REPORT

Glenbrook Steel Mill Discharges

Marine Ecological Effects Assessment

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NZ Steel
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Glossary

Term	Meaning / description
Benthic	Of, relating to, or occurring at the bottom of a body of water or the depths of the ocean.
Best Practicable Option (BPO)	Defined in section 2(1) of the Resource Management Act 1991 (RMA), as: *“in relation to a discharge of a contaminant or an emission of noise, means the best method for preventing or minimising the adverse effects on the environment having regard, among other things, to —* *(a) the nature of the discharge or emission and the sensitivity of the receiving environment to adverse effects; and* *(b) the financial implications, and the effects on the environment, of that option when compared with other options; and* *(c) the current state of technical knowledge and the likelihood that the option can be successfully applied.*
Bioaccumulation	Gradual accumulation of substances, such as pesticides or other chemicals, in an organism. Occurs when an organism absorbs a substance at a rate faster than that at which the substance is lost or eliminated by catabolism and excretion.
Biodiversity compensation	Means a conservation outcome that meets the requirements in Appendix 4 of the NPSIB and results from actions that are intended to compensate for any more than minor residual adverse effects on indigenous biodiversity after all appropriate avoidance, minimisation, remediation, and biodiversity offsetting measures have been sequentially applied.
Biodiversity Compensation Model (BCM)	A decision support tool to provide guidance on the type and amount of compensation required to achieve positive effects on specified biodiversity values that outweigh residual adverse effects associated with project activities.
Biodiversity offset	Means a measurable conservation outcome that meets the requirements in Appendix 3 of the NPSIB and results from actions that are intended to: • Redress any more than minor residual adverse effects on indigenous biodiversity after all appropriate avoidance, minimisation, and remediation measures have been sequentially applied; and • Achieve a net gain in type, amount, and condition of indigenous biodiversity compared to that lost.
Coastal Marine Area	Defined in section 2(1) of the RMA, as: *“the foreshore, seabed, and coastal water, and the air space above the water—* *(a) of which the seaward boundary is the outer limits of the territorial sea:* *(b) of which the landward boundary is the line of mean high water springs, except that where that line crosses a river, the landward boundary at that point shall be whichever is the lesser of—* *(i) 1 kilometre upstream from the mouth of the river; or* • *(ii) the point upstream that is calculated by multiplying the width of the river mouth by 5”.*
Compensation	Compensation is any measure proposed or agreed to by the applicant for the purpose of ensuring positive effects on the environment to compensate for any adverse effects on the environment that will or may result from allowing the activity.
Conductivity	Conductivity is a measure of the ability of water to pass an electrical current. It is an indirect measure of charged particles, such as dissolved salts and other inorganic chemicals. High conductivity is an indication of high salinity.
Consent Limit	A measurable restriction for individual environmental parameters specified by Schedule 1 of the conditions of consent (proposed at Appendix Q). These

Term	Meaning / description
	restrictions are required by consent to be complied with to ensure adverse effects are appropriately managed.
Contaminant	Defined in section 2(1) of the RMA, as: *“including any substance (including gases, odorous compounds, liquids, solids, and micro— organisms) or energy (excluding noise) or heat, that either by itself or in combination with the same, similar, or other substances, energy, or heat— (a) when discharged into water, changes or is likely to change the physical, chemical, or biological condition of water; or (b) when discharged onto or into land or into air, changes or is likely to change the physical, chemical or biological condition of the land or air onto or into which it is discharged.”*
Consented mixing zone	The mixing zone defined in the existing Northside and Southside Outfall discharge permits (Permits 21575 and 21576)
Council	Auckland Council
Cumulative effects	Changes to the environment that are caused by an action in combination with other past, present and future human actions.
Current Environment	The environment as it currently exists. Monitoring data and investigations undertaken during the preparation of this application describe the Current Environment, which reflects the effects of the operation of the Steel Mill over the past 53 years.
Dewatering Plant	Where the ironsand (or PC) slurry received from the ironsand mine is dewatered before stockpiling. This plant also includes a dedicated water treatment facility.
Existing Consents	NZ Steel’s existing resource consents relating to the discharge of ITA stormwater and process water that this application seeks to replace are: • Permit 41027 – Industrial or Trade Activity (ITA) discharges – expires 31 December 2021. • Permit 21575 – Northside Outfall discharge – expires 31 December 2021. • Permit 21576 – Southside Outfall discharge – expires 31 December 2021. • Permit 21577 – Dewatering Plant discharge – expires 31 December 2021. • Permit 23877 – Occupation of the coastal marine area by the Southside Outfall structure – expires 31 December 2021. Water Right 812691 – North Drain diversion and discharge – expires 1 October 2016
Existing Permits	NZ Steel’s existing discharge permits authorising the discharge of stormwater from the ITA Area, process water from the Steel Mill, and leachate from the East and West Landfills: • Permit 41027 – Industrial or Trade Activity (ITA) discharges. • Permit 21575 – Northside Outfall discharge. • Permit 21576 – Southside Outfall discharge. • Permit 21577 – Dewatering Plant discharge. These discharge permits all expire on 31 December 2021.
Ferrous Scrap	Scrap that will be used in the EAF will consist of ferrous scrap from two sources: from existing internal NZ Steel processes (uprisings) and externally sourced ferrous scrap.
ITA Area	The ITA Area is the area of the Site from which the ITA stormwater is discharged. It includes all ITA activities and stockpiling landholdings, including provisional areas for potential future expansion. The area is bound to the north by Brookside Road and to the east by Mission Bush Road, and the west by the Waiuku Estuary.

Term	Meaning / description
ITA Stormwater discharges	Rainfall runoff from ITA activity areas
Kahawai Stream	The Kahawai Stream is a small tributary of the Waiuku River that lies to the north of the Steel Mill. The stream is approximately 1 km in length and lies immediately to the north of a consented, but not constructed, Managed Fill site. The Kahawai Stream is not officially named and has been previously known as the MFS Stream.
Lower North Stream	The Lower North Stream is located to the north of the Steel Mill and flows in a generally northerly direction between the East and West Landfills. Much of the original Lower North Stream was diverted to its current alignment along the West Landfill access road. The Lower North Stream is not officially named. It was previously (erroneously) known as the Northside Stream, however this was incorrect as the Northside Stream was a historical watercourse that flowed through the site to discharge at the current location of the Northside Outfall. The Northside Stream and valley were removed in the 1980s to facilitate the expansion of the Steel Mill.
Macroalgae	Seaweed, or macroalgae, refers to thousands of species of macroscopic, multicellular, marine algae.
Mean High Water Springs	The average of each pair of successive high waters during that period of about 24 hours in each semi-lunation (approximately every 14 days), when the range of the tide is greatest.
Modelled mixing extent	The area of the coastal marine area as modelled in the DHI (2022) report (included as Appendix E to this report) beyond which metals, temperature, and changes in salinity are no longer discernible from background concentrations. Note that the "modelled mixing extent" is different to the "zone of reasonable mixing".
No Net Loss / Net Gain	The values that are adversely affected by an activity are addressed through offset that seeks to achieve a No Net Loss / Net Gain outcome as assessed using a quantitative biodiversity modelling tool.
North Drain	The North Drain is a constructed drain that was constructed in the 1980s to convey Steel Mill discharges and is an artificial watercourse in accordance with the AUP definition. The North Drain flows entirely within the ITA Area and discharges into the Lower North Stream north of Brookside Road.
North Stream Catchment	The North Stream Catchment is the modified catchment area that includes the artificial North Drain catchment and the Lower North Stream catchment.
Northside ITA Catchment	The portion of the ITA Area where stormwater drains to the Northside Ponds and Northside Outfall.
Northside Ponds	Two large water quality treatment ponds that receive process water from the Steel Mill, including the Primary Plants, stormwater from the Northside ITA Catchment, and leachate from the East and West Landfills. Treated water from the Northside Ponds discharges to the coastal marine area via the Northside Outfall.
Northside Outfall Structure	The outfall structure from the Northside Ponds to the Waiuku Estuary.
NZ Steel	New Zealand Steel Limited
Outer Zone	An Outer Zone (OZ) is an estuarine area beyond the Settling Zone (SZ) (i.e. beyond where the majority of the sediment and associated contaminants settle onto the seabed.)

Term	**Meaning / description**
Physicochemical	Of or pertaining to both physical and chemical properties, changes, and reactions.
Positive effects	Positive effect(s) associated with compensation action(s) for specified biodiversity values that are expected to outweigh residual adverse effects from project activities.
Process water	Process water is water that is used for a variety of manufacturing processes at the Steel Mill. For the purposes of this application, discharged process water includes both waste process water and landfill leachate.
Proposal	Resource consent application to authorise activities associated with the discharge of stormwater and process water at the Glenbrook Steel Mill (the Steel Mill) in accordance with sections 9, 12, 14 and 15 of the RMA
Receiving Environment	The environment against which the effects of the proposed discharges are assessed. The manner in which the Receiving Environment has been determined in this application is described in detail in Section 2.2 of this report. However, by way of brief summary it is the Current Environment, modified to exclude ongoing effects of the activity that are the subject of the application but including legacy effects of the past discharges associated with the Existing Consents (e.g. build-up of metals in sediment, diversion of water in the North Drain, coastal structures).
Residual effect	Effects on biodiversity or ecological values that cannot be avoided, minimised, remedied and/or mitigated.
Riparian margin	An area of land immediately adjacent to a permanent or intermittent river or stream.
Ruakohua Stream	The Ruakohua Stream (sometimes referred to as Ruakahua Stream) is located to the south of the main operational areas of NZ Steel's site. It is approximately 4km in length and flows in a south westerly direction to discharge to NZ Steel's Ruakohua Dam. The lower reaches of the Ruakohua Stream were diverted around the NZ Steel development area during the 1970s/ 1980s.
Settling Zone	The area where the majority of sediment and associated contaminants discharged from a catchment settles out in the coastal marine area.
Site	Includes all NZ Steel landholdings in relation to the Steel Mill at Glenbrook, which includes the Steel Mill, industrial landfills and farming activities as well as the adjoining coastal esplanade strip owned by Auckland Council.
Southside Ponds	Two water quality treatment ponds that receive treated process water from the Rolling Mills, primarily the Acid Regeneration Plant (ARP), and stormwater from the Southside Catchment. Treated water from the Southside Ponds is recycled to the Ruakohua Dam, however some discharges to the coastal marine area via the Southside Outfall.
Southside Outfall Structure	The outfall structure from the Southside Ponds to the Waiuku Estuary.
Steel Mill/Glenbrook Steel Mill	The integrated steel making facility in Glenbrook and ancillary activities on the Site.
Stormwater	Rainfall runoff from land, including constructed impervious areas such as roads, pavement, roofs and urban areas which may contain dissolved or entrained contaminants, and which is diverted and discharged to land and water.
Substrate	The material that rests at the bottom of a body of water.
Taihiki Estuary	An estuarine side arm adjoining the lower Waiuku Estuary.
Total suspended solids (TSS)	The total amount of particulate matter that is suspended in the water column, that are not dissolved, that can be trapped by a filter.

Term	Meaning / description
Trigger Investigation Level	A numerical value above which investigation actions will be taken. Trigger Investigation Levels are included in the existing Stormwater Monitoring and Management Programme required by the Existing Permits and are proposed in consent conditions to be specified in the Water Quality Management Plan.
Turbidity	A measure of the clarity of water. Turbidity is the measurement of the amount of light scattered by suspended particulates present in the water when a light is shined through the water. The more total suspended particulates in the water, the murkier it can appear and the higher the turbidity.
Waiuku Estuary	The Steel Mill is located on the eastern bank of the Waiuku River which, despite its name, is a long and relatively narrow tidal arm (estuary) of the Manukau Harbour. For the avoidance of confusion, the term "Waiuku Estuary" is therefore used in this report to describe this area.
Wastewater	Liquid (and liquids containing solids) waste from domestic, industrial, commercial premises including (but not limited to) toilet wastes, sullage, trade wastes and gross solids
Wastewater Treatment Plant	A wastewater treatment plant (WWTP) is a facility in which a combination of various processes (physical, chemical and biological) are used to treat industrial wastewater and remove pollutants. There are multiple industrial wastewater treatment plants at the Steel Mill to treat process water discharges from a variety of plant. The processes used are dependent on the characteristics of the wastewater at each plant.
Water column	Column of water from the surface of a sea, river or lake to the bottom sediment.
West Landfill	NZ Steel's closed landfill located on the northern side of Brookside Road within the Site. This is subject to separate resource consents that are not within the scope of this replacement consents application.
Zone of Influence (ZOI)	The areas/resources that may be affected by the biophysical changes caused by the Proposal and associated activities.
Zone of reasonable mixing	The area within which 'reasonable mixing' of contaminants from discharges occurs in receiving waters and within which the relevant water quality standards do not apply. Note that the "zone of reasonable mixing" is different to the "modelled mixing extent".

Abbreviations

Abbreviation	Meaning / description
AEE	Assessment of Effects on the Environment
ANZWQG	Australia and New Zealand Water Quality Guidelines 2018 (formerly ANZECC 2000)
ASCV	Area of Significant Conservation Value
AUP	Auckland Unitary Plan - Operative in Part
BCM	Biodiversity Compensation Model
BHM	Benthic Health Model
BPO	Best Practicable Option
CBMP	Coastal Bird Management Plan
CMA	Coastal Marine Area
Council	Auckland Council
DHI	Danish Hydraulic Institute
DOC	Department of Conservation
EAF	Electric Arc Furnace
EcIAG	Ecological Impact Assessment Guidelines
EIANZ	Environment Institute of Australia and New Zealand
ERC	Environmental Response Criteria
FSANZ	Food Safety Australia and New Zealand
FWMT	Freshwater Management Tool (Auckland Council)
GELs	Generally Expected Levels
ITA	Industrial and Trade Activity
IUCN	International Union for Conservation of Nature
MHWS	Mean High Water Springs
MZ	Mangrove Zone
NIWA	National Institute of Water and Atmospheric Research
NPSIB	National Policy Statement for Indigenous Biodiversity 2023 – Gazetted 7 July 2023
NG	Net Gain
NNL	No Net Loss
NZ Steel	New Zealand Steel Limited
OZ	Outer Zone
PSU	Practical Salinity Units
RMA	Resource Management Act 1991
SCMP	Shellfish Contaminant Monitoring Programme
SEA-M	Significant Ecological Area- Marine
SPL	Species Protection Level
TBI	Traits Based Index
TSS	Total Suspended Solids
WQI	Water Quality Index
WWTP	Wastewater Treatment Plant
ZOI	Zone of Influence

Executive summary

New Zealand Steel Ltd (NZ Steel) owns and operates the Glenbrook Steel Mill near Waiuku, Auckland (the Steel Mill). NZ Steel holds resource consents (discharge permits[1]) that authorise the discharge of stormwater and process water[2] from the Steel Mill to surface water and the Coastal Marine Area (CMA). These existing discharge permits expired on 31 December 2021. However, the application to renew the permits was lodged by NZ Steel six months prior to this expiry date, allowing the Steel Mill to continue operating while the resource consent application is being processed. NZ Steel is seeking to replace the discharge permits that authorise the stormwater and process water discharges from the Steel Mill to freshwater and the CMA.

This report provides an assessment of the estuarine and marine ecological values in the CMA that directly or indirectly receive stormwater and / or process water discharges. The report presents an assessment of estuarine and marine ecological effects to inform the resource consent applications.

Field data, hydrodynamic modelling and expert knowledge of the CMA have been used to characterise the current state of the CMA - referred to as the 'Current Environment' for the purposes of the assessment. Information on the Current Environment is then used to understand what the likely effects of the proposed replacement of the existing discharge consents would be over the proposed 35 year term.

The assessment of the effects of the proposed discharges has been undertaken as if the currently authorised discharges have been discontinued and the Proposal is an application for a new activity. That is, in simplistic terms, the discharges cease, and the effects assessment relates to recommencement of the discharges. Any legacy effects of past authorised discharges are also included in the environment against which the Proposal is assessed. This hypothetical scenario where the discharges have ceased is referred to as the 'Receiving Environment'. This report therefore assesses the effects of the Proposal against the Receiving Environment.

Environmental context

The Steel Mill site is located on the eastern bank of the Waiuku River which is a long and relatively narrow tidal arm (estuary) of the Manukau Harbour (hereafter referred to as the Waiuku Estuary). NZ Steel owns 550 ha of land in the Glenbrook area (the Site) and the operational aspects of the Steel Mill occupy 190 ha within the Site (see Figures contained at Appendix E of the Assessment of Effects on the Environment (AEE)). The land use in the area surrounding the Steel Mill is varied and includes pastoral farming (particularly dairy farming), horticulture, and lifestyle blocks. The Site is drained by three main catchments: the North Stream Catchment (the North Drain and Lower North Stream), the Ruakohua Stream, and the Kahawai Stream.

Glenbrook Steel Mill discharges

The main discharges of stormwater and process water from the Steel Mill to the CMA are from the Northside and Southside Ponds, and via discharges to the North Drain which then flows into the Lower North Stream then the CMA. The Northside and Southside Ponds provide final polishing of the ITA stormwater and process water. Discharges from these ponds are directed to the adjacent CMA via the Northside and Southside Outfalls (see Figures contained in Appendix E of the AEE).

There are several other discharge points that direct stormwater from smaller areas of the Steel Mill catchment to streams. The North Drain, the Ruakohua Stream and the Kahawai Stream all receive stormwater from parts of the Steel Mill. The North Drain also receives the ironsand Dewatering Plant

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[1] Permits 41027, 21575, 21576, 21577 (each expiring on 31 December 2021)

[2] Includes waste process water and landfill leachate

discharge, which contains water abstracted from lower Waikato River at Maioro (Waikato North Head mine site).

Subsequent to carrying out this assessment[3] NZ Steel secured co-funding from the New Zealand Government to enable the installation of an electric arc furnace (EAF) at the Site. If the EAF goes ahead, it is anticipated that it will be fully operational by early 2027. If installed, the EAF will reduce the use of virgin steelmaking materials (iron sand and coal) and provide for recycling of externally sourced ferrous scrap.

As detailed below, the EAF is anticipated to result in benefits to the marine receiving environment (by comparison to the existing operation) as a result of reduced process water discharges and reduced contaminant discharges. The only additional discharge (from the EAF's new ferrous scrap yards) will be managed to minimise effects on water quality via a newly installed treatment train system. Consequently, with the EAF installed, it is expected that effects on the Receiving Environment will be considerably reduced from those detailed in this assessment. However, to remain conservative, any potential improvement in discharge quality has not been factored into this assessment. This assessment therefore presents a 'worst case scenario' based on the current operations. Further information regarding the implications of the change to the EAF system are detailed in the ITA Report (T+T 2024a, Appendix G of the AEE).

Assessment of effects methodology

Usually, an ecological effects assessment includes an assessment of the magnitude of any effects both before and after efforts to avoid, minimise, remedy and/or mitigate those effects. However, in the case of the current application, mitigation measures (treatment systems) are already in place. As such we have not assessed effects prior to mitigation. Instead, the assessment proceeds directly to describing the magnitude of any residual effects[4] with the current treatment systems in place.

The assessment of ecological effects generally follows the approach set out in the Ecological Impact Assessment Guidelines (EcIAG) (EIANZ, 2018), where the overall level of ecological effect is based on ecological value and the magnitude of the effect. The EcIAG have been used to determine the ecological values of the existing environment using monitoring information and a desktop assessment. Modelling tools and professional judgement are then used to determine the ecological values of the Receiving Environment. Whilst these guidelines are designed for freshwater and terrestrial systems, we have broadly followed a version of the guidelines suitable for marine systems and modified them further to apply to the current applications.

A report was prepared by DHI (DHI 2022) which assesses the current and ongoing effects of the discharges from the Steel Mill on the Waiuku Estuary, using a suite of modelling tools. DHI's modelling includes quantification of current water column effects relating to salinity, temperature, suspended sediment, copper and zinc[5] as well as predicted sediment deposition rates due to both the Steel Mill discharges and loads from the surrounding catchments. These sediment deposition rates and water column metal concentrations are then used to model the short term[6] and future state concentrations of zinc and copper in surface sediments over the duration of the sought consents. The relative contribution of the Steel Mill discharges to these predicted future state concentrations of zinc and copper in surface sediments is also modelled.

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[3] The original assessment was undertaken in 2021 and presented in the version of this report dated June 2021. Subsequent updates were made in response to section 92 requests and presented in the version of this report dated October 2022.

[4] Residual effects are those that remain after all efforts to avoid, minimise, remedy and/or mitigate effects. Residual effects may warrant additional management through ecological offsets or compensation.

[5] These parameters were identified as key parameters of concern in the ITA report (T+T 2024a).

[6] For the purposes of this assessment short-term is after a few tidal cycles once the discharge water is no longer discernible from other estuary water.

Current Environment values

A description of the Current Environment of the Waiuku and Taihiki Estuaries in the vicinity of the Steel Mill is given with reference to a potential Zone of Influence (ZOI) of discharges from the Steel Mill on the CMA. This potential ZOI is essentially the Waiuku Estuary and Taihiki Estuary extents and is estimated at 2,500 ha. The ZOI is based on the measured and modelled contaminant concentrations described in Bioresearches (2022) and DHI (2022) respectively.

The existing values of the ZOI have been adversely affected by land use in the surrounding catchment, which is predominantly rural. These activities have degraded the quality of freshwater inflows into the harbour through release of contaminants, nutrients and sediment, with sedimentation contributing to the proliferation of mangroves and a change in the benthic ecology to a more mud tolerant community. In addition to the Steel Mill discharges, the Waiuku and Clarks Beach Wastewater Treatment Plant (WWTP) discharges are also contributing factors. While benthic habitats are degraded in many areas through sedimentation, and in some areas from metal contaminants, they still support a range of ecological values.

More specifically, the Waiuku and Taihiki Estuaries (and therefore the ZOI) support a number of high value fish species and are recognised nationally as a hotspot for coastal bird diversity, constituting an important area within the Manukau Harbour for waders and seabirds. This is acknowledged in the Auckland Unitary Plan Operative in Part (AUP), with a number of 'Significant Ecological Areas – Marine' in the Waiuku and Taihiki Estuaries recognised both for the extensive intertidal flats that provide foraging habitat for birds, and for the high tide roost sites that provide roosting habitat for two 'Threatened' and twelve 'At Risk' endemic and migratory species. Fringing mangrove forest and salt marsh vegetation also provides habitat for cryptic (hard to detect) bird species. Anecdotally, marine mammals may occasionally visit the Waiuku estuary (particularly Orca), although no official sightings have been recorded.

As a result, the Current Environment in the modelled mixing extent[7] and wider ZOI is considered to have a 'Very High' ecological value for coastal birds and marine mammals, 'Negligible' to 'Moderate' value for benthic habitat, 'High' value for fish and a 'Moderate' to 'High' value for coastal vegetation (see summary Table below).

Ecological effects summary and conclusion

The ITA Area of the Site covers approximately 1.5% of the land area of the wider Waiuku catchment. The proposed discharges from this 1.5% land area contribute the following approximate loads to the Waiuku Estuary:

- 7.0% of the total freshwater flow volume;
- 1.3% of the total sediment load, which contains 6.4% of the very fine sediment load;
- 17.2% of the total copper load; and
- 62.4% of the total zinc load.

The main contaminant of concern for marine ecology in the areas closest to where the discharges from the Steel Mill enter the CMA is therefore zinc (and to a lesser degree copper and suspended and deposited sediment). Proportionally, the Northside and Southside Outfall discharges deliver a much greater water volume and contaminant load to the Waiuku Estuary than the other ITA discharges, particularly for zinc (approximately 95% of the zinc load).

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[7] The area of the coastal marine area modelled in the DHI modelling report (2022) beyond which metals, temperature, and changes in salinity driven by discharges from the Northside and Southside Outfalls are no longer discernible from background concentrations.

While the proposed discharges will contribute to overall sedimentation rates, the Steel Mill has a slightly lower sediment discharge rate than the average land use across the wider Waiuku Estuary catchment, and the Steel Mill only constitutes approximately 1.5% of the total Waiuku catchment area. Consequently, the Steel Mill's sedimentation effects are proportionally small and spatially constrained compared to the predicted sedimentation rates driven by land use in the catchment other than the Steel Mill. However, the proposed discharges do contribute a comparatively high 'very fine' sediment load for their equivalent land area.

Regarding physicochemical stressors, plumes of water with increased temperature and decreased salinity (driven primarily by the freshwater discharge from the Northside Outfall) have a similar size modelled mixing extent to zinc.

The settling zones[8] of the Lower North Stream, and to a lesser extent the Kahawai Stream, also show signs of ecological effects from the Steel Mill discharges.

In the wider Waiuku Estuary, suspended and deposited sediment are clearly having the most widespread effect on ecology. While the proposed discharges do contribute to this, most of the sediment is derived from rural land use in other catchments and the proposed discharges contribute slightly less sediment per unit area than the surrounding catchments.

In conclusion, we consider the marine ecological effects of the proposed activity on the Receiving Environment to be most pronounced within the modelled mixing extent and the settling zone of the Lower North Stream compared to the rest of the ZOI. However, based on assessment of the current discharges, effects are likely to become more pronounced across the ZOI as the consent term progresses. These spatial and temporal differences in the effects are described below.

Defining an ecologically relevant zone of reasonable mixing

A 'zone of reasonable mixing' is required to dilute or chemically or biologically convert contaminants to concentrations which do not exceed relevant guidelines or have significant adverse effects (AUP, section 107 of the RMA, ANZWQG 2018, NZCPS 2010, Cook *et al.* 2010).

The modelled mixing extent in the DHI (2022) report (i.e., the area beyond which metals, temperature, and changes in salinity driven by discharges from the Northside and Southside Outfalls can no longer be differentiated from background levels) extends a maximum of 400 m from the Northside Outfall and 200 m from the Southside Outfall. This modelled mixing extent constitutes a total combined area of approximately 8 ha, with the Northside Outfall discharge contributing 6.3 ha and the Southside Outfall discharge 1.6 ha. The existing consented mixing zone[9] is approximately 44 ha, so the modelled mixing extent is considerably smaller overall, especially around the Southside discharge.

Based purely on the proposed discharges, at certain times water column contaminant concentrations exceed relevant guidelines (primarily for zinc and to a lesser extent temperature and copper) in this modelled mixing extent, usually around low tide. However, for much of the time, more stringent guidelines for all parameters are often not exceeded at all.

Ambient background concentrations of zinc and copper in the water column are also elevated at times but these are driven by catchment discharges other than the proposed NZ Steel discharges. When combined with the proposed discharges, more permissive guidelines are exceeded more frequently in the modelled mixing extent.

However, the ANZWQG (2018) 95% Species Protection Level (SPL) guidelines for 'slightly to moderately disturbed systems' for zinc and copper, and the AUP guidelines for temperature, are met

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[8] The area where the majority of sediment and associated contaminants discharged from a catchment settles out in the CMA.

[9] The mixing zone defined in the 2003 consents, authorising discharges from the Northside and Southside Outfalls.

before the edge of this modelled mixing extent. These are the primary stressors of concern (particularly zinc) and, based on the state of the Receiving Environment, these guidelines are considered appropriate to apply to this location. Therefore, based on these guidelines, the ecologically relevant zone of reasonable mixing[10] is likely to be smaller than the modelled mixing extent, and extends approximately 300 m from the Northside Outfall and 60 m from the Southside Outfall. This equates to a total combined area of the zone of reasonable mixing of approximately 3.75 ha, with the Northside Outfall discharge contributing 3.6 ha and the Southside Outfall discharge 0.15 ha. Based on monitoring and modelling data, a similar size area of effect is likely to apply in regard to sediment quality guidelines, primarily driven by zinc.

The combination of elevated zinc, copper, increased water temperature, reduced salinity and elevated Total Suspended Solids (TSS) may have a discernible cumulative ecological effect within the modelled mixing extent. However, it is not expected that there would be cumulative effects from the combination of these parameters in the water column outside the modelled mixing extent once they become fully mixed with estuary water. In fact, all guidelines are met prior to the edge of the modelled mixing extent, and only one stressor ever exceeds a relevant guideline within the smaller zone of reasonable mixing at any one time. Potential cumulative effects from metal levels in sediments and sedimentation rates outside the modelled mixing extent are discussed below.

Given the scale of the activity, the level of existing treatment of the discharge water, the state of the Receiving Environment, the amount of similar habitat type outside the area, and NZ Steel's ongoing commitment to continual improvement (including the investigations and resulting improvement in discharge quality discussed in the ITA Report; T+T 2024a, Appendix G of the AEE), a zone of reasonable mixing based on 95% SPL guidelines is considered appropriate from a water and sediment quality perspective. Regular review of the Best Practicable Option (BPO) for the treatment systems should ensure that the size of the zone of reasonable mixing remains reasonable over the life of the consent.

Effects on the scale of the Zone of Influence (ZOI)

The modelled mixing extent constitutes a total combined area of approximately 8 ha and the zone of reasonable mixing an area of approximately 3.75 Ha. These areas represent < 0.5% and < 0.2% respectively of the 1,900 ha of intertidal habitat in the ZOI of the Waiuku and Taihiki Estuaries and are therefore of a relatively small spatial scale. As such, when effects inside and outside the modelled mixing extent (i.e., across the ZOI as a whole) are taken together over the 35 year consent term, the overall levels of effect are generally predicted to be 'Low' on the scale of the ZOI. However, the level of effect on coastal birds is considered to be 'Moderate' due to their 'Very High' ecological value (see the summary of effects table below)[11]. These effects on birds are primarily due to effects on foraging habitat quality, driven by small increasing concentrations of zinc, and to a lesser degree copper, suspended sediment, and sedimentation rates. In combination, these increases in contaminants could lead to a minor shift in baseline ecological conditions and contribute to cumulative effects across the ZOI. However, it is considered that effects driven by the proposed discharges from the ITA Area are small on the scale of the ZOI, particularly in comparison to catchment drivers other than the Steel Mill.

The EcIAG specify that effects that are 'Moderate' and above warrant further effects management, which are proposed to be addressed through a residual effects management and monitoring programme summarised below.

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[10] The area beyond which metals, temperature, and changes in salinity meet relevant ecological guidelines, as described further in Section 7.2

[11] Note that these effects are at the lower end of the range at the beginning of the 35 year term and increase to the upper end of the range towards the end of the 35 year period.

Proposed residual effects management and monitoring

NZ Steel has existing comprehensive treatment systems which are designed to achieve the smallest practicable mixing zone and to minimise the level of effects of the discharges. These treatment systems have been progressively improved over time (with a marked improvement in discharge quality in the last two years) and further improvements in discharge quality are anticipated over the term of the consent through continual improvement actions (detailed in the ITA Report; Appendix G of the AEE).

Marine ecological effects are generally assessed as being ‘Low’ or ‘Very Low’ on the scale of the ZOI (see the summary of effects table below). Therefore, based on the EcIAG assessment framework and the findings of this assessment, further management measures are not warranted for most effects. The exception is the potential adverse effects on coastal birds, which are considered to be ‘Moderate’, and additional measures are proposed to address these residual effects.

The proposed approach to manage and monitor residual adverse effects on coastal birds will be set out in a Coastal Bird Management Plan (CBMP), which is proposed as a condition of consent. The proposed CBMP condition includes the objective of the CBMP and describes the management and monitoring practices and procedures that are required to compensate for residual effects on coastal birds.

While offsetting measures were considered in the first instance, the proposed measures to address residual effects on coastal birds are all defined as forms of compensation. The measures do not meet the definition of offsetting on the grounds that the nature of residual effects and their management do not readily lend themselves to accounting for gains and losses with the necessary degree of confidence to constitute an offset.

To ensure that compensation is appropriate, the CBMP will be based on a Biodiversity Compensation Model (BCM), which will be used to determine the type and quantum of compensation that is likely required to address residual effects on coastal birds to enable a positive effect that outweighs the residual adverse effects.[12]

The key focus of the CBMP is to demonstrably and adaptively address residual effects in alignment with key ecological and biodiversity compensation principles. It is anticipated that the CBMP could provide for enhancement of existing bird roost and intertidal feeding habitat through selective mangrove management, the enhancement of existing roosts in the vicinity of the Site, and protective measures including fencing and the control of weeds and predators. Work has commenced on identifying appropriate bird roost compensation sites and will be informed by the factors required in the CBMP condition as well as the detailed design of the relevant works and location-specific factors. We consider that the implementation of, and compliance with, the CBMP will adequately address residual effects on coastal birds.

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[12] Positive effects that outweigh adverse residual effects are those where values that are adversely affected by an activity are addressed through compensation as assessed using a BCM tool.

Summary of residual ecological effects over the duration of the consent across the ZOI as a whole (including the modelled mixing extent).

Habitat/species type	**Ecological values**	**Magnitude of residual effects after measures to avoid, minimise, remedy and/or mitigate effects**	**Overall level of residual effects on ecological values**[1]
Estuarine habitat	'Negligible' to 'Moderate' value benthic habitat and water quality (depending on proximity to the Steel Mill and other catchment discharges)	'Negligible' to 'Low' magnitude of effects from zinc, copper, sediment, increased temperature and reduced salinity, which reduce with distance from the discharges	'Low'[2]
Fish	'High' value due to high fish diversity and the presence of nursery grounds	'Low' magnitude of effects on fish, which reduce with distance from the discharges	'Low'
Marine Mammals	'Very High' value, due to the possible presence[3] of 'Threatened' species	'Negligible', as unlikely to be present and any use of the discharge area likely to be of very short duration	'Low'
Coastal vegetation	'Moderate' to 'High' value, due to habitat provision for birds, and rarity of some vegetation types	'Negligible', as the vegetation types are resilient to effects from the discharges	'Very Low'
Coastal birds	'Very High' value, due to the presence of several 'Threatened' and 'At Risk' species	'Low' magnitude of effects on foraging habitat, which reduce with distance from the discharges	'Moderate'[2]

[1] The 'Overall level of residual effects' categories are derived by combining the 'Ecological values' and 'Magnitude of residual effects' column categories using the EcIAG 'Overall level of effects' matrix.

[2] Note that these effects start at the lower end of the range in the short term and increase to the upper end of the range towards the end of the 35 year period.

[3] While there is anecdotal evidence that the ZOI is sporadically visited by marine mammals (particularly Orca), no official sightings have been made.

1 Introduction

NZ Steel owns and operates the Glenbrook Steel Mill near Waiuku, Auckland. NZ Steel holds resource consents (Existing Permits[13]) that authorise the discharge of stormwater and process water from the Steel Mill to surface water and the Coastal Marine Area (CMA). The North Drain, the Ruakohua Stream and the Kahawai Stream all receive discharges from the Steel Mill and in turn discharge to the CMA of the Waiuku Estuary. Further, there are two direct discharges to the CMA, the Northside and Southside Outfalls, which discharge treated stormwater and process water from the Steel Mill (See Appendix E of the AEE Figure W5).

The existing discharge permits to surface water and the CMA held by NZ Steel expire on December 31, 2021. NZ Steel is seeking to replace the discharge permits that authorise the stormwater and process water discharges from the Steel Mill to freshwater and the CMA.

This report provides a marine ecological effects assessment of the CMA that receives stormwater and process water discharges from the Steel Mill.

1.1 Scope of the report

This marine ecological effects assessment report comprises:

- A description of the CMA and the discharges to it;
- A desktop assessment of existing information and data relating to the ecology of the CMA and the surrounding area;
- Information from the Bioresearches (2022) Environmental Monitoring of Discharge Receiving Environments 2020 - 2021 Report (attached as **Appendix C**) which includes consent monitoring data and analysis of information on shellfish and sediment quality, benthic ecology, coastal vegetation and coastal birds;
- Information from the Waiuku Estuary modelling carried out by DHI (DHI 2022 report attached as **Appendix F**). This modelling report includes an assessment of the fate of sediment, copper and zinc discharges to the CMA from the Northside and Southside Outfalls, and from the ITA Area and Dewatering Plant discharges to the Lower North Stream, Kahawai Stream and Ruakohua Spillway[14] which eventually end up in the CMA and forecasts the trajectory of effects of the discharges 35 years into the future. This report also includes information on temperature and salinity effects from the Northside and Southside Outfall discharges;
- An assessment of ecological effects following the framework outlined in the Environment Institute of Australia and New Zealand (EIANZ) Ecological Impact Assessment Guidelines (EcIAG) (Roper-Lindsay *et al.*, 2018). This brings together the values of the CMA, the magnitude of effects of the proposed activity on the CMA (with existing mitigation in place), and the overall level of effect of the activity based on the combination of the values and magnitude of effects. This assessment also discusses any potential requirements for additional mitigation, offset or compensation; and
- Considerations for the resource consent conditions and monitoring.

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[13] Permits 41027, 21575, 21576, 21577 (each expiring on 31 December 2021)

[14] Note that the Ruakohua Dam Spillway already has a consent to discharge to the CMA and so is not explicitly assessed as part of this application but is included in the modelling inputs and outputs to account for overall contaminant loads and is included in some parts of the effects assessment for wider context.

1.2 Affiliated reports

This marine ecological effects assessment should be read in conjunction with:

- The water discharges and industrial or trade activities assessment (the ITA Report) (T+T 2024a) (Appendix G to the AEE);
- The freshwater ecological assessment (the Freshwater Report) (T+T 2024b) (Appendix H to the AEE); and
- The Assessment of Environmental Effects (AEE) (T+T 2024c), to which this report is appended.

2 Environmental context

2.1 Overview

The Site is located on the eastern bank of the Waiuku Estuary (see Appendix E of the AEE Figure W1). The Waiuku Estuary extends approximately 5 km by road north of the Waiuku township. The settlement of Glenbrook Beach is three kilometres to the north of the Site. Access to the Site from the south is via Mission Bush Road and access from the east is via Glenbrook Beach Road and Glenbrook Road. To the east of the Site, the Franklin lowlands stretch eastward all the way to Papakura.

NZ Steel owns approximately 550 ha of land in the Glenbrook area, located in the south of Auckland (the Site). Of this, the working Steel Mill occupies an area of approximately 190 ha and is within the AUP Business – Heavy Industry Zone. Outside the working area of the Steel Mill, NZ Steel owns land to the north, east and south, which is farmed and contains a closed and an operational landfill. The farmland forms a greenbelt and buffer between the Steel Mill and the surrounding farmland and communities. The land use in the area surrounding the Steel Mill is varied and includes pastoral farming (particularly dairy farming), horticulture, and lifestyle blocks.

The Site and the associated upstream areas are drained by three main catchments: the North Stream catchment (comprised of the North Drain and Lower North Stream), the Ruakohua Stream, and the Kahawai Stream. The North Stream and Kahawai Stream names are not the legal names for these watercourses but have been used in this assessment as the watercourses do not have a legal name. Within the Site the proposed discharges are generated from an equivalent land area of approximately 170 ha[15]. The combined remaining area of the three contributing catchments (i.e., catchments outside of the ITA Area) is 570 ha (so together these areas cover 740 ha). The locations of these features are shown on Figures W5 and W-ME3 in Appendix E of the AEE. Further explanation of the discharges to the CMA is provided in Section 3, in the DHI (2022) modelling report (attached to this report as **Appendix E**), and in the ITA Report (Appendix G of the AEE).

Note that this report does not include any assessment of marine ecological effects for the coastal occupation of the Northside and Southside Outfalls, as these structures form part of the existing Receiving Environment. This is covered further in the AEE (T+T 2024c).

2.2 Statutory context for environment

Schedule 4 of the RMA requires that an application for a resource consent must include an assessment of the activity's effects on the environment. Similarly, section 104 of the RMA requires that a consent authority must have regard to any actual and potential effects on the environment of allowing an activity.

As explained in the AEE (T+T 2024c), the "environment" relevant to both Schedule 4 and section 104 includes both the "Current Environment" (the environment as it currently exists) and the "future environment", which while not being artificial, may be amended to include or exclude various activities and associated effects. In particular, in relation to applications to replace expiring resource consents such as this one, consideration must be given to the environment that would exist without the continuation of activities and associated effects authorised by the expiring consents (i.e., removing the effects that arise as a result of current operations). However, the effects of past activities that will persist also remain relevant to the environment against which effects are assessed.

The assessment of the effects of the proposed discharges has been undertaken as if the currently authorised discharges have been discontinued and the Proposal is an application for a new activity.

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[15] Note this is the same spatial area as the ITA Area.

That is, in simplistic terms, the discharges cease, and the effects assessment relates to recommencement of the discharges. Any legacy effects of past authorised discharges are also included in the environment against which the Proposal is assessed.

This hypothetical scenario where the discharges are ceased is referred to as the 'Receiving Environment'. This report therefore assesses the effects of the proposed activity against the Receiving Environment. The inclusions and exclusions are set out in the table below, together with assumptions made in relation to these applications.

Table 2.1: Description of activities and effects included and excluded from the Receiving Environment.

	Activities and effects included and excluded from the Receiving Environment	**Comments and assumptions**
Base case	The Current Environment	Monitoring data and investigations undertaken during the preparation of this application provide a baseline. This "Current Environment" reflects the effects of the operation of the Steel Mill over the past 55 years since operations began in 1968.
Excluded	The effects of the activity that are the subject of the application	In order to exclude the effects of the expiring consents from the "environment", it has been assumed that the consented activities, and in particular relevant discharges, cease on expiry. Cessation of these discharges would essentially mean that the Steel Mill operation would cease, including other discharges from the Site (e.g., air discharges). This is a hypothetical scenario as, even if the Steel Mill operation were to cease, and the Site was made safe, there would be ongoing discharges of stormwater runoff from impervious surfaces that may require consent, or with active management, may meet permitted activity standards. However, to take a conservative approach, it has been assumed that there are no ongoing discharges from the Site. This assumption produces the most conservative (high) magnitude of effect of the ongoing operation of the Steel Mill.
Included	Any effects of the activity that are the subject of the application that unavoidably persist	In a scenario where expiring consent activities cease, there would be effects of past activities that would persist. Examples of these activities and effects include: • Build-up of metals in sediment • Ongoing diversion of water in the North Drain
Included	Non-fanciful permitted activities that can occur as of right without additional resource consents	While some minimal industrial development could occur on the Heavy Industry Zone land to the south of the Steel Mill as of right, most industrial development would trigger resource consent requirements and therefore our assumptions have not included development of the Heavy Industry Zone land. No permitted land use changes or discharges have been assumed in the wider area.
Included	Activities that have been granted resource consents that are likely to be implemented	There are no known unimplemented resource consents in the wider area that would have a bearing on this application.

The descriptions and information throughout Section 5 predominantly describe the Current Environment. In Section 6, the Receiving Environment is described based on the criteria above and assumptions about how these would alter the Current Environment. Ultimately, the effects are assessed against the Receiving Environment, this approach is discussed further in Section 4.

3 Glenbrook Steel Mill discharges

3.1 Overview

The main discharges of stormwater and process water from the Steel Mill to the CMA are the Northside and Southside Ponds (see Appendix E of the AEE Figure W1). The Northside and Southside Ponds capture the majority of stormwater and process water from the Steel Mill. Discharges from these ponds are directed to the adjacent CMA via outfalls (see Appendix E of the AEE Figure W1) that operate 24 hours per day via a gravity feed system.

There are also several other discharge points that direct stormwater from the ITA Area to streams. The North Drain (which drains to the Lower North Stream), the Ruakohua Stream and the Kahawai Stream all receive stormwater from the ITA Area of the Site. The North Drain also receives the ironsand Dewatering Plant discharge, which contains water abstracted from the lower Waikato River at Maioro. Appendix E of the AEE Figure W-ITA3 shows the locations of the points where these discharges eventually enter the CMA and Figure W-ME3 shows the differentiation between the ITA catchment areas used in the DHI (2022) modelling and the catchments outside the ITA Area that contribute to the ultimate discharges to the CMA.

Subsequent to carrying out this assessment[16] NZ Steel secured co-funding from the New Zealand Government to enable the installation of an electric arc furnace (EAF) at the Site. If the EAF goes ahead, it is anticipated that it will be fully operational by early 2027. If installed, the EAF will reduce the use of virgin steelmaking materials (iron sand and coal) and provide for recycling of externally sourced ferrous scrap. Once fully operational, only one of the current two ironmaking streams would operate at any one time and this molten iron would be also fed into the EAF. Initial analysis suggests this change will result in the following changes when compared to current operations:

- Reduction of the amount of process water entering the Northside Pond by approximately 30 percent,
- Reduction of the associated contaminant load to the Northside Pond by approximately 40 to 50 percent, and;
- Reduction of the process water discharge from the Dewatering Plant by up to 50 percent.

Each of the above changes are expected to have flow on benefits to the marine receiving environment, when compared to existing operations.

The only new contaminant generating activity associated with the EAF will be stormwater runoff from the new external sourced ferrous scrap yards. The primary contaminants identified of interest for this discharge are Polycyclic Aromatic Hydrocarbons (PAHs), oils and grease. However, this runoff will be treated through the installation of an at source treatment train system which will remove and treat contaminants prior to discharge to the Northside Pond. Consequently, the ferrous scrap yard run off is not expected to increase the contaminant loads to the Northside Pond or impact on existing water quality. Further detail is provided in the ITA report (T+T 2024a, Appendix G of the AEE).

Based on the above, it is expected that effects on the Receiving Environment will be considerably reduced from those detailed in this assessment once the EAF is fully operational. However, to remain conservative, any potential improvement in discharge quality has not been factored into this assessment. This assessment therefore presents a ‘worst case scenario’ based on the current

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[16] The original assessment was undertaken in 2021 and presented in the version of this report dated June 2021. Subsequent updates were made in response to section 92 requests and presented in the version of this report dated October 2022.

operations. Further information regarding the implications of the change to the EAF system are detailed in the ITA Report (T+T 2024a, Appendix G of the AEE).

3.2 Current discharge quality and quantity

T+T has conducted a review of existing water quality data for the proposed discharges (T+T, 2024a). The proposed discharges are monitored regularly for water quality. Pre-treatment water quality data is also available for water entering the Northside and Southside Outfall Ponds. This data show that while absolute loads are not immaterial, removal rates before the treated water is discharged to the CMA are high (see DHI 2022 and T+T, 2024a). More specifically, the average pre-treatment removal rates are as follows for the Northside Outfall ponds[17]:

- Copper: 91% removal;
- Zinc: 97% removal; and
- Suspended solids: 98% removal.

The existing discharge consents place limits on the discharges from the Northside, Southside, and Dewatering Plant discharges in terms of flow volume and concentrations and loads of contaminants. **Table 3.1** below lists the main parameters of interest for each of the proposed water discharges. These are parameters for which occasional exceedances of Consent Limits, Trigger Investigation Levels, and/or guidelines have been recorded (refer to T+T, 2024a for details of this analysis).

Table 3.1: Parameters of interest for each discharge

Discharge	Parameters of interest
Northside Outfall	Total suspended solids, turbidity, heavy metals (in particular zinc), PAHs, oils and grease
Southside Outfall	Heavy metals (in particular zinc), pH, Total suspended solids, turbidity
Dewatering Plant (North Drain)	Conductivity, turbidity, heavy metals (in particular zinc)[18]
ITA discharges to North Drain	Total suspended solids, turbidity, heavy metals (in particular zinc)
ITA discharges to Kahawai Stream	Total suspended solids, heavy metals, pH
ITA discharges to Ruakohua Stream	Total suspended solids, heavy metals

The monitoring results in **Table 3.1** suggest that the discharges contain contaminants that could result in adverse effects on freshwater and marine ecological values. However, based on further assessment carried out in the ITA Report (Appendix G of the AEE) and DHI (2022) Report, zinc, copper, suspended solids, temperature and salinity changes (driven by freshwater discharge volumes from the outfalls) are considered the key stressors requiring consideration with respect to the proposed discharges' effects on the CMA.

Further information regarding Steel Mill activities, discharge quantity and quality compared to both existing consent conditions and new proposed Consent Limits and Trigger Investigation Levels, can be found in the ITA Report (T+T 2024a) (Appendix G to the AEE) and the Freshwater Ecological Values and Effects Assessment Report (T+T 2024b) (Appendix H to the AEE).

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[17] Removal efficiencies are likely to be similar for the Southside Outfall ponds but less data is available to assess this.

[18] Note that one Dewatering Plant result for zinc on 28 October 2020 was particularly elevated. This data point is considered to be an outlier anomaly and may not be correct as the other metals and flow data were not elevated and there is no apparent explanation for the result. This individual result substantially increases the apparent zinc load from the Dewatering Plant (by 27%), however, it has been left it in the data set and included in the DHI (2022) modelling to be conservative. See DHI (2022) and T+T (2022a) for further explanation.

4 Methods

4.1 Desktop study

A desktop assessment was undertaken to compile information and data relating to the environmental state and ecology of the marine area surrounding the Site and across the wider Waiuku and Taihiki Estuaries. A full list of information sources is provided in the References section.

4.2 Review of the DHI Modelling report

A report was prepared by DHI (DHI 2022, attached in **Appendix F**) which assesses the current state and ongoing effects of the proposed discharges on the Waiuku Estuary using a suite of modelling tools. DHI's modelling includes quantification of current water column effects relating to salinity, temperature, suspended sediment and metals, as well as predicted sediment deposition rates due to both the proposed discharges and loads from the surrounding catchments. These sediment deposition rates and water column metal concentrations are then used to model the short term[19] and future state concentrations of zinc and copper in surface sediments over the proposed consent term. The relative contribution of the proposed discharges to these predicted future state concentrations of zinc and copper in surface sediments is also modelled.

The modelled current and future states of water, sediment metal concentrations and sedimentation rates under both the current operational scenario and with operations ceased are incorporated into each of the relevant parts of the values and effects sections below. The DHI (2022) report was reviewed in the context of the potential ecological effects that could arise from the fate of the modelled contaminants from both the wider catchment and the proposed discharges. This report should be read in tandem with the DHI (2022) report.

4.3 Assessment of effects methodology

4.3.1 Statutory context for assessment

As discussed in Section 2.2, Schedule 4 and section 104 of the RMA require assessment of effects on the environment of allowing an activity. The "environment" against which effects of this application must be assessed is the "Receiving Environment" (as described in Section 2.2). In particular, the Receiving Environment assumes the cessation of the discharge activities (and associated effects) authorised by the expiring consents (i.e., removing the effects that arise as a result of current operations). However, the legacy effects of past activities that persist also remain relevant to the environment against which effects are assessed.

To assess the effects on the Receiving Environment, a three-stage process has been undertaken:

- Stage 1: Identify and assess the environmental state of the Receiving Environment (i.e., based on the Current Environment but assuming the Steel Mill operation has ceased);
- Stage 2: Identify and assess the environmental state of the environment following continued operation of the Steel Mill discharges as sought by this application; and
- Stage 3: Identify the differences in the environmental state between Stage 1 and Stage 2.

The differences in environmental state identified in Stage 3 are the actual and potential effects of the proposed Steel Mill activities that are the subject of this application and constitute the scenario for assessing the magnitude of effects on the Receiving Environment, as described in Section 4.3.2 below.

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[19] For the purposes of this assessment short-term is after a few tidal cycles once the discharge water is no longer discernible from other estuary water.

The cumulative nature of some discharges invariably means that the scale of some effects will increase over the term of the consent. Rather than applying a sliding scale of effects, the assessment in this AEE (and in the attached specialist assessments) takes a conservative approach, based on the maximum consent term provided for by the RMA (35 years). That is, Steps 1 and 2 assess the environmental state in 35 years' time and therefore, the differences identified in Step 3 will be the accumulated effects over the 35 year consent term. The actual effects would initially be much less than that, and only increase to that level over time.

An assessment of effects on marine ecology (Section 6) was carried out based on the information above and the details of the proposed activity.

4.3.2 Ecological effects assessment framework

Our assessment of ecological effects follows the framework outlined in the Environment Institute of Australia and New Zealand (EIANZ) Ecological Impact Assessment Guidelines (EcIAG) (Roper-Lindsay *et al.*, 2018), which provides a transparent approach to effects assessments that can be replicated. Whilst these guidelines are designed for freshwater and terrestrial systems, we have broadly followed a version of the guidelines for assigning values to marine systems developed by Boffa Miskell and modified them further to apply to the current applications[20]. The EcIAG state that the purpose of the document is to outline a framework to provide guidance on good practice, however, practitioners may deviate from the guidelines where it is considered ecologically relevant and justifiable to do so. The basis of the EcIAG assessment comprises a series of tables that are included for reference in **Appendix A**.

The EcIAG approach follows these steps:

Step one - Assigning ecological value

Categories used to assign an ecological value to habitats or species include 'Negligible', 'Low', 'Moderate', 'High' or 'Very High'. Species and habitat values are identified against criteria set out in **Appendix A Table 1** and **Appendix A Table 2** respectively. For habitats, the ecological value assessment is broadly based on habitat threat status and habitat condition or quality and assessed on four sub-criteria, including representativeness, rarity/distinctiveness, diversity and ecological context. For species, the value assigned is based on the national threat status (Townsend et al. 2007), i.e. ' Not Threatened', 'At Risk [21]', 'At Risk' (declining) or 'Nationally Threatened'. If applicable, the regional threat status may also be used, and species that are 'Not Threatened' but that are critical to ecological integrity may also be assessed as being of higher ecological value than that assigned by their national threat status.

Step two - Assess magnitude of effect

The 'Magnitude of Effect' is a measure of the extent or scale of the effect of an activity and the degree of change that it will cause after measures to avoid, minimise, remedy and/or mitigate for effects.

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[20] The characteristics of marine and estuarine sites with 'Negligible' to 'Very High' ecological values were originally developed by Dr Sharon De Luca, Boffa Miskell Ltd, then modified further here to provide a transparent approach that can be replicated. The characteristics have been accepted by decision-makers in Environment Court and Board of Inquiry hearings, including a number of NZTA projects (Transmission Gully, MacKays to Peka Peka, Ara Tūhono Project Puhoi to Warkworth and Warkworth to Wellsford Sections). Table 2 in Appendix B is based on the approach taken in these projects, and has been further developed with additional available indices to improve its use for the current consent applications.

[21] All 'At Risk' categories except 'At Risk (declining), i.e., At Risk (relict), At Risk (Recovering) and At Risk (Naturally uncommon).

The magnitude of an effect categories include: 'Negligible', 'Low', 'Moderate', 'High' or 'Very High' (**Appendix A Table 3**) and are assessed in terms of:

- Spatial scale of the effect;
- Spatial scale of the effect proportional to the availability of that particular habitat in the immediate surrounds and wider landscape;
- Intensity of the effect;
- Duration, frequency and permanence of the effect; and
- Level of confidence in understanding the expected effect.

As explained in the AEE to which this report is appended (T+T 2024c), and in Section 2.2 and above, the application assesses the magnitude of the effects of the discharges on the Receiving Environment that would exist if the Steel Mill operations ceased, both in the short-term[22] and over the maximum term of the consents that are sought (35 years). Effects are assessed both within and outside of the modelled mixing extent.

Step three - Assessment of the overall level of effects

The overall level of effect is determined using a matrix based on the ecological values and the magnitude of effects on these values after measures to avoid, minimise, remedy and/or mitigate. Level of effect categories include 'Positive', 'Negligible', 'Low', 'Moderate', 'High' and 'Very High' (**Appendix A Table 4** and **Table 4.1**).

The overall level-of-effect categories are used to determine if residual effects management is required over and above measures to reduce the severity of effects through efforts to avoid, minimise, remedy and/or mitigate adverse effects. Usually, if the level of residual effect is assessed as being 'Moderate' or greater (**Appendix A Table 4**) this warrants efforts to offset or compensate for these effects, unless these effects are otherwise accepted (for example within a zone of reasonable mixing).

The effects management hierarchy as defined in the NPS-IB (2023; relevant to Specified Highly Mobile Fauna) offers a slightly different hierarchy than that in the EcIAG. Effects are avoided where practicable, and then sequentially minimised or remedied. Where there are "more than minor" residual adverse effects following the above, then biodiversity offsetting or compensation is warranted. If this is not possible, then the activity itself should be avoided.

The determination of "more than minor" under the RMA is an assessment made by a planner rather than an ecologist, where the planner makes an assessment drawing on the technical information presented alongside their own professional judgement. The authors of this report have been advised that the 'Moderate' overall level of effects terminology under the EcIAG is generally considered to equate to the "more than minor" RMA effects terminology used by planners. However, within this report, as ecologists, we rely on the terminology of the EcIAG.

For the current resource consent applications, the discharges and mitigation measures are already in place, as opposed to being a completely new set of activities. As such, it is difficult to accurately assess the level of effects that would be occurring without the current treatment systems in place. However, it is assumed for the purposes of this assessment that the overall level of effects would require mitigation. Therefore, the assessment proceeds straight to assessing any residual effects with the existing treatment systems already in place.

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[22] For the purposes of this assessment short-term is after a few tidal cycles once the discharge water is no longer discernible from other estuary water.

Table 4.1: Criteria for describing overall level of ecological effects.

Magnitude of effect	**Ecological Value**				
	Very High	**High**	**Moderate**	**Low**	**Negligible**
Very High	Very High	Very High	High	Moderate	Low
High	Very High	Very High	Moderate	Low	Very Low
Moderate	High	High	Moderate	Low	Very Low
Low	Moderate	Low	Low	Very low	Very Low
Negligible	Low	Very low	Very low	Very low	Very Low
Positive	Net gain	Net gain	Net gain	Net gain	Net gain

5 Current Environment

5.1 Introduction

A full description of the Current Environment of the Waiuku and Taihiki Estuaries in the vicinity of the Steel Mill is given below, with reference to a potential Zone of Influence (ZOI) of the proposed discharges on the CMA.

This potential ZOI is estimated at 2500 ha and is outlined on the maps in DHI (2022) and on Appendix E of the AEE Figure W-ME1 as essentially the Waiuku Estuary and Taihiki Estuary extents. The ZOI is defined for the purposes of this Proposal as "estuarine and marine areas and habitats that could be potentially impacted by the project" (**Appendix A Table 1**). The potential ZOI for the proposed discharges has been based on the measured and modelled contaminant concentrations described in Bioresearches (2022) and DHI (2022) respectively. A map of the DHI estuary modelling area is provided in Appendix E of the AEE Figure W-ME1, and a map of the proposed discharges modelled area[23] and the wider associated catchment areas is provided in Figure W-ME3.

Within the ZOI, the core area of influence of dissolved contaminants in the water column is immediately adjacent to the Northside and Southside Outfall discharge points (and to a lesser extent at the mouths of the Lower North Stream and Kahawai Stream). Concentrations lessen with distance from the discharge points as discharge water is mixed with water from the wider estuary. However, sediment from the discharges, and any metals bound to it, are spread more widely throughout the estuary and within the ZOI, as detailed in the DHI (2022) report. The spatial extent of the core area of influence and the extent of sediment deposition throughout the wider ZOI is described further in sections 5.4 and 5.5 below.

Across the ZOI key factors that are likely to have had a major influence on the environmental quality in the ZOI are:

- Sedimentation – build-up of fine-grained muddy sediment. The change in sediment texture from sandy to muddy has almost certainly changed the benthic ecology of much of the estuary to a more mud tolerant community;
- Mangrove proliferation, which is related to the increased build-up of fine sediments;
- The quality of the freshwater inflows to the estuary, particularly during rainfall events when contamination by microorganisms, nutrients, suspended sediments and (to a lesser degree) urban-sourced contaminants such as heavy metals is greater. Nutrient inputs from the primarily rural catchment are likely to be a significant factor for the estuaries, and possibly the wider harbour's, biological productivity;
- Discharges from the Steel Mill, which add freshwater, metals and sediment to the estuary; and
- The Waiuku and Clarks Beach Wastewater Water Treatment Plants (WWTP) discharges, which add nutrients, suspended sediments and potentially metals and pathogenic microorganisms to the estuary.

5.2 Waiuku and Taihiki estuaries and immediate surrounds

Kelly (2009) provides a wealth of information on the Manukau Harbour and its tidal arms. Mills (2014) extends this information and reviews available data as at 2014 to provide a summary of environmental state and trends for shellfish, sediment, ecology and water quality monitoring for the Waiuku and Taihiki Estuaries. The following notes are taken primarily from those reviews.

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[23] Note the land area used in the modelling for the proposed discharges is equivalent to the ITA Area.

The Waiuku Estuary is one of the four main branches of the Manukau Harbour (**Figure 5.1**), running about 11 km from its mouth at Clarks Beach upstream to Waiuku. The estuary is considered to be an ancient discharge point for the Waikato River, which was cut off by lava flows from the South Auckland volcanic field around 3 million years ago.

The Taihiki Estuary is a major offshoot of the Waiuku Estuary which extends eastward from a junction between Clarks and Glenbrook Beaches. A large proportion of the water within the Waiuku and Taihiki estuaries drains at low tide.

The Waiuku Estuary (including the Taihiki arm) receives freshwater inputs from a catchment totalling approximately 184 km^2 (LCDB v5.0). Land use in the Waiuku and Taihiki river catchments is predominantly rural, with several small rural townships present. These include Waiuku, Clarks Beach, Patamahoe, and Glenbrook. Rural activities in the catchment include dairy and dry stock farming, horticulture and market gardening. As of 2018 some 75% of the catchment was in pastoral vegetation, 15% in cropland, 4% in native vegetation, 4% in urban use, and 2% in exotic forest (LCDB v5.0).

The presence of the Steel Mill is a notable feature in the Waiuku Estuary catchment. It is among the largest heavy industrial sites in the Auckland region and discharges treated stormwater and process water directly into the Waiuku Estuary via the engineered Northside and Southside Outfalls and indirectly via the Lower North Stream, Kahawai Stream and Ruakohua Dam Spillway (Appendix E of the AEE Figure W-ME1).

The Taihiki Estuary is comprised of diverse sheltered harbour habitats ranging from predominantly sandy intertidal flats, to mangroves and to pockets of salt marsh. It is considered to be an important nursery area for young flounder and grey mullet. This area remains one of the least impacted areas containing these harbour habitats in the Manukau because of the lack of major inputs of sediment from the catchment and its vegetated shoreline.

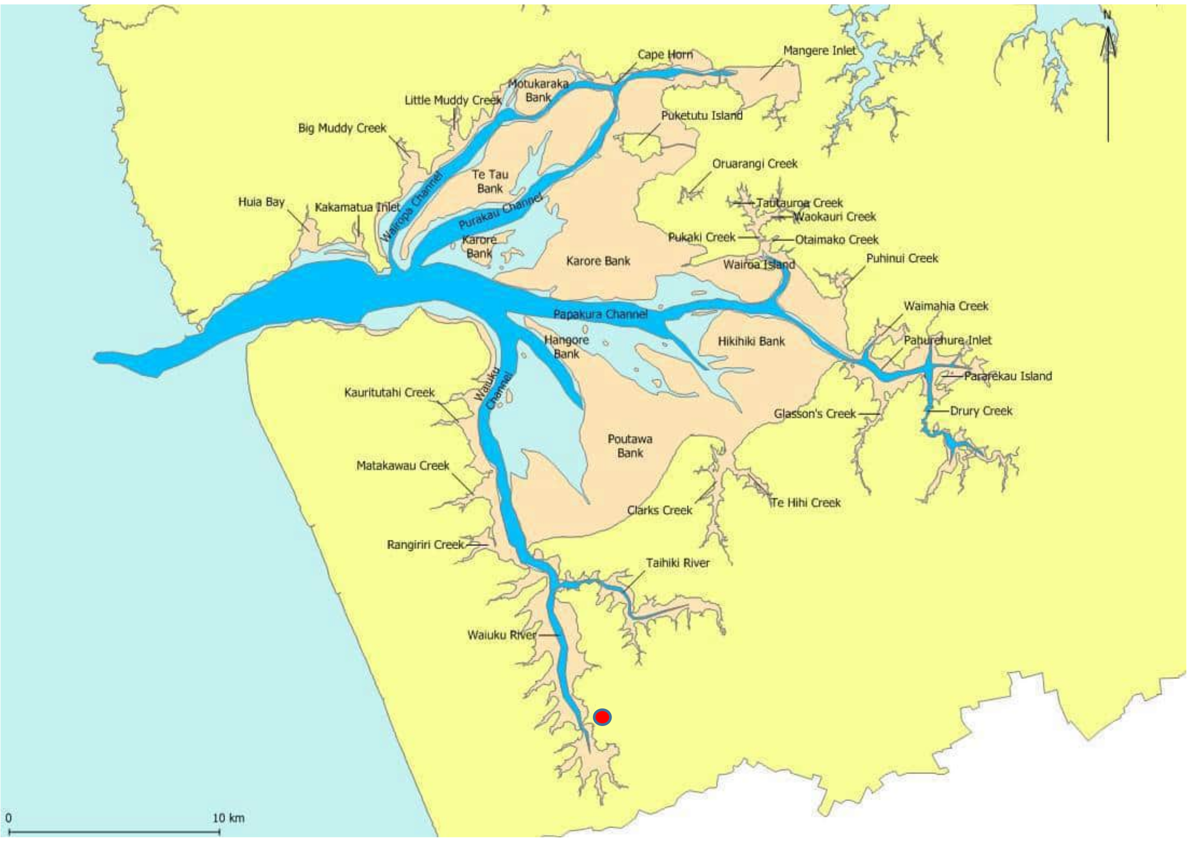

Figure 5.1: Major channels (dark blue), inlets and intertidal sand and mud banks (light brown) in Manukau Harbour (from Kelly 2009). Light blue is shallow subtidal area. Red dot indicates location of the Steel Mill.

Outside the mouth of the Waiuku Estuary, the Manukau Harbour has very high ecological values. North of the mouth, at Awhitu, a range of habitats are found along the shores of Awhitu Regional Park and in the Kauritutahi Stream. These support a large range of wading and coastal birds, including species that utilise saline vegetation for foraging and nesting. The area is an integral part of the Manukau Harbour, an internationally important wetland selected by the Department of Conservation as an Area of Significant Conservation Value (ASCV).

East of the mouth, from Clarks Beach to Karaka Point is an area of intertidal banks and shell banks that provide high quality habitat for a variety of animal and plant communities. The extensive gently graded, predominantly fine sand flats support the greatest diversity and abundance of intertidal sand flat organisms in the Manukau Harbour. They are an excellent feeding ground for many thousands of international migratory and New Zealand endemic wading birds including a number of nationally ’Threatened’ and ‘At Risk’ species. Several shell banks have developed just offshore at Karaka since the early to mid 1980s and are now the most important coastal bird roost sites on the Manukau Harbour. There are a number of other roosts along the shore, most notably near Seagrove, the second most important roosting site on the harbour. The Department of Conservation has selected the roosts and closely adjacent intertidal banks as an ASCV.

Sediments in the Waiuku Estuary range from predominantly sandy, through to mud. The exposed mud and sand banks provide valuable habitat for a range of bird species, and benthic fauna. Several species of fish use the estuary, including anchovy, flatfish, and mullet. The natural character of the Waiuku Estuary has been modified to varying degrees by urban development, sedimentation, and mangrove expansion.

A number of small freshwater stream inlets enter the estuary along its length. The inlets are characterised by mudflat and mangrove communities, where streams discharge into the embayments via shallow channels. Small areas of rocky intertidal habitats are present on the fringes of some inlets. Biological communities are dominated by mud snails (*Amphibola crenata*) within mangrove areas, large numbers of cockles (*Austrovenus stutchburyi*) in the sandy mid-tide habitats, and abundant crabs and shrimps lower on the shoreline. Pacific oysters (*Crassostrea gigas*) are well established with numerous localised clumps present along the coastline.

The Waiuku Estuary serves both amenity and practical purposes. In terms of direct human use of the estuary, it has been reported that there is limited contact recreation, however, it is utilised for boating, fishing and shellfish gathering.

5.3 Environmental Monitoring

The locations of monitoring sites used in this assessment are shown in Appendix E of the AEE Figure W-ME1. These include sites run by NZ Steel as part of their existing consent monitoring programme and those from Auckland Council run monitoring programmes. In combination, these sites provide the ability to assess the effects of the proposed discharges to date and put these effects into context based on the past and current environmental state of the wider ZOI.

5.4 Water quality

5.4.1 Water quality drivers in Waiuku Estuary other than the Steel Mill

Marine water quality at the Auckland Council monitoring sites at Waiuku Town Basin and Clarks Beach (Appendix E of the AEE Figure W-ME1) is reported against their Water Quality Index ("WQI") system which reports scores as Poor, Marginal, Fair, Good and Excellent (Ingley, 2020).

The Waiuku Town Basin site has been ranked as “Poor” for all of the three-year rolling average periods between 2014 and 2019. The main drivers of these results are elevated suspended sediment, all nutrient parameters derived from nitrogen and phosphorus and chlorophyll *a*, likely as a result of sediment and nutrient loading from high intensity horticulture and pastoral farming activities and urban landuse around Waiuku town (Ingley, 2020). It is also noted that the Waiuku Wastewater Treatment Plant discharge is located north of the town basin monitoring site. Also, there are three significant stream inflows to the Waiuku town basin from both urban and rural catchments (Mills, 2014).

Marine water quality at the Clarks Beach monitoring site (see Appendix E of the AEE M-ME1) at the mouth of the Waiuku and Taihiki Estuaries, was reported by Auckland Council as “Marginal” for all of the three-year rolling average periods between 2014 and 2019. This is better than the Waiuku Town Basin site as it is further away from potential contaminant sources and subject to considerable additional mixing with cleaner waters of the wider Manukau Harbour. The main drivers of these results are all nutrient parameters derived from nitrogen and phosphorus, chlorophyll *a*, and to a lesser extent suspended sediment. These results likely have the same drivers as those for the Waiuku Town Basin site including sediment and nutrient loading from high intensity horticulture and pastural farming activities, and the Clarks Beach WWTP discharge.

The small Clarks Beach treatment plant discharges to the mouth of the Waiuku Estuary. Resource consent has been granted for a new wastewater treatment plant at this location which will service Waiuku, Clarks Beach, Glenbrook and Kingseat and replace the existing plants at Clarks Beach and Waiuku under Watercare Services Ltd 2018-2038 Asset Management Plan (collectively servicing < 1% of Auckland’s population) (Watercare Services Ltd 2018). This treatment plant should improve water quality in the upper Waiuku Estuary once the Waiuku WWTP outfall has been decommissioned. However, water quality may not improve near the existing Clarks Beach outfall as the new combined outfall will discharge nearby. A comprehensive hydrodynamic and water quality model is currently being developed for the Manukau Harbour by Watercare to clarify potential reasons for the poor water quality at all six Auckland Council monitoring sites in the Manukau Harbour (Watercare Services Ltd 2019).

Metals are not sampled in the Auckland Council marine water quality monitoring programme so there was no information available on baseline concentrations derived from physical samples in the CMA for which to assess water quality. However, metals and TSS sampling carried out by NZ Steel at the Northside and Southside Outfall discharge points and metals, temperature and salinity modelling carried out by DHI in the Waiuku Estuary, provide sufficient information to understand the potential effects of both catchment and proposed discharges on water quality in the Waiuku Estuary adjacent to the Steel Mill. These effects on water quality within the existing consented mixing zone[24] **Figure 5.6** are described below.

Based on information in the DHI (2022) report dissolved metals section, background concentrations of copper and zinc in the wider Waiuku Estuary (i.e. those not driven by the proposed discharges) may be elevated above the ANZECC (2000)[25] and ANZWQG (2021) 99% species protection levels (SPL) respectively (**Table 5.1**) in nearshore areas directly adjacent to discharges from the major catchments. For the area within the currently consented mixing zone of the Steel Mill, background concentrations of copper are generally between the ANZECC (2000) 99% and 95% SPLs. For zinc, background concentrations are generally at or below the ANZWQG (2021) 99% SPL.

In summary, existing water quality in the upper to middle reaches of the Waiuku Estuary is considered to fall into the ‘Low’ value category from **Appendix A Table 2**. In the outer reaches of the

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[24] The mixing zone defined in the 2003 consents, authorising discharges from the Northside and Southside Outfalls

[25] In May 2023 an updated draft marine copper guideline was released for consultation. As these guidelines are still draft and the final version may change, the existing ANZECC (2000) guidelines are still being used for this assessment. However, based on an initial review of the draft guidelines it does not appear that they would change the conclusions of this assessment.

Waiuku Estuary the water quality may improve to the 'Moderate' value category, but this is uncertain based on the currently available information.

Table 5.1: Guidelines used for water column zinc and copper concentrations.

Contaminant	High Conservation value system	Slightly to moderately disturbed systems	Highly Disturbed Systems	
	99% species protection	95% species protection	90% species protection	80% species protection
Dissolved Zinc (µg/L) (ANZWQG 2021 update)[1]	3.3	8.0	12	21
Dissolved Copper (µg/L) (ANZECC 2000 values)[2]	0.3	1.3	3.0	8.0

[1] Note that updated guidelines for zinc were released for consultation in July 2020 and finalised in September 2021.

[2] In May 2023 an updated draft ANZWQG marine copper guideline was released for consultation. As these guidelines are still draft and the final version may change, the existing ANZECC (2000) guidelines are still being used for this assessment. However, based on an initial review of the draft guidelines it does not appear that they would change the conclusions of this assessment.

5.4.2 Water quality drivers from the Steel Mill discharges

The consented mixing zone as defined in the existing discharge consents for the Northside and Southside Outfalls covers the whole of the inter-tidal area within the embayment immediately west of the Steel Mill (**Figure 5.6**).

Based on the sediment quality results described in Section 5.5, discharge water quality described in T+T (2024a and 2024b) and the modelling results from DHI (2022), conclusions can be drawn about water quality within the existing consented mixing zone and the wider ZOI. Based on T+T (2024a and b) and DHI (2022) the key parameters of interest in the current consented mixing zone are copper and zinc, with temperature, salinity and TSS the key physicochemical stressors. These are discussed in more detail below.

Zinc and Copper

Zinc and copper are trace metals that are essential for most organisms' growth and development and are found at low concentrations in most natural waters. However, at higher concentrations they can be toxic to marine fish, invertebrate and plant species, and indirectly toxic to birds and marine mammals via the food chain.

NZ Steel discharges in isolation

Based on information in T+T (2024a) and in the DHI (2022) dissolved metals section, 95th percentile[26] concentrations of **copper** (based only on the proposed discharges) exceed the ANZECC (2000) 99% SPL within 100 m of the Northside Outfall discharge, and come close to, but do not exceed the 95% SPL in this area. (**Figure 5.2** and **Figure 5.3**). For the Southside Outfall discharge, the 99% SPL guideline is only exceeded within 50 m of the discharge point.

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[26] A percentile is the value at a particular rank in a dataset. For example, a value on the 95th percentile can be interpreted as one that only 5% of the values in the dataset are higher than. The median is the 50th percentile, so it is commonly assumed that 50% of the values in a data set are above the median, and 50% are below the median.

For **zinc**, 95th percentile concentrations (based only on the proposed discharges) exceed the ANZWQG (2021) 80% SPL within 60 m of the Northside Outfall discharge, but improve to 95% SPL within 100 m, and 99% SPL just after 200 m (**Figure 5.2** and **Figure 5.3**). For the Southside Outfall discharge the 99% SPL guideline is never exceeded.

NZ Steel discharges plus background concentrations

The **zinc** concentrations described above are only those contributed by the proposed discharges. DHI (2022) modelled Auckland Council Freshwater Management Tool (FWMT) catchment discharge data and estimated that background 95th percentile concentrations of zinc in the intertidal area around the Northside and Southside Outfalls could be up to 2 µg/L (which is still below the 99% SPL value of 3.3 µg/L). In this case the distances needed to meet the zinc guidelines above or equilibrate with background concentrations could be extended by up to 100 m for the Northside Outfall discharge and 10 m for the Southside Outfall discharge. i.e., 300 m and 60 m are required for zinc to meet the 95% SPL guideline or equilibrate with background concentrations for the Northside and Southside Outfall discharges respectively (see Figures 5-29 and 5-30 in DHI (2022)). Note that even with background and discharge concentrations combined, zinc never exceeds the 99% SPL at the Southside Outfall discharge.

For **copper**, when 95th percentile background concentrations are added to 95th percentile concentrations from the Northside and Southside Outfall discharges, 100 m and 60 m are required to equilibrate with background concentrations respectively. Note that copper always exceeds the 99% SPL when the discharges and background concentrations are combined, but does not exceed the 95% SPL.

However, 50th percentile concentrations represent a situation that occurs more commonly. From **Figure 5.3** we can see that, when only accounting for metal concentrations driven by the proposed discharges, 50th percentile concentrations generally do not exceed the 99% SPL for either copper or zinc, even within the first 50 m of both the Northside and Southside Outfall discharges.

When 95th percentile background concentrations are added to concentrations driven by the proposed discharges (for example during a rainfall event that washes sediment and metals off the wider catchment), several hundred metres more may be required to meet 99% SPLs for copper and zinc. 99% SPLs for zinc may also not be met in areas close to the discharge points of larger catchments elsewhere in the estuary and may not be met for much of the estuary for copper (see DHI 2022, Section 5.4). This is consistent with the upper half of the Waiuku Estuary being considered a ‘slightly to moderately disturbed system’ (ANZWQG 2018, **Table 5.1**). So, 95% SPL concentrations are considered appropriate to apply to this system.

Percentage of time above zinc and copper guideline thresholds

As well as providing water column percentile estimates, DHI (2022) interrogated the model to provide estimates of the amount of time that the various water quality guideline thresholds are exceeded for copper and zinc based on the NZ Steel discharges alone (i.e. not including background concentrations) at different radial distances from the Northside and Southside discharges.

As for the percentile results, the effects of the discharge are seen predominantly within the first 100 m of the Northside Outfall with the zinc 99% SPL exceeded up to 30% of the time in the first 50 m, dropping to 15% of the time out to 100 m, and only 0.4% of the time out to 200 m. The 80% SPL is exceeded up to 10% of the time in the first 50 m and only 0.3% of the time out to 100 m.

For copper at the Northside Outfall, only the 99% SPL is exceeded, primarily out to 50 m, up to 24% of the time.

For the Southside Outfall only the copper 99% SPL is exceeded, only out to 50 m (and primarily out to 20 m) and only up to 14% of the time. The zinc 99% SPL is not exceeded at all.

The exceedances described above primarily occur at low water when there is little or no mixing with other water in the estuary.

Salinity

Salinity changes are driven by freshwater discharge volumes from the Outfalls[27]. The DHI (2022) modelling estimates that in the area within about 50 m of the Northside Outfall discharge the water in the CMA has a mean salinity of around 22 Practical Salinity Units (PSU). Ambient mean salinity is about 26 PSU, meaning the discharge water reduces salinity by about 4 PSU on average in this area (**Figure 5.4**).

The 25th percentile salinity drops to less than 12 PSU compared to an ambient salinity of about 19 PSU with the difference due to the volume of freshwater in the discharge and the different states of the tide. The 75th percentile value is around 27 PSU while ambient salinity is around 29 PSU. The 25th percentile salinity increases with distance from the Northside discharge point out to around 200 m. Beyond this distance the salinity becomes relatively constant, indicating the discharge water is no longer having an obvious effect on salinity (**Figure 5.4**). The effect on salinity is less pronounced at the Southside Outfall, and is no longer obvious within about 50 m of the discharge.

Temperature

Temperature difference between discharge water and ambient sea temperature

The existing discharge permits for the Northside and Southside Outfalls specify that the discharge water temperature shall not exceed the ambient water temperature in the CMA by more than 20 °C.

DHI (2022) conservatively assessed NZ Steel discharge temperature monitoring data and estimated ambient sea surface temperature from climate data to assess compliance with this consent condition. When averaged over a 24-hour period, the difference between the discharge temperature and the ambient sea surface temperature for both the Northside and Southside Outfall discharges always remains below the threshold of 20 °C. However, the temperature difference regularly exceeds 15 °C for the Northside Outfall discharge (see DHI Section 4.4). For both discharges there is very little evidence of any seasonal variation in excess temperature. Therefore, this consent condition is always met.

Temperature excess in the CMA

The AUP permitted activity standards state that after reasonable mixing a discharge must not change the natural temperature of the receiving water by more than 3 °C.

Figure 5.5 shows the 95th percentile excess temperature in the CMA caused by the Northside and Southside Outfall discharges during summer. This reflects the predicted excess temperature (being the temperature above ambient CMA temperatures) that will occur around low tide, due to the temperature of the Northside and Southside Outfall discharges increasing the temperature of receiving water in the CMA.

The excess temperature modelling shows that a 95th percentile excess temperature of 20 °C may occur at the Northside Outfall discharge point in the CMA during winter (when daytime heating of ambient water is minimal). However, the 95th percentile excess temperature in summer would be 15 °C (this reduced heating is explained by the natural effect of shallow ambient water heating in summer). However, these values only occur around low tide, and beyond 100-150 m of the Northside Outfall discharge excess temperatures do not exceed 3 °C.

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[27] Note that prior to the construction of the Northside Outfall there was a stream in this location. However, the consistent high volume of water from the site (due to process water discharges) means a greater inflow of freshwater when there is no rainfall in the catchment.

Excess temperatures at the Southside Outfall discharge are much lower. The maximum increase in the 95th percentile excess temperature is 4.1 °C in winter and 2.5 °C in summer due to the lower discharge rate and lower discharge temperature. The 95th percentile excess temperature is only exceeded within 50 m of the Southside Outfall discharge point in winter and is never exceeded in summer.

Percentage of time above 3 °C temperature thresholds

As well as providing water column percentile estimates, DHI (2022) interrogated the model to provide estimates of the percentage of time that the AUP 3 °C threshold is exceeded based on the NZ Steel discharges at different radial distances from the Northside and Southside Outfalls.

As for the percentile results, the effects of the discharge are seen predominantly within the first 100 m of the Northside Outfall. The 3 °C threshold is exceeded up to 23.5% of the time out to 20m, 12.5% of the time at 50 m, then drops to 3.8% of the time at 100 m, and is not exceeded at all beyond 200 m.

For the Southside Outfall the 3 °C threshold is only exceeded up to 6.1% of the time in the first 20 m and not at all beyond 50m.

The exceedances described above primarily occur at low water when there is little or no mixing with other water in the estuary.

Summary of current estuarine habitat value categories for water quality:

Based on the results described above, and including background concentrations for copper and zinc from the wider catchment, with reference to the estuarine habitat value categories in **Appendix A Table 2**, water quality in the ZOI can currently be considered as follows:

- Northside Outfall discharge - ‘Negligible’ habitat value category at times in the area up to 100 m from the outfall, improving to ‘Low’ between 100 and 200 m from the outfall;
- Southside Outfall discharge – ‘Low’ habitat value category up to 100 m from the outfall; and
- Wider ZOI - ‘Low’ habitat value category beyond 200 m of the Northside Outfall discharge and 100 m of the Southside Outfall discharge in the area closer to the main channel once this water has mixed with ‘Low’ value water in the wider estuary. Some areas at the mouths of other sub-estuaries may fall within the ‘Negligible’ habitat value category during rainfall events, due to increased sediment and metal concentrations from sources other than the proposed discharges. In the outer reaches of the Waiuku Estuary the water quality may improve to the ‘Moderate’ habitat value category, but this is uncertain based on the currently available information.

Overall, the water quality habitat value categories in the potential ZOI, where data exist, are therefore considered to be between **‘Negligible’** and **‘Low’**, depending on distance from the Site discharge points, and from other discharge points in the wider catchment.

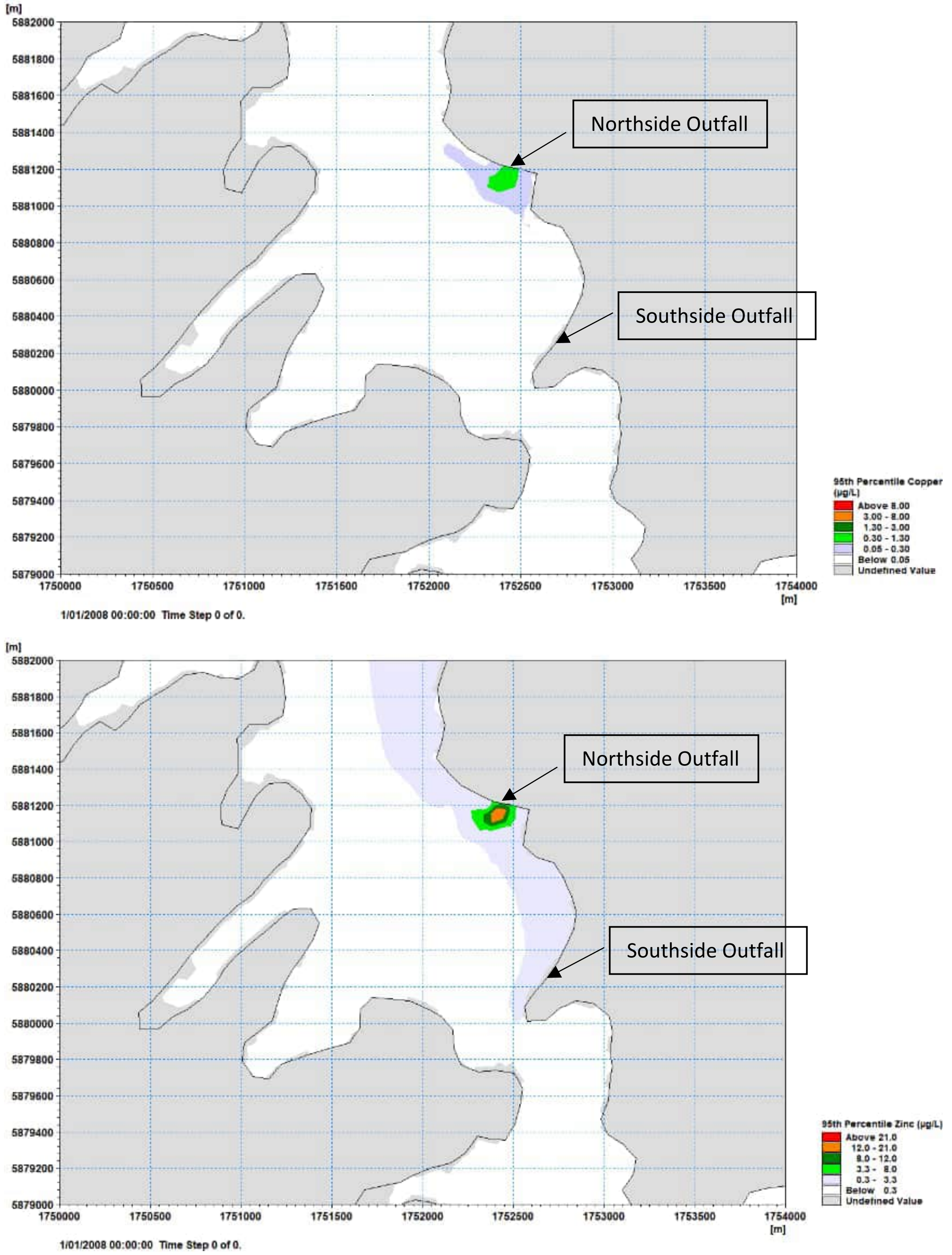
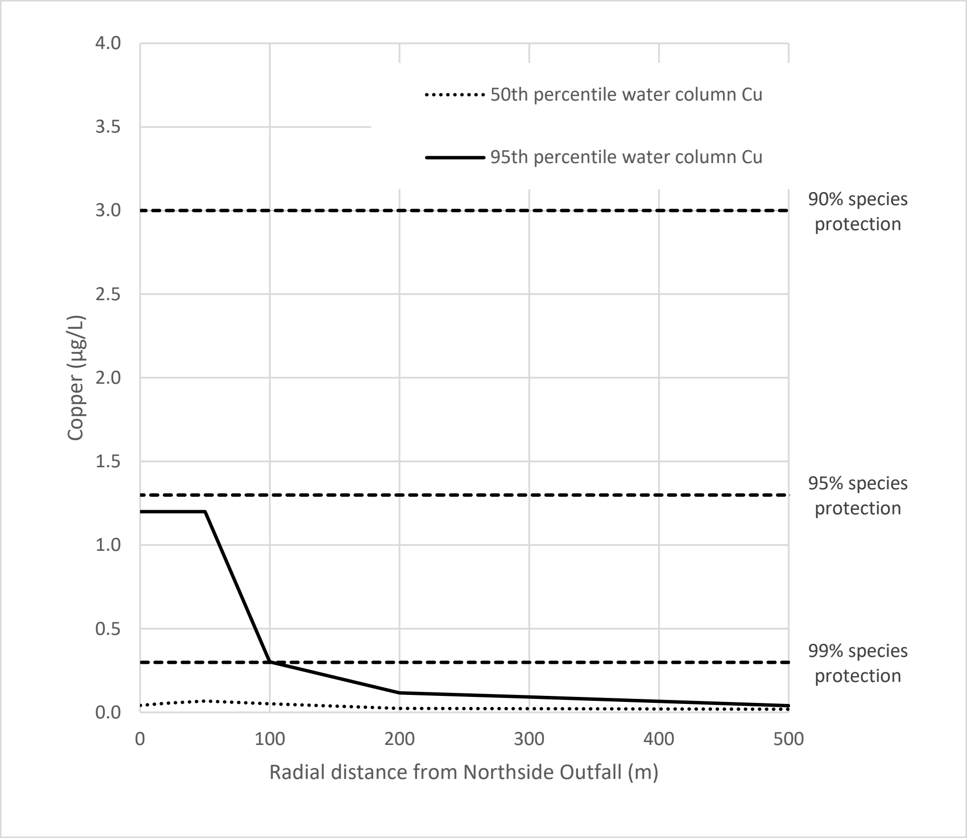


Figure 5.2: Predicted 95th percentile water column concentrations for the Northside Outfall for Copper (top panel) and Zinc (bottom) panel. Colour coding reflects the banding of the ANZWQG (2021) default marine guidelines for Zinc and the existing ANZECC (2000) marine guidelines for Copper. Maximum 95th percentile concentrations are 1.2 µg/L for Copper and 25.1 µg/L for Zinc. Figures taken from DHI (2022).



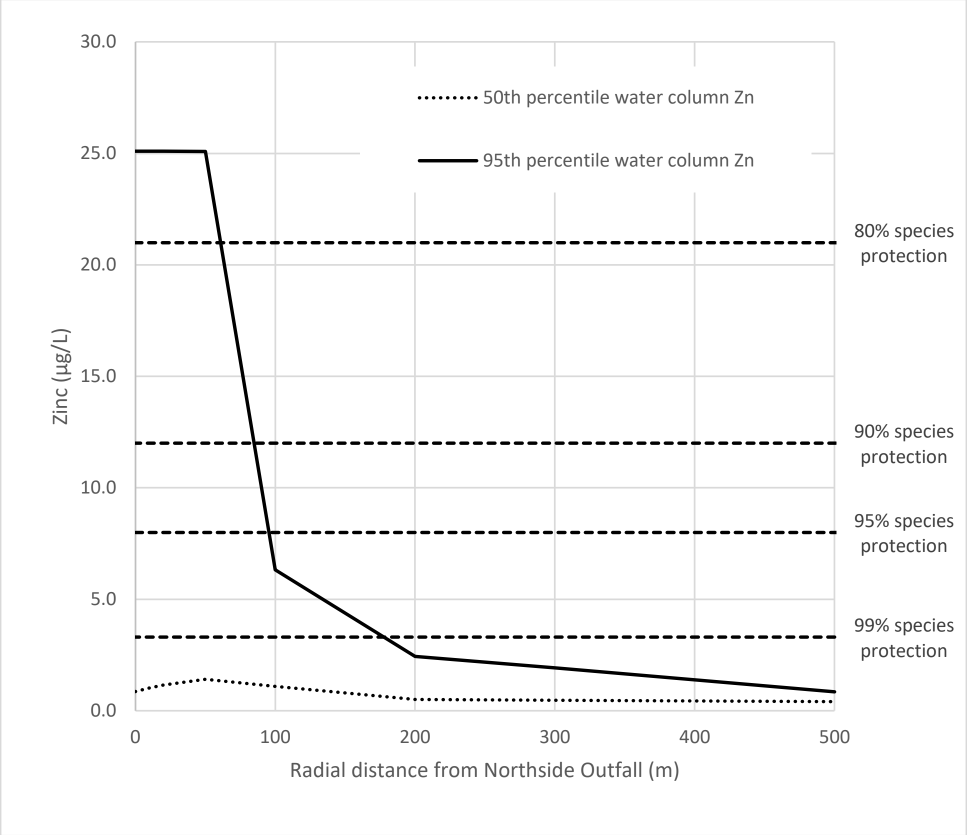


*Figure 5.3: Predicted 50th and 95th percentile Copper (top) and Zinc (bottom) water column concentrations for the Northside discharge as a function of radial distance from the discharge point. Dashed lines show the species protection levels (**Table 5.1**). Figures taken from DHI (2022).*

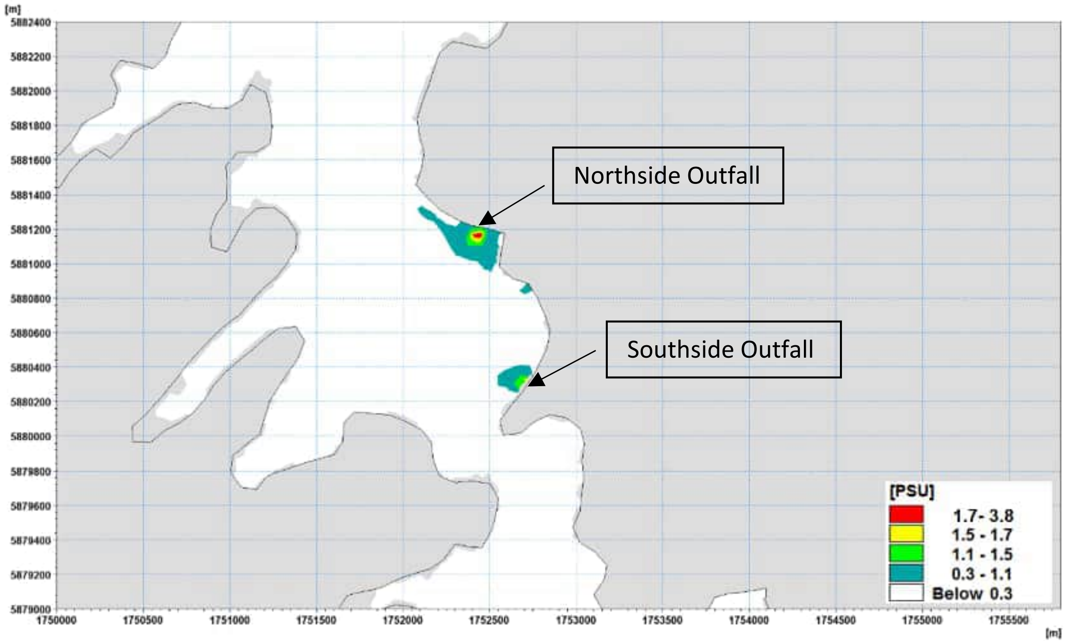


Figure 5.4: Predicted decrease in mean salinity on an annual average basis due to the NZ Steel Northside and Southside Outfall discharges. PSU = Practical Salinity Units and is equivalent to the Parts Per Thousand (PPT) salinity scale. Mean salinity in the fully mixed adjacent channel is approximately 25 PSU.

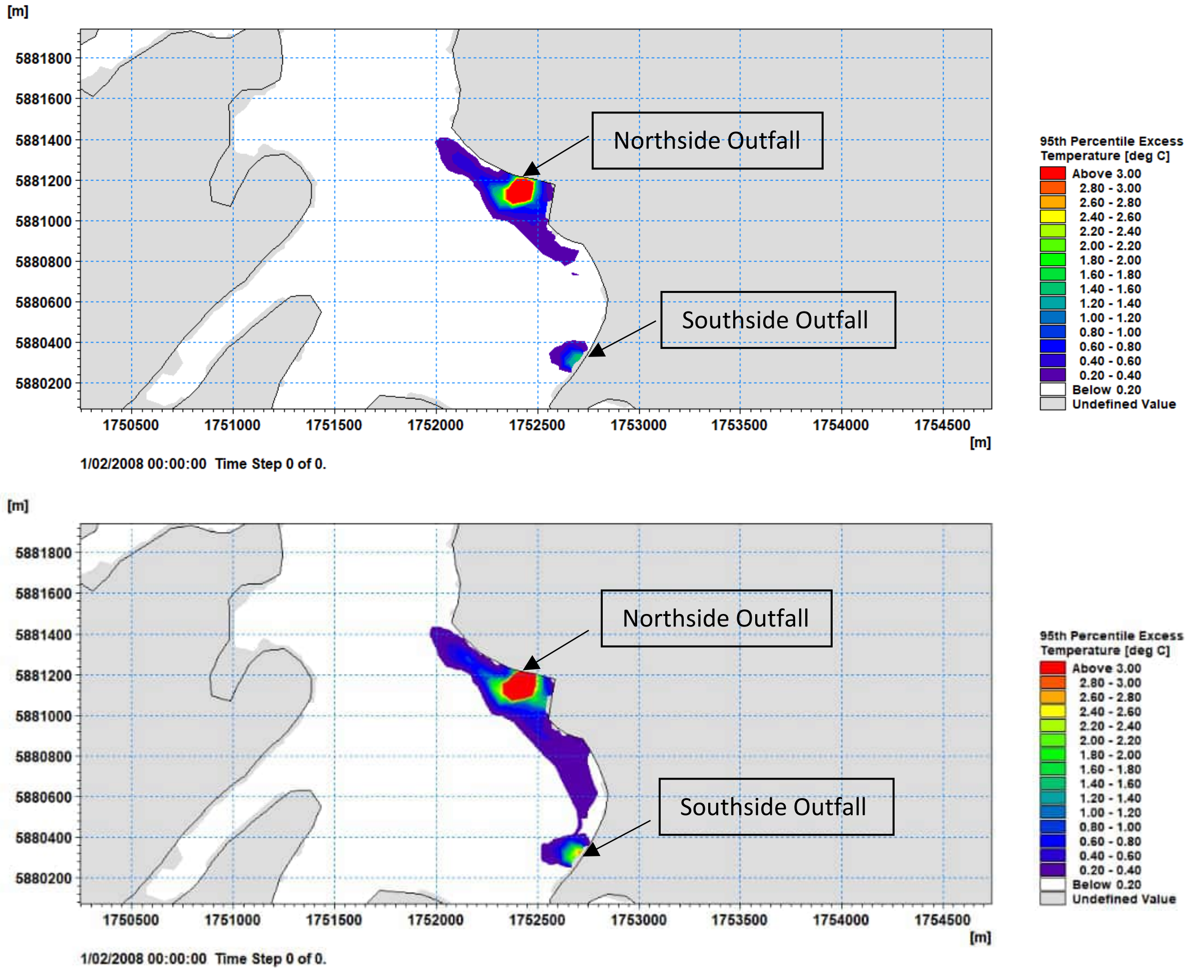


Figure 5.5: 95th percentile excess temperature for the Summer situation (top panel) and Winter situation (bottom panel).

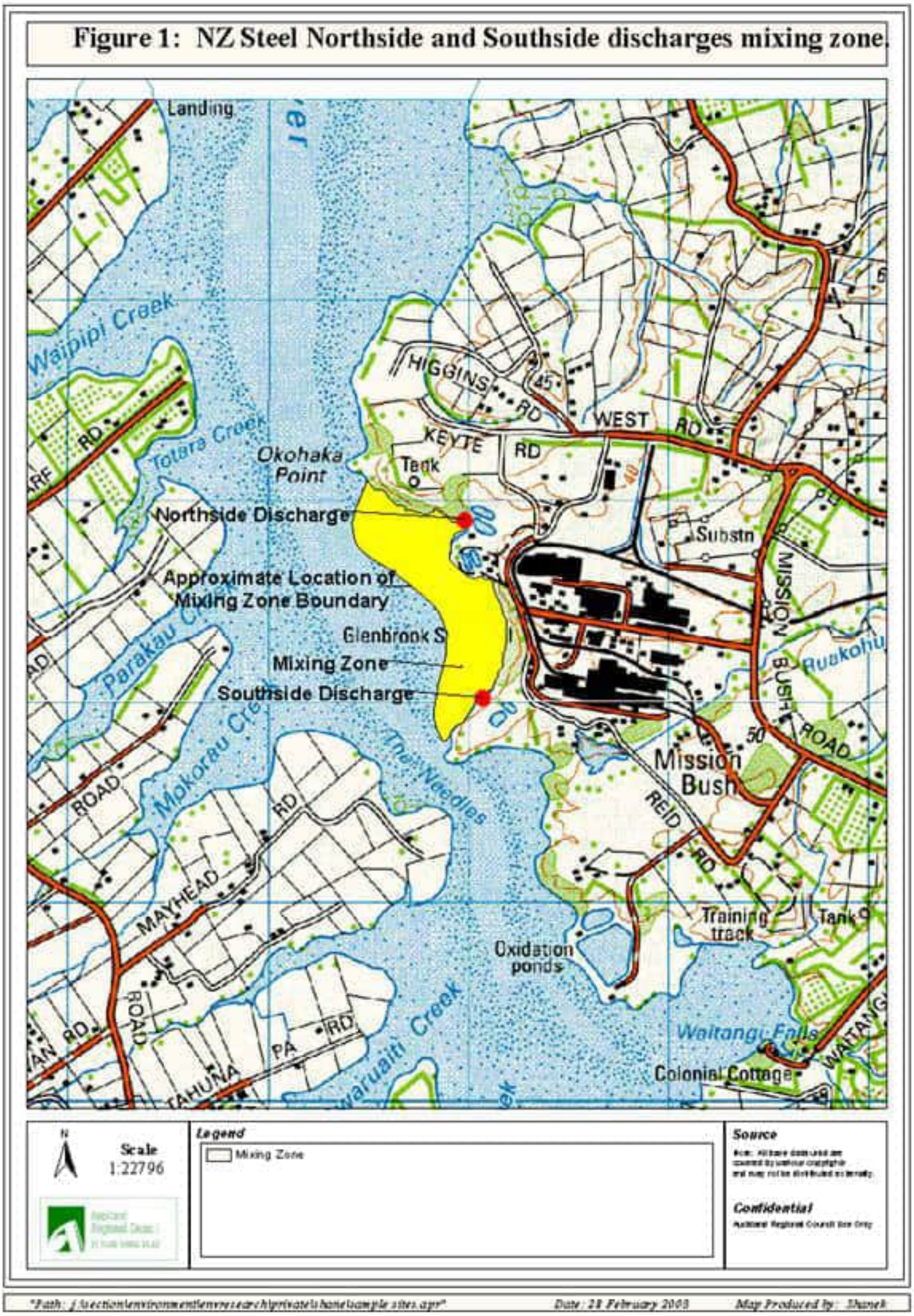


Figure 5.6: Consented mixing zone from the 2003 consents, authorising discharges from the Northside and Southside Outfalls

5.5 Sediment quality

Sediment quality is described in terms of contaminants, muddiness and sedimentation rate to differentiate between the different drivers of sediment quality.

5.5.1 Sediment contaminants

Sediment contaminants at sites monitored by Auckland Council

Sediment quality guidelines are used to assess whether the concentrations of contaminants present in sediments are likely to result in adverse effects on marine biota. They are not pass/ fail numbers, rather they are a trigger for further investigation, usually an assessment of benthic invertebrate community health.

Sediment quality at the Auckland Council monitoring sites at Waiuku Town Basin and Clarks Beach (see Appendix E of the AEE Figure W-ME1) is reported against the Auckland Council Environmental Response Criteria (ERC) “traffic light” system as described in TP168 (ARC 2004) (**Table 5.3**).[28] This reporting system is more conservative than the trigger values provided in the Australian and New Zealand Water Quality Guidelines (ANZWQG 2018) because Auckland Council considers that some of these trigger values are too permissive for the Auckland Region, based on evidence from the Benthic Health Model of ecological effects even within the ERC ‘Green’ band. As such, Auckland Council has modified them (Mills and Allen 2021). This is consistent with the ANZWQG (2018) philosophy of developing trigger values appropriate to local conditions.

The Waiuku Town Basin site was most recently sampled for contaminants in 2017 (Mills and Allen, 2021) and previously in 2012 and 2002 (Mills 2014). Results from these sampling rounds are presented in **Table 5.2**. While there is not yet enough data from this site to assess trends fully over time, the key findings with respect to metals are:

- Zinc: Zinc concentrations have increased slightly since 2002, from a median value of 92 mg/kg in 2002 to a median value of 110 mg/kg in 2017. While these concentrations are still in the ERC-Green band, slowly increasing zinc concentrations in sediments in the Waiuku Estuary is consistent with the modelling carried out by DHI (2022). The model suggests these increases are being driven by various different catchment land uses, including but not limited to the NZ Steel discharges. This is discussed further in Section C1.2; and
- Copper and lead: Copper and lead concentrations appear to be stable. While elevated compared to background concentrations, Copper and lead concentrations are low and approximately half the ERC Green/Orange threshold values. It is possible that sediment muddiness has also increased between 2002 and 2017 from a value of 90.7% to 95%.

The Clarks Beach (CB) ecology site (see Appendix E of the AEE W-ME1) was most recently sampled for contaminants in 2002. All metal concentrations were very low at this site and well within the ERC Green band (**Table 5.2**). This is expected as the site is further away from potential contaminant sources and subject to considerable additional mixing with cleaner waters of the wider Manukau Harbour. Note this site is outside the ZOI for the Proposal but is included for context.

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[28] NZ Steel Consent Limits are also based on the Auckland Council ERC system as described further in Bioresearches (2022).

Table 5.2: Total recoverable metal concentrations in the < 500 µm sediment fraction at Waiuku estuary and Clarks Beach Auckland Council monitoring sites as measured against ERC criteria (Cu, Pb and Zn) in Table 5.3

Site	Year	% Mud (<63 µm)	Cu	Pb	Zn
Waiuku	2017	95.0	8.8	16.3	110.2
Waiuku	2012	92.0	10.7	16.1	99.0
Waiuku	2002	90.7	9.3	17.0	92.0
Clarks Beach	2002	4.3	2.0	3.2	26.4

Table 5.3: Auckland Council Environmental Response Criteria (ERC) and the sediment quality guidelines on which they are based

	Auckland Council Environmental Response Criteria (ERC)			ANZWQG (2018)		Long et al. 1995		MacDonald et al. 1996	
Metals (mg/kg)	Green	Amber (TEL)	Red (ERL)	DGV	DGV-High	ERL	ERM	TEL	PEL
Cd	<0.7	0.7 - 1.2	>1.2	1.5	10	1.2	9.6	0.68	4.21
Cr	<52	52 - 80	>80	80	370	81	370	52.3	160
Cu	<19	19-34	>34	65	270	34	270	18.7	108
Pb	<30	30-50	>50	50	220	46.7	218	30.2	112
Zn	<124	124-150	>150	200	410	150	410	124	271

Sediment contaminants at sites monitored by NZ Steel

As set out in Bioresearches (2022), NZ Steel has been monitoring contaminants in sediments (cadmium, chromium, copper, lead and zinc) at sites Northside A (NA), Northside B (NB), Southside C (SC) approximately every two years in August since 2003 (See Appendix E of the AEE Figure W-ME1, **Figure 5.7**). A control site was added near the mouth of Taihiki Inlet in 2021 (referred to as the Taihiki Control site (CD).

