted

The northern coastline is partially protected from erosion by a mixture of tipped rock, vertical seawalls and engineered riprap revetments. Coastal protection works along part of the northern coastline were inspected, as depicted in **Error! Reference source not found.** - inspection notes and photos are included in Appendix A. At Alfred Street there was a masonry seawall in average condition as it exhibited lost rock units and minor scouring but was still functioning. The majority of northern coastline was lined with a riprap seawall. The riprap and walkway lining Anns Creek (Hugo Johnston Drive inspection) was in poor condition or not visible due to dense debris and vegetation growth. It is estimated the rock sizing along the coastline has a diameter of 800-900mm at the top of the wall and 200-300mm at the base and on average the wall was 1.5m high. Overall, there is no evidence of any significant erosion along the northern coastal edge.

5.1.2 Onehunga Bay

Onehunga Bay is at the north-eastern end of Manukau Harbour. It was an important route for Māori who portaged waka between the Tāmaki River and the Manukau Harbour. It has been a popular port location for Europeans since the late 1800s. Onehunga Wharf was completed in stages with the most recent wharf completed in early 1960s.

Reclamation surrounds the area of port operations. Post 1940s Te Hōpua crater (forming Gloucester Park) was filled for local and arterial road projects.

The coastal fringe is lined with conventional sloping rock revetments along the majority of SH20.

In 2015 the Onehunga Foreshore Project was completed, including new sand and rocky beaches, backshore and amenity areas. This involved some 10ha of reclamation. See Figure 5-3.

Figure 5-3: Onehunga Foreshore Project (Auckland Council)

5.1.3 Manukau Harbour

Manukau Harbour is a large coastal lagoon on the west coast of the North Island NZ. It is a meso-tidal lagoon which has a sizable spring tidal prism of 9138 million m^3. (The tidal prism is the volume of seawater exchanged between MHWS and MLWS upstream of a reference point, e.g. old Māngere Bridge). The harbour is connected to the Tasman Sea by an entrance channel, 45m deep and 2km wide. At Mean High Water Springs (MHWS) there is a surface area of 368km^2 which is reduced 60% at Mean Low Water Springs (MLWS) and exposes low-gradient tidal flats and banks covering 145km^2 (Bell et al, 1998).

There has been no formal estimate of reclamation areas within the Manukau Harbour. Auckland Council advised the hearing panel for the Onehunga Foreshore Project that their estimate of total reclamation was 2.3% of the Harbour area. This translates into a total reclamation area of 8.5km^2. As part of this Project, reclamation areas were re-estimated with a similar finding that total reclamation within the Manukau Harbour is 8.5km^2.

5.2 Coastal Processes

The following is a description of the coastal processes based on existing literature and data. NIWA has undertaken numerical modelling of the existing coastal hydrodynamics and sedimentation and their work is included as Appendix C.

5.2.1 Tidal Levels and Currents

Onehunga Bay is characterised as a predominantly semi-diurnal (twice daily) tide. At Onehunga Wharf the peak-flood velocity is only 1.75 hours before high water whereas peak ebb occurs 2.5 hours after high water. (Bell et al, 1998).

Tidal velocity information is available within the main channel adjacent to the Onehunga Wharf (NZ4314, LINZ). The data suggests peak flood tide velocities at the neck of Māngere Inlet reach 1 m/s during spring tides and up to 0.5 m/s during neap tides (Bell et al. 1998). During ebb tidal flows, peak spring and neap tidal velocities of 0.80 m/s and 0.45 m/s respectively are expected. At these velocities the tidal flow are capable of mobilising and transporting sediment.

The tidal wave within the Manukau Harbour is amplified from a spring tidal range of 2.9m at Manukau Heads to 3.8m at the Port of Onehunga. The tidal characteristic for the Port of Onehunga, based on recorded tide levels since 1925, are given in Table 5-1 (LINZ, 2016). These tidal levels have been adopted for the Project in terms of the Auckland Vertical Datum (AVD, 1946).

Table 5-1: Tidal Levels for project in terms of Auckland Vertical Datum 1946

Tidal levels	Chart Datum (m) for 2016	Auckland Vertical Datum (1946 –m)
Highest Recorded Tide (1965)	5.24	3.04
Highest Astronomical Tide (HAT)	4.54	2.34
Mean High Water Springs (MHWS)	4.25	2.05
Mean High Water Neaps (MHWN)	3.44	1.24
Mean Sea Level (MSL)	2.42	0.22
Mean Low Water Neaps (MLWN)	1.33	-0.87
Mean Low Water Springs (MLWS)	0.45	-1.75
Lowest Astronomical Tide (LAT)	0.10	-2.10
Lowest recorded tide	-0.48	-2.68

The highest recorded storm-tide to date since measurements started at the Port of Onehunga was RL 2.75 which occurred on 21 June 1947 but an event on 31 July 1965 is believed to have reached RL 3.04 (as the gauge had already reached its upper limit).

Extreme sea levels represent a storm tide, based on a high tide plus storm surge. Extreme sea levels have been modelled for Auckland City at the site and probability based levels reported in NIWA (2013). Along the Māngere Inlet storm tide levels are given in Table 5-2.

Table 5-2 Extreme sea-level events

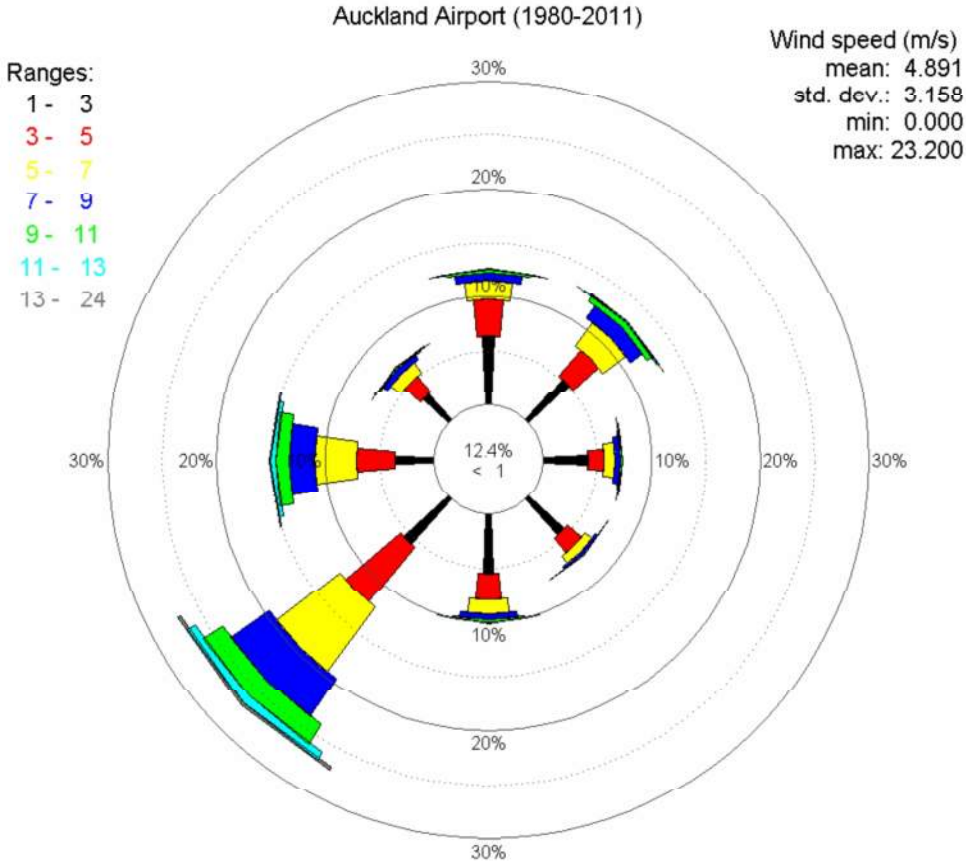
Frequency (Annual Recurrence Interval - yr.)	Still Water Level (AVD –m)
2	2.56
5	2.64
10	2.72
20	2.80
50	2.92
100	3.00
200	3.09

5.2.2 Wind

Wind generates local currents and waves. Wind generated currents are a frequent feature within Māngere Inlet, with currents reaching about 2% of the wind speed. For wind speeds less than 7m/s, wind generated currents predominate whereas for wind speeds greater than 7 m/s, wave conditions predominate.