Northside A and Northside B are located approximately 160 m and 325 m respectively from the Northside Outfall and Southside C is located approximately 160 m southwest from the Southside Outfall. Northside A and Southside C are located in settling zones, and Northside B is an outer zone environment. Based on the modelled mixing extent and zone of reasonable mixing identified in the DHI (2022) report and discussed in Section 7.2, site Northside A lies within the zone of reasonable mixing while site Northside B is on the fringe of the zone of reasonable mixing and site Southside C is just outside the modelled mixing extent.

Contaminants in sediments have been monitored at three sites in the CMA at the mouth of the Lower North Stream (MZ, SZ and OZ) in 1997, 2008 and in 2020 (**Figure 5.7**).

Contaminants in sediments were also monitored at two sites at Ruakohua Spillway (RS and RO)[29] and Kahawai Stream (KS) sites in May 2020. See Appendix E of the AEE M-ME1 for all site locations.

Full results are presented in Bioresearches (2022) and are summarised for the August 2020 and September 2021 sampling rounds in **Figure 5.8** and in the text below.

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[29] Note that the Ruakohua Dam Spillway already has a consent to discharge to the CMA and so sediment sampling is not technically required at the two Ruakohua sediment sampling sites. However, the Ruakohua sediment sites will continue to be sampled in the short term (for sediment grain size and contaminants only) to provide further data to validate the DHI modelling and assist with the implementation of the Coastal Bird Management Plan (see sections 6.10 and 8.3).

Important points to note from the Bioresearches report are:

2021 status

- The Northside Outfall site Northside A had zinc concentrations in the mud fraction in the ERC 'Green' band. However, the total recoverable zinc concentration was in the ERC 'Red' band. This therefore triggered a benthic community health assessment at the site, which was also extended to the Taihiki Control site (CD) for comparison.
- Total recoverable and weak acid extractable concentrations of cadmium, chromium, copper, lead and zinc were all in the ERC 'Green' band at sites Northside B, Southside C and Control D. Except for zinc, Northside A also recorded concentrations in the ERC 'Green' band for the above contaminants.

Trends over time

Over time, the total recoverable concentrations of cadmium, chromium, copper and lead have remained similar at the three outfall sites between 2003 and 2020, although concentrations of these metals at site Northside A may have followed a similar pattern to zinc as described below.

At site Northside A, zinc concentrations in the total recoverable fraction have been in the ERC 'Red' band in the last four sampling rounds (August 2019, March 2020, August 2020 and September 2021) and were also ERC 'Red' between 2003 and 2011. In 2013, 2014 and 2015 they were ERC 'Orange' and in 2017 they were ERC 'Green' (**Figure 5.7**). Consequently, the results were trending down from the ERC 'Red' band to the ERC 'Green' band between 2003 and 2017, however, results moved up into the ERC 'Red' band again in the 2019, the two 2020 sampling rounds, and September 2021. However, we note that the ERC 'Orange' band for zinc is quite narrow, so a relatively small change can result in either dropping into the ERC 'Green' band or rising into the ERC 'Red' band.

Results for the weak acid extractable fraction for sediments < 63 µm have always fallen in the ERC 'Green' band (**Figure 5.7**). This analysis approach is used to try to give an indication of the bioavailability of contaminants in sediment. However, analytical variability can be higher than that for the total recoverable fraction. In addition, the relationship between the analysis types and benthic ecological health has been shown to be stronger for the total recoverable fraction (Mills & Allen 2021, Drylie 2021)

Note that ERC 'Orange' or 'Red' results trigger a benthic community health assessment under the existing consent conditions. Benthic community health assessments were carried out at site NA in 2009, 2011, 2013, 2014, 2015, 2019, March 2020, August 2020 and August 2021. This was also carried out at site NB in 2009 as the site was ERC 'Orange'. In addition, primarily to provide further context for the NA site results, this assessment was also carried out in 2014, March 2020 and August 2020, when the site was ERC 'Green'. The benthic ecological health assessments are discussed further in Section 5.6., In summary, benthic ecological health at both sites is highly degraded.

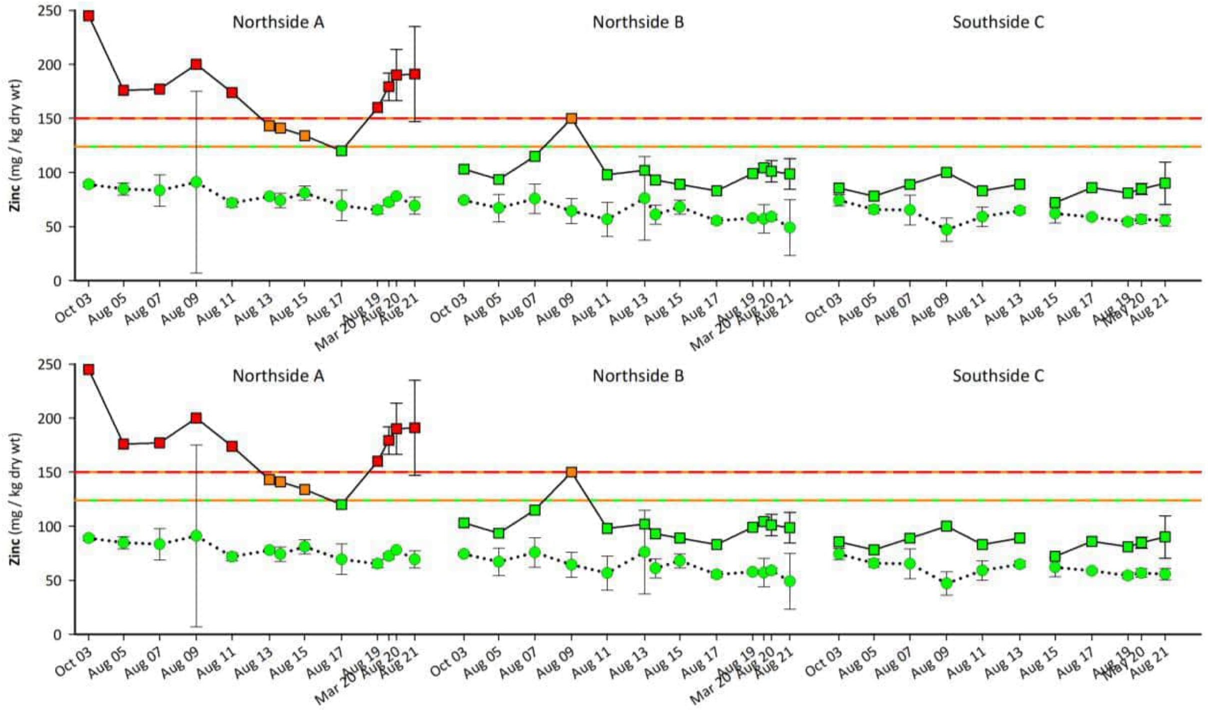

*Figure 5.7: Concentration of Zinc in Sediments over time at Northside A, Northside B and Southside C sites (○ Extractable, □ Total Recoverable) (mean ± 95% confidence intervals (*I*)) The orange and red hashed line indicates the ERC 'Orange' to 'Red' transition and the green and orange hashed line the ERC 'Green' to 'Orange' threshold (figure taken from Bioresearches 2022).*

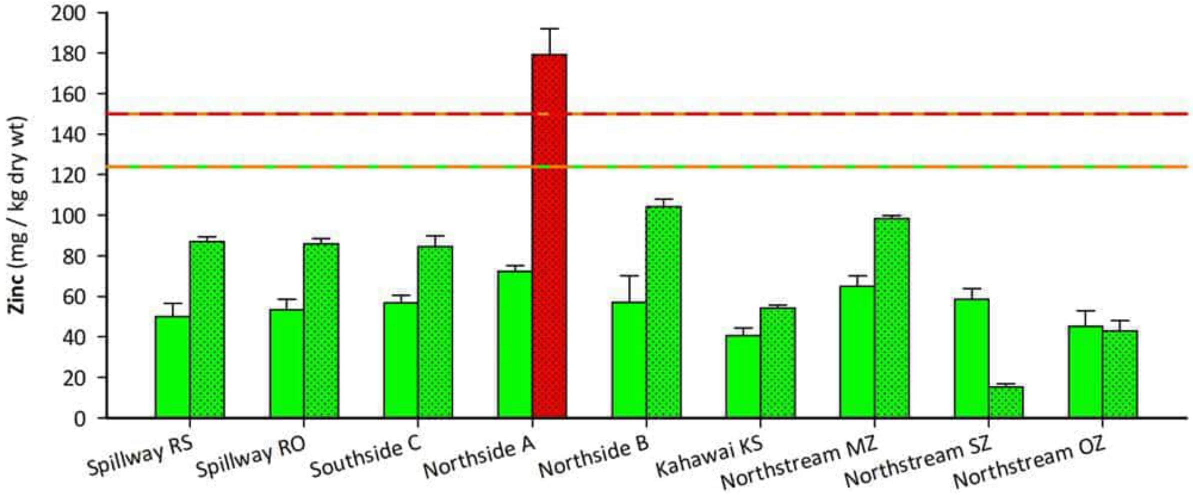

*Figure 5.8: Dry Weight Concentrations of Zinc in Sediments (🟩 Extractable, ░ Total Recoverable) (mean ± 95% confidence intervals (*I*)) for all sites in 2020. The orange and red hashed line indicates the ERC 'Orange' to 'Red' transition and the green and orange hashed line the ERC 'Green' to 'Orange' threshold (figure taken from Bioresearches 2022).*

At the other sites the only trend of note is a possible increase in total recoverable zinc, chromium and copper at the North Stream mangrove zone (MZ) site, and zinc at the OZ site, between 1997 and 2020. While the concentrations were still classified as 'Green', the additional monitoring proposed for the North Stream Catchment in the ITA Report (Appendix G of the AEE) will help to understand whether any of the ITA discharges are contributing to this possible trend (see monitoring recommendation in Section 8.5).

The effect of current and potential future sediment contaminant concentrations over the 35 year consent term is discussed in the ecological effects assessment in Section 6.6.

Summary of current habitat value categories for sediment contaminants:

Table 5.4: Based on the results described above, and with reference to the categories in Appendix A Table 2, existing sediment quality habitat value categories for contaminants can be considered as follows:

Site/Area	Habitat Value Category
Inner Waiuku Estuary	'Moderate' to 'High'
Northside Outfall to Northside A site area	'Low' improving to 'Moderate' towards the Northside B site and the channel
Southside Outfall, North Stream and Kahawai Stream settling zone areas	'Moderate' increasing to 'High' in the outer zone areas[30] towards the channel;
Wider ZOI	'High'
Manukau Harbour directly outside the entrance to the Waiuku Estuary (but note the Manukau harbour is outside the ZOI of the discharges)	'Very High'

Overall, habitat value categories for sediment contaminants within the ZOI where data exists range from **'Low'** to **'High'**.

5.5.2 Sediment muddiness

Sediment muddiness (based on the proportion of a sediment sample made up of silt and clay particles less than 63 µm in diameter) is used to assess whether the sediment grain size profile at a site is likely to result in adverse environmental effects on benthic ecology. The Benthic Health Model for muddiness (BHMmud) is used by Auckland Council to assess the likely influence of sediment muddiness on benthic ecological health (Greenfield *et al.* 2019). Benthic health results are discussed further in the Benthic Ecology section (Section 5.6). As can be seen from **Table 5.5** and **Table 5.6**, sediment muddiness at NZ Steel monitoring sites follows a similar pattern to sediment zinc concentrations, although site North Stream (SZ) has low muddiness levels compared to its zinc concentrations.

In 2020, the sediments from both sites in the embayment near the Ruakohua Spillway (RO and RS) contained high proportions of silt and clay (mud) sized particles. The sediments at the three outfall (Northside A, Northside B and Southside C) sites had lower proportions of silt and clay sized particles than the spillway sites. Sediment at the Kahawai Stream (KS) settling zone site (i.e. the area closest to the stream mouth where most sediment discharged from the stream is likely to settle out) contained a low to moderate proportion of silt and clay. At the Lower North Stream sites, the mangrove zone site (MZ) contained high proportions of silt and clay sized particles, the settling zone site (SZ) was dominated by fine sand, and the outer zone site (OZ) (furthest from the stream mouth) was largely sandy with fine and very fine sand.

Looking at overall trends of sediment grain size between 2003 and 2021, all sites now have a sediment classification of "gravelly sandy Mud, (g)sM[31]". Northside A has had an increase in the proportion of sand over time and has been (g)sM since 2019. Northside B had a 10-year period between 2009 and 2019 of "sandy Mud" with the exception of 2015 which had a larger proportion

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[30] Outer Zones (OZ) are estuarine areas beyond the Settling Zones (SZ) i.e. the area beyond where the majority of the sediment and associated contaminants discharged from the catchment settle onto the seabed.

[31] Further information on grain size descriptions is provided in Bioresearches (2021) section 1.2.1.3

of granules in the sample (as did Northside A and Northside B). Southside C has remained mostly (g)sM. The new Taihiki Control site (CD) is also classed as (g)sM.

Sediment muddiness levels at the Auckland Council monitoring sites at Clarks Beach measured in 2018 was 3.2% (Greenfield *et al.* 2019) and at site Waiuku Town in 2017 was 95% (Mills and Allen, 2021). While the muddiness level at Waiuku Town is very high, this is not uncommon in the upper settling zone areas of tidal creeks and estuaries within the Manukau Harbour.

Table 5.5: Sediment grain size at NZ Steel monitoring sites May 2020 (see Appendix E of the AEE Figure W-ME1)

Grain Size		Percentage Dry Weight								
		Ruakohua Spillway		Southside	Northside		Kahawai Stream	North Stream		
(mm)	Class	RS	RO	SC	NA	NB	KS	MZ	SZ	OZ
> 3.35	Gravel									
3.35 – 2.00	Granules	< 0.1	< 0.1	0.9	0.4	< 0.1	5.1	1.1	1.7	1.7
2.00 – 1.00	Very Coarse Sand	< 0.1	< 0.1	2.9	0.6	< 0.1	0.4	0.4	< 0.1	0.8
1.00 – 0.500	Coarse Sand	< 0.1	< 0.1	3.8	0.9	0.2	1.0	0.5	0.2	1.4
0.500 – 0.250	Medium Sand	1.1	0.8	8.1	4.6	0.9	3.9	0.5	2.1	2.9
0.250 – 0.125	Fine Sand	5.1	3.6	23.6	15.5	7.0	28.1	1.9	77.3	44.0
0.125 – 0.063	Very Fine Sand	5.3	4.7	6.1	8.7	10.1	16.2	1.6	9.9	14.0
< 0.063	Silt & Clay	88.4	90.8	54.7	69.3	81.9	45.3	94.0	8.7	35.3
Classification		**(g)sM[32]**	**(g)M**	**(g)sM**	**(g)sM**	**(g)sM**	**(g)mS**	**(g)M**	**(g)S**	**(g)mS**

Table 5.6: Sediment grain size at NZ Steel monitoring sites Northside A and B, Southside C and Taihiki Control, (CD), August/September 2021 (see Appendix E of the AEE Figure W-ME1)

Grain Size		Percentage Dry Weight			
(mm)	Class	Northside A (NA)	Northside B (NB)	Southside C (SC)	Taihiki Control D (CD)
> 3.35	Gravel	2.6	< 0.1	2.1	< 0.1
3.35 - 2.00	Granules				
2.00 - 1.18	Very Coarse Sand	1.0	< 0.1	3.1	< 0.1
1.18 - 0.600	Coarse Sand	1.1	0.2	4.2	< 0.1
0.600 - 0.300	Medium Sand	4.2	0.9	5.1	0.6
0.300 - 0.150	Fine Sand	15.1	10.6	10.8	4.4
0.150 - 0.063	Very Fine Sand	10.7	9.2	6.7	21.3
< 0.063	Silt & Clay	65.3	79.1	68.1	73.6
Description		**(g)sM**	**(g)sM**	**(g)sM**	**(g)sM**

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[32] Sediment samples are assigned a description based on the principal grain size fraction with modifiers based on the next important grain sizes. These descriptions are given as letter codes (gravel=G, sand=S, mud=M, silt=Z). For example, a sample which consisted of mostly sand with a significant proportion of silt and clay (mud) would be described as muddy sand, and denoted mS. If the sample had a gravel component it would be described as slightly gravelly muddy sand, and denoted (g)mS. See Bioresearches (2022) for further explanation.

Summary of current habitat value categories for sediment muddiness:

Table 5.7: Based on the results described above, and with reference to the categories in Appendix A Table 2, current sediment muddiness habitat value categories in the ZOI can be considered as follows:

Site/Area	**Habitat Value Category**
Lower North Stream	For the mangrove zone area, 'Negligible', increasing to 'High' in the settling zone and outer zone areas closer to the channel
Kahawai Stream settling zone	'Moderate'
Northside A	'Low'
Northside B	'Low'
Southside C	'Moderate'
Taihiki Control (CD)	'Low'
Waiuku Town basin Auckland Council site	'Negligible'
Clarks Beach Auckland Council site (but note this site is outside the ZOI)	'Very High'

Overall, habitat value categories for sediment muddiness within the ZOI where data exists range from **'Negligible'** to **'Moderate'**.

5.5.3 Sedimentation

Sedimentation can be measured as an accumulation rate over time (mm/year). Sedimentation rates for the ZOI have been modelled by DHI (2022), with the current day accumulation rates presented in **Figure 5.9**. We have assessed sedimentation on the basis of the DHI modelling outputs and with reference to the habitat value characteristics for sedimentation in **Appendix A Table 2**.

In summary, sedimentation rates correspond to the habitat value categories in **Appendix A Table 2** in the following way:

- 'Negligible' category in areas with sedimentation rates greater than 10 mm/yr;
- 'Low' category for areas with sedimentation rates between 5 and 10 mm/yr;
- 'Moderate' for areas with sedimentation rates between 2 and 5 mm/yr;
- 'High' for areas with sedimentation rates between 1 and 2 mm/yr; and
- 'Very High' for areas with sedimentation rates less than 1 mm/yr.

Sedimentation rates greater than 2 mm/yr above natural background levels also warrant further consideration of sources and effects as recommended in the ANZWQG (2018) estuary sedimentation guidelines.

Based on the results of the DHI (2022) modelling, sedimentation rates in the ZOI driven by all catchment sources combined can be as high as 75 mm/yr in the upper eastern arm of the Waiuku town basin. The Waiuku town basin sub-estuary receives approximately one third of the total sediment load to the Waiuku Estuary as a whole from its large and predominantly rural land use catchments. Rates can be greater than 5 mm/yr in the settling zones of several of the western estuary arms, which also have larger rural catchments. Across quite a wide area of the ZOI in areas closer to the channel, or away from major estuary arms, sedimentation rates can be 2 mm/yr or greater.

Sedimentation rates driven by the Northside Outfall discharge alone are around 6.5 mm/yr immediately adjacent to the Northside Outfall, reducing to a < 2 mm/yr closer to the channel (that is, at the margin of the NZ Steel consented mixing zone). Sedimentation rates driven solely by the discharges from the Southside Outfall, Lower North Stream and Kahawai Stream are estimated to be < 2 mm/yr in the settling zone areas around their outflows to the CMA. Further information on sedimentation rates driven by the proposed discharges and other catchment discharges are discussed in Section C1.2 and the DHI (2022) report.

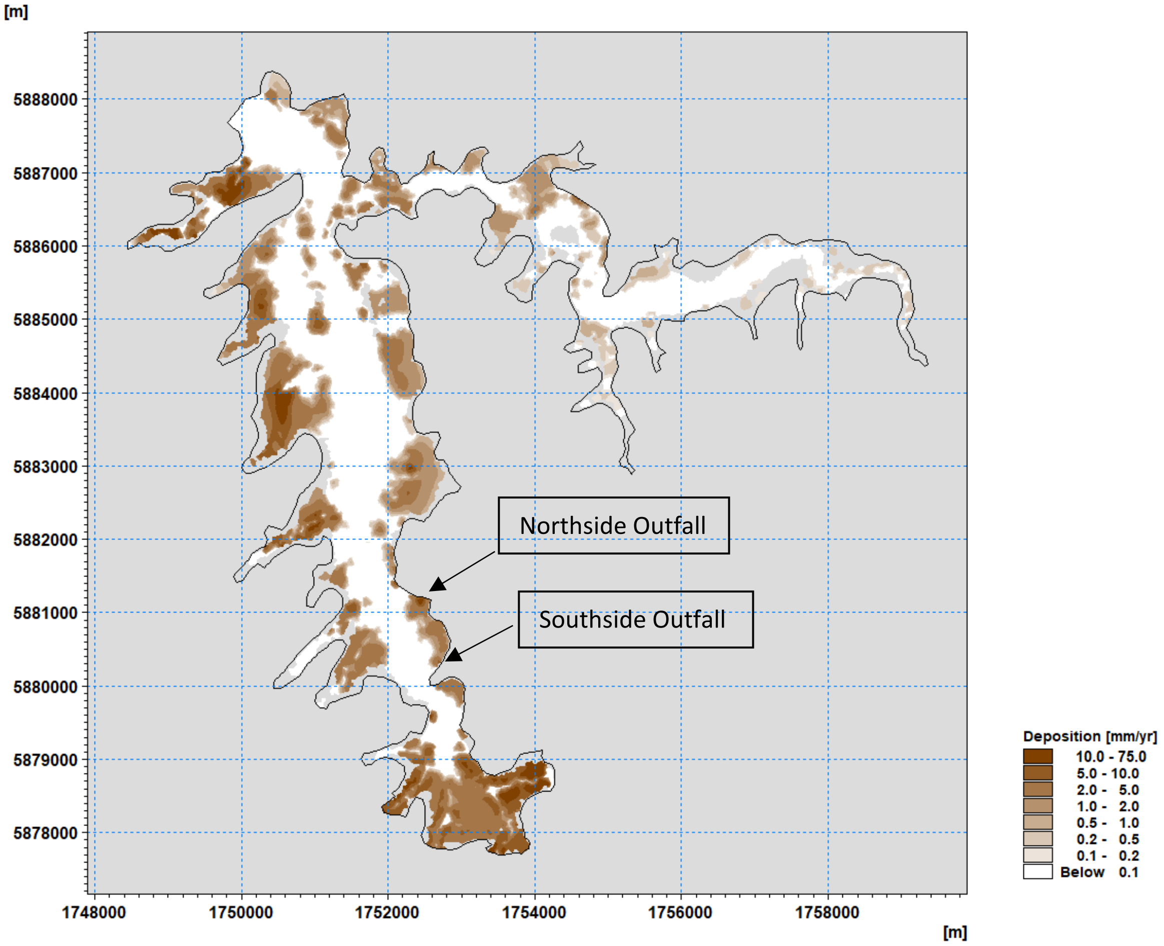

Figure 5.9: Predicted sediment accumulation rate (mm/yr) from all catchment sources based on the 2008 'average' year annual sediment transport model simulation (Taken from DHI (2022) Figure 7-2).

Summary of current habitat value categories for sedimentation:

Table 5.8: Based on the results described above, and with reference to the categories in Appendix A Table 2, current sedimentation rate habitat value categories can be considered as follows:

Site/Area	Habitat Value Category
Northside Outfall modelled mixing extent	'Negligible', improving to 'Low' towards the low tide channel;
Southside Outfall modelled mixing extent, Lower North Stream and Kahawai Stream outflow to the CMA	'Moderate'

Site/Area	Habitat Value Category
Wider ZOI	'Negligible' to 'High' depending on proximity to stream mouths and settling zones.

Overall, habitat value categories for sedimentation in the ZOI where data exists range from **'Negligible'** to '**High**'.

5.6 Benthic ecology

Benthic biological communities in the Waiuku Estuary are dominated by mud snails (*Amphibola crenata)* within mangrove areas, large numbers of cockles (*Austrovenus stutchburyi*) can be found in sandy mid-tide habitats, and abundant crabs and shrimps lower on the shoreline. Pacific oysters (*Crassostrea gigas*) are well established with numerous localised clumps present along the coastline. In this sense, the Waiuku Estuary is typical of many muddy tidal estuaries in the Auckland region.

Auckland Council benthic ecology data

The nearest benthic ecology sampling and analysis, using Auckland Council monitoring protocols, was undertaken at the Waiuku Town Basin site in 2017 (along with the sediment contaminant sampling covered in Section 5.5.1) and at the Clarks Beach site in 2017.

Auckland Council uses the Benthic Health Model (BHM) to score the benthic health of estuarine soft sediment environments as described in Greenfield *et al.* (2019). This approach is also applied in Bioresearches (2022) to NZ Steel's monitoring data.

Auckland Council uses a combination of three indices to come to an overall health score for a particular site. These three indices are the BHMmetals, BHMmud and Traits Based Index (TBI). Scores for the BHMmetals and BHMmud range from 1 (most healthy) to 5 (least healthy).

Values for the Traits Based Index (TBI) range from 0 – 1. TBI scores < 0.3 indicate low levels of functional redundancy[33] and highly degraded sites (TBI group 3). TBI scores of 0.3-0.4 indicate intermediate conditions (TBI group 2). TBI Scores > 0.4 indicate high levels of functional redundancy (TBI group 1), indicative of healthy areas (Hewitt *et al.* 2012).

The three indices are then combined to give an overall score of "extremely good"; "good"; "moderate"; "poor" and "unhealthy with low resilience".

The health scores at the Clarks Beach and Waiuku Town Basin monitoring sites were last reported using these indices in 2017 (Greenfield *et al.* 2019) and scores were as follows:

- Waiuku Town Basin – BHMmetals = 4, BHMmud = 5, TBI < 0.3, Overall score of "Unhealthy with low resilience"; and
- Clarks Beach – BHMmetals = 3, BHMmud = 3, TBI > 0.4, Overall score of "moderate" (Note this site is only just in the "moderate" category – it scored "good" in 2017 and 2016).

NZ Steel benthic ecology data

NZ Steel's current consent conditions require an Environmental Management and Monitoring Plan that specifies when benthic health will be monitored. The Plan specifies that benthic health should be assessed at the NZ Steel monitoring sites if sediment contaminant concentrations are in the ERC 'Orange' or 'Red' categories as outlined in Section 5.5.1.

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[33] Higher functional redundancy provides resilience against stressors whereby multiple species across a variety of species groups share similar roles in ecosystem function. This stability can be realized as either enhanced resistance to change, or enhanced ability to recover from disturbance.

NZ Steel has assessed benthic ecological health within the consented mixing zone at site Northside A in 2009, 2011, 2013, 2014, 2015, 2019, twice in 2020 (to support the consent application) and in 2021; and at site Northside B in 2009, 2014, and twice in 2020 (also to support the consent application). The most recent screening of surficial sediment quality in September 2021 showed that site Northside A was the only site to exceed the ERC 'Red' threshold for zinc, triggering the requirement for a benthic community health assessment at site Northside A. The assessment was also carried out at Taihiki Control site in September 2021 (Bioresearches 2022). Whilst neither Northside B results in 2020, or the Taihiki Control site in 2021, triggered the requirement for benthic health assessment, this was carried out anyway to provide additional context for the Northside A results (to support the consent application).

Based on the modelled mixing extent and zone of reasonable mixing identified in the DHI (2022) report and discussed in Section 7.2, site Northside A lies within the zone of reasonable mixing while sites Northside B and Southside C lie at the fringes of the modelled mixing extent. The Taihiki Control site is well outside the modelled mixing extent and lies in the northern part of the ZOI (see Appendix E of the AEE map W-ME1 for locations).

Up until 2020, only the underlying information needed to run the BHMmetals index was available to Bioresearches and hence this was the only index assessed.

To add further information to the programme, in 2021 Bioresearches obtained additional BHM indices from Auckland Council which were then run over all data collected since 2009. This included the BHMmetals, BHMmud and the Traits-Based Index (TBI) to make the analysis consistent with the assessments of benthic community health carried out by Auckland Council.

To carry out this analysis, Bioresearches (2022) applied a Canonical Analysis of Principal (CAP) coordinates[34] to the NZ Steel data for all years assessed. The results of the CAP analysis were used to rate the NZ Steel data for benthic health using a 1 to 5 scale provided in **Table 5.9**.

Table 5.9 Boundaries for ranking benthic health CAP metals and CAP mud (from Drylie 2021)

	Health group	CAP Metals		CAP Mud	
		Min	Max	Min	Max
healthy	1 - Extremely good		-0.164		-0.12
	2 - Good	-0.164	-0.0667	-0.12	-0.05
↓	3 - Moderate	-0.0667	0.0234	-0.05	0.02
	4 - Poor	0.0234	0.1	0.02	0.1
polluted	5 - Unhealthy	0.1		0.1	

BHMmetals and BHMmud scores for Northside A and B were 4's for both indices for all years from 2009 to 2021 (except for 3's for metals at both sites in 2014), which is indicative of 'poor' ecological health. The Taihiki Control site scored a 3 for BHMmetals and a 4 for BHMmud, indicating 'moderate' ecological health for metals and 'poor' ecological health for mud.

The Trait-Based Index (TBI) was also calculated in 2021. Benthic ecosystem function is directly affected by benthic biodiversity, and to help understand this macrofauna are categorised according to characteristics (or traits) that likely influence function e.g., feeding mode, mobility, size, living habit and so on. The TBI was developed based on the richness (count) of species exhibiting seven particular traits which are important for benthic ecosystem function, which are:

- Living in the top 2 cm of sediment
- Having an erect structure or tube

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[34] Canonical Analysis of Principal coordinates (CAP) is a multivariate statistical analysis technique for ecological data which takes into account correlation structure among variables in the response data cloud. It is used to uncover important patterns in the multivariate data by reference to relevant hypotheses.

- Moving sediment around within the top 2 cm of the sediment column
- Being sedentary or only moving within a fixed tube
- Being a suspension feeder
- Being of medium size
- Being worm shaped

Index values range from 0-1, with TBI scores < 0.3 indicating low levels of functional redundancy[35] and highly degraded sites, scores of 0.3-0.4 indicate intermediate conditions, and scores > 0.4 indicating high levels of functional redundancy. An increase in TBI score represents an improvement in functional resilience and hence health. The detailed methodology is described in Hewitt *et al.* 2012.

Calculations for all samples taken since August 2009 for Northside A and Northside B resulted in "low" levels of functional redundancy (Drylie, 2021), indicating the sites were highly degraded. Results at Northside A have fluctuated throughout time between 0.12 and 0.24, but have generally been lower in more recent years. Scores for Northside B were calculated for 2009, 2014, 2020 and 2021 and have decreased over time from 0.20 in 2009 to 0.11 in 2020. 2021 was the first year that the Taihiki Control site was assessed, and while the result is still considered low, a 0.24 score gives it the highest score for all sites.

This low functional redundancy is consistent with low scores for other sheltered tidal creeks in the Auckland Council monitoring programme elsewhere in the Manukau Harbour, including at the Council Waiuku Town Basin site further up the estuary (Drylie, 2021).

Combined health scores for all three indices (BHMmetals, BHMmud and TBI) were calculated over time for both Northside A and Northside B where 1 = poor health, 0.8 = marginal, 0.6 = fair, 0.4 = good and 0.2 = excellent (Drylie, 2021). With the exception of 2014, where the combined health score was 'marginal', all years for Northside A and Northside B scored as 'unhealthy with low resilience'. The Taihiki Control site surveyed in 2021 was scored as 'marginal' (Bioresearches, 2022).

Also of note is that the health of the benthic community at the Northside A and B and Taihiki Control sites is worse than that predicted by the metal concentrations in the sediments at those sites. This indicates that stressors other than metals may be influencing the health of the benthic community. The poor health scores for BHMmud, the high levels of muddiness (see Section 5.5.2), and the elevated sedimentation rates of 5 to 10 mm per year (Section 5.5.3), indicate that suspended and deposited fine sediment are likely to be the other stressors influencing poor benthic health. This assertion is supported by the results from the Auckland Council monitoring site at Waiuku Town Basin where the BHMmud score of 5 is worse than the BHMmetals score of 4 (and where sediment muddiness and contaminant concentrations are similar to the Northside B site).

Based on DHI (2022) modelling, only 1.3% of the total annual average sediment load, and 6.4% of the very fine sediment load to the Waiuku Estuary is coming from the Northside and Southside Outfalls, the Lower North Stream, Ruakohua Spillway and Kahawai streams combined. As such, it can be assumed that the elevated sediment muddiness and sedimentation rates within the ZOI are primarily being driven by sediment sources other than the proposed discharges.

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[35] Functional redundancy implies that any species loss is compensated by other species contributing similarly to that ecological function

Summary of current habitat value categories for benthic ecology:

Table 5.10: Based on the results described above, and with reference to the categories in Appendix A Table 2, existing benthic ecology habitat value categories can be considered as follows:

Site/Area	**Habitat value category**
The area around Northside A and the modelled mixing extent	'Negligible'
Northside B	'Negligible'
Taihiki Control	'Low'
Waiuku Town basin Auckland Council site	'Negligible'
Clarks Beach Auckland Council site	'Moderate' (but note this site is outside the ZOI of the Proposal);
Some areas in the ZOI where effects from stressors are expected to be low (Based on the DHI (2022) modelling of contaminant concentrations and sedimentation rates)	'Moderate'

Overall, habitat value categories for benthic ecology in the ZOI where data exists range from **'Negligible'** to '**Moderate**'.

5.7 Shellfish

NZ Steel Monitoring

As part of the existing discharge consents for the Northside and Southside Outfalls, every year since 1985 NZ Steel has been monitoring the density of oyster beds, the condition of oyster flesh and the concentrations of copper and zinc in oyster flesh (Bioresearches, 2022) (Appendix E of the AEE Figure W-ME1). There are five monitoring sites around the Northside and Southside Outfalls, and a control site in lower Taihiki Estuary (TC) (Appendix E of the AEE Figure W-ME1).

The five sites sampled by the outfalls are:

- Site N6a approximately 50 m from Northside Outfall;
- Site N5 approximately 350 m south of Northside Outfall;
- Site N10 approximately 500 m north of Northside Outfall;
- Site S3a approximately 20 m from Southside Outfall; and
- Site S5a approximately 350 m south of Southside Outfall.

Sites N6a, N5, and S3a are within the existing consented mixing zone of the Northside and Southside Outfalls. Sites N10 and S5a are on the consented mixing zone boundary.

Full results of the monitoring are reported in Bioresearches (2022) and a brief summary is provided here.

Oyster bed density and shell length

Prior to 2010, oyster bed densities at the monitoring sites declined to levels where sampling was no longer feasible at N6, S3, S5 and the Taihiki Control (TC) sites. The declining number of oysters present was attributed to proliferation of mangroves at the Southside sites (S3 and S5) and sedimentation in the Taihiki Control site, and no specific reason was given in Bioresearches (2022) for N6. Due to these declines, these four sites were moved to alternate sites in August 2010 (TC, N6a, S3a and S5a, Bioresearches, 2022). A widespread oyster herpes virus outbreak was recorded in New Zealand between 2010 and 2011 and the low numbers during these sampling years could be attributed to this (Bioresearches, 2022).

The most recent oyster bed density survey in September 2021, showed relatively similar results to those recorded in August 2020, with small decreases at N5, N10 and S3a, a continued decrease at S5a and small to moderate increases at Taihiki Control and N6a (Bioresearches, 2022).

There has been no overall long-term trend of increasing or decreasing oyster length across the sites. The various changes in length that have been recorded are considered to be the result of normal ageing and recruitment of oyster populations, with some effects from habitat change as a result of sedimentation and mangrove proliferation (Bioresearches, 2022).

Oyster Condition Indices (CI)[36]

Oyster flesh at the NZ Steel discharge monitoring sites varies in condition, with no significant change within each station between 2020 and 2021 sampling. The Taihiki Control site recorded the poorest condition and S5a the best. Site S5a had a statistically significantly higher CI than the other consented mixing zone sites and the Taihiki Control site, likely as it is close to the channel and subject to higher flushing rates. While the Taihiki Control site has a similar range to the discharge sites, it appears to have worsened slightly since relocating to the new site in 2010. Oyster flesh condition appears to improve with distance from the Northside Outfall (N6a to N10, and to a lesser degree, N6a to N5), and also slightly for the Southside Outfall (S3a to S5a). Oyster flesh condition is generally variable and without clear consistent trends over time at all NZ Steel discharge sites. However, where there are patterns in oyster condition indices these have generally been decreases over time, with the exception of S5a, which showed an improvement in oyster condition index after the site was moved in 2010.

Oyster condition is assessed differently in the NZ Steel Programme to the former Auckland Council Shellfish Contaminant Monitoring Programme (SCMP) (refer to **Figure 5.10**), so direct comparisons cannot be made between programmes for oyster condition.

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[36] A calculation of how well an oyster is utilising the internal shell volume available for tissue growth

Figure 5.10: Map extract from Mills (2014); location of former Regional Council regional shellfish (oyster) contaminant monitoring sites in the Manukau Harbour. Tan sites were monitored for the full programme duration of 1987 – 2013, grey sites from 1987-1991, Waiuku Yacht Club once in 1988, and Mill Bay from 2009 to 2013

Metals in oyster flesh

The NZ Steel discharges are having a clear effect on zinc and copper wet weight concentrations in oyster flesh (**Figure 5.11**). The greatest effect is for zinc at site N6a, closest to the Northside Outfall. Zinc was also elevated at sites N5 and S3a (Bioresearches, 2022). The effects are localised within the NZ Steel consented mixing zone, however zinc concentrations at site N10 (which is 500 m from the Northside Outfall) are still approximately 50% higher than those in the Taihiki Control site oysters. Zinc concentrations at the site closest to the Northside Outfall (N6a) are statistically higher than all other stations and are higher than any sites previously monitored by Auckland Council in the SCMP (**Figure 5.10**). The remaining sites' (including the Taihiki Control site) zinc concentrations are intermediate between the site with the highest zinc concentrations in the SCMP (Granny's Bay) and that with the lowest (Mill Bay).

The effect of NZ Steel discharges on copper concentrations are not as notable as those for zinc. Copper concentrations were the highest at N6a, while the Taihiki Control site had the lowest concentrations. Copper concentrations are higher at NZ Steel sites than the Auckland Council SCMP median concentration for Manukau Harbour 'tan' plus Mill Bay sites (**Figure 5.10**) but were much lower than the highest concentrations at Granny's Bay (Mills, 2014).

With regard to long term trends, dry weight[37] zinc and copper concentrations have generally decreased (i.e., improved) over time at sites N6a (for copper only), N5, S5a and S3a, (particularly since the mid-1990s) and remained fairly constant at sites N6a (for zinc only), N10, and the Taihiki Control. Since the mid to late 2000's, all consented mixing zone sites, have shown stable or declining

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[37] Dry weight data are generally considered more suitable for assessing trends than wet weight data as they are less susceptible to fluctuations in wet weight condition and moisture content.

dry weight zinc concentration trends, and concentrations are becoming more similar to those recorded at the Taihiki Control site (Bioresearches, 2022). This is consistent with the discharge treatment systems having been progressively improved over time since 1985, with a marked improvement in discharge quality noted in the last two years (Appendix G of the AEE). However, Dry weight zinc concentration appeared to have increased in oyster flesh between 2019 and 2020 at the Northside Outfall monitoring sites, particularly N6a, which is consistent with increases observed in zinc in sediments at the Northside Outfall monitoring sites (Section 5.5.1). That said, in 2021, while zinc concentrations at site N5 remained similar, the concentrations at N6a and N10 decreased from those in 2020.

A review of zinc concentrations in Pacific Oysters that could be used as environmental effect criteria in NZ Steels' Environmental Monitoring Program was undertaken in 1988 (Stanley Associates, 1988). As a result, agreement was reached with the Auckland Regional Water Board on two criteria for defining unacceptable levels for the zinc concentrations in Pacific Oysters (Bioresearches, 1998). Later reviews, undertaken as part of NZ Steel's process to replace its expiring Existing Permits (which was approved in 2003), have supported the continuation of the use of these criteria. The existing resource consent Permit (21575) specifies the following criteria, which are shown in the corresponding colours on **Figure 5.11**.

- **Outside the existing consented mixing zone,** the maximum concentration of zinc in Pacific oysters should not exceed the Response Level (500 mg/kg zinc, wet weight).; and
- **Within the existing consented mixing zone**, the maximum concentration of zinc in Pacific oysters should not exceed the Alert Level (1,000 mg/kg zinc, wet weight).

The 500 mg/kg wet weight criterion applied outside the consented mixing zone was based on worldwide data on zinc concentrations in uncontaminated populations of oysters. The 1000 mg/kg wet weight criterion applied within the consented mixing zone was derived from a consideration of emetic response data for zinc and is set at the lower threshold of the emetic dose (dose which causes vomiting) for a consumer of 200 grams of oyster flesh.[38]

Average concentration of zinc for each annual survey since 2000 show that none of the sites within or outside the consented mixing zone have reached the Alert Level concentration of 1,000 mg/kg zinc wet weight (as indicated by solid red reference line in **Figure 5.11**), during the period of the existing resource consent Permit 21575.

Sites S5a and N10 are located either on the consented mixing zone boundary or just inside, and the Taihiki Control site is located outside the consented mixing zone, none of the wet weight zinc concentration at these sites have reached the Response Level concentration of 500 mg/kg zinc wet weight, during the period of the existing Resource Consent 21575 (as indicated by dashed orange reference lines in **Figure 5.11**).

Potential for shellfish harvest and consumption

While oysters in the vicinity of the Steel Mill discharges could be harvested recreationally for consumption, it is considered this would occur infrequently due to access constraints, the obvious presence of the Steel Mill, and more attractive harvesting locations elsewhere in the estuary (T+T 2024e). Cockles have only ever been found in very low numbers by Bioresearches (2022) sampling and any recreational harvest in the vicinity of the Steel Mill discharges is considered highly unlikely.

While zinc concentrations in oysters at the NZ Steel monitoring sites are elevated above "Generally Expected Levels" (GELs) according to Food Safety Australia and New Zealand (FSANZ) guidelines, there are no maximum concentrations for zinc or copper in oyster flesh for consumption as they are

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[38] Wet weight data are used for human health risk assessment as they are relevant to the state in which the oysters would be consumed.

both essential elements for humans. According to FSANZ, GELs for shellfish zinc have a median of 130 mg/kg, and a 90th percentile of 290 mg/kg. All NZ Steel monitoring sites, including the Taihiki Control site, have zinc concentrations above the median GEL. However, only site N6a is consistently above the 90th percentile value (approximately double). Auckland Council shellfish contaminant monitoring programme sites at Granny's Bay and Pahurehure also have concentrations above the 90th percentile GEL and Hingaia, Cornwallis and Mill Bay are above the median concentration.

The Human Health Risk Assessment carried out by T+T (T+T 2024e) following a request for further information from Auckland Council, concluded that "*Measured (metal*[39]*) concentrations in shellfish and in roof-collected drinking water are below screening level guidelines for safe consumption*".[40] Combined with the low likelihood of shellfish gathering occurring, the consumption of shellfish from the vicinity of the NZ Steel discharges is therefore not considered to pose a risk to human health.

Summary of current habitat value categories for shellfish:

Table 5.11: Based on the results described above, and with reference to the categories in Appendix A Table 2, current habitat value categories for shellfish quality can be considered as follows:

Oyster Sampling Site	**Habitat Value Category**
N6a	Negligible
N5	Low
N10	'Moderate'
S5a	'Moderate'
S3a	'Moderate'
Taihiki Control	'Moderate'

Overall, habitat value categories for shellfish quality in the ZOI where data exists range from **'Negligible'** to '**Moderate**'.

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[39] Aluminium, Arsenic, Cadmium, Chromium, Cobalt, Copper, Lead, Manganese, Mercury, Molybdenum, Nickel, Vanadium and Zinc.

[40] Section 5, Page 22, T+T 2024e

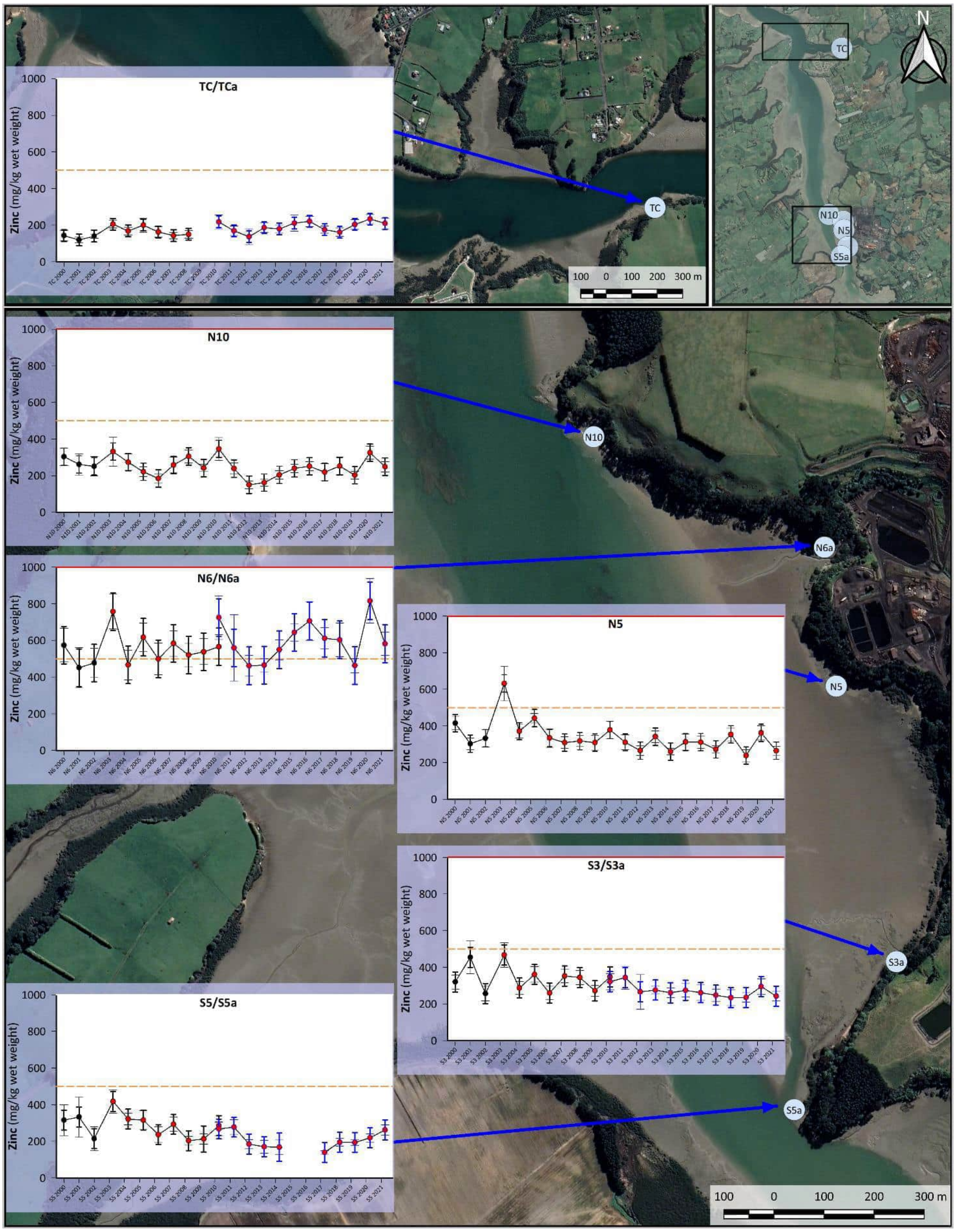

Figure 5.11: Zinc Concentrations in Oysters (wet weight) - Annual Results 2000 - 2021.
(mean ± 95% confidence intervals (thin bar) and HSI (α=0.05) (bold bar))
(● = May samples, ● = August samples from 2003, ● = August samples from relocated site). Figure taken from Bioresearches (2022). See Appendix E of the AEE Figure W-ME1 for site locations.

5.8 Fish

The Manukau Harbour, including the Waiuku Estuary arm, provides important habitat for fish species, including shelter and nursery grounds for bony fish, sharks and rays (Morrison *et al.* 2014).

Surveys of fish use of intertidal to low tide sand and mudflats conducted by NIWA and summarised in Kelly (2009) indicated that southern side-branches of the Manukau Harbour tended to have more fish species per site than central or northern parts of the harbour. Fish diversity was greatest in the Waiuku Estuary (8 to 12 species), with the highest number of species being obtained from the upper reaches of the Taihiki Estuary. Waiuku Estuary (including Taihiki Estuary) had the highest counts of anchovy, exquisite goby, garfish, mottled triplefin, grey mullet, estuarine triplefin, red gurnard, smelt and speckled sole.

Commercial fishery species were also identified using the fisheries 'catch effort' database (NABIS[41]) for the Big Blue Waitakere Coastal and Marine Information Report (Davis *et al.,* 2018). The report identified that the Manukau Harbour is home to at least 15 species of shark, eight of which are listed as threatened and seven are listed as 'Not Threatened' under the IUCN Red List of Threatened Species.

There are three common ray species found in New Zealand coastal waters. All three species are known to be present the Manukau Harbour (Le Port, 2009):

- Short tail stingray (Least concern) (*Bathytoshia brevicaudata*);
- Long tail stingray (Data deficient) (*Dasyatis longa*); and
- New Zealand eagle ray (Least concern) (*Myliobatis tenuicaudatus*).

It is likely that the harbour is used as a nursery and feeding ground for shark and ray species; DOC is currently researching the importance of the Manukau Harbour for sharks including the Great White Shark (*Carcharodon carcharias*).

NABIS also identified 26 bony fish species that are known to be present in the Manukau Harbour and surrounding west coast nearshore waters (Davis *et al*., 2018). Mangrove habitat in the harbour is likely to act as shelter and nurseries for fish species in their juvenile stage but is extensive and expanding.

The Waiuku and Taihiki Estuaries (including the areas around the NZ Steel discharges) are therefore considered to have a **'High'** value for fish and these habitats are also considered to be important for the overall health of fish stocks in the Manukau Harbour.

5.9 Marine mammals

The Manukau Harbour is home to six species of marine mammals which are described in **Table 5.12** below, with the majority of sightings concentrated around the entrance to the Harbour (Davis *et al*., 2018). This data is based on marine mammal sightings recorded by DOC between 2006 and 2016, and more recent survey data on Māui dolphin.

Although there are no official records of 'Threatened' or 'At Risk' marine mammals in the Waiuku Estuary, media and anecdotal evidence suggests that these species (particularly Orca) may be sporadically found within the ZOI. As such, the potential ecological value for marine mammals is considered to be **'Very High'**, on the basis that these species could be found within the ZOI, though the frequency and duration of any visitation is likely to be limited.

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[41] National Aquatic Biodiversity Information System.

Table 5.12: Marine mammal species in the Manukau Harbour, threat status and comments on respective range within the harbour

Common name	Species name	Threat status (Baker *et al*., 2016)	Comments on range in the Manukau Harbour
Māui dolphin	*Cephalorhynchus hectori maui*	'Threatened' – Nationally Critical	Maui's dolphins have been recorded along the west coast and as far into the Manukau harbour as Cornwallis / Karangahape Peninsula.
Orca	*Orcinus orca*	'Threatened' – Data deficient	There have been sporadic sightings of orca in the main harbour and in Waiuku Estuary.
NZ fur seal	*Arctocephalus forsteri*	Not Threatened	Known seal colony at Waterfall Bay (near the harbour entrance). Seals have also been observed up-harbour near the Mangere WWTP.
Common dolphin	*Delphinus delphis*	Not Threatened	There are no official sightings of common or bottlenose dolphin in the Manukau Harbour, but this area is within their potential range.
Bottlenose dolphin	*Tursiops truncatus*	Nationally Endangered	
Southern right whale	*Eubalaena australis*	Nationally Vulnerable	Range likely restricted to harbour entrance.

5.10 Coastal vegetation

On behalf of NZ Steel two surveys were undertaken in May 2020 to assess the coastal vegetation present across 9 km of the coastal zone on the eastern side of Waiuku Estuary, Manukau Harbour (Bioresearches, 2022). The survey reach extended from 300 m south of the Southside Outfall to the western point of 381-389 Glenbrook Beach Road, north of the Site (Bioresearches, 2022). The distribution of each vegetation type along sub reaches within this overall reach is presented in Bioresearches (2022).

Terrestrial, freshwater and saline vegetation communities are described below and have been classified in accordance with Singer *et al.*, (2017). Note that terrestrial and freshwater vegetation are included here for completeness, however, are not included in the effects assessment (Section 6.9) as they are outside the ZOI. Instead, they are assessed in the Freshwater Report (Appendix H of the AEE).

Terrestrial vegetation was present outside the area of tidal influence and therefore outside the ZOI. Terrestrial vegetation along the coastal margin included native coastal vegetation (Pōhutukawa treeland; Singers *et al.*, 2017) dominated by pōhutukawa (*Metrosideros excelsa*).

Other native coastal terrestrial vegetation comprised of common trees, shrubs and ferns including karaka (*Corynocarpus laevigatus*), ponga (*Cyathea dealbata*), mamaku (*C. medullaris*), whekī (*Dicksonia squarrosa*), māpou (*Myrsine australis*), māhoe (*Melicytus ramiflorus*), karamu (*Coprosma robusta*), koromiko (*Veronica stricta*), coastal five-finger (*Psuedopanax lessonii* x *crassifolius*), kawakawa (*Piper excelsum*), tī kouka cabbage trees (*Cordyline australis*), mature exotic pines (Pinus radiata) and exotic weeds including grasses (*Cortaderia selloana*, *C. jubata*), woolly nightshade (*Solanum mauritianum*), coastal wattle (*Acacia sophorae*), boxthorn (*Lycium ferocissimum*) gorse (Ulex europaeus) and tree privet (Ligustrum lucidum) (Bioresearches, 2022).

Freshwater wetlands are present outside the area of tidal influence (and therefore outside the ZOI) and are typically present where flow paths interfaced with coastal and inter-tidal zones. These areas were dominated by raupō (*Typha orientalis*) in the south (raupō reedland, WL9; Singers *et al.*, 2017), between the Southside Outfall and Northside Outfall and exotic reed sweet grass (*Glyceria maxima*) in the north at the Brookside Road-Glenbrook Road Catchment Estuary. Patches of giant umbrella sedge (*Cyperus usulatus*), harakeke (*Phormium tenax*) and marsh clubrush (*Bolboschoenus fluviatilis*) formed part of these transitional wetland areas (Bioresearches, 2022).

Saline vegetation within the coastal margin and intertidal habitat is expected to be within the potential ZOI and within areas of tidal influence.

Intertidal vegetation is dominated by mangroves (*Avicennia marina* subsp. *australascia*) (Mangrove forest and scrub; Singers *et al.*, 2017) which formed considerable swathes of monotypic communities in the upper to mid-tidal area, common in the sheltered embayments with soft substrate, including some contiguous areas of over 11 ha. Mangrove forests are patchily distributed along the entire surveyed reach (Bioresearches, 2022).

Oioi (*Apodasmia similis*), sea rush (*Juncus krausii* subsp. *australiensis*) and coastal spear grass (*Austrostipa stipoides*) communities (Sea rush, SA1.3; Singers *et al.*, 2017) are present in small, isolated patches (10 m^3 or less) or in narrow bands averaging 2m wide along the coastal fringe (Bioresearches, 2022).

Salt marsh meadow habitats (herbfields, SA1.4; Singers *et al*., 2017) were present in discrete areas in the upper intertidal zone generally above the upper extent of the mangroves, or occasionally as a mosaic around the salt marsh. The community is common at the stream-intertidal interface, and consisted of sea primrose (*Samolus repens*), selliera (*Selliera radicans*), glasswort (*Salicornia quinquefolia*), New Zealand celery (*Apium prostratum*), slender clubrush (*Isolepis cernua var. cernua*), and occasional exotic orache (*Atriplex prostrata*) (Bioresearches, 2022).

The values of coastal saline vegetation are therefore considered to be **‘Moderate’** to **‘High’.**

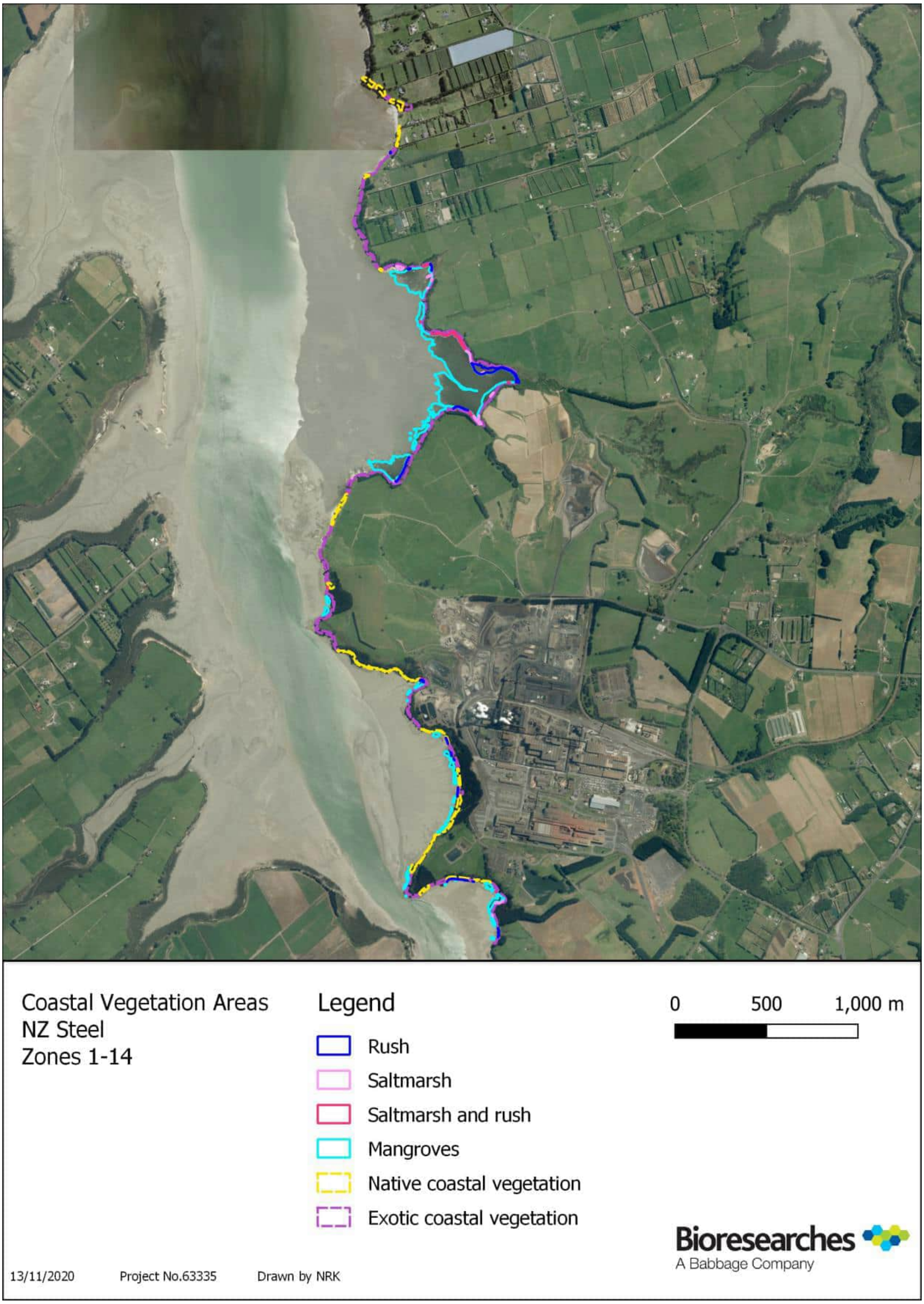

Figure 5.12: Distribution of vegetation types along the survey reach around the NZ Steel site. Expanded from Figures 5.3 to 5.14 in Bioresearches (2022)

5.11 Coastal birds

Coastal birds comprise both seabirds (birds that spend most of their time on open ocean waters and come to shore only to breed) and waders (birds that spend much of their time near bodies of water for foraging and roosting).

Waiuku and Taihiki Estuaries are side arms of the Manukau Harbour, which is recognised nationally as a hotspot for coastal bird diversity (Robertson *et al*., 2007). Manukau Harbour supports over 20% of the total New Zealand wader population, and it is likely that more than 60% of all New Zealand waders use the harbour on a temporary basis (Watercare Services Ltd, 2008).

The Waiuku and Taihiki estuaries constitute some of the most important areas within the Manukau Harbour for seabirds. This is recognised in the AUP, which identifies a number of Significant Ecological Areas – Marine (SEA-M) in the vicinity of the NZ Steel discharge points (being the Northside and Southside Outfalls and the mouths of the Lower North Stream, Ruakohua Stream and Kahawai Stream).

These designated SEA-Ms in the vicinity of the Site recognise the importance of the extensive intertidal flats that provides both foraging habitat for nationally 'Threatened' and 'At Risk' endemic and migratory species and also large areas of mangrove forest and salt marsh vegetation that provide foraging and nesting habitat for the 'At Risk' – declining banded rail (*Gallirallus philippensis*) (Robertson *et al.* 2021)).

In addition, the Waipipi roosts (located on the opposite side of the Waiuku Estuary and approximately 1 km from the Kahawai Stream mouth) and other high tide roost sites[42] in the area, are recognised by DOC as an Area of Significant Conservation Value (ASCV) as providing significant high-tide roosting habitat for coastal birds; during high tides at roosting sites birds spend their time sleeping, resting and digesting food and this is a critical component of the coastal bird lifecycle.

These SEA-Ms are listed in **Table 5.13** which includes their proximity to the Steel Mill and a description from Schedule 4 of the AUP, and they are delineated in Appendix E of the AEE Figure W-ME2.

Table 5.13: Significant Ecological Areas – Marine (SEA-M) in Waiuku Estuary

AUP SEA-M Identifier	Proximity to Glenbrook site	Description
M2 – 32a	Kahawai Stream and Lower North Stream discharge directly to this SEA-M	**Salt marsh and intertidal flats** Waders congregate on the adjacent intertidal flats (32a) before moving onto the roost. This is one of the smaller of the major high tide wader roosts on the Manukau Harbour. Salt marsh and mangroves fringe the tidal creeks and inlets in Waiuku River providing habitat for banded rail.
M2 – 32 w1	Kahawai Stream and Lower North Stream discharge directly to this SEA-M	Extensive areas of feeding habitat for waders along this coastline (32a).
M1 – 32 w2 and M1 – 32b	~1 km on the opposite side of Waiuku Estuary from	**Waipipi roosts** Shell and sand banks at the entrance to Waipipi Creek (32b) which are isolated from the shore at high tide are

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[42] An area that remains exposed at high tide where coastal birds congregate until the tide recedes and allows birds to commence feeding.

AUP SEA-M Identifier	Proximity to Glenbrook site	Description
	the Kahawai Stream discharge point	used as a high tide roost by a variety of coastal birds and several hundred to a few thousand international migratory and New Zealand endemic wading birds including a number of threatened species. This is one of the smaller of the major high tide wader roosts on the Manukau Harbour. The Department of Conservation has selected the roosts and closely adjacent intertidal banks as an Area of Significant Conservation Value (ASCV).
M2 – 319 and w1	~2.5 km to the south of the North and Southside outfalls	Extensive areas of feeding habitat for waders along this coastline.

Four site specific coastal bird surveys (six hourly counts) were conducted in May, August and October 2020 and January 2021 (broadly autumn, winter, spring and summer) to cover the annual pattern of bird use. Seasonal changes to coastal avifauna are associated with the movements of overseas migrant species that arrive in September and depart for the northern Hemisphere in about March; NZ migrants leave for (mainly) the South Island in about August and return from January.

The methods and results for the bird surveys are provided in Section 1.15 and 6 of the Bioresearches (2022) report, with the results summarised in **Appendix B**[43]. The average (mean) number of birds observed in the habitat (and how they use the habitat) is provided, based on averaging data across the six hourly counts. The location and extent of monitoring areas are also shown in Figures 1.8 and 1.9 of the Bioresearches (2022) report.

The survey results (outlined in **Appendix B**) identify 23 different species that are utilising habitat in the vicinity of the Site either for feeding or resting in the intertidal habitat or for feeding and resting in or over the water. In addition, we have assumed banded rail are present in the Site vicinity. These results indicate a relatively high species diversity and favourable overall habitat conditions for coastal birds, of which two are 'threatened' and twelve are 'at risk' (Robertson *et al*., 2021)[44].

Appendix B also denotes the four broad 'functional groups' that are characterised based on the predominant use of habitat at the site and that may be affected differently by activities from the Proposal; these coastal bird functional groups include:

- '**Waders**' such as godwits or oyster catchers, which predominately feed on benthic marine fauna within the inter-tidal mud/sand flats;
- '**Water column feeders'** such as shags or terns, that predominately forage on fish or other marine organisms within the water column when the inter-tidal habitat is inundated;
- '**Generalist feeders**', such as seagulls and herons that forage (herons) or scavenge (seagulls) on both benthic marine fauna and fish can be found within the inter-tidal habitat at all or most tidal cycles; and
- '**Coastal fringe and wetland species'**, e.g. banded rail that forage and nest within mangrove forest and salt marsh vegetation.

The Bioresearches (2022) report notes the following with regard to the surveyed areas:

- **Northside – Southside Outfall area**: The highest numbers of birds were recorded in the autumn and summer surveys with relatively low numbers in winter and spring, mainly related

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[43] **Appendix B** also denotes coastal birds listed as 'Specified highly mobile fauna' in Appendix 2 of the NPSIB.

[44] Supporting database E-bird includes hotspot data for the nearby Sandspit Reserve (approximately 2 km south from the Glenbrook site), however there were no additional species noted over and above those identified during surveys by Bioresearches.

to the absence of most of the overseas migrants (e.g. eastern bar-tailed godwit and lesser knot) in winter, and the absence of most of the birds that migrate within New Zealand to breed (e.g. South Island pied oystercatcher and banded dotterel) in spring. Feeding in the intertidal was the predominant habitat use activity (with an overall average of 65.6% of records), followed by resting in the intertidal habitat;

- **Ruakohua Spillway area**: Relative to the other two survey areas, the embayment adjacent to the Spillway is small and presents limited habitat that is dominated by a muddy substrate and rock outcrops. Numbers of birds were relatively low throughout the surveys; the average number was highest in autumn and enhanced by notable numbers of pied stilt, South Island pied oystercatcher and white-faced heron given the small area of feeding habitat.

  The most dominant species was white-faced heron that commonly utilised the muddy substrate that is likely to have supported a population of mud crabs. Feeding in the intertidal area was the predominant activity (with 82.2% of records overall) and a relatively low level of resting. Aside from white-faced heron, birds using this area were generally transient in comparison with the other survey areas;
- **Kahawai to Lower North Stream area**: Relatively high numbers of birds were recorded in autumn, spring and summer with lower numbers in winter. The most common species overall was the South Island pied oystercatcher with notable numbers of eastern bar-tailed godwit and lesser knot, both overseas migrants. The results indicate a diverse, and at times abundant, coastal bird population, with high numbers generally occurring towards or at the time of low water; and

  Feeding was the predominant habitat use activity (with an overall average of 81.9% of records), followed by resting in the intertidal area. Also of note was the use of the area in August 2020 for foraging by three wrybill (*Anarhynchus frontalis*), classified as Threatened – Nationally Vulnerable.

In addition to the three survey areas, a high tide roost site located in the vicinity of the Kahawai Stream mouth was surveyed in May and October 2020 and January 2021[45] (refer to Table 6.25 in the Bioresearches (2022) report). The high tide roost was used by a total of 10 species with high numbers of some species at a given time, e.g. up to 290 eastern bar-tailed godwit, 80 lesser knot, 100 pied stilt and 320 South Island pied oystercatcher. The roost is significant in a wider context as suitable habitat availability at high tide is limited on a harbour-wide basis and this area has the added advantage of being relatively disturbance free from both predators and humans. This is because it is separated from the land at high tide and there is limited public access through this area.

Annual wader census data for the Manukau Harbour was reviewed by T+T to provide context to the number of waders observed either feeding or roosting in areas surveyed by Bioresearches. Data was provided by the Ornithological Society of New Zealand (OSNZ) for the years 2010-2020. Samples from OSNZ data across the wider Manukau Harbour shows that the harbour regularly supports an average of 13,334 (8,460-21,110) eastern bar-tailed godwit, 9,217 (6,310 – 11,513) lesser knot, 22,495 (15,926 – 27,692) South Island pied oystercatcher, and 1,729 (1,008 – 2,709) wrybill[46].

With reference to the number of birds observed foraging in the intertidal during the census surveys, the Waiuku and Taihiki Estuaries are of minor importance for foraging bird species, when viewed in comparison to overall populations in the wider Manukau Harbour. For example, during these census surveys, three wrybill were observed foraging in the intertidal area, however this comprises less

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[45] No suitable high tide occurred in the limited August (winter) period available once Covid-19 restrictions had been lifted.

[46] These figures are based on the average of winter counts for South Island pied oystercatchers and wrybill, and the average of summer counts for lesser knot and eastern bar-tailed godwit, based on seasonal use of the Manukau Harbour.

than 1 % of the Manukau Harbour's population. Likewise, the 'Threatened' Caspian tern observed during Bioresearches surveys comprise approximately 1.5 % of the Manukau Harbour population[47].

Eastern bar-tailed godwit, lesser knots, and South Island pied oystercatchers were observed in larger numbers on the Kahawai Roost. Proportionally, these counts represent approximately 2 % of godwits, less than 1 % of lesser knot and approximately 1.5 % of South Island pied oystercatchers found seasonally in the wider Manukau Harbour.

These data provide additional context to the ecological value of coastal bird species located in the ZOI.

The modelled mixing extent and wider ZOI are considered to have a **'Very High'** ecological value for coastal birds due to the diversity and abundance of 23 species including two species that are classified as nationally 'Threatened' and twelve species that are 'At Risk' (Robertson *et al.*, 2021).

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[47] Memo from Tim Lovegrove to Tracey Grant, 30/07/2021: Assessment of effects on avifauna of renewal of consents to discharge stormwater and process water from Glenbrook Steel Mill to the CMA.

6 Ecological Effects Assessment

6.1 Outline

This section presents an assessment of the actual and potential effects of the proposed discharges that are the subject of this application on the ZOI of the CMA and is set out in the following way:

1. A summary of the Current Environment ecological values from Section 5;
2. An overview of the actual and potential effects of the discharges on the CMA;
3. Reference to the mitigation measures (treatment systems) that are already in place;
4. An overview of the approach to the assessment of effects;
5. An assessment of the magnitude of residual effects, and the overall level of effects, on marine ecological values in the ZOI with the existing mitigation measures in place, split out based on:
   - The short term[48] and 35-year consent period Receiving Environment values inferred from the Current Environment values in Section 5 (noting that marine habitat value is based on the combined habitat attributes of water and sediment quality, benthic ecology and shellfish quality);
   - The magnitude of residual effects on those values inside the modelled mixing extent, and on those values outside this area but within the wider ZOI; and
   - An overall level of effects assessment which combines ecological values with the magnitude of residual effects based on the same structure as the magnitude of effects assessment above.

Section 7 brings together all the individual level of effects assessments above and summarises them in text and in **Table 7.1**. A more detailed assessment of the magnitude of effects is included in **Appendix C**, and an accompanying detailed set of overall level of effects tables is included in **Appendix D**. These four tables break down the effects in the short term and the long term both inside the modelled mixing extent and outside this area (but within the wider ZOI).

6.2 Summary of Current Environment ecological values

As described in Section 5 there are a number of important ecological values that currently exist throughout the wider ZOI and within the modelled mixing extent. These values range from **'Negligible'** to **'Very High'** depending on location, species, habitat types and habitat attributes. These values are summarised in **Table 6.1** with brief reasoning, which is expanded further in the subsequent sections. Note that **Table 6.1** presents Current Environment values while the following sections present Receiving Environment values excluding the proposed discharges. This approach is taken for brevity as the only difference between the Receiving Environment values and the Current Environment values is for water quality in the short term[49].

As described above and expanded further in Section 6.6, an overall value for estuarine habitat has been determined based on the combined habitat attributes of water and sediment quality, benthic ecology and shellfish quality. This is summarised in Table 6.1.

Current estuarine habitat values are generally higher outside of the modelled mixing extent than they are inside this area. Values inside the mixing extent range from **'Negligible'** to '**Low'**, while

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[48] For the purposes of this assessment short-term is after a few tidal cycles once the discharge water is no longer discernible from other estuary water.

[49] The habitat attribute value category of 'Negligible' to 'Low' for water quality is the only category to change between the Current Environment and Receiving Environment (Table 6.2 – Low) values. This is due to an instant improvement in water quality if the Steel Mill discharges ceased, whereas the other attributes have a time lag before improving. This improvement in water quality is not enough to change the overall habitat value in the Receiving Environment however.

values outside these areas and within the ZOI range from **'Low'** to **'Moderate'**. This reflects the fact that effects from the discharges from the Steel Mill over the last 53 years tend to be most concentrated in the immediate area where they enter the CMA. It also reflects the fact that the Waiuku and Taihiki estuaries as a whole are currently, and have historically been, degraded by sediment (in particular), and also metals and nutrients from catchment sources other than the Steel Mill.

On the other hand, current values for fish, marine mammals, saline vegetation and coastal birds are generally the same both within the modelled mixing extent and outside this area (but within the wider ZOI). These values range between **'Moderate'** to **'Very High'**. This reflects the fact that these species are mobile and are known to, or may potentially, use the modelled mixing extent and the wider ZOI.

Table 6.1: Summary of Current Environment estuarine ecological values based on the EcIAG values assessment guidelines

Habitat attribute / species	**Current Environment habitat values based on Appendix A Table 1 & Appendix A Table 2**	
	Inside the modelled mixing extent	**Outside the modelled mixing extent**
Water quality (Habitat attribute)	'Negligible' to 'Low' (elevated zinc, copper, temperature, sediment and reduced salinity)	'Low' (poor water quality driven mainly by sediment, metals and nutrients from other catchments)
Sediment quality (Habitat attribute)	'Negligible' to 'Low' (elevated zinc, copper, muddiness and sedimentation rates)	'Low' to 'Moderate' (elevated zinc, copper, muddiness and sedimentation rates)
Benthic ecology (Habitat attribute)	'Negligible' to 'Low' (elevated zinc, copper, muddiness and sedimentation rates)	'Low' to 'Moderate' (elevated muddiness, sedimentation rates and isolated metals)
Shellfish quality (Habitat attribute)	'Low' (elevated zinc and copper, and reduced condition, In oysters)	'Low' to 'Moderate' (elevated zinc and copper, reduced condition)
Overall marine habitat value based on the attributes above	**'Negligible' to 'Low'**	**'Low' to 'Moderate'**
Fish	'High' (High diversity, nursery area)	
Marine mammals	'Very High' (Possible but limited presence of 'Threatened' species)	
Coastal vegetation	'Moderate' to 'High' (habitat for 'Threatened' and 'At Risk' bird species and rarity of some vegetation types)	
Coastal birds	'Very High' (presence of 'Threatened' and 'At Risk' species)	

6.3 Actual and potential effects of the discharges on marine ecological values

Actual and potential marine ecological effects of the proposed discharges from the Steel Mill[50] have been identified as:

- Effects on estuarine habitat quality using indicators of water quality, sediment quality, benthic health and shellfish quality;
- Effects on fish;
- Effects on marine mammals;
- Effects on coastal vegetation; and
- Effects on coastal birds.

In general terms, effects on marine ecology from the proposed discharges from the Steel Mill are the following:

- Elevated concentrations of metal contaminants in the water column, particularly in the modelled mixing extent closest to the Northside Outfall discharge. The primary contaminants of concern are zinc, and to a lesser degree copper. Metal contaminants can have toxic effects on marine biota, particularly sensitive larval life stages, and can accumulate in biota;
- Increased temperature and decreased salinity, particularly in the modelled mixing extent, driven primarily by the steady freshwater discharge from the Northside Outfall[51]. Temperature and salinity changes can cause physiological stress;
- Suspended and deposited sediment. Suspended sediment can clog gills and feeding apparatus and reduce visibility for feeding. Deposited sediment can smother organisms, reduce oxygen levels and increase the muddiness of the sediment, excluding species that are sensitive to mud. Sediment can also transport attached contaminants outside the modelled mixing extent on currents, and deposit these throughout the wider ZOI; and
- For coastal birds the key effects include a reduction in the quality of foraging habitat through effects on benthic invertebrates or fish, and effects on the ability to detect prey due to reduced visibility in the water column.

The above effects are most pronounced within a few hundred metres radius of the Northside Outfall, and to a lesser extent around the Southside Outfall and a lesser extent again in the settling zones of the mouths of the Lower North Stream and the Kahawai Stream.

Further information on specific effects for individual habitats and attributes, and on species groupings, is given in the magnitude of effects in Sections 6.6 to 6.10 below.

6.4 Existing measures to avoid, minimise, remedy and/or mitigate effects

Usually, an ecological effects assessment following the EcIAG framework includes an assessment of the magnitude of any effects both before and after efforts to avoid, minimise, remedy and/or mitigate those effects. However, as mentioned in the effects assessment methodology, the discharges and mitigation measures (treatment systems) are already in place, in contrast to a completely new set of activities. As such, it is difficult to accurately assess the magnitude and level of effects that would be occurring without the current mitigation measures in place. However, it is

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[50] Note that the Ruakohua Dam Spillway already has a consent to discharge to the CMA and so is not explicitly being assessed as part of this application but is included in some parts of the effects assessment for wider context.

[51] Note that prior to the creation of Northside Pond and Outfall there was a stream that discharged at this location. However, the Northside Outfall discharges constantly while a natural stream would only discharge at elevated volumes during storm events. However, during rainfall events other catchments contribute much more freshwater volume to the estuary than the Northside and Southside discharges, so the receiving environment is subject to periodic reductions in salinity outside of NZ Steel's activities.

assumed that the effects would be at least 'Moderate' or greater for many aspects and would require effects mitigation measures. As such we have not assessed effects prior to mitigation. Instead, the assessment proceeds directly to describing the magnitude of any residual effects[52] with the current mitigation measures (treatment systems) in place.

As detailed in the ITA Report (Appendix G of the AEE)) all the existing mitigation in the form of the treatment systems will continue to be utilised if consent is granted, as these systems are considered to be the Best Practicable Option (BPO). A continual improvement plan will continue to be implemented, including new measures identified during preparation of this application. Based on the list of potential improvements included in the ITA Report (Appendix G of the AEE), small improvements to discharge quality are expected over the short to medium term, with a marked improvement in discharge quality already evident in the last two years. From there, additional incremental improvements are also expected.

However, for the purposes of this assessment, and in order to be conservative in the approach, we have assumed that the existing extent of mitigation will remain as it currently stands over the 35-year consent term. Therefore, the magnitude of effects assessment has been carried out on this basis.

The current mitigation treatment systems for the various discharges reduce contaminant loads by at least 57% for copper, 94% for zinc, and 98% for suspended solids for the Northside (and likely the Southside) ponds before the treated water is discharged to the CMA. The treatment systems in place significantly reduce the magnitude of potential adverse effects across all the marine areas affected by discharges from the Steel Mill, particularly in the water column and settling zone areas close to the discharge points, and particularly for the Northside Outfall discharge. The treatment systems have also been progressively improved over time since 1985, with a marked improvement in discharge quality in the last two years (Appendix G of the AEE). After initial signs of improvement when monitoring began in 2003, concentrations of metals in sediments have been fairly consistent since 2005 (**Figure 5.7**).

6.5 Approach to the effects assessment

As explained in Section 4 and the introduction to this section, the application assesses the magnitude of residual effects of the discharges (with current mitigation in place) on the assumed values of the Receiving Environment that would exist if the Steel Mill operations ceased.

In theory some Receiving Environment values could differ from Current Environment values in the short term[53] as a result of the Steel Mill operations being ceased. In reality, however, the only species or habitat attribute value that changes in the short term is water quality, as the difference in quality would be immediate if the Steel Mill operations ceased. However, when the water quality habitat attribute is combined with the sediment quality, benthic health and shellfish quality attributes into an overall estuarine habitat value, the overall value does not change between the Current Environment and the Receiving Environment in the short term, as there is a lag in the improvement in the quality of the other attributes. As such, all the Receiving Environment values over the short term are the same as the Current Environment values. The same values are therefore used for the magnitude assessment.

Following the EcIAG effects assessment framework, ecological values have been assigned to the general estuarine habitat in the ZOI based on the attributes set out in **Appendix A Table 2**. Habitat values have been assigned separately to the area within the modelled mixing extent and the area

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[52] Residual effects are those that remain after all efforts to avoid, minimise, remedy and/or mitigate effects. Residual effects may warrant additional management through ecological offsets or compensation.

[53] For the purposes of this assessment short-term is considered to be after a few tidal cycles once the discharge water is no longer discernible from other estuary water

outside the modelled mixing extent (but within the wider ZOI) based on the spatial differences in habitat attributes described in Section 5 and on professional judgement.

The magnitude of effects is then assessed against the individual habitat attributes, then combined to give an overall level of residual effect from the proposed discharges on the general estuarine habitat values both inside and outside the modelled mixing extent, both in the short term and over 35 years.

Values for fish, marine mammals, coastal saline vegetation and coastal birds have been assigned to individual species or species groups as per the criteria in **Appendix A Table 1**. The magnitude and overall level of effects of the discharges have then been assessed on those species or groups both inside and outside the modelled mixing extent (spatially), and both in the short term and over the maximum consent term of 35 years (temporally).

The magnitude and overall level of residual effects assessment of the Proposal on each ecological value has therefore been broken into the following four modelling scenarios[54]:

- **Modelling Scenario 1** – **Inside** the Receiving Environment modelled **mixing extent** – **short term effects**;
- **Modelling Scenario 2** – **Outside** the Receiving Environment modelled **mixing extent** but within the ZOI – **short term effects**;
- **Modelling Scenario 3** – **Inside** the Receiving Environment modelled **mixing extent** – **effects over the 35 year consent term**; and
- **Modelling Scenario 4** – **Outside** the Receiving Environment modelled **mixing extent** but within the ZOI – **effects over the 35 year consent term.**

A range of values, magnitudes of effect and overall levels of effect are provided in the assessments below. However, a conservative approach has been taken to evaluating the need for further residual effects management by assessing the highest overall level of effect on each of the various habitat types, species, and spatial areas (both within and outside the modelled mixing extent). If the overall level of effect for a particular element outside of the modelled mixing extent is ‘Moderate’ or greater, then further effects management may be warranted and is discussed in Section 8.

However, within a ‘zone of reasonable mixing’, initial dilution takes place and relevant water quality standards do not apply (ANZWQG 2018, NZCPS 2010, Cook *et al.* 2010). Provided the size of the mixing zone is ‘reasonable’, a greater level of ecological effect is acceptable compared to areas outside the zone of reasonable mixing. This aspect is discussed further in Sections 7 and 8.

6.6 Effects on estuarine habitats

The following section brings together the Current Environment habitat value category information for water quality, sediment quality, benthic ecology and shellfish (from Sections 5.4 to 5.7 and **Table 6.1**) into an overall estuarine habitat ecological effects assessment for the Receiving Environment.

The results presented below provide a summary of the more detailed magnitude of effects assessment which is appended in **Appendix C**. **Appendix C** includes assessment of the magnitude of effects on the individual habitat attributes (as some individual effects are quite different) and then combines this into a magnitude of effects assessment on the overall estuarine habitat values. Finally, the overall level of effects assessment is brought together based on the summary Receiving Environment values and the summary magnitude of effects assessments. **Table 6.2** and the text below summarise the outcomes from this effects assessment.

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[54] For the purposes of this assessment each ‘modelling scenario’ is just a component of the overall assessment based on the DHI (2021) modelling approach and does not represent an alternative outcome.

Current estuarine habitat values are generally higher outside the modelled mixing extent (but within the wider ZOI) than they are inside this area. **Values** inside the modelled mixing extent range from **'Negligible'** to '**Low'**, while values outside this area but within the ZOI range from **'Low'** to '**Moderate**'. This reflects the fact that effects from the discharges from the Steel Mill over the last 53 years tend to be most concentrated in the immediate area where they enter the CMA. It also reflects the fact that the Waiuku and Taihiki estuaries as a whole are currently being, and have historically been, degraded by sediment (in particular), as well as metals and nutrients from catchment sources other than the proposed discharges.

Table 6.2 describes the Receiving Environment habitat attribute and overall habitat values that would exist over the short term and the 35 year consent term if the proposed discharges were removed, and the reasons for those values as compared to Current Environment values. The magnitude of effect on each habitat attribute and the overall magnitude of effect on overall habitat values is then presented in **Table 6.3** to provide an overall level of ecological effect.

The following is a summary of **Table 6.2** and **Table 6.3**:

- **Modelling Scenario 1 – Inside** the Receiving Environment modelled **mixing extent – short term**;
  - It is considered that habitat value overall would improve in the short term. This is predominantly due to improved water quality and reduced toxicity and sediment effects to both benthic organisms and those utilising the water column. However, sediment quality will not improve substantially in the short term, as sediment contaminant concentrations and muddiness take time to respond to changes in contaminant loads, and poor benthic ecological health is also driven by sediment loads from the wider catchment.
  - Therefore, overall habitat value would remain **'Negligible' to 'Low'**;
- **Modelling Scenario 2 – Outside** the Receiving Environment modelled **mixing extent** but within the ZOI – **short term**;
  - It is considered that habitat value overall would remain 'Low' to 'Moderate' in the short term. This is predominantly due to similar water and sediment effects on both benthic organisms and those utilising the water column, as much of the ecological effect in the wider ZOI is driven by sediment and contaminant loads from the wider catchment. Furthermore, sediment quality will not improve substantially in the short term, as sediment contaminant concentrations and muddiness take time to respond to changes in contaminant loads from the proposed discharges.
  - Therefore, overall habitat value would remain **'Low' to 'Moderate'**;
- **Modelling Scenario 3 – Inside** the Receiving Environment modelled **mixing extent – over the 35 year consent term**;
  - It is considered that without the proposed discharges habitat value overall would improve to 'Low' to 'Moderate' over the 35 year term. This is predominantly due to improved water quality and reduced toxicity from zinc, copper, temperature and salinity changes. As well as reduced sediment effects on both benthic organisms and those utilising the water column. Sediment quality is also predicted to improve substantially, with sediment zinc concentrations predicted to drop by around 40%, moving from ERC-Red to the boundary of ERC-Green levels. Sediment deposition rate will also reduce by more than 2 mm/yr.
  - Therefore, overall habitat value without the Steel Mill discharges would improve to **'Low'** to **'Moderate'**; and

- **Modelling Scenario 4 – Outside** the Receiving Environment modelled **mixing extent** but within the ZOI – **over the 35 year consent term**;
  - It is considered that while habitat value would improve due to reduced sediment and contaminant loads from the proposed discharges, overall, it would still be 'Low' to 'Moderate' in 35 years' time. While there is an improvement, elevated sediment and metals from sources other than the Steel Mill would, assuming they remain the same, continue to drive similar water and sediment quality effects on both benthic organisms and those utilising the water column.
  - Therefore, overall habitat value would remain **'Low' to 'Moderate'.**

The effects on estuarine habitat in the ZOI as a whole, and residual effects management, are discussed in Section 8.

Table 6.2: Summary of Receiving Environment estuarine habitat attribute value categories for water quality, sediment quality, benthic ecology and shellfish quality. Further details included in Appendix C.

Habitat attribute type	**Habitat attribute value categories**	
	Inside the modelled mixing extent	**Outside the modelled mixing extent but within the ZOI**
Water quality (Habitat attribute) – short term	'Low'[55] (Improves to same level as wider estuary after Mill discharges cease)	'Low' (Elevated sediment, nutrients and metals from sources other than the Steel Mill continue to drive 'Low' values)
Water quality (Habitat attribute) – over the 35 year consent term	'Low' (Improves to same level as wider estuary after Mill discharges cease)	'Low' (while there is an improvement, elevated sediment, nutrients and metals from sources other than the Steel Mill continue to drive 'Low' values)
Sediment quality (Habitat attribute) – short term	'Negligible' to 'Low' (very little improvement over current values due to lag in response time)	'Low' to 'Moderate' (Elevated sediment and metals from sources other than the Steel Mill continue to drive 'Low' to 'Moderate' values)
Sediment quality (Habitat attribute) – over the 35 year consent term	'Low' to 'Moderate' (Sediment quality improves markedly due to reduction in metals (ERC-Red to Green) and sediment loads, and normal temperature and salinity)	'Low' to 'Moderate' (while there is an improvement, elevated sediment and metals from sources other than the Steel Mill continue to drive 'Low' to 'Moderate' values)
Benthic ecology (Habitat attribute) – short term	'Negligible' to 'Low' (Some improvement over current values due to reduced water	'Low' to 'Moderate' (elevated sediment and metals from sources other than the Steel Mill

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[55] Note that the habitat attribute value category of 'Low' for water quality in the short term is the only category to change between the Current Environment (Table 6.1 – 'Negligible' to Low) and Receiving Environment values. This is due to an instant improvement in water quality if the Steel Mill discharges were to cease, whereas the other attributes have a time lag before improving. This improvement in water quality is not enough to change the overall habitat value however.

Habitat attribute type	Habitat attribute value categories	
	Inside the modelled mixing extent	**Outside the modelled mixing extent but within the ZOI**
	toxicity, but lag in response time = no change in value category)	continue to drive 'Low' to 'Moderate' values)
Benthic ecology (Habitat attribute) – over the 35 year consent term	'Low' (Marked improvement over current values due to reduction in metals (ERC-Red to Green), sediment loads, normal temp and salinity)	'Low' to 'Moderate' (while there is an improvement, elevated sediment and metals from sources other than the Steel Mill continue to drive 'Low' to 'Moderate' values)
Shellfish quality (Habitat attribute) – short term	'Low' (Some improvement over current values due to reduced water toxicity, but lag in response time = no change in value category)	'Low' to 'Moderate' (elevated sediment and metals from sources other than the Steel Mill continue to drive 'Low' to 'Moderate' values)
Shellfish quality (Habitat attribute) – over the 35 year consent term	'Low' to 'Moderate' (Marked improvement over current values due to reduction in metals and sediment loads, and normal temperature and salinity)	'Low' to 'Moderate' (while there is an improvement, elevated sediment and metals from sources other than the Steel Mill continue to drive 'Low' to 'Moderate' values)

Table 6.3: Summary of ecological effects on overall estuarine habitat in the Receiving Environment modelled mixing extent and within the wider ZOI[56].

	Inside the modelled mixing extent	**Outside the modelled mixing extent and within ZOI**
Overall habitat **Value** (based on 4 attributes) – **short term**	'Negligible' to 'Low'	'Low' to 'Moderate'
Overall habitat **Value** (based on 4 attributes) – over the **35 year** consent term	'Low' to 'Moderate'	'Low' to 'Moderate'
Greatest **Magnitude** of effect – **short term**	'Moderate'	'Negligible'
Potential EcIAG **Overall** level of effect – **short term**	'Low'	'Very Low'
Greatest **Magnitude** of effect over the **35 year** consent term	'Moderate' to 'High'	'Negligible' to 'Low'
Potential EcIAG **Overall** level of effect over the **35 year** consent term	'Moderate'	'Low'

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[56] Details of the magnitude and overall level of effects assessment are included in Appendix C

6.7 Effects on fish

6.7.1 Fish values

With reference to the Current Environment values (Section 5.8) and the approach to the assessment of effects methodology (Section 4.3), it is expected that there would be **'High'** ecological value for fish species in the Receiving Environment in the short term in the modelled mixing extent[57], and that these values would remain **'High'** over the 35-year period if the Steel Mill discharges were ceased. This is on the basis that improvements in water quality (and therefore estuarine habitat quality) in the modelled mixing extent over time may benefit fish and acknowledging that continued external inputs (particularly sediment) to the Waiuku Estuary from other land uses may reduce the extent to which those improvements benefit fish.

Within the wider ZOI, it is also expected that the ecological value of fish would remain **'High'** over the 35-year time period and that the same species would continue to use habitat in the ZOI, notwithstanding other external influence (e.g., climate change, overfishing, changes to sea surface temperatures affecting food resources etc).

6.7.2 Magnitude of effect on fish

Based on the state of the Current Environment, foraging habitat for fish species in the modelled mixing extent is likely to be of lower quality than adjacent areas in the Waiuku Estuary.

Potential adverse effects on fish species and values in the Receiving Environment include effects on food resources and risk of predation, avoidance and displacement due to reductions in water clarity, changes in temperature and salinity, and other water and sediment quality related parameters including accumulation of contaminants in the flesh of fish (Lowe *et al.*, 2015).

Rays in particular feed primarily on benthic bony fishes and invertebrates such as molluscs, worms and crustaceans, by repeatedly inhaling sediments and water through the mouth and venting this out through gill slits (NZ Geographic, 2008). Speckled sole and other flatfish also feed directly on the benthos. In this regard, any adverse impacts on benthic fauna assemblages (including shellfish) are likely to impact available food resources for fish and contaminants could be passed on up the food chain and carried outside the mixing extent when fish move away.

Only 1.4% of the total annual average sediment load and 6.7% of the very fine sediment load to the Waiuku Estuary is derived from the Northside and Southside Outfalls and the ITA Area discharges to the North Drain, Ruakohua Spillway and Kahawai streams combined. Given this, it can be assumed that the elevated suspended sediment, sediment muddiness and sedimentation rates across the ZOI are primarily being driven by sediment sources unrelated to this application and the proposed discharges (Appendix E of the AEE, Figure W-ME3). As such, the proposed discharges are unlikely to be a primary contributor to reduced water clarity outside the modelled mixing extent described above.

Mobile fauna, fish and rays are also likely to enact a behavioural response and avoid the area immediately adjacent to the discharge points where either the discharge has impacted food resource abundance, or the water clarity has reduced to the degree where foraging ability has declined and predation risk has increased (Lunt and Smee, 2015). Some fish may also elicit an avoidance response to the increased temperature and decreased salinity in the modelled mixing extent as a result of the Northside Outfall discharge (Cherry *et al.* 2011, Kültz 2015).

Based on this information, the magnitude of effect on fish values from the proposed discharges under the four modelling scenarios is presented in **Table 6.4**.

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[57] Noting that fish are more likely to be present in the mixing zone at high tide than low tide.

6.7.3 Overall ecological effect on fish

Based on a **'High'** current and future ecological value for fish, **Table 6.4** identifies the magnitude and overall level of ecological effects based on the four-step process outlined in Section 4.3 to assess the effects on the CMA. The effects on fish in the ZOI as a whole and residual effects management, is discussed in Section 8.

Table 6.4: Summary of ecological effects on fish in the Receiving Environment modelled mixing extent and within the wider ZOI

	Inside the modelled mixing extent	**Outside the modelled mixing extent but within ZOI**
Fish **Values** – short term and over the 35 year consent term	'High' across all modelling scenarios	
Greatest **Magnitude** of effect – **short term**	'Low' – immediate improvements to water quality in the modelled mixing extent, and potential for improved fish habitat if the Steel Mill discharge ceased	'Negligible' – positive water quality effects unlikely to be discernible beyond the modelled mixing extent
Potential EcIAG **Overall** level of effect – **short term**	'Low'	'Very low'
Greatest **Magnitude** of effect over the **35 year** consent term	'Moderate' – based on sustained improvements to water quality in the modelled mixing extent and potential for improved fish habitat if the Steel Mill discharge ceased	'Low' – positive water quality effects beyond the modelled mixing extent may increase over time
Potential EcIAG **Overall** level of effect over the **35 year** consent term	'High'	'Low'

6.8 Effects on marine mammals

6.8.1 Marine mammal values

Marine mammals are unlikely to be found within the modelled mixing extent as it is shallow and intertidal in nature and no official sightings of marine mammals have been recorded in this area.

With reference to Section 4.3 and the approach to the assessment of effects methodology, it is expected that the **'Very High'** ecological value of marine mammal species in the Current Environment (Section 5.9), both in the modelled mixing extent and the wider ZOI, would not notably change in the Receiving Environment in the short term or over the 35-year consent period.

Notwithstanding some external influence (e.g. major loss of intertidal habitat or prey species, climate change, over fishing, changes to sea surface temperatures affecting food resources etc) the same species could continue to use available habitat in the modelled mixing extent and wider ZOI over the 35 year period.

6.8.2 Magnitude of effect on marine mammals

DHI (2022) modelling and the information in Section 5 has identified that the largest effects on the CMA from the Steel Mill discharges is near the Northside Outfall discharge, and to a lesser degree the Southside Outfall discharge and to a lesser degree again in the settling zones of the Lower North Stream and Kahawai Stream. These effects are primarily within the intertidal zone, with effects becoming progressively less pronounced towards the main channel of the Waiuku Estuary.

It is considered that there is a low likelihood of marine mammals being present in the Waiuku Estuary channel on a more than infrequent basis. Any sightings are likely to be marine mammals in transience or opportunistically feeding and marine mammals are unlikely to be found within the modelled mixing extent or settling zones (which are shallow and intertidal in nature), especially towards the beginning of the consent period while food resources are likely to be of poorer quality and quantity.

As such the magnitude of any effects of the proposed activity on the Receiving Environment for the known population or range of the marine mammal species identified in **Table 5.12** above is considered to be **'Negligible'** in the short term and over the 35 year consent term, both inside and outside the modelled mixing extent.

Based on this information the magnitude of effect on marine mammal values from the proposed activity under the four modelling scenarios is presented in **Table 6.5**.

6.8.3 Overall ecological effect on marine mammals

Based on a **'Very High'** current and future ecological value for marine mammals, **Table 6.5** further identifies the magnitude and overall level of ecological effects based on the four-step process outlined in Section 4.3 to assess the effects of the proposed discharges on marine mammals.

The effects on marine mammals in the ZOI as a whole, and residual effects management, is discussed in Section 8.

Table 6.5: Summary of ecological effects on marine mammals in the Receiving Environment modelled mixing extent and within the wider ZOI

	Inside the modelled mixing extent	**Outside the modelled mixing extent but within ZOI**
Marine mammal **Values** – short term and over the 35 year consent term	'Very High' across all Modelling Scenarios	
Greatest **Magnitude** of effect – **short term**	'Negligible'	'Negligible'
Potential EcIAG **Overall** level of effect – **short term**	'Low'	'Low'
Greatest **Magnitude** of effect over the **35 year** consent term	'Negligible' effect on the known population or range, any use of the area unlikely and of very short duration	'Negligible' based on marine mammals unlikely to be affected outside of the modelled mixing extent, with any change barely distinguishable

	Inside the modelled mixing extent	**Outside the modelled mixing extent but within ZOI**
Potential EcIAG **Overall** level of effect over the **35 year** consent term	'Low'	'Low'

6.9 Effects on coastal saline vegetation

6.9.1 Coastal saline vegetation values

The Current Environment ecological values of the coastal vegetation communities in close vicinity to the proposed discharge points are assessed as ranging from **'Moderate'** to '**High**'. The reasoning is provided below. It is expected that the **'High'** ecological value of coastal vegetation in the Receiving Environment, both in the modelled mixing extent and the wider ZOI, would not notably change as a result of the proposed discharges in either the short term or over the 35-year consent period.

Areas dominated by mangroves are classified with a regional IUCN threat status of Least Concern and are locally and nationally common. However, mangroves provide important habitat for species such as banded rail (*Gallirallus philippensis*) with a threat classification of 'At Risk' – Declining. Banded rail utilise mangrove habitat for foraging (particularly where mangroves are connected to saltmarsh habitats) and prefer larger stature mangroves to provide cover from aerial predators (Waikato Regional Council, 2017). Mangroves are widespread in the Manukau Harbour, Waiuku Estuary and its tidal tributary the Taihiki Estuary and are generally considered to be expanding in extent. Some mangrove removal has been proposed in the Waiuku Estuary where mangroves are encroaching on important wading bird habitat, including at Pollock/Rangiriri Spit, Waipipi Spit and Clarkes Beach to Karaka Point. Mangroves are therefore considered to be of **'Moderate'** ecological value.

Rush marsh consisting of oioi, sea rush and coastal spear grass is one of the variants of the mangrove forest and scrub ecosystem classified with a regional IUCN status of Least Concern. However, rush marsh is less common than mangrove communities, provides nesting and foraging habitat for indigenous fauna such as banded rail and other shore birds, and therefore is of **'High'** ecological value.

The salt marsh meadow habitat consisting of herbfields within a mosaic of sea rush is one of the variants of mangrove forest and scrub ecosystem classified by Singers *et al.*, (2017) with a regional IUCN threat status of Least Concern. However, coastal turfs are an historically rare ecosystem[58]. Salt marsh meadows provide foraging habitat for indigenous fauna including banded rail and other shore birds. Considering this, the areas of salt marsh meadow are considered of **'High'** ecological value.

In summary, the ecological value of the coastal saline vegetation in close vicinity to the Northside and Southside Outfall discharges, and the Kahawai Stream and Lower North Stream, range from **'Moderate'** to **'High'**.

6.9.2 Magnitude of effect on coastal saline vegetation

The highlighted water quality guideline and Consent Limit exceedances in **Table 3.1** suggest the proposed discharges from the ITA Area contain contaminants, particularly heavy metals, that could result in adverse effects on coastal saline vegetation communities within the ZOI of the discharges (i.e. those exposed to water that could be influenced by discharge water). Adverse effects might

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[58] Williams, P. A., Wiser, S., Clarkson, B., & Stanley, M. C. (2007). New Zealand's historically rare terrestrial ecosystems set in a physical and physiognomic framework. *New Zealand Journal of Ecology*, 119-128.

include the degradation of vegetation communities through a loss of species richness, overall extent, or habitat quality.

The following section describes the expected magnitude of effect on coastal vegetation under the four modelling scenarios.

The effects expected from the proposed discharges are predominantly from heavy metals, with a **'Very Low'** to **'High'** magnitude of effect on sediment quality as outlined in Sections 5.5 and 6.6. These effects are expected to be most acute in the modelled mixing extent and to a lesser extent the settling zones of the Lower North Stream and Kahawai Stream.

Under Modelling Scenarios 1 and 2, proposed discharges are expected to be concentrated at the Lower North Stream, Kahawai Stream, Northside Outfall and Southside Outfall discharge locations (Bioresearches, 2022). Mixing with water and sediment from the wider catchment in the intertidal zone is expected to reduce contaminant effects once these discharges reach the wider Waiuku Estuary. Existing vegetation in the CMA consists of species and communities tolerant to contaminants, such as mangrove forest and scrub, and further discharges are expected to result in at most only a minor shift from Current Environment conditions. The Lower North Stream and Northside Outfall intertidal areas are dominated by mangroves. Mangroves are distributed across all the areas where discharges meet the CMA. Mangroves are tolerant to a wide range of environmental conditions and accumulate heavy metals, buffering the wider environment from pollutants (Bastakoti *et al.*, 2018). Furthermore, any increase in sediment is expected to increase available mangrove habitat (Lovelock *et al.*, 2007).

The existing concentrations of contaminants being discharged, or even a slight increase in contaminant discharge concentrations, as well as changes to sediment, are expected to have a **'Negligible'** magnitude of effect on mangroves for Modelling Scenarios 1, 2 and 4. For Modelling Scenario 3, over the longer term inside the modelled mixing extent, a reduction in discharge as a result of discontinued operation of the Steel Mill is expected to reduce sedimentation levels slightly in the immediate vicinity of the discharge areas, particularly for the Northside Outfall discharge. This is expected to reduce mangrove expansion, and potentially reduce mangrove regeneration. Therefore, Modelling Scenario 3 is expected to have a **'Low'** magnitude of effect on mangrove communities.

Rush marsh communities dominated by oioi located south of Ruakohua Stream outlet, between the Southside and Northside Outfalls, and in the Brookside Road to Glenbrook Road catchment (Bioresearches, 2022) are expected to be resilient to adverse environmental conditions. Oioi is frequently used in swale plantings due to its ability to take up and tolerate increased concentrations of heavy metals (NZTA Waka Kotahi, 2011).

Salt marsh wetlands are effective sinks for metal contaminants and the concentration of heavy metals is unlikely to cause adverse effects for salt marsh communities (Williams *et al.*, 1994). Salt marsh communities are also predicted to be relatively resilient to sedimentation effects and can be used to remove sediment loads (Thomsen *et al.*, 2009). Nonetheless, few studies have assessed the effects of pollutants on salt marsh communities and there may be effects.

In summary, discharge reductions as a result of Modelling Scenario 1 have been assessed as having a **'Negligible'** magnitude of effect on rush marsh and salt marsh communities. The effects of Modelling Scenario 3 are expected to be **'Low'** due to potential effects on salt marsh communities[59], while the effects of Modelling Scenarios 2 and 4 are expected to be **'Negligible'**, as a slight reduction in sediment and contaminants is considered to have limited impact on these communities.

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[59] A 'Low' magnitude of effect indicates there could be a minor shift away from current baseline conditions.

6.9.3 Overall ecological effect on coastal saline vegetation

The overall ecological effects are summarised in Section 7 and **Table 6.2** based on the combined ecological value and magnitude of effect scores using the EcIAG (2018) criteria in **Appendix A** and as described in the above sections. Existing saline vegetation communities are expected to be relatively resilient to changes in contaminant and sediment levels. An overall level of effect of **'Low'** or **'Very Low'** is expected as a result of each of the four modelling scenarios described in Section 4.3.

Table 6.6 presents a summary of the ecological value, magnitude of effect and overall level of effect for each modelling scenario on coastal saline vegetation. The effects on coastal vegetation across the ZOI as a whole, and residual effects management, is discussed in Section 8.

Table 6.6: Summary of ecological effects on coastal saline vegetation in the Receiving Environment modelled mixing extent and within the wider ZOI.

	Inside the modelled mixing extent	**Outside the modelled mixing extent but within ZOI**
Coastal saline vegetation **Values** – short term and over the 35 year consent term	'Moderate' to 'High' for all Modelling Scenarios	
Greatest **Magnitude** of effect – **short term**	Mangroves – 'Negligible' Rush marsh – 'Negligible' Salt marsh – 'Negligible'	Mangroves – 'Negligible' Rush marsh – 'Negligible' Salt marsh – 'Negligible'
Potential EcIAG **Overall** level of effect – **short term**	Mangroves – 'Very Low' Rush marsh – 'Very Low' Salt marsh – 'Very Low'	Mangroves – 'Very Low' Rush marsh – 'Very Low' Salt marsh – 'Very Low'
Greatest **Magnitude** of effect over the **35 year** consent term	Mangroves – 'Low' Rush marsh – 'Negligible' Salt marsh – 'Low'	Mangroves – 'Negligible' Rush marsh – 'Negligible' Salt marsh – 'Negligible'
Potential EcIAG **Overall** level of effect over the **35 year** consent term	Mangroves – 'Low' Rush marsh – 'Very low' Salt marsh – 'Low'	Mangroves – 'Very Low' Rush marsh – 'Very Low' Salt marsh – 'Very Low'

6.10 Effects on coastal birds

6.10.1 Coastal bird values

The modelled mixing extent and wider ZOI are considered to have a **'Very High'** ecological value for coastal birds in the Current Environment due to the presence of 24 different species including two species that are classified as nationally 'Threatened' and twelve species that are 'At Risk' (Robertson *et al.*, 2021) (**Table 6.7**)**.** Of particular note, the ZOI supports an abundance of bar-tailed godwit, red knot, pied stilt, South Island pied oystercatchers and white-faced heron, although these numbers are considered low in the context of wider Manukau Harbour populations. This is likely due to the combination of intertidal sand/mudflats for foraging, and the presence of important high-tide roosting habitats in relatively close proximity to foraging habitat[60].

It is expected that the **'Very High'** ecological value of coastal birds in the Current Environment, both in the modelled mixing extent and the wider ZOI, would not notably change in the Receiving Environment were the proposed discharges to cease both in the short term or over the 35-year consent period. Notwithstanding some external influence (i.e. loss of intertidal feeding ground to mangrove expansion or erosion of high tide roost sites) the same species would continue to use habitat in the modelled mixing extent and wider ZOI over the 35 year period.

Table 6.7: 'Threatened' or 'At Risk' coastal birds that are present or potentially present in the modelled mixing extent and wider ZOI, their functional group threat status and associated EcIAG value (refer to Appendix A Table 1). *Denotes coastal birds listed as 'Specified highly mobile fauna' in Appendix 2 of the NPSIB

Common name	**Species name**	**Threat status (Robertson *et al.*, 2021)**	**Functional group**	**Ecological value category**
Banded dotterel*	*Charadrius bicinctus*	At Risk–-Declining	Wader	'High'
Banded rail*	*Gallirallus philippensis*	At Risk – Declining	Nesting and foraging in coastal fringe vegetation	'High'
Black shag	*Phalacrocorax carbo*	At Risk – Relict	Feed in the water column and roosting in coastal fringe	'Moderate'
Caspian tern*	*Hydroprogne caspia*	Nationally vulnerable	Feed in the water column	Very High
Eastern bar-tailed godwit*	*Limosa lapponica*	At Risk – Declining	Wader	'High'
Lesser knot (Red knot)*	*Calidris canutus*	At Risk–-Declining	Wader	'High'
Little black shag	*Phalacrocorax sulcirostris*	At Risk – naturally uncommon	Feed in the water column and roosting in coastal fringe	'Moderate'
Pied shag*	*Phalacrocorax varius*	At Risk – Recovering	Feed in the water column and roosting in coastal fringe	'Moderate'
Red-billed gull*	*Chroicocephalus novaehollandiae*	At Risk – Declining	Generalist	'High'

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[60] Shorebirds will prefer to roost as close to their foraging areas as possible to minimise energy costs during non-foraging periods around high tide (Jackson, 2017)

Common name	**Species name**	**Threat status (Robertson *et al.*, 2021)**	**Functional group**	**Ecological value category**
Royal spoonbill	*Platalea regia*	At Risk – naturally uncommon	Wader	'Moderate'
South Island pied oystercatcher*	*Haematopus finschi*	At Risk – Declining	Wader	'High'
Variable oystercatcher*	*Haematopus unicolor*	At Risk – Recovering	Wader	'Moderate'
White-fronted tern*	*Sterna striata*	At Risk – Declining	Feed in the water column	'High'
Wrybill*	*Anarhynchus frontalis*	Nationally increasing	Wader	'Very High'

6.10.2 Magnitude of effect on coastal birds

Potential adverse effects on coastal birds in the ZOI of the proposed discharges include:

- Impacts on foraging habitat quality and quantity for waders including reduced benthic invertebrate species diversity and condition and increased metal concentrations in shellfish, benthic invertebrates and some fish;
- Impacts on high tide roost sites from sedimentation and subsequent mangrove expansion and encroachment;
- Suspended sediment in the water column impacting on the visual foraging ability of birds feeding in the water column; and
- Potential impacts on saline vegetation (mangroves, salt marsh and large roost trees) that provide habitat for cryptic birds and nesting / roosting coastal birds.

As described in Sections 5.6 and 5.7, the discharges from the Steel Mill to the CMA have an impact on benthic ecology and shellfish, primarily from: elevated metal concentrations in the water column and in sediment, increased sedimentation rates, and increased water temperature and decreased salinity in the modelled mixing extent. These effects are particularly pronounced in the immediate vicinity of the Northside and Southside Outfalls, with effects progressively lessening towards the subtidal channels and across the wider ZOI. However, the DHI (2022) modelling shows that proposed discharges do have a small and measurable effect on sedimentation rates and sediment metal levels across a relatively large area of intertidal habitat in the ZOI outside the modelled mixing extent (Figure Appendix C.1, Figure Appendix C.2 and Figure Appendix C.3)

These effects can result in reduced diversity and condition of benthic invertebrate species available for foraging coastal birds. A recent literature review by Lukies *et al*. (2021) further supports that sedimentation (and associated contaminants such as metals) can impact marine predatory feeders, such as seabirds and waders, by indirectly altering the marine ecosystem processes and food webs that they or their prey rely on. Jackson *et al*. (2020) goes further and suggests that it is because of the impacts of sedimentation on macroinvertebrates that sediment-impacted areas are likely to support fewer shorebirds; the study does not include impacts of metals on food webs, although the effect is similar. In addition, Section 5.7 identifies that the proposed discharges are having a clear effect on zinc and copper concentrations in oysters, a food resource for coastal bird species. The greatest effect is for zinc at site N6a, closest to the Northside Outfall.

The intertidal foraging habitat in the ZOI is extensive (~1,900 ha, which is 76% of the ZOI; the remainder is subtidal) and coastal birds can self-relocate to adjacent intertidal habitat if foraging conditions are temporarily unsuitable; the SEA-Ms identified in Appendix E of the AEE Figure W-ME2 identify that there is other suitable foraging habitat within the Waiuku Estuary. However, we consider that the impact on benthic ecology in the modelled mixing extent is essentially a permanent effect[61] (i.e. it will continue for as long as the discharges take place and assuming the quality of the discharge is unchanged) that occurs continuously and regardless of the timing of the discharges.

When considering the magnitude of effect on waders from feeding on impacted benthic species in the modelled mixing extent, it is unknown how frequently individual waders are utilising the impacted habitat to feed due to the absence of data on site fidelity (i.e. how loyal birds are to a specific site for feeding). Waders are also mobile and could enter the mixing extent to feed, then potentially carry effects back outside the mixing extent when they move away. Therefore, the duration of the impact on the individual birds is uncertain. Given this uncertainty, a level of conservatism should be applied to the magnitude of effects assessment on waders feeding on impacted benthic habitat in the modelled mixing extent and wider ZOI.

The Waiuku Estuary also contains a number of significant high tide roost sites; the carrying capacity of intertidal areas for shorebirds is linked to the proximity of good high tide roosts. If roosts are degraded or lost, the number of shorebirds using the adjacent intertidal feeding areas may decline (personal observation by Dr Tim Lovegrove (Lee, 2019)). Wading birds also typically rest following a period of feeding and may cease feeding entirely after about half tide rising, to 'stage' or aggregate prior to moving to a high tide roost elsewhere (Bioresearches 2022). The presence of high tide roost sites in close proximity to the Steel Mill discharge points indicates that the intertidal feeding habitat in the vicinity of the Site is of additional importance to coastal bird species (over and above feeding), and likely providing a point of aggregation for coastal birds prior to relocation to high tide roosts.

High tide roost sites in the Waiuku Estuary are currently under threat from mangrove encroachment. If roost sites become overgrown with vegetation, the line of sight (to predators) is impacted and the site becomes unfavourable for use by coastal birds during roosting periods. Mangrove encroachment is in part due to the accelerated rate of New Zealand mangrove (*Avicennia marina subsp australasica*) expansion, predominantly due to increased sediment and nutrient runoff from surrounding catchments (Lundquist *et al.*, 2017). The identified sediment load coming from proposed discharges contributes to this effect as one, albeit relatively minor, source of sediment to the Waiuku Estuary, (noting that only 1.4% of the total annual average sediment load and 6.7% of the very fine sediment load to the Waiuku Estuary is derived from the proposed discharges).

International and local studies indicate that coastal birds can be impacted by contaminants from industrial sources (Thompson and Dowding, 1999; Einoder *et al.*, 2018; Lock *et al.*, 1992; Burger *et al.*, 1994; Hosseini *et al.*, 2013). While uncertainties exist and potential effects cannot be ruled out, contaminant concentrations from the proposed discharges are unlikely to be at high enough concentrations to cause lethal or sublethal bioaccumulation in coastal bird populations. Zinc and copper bioaccumulation in coastal birds is considered unlikely, as they are essential elements and their levels can be regulated to some extent by normal homeostatic mechanisms (see Koivula and Eava 2010, and references related to zinc and copper therein).

Increased suspended sediment concentrations in the water column can adversely impact the foraging ability of birds (i.e. shags and terns) feeding in the water column at or near the water surface (Lukies *et al.*, 2021); this is where effects from increased suspended sediment are more noticeable (and more pronounced due to stratification of the water column). Given that 1.4% of the

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[61] EIANZ (2018) describe 'permanent' effects as 'continuing for an undefined time beyond the span of one human generation (taken as approximately 25 years)'.

total annual average sediment load and 6.7% of the very fine sediment load to the Waiuku Estuary is currently derived from the Northside and Southside Outfalls and the other proposed discharges to the Lower North Stream, Ruakohua Spillway and Kahawai streams, it can be assumed that any elevated sediment muddiness and sedimentation rates are primarily being driven by sediment sources other than the proposed discharges, except in the modelled mixing extent where suspended sediment concentrations are likely to be more elevated.

Potential effects on coastal vegetation (mangroves, salt marsh and large roost trees) that provide habitat for cryptic birds (such as banded rail) and nesting / roosting for coastal birds (such as shags and herons) are likely to be '**Low'** to '**Very Low'** (as outlined in Section 6.9.3).

Overall, the magnitude of effects on coastal birds based on the modelling scenarios outlined in Section 6.5 are as follows:

- **Modelling Scenario 1** (**Inside** the Receiving Environment modelled **mixing extent** – **short term),** magnitude of effect is **'Low'** on the basis that:
  - The level of sediment and contaminants resulting from the proposed discharges within the modelled mixing extent is unlikely to have lethal or sub-lethal impacts on coastal birds, although the discharges are known to impact on foraging quality within the modelled mixing extent;
  - The Receiving Environment which excludes the proposed discharges, would be expected to have improved water quality and foraging ability in the water column in the modelled mixing extent which would be adversely affected by the proposed discharges;
  - However, historical discharges have already compromised the quality of foraging habitat and the proposed ongoing discharges are not expected to further reduce the quality of the existing foraging resource to a notable degree at the beginning of the consent term;
  - While there are undoubtedly localised and permanent effects on the quality of coastal bird foraging habitat within the modelled mixing extent, the modelled mixing extent is less than 8 ha (6.3 ha for the Northside Outfall discharge and 1.6 ha for the Southside Outfall discharge), which equates to a relatively small proportion (< 0.5%) of the available inter-tidal habitat in the Waiuku and Taihiki estuaries (~1,900 ha); and
  - The surveyed area for coastal birds is larger than the modelled mixing extent (essentially the full intertidal area of the currently consented mixing zone), therefore the average number of coastal birds found within the 8 ha is likely to be less than the full area surveyed.
- **Modelling Scenario 2** (**Outside** the Receiving Environment modelled **mixing extent** but within the ZOI – **short term),** magnitude of effect is **'Negligible'** on the basis that:
  - The level of sediment and contaminants in the ZOI outside the modelled mixing extent resulting from the discharges is expected to have a '**Negligible'** effect on the quality of coastal bird foraging habitats in the short term;
  - The existing discharge activities are currently compromising the quality of foraging habitat in the wider ZOI (though to a lesser degree than within the modelled mixing extent) and the proposed ongoing discharges are not expected to further reduce the quality of the existing foraging resource in the short term;
  - The effect on high tide roost sites in the ZOI from sediment would be '**Negligible'** in the short term;
  - A Receiving Environment in which the proposed discharges have ceased, would have improved water quality and foraging ability in the water column in the wider ZOI, but such improvement would not be marked; and

  - Potential effects on coastal vegetation (mangroves, salt marsh and large roost trees) that provide habitat for cryptic birds (such as banded rail) and nesting / roosting coastal birds (such as shags and herons) are likely to be '**Low'** or '**Very Low'** (as outlined in Section 6.9.3).
- **Modelling Scenario 3** (**Inside** the Receiving Environment modelled **mixing extent** – **35 years),** magnitude of effect of the ongoing operation of the Steel Mill is **'Moderate'** on the basis that:
  - The Receiving Environment would improve markedly over the longer term compared to the discharges continuing. In particular, the estuarine habitat values would improve based on reduced toxicity from zinc, copper, temperature and salinity changes, and reduced sediment metals and sedimentation effects on benthic organisms.
  - Additionally, water quality and foraging ability in the water column would improve quickly and substantially with the discharges ceased. This would lead to subsequent improvements for fish habitat, and food resource for birds feeding in the water column; and
  - While there would be localised improvements to the quality of coastal bird foraging habitat within the modelled mixing extent with the discharges ceased, the modelled mixing extent is a relatively small proportion (< 0.5%) of the available inter-tidal habitat in the Waiuku and Taihiki Estuaries (~1,900 ha).
- **Modelling Scenario 4** (**Outside** the Receiving Environment modelled **mixing extent** but within the ZOI – **35 years),** magnitude of effect is **'Low'** on the basis that:
  - Similar to Modelling Scenario 3, with the proposed discharges ceased, the habitat value in the wider ZOI would improve due to improvements to water and sediment quality and effects on both benthic organisms and those utilising the water column;
  - The effect on high tide roost sites in the ZOI would be '**Low'** during the 35 year time period, due to ongoing sedimentation inputs contributing to mangrove encroachment on roost sites; and
  - Potential effects on coastal vegetation (mangroves, salt marsh and large roost trees) that provide habitat for cryptic birds (such as banded rail) and nesting / roosting coastal birds (such as shags and herons) are likely to be '**Very Low'** (as outlined in Section 6.9.3).

6.10.3 Overall ecological effect on coastal birds

Based on a **'Very High'** current and future ecological value for coastal birds, **Table 6.8** identifies the magnitude and overall level of ecological effects based on the four-step process outlined in Section 6.5 to assess effects on the CMA. The effects on coastal birds in the ZOI as a whole and residual effects management is discussed in Section 8.

Table 6.8: Summary of ecological effects on coastal birds in the Receiving Environment modelled mixing extent and within the wider ZOI

	Inside the modelled mixing extent	**Outside the modelled mixing extent and within ZOI**
Coastal bird **Values** – short term and over the 35 year consent term	'Very High' for all Modelling Scenarios	
Greatest **Magnitude** of effect – **short term**	'Low' – assumes that effects on food source (benthic	'Negligible' – assumes that effects on food source

	Inside the modelled mixing extent	**Outside the modelled mixing extent and within ZOI**
	ecology) mostly remain in the short term.	(benthic ecology) remain in the short term.
Potential EcIAG **Overall** level of effect – **short term**	'Moderate' (but small spatial scale)	'Low' (but large spatial scale)
Greatest **Magnitude** of effect over the **35 year** consent term	'Moderate' – assumes improvement to benthic ecology over a 35 year period, within the limitations of external factors	'Low' – assumes improvement to benthic ecology over a 35 year period, within the limitations of external factors
Potential EcIAG **Overall** level of effect over the **35 year** consent term	'High' (but small spatial scale)	'Moderate' (but large spatial scale)

7 Ecological effects summary and conclusion

7.1 Ecological effects of the Steel Mill discharges

The proposed discharges include both process water and stormwater discharging to the CMA of the Waiuku Estuary. Based on the monitoring information from NZ Steel and the catchment and estuary modelling carried out by DHI (2022), the main contaminant of concern for marine ecology in the areas closest to where the proposed discharges from the Mill enter the CMA is zinc (and to a lesser degree copper and suspended and deposited sediment), particularly in the few hundred metres around the Northside Outfall.

In combination, the proposed discharges contribute the following approximate loads[62] to the Waiuku Estuary:

- 7.0% of the total freshwater flow volume;
- 1.3% of the total sediment load, which contains 6.4% of the very fine sediment load;
- 17.2% of the total copper load; and
- 62.4% of the total zinc load.

Note that these loads do not account for the likely reduction in flow volumes and contaminant loads should the EAF be installed and operated. Therefore, these loads present a worst-case scenario and a conservative assessment based on current operations.

The spatial extent of all the NZ Steel's contributing catchments is approximately 1.5% of the total Waiuku Estuary catchment area, with the Northside and Southside Outfall ITA catchments constituting around 0.6% and 0.4% of this area. Proportionally, the Northside Outfall ITA Catchment therefore delivers a much greater water volume and contaminant load to the Waiuku Estuary than the other NZ Steel catchments, particularly for zinc (approximately 95% of the zinc load from the Steel Mill).

Rates of sediment deposition onto the seabed across the Waiuku Estuary are elevated above natural background (pre-human) levels, including near the NZ Steel discharges and particularly near the Northside Outfall. Sediment deposition rates driven by the Northside Outfall are up to 6.5 mm/yr from the discharge itself, while pre-human natural background rates in estuaries are usually less than 1 mm/yr (ANZWQG, 2018). The Northside and Southside Outfall discharges drive 6.6% and 0.4% respectively of the total predicted sediment deposition across the Waiuku Estuary, with the majority of this deposited within the modelled mixing extent.

While the proposed discharges will contribute to overall sedimentation rates, the Steel Mill has a slightly lower total sediment discharge rate than the average land use across the wider Waiuku Estuary catchment, and the Steel Mill only constitutes approximately 1.5% of the total Waiuku catchment area. Consequently, the Steel Mill's sedimentation effects are proportionally small and spatially constrained compared to the predicted sedimentation rates driven by land use in the catchment other than the Steel Mill. However, the Steel Mill does contribute comparatively high very fine sediment loads for its land area.

Regarding physicochemical stressors, plumes of water with increased temperature and decreased salinity (driven primarily by the freshwater discharge from the Northside Outfall) have a similar modelled mixing extent to zinc, before becoming fully mixed with water from the wider estuary.

Ecological effects from the proposed discharges are most pronounced within the few hundred metres radius from the Northside Outfall, and to a lesser extent around the Southside Outfall and

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[62] For the load volumes and weights see Table 4-12 in Section 4.3 of the DHI (2022) report attached as **Appendix F**

the settling zones[63] of the Lower North Stream and the Kahawai Stream. However, these areas are quite small on the scale of the Waiuku Estuary, with the modelled mixing extent only covering approximately 0.5% of the total intertidal area of the Waiuku and Taihiki Estuaries (i.e. the ZOI). Similar, potentially higher quality, benthic habitat is available in many other parts of the estuary.

In the wider Waiuku Estuary, suspended and deposited sediment are clearly having the most widespread effect on ecology. While the proposed discharges do contribute to this, most of the sediment is derived from rural catchments unrelated to the proposed discharges, and this process is mostly driven by sediment loading from rural land uses in those catchments.

As explained in Sections 2.2 and 4.3.1, the effects of the proposed activity are assessed against the Receiving Environment, which is the environment that would be expected to exist over a period of 35 years after the proposed discharges ceased.

In conclusion, as presented in detail in **Appendix D** and summarised in **Table 7.1** below, we consider the marine ecological effects of the proposed activity on the Receiving Environment **outside the modelled mixing extent** to be:

- In the **short term** – **'Very Low' to 'Low'** adverse effects on marine ecology. Based on the EcIAG framework no further action is required; and
- **Over the 35 year consent term** – an overall **'Very Low' to 'Moderate' (for coastal birds)** adverse ecological effect on marine ecology. The 'Moderate' effect relates to coastal birds, which have a 'Very High' value. Based on the EcIAG framework, this level of residual effects warrants efforts to manage effects, including through offsetting or compensation for adverse effects on ecology.

The modelled mixing extent only constitutes a small spatial area of the overall ZOI – < 0.5% of the total intertidal area of the Waiuku and Taihiki Estuaries. As presented in detail in **Appendix D** and summarised in **Table 7.1** below, we consider the marine ecological effects of the proposed activity on the Receiving Environment **inside the modelled mixing extent** to be:

- In the **short term** – **'Very Low' to 'Moderate' (for coastal birds)** adverse effects on marine ecology. Based on the EcIAG framework, this level of residual effects may warrant efforts to offset or compensation for adverse effects on ecology. However, the spatial scale of the effects is small, and the extent of any potential residual effects management also depends on how the modelled mixing extent aligns with any zone of 'reasonable' mixing (see below); and
- **Over the 35 year consent term** – **'Low' to 'High' (for coastal birds and fish)** adverse ecological effect on marine ecology. Based on the EcIAG framework, this level of residual effects may warrant efforts to offset or compensate for adverse effects on ecology. However, the spatial scale of the effects is small, and the extent of any potential residual effects management also depends on how the modelled mixing extent aligns with any zone of 'reasonable' mixing (see below).

7.2 Defining an ecologically relevant zone of reasonable mixing

Whilst short term and longer-term effects within the modelled mixing extent may be 'Moderate' or 'High' respectively, it is accepted that a 'zone of reasonable mixing' is required to dilute or chemically or biologically convert contaminants to levels which do not exceed relevant guidelines or have significant adverse effects (ANZWQG 2018, NZCPS 2010, Cook *et al*. 2010).

The current consented mixing zone was set based on dye tracer studies carried out by Bioresearches in the early 1980's as part of investigations prior to the expansion of the Steel Mill in the mid 1980's. Dye tracer studies are useful to capture the potential extent of a mixing zone at a specific point in

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[63] The area where the majority of sediment from the catchment settles out in the CMA

time, but cannot capture the full range of potential conditions and drivers that could affect the extent of a mixing zone at different times. The size of the consented mixing zone was therefore likely set larger than the modelled mixing extent as sampling limitations in dye tracer studies mean these studies can't capture the full range of potential environmental conditions that current modelling capabilities allow. Therefore, the consented mixing zone is likely to have been set more permissively due to this uncertainty. Detailed hydrodynamic, water quality and sediment transport modelling was therefore carried out as part of the current application to better define the extent of the mixing zone under different environmental conditions. The full results of this modelling are reported in DHI (2022) and summarised below.

Based on the DHI (2022) modelling, background concentrations (i.e., concentrations not driven by discharges from the Mill) of copper and zinc in parts of the Waiuku Estuary can exceed 99% SPL guideline concentrations at times, and may even exceed 95% SPL guideline concentrations very close to catchment sources during larger rainfall events. The Council WQI also indicates that water quality is "Poor" in the upper reaches of the estuary and "Moderate" at the estuary mouth. As such it is considered appropriate to use the ANZWQG (2018) 95% SPL to define the edge of an 'ecologically relevant' zone of reasonable mixing for the Northside and Southside discharges, as the 95% SPL guideline is designed to be applied to 'slightly to moderately disturbed systems' (ANZWQG 2018).

The boundary between the Auckland Council Environmental Response Criteria (ERC) 'Red' and 'Orange' sediment quality guidelines also fits this description and is also considered appropriate to apply to the edge of the zone of reasonable mixing.

Considering 'worst case' 95th percentile[64] Northside and Southside Outfall discharge concentrations in isolation (i.e. in the absence of background concentrations), 95% SPL guidelines for copper and zinc are met within approximately 200 m of the Northside Outfall and 50 m of the Southside Outfall (**Figure 5.2** to **Figure 5.5** and detailed further in DHI 2022). Excess temperature also reduces below 3 ºC within this area, after approximately 150 m.

However, this zone doesn't account for potential additive ecological effects when background concentrations are taken into account. As such, when 'worst case' 95th percentile background concentrations are accounted for, 95% SPL guidelines are met, or concentrations equilibrate, within approximately 300 m of the Northside Outfall and 60 m of the Southside Outfall. This zone is therefore considered to be the 'ecologically relevant' zone of reasonable mixing for the Northside and Southside Outfall discharges.[65] This zone also fits with the Northside A and Northside B sediment monitoring sites being located approximately 160 m and 325 m from the Northside Outfall respectively, in that the Northside A site regularly exceeds the ERC-Red guideline but the Northside B site does not.

Based on these distances of 300 m and 60 m, the size of the 'ecologically relevant' zones of reasonable mixing for the Northside and Southside Outfall discharges are approximately 3.6 Ha and 0.15 Ha respectively.[66]

Metal concentrations in the water column and sediments, increased temperature, reduced salinity, elevated TSS and sedimentation rates may have a cumulative ecological effect within the modelled

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[64] Note that 95th percentile zinc and copper concentrations and temperature excess values occur only 5% of the time, usually around low tide. According to the 50th percentile values, the more stringent guidelines are often not exceeded at all.

[65] Note that while the DHI (2022) modelling concludes that changes in salinity can be detected up to around 400 m from the Northside Outfall discharge and 200 m from the Southside Outfall discharge, this zone is not considered 'ecologically relevant' as no relevant ecological guidelines are exceeded within the outer reaches of this area.

[66] Note that the maximum potential area from the mixing zone plots and distances outlined in Section 5.4 and in the DHI (2022) report has been used to calculate this mixing zone area. However, the mixing zone area is not uniform or constant in shape and extends further in some directions than others depending on the state of the tide and weather conditions and is therefore likely to be less than this area at any one point in time.

mixing extent, and are likely to have a cumulative effect within the 'ecologically relevant' zone of reasonable mixing described above, both in the short-term and the long-term. This is because their effects may be additive to each other. However, it is not expected that there would be cumulative effects in the water column outside the modelled mixing extent either in the short term or long term as all guidelines are actually met prior to this point, and only one stressor ever exceeds an ecologically relevant guideline at the edge of the smaller zone of reasonable mixing at any one time. Potential cumulative effects from metal levels in sediments and sedimentation rates outside the modelled mixing extent are discussed in the section below.

Given the scale of the activity, the level of existing treatment of the discharge water, the state of the Receiving Environment, the amount of similar habitat type outside the area, and NZ Steel's ongoing commitment to continual improvement (including the recently improved discharge quality discussed in the ITA Report; T+T 2024a), a zone of reasonable mixing based on 95% SPL guidelines is therefore considered appropriate from a water and sediment quality perspective. Regular review of BPO should ensure that the size of the zone of reasonable mixing remains reasonable over the life of the consent.

7.3 Effects on the scale of the Zone of Influence (ZOI)

The area of 8 ha of the modelled mixing extent is of a small spatial scale, representing < 0.5% of the 1,900 ha of intertidal habitat in the ZOI of the Waiuku and Taihiki Estuaries. As such, when effects inside and outside the mixing extent (i.e. across the whole ZOI) are taken together over the 35 year consent term, the overall levels of effects are generally predicted to be 'Low' on the scale of the ZOI, with only a 'Moderate' level of effects on coastal birds due to their 'Very High' value (**Table 7.1**).[67] These effects on birds are primarily due to effects on foraging habitat quality, driven by small increasing concentrations of zinc, and to a lesser degree copper, suspended sediment, and sedimentation rates.

The DHI (2022) modelling predicts there will be small increases in sediment zinc concentrations over the 35 year consent period across much of the wider ZOI with the ongoing operation of the Steel Mill. Predictions are up to a maximum of 22 mg/kg from the Steel Mill discharges outside the modelled mixing extent, and up to 35.2 mg/kg along the upper fringes of the inter-tidal area near the Northside discharge. This compares to a combined maximum of 37 mg/kg when sources other than the Steel Mill are included. For the Receiving Environment, decreases in maximum zinc values of up to 120.9 mg/kg are predicted to occur in the modelled mixing extent over the 35 year consent period if the Steel Mill discharges ceased, but this is on a small scale compared to the wider ZOI.

While the proposed discharges will contribute to overall sedimentation rates, the Steel Mill has a slightly lower total sediment discharge rate than the average land use across the wider Waiuku Estuary catchment. Consequently, the Steel Mill's sedimentation effects are proportionally small and spatially constrained compared to the predicted sedimentation rates driven by land use in the catchment other than the Steel Mill. However, the Steel Mill does contribute comparatively high very fine sediment loads for its land area.

In combination, these predicted increases in contaminants compared to the Receiving Environment could lead to a minor adverse shift in ecological condition and contribute to cumulative effects across the ZOI. However, it is considered that effects driven by the discharges from the Steel Mill are small on the scale of the ZOI, particularly in comparison to catchment drivers other than the Steel Mill.

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[67] Note that these effects are at the lower end of the range at the beginning of the 35 year term and increase to the upper end of the range towards the end of the 35 year period

Nevertheless, the EcIA Guidelines specify that effects that are 'Moderate' and above (i.e. those on coastal birds in Section 6.10) warrant further effects management, which is proposed to be addressed through a residual effects management and monitoring programme outlined in Section 8.

Table 7.1: Summary of residual ecological effects over the duration of the consent across the ZOI as a whole (including the modelled mixing extent).

Note: This table summarises the four tables in **Appendix D**, which include the assessment of effects over the short term and the longer term both inside and outside the modelled mixing extent.

Habitat/species type	Ecological values	Magnitude of residual effects of the proposal on ecological values after measures to avoid, minimise, remedy and/or mitigate effects	Potential EcIAG overall level of residual effects on ecological values[1]
Estuarine habitat	'Negligible' to 'Moderate' value benthic habitat and water quality depending on proximity to the Steel Mill and other catchment discharges	'Negligible' to 'Low'[1] magnitude of effects from zinc, copper, sediment, increased temperature and reduced salinity, which reduce with distance from the discharges	'Low'[2]
Fish	'High' value due to high fish diversity and the presence of nursery grounds	'Low' magnitude of effects on fish habitat from the discharges, which reduce with distance from the discharges	'Low'
Marine Mammals	'Very High' value, due to the possible presence[3] of 'Threatened' species	'Negligible', as unlikely to be present and any use of the discharge area of very short duration	'Low'
Coastal vegetation	'Moderate' to 'High' value, due to habitat provision for birds, and rarity of some vegetation types	'Negligible', as the vegetation types are resilient to effects from the discharges	'Very Low'
Coastal birds	'Very High' value, due to the presence of several 'Threatened' and 'At Risk' species	'Low' magnitude of effects from the discharges on foraging habitat, which reduce with distance from the discharges	'Moderate'[2]

[1] The 'Overall level of residual effects' categories are derived by combining the 'Ecological values' and 'Magnitude of residual effects' column categories using the 'Overall level of effects' matrix in **Appendix A Table 4**.

[2] Note that these effects start at the lower end of the range in the short term and increase to the upper end of the range towards the end of the 35 year period.

[3] While there is anecdotal evidence that marine mammals sporadically visit the ZOI (particularly Orca), no official sightings have been made.

8 Recommended residual effects management and monitoring

As identified in **Table 7.1** there is an overall '**Moderate'** residual effect on coastal birds, which relates to a '**Low'** magnitude of effect on several '**Very high'** and '**High'** value 'Threatened' and 'At Risk' species respectively. Therefore, residual effects management for the Steel Mill discharges, will be undertaken in accordance with best practice guidelines for biodiversity offsetting and compensation.

8.1 Residual effects management under the NPSIB

Management of residual effects after efforts to avoid, minimise or remedy impacts fall to offsetting or compensation. Under the National Policy Statement for Indigenous Biodiversity 2023 (NPSIB) (gazetted 7 July 2023), biodiversity offset and compensation are interpreted as follows:

> ***"biodiversity offset"*** *means a measurable conservation outcome that meets the requirements in Appendix 3 (of the NPSIB) and results from actions that are intended to:*
>
> (a) *redress any more than minor residual adverse effects on indigenous biodiversity after all appropriate avoidance, minimisation, and remediation measures have been sequentially applied; and*
>
> (b) *achieve a net gain in type, amount, and condition of indigenous biodiversity compared to that lost.*
>
> ***"biodiversity compensation"*** *means a conservation outcome that meets the requirements in Appendix 4 (of the NPSIB) and results from actions that are intended to compensate for any more than minor residual adverse effects on indigenous biodiversity after all appropriate avoidance, minimisation, remediation, and biodiversity offsetting measures have been sequentially applied."*

8.2 Proposed residual effects management approach

The proposed residual effects management approach seeks to achieve positive effects for residual effects on coastal birds that are consistent with biodiversity compensation principles under the NPSIB.

Measures to address the assessed **'Moderate'** ecological effects on coastal birds outside the modelled mixing extent for the proposed discharges are listed below (Section 8.3).

These proposed measures do not constitute an offset under the NPSIB as a 'like-for-like' quantitative loss/gain calculation cannot be applied on the basis that:

- Project impacts on coastal birds relate to water quality effects on foraging resource, which is difficult to quantify with adequate precision, i.e. to determine the number of birds impacted and the degree to which individual birds are impacted (which if impacted would almost certainly be sub-lethal).
- It is difficult to quantify with precision the net increase in the number of birds that would result from the proposed habitat restoration, enhancement or maintenance measures once these measures are implemented. As highly mobile species, their extensive home ranges further obscure site-specific cause and effects that may occur at the impact site and the benefits that are expected to occur at the restoration or habitat enhancement sites.

Although biodiversity compensation does not require the same numerical rigour as offsetting, it is generally recognised that ecological outcomes are improved where offset principles are applied as a guideline when designing compensation packages. Moreover, the type and magnitude of proposed compensation measures will be guided by the application of a Biodiversity Compensation Model

(BCM) (Baber *et al.*, 2021a; Baber *et al.*, 2021b)[68]. These models provide additional objective transparency, process and justification for the overall compensation package (Baber *et al*. 2021). In summary, BCMs:

- Use accounting formulas to estimate whether compensation measures are likely to achieve positive effects.
- Are informed by field investigations at the impact site(s) and by expected gains at the proposed 'compensation' site(s), using science-based qualitative data where quantifiable data is not available or lacks precision.
- Incorporate the use of a discount rate to account for the time lag between impact associated with project activities and the gain at the proposed compensation site.
- Adjust for the likelihood of success regarding the proposed compensation actions and account for the risk of under-estimating losses at the impact site or over-estimating gains at enhancement sites.

8.3 Coastal bird compensation package

Measures to compensate for effects on coastal birds are set out below. It is proposed that these measures are actioned through the implementation of a Coastal Birds Management Plan (CBMP), which is proposed as a condition of consent. The key focus of the CBMP is to demonstrably and adaptively address residual effects in alignment with key ecological and biodiversity compensation principles.

The proposed CBMP condition includes the objective of the CBMP (being to describe the management and monitoring practices and procedures to be implemented to compensate for residual effects on coastal birds) and also requires that the CBMP include:

- Results of a BCM, applied to guide the type and quantum of proposed compensation measures;
- Identification of the area/s for coastal bird compensation activities including a map showing the location/s;
- Description of compensation to be implemented, including details of scope, methodology and timing;
- Details of maintenance to be undertaken on an ongoing basis to support compensation activities undertaken, including any animal and plant pest control;
- Details on how the Consent Holder will assess the effectiveness of the compensation once implemented including a monitoring programme, and duration of the monitoring programme;
- Adaptive management process for reviewing and amending the CBMP, including review and amendment of the management and monitoring programme;
- Reporting requirements for implementation of the CBMP, including compensation activities, maintenance, and monitoring; and
- Identification of employee roles and responsibilities in relation to the CBMP.

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[68] The BCM approach has been recently used and accepted on the Te Ahu a Turanga Manawatū Tararua Highway project (decision of Independent Environment Court Commissioners, 13 November 2020) and the Wayby Valley Landfill project (split decision of Hearing Commissioners, 11 June 2021).

We consider that the implementation of, and compliance with, the CBMP is necessary to adequately address residual effects on coastal birds. The following compensation measures are currently under consideration as part of the CBMP:

- Enhancement of the mid-high tide roost sites in the vicinity of the Kahawai Stream discharge to the CMA (referred to as the Kahawai roost complex) (Figure W-ME4). Mangroves are encroaching on these locally important roost sites, compromising the line of sight (to predators) rendering roost sites less favourable for roosting. Mangrove removal in this location would help to restore the roost and increase available space for roosting birds;
- Where recent historical aerials show the area to be mangrove free in the vicinity of the Kahawai roost (between the Lower North Stream and Kahawai Stream mouths), selective mangrove removal (enhancement) and ongoing mangrove seedling removal (maintenance). These actions will assist with enhancing and maintaining the quality of intertidal feeding habitat for almost all of the coastal birds present in the ZOI; and
- Expand on mangrove management being undertaken by Auckland Council at the Waipipi Roost to improve the quality of this high tide roost through maintenance of line of sight for roosting birds. Historical aerials show the encroachment of mangroves onto Waipipi Roost and the surrounding intertidal flats over a period of 20-30 years. Auckland Council has acquired resource consent to undertake initial mangrove clearance on Waipipi Roost (2.88 ha). Mangrove clearance over and above what is currently proposed by Auckland Council will provide additional availability of roosting sites for coastal birds.

A preliminary BCM based on the options above has been developed to inform the draft CBMP (refer to **Appendix G**).

In addition to compensation actions described above, there exists further potential to create a high tide roost above mean high water springs (MHWS) on NZ Steel land adjacent to the Kahawai roost complex. During a site visit on 15 April 2021 (high tide of 3.9 m), significant numbers of South Island pied oystercatchers and pied stilt were present at the Kahawai roost prior to high tide. Closer to high water the birds were displaced and flew to grazed paddocks on the opposite side of the Waiuku Estuary. There did not appear to be a similarly attractive roosting area closer to the Kahawai roost. A closer roost on NZ Steel land would be preferred because the aim is to reduce energy expenditure, especially at times prior to birds migrating to their breeding habitats. Creation of a high tide roost on NZ Steel land should consider the following:

- Permanence;
- Material to create the roost, including the surficial covering material (e.g., shell hash);
- Predator control of species that pose a risk to coastal birds, weed control and fencing integrity to provide long term assurance and confidence in the site; and
- Small scale terrestrial vegetation clearance along the immediate coastal edge to enhance seaward visibility to improve roost quality.

If there are significant constraints around construction of a land-based high tide roost site on NZ Steel land, there is an opportunity to look for sites in the Waiuku Estuary to construct high tide roosts in the CMA. Constructed roosts have been shown to work effectively elsewhere in the Manukau Harbour (e.g., the Ambury foreshore roost created by Watercare after the removal of the oxidation ponds at the Mangere WWTP).

The creation of roosts that are further away from the Steel Mill is less desirable from an offset and compensation perspective (i.e., effort to address residual effects should be as close to the point of impact as possible). However, an artificial roost would provide encouragement for waders to use intertidal feeding grounds closer to the roost site and away from the Steel Mill discharge points.

Consideration of high tide roost construction should holistically consider the location in the Waiuku Estuary that would most benefit wading bird species.

An additional project to undertake mangrove removal at Pollok Spit, a significant high tide roost, is currently being investigated by Auckland Council. Depending on the status of this project, there is an opportunity to collaborate and provide additional support to enable the project objectives (i.e., enhancement of roosts) to be achieved. This could take the form of volunteer hours, physical removal of mangrove trees and ongoing mangrove seedling removal.

One of the key benefits of the CBMP approach is that the proposed compensation measures listed above do not preclude alternative opportunities that may arise through further consideration. During development of the CBMP, the type and quantum of compensation measures required to adequately address residual adverse effects on coastal birds will be determined through the objective application of the preliminary BCM (**Appendix G**).

For completeness, it is noted that compensation for coastal birds is being proposed <u>in addition</u> to the water quality improvements included in the ITA and Freshwater Reports (T+T 2024a, T+T 2024b). These improvements include enhancement of wetland margin and wetland areas in the Site, which would reduce sediment, metals, microbes and nutrients entering the CMA.

8.4 Assessment of the proposed coastal bird compensation package against NPSIB biodiversity compensation principles

Table 8.1 below sets out an assessment of the proposed coastal bird compensation measures against the biodiversity compensation principles defined in the NPSIB (Appendix 4).), as discussed above. Based on the assessment below, we consider that the proposed coastal bird compensation measures meet biodiversity compensation principles.

Table 8.1: Assessment of the proposed coastal bird compensation measures against biodiversity compensation principles

Compensation principle	NPSIB (2023) Appendix 4 Principles for biodiversity compensation	Assessment
1 Adherence to effects management hierarchy	Biodiversity compensation is a commitment to redress more than minor residual adverse effects, and should be contemplated only after steps to avoid, minimise, remedy, and offset adverse effects are demonstrated to have been sequentially exhausted.	We consider this principle to be met and exceeded because measures to firstly avoid then minimise effects (through water management processes) have been considered and exhausted. This approach is set out in the AEE (T+T, 2024c, Sections 5 and 7.4), including reference to consideration of alternative discharge points, on site contaminant sources and controls, NZ Steel's continual improvement programme and the BPO approach to the current discharges and relevant proposed consent conditions. Subsequently, steps to offset have also been considered and ruled out on the basis that the proposed measures to address '**moderate**' effects on coastal birds cannot meet the NPSIB definition of offsetting. This is due to difficulties with calculating

Compensation principle	NPSIB (2023) Appendix 4 Principles for biodiversity compensation	Assessment
		quantitative data on impacts and expected gains with adequate precision. Following efforts to avoid, minimise and then offset effects, biodiversity compensation measures are required to address residual effects. These measures are outlined in Section 8.3 and in the draft CBMP (T+T, 2024f).
2 When biodiversity compensation is not appropriate	Biodiversity compensation is not appropriate where indigenous biodiversity values are not able to be compensated for. Examples of biodiversity compensation not being appropriate include where: • (a) the indigenous biodiversity affected is irreplaceable or vulnerable; • (b) effects on indigenous biodiversity are uncertain, unknown, or little understood, but potential effects are significantly adverse or irreversible; • (c) there are no technically feasible options by which to secure a proposed net gain within acceptable timeframes.	We consider this principal to be met. This is because the impacts are not expected to result in a decline in the local coastal bird assemblage and net positive outcomes are expected through implementation of coastal bird habitat restoration and enhancement measures within acceptable timeframes (2 years as outlined in the BCM (**Appendix G**)).
3 Scale of biodiversity compensation	The indigenous biodiversity values lost through the activity to which the biodiversity compensation applies are addressed by positive effects to indigenous biodiversity (including when indigenous species depend on introduced species for their persistence), that outweigh the adverse effects.	We consider this principle to be met. This is on the basis that net positive outcomes are predicted by the BCM. These predicted outcomes will be verified via biodiversity outcome monitoring in the AOI and in the compensation sites as described in the CBMP (T+T, 2024f).
4 Additionality	Biodiversity compensation achieves gains in indigenous biodiversity above and beyond gains that would have occurred in the absence of the compensation, such as gains that are additional to any minimisation and remediation or offsetting undertaken in relation to the adverse effects of the activity.	We consider this principle will be met. The coastal bird habitat restoration and enhancement measures proposed would not otherwise occur.
5 Leakage	Biodiversity compensation design and implementation avoids displacing harm to other indigenous biodiversity in the same or any other location.	We consider this principle met to the extent possible. Mangrove management (selective removal and ongoing seedling management) is proposed to enhance existing roosts and intertidal foraging habitat. The management of mangrove will avoid or minimise impacts on mangrove-

Compensation principle	NPSIB (2023) Appendix 4 Principles for biodiversity compensation	Assessment
		associated biodiversity by only removing young mangroves in recently colonised sand/mudflats, and avoiding older, higher stature mangroves with higher biodiversity values.
6 Long-term outcomes	Biodiversity compensation is managed to secure outcomes of the activity that last as least as long as the impacts, and preferably in perpetuity. Consideration must be given to long-term issues around funding, location, management, and monitoring.	We consider this principle will be met. The proposed coastal bird restoration and enhancement activities are intended to provide benefits at least as long as the term of the consent. This includes maintaining mangrove free areas on roost sites and periodic mangrove seedling removal to maintain foraging habitat for the duration of consent. These management actions are included in the CBMP (T+T, 2024f), which is required by draft consent conditions.
7 Landscape context	Biodiversity compensation is undertaken where this will result in the best ecological outcome, preferably close to the impact site or within the same ecological district. The action considers the landscape context of both the impact site and the compensation site, taking into account interactions between species, habitats and ecosystems, spatial connections, and ecosystem function.	We consider this principle will be met. The proposed coastal bird habitat restoration and enhancement is in close proximity to the area of impact and will benefit the coastal bird assemblage that may potentially be impacted by project activities. Moreover, the proposed coastal bird compensation measures are expected to increase roost site and foraging habitat availability and thus increase ecological connectivity in the area.
8 Time lags	The delay between loss of, or effects on, indigenous biodiversity values at the impact site and the gain or maturity of indigenous biodiversity at the compensation site is minimised so that the calculated gains are achieved within the consent period or, as appropriate, a longer period (but not more than 35 years).	We consider that this principle will be met. The proposed coastal bird compensation gains are expected to be commence within 2 years of implementation. The BCM also accounts for time lag between commencement of impacts via water discharge and commencement of coastal bird gains at compensation sites via the application of a discount rate (Net Present Biodiversity Value). We note that both water discharge impacts and benefits to coastal birds from the proposed habitat restoration and enhancement actions will be ongoing.
9 Trading up	When trading up forms part of biodiversity compensation, the proposal demonstrates that the indigenous biodiversity gains are demonstrably greater or higher than those lost. The proposal also shows the values lost are not to Threatened or At Risk (declining) species or to species considered vulnerable or irreplaceable.	We consider that this principle will be met in part. Potential impacts are on Threatened or At Risk species as is the case in all instances where biodiversity compensation are proposed. The proposed biodiversity compensation package constitutes a trade-up in that potential impacts on coastal bird foraging

Compensation principle	NPSIB (2023) Appendix 4 Principles for biodiversity compensation	Assessment
		habitat will be compensated in part through an increase in roosting habitat availability. This is deemed a trade-up because high quality, functional coastal bird roosting sites in the local area and more broadly the Manukau harbour are significantly more threatened than the foraging habitat that is potentially affected by water discharge.
10 Financial contributions:	A financial contribution is only considered if: (a) there is no effective option available for delivering biodiversity gains on the ground; and (b) it directly funds an intended biodiversity gain or benefit that complies with the rest of these principles.	We consider this principle to be met as there are effective options available for delivering biodiversity gains on site and no financial contribution has been proposed.
11 Science and mātauranga Māori	The design and implementation of biodiversity compensation is a documented process informed by science, and mātauranga Māori.	We consider this principle to be met in part in that the assessment and effects management has been informed by professional expert opinion, underpinned by desktop and field investigations. Mana whenua have been involved in discussions regarding the proposed compensation actions and draft CBMP to ensure they have been developed with the benefit of mātauranga Māori.
12 Tangata whenua and stakeholder participation	Opportunity for the effective and early participation of tangata whenua and stakeholders is demonstrated when planning for biodiversity compensation, including its evaluation, selection, design, implementation, and monitoring.	We consider this principle will be met because there has and will continue to be tangata whenua participation in the process. NZ Steel has a long-standing relationship with Ngāti Te Ata and Ngāti Tamaoho and has undertaken specific engagement with both parties in relation to this application (as discussed in the AEE). NZ Steel has consulted with Ngāti Te Ata in the development of the proposed compensation package. NZ Steel will continue to consult with both Ngāti Te Ata and Ngāti Tamaoho on the design of the management plan and its implementation and subsequent monitoring.

Compensation principle	NPSIB (2023) Appendix 4 Principles for biodiversity compensation	Assessment
13 Transparency	The design and implementation of biodiversity compensation, and communication of its results to the public, is undertaken in a transparent and timely manner.	We consider this principle to be met through the assessment of effects and the application of a BCM to provide transparency on the design and implementation of the compensation package. NZ Steel will also communicate the results to the public through its long standing Environment Committee which includes public and community representation.

8.5 Marine Ecological Monitoring Programme

The marine ecological monitoring programme currently in place under the Existing Consents provides an extensive and robust data set against which the current application, and the ongoing effects of the operation of the Steel Mill, can be assessed.

The current marine ecological monitoring programme includes monitoring of the following elements:

- Metal contaminants and grain size in marine sediments at ten[69] locations every two years (zinc, copper, lead, cadmium and chromium);
- Benthic community health at any sediment contaminant monitoring sites that exceed the Council ERC-Red guideline value, and at the newly established control site regardless of contaminant concentrations; and
- Zinc, copper, population density, length, and condition of pacific oysters at six locations annually.

Monitoring sites are shown on Figure W-ME1 in Appendix E of the AEE. Further detail of the marine monitoring programme can be found in the Bioresearches (2022) report attached as **Appendix F**.

This current monitoring is considered appropriate for assessing the ongoing effects of the operation of the Mill (and more than adequate in the scenario where the EAF becomes operational) and should be continued. In order to strengthen this dataset further and assess the outcomes of any additional mitigation or compensation as a result of consent being granted, additions to the current monitoring programme are proposed.

The following indicative monitoring programme is proposed as part of the CBMP. The specific details of the monitoring will be informed by the type and quantum of compensation that is proposed as part of the CBMP but is anticipated to include:

- Seasonal coastal bird surveys to support the existing baseline surveys with a particular focus on proposed compensation actions such as constructed or enhanced roosts as part of the CBMP; and
- Coastal vegetation surveys where any vegetation management is proposed as part of the CBMP.

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[69] Note that the Ruakohua Dam Spillway already has a consent to discharge to the CMA and so sediment sampling is not technically required at the two Ruakohua sites. However, the Ruakohua sites will continue to be sampled in the short term (for sediment grain size and contaminants only) to provide further data to validate the DHI modelling and assist with the implementation of the Coastal Bird Management Plan.

In addition to the CBMP, the following additional monitoring is being developed and implemented to strengthen the existing monitoring programme and provide additional information to better understand effects and their drivers:

- In discussion with Auckland Council, it was recommended that a sediment contaminant and benthic ecology 'control' site was created, against which any changes at the ecology sites adjacent to the Steel Mill discharges could be assessed. It was recommended that this site be located where sedimentation rates and sediment metal accumulation are predicted to be minimal over the 35 year consent period, and close to the oyster monitoring control site in Taihiki Estuary. This site has now been established as of August 2021, see Section 5.6;
- It was also recommended that the Benthic Health Model (BHM) for mud and the Traits Based Index (TBI) be incorporated into the ecological scoring system, as per that used by Auckland Council. This will allow the effects from sedimentation and sediment metal accumulation to be better separated out. These metrics have now been incorporated into the programme as of August 2021, see Section 5.6.
- It was also recommended that benthic ecology monitoring be undertaken at the Northside A sediment site each time that sediment samples are collected regardless of contaminant status. This is to create a continuous record at this site so ecology trends that may be influenced by factors other than contaminants (such as muddiness and sedimentation) can be better understood. This monitoring is now included in the proposed conditions. Furthermore, to provide additional baseline information, benthic ecology was sampled at all monitored sediment contaminant monitoring sites during 2022/2023 monitoring, regardless of contaminant concentration status.
- Assessment of the additional monitoring proposed in the ITA Report at Site 1 (Brookside Rd) (Appendix G of the AEE) for the discharge to the North Drain to understand whether any of the ITA discharges are contributing to the possible increasing trend in total recoverable zinc, chromium and copper at the North Stream mangrove zone (MZ) site, and for zinc at the Outer Zone (OZ) site. Data analysis will occur as part of the ITA monitoring and then be compared to data from the marine sediment monitoring sites.

9 Applicability

This report has been prepared for the exclusive use of our client NZ Steel Ltd, with respect to the particular brief given to us and in accordance with the scope of work set out in our letter of engagement dated 17 June 2019 and associated variations. It may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

We understand and agree that our client will submit this report as part of an application for resource consent and that Auckland Council as the consenting authority will use this report for the purpose of assessing that application.

Tonkin & Taylor Ltd

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Appendix A EIANZ EcIAG (2018) modified guidelines summary tables

Appendix A Table 1: Criteria for assigning ecological value to estuarine and marine species

Ecological Value	Species
Very High	- 'Nationally Threatened' species (Nationally Critical, Nationally Endangered, Nationally Vulnerable) found in the ZOI* either permanently or seasonally.
High	- Species listed as Nationally 'At Risk' – Declining, found in the ZOI either permanently or seasonally.
Moderate	- Locally uncommon or distinctive species; or - Species listed as any other category of 'At Risk', found in the ZOI either permanently or seasonally.
Low	- Nationally and locally common indigenous species.
Negligible	- Exotic species, including pests, species having recreational value.

*In this case the Zone of Influence (ZOI) refers to all estuarine and marine water bodies and environments that could be potentially impacted by the Project. It includes the Project Site and any environments beyond the Project Area where 'indirect effects' such as discharges may extend (sometimes called the Study Area).

Appendix A Table 2: Characteristics of estuarine and marine areas/habitats and associated ecological values[70]

Ecological Value	Characteristics
Very High	- Benthic invertebrate community typically has very high diversity, species richness and abundance. - Benthic invertebrate community is dominated by taxa that are sensitive to organic enrichment, contaminants and mud and/or rated as 'Extremely Good' using the Auckland Council Benthic Health Index. - Marine sediments typically comprise < 20% silt and clay grain sizes (mud). - Surface sediment oxygenated with no anoxic sediment present. - Annual average sedimentation rates typically less than 1 mm above background levels. - Contaminant concentrations in surface sediment significantly below DGV and Auckland Council ERC-Orange effects threshold concentrations[71]. - Water column contaminant values typically at or better than ANZWQG 99% species protection level and/or scored as 'Excellent' on the Auckland Council Water Quality Index (WQI). - Fish community typically has very high diversity, species richness and abundance. - Invasive opportunistic and disturbance tolerant species absent. - Vegetation likely to be nationally important and recognised as such. - Macroalgae sequences intact and provides significant habitat for native fauna. - Habitat unmodified.

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[70] The characteristics of marine and estuarine sites with 'Negligible' to Very High ecological values were originally developed by Dr Sharon De Luca, Boffa Miskell Ltd, then modified further here, to guide valuing estuarine environments, and to provide a transparent approach that can be replicated. The characteristics have been accepted by decision-makers in Environment Court and Board of Inquiry hearings, including a number of NZTA projects (Transmission Gully, MacKays to Peka Peka, Ara Tūhono Project Puhoi to Warkworth and Warkworth to Wellsford Sections). Table 2 is based on the approach taken in these projects and has been further developed with additional available indices to improve its use for the current consent applications.

[71] ANZWQG (2018) Default Guideline Value concentrations, or Auckland Council's Environmental Response Criteria contaminant threshold concentrations (Auckland Regional Council, 2004).

High	• Benthic invertebrate community typically has high diversity, species richness and abundance. • Benthic invertebrate community contains many taxa that are sensitive to organic enrichment, contaminants and mud and/or rated as ‘Good’ using the Council Benthic Health Index. • Marine sediments typically comprise < 40% silt and clay grain sizes. • Surface sediment oxygenated. • Annual average sedimentation rates typically less than 2 mm above background levels. • Contaminant concentrations in surface sediment rarely exceed DGV and Auckland Council ERC-Orange effects threshold concentrations. • Water column contaminant values typically between ANZWQG 95% and 99% species protection levels and/or scored as ‘Good’ on the Auckland Council WQI. • Fish community typically has high diversity, species richness and abundance. • Invasive opportunistic and disturbance tolerant species largely absent. • Vegetation likely to be regionally important and recognised as such. • Macroalgae provides significant habitat for native fauna. • Habitat largely unmodified.
Moderate	• Benthic invertebrate community typically has moderate species richness, diversity and abundance. • Benthic invertebrate community has both tolerant and sensitive taxa to organic enrichment, contaminants and mud present and/or rated as ‘Moderate’ using the Auckland Council Benthic Health Index. • Marine sediments typically comprise < 60% silt and clay grain sizes. • Shallow depth of oxygenated surface sediment. • Annual average sedimentation rates typically less than 5 mm above background levels. • Contaminant concentrations in surface sediment generally below DGV-high or Auckland Council ERC-Red effects threshold concentrations. • Water column contaminant values typically between ANZWQG 90% and 95% species protection levels and/or scored as ‘Fair’ on the Auckland Council WQI. • Fish community typically has moderate species richness, diversity and abundance. • Few invasive opportunistic and disturbance tolerant species present. • Vegetation likely to be important at the level of the ecological district. • Macroalgae provides moderate habitat for native fauna. • Habitat modification limited.
Low	• Benthic invertebrate community degraded with low species richness, diversity and abundance. • Benthic invertebrate community dominated by organic enrichment tolerant, contaminant tolerant, and mud tolerant organisms with few/no sensitive taxa present and/or rated as ‘Poor’ using the Auckland Council Benthic Health Index. • Marine sediments dominated by silt and clay grain sizes (> 60%). • Surface sediment predominantly anoxic (lacking oxygen). • Annual average sedimentation rates typically less than 10 mm above background levels. • Elevated contaminant concentrations in surface sediment, above DGV-high or Auckland Council ERC-Red effects threshold concentrations.

	• Water column contaminant values typically between ANZWQG 80% and 90% species protection levels and/or scored as 'Marginal' on the Auckland Council WQI. • Fish community depleted with low species richness, diversity and abundance. • Invasive, opportunistic and disturbance tolerant species dominant. • Vegetation has limited ecological value other than as local habitat for tolerant native species. • Macroalgae provides minimal/limited habitat for native fauna. • Habitat highly modified.
Negligible	• Benthic invertebrate community degraded with very low species richness, diversity and abundance. • Benthic invertebrate community dominated by organic enrichment tolerant, contaminant tolerant and mud tolerant organisms with no sensitive taxa present and/or rated as 'Unhealthy with low resilience' using the Auckland Council Benthic Health Index. • Marine sediments dominated by silt and clay grain sizes (>80%). • Surface sediment anoxic (lacking oxygen). • Annual average sedimentation rates typically greater than 10 mm above background levels. • Elevated contaminant concentrations in surface sediment, above DGV-high effects threshold concentrations. • Water column contaminant values typically at or worse than ANZWQG 80% species protection levels and/or scored as 'Poor' on the Auckland Council WQI. • Fish community depleted with very low species richness, diversity and abundance. • Invasive, opportunistic and disturbance tolerant species highly dominant. • Vegetation/macroalgae absent or so sparse as to provide very limited ecological value. • Habitat extremely modified.

Appendix A Table 3: Summary of the criteria for describing the magnitude of effect

Magnitude	**Description**
Very High	Total loss of, or very major alteration to, key elements/features/ of the existing baseline conditions, such that the post-development character, composition and/or attributes will be fundamentally changed and may be lost from the site altogether; AND/OR Loss of a very high proportion of the known population or range of the element/feature.
High	Major loss or major alteration to key elements/features of the existing baseline conditions such that the post-development character, composition and/or attributes will be fundamentally changed; AND/OR Loss of a high proportion of the known population or range of the element/feature.
Moderate	Loss or alteration to one or more key elements/features of the existing baseline conditions, such that the post-development character, composition and/or attributes will be partially changed; AND/OR Loss of a moderate proportion of the known population or range of the element/feature.
Low	Minor shift away from existing baseline conditions. Change arising from the loss/alteration will be discernible, but underlying character, composition and/or

Magnitude	Description
	attributes of the existing baseline condition will be similar to pre-development circumstances or patterns; AND/OR Having a minor effect on the known population or range of the element/feature.
Negligible	Very slight change from the existing baseline condition. Change barely distinguishable, approximating to the 'no change' situation; AND/OR Having negligible effect on the known population or range of the element/feature.

Appendix A Table 4: Criteria for describing overall level of ecological effects. Overall level-of-effect categories are used to determine if residual effects management is required over and above measures to reduce the severity of effects through efforts to avoid, minimise, remedy and/or mitigate adverse effects. Usually, if the level of residual effect is assessed as being "Moderate" or greater, this warrants efforts to offset or compensate for these effects.

Magnitude of effect	Ecological Value				
	Very High	**High**	**Moderate**	**Low**	**Negligible**
Very High	Very High	Very High	High	Moderate	Low
High	Very High	Very High	Moderate	Low	Very Low
Moderate	High	High	Moderate	Low	Very Low
Low	Moderate	Low	Low	Very low	Very Low
Negligible	Low	Very low	Very low	Very low	Very Low
Positive	Net gain	Net gain	Net gain	Net gain	Net gain

Appendix B Coastal bird surveys summary

Appendix B Table 1: Coastal birds observed during May, August and October 2020 and January 2021 surveys, functional grouping and average number recorded. NSO = Northside to Southside Outfall, RS = Ruakohua Spillway, KNS = Kahawai to Lower North Stream. * denotes coastal birds listed as 'Specified highly mobile fauna' in Appendix 2 of the NPSIB.

Common name	**Species name**	**Threat status (NZTCS, 20217)**	**Functional group**	**Survey 2020 / 2021**	**Where observed and average number**		
					NSO	**RS**	**KNS**
Australasian gannet	*Morus serrator*	Not Threatened	Feed in the water column	May			
				August	1		
				October			
				January			
Banded dotterel*	*Charadrius bicinctus*	At Risk – Declining	Wader	May	0.2		0.2
				August			
				October			
				January			
Black-backed gull	*Larus dominicanus*	Not Threatened	Generalist	May	0.5		0.3
				August	3.5	0.2	2
				October	0.3	0.7	
				January	0.2		0.3
Black shag	*Phalacrocorax carbo*	At Risk – Relict	Feed in the water column and roosting in coastal fringe	May			
				August	0.7		
				October			
				January			
Canada goose	*Branta canadensis*	Introduced and naturalised	Generalist	May			
				August	9.2	1.5	
				October			
				January			
Caspian tern*	*Hydroprogne caspia*	Nationally vulnerable	Feed in the water column	May	1		0.2
				August	0.3		0.5
				October	0.3	0.5	
				January	0.7		0.7
Eastern bar-tailed godwit*	*Limosa lapponica*	At Risk – Declining	Wader	May			
				August	0.5		11.7
				October			87.8
				January	24.8		19.5
Kingfisher	*Todiramphus sanctus*	Not Threatened	Feed in the water column	May		0.2	0.7
				August	0.2	0.5	3.5
				October	0.2	0.2	0.5
				January			0.3
Lesser knot (Red knot)*	*Calidris canutus*	At Risk – Declining	Wader	May			
				August			

Common name	**Species name**	**Threat status (NZTCS, 20217)**	**Functional group**	**Survey 2020 / 2021**	**Where observed and average number**		
					NSO	**RS**	**KNS**
				October			13.5
				January	0.2		36
Little black shag	*Phalacrocorax sulcirostris*	At Risk – Naturally uncommon	Feed in the water column and roosting in coastal fringe	May	0.5		
				August			
				October			
				January			
Little shag	*Phalacrocorax melanoleucos*	At Risk – Relict	Feed in the water column and roosting in coastal fringe	May	1	1.5	
				August	1	0.5	
				October			
				January	0.3		0.3
Mallard	*Anas platyrhynchos*	Introduced and naturalised	Feed in the water column	May	26.8	0.3	26.8
				August	2.8		6.5
				October	1	0.7	16.5
				January	1.8		
Pied shag*	*Phalacrocorax varius*	At Risk – Recovering	Feed in the water column and roosting in coastal fringe	May	1.5	0.74	
				August	2.7		
				October			
				January	4.8		
Pied stilt	*Himantopus himantopus*	Not Threatened	Wader	May	18.8	8.3	4.5
				August	15.7	1.8	8.8
				October	0.2		
				January	17.7	0.2	3.2
Pukeko	*Porphyrio melanotus*	Not Threatened	Generalist	May			
				August			
				October			
				January			0.2
Red-billed gull*	*Larus novaehollandiae*	At Risk – Declining	Generalist	May	0.8	0.3	0.3
				August		1.2	
				October			
				January			
Royal spoonbill	*Platalea regia*	At Risk – Naturally uncommon	Wader	May		0.2	
				August			3
				October	2.3		2
				January			
	Haematopus finschi	At Risk – Declining	Wader	May	62.7	14.7	83
				August	11.6	1.5	13.5

Common name	**Species name**	**Threat status (NZTCS, 20217)**	**Functional group**	**Survey 2020 / 2021**	**Where observed and average number**		
					NSO	**RS**	**KNS**
South Island pied oystercatcher*				October	7.3	6.8	13.5
				January	82.5	0.2	50.3
Spur-winged plover	*Vanellus miles*	Not Threatened	Wader	May			0.2
				August			
				October			0.3
				January			
Variable oystercatcher*	*Haematopus unicolor*	At Risk – Recovering	Wader	May	1.3	0.2	0.7
				August	1		0.2
				October	0.2	0.7	0.7
				January	0.8		1.5
White-faced heron	*Egretta novaehollandiae*	Not Threatened	Wader and roosting in coastal fringe	May	7.3	35.3	17.3
				August	1.3	2.8	7.8
				October	4.8	22.5	20
				January	2	11.2	15.2
White-fronted tern*	*Sterna striata*	At Risk – Declining	Feed in the water column	May	0.2		
				August			
				October			
				January	0.5	0.7	
Wrybill*	*Anarhynchus frontalis*	Nationally increasing	Wader	May			
				August			0.5
				October			
				January			

Appendix C Detailed magnitude and overall level of effects assessment to support Section 6.6 “Effects on estuarine habitats”

C1 Magnitude of effect on individual habitat attributes

This section discusses the magnitude of effects of the Steel Mill discharges on the individual habitat attributes of water quality, sediment quality, benthic ecology and shellfish quality separately. These individual effects are then combined into an overall habitat assessment of the magnitude and overall level of effects of the Steel Mill discharge modelling scenarios on the combined habitat values.

C1.1 Effects on water quality

Degraded water quality due to elevated levels of sediment can reduce visibility, clog gills and smother benthic organisms (Wilber and Clarke, 2011; Gibbs and Hewitt, 2004; Hewitt *et al.*, 2001). Elevated contaminant levels can have toxic effects on marine life, particularly sensitive larval life stages.

T+T has conducted a review of existing water quality data for the Steel Mill discharges to the streams and to the CMA (T+T, 2024a). Some of the parameters of interest were found to regularly exceed relevant Australia and New Zealand Guidelines for Fresh and Marine Water Quality (ANZWQG, 2018) or consent-based limits for the discharges that enter the North Drain, Kahawai Stream, Ruakohua Stream, and at the Northside and Southside Outfalls (**Table 3.1**).

The highlighted exceedances in **Table 3.1** suggest the discharges contain contaminants, particularly heavy metals, that could result in adverse effects on water quality in mixing zones within both the freshwater environment and the CMA. Adverse effects on freshwater quality are covered in the Freshwater Ecological Assessment Report (Appendix H of the AEE).

The current and historical state of marine water quality, based on monitoring to date, are detailed in Bioresearches (2022), and summarised in Section 5.4. The current and potential future states of marine water quality based on modelling are detailed in DHI (2022).

Based on this information, the primary contaminant of concern for the Steel Mill discharges to the CMA is zinc, due to the most pronounced exceedances of ANZWQG (2018) guidelines (T+T 2024a, DHI 2022). Furthermore, the Steel Mill currently contributes around 62.4% of the total zinc load to the Waiuku Estuary (DHI 2022). As such, zinc is likely to require the largest mixing zone of any of the contaminants to meet ANZWQ (2018) guidelines (DHI 2022). However, temperature and salinity effects are likely to require a similar sized mixing zone to meet relevant existing Consent Limits and ecological guidelines (DHI 2022). Therefore, rather than assessing the effects of each individual contaminant, zinc (and to a lesser extent temperature and salinity) have been used to assess the greatest potential extent of effect on water column quality. i.e., where zinc, temperature and salinity guidelines are being met, other contaminant guidelines are also very likely to be met, and as such do not need to be assessed individually.

With the existing treatment ponds and Mill operations in place, the modelled mixing extent for the Northside Outfall 95th percentile zinc concentrations extends towards the northern and western edge of the existing consented mixing zone (approximately 200 m radial distance out from the Northside Outfall (DHI 2022, **Figure 5.2**) before meeting the 99% SPL in the updated 2020 ANZWQ Guidelines. The most permissive ANZWQ Guidelines for dissolved zinc (i.e., the 80% SPL in the draft 2020 guideline) are only exceeded within the first 60 m of this zone (**Figure 5.3**). In comparison, 95th percentile copper concentrations require a smaller mixing zone to meet guidelines (DHI 2022).

For the Southside Outfall discharge the modelled mixing extent for zinc and copper is much smaller than the Northside. The 95th percentile zinc concentrations only extend approximately 50 m radial distance out from the Southside Outfall before meeting the 99% SPL (see DHI 2022 Section 4).

However, based on the criteria in ANZWQG (2018) the CMA is considered to be a ‘Highly disturbed system’ in the 100 m closest to the Northside Outfall discharge, and as such, the 80% SPL guideline is appropriate to apply in this area.

Whilst ANZWQG (2018) 99% SPLs may be met for dissolved metals at the edge of the modelled mixing extent a proportion of the metal load leaves the modelled mixing extent attached to sediment particles. It is this particulate metal load from the Steel Mill which contributes to increasing sediment metal concentrations in the wider ZOI over the 35 year consent period as predicted by the DHI modelling. This is discussed further in the next section.

Water quality is predicted to remain degraded to the levels described above (but not worsen) if the current discharge quality is maintained over 35 years (DHI 2022, T+T 2024a).

Summary of magnitude of effect on water quality

The magnitude of effect on water quality within the modelled mixing extent of the Northside and Southside Outfalls is considered to be **‘Moderate’ to ‘Very High’**, dropping to a **‘Low’** level of effect outside the modelled mixing extent. This effect applies both in the short term and over the 35 year consent period.

Appendix C Table 1: Summary of the magnitude of effects of the discharges on water quality inside the modelled mixing extent and within the wider ZOI over the short term and over the 35 year consent term

	Discharge effects	**Inside modelled mixing extent**	**Outside modelled mixing extent and within ZOI**
Magnitude of effect in the short term on the Receiving Environment if the Steel Mill operations continued	Elevated zinc, copper, TSS, temperature, and reduced salinity	‘Moderate’ to ‘Very High’	‘Low’
Magnitude of effect **over the 35 year consent term** on the Receiving Environment if the Steel Mill operations continued	Ongoing Elevated zinc, copper, TSS, temperature, and reduced salinity	‘Moderate’ to ‘Very High’	‘Low’

C1.2 Effects on sediment quality

Note that while the ZOI covers the Taihiki Estuary and the modelling outputs in the DHI (2022) report also show sediment and metal accumulation in Taihiki Estuary, the sediment and metal loads used in the modelling are only derived from catchments draining to the Waiuku Estuary. That is the model outputs do not include sediment and metal accumulation that could be occurring in the Taihiki Estuary from inputs of sediment and metals from Taihiki Estuary catchments. This approach was taken so that the NZ Steel discharges could be put in the more relevant context of the Waiuku Estuary catchment discharges, and to simplify the modelling process.

Contaminants

*With the treatment ponds in place, the DHI (2022) modelling predicts that the Steel Mill will contribute to small increases in concentrations of zinc, and to a lesser extent copper, in sediments in several areas across the ZOI outside the modelled mixing extent over the 35 year consent period (**Figure Appendix C.1**). However, these increases over time are smaller than those driven by other Waiuku Estuary catchment sources (see DHI 2022 for further figures).*

The Bioresearches (2022) monitoring for total recoverable metals at the North Stream mangrove (MZ) and outer zone (OZ) sites indicates that zinc, chromium and copper may be increasing. While the concentrations were classified as ERC 'Green' the increases here suggest an investigation of the source(s) should be considered for future monitoring.

Based on recent monitoring results for total recoverable metals at Outfall sites Northside A and B, and Southside C, zinc, lead, chromium and cadmium may also have increased since 2017, particularly for zinc. However, as discussed in Section 5.5 and DHI (2022) some of this increase could be attributable to climatic factors and/or technical issues with the treatment systems that have since been rectified.

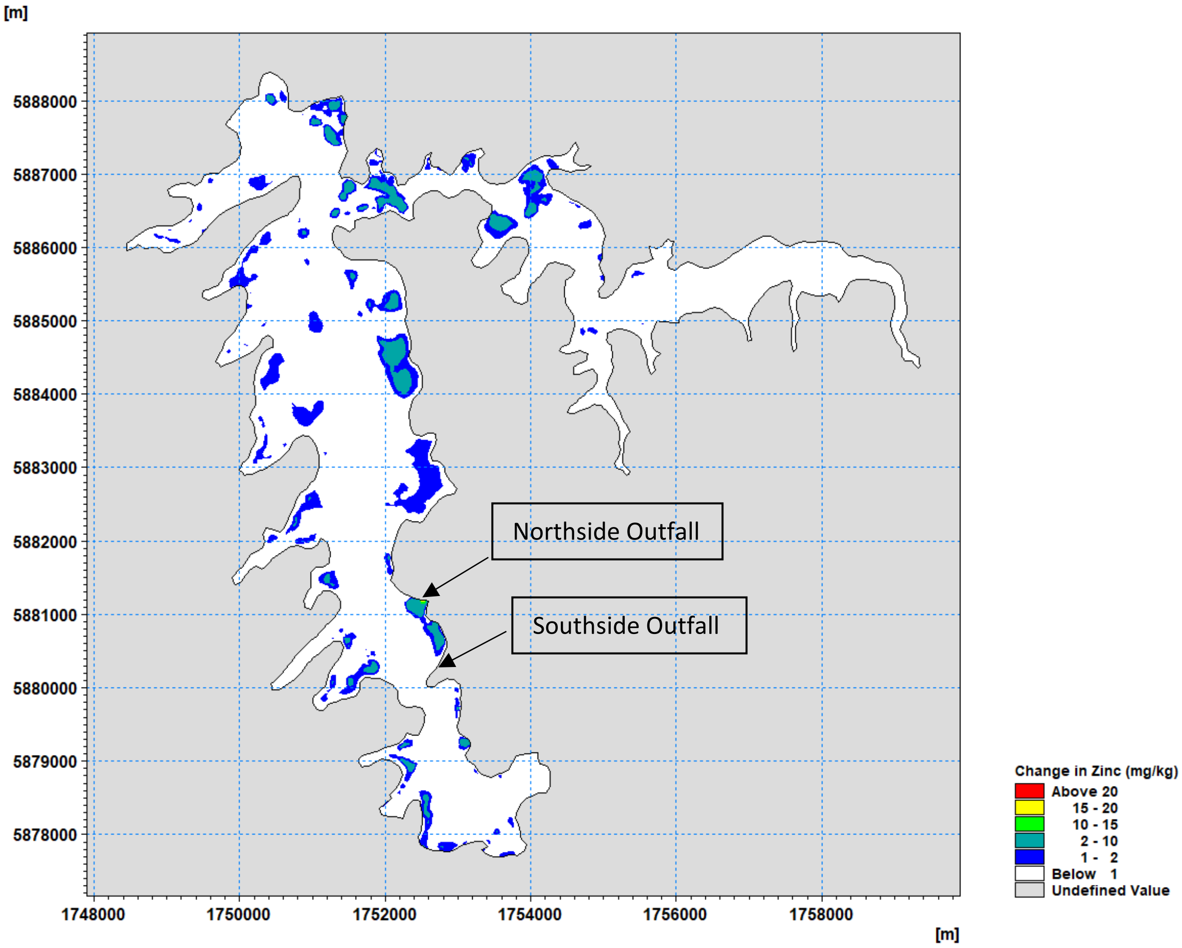

Figure Appendix C.1: Change in surface sediment Zinc concentration (mg/kg) 35 years from present day with just NZ steel inputs of particulate Zinc. A maximum change of 35.2 mg/kg is predicted to occur along the upper fringes of the inter-tidal area near the Northside discharge. (taken from DHI 2022 Figure 7-8).

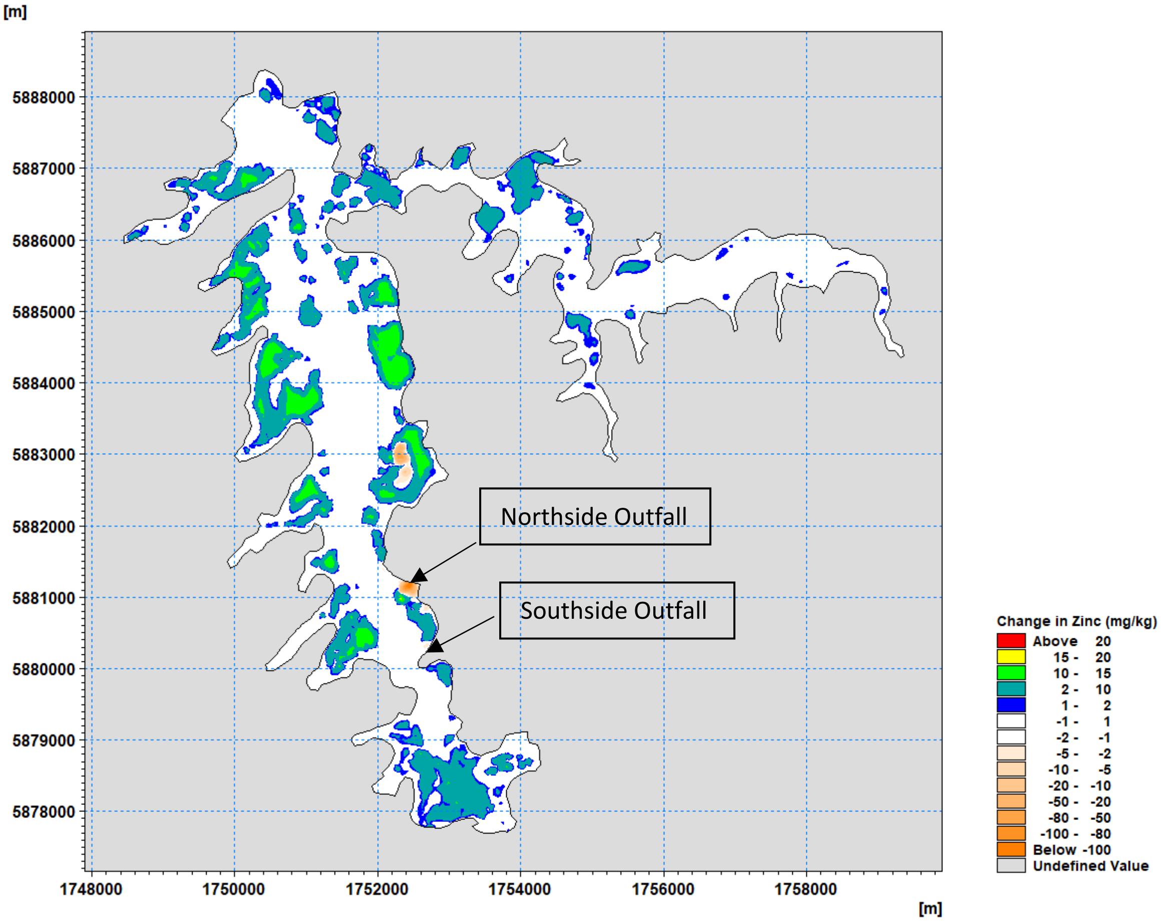

Figure Appendix C.2: Change in surface sediment Zinc concentration (mg/kg) 35 years from present day for the "discharges ceased" scenario. A maximum increase of Zinc of 22.0 mg/kg occurs due to the ongoing input of catchment derived Zinc while around the Northside discharge decreases in maximum concentrations of up to 120.9 mg/kg occur. (taken from DHI 2022 Figure 7-15).

Muddiness

For muddiness there is only current monitoring data to assess the magnitude of effect as the model focusses on sedimentation rate. However, given the monitoring to date and the modelling of sedimentation rates, the Steel Mill is only expected to have a small influence on changes in muddiness over time when compared to the influence of sediment sources from the wider Waiuku Estuary catchment.

Sedimentation

For sedimentation the model predicts that the Northside Outfall discharge will influence sedimentation rates on an annual average basis across the ZOI over the 35 year period as shown in **Figure Appendix C.3**. Sedimentation rates immediately adjacent to the Northside Outfall are up to 5.6 mm/yr from the Northside discharge alone, reducing to a few mm/yr closer to the channel. Rates are estimated to be up to 1.4 mm/yr in the area around the Southside Outfall, 4.1 mm/yr in the embayment offshore of the Lower North Stream and up to 0.2 mm/yr in the embayment offshore of the Kahawai Stream based on the outflows from these discharge points to the CMA alone. The individual contributions from the Steel Mill discharges and Streams to these rates are discussed in more detail in DHI (2022).

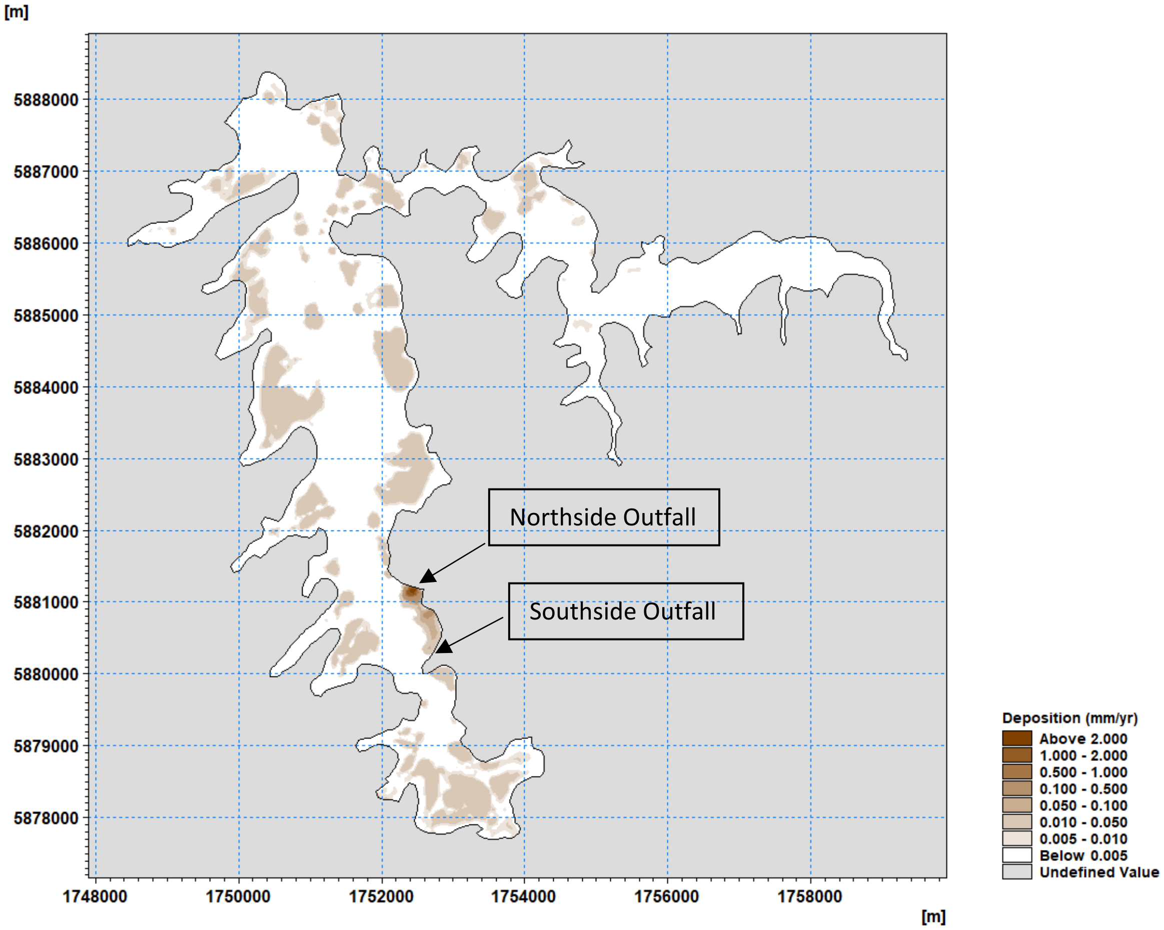

Figure Appendix C.3: Annual average Depositional footprint of sediment for NZ Steel Northside discharge (taken from DHI 2022 Figure C-1). The maximum predicted level of deposition near the Northside discharge is 5.6 mm/yr.

Summary of magnitude of effects on overall sediment quality:

- **Modelling Scenario 1** – **'Negligible'** magnitude of effect in the modelled mixing extent in the short term **based on** a lag in response time for sediment quality to recover after discharges cease.
- **Modelling Scenario 2** – **'Negligible'** magnitude of effect outside the modelled mixing extent in the short term is **based on** a lag in response time for sediment contaminant concentrations outside the modelled mixing extent to improve after discharges cease, and continued levels of sedimentation and sediment muddiness driven by catchment sources other than the Steel Mill.
- **Modelling Scenario 3** – **'High'** magnitude of effect in the modelled mixing extent over the 35 year consent term **based on** a substantial improvement in sediment quality for contaminants – ERC Red to ERC Green for zinc if discharges were to cease. Marked improvement in sedimentation rates directly adjacent to the Northside Outfall. Small improvement in copper concentrations and possibly sediment muddiness. However, background levels of sedimentation and sediment muddiness remain high over this period as they are strongly driven by catchment sources other than the Steel Mill.
- **Modelling Scenario 4** – **'Low'** magnitude of effect outside the modelled mixing extent over the 35 year consent term **based on** a small improvement in sediment contaminant

concentrations if discharges were to cease but similar continued levels of sedimentation and sediment muddiness driven by catchment sources other than the Steel Mill.

Appendix C Table 2: Summary of the magnitude of effects of the discharges on overall sediment quality inside the modelled mixing extent and within the wider ZOI over the short term and over the 35 year consent term

	Discharge effects	**Inside modelled mixing extent**	**Outside modelled mixing extent but within ZOI**
Magnitude of effect in the short term on the Receiving Environment if the Steel Mill operations continued	Zinc, copper, TSS increasing sediment contaminants, muddiness and sedimentation	‘Negligible’	‘Negligible’
Magnitude of effect over the 35 year consent term on the Receiving Environment if the Steel Mill operations continued	Zinc, copper, TSS increasing sediment contaminants, muddiness and sedimentation	‘High’	‘Low’

C1.3 Effects on benthic ecological health

The pattern of effects on benthic ecology generally follows that for sediment quality, and to a lesser extent water quality, as these are major drivers of benthic health. As such, benthic ecology is predicted to remain broadly the same in the short term and improve to a certain extent over time if the Steel Mill discharges ceased, particularly within the modelled mixing extent closest to the Northside Outfall. However, much of the effect on sediment muddiness and sedimentation across the wider ZOI is driven by sources of sediment other than the Steel Mill. As such the recovery in benthic ecological health outside the modelled mixing extent with the Steel Mill discharges ceased is unlikely to be substantial, except perhaps in the depositional area offshore of the mouth of the North Stream.

Summary of magnitude of effects on benthic ecology

- **Modelling Scenario 1** – **‘Low’** magnitude of effect in the modelled mixing extent in the short term **based on** a lag in response time for sediment quality and benthic ecology to recover after discharges cease.
- **Modelling Scenario 2** – **‘Negligible’** magnitude of effect outside the modelled mixing extent in the short term **based on** a lag in response time for sediment contaminant concentrations outside the modelled mixing extent to improve and continued levels of sedimentation and sediment muddiness driven by catchment sources other than the Steel Mill.
- **Modelling Scenario 3** – **‘Moderate’** magnitude of effect in the modelled mixing extent over the 35 year consent term **based on** a substantial improvement in sediment quality for contaminants (ERC Red to ERC Green) and on sedimentation rates in close proximity to the Northside Outfall if the Steel Mill discharges ceased. These changes will have a flow on effect on improved benthic ecology. However, sedimentation and sediment muddiness are not likely to improve substantially over this period (except directly adjacent to the Northside Outfall) as they are mainly driven by catchment sources other than the Steel Mill.
- **Modelling Scenario 4** – **‘Low’** magnitude of effect outside the modelled mixing extent over 35 years **based on** a small improvement in sediment contaminant concentrations outside the modelled mixing extent if the Steel Mill discharges ceased (with somewhat larger

improvements offshore of the mouth of the North Stream), and continued levels of sedimentation and sediment muddiness driven by catchment sources other than the Steel Mill.

Appendix C Table 3: Summary of magnitude of effects of the discharges on benthic ecology inside the modelled mixing extent and within the wider ZOI over the short term and over the 35 year consent term

	Discharge effects	**Inside modelled mixing extent**	**Outside modelled mixing extent but within ZOI**
Magnitude of effect in the short term on the Receiving Environment if the Steel Mill operations continued	Zinc, copper, TSS, increasing sediment contaminants, muddiness and sedimentation	'Low'	'Negligible'
Magnitude of effect over the 35 year consent term on the Receiving Environment if the Steel Mill operations continued	Zinc, copper, TSS, increasing sediment contaminants, muddiness and sedimentation	'Moderate'	'Low'

C1.4 Effects on shellfish

Metal concentrations in the water column, and therefore in shellfish, are not forecasted to change over 35 years if the existing discharge quality levels are maintained. However, they would improve substantially, perhaps to levels similar to the Taihiki Control site, if the Steel Mill discharges ceased.

Based on recent monitoring results at Outfall sites Northside N6a, N5, N10, S3a and S5a, zinc may have increased between 2019 and 2020. However, as discussed in Section 5.5 and DHI (2022) some of this increase could be attributable to climatic factors and/or technical issues with the treatment systems that have since been rectified. Metal concentrations in shellfish flesh at all sites (except S5a) have since dropped in 2021.

Summary of magnitude of effects on shellfish

- **Modelling Scenario 1** – **'Low'** magnitude of effect in the modelled mixing extent in the current day between the operational Steel Mill with existing mitigation and the Steel Mill discharges ceased **based on** a lag in response time for shellfish quality to improve after discharges cease.
- **Modelling Scenario 2** – **'Moderate'** magnitude of effect in the modelled mixing extent over the 35 year consent term between the operational Steel Mill with existing mitigation and the Mill discharge ceased **based on** a substantial improvement in long term water quality and sediment quality for contaminants (ERC Red to ERC Green) and the flow on effect of that on improved shellfish quality. However, suspended sediment concentrations are not likely to improve substantially over this period as they are mainly driven by catchment sources other than the Steel Mill.
- **Modelling Scenario 3** – **'Negligible'** magnitude of effect outside the modelled mixing extent in the current day between the operational Steel Mill with existing mitigation and the Steel Mill discharge ceased **based on** a lag in response time for shellfish quality to improve outside the modelled mixing extent, and continued levels of suspended sediment driven by catchment sources other than the Steel Mill.

- **Modelling Scenario 4** – **‘Negligible’** magnitude of effect outside the modelled mixing extent over the 35 year consent term between the operational Steel Mill with existing mitigation and the Mill discharge ceased **based on** a small improvement in long term water quality and sediment quality for contaminants (with somewhat larger improvements offshore of the mouth of the North Stream) and the flow on effect of that on improved shellfish quality. However, suspended sediment levels are not likely to improve substantially over this period as they are mainly driven by catchment sources other than the Steel Mill.

Appendix C Table 4: Summary of magnitude of effects of the discharges on shellfish inside the modelled mixing extent and within the wider ZOI over the short term and over the 35 year consent term

	Discharge effects	**Inside modelled mixing extent**	**Outside modelled mixing extent but within ZOI**
Magnitude of effect in the short term on the Receiving Environment if the Steel Mill operations continued	Zinc, copper, TSS in the water column and sedimentation	‘Low’	‘Negligible’
Magnitude of effect over the 35 year consent term on the Receiving Environment if the Steel Mill operations continued	Zinc, copper, TSS in the water column and sedimentation	‘Moderate’	‘Negligible’

C2 Magnitude and overall level of effect on overall estuarine habitat values

Estuarine habitat values in the CMA, both within and outside the modelled mixing extent, and both in the short term (a few tidal cycles) and the longer term (35 year consent period), have been determined based on the combination of habitat elements in Sections 5.4 to 5.7 assessed against **Appendix A Table 2** and summarised in Section 6.6. These habitat elements include: water, sediment and shellfish quality, and benthic ecological health.

C2.1 Short term effects on habitat values within the modelled mixing extent (Modelling Scenario 1)

- Based on **Appendix A Table 2**, and the estuarine habitat characteristics described in Section 5, the overall habitat **value** in the modelled mixing extent over the short term with continued operation of the Steel Mill is considered to be **‘Negligible’ to ‘Low’.**
- Were the Steel Mill discharges to cease it is considered that a greater proportion of habitat **value** overall would be **‘Low’** but some values in the area would still be **‘Negligible’** in the short term. This is predominantly due to improved water quality and reduced toxicity and sediment effects to both benthic organisms and those utilising the water column. However, sediment quality will not improve substantially in the short term, as sediment contaminant concentrations and muddiness take time to respond to changes in contaminant loads and poor benthic ecological health is also driven by sediment loads from the wider catchment.

The difference between these two habitat values constitutes the magnitude of effect of the Steel Mill continuing operations in the short term. Based on **Appendix A Table 3** it is therefore considered that the **magnitude** of effect in the short term is ‘Moderate’.

Based on a **'Moderate' magnitude** of effect on **'Low'** habitat **values,** and the criteria in **Appendix A Table 3**, the **overall** level of effect of in the short term of continued operations of the Steel Mill in the modelled mixing extent in the short term is considered to be **'Low'.**

C2.2 Short term effects on habitat values in the wider ZOI (Modelling Scenario 2)

- Based on **Appendix A Table 2**, and the estuarine habitat characteristics described in Section 5, the overall habitat value outside the modelled mixing extent (but inside the ZOI) over the short term with continued operation of the Steel Mill is considered to predominantly be 'Moderate'
- Were the Steel Mill discharges to cease it is considered that habitat value overall would also be 'Moderate' in the short term, predominantly due to similar water and sediment effects on both benthic organisms and those utilising the water column as much of the ecological effect in the wider ZOI is driven by sediment and contaminant loads from the wider catchment. Furthermore, sediment quality will not improve substantially in the short term, as sediment contaminant concentrations and muddiness take time to respond to changes in contaminant loads from the Steel Mill.

The difference between these two habitat values constitutes the magnitude of effect of the Steel Mill continuing operations. Based on **Appendix A Table 3** it is therefore considered that the **magnitude** of effect is '**Negligible'**.

Based on a **'Negligible' magnitude** of effect on **'Moderate'** habitat **values,** and the criteria in **Appendix A Table 3**, the **overall** level of effect of continued operations of the Steel Mill outside the modelled mixing extent in the short term is considered to be **'Very Low'.**

Appendix C Table 5: Summary of magnitude of effects of the discharges on estuarine habitat inside the modelled mixing extent and within the wider ZOI over the short term and after 35 years

Summary of Effects on estuarine habitat values in the short term	Inside modelled mixing extent	Outside modelled mixing extent and within ZOI
Estuarine habitat values – Steel Mill operational, short term	'Negligible' to 'Low'	'Moderate'
Estuarine habitat values – Steel Mill discharges ceased, short term	'Low'	'Moderate'
Magnitude of effect in the short term on the Receiving Environment if the Steel Mill operations continued	'Moderate'	'Negligible'
Greatest overall level of effect in the short term on the Receiving Environment if the Steel Mill operations continued	'Low'	'Very Low'

C2.3 35 Year consent term effects on general habitat values inside the modelled mixing extent (Modelling Scenario 3)

- Based on **Appendix A Table 2**, and the general habitat characteristics described in Section 5, the overall habitat **value** in the modelled mixing extent over the consent term with continued operation of the Steel Mill is considered to be **'Negligible' to 'Low'**
- Were the Steel Mill discharges to cease it is considered that habitat **value** overall would improve to **'Moderate'** over the consent term, predominantly due to improved water quality and reduced toxicity from zinc, copper, temperature and salinity changes, and reduced

sediment effects on both benthic organisms and those utilising the water column. Sediment quality is also predicted to improve substantially, with maximum sediment zinc concentrations predicted to drop by more than 40%, moving from ERC-Red to ERC-Green levels. Sediment deposition rate will also reduce by more than 2 mm/yr.

The difference between these two habitat values constitutes the magnitude of effect of the Steel Mill continuing operations. Based on **Appendix A Table 3** it is therefore considered that the **magnitude** of effect is **'Moderate' to 'High'**.

Based on a **'Moderate' to 'High' magnitude** of effect on **'Moderate'** habitat **values,** and the criteria in **Appendix A Table 3**, the **overall** level of effect of continued operations of the Steel Mill in the modelled mixing extent over the consent term is considered to be **'Moderate'.**

C2.4 35 year consent term effects on estuarine habitat values in the wider ZOI (Modelling Scenario 4)

- Based on **Appendix A Table 2**, and the general habitat characteristics described in Section 5, the overall habitat **value** outside the modelled mixing extent (but inside the ZOI) over the consent term with continued operation of the Steel Mill is considered to predominantly be **'Low' to 'Moderate'**
- Were the Steel Mill discharges to cease it is considered that habitat **value** overall would be **'Low' to 'Moderate'** in 35 years time, predominantly due to similar water and sediment effects on both benthic organisms and those utilising the water column (with somewhat larger improvements offshore of the mouth of the North Stream).

The difference between these two habitat values constitutes the magnitude of effect of the Steel Mill continuing operations. Based on **Appendix A Table 3** it is therefore considered that the **magnitude** of effect is '**Negligible'**.

Based on a **'Negligible' magnitude** of effect on **'Moderate'** habitat **values,** and the criteria in **Appendix A Table 3**, the **overall** level of effect of continued operations of the Steel Mill outside the modelled mixing extent over the 35 year consent term is considered to be **'Very Low'.**

Appendix C Table 6: Summary of the magnitude and overall level of effects on estuarine habitat values

Summary of Effects on Estuarine habitat values over 35 years	Inside modelled mixing extent	Outside modelled mixing extent and within ZOI
Estuarine habitat values over the 35 year consent term – Steel Mill operational	'Negligible' to 'Low'	'Low' to 'Moderate'
Estuarine habitat values over the 35 year consent term – Steel Mill discharges ceased	'Moderate'	'Moderate'
Magnitude of effect over the 35 year consent term on the Receiving Environment if the Steel Mill operations continued	'Moderate' to 'High'	'Negligible' to 'Low'
Greatest overall level of effect over the 35 year consent term on the Receiving Environment if the Steel Mill operations continued	'Moderate'	'Low'

Appendix D Detailed overall ecological effects tables for Modelling Scenarios 1 to 4

Appendix D Table 1: Summary of short-term[72] ecological effects inside the Receiving Environment modelled mixing extent (but note this area constitutes a small spatial scale) (Modelling Scenario 1).

Habitat/species type	Ecological values inside the Receiving Environment modelled mixing extent – short term	Greatest Magnitude of effect inside the Receiving Environment modelled mixing extent - short term	Potential EcIAG overall level of effect inside the Receiving Environment modelled mixing extent - short term
Estuarine habitat	‘Negligible’ to ‘Low’	‘Moderate’	‘Low’
Fish	‘High’	‘Low’	‘Low’
Marine Mammals	‘Very High’	‘Negligible’	‘Low’
Coastal vegetation	‘Moderate’ to ‘High’	‘Negligible’	‘Very Low’
Coastal birds	‘Very High’	‘Low’	‘Moderate’

Appendix D Table 2: Summary of ecological effects over the 35 year consent term inside the Receiving Environment modelled mixing extent (but note this area constitutes a small spatial scale) (Modelling Scenario 3).

Habitat/species type	Ecological values inside the Receiving Environment modelled mixing extent - over the 35 year consent term	Greatest Magnitude of effect inside the Receiving Environment modelled mixing extent - over the 35 year consent term	Potential EcIAG overall level of effect inside the Receiving Environment modelled mixing extent - over the 35 year consent term
Estuarine habitat	‘Low’ to ‘Moderate’	‘‘Moderate’ to ‘High’	‘Moderate’
Fish	‘High’	‘Moderate’	‘High’
Marine Mammals	‘Very High’	‘Negligible’	‘Low’
Coastal vegetation	‘Moderate’ to ‘High’	‘Low’	‘Low’
Coastal birds	‘Very High’	‘Low’ to ‘Moderate’	‘Moderate’ to ‘High’

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[72] For the purposes of this assessment short-term is considered to be after a few tidal cycles once the discharge water is no longer discernible from other estuary water.

Appendix D Table 3: Summary of short-term ecological effects on the Receiving Environment outside the modelled mixing extent but within the ZOI (Modelling Scenario 2).

Habitat/species type	**Ecological values outside the Receiving Environment modelled mixing extent – short term**	**Greatest Magnitude of effect outside the Receiving Environment modelled mixing extent - short term**	**Potential EcIAG overall level of effect outside the Receiving Environment modelled mixing extent - short term**
Estuarine habitat	‘Moderate’	‘Negligible’	‘Very Low’
Fish	‘High’	‘Negligible’	‘Very Low’
Marine Mammals	‘Very High’	‘Negligible’	‘Low’
Coastal vegetation	‘Moderate’ to ‘High’	‘Negligible’	‘Very Low’
Coastal birds	‘Very High’	‘Negligible’	‘Low’

Appendix D Table 4: Summary of ecological effects over 35 years on the Receiving Environment outside the modelled mixing extent but within the ZOI (Modelling Scenario 4).

Habitat/species type	**Ecological values outside the Receiving Environment modelled mixing extent - 35 years**	**Greatest Magnitude of effect outside the Receiving Environment modelled mixing extent - 35 years**	**Potential EcIAG overall level of effect outside the Receiving Environment modelled mixing extent - 35 years**
Estuarine habitat	‘Moderate’	‘Negligible’ to ‘Low’	‘Low’
Fish	‘High’	‘Low’	‘Low’
Marine Mammals	‘Very High’	‘Negligible’	‘Low’
Coastal vegetation	‘Moderate’ to ‘High’	‘Negligible’	‘Very Low’
Coastal birds	‘Very High’	‘Low’	‘Moderate’

Appendix E DHI modelling report

NZ Steel Waiuku Discharge Assessment

New Zealand Steel

Report 44801638/01

October 2022

NZ Steel Waiuku Discharge Assessment

Prepared for	New Zealand Steel
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CONTENTS

Executive Summary

This report provides details of the work carried out to assess the discharges from the NZ Steel Mill to the Waiuku Estuary and includes quantification of water column effects relating to salinity, temperature and dissolved metals as well as predicted sediment deposition rates due to both the NZ Steel discharges and loads from the surrounding catchments, and the current day and future concentrations of Zinc and Copper in the surface sediments. The relative contribution of the NZ Steel discharges to predicted future increases in Zinc and Copper in sediments are also quantified.

An analysis of NZ Steel monitoring data has been carried out to determine the discharge volume and loads of sediment, Zinc and Copper associated with the NZ Steel discharges. These include the Northside and Southside Outfall discharges (which account for 70% of the total NZ Steel discharge volumes) and the discharges that occur to the North Stream (including the Dewatering Plant discharge), Kahawai Stream and Ruakohua Stream.

Figure W-ME3 of the main map set in Appendix E of the AEE provides an allocation diagram of the discharge locations.

The analysis of monitoring data includes the partitioning of the total metal loads into dissolved and particulate fractions.

The modelling carried out to assess the NZ Steel discharges builds on an earlier model developed for Watercare in the Waiuku Estuary which quantified the mixing of the discharge of treated wastewater from both the Waiuku and Clarks Beach wastewater treatment plants.

For this assessment of the NZ Steel discharges undertaken for the purposes of this report, the existing model mesh was refined so that the NZ Steel discharges and inputs from the Auckland Council Freshwater Management Tool (FWMT) could be included in the model.

In addition, a sediment transport model was developed based on earlier work carried out by NIWA in the Manukau Harbour and (based on the results of the sediment transport modelling) a surface sediment metal accumulation model was calibrated against present day observations of Zinc and Copper in Waiuku Estuary sediments.

The NZ Steel discharge loads and flows, and the predicted flows and loads from the FWMT for 2008 are included in the refined model of the Waiuku and Taihiki estuaries.

Based on the analysis undertaken, 2008 was chosen as being representative of average flow and load conditions in the FWMT for the period 2003 to 2017.

The Northside and Southside Outfall discharge volumes represent 4.9 % of the total freshwater inputs to the Waiuku Estuary, while the Sediment, Total Copper and Total Zinc loads represent 0.7%, 11.1% and 59.3% of the Total Sediment, Total Copper and Total Zinc delivered to the Waiuku Estuary, respectively. The Northside and Southside Outfall discharges represent 3.4% of the total catchment load of fine sediments to the Waiuku Estuary.

Flows and loads from the other NZ Steel discharges contribute 2.1% of the total freshwater inputs to the Waiuku Estuary and 0.6%, 6.1% and 3.1% of the Total Sediment, Total Copper and Total Zinc delivered to the Waiuku Estuary, respectively. These other NZ Steel discharges represent 3.0% of the total catchment load of fine sediments to the Waiuku Estuary.

Modelled Mixing Zone

The dynamics of the NZ Steel Northside and Southside Outfall discharge plumes are highly variable and relate to the significant flooding and drying that occurs within the inter-tidal area immediately offshore of the discharge points. Highest concentrations of the plumes in the water column (and lowest salinities) occur near low tide with significant levels of dilution occurring on the subsequent incoming tide and from high tide through to the next low tide.