The prevailing surface wind direction is predominantly from the south-west (26%), west (15%) and from the north to north-east (15%). A wind rose for the area is illustrated in Figure 5-5.

Figure 5-4: Wind Rose from Auckland Airport



5.2.3 Wave Climate

The northern coastline of Māngere Inlet has a maximum fetch of 2.2km at MHWS from the south west, 1.6km from the south, and 3.2km from the south east. As it lies at the north-eastern end of Manukau Harbour it is sheltered from higher energy wave climate of the main body of the harbour.

Typical significant wave heights (Hs - m), peak wave periods (Tp - s) and the percentage exceedence per year (%/yr) at MHWS are presented in Table 5-3. These wave characteristics are based on predictive wave hindcast techniques (CIRIA et al, 2006) using wind speed, fetch length and water depth as input parameters.

Table 5-3: Predicted Wave climate within Māngere Inlet

Wind Speed	3 m/s			7 m/s			10 m/s			15 m/s		
Wind Direction	Hs	Tp	%/y	Hs	Tp	%/y	Hs	Tp	%/y	Hs	Tp	%/y
S	0.1	1.00	7.2	0.15	1.6	0.9	0.2	1.80	0.2	0.3	2.2	0.01

SW	0.1	1.00	23	0.2	1.7	8	0.2	2.00	2.7	0.4	2.6	0.1
SE	0.1	1.10	4.4	0.2	1.9	0.4	0.3	2.2	0.1	0.4	2.1	0.01

Based on the wave heights in Table 5-3 ambient wave conditions are generally less than 0.3m within Māngere Inlet for the majority of the time.

Extreme significant wave heights (Hs - m), peak wave periods (Tp - s) and sustained wind speed (W - m/s) at MHWS are presented in Table 5-4. An average water depth of 2.5m was assessed at MHWS.

Table 5-4: Predicted Extreme Wave climate within Māngere Inlet

Event	2 year ARI			10 year ARI			50 year ARI			100 year ARI		
Wind Direction	Hs	Tp	W	Hs	Tp	W	Hs	Tp	W	Hs	Tp	W
S	0.3	2.2	16	0.4	2.4	18	0.4	2.5	21	0.4	2.6	22
SW	0.4	2.6	19	0.5	2.7	20	0.5	2.1	23	0.6	2.9	24
SE	0.4	2.6	16	0.5	2.8	19	0.6	3.0	22	0.6	3.1	24

5.2.4 Seabed Levels

Most historical sounding surveys have not recorded seabed levels within the Māngere Inlet as it is relatively shallow, indicating limited navigability. As part of this Project a sounding chart has been prepared based on a combination of LiDAR data and a hydrographic survey. The chart is included as Appendix B.

Within the Inlet the spring intertidal area is estimated to be 5.0km^2 and the neap intertidal area is 4.2km^2. Given that the overall area of the Inlet is 5.7km^2, this illustrates how shallow the Inlet is.

5.2.5 Sedimentation

Tide and wind generated currents in combination with locally generated wind waves act together to suspend and transport fine sediments from the exposed intertidal banks, leading to enhanced turbidity levels. In shallow zones these are referred to as turbid fringes.

A survey by Williamson et al. (1996) found that mass fluxes of suspended sediment in Māngere Inlet were greater during the flood than ebb tide and concluded that the inlet acted as a sediment and contaminant sink. Their research concludes that the annual catchment inputs of suspended solids and associated contaminants are considerably less than the amounts of sediment transported in and out of the Inlet during one tidal cycle.

Core sampling has indicated that sediment texture has been muddy since pre-human times. Seabed sediments within the Māngere Inlet and Onehunga Bay are comprised of sandy mud with outcrops of gravelly sandy mud with areas of calcium carbonate in excess of 50% (Northern Gateway Alliance, 2006). Hume et al (1989) reported that sediments in the Māngere Inlet were 15% sand and 85% mud (silt and clay).

There has been a wide range of sedimentation rates reported in the literature within Māngere Inlet and adjoining areas. At the lower end of the range, Croucher (2005) predicted sedimentation rates ranged from 0.01mm/year to 0.5 mm/year from numerical modelling. At the higher end of the range, sediment deposition rates at the Port of Onehunga are about 1 m/year, based on annual maintenance dredging records.

Research by Wilcock et al (1995) derived sedimentation rates by examining the change in PAH levels over the depth of 2 sediment cores. They established that the sedimentation rates were 30 and 49 mm/yr., with reference to the pre-1950 sedimentation levels being less than 5 mm/yr. Williamson et al (1996) measured the net influx of sediment into the inlet on a spring tide with elevated levels of suspended sediment as 210 tonne (which equates to about 0.05mm/tide of deposition). They provided sediment fluxes for spring and neap tides (700 tonnes for flood and ebb spring tides and 350 tonnes for neap tides), which if the net fluxes were all deposited in the Inlet, the average sedimentation rate would be 8mm/yr. This compares with measured sedimentation rates of 5mm/yr in the Drury Creek estuary in the south-eastern reaches of the Manukau Harbour (Hume et al, 1989). These rates of sedimentation are not inconsistent (but slightly higher) with measured rates in the upper Waitematā Harbour (3mm/yr.) and Okura Estuary (5mm/yr.).

Based on Williamson et al (1996) and assuming fully mixed conditions the average suspended sediment concentration in the Māngere Inlet was 32 g/m^3 during a spring tide and 30 g/m^3 during a neap tide. Higher concentration could be expected around mid-tide when the tidal currents are highest. Measured suspended sediment concentrations in the Manukau Harbour are relatively high with a median of 26 g/m^3 with a long term range between 10 to 150 g/m^3 (ARC, 2009).

In an attempt to gauge the recent sedimentation rates in the Inlet a comparison was made of the intertidal seabed levels between the 2006 and 2013 LIDAR information. A summary of this comparison is given in Appendix D. Sedimentation rates were derived over block areas which included many surface points so as to balance out the inherent inaccuracies in the LIDAR data. Overall, across all the common areas of data, the average sedimentation rate was 10mm/yr which equates to a total deposition volume of 57,000m^3 or 43,000 tonnes. Areas of mangroves and exposed intertidal flats had similar rates with an average sedimentation rate of 17mm/yr while in areas near tidal channels, in tidal channels and around islands the average erosion rate was 26 mm/yr. In general the northern coastline had higher sedimentation rates than the southern coastline.