In the immediate vicinity of the discharges the mean reduction in salinity due to the NZ Steel discharges ranges from 2-4 Practical Salinity Units (PSU) with background levels ranging from 10-28 PSU.

The existing discharge consents relating to the Northside and Southside Outfall define a mixing zone which extends over all the inter-tidal area of the embayment immediately offshore of where the NZ Steel Northside and Southside Outfall discharges occur (approximately 44 ha).

The modelling carried out shows that a mixing zone for the Northside and Southside Outfalls can be defined based on detectable changes in salinity which extends some 400 m from the Northside Outfall discharge and approximately 200 m from the Southside Outfall discharge. 400m is approximately the same distance from the Northside discharge as the edge of the existing consented mixing zone. This area equates to a detectable mixing zone extent for the discharge plumes of approximately 6.3 ha for the Northside Outfall and 1.6 ha for the Southside Outfall. Beyond this area the NZ Steel discharges' influence on salinity and temperature are relatively small, and water column guidelines for 95% species protection in relation to dissolved Zinc and Copper are unlikely to be exceeded.

Furthermore, the majority of the effects of the Northside and Southside Outfalls (without consideration of background concentrations) on temperature, salinity, dissolved Copper and dissolved Zinc are likely to occur within 200 m of the Northside Outfall and less than 100 m from the Southside Outfall.

Dissolved Metals and Temperature - Water Column Predictions

The NZ Steel Northside and Southside Outfall discharges contribute 11.1% and 59.3% of the input of Copper and Zinc to the Waiuku Estuary respectively with, on average (based on conservative assumptions), 60-70% of the Total Copper being discharged as Dissolved Copper and, on average, 20% and 50% of the Total Zinc being discharge as Dissolved Zinc at the Northside and Southside Outfall discharge points respectively.

Based on conservative assumptions around the partitioning of the dissolved component of Copper and **considering the NZ Steel discharges in isolation,** the 95th percentile estimates of dissolved Copper (i.e., the value only exceeded in 5% of the annual simulation data) exceeds the ANZECC (2000) Copper 99% species protection guideline of 0.3 µg/L[1] within a radius of 100 m of the Northside Outfall discharge.

Similarly, the 95th percentile estimates of Dissolved Zinc only exceeds the Australian and New Zealand Water Quality Guidelines (ANZWQG 2021) updated Zinc 99% species protection guideline of 3.3 µg/L[2] within 200 m of the Northside Outfall discharge.

For the Southside Outfall, the 95th percentile estimates of dissolved Copper only exceed the 99% species protection guideline for Copper of 0.3 µg/L within 50 m of the discharge point.

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[1] Values are based on the ANZECC (2000) copper guideline as no update to the ANZECC (2000) values has yet been released.

[2] The ANZWQG (2018) marine zinc guidelines were recently updated with new more conservative values in June 2020

The 95th percentile estimates of dissolved Zinc from the Southside discharge do not exceed the 99% species protection guideline of 3.3 µg/L at all.

The 50th percentile estimates of Dissolved Copper and Zinc (i.e., the value exceeded in 50% of the annual simulation data) remain below the 99% species protection guidelines for both the Northside and Southside Outfalls.

When considering the percentage of time particular guideline values are exceeded, effects of the discharge are again predominantly seen within the first 100 m of the Northside outfall. The 99% Species Protection Guideline for Zinc is exceeded around 30% of the time in the first 50 m, around 15% of the time out to 100 m, and less than 0.5% of the time out to 200 m. The 80% Species Protection Guideline for Zinc is exceeded up to 10% of the time in the first 50 m and only 0.3% of the time out to 100 m.

At the Northside Outfall the 99% Species Protection Guideline for Copper is exceeded primarily out to 50 m, and up to 24% of the time.

For the Southside Outfall only the copper 99% Species Protection Guideline is exceeded, only out to 50 m (and primarily out to 20 m) and only up to 14% of the time. The Zinc 99% Species Protection Guideline is not exceeded at all at the Southside Outfall.

With the **inclusion of background levels** of Copper and Zinc from catchment derived sources the 95th percentile estimates of Dissolved Copper and Zinc only exceed the 95% species protection guidelines within 100 m of the Northside Outfall discharge, and the 99% species protection guideline within 300 m of the Northside Outfall discharge. 300m equates to a mixing zone area of approximately 3.6 ha.

At the Southside Outfall discharge, the 95th percentile estimates of Dissolved Copper do not exceed the 95% species protection guideline of 1.3 µg/L and the 95th percentile estimates of Dissolved Zinc do not exceed the 99% species protection guideline of 3.3 µg/L. However, approximately 60 m is required before discharge concentrations equilibrate with background concentrations. 60 m equates to a mixing zone area of approximately 0.15 ha.

The 50th percentile estimates of Dissolved Copper and Zinc are below the 99% species protection guidelines at all distances from both the Northside and Southside Outfall discharges.

Modelling of the excess temperature of the Northside and Southside Outfall discharges shows that, because of the significant level of mixing that occurs with cooler ambient waters, the average excess temperature (i.e., averaged over all states of tide) at the discharge sites is less than 1 ^{o}C for representative Summer and Winter scenarios.

Predicted maximum excess temperature will occur around low tide with the 95th percentile excess temperature (i.e., an excess temperature that is exceeded only 5% of the time) ranging from 15.0 ^{o}C in Summer and 20.0 ^{o}C in Winter for the Northside Outfall (which has a higher discharge volume and excess temperature) compared to the 95th percentile excess temperatures of 2.5 ^{o}C (in Summer) and 4.1 ^{o}C (in Winter) at the Southside Outfall. The smaller excess temperatures in Summer are a result of the increased heating in the ambient surface waters that occur during the Summer months (which brings the ambient inter-tidal temperatures closer to the discharge temperatures, compared to a Winter discharge) and the increased effect of evaporative cooling of the discharge waters in Summer.

Moving away from the discharge points, a 95th percentile excess temperature of 3 ^{o}C is only exceeded within 100-150 m of the Northside Outfall, while at the Southside Outfall the 95th percentile excess temperature falls to less than 3 ^{o}C within 50 m of the discharge point in Winter and is never exceeded in Summer.

Sediment Dynamics

The sediment transport model results show that the highest annual sediment deposition rates (> 25 mm/yr) occur within the Waiuku Town Basin sub-estuary (which directly receives around one-third of the total sediment load to the Waiuku Estuary), and that localised elevated deposition rates occur close to all of the catchment sediment sources (including the Northside and Southside Outfall discharges).

Around 60% of the catchment derived fine sediments delivered to the Waiuku Estuary are exported to the wider Manukau Harbour. Subcatchments nearer the entrance to the Waiuku Estuary typically having higher export rates (i.e. 80-90%) while around half of the fine sediments delivered to the Waiuku Basin are deposited within the Waiuku Estuary.

The Northside and Southside Outfall discharges contribute less than 4% of the input of fine sediments to the Waiuku Estuary.

Around 30% of the sediments from the Northside and Southside Outfalls are exported to the wider Manukau Harbour with the remaining 70% being deposited within the Waiuku Estuary.

Approximately 30% of the Northside Outfall sediment deposition occurs within the inter-tidal area immediately offshore of the discharge point (i.e., within the mixing zone defined in the current consent), around 12% of the Northside Outfall sediment deposition occurs within the intertidal areas in the sub-estuaries immediately north, south and opposite of the discharge points. Around 12% of the Northside Outfall sediment deposition occurs within the Waiuku Town Basin sub-estuary. A further 13% of the Northside Outfall sediment deposition occurs within the Taihiki Estuary sub-estuary with the remaining 33% of the Northside Outfall sediment deposition occurring within the sub-estuaries in the north of the Waiuku Estuary.

Approximately 36% of the Southside Outfall sediment deposition happens within the inter-tidal zone immediately offshore of the discharge point (i.e., within the mixing zone defined in the current consent), around 12% of the Southside Outfall sediment deposition occurs within the intertidal areas in the sub-estuaries immediately north, south and opposite of the discharge points. Around 18% of the Southside Outfall sediment deposition occurs within the Waiuku Town Basin. A further 10% of the Southside Outfall sediment deposition occurs within the Taihiki Estuary sub-estuary with the remaining 25% of the Northside Outfall sediment deposition occurring within the sub-estuaries in the north of the Waiuku Estuary.

The overall contribution of Northside and Southside Outfall sediments to the predicted deposition rates in the Waiuku Basin is low because of the high catchment sediment load that discharges directly to the Waiuku Basin (i.e., unrelated to the NZ Steel discharges).

Sediment Metals Predictions

Using the inputs described above, a sediment metal accumulation model for the Waiuku Estuary was set up and run over a 35-year time horizon from the current day. In addition, the scenario where NZ Steel discharges cease has been run, which quantifies the changes in metal concentrations that my occur over the next 35 years excluding the current NZ steel discharges.

Results from the sediment metal accumulation modelling show that the predicted current day surface sediment Zinc and Copper concentrations near the Northside and Southside monitoring sites are likely to be at or very close to equilibrium values and that variations in historical observed sediment metal concentrations are likely to relate to inter-annual variability of rainfall, sediment yield from the catchment, and the associated changes in dynamics of sediment deposition within the current mixing zone.

As such, the metal accumulation model shows only relatively small increases in future surface sediment Zinc and Copper concentrations within 100-400 m of the NZ Steel Northside and Southside Outfall discharges.

For Copper, both the predicted current and future surface sediment Copper concentrations are well below the Auckland Council ‘Amber’ Environmental Response Criteria (ERC) threshold of 19 mg/kg.

The maximum current day surface sediment Copper concentrations at the Northside Outfall, Southside Outfall and North Stream Discharge (which contains the Dew Plant discharges) are 9.4 mg/kg, 10.5 mg/kg and 10.9 mg/kg respectively.

The maximum sediment Copper concentrations at the Northside Outfall and North Stream Discharge (which contains the Dew Plant discharges) do not change in the future but at the Southside Outfall discharge the maximum future sediment Copper concentration increases to? 10.7 mg/kg.

Predicted future surface sediment Copper concentrations in the intertidal and shallow subtidal areas of the wider Waiuku Estuary (i.e. outside the modelled mixing zone) are predicted to increase by less than 1.9 mg/kg over the next 35 years and remain well below the Auckland Council ‘Amber’ Environmental Response Criteria (ERC) threshold of 19 mg/kg.

These future increases in surface sediment Copper are predominantly due to the ongoing input of catchment derived Copper.

The maximum future increase due to the NZ Steel discharge of 1.5 mg/kg occurs near the Northside Outfall with future increases being no more than 0.6 mg/kg due to the NZ Steel discharges elsewhere across the Waiuku Estuary.

For Zinc, both the predicted current and future surface sediment Zinc concentrations are above the Auckland Council ‘Red’ ERC threshold of 150 mg/kg within 75-100 m of the NZ Steel Northside Outfall.

A maximum current day surface sediment Zinc concentration of 207.1 mg/kg occurs over a very small area of the upper flanks of the inter-tidal near the Northside Outfall discharge.

The maximum current day surface sediment Zinc concentration near the North Stream discharge (which contains the Dew Plant discharges) sits just on the Auckland Council ‘Red’ ERC threshold of 150 mg/kg.

The maximum current day surface sediment Zinc concentration near the Southside discharge is 85.0 mg/kg (below the ERC ‘Amber’ threshold of 124 mg/kg).

The maximum sediment Zinc concentrations at the Northside Outfall and North Stream discharge (which contains the Dew Plant discharge) discharges do not change in the future but at the Southside discharge the maximum future sediment Zinc concentration increases to 92.1 mg/kg (still well below the ERC ‘Amber’ threshold of 124 mg/kg).

Predicted future surface sediment Zinc concentrations in the intertidal and shallow subtidal areas of the wider Waiuku Estuary (i.e. outside the modelled mixing zone) are predicted to increase by no more than 26.0 mg/kg over the next 35 years and they remain below the ERC ‘Amber’ threshold of 124 mg/kg.

These future increases in surface sediment Zinc are predominantly due to the ongoing input of catchment derived Zinc.

The maximum future increase due to the NZ Steel discharges (35.2 mg/kg) occurs on the very upper fringes of the inter-tidal area near the Northside Outfall, and reduces to less than 12 mg/kg moving towards the Southside discharge. Near the North Stream discharge (which contains the Dew Plant discharge), the maximum future increases due to the NZ Steel discharges are less than 3 mg/kg.

Receiving Environment scenario

The starting point for the Receiving Environment scenario in which the NZ Steel discharges have ceased is the current day predicted Zinc and Copper concentrations. The metal accumulation model is then run 35 years ahead, with just the ongoing input of catchment derived sediment, Copper and Zinc.

Under this Receiving Environment scenario (in which the NZ Steel discharges have ceased), the ongoing input of catchment derived Zinc to the system results in increases of up to 22.0 mg/kg Zinc in the sediment over the next 35 years at sites away from the NZ Steel discharge sites, but levels are still below the ERC Amber threshold for Zinc of 124 mg/kg. The ongoing mixing of catchment derived sediments (with lower Zinc concentrations than the underlying sediments) results in the gradual reduction in Zinc concentrations in the immediate vicinity of the discharges – with average reductions of 36.4 mg/kg near the Northside Outfall discharge, 4.5 mg/kg near the Southside discharge and 30.5 mg/kg near the North Stream discharge (which contains the Dew Plant discharge).

Near the Northside Outfall, the maximum Zinc estimate 35 years from now drops from 207.1 mg/kg to 86.2 mg/kg, the maximum future Zinc concentration near the Southside Outfall drops from 92.1 mg/kg to 82.2 mg/kg while near the North Stream discharge (which contains the Dew Plant discharge) the maximum estimate reduces from 150.0 mg/kg to 111.4 mg/kg.

As for the Zinc predictions, Copper predictions for the Receiving Environment scenario (in which the NZ Steel discharges have ceased) result in both increases away from the NZ Steel site, and decreases in the immediate vicinity of the NZ Steel site, with a maximum increase over the proposed consent term of 1.7 mg/kg at sites away from the NZ Steel discharge sites and gradual reduction in Copper concentrations in the immediate vicinity of the discharges – with average reductions of 1.6 mg/kg near the Northside Outfall discharge, 1.9 mg/kg near the Southside discharge and 1.8 mg/kg near the North Stream discharge (which contains the Dew Plant discharge).

Near the Northside Outfall discharge, the maximum future Copper concentration drops from 9.4 mg/kg to 6.2 mg/kg, the maximum future Copper concentration near the Southside discharge drops from 10.7 mg/kg to 6.2 mg/kg while near the North Stream discharge (which contains the Dew Plant discharge) the maximum estimate reduces from 10.9 mg/kg to 8.3 mg/kg.

The ERC Green/Amber threshold for Copper of 19 mg/kg is therefore not exceeded 35 years from now under either of the Receiving Environment (discharges ceased) or discharges continued scenarios.

1. Introduction

This report provides details of the work carried out to assess the discharges from the NZ Steel Mill to the Waiuku River (Figure 1-1).

The NZ Steel Mill site is located on the eastern bank of the Waiuku River (Figure 1-1) which is a long and relatively narrow tidal arm (estuary) of the Manukau Harbour and is hereafter referred to as the Waiuku Estuary.

A previously calibrated hydrodynamic model of the Waiuku Estuary is used as the basis for quantifying the relative role that the discharge of freshwater, sediment, Zinc and Copper from the NZ Steel site have in relation to catchment derived inputs.

This includes water column effects as well as predicted sediment deposition and accumulation of Zinc and Copper in the surface sediments.

The mixing zone defined in the existing discharge consents covers all of the inter-tidal area just south of Okohaka Point through to The Needles (Figure 1-1).

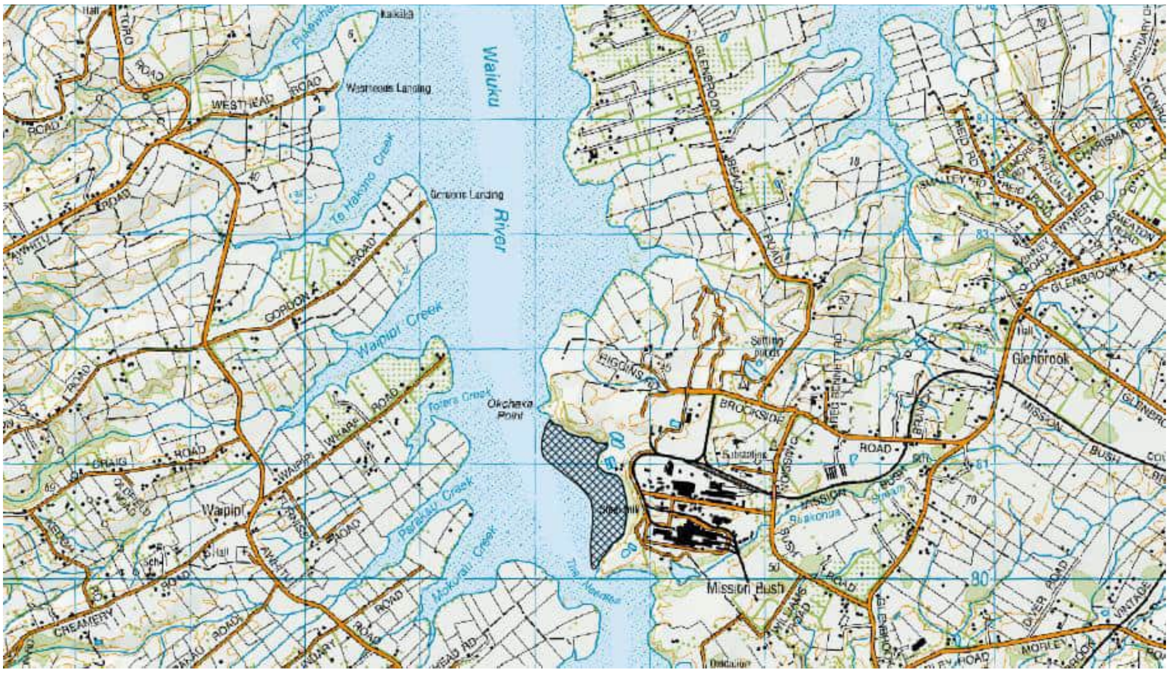

Figure 1-1. Central section of Waiuku Estuary showing the location of the NZ Steel Site. Approximate location of existing mixing zone (hatched area) shown on the inter-tidal area west of the NZ Steel site. NZ Topo Map images sourced from LINZ.

2. Models Used

The work presented in this report builds on the model developed for earlier work that DHI carried out for Watercare in relation to the Clarks Beach and Waiuku Wastewater Treatment Plants (WWTP) (DHI, 2014, 2016, 2018).

That work involved calibration of a Manukau Harbour MIKE21 hydrodynamic (HD) and advection-dispersion (AD) model with a focus on calibration within the Waiuku Estuary.

The MIKE21 HD module simulates water level variations and flows in response to tidal forcing and wind effects and takes into account density variations (due to freshwater inputs), bottom shear stress, wind shear stress and flooding and drying of inter-tidal areas. The basis for the module is the depth-integrated incompressible Reynolds averaged Navier-Stokes equations as detailed in the user manual[3].

The MIKE21 HD module includes heat exchange formulation which considers the heating and cooling of the water due to a combination of latent heat loss (due to evaporation), convective heat transfer between the water and the atmosphere and incoming shortwave and longwave radiation. Exchange processes are driven by air temperature, relative humidity and cloud cover.

The MIKE21 AD module simulates the spreading of dissolved substances due to the combination of advection and dispersion using a mass-conservation approach as detailed in the user manual1.

The whole harbour model was extensively calibrated against harbour wide currents, water level variations and salinity observations as well as site specific data collected for the Clarks Beach work and available salinity data in the vicinity of the Clarks Beach WWTP (as detailed below). The work involved considering the role of the discharges from the Clarks Beach and Waiuku WWTPs in relation to freshwater inputs and nutrients loads to the Manukau Harbour.

The MIKE21 model used for this assessment is depth-averaged and only includes the Waiuku and Taihiki Rivers sections of the Manukau Harbour model.

Predicted water level data from a 2008 simulation of the Manukau Harbour model was used to create the 15 minute water level boundary condition for the Waiuku/Taihiki model. That is, predicted water level variations due to tides and winds from the whole harbour model at the entrance to the Waiuku River were applied at the boundary of the Waiuku/Taihiki model.

One-hourly wind data was obtained from the Auckland Airport automated weather station.

For the temperature modelling 3-hourly air-temperature, relative humidity, and solar radiation from the Auckland Airport automated weather station were used.

Winds for 2008 were relatively representative of the long term wind climate (Table 2-1 and Table 2-2 and Figure 2-1)

The model grid used for this assessment only covers the Waiuku and Taihiki Rivers (Figure 2-2).

The mesh elements (refined for this assessment) are relatively uniform in size across the whole of the model domain at around 60 m^2 (representing element sides of approximately 10m). 90% of the elements in the domain range from 40-90 m^2 with the largest element (170 m^2) being in the Taihiki River and the smallest (15 m^2) being in the Waiuku Town Basin. Figure 2-3 shows the detail of the mesh in the immediately vicinity of the Northside and Southside Outfall discharges.

All model predictions are therefore averages over the full water column.

A detailed description of the rationale behind choosing to run a two-dimensional model for this assessment is provided in Appendix D.

The Harbour wide model was calibrated against historical data at the sites shown in Figure 2-4 and data collected at the entrance of the Waiuku River for the assessment of the discharge from the Clarks Beach Wastewater Treatment Plant.

Calibration of the model consisted of examining the fit between the broad and local scale field data and adjusting model parameters to achieve the best predictions of water levels and currents possible.

At a broad scale the model performs well in terms of predicting the propagation of the tide within the Manukau Harbour (Figure 2-4). Towards Onehunga the tidal range becomes under-predicted

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[3] https://manuals.mikepoweredbydhi.help/2020/MIKE_21.htm

by the model but given the area of interest for this study this is not of concern. Tidal current constituent data for the two major tidal constituents are closely matched by the model (Table 2-4, Table 2-5).

Time-series plots of observed and modelled water levels in the entrance to the Waiuku Channel (near the proposed outfall for the Waiuku Wastewater Treatment Plant) are shown in Figure 2-5, Figure 2-6 and Figure 2-7. Overall the phasing and range of the modelled tides are well matched with the observations except during neap tides when high water levels are generally under-predicted by the model. Thus the model may potentially provide conservative under-estimates of dilutions at neap high tide.

The linear regression for the scatter plot of observed and modelled water levels (Figure 2-8) indicates that overall the range of water levels observed at the Waiuku River Entrance are well represented in the model.

Calibration against the observed discharge through the Waiuku River entrance was very good Figure 2-9) with the accumulated discharge on the flooding tide matching the observations very well. The phasing of the slack water at high tide was very well matched by the model. On the ebbing tide the model slightly under predicts the accumulated discharge within the Waiuku River. The model therefore provides good estimates of the tidal prism through the Waiuku Entrance.

Calibration of the whole harbour model against the observed currents near the Waiuku Entrance was problematic mainly due to the location of the current meter on the flanks of the sub-tidal area where a strong eddy formed on flooding tide.

Data from the ADCP shows relatively uniform average current speeds through the water column (Figure 2-10) ranging from 0.14 to 0.15 m/s with no clear indication of any stratification effects or strong non-tidal (wind driven) currents near the surface (Figure 2-12).

The whole harbour model was run for a year using previous estimates of freshwater inputs from the Manukau catchment[4] to provide estimates of the mean salinity at a number of State of Environment monitoring sites in the Harbour. The average salinity from the State of Environment sites compares favourably with the averages from the model simulation (Figure 2-12).

For the assessment of the NZ Steel discharge, the mesh for the Waiuku Estuary has been refined to accommodate the input of 25 Freshwater Management Tool (FWMT) marine nodes from the wider Waiuku Estuary Catchment (detailed in Section 3) and the inputs from the NZ Steel site (summarised in Section 5). The minimum area of the mesh elements is around 60 m^2 (representing element sides of approximately 10m).

The calibrated hydrodynamic model includes the 3-hourly staged average dry weather discharge of 0.10 m^3/s from the Waiuku WWTP (just to the south of the NZ Steel site) and a 4-hourly staged average dry weather of 0.16 m^3/s discharge from the Clarks Beach WWTP. The contribution of these discharges in terms of sediments are minimal and have not been separately considered.

All the discharges to the model (NZ Steel, Waiuku and Clarks Beach WWTP and catchment inflows) are added as a discharge and/or concentrations into a single cell in the model. Minor adjustments to the model mesh around some of the discharge points was required to ensure the was no “pooling” at the discharge cell on the falling tide.

In addition, a sediment transport model has been developed based on the calibration process outlined in Auckland Regional Council (2008) for the MIKE21 Mud Transport module which simulates erosion, transport and deposition of muds under the action of currents derived from the MIKE 21 HD module. This model provides estimates of suspended sediment concentrations

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[4] Green, M. 2008. Southeastern Manukau Harbour / Pahurehure Inlet Contaminant Study. Implementation and Calibration of the USC-3 Model. Prepared by NIWA for Auckland Regional Council. Auckland Regional Council Technical Report 2008/057.

(g/m^3) and predicted annual sedimentation rates (mm/yr) based on the sediment loads from the catchment from the FWMT (detailed in Section 3) and the NZ Steel discharges (summarised in Section 4).

The sediment transport model does not include a wave model. The rationale behind this is provided in Appendix E.

Based on predicted levels of deposition from the sediment transport model, a metal accumulation model has been developed and calibrated. This provides estimates of future Zinc and Copper concentrations in surface sediments across all of the Waiuku Estuary.

Details of the metal accumulation modelling methodology are provided in Appendix A.

The modelling does not take into account the effects of climate change over the duration of the proposed consent.

Sea-level rise will increase water depths offshore of the NZ Steel site which will increase the level of dilution achieved. This would result in lower excess temperatures, dissolved Zinc and Copper concentrations than have been modelled.

In areas where deposition rates outstrip sea level rise (as is likely to be the case in the Waiuku Town Basin) ongoing accretion will ultimately lead to a restriction in the volume of sediment that can be retained within such areas[5]. This has the potential to lead to greater export of sediments away from catchment sources[6].

However, quantifying the potential net effect of other factors relating to climate change (increased evaporation, sea surface temperature, saline intrusion, changes to the frequency and magnitude of rainfall events and a changing wind climate) that will occur in parallel with the ongoing infilling of the Waiuku River from catchment derived sediments is difficult and it is not practical to attempt to analyse all these factors.

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[5] Swales, A., Bentley, S. J., Lovelock, C.E. 2015. Mangrove-forest evolution in a sediment-rich estuarine system: opportunists or agents of geomorphic change?. Earth Surface Processes and Landforms 40 (12) 1672-1687.

[6] Passeri, D.L., Hagen, S.C., Medeiros, S.C., Bilskie, M.V., Alizad, K. and Wang, D. 2015. The dynamic effects of sea level rise on low-gradient coastal landscapes: A review. Earth's Future, 3: 159-181.

Table 2-1. Distribution of winds based on wind sectors and percentile values for the full Auckland Aero automated weather station (1989-2013).

Percentile	(0 to 45) deg.	(45 to 90) deg.	(90 to 135) deg.	(135 to 180) deg.	(180 to 225) deg.	(225 to 270) deg.	(270 to 315) deg.	(315 to 360) deg.
5	1.0	0.7	0.5	1.0	1.5	2.1	1.5	1.0
10	1.5	1.0	1.0	1.0	2.1	3.1	2.4	1.5
15	1.5	1.5	1.0	1.5	2.6	3.6	2.6	1.8
20	2.1	1.5	1.5	1.5	2.6	4.1	3.1	2.1
25	2.6	2.1	1.5	1.9	3.1	4.6	3.6	2.2
30	2.6	2.6	1.8	2.1	3.6	5.1	4.1	2.6
35	3.1	3.0	2.1	2.1	4.1	5.2	4.6	2.6
40	3.6	3.1	2.1	2.6	4.4	5.7	4.6	3.1
45	3.8	3.6	2.6	2.6	4.6	6.2	5.1	3.1
50	4.1	4.1	2.6	3.1	5.1	6.2	5.7	3.4
55	4.6	4.6	3.1	3.1	5.7	6.7	6.2	3.6
60	5.1	5.1	3.1	3.6	6.2	7.2	6.2	3.8
65	5.6	5.7	3.6	3.6	6.2	7.6	6.7	4.1
70	5.7	6.2	4.1	4.1	6.7	7.7	7.2	4.6
75	6.2	6.7	4.6	4.6	7.2	8.2	7.7	5.0
80	6.7	7.2	5.1	5.1	7.7	8.8	8.2	5.1
85	7.4	7.7	5.7	5.7	8.2	9.8	8.8	5.7
90	8.2	8.2	6.2	6.2	9.3	10.3	9.8	6.2
95	9.3	9.4	7.7	7.2	10.3	11.8	10.8	7.7

Table 2-2. Distribution of winds based on wind sectors and percentile values for the full Auckland Aero automated weather station for 2008.

Percentile	(0 to 45) deg.	(45 to 90) deg.	(90 to 135) deg.	(135 to 180) deg.	(180 to 225) deg.	(225 to 270) deg.	(270 to 315) deg.	(315 to 360) deg.
5	1.0	1.0	0.5	1.0	1.5	2.1	1.5	1.0
10	1.5	1.0	1.0	1.0	1.5	3.1	2.1	1.5
15	1.5	1.5	1.0	1.0	2.1	3.6	2.6	1.5
20	2.1	1.5	1.5	1.5	2.6	4.1	3.1	2.1
25	2.6	2.1	1.5	1.5	2.6	4.6	3.6	2.1
30	3.1	2.6	1.5	1.5	3.1	5.1	4.1	2.6
35	3.6	3.1	2.1	2.1	3.1	5.1	4.1	2.6
40	4.1	3.6	2.1	2.1	3.6	5.7	4.6	3.1
45	4.6	4.1	2.1	2.1	4.1	6.2	5.1	3.1
50	4.6	4.1	2.6	2.6	4.6	6.2	5.1	3.1
55	5.1	4.6	2.6	2.6	4.6	6.7	5.7	3.6
60	5.7	5.1	3.1	3.1	5.1	6.7	6.2	3.6
65	5.7	5.7	3.1	3.1	5.1	7.2	6.7	4.1
70	6.2	6.2	3.6	3.6	5.7	7.7	7.2	4.6
75	6.7	6.2	4.1	4.1	6.2	8.2	7.7	4.6
80	7.2	6.7	5.1	4.1	6.7	8.2	8.2	5.1
85	7.7	7.7	5.7	4.6	7.2	8.8	8.8	5.7
90	8.5	8.2	6.2	5.1	7.7	9.8	9.3	6.7
95	9.8	9.8	7.7	6.2	8.8	10.3	10.3	8.2

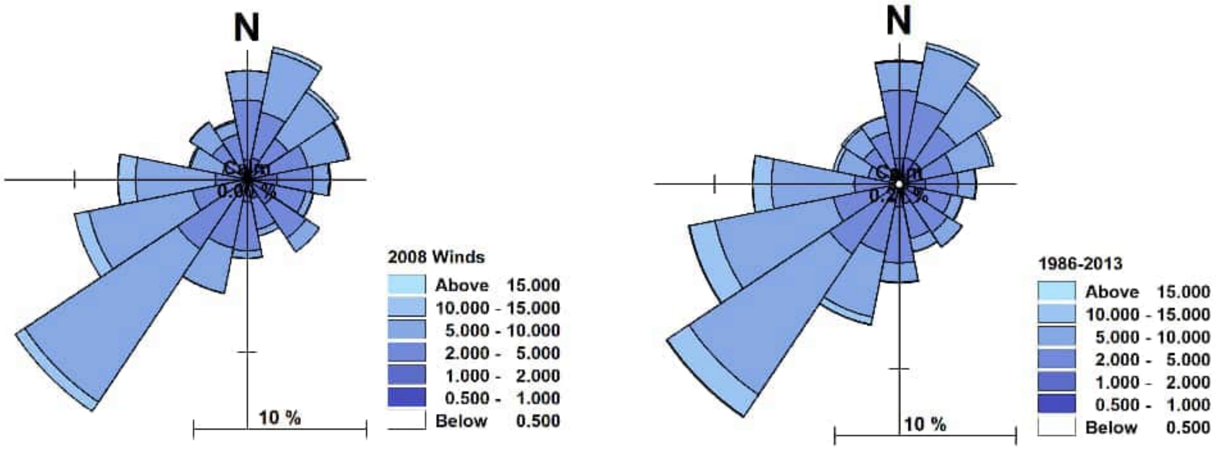

Figure 2-1. Wind roses for 2008 (left) winds and winds from 1986-2013 (right).

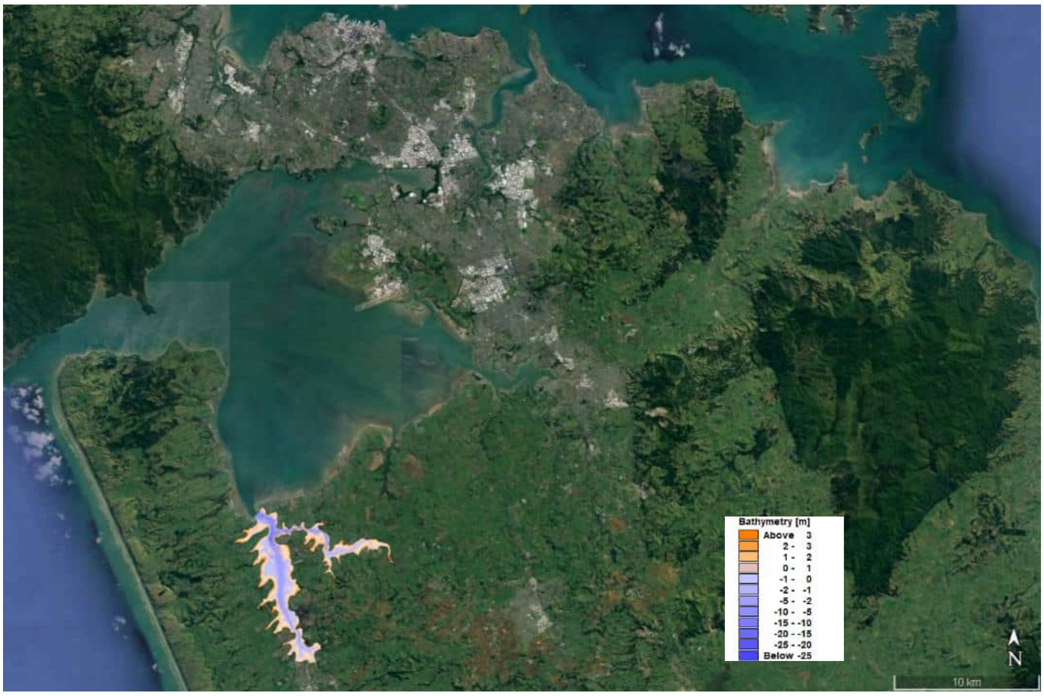

Figure 2-2. Waiuku/Taihiki mesh coverage and bathymetry.

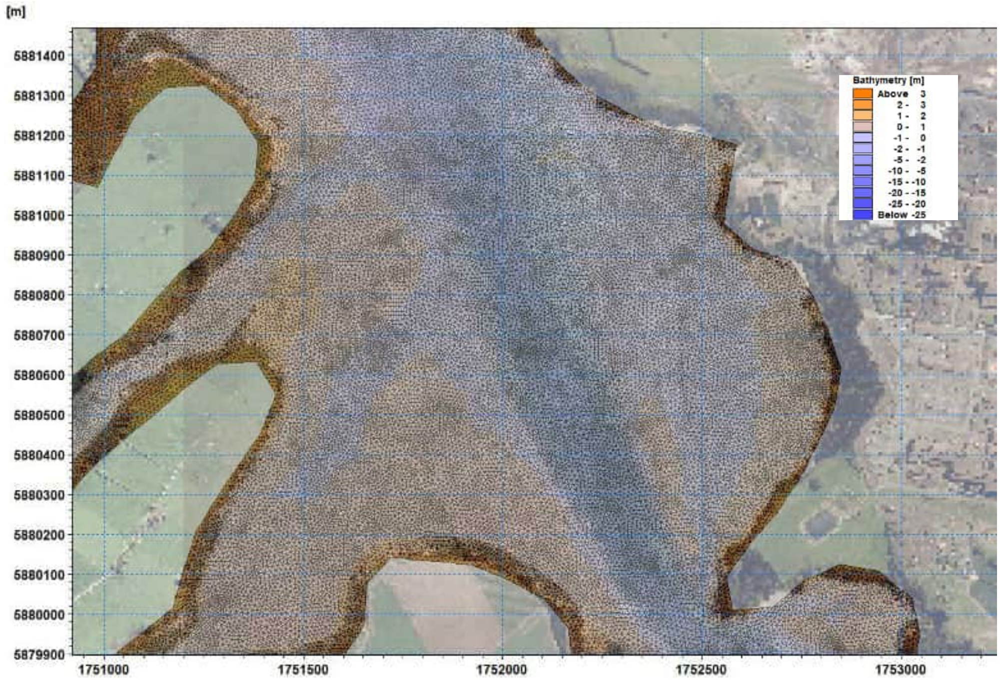

Figure 2-3. Detail of the mesh in the immediate vicinity of the NZ Steel site in the middle section of the Waiuku River. Individual mesh elements shown in red. Axes are NZTM coordinates (m).

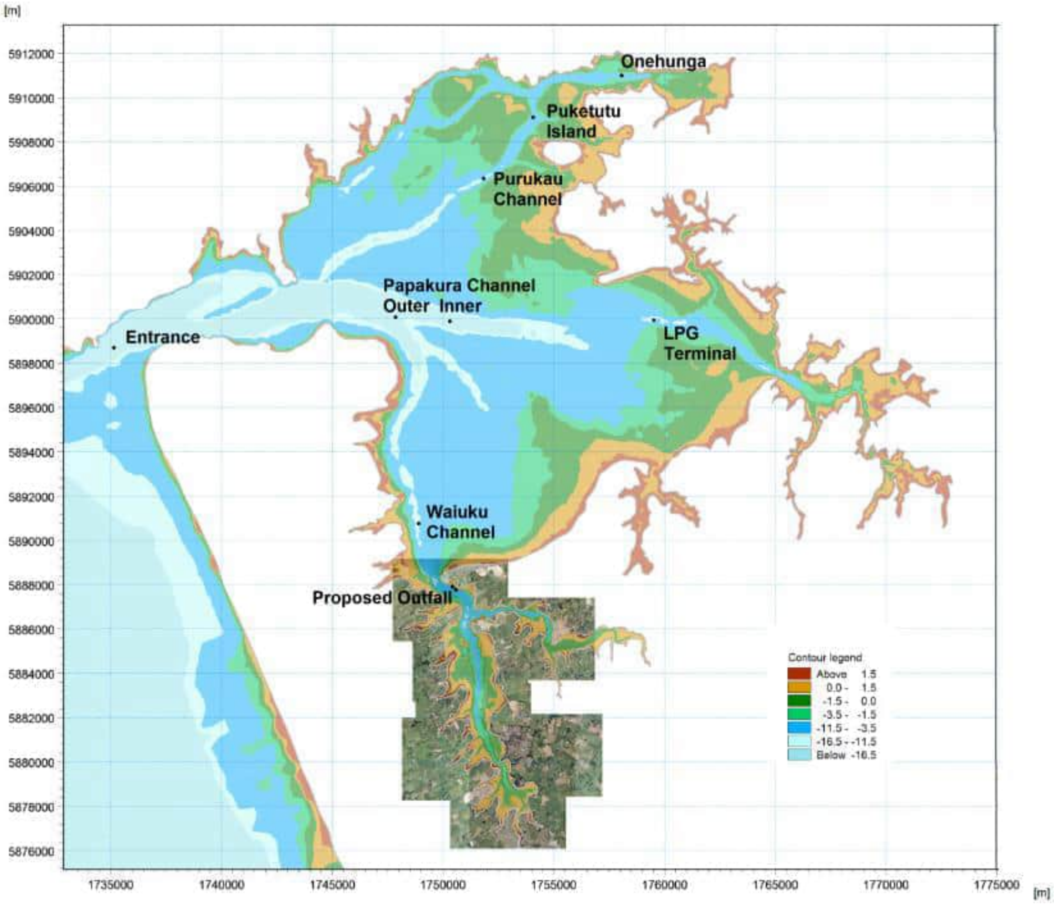

Figure 2-4. Manukau Harbour showing location of proposed Watercare Clarks Beach Wastewater Treatment Plant outfall location within field data sites from Bell et. al (1998). Depth contours relative to mean sea level and coordinate system in NZTM.

Table 2-3. Tidal height constituent amplitude calibration against data from Bell et al (1998) sites (Figure 2-4).

Site	Field M2 range (m)	Model M2 range (m)	% Error	Error (m)
Entrance	2.19	2.22	-1.4%	0.03
Waiuku Channel	2.63	2.58	1.8%	-0.05
Papakura Channel (Outer)	2.44	2.48	-1.6%	0.04
Papakura Channel (Inner)	2.51	2.52	-0.5%	0.01
LPG Terminal	2.65	2.62	1.1%	-0.03
Purakau Channel	2.52	2.52	0.0%	0.00
Puketutu Island	2.60	2.54	2.2%	-0.06
Onehunga	2.65	2.52	4.8%	-0.13

Table 2-4. Modelled tidal current constituent data for the M2 and S2 tidal component from calibrated MIKE 21 model for Bell sites (Figure 2-4).

Site	Constituent	Major (m/s)	Minor (m/s)	Inclination (º)	Phase (º)
Papakura Channel (Inner)	M2	0.65	<0.01	263	40
	S2	0.21	<0.02	263	78
Purakau Channel	M2	0.55	<0.01	69	29
	S2	0.17	<0.01	69	78

Table 2-5. Observed tidal current constituent data for the M2 tidal component from Bell et al (1998). Sites as shown in Figure 2-4.

Site	Constituent	Major (m/s)	Minor (m/s)	Inclination (º)	Phase (º)
Papakura Channel (Inner)	M2 (near-bed)	0.53	0.01	279	37.8
	S2 (near-bed)	0.15	0.02	277	72.0
	M2 (mid-depth)	0.82	0.01	278	36.0
	S2 (mid-depth)	0.23	0.01	277	74.0
Purakau Channel	M2 (mid-depth)	0.54	-0.01	60	30.1
	S2 (mid-depth)	0.18	-0.00	63	73.5

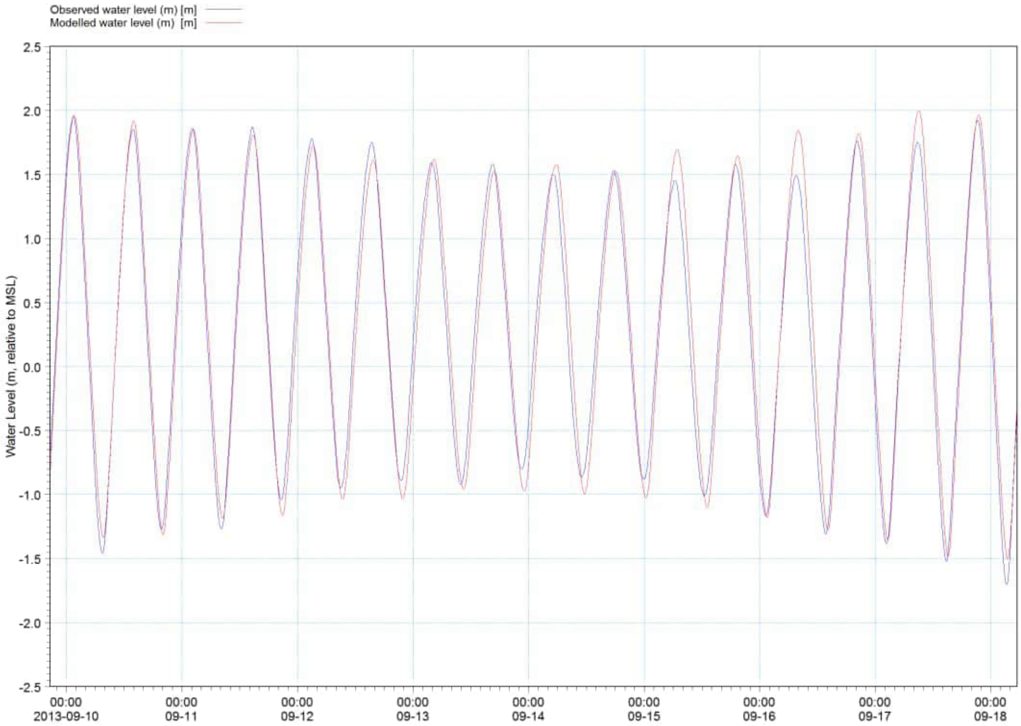

Figure 2-5. Water level calibration 10th September through to 18th September 2013.

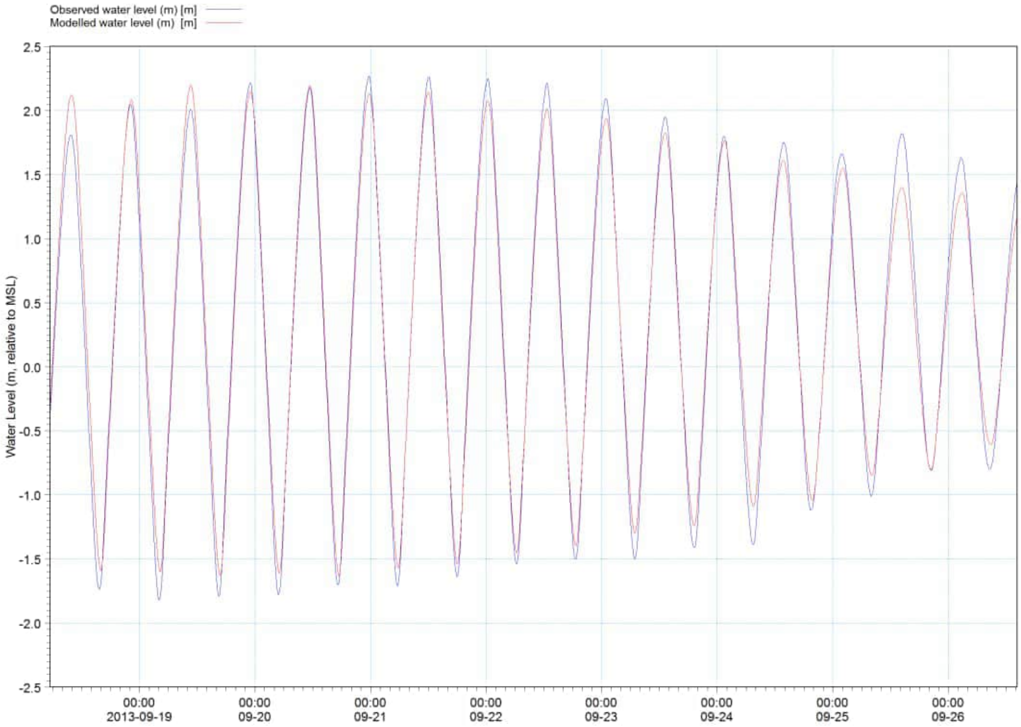

Figure 2-6. Water level calibration 18th September through to 26th September 2013.

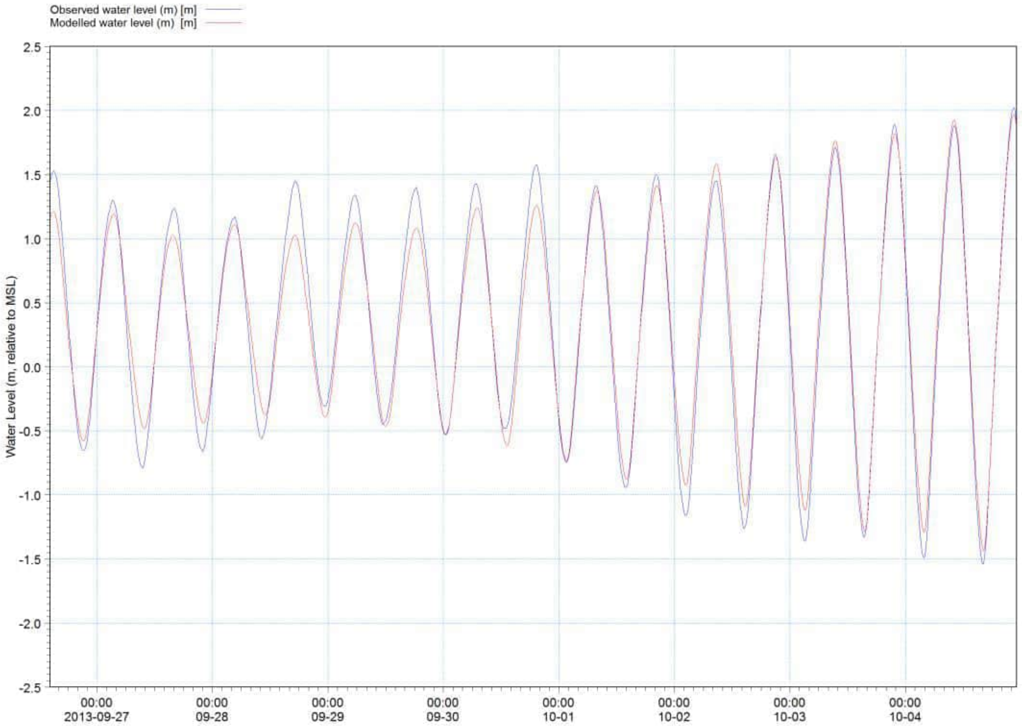

Figure 2-7. Water level calibration 27th September through to 4th October 2013.

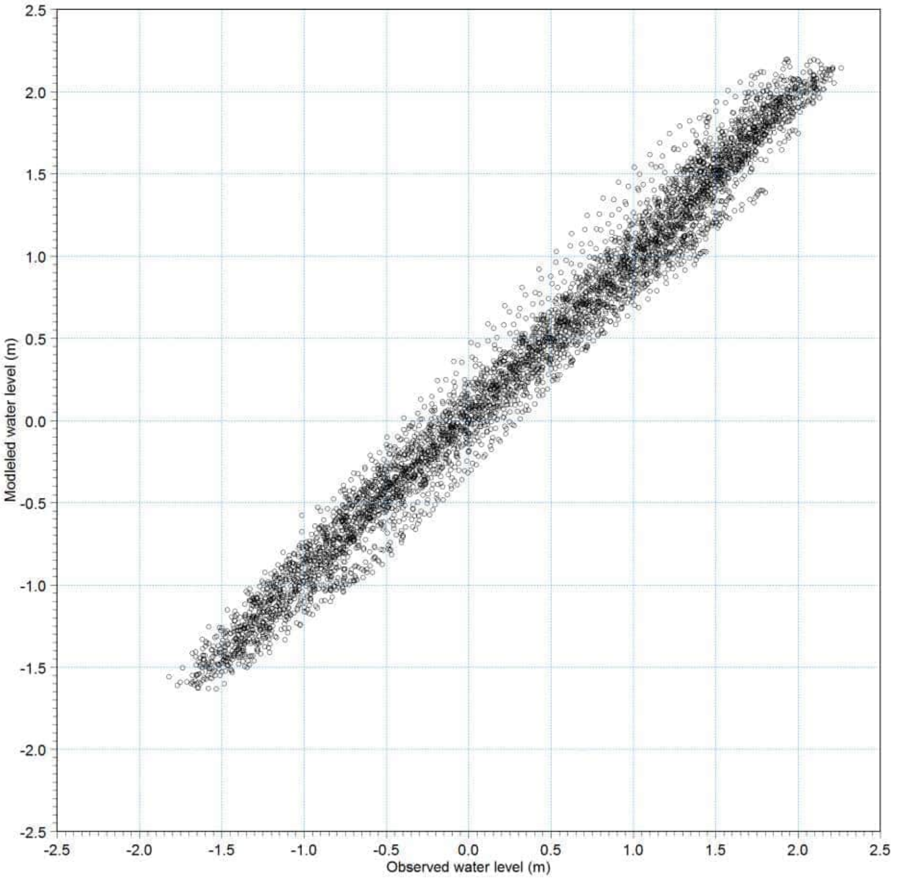

Figure 2-8. Scatter plot of modelled and observed water levels at the outfall site. Linear regression; Modelled = 0.9722* Observed – 0.0317, r-squared = 0.9789.

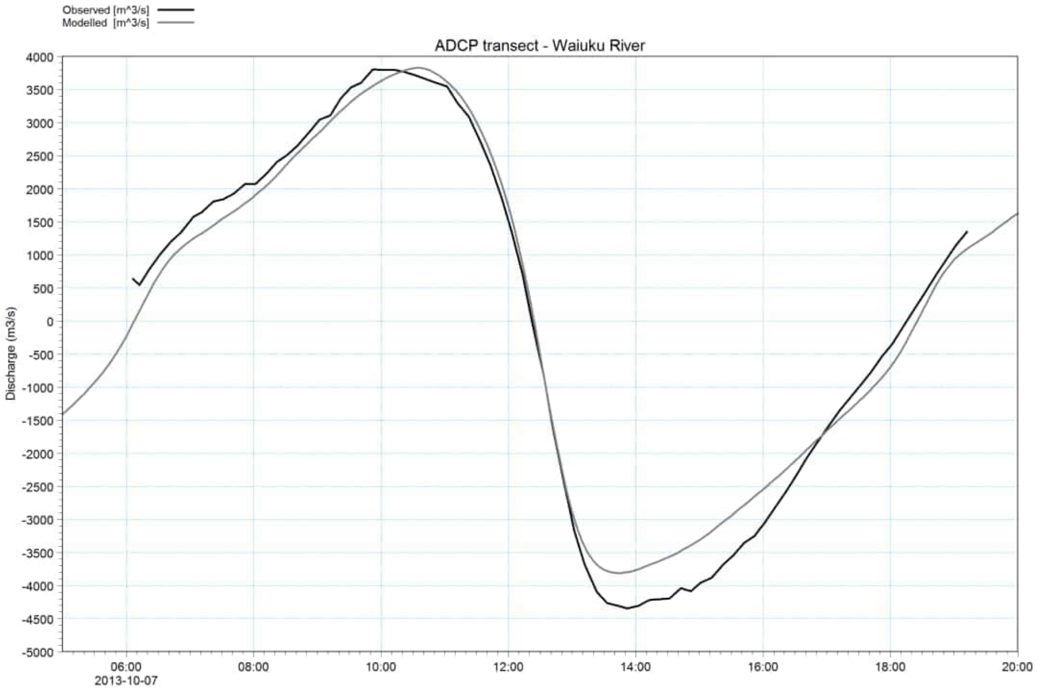

Figure 2-9. ADCP transect observed and modelled discharge and observed water levels (7th October 2013, tide range 3.6 m).

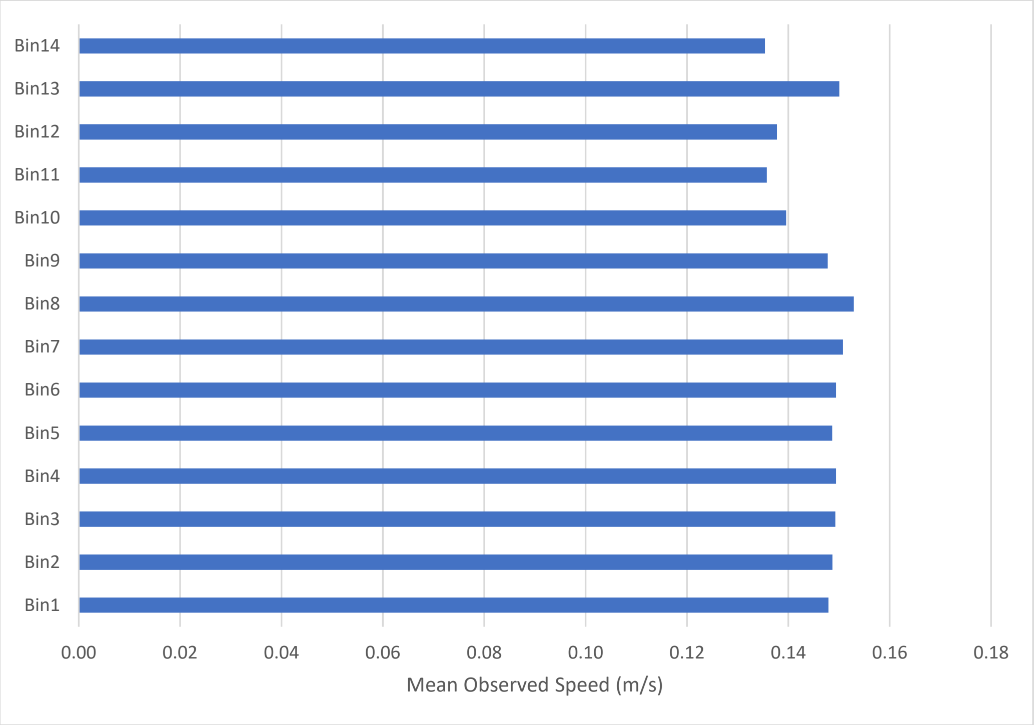

Figure 2-10. Mean current speed over the duration of the ADCP deployment for each of the 0.5 m bins. Bin 1 is near-bed and Bin 14 is near surface.

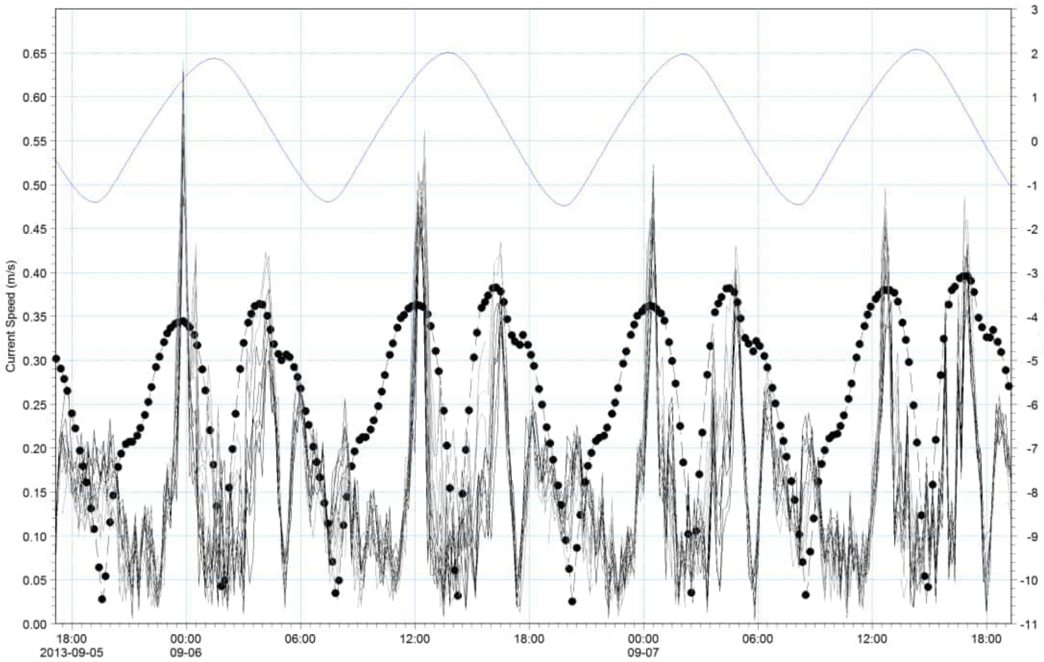

Figure 2-11. Observed currents (solid line) at the ADCP, predicted water level (blue line) and predicted currents from the MIKE 21 hydrodynamic model (black line + symbol) 6th-7th September 2013.

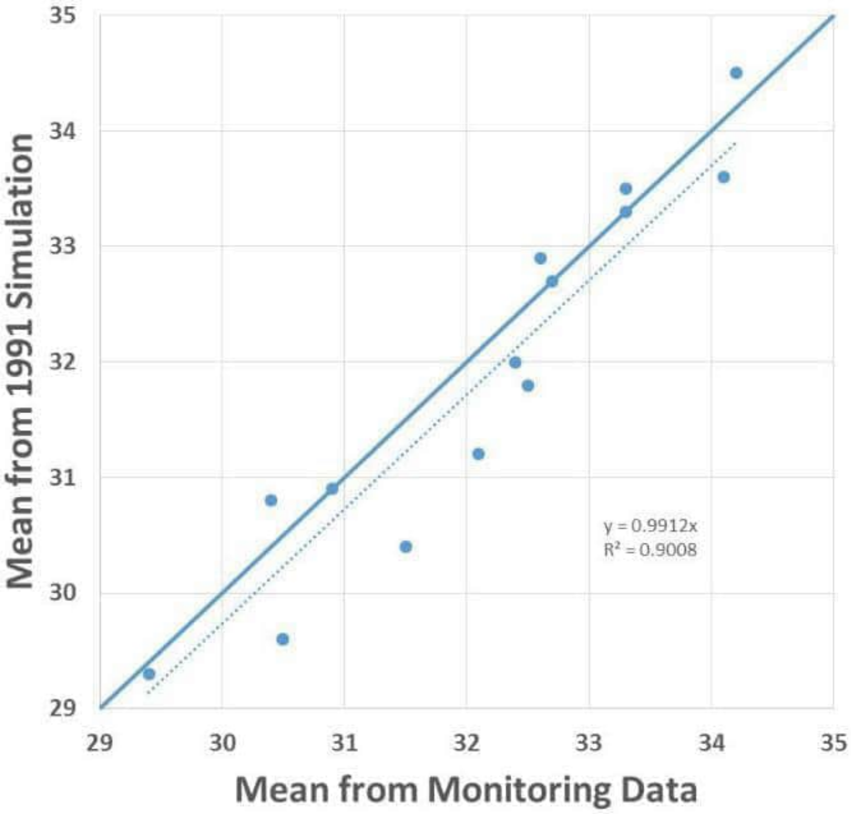

Figure 2-12. Comparison of long-term Auckland Council monitoring data and results from an annual simulation of the whole harbour model that include estimates of catchment wide inflows to the harbour (including existing wastewater treatment plants).

3. Freshwater Management Tool Catchment Data

The Freshwater Management Tool (FWMT) is a region-wide hydrological and contaminant load model currently under development by the Healthy Waters Department of Auckland Council. The primary purpose of the FWMT is to support planning and policy decisions associated with the National Policy Statement for Freshwater Management (NPS-FM). The FWMT is composed of two process-based, continuous simulation models, LSPC (Loading Simulation Program in C++) and SUSTAIN (a scenario modelling tool for treatment devices or other intervention types). LSPC is the 'Current State' model used to simulate watershed runoff, contaminant build up/wash-off, and downstream loading to the CMA utilizing detailed land use, soil type and instream wash off information. LSPC estimates stream flow and pollutant concentrations (Total Suspended Solids (TSS), Total Copper, Total Zinc, *E. coli*, Nitrogen and Phosphorus) across a multi-year time series at a 15-minute time step and output data has been calibrated against relevant regional monitoring data.[7] This continuous simulation approach allows consideration of the variability of rainfall runoff parameters in water quality and flow characteristics.

Daily FWMT LSPC output data for the Waiuku Catchment for flow, TSS, Total Copper and Total Zinc were provided by Auckland Council to DHI specifically for the current project.

Data from each of the 62 identified FWMT marine nodes that have no downstream catchment connection (i.e. those that discharge to the marine receiving environment) Waiuku Estuary were merged and post-processed into a daily time-series from 2003-2017 of predicted flows, Zinc, Copper and suspended sediment concentrations at 25 marine nodes (Figure 3-1). This aggregated time-series data was used as input to the marine models.

Three sediment fractions are defined within the FWMT being representative of sand, silt and clay with nominal grain size of 0.250, 0.016 and 0.001 mm respectively.

Only the silt and clay fractions are considered in the Mud Transport model.

Coarser sized sand fractions (which make up more than 20% of the total sediment load) tend to deposit directly near catchment sources (because of its high fall velocity) and as such do not influence the wider pattern of predicted deposition within the Waiuku Estuary system.

The tabulated summary of the data for each of the FWMT marine nodes is shown in Table 3-1.

The table is ranked by catchment area and shows that the Waitangi Stream 8 marine node (to the east of the Waiuku Town Basin - Figure 3-1) accounts for nearly 15% of the total freshwater inputs to the Waiuku Estuary and provides some of the highest loads to the system – contributing around 5% of the total catchment derived sediment load to the Waiuku Estuary and 7-8% of the overall catchment derived metal loads.

The next largest catchment inflows are for the Waiuku River 17 marine node (to the west of the Waiuku Town Basin- Figure 3-1) and the Waiuku River 2 marine node (to the north of the Waiuku River - Figure 3-1).

The Waiuku River 17 marine node delivers around 6% of the overall sediment load to the Waiuku Estuary and 5-6% of the metal load.

The Waiuku River 2 marine node delivers around 30% of the overall sediment load to the Waiuku Estuary and 26-28% of the metal load.

The load of fine sediments discharged directly to the Waiuku Town Basin (via the Waitangi Stream 7, Waitangi Stream 8, Waiuku Town 1, Waiuku Town 3, Waiuku Town 7, Waiuku Town 8, Waiuku

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[7] Note that more regional monitoring calibration data was available for urban environments than rural environments, so there is less confidence in rural yields of the various pollutants than there is for urban yields.

River 16 and Waiuku River 16 FWMT marine nodes) account for nearly one-third of the whole catchment load of fine sediments.

Appendix B provides a summary of the yield and load distribution across all the FWMT nodes as summarised in Table 3-1 as well as an overview of the catchments associated with each of the 25 marine nodes.

This data shows the range of yields for each of the FWMT subcatchments is comparable to the typical default non-urban Sediment, Zinc and Copper yields in the Auckland Council Contaminant Load Model (Auckland Council, 2010) for the typical land-use classes within the Waiuku catchment.

Based on the analysis of loads from all the FWMT nodes, 2008 was chosen as being representative of average freshwater flows and loads to the system over the 15-year FWMT dataset.

Figure 3-2 shows the inter-annual variability of the clay fraction of the sediment load (tonnes/yr) for the Waitangi River 8 FWMT node. The average clay fraction sediment load for the period 2003-2017 is 58 tonnes/yr and the annual clay fraction sediment load delivered in 2008 is 56 tonnes/yr.

Higher than average loads were delivered to the system in 2004, 2011, 2016 and 2017. In these years, more than two-thirds of the annual sediment load is delivered during individual events, the overall inflow to the system is 30% higher than average and the seasonally averaged inflows were nearly double the long-term average in Summer (2004 and 2011), Autumn (2017) or Spring (2010). While 2005 delivers close to the average clay fraction sediment load for the period 2003-2017, inflows during 2005 were around 15% lower than the long-term average inflow. Inflows for 2008 were just over 10% higher than the long-term average inflow so this year was chosen as being representative in terms of inflows and sediment loads.

The plot of cumulative flow and sediment load throughout 2008 are shown in Figure 3-3 and Figure 3-4 respectively.

The majority of the sediment delivered to the system during 2008 occurs during events in July, August and November which is a more typical distribution of sediment delivery than occurs during the high sediment load years of 2004, 2011, 2016 and 2017.

Figure 3-5 shows the observed flows from the Auckland Council Waitangi Stream site and the modelled daily flow from the FWMT Waitangi 8 node for 2009. Allowing for the daily averaging of the FWMT data, the majority of the peak flows are well represented in the model although the flows following rain events (on the recession of the hydrograph) tends to be overpredicted by the model.

The average of the observed data for the full period of the FWMT record (2003-2017) is 0.27 m^3/s while the average of the modelled FWMT Waitangi 8 node is 0.30 m^3/s

For 2008, the average of the observed data is 0.28 m^3/s while the average of the modelled FWMT Waitangi 8 node data is 0.34 m^3/s.

Such over-predictions will affect the localised dynamics of catchment derived contaminants but will have little effect on the overall dilution processes of the NZ Steel discharges (which are dominated by the hydrodynamics within the mixing zone embayment).

For example, the average flux through the entrance of the Waiuku Estuary is around 1800 m^3/s (Figure 2-9) compared to the mean inflow for the whole catchment of 2.0 m3/s.

Figure 3-1. Subcatchments associated with each of the 25 FWMT marine nodes (Table 3-1).

Table 3-1. Summary of average flow and load data for each of the FWMT marine nodes (Figure 3-1) over the period 2003-2017.

FWMT Node Name	Catchment Area (ha)	Mean Flow (m^3/day)	Sand Load (kg/day)	Silt Load (kg/day)	Clay Load (kg/day)	Cu Load (kg/day)	Zn Load (kg/day)
Waitangi Stream 8	1937	25808	116	207	158	0.0117	0.0490
Waiuku River 17	1264	22025	227	249	113	0.0091	0.0401
Waiuku River 2	1114	19296	501	2019	490	0.0476	0.1142
Waiuku River 8	896	15627	143	339	124	0.0103	0.0358
Waiuku River 11	744	8022	80	180	60	0.0055	0.0192
Waiuku River 16	656	12146	126	191	124	0.0081	0.0281
Waiuku River 7	654	10343	169	706	170	0.0169	0.0442
Waiuku Town 3	591	9236	169	126	111	0.0101	0.0635
Waiuku River 5	438	5356	68	424	101	0.0104	0.0264
Waiuku Town 7	357	6038	57	153	38	0.0043	0.0158
Waiuku River 14	351	6249	46	189	45	0.0050	0.0166
Waitangi Stream 6	326	4043	30	8	13	0.0011	0.0065
Waiuku Town 1	282	3993	53	71	37	0.0033	0.0140
Waitangi Stream 7	196	2719	19	62	15	0.0017	0.0059
Waitangi Stream 3	186	2855	73	41	46	0.0031	0.0105
Waitangi Stream 1	173	2259	12	58	14	0.0017	0.0073
Waiuku River 13	158	8487	78	116	53	0.0044	0.0171
Waitangi Stream 5	137	1939	18	8	12	0.0008	0.0036
Waiuku River 6	129	2031	17	58	13	0.0015	0.0051

FWMT Node Name	Catchment Area (ha)	Mean Flow (m^3/day)	Sand Load (kg/day)	Silt Load (kg/day)	Clay Load (kg/day)	Cu Load (kg/day)	Zn Load (kg/day)
Waiuku River 3	120	2215	40	230	53	0.0054	0.0130
Waiuku River 4	108	3249	42	137	32	0.0034	0.0099
Waitangi Stream 4	92	1321	21	9	13	0.0008	0.0031
Waiuku Town 8	80	1212	8	28	6	0.0008	0.0029
Waiuku River 10	70	1258	21	69	16	0.0017	0.0046
Waitangi Stream 2	60	1000	14	34	10	0.0009	0.0029
Total	**11119**	**178725**	**2150**	**5711**	**1867**	**0.1695**	**0.5594**

Table 3-2. Summary of total suspended sediment concentrations for each of the FWMT marine nodes (Figure 3-1) over the period 2003-2017.

FWMT Node Name	50th Percentile Total Suspended Sediment Concentration (mg/L)	90th Percentile Total Suspended Sediment Concentration (mg/L)
Waitangi Stream 8	2.3	7.2
Waiuku River 17	3.3	12.5
Waiuku River 2	3.0	18.9
Waiuku River 10	1.0	5.0
Waiuku River 13	2.6	11.4
Waiuku River 16	2.8	11.9
Waiuku River 7	1.9	9.6
Waiuku Town 3	2.5	25.3
Waiuku River 5	1.4	7.8
Waitangi Stream 6	1.9	12.3
Waiuku Town 7	2.1	9.0
Waiuku River 14	1.2	3.9
Waiuku River 4	1.0	5.0
Waiuku River 11	2.5	9.8
Waiuku Town 1	1.0	14.5
Waitangi Stream 3	1.0	7.4
Waiuku River 3	1.1	7.8
Waitangi Stream 4	1.0	1.6

FWMT Node Name	50th Percentile Total Suspended Sediment Concentration (mg/L)	90th Percentile Total Suspended Sediment Concentration (mg/L)
Waiuku River 6	1.0	4.1
Waiuku River 8	2.5	9.9
Waitangi Stream 7	1.0	4.7
Waitangi Stream 5	1.0	3.7
Waiuku Town 8	1.0	6.6
Waitangi Stream 2	1.0	1.0
Waitangi Stream 1	1.0	6.7

Table 3-3. Summary of average yield data (kg/ha/yr) for each of the FWMT nodes (Figure 3-1) over the period 2003-2017.

FWMT Node	Sand Yield (kg/ha/yr)	Silt Yield (kg/ha/yr)	Clay Yield (kg/ha/yr)	CU Yield (kg/ha/yr)	ZN Yield (kg/ha/yr)
Waitangi Stream 8	21.8	39.1	29.7	0.0022	0.0092
Waiuku River 17	65.4	71.7	32.6	0.0026	0.0115
Waiuku River 2	171.1	689.5	167.5	0.0163	0.0390
Waiuku River 10	8.3	27.3	6.3	0.0007	0.0018
Waiuku River 13	39.3	58.1	26.6	0.0022	0.0086
Waiuku River 16	81.1	122.6	79.5	0.0052	0.0180
Waiuku River 7	112.7	472.1	113.4	0.0113	0.0296
Waiuku Town 3	120.4	89.6	78.8	0.0072	0.0452
Waiuku River 5	69.7	433.1	102.9	0.0106	0.0270
Waitangi Stream 6	31.9	8.8	13.6	0.0011	0.0069
Waiuku Town 7	64.2	172.0	43.0	0.0048	0.0178
Waiuku River 14	61.7	252.1	59.8	0.0066	0.0221
Waiuku River 4	69.9	227.0	52.6	0.0056	0.0165
Waiuku River 11	144.7	326.3	109.4	0.0100	0.0348
Waiuku Town 1	105.3	141.8	74.9	0.0066	0.0280
Waitangi Stream 3	156.2	87.0	97.1	0.0066	0.0223
Waiuku River 3	88.1	508.9	117.9	0.0120	0.0288

FWMT Node	Sand Yield (kg/ha/yr)	Silt Yield (kg/ha/yr)	Clay Yield (kg/ha/yr)	CU Yield (kg/ha/yr)	ZN Yield (kg/ha/yr)
Waitangi Stream 4	55.9	23.7	34.9	0.0021	0.0080
Waiuku River 6	46.1	153.0	35.4	0.0040	0.0134
Waiuku River 8	449.1	1062.4	387.2	0.0322	0.1121
Waitangi Stream 7	67.8	223.2	54.5	0.0061	0.0214
Waitangi Stream 5	68.6	31.3	43.8	0.0030	0.0136
Waiuku Town 8	34.5	116.0	26.9	0.0032	0.0121
Waitangi Stream 2	83.9	201.3	59.8	0.0056	0.0170
Waitangi Stream 1	77.5	380.8	92.5	0.0115	0.0484

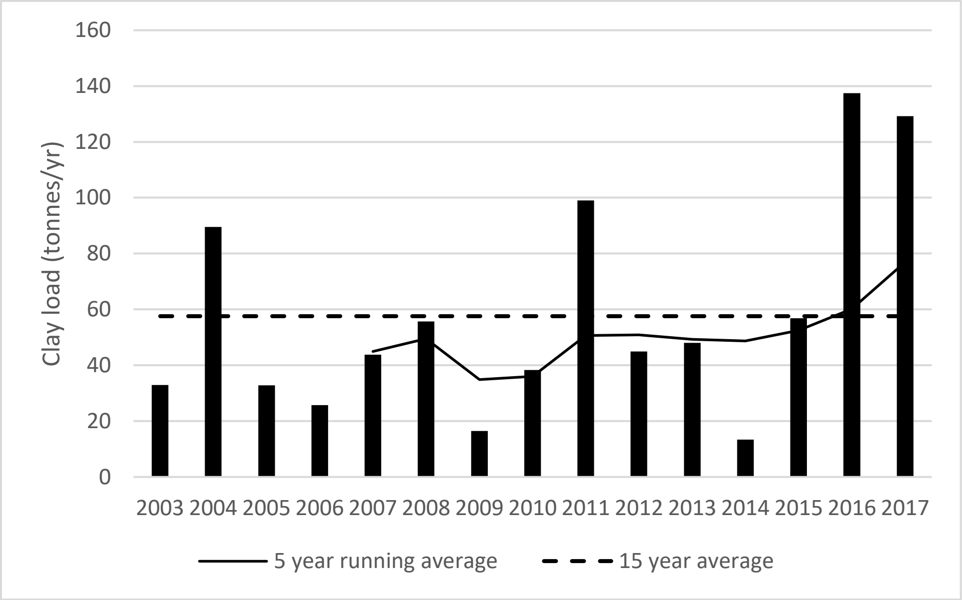

Figure 3-2. Clay fraction load (tonnes/yr) for the Waitangi Stream 8 FWMT node. Dashed line indicates average sediment load for all years 2003 to 2017.

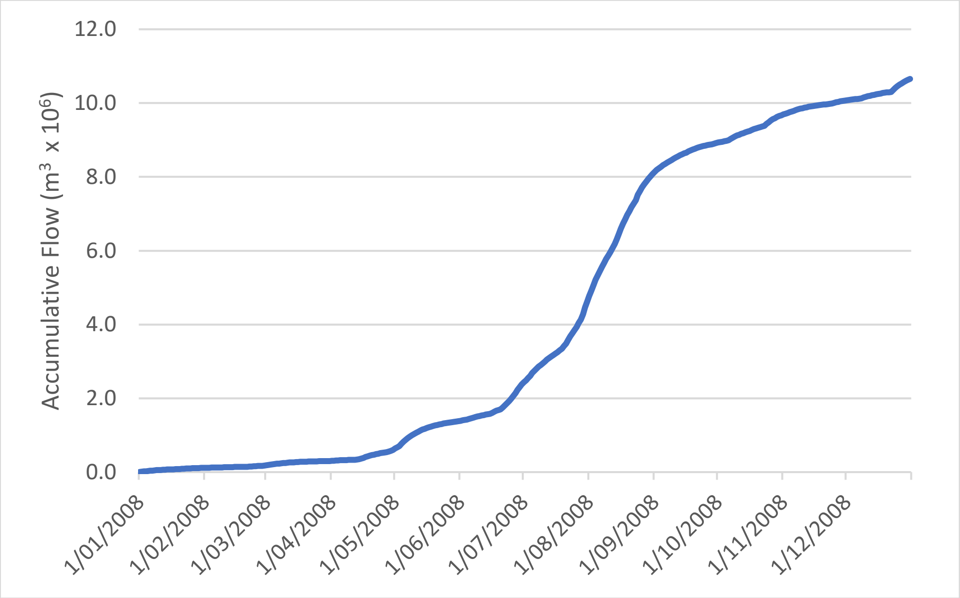

Figure 3-3. Cumulative freshwater input (m^3) for the Waitangi Stream 8 FWMT marine node for 2008.

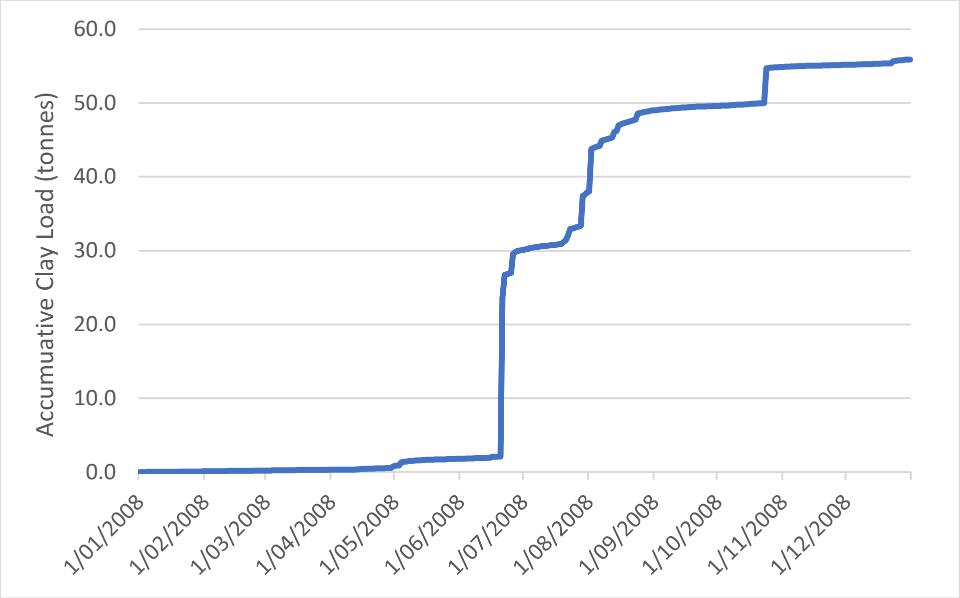

Figure 3-4. Cumulative clay fraction load (tonnes) for the Waitangi Stream 8 FWMT marine node for 2008.

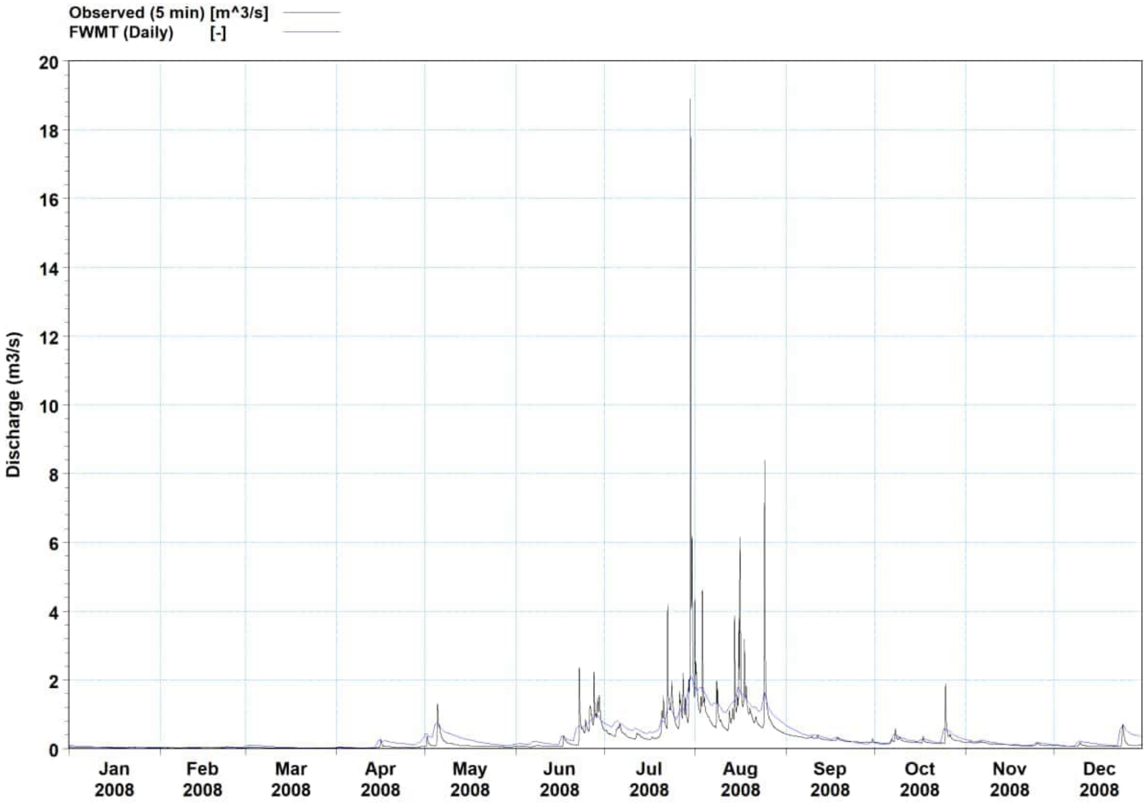

Figure 3-5. Observed 5-minute observations from the Waitangi Stream (Highway) site and predicted daily flow from the FWMT Waitangi 8 node for 2008.

4. NZ Steel Monitoring Data Summary

This section of the report summarises the NZ Steel monitoring data. This data was used to determine the flows and loads to apply for the NZ Steel Northside and Southside Outfall discharges; to determine the necessary modifications to the FWMT data to account for the on-site water budgeting; and to quantify the portioning of Zinc and Copper loads to dissolved and particulate fraction for the water column modelling.

4.1 NZ Steel Discharge and Load Summary

For the Northside Outfall, Southside Outfall and Dewatering (Dew) Plant discharges, monitoring data between the 21st of September 2019 and the 20th of September 2021 have been used to define the mean daily flow and loads for the modelling.[8]

This period was chosen to reflect the recent changes to on-site operations which have optimised the treatment systems (primarily for the year of September 2020 to September 2021) as well as a years' worth of previous data which is reflective of 'normal' operations prior to treatment system optimisation (for the year from September 2019 to September 2020).

For the North Stream (other than discharges from the Dew plant), Kahawai Stream and Ruakohua Stream discharges, monitoring data between November 2017 and December 2020 has been used to define the mean daily flow and loads for the modelling as more recent detailed monitoring data in the necessary format was not available. These other North Stream discharges were then combined with the Dew plant discharge to give an overall discharge for the North Stream catchment.

The average daily flows for the above periods are shown in Table 4-1.

The average daily flows for the NZ Steel discharges during this two-year period are shown in Table 4-1.

Tables 4-2 through to 4-6 show the average concentrations and loads for Total Zinc, Total Copper and Total Suspended Solids (TSS) for the NZ Steel discharges based on above monitoring periods.

Table 4-1. Average daily flows for the NZ Steel discharges and the relative contribution to the overall NZ Steel discharge volume of each of the individual NZ Steel discharges.

Discharge	**Mean Daily flow (m^3/day)**	**Mean Daily flow (m^3/s)**	**Percentage of Combined NZ Steel discharge volume**
Northside Outfall	8,213	0.0951	61.5%
Southside Outfall	1,086	0.0126	8.1%
North Stream	203	0.0023	1.5%
Dewatering (Dew) Plant	3,638	0.0421	27.3%

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[8] Note that one Dew Plant result for zinc was particularly elevated on the 28th of August 2020. This data point is considered to be an outlier anomaly and may not be real as the other metals and flow data were not elevated and there is no apparent explanation for the result. This individual result increases the zinc load from the Dew plant by approximately 27 %, however, it has been left in the data set and included in the modelling to be conservative. See T+T (2022) for further explanation.

Discharge	**Mean Daily flow (m^3/day)**	**Mean Daily flow (m^3/s)**	**Percentage of Combined NZ Steel discharge volume**
Kahawai Stream	31	0.0004	0.2%
Ruakohua Stream	174	0.0020	1.3%

Table 4-2. Summary of concentration and load data from the Northside Outfall based on monitoring data from 21st of September 2019 and the 20th of September 2021.

Northside Outfall	**Total Copper**	**Total Zinc**	**Total Suspended Solids**
Average concentration	2.5 µg/L	105.1 µg/L	7.71 g/m^3
Average total Load (kg/day)	0.0207	0.8633	63.3
Median concentration	1.5 µg/L	78.5 µg/L	7.60 g/m^3

Table 4-3. Summary of concentration and load data from the Southside Outfall based on monitoring data from 21st of September 2019 and the 20th of September 2021.

Southside Outfall	**Total Copper**	**Total Zinc**	**Total Suspended Solids**
Average concentration	2.2 µg/L	8.0 µg/L	4.36 g/m^3
Average total Load (kg/day)	0.0024	0.0087	4.74
Median concentration	1.5 µg/L	5.0 µg/L	2.50 g/m^3

Table 4-4. Summary of concentration and load data from the North Stream discharge based on monitoring data from November 2017 through to December 2020.

North Stream	**Total Copper**	**Total Zinc**	**Total Suspended Solids**
Average total concentration	0.8 µg/L	2.1 µg/L	31.65 g/m^3
Average total Load (kg/day)	0.0016	0.0043	6.4

Table 4-5. Summary of concentration and load data from the Kahawai Stream discharge based on monitoring data from November 2017 through to December 2020.

Kahawai Stream	**Total Copper**	**Total Zinc**	**Total Suspended Solids**
Average total concentration	1.0 µg/L	1.2 µg/L	23.60 g/m^3
Average total Load (kg/day)	0.0003	0.0004	0.7

Table 4-6. Summary of concentration and load data from the Ruakohua Stream discharge based on monitoring data from November 2017 through to December 2020.

Ruakohua Stream	**Total Copper**	**Total Zinc**	**Total Suspended Solids**
Average total concentration	1.0 µg/L	1.3 µg/L	10.93 g/m^3
Average total Load (kg/day)	0.0017	0.0023	1.9

Weekly sampling from May 2020 through to August 2020 has been carried out to quantify the ratio of dissolved to particulate Zinc and Copper at the Northside and Southside Outfalls as summarised in Table 4-7 and Table 4-8 respectively.

The observed dissolved metal fraction is used to define the portion of total Zinc and Copper loads assigned to the Northside and Southside Outfalls to predict water column metal levels and mixing zone in Section 5.

The ratio of dissolved to total Zinc for the Southside Outfall is nearly double the Northside Outfall discharge but the ratio for dissolved to total Copper is relatively consistent between the two Outfalls.

For the purposes of quantifying the dissolved component of the discharges it has been assumed that the estimated mean (μ) plus standard deviation (σ) ratio of total to dissolved Zinc and Copper from the monitoring data from May 2020 through to August 2020 has be applied. More recent monitoring data has confirmed that this is a conservative assumption (i.e. the actual ratio of total to dissolved metals is often much less than has been assumed for the modelling.

This provides a degree of conservatism in that the ratio of dissolved to particulate is often (i.e. 68% of the time) less than has been assumed.

Data collected after August 2020 at the Northside Outfall discharge confirms that the assumed ratios of dissolved to Total Zinc and Copper are less than has been assumed around 80% of the time.

Based on the monitoring data and the above calculation the assumed dissolved concentrations for Zinc and Copper for the Northside and Southside Outfall discharges are as shown in Table 4-9.

Table 4-7. Summary of ratio of dissolved to Total Zinc for the Northside and Southside Outfalls from monitoring data collect weekly from May through to August 2020.

	North	South
Mean (μ)	23%	51%
Standard deviation (σ)	9%	23%
μ-σ	14%	28%
μ+σ	32%	75%

Table 4-8. Summary of ratio of dissolved to Total Copper for the Northside and Southside Outfalls from monitoring data collect weekly from May through to August 2020.

	North	South
Mean (μ)	72%	63%
Standard deviation (σ)	11%	15%
μ-σ	60%	48%
μ+σ	83%	78%

Table 4-9. Assumed dissolved metal concentration (µg/L) of Zinc and Copper for the Northside and Southside Outfalls based on observed median concentrations (Table 4-2 and Table 4-3) and observed mean plus standard deviation ratio of Total to Dissolved Zinc and Copper (Table 4-7 and Table 4-8).

	North	South
Dissolved Copper (µg/L)	1.2 µg/L	1.2 µg/L
Dissolved Zinc (µg/L)	25.1 µg/L	3.8 µg/L

4.2 Marine Sediment Sampling Data

Details of the ongoing monitoring of Zinc and Copper accumulation in sediments near the NZ Steel discharges are detailed in Bioresearches (2021).

Sampling has been carried out since 2003 at the sites shown in Figure 4-1, with the details of which sites have been sampled when outlined in Bioresearches (2021). addition, long term monitoring of metal accumulation is carried out as part of Auckland Councils' State of the Environment monitoring at the Waiuku Town site.

Figure 4-1. Sediment sampling sites.

Figure 4-2 and Figure 4-3 show the time series of the total recoverable Copper and Zinc concentrations respectively at the Northside A, B and Southside monitoring sites from the latest monitoring report (Bioresearches, 2021).

It is possible that the recent increase in Zinc concentrations could be due to the downward trend in observed rainfall from the Auckland Airport weather station since 2017 (Figure 4-4). Lower rainfall will result in lower than average catchment derived sediment loads entering the system meaning the relative role of the NZ Steel discharge could be higher in dry years than occurs on average[9].

Table 4-10 show the summary of the metal monitoring data used as the basis for calibrating the metal accumulation mode. The values used for the calibration are close to the mean of the monitoring data from August 2019 to August 2021 at the Northside and Southside monitoring sites.

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[9] The models use the load derived from the FWMT data in 2008 which has close to the long-term average loads for 2003-2017 and close to the long-term average rainfall.

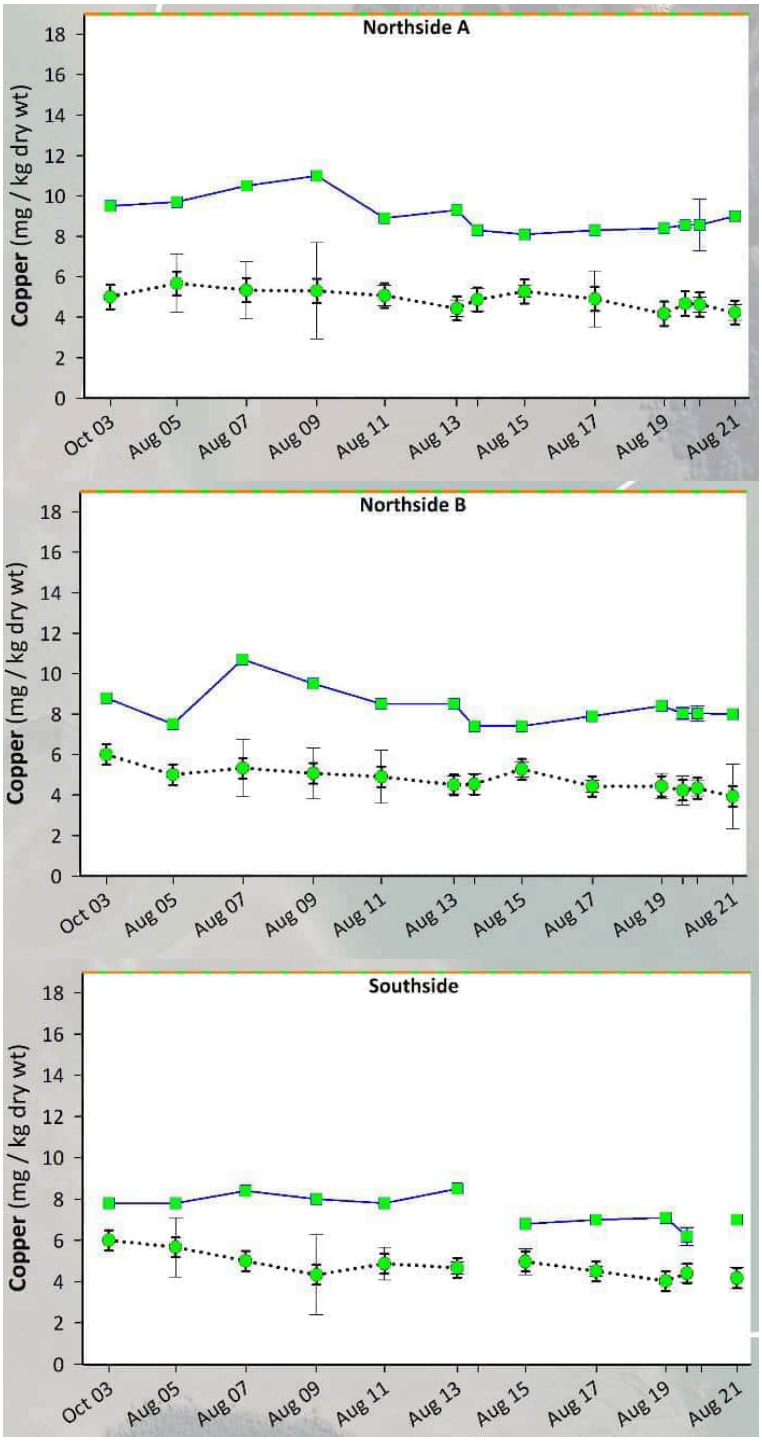

Figure 4-2. Concentration of Copper in Sediments at the Northside A (top), Northside B (middle) and Southside (bottom) monitoring sites (Bioresearchers, 2021). Data is mean dry weight (○ Extractable), (□ Total Recoverable) with ± 95% confidence intervals.

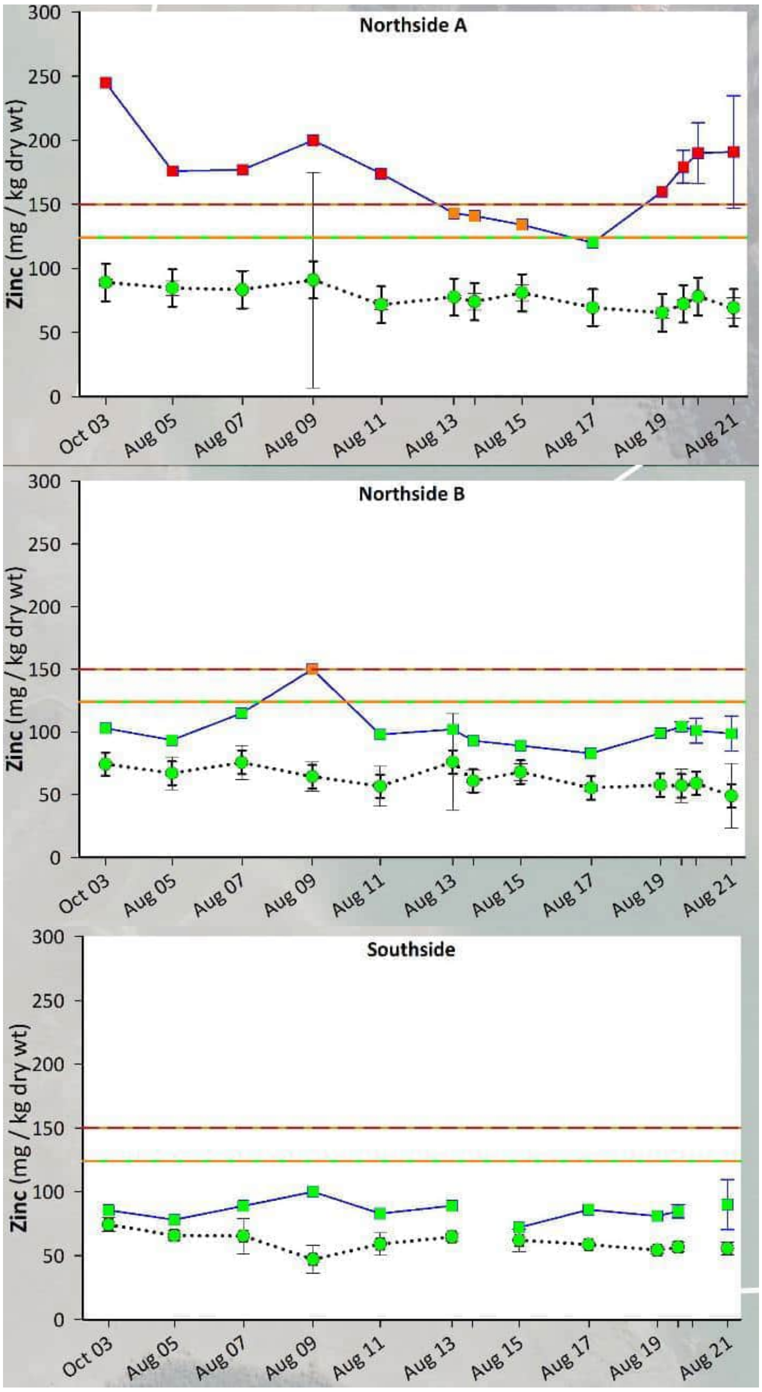

Figure 4-3. Concentration of Zinc in Sediments at the Northside A (top), Northside B (middle) and Southside (bottom) monitoring sites (Bioresearchers, 2021). Data is mean dry weight (○ Extractable), (□ Total Recoverable) with ± 95% confidence intervals.

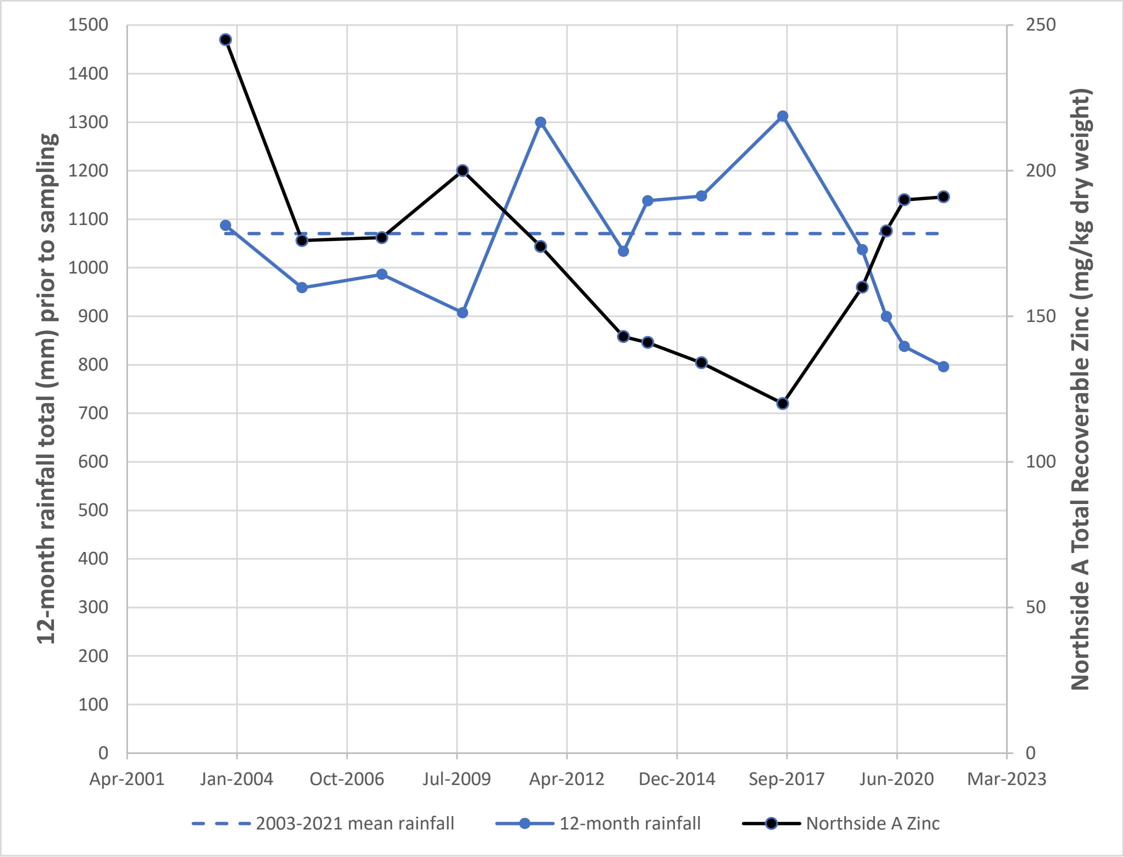

Figure 4-4. Twelve-monthly rainfall totals prior to sediment sampling from Oct 1st 2003 through to 16th August 2021, Zinc sediment monitoring data from Northside A and the mean rainfall (mm/yr) for the period Oct 1st 2003 through to 16th August 2021.

Table 4-10. Summary of sediment monitoring data at each of the NZ Steel monitoring sites shown in Figure 4-1 and the Auckland Council Waiuku Town site. Values are the mean of all replicates for the dates shown. Values in brackets are the mean of the observations from 2019-2021.

Monitoring Site	Sampling Date	Total Recoverable Zinc (mg/kg)	Total Recoverable Copper (mg/kg)
North Stream SZ	May 2020	15.4	0.9
North Stream OZ	May 2020	43.0	3.4
North Stream MZ	May 2020	98.3	10.4
Kahawai Stream	May 2020	54.3	4.4
Northside A	May 2020	179.3 (184.1)	8.6 (8.7)
Northside B	March 2020	104.3 (101.1)	8.0 (8.1)
Southside	March 2020	84.7 (86.4)	6.2 (6.7)
Spillway RS	May 2020	87.0	7.5
Spillway RO	May 2020	86.0	7.6
Waiuku Town	November 2017	107.9	9.0

4.3 Modifications to flow data for NZ Steel operations

The following modifications were applied to the FWMT data to account for the on-site water budgeting and routing.

These adjustments affect the flows for the Waitangi Stream marine nodes 3, 4, 5 and 6 (Figure 3-1, Figure 4-5 and Table 3-1).

Figure 4-5. Catchment areas used to adjust the FWMT flow and load data for the Waitangi Stream 3 (blue), Waitangi Stream 4 (red) and Waitangi Stream 6 (green) nodes based on operational data from NZ Steel. Adjustments to the FWMT Waitangi Stream 5 data accounted for on site processing of flows and the analysis of the Northside and Southside Outfall data.

Waitangi Stream 3

A constant value of 3638 m^3/day was added for the Dewatering (Dew) Plant (from the iron sand slurry processing).

57.9% of the flow from the Waitangi Stream 5 node was diverted to the Waitangi Stream 3 node. This portion of the subcatchment is shaded blue in Figure 4-5.

The above resulted in the mean flow for this FWMT node increasing from 2855 m^3/day (Table 3-1) to 3701 m^3/day.

Waitangi Stream 4

14.3% of the FWMT node flow that actually goes to the NZ Steel Northside Outfall was removed. This portion of the subcatchment is shaded red in Figure 4-5.

The above resulted in the mean flow for this FWMT node decreasing from 1321 m^3/day (Table 3-1) to 1132 m^3/day.

Waitangi Stream 5

57.9% of the FWMT flow was removed and diverted to the Waitangi Stream 3 FWMT node. To avoid double counting of flow data the remaining 42.1% of the FWMT flow data for this node was not included in the marine model as it is accounted for in the observed Northside Outfall data.

Waitangi Stream 6

39.7% of the FWMT flow was removed as it is included in the Northside and Southside Outfall data. This portion of the subcatchment is shaded green in Figure 4-5.

A net abstraction rate of 300 m^3/day was removed to account for the Ruakohua Dam abstraction.

The above resulted in the mean flow for this FWMT node decreasing from 4043 m^3/day (Table 3-1) to 2138 m^3/day.

Table 4-11. Summary of the modelled flows and loads for the FWMT nodes that have been adjusted for NZ Steel on-site water budgeting. Note, Waitangi Stream 5 data from the FWMT data has been replaced by NZ Steel monitoring data. Data from all other FWMT nodes are input to the models as per Table 3-1.

FWMT Node	Associated NZ Steel Discharge	Catchment Area Outside NZ Steel ITA Area (Ha)	Mean Daily Discharge (m^3/day)	Total Sediment (kg/day)	Copper (kg/day)	Zinc (kg/day)
Waitangi Stream 3	North Stream	210.3	3,701	181.9	0.0035	0.0126
Waitangi Stream 4	Kahawai Stream	74.4	1,132	37.5	0.0007	0.0026
Waitangi Stream 6	Ruakohua Stream	273.5	2,138	26.8	0.0006	0.0034

Modelled Flows and Loads

Based on the above modifications, Table 4-12 shows the flows and loads used for the NZ Steel discharges in the models.