It is concluded that Māngere Inlet is a sediment sink and experiences a significant amount of sediment movement, particularly during windy conditions. Sediment in the Māngere Inlet is derived predominantly from redistribution around the harbour and Inlet rather than from local catchment sources. The increase in mangrove distribution throughout the Inlet over the past 50 years has probably increased sedimentation levels. Overall it is assessed that the average present day sedimentation rate is 10mm/yr whereas the pre-1950 rate was probably around 5 mm/yr. Over the period 1950-1990, sedimentation rates were probably higher than present day rates.

5.2.6 Sediment Quality

Sediment quality investigation, results and assessment are contained in Appendix E. For the Inlet, the following conclusions can be drawn from the sediment quality investigations:

- Generally, metal concentrations were consistent with that of concentrations measured in sediments in other parts of the Auckland region, and likely to be generally representative of background concentrations;
- Some localised concentrations for chromium, copper, zinc, and nickel in excess of the ANZECC ISQG low. These exceedences are not considered statistically significant, and overall concentrations appear to be relatively consistent with concentrations in parent soil / rock material;
- The exception to this was arsenic where some concentrations were elevated above natural concentrations (parent materials), and above ANZECC low acceptance criteria at approximately half the locations. This may indicate that that some organisms may be adversely impacted by arsenic concentrations in sediments, if bioavailable;

- Low concentrations of organic compounds where detected at some locations. Organic contaminant concentrations were within acceptance criteria;
- No significant trends were observed for contaminant distribution within the Māngere inlet, however it can be concluded that contaminant concentrations were higher in the vicinity of stormwater outfalls. No significant trends noted with contaminant depth profiles;
- Contaminant concentrations were most elevated in sediment samples collected from Miami Stream, upstream of the culvert at the foreshore; and
- Concentrations of ammoniacal nitrogen in porewater is likely to be rapidly diluted within the marine water within the subtidal areas. Any ammoniacal nitrogen released in the intertidal area is likely to be rapidly diluted within tidal movement of water.

5.3 Historical Changes

As a general principle, it can be assumed that natural changes in hydrodynamics and morphology are slow enough that an inlet can adapt gradually. However sudden changes caused by human intervention (structures, landfill) will shift the inlet's equilibrium. These shifts will force a change within the inlet until it reaches a new equilibrium.

Historical human intervention to the inlet was compared with local hydrodynamic and morphological changes to gain a better understanding of how it will react to the Project.

5.3.1 Surface Area of Māngere Inlet

Surface area (east of the Old Māngere Bridge) of the Māngere Inlet is based on aerial photos dating back to 1940 and earlier sounding surveys. Table 5-5 summarises the Inlet's historical and present day surface areas.

Table 5-5: Estimated area of Māngere Inlet from photos and charts back to 1853 to Present

Māngere Inlet	Inlet Surface Area (km^2)
1853	7.5
1940	7.2
1960	7.0
1980	6.0
Present	5.7

From Table 5-5, it is estimated that 1.8km^2 of reclamation has occurred within the inlet, or 24% of the original inlet area. This loss is area is mainly a result of reclamation filling and landfill activities that occurred along the northern and eastern coastlines. Other small reclamations occurred at the southern end of the SH20 Bridge and inside Harania creek. The reduction in the inlet area has led to the loss of natural features and reduction in tidal prism.

5.3.2 Inlet entrance

A sounding chart completed in 1853 (Drury et al.) shows that the inlet was an open basin (Figure 2.2) with an estimated entrance 630m wide. However with construction of the impervious rock causeway at the south end of the Old Māngere Bridge (first built in 1875) the width of the entrance is estimated to have been reduced to 240m. Using a transect taken along the alignment of the old Māngere Bridge, Figure 5-5 shows how the entrance has changed over time.

Figure 5-5: Changes to Māngere channel entrance over time

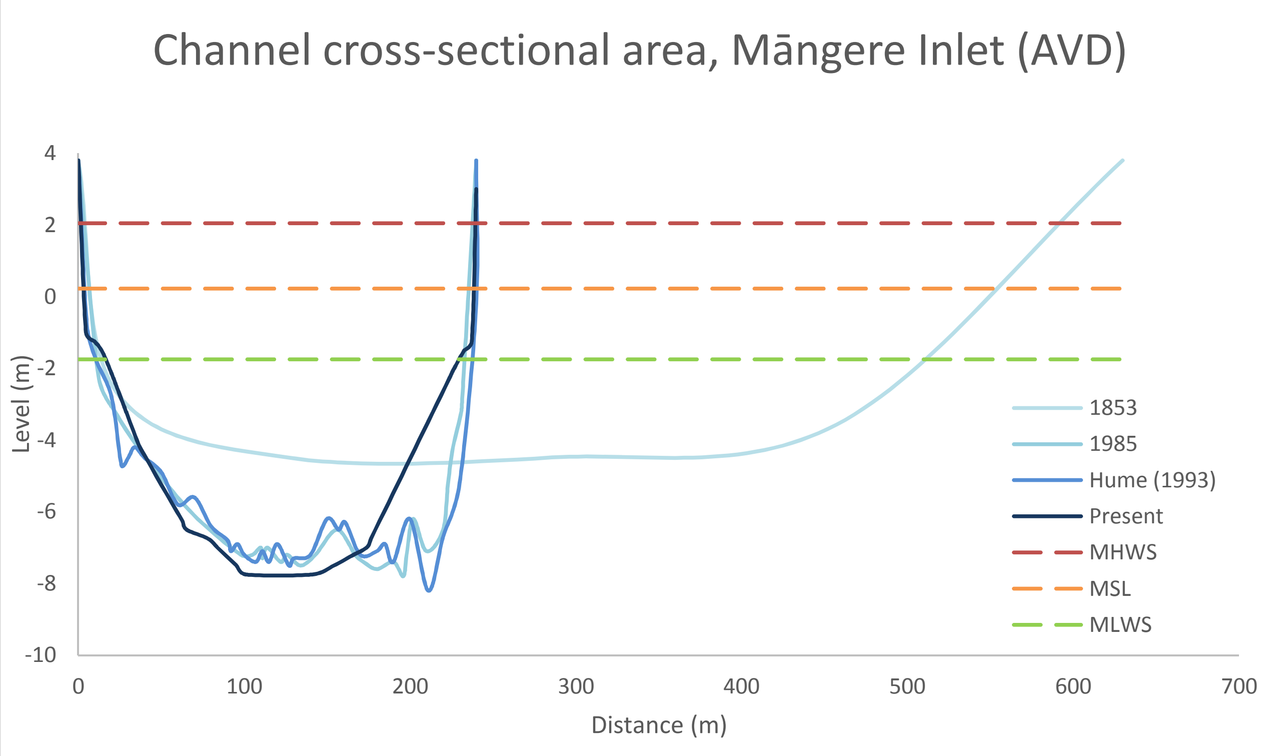


Table 5-6 summaries the changes in cross sectional area of the Inlet at old Māngere Bridge, below mean sea level (MSL).