Table 4-12 also shows the percentage of the total catchment flow and loads (based on the FWMT data – Table 3-1) that can be attributed to the NZ Steel discharges. Table 4-13 shows the source concentrations for the NZ Steel discharges.

Table 4-12. Summary of flow and load for the NZ Steel discharges based on monitoring data and adjustment for on-site water budgeting (not accounted for in the FWMT). Percentage to overall catchment inflow and load is based on raw FWMT inputs (Table 3-1) with adjustments described above.

Discharge	Associated Area within the ITA (Ha)	Mean Daily Discharge (m^3/day)	Sediment (kg/day)	Copper (kg/day)	Zinc (kg/day)
Northside Outfall	68.39	8,213	63.3	0.0207	0.8633
Southside Outfall	41.12	1,086	4.7	0.0024	0.0087

Discharge	**Associated Area within the ITA (Ha)**	**Mean Daily Discharge (m^3/day)**	**Sediment (kg/day)**	**Copper (kg/day)**	**Zinc (kg/day)**
North Stream	44.13	203	6.4	0.0016	0.0043
Dew Plant		3,638	50.0	0.0088	0.0382
Kahawai Stream	1.96	31	0.7	0.0003	0.0004
Ruakohua Stream	13.38	174	1.9	0.0017	0.0023
NZ Steel Combined Discharges	168.98	13,345	127.0	0.0354	0.9172
Percentage of Total Catchment Area or Input	1.52%	7.1%	6.4% of Clay Load 1.3% of Total Sediment Load	18.7%	62.3%

Table 4-13. Summary of sediment and metal source concentrations for the NZ Steel discharges based on monitoring data and adjustment for on-site water budgeting (not accounted for in the FWMT).

Discharge	**Sediment Concentration (mg/L)**	**Copper Concentration (mg/kg)**	**Zinc Concentration (mg/kg)**
Northside Outfall	7.71	326	13634
Southside Outfall	4.36	499	1829
North Stream	31.5	251	671
Dew Plant	13.7	177	764
Kahawai Stream	22.6	424	510
Ruakohua Stream	10.9	915	1228

4.4 Temperature Data

One of the existing consent’s conditions is that the daily discharge temperature must not exceed 20 °C above the ambient sea surface temperature (SST). Historically, there have been issues with obtaining representative ambient SST which relates to the dynamic nature of the inter-tidal area offshore of the NZ Steel site and defining an appropriate location (and water depth) to measure ambient SST data.

Based on mean monthly SST data (sourced from www.climate-data.org) and the NZ Steel monitoring data, the mean monthly discharge temperature excess above ambient SST for the two main discharges is always below the consent threshold of 20 ºC (Table 4-14).

Note that the mean monthly excess temperature data does not consider the range of discharge temperatures than can occur or ambient SSTs that can occur within a given month. Results from the excess temperature modelling are detailed in Section 5.5.

Figure 4-6 shows the range of discharge temperatures that have been observed at the Southside and Northside Outfalls from 2017-2020 along with a polynomial fit to the upper limit of the discharge temperatures as a function of day number (i.e. the upper limit of what the discharge temperature may be on a given day of the year).

Figure 4-7 shows the excess discharge temperature based on the estimated mean monthly sea surface temperature and the observed discharge temperatures. It can be seen that the excess discharge temperature for the two discharges remains below the threshold of 20 ºC, but regularly exceeds 15 ºC at the Northside Outfall. For both discharges there is very little evidence of any seasonal variation in excess temperature.

Based on the above analysis, there is a possibility that the 20ºC excess could be exceeded around low tide for the Northside Outfall when ambient sea surface temperatures are at their lowest over any given 24-hour period.

However, the mean monthly ambient sea surface temperature does not consider the diurnal nature of the sea-surface temperature - warming during the day, cooling at night and also being influenced by the diurnal nature of catchment derived freshwater inputs. For example, data from the FWMT for the Waitangi Stream 5 node shows the maximum and minimum instantaneous reach temperatures[10] can be up to 5 ºC higher and lower than the average daily reach temperatures (Figure 4-8).

The variability in sea temperature as a result of the above processes in February (when ambient temperature is highest) and August (when ambient temperature is lowest) and the resulting dynamics of the excess temperature (based on the upper limit of the discharge temperatures shown in Figure 4-6) are discussed in detail in Section 5.

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[10] The daily FWMT data is derived from the underlying 15-minute timestep of the FWMT. While the minimum and maximum values are the minimum and maximum that occur at any time during each day.

Table 4-14. Monthly mean Waiuku sea surface temperature data, Northside and Southside Outfall temperature data and predicted monthly discharge temperature excess.

Month	**Waiuku Estuary Sea Surface Temperature[11] (ºC)**	**Mean Temperature (ºC) Northside Outfall**	**Mean Temperature (ºC) Southside Outfall**	**Mean Sea Surface Temperature Excess (ºC) Northside Outfall**	**Mean Sea Surface Temperature Excess (ºC) Southside Outfall**
Jan	20.1	31.5	25.9	11.4	5.8
Feb	20.9	31.9	24.9	11.0	4.0
Mar	20.2	31.1	23.6	10.9	3.4
Apr	19.0	29.3	22.1	10.3	3.1
May	17.4	28.2	21.0	10.8	3.6
Jun	15.6	26.7	18.5	11.1	2.9
Jly	14.4	26.2	18.6	11.8	4.2
Aug	13.9	25.4	19.2	11.5	5.3
Sep	14.3	26.9	19.4	12.6	5.1
Oct	15.3	28.0	20.5	12.7	5.2
Nov	16.8	30.0	22.2	13.2	5.4
Dec	18.7	30.7	24.8	12.0	6.1

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[11] Data is consistent with mean monthly sea surface temperature data for Leigh. Chiswell, S. and Grant. B. 2018. New Zealand Coastal Sea Surface Temperature. NIWA Report 2018295WN prepared for NZ Ministry for the Environment.

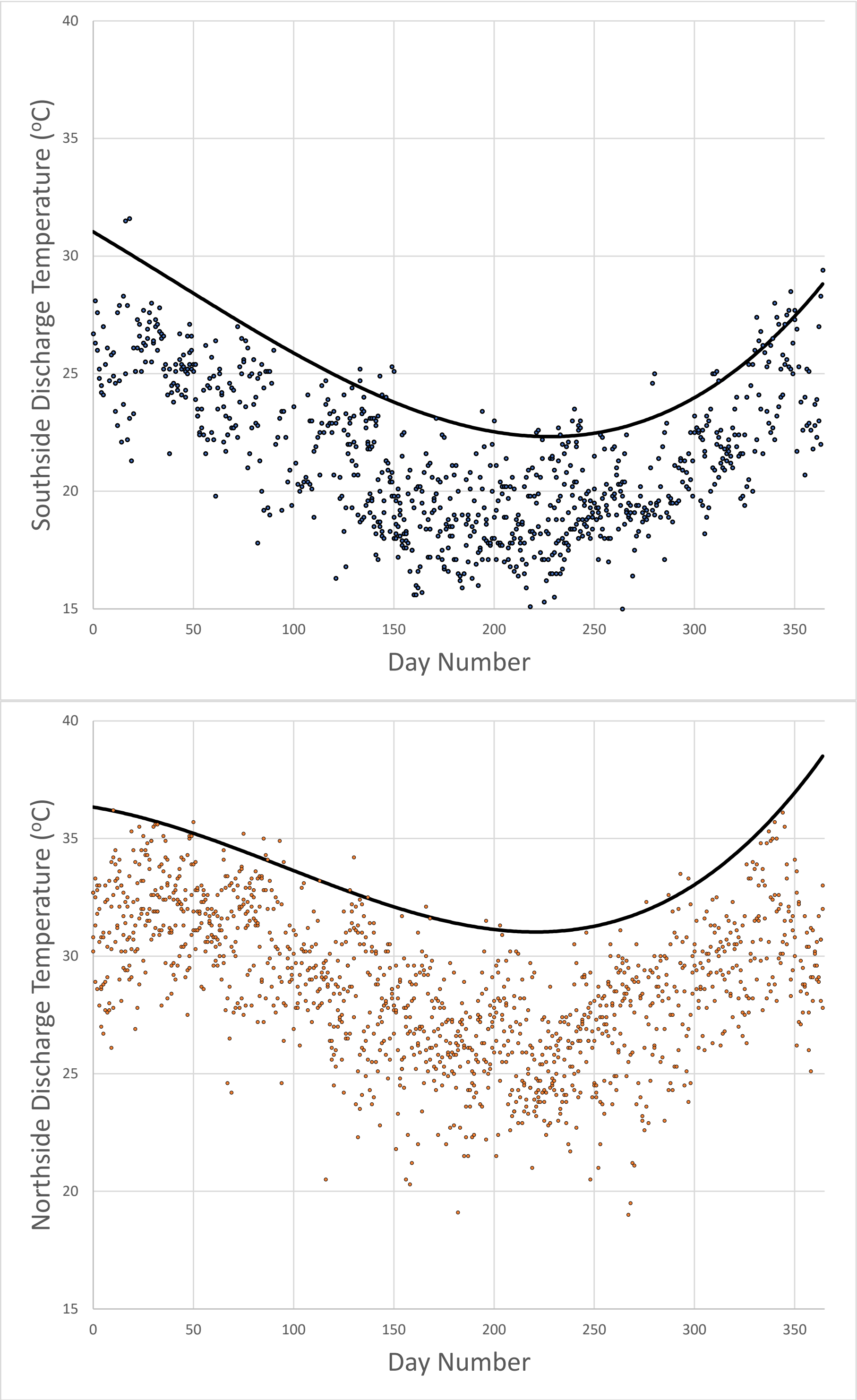

Figure 4-6. Observed Southside and Northside Outfall temperatures based on monitoring data (2017-2020). Solid line shows the polynomial fit through the upper envelop of the observed discharge temperatures.

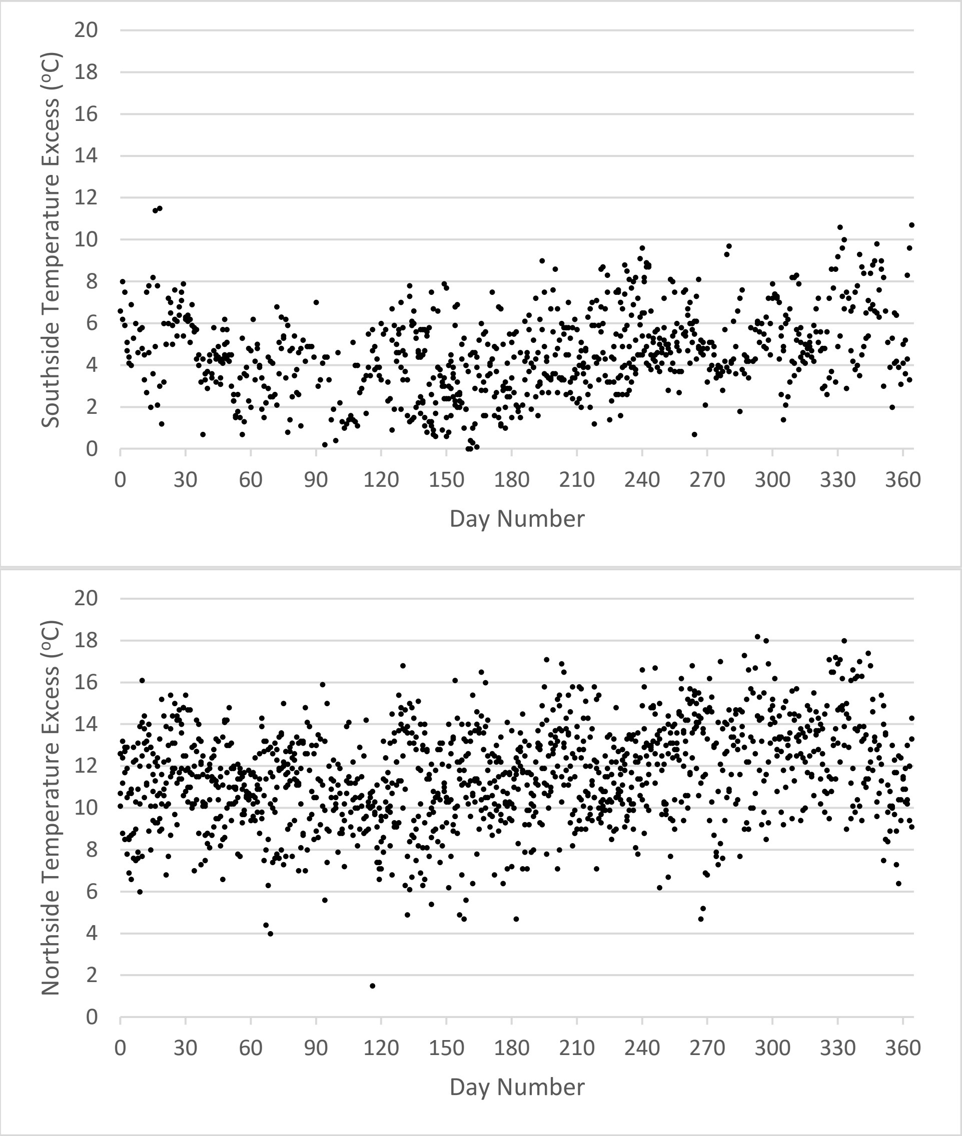

Figure 4-7. Predicted temperature excess for the Southside and Northside Outfall based on monitoring data (2017-2020) and assumed mean monthly sea surface temperature data for the Waiuku Estuary.

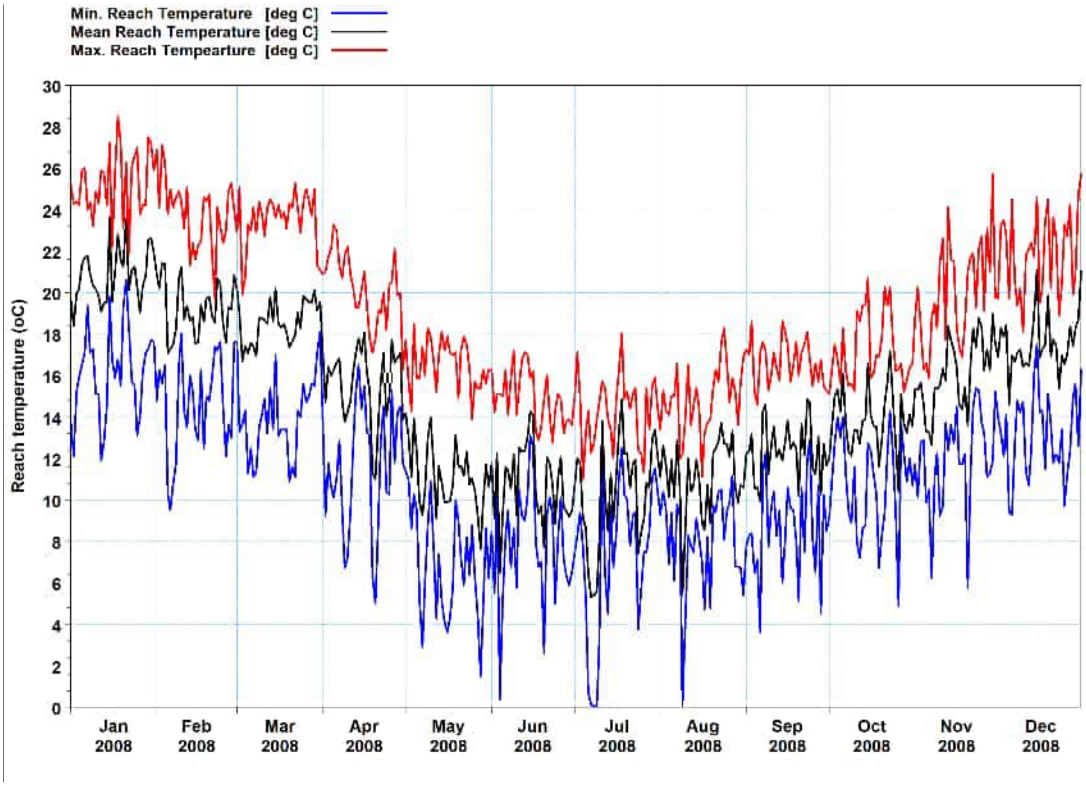

Figure 4-8. Predicted minimum daily, daily mean, and maximum daily temperatures for the FWMT Waitangi Stream 5 node (Figure 3-1).

5. Hydrodynamic Model Results

5.1 Predicted Currents

Predicted peak currents during the incoming (flood) tide and outgoing (ebb) tide (Figure 5-1) show the strong cross shore gradients that occur offshore of the NZ Steel site with strongest currents within the main channel and progressively weaker tidal currents moving towards the shoreline.

Within the main channel directly offshore of the NZ Steel site, peak currents often exceed 0.50 m/s. On the inter-tidal area currents are generally less than 0.30 m/s, while near the shoreline itself, currents are generally lower than 0.15 m/s.

Relatively uniform flows occur within the main channel north of the NZ Steel site, however much stronger flows occur to the south of the NZ Steel site through the area known as The Needles. Weaker currents are predicted to occur south of this point moving towards the major freshwater sources within the Waiuku Town Basin.

At the time of local low tide (i.e. when currents directly offshore of the NZ Steel site are close to zero), predicted currents to the north of the NZ Steel site have begun to flood (influenced by the incoming tide at the entrance to the Waiuku Estuary) while flows within the Waiuku Basin are still ebbing due to water still draining from the Waiuku Basin (Figure 5-2). At the time of local high tide strong currents are predicted to occur at The Needles (Figure 1-1) and on the inter-tidal area immediately north of the NZ Steel site around Okohaka Point (Figure 1-1).

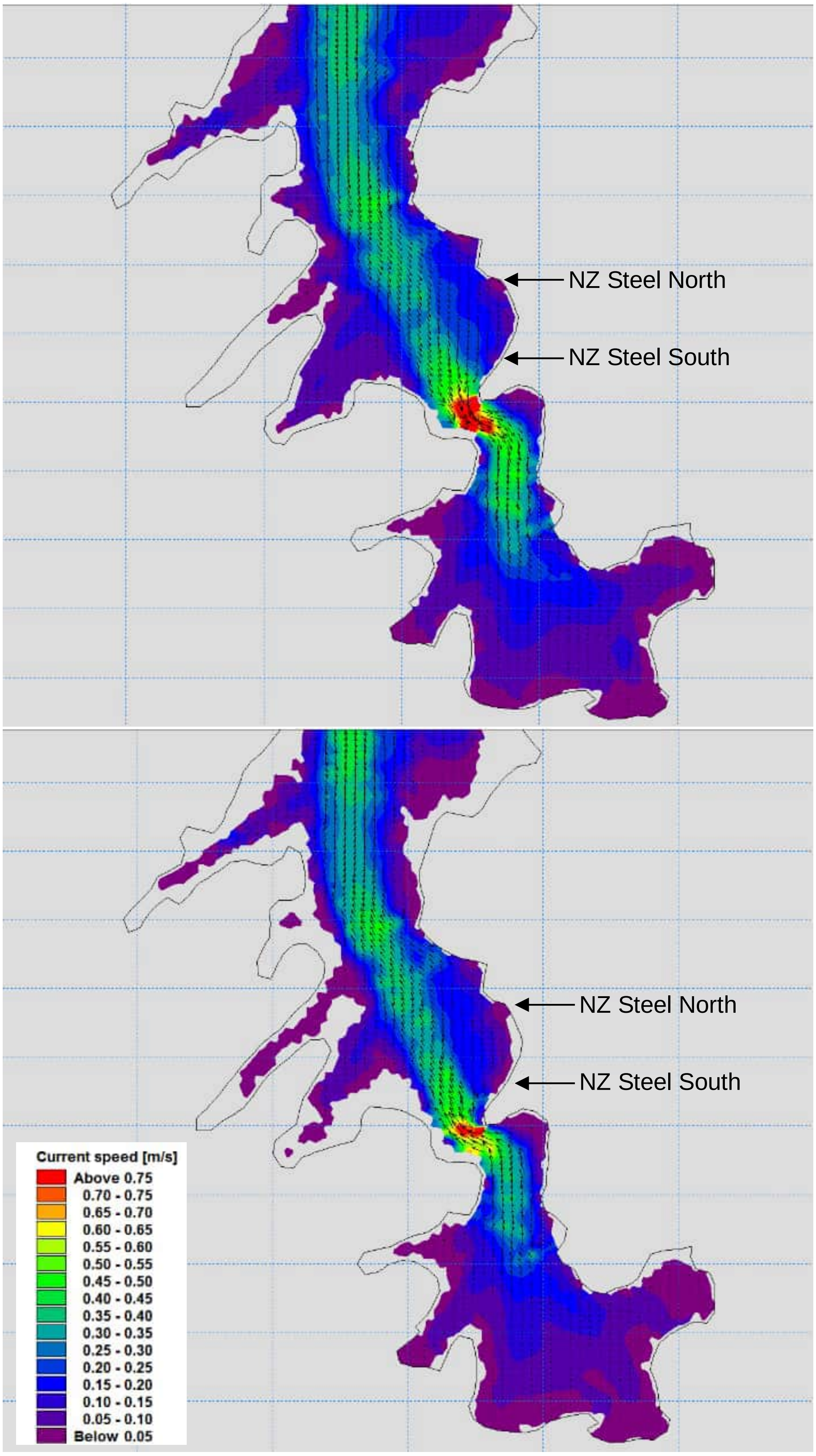

Figure 5-1. Predicted currents for a mid-flood (top panel) and mid-ebb (bottom panel) tide.

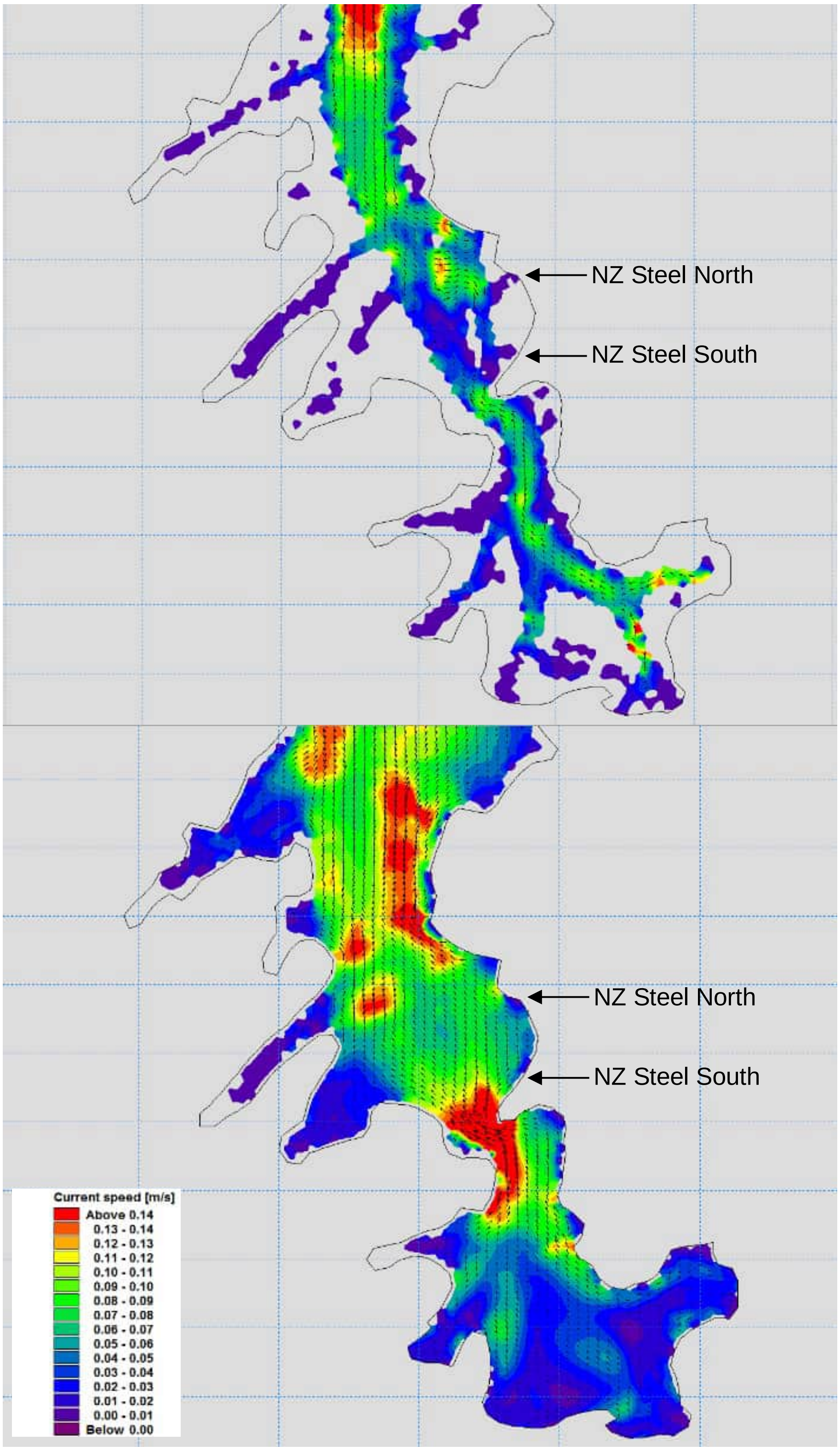

Figure 5-2. Predicted currents at low tide (top panel) and high tide (bottom panel). Low tide and high tide times are defined by when currents offshore fo the NZ Steel site are close to zero.

5.2 Salinity

Figure 5-3 shows the predicted mean salinity across the Waiuku and Taihiki estuaries. Each of the freshwater sources in the model from the FWMT nodes (Figure 3-1) and the NZ Steel discharges have localised effects in terms of the predicted gradients in salinity. The combined effect of the freshwater sources discharging to the Waiuku Town Basin is a reduction in mean salinity to around 15 Practical Salinity Units (PSU[12]). Other freshwater sources along the western side of the Waiuku Estuary result in similar localised reductions in mean salinities. Within the embayment immediately offshore of the NZ Steel site, the mean salinity is around 20 PSU, however there is a gradient in predicted salinities moving away from the NZ Steel discharge points due to the dynamic nature of the hydrodynamics of the area (discussed above).

Figure 5-4 and Figure 5-5 shows the variation in predicted salinity at the Southside and Northside Outfalls with radial distance from the discharge point. A radial distance is used because at times the plume is transported north of the discharge points, at times it is transported south of the discharge point and around low tide it moves predominantly offshore of the discharge point. Model data was interpolated along the circumference of 10, 20, 50, 100, 200, 300 and 500 m circles out from the discharge point.

At the Southside Outfall discharge site (Figure 5-4), the mean salinity is just under 22 PSU while the 25th percentile salinity drops to less than 15 PSU and the 75th percentile value is in excess of 25 PSU.

Percentile values take into account flooding and drying of cells. If a cell is dry for the majority of the model simulation the 95th percentile value is the value that is exceeded for the amount of time the cell is inundated.

Percentile values for subtidal areas (that are permanently inundated) include the full year of estimates.

The 25th percentile salinity beyond around 50 m of the discharge point remain relatively constant indicating the relatively small influence the Southside Outfall has on predicted salinities away from the discharge point. This is in part due to relatively low discharge rate from the Southside Outfall (Table 4-12) and the influence of the mixing of lower salinity waters from the Waiuku Basin into this area on the outgoing (ebb) tide (e.g. Figure 5-1).

At the Northside Outfall (Figure 5-5), the mean salinity is just under 22 PSU while the 25th percentile salinity drops to less than 12 PSU due to the higher Northside Outfall discharge volume (Table 4-12) and the 75th percentile value is in excess of 25 PSU. The 25th percentile salinity increases with distance from the Northside Outfall out to around 200 m. Beyond this distance the minimum salinity remains relatively constant indicating the influence of the mixing of more saline waters on the incoming (flood) tide from the north into this area (e.g. Figure 5-1).

The influence of the dynamics of the NZ Steel discharges can be quantified by running the hydrodynamic model with the NZ Steel discharges removed. Figure 5-6 shows the predicted decreases in average salinity that can be attributed to the NZ Steel discharges – with a predicted decrease in average salinity of 3.8 PSU immediately offshore of the Northside Outfall site and a decrease of 2.4 PSU at the Southside Outfall.

The plot shows that the water column footprint for the Northside Outfall is larger than that for the Southside Outfall due to the combination of higher discharge volume and the different hydrodynamics near the Northside Outfall.

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[12] PSU is a measure of the total grams of salt per kilogram of seawater. The average salinity of the ocean is 35 PSU and pure freshwater has a PSU of zero.

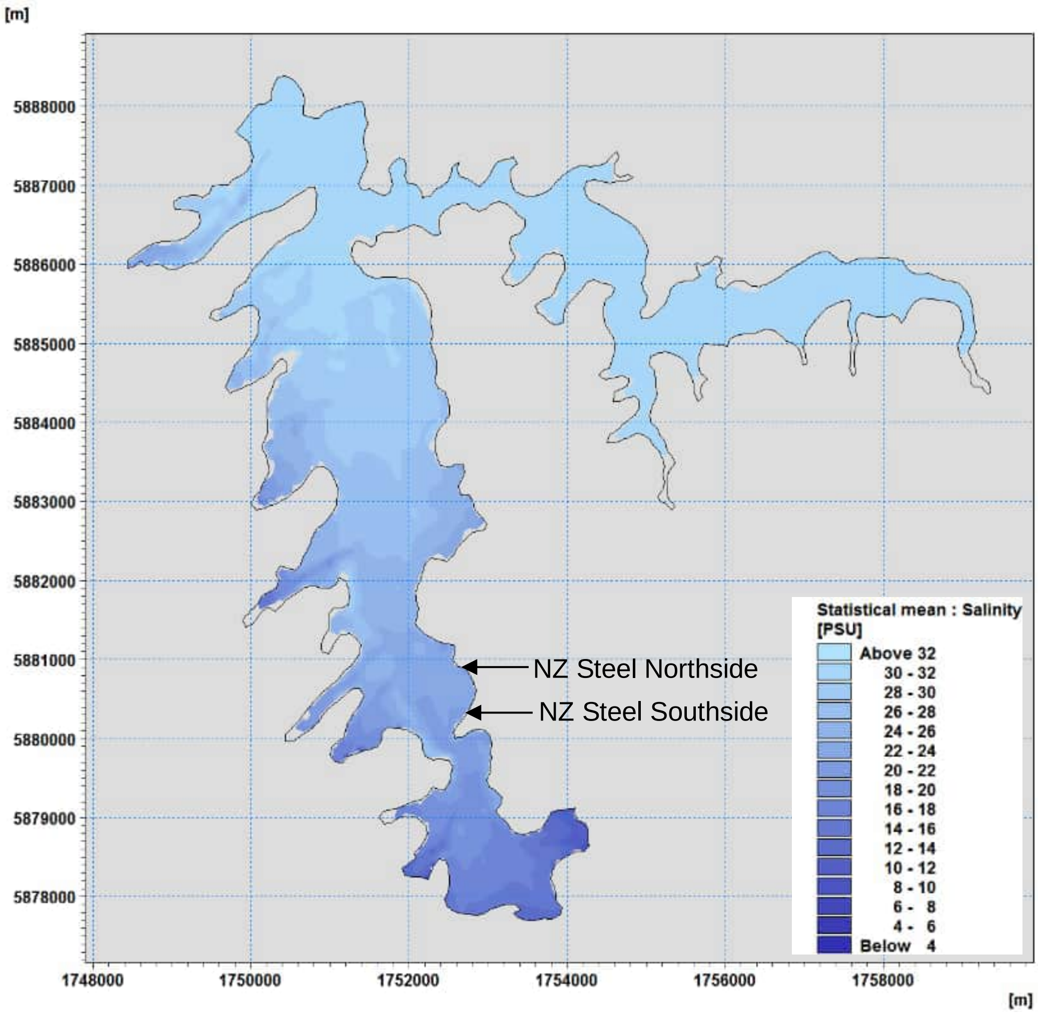


Figure 5-3. Predicted mean salinity (PSU) for all of 2008.

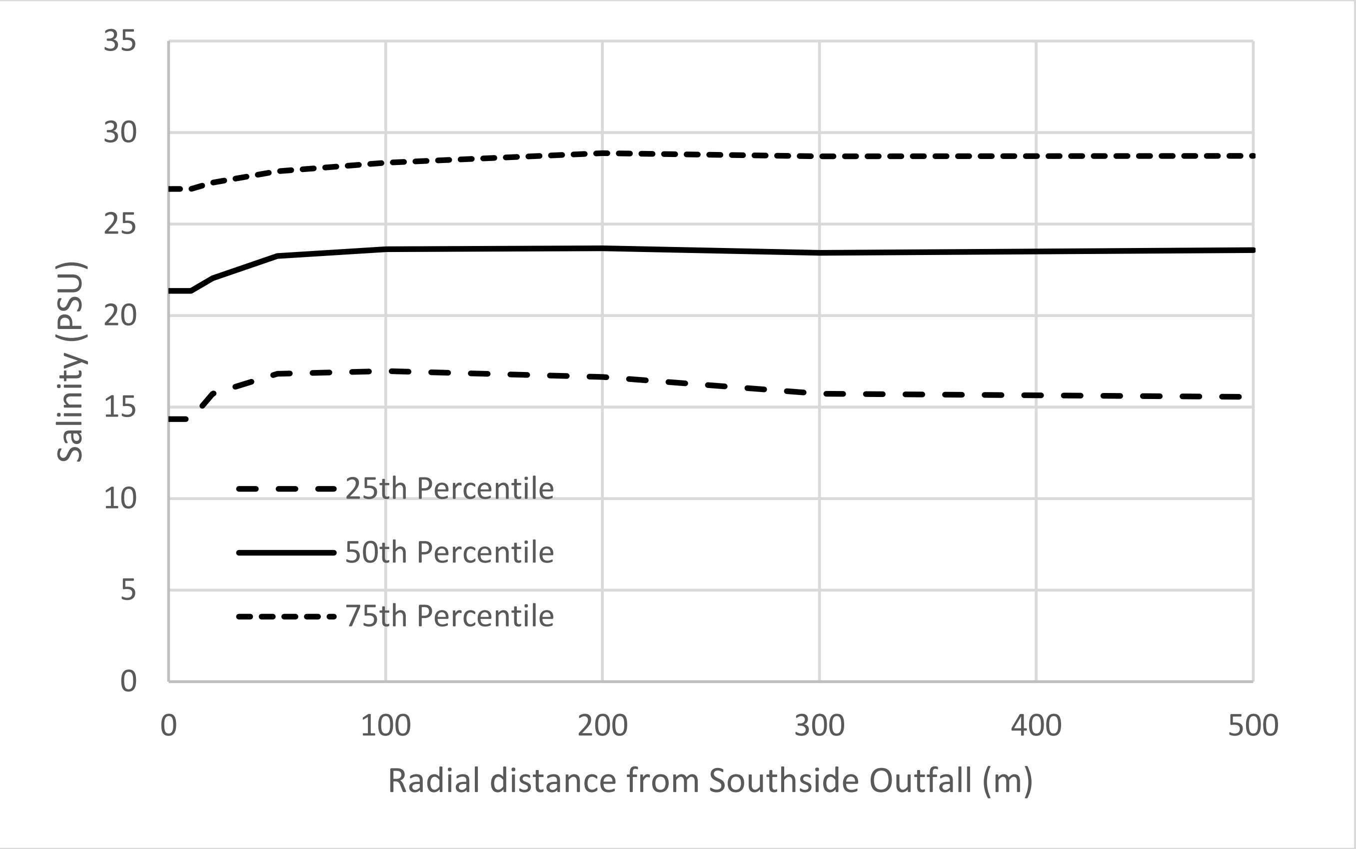


Figure 5-4. Mean, 25th and 75th percentile salinities (PSU) versus distance (m) from the Southside Outfall.

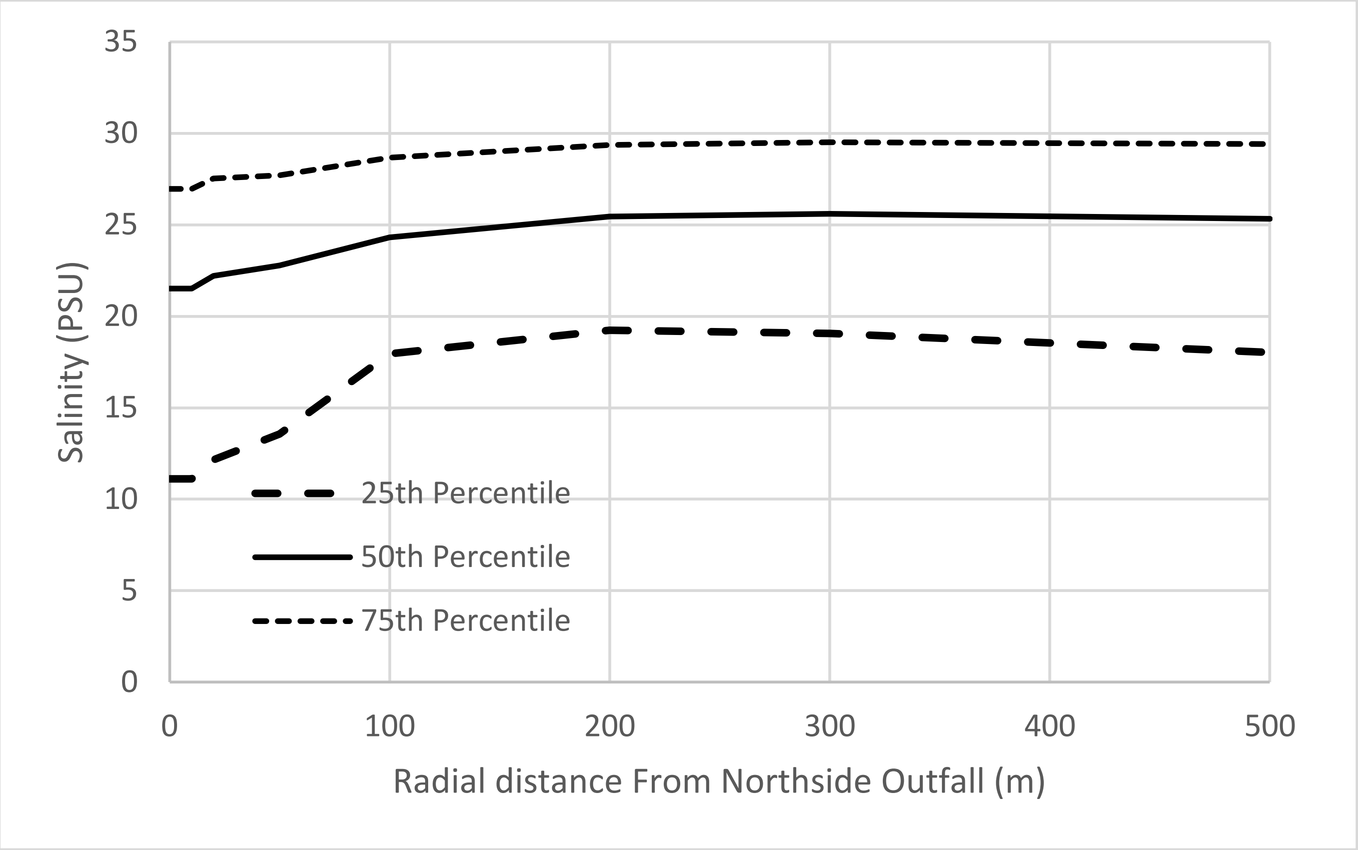


Figure 5-5. Mean, 25th and 75th percentile salinities (PSU) versus distance (m) from the Northside Outfall.

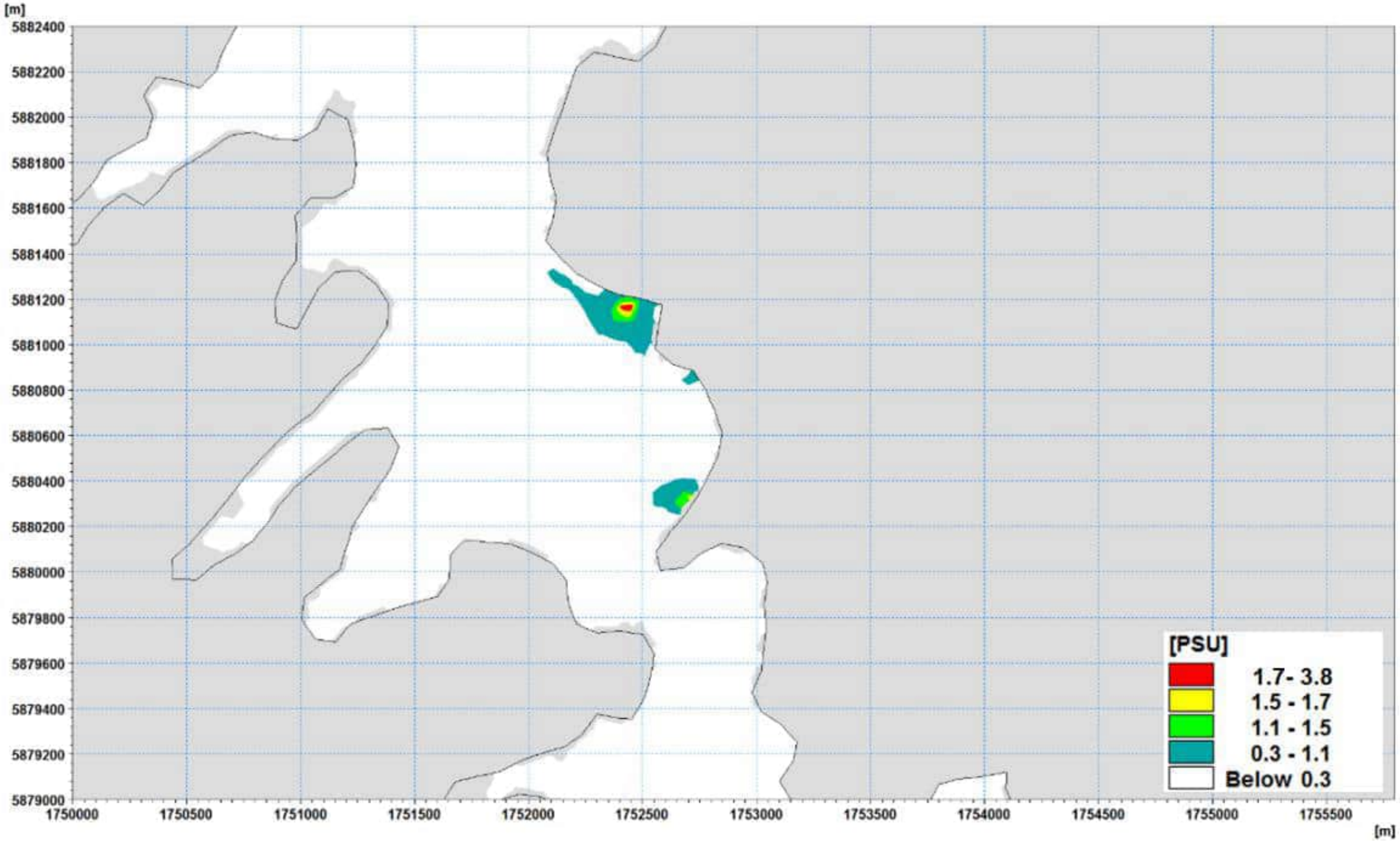


Figure 5-6. Predicted decrease in mean salinity for all of 2008 due to the Northside and Southside Outfalls.

5.3 Plume Dynamics

The dynamics of the discharge plumes as they mix with the ambient waters of the Waiuku Estuary can be illustrated by examining the predicted water column concentrations of a conservative tracer (akin to adding dye to the water) expressed as a percentage of a source concentration of 100% at sites moving away from the discharge points as shown in Figures 5-7 to 5-14.

The use of a conservative tracer is used to assist with an explanation of the dynamics of discharge plumes in the area without the complication of any chemistry, decay or other processes (e.g. heating/cooling). This provides a useful description of the mixing processes and degree of water column dilution that is achieved near the discharges which aids with the discussion around water column Zinc and Copper results (Section 5.4 of the report) and excess Temperature results (Section 5.5 of the main report).

Results for the conservative tracer are presented in terms of percentage contaminants. That is, the source concentration is assumed to be 100%.

For the Northside Outfall the concentration near the discharge point is close to 100% at low tide for the first half of June (Figure 5-7). During neap tides (towards the end of June) the water depth at low tide is around 0.5 m so there is a reduction in the maximum predicted concentration at low tide to around 50%. These predicted peak concentrations at low tide are significantly reduced at other states of tide as the water depth increases at this site (increasing dilution) and the plume is moved away from the discharge point due to increasing tidal currents.

The predicted peak concentration at low tide reduces with distance from the Northside Outfall reducing to less than 15% at 200 m from the Northside Outfall (Figure 5-9) and to less than 8% at a distance of 500 m from the Northside Outfall (Figure 5-10).

For the Southside Outfall the concentration close to the discharge point is less than 25% at low tide. The predicted peak concentrations at low tide are significantly reduced at other states of tide due (as water depth increases at this site).

The predicted peak concentration at low tide reduces with distance from the Southside Outfall reducing to less than 3% at 200 m from the Southside Outfall (Figure 5-13) and to less than 2% at a distance of 500 m from the Southside Outfall (Figure 5-14).

By running long-term model simulations, it is possible to derive meaningful statistical predictions of water column concentrations that account for the very dynamic nature of the discharge plumes.

For example, a 95th percentile estimate of concentration at the sites considered quantifies the value that is only exceeded 5% of the time (i.e. a statistical estimate of the concentration that will occur around low tide which takes into account the variability of predicted peak concentrations that will occur due to effects of winds and variable tide range).

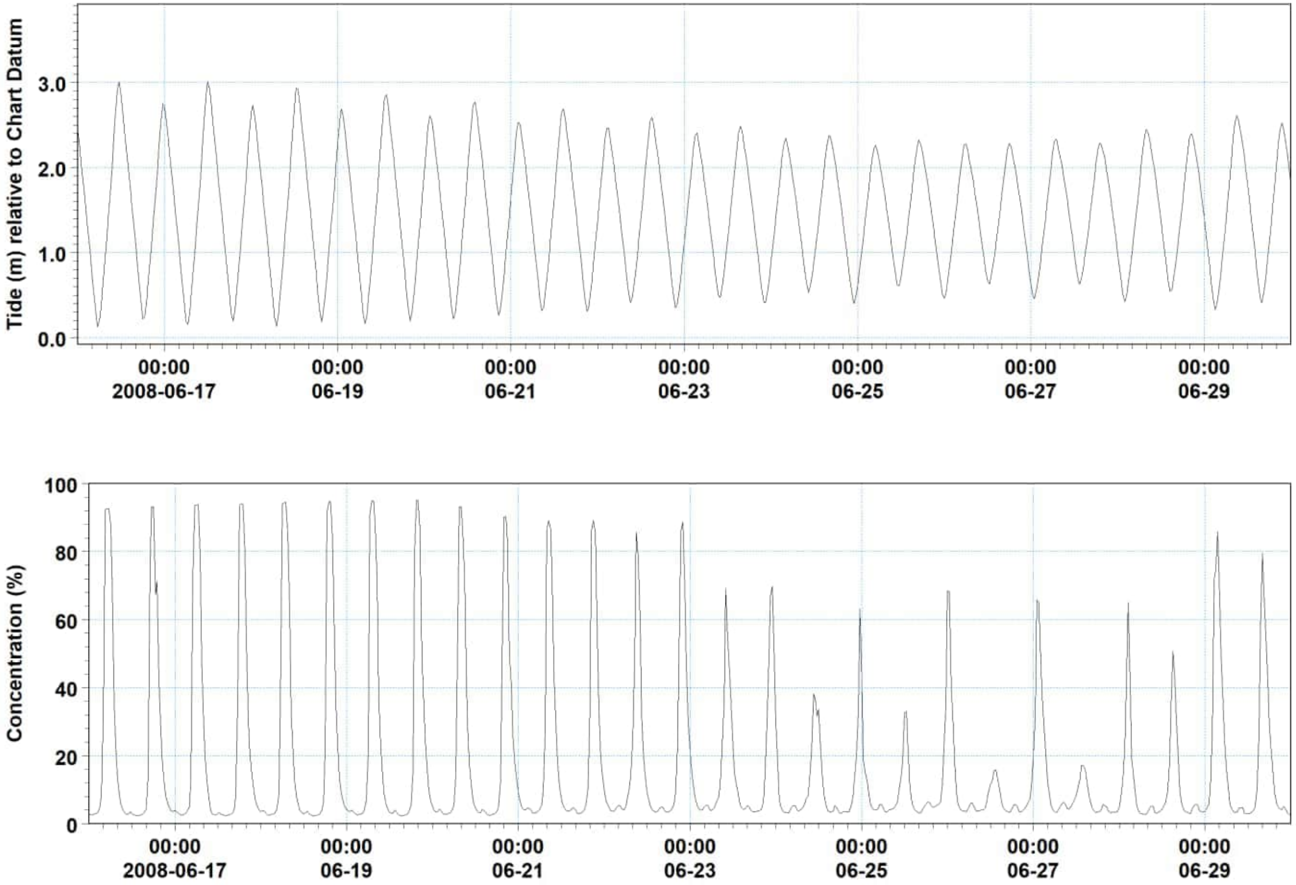


Figure 5-7. Predicted tide offshore of the NZ steel site (top panel) and predicted concentration (expressed as a percentage of the source concentration) at a site 50 m from the Northside Outfall for June 2008.

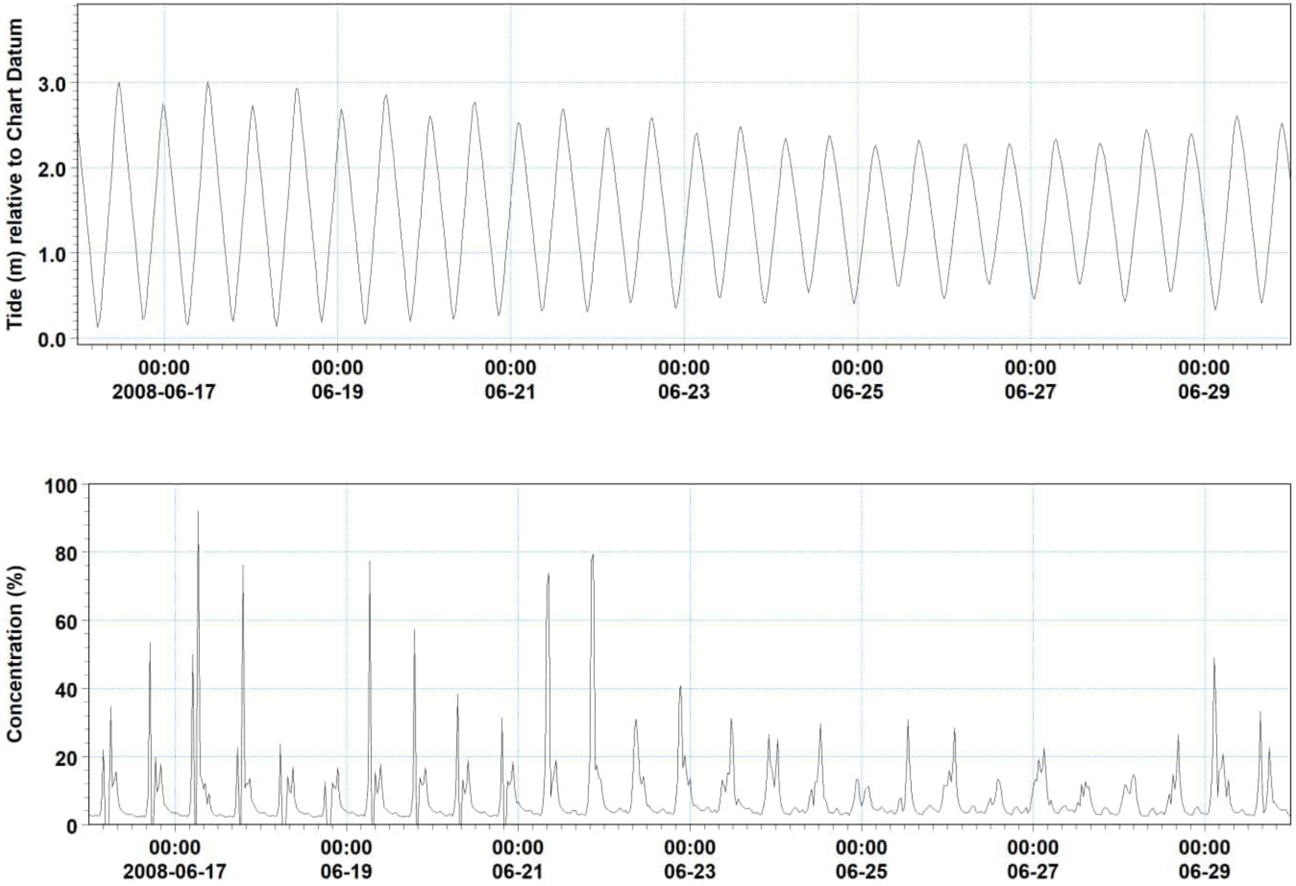


Figure 5-8. Predicted tide offshore of the NZ steel site (top panel) and predicted concentration (expressed as a percentage of the source concentration) at a site 100 m from the Northside Outfall for June 2008.

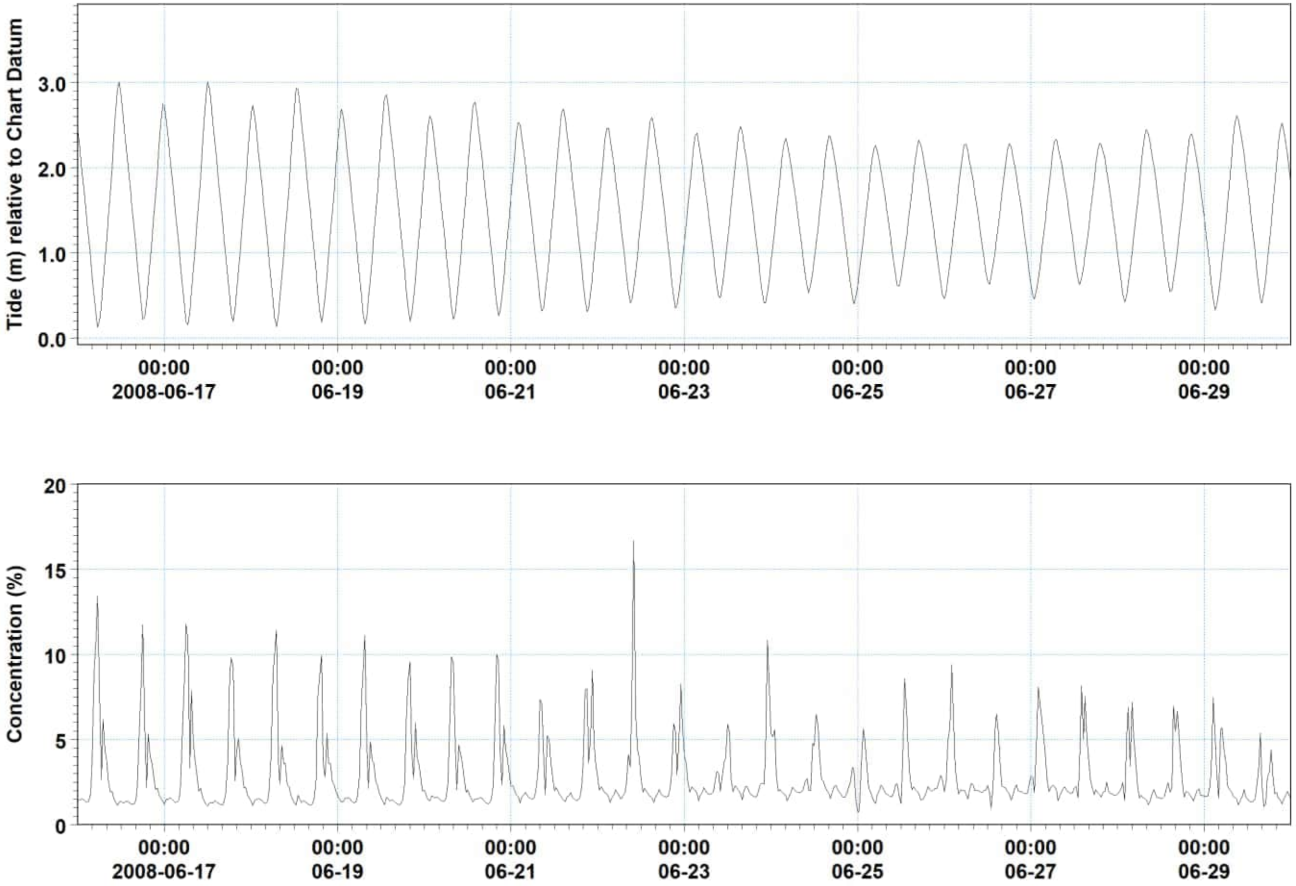


Figure 5-9. Predicted tide offshore of the NZ steel site (top panel) and predicted concentration (expressed as a percentage of the source concentration) at a site 200 m from the Northside Outfall for June 2008.

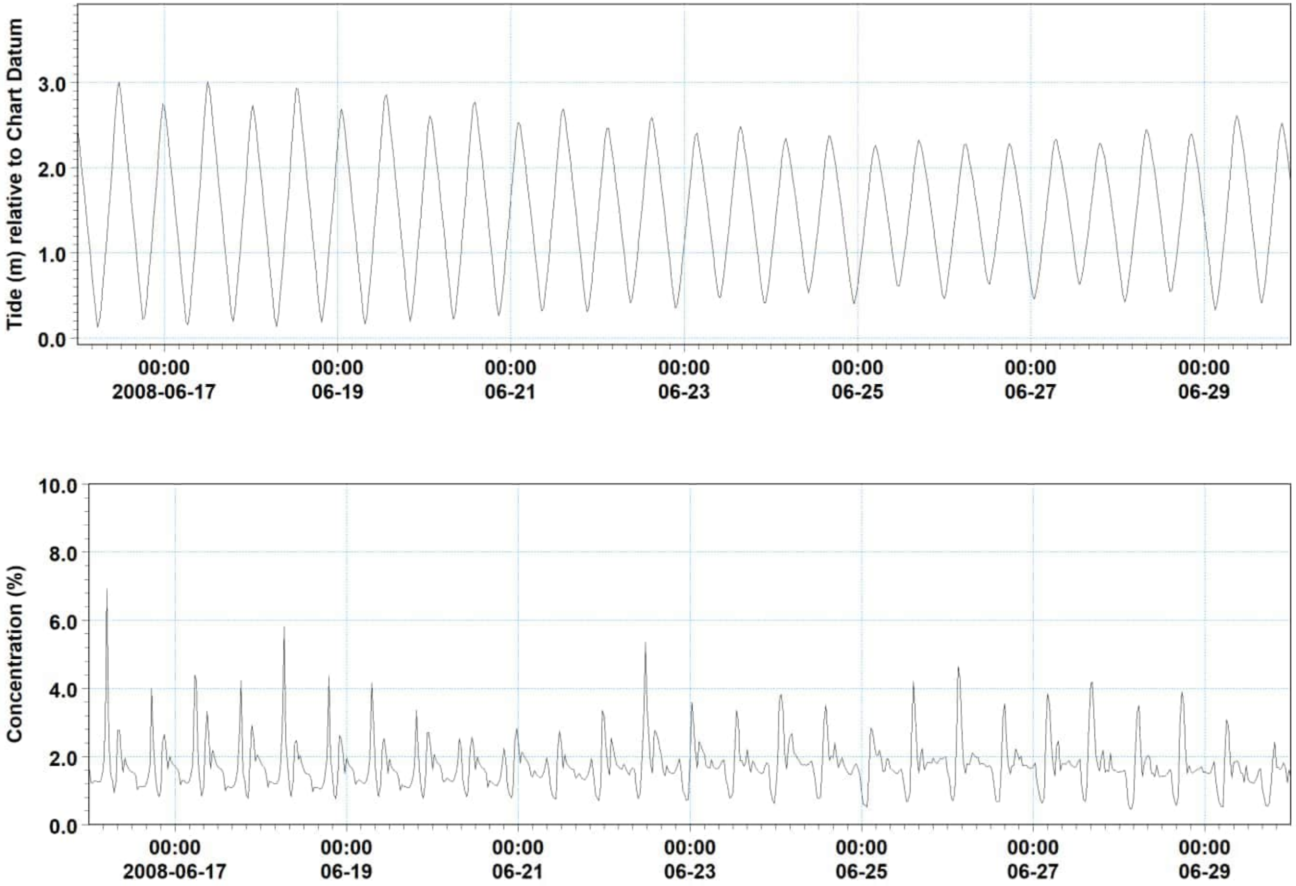


Figure 5-10. Predicted tide offshore of the NZ steel site (top panel) and predicted concentration (expressed as a percentage of the source concentration) at a site 500 m from the Northside Outfall for June 2008.

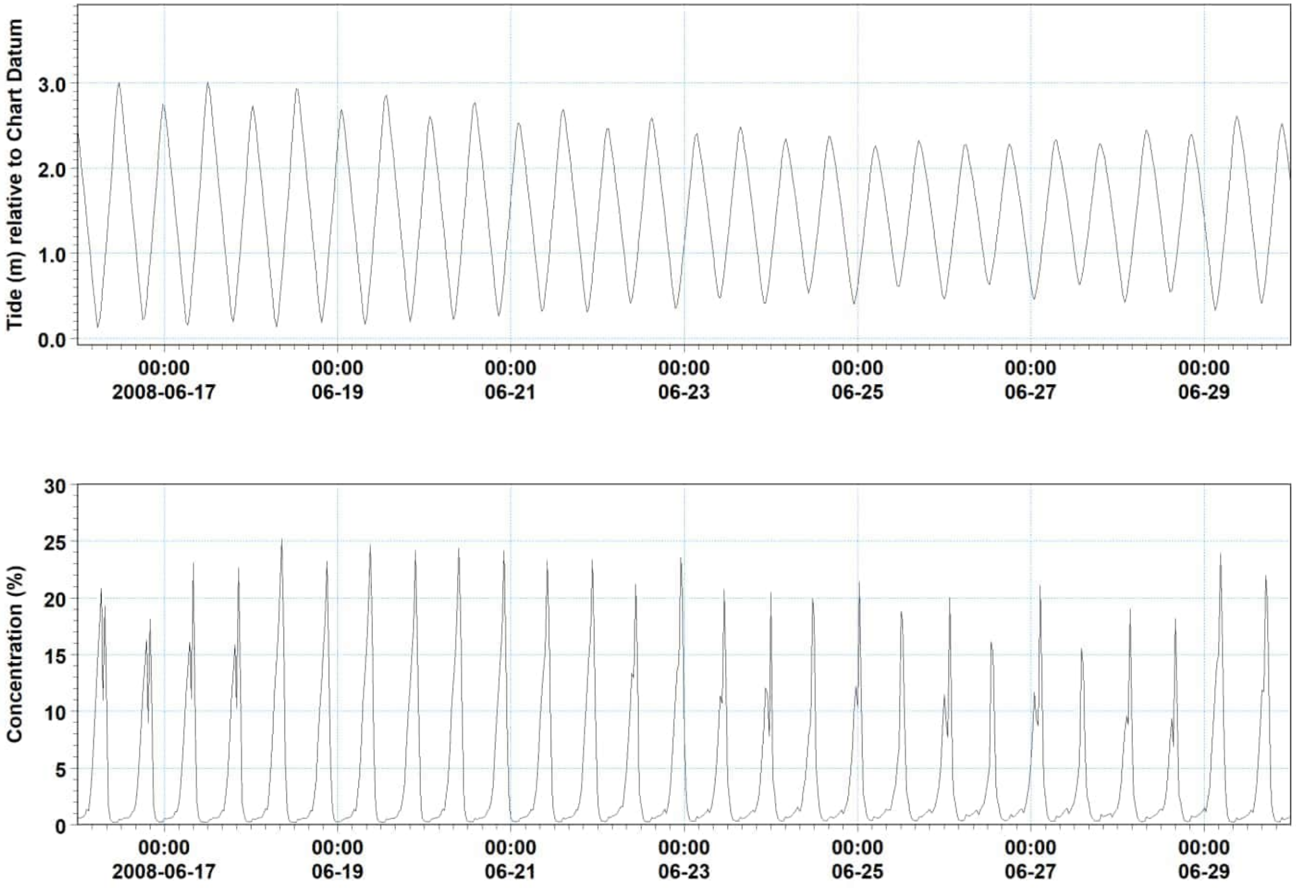


Figure 5-11. Predicted tide offshore of the NZ steel site (top panel) and predicted concentration (expressed as a percentage of the source concentration) at a site 50 m from the Southside Outfall for June 2008.

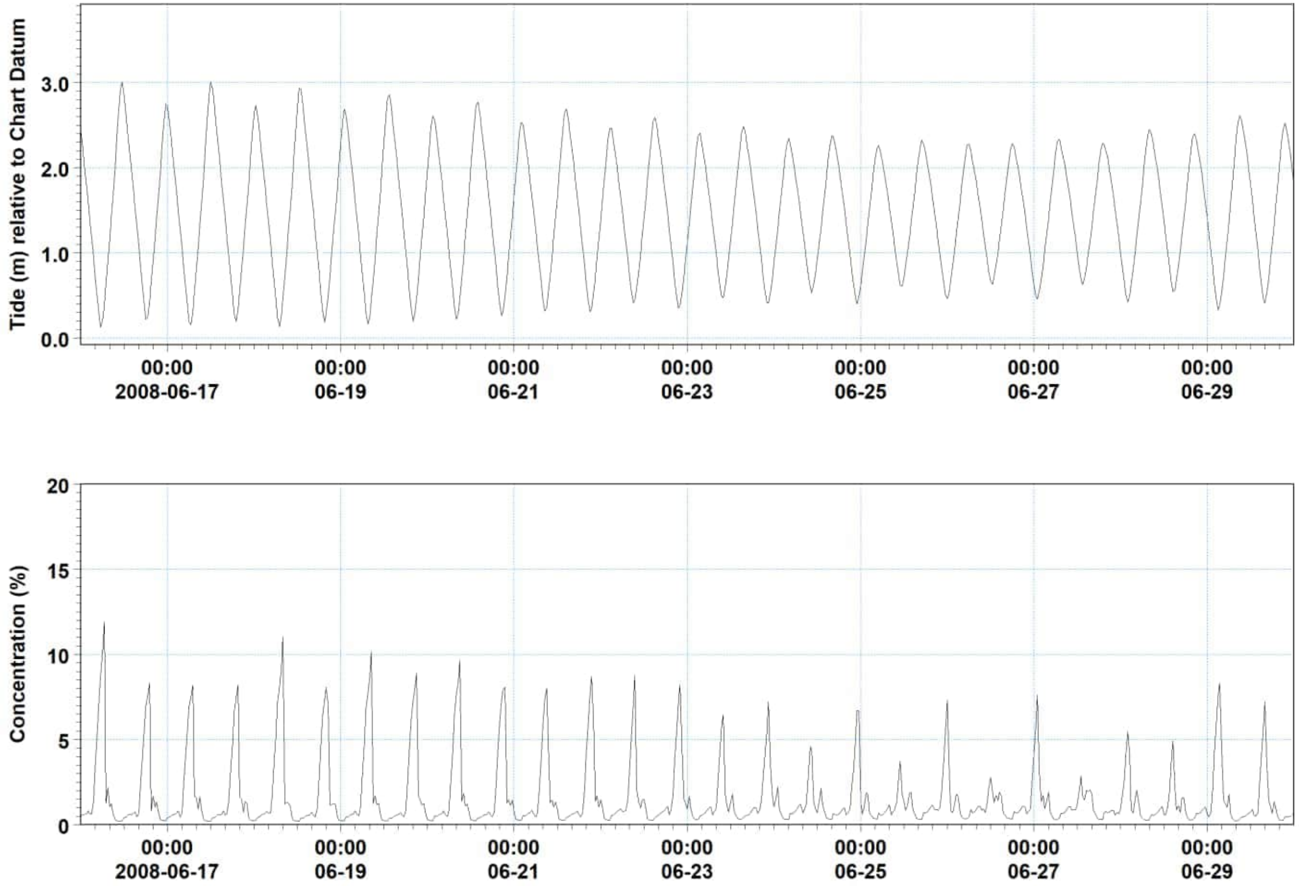


Figure 5-12. Predicted tide offshore of the NZ steel site (top panel) and predicted concentration (expressed as a percentage of the source concentration) at a site 100 m from the Southside Outfall for June 2008.

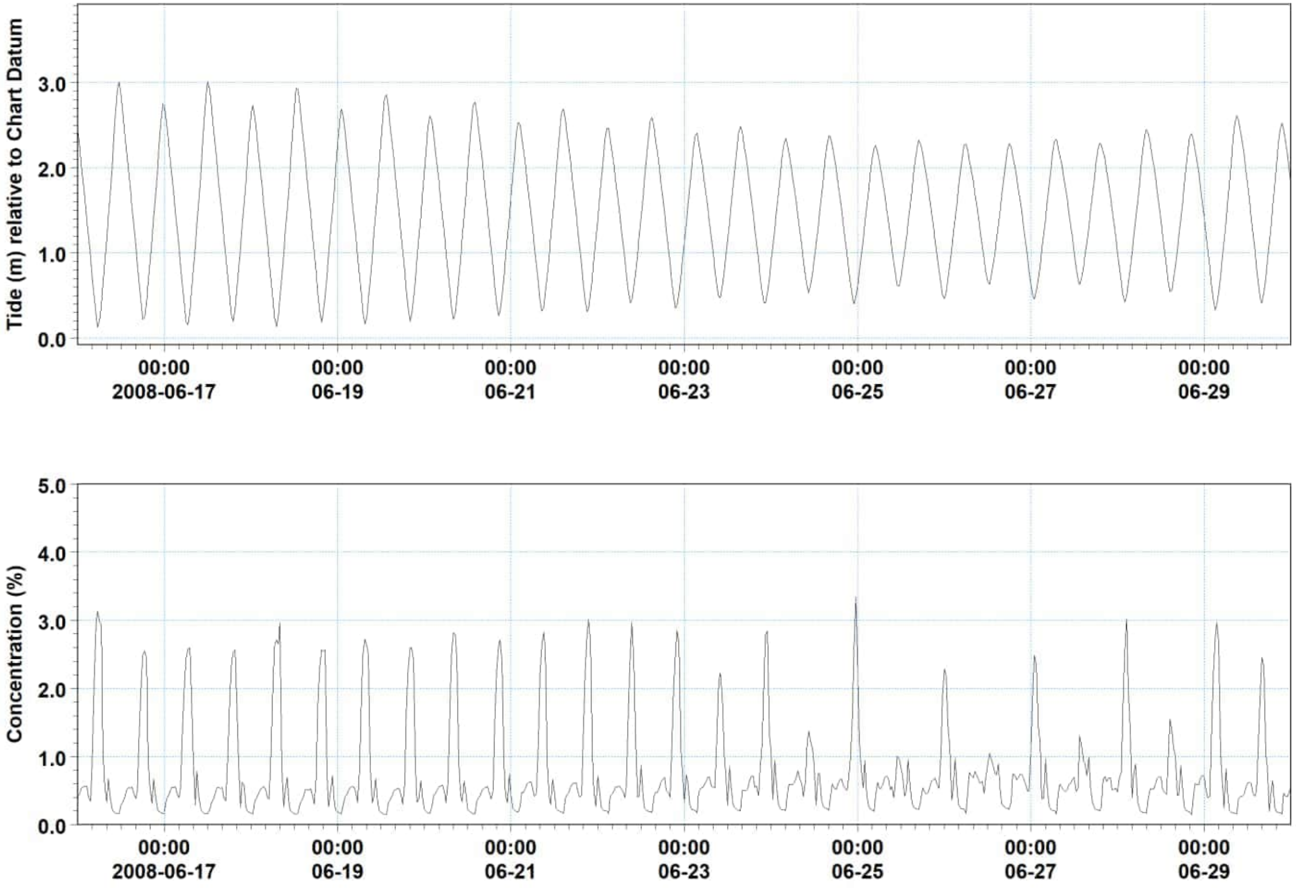


Figure 5-13. Predicted tide offshore of the NZ steel site (top panel) and predicted concentration (expressed as a percentage of the source concentration) at a site 200 m from the Southside Outfall for June 2008.

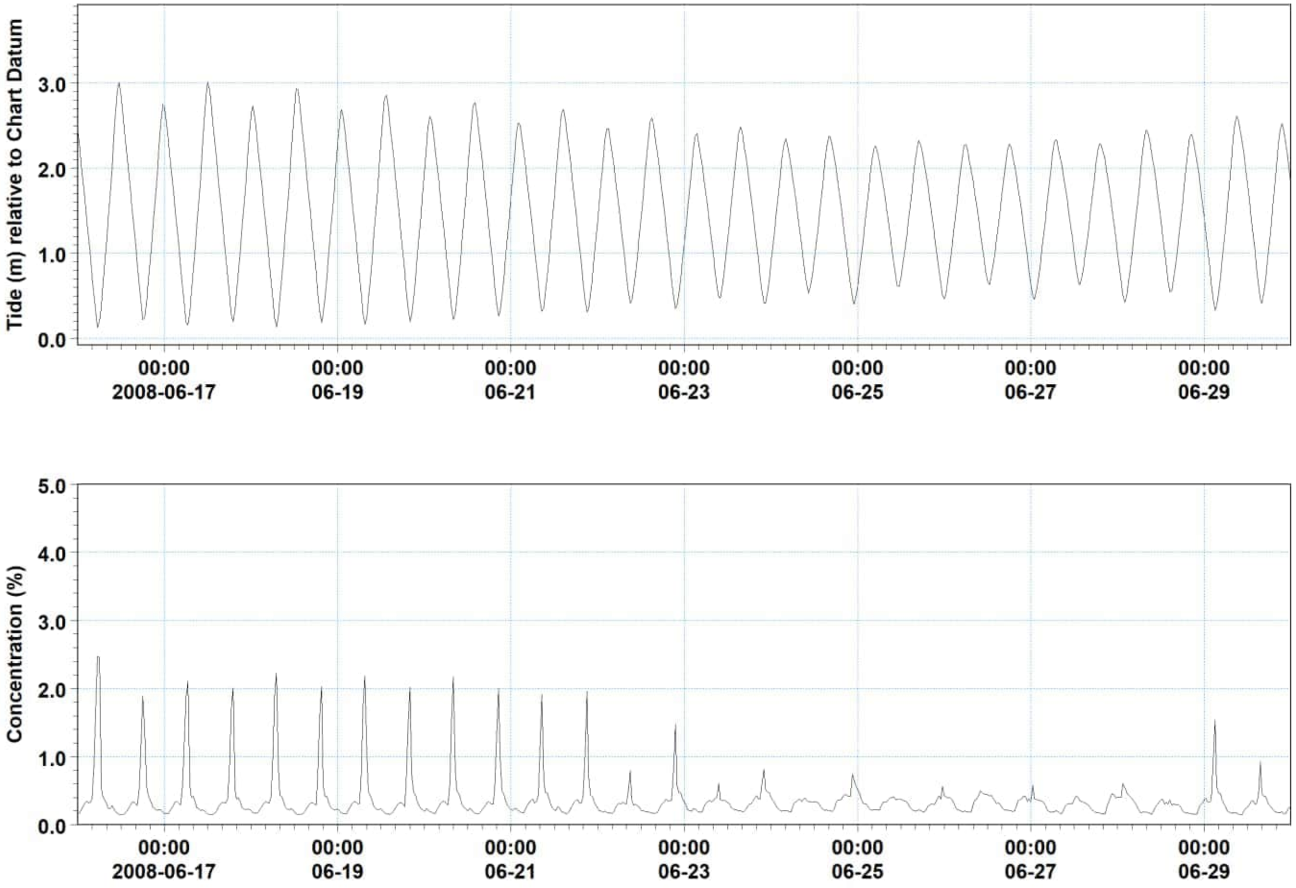


Figure 5-14. Predicted tide offshore of the NZ steel site (top panel) and predicted concentration (expressed as a percentage of the source concentration) at a site 500 m from the Southside Outfall for June 2008.

5.4 Dissolved Metals

NZ Steel discharges of Copper and Zinc

Using the assumed median source concentrations of dissolved Zinc and Copper for the Northside and Southside Outfalls (Table 4-9) the advection-dispersion module was run for all of 2008 to provide predictions of water column concentrations of Zinc and Copper.

The reasoning for using the median for the source concentration is that model results are presented as percentiles. The percentile values are calculated by extracting the predicted concentrations from the model every 30-minutes in each element of the model for all of 2008. The 50th and 95th percentile value in each element is then quantified by determining the concentration that is exceeded fifty or five percent of the time for the full 2008 simulation. For consistency with this approach the source concentration is set to the median value (i.e. the value that occurs at the source 50 percent of the time).

Northside Outfall

Figure 5-15 and Figure 5-16 show spatial plots of the 50th and 95th percentile Zinc and Copper concentrations for the Northside Outfall.

The colour coding in these figures is based on the 2021 ANZWQG default marine guidelines for Zinc and the existing ANZECC (2000) marine guidelines for Copper as shown in Table 5-1.

Table 5-1. Species Protection Level (SPL) guidelines used for water column Zinc and Copper concentrations.

Contaminant	High Conservation value system	Slightly to moderately disturbed systems	Highly Disturbed Systems	
	99% species protection	95% species protection	90% species protection	80% species protection
Dissolved Zinc (µg/L) **2021 ANZWQG guideline values)**	3.3	8.0	12.0	21.0
Dissolved Copper (µg/L) **2000 ANZECC guideline values)**	0.3	1.3	3.0	8.0

Figure 5-17 shows the 50th and 95th percentile water column concentrations of Zinc and Copper as a function of radial distance from the Northside Outfall. A radial distance is used because at times the plume is transported north of the discharge points, at times it is transported south and around low tide it moves predominantly offshore of the discharge point. Model data was interpolated along the circumference of 10, 20, 50, 100, 200, 300 and 500 m circles out from the discharge point.

The 95th percentile estimate of Copper only exceeds the 99% species protection guideline value of 0.3 µg/L within 100 m of the Northside Outfall.

The maximum 95th percentile estimate for Copper at the Northside Outfall is 1.2 µg/L - below the 95% species protection guideline value of 1.3 µg.

The maximum 95th percentile estimate for Zinc at the Northside Outfall is 25.1 µg/L meaning that the 80% protection guideline values for Zinc is exceeded within 60 m of the Northside Outfall.

The 95th percentile estimate for Zinc exceeds the 90% and 95% protection guideline values within 90-100 m of the Northside Outfall.

The 95th percentile value for Zinc exceeds the 99% species protection guideline of 3.3 µg/L within a radius of ~200 m of the Northside Outfall.

The 50th percentile estimates of Zinc and Copper remain below the 99% species protection guidelines at the Northside Outfall.

Southside Outfall

Figure 5-18 and Figure 5-19 show spatial plots of the 50th and 95th percentile Zinc and Copper concentrations for the Southside Outfall.

Figure 5-20 shows the predicted 50th and 95th percentile water column concentrations of Zinc and Copper as a function of radial distance from the Southside Outfall discharge point. A radial distance is used because at times the plume is transported north of the discharge points, at times it is transported south and around low tide it moves predominantly offshore of the discharge point. Model data was interpolated along the circumference of 10, 20, 50, 100, 200, 300 and 500 m circles out from the discharge point.

The Zinc and Cooper loads from the Southside Outfall are much less than those from the Northside Outfall (Table 4-12).

The 95th percentile estimate of Copper only exceeds the 99% species protection guideline value of 0.3 µg/L within 50 m of the Southside Outfall.

The maximum 95th percentile estimate for Copper is 0.5 µg/L so the 95% species protection guideline value of 1.3 µg/L is not exceeded at the Southside Outfall.

The maximum 95th percentile estimate for Zinc is 0.7 µg/L so none of the species protection guideline values for Zinc are exceeded at the Southside Outfall.

The 50th percentile estimates of Zinc and Copper remain below the 99% species protection guidelines at the Southside Outfall.

Section 5.4 provides tables and figures of the percentage of time above thresholds for the above model simulations.

Note that all of the above assume background levels of dissolved Zinc or Copper due to catchment sources. The above results therefore provide quantification of the individual water column footprints from the Northside and Southside Outfalls.

Catchment derived Copper and Zinc

Figures 5-21 through to 5-24 show the predicted 50th and 95th percentile water column concentrations of Copper and Zinc from the annual simulation of the inputs of the model just with the catchment derived inputs of Copper and Zinc from the FWMT data. For this simulation it has been assumed that 75% of the FWMT derived loads are in dissolved form.

50th percentile Copper levels are around 0.5 µg/L within the Waiuku Basin and the 95th percentile Copper levels increase to around 1.5 µg/L within the Waiuku Basin.

For Zinc, the 50th percentile levels are around 0.75 µg/L within the Waiuku Basin and the 95th percentile levels increase to around 1.8-3.0 µg/L both within the Waiuku Basin and near other catchment sources. Gradients in catchment derived Zinc and Copper away from the catchment sources reflect the general water column mixing processes that occur (as discussed in Section 5.2).

These 95th percentile plots reflect the higher metal loads delivered to the Waiuku Estuary during winter while the 50th percentile plots are more representative of the typical summer loading to the system.

Combined NZ Steel and catchment derived Copper and Zinc

For the NZ Steel simulations the 95th percentile data reflects the lowest level of dilution achieved over a tidal cycle (i.e. around low tide) while the 50th percentile data reflects what happens, on-average, over a tidal cycle.

This must be taken into account when considering the 50th and 95th percentile data for the combined NZ Steel and catchment derived Copper and Zinc.

Figures 5-25 through to 5-28 show the predicted 50th and 95th percentile estimates of Copper and Zinc for the combined inputs of Copper and Zinc from the NZ Steel site and the catchment.

The 50th percentile combined Copper levels are below the 99% species protection guideline of 0.3 µg/L within much of the Waiuku Estuary and are only exceeded in the southern parts of the Waiuku Estuary close to catchment sources.

The 95th percentile combined Copper levels are above the 99% species protection guideline of 0.3 µg/L within much of the Waiuku Estuary and the 95% species protection guideline of 1.3 µg/L is only exceeded close to some of the catchment sources.

The 50th percentile combined Zinc levels are below the 99% species protection guideline of 3.3 µg/L within all of the Waiuku Estuary.

The 95th percentile combined Zinc levels are above the 99% species protection guideline of 3.3 µg/L near the NZ Steel discharges (discussed below) and close to some of the catchment sources.

Figures 5-29 and 5-30 show the predicted 95th and 50th percentile estimates of Copper and Zinc for the Northside and Southside Outfalls respectively.

Copper – Northside Outfall

With the inclusion of the effects of the catchment derived Copper, the 95th percentile estimates of Dissolved Copper (i.e. the value only exceeded in 5% of the annual simulation data when background concentrations of copper are higher in winter) is above the Copper 99% species protection guideline of 0.3 µg/L near the Northside Outfall.

The Copper 95% species protection guideline of 1.3 µg/L is exceeded within 100 m of the Northside Outfall and the Copper 90% species protection guideline of 3.0 µg/L is never exceeded.

The 50th percentile estimates of Dissolved Copper remain below the 99% species protection guideline of 0.3 µg/L near the Northside Outfall.

Zinc – Northside Outfall

With the inclusion of the effects of the catchment derived Zinc the 95th percentile estimates of Dissolved Zinc (i.e. the value only exceeded in 5% of the annual simulation data when background concentrations of Zinc are higher in winter) is above the ANZWQG (2021) Zinc 99% species protection guideline of 3.3 µg/L within 300 m of the Northside Outfall.

The Zinc 95% species protection guideline of 8.8 µg/L is exceeded within 100 m of the Northside Outfall, the Zinc 90% species protection guideline of 12.0 µg/L is exceeded within 90 m of the Northside Outfall and the Zinc 80% species protection guideline of 21.0µg/L is only exceeded within 75 m of the Northside Outfall.

The 50th percentile estimates of Dissolved Zinc remains below the Zinc 99% species protection guideline of 3.3 µg/L near the Northside Outfall

Copper – Southside Outfall

With the inclusion of the effects of the catchment derived Copper the 95th percentile estimates of Dissolved Copper (i.e. the value only exceeded in 5% of the annual simulation data when background concentrations of Zinc are higher in winter) is above the Copper 99% species protection guideline of 0.3 µg/L near the Southside Outfall.

The Copper 95% species protection guideline of 1.3 µg/L is only just exceeded in the vicinity of the Southside Outfall.

The 50th percentile estimates of Dissolved Copper are at or just below the Copper 99% species protection guideline of 0.3 µg/L near the Southside Outfall.

Zinc – Southside Outfall

With the inclusion of the effects of the catchment-derived Zinc the 95th percentile estimates of Dissolved Zinc (i.e. the value only exceeded in 5% of the annual simulation data when background concentrations of Zinc are higher in winter) remain below the Zinc 99% species protection guideline of 3.3 µg/L near the Southside Outfall.

The 50th percentile estimates of Dissolved Zinc remains well below Zinc 99% species protection guideline of 3.3 µg/L near the Southside Outfall.

Percentage of time above thresholds

In addition to providing water column percentile estimates, model data has been interrogated to provide estimates of the amount of time that the various water column thresholds are exceeded for copper and zinc for the discharges in isolation.

Table 5-2 to Table 5-5 show the percentage of time above the guidelines at different radial distances from the Northside and Southside Outfall discharges and Figure 5-31 through to Figure 5-36 shows the spatial plots of the time that water column estimates are above the guidelines.

As for the percentile results, the effects of the discharge are seen predominantly within the first 100 m of the Northside Outfall with the zinc 99% SPL exceeded up to 30% of the time in the first 50 m, dropping to 15% of the time out to 100 m, and only 0.4% of the time out to 200 m. The 80% SPL is exceeded up to 10% of the time in the first 50 m and only 0.3% of the time out to 100 m.

For Copper at the Northside Outfall only the 99% SPL is exceeded, primarily out to 50 m, and up to 24% of the time.

For the Southside Outfall only the copper 99% SPL is exceeded, only out to 50 m (and primarily out to 20 m) and only up to 14% of the time. The zinc 99% SPL is not exceeded at all.

These exceedances primarily occur at low water when there is little or no mixing with other water in the estuary.

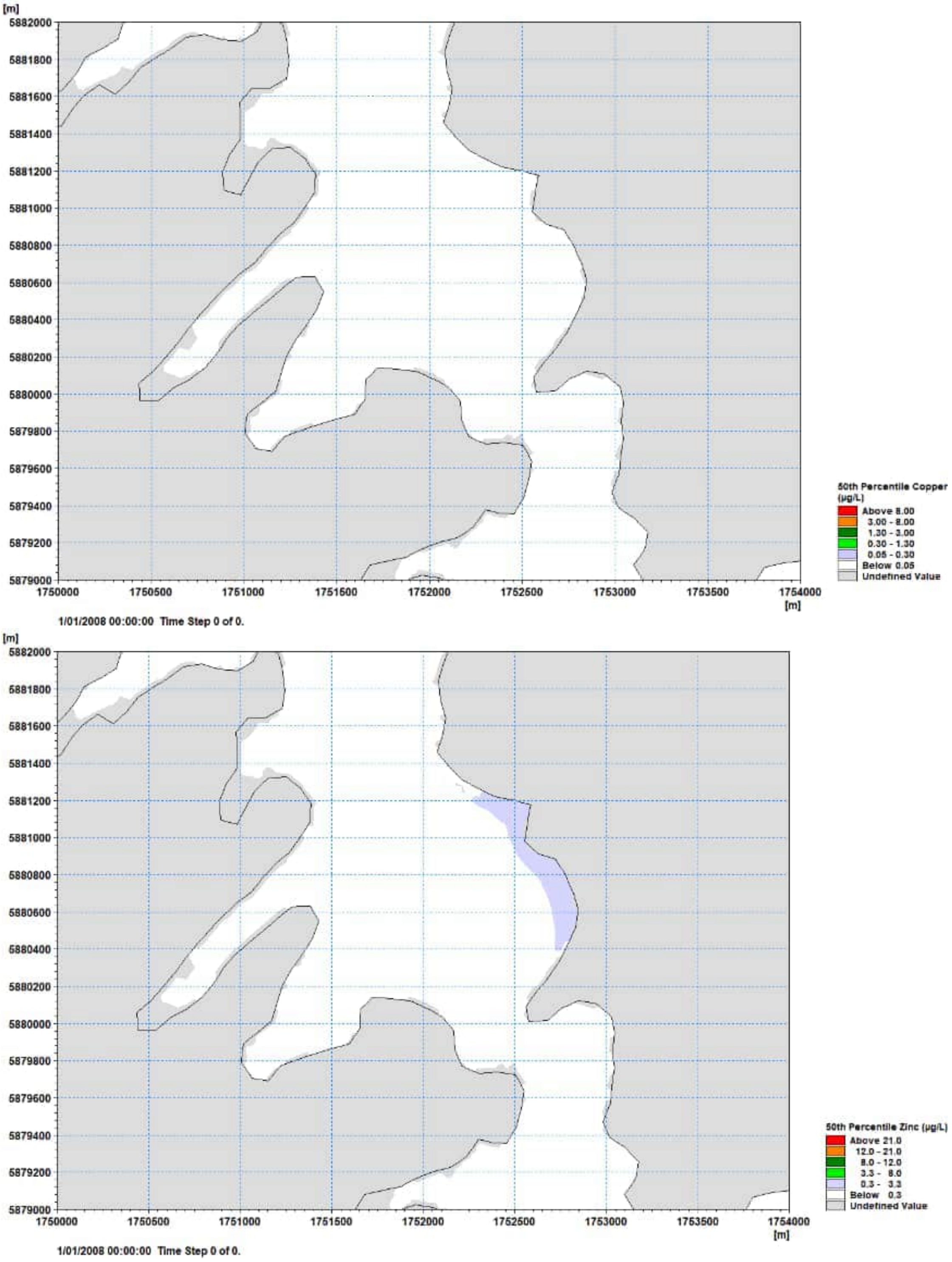


Figure 5-15. Predicted 50th percentile water column concentrations for the Northside Outfall for Copper (top panel) and Zinc (bottom) panel. Colour coding reflects the banding of the ANZWQG (2020) default marine guidelines for Zinc and the existing ANZECC (2000) marine guidelines for Copper (Table 5-1). The 50th percentile concentration for Copper is less than 0.1 µg/L and is 1.3 µg/L for Zinc.

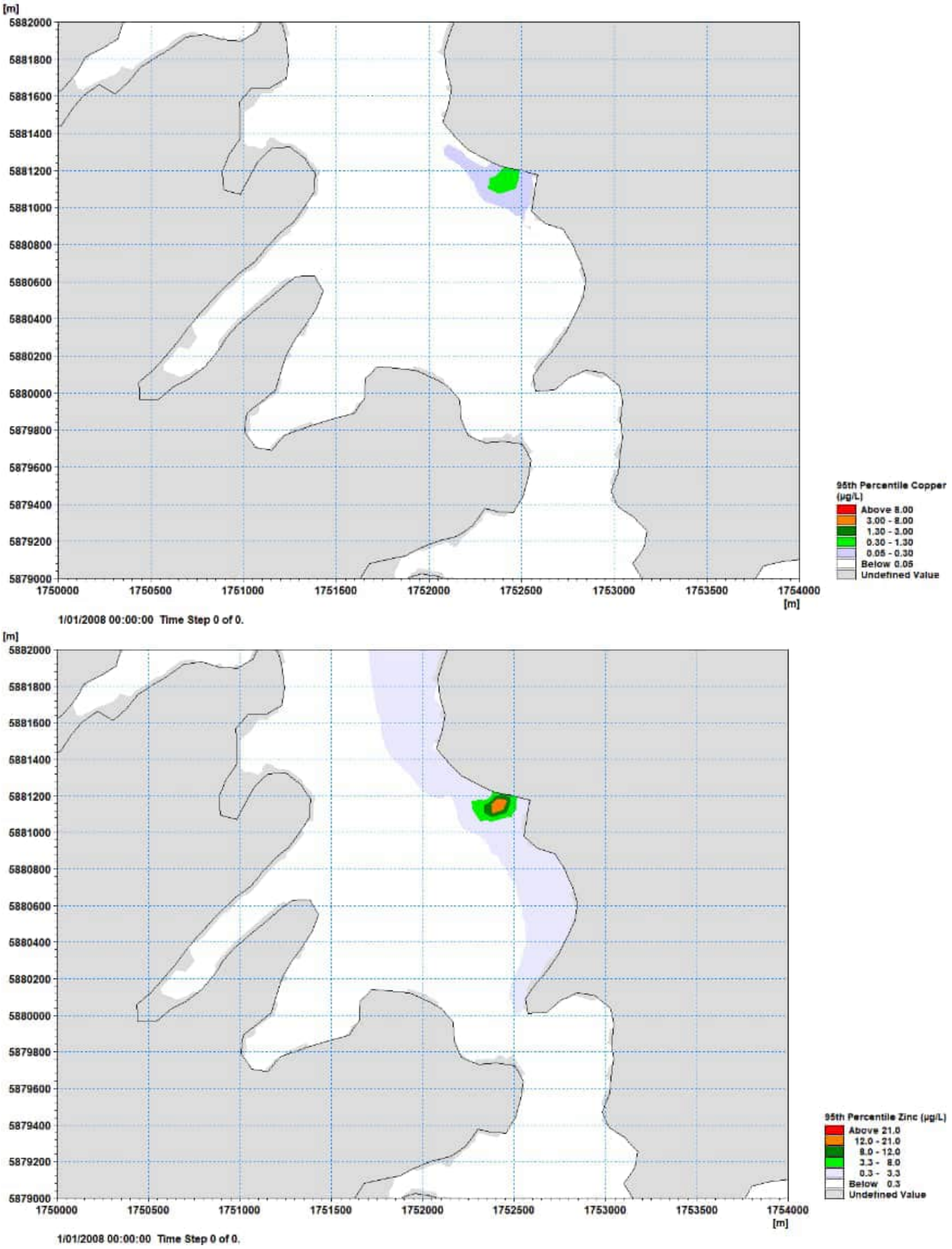


Figure 5-16. Predicted 95th percentile water column concentrations for the Northside Outfall for Copper (top panel) and Zinc (bottom) panel. Colour coding reflects the banding of the ANZWQG (2021) default marine guidelines for Zinc and the existing ANZECC (2000) marine guidelines for Copper (Table 5-1). Maximum 95th percentile concentrations are 1.2 µg/L for Copper and 25.1 µg/L for Zinc.

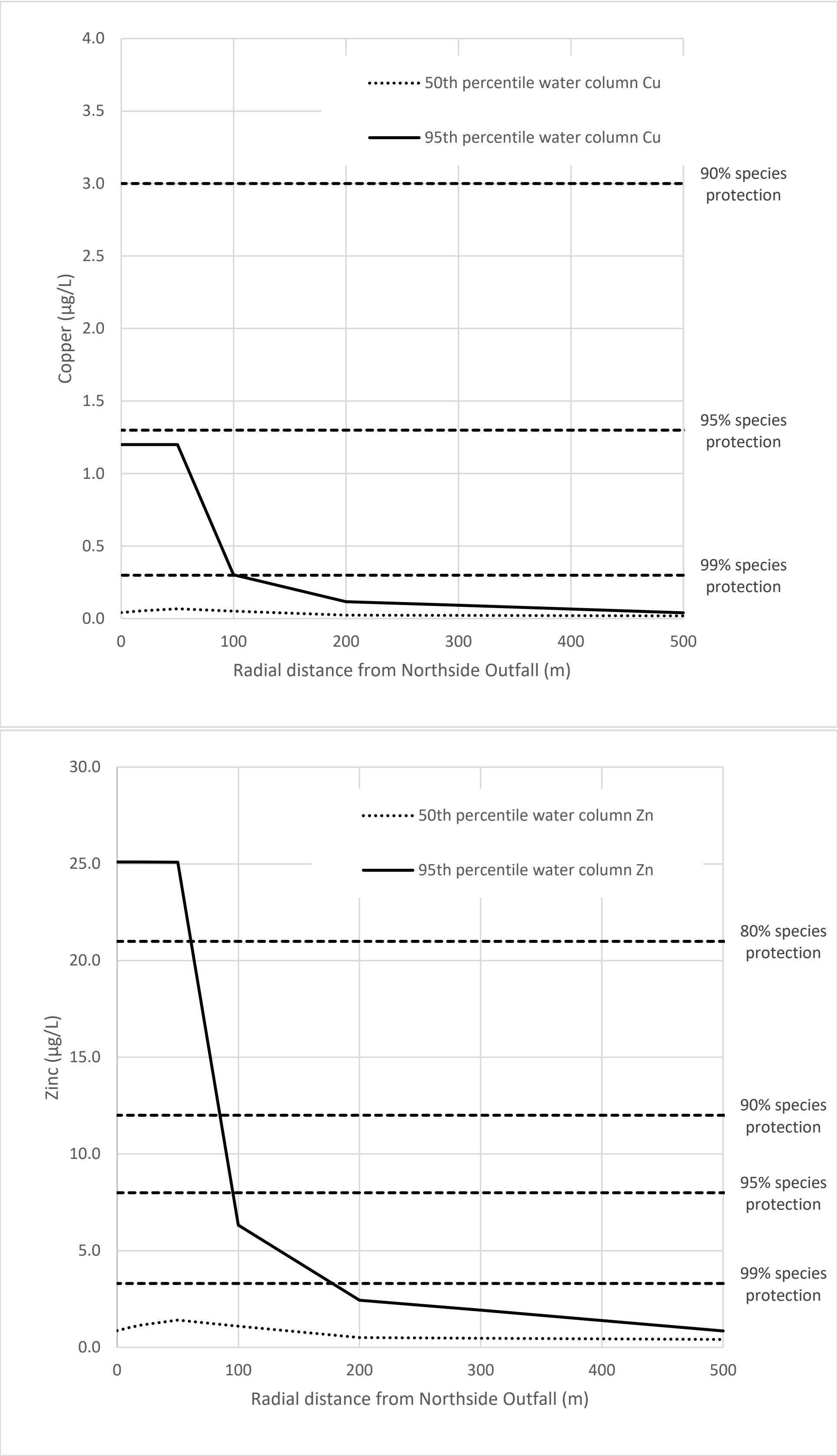


Figure 5-17. Predicted 50th and 95th percentile Copper and Zinc water column concentrations for the Northside Outfall as a function of distance from the discharge point. Dashed lines show the species protection guidelines (Table 5-1).

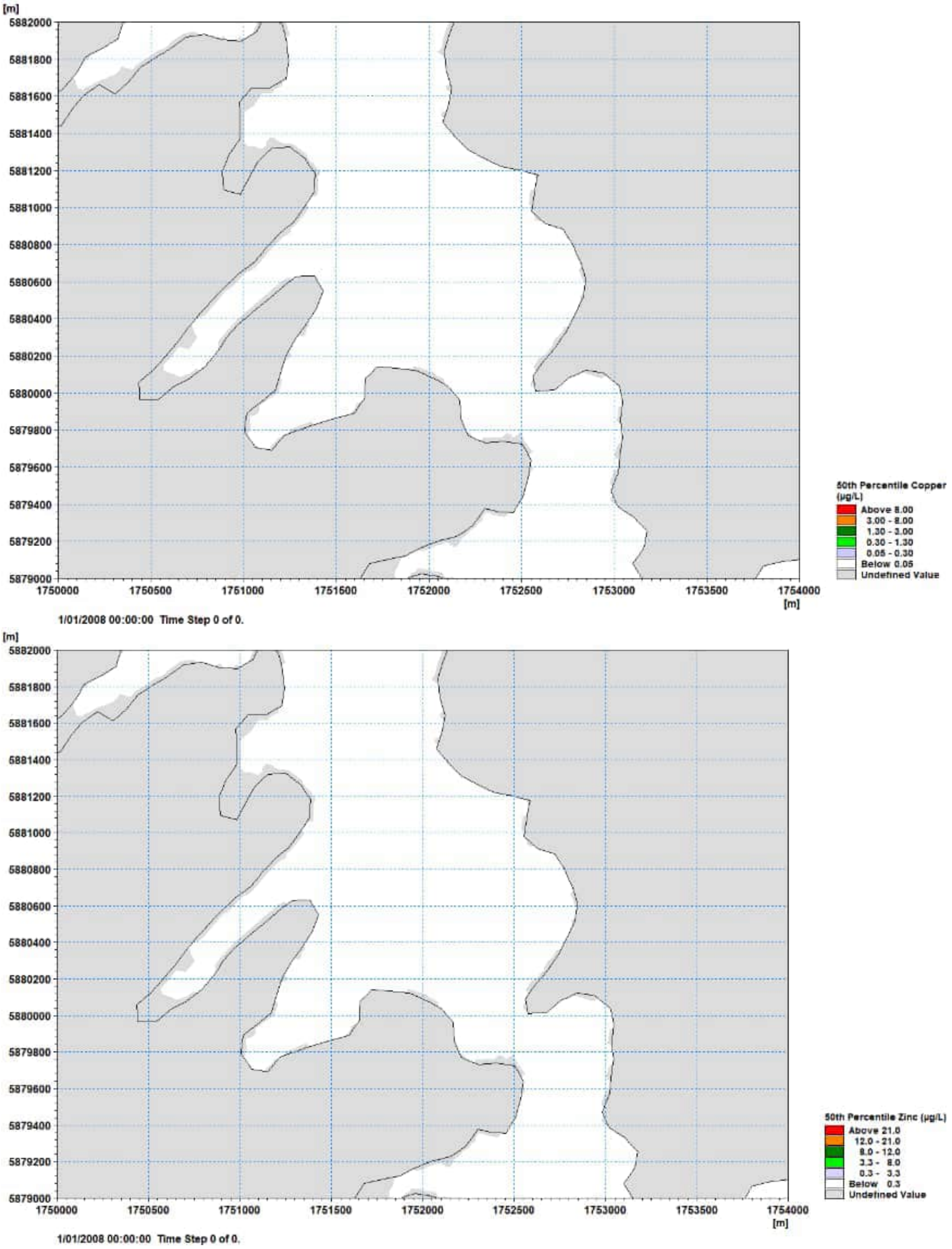


Figure 5-18. Predicted 50th percentile water column concentrations for the Southside Outfall for Copper (top panel) and Zinc (bottom) panel. Colour coding reflects the banding of the ANZWQG (2020) default marine guidelines for Zinc and the existing ANZECC (2000) marine guidelines for Copper (Table 5-1). Maximum concentrations are < 0.1 µg/L for Copper and Zinc.

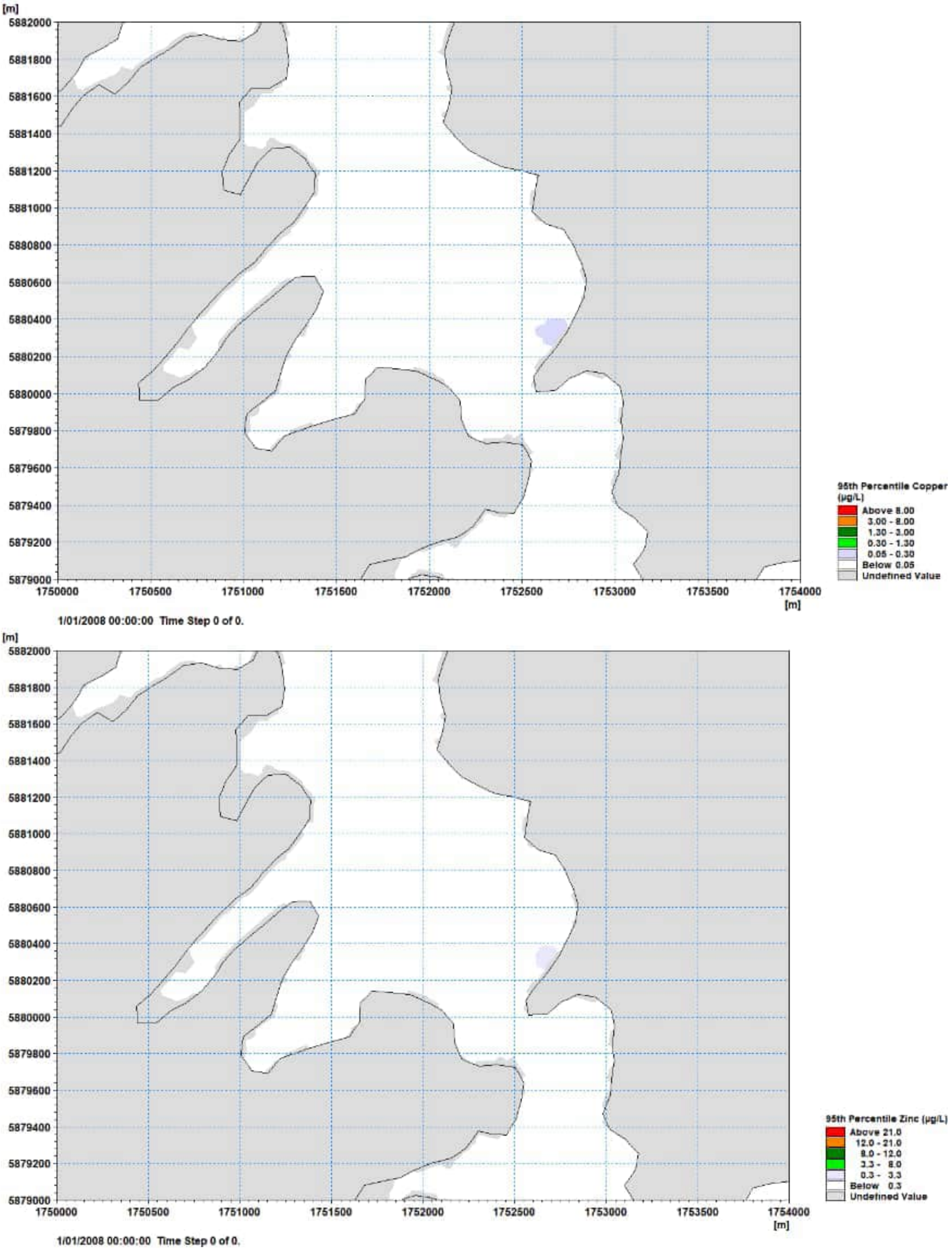
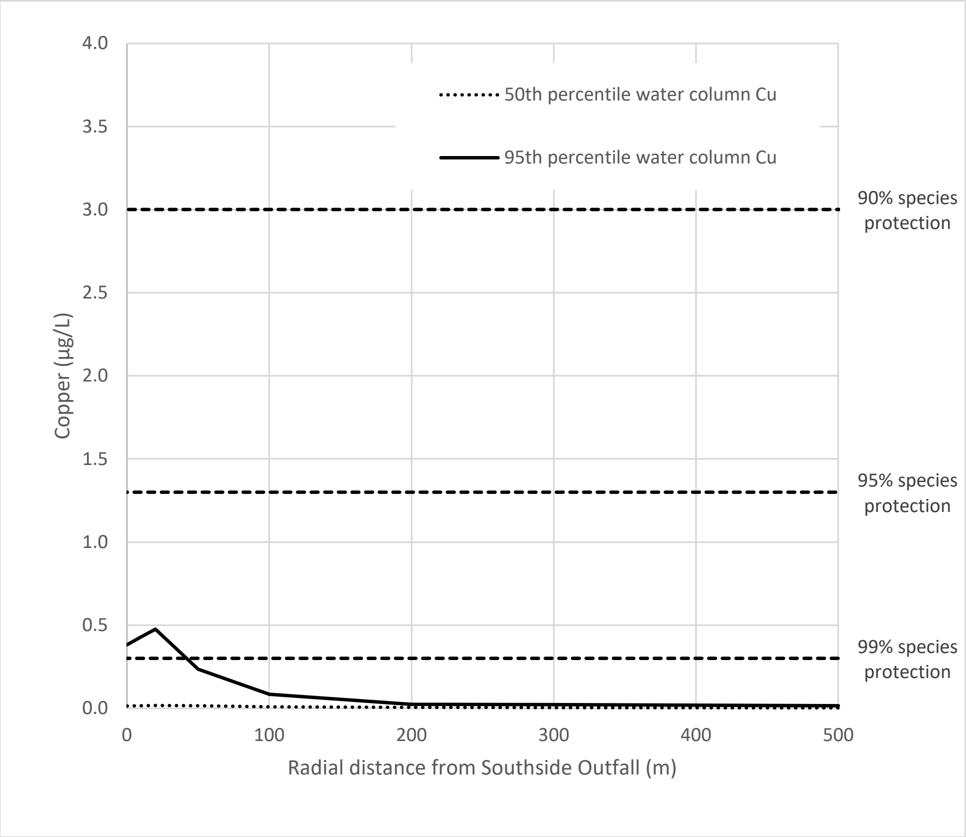


Figure 5-19. Predicted 95th percentile water column concentrations for the Southside Outfall for Copper (top panel) and Zinc (bottom) panel. Colour coding reflects the banding of the ANZWQG (2020) default marine guidelines for Zinc and the existing ANZECC (2000) marine guidelines for Copper (Table 5-1). Maximum concentrations are for 0.5 µg/L for Copper and 0.7 µg/L for Zinc.



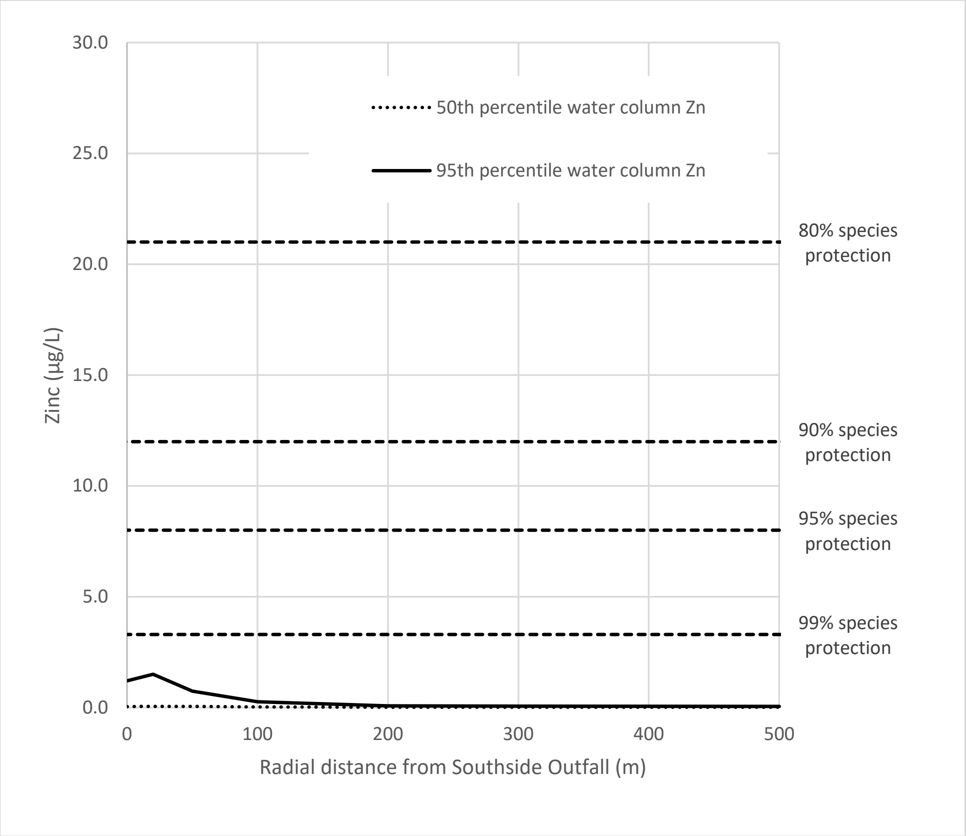


Figure 5-20. Predicted 50th and 95th percentile Copper and Zinc water column concentrations for the Southside Outfall as a function of distance from the discharge point. Dashed lines show the species protection guidelines (Table 5-1).

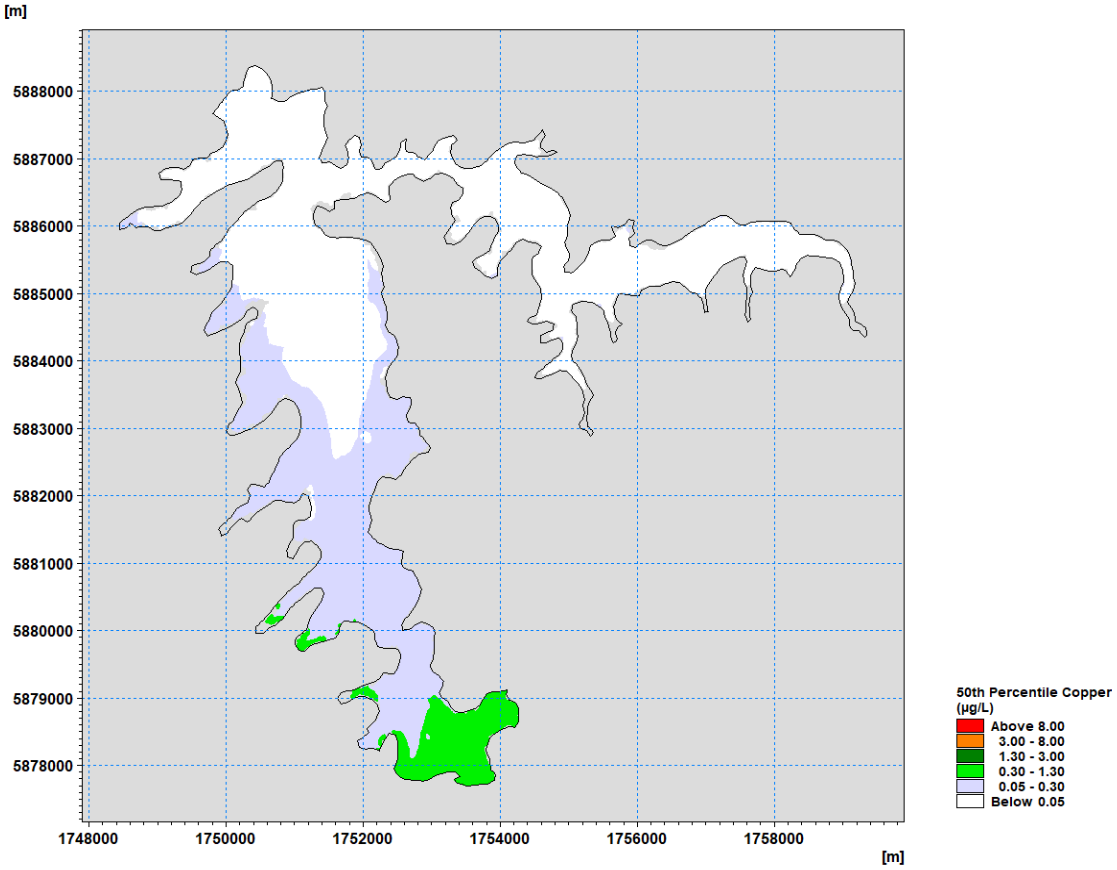


Figure 5-21. Predicted 50th percentile water column Copper concentrations due to the input of catchment derived Copper from the FWMT nodes. Colour coding reflects the banding of the ANZWQG (2020) default marine guidelines for Zinc and the existing ANZECC (2000) marine guidelines for Copper (Table 5-1). The maximum 50th percentile value is 1.8 µg/L.

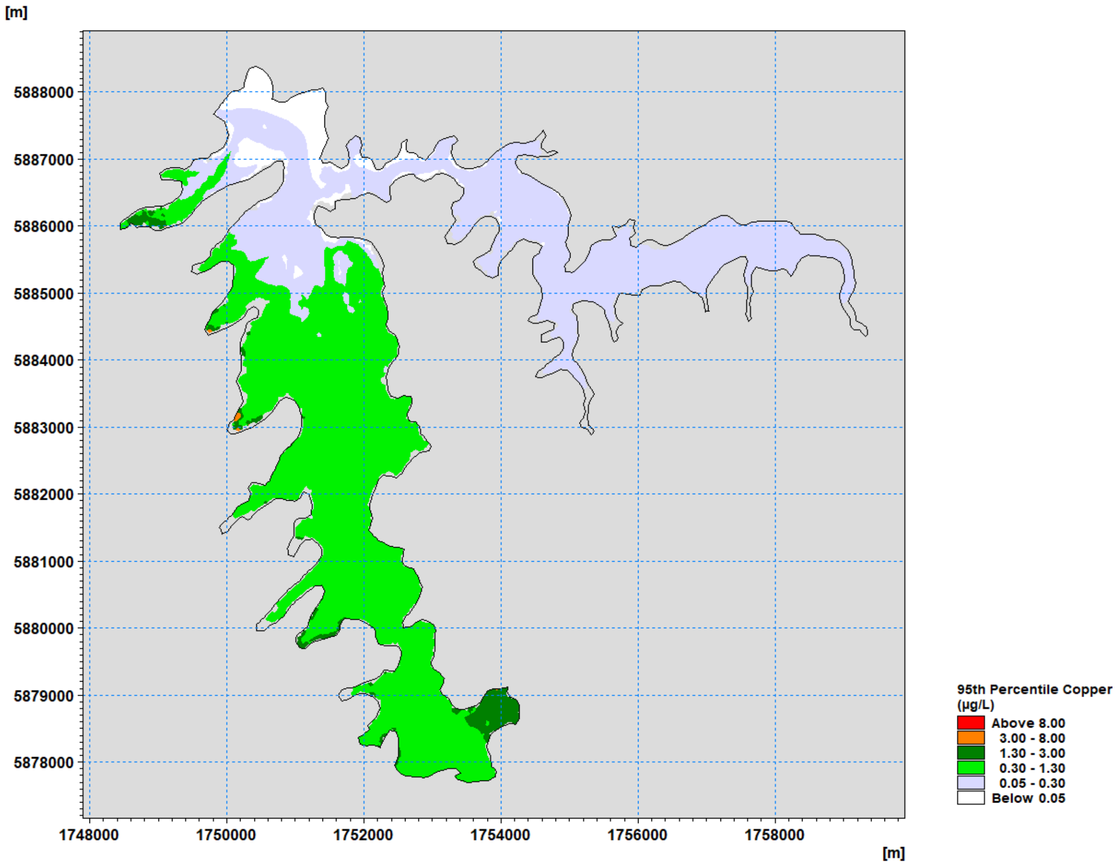


Figure 5-22. Predicted 95th percentile water column Copper concentrations due to the input of catchment derived Copper from the FWMT nodes. Colour coding reflects the banding of the ANZWQG (2020) default marine guidelines for Zinc and the existing ANZECC (2000) marine guidelines for Copper (Table 5-1). The maximum 95th percentile value is 8.6 µg/L.

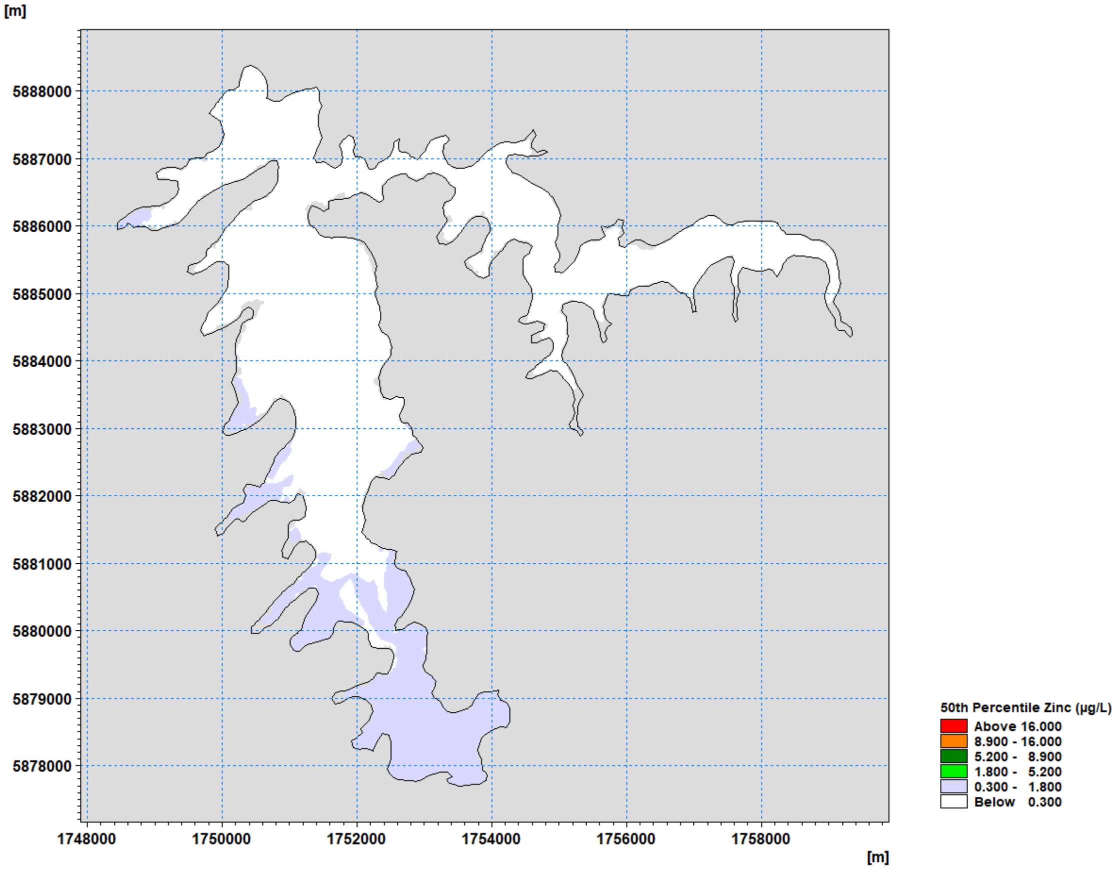


Figure 5-23. Predicted 50th percentile water column Zinc concentrations due to the input of catchment derived Zinc from the FWMT nodes. Colour coding reflects the banding of the ANZWQG (2020) default marine guidelines for Zinc and the existing ANZECC (2000) marine guidelines for Copper (Table 5-1). The maximum 50th percentile value is 2.4 µg/L.

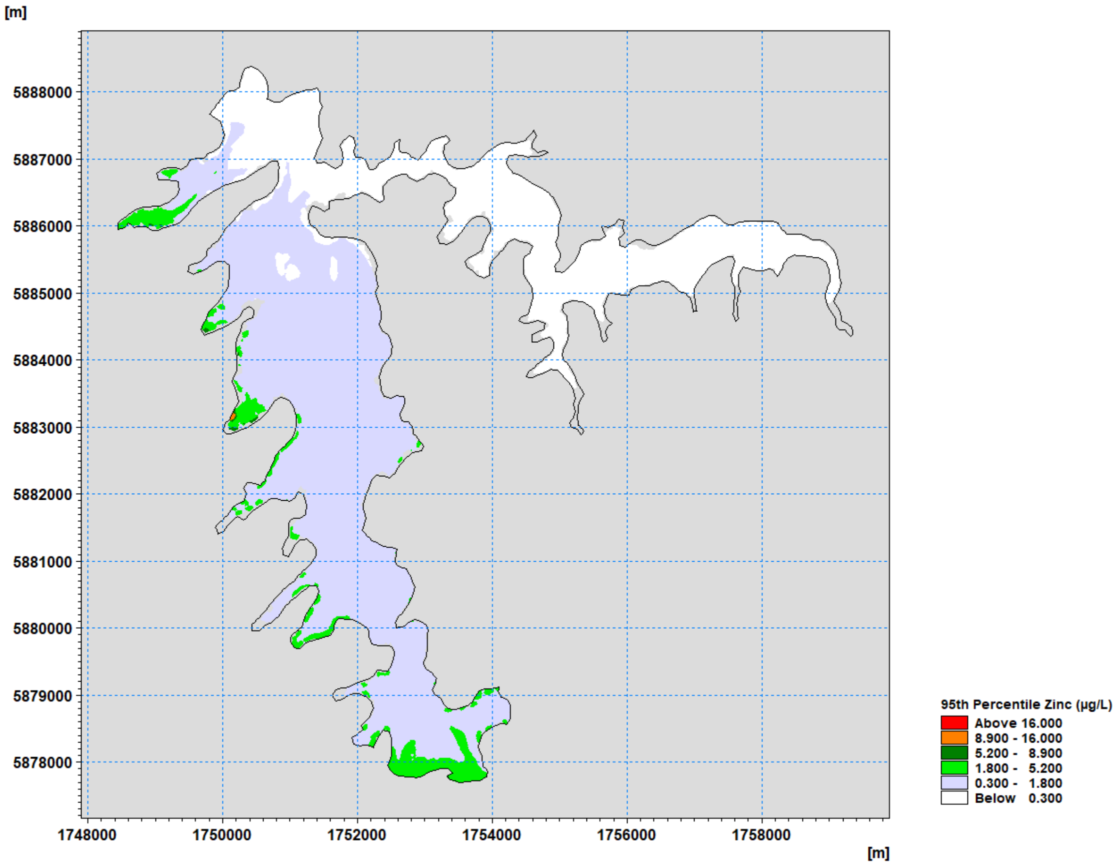


Figure 5-24. Predicted 95th percentile water column Zinc concentrations due to the input of catchment derived Zinc from the FWMT nodes. Colour coding reflects the banding of the ANZWQG (2020) default marine guidelines for Zinc and the existing ANZECC (2000) marine guidelines for Copper (Table 5-1). The maximum 95th percentile value is 17.7 µg/L.

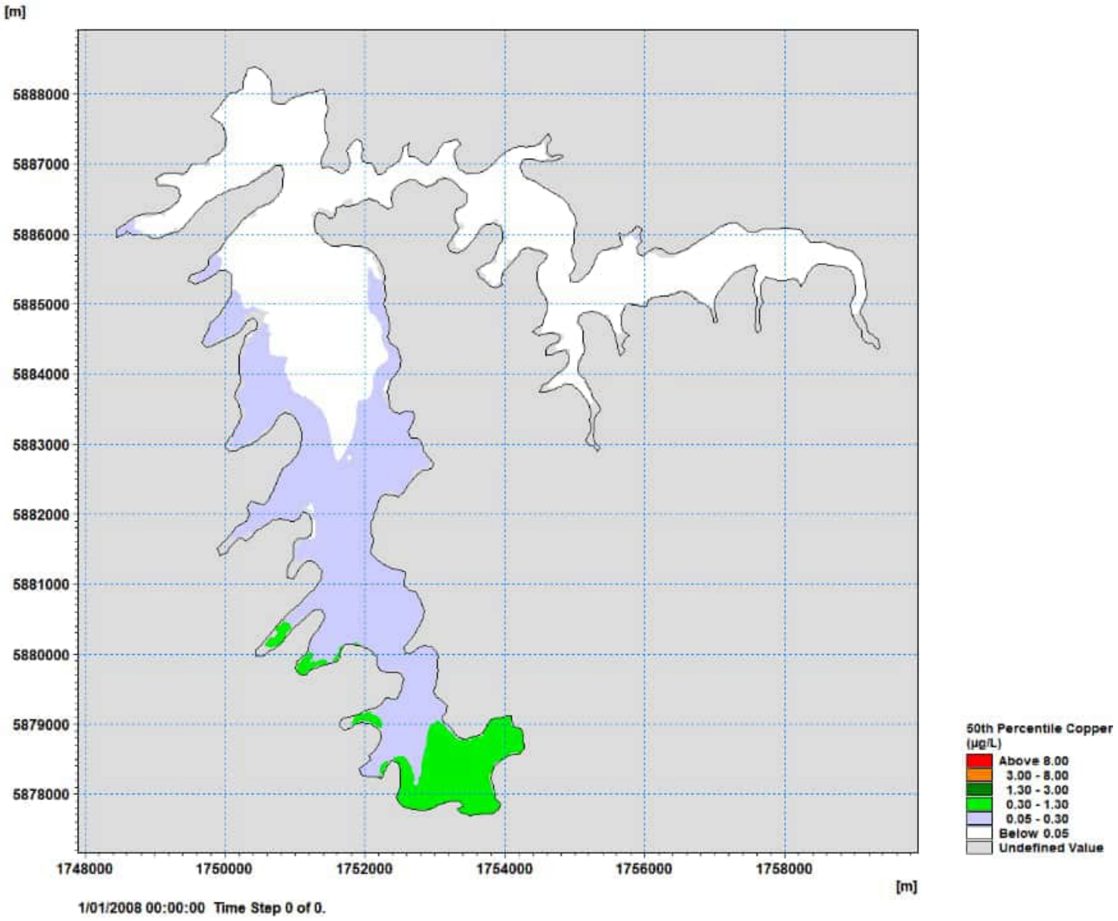


Figure 5-25. Predicted 50th percentile water column Copper concentrations due to the input of catchment derived Copper from the FWMT nodes and the Northside and Southside Outfalls. Colour coding reflects the banding of the ANZWQG (2020) default marine guidelines for Zinc and the existing ANZECC (2000) marine guidelines for Copper (Table 5-1). The maximum 50th percentile value is 1.8 µg/L.

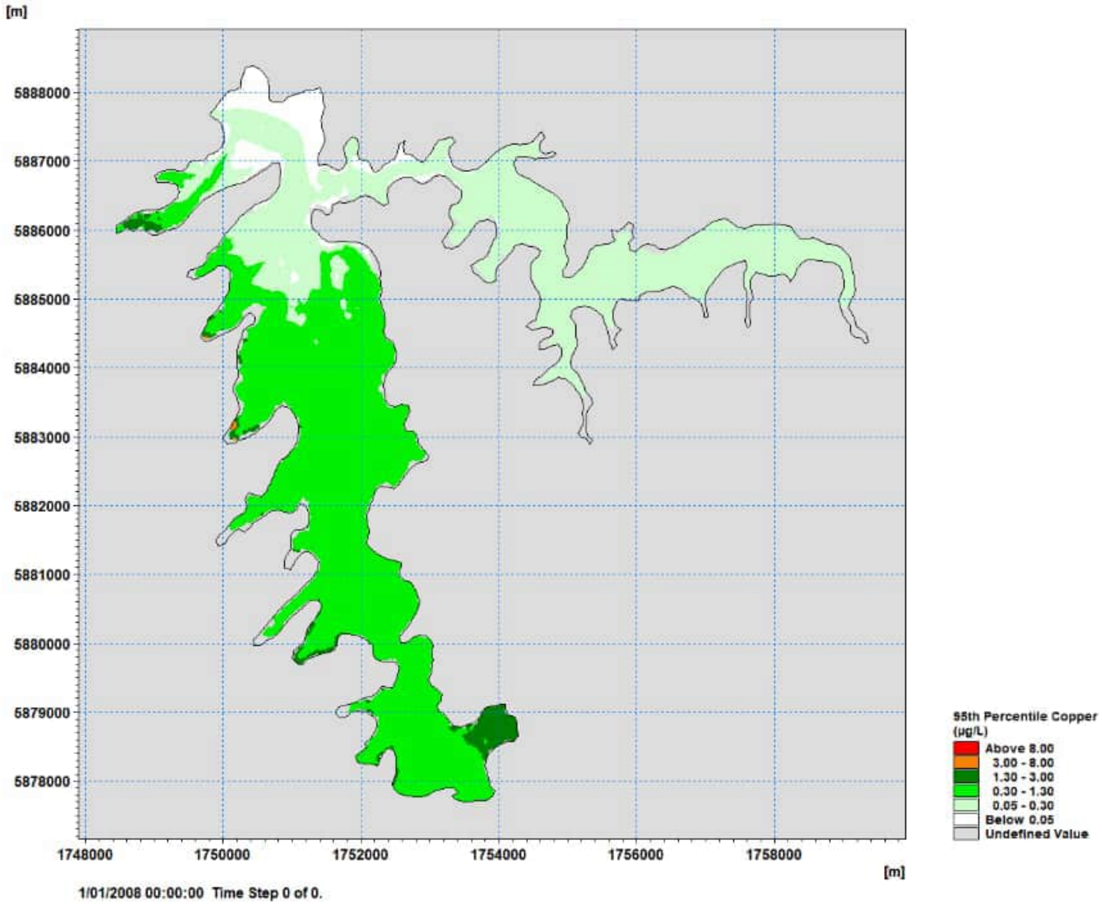


Figure 5-26. Predicted 95th percentile water column Copper concentrations due to the input of catchment derived Copper from the FWMT nodes and the Northside and Southside Outfalls. Colour coding reflects the banding of the ANZWQG (2020) default marine guidelines for Zinc and the existing ANZECC (2000) marine guidelines for Copper (Table 5-1). The maximum 95th percentile value is 8.6 µg/L.

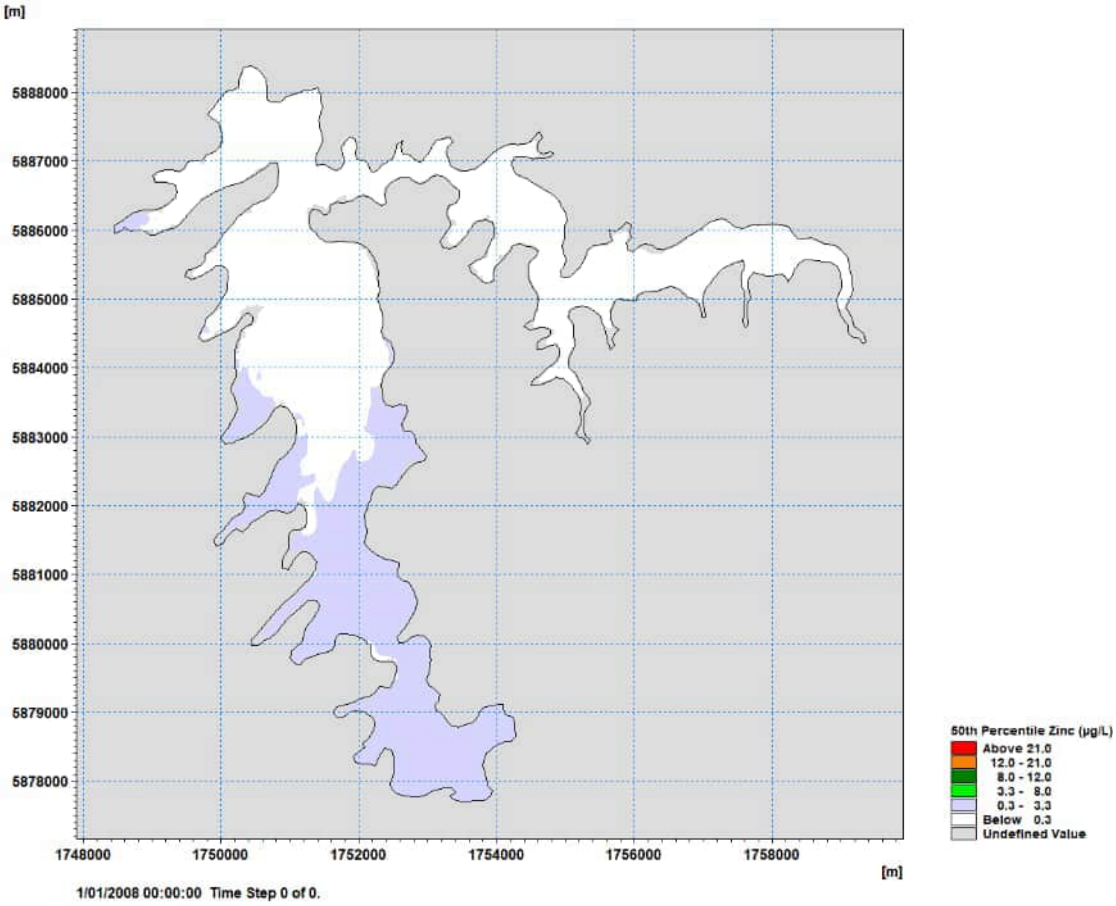


Figure 5-27. Predicted 50th percentile water column Zinc concentrations due to the input of catchment derived Zinc from the FWMT nodes and the Northside and Southside Outfalls. Colour coding reflects the banding of the ANZWQG (2020) default marine guidelines for Zinc and the existing ANZECC (2000) marine guidelines for Copper (Table 5-1). The maximum 50th percentile value is 2.4 µg/L.

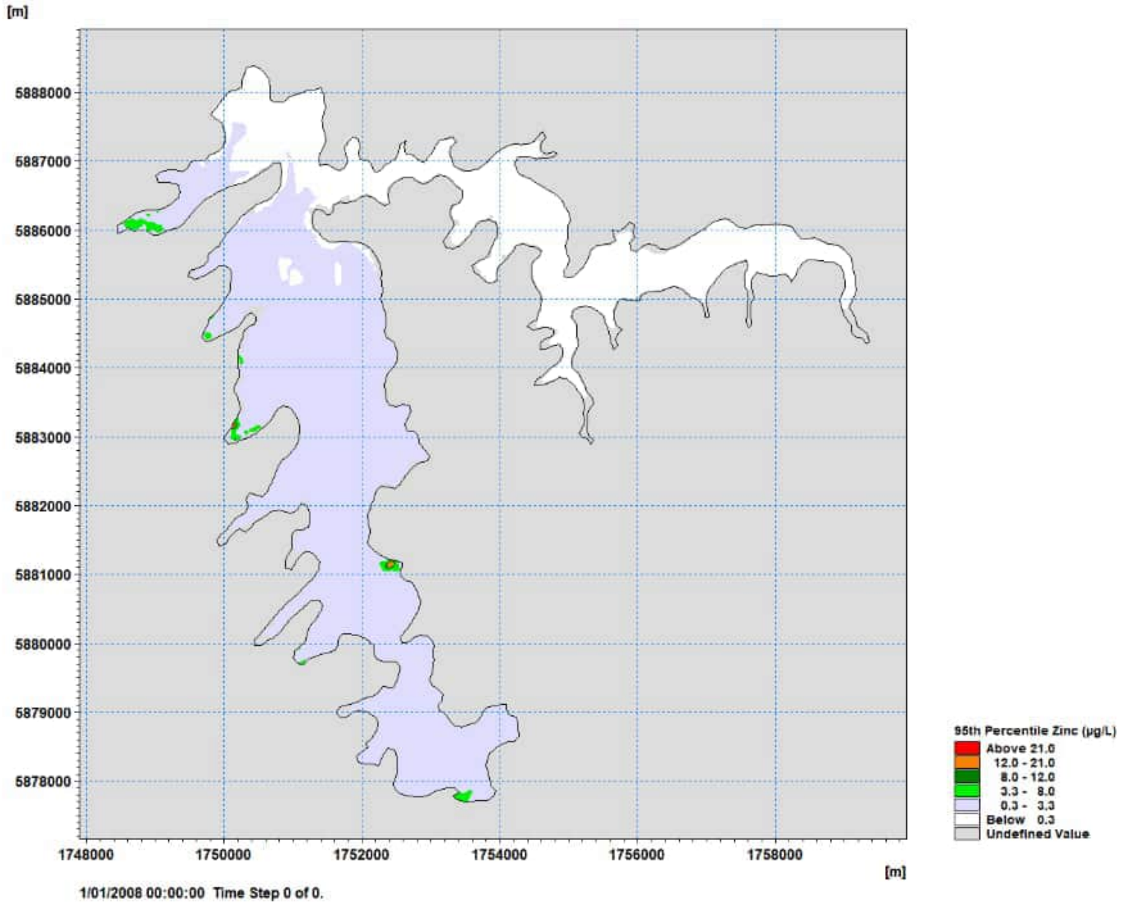


Figure 5-28. Predicted 95th percentile water column Zinc concentrations due to the input of catchment derived Zinc from the FWMT nodes and the Northside and Southside Outfalls. Colour coding reflects the banding of the ANZWQG (2020) default marine guidelines for Zinc and the existing ANZECC (2000) marine guidelines for Copper (Table 5-1). The maximum 95th percentile value is 25.1 µg/L.

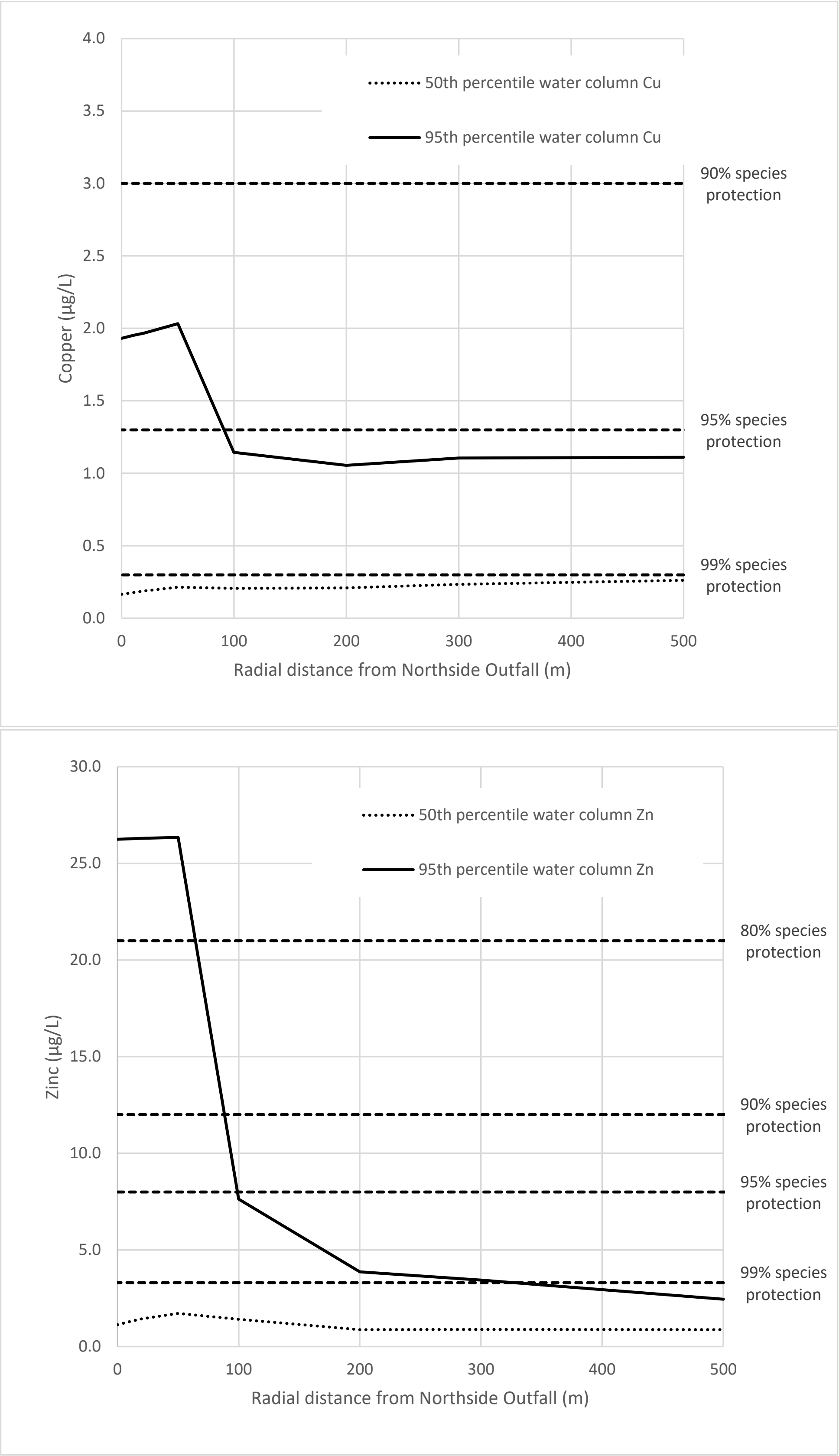
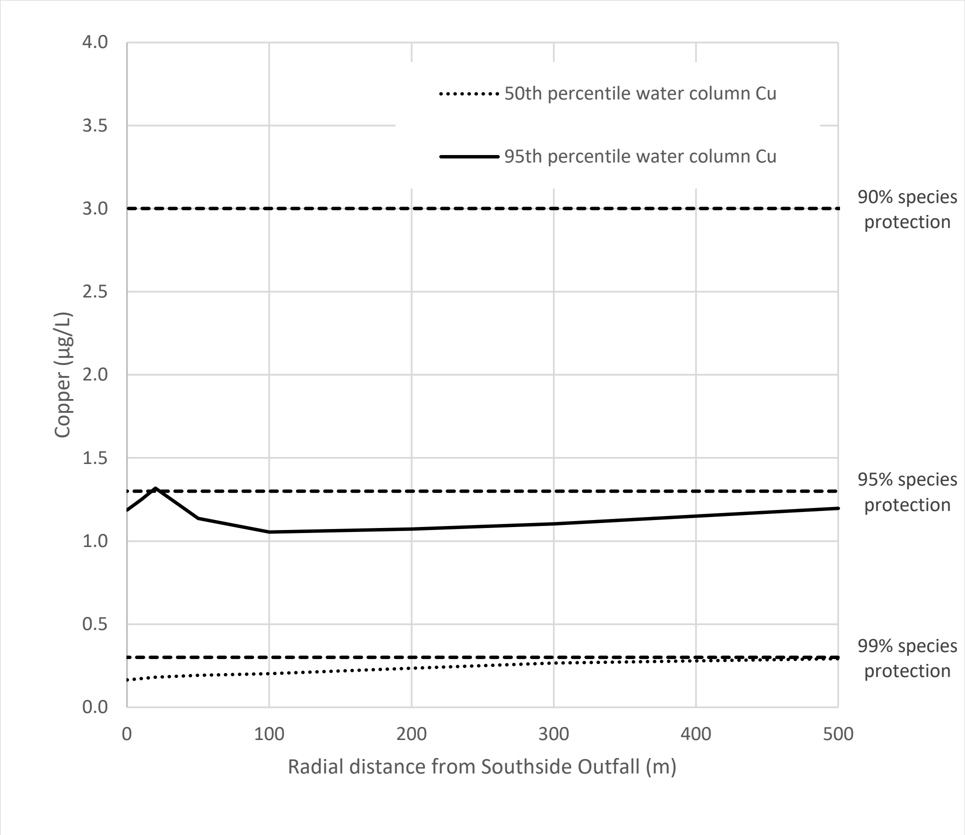


Figure 5-29. Predicted 50th and 95th percentile Copper and Zinc water column concentrations for the Northside Outfall as a function of distance from the discharge point with the consideration of catchment derived Copper and Zinc. Dashed lines show the species protection guidelines (Table 5-1).



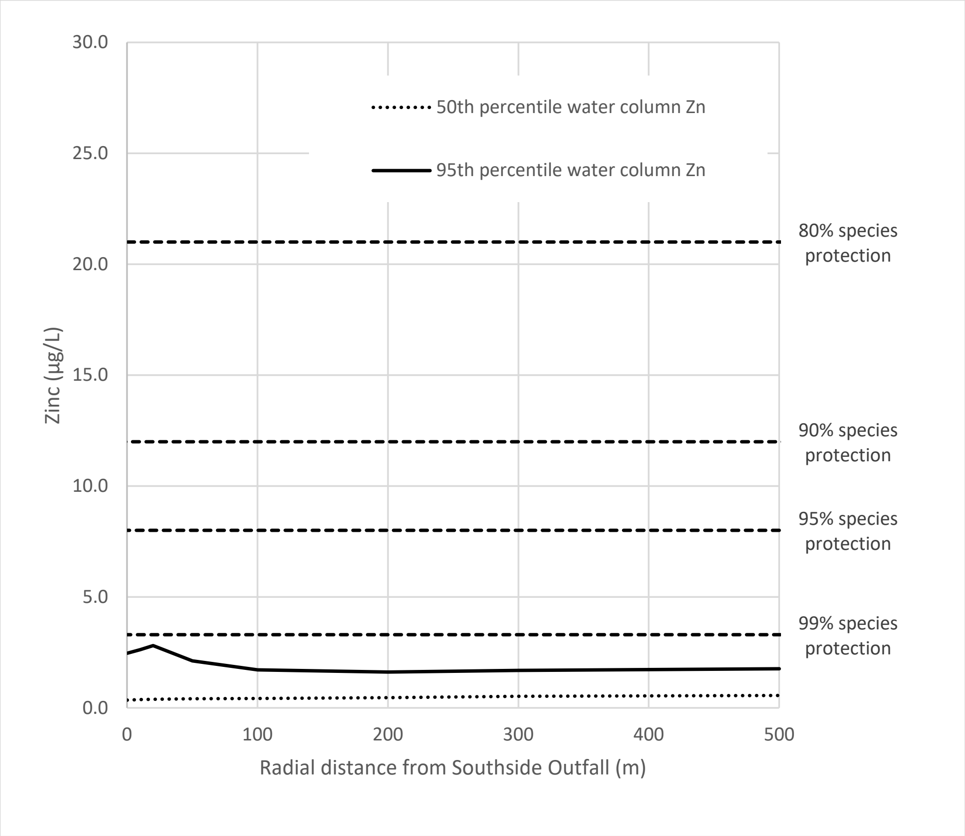


Figure 5-30. Predicted 50th and 95th percentile Copper and Zinc water column concentrations for the Southside Outfall as a function of distance from the discharge point with the consideration of catchment derived Copper and Zinc. Dashed lines show the species protection guidelines (Table 5-1).

Table 5-2. Summary of percentage of time above Copper guidelines as a function of distance (in metres) from the Northside Outfall.

Radial distance from Northside Outfall	0	10	20	50	100	200	300	500
Above 99% species protection Guideline	18.8%	20.3%	21.6%	23.7%	5.0%	0.0%	0.0%	0.0%
Above 95% species protection Guideline	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Above 90% species protection Guideline	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Above 80% species protection Guideline	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table 5-3. Summary of percentage of time above Zinc guidelines as a function of distance from the Northside Outfall.

Radial distance from Northside Outfall	0	10	20	50	100	200	300	500
Above 99% species protection Guideline	25.2%	26.9%	29.0%	32.0%	15.1%	0.4%	0.0%	0.0%
Above 95% species protection Guideline	16.8%	18.2%	19.4%	21.0%	4.1%	0.0%	0.0%	0.0%
Above 90% species protection Guideline	13.3%	14.5%	15.8%	16.6%	2.6%	0.0%	0.0%	0.0%
Above 80% species protection Guideline	9.4%	9.6%	9.9%	8.7%	0.3%	0.0%	0.0%	0.0%

Table 5-4. Summary of percentage of time above Copper guidelines as a function of distance from the Southside Outfall.

Radial distance from Southside	0	10	20	50	100	200	300	500
Above 99% species protection Guideline	9.9%	12.0%	13.6%	0.2%	0.0%	0.0%	0.0%	0.0%
Above 95% species protection Guideline	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Above 90% species protection Guideline	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Above 80% species protection Guideline	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table 5-5. Summary of percentage of time above Zinc guidelines as a function of distance from the Southside Outfall.

Radial distance from Southside	0	10	20	50	100	200	300	500
Above 99% species protection Guideline	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Above 95% species protection Guideline	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Above 90% species protection Guideline	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Above 80% species protection Guideline	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

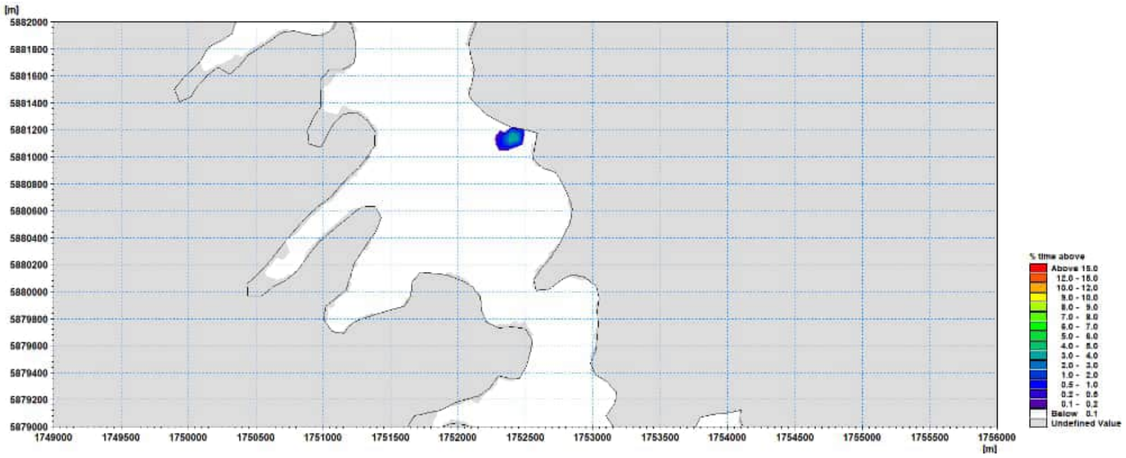


Figure 5-31. Percentage of time that the water column estimates of dissolved Zinc are above the 80% species protection Guideline near the Northside Outfall discharge.

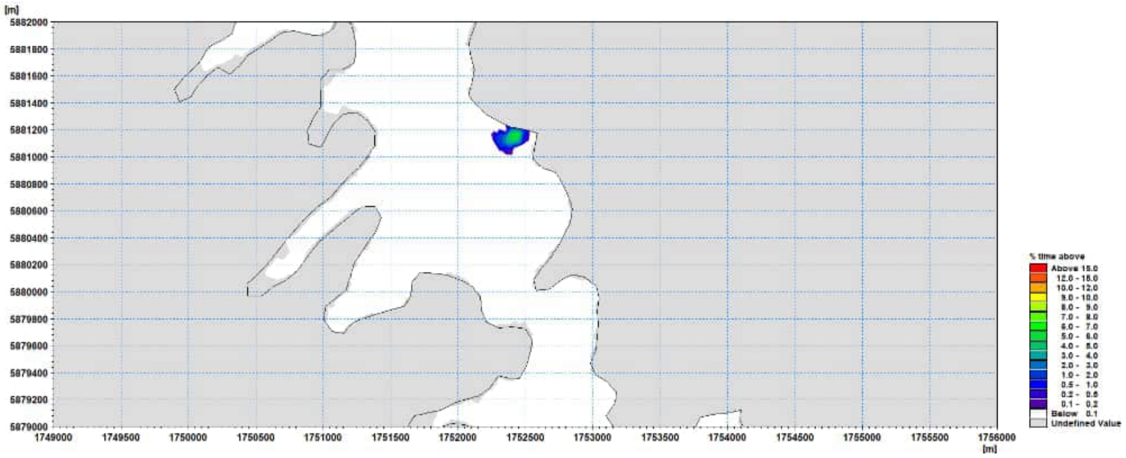


Figure 5-32. Percentage of time that the water column estimates of dissolved Zinc are above the 90% species protection Guideline near the Northside Outfall discharge.

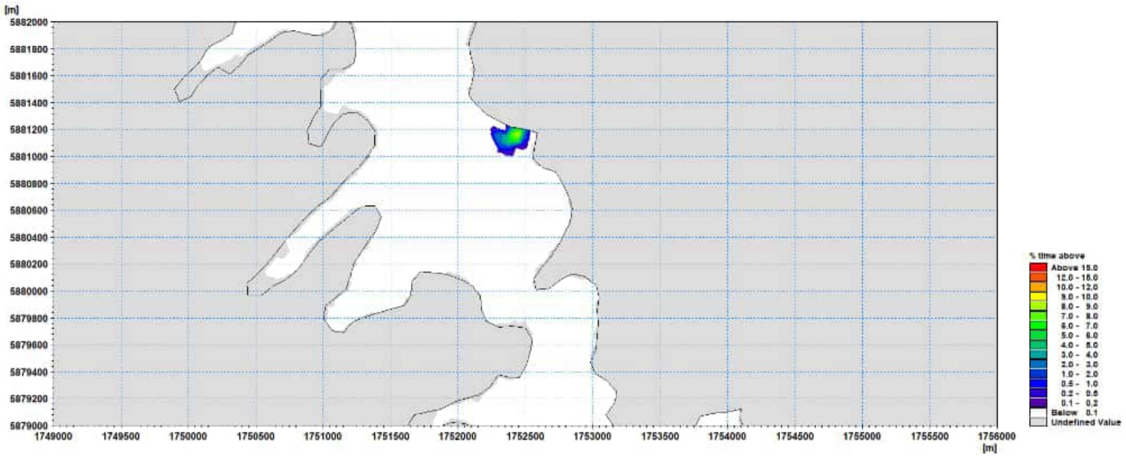


Figure 5-33. Percentage of time that the water column estimates of dissolved Zinc are above the 95% species protection Guideline near the Northside Outfall discharge.

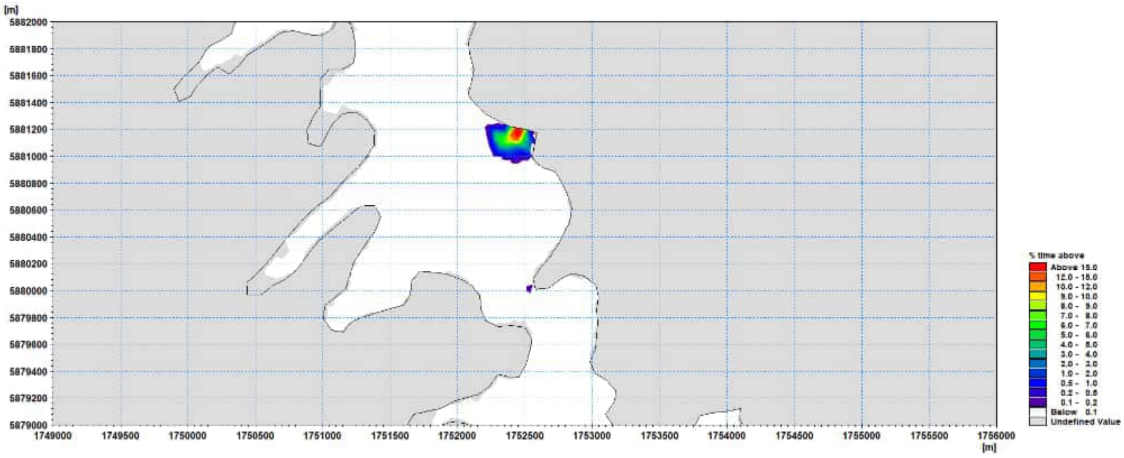


Figure 5-34. Percentage of time that the water column estimates of dissolved Zinc are above the 99% species protection Guideline near the Northside Outfall discharge.

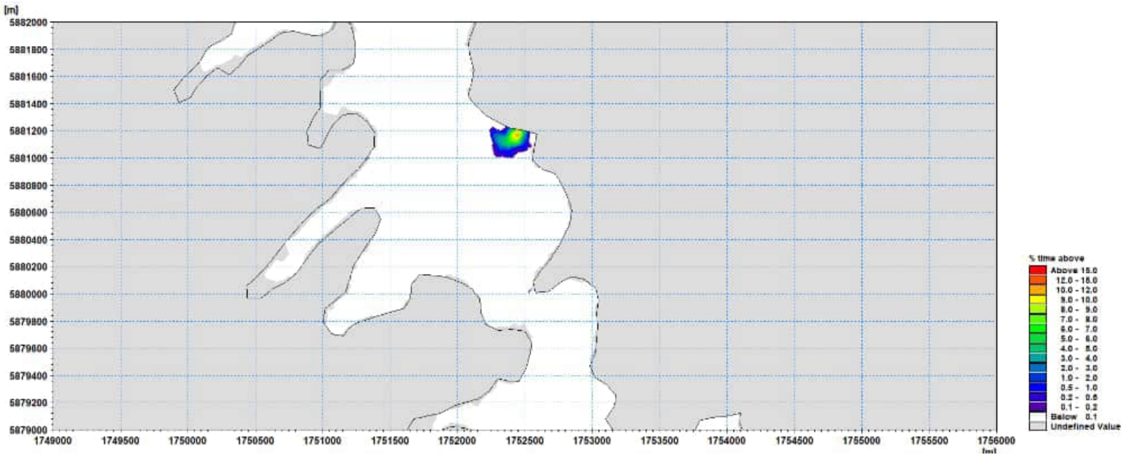


Figure 5-35. Percentage of time that the water column estimates of dissolved Copper are above the 99% species protection Guideline near the Northside Outfall discharge.

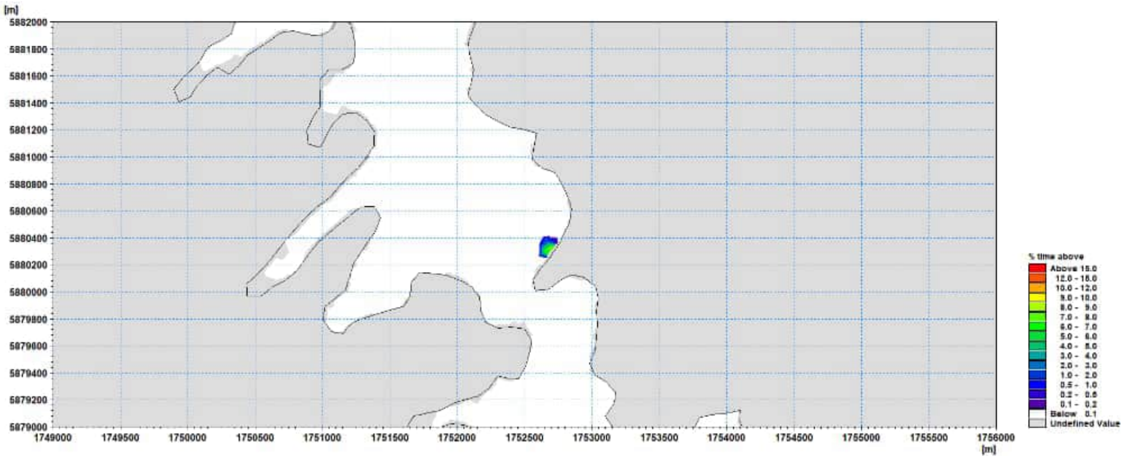


Figure 5-36. Percentage of time that the water column estimates of dissolved Copper are above the 99% species protection Guideline near the Southside Outfall discharge.

5.5 Excess Temperature Modelling

To quantify the dynamics of the temperature excess due to the Northside and Southside Outfalls, month long model simulations were carried out under Summer and Winter conditions (February and August respectively). For the Summer scenario the initial water temperature and boundary temperature were set to 20.9 ^{o}C while for the Winter scenario the initial water temperature and boundary temperature were set to 13.9 ^{o}C (as per data in Table 4-14). The mean daily water temperature data from the FWMT (e.g. Figure 4-8) were applied at each of the FWMT nodes and the discharge temperatures for the Northside and Southside Outfalls were assigned the values derived from the maximum daily temperature estimates from the monitoring data (Figure 4-6) as shown in Table 5-6. This approach provides a conservative approach as the actual discharge temperatures can be up to 8 ^{o}C cooler than has been assumed in the model simulations (Figure 4-6).

For the schematic Summer and Winter simulations the initial temperatures at the northern boundary of the model were set to a specified temperature (20.9 ^{o}C and 13.9 ^{o}C respectively). The boundary type was set zero-gradient meaning that any changes in temperature within the domain due to the addition of the NZ Steel discharge (increasing temperatures locally) and heat exchange processes (both heating and cooling the water across the whole domain) are propagated through to the boundary.

The Summer and Winter scenarios were run to provide representative results for when sea temperatures are at their maximum (January) and minimum (August).

For both scenarios, a high estimate of excess temperature was modelled.

Model results therefore span the potential envelop of conditions that can occur in the receiving environment in terms of heat exchange processes.

The model was firstly run with no temperature excess for the Northside and Southside Outfalls (i.e. the discharge volumes only) and then rerun with the inclusion of the time-varying temperature for both the Northside and Southside Outfalls.

Table 5-6. Range of discharge temperatures modelled for the Summer (February) and Winter (August) scenarios.

Discharge	**Summer Discharge Temperature Range (^{o}C)**	**Winter Discharge Temperature Range (^{o}C)**
Northside Outfall	35.0-35.7	31.0-31.1
Southside Outfall	27.9-29.4	22.3-22.4

Temperature Dynamics of the receiving environment (excluding NZ Steel temperature effects)

The following provides a brief overview of the temperature dynamics for the Summer and Winter receiving environment scenario (in which the excess temperatures of the NZ Steel discharges have been excluded from the model).

In Summer (Figure 5-37) temperatures on the inter-tidal areas are generally higher than the background temperature of 20.9 ^{o}C reflecting the higher levels of incoming solar radiation and longer daylight hours. The freshwater temperature values are generally around those of the assumed background temperature (Figure 4-8) so there is very little evidence of cooling due to freshwater inputs.

In Winter (Figure 5-38) temperatures on the inter-tidal areas are generally lower than the background temperature of 13.9 ^{o}C reflecting the switch to net cooling of shallow waters due to the shorter daylight hours and reduced daytime heating. The freshwater temperature values are generally less than those of the assumed background temperature (Figure 4-8) so there is evidence of patches of cooler water near the freshwater sources.

Figure 5-39 shows the time-series of predicted temperatures at a site just offshore of the Northside Outfall. The plot shows that, at times, there is a 6 ^{o}C diurnal variation in temperature and there is a general downward trend in temperature for the Summer scenario (as air temperature and daylight length decrease). For the Winter scenario there is a much smaller diurnal variation (<3 ^{o}C) in temperature and a general increase in temperature for the Winter scenario.

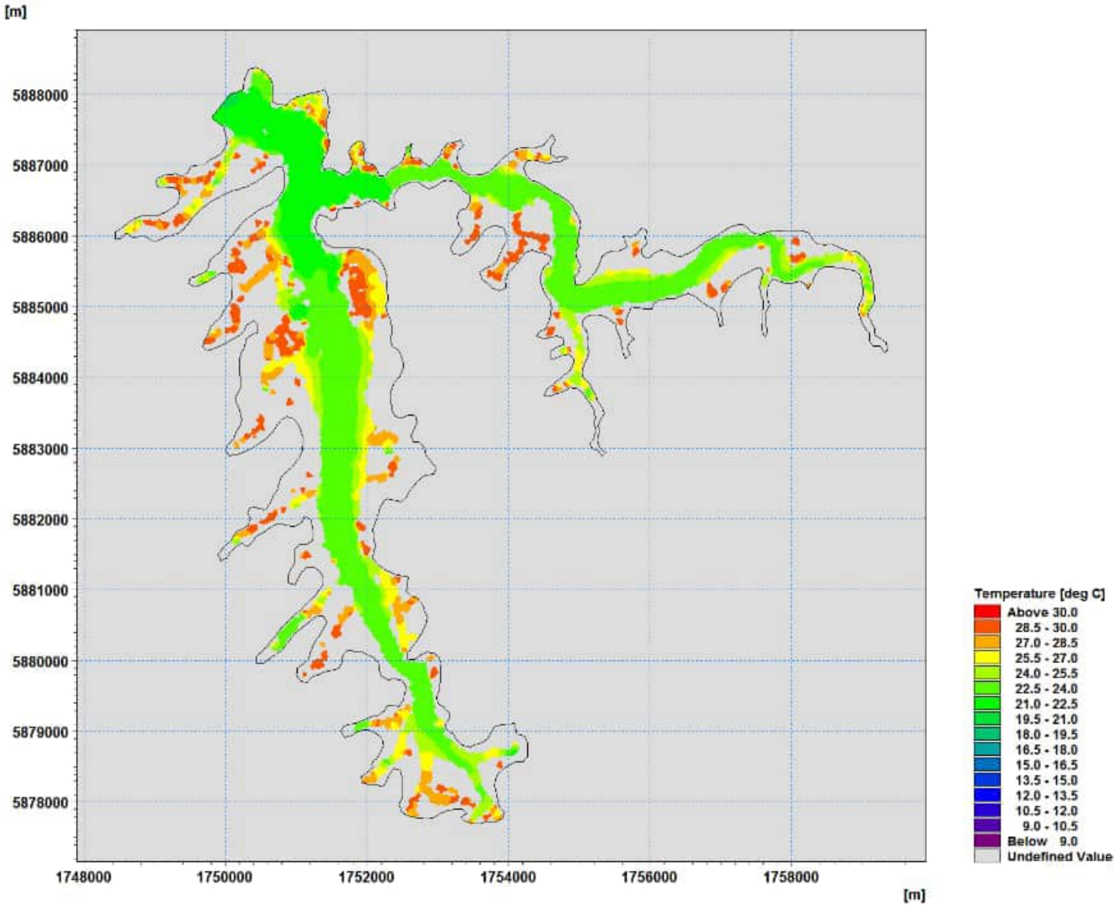


Figure 5-37. Predicted temperature at low tide halfway through the Summer scenario.

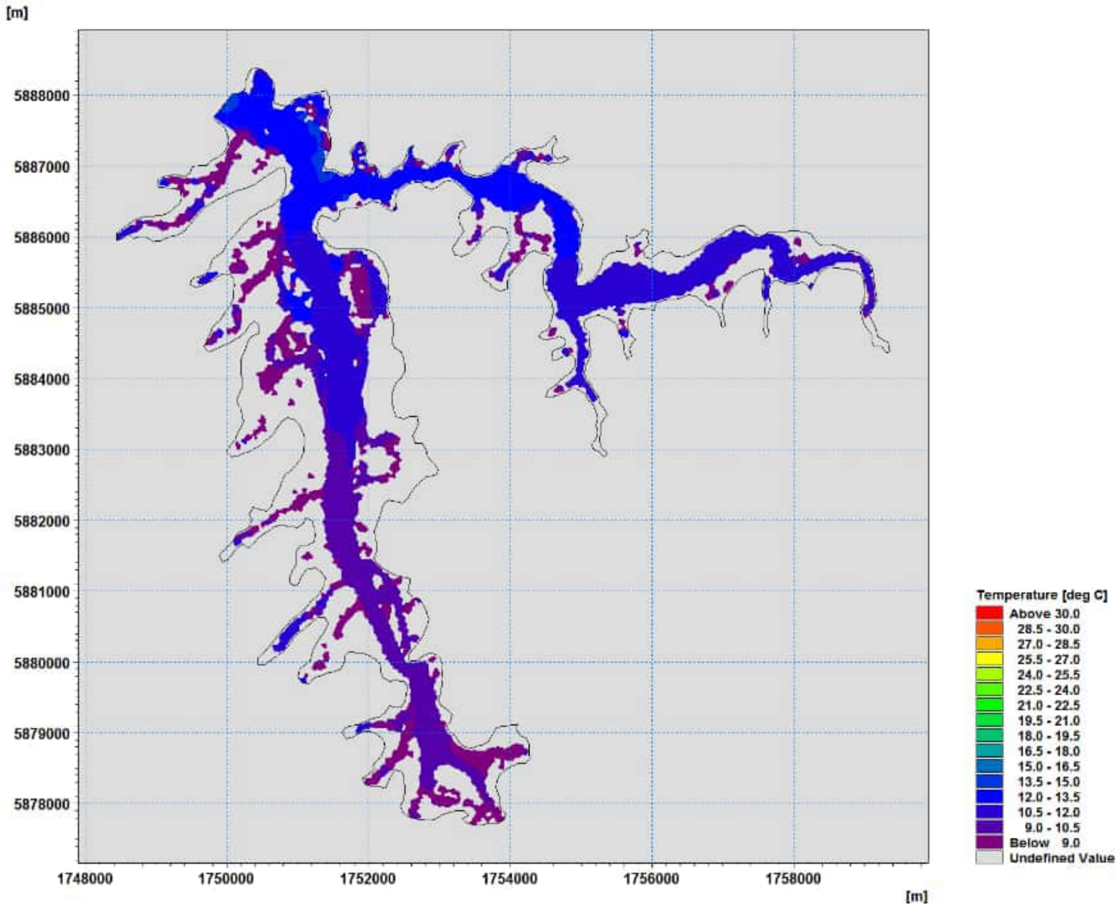


Figure 5-38. Predicted temperature at low tide halfway through the Winter scenario.

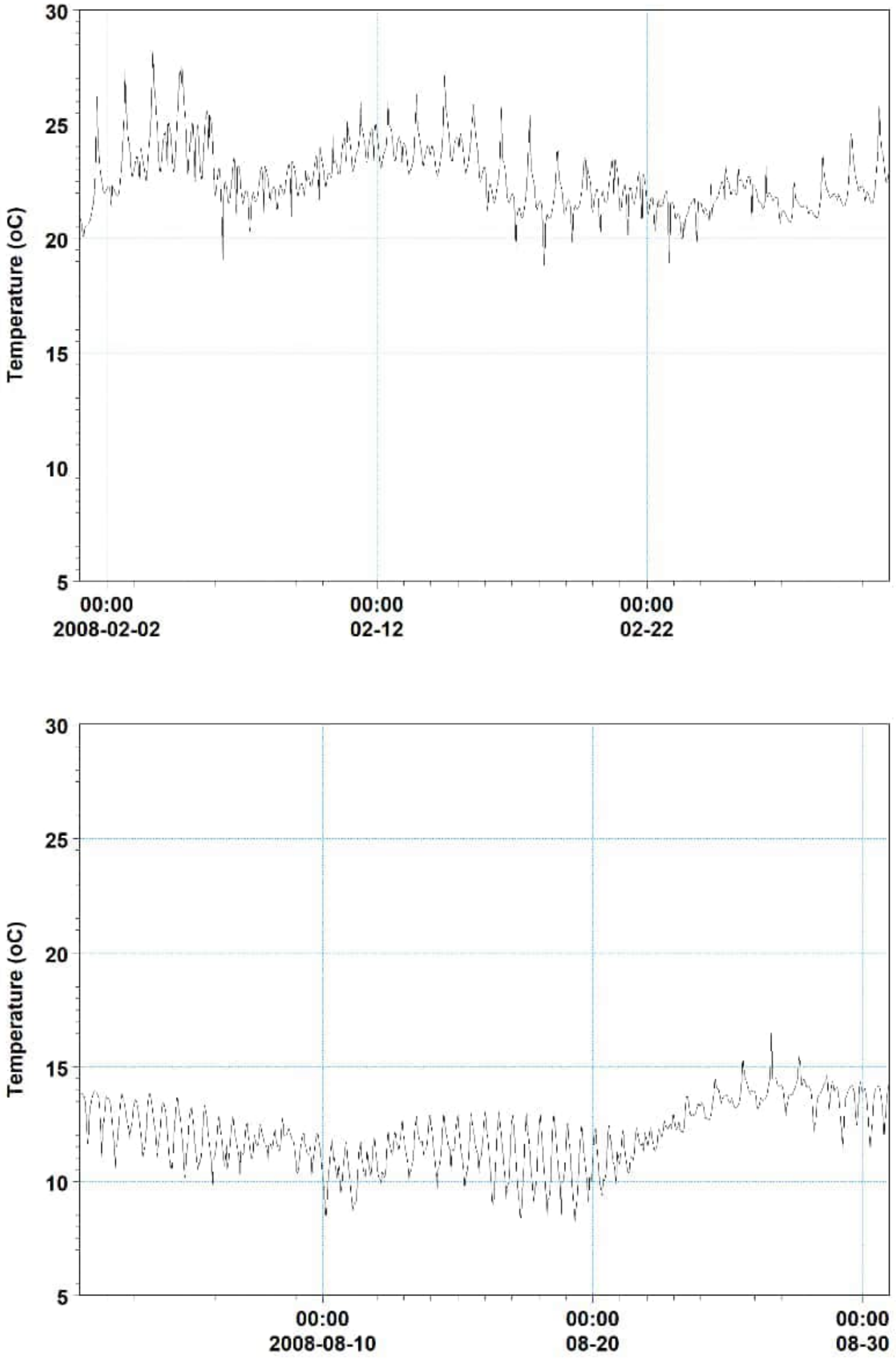


Figure 5-39. Time-series of predicted temperatures at a site just offshore of the Northside Outfall for the Summer (top panel) and Winter (bottom panel) scenarios.

Excess Temperature due to NZ Steel Discharges

The following provides an overview of the predicted excess temperatures that occur due to the Northside and Southside Outfall discharges. These results are created by subtracting the results from the hydrodynamic model run without any temperature excess from a model which includes the time-varying discharge temperatures (Figure 4-6).

Figure 5-40 shows the 50th percentile excess temperature for the Summer and Winter scenarios.

The maximum increase in average excess temperature at the Northside Outfall is 0.7 ^{o}C in Winter and 0.5 ^{o}C in Summer.

At the Southside Outfall, the maximum increase in average excess temperature is 0.8 ^{o}C in Winter and 0.2 ^{o}C in Summer.

These small increases in average excess temperatures reflect the level of mixing of ambient cooler water that occurs over all states of tide (as discussed in Section 5.3).

Figure 5-41 shows the 95th percentile excess temperature for the Summer and Winter scenarios and reflects the predicted excess temperature that will occur around low tide.

The maximum increase in the 95th percentile excess temperature at the Northside Outfall is 20.0 ^{o}C in Winter and 15.0 ^{o}C in Summer. At the Southside Outfall the maximum increase in the 95th percentile excess temperature is 4.1 ^{o}C in Winter and 2.5 ^{o}C in Summer.

The smaller excess temperatures in Summer are a result of the increased heating in the surface waters that occur during the Summer months which brings the ambient inter-tidal temperatures closer to the discharge temperatures compared to the Winter discharge (e.g., Figure 5-37 compared to Figure 5-38) and the increased effect of evaporative cooling in Summer.

Figure 5-42 and Figure 5-43 show the 50th and 95th percentile excess temperatures that occur as a function of radial distance from the discharge points for both the Summer and Winter scenarios. A radial distance is used because at times the plume is transported north of the discharge points, at times it is transported south and around low tide it moves predominantly offshore of the discharge point. Model data was interpolated along the circumference of 10, 20, 50, 100, 200, 300 and 500 m circles out from the discharge point.

Within 100-150 m of the Northside Outfall the 95th percentile excess temperature drops below 3 ^{o}C. For the Southside Outfall, the 95th percentile excess temperature is less than 3 ^{o}C within 50 m of the discharge point (and is never exceeded in Summer).

Table 5-7 and Table 5-8 show the percentage of time that an excess of 3 ^{o}C occurs as a function of radial distance from the Northside and Southside discharges for both the summer and winter simulations.

Figure 5-44 and Figure 5-45 show the spatial plots of the time when an excess of 3 ^{o}C occurs during the summer and winter simulations respectively.

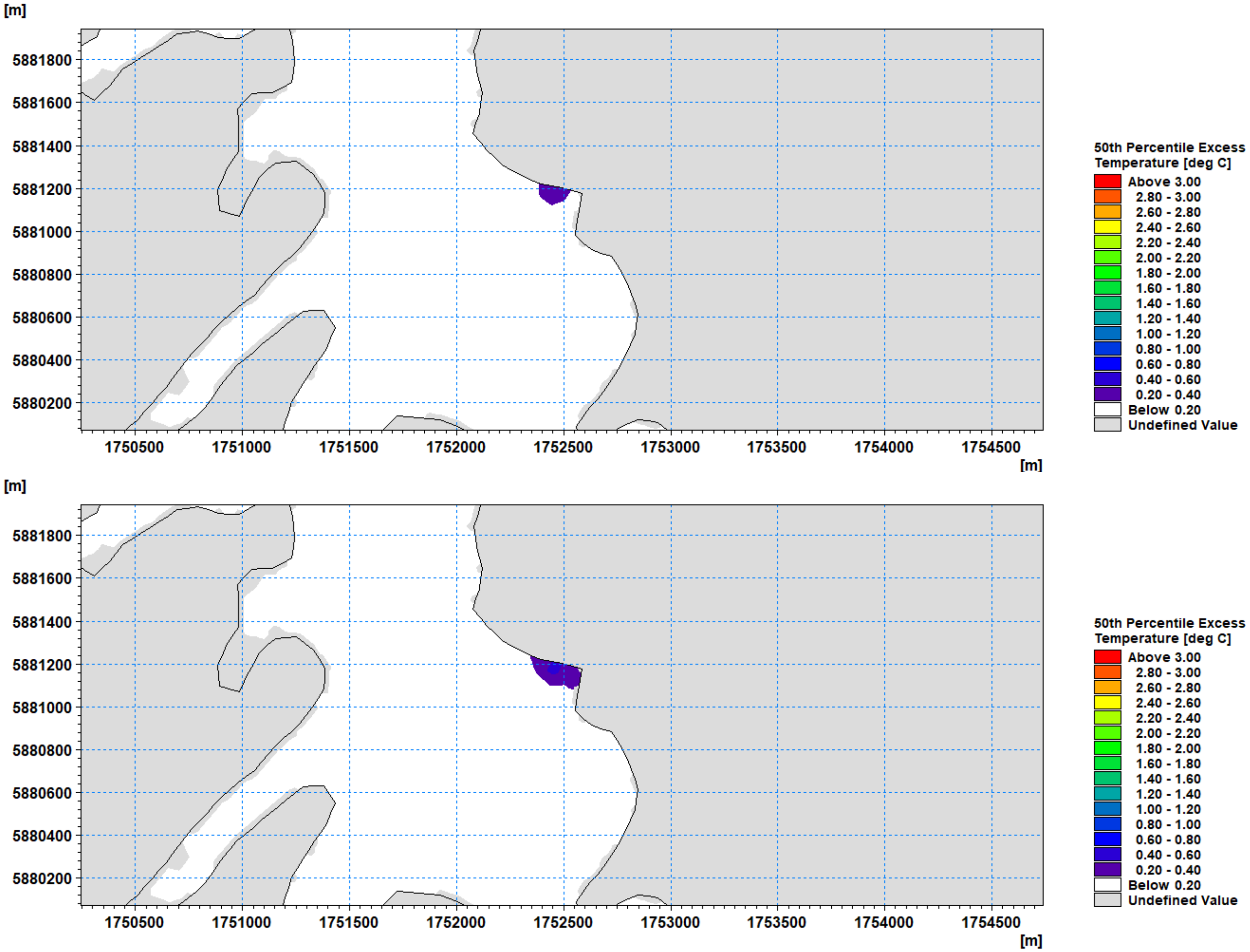


Figure 5-40. 50th percentile excess temperature for the Summer scenario (top panel) and Winter scenario (bottom panel).

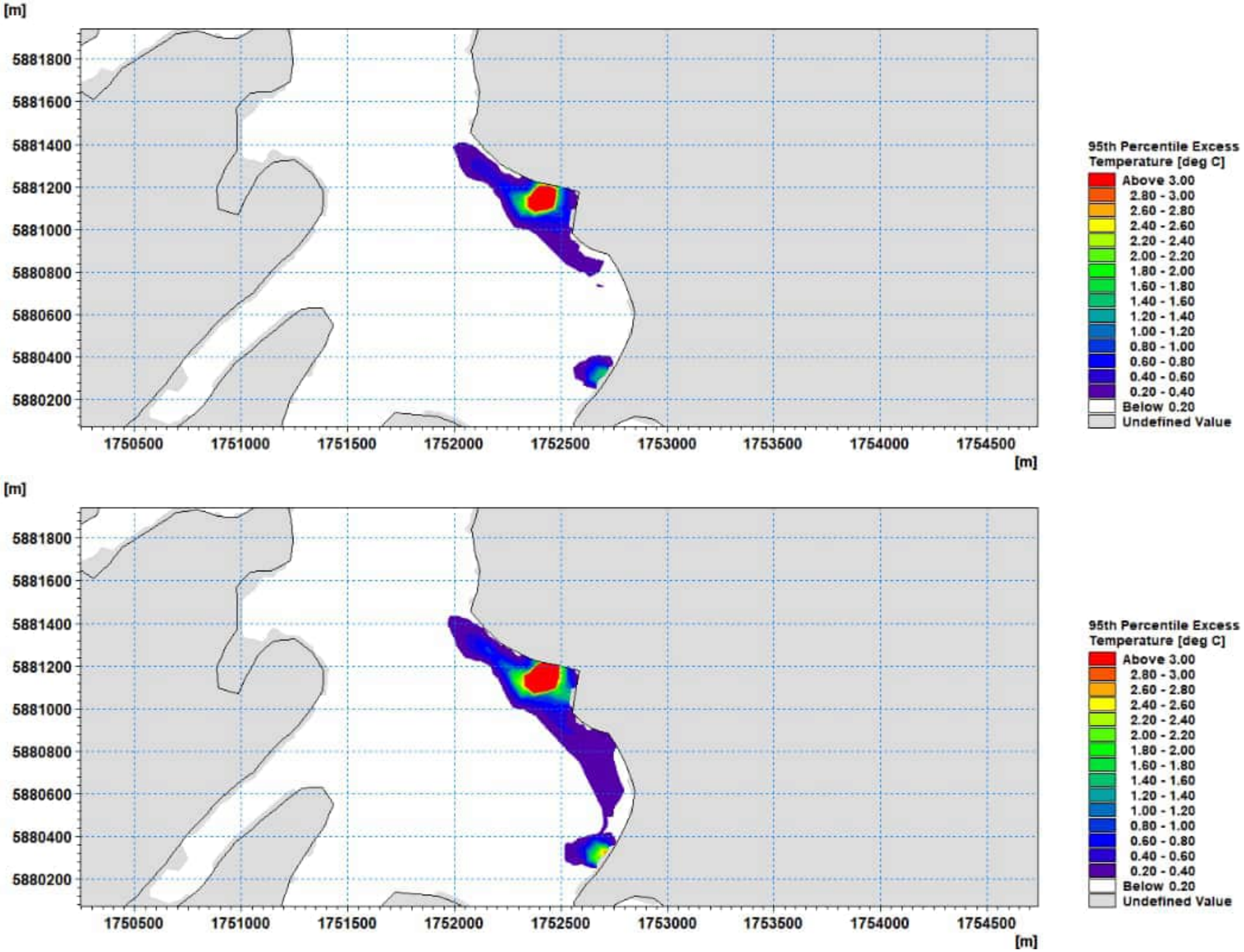


Figure 5-41. 95th percentile excess temperature for the Summer scenario (top panel) and Winter scenario (bottom panel).

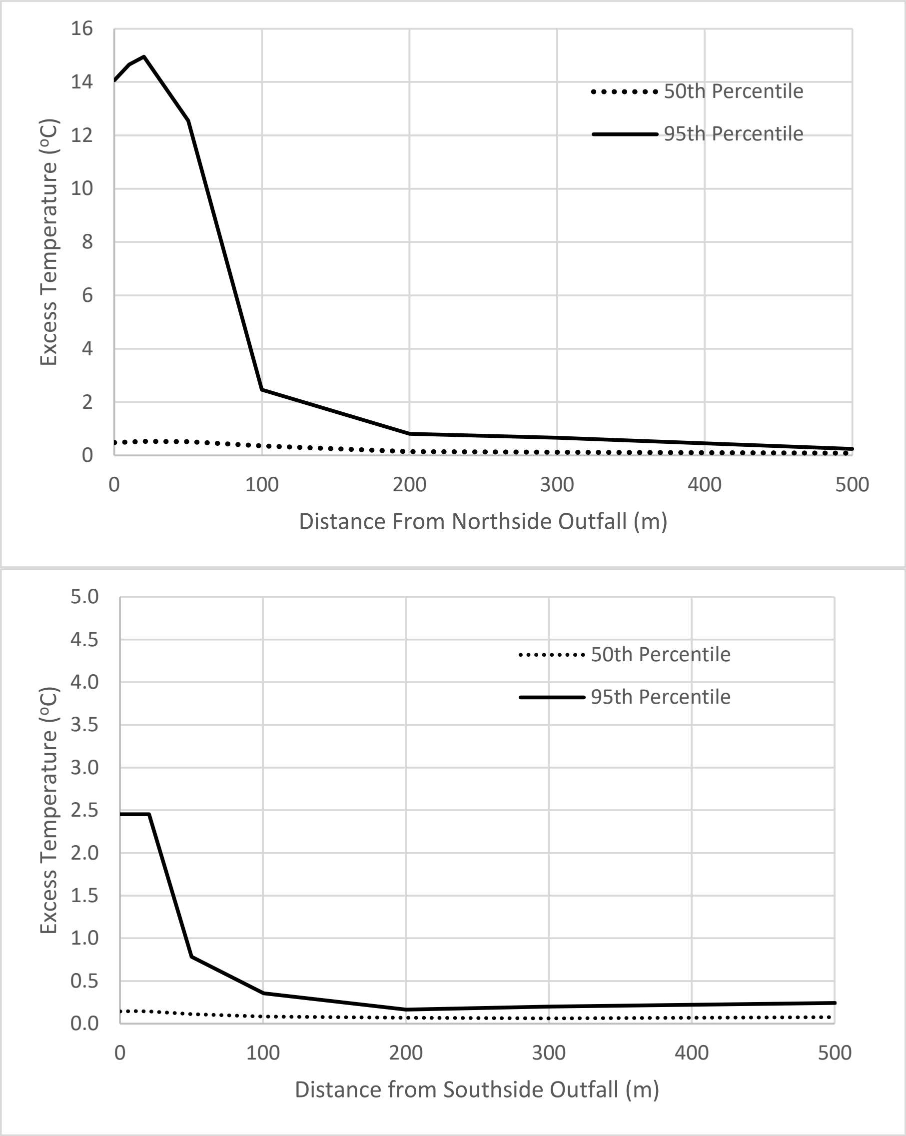


Figure 5-42. 50th and 95th percentile excess water column temperatures (ºC) during Summer at the Northside Outfall (top panel) and Southside Outfall (bottom panel) discharge sites as a function of radial distance (m) from the discharge point.

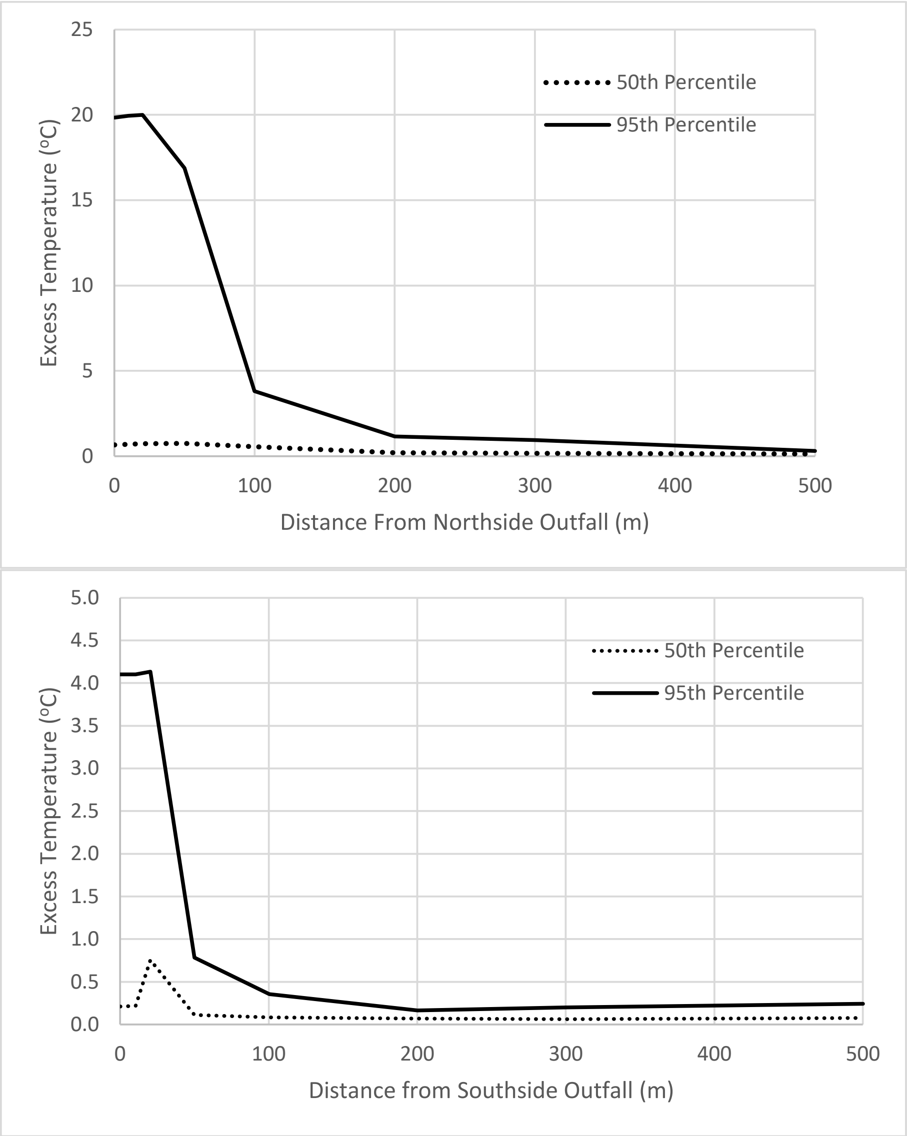


Figure 5-43. 50th and 95th percentile excess water column temperatures (°C) during Winter at the Northside Outfall (top panel) and Southside Outfall (bottom panel) discharge sites as a function of radial distance (m) from the discharge point.

Table 5-7. Summary of percentage of time an excess of 3 ^{o}C occurs as a function of distance (in metres) from the Northside Outfall over summer and winter,

Radial distance from Northside Outfall	0	10	20	50	100	200	300	500
Above 3 ^{o}C excess	23.5%	23.5%	20.1%	12.5%	3.8%	0.0%	0.0%	0.0%

Table 5-8. Summary of percentage of time an excess of 3 ^{o}C occurs as a function of distance (in metres) from the Southside Outfall over summer and winter,

Radial distance from Southside	0	10	20	50	100	200	300	500
Above 3 ^{o}C excess	6.1%	6.1%	1.9%	0.0%	0.0%	0.0%	0.0%	0.0%

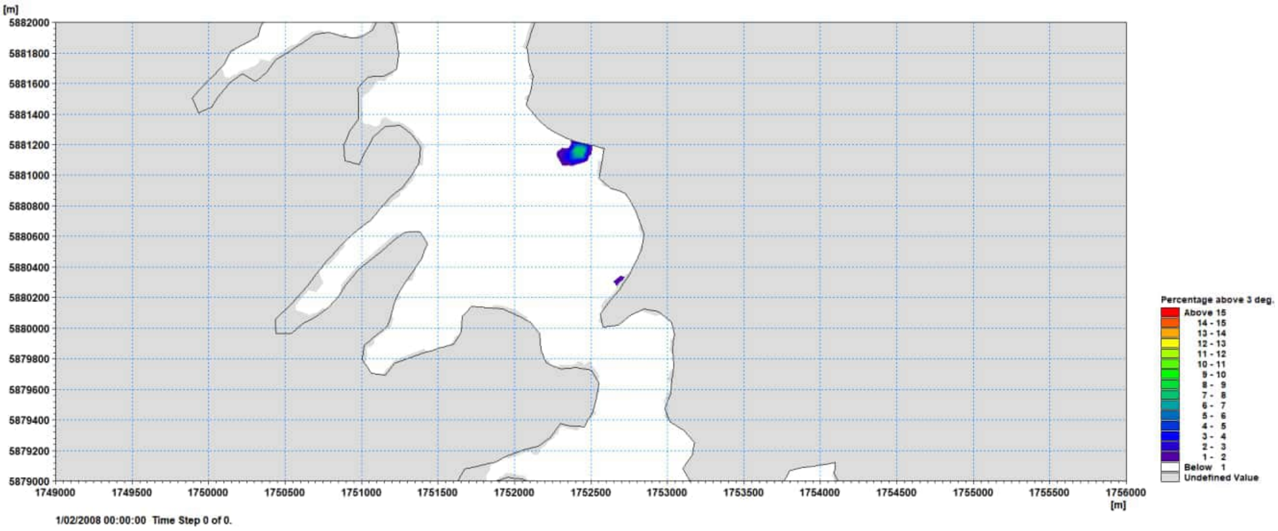


Figure 5-44. Percentage of time an excess temperature of 3 ^{o}C occurs during the summer simulation.

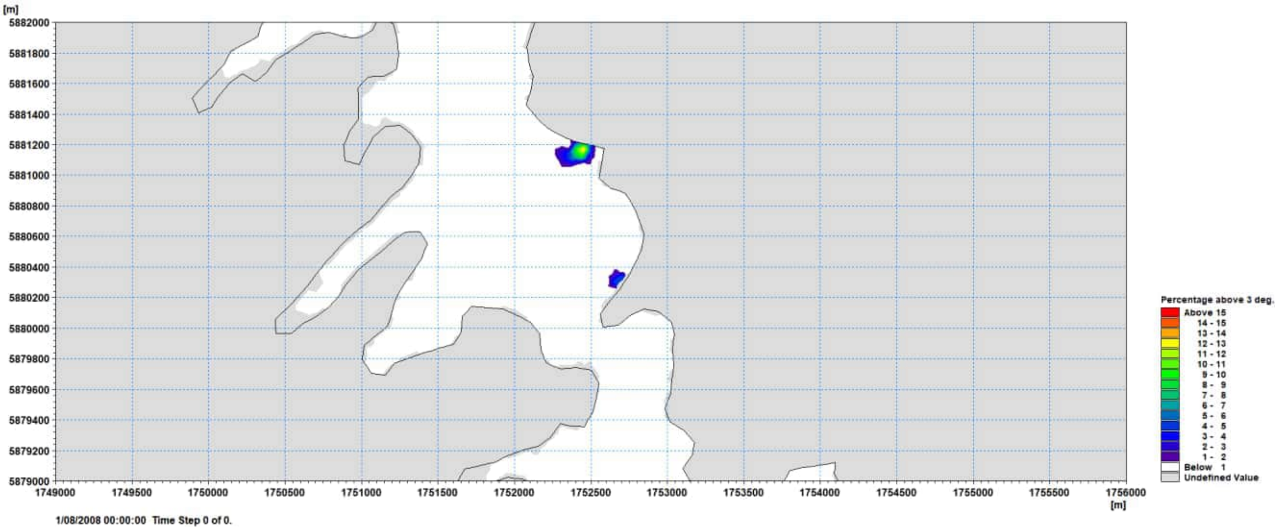


Figure 5-45. Percentage of time an excess temperature of 3 ^{o}C occurs during the winter simulation.

5.6 Water Column Mixing Zone Discussion

Due to a combination of the higher load for the Northside Outfall, and the different dynamics of the tidal flows to the north of the NZ Steel embayment compared to the area to the south, the water column footprint for the Northside Outfall is larger than the one associated with the Southside Outfall.

When considering the NZ Steel discharges in isolation, the Model results for dissolved metals indicate that 99% species protection level dissolved guidelines are exceeded within around 200 m and 100 m of the Northside Outfall for Zinc and Copper respectively. However, when background concentrations of copper and zinc are taken into account 99% species protection level guidelines are exceeded within around 300 m of the Northside Outfall for zinc and equilibrate with background concentrations after approximately 150 m for copper. This 300 m distance for zinc equates to a 95% species protection level mixing zone area of approximately 3.6 ha for the Northside Outfall discharge.

The influence of the Northside Outfall is only evident in the modelled salinities less than 400 m from the discharge point. This 400 m distance equates to a maximum mixing zone area for the discharge plume of approximately 6.3 ha for the Northside Outfall discharge.

For the Southside Outfall, the 99% species protection dissolved Copper guidelines are only exceeded within 50 m of the discharge point and the 99% species protection dissolved Zinc guideline is not exceeded. However, when background concentrations of copper and zinc are taken into account, zinc and copper concentrations equilibrate with background concentrations approximately 60 m from the Southside Outfall. This 60 m distance equates to a zinc and copper mixing zone area of approximately 1.3 ha for the Southside Outfall discharge.

The influence of the Southside Outfall is only evident in the modelled salinities less than 200 m from the discharge point. This 200 m distance equates to a mixing zone area for the discharge plume of approximately 1.6 Ha for the Southside Outfall discharge.

Monitoring data and estimates of ambient sea surface and freshwater input temperatures indicate that a 20 ^{o}C excess temperature may occur at the Northside Outfall when ambient temperatures are at their lowest – either during winter or at night when ambient sea surface temperatures decrease compared to daytime temperatures.

The excess temperature modelling shows that a 95th percentile excess temperature of 20.0 ^{o}C may occur at the Northside Outfall during winter (when daytime heating of ambient waters is minimal) but the 95th percentile excess temperature in summer would be 15.0 ^{o}C (due to the heating of shallow ambient water in summer). These values will only occur around low tide and within 100-150 m of the Northside Outfall excess temperatures will not exceed 3 ^{o}C.

Excess temperatures at the Southside Outfall are much lower (< 5 ^{o}C) due to the lower discharge rate and lower discharge temperature.

Averaged over a 24-hour period (i.e., over all states of tide) excess temperatures for the Northside and Southside Outfalls will be well below the current consented value of 20 ^{o}C.

6. Sediment Transport Model

The sediment transport model is setup based on the extensively calibrated model that was developed for the South-East Manukau Study (ARC, 2008). The most important parameters for the sediment transport model are the erosion threshold, erosion rate and depositional threshold.

The sand fraction of sediment from the FWMT is not modelled. This fraction will deposit very close to the catchment source and will have very little effect on wider depositional effects.

The deposition thresholds for the silt and clay fractions were set to 0.078 and 0.124 N/m^2 respectively while the erosion rate was set to 6.5 $x10^{-5}$ $kg/m^2/s$ with a power term of 4 (as per ARC, 2008).

The erosion threshold used in the South-East Manukau Study was set to 0.15 N/m^2 for all of the Manukau Harbour. It was found that applying this value across the Waiuku model domain resulted in limited erosion of sediments and consequently very little deposition of sediments away from the sediment sources and very high deposition rates in the immediate vicinity of all the catchment sources. Based on literature values (e.g., Zhu et al, 2018) and recent work carried out in the Okura-Wēiti system (DHI, 2019) the erosion threshold was varied spatially with a mean value of 0.05 N/m^2 on the inter-tidal areas and a maximum value of 0.15 N/m^2 in the deeper channels (Figure 6-1).

Based on the FWMT node input data for silt and clay the sediment transport model was run for all of 2008.

The predicted deposition rate at the end of the simulation (mm/yr) is shown in Figure 6-2. The maximum level of deposition (> 20 mm/yr) occurs closest to the FWMT nodes with the highest sediment loads. These are within the eastern sector of the Waiuku Town Basin and the two embayment’s to the very north-west of the Waiuku Estuary.

Appendix C provides the depositional footprint estimates for the clay fraction for each of the sediment sources and provides an indication of the areas where sediment from each of the sources is deposited within the Waiuku and Taihiki estuaries.

Dividing the model domain into broader scale sub-estuaries (Figure 6-3), the model results can be used to determine the contribution that each sediment source makes to the overall deposition in the Waiuku and Taihiki estuaries (Table 6-1) and the percentage of the Northside and Southside Outfall sediment loads that are deposited in each of the sub-estuaries (Table 6-2, Figure C-1).

These results give a good indication of the largest contributors to the deposition within the system and also how the sediments are distributed across the system.

The Northside and Southside Outfalls contribute 6.6% and 0.4% respectively of the total predicted sediment deposition across the Waiuku Estuary (Table 6-1) with the majority of this sediments from the Northside and Southside Outfalls being deposited within the embayment immediately offshore of the NZ Steel site (Table 6-2) with relatively strong connections through to the Town Basin, Te Hakono and North Stream sub-estuaries (Figure C-1).

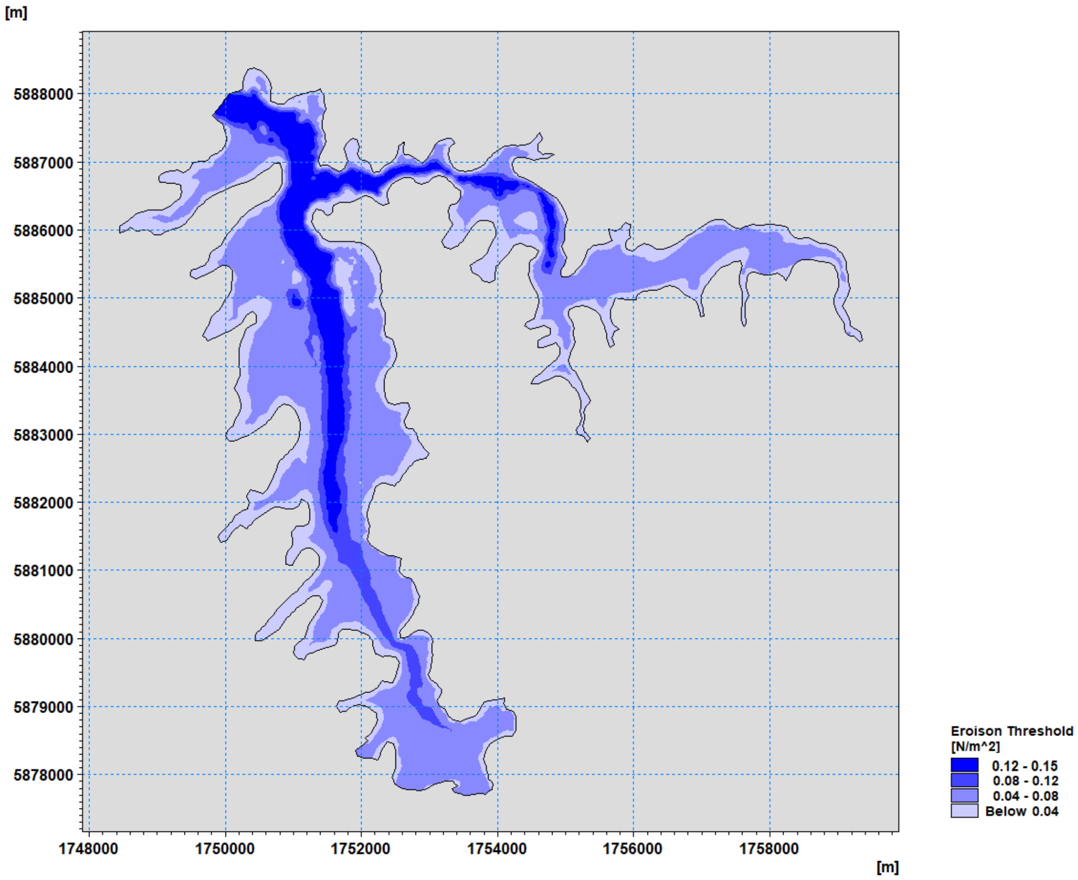


Figure 6-1. Spatially varying erosion threshold (N/m^2).

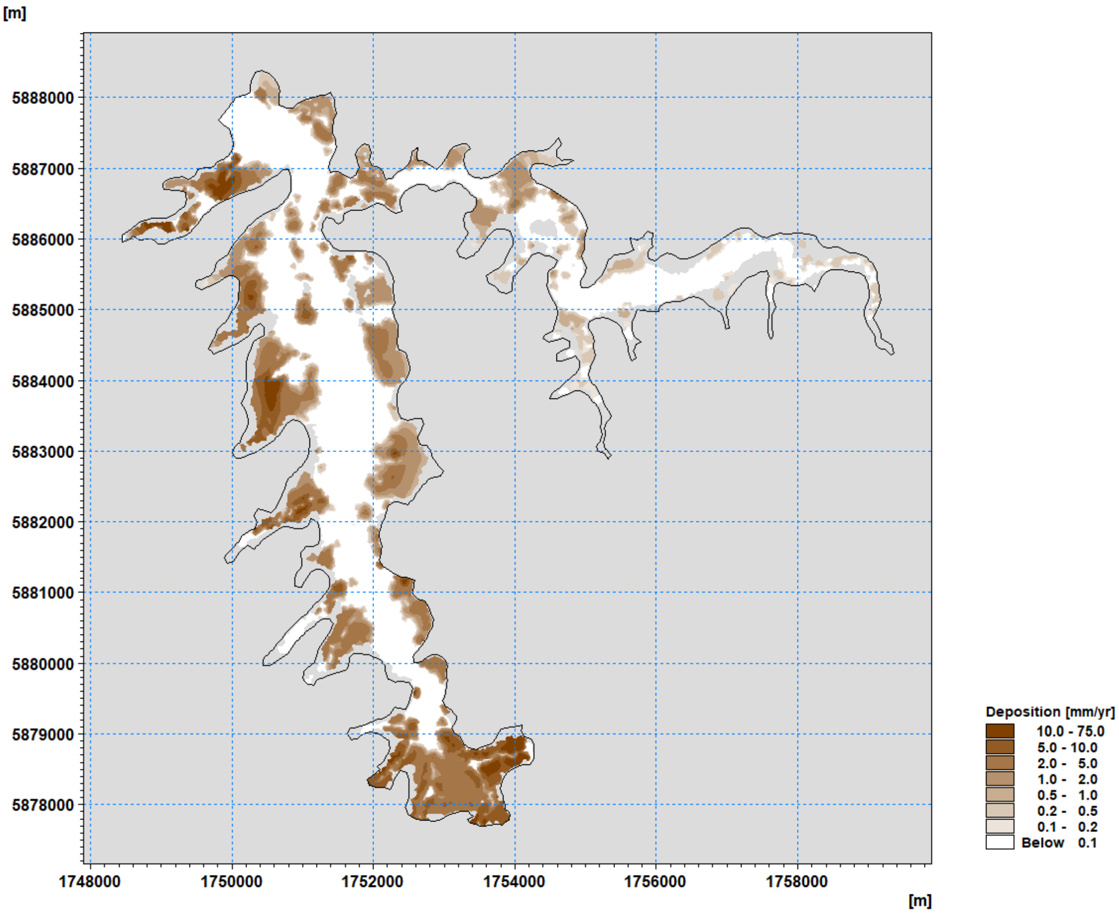


Figure 6-2. Predicted sediment accumulation rate (mm/yr) based on the 2008 annual sediment transport model simulation.

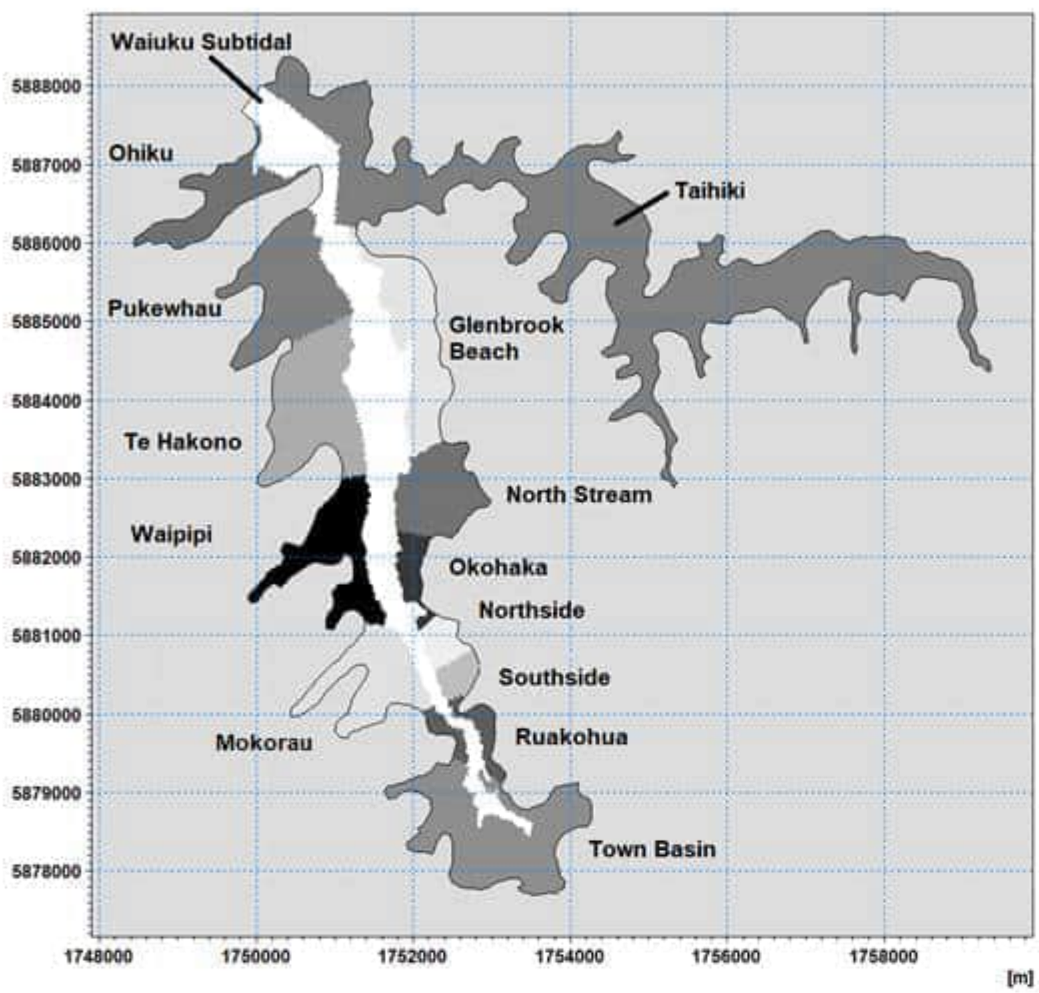


Figure 6-3. Sub-estuary zones within the Waiuku Estuary and the Waiuku sub-tidal subestuary and Taihiki Estuary subestuary.