Table 5-6: Historical cross-sectional area (m^2) of Māngere Inlet channel entrance

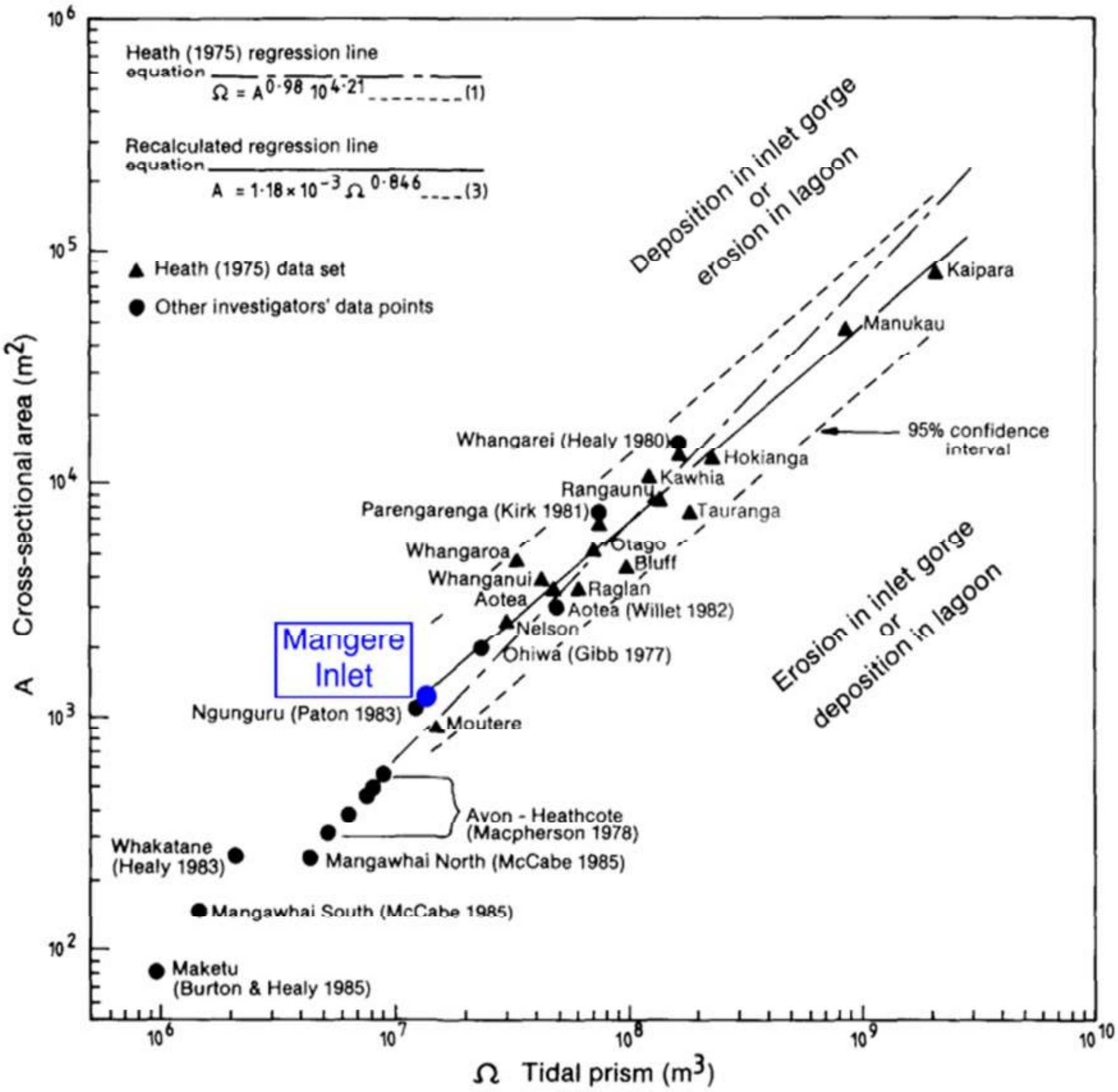
Māngere Inlet (year)	Cross-Sectional Area of entrance below MSL (m^2)
1853	2055
1985	1424
1993	1449
Present	1339

It is estimated that the construction of the Māngere Bridge causeway in 1875 reduced the original cross-sectional entrance area by over 60%. Although scouring has deepened the entrance over time the cross-sectional area is still much less than in 1853.

5.3.3 Tidal Prism

Based on the 2016 hydrographic/LiDAR survey (Appendix B), the tidal prism of Māngere Inlet is 11, 900,000m^3 to MHWS at Māngere Bridge. Based on work of Hume and Herdendorf (1988), the tidal prism/cross-sectional area regression line is $A=1.18x10^{-3}\ \Omega^{\ 0.846}$ as illustrated in Figure 5-6. When Māngere Inlet was plotted using the cross sectional area (A) versus the tidal prism (Ω) it was at the lower end of the regression and indicating it is in equilibrium.

Figure 5-6 : Tidal Prism/Cross-sectional Area Relationship (Hume and Herdendorf 1988)



5.3.4 Bathymetry

Historical bathymetric data of Māngere Inlet entrance was found for 1853, 1985 and 1993 (Hume). These charts were studied to develop an understanding of how the morphology has changed over time and finally compared to a 2016 detailed survey (POAL, 2016). The most noticeable change over time is seen at the channel entrance, where it appears to have deepened by 5.5m from 1853, as reflected in Figure 5-5. Table 5-7 summarises the channel entrance depths over time.

Table 5-7: Changes over time of the channel entrance depth at Māngere Inlet

Māngere Inlet	Max Depth at Inlet Opening (m) (AVD)

1853	-2.3
1985	-7.5
1993	-7.4
Present	-7.8

The inlet acts as a sediment sink but the channel inlet entrance has experienced scouring (Figure 5-5) over time. The inlet has adjusted to unnatural morphological changes by a combination of entrance scouring and potentially sedimentation within the inlet. These processes appear to be ongoing. It is noted however that the large sediment fluxes experienced within the inlet and its entrance are a natural phenomenon. A description of likely sedimentation rates within the Inlet was provided in Section 5.2.5.

Figure 5-7 illustrates the change in location of the main tidal channels within the Inlet. The 1853 bathymetry plan has been used as a base map for the illustration. Overall it appears that the channels have moved slightly south over time but have migrated in a northerly direction over recent time. The main channel alignment is restricted to any further northward movement by structural controls such as the remaining lava flow reefs, seaward of Albert St and Pikes Point.

Figure 5-7: Māngere Inlet Tidal Channels over time

5.3.5 Coastal Process Changes resulting from Historical Works

Overall the Māngere Inlet is a depositional (or accreting) coastal environment. The coastline of the Inlet is not experiencing any noticeable erosion and as such natural coastal features like the volcanic outcrops and shell banks have remained intact.

It has been estimated that $1.8km^2$ of the coastal marine area has been reclaimed within the Inlet. Observed historical changes have been more pronounced with narrowing of the tidal Inlet channel than with reclamation.

Changes to the Inlet due to reclamation have tended to be relatively benign, as reclamation did not encroach into the main tidal channels. It has probably been masked by the effects of narrowing the tidal Inlet channel and the increase in mangrove coverage (now occupy 20% of the inlet over the past 60 years). Narrowing of the tidal Inlet channel has created a coastal inlet whereas it was originally part of the wider harbour environment. This has resulted in deepening of the inlet channel and a reduction of wave energy entering the Inlet.

The main tidal channels have remained more-or-less in the same location. This indicates that, apart from a change in coastline shape, the intertidal morphology has been stable.

This review of the historical changes to the Inlet has been used to inform the assessment of effects.

6 Existing Environment: Ōtāhuhu Creek Bridge

6.1 Physical Environment

6.1.1 Ōtāhuhu Creek

Ōtāhuhu Creek is a tidal creek which flows east to northeast into the Tāmaki Estuary. Mount Wellington is directly north of the creek and Ōtāhuhu is directly south. There has been extensive urban development surrounding the creek since 1940.

Currently the approximate coastal marine area (CMA) of the creek to the west of SH1 is 5 ha, 95% of which is covered with mangroves. The mostly urbanised catchment has a contributing area of 144ha. The soils in this catchment are well drained, being of volcanic origin.

In the late 1950s, triple culverts were installed under SH1. The culverts comprise three 2.1x2.1m box culverts, 33m long, with their invert at about 0.5m above mean sea level.

Figure 6-1: Ōtāhuhu Creek Aerial Photo (LINZ)

6.1.2 Tāmaki Estuary

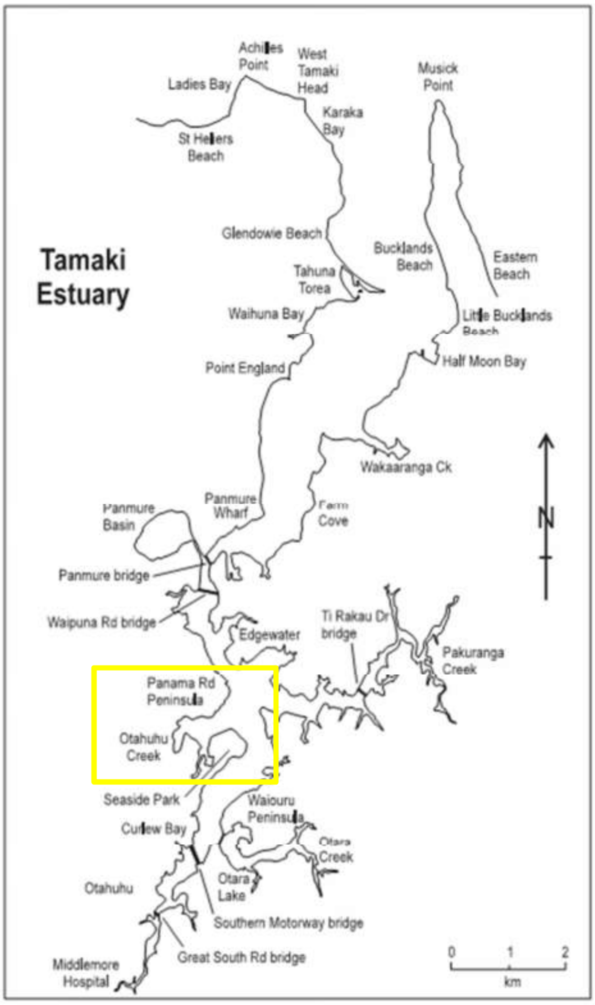
Tāmaki Estuary is on the eastern side of Auckland City and forms a long narrow channel about 17km in length. The estuary is noted for its geographic location within the central part of Auckland, the urbanisation and industrialisation along its shores, the presence of rock outcrops of both Waitematā sedimentary strata and lavas and ash from the Auckland Volcanic Field, thick Holocene estuarine sedimentary sequences and the influence of both marine and fluvial processes on these sediments.

The Tāmaki Estuary is a flooded river valley system. Its many branches reflect the drainage pattern prior to flooding. The orientation of the branches suggests that the drainage pattern was formed by a river system that flowed southwards into the Manukau Harbour. This south-flowing river system was presumably dammed by eruption of McLennan Hills, Mt Richmond and Crater Hill between 200,000 and 20,000 years ago. The present day river was formed about 7000 years ago when rising sea levels, after the low of the Last Ice Age, flooded the Tāmaki River and its branches (ARC, 2005).

The upper reach of Tāmaki Estuary has four main arms – Ōtāhuhu, Middlemore, Otara, and Pakuranga creek. The shores of all four are dominated by mangrove forests with muddy channels. The middle reaches of the estuary are a mix of tidal mud flats, patchy marginal strips of mangroves, mud covered low-lying shore platforms, and sandy, high-tidal beaches. In the outer reaches of the estuary, the tidal flats are sandier and shellier, the shore platforms have less mud cover, and the shell spits and banks are more prevalent (ARC, 2005).

Around the outside the Tāmaki Estuary mouth the shore is primarily rocky cliffs and platforms interspersed with sand beaches and occasional stable cobble beaches.

Figure 6-2: Tāmaki Estuary Extent



6.2 Coastal Processes

6.2.1 Tidal Levels and Currents

Tāmaki Estuary is characterised as a predominantly semi-diurnal (twice daily) tide. Tidal velocities from LINZ chart 5325 suggest the peak flood and ebb-velocity occurs 2 hours after high water with spring tides reaching velocities of up to 0.7 m/s and 0.4m/s for neap tides. At 1.5hrs before a high spring tide level with no stormwater flows, the velocity through the culvert it estimated to be about 2.3 m/s.

Tidal levels shown below in Table 6-1 have been adopted from Waitematā Harbour but it is expected that the tidal levels will be slightly amplified up the estuary. The tidal levels have been converted in terms of Auckland Vertical Datum which is the adopted datum for the project.

Table 6-1: Tidal Levels for project in terms of Auckland Vertical Datum 1946

Tidal levels	Chart Datum (m) for 2016	Auckland Vertical Datum (AVD,1946 –m)
Highest Astronomical Tide (HAT)	3.70	1.96
Mean High Water Springs (MHWS)	3.38	1.64
Mean High Water Neaps (MHWN)	2.86	1.12
Mean Sea Level (MSL)	1.89	0.15
Mean Low Water Neaps (MLWN)	0.93	-0.81
Mean Low Water Springs (MLWS)	0.40	-1.34
Lowest Astronomical Tide (LAT)	0.04	-1.7

Extreme sea levels represent a storm tide, based on a high tide plus storm surge. Extreme sea levels have been modelled for Auckland City at the site and probability based levels reported in NIWA (2013). Storm tide values for just outside Ōtāhuhu creek are given in Table 6-2.

Table 6-2: Extreme Water Levels in terms of Auckland Vertical Datum 1946

Frequency (Annual Recurrence Interval - yr.)	Still Water Level (AVD –m)
2	2.13
5	2.23
10	2.28
20	2.33
50	2.39
100	2.42
200	2.45

6.2.2 Wind

The prevailing surface wind direction is south westerly followed by nor-easterly conditions.

6.2.3 Wave Climate

Ōtāhuhu Creek is a shallow tidal creek with extensive mangroves covering the majority of the creek. Wave conditions are highly dependent on water levels with depth limiting and friction losses occurring as the wave propagates across the shallow creek flat. Waves would be wind generated and most likely be dissipated by the mangroves. The combination of a small wind fetch length and large mangrove area does not promote any significant wave action.

6.2.4 Seabed Levels

As part of the Project the area around Ōtāhuhu Creek was surveyed. The surveyed confirmed that the downstream level of the culverts is about 0.5m above mean sea level. Upstream and downstream seabed levels in the main tidal channel are lower. This indicates that the tidal flows are sufficient to maintain a formed channel rather than for it to be in filled.