Table 6-1. Percentage contribution that individual sediment sources make to overall deposition of clay in the Waiuku and Taihiki estuaries.

Sediment Source	Percentage of total deposition from given Source
Waiuku River 7	10.3%
Waitangi Stream 8	10.1%
Waiuku River 17	9.7%
Waiuku Town 3	7.8%
Waiuku River 16	7.7%
Waiuku River 8	7.6%
Waiuku River 2	7.2%
Waiuku River 5	5.7%
Waitangi Stream 3	4.4%
Waiuku River 11	2.9%
Waiuku Town 7	2.6%
Waiuku Town 1	2.6%
Waiuku River 13	2.5%
Waiuku River 14	2.0%
Waiuku River 6	1.5%
Waiuku River 4	1.2%
Waiuku River 3	1.1%
Waitangi Stream 7	1.0%
Waiuku River 10	0.9%
Waitangi Stream 4	0.7%
Waitangi Stream 6	1.2%
Waitangi Stream 2	0.4%
Waiuku Town 8	0.4%
Waitangi Stream 1	0.4%
Northstream	0.7%
Kahawai Stream	0.1%
Ruakohua Stream	0.2%
Southside Outfall	0.4%
Northside Outfall	6.6%

Table 6-2. Distribution of predicted deposition of Northside and Southside Outfall sediments within each of the sub-estuaries (Figure 6-3).

Subestuary	Southside Outfall	Northside Outfall
Northside	4.2%	26.8%
Southside	31.8%	2.6%
Town Basin	18.3%	12.2%
Ruakohua	2.1%	1.6%
Mokorau	5.2%	5.0%
Waipipi	3.6%	4.2%
Okohaka	0.7%	1.1%
North Stream	5.6%	7.1%
Te Hakano	6.9%	9.3%
Glenbrook Beach	4.2%	5.9%
Pukewhau	2.7%	3.9%
Ohiku	1.8%	2.5%
Waiuku Subtidal	3.5%	4.3%
Taihiki Estuary	9.3%	13.4%

7. Metal Accumulation Model

This section of the report provides details of the results of the metal accumulation model calibration and the predicted metal accumulation over the proposed 35 year consent term based on the continuation of NZ Steel's existing discharge regime (as outlined in Section 4).

In addition, the receiving environment scenario (under which the discharges from the NZ Steel site cease) has been run by removing the metal and sediment NZ Steel loads from the metal accumulation model.

The starting point for this receiving environment scenario is the current day predictions of Copper and Zinc levels (from the calibration process). The future inputs are then just the inputs of catchment derived sediment, Copper and Zinc over the proposed 35 year consent term.

7.1 Current Discharge – Calibration and Future Predictions

Using the methodology set out in Appendix A the metal accumulation was calibrated against the metal monitoring data (detailed in Table 4-10) for both Zinc and Copper.

The source concentrations of metals for each marine node are defined based on the ratio of the total metal to sediment load (Table B-1).

The calibration involved setting the surface mixed layer depth to 4 cm as was assumed in the South-East Manukau Study (ARC, 2008) and adjusting the particulate loss term which defines the degree of mixing between the incoming and legacy sediments and the effective net loss to dissolved form of metals that takes place. This loss term is the combination of the source particulate/dissolved partitioning and the subsequent desorption of metals to the water column from particulates in both the sediments and the water column.

For Zinc, to achieve a reasonable level of calibration the particulate loss term in the metal accumulation model was set to 95% which is much higher than the observed dissolved/particulate partitioning in Table 4-7, suggesting a significant level of desorption of particulate Zinc to the water column occurs. This high level of removal of particulate Zinc is consistent with data collected within the Whau Estuary (Ellwood et al. 2008) indicating that a large portion of the particulate Zinc is lost via the dissolution of particulate Zinc via pore water and then to overlying water. Modelling this process is very complex as the rate at which this process occurs is dependent on the salinity, pH and dissolved oxygen levels in overlying water and the degree to which surficial sediment are disturbed or consolidated (Atkinson et al. 2007).

For Copper, the particulate loss term in the metal accumulation model was set to 69% which is consistent with the observed dissolved/particulate partitioning in Table 4-8 suggested very little desorption of particulate Copper to the water column occurs. As for Zinc, this indicates that a portion of the particulate Copper is lost via the dissolution of particulate Copper to pore water and then to overlying water.

The calibrated metal accumulation model was then used to make predictions out to 35 years from present.

The Northside B monitoring site (Figure 4-1) is on the very edge of the inter-tidal area (Figure 5-2) and the bathymetry in this area may not be that well resolved in the model as the sediment transport model predicts very little deposition in this area (Figure 6-2). As such, the metal accumulation model only predicts very low metal concentrations at this site. This site was accordingly excluded from the calibration process.

The North Stream MZ monitoring site (Figure 4-1) can be considered part of the freshwater network and as such is not included in the marine model and was excluded from the calibration process.

Results are discussed in the context of the Environmental Response Criteria (ERC) guideline criteria set out in Auckland Regional Council (2004) and summarised in Table 7-1 for Zinc and Copper.

Table 7-1. Environmental Response Criteria (ERC) for Zinc and Copper in sediments (mg/kg) from Auckland Regional Council (2004).

	Green	Amber	Red
Zinc	< 124	124-150	> 150
Copper	< 19	19-34	> 34

Zinc

The calibration of the metal accumulation against current day Zinc concentrations is shown in Figure 7-2.

Overall, there is a good fit between the observed and simulated sediment concentrations across all the calibration sites considered.

In addition, the historical monitoring data from the Auckland Council Waiuku Town site have been used to check the hindcast model data (i.e. those prior to current day). Figure 7-3 shows that the overall increases in Zinc over the last 15 years at this site are well matched by the model.

Table 7-2 shows the current concentrations of Zinc at the calibration sites and those predicted 35 years from now. The maximum future increase in surface sediment Zinc at the monitoring sites is less than 22 mg/kg and, except at the Northside A site, the 35 year predictions at the monitoring sites remain below the lower limit of the Environmental Response Criteria Amber threshold of 124 mg/kg.

Over the next 35 years, the predicted sediment Zinc concentrations at the Northside A site are estimated to change by 1.5 mg/kg. This indicates that the current day values have already reached an equilibrium value – reflecting a steady state equilibrium between incoming sediments and metals, and the underlying metal concentrations in the surface mixed layer. Any variation in observed concentrations therefore relate to inter-annual variability of the dynamics of sediment deposition and/or the NZ Steel plant loads.

The spatial distribution of current day surface sediment Zinc concentrations is shown in Figure 7-4, and the predictions 35 years from now are shown in Figure 7-5.

Figure 7-6 shows the spatial plot of the change in surface sediment Zinc over the next 35 years (i.e. the difference between data in Table 7-2 and Figure 7-5).

The change is made up of the contribution from the catchment derived particulate Zinc (Figure 7-7) and the NZ Steel particulate Zinc (Figure 7-8) which reflects the pattern of sediment deposition from the individual sediment sources (Appendix C).

The following text provides a description of the metal model results focussing on the areas in the immediate vicinity of the Dew Plant, Northside and Southside Outfall discharges (Figure 7-1). Note that these zones do not correspond to the mixing zone discussed in Section 5.6.

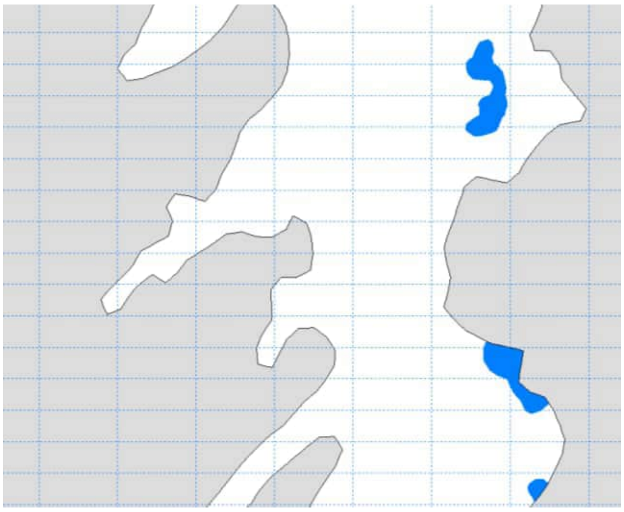


Figure 7-1. Zones used to describe the metal model accumulation predictions in the immediate vicinity of the North Stream (which contains the Dew plant discharge), Northside and Southside Outfall discharges.

Current day modelled estimates for Zinc

In the immediate vicinity of the NZ Steel discharges, the average modelled current day Zinc concentration is 81.9 mg/kg near the Northside Outfall discharge, 27.1 mg/kg near the Southside discharges and 95.3 mg/kg near the North Stream discharge (which contains the Dew Plant discharge).

A maximum current day modelled Zinc concentration of 207.1 mg/kg occurs on the very upper flanks of the inter-tidal area over an area of ~1100 m^2 near the Northside Outfall discharge. The maximum current day modelled Zinc concentration near the North Stream discharge (which contains the Dew Plant discharge) is 150.0 mg/kg (on the threshold of the Amber threshold and it occurs within an area of < 2000 m^2) while the maximum current day modelled Zinc concentration near the Southside discharge is 85.0 mg/kg (within an area of < 1000 m^2).

Beyond the immediate vicinity of the NZ Steel discharges, the average current day modelled Zinc concentration is 11.2 mg/kg. The maximum current day Zinc concentration of 156.4 mg/kg occurs within a small area (< 2000 m^2) on the very flanks on the fringes of the inter-tidal area within the Waiuku Town Basin.

Future predictions for Zinc

In the immediate vicinity of the NZ Steel discharges, the average future Zinc concentration is 97.5 mg/kg (an average increase of 11.8 mg/kg from current day estimates) made up an average future Zinc concentration of 90.5 mg/kg near the Northside Outfall discharge (+8.6 mg/kg above current day estimates), 29.5 mg/kg near the Southside discharges (+2.4 mg/kg above current day estimate) and 110.3 mg/kg near the North Stream discharge (which contains the Dew Plant discharge) (+15.0 mg/kg above current day estimates).

Near the Northside Outfall discharges, the predicted 35-year increases in Zinc levels are due to a combination of the Northside Outfall discharge (along the upper flanks of the inter-tidal area) and the ongoing input of catchment derived Zinc (more broadly across the inter-tidal area offshore of the Northside Outfall discharge). Near the North Stream discharge (which contains the Dew Plant discharge), a similar pattern of increases is seen with increases due the NZ Steel discharges towards the shoreline extent of the inter-tidal area and the catchment derived increases occurring over a much broader extent of the inter-tidal area. The area of where the maximum metal concentrations occur corresponds to a small embayment on the outer fringes of the inter-tidal area. Because of the bathymetry within the model this area (which covers an area of around 1600 m^2) acts as a sink for sediments (from all sources). Sediments are transported into the embayment (from all sources) and the currents within the embayment are not strong enough to remobilise it. Hence there is the long-term build up of sediments (and their associated metals).

The maximum future Zinc concentrations near the Northside Outfall discharge and North Stream (which contains the Dew Plant discharges) discharge do not change in the future but near the Southside discharge, the maximum future Zinc concentration increases to 92.1 mg/kg (+7.1 mg/kg from current day estimate).

The maximum future increases in Zinc due the NZ Steel discharges (35.2 mg/kg) occurs on an area of ~1200 m^2 on the very upper fringes of the inter-tidal area near the Northside Outfall, the maximum future increases due the NZ Steel discharges reduces to less than 12 mg/kg moving towards the Southside discharge. Near the North Stream discharge (which contains the Dew Plant discharge), the maximum future increases due to the NZ Steel discharges are less than 3 mg/kg.

Beyond the immediate vicinity of the NZ Steel discharges, the average future Zinc concentration is 13.9 mg/kg (+2.7 mg/kg above current day estimates) and the maximum concentration within the Waiuku Town Basin increases to 156.9 mg/kg (+0.5 mg/kg above the current day estimate).

Averaging the predicted surface sediment Zinc concentrations across each of the subestuaries shown in Figure 6-3, the contribution that the NZ Steel Zinc discharge makes to the predicted future increases in surface sediment Zinc can be estimated within each subestuary (Table 7-3).

Within the Northside and Southside subestuaries approximately 20% of the estuary wide increase in Zinc can be attributed to the NZ Steel discharge. This is made up of only a small change seen in the immediate vicinity of the NZ Steel discharges (Figure 7-8) where the ERC Red threshold is currently exceeded (consistent with the changes predicted at the Northside A calibration site) and increases of between 5 and 10 mg/kg moving away from the discharge sites (where Zinc levels remain below the ERC Green threshold). Within the other subestuaries, the relative contribution of the NZ Steel discharge to future increases in surface sediment Zinc ranges from 7 to 24%. The largest percentage increase occurs within the Taihiki Estuary (although this reflects the very low current day predicted level of less than 2 mg/kg across all of this subestuary and the fact that no Taihiki catchment loads are considered).

Copper

The calibration of the metal accumulation against current day Copper concentrations is shown in Figure 7-9.

Overall, there is a good fit between the observed and simulated sediment concentrations across all the calibration sites considered.

Table 7-4 shows the predicted future concentrations of Copper at the monitoring sites and those predicted 35 years from now. The maximum future increase in surface sediment Copper at the monitoring sites is less than 1.6 mg/kg and the 35 year predictions at the monitoring sites all remain below the ARC Green threshold of 19 mg/kg.

The predicted sediment Copper concentrations at the Northside A site only change by less than 0.1 mg/kg. This indicates that the current day estimates have already reached an equilibrium value – reflecting a steady state equilibrium between incoming sediments and metals, and the underlying metal concentrations in the surface mixed layer. Any variation in observed concentrations therefore relate to inter-annual variability of the dynamics of sediment deposition and/or the NZ Steel plant loads.

The spatial distribution of current day surface sediment Copper concentrations is shown in Figure 7-10 , and the predictions over the next 35 years are shown in Figure 7-11. Surface sediment Copper concentrations remain below the ERC Green threshold of 19 mg/kg over the 35-year period.

The change is made up of the contribution from the catchment derived particulate Copper (Figure 7-12) and the NZ Steel particulate Copper (Figure 7-13) and reflects the pattern of sediment deposition from the individual sediment sources (Appendix C).

Current day modelled estimates for Copper

In the immediate vicinity of the NZ Steel discharges, the average current day modelled Copper concentration is 5.9 mg/kg made up of an average current day modelled Copper concentration of 4.9 mg/kg near the Northside Outfall discharge, 2.7 mg/kg near the Southside discharge and 6.9 mg/kg near the North Stream discharge (which contains the Dew Plant discharge).

The maximum current day modelled Copper concentration of 10.9 mg/kg occurs on the inter-tidal area near the North Stream discharge (which contains the Dew Plant discharge). The maximum current day modelled Copper concentration near the Northside Outfall discharge is 9.4 mg/kg while the maximum current day modelled Copper concentration near the Southside discharge is 10.5 mg/kg.

Beyond the immediate vicinity of the NZ Steel discharges, the average current day modelled Copper concentration is 0.9 mg/kg. The maximum current day modelled Copper concentration of 9.5 mg/kg occurs within a small area (< 1300 m^2) on the very flanks on the fringes of the inter-tidal area towards the northern end of Glenbrook Beach.

Future predictions for Copper

In the immediate vicinity of the NZ Steel discharges, the average future modelled Copper concentration is 6.7 mg/kg (an average increase of 0.8 mg/kg from current day estimates), made up of an average future modelled Copper concentration of 5.4 mg/kg near the Northside Outfall discharge (an average increase of 0.5 mg/kg from current day estimates), 2.9 mg/kg near the Southside discharge (an average increase of 0.2 mg/kg from current day estimates), and 8.0 mg/kg near the North Stream discharge (which contains the Dew Plant discharge) (an average increase of 1.1 mg/kg from current day estimates).

As for the modelled Zinc predictions, the predicted 35-year increases in Copper levels near the Northside Outfall discharges are due to a combination of the Northside Outfall discharge (along the upper flanks of the inter-tidal area) and to the ongoing input of catchment derived Copper (more broadly across the inter-tidal area offshore of the Northside Outfall discharge). Near the North Stream discharge (which contains the Dew Plant discharge), a similar pattern of increases is seen with increases due the NZ Steel discharges towards the shoreline extent of the inter-tidal area and the catchment derived increases occurring over a much broader extent of the inter-tidal area.

The maximum future modelled Copper concentrations near the Northside Outfall and North Stream discharge (which contains the Dew Plant) discharges do not change but the maximum future modelled Copper concentration near the Southside discharge increases to 10.7 mg/kg (+0.2 mg/kg from current day estimates).

The maximum future modelled increase in Copper concentration due the NZ Steel discharges (1.5 mg/kg) occurs on an area of ~1200 m^2 on the very upper fringes of the inter-tidal area near the Northside Outfall, The maximum future modelled Copper concentration increases due the NZ Steel discharges are less than 0.6 mg/kg moving towards the Southside discharge. Near the North Stream discharge (which contains the Dew Plant discharge) the maximum future modelled increases in Copper concentration due to the NZ Steel discharges are less than 0.4 mg/kg while near the Southside discharge itself the maximum future increases in Copper concentration due to the NZ Steel discharges are less than 0.2 mg/kg

Beyond the immediate vicinity of the NZ Steel discharges, the average future modelled Copper concentration is 1.1 mg/kg (+0.2 mg/kg above current day estimates) and the maximum future concentration (that occurs on the very flanks on the fringes of the inter-tidal area towards the northern end of Glenbrook Beach) increases to 10.4 mg/kg (+0.9 mg/kg above the current day estimate).

Within the Northside and Southside subestuaries around 15% of the estuary wide increase in Copper can be attributed to the NZ Steel discharge. This is made up of only a small change seen in the immediate vicinity of the NZ Steel discharges (Figure 7-14) – consistent with the changes predicted at the Northside A calibration site and increases of less than 0.5 mg/kg moving away from the discharge sites. Within the other subestuaries, the relative contribution of the NZ Steel discharge to future increases in surface sediment Copper ranges from 5% to 16%. The largest percentage increases occurs within the Taihiki Estuary (although this reflects the very low current day predicted level of less than 0.2 mg/kg across all of this subestuary and the fact that no Taihiki catchment loads are considered).

Zinc

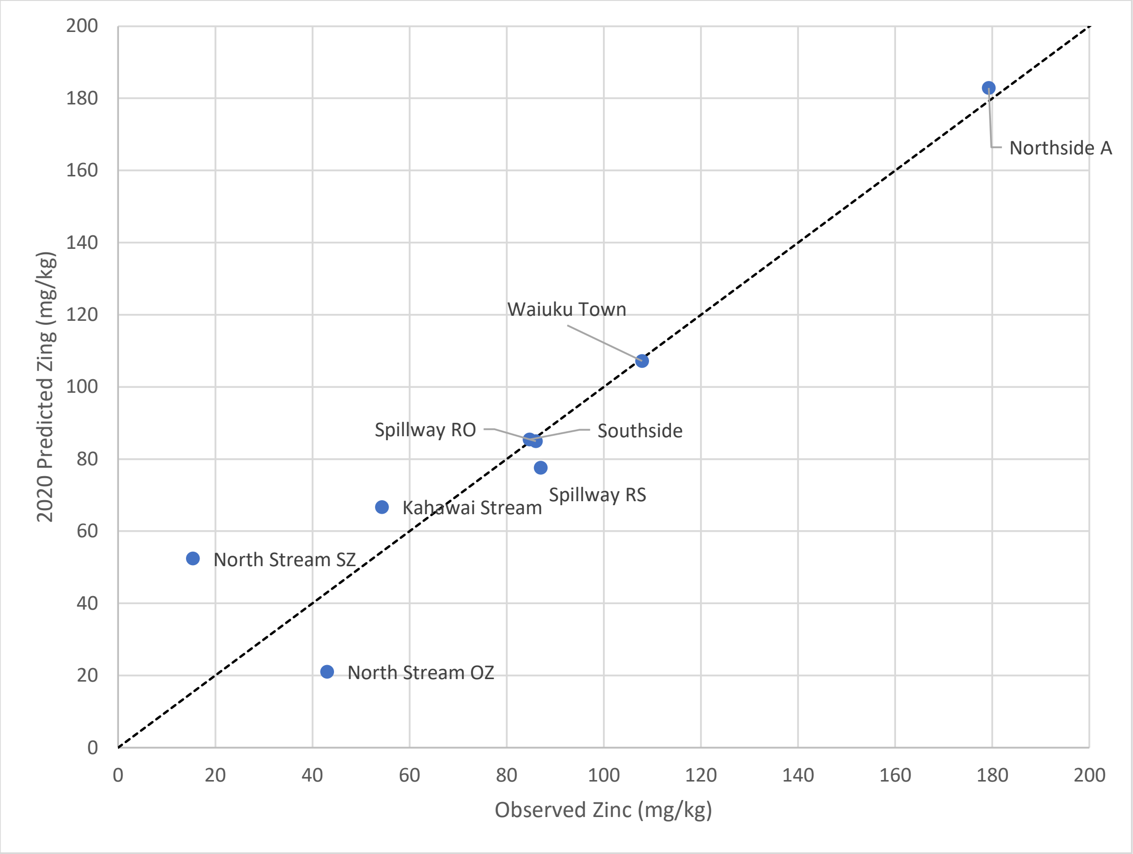


Figure 7-2. Calibration of the predicted surface sediment Zinc concentrations (mg/kg) against 2020 sediment monitoring data.

Table 7-2. Predicted current and 35 year surface sediment Zinc concentrations (mg/kg) at the calibration sites.

Calibration Site	Current day surface sediment Zinc (mg/kg)	Surface sediment Zinc (mg/kg) 35 years from present	35 year change in surface sediment Zinc (mg/kg)
North Stream SZ	52.4	73.3	20.9

Calibration Site	Current day surface sediment Zinc (mg/kg)	Surface sediment Zinc (mg/kg) 35 years from present	35 year change in surface sediment Zinc (mg/kg)
North Stream OZ	21.1	33.1	12.1
Kahawai Stream	66.7	88.6	21.8
Northside A	182.9	184.4	1.5
Southside	85.5	95.0	9.5
Spillway RS	77.6	91.7	14.0
Spillway RO	85.0	95.4	10.4
Waiuku Town	107.2	112.1	5.0

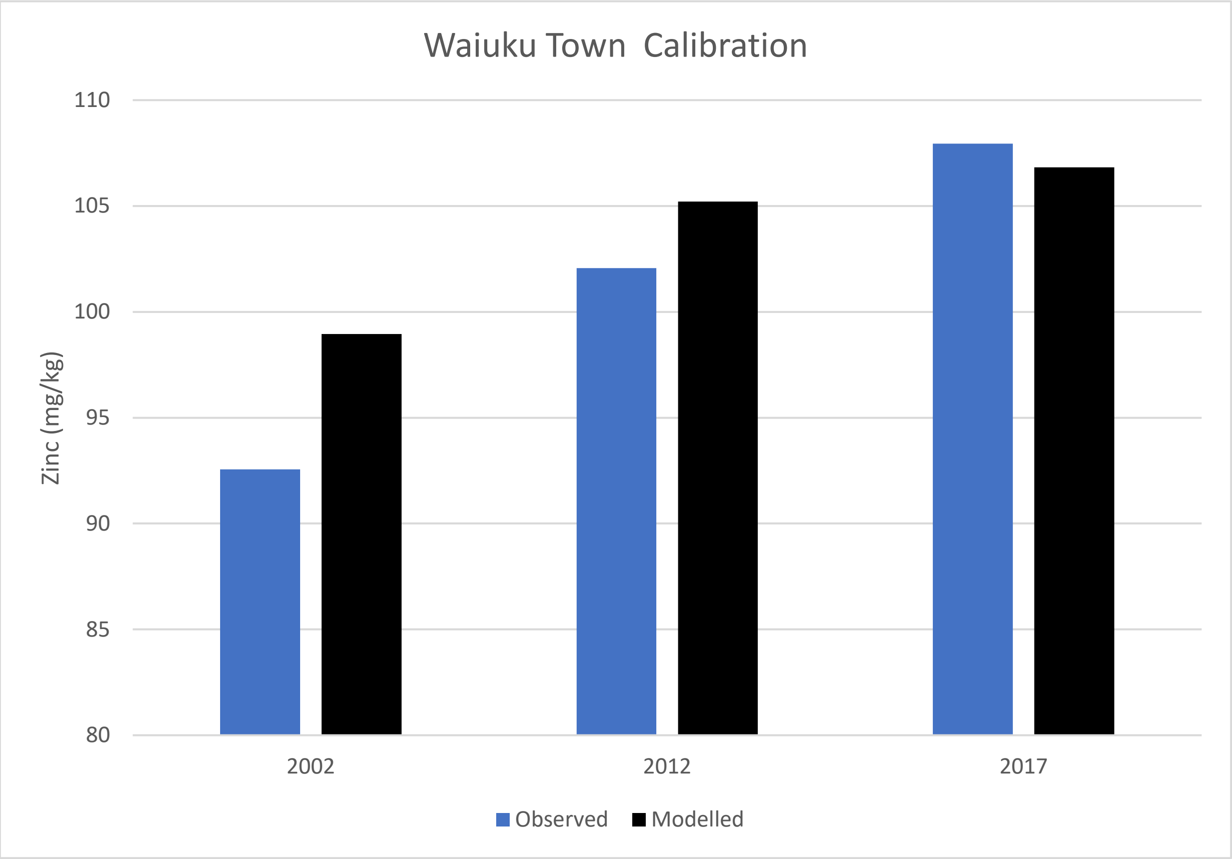


Figure 7-3. Validation of the metal accumulation model against historic Zinc concentrations at the Auckland Council Waiuku Town monitoring site.

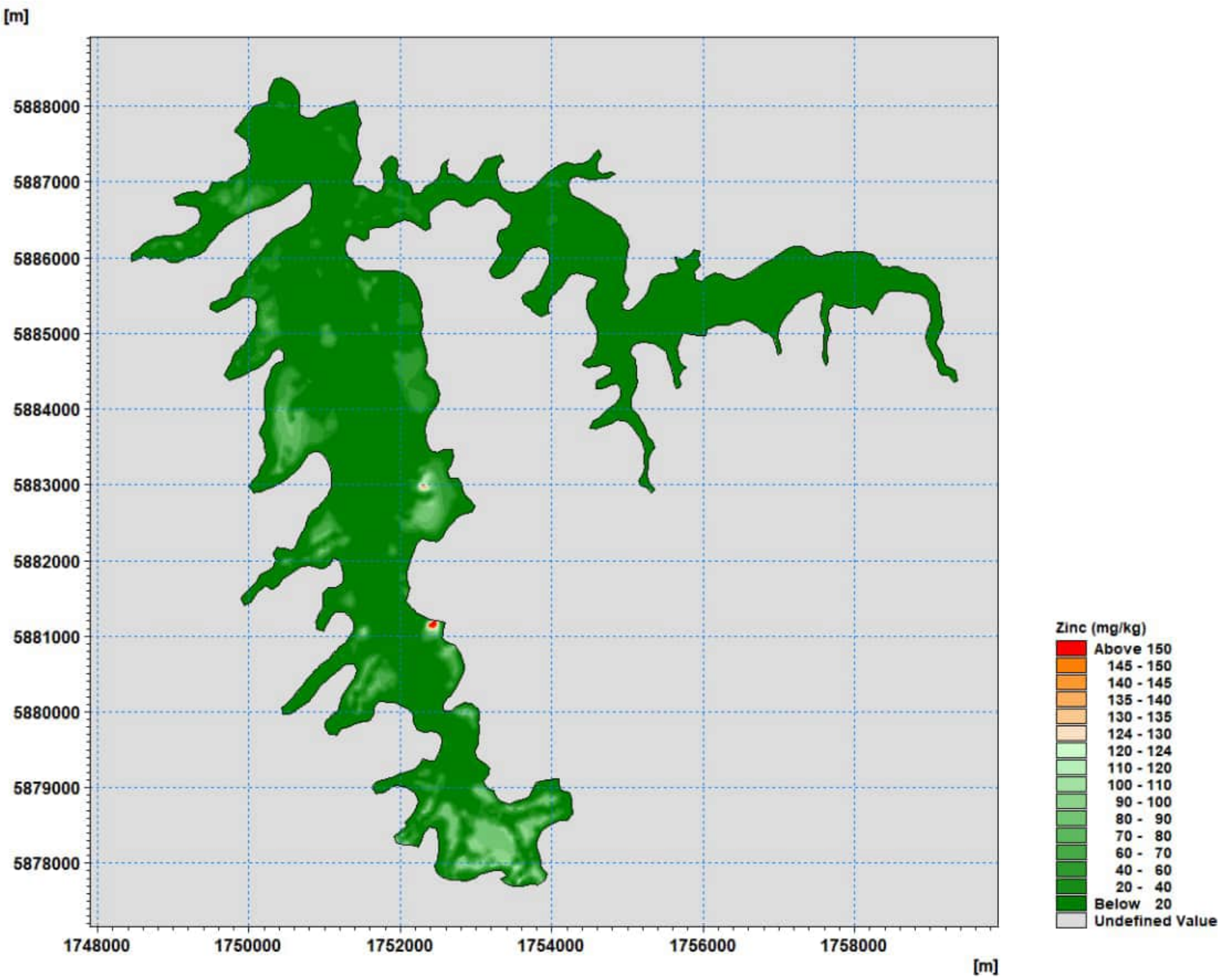


Figure 7-4. Predicted spatial distribution of current day surface sediment Zinc concentrations (mg/kg) with catchment and NZ Steel inputs of particulate Zinc. A maximum predicted Zinc concentration of 207.1 mg/kg occurs on the upper flanks of the inter-tidal area near the Northside Outfall discharge. The average current day predicted Zinc concentration in the immediate vicinity of the NZ Steel discharges is 81.9 mg/kg near the Northside Outfall discharge, 27.1 mg/kg near the Southside discharges and 95.3 mg/kg near the North Stream/Dew Plant discharge.

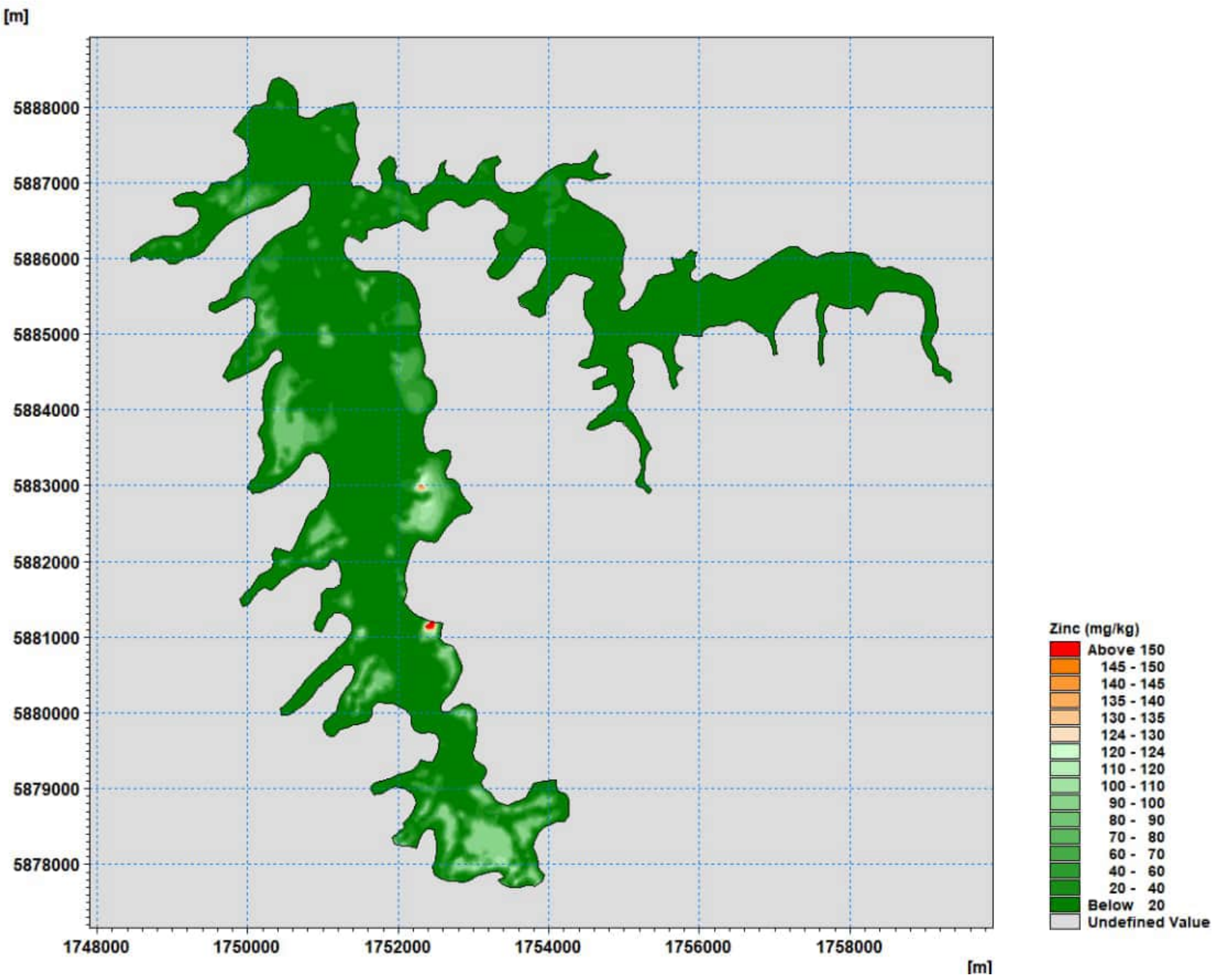


Figure 7-5. Predicted spatial distribution of surface sediment Zinc concentrations (mg/kg) 35 years from present with catchment and NZ Steel inputs of particulate Zinc. A maximum predicted Zinc concentration of 207.1 mg/kg occurs on the upper flanks of the inter-tidal area near the Northside Outfall discharge. The average future Zinc concentrations in the immediate vicinity of the NZ Steel discharges are predicted to be 90.5 mg/kg near the Northside Outfall discharge, 29.5 mg/kg near the Southside discharges and 110.3 mg/kg near the North Stream/Dew Plant discharge.

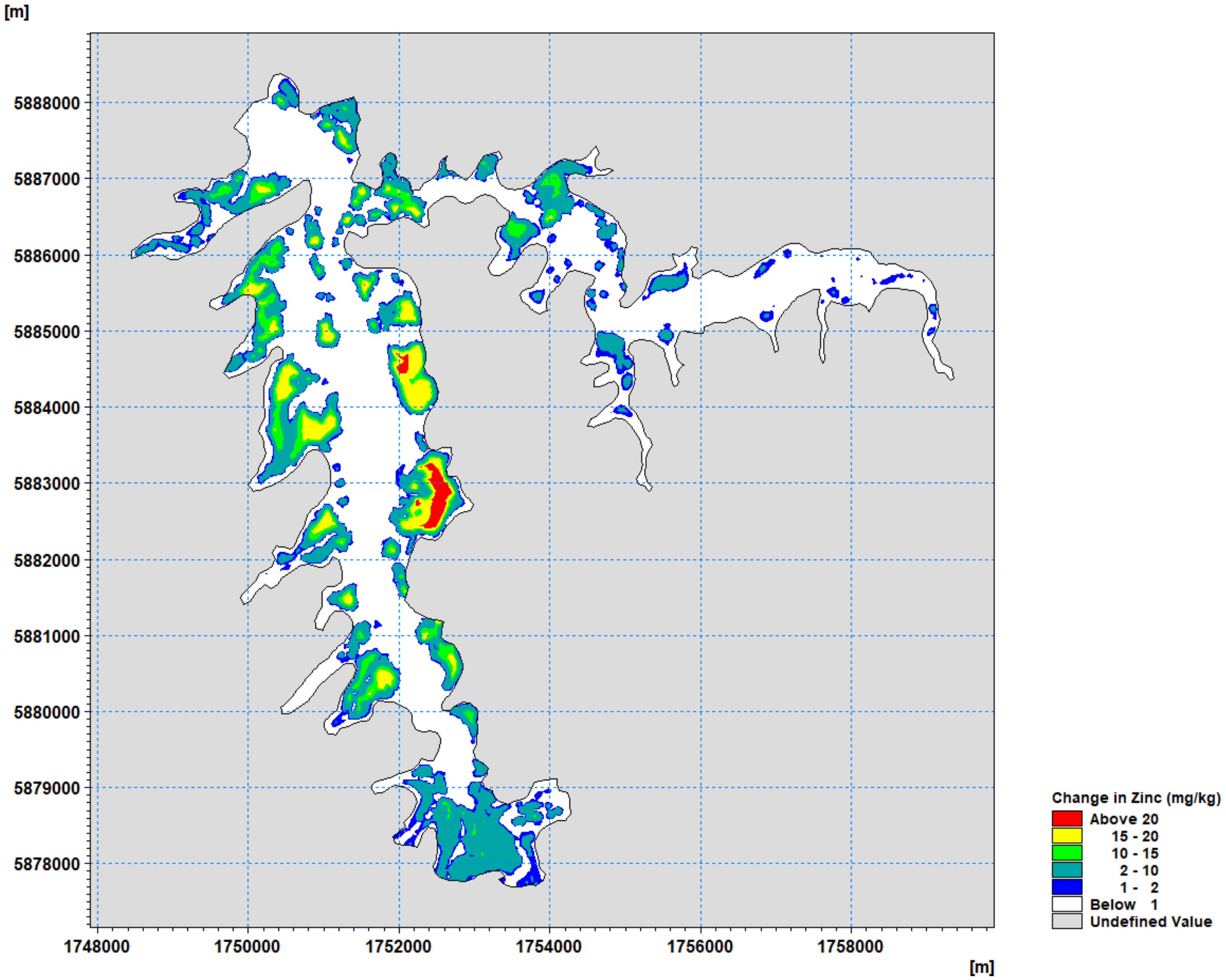


Figure 7-6. Change in surface sediment Zinc concentration (mg/kg) 35 years from present day with catchment and NZ Steel inputs of particulate Zinc. A maximum predicted change in Zinc concentration of 37.0 mg/kg is predicted to occur on the upper flanks of the inter-tidal area near the Northside Outfall discharge.

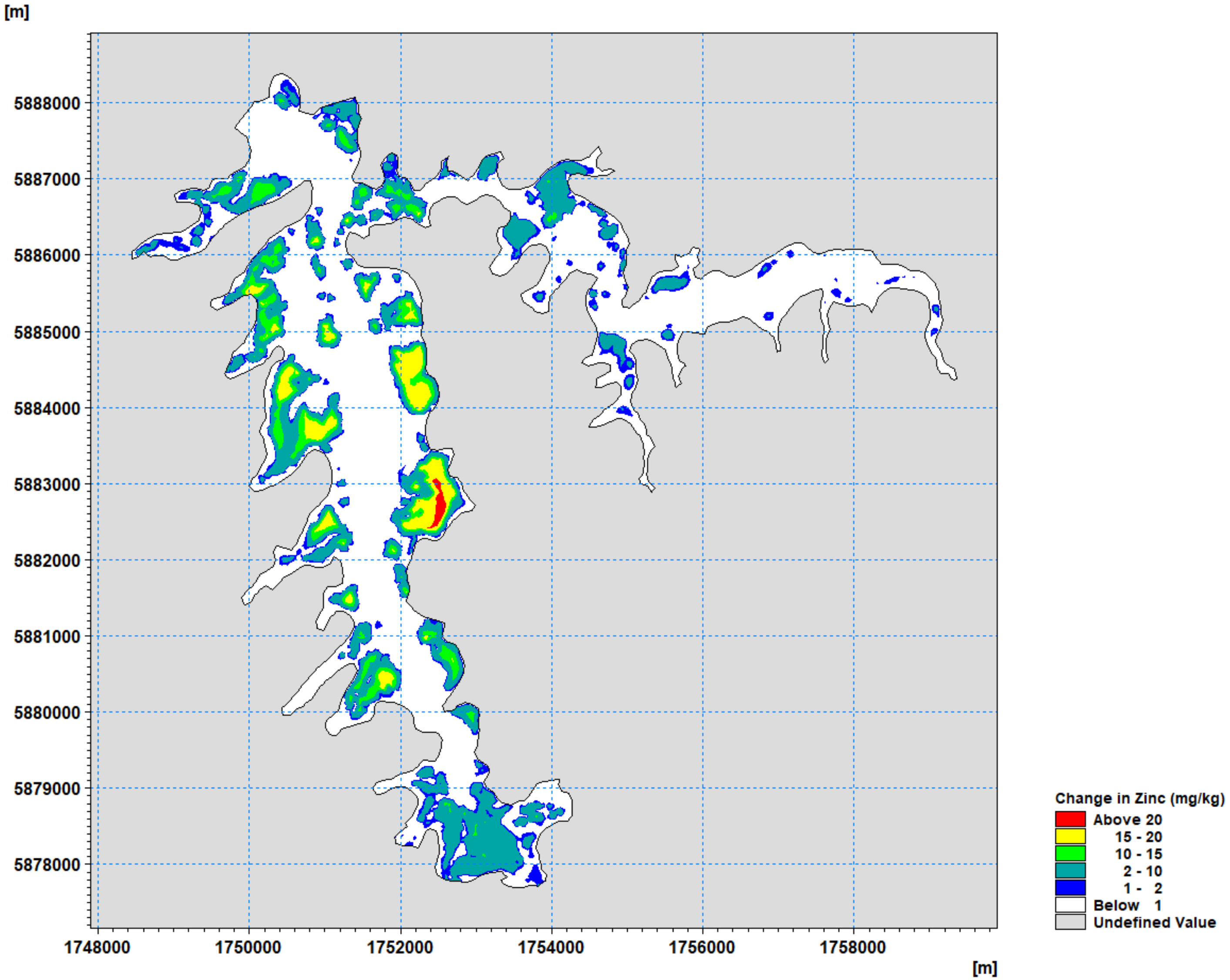


Figure 7-7. Change in surface sediment Zinc concentration (mg/kg) 35 years from present day with just catchment inputs of particulate Zinc. A maximum predicted change in Zinc concentration of 24.9 mg/kg is predicted to occur on the in the inter-tidal area to the north of the Glenbrook Beach.

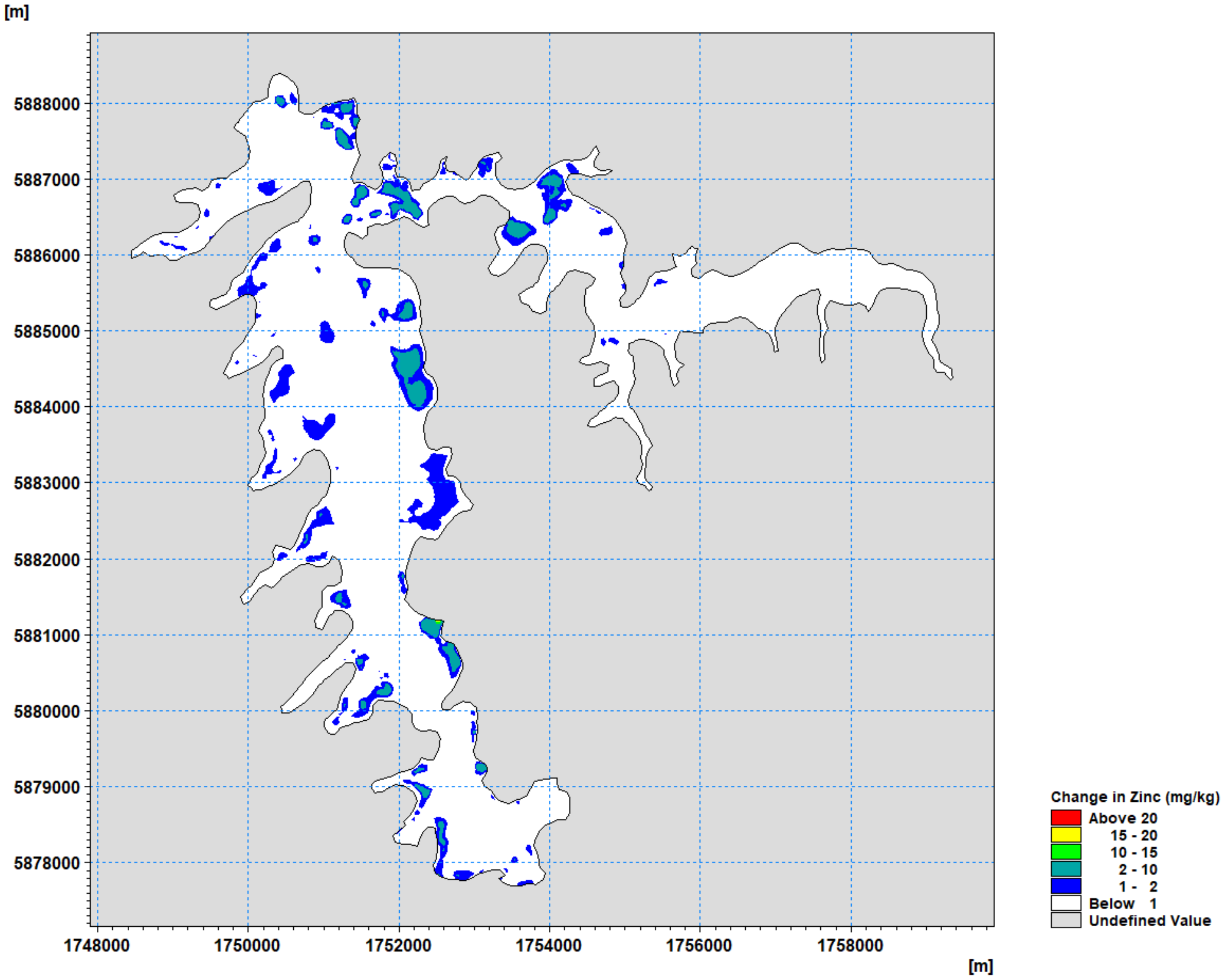


Figure 7-8. Change in surface sediment Zinc concentration (mg/kg) 35 years from present day with just NZ steel inputs of particulate Zinc. A maximum predicted change in Zinc concentrations of 35.2 mg/kg is predicted to occur along the upper fringes of the inter-tidal area near the Northside Outfall discharge.

Table 7-3. Sub estuary wide average estimates of surface sediment Zinc (mg/kg) for present day, 35 years from now, changes 35 years from now and relative contribution of NZ Steel and catchment derived Zinc to the 35 year increases.

Subestuary	Present day sub estuary wide surface sediment Zinc (mg/kg)	Sub estuary wide surface sediment Zinc (mg/kg) 35 years from present day	Sub estuary wide 35 year change in surface sediment Zinc (mg/kg)	NZ Steel Contribution to 35 year change	Catchment Derived Zinc Contribution to 35 year change
Northside	30.66	35.44	4.78	23%	77%
Southside	16.34	20.25	3.91	18%	82%
Town Basin	39.49	42.46	2.97	12%	88%
Ruakohua	11.47	13.37	1.90	21%	79%
Mokorau	16.07	19.82	3.75	13%	87%
Waipipi	14.25	17.37	3.12	13%	87%
Okohaka	8.11	10.68	2.57	14%	86%
North stream	31.19	40.40	9.21	9%	91%
Te Hakano	22.21	27.10	4.89	8%	92%
Glenbrook Beach	13.25	19.44	6.19	13%	87%
Pukewhau	9.48	12.79	3.31	10%	90%
Ohiku	15.42	18.41	2.98	11%	89%
Waiuku Subtidal	2.73	3.60	0.88	18%	82%
Taihiki Estuary	2.59	4.12	1.53	25%	75%

Copper

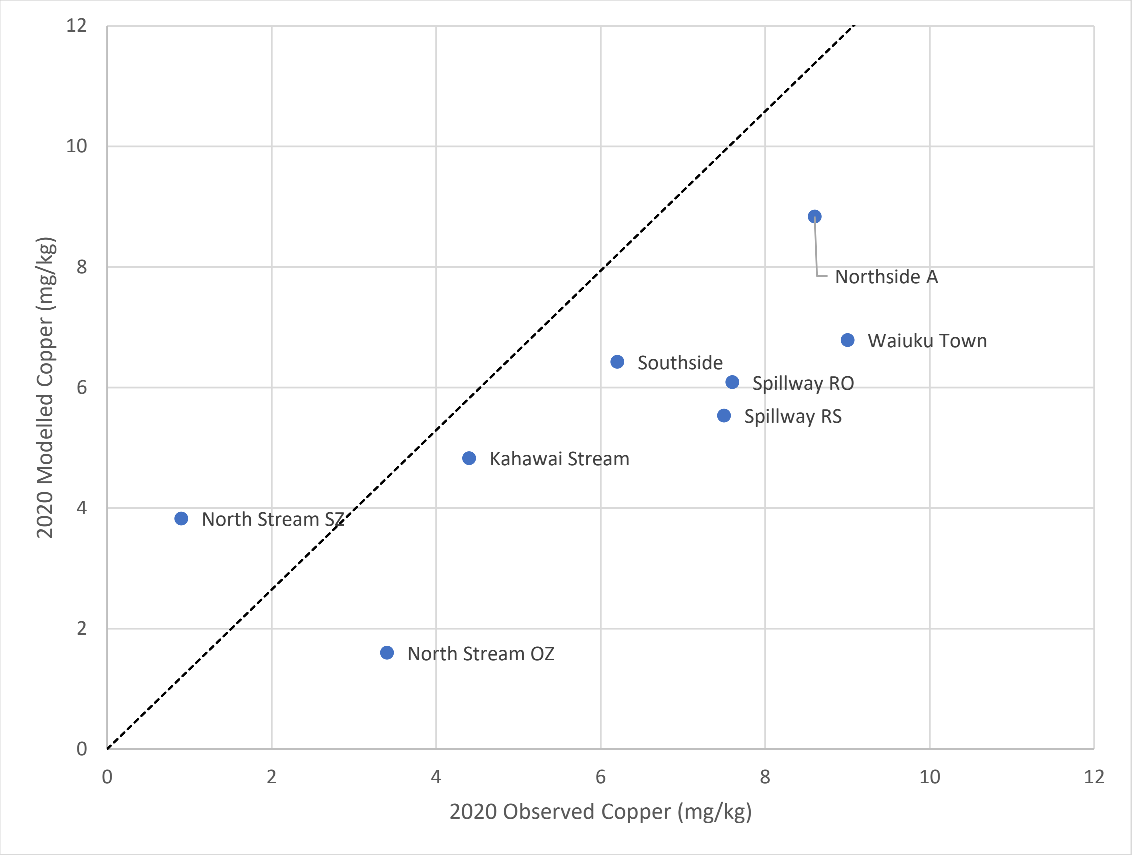


Figure 7-9. Calibration of predicted surface sediment Copper against 2020 sediment monitoring data.

Table 7-4. Current and 35 year surface sediment Copper concentrations (mg/kg) at the calibration sites.

Calibration Site	Current surface sediment Copper (mg/kg)	Surface sediment Copper (mg/kg) at 35 years from present	35 year change in surface sediment Copper (mg/kg)
North Stream SZ	3.8	5.4	1.5
North Stream OZ	1.6	2.5	0.9
Kahawai Stream	4.8	6.4	1.6
Northside A	8.8	8.9	0.1
Southside	6.4	7.1	0.7
Spillway RS	5.5	6.5	1.0
Spillway RO	6.1	6.8	0.7
Waiuku Town	6.8	7.1	0.3

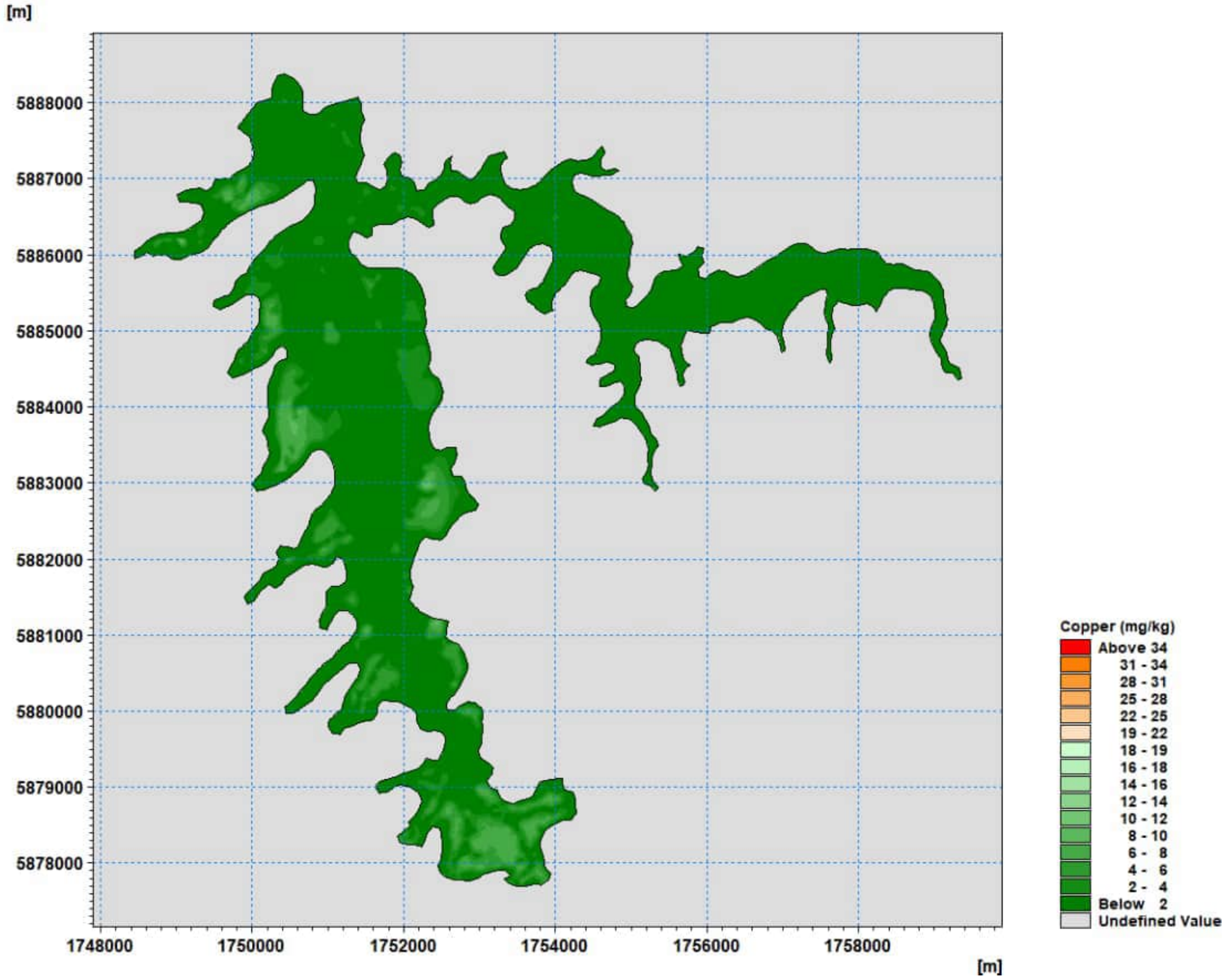


Figure 7-10. Predicted spatial distribution of current day surface sediment Copper concentrations (mg/kg) with catchment and NZ Steel inputs of particulate Copper. A maximum predicted Copper concentration of 10.9 mg/kg is predicted to occur on the inter-tidal area within the North Stream subestuary. The average predicted future Copper concentration in the immediate vicinity of the NZ Steel discharges are 4.9 mg/kg near the Northside Outfall discharge, 2.7 mg/kg near the Southside discharge and 6.9 mg/kg near the North Stream/Dew Plant discharge.

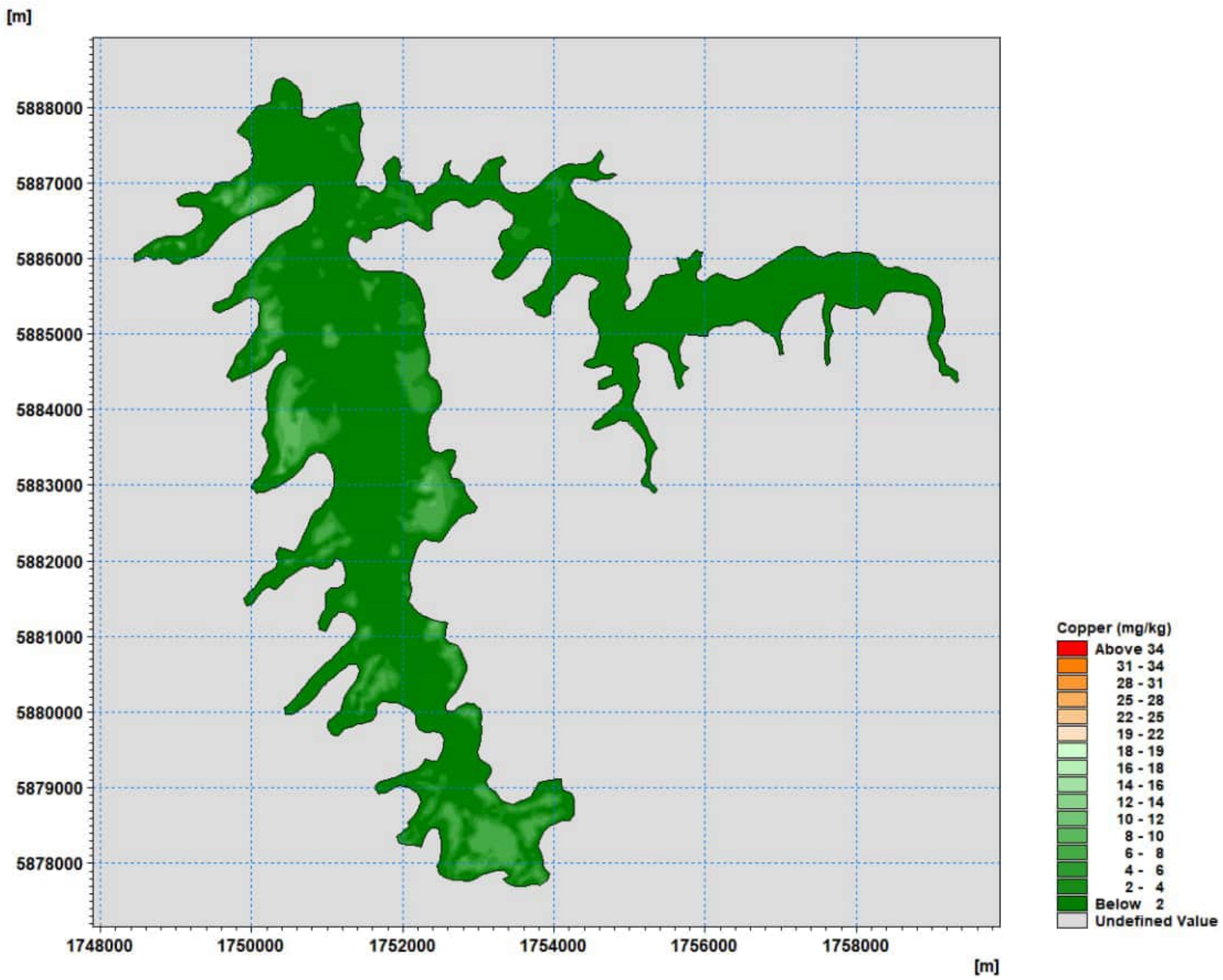


Figure 7-11. Predicted spatial distribution of surface sediment Copper concentrations (mg/kg) 35 years from present with catchment and NZ Steel inputs of particulate Copper. A maximum predicted Copper concentration of 10.9 mg/kg is predicted to occur on the inter-tidal area within the North Stream subestuary. The average predicted future Copper concentration in the immediate vicinity of the NZ Steel discharges are 5.4 mg/kg near the Northside Outfall discharge, 2.9 mg/kg near the Southside discharge and 8.0 mg/kg near the North Stream/Dew Plant discharge

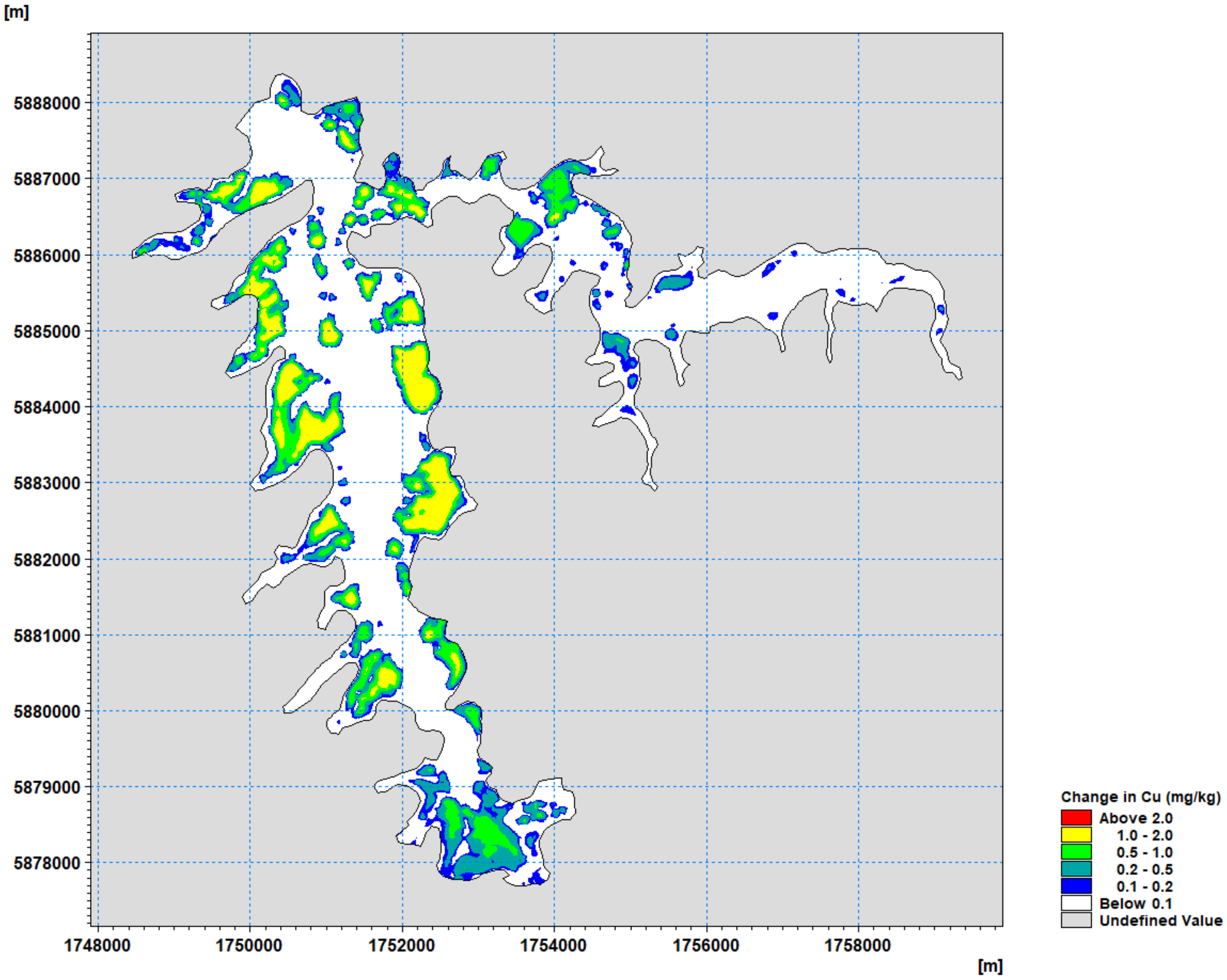


Figure 7-12. Change in surface sediment Copper concentration (mg/kg) 35 years from present day with catchment and NZ Steel inputs of particulate Copper. A maximum predicted change in Copper concentration of 1.9 mg/kg is predicted to occur along the upper fringes of the inter-tidal area near the Northside Outfall discharge.

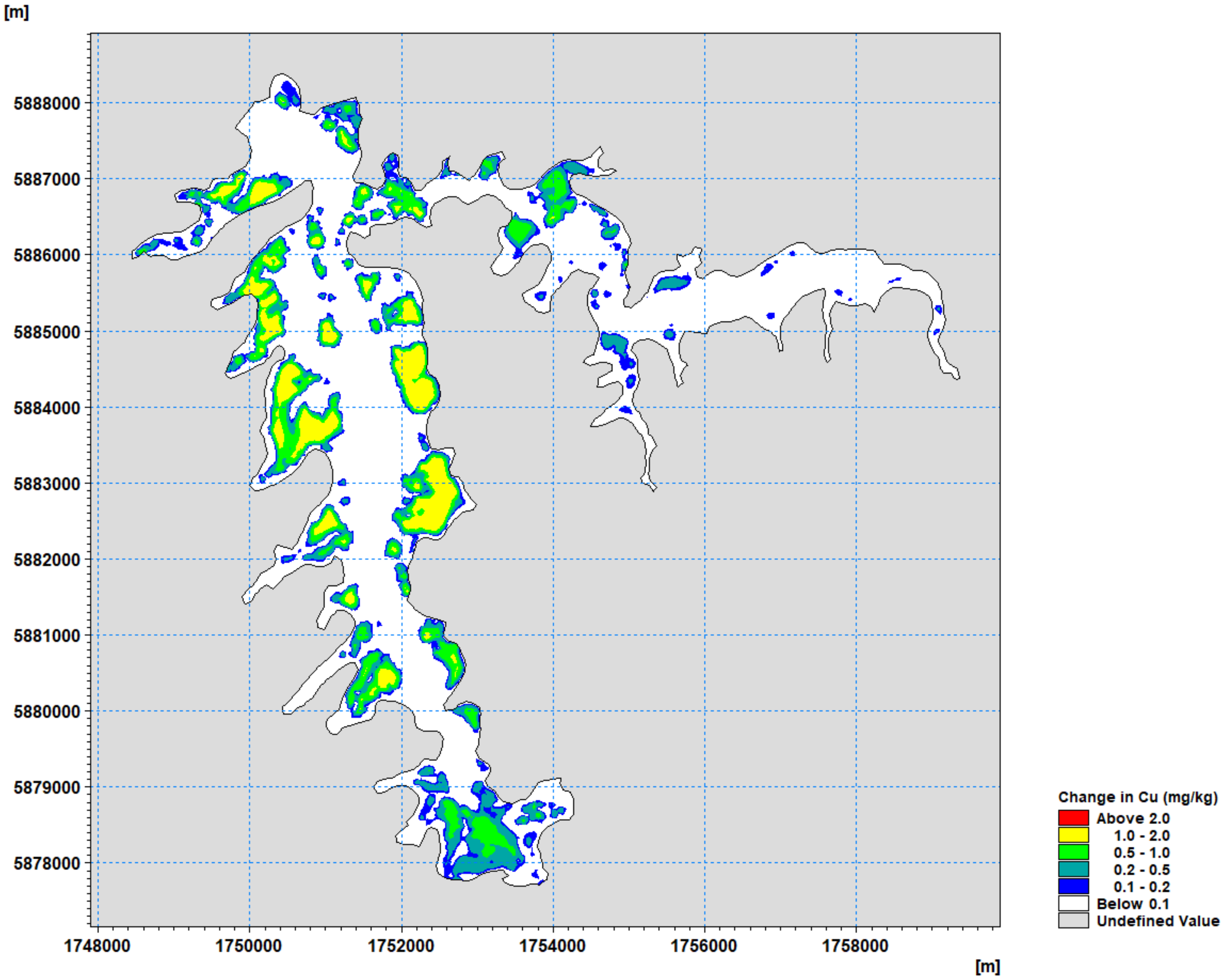


Figure 7-13. Change in surface sediment Copper concentration (mg/kg) 35 years from present day with just catchment inputs of particulate Copper. A maximum predicted change in Copper concentration of 1.7 mg/kg is predicted to occur on the inter-tidal area within the Pukewhau subestuary.

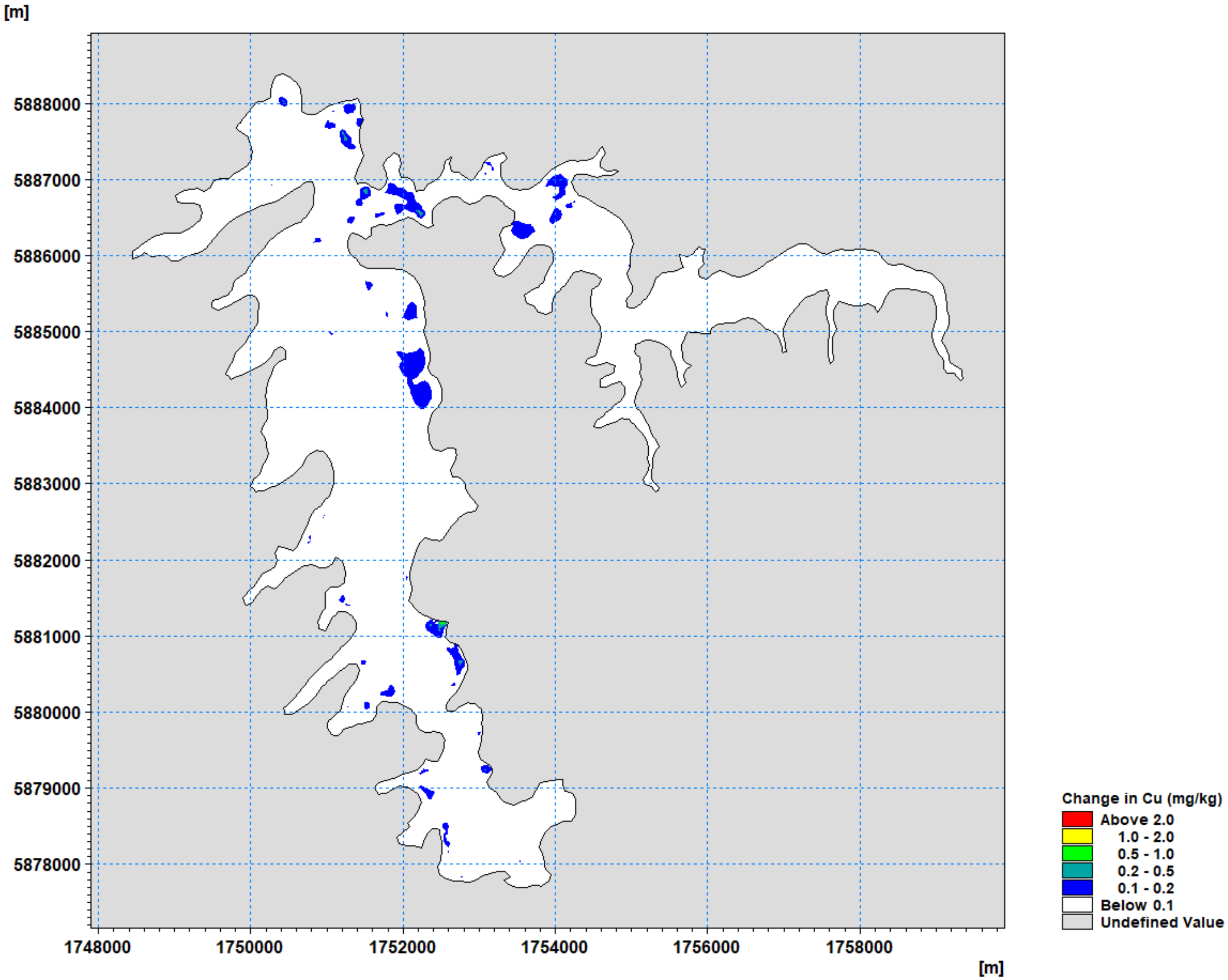


Figure 7-14. Change in surface sediment Copper concentration (mg/kg) 35 years from present day with just NZ steel inputs of particulate Copper. A maximum predicted change in Copper concentration of 1.5 mg/kg is predicted to occur along the upper fringes of the inter-tidal area near the Northside Outfall discharge.

Table 7-5. Sub estuary wide average estimates of surface sediment Copper (mg/kg) for present day, 35 years from now, changes 35 years from now and relative contribution of NZ Steel and catchment derived Copper to the 35 year increases.

Subestuary	Present Day Sub estuary wide surface sediment Copper (mg/kg)	Sub estuary wide surface sediment Copper (mg/kg) 35 years from present day	Sub estuary wide 35 year change in surface sediment Copper (mg/kg)	NZ Steel Contribution to 35 year change	Catchment Derived Copper Contribution to 35 year change
Northside	1.93	2.25	0.32	17%	83%
Southside	1.20	1.48	0.28	16%	84%
Town Basin	2.75	2.95	0.20	10%	90%
Ruakohua	0.81	0.94	0.13	18%	82%
Mokorau	1.18	1.45	0.27	11%	89%
Waipipi	1.07	1.29	0.23	11%	89%
Okohaka	0.58	0.76	0.18	13%	87%
North stream	2.28	2.95	0.67	14%	86%
Te Hakano	2.05	2.48	0.43	6%	94%
Glenbrook Beach	0.99	1.45	0.46	13%	87%
Pukewhau	0.89	1.18	0.30	8%	92%
Ohiku	1.73	2.04	0.31	7%	93%
Waiuku Subtidal	0.21	0.28	0.07	16%	84%
Taihiki Estuary	0.19	0.31	0.11	24%	76%

7.2 NZ Steel Discharges Ceased Scenario

The starting point for the discharges ceased scenario are the current day Zinc and Copper concentrations (Figure 7-4 and Figure 7-10). The metal accumulation is then run 35 years ahead with the predicted deposition from the NZ Steel discharges removed and the NZ Steel Zinc and Cooper sources removed – leaving just the ongoing input of catchment derived Copper and Zinc.

Zinc

The resulting spatial distribution of the predicted Zinc 35 years from now for the discharges ceased scenario are shown in Figure 7-15.

With the removal of the NZ Steel Sediment and Zinc loads the maximum predicted modelled Zinc concentration within the immediate vicinity of the NZ Steel discharges is less than the ARC Amber threshold.

A maximum modelled Zinc concentration of 156 mg/kg (just above the ARC Red threshold of 150 mg/kg) occurs within a small area within the Waiuku Town Basin.

The change in modelled Zinc concentrations 35 years from now is shown in Figure 7-16 – this plot shows the combined effect of the ongoing input of catchment derived Zinc to the system (resulting in increases of up to 22.0 mg/kg away from the NZ Steel discharge sites – as discussed above) and the ongoing addition of catchment derived sediments to the area immediately offshore of the NZ Steel site. Because these catchment derived sediments have lower levels of Zinc than are currently predicted in this area (i.e. 150-200 mg/kg – see Figure 7-4) the ongoing mixing of new (catchment derived) sediments with the underlying sediments results in the gradual reduction in Zinc in the area immediately offshore of the NZ Steel discharges (Figure 7-17).

In the immediate vicinity of the NZ Steel discharges, the average future modelled Zinc concentration under the discharges ceased scenario is 66.6 mg/kg (a reduction of 30.9 mg/kg compared to current discharge estimates 35-years from now) made up of an average of 54.1 mg/kg near the Northside Outfall discharge (a reduction of 36.4 mg/kg compared to current discharge estimates 35-years from now), 25.0 mg/kg near the Southside discharges (a reduction of 4.5 mg/kg compared to current discharge estimates 35-years from now) and 79.8 mg/kg near the North Stream discharge (which contains the Dew Plant discharge) (a reduction of 30.5 mg/kg compared to current discharge estimates 35-years from now).

A maximum future Zinc concentration of 111.4 mg/kg occurs on the flanks of the inter-tidal area near the North Stream discharge (which contains the Dew Plant discharge) (compared to 150.0 mg/kg under the current discharge estimates 35-years from now). The maximum future Zinc concentration near the Northside Outfall discharge is 86.2 mg/kg (compared to 207.1 mg/kg under the current discharge estimates 35-years from now) while the maximum future Zinc concentration near the Southside discharge is 82.2 mg/kg (compared to 92.1 mg/kg under the current discharge estimates 35-years from now).

Copper

The spatial distribution of the predicted Copper 35 years from now for the discharges ceased scenario are shown in Figure 7-18.

The ARC Green threshold of 19 mg/kg is not exceeded 35 years from now under the discharges ceased scenario.

As for the Zinc predictions, the discharges ceased scenario results in both increases and decreases in Copper 35 years from now (Figure 7-19). As for the Zinc predictions, the ongoing mixing of new (catchment derived) sediments with the underlying sediments results in the gradual reduction in Copper in the area immediately offshore of the NZ Steel discharges (Figure 7-20).

In the immediate vicinity of the NZ Steel discharges, the average future Copper concentration is 5.1 mg/kg (compared 6.7 mg/kg to under the current discharge estimates 35-years from now) made up of 3.8 mg/kg near the Northside Outfall discharge (compared to 5.4 mg/kg under the current discharge estimates 35-years from now), 1.9 mg/kg near the Southside discharge (compared to 2.9 mg/kg under the current discharge estimates 35-years from now) and 6.3 mg/kg near the North Stream discharge (which contains the Dew Plant discharge) (compared to 8.0 mg/kg under the current discharge estimates 35-years from now).

A maximum future Copper concentration of 8.3 mg/kg occurs on the inter-tidal area near the North Stream discharge (which contains the Dew Plant discharge) (compared to 10.9 mg/kg under the current discharge estimates 35-years from now). The maximum future Copper concentration near the Northside Outfall discharge is 6.2 mg/kg (compared to 9.4 mg/kg under the current discharge estimates 35-years from now) while the maximum future Copper concentration near the Southside discharge is 6.2 mg/kg (compared to 10.7 mg/kg under the current discharge estimates 35-years from now).

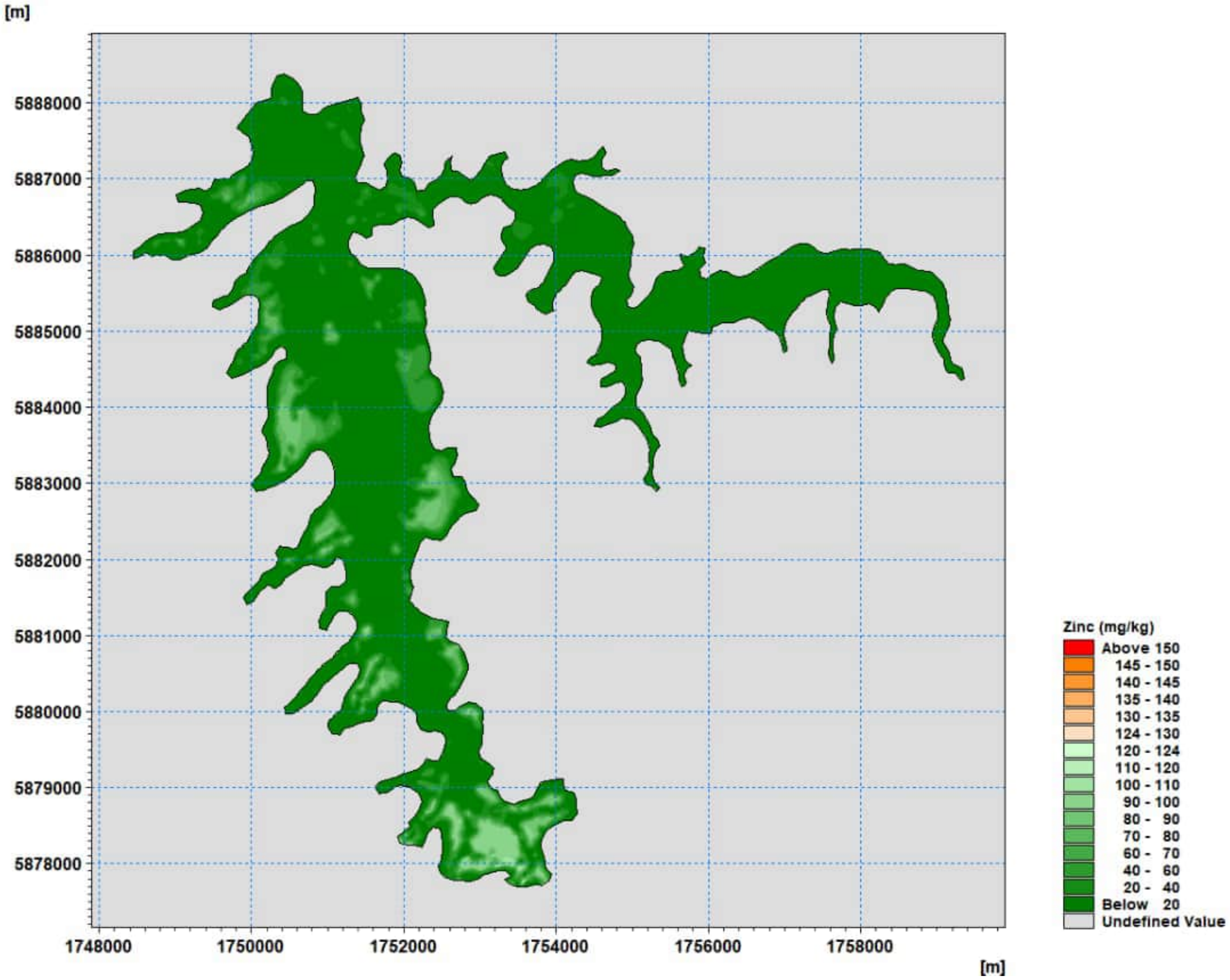


Figure 7-15. Predicted spatial distribution of surface sediment Zinc concentrations (mg/kg) 35 years from present with no discharges from the NZ Steel plant. A maximum predicted Zinc concentration of 156.4 mg/kg occurs within the Waiuku Town Basin.

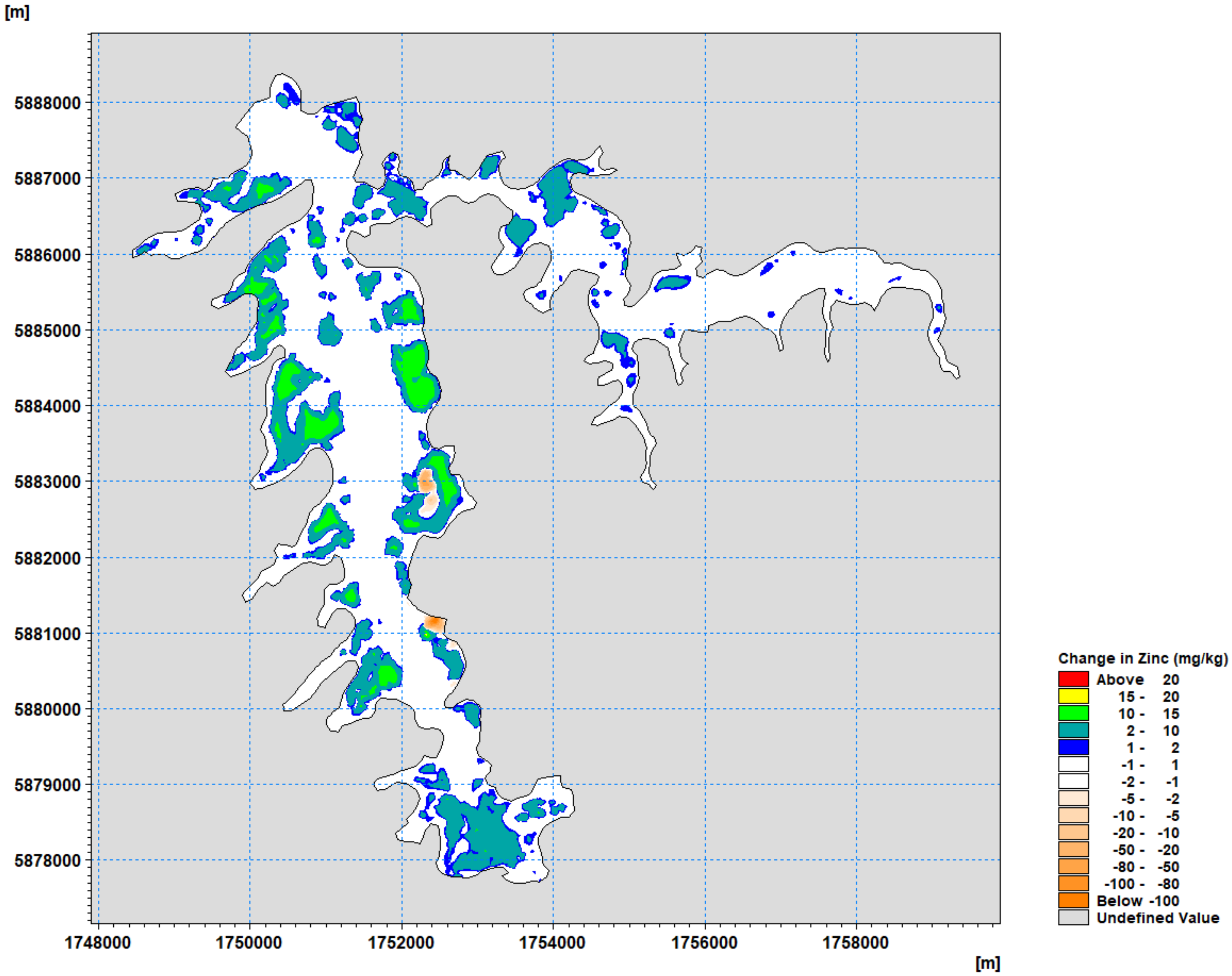


Figure 7-16. Change in surface sediment Zinc concentration (mg/kg) 35 years from present day for with no discharges from the NZ Steel plant. A maximum increase of Zinc of 22 mg/kg occurs due to the ongoing input of catchment derived Zinc while around the Northside Outfall a maximum decrease of 120.9 mg/kg occurs.

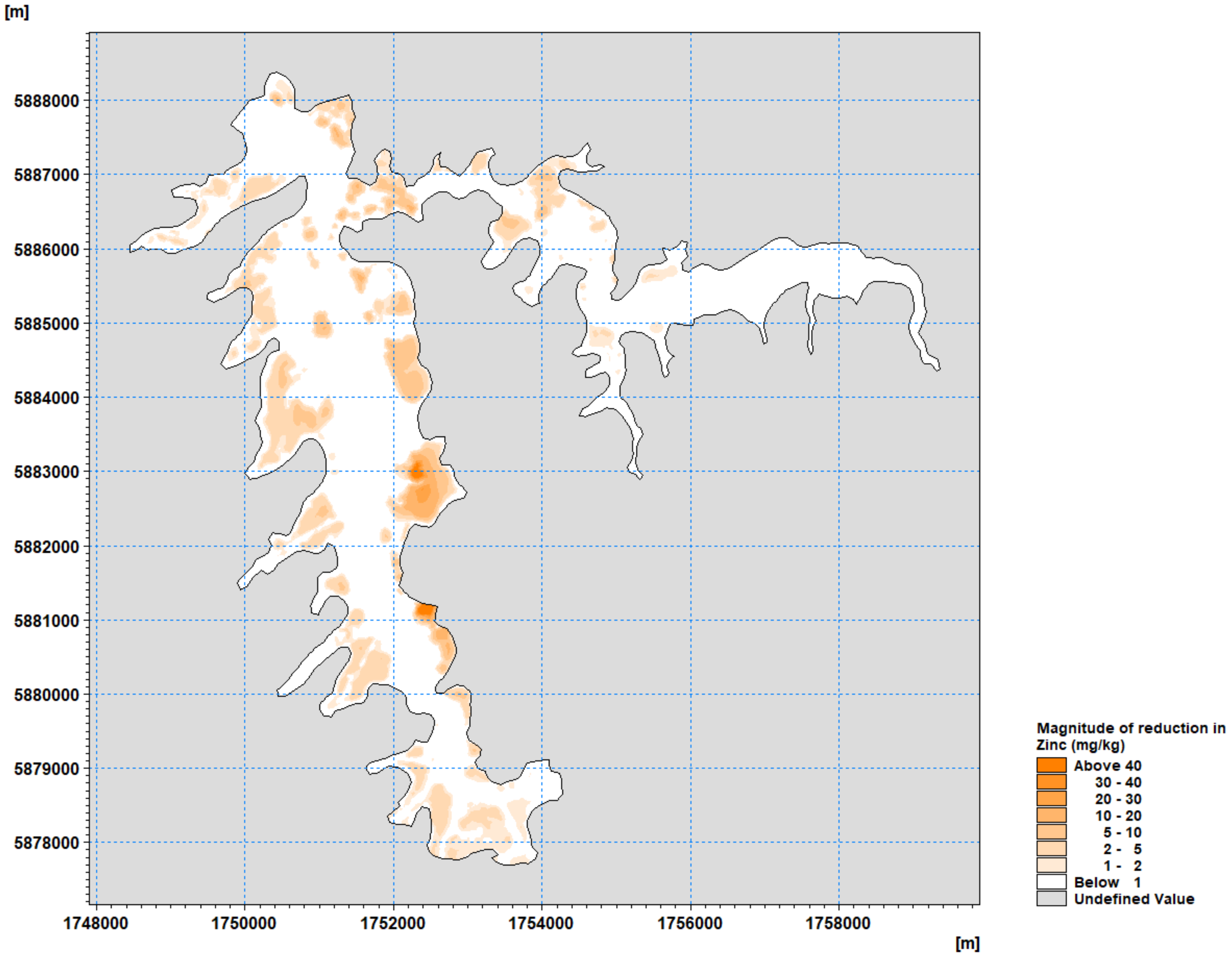


Figure 7-17. Predicted magnitude of the reduction in surface sediment Zinc concentration (mg/kg) 35 years from now. The plot shows the change in Zn 35 years from now with the removal of the NZ Steel discharges compared to the predictions 35 years from now with the discharges from the NZ Steel plant. The maximum reduction (near the Northside Outfall) is 120.9 mg/kg.

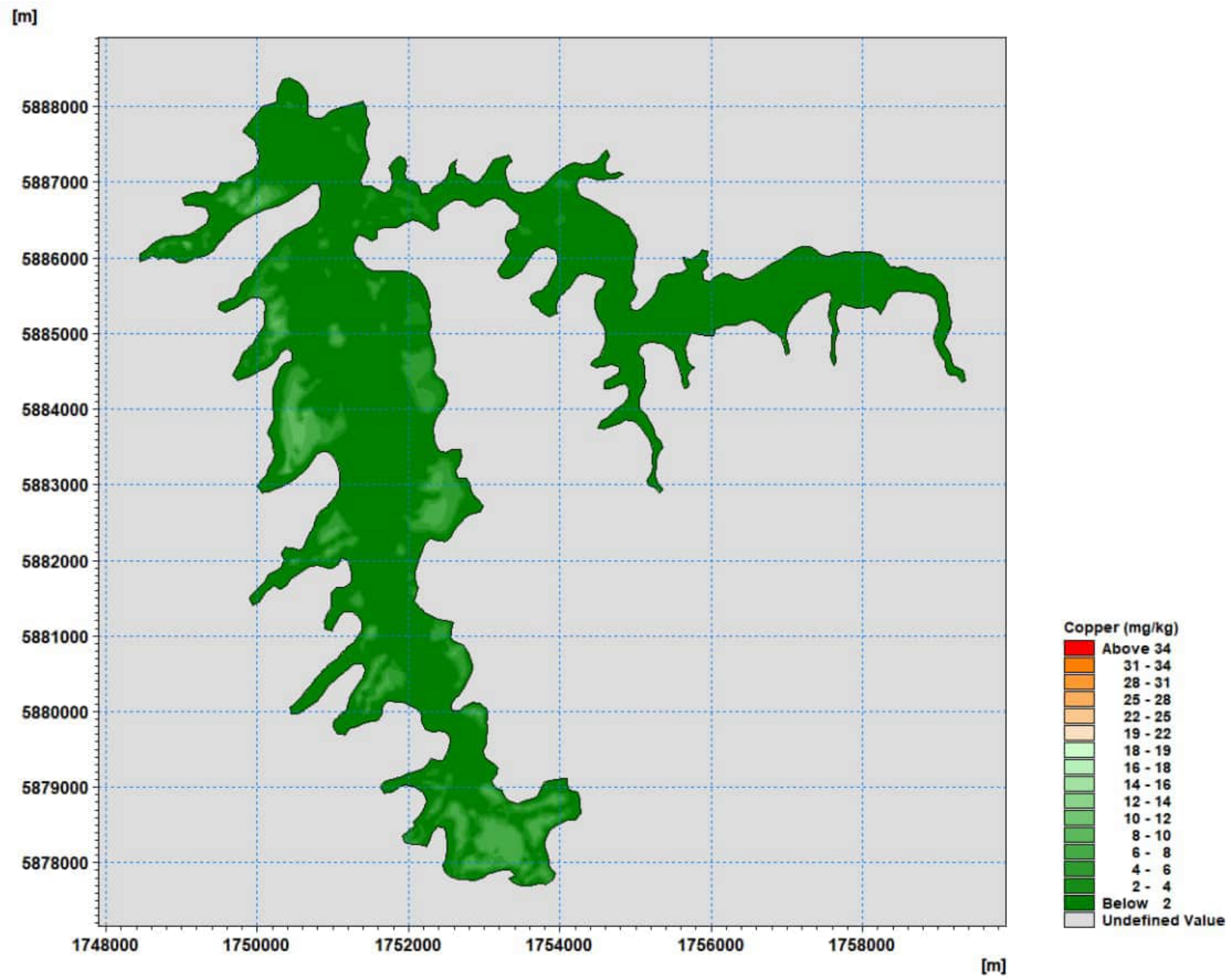


Figure 7-18. Predicted spatial distribution of surface sediment Copper concentrations (mg/kg) 35 years from present with no discharges from the NZ Steel plant. Maximum predicted Copper concentration is 10.2 mg/kg.

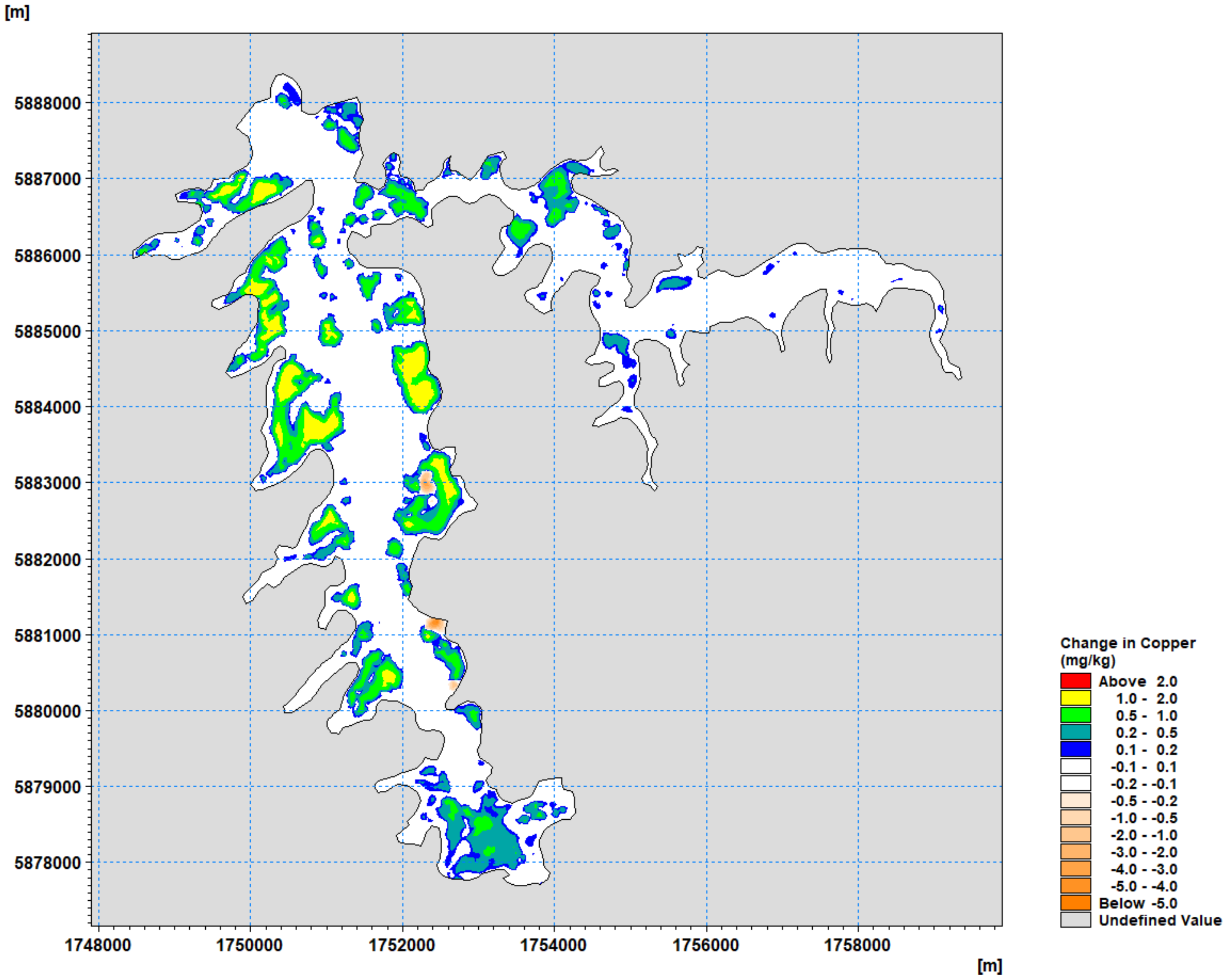


Figure 7-19. Change in surface sediment Copper concentration (mg/kg) 35 years from present day for the no discharges from the NZ Steel plant. A maximum increase of Copper of 1.7 mg/kg occurs due to the ongoing input of catchment derived Copper while around the Northside Outfall decreases of up to 8.0 mg/kg occur.

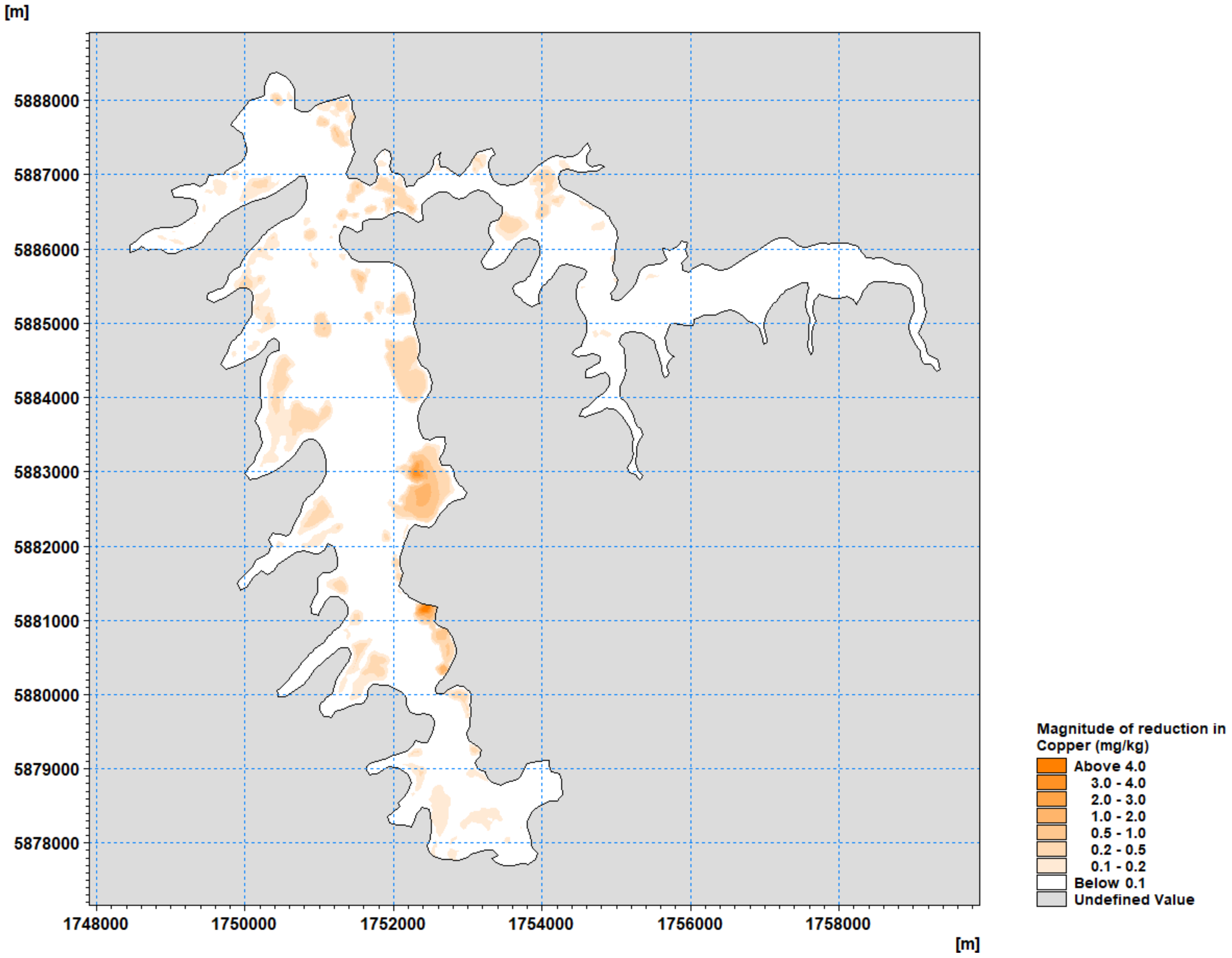


Figure 7-20. Predicted magnitude of the reduction in surface sediment Cu concentration (mg/kg) 35 years from now. The plot shows the change in Cu 35 years from now with the removal of the NZ Steel discharges compared to the predictions 35 years from now with the discharges from the NZ Steel plant. The maximum reduction (near the Northside Outfall) is 8.0 mg/kg.

8. References

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Appendix A – Metal Accumulation Model Methodology

The metal accumulation model calculates within each element of the MIKE21 model an equilibrium metal concentration.

For each model element the following methodology is applied.

It is assumed that there is a surface mixed layer on seabed that is uniformly mixed to a depth of λ (m) during each year by a combination of physical and bioturbation processes. Thus, at the end of each year, the sediment in the surface mixed layer consists of the sediment deposited from the catchment mixed uniformly with the existing bed sediments.

The mass of catchment derived sediment that accumulates on the seabed (S) over the course of a year is given by:

$$S_c = \rho\eta \text{ (kg/m}^2\text{)} \qquad (1)$$

where η is the sediment deposition rate (m/y) derived from the sediment transport model and ρ is the density (kg/m3) of the bed sediments (assumed to be 1200 kg/m^3).

At the end of the year (t = 1) the sediment in the surface mixed layer consists of the catchment derived sediment deposited during the year mixed uniformly to a depth of $(\lambda - \eta)$ metres with pre-existing sediments. Hence, at the end of the year, the mass of sediment per unit area of seabed exhumed to a depth of $(\lambda - \eta)$, metres given by:

$$S_e = \rho(\lambda - \eta) \text{ (kg/m}^2\text{)} \qquad (2)$$

The total mass of sediment per unit area of seabed in the surface mixed layer at the end of the year (St) is given by the sum of sediment deposited (Sc) and sediment exhumed (Se):

$$S_t = \rho\eta + \rho(\lambda - \eta) \text{ (kg/m}^2\text{)} \qquad (3)$$

Assuming that the catchment derived sediment deposited during the course of the year carries metal at a concentration of Cc (kg metal / kg sediment – derived from the FWMT data), the mass of catchment derived metal that accumulates on the seabed per unit area of seabed over the year is:

$$M_c = \rho\eta C_c \text{ (kg)} \qquad (4)$$

At the beginning of the simulation period (time = 0) the metal concentration in the seabed surface mixed layer is C0 (kg metal / kg sediment). The mass of metal per unit area of seabed that is exhumed from below during the year is:

$$M_e = \rho(\lambda - \eta)C_0 \text{ (kg)} \qquad (5)$$

Hence, the total mass of metal in the surface mixed layer at the end of the year is:

$$M_t = \rho[\eta C_c + (\lambda - \eta)C_0] \text{ (kg)} \qquad (6)$$

The metal concentration in the surface mixed layer at the end of the year, C1, is given by the total mass of metal in the surface mixed layer (Mt) divided by the total mass of sediment in the surface mixed layer:

$$C_1 = \frac{\rho[\eta C_c + (\lambda - \eta)C_0]}{\rho\lambda} \text{ (kg metal/kg sediment)} \qquad (7)$$

Which reduces to:

$$C_1 = \frac{[\eta C_c + (\lambda - \eta) C_0]}{\lambda} \text{ (kg metal/kg sediment)} \qquad (8)$$

For the following year, the initial concentration (C0) becomes the predicted concentration at the end of year C1, hence:

$$C_2 = \frac{[\eta C_c + (\lambda - \eta) C_1]}{\lambda} \text{ (kg metal/kg sediment)} \qquad (9)$$

Sediment and metal load data is used to define the source concentration for each of the FWMT nodes and the NZ Steel discharge (Table 3-1, Table 4-12 and Table B-1).

Outputs from the sediment transport model are used to determine the contribution that each source makes to the overall deposition seen in each model element (as summarised in Table 6-1 and Table 6-2 at a subestuary level).

For each model element Cc can then be derived by summing the percent contribution to the overall deposition of each subcatchment by the predicted subcatchment source concentration.

Data from the sediment transport model is used to define η for each model element and global values of λ are assigned as part of the calibration process (based on data in Auckland Regional Council (2008) and the spatial variability of the predicted sedimentation rates).

In the absence of historical load information, the initial surface layer concentrations of Zinc and Copper (C_0) are assumed to be zero 50 years before present. The model is then calibrated to achieve the best fit against current day observations (including consideration the ten years of Auckland Council data at the Waiuku Town Basin site. Sensitivity testing of the metal accumulation model shows that the assumed zero background only significantly influences the first few years of the model predictions (i.e. 50-40 years from present). The same method has been successfully (i.e. a good present day calibration) applied in a number of studies that DHI has carried out. Importantly, the focus of the metal model is to predict the relative changes in Zinc and Copper over the term f the proposed consent.