6.2.5 Sedimentation

Aerial photography indicates that the total area covered by mangrove forest has increased since 1940 especially upstream of the bridge. This suggests that the culverts limited the transportation of sediment out into the estuary promoting a better environment for mangrove growth.

Based on the as-built drawings it appears that the area was reclaimed with the SH1 construction. The reclamation area was in the order of 0.6ha or about 12% of the Ōtāhuhu Creek CMA.

6.2.6 Flood Flows

Based on the urbanised catchment infrequent flood flows (using TP 108) are summarised in Table 6-3.

Table 6-3: Flood Flows

Average Recurrence Interval (ARI in years)	Existing Catchment (m^3/s)	Existing catchment with climate change (m^3/s)
2	10	12
10	18	21
100	22	28

For the 100 year flow with drowned outlet conditions, the culvert has a head loss of less than 800mm. Even at MHWS for a sea level rise of 1m and for climate changed adjusted flows, the upstream would be more than 2m below the SH1 road level of RL 5.2m. Completed blockage of one culvert barrel would also accommodate the 100 year ARI event.

7 Assessment of Potential Coastal Processes Effects: Foreshore Works

7.1 Physical Changes related to the Project

The layout of the project is shown in Figure 7.1.

Figure 7-1: Foreshore Works

In designing the overall layout consideration was given to the potential effect on coastal processes by:

- Minimising intrusive reclamation in the area near the Inlet entrance (by Galway Street up to Albert St). From a review of the effect of historical changes, intrusion into the Inlet entrance has resulted in more noticeable effects;
- Avoiding reclaiming into the tidal channels. This would alter the morphology of the channels and result in a different distribution of tidal flows and sedimentation regime. See NIWA report in Appendix C for changes in tidal currents and sedimentation associated with a range of new coastline scenarios. The exception was at the eastern end where a secondary tidal channel that feeds into Anns Creek is located close to the northern coastline. In this location (shown on Figure F-1, Appendix F) a new tidal channel has been included in the design with the same dimensions as the existing channel. This channel has similar dimension to the existing channel;
- Discharging stormwater from the proposed treatment system through the headland structures into the tidal channels; and
- Incorporating coastal features such as headland structures and shingle beaches into the recreated coastline.

The Project has a reclamation area (above MHWS) of 18.3ha and a footprint of 24.2ha, compared to the existing CMA surface area of the Inlet of 5.7km^2. The new reclamation represents a change of 3.2% in area. (It is noted that the reclamation due to the road embankment of the Project is 5.6ha whereas the wetlands and recreated coastline is 12.7ha.) The Project also reduces the tidal prism by 3.5% to 11.5 million m^3.

The Manukau Harbour CMA surface area is estimated at 368km^2 with a historical area of harbour reclamation of 8.5km^2. This project will therefore increase the reclamation area from 2.3% of the harbour area to 2.4%.

For the structures in the CMA through Anns Creek, there are 21 No. 2.1m diameter piles which will occupy an area of about 73m^2 or 0.001% of the Inlet area.

7.2 Predicted Project Effects

Reclamation reduces the footprint of the CMA and correspondingly reduces the tidal prism. (The tidal prism is the volume of seawater exchanged between MHWS and MLWS upstream of a reference point, e.g. old Māngere Bridge). Reducing the tidal prism reduces the tidal currents. For the Inlet, where the flood tidal currents are stronger than the ebb tidal currents it could be expected that the transport of sediment into the Inlet could reduce but this is more likely to depend on the extent of wind driven currents and waves which tend to transport sediment into the Inlet. As these wind driven currents and waves, which originate outside of the Inlet, are unlikely to change the level of sedimentation is not expected to change significantly. Sedimentation in the Inlet is likely to continue with an increase in the extent of mangrove coverage.

The entrance is also likely to respond to the change in the tidal prism. With a lesser tidal prism the cross-sectional area of its entrance will reduce to reach a new equilibrium condition. Some accretion could therefore be expected at the seabed of the entrance, probably in the order of 35m^2 cross-sectional area or 0.25m depth. (This estimate is based on the change in cross-sectional inlet area based on the of Hume and Herdendorf (1988) relationship, as discussed in Section 5.3.3, and the change in tidal prism). Historically the seabed has been more elevated. The entrance will continue to limit the amount of wave energy entering the Inlet.

NIWA has modelled the Project in terms of tidal currents and sedimentation and their report is contained in Appendix C, including difference plots of maximum tidal currents and sediment deposition. A summary of changes between the existing environment and the environment after the implementation of the Project is given below:

- The maximum reduction in tidal current occurs within the new embayments along the northern coastline with change of 0.1 m/s in a spring tide. The maximum increase in tidal current occurs offshore of the new headlands with change of 0.1 m/s. Away from these locations, the maximum change in tidal currents is less than 0.05 m/s during a spring tide;
- The general circulation and extent of tidal currents is the same as the existing regime;
- Overall there is a slight increase in average sediment deposition within the inlet from 9.8mm to 10.5mm (7% change);
- There is an increase in deposition within the new embayments along the recreated coastline with an increase of 5mm/year to a new level of up to 30mm/yr. Mud deposits could therefore be expected in these locations as would have occurred with the original and existing environment;
- Sedimentation will continue within the Inlet at a rate of about 10mm/year. This has the potential to affect the discharge of stormwater as the intertidal areas in front of stormwater pipes silt up. The recreated coastline design, however, incorporates discharging the stormwater into the tidal channels which have a tendency to erode rather than accrete. This effect is therefore minimised;
- The tidal channels have more-or-less the same level of erosion as the existing situation. These channels should therefore remain in a morphological stable condition; and

- Within the area of the structure over Anns Creek the peak tidal velocities are less than 0.2m/s. As this is less that the velocity required to mobilise marine mud, no scouring of sediment around the piles is expected.

7.3 Assessment of Effects on the Environment

This assessment assumes that this Project along with other probable activities should be assessed on the environment as it exists. Other probable activities include other coastal works which have resource consents and natural processes such as climate change and tsunami. It is understood that the only coastal project which has resource consents but which have not been implemented is the replacement of the Old Māngere Bridge. The proposed replacement bridge will not include any reclamation and will be a piled structure. This new structure is not expected to add any additional adverse effects associated with this Project.

Effects related to climate change and tsunami are discussed in Section 7.4.

Based on an understanding of how the existing environment (see Section 5) has responded to historical developments, the following changes have been inferred:

- Narrowing of the Inlet entrance has reduced the Inlet channel area and deepened the channel. It has also reduced the wave energy entering the Inlet which has probably increased the rate of sedimentation;
- Increase in mangrove coverage (now 20% of the inlet) has probably increased the rate of sedimentation; and
- The reclamation has reduced the tidal prism (by about 24%) which would have reduced the tidal currents but probably not affected the rate of sedimentation significantly. The main tidal channels have remained more-or-less in the same location. This indicates that, apart from a change in coastline shape, the intertidal morphology has been stable.

It is reasonable to judge that the cumulative historical developments have probably had a significant adverse effect on the original environment. But the changes related to those effects have now become part of the existing environment for which this Project is assessed against. It is considered that this project will have the following effects:

- The Inlet will remain a depositional environment with minimal erosion risk to the coastline;
- Potential erosion risk of the coastline associated with this Project is low as it will be protected from inundation and wave action;
- Adverse effects associated with coastal processes within the Inlet for the Foreshore Works are minor. The Project design needs to careful consider the design of any new tidal channel works at the eastern end of the project so as to closely mimic the geometry of the existing channel; and
- Adverse effects associated with coastal processes within Anns Creek for the elevated structures are negligible.

While the reclamation associated with the recreated coastline does have adverse effects on the existing environment, the recreation of coastal features such as headlands and shingle beaches is beneficial in terms of the coastal processes related to natural character. As shown in Figure 7-2, although reclamation has already taken place, the remaining original coastline in 1949 was a mixture and headlands and embayments, delineating a non-linear coastline.

Figure 7-2: Māngere Inlet Foreshore (1949)

7.4 Effects of Climate Change

The NZCPS (Policies 24 and 25) requires hazards to be identified and development to consider these hazards over at least the next 100 years, having regard to:

- Sea level rise (1.0m as required by the Unitary Plan (2016));
- Tides and storm surge (see Table 5.4); and
- Wave climate (10% increase as per MfE, 2008) in extreme winds which affect wave generation.

The effect of sea level rise, tides and storm surge will be to increase water levels given in Table 5.4 by 1.0m. For example, the 100 year ARI event will have a still water level of RL 4.0m.

The effect of increased windiness by 10% will increase wave heights. Information on significant wave heights (H_s - m), peak wave periods (T_p - s) and sustained wind speed (W - m/s) at MHWS are presented Table 7.1 for this increase in wind speed. For example, a 100yr SE wave increases in height from 0.6m to 0.7m.

Table 7-1: Predicted Extreme Wave climate within Māngere Inlet for increased windiness

Event	2 year ARI			10 year ARI			50 year ARI			100 year ARI		
Direction	Hs	Tp	W	Hs	Tp	W	Hs	Tp	W	Hs	Tp	W
S	0.3	2.3	17	0.4	2.5	20	0.4	2.6	24	0.5	2.7	24
SW	0.4	2.7	20	0.5	2.8	22	0.5	3.0	25	0.6	3.0	26
SE	0.4	2.7	17	0.5	3.0	21	0.6	3.1	25	0.7	3.2	26

NIWA has modelled the effect of a sea level rise of 1.0m on tidal currents and sedimentation. The difficulty in modelling this scenario is in determining the level of sediment input and sedimentation associated with sea level rise. For example, if sedimentation continued at 10mm/year over 100 years then that equates to a general raising of the intertidal area by 1.0m, the same as a sea level rise of 1.0m. Therefore the effects would be similar to the situation today. Assuming no sedimentation would be unrealistic as the Inlet is a known depositional environment. In order to gauge the likely effects, it was assumed for the modelling scenario that the sediment input would remain the same as today, a sea level rise of 1.0m, and an average sedimentation increase of 500mm (i.e. raising of the existing sea bed by 500mm).

Results of modelling this sea level rise scenario are given in Appendix C (Section 6). A summary of changes is given below:

- The tidal prism increases from 11.9×10^6 m^3 to 14.5×10^6 m^3, a 22% increase;
- The general circulation of tidal currents is the same as the existing regime; and
- There is negligible change in overall sedimentation compared with the Project coastline. The central flat area will tend to erode while the edges of the Inlet will tend to be more depositional.

The Project design has allowed for the effects of climate change by:

- The edge road embankment level has been set at RL 4.50m based on:

100 year ARI tide + storm surge	RL 3.0m
Sea level rise	1.0m
Wave run-up allowance	0.5m
Total	**RL 4.5m**

- Coastal protection works are designed for a wave climate that allows for a 10% increase in wind speed; and
- The outer bund level of RL 2.8 to 3.0m has been based on the existing walkway levels (for amenity purposes) but the foundations have allowed for a gradual increase in height up to 1.0m. There are small sections of the coastline set at RL 2.5m so as to provide relief from extreme storm events. Higher level boardwalks will be provided over these areas. These areas will be raised in the future in response to sea level rise.

Overall it is considered that the Project is resilient to the potential effects of climate change, although sections of it will need to be raised in the future.

7.5 Effects of tsunami

The NZCPS (Policies 24 and 25) requires hazards to be identified and development to consider these tsunami hazards over at least the next 100 years. Tsunami wave heights have been predicted by Power (2013) as 1.5m for the 100 year ARI event and 2.6m for the 500 year event (based on a 50% confidence level) for the Manukau Harbour.

The effect of tsunami on the Project will be dependent on the tide level. At a median tide level (MSL) the tsunami water level could reach RL 1.72m or RL 2.72m with sea level rise for 100 year ARI event. At mean high water springs the tsunami water level could reach RL 3.77m or RL 4.77m, but this would be a more extreme event than the 100 year ARI.

The project can accommodate inundation levels associated with a 100 year ARI tsunami and a 1m sea level rise. It is noted that there is considerable uncertainty in the estimated tsunami levels.

7.6 Recommendations

Recommendations for proposed monitoring/mitigation/design changes include:

- Options for declamation in the Manukau Harbour be investigated to evaluate whether the level of adverse effects of reclamation can be reduced;
- Any tidal channel for which the Project covers over, a new channel be created (with similar geometry) to minimise morphological changes;
- Peer review of the detailed design to ensure the effects of climate change and tsunami have been adequately allowed for; and
- Detailed design of the Foreshore Works needs to recognise that elements will be subject to seawater spray and corrosion.

8 Assessment of Potential Coastal Processes Effects: Ōtāhuhu Creek Bridge

8.1 Physical Changes related to the Project.

Although the existing culverts perform their hydraulic function, the Transport Agency has agreed to replace the culverts with a new bridge as part of this Project. The proposed bridge is shown in Figure 8-1 and comprises five 22.5m spans to give a total bridge length of 112.5m and width of 50m. There are proposed to be 19 No. 900mm piles which will occupy and area of about $10m^2$ or 0.02% of the upstream CMA.

Figure 8-1: Ōtāhuhu Creek Bridge

The proposed bridge will span the original creek to effectively declaim the area. On the northern side, the abutment more-or-less follows the original landform. On the southern side the new landform will declaim about 0.5ha of land. Complete declamation was not feasible as it would interfere with private property. Some $20{,}000m^3$ of material will need to be removed to form a new landscape similar to the original landform.

Under the bridge abutments, rock armour should be installed to provide protection from waves/currents as plant growth could be limited. At the base, the armour should extent out by 3m to form a buried apron. Outside of the underbridge the slope should be planted. A 10m strip seaward of the base of the new slope should be planted in mangroves to aid stability and resistance to any new stream migration.

A new tidal channel will be formed to be located in a similar alignment to the original channel at a mid-span location.

8.2 Predicted Project Effects

From a coastal processes perspective the following is noted:

- The area has a low energy wave climate, particularly with the presence of the mangroves and this will continue;
- The tidal currents, without the culverts, will be relatively low. Tidal flows will be in the order of $5m^3/s$ at 0.5m RL. With a new channel with similar dimensions to the original channel, tidal currents will be below 1m/s at 0.5m RL;
- Flood flows could be in the order of $30m^3/s$ for the 100 year ARI. This is easily accommodated within the new bridge opening;
- Although the culverts were installed with an invert of 0.8m RL at the upstream end, an upstream channel has been maintained deeper than 0.8m RL. Therefore it has probably reached some equilibrium where the extent of upstream sedimentation is limited. This could be attributed to the occasional flushing of flood flows from the local urban catchment;
- The tidal channel alignment has changed with the installation of the culverts, probably because it was installed off-line from the original channel. It is recommended that the channel be realigned close to its 1940's alignment. This will move it southwards and away from the northern abutment. The new channel should be about 3m wide and 1m depth, subject to confirming downstream dimensions. This excavated material can be used to fill in the existing channel; and
- Given the extent of the mangrove forest, erosion of the flat intertidal area would be limited. Some erosion of the tidal channel could be expected as part of the readjustment and would be on on-going process.

8.3 Assessment of Effects on the Environment

This assessment assumes that this Project along with other probable activities should be assessed on the environment as it exists. Other probable activities include other coastal works which have resource consents and natural processes such as climate change and tsunami. It is understood that there are no coastal projects which have resource consents but which have not been implemented in the Ōtāhuhu Creek. Effects related to climate change and tsunami are discussed in Section 8.4.

It is reasonable to judge that the historical developments have probably had a significant adverse effect on the original environment. It is considered that this new bridge will have the following effects:

- The estuary will remain a depositional environment with minimal erosion risk to the coastline although the tidal channel will exhibit erosion from time to time; and
- Replacement of the existing culverts with a new bridge structure and landform will have a beneficial effect. This effect is mainly as a result of re-introducing the coastal processes that relate to natural character.
- The existing culverts are cast in-situ reinforced concrete and will need to be broken up on site. Removal of the culverts should be carefully undertaken, with minimal discharge of construction materials and debris from the site. This process should be developed as part of the construction management plan.

8.4 Effects of Climate Change

The NZCPS (Policies 24 and 25) requires hazards to be identified and development to consider these hazards over at least the next 100 years, having regard to:

- Sea level rise (1.0m as required by the Unitary Plan (2016));
- Tides storm surge; and

- Wave climate (10% increase as per MfE, 2008) in extreme winds which affect wave generation.

The effect of sea level rise, tides and storm surge will be to increase water levels given in Table 6.2 by 1.0m. For example, the 100 year ARI event will have a still water level of RL 3.42m. The approach embankments are at RL 5.4m, significantly above extreme tide levels allowing for storm surge and sea level rise.

The increase in potential wave energy with increased wind speed will not be noticeable. Extreme significant wave heights will be nominal at less than 0.3m.

8.5 Effects of Tsunami

The NZCPS (Policies 24 and 25) requires hazards to be identified and development to consider these tsunami hazards over at least the next 100 years. Tsunami wave heights have been predicted by Power (2013) as 2.2m for the 100 year ARI event and 3.5m for the 500 year event (based on a 50% confidence level) for the Auckland, with focus on the Waitematā Harbour. For this assessment tsunami related to the Tāmaki River will be assumed the same as for the Waitematā Harbour.

The effect of tsunami on the Project will be dependent on the tide level. At an average tide level (MSL) the tsunami water level could reach RL 2.35m or RL 3.35m with sea level rise for 100 year ARI event. At mean high water springs the tsunami water level could reach RL 3.84m or RL 4.84m, which is lower than the approach embankment levels to the new bridge at RL 5.2m.

The project can accommodate inundation levels associated with a 100 year ARI tsunami and a 1m sea level rise. It is noted that there is considerable uncertainty in the estimated tsunami levels.

8.6 Recommendations

It is recommended that the Construction management Plan for removal of the existing culverts address the demolition and removal process, particularly with regard to discharges to the CMA.

Detailed design of the Otahuhu Creek bridge needs to recognise that elements will be subject to seawater spray and corrosion.

9 Conclusions

- Adverse effects associated with coastal processes for the Foreshore Works alone are considered to be minor.
- The recreated coastline which is part of the Foreshore Works has a beneficial effect in that the coastal processes are part of the overall processes to enhance natural character;
- Effects associated with coastal processes for the replacement of the existing culverts on Ōtāhuhu Creek with a new bridge are beneficial; and
- The Project design has allowed for sea level rise and tsunami for at least the next 100 years.

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Appendix A

Coastal Protection Condition Assessment

Inspection Map

Location	Site Images	Notes
Site 1 - Manukau Foreshore East Walkway Seawall (western end) (Access via Alfred Street)	 	Inspected at 12.10pm on 5/6/2016 Low tide/ebbing tide Average wall height 1.5m Min height 0.8m Masonry seawall in good condition Some scouring at base and lost rock units

<table>
<tr><th>Location</th><th>Site Images</th><th>Notes</th></tr>
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Location	Site Images	Notes
Site 2 - Manukau Foreshore East Walkway Riprap (western end)	  	Inspected at 12.30pm on 5/6/2016 Low tide/ebbing tide Riprap ~1.5m high Rock Diameter 80-90cm at top Rock Diameter 20-30cm at base

Location	Site Images	Notes
Site 3 - Manukau Foreshore East Walkway Riprap (western end)	 	Inspected at 12.30pm on 5/6/2016 Low tide/ebbing tide Riprap ~1.5m high Rock Diameter 80-90cm at top Rock Diameter 20-30cm at base

Location	Site Images	Notes
Site 4 - Manukau Foreshore East Walkway (eastern entrance - Access via Hugo Johnston Drive)	 	Overgrown debris and vegetation obstructing view of wall Loose rock units

Location	Site Images		Notes
Site 5 - Manukau Foreshore East Walkway (eastern end – Anns Creek)			1.0m high rock wall Bank in good condition

Location	Site Images	Notes
Site 6 - Eastern end of Manukau Foreshore East Walkway		Very low lying ground, possible site of inundation especially with sea level rise. No wall in places Wall height varies along path some have lost wall structure all together.

Location	Site Images	Notes
Site 7 - Eastern end of Manukau Foreshore East Walkway		2.5 meters high No fencing Rock units fallen out of rock face onto bed
Site 8 - Second bridge along Manukau Foreshore East Walkway		Wall and bridge in good condition

Location	Site Images	Notes
Site 9 - Manukau Foreshore East Walkway rip rap (eastern end)	 	Inspected at 1.00pm 5/6/2016 Low tide Riprap ~1.5m high Fair amount of debris trapped in Rip Rap

Appendix B

Bathymetric Survey


PORTS OF AUCKLAND
TĀMAKI HERENGA WAKA
Hydrographic Section
Mangere Inlet
Upper Manukau Harbour
Scale 1:5000
Datum NZGD 2000, Mount Eden Circuit 2000 (m)
Orientation: North
Depths reduced to MSL 1946 (LINZ Datum)
Depths in metres and decimetres
Depths represent the minimum depths surveyed
Contour Interval 0.25m
Dwg. No: H6/8/4
Compiled: ....
D H Bate
Amendment: 0
Approved: ....
B R Wallen (FIG IHO Cat.A)
DATA SOURCES
MANGERE INLET
Depths below -1.0m MSL from bathymetric survey, 23 Feb 2016
Depths above -1.0m MSL from LIDAR source, date unknown
STATE HIGHWAY 20
Depths directly east and west of SH20 Bridge from bathymetric survey, 2011
OLD MANGERE BRIDGE
Depths west of Old Mangere Bridge from bathymetric survey, 2011
Depth Colour Band Interval 1.00m
Contour Interval 0.25m
NOTE: Coast & structure outline indicative only
E402000
E402500
E403000
E403500
E404000
E404500
E405000
E405500
N794500
N794000
N793500
N793000
N792500
N792000