Future Zinc and Copper concentrations in the surface mixed layer across the model domain are then derived starting with equation 8, current day estimates from the model and iterating equation 9 over a 35-year interval.

Appendix B – Summary of Freshwater Management Tool marine node yields and loads and marine node aggregation.

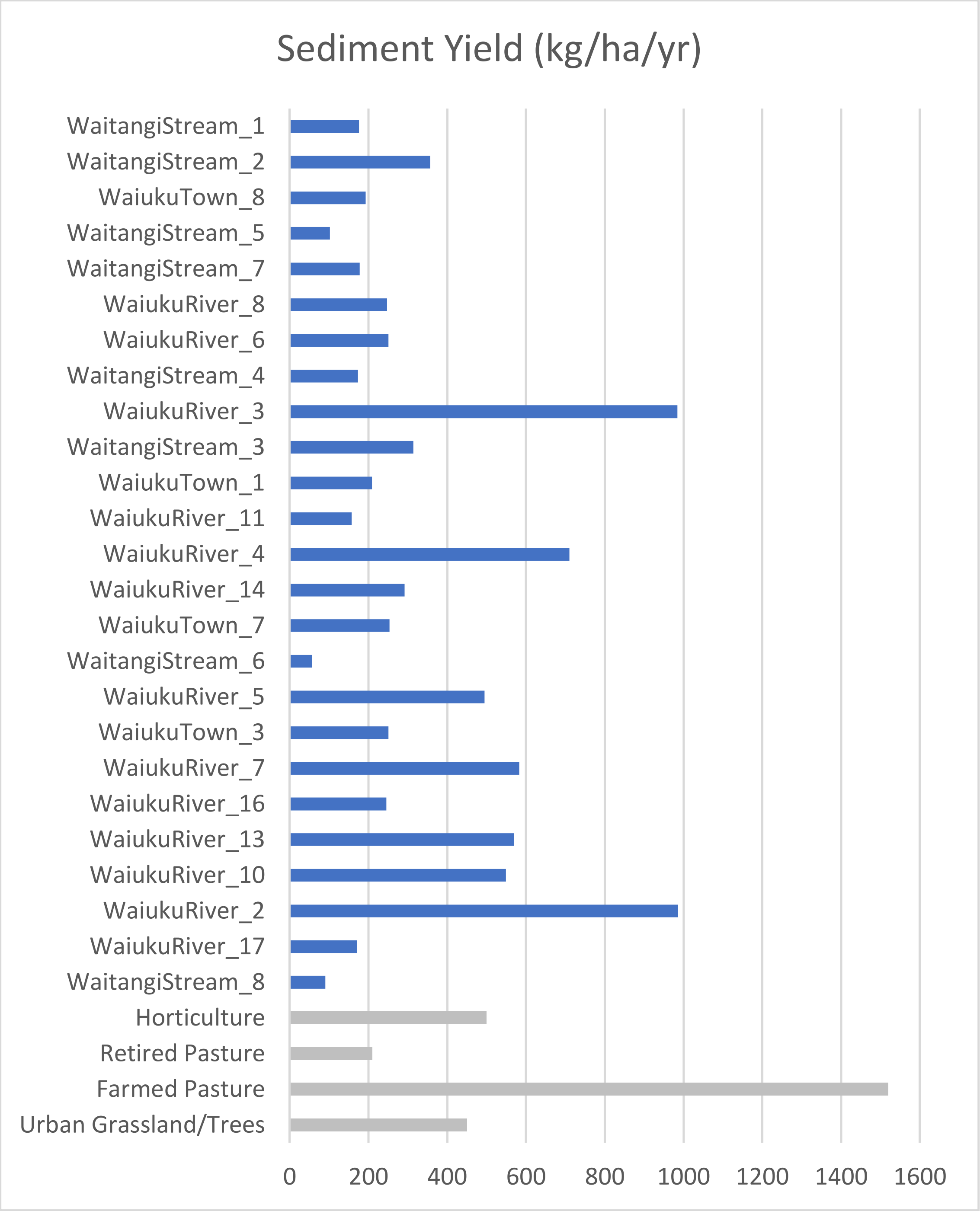

Figure B-1. Freshwater Management Tool sediment yields (kg/ha/yr) for each of the marine nodes for the Waiuku Catchment. Grey bars show the default yields for specific land uses from the Catchment Load Model (Auckland Council, 2010).

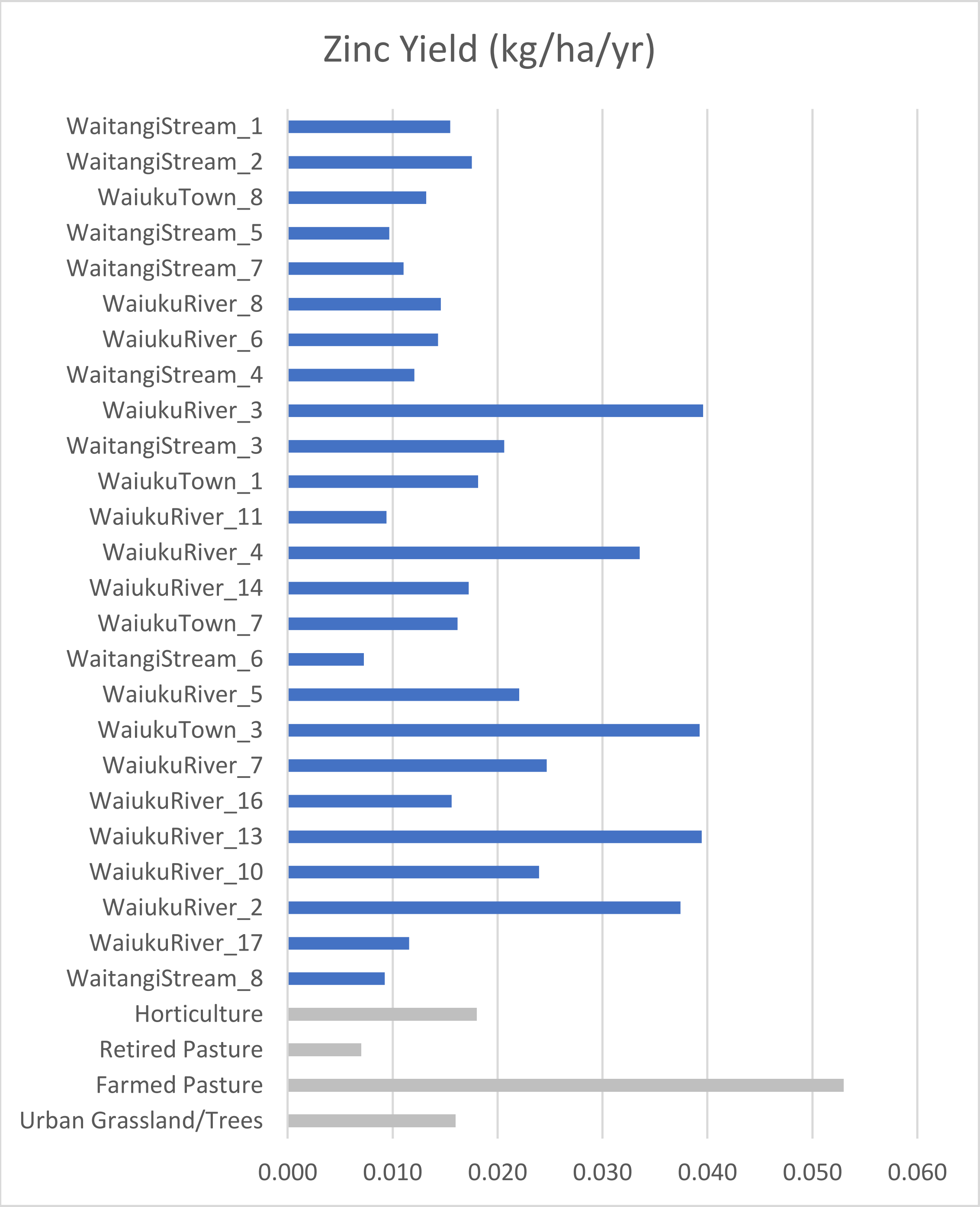

Figure B-2. Freshwater Management Tool Zinc yields (kg/ha/yr) for each of the marine nodes for the Waiuku Catchment. Grey bars show the default yields for specific land uses from the Catchment Load Model (Auckland Council, 2010).

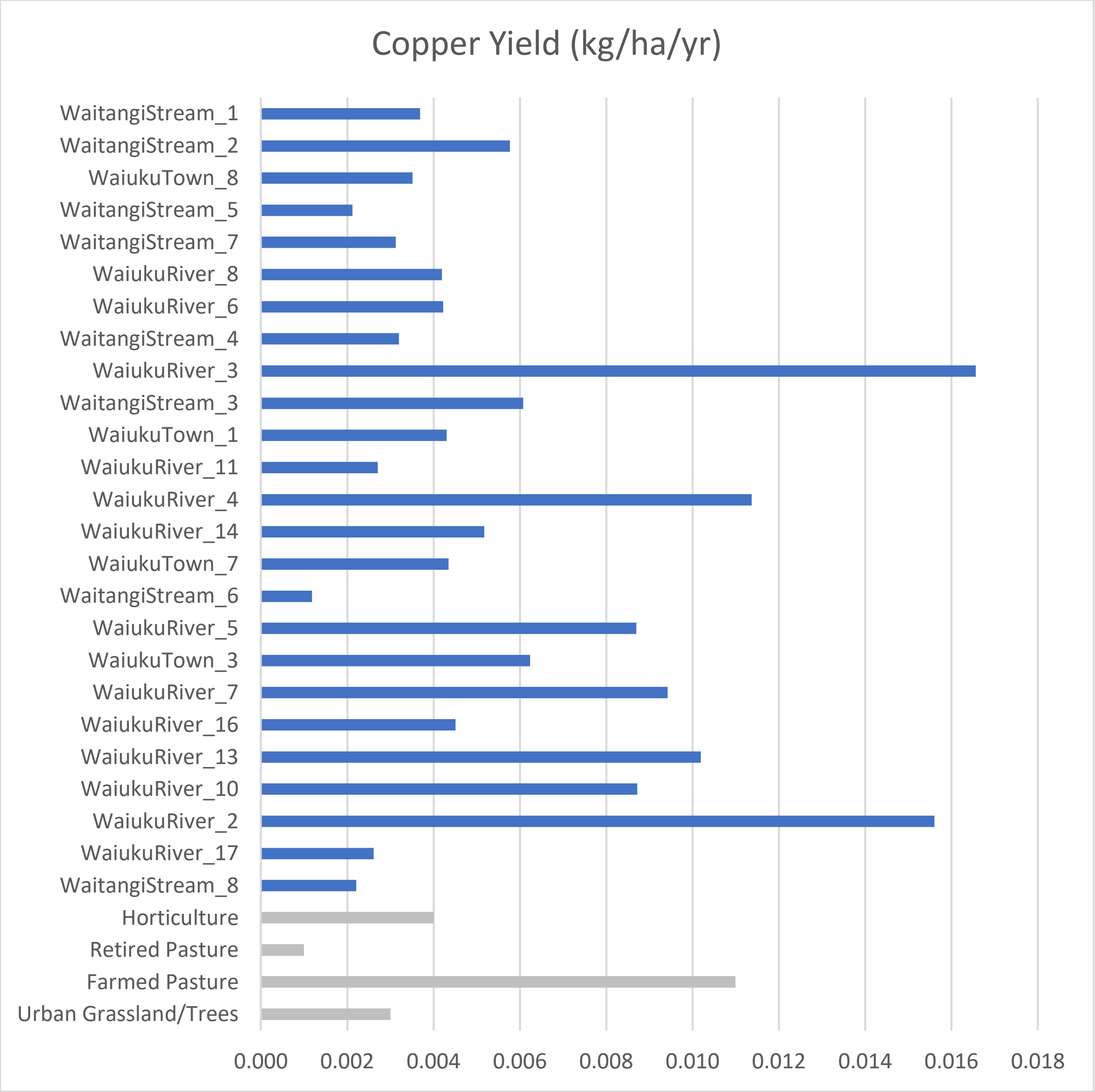

Figure B-3. Freshwater Management Tool Copper yields (kg/ha/yr) for each of the marine nodes for the Waiuku Catchment. Grey bars show the default yields for specific land uses from the Catchment Load Model (Auckland Council, 2010).

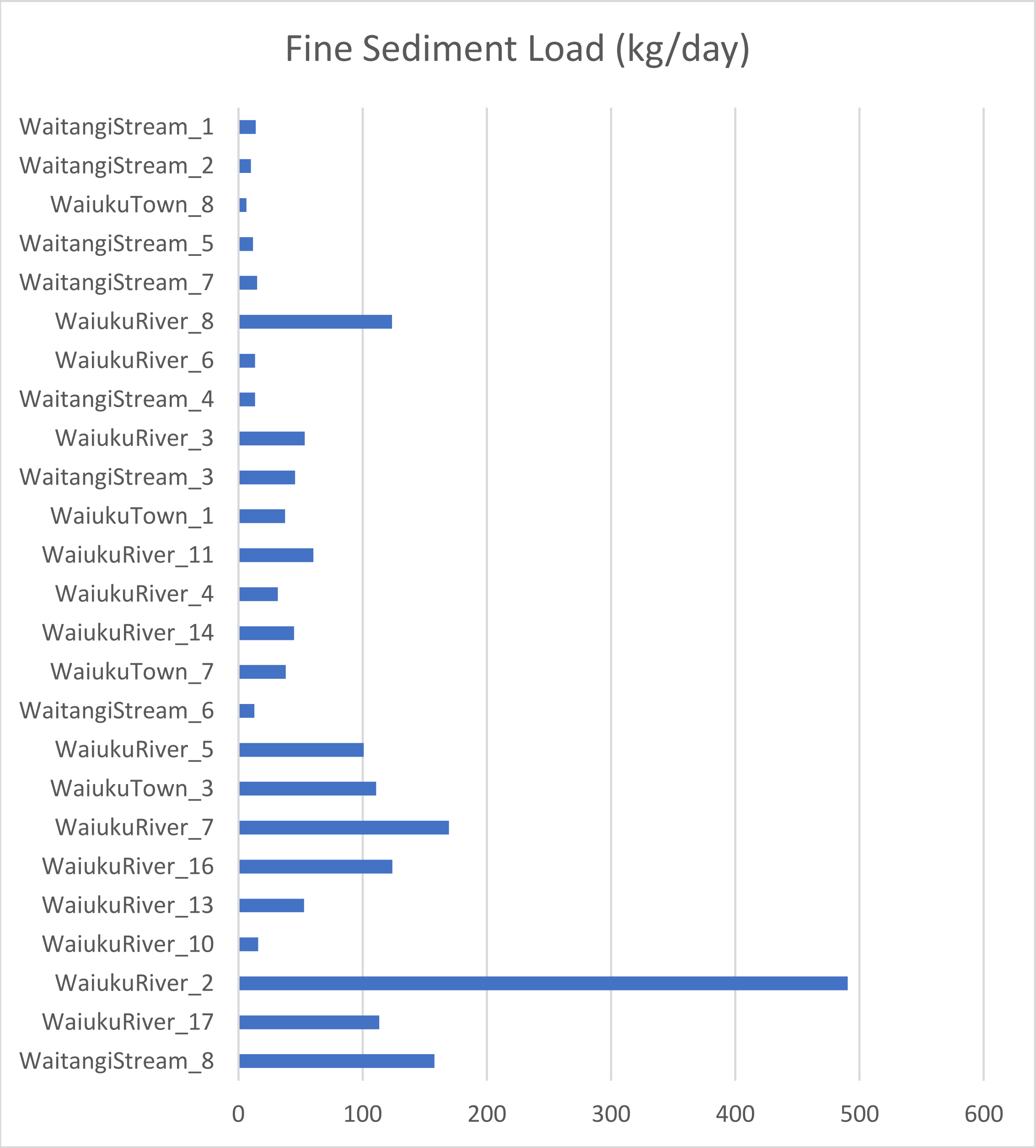

Figure B-4. Freshwater Management Tool fine sediment load data (kg/day) for each of the marine nodes for the Waiuku Catchment.

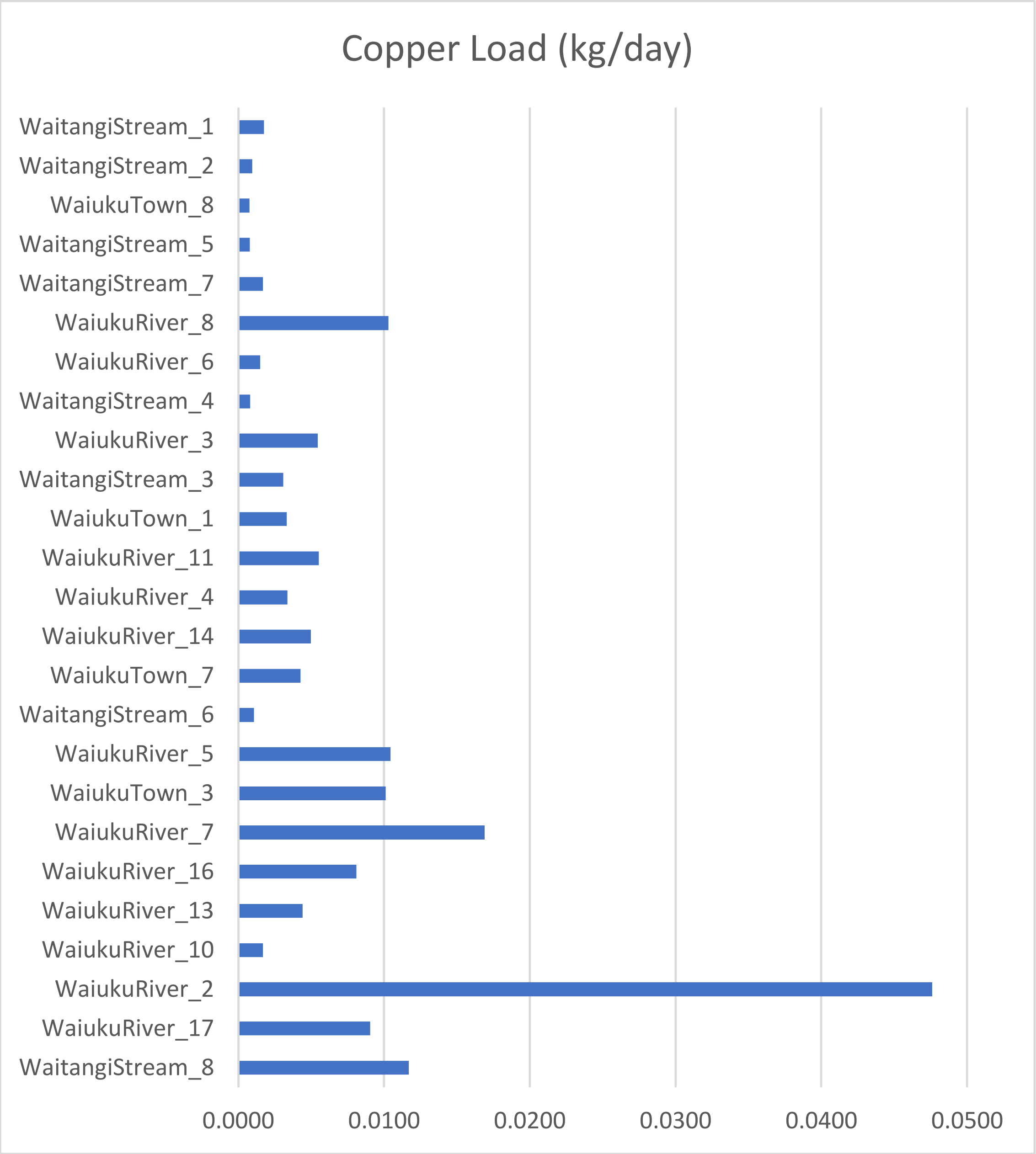

Figure B-5. Freshwater Management Tool Zinc load data (kg/day) for each of the marine nodes for the Waiuku Catchment.

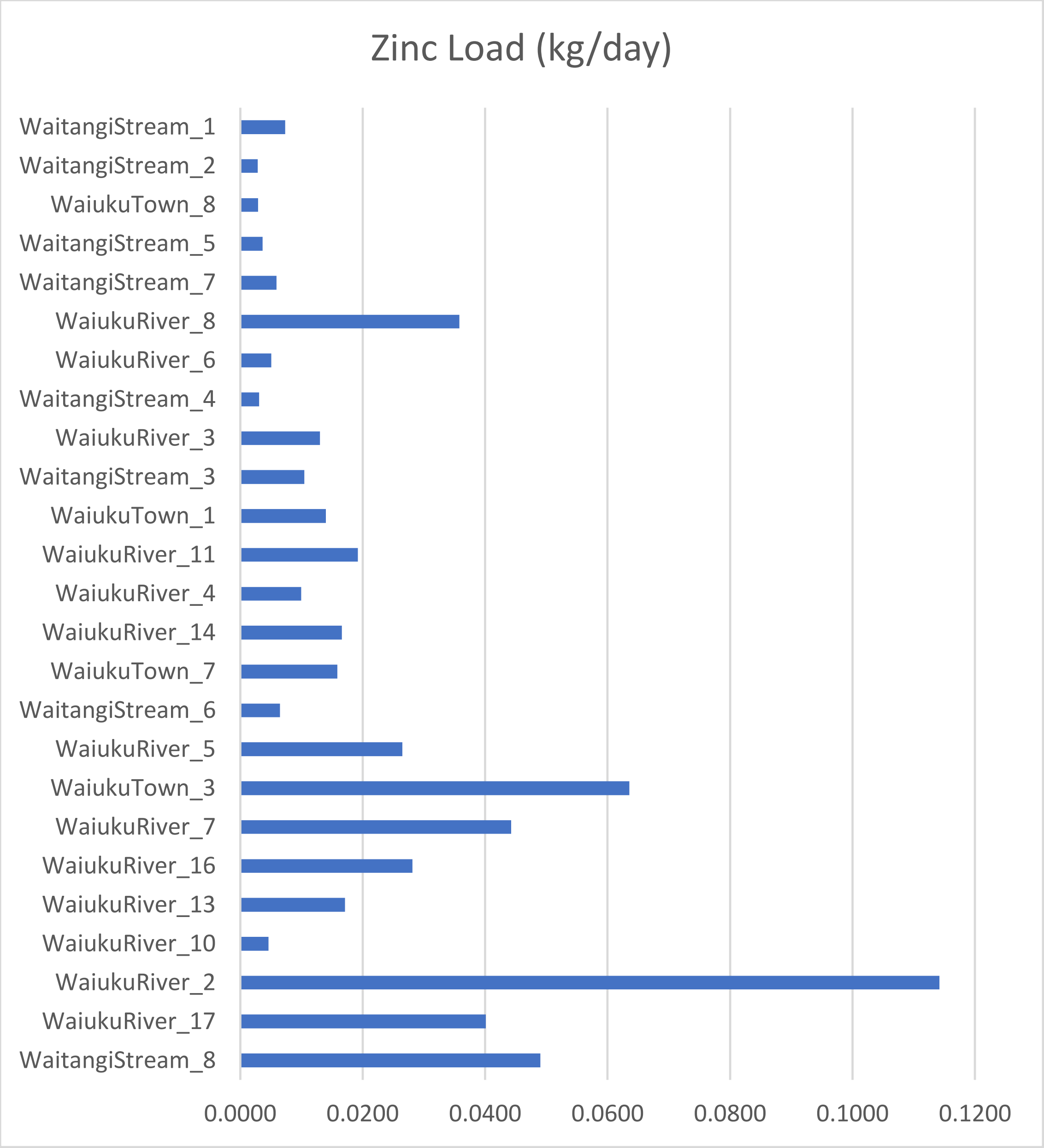

Figure B-6. Freshwater Management Tool Zinc load data (kg/day) for each of the marine nodes for the Waiuku Catchment.

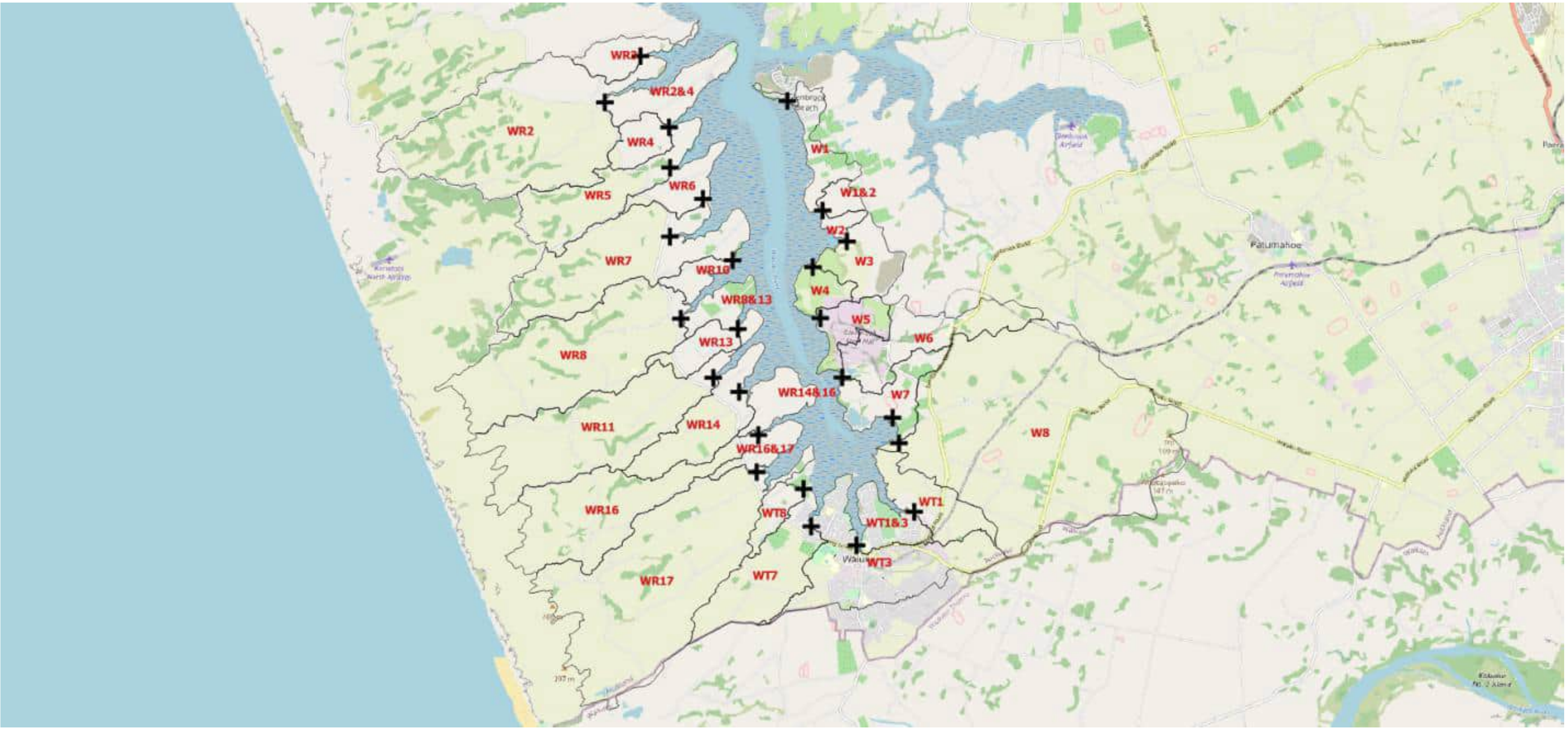

Figure B-7. Identified FWMT subcatchments extents. Subcatchments are labelled WR=Waiuku River, WT=Waiuku Town and W=Waitangi Stream. The flows and loads from subcatchments that straddle two marine nodes (**+**) are split evenly between adjacent marine nodes. For example, flows and loads from subcatchment labelled WT1&3 is split evenly between the marine node Waitangi Town 1 (to the east of the catchment) and Waitangi Town 3 (to the west of the subcatchment).

Table B-1. Source concentrations of Zinc and Cooper based on predicted sediment and metal loads from the FWMT and (Table 3-1) and NZ Steel monitoring data (Table 4-2 and Table 4-3).

	Particulate Copper (mg/kg)	**Particulate Zinc (mg/kg)**
Waiuku River 2	99	235
Waitangi Stream 8	72	260
Waiuku River 7	100	250
Waiuku River 17	73	350
Waiuku River 10	73	267
Waiuku River 5	104	262
Waiuku River 13	82	303
Waiuku River 16	62	214
Waiuku River 3	102	245
Waiuku Town 3	96	625
Waiuku Town 7	106	423
Waiuku River 14	110	366
Waiuku River 4	106	308
Waitangi Stream 3	70	222
Waiuku Town 1	90	394
Waiuku River 11	112	378
Waitangi Stream 6	97	553
Waiuku River 6	111	368
Waitangi Stream 1	124	513
Waiuku River 8	114	408
Waitangi Stream 2	119	464
Waitangi Stream 7	118	513
Waiuku Town 8	126	482
Waitangi Stream 4	62	269
Waitangi Stream 5	70	382
Northside Outfall	303	11736
Southside Outfall	440	2911

Appendix C – Sediment Source Footprints

This appendix provides the individual depositional footprint maps for the NZ Steel discharges and the FWMT nodes shown in Table C-1. The low sediment load from the NZ Steel Ruakohua Stream is widely dispersed (as per the results for the Waitangi Stream 6 node – Figure C-14) resulting in very low deposition rates which are not presented.

The colour scale is logarithmic and shows the prediction annual sedimentation rate (mm/yr) for each individual sediment source.

Table C-1. NZ Steel sediment loads and FWMT node clay loads (Figure 3-1) for 2015, percentage of sediment load deposited and tonnes per year deposited for each of the depositional maps (FWMT data is sorted from highest to lowest mass deposited).

NZ Steel Discharge	**Sediment load (kg/day)**	**Sediment load (tonnes/yr)**	**Percentage deposited**	**Tonnes deposited**
Northside Outfall	63.3	23.1	73.4%	17.0
Southside Outfall	4.7	1.7	61.9%	1.1
North Stream (including Dew Plant)	56.4	20.6	74.4%	15.3
Kahawai Stream	0.7	0.3	78.9%	0.2
Ruakohua Stream	1.9	0.7	67.5%	0.5
All discharges	127.0	46.4	73.4	34.0
FWMT Node	**Clay load (kg/day)**	**Clay load (tonnes/yr)**	**Percentage deposited**	**Tonnes deposited**
Waiuku River 7	163.9	59.8	44.2%	26.4
Waitangi Stream 8	152.6	55.7	46.8%	26.1
Waiuku River 17	109.6	40.0	62.3%	24.9
Waiuku Town 3	107.1	39.1	51.0%	19.9
Waiuku River 16	119.7	43.7	45.5%	19.9
Waiuku River 8	119.6	43.6	44.4%	19.4
Waiuku River 2	474.1	173.1	10.7%	18.5
Waiuku River 5	97.4	35.6	41.1%	14.6
Waitangi Stream 3	44.1	16.1	71.1%	11.4
Waiuku River 11	58.4	21.3	35.8%	7.6
Waiuku Town 7	36.9	13.5	50.7%	6.8
Waiuku Town 1	36.2	13.2	50.9%	6.7
Waiuku River 13	51.2	18.7	34.3%	6.4

Waiuku River 14	43.4	15.8	33.4%	5.3
Waiuku River 6	12.9	4.7	83.8%	4.0
Waiuku River 4	30.6	11.2	28.7%	3.2
Waiuku River 3	51.5	18.8	14.6%	2.7
Waitangi Stream 7	14.6	5.3	51.1%	2.7
Waiuku River 10	15.3	5.6	43.9%	2.5
Waitangi Stream 4	12.9	4.7	40.2%	1.9
Waitangi Stream 6	12.3	4.5	67.5%	3.0
Waitangi Stream 2	9.8	3.6	28.9%	1.0
Waiuku Town 8	6.2	2.3	41.2%	0.9
Waitangi Stream 1	13.5	4.9	18.6%	0.9
Total	**1880.8**	**686.5**	**37.9%**	**260.1**

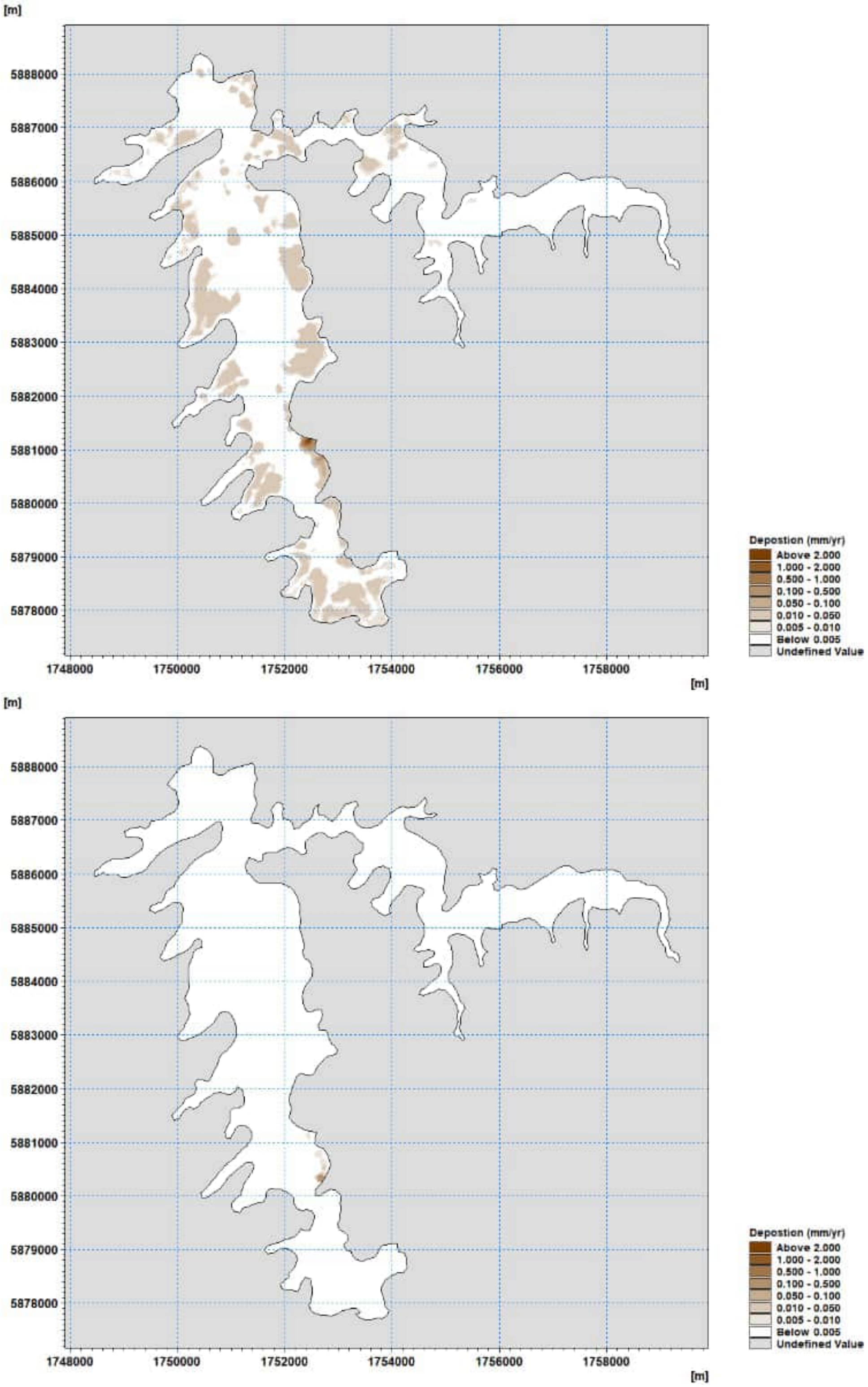

Figure C-1. Depositional footprint for Northside Outfall (top) and Southside Outfall (bottom) sediments. The maximum predicted level of deposition near the Northside and Southside Outfalls are 5.6 mm/yr and 1.4 mm/yr respectively.

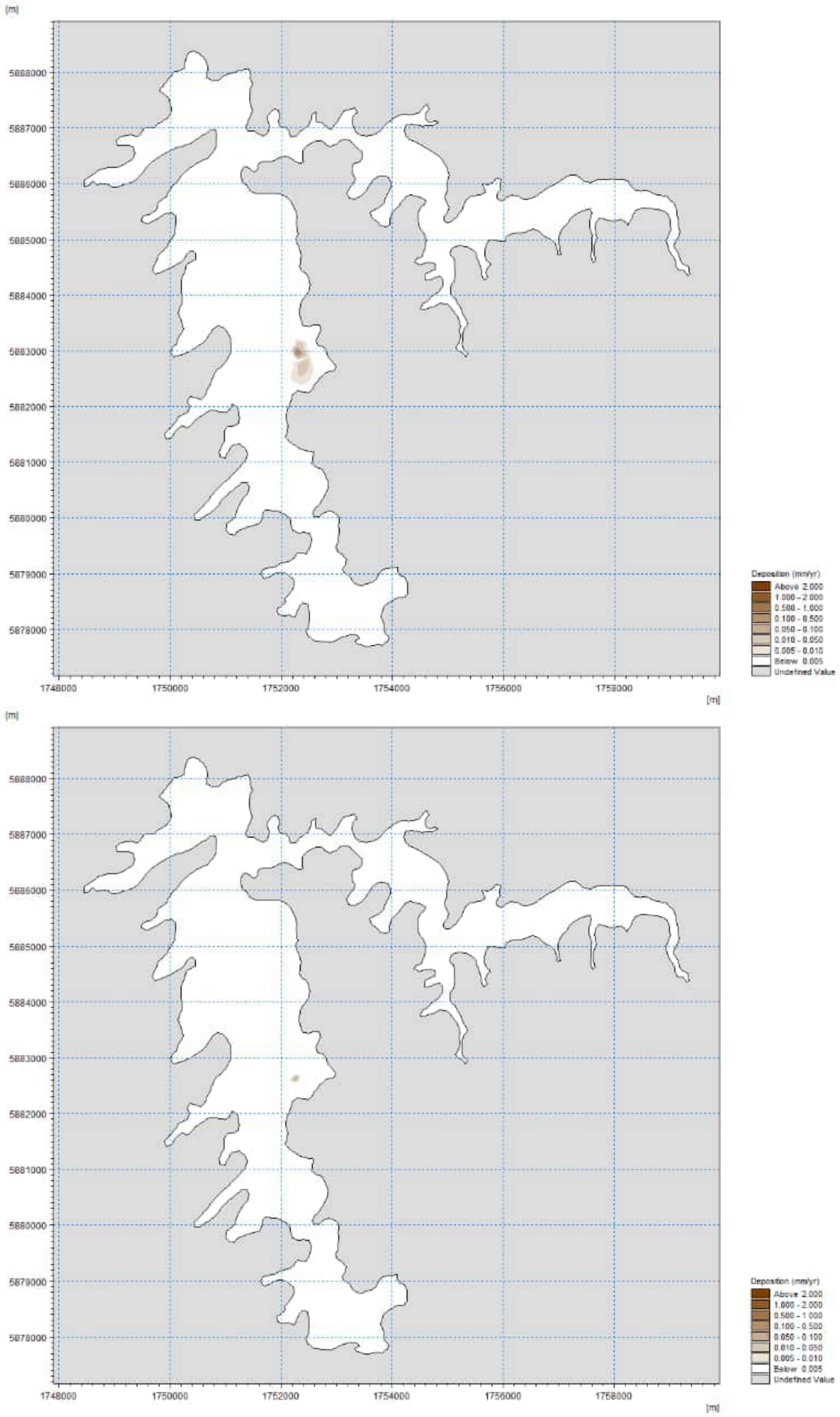

Figure C-2. Depositional footprint for the North Stream (top) and Kahawai Stream (bottom) sediments. The maximum predicted level of deposition near the North Stream and Kahawai Stream discharges are 0.6 mm/yr and 0.2 mm/yr respectively.

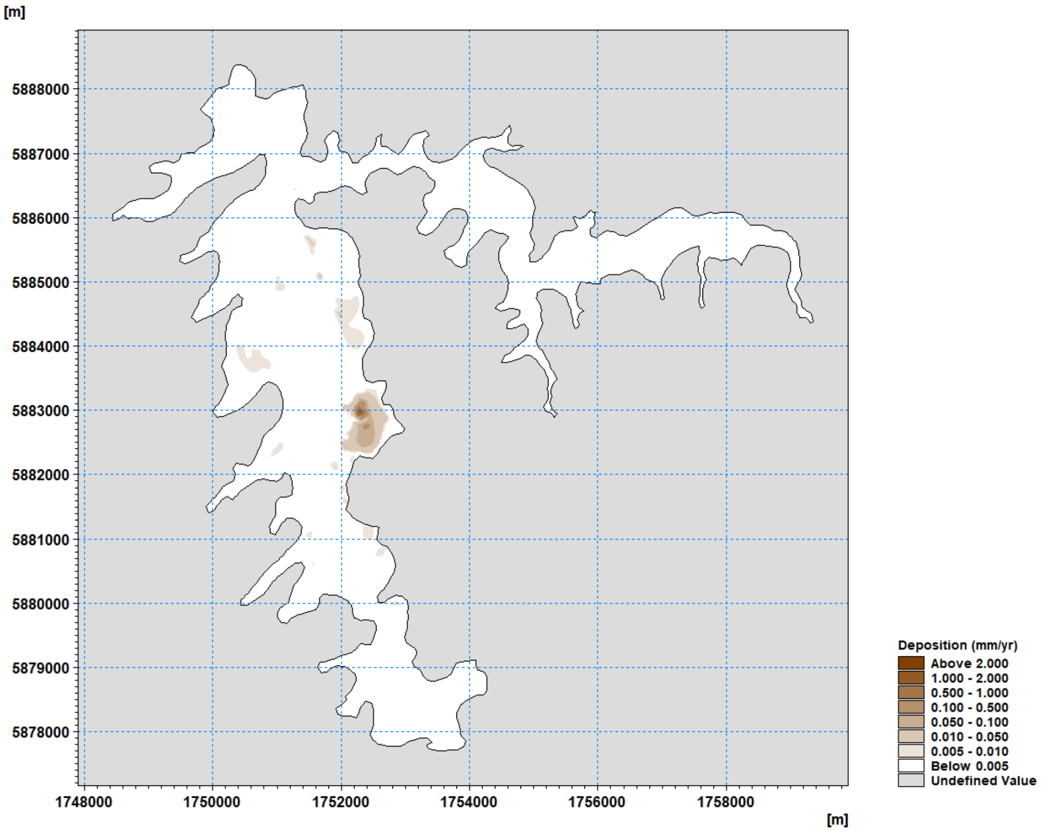

Figure C-3. Depositional footprint for the Dew Plant sediments. The maximum predicted level of deposition near the Dew Plant discharge is 3.5 mm/yr.

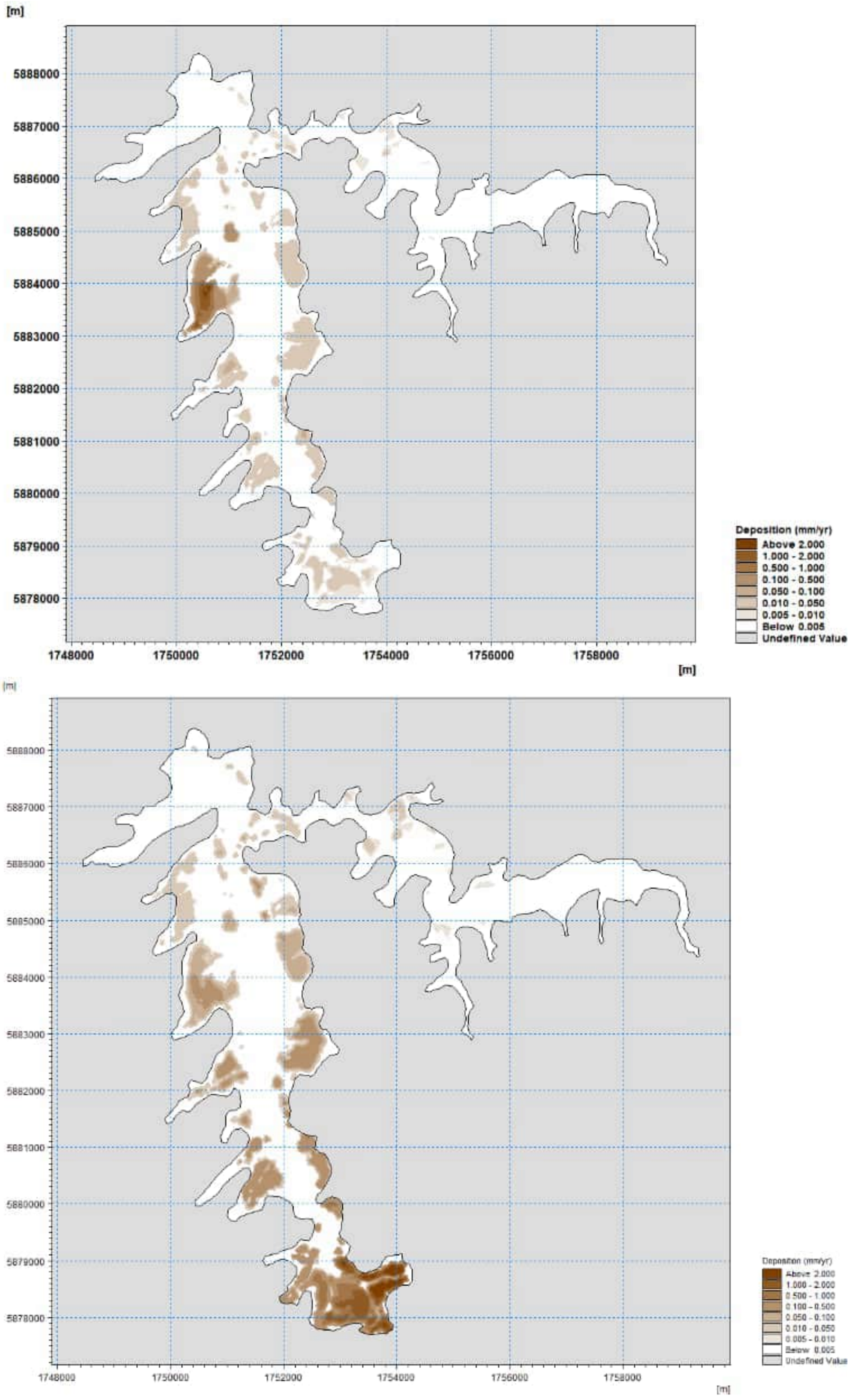

Figure C-4. Depositional footprint for the Waiuku River 7 (top) and Waitangi Stream 8 (bottom) sediments. The maximum predicted level of deposition near the Waiuku River 7 and Waitangi Stream 8 discharges are 5.5 mm/yr and 7.5 mm/yr respectively.

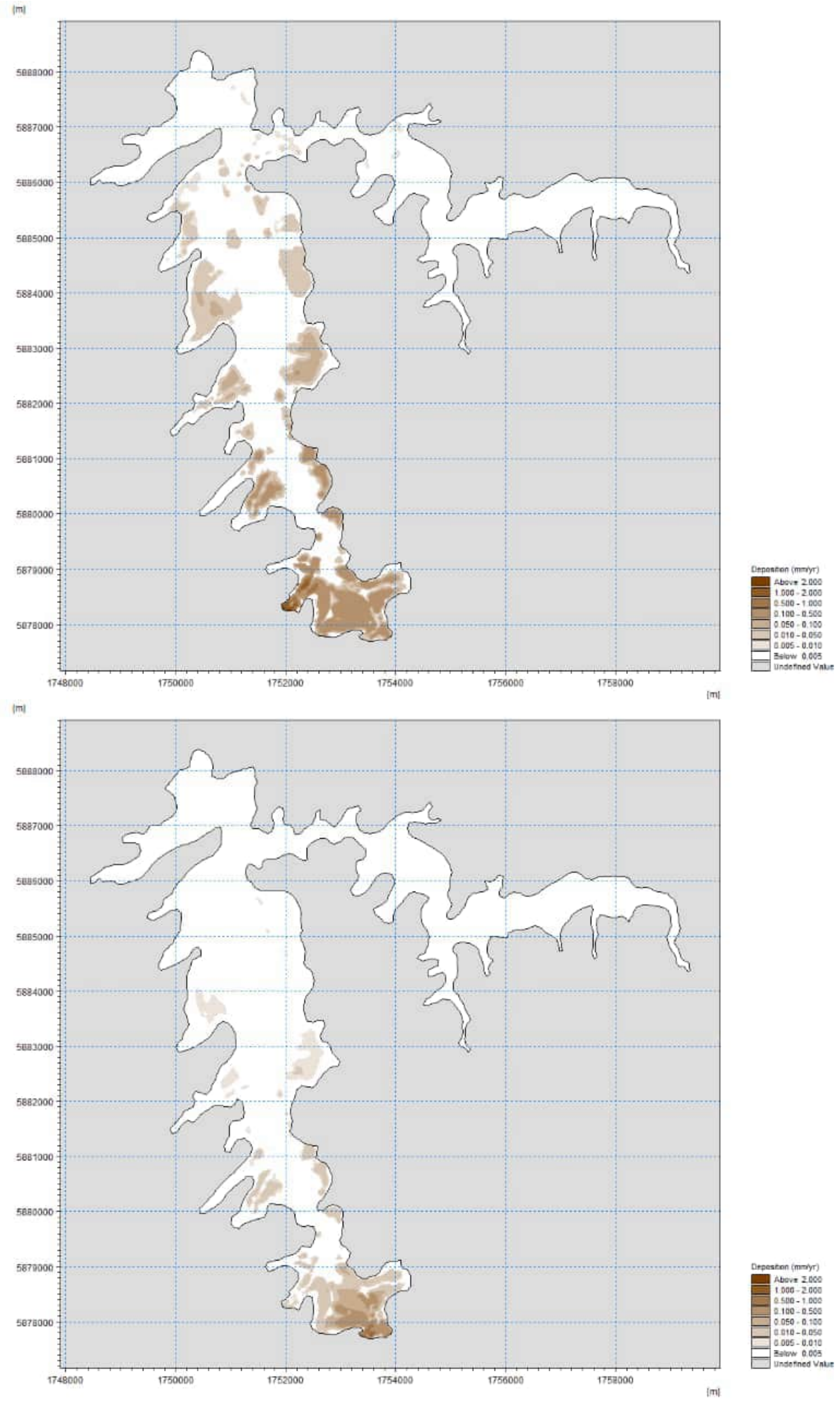

Figure C-5. Depositional footprint for the Waiuku River 17 (top) and Waiuku Town 3 (bottom) sediments. The maximum predicted level of deposition near the Waiuku River 17 and Waiuku Town 3 discharges are 3.2 mm/yr and 2.6 mm/yr respectively.

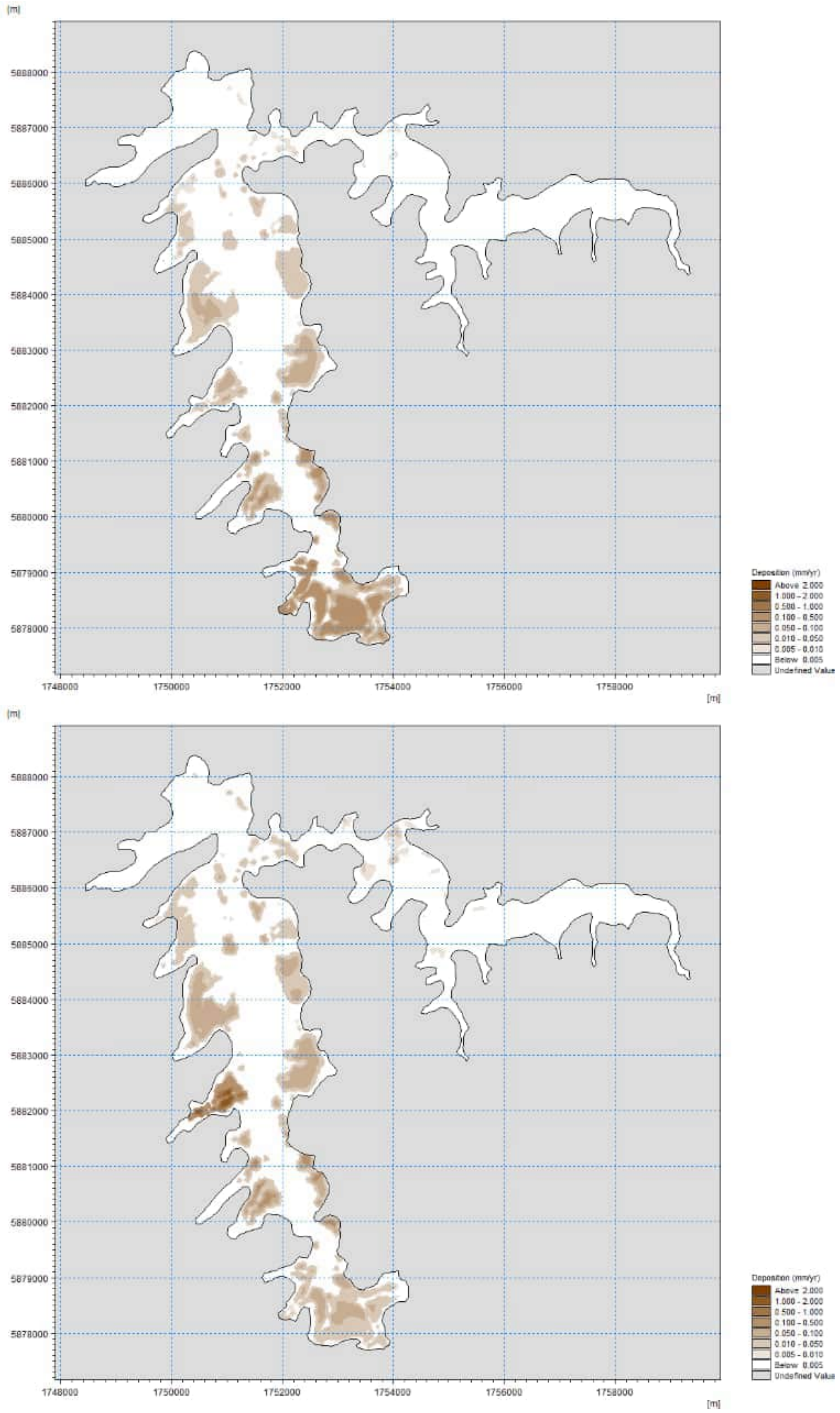

Figure C-6. Depositional footprint for Waiuku River 16 (top) and Waiuku River 8 (bottom) sediments. The maximum predicted level of deposition near the Waiuku River 16 and Waiuku River 8 discharges are 2.1 mm/yr and 3.9 mm/yr respectively.

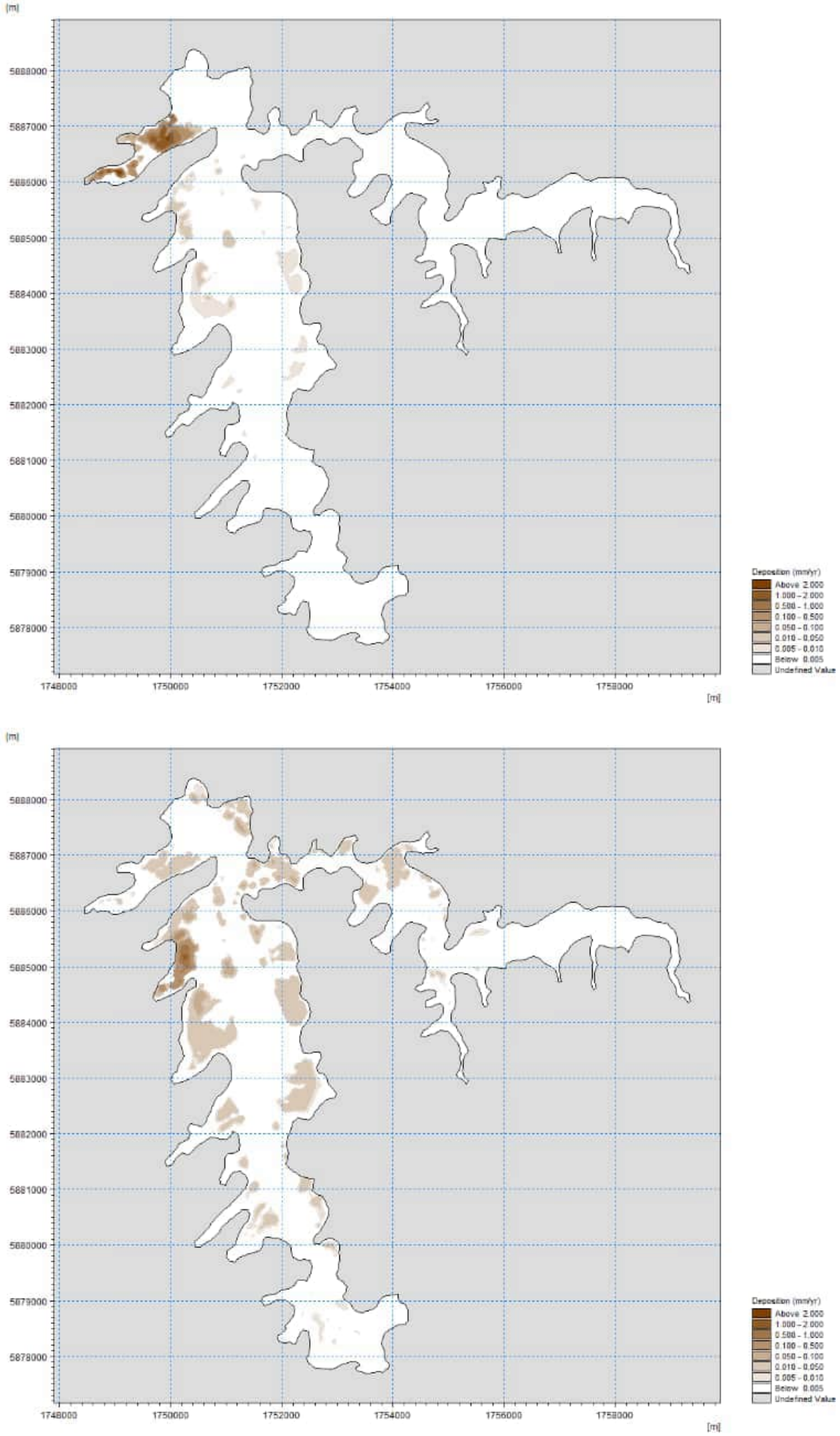

Figure C-7. Depositional footprint for Waiuku River 2 (top) and Waiuku River 5 (bottom) sediments. The maximum predicted level of deposition near the Waiuku River 2 (top) and Waiuku River 5 are 7.2 mm/yr and 2.2 mm/yr and respectively.

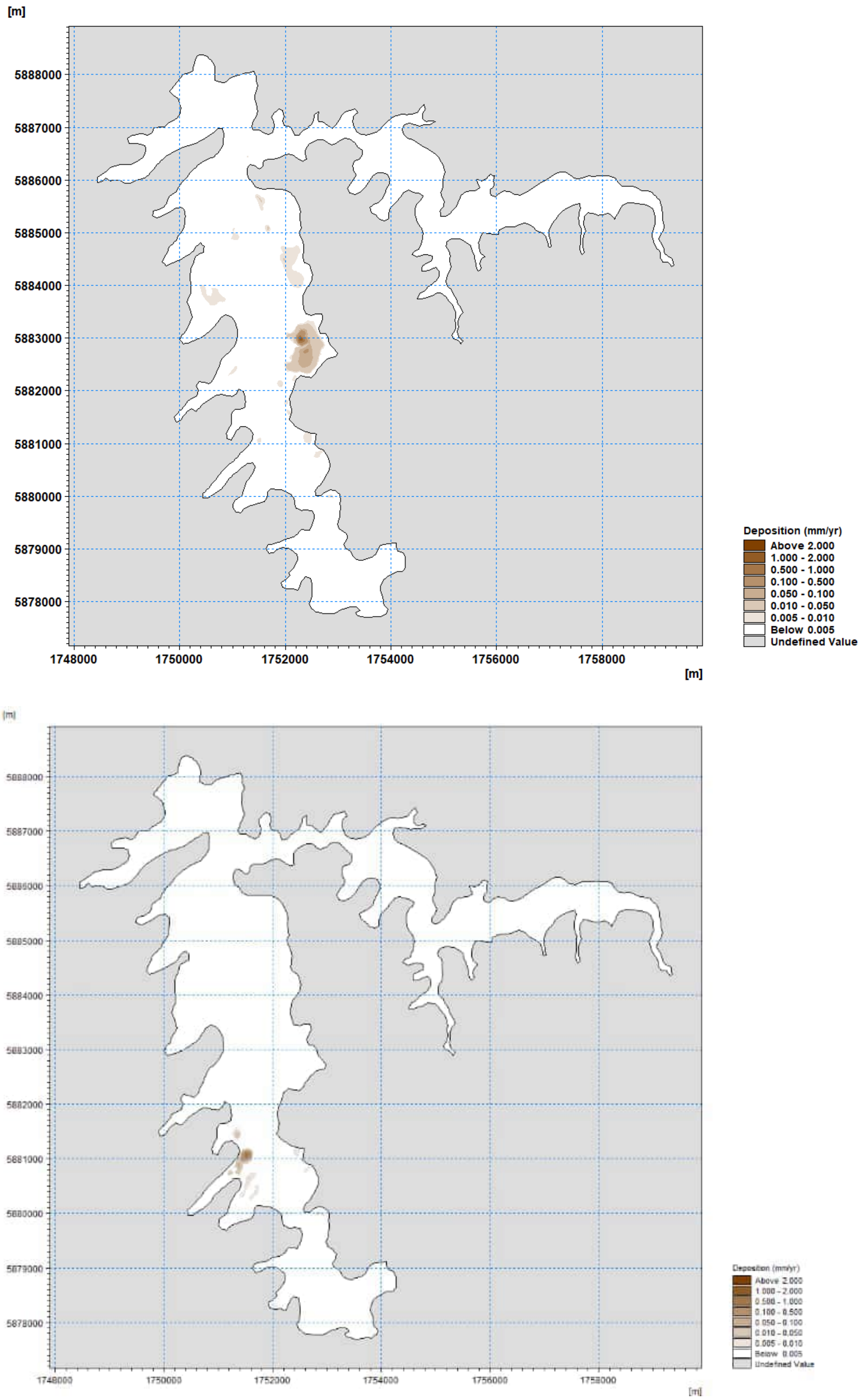

Figure C-8. Depositional footprint for Waitangi Stream 3 discharge (top) and Waiuku River 11 (bottom) sediments. The maximum predicted level of deposition near the Waitangi Stream 3 catchment outlet (and Dew Plant discharge) and the Waiuku River 11 catchment outlets is 3.3 mm/yr and 2.0 mm/yr and respectively.

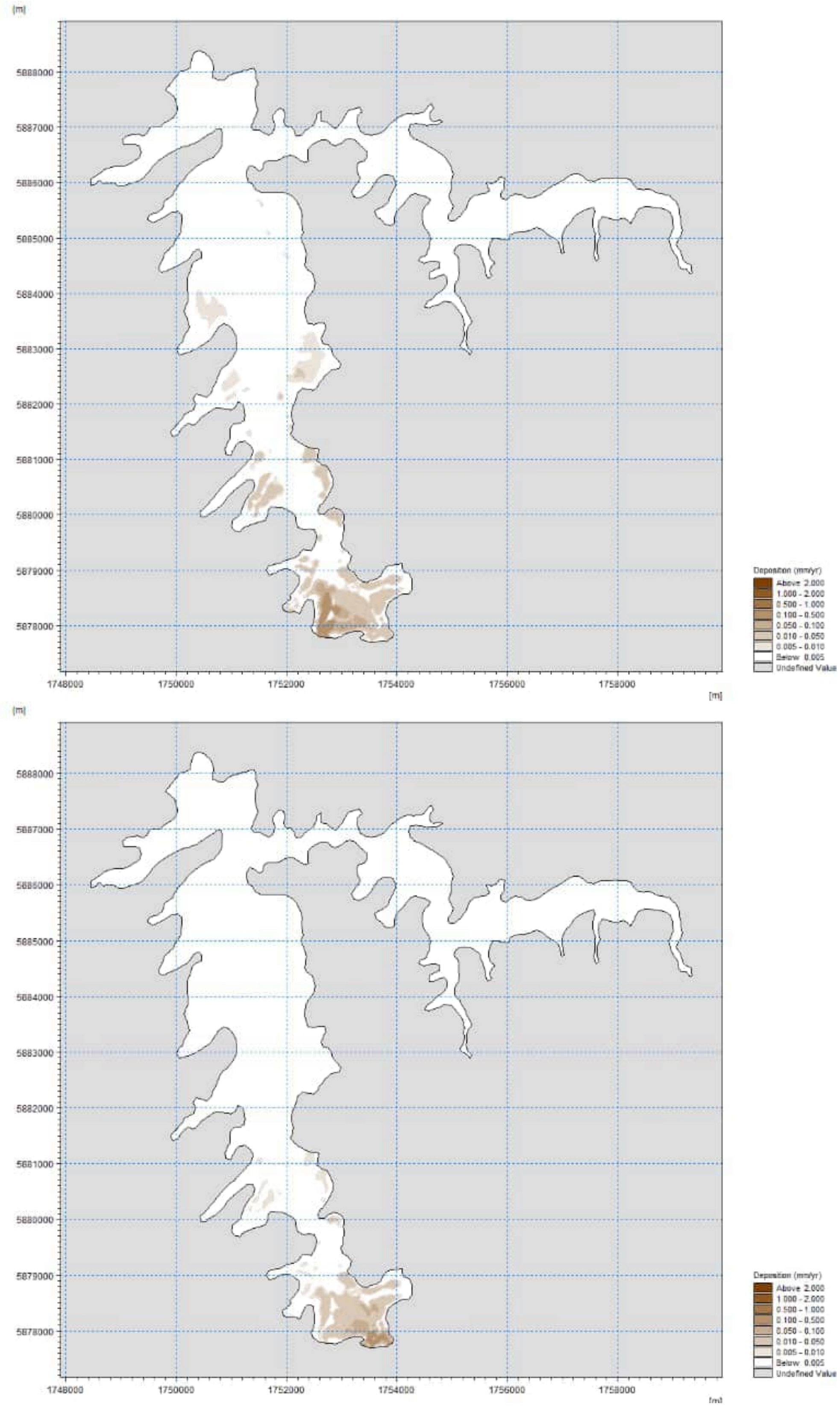

Figure C-9. Depositional footprint for Waiuku Town 7 (top) and Waiuku Town 1 (bottom) sediments. The maximum predicted level of deposition near the Waiuku Town 7 (top) and Waiuku Town 1 is 0.7 mm/yr and 0.3 mm/yr and respectively.

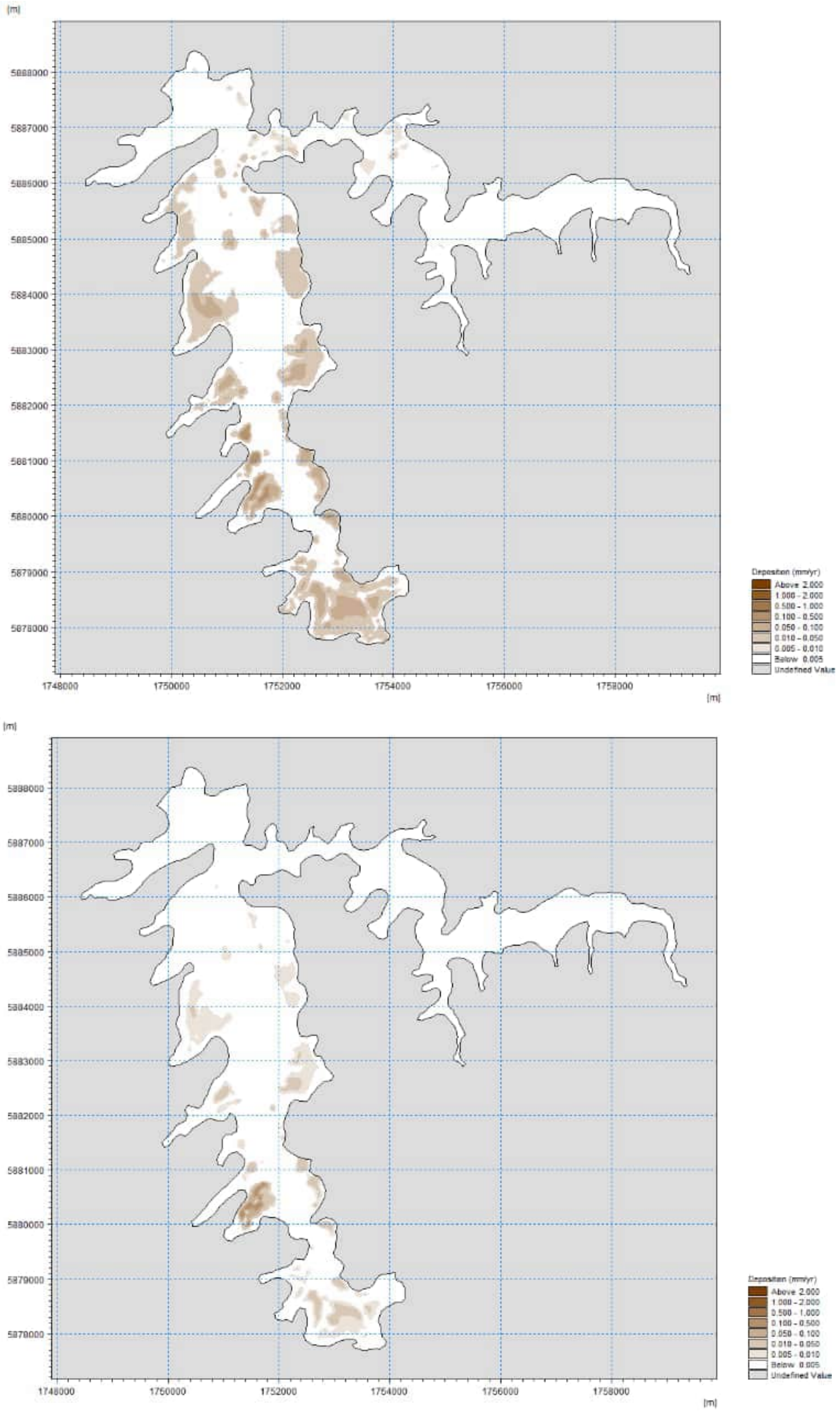

Figure C-10. Depositional footprint for Waitangi River 13 (top) and Waiuku River 14 (bottom) sediments. The maximum predicted level of deposition near the Waitangi River 13 (top) and Waiuku River 14 discharges are 0.7 mm/yr and 0.6 mm/yr respectively.

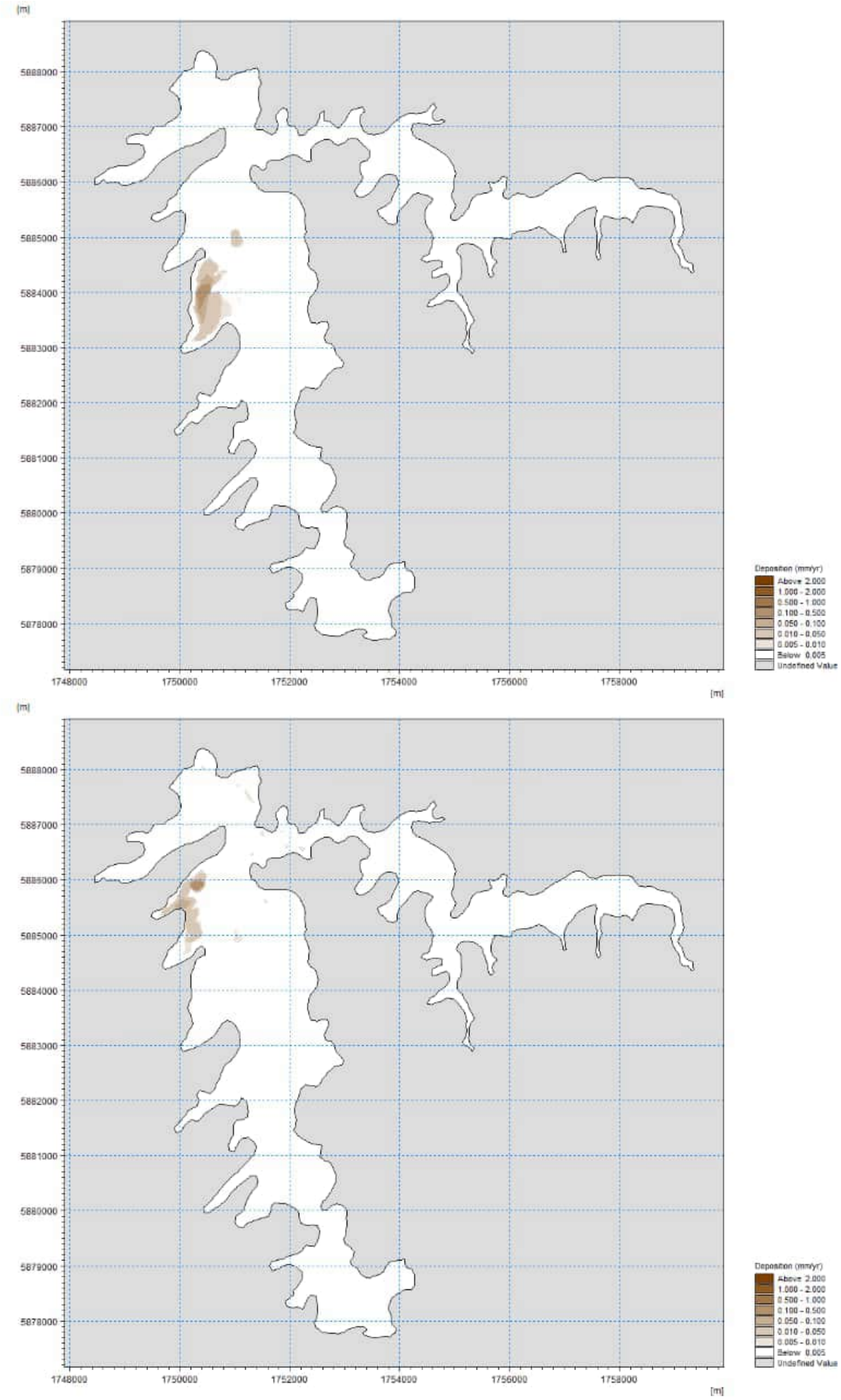

Figure C-11. Depositional footprint for Waiuku River 6 (top) and Waiuku River 4 (bottom) sediments. The maximum predicted level of deposition near the Waiuku River 6 (top) and Waiuku River 4 discharges are 1.1 mm/yr and 1.3 mm/yr and respectively.

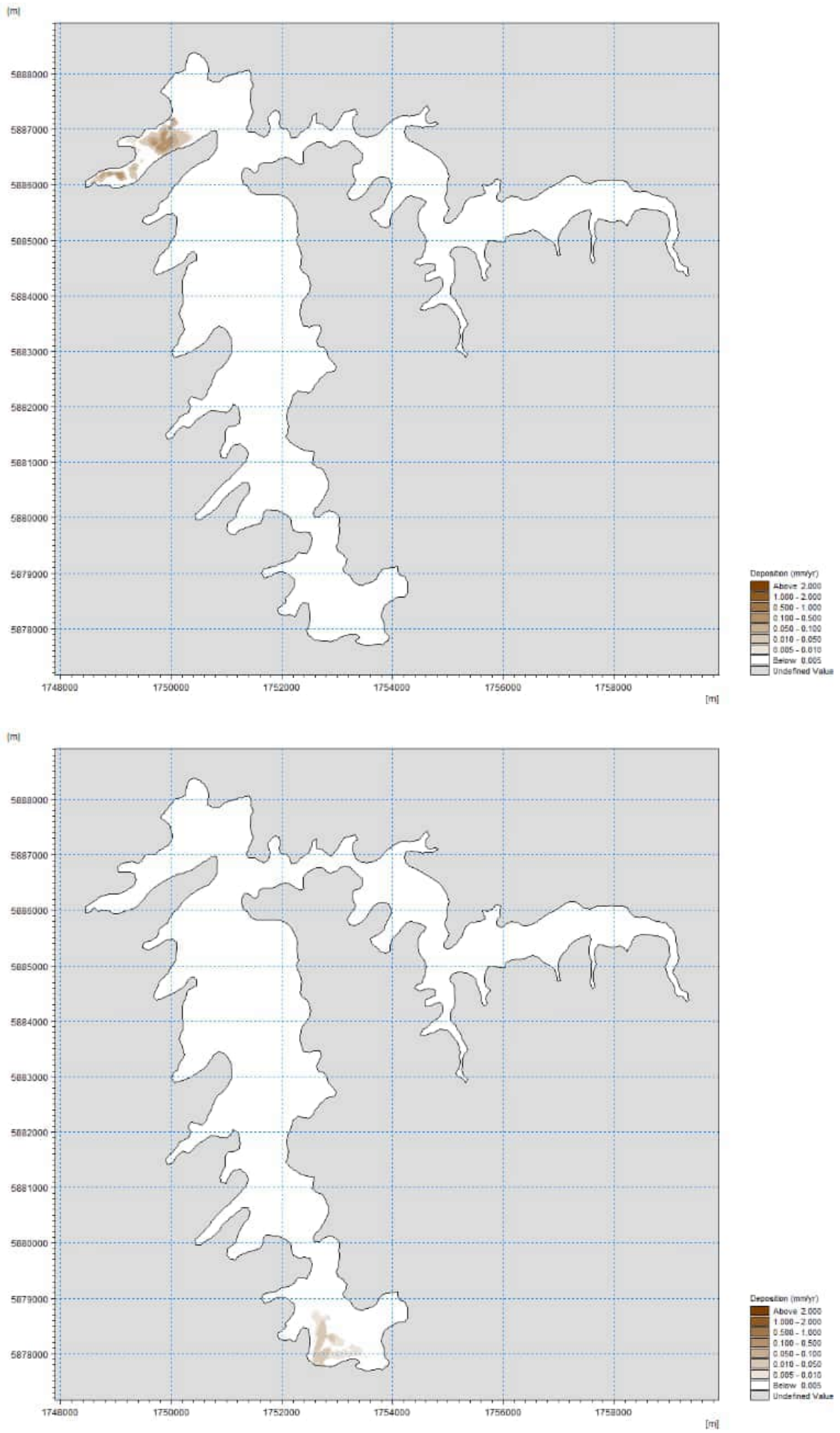

Figure C-12. Depositional footprint for Waiuku River 3 (top) and Waiuku Town 7 (bottom) sediments. The maximum predicted level of deposition near the Waiuku River 3 and Waiuku Town 7 discharges are 0.7 mm/yr and 0.1 mm/yr and respectively.

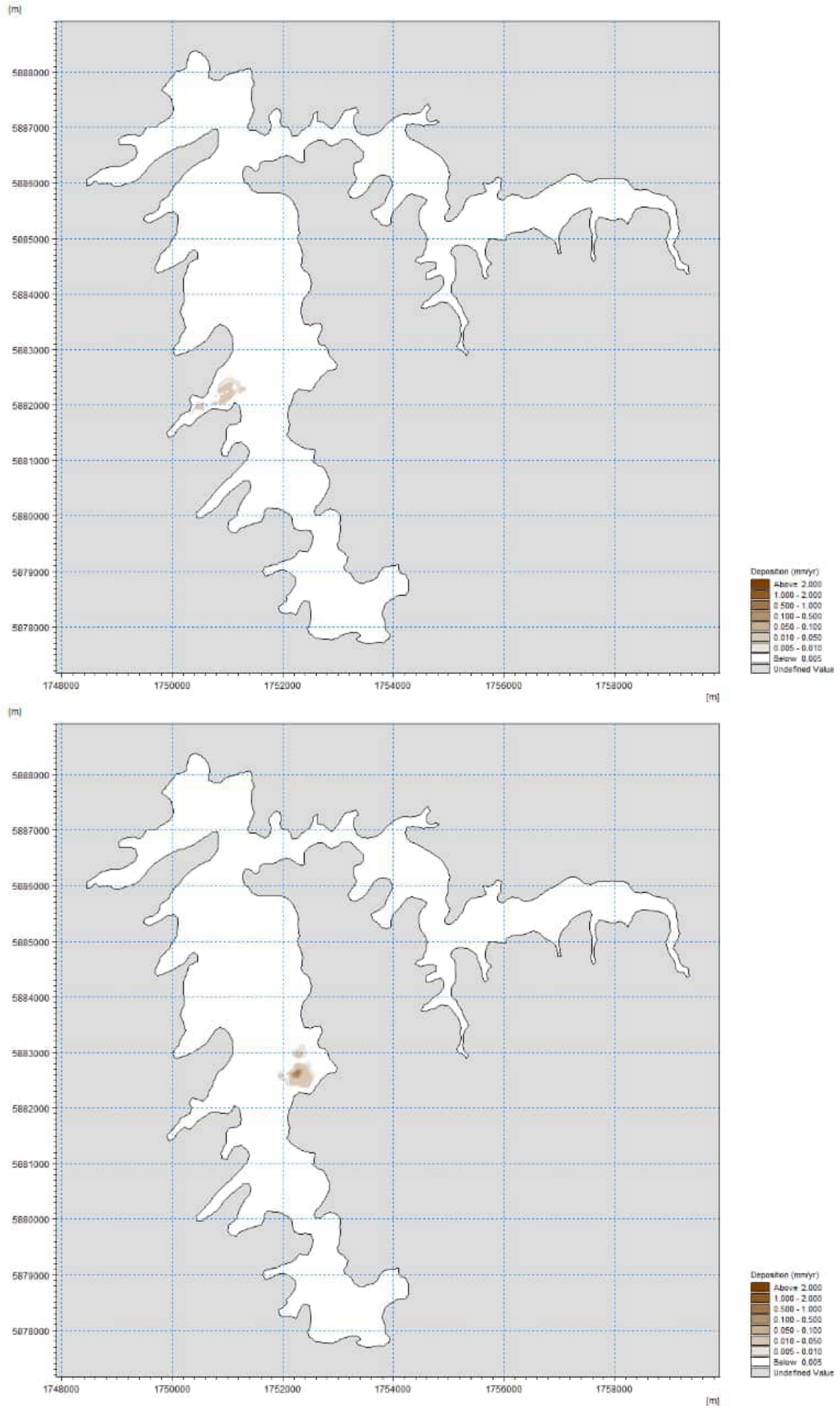

Figure C-13. Depositional footprint for Waiuku River 10 (top) and Waitangi Stream 4 (bottom) sediments. The maximum predicted level of deposition near the Waiuku River 10 (top) and Waitangi Stream 4 discharges are 0.1 mm/yr and 2.2 mm/yr and respectively.

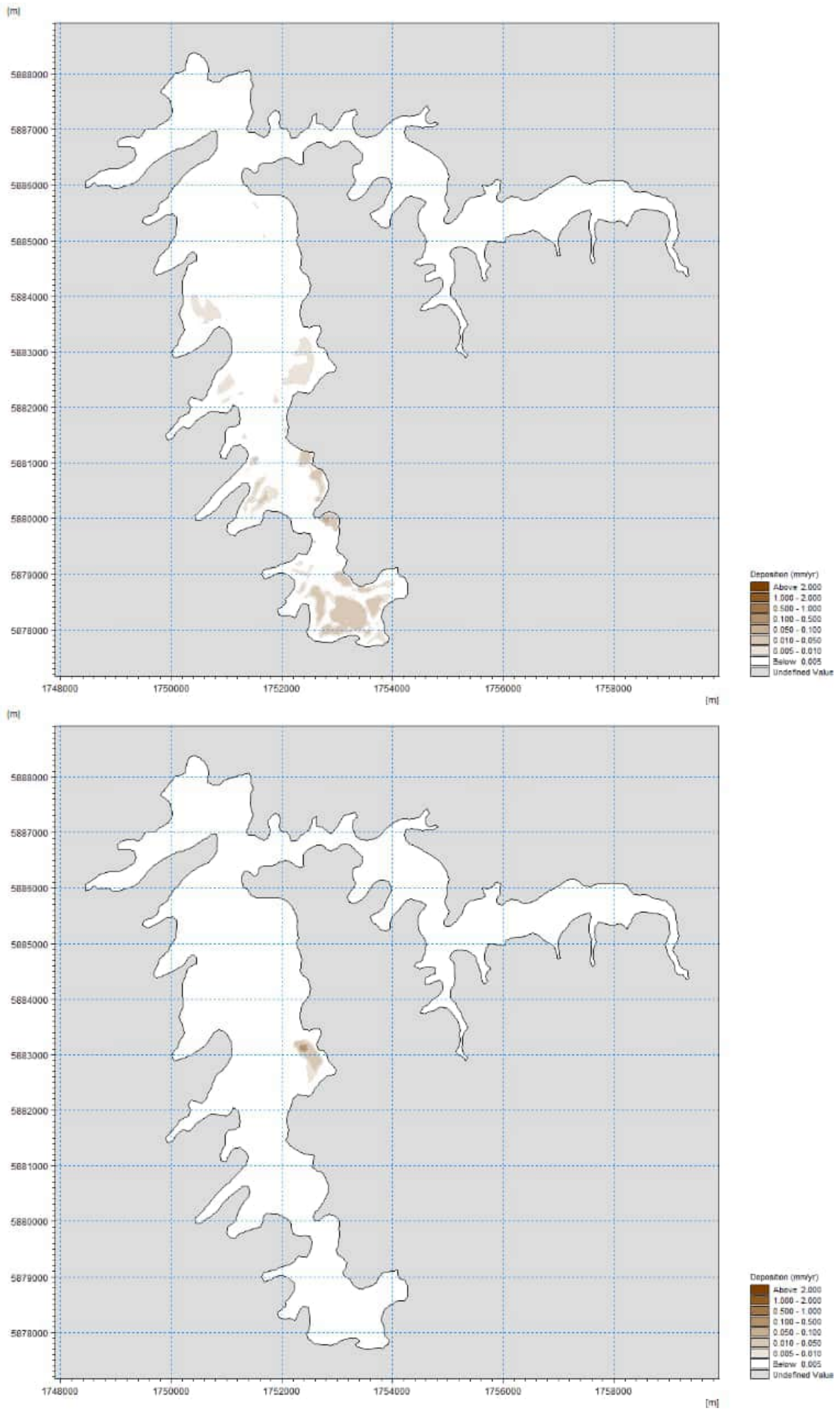

Figure C-14. Depositional footprint for Waitangi Stream 6 (top) and Waitangi Stream 2 (bottom) sediments. The maximum predicted level of deposition near the Waitangi Stream 6 (top) and Waitangi Stream 2 discharges are 0.2 mm/yr and 0.7 mm/yr and respectively.

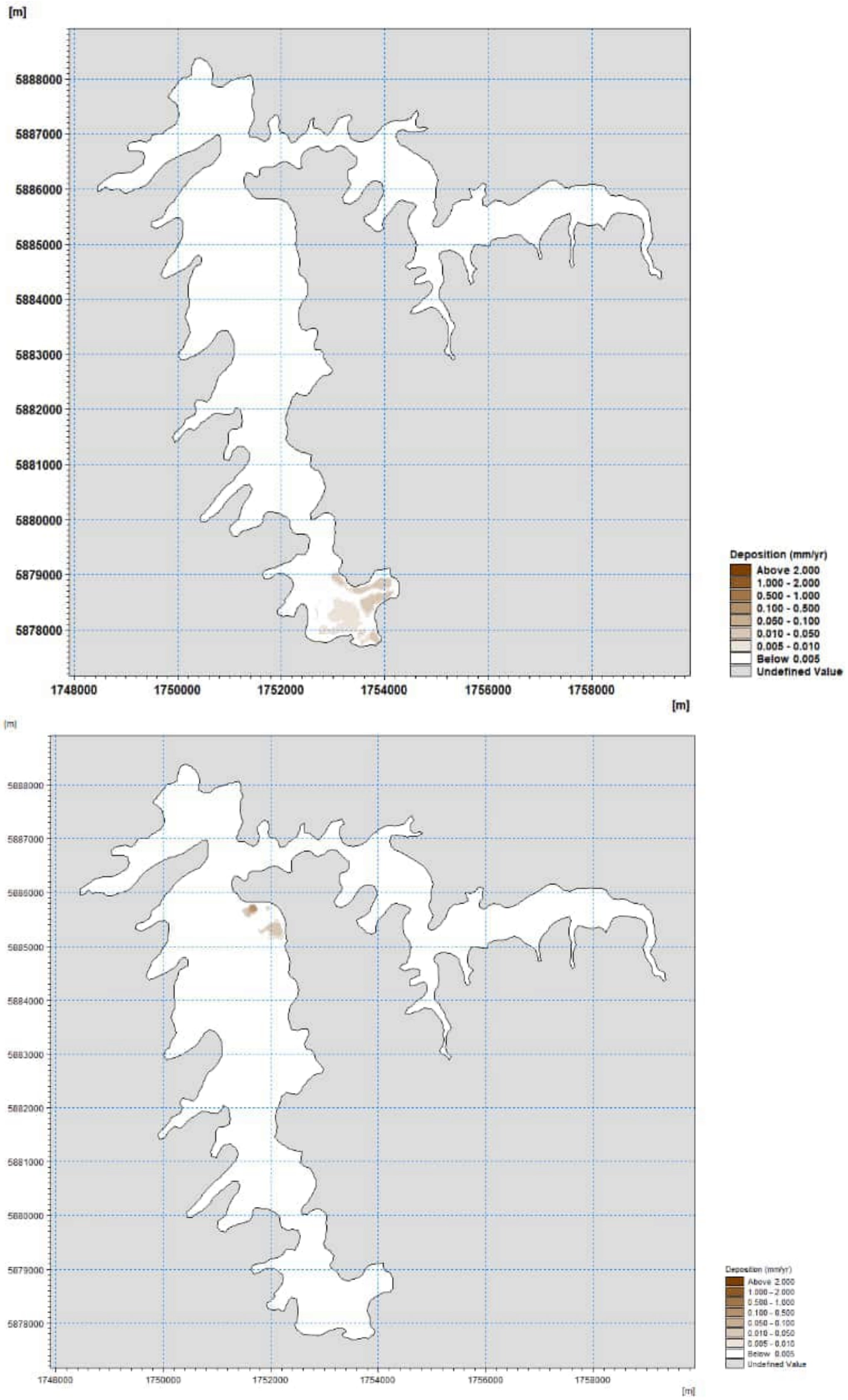

Figure C-15. Depositional footprint for Waiuku Town 8 (top) and Waitangi Stream 1 (bottom) sediments. The maximum predicted level of deposition near the Waiuku Town 8 (top) and Waitangi Stream 1 discharges are 0.1 mm/yr and 1.4 mm/yr and respectively.

Appendix D – Detailed rationale for using a depth-averaged model.

The NZ Steel discharges occur into the small inter-tidal channels to the north and south of the embayment offshore of the NZ Steel site.

Within the model the Northside and Southside Outfall discharges are assumed to be the sole contributor to flows into these schematised inter-tidal channels.

It is only at the point of contact with the ambient saline water that some degree of stratification in the water column will occur.

Given the dynamic nature of the area, quantifying the size of the zone where vertical mixing may occur would be difficult to measure and also difficult to accurately model.

However, assuming zero ambient current speed (i.e. the discharge itself is the only momentum term driving mixing) then the distance to achieve full horizontal and vertical mixing for a bankside discharge can be estimated using the following empirical formula of Rutherford (1992).

$$L_x = \rho \frac{(0.5\,b)^2}{\beta_1\,h}$$

$$L_y = \rho \frac{(0.5\,b)^2}{\beta_2\,h}$$

Assuming the width of the discharge (*b)* is 4 m (based on the size if the inter-tidal channel) and the typical average water depth (*h*) just beyond the waters edge is 0.5 m (based on the slope of the inter-tidal area) and taking the default values of ρ of 0.536, β_1 of 0.4 and β_2 of 0.07 then the horizontal and vertical mixing distances (L_x and L_y) are 10 and 60 metres respectively.

These values assume still water conditions which will only be the case at high water and low water. As the tide rises and falls ambient tidal currents will enhance vertical and horizontal mixing so it is likely that the values of L_x and L_y will be much less.

A test case of a depth-averaged model and three-dimensional model using the bathymetry offshore of the NZ Steel site and the assumed Northside Outfall discharge was run to cross-check the above empirical formula.

Just prior to high water (Figure D-1) the incoming tide brings denser, saline water towards the discharge point, but it can be seen that at the point of discharge the predicted salinity is uniform through the water column.

At high water (Figure D-2) the denser, saline ambient water underlies the NZ Steel discharge water (which is warmer and of a lower salinity) resulting in stratification within the water column.

One hour after high tide (Figure D-3) a similar pattern of predicted salinity occurs compared to one hour before high water.

In all three figures it can be seen that the area of strong stratification (i.e. where the salinity contours are close to vertical) generally occurs within the first 40-60 m of the discharge point – in good agreement with the empirical estimates.

Plots of temperature for the high-resolution three-dimensional model and the depth-averaged equivalent model at high water (Figure D-4) show the extent of the zone where strong stratification occurs. These plots confirm that the area of strong stratification is likely to occur within 40-60 m of the discharge at high water.

The zone itself will move depending on the state of tide (e.g. Figure D-1) and it will reduce in size when ambient currents increase on the rising and falling tide (or due to stronger winds).

Within this zone, the depth-average model predictions will under-predict concentrations (and temperatures) at the surface and over-predict concentrations (and temperatures) near the bed.

That is, dissolved Zinc and Copper concentrations and excess temperature will be higher in the surface waters and lower near the bed within this zone than are predicted by the depth-averaged model.

Given the dynamic nature of the location of this zone the overall error associated with the use of a depth-averaged model will be minimal.

In addition, the lowest level of dilution occurs at low tide (when stratification is minimal). Changes in predictions at other states of tide due to stratification effects will have little effect on the 95th percentile values.

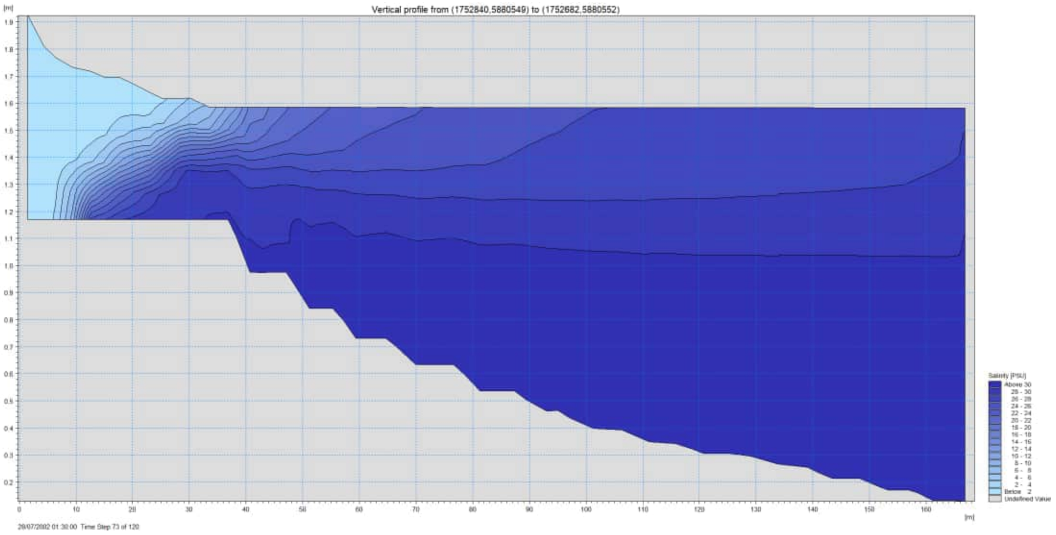

Figure D-1. Cross shore profile of predicted salinity one hour prior to high water for a high-resolution three-dimensional model of the Northside Outfall discharge.

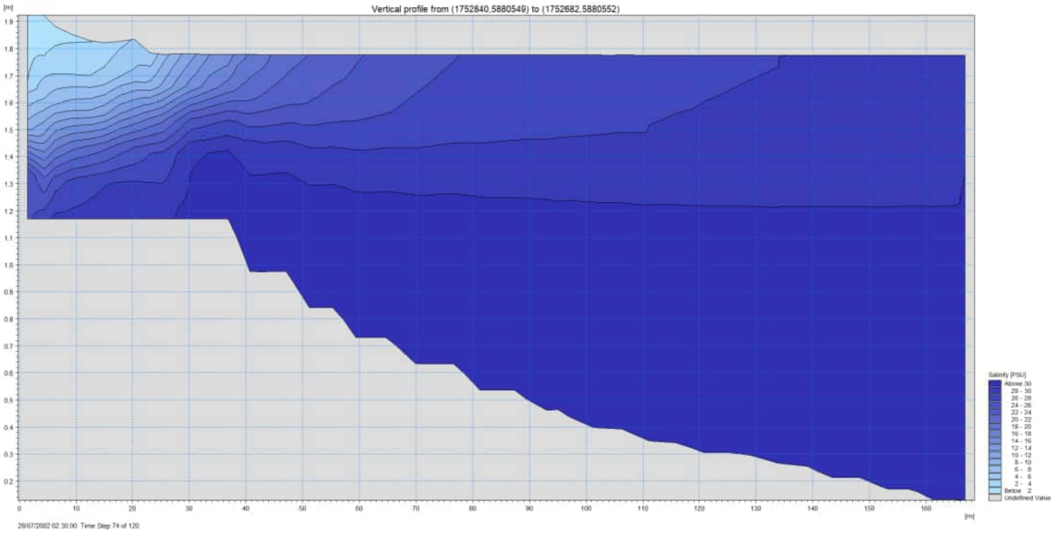

Figure D-2.Cross shore profile of predicted salinity at high water for a high-resolution three-dimensional model of the Northside Outfall discharge.

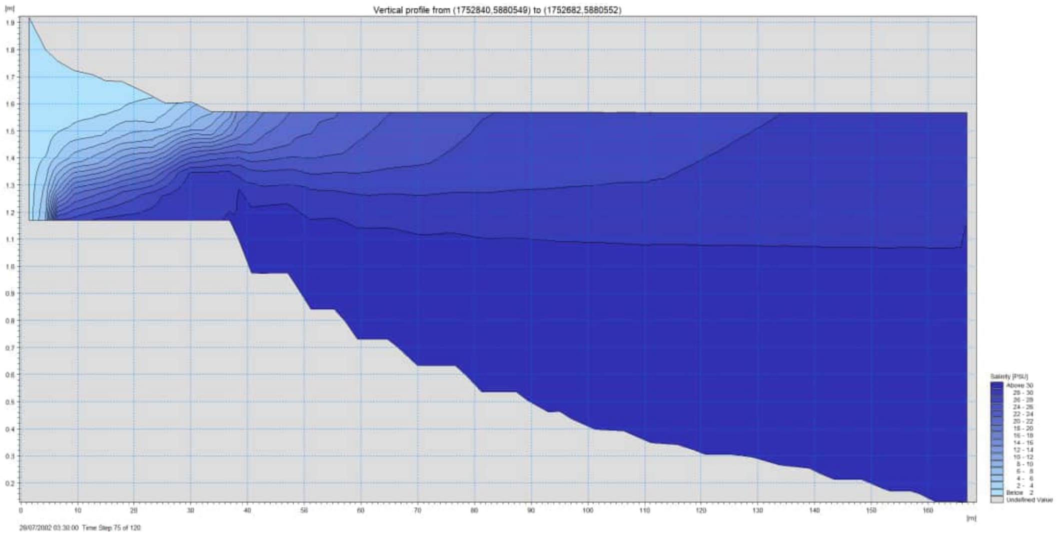

Figure D-3.Cross shore profile of predicted salinity one hour after high water for a high-resolution three-dimensional model of the Northside Outfall discharge.

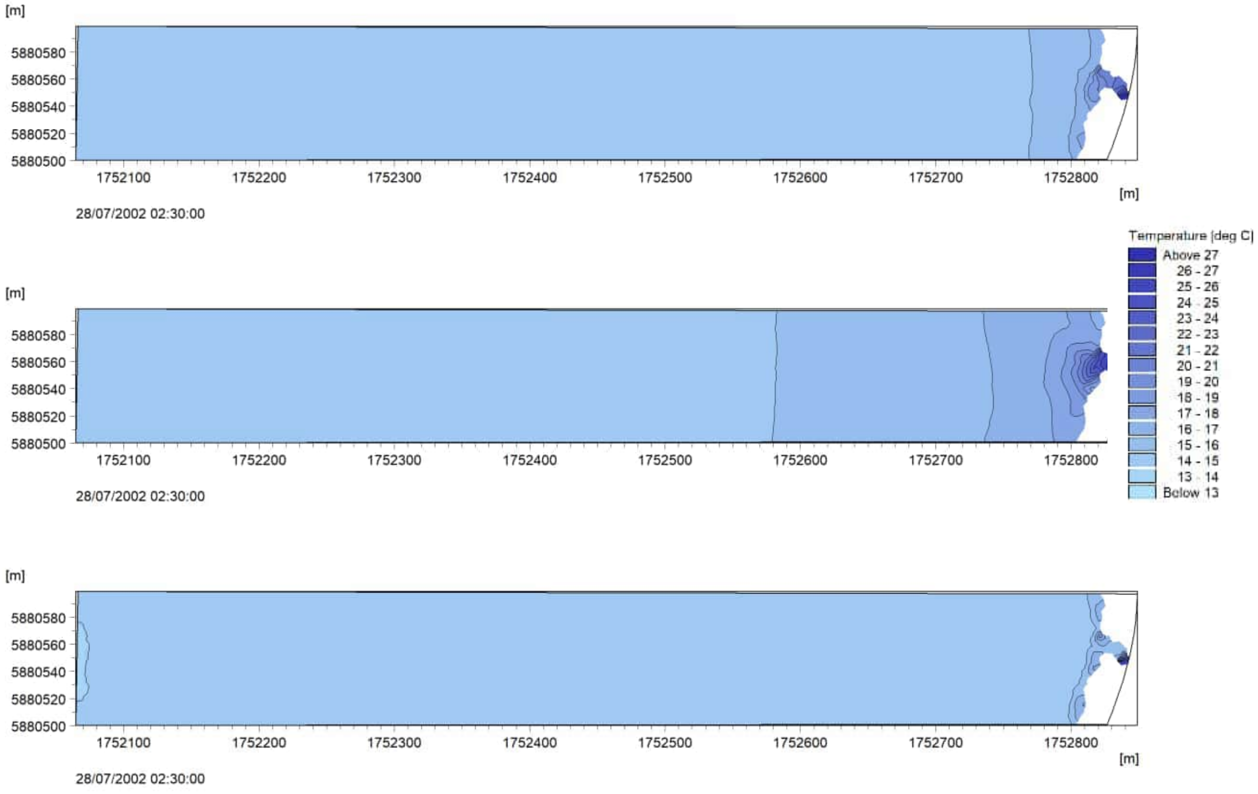

Figure D-4.Comparison of depth-average (top panel), near-surface (middle panel) and near bed (bottom panel) temperatures at high water for a high-resolution three-dimensional model of the Northside Outfall discharge.

Figure D-5.Aerial image of the Northside Outfall inter-tidal channel.

Appendix E – Detailed rationale for not including a wave model in the sediment transport model.

The maximum fetch for the embayment directly offshore of the NZ Steel site is around 2700m.

This fetch occurs for winds from the north-west which occur for around 10% of the time. The 95th percentile wind speed for this sector is 10.8 m/s.

Empirical formula of fetch limited waves[13] indicate that a wind of this strength and direction may result in a wave with height of 0.35 m and period of 2.0 s.

However, the significant degree of flooding and drying on each tide (reducing fetch and limiting to time for waves to develop) plus wave frictional and wave breaking processes will lead to much smaller waves than these empirical estimates occurring offshore of the NZ steel site.

Testing of a wind generated wave model of the Waiuku River for a 12 m/s wind from the north-west indicate that the flooding and drying effects on fetch length are such that any evolution and growth of wind driven waves are largely offset by losses due to bottom friction and depth-induced wave breaking. As a result predicted wave heights and periods are much less than suggested by empirical formula. Calibration of such a model (especially in relation to sediment transport) would require observations of a cross-shore profile of waves and suspended sediment concentrations under of ranges of wind conditions. Typically, to achieve an adequate calibration of such a model, a much higher resolution wind field would be required to adequately resolve topographic steering within the Waiuku River.

Winds in excess of around 8 m/s are generally required to initiated significant sediment transport in shallow water systems[14]. An analysis of the wind record shows that winds of greater than 8 m/s from the north-west one hour either side of high water occur for less than 2% of the time.

A series of schematic wave events based on the empirical estimates (0.35 m wave height and 2.0 s period) were created for all of 2008 based on the above criteria – that is, a schematic uniform wave field was defined only when winds from the north-west exceeded 8 m/s one hour either side of high water.

The sediment transport model was run then run with and without these schematised waves.

The mean bed shear stress for the month of May 2008 (the windiest month in the record) is shown in Figure E-1 (without waves) and Figure E-2 (with schematic waves). Only very small increases are seen in the mean bed shear stress because of the relatively low occurrence of the schematic wave events.

Figure E-3 shows the mean and maximum bed shear due to currents across a transect running from the subtidal channel to shoreline immediately offshore of the NZ Steel site and the increase in bed shear stress predicted during the wave events in May 2008.

The increase in bed shear stress due to schematic waves is less than 0.005 N/m^2 – an order of magnitude less than the mean bed shear stress across the middle section of the profile and much less than the maximum predicted shear stress due to currents only (which occurs during periods of higher winds during a mid-ebb or mid-flood tide).

These increases would result in small increases in the mass of sediment eroded from the sea bed towards high water – leading to localised increases in suspended sediment concentrations.

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[13] For example, https://swellbeat.com/wave-calculator/

[14] So,S., Khare, K., Mehta, A. 2013. Critical wind and turbidity rise in a shallow Florida lake. WIT Transactions on Ecology and the Environment Vol. 169.

However, because of the small currents that occur around high water there will be limited movement of this additional sediment and as a result there will be very little net influence on predicted deposition.

Therefore it is considered that the existing information in the report is sufficient and there is no material benefit in re-running the full model to account for the effects of wind driven waves on bed shear stress.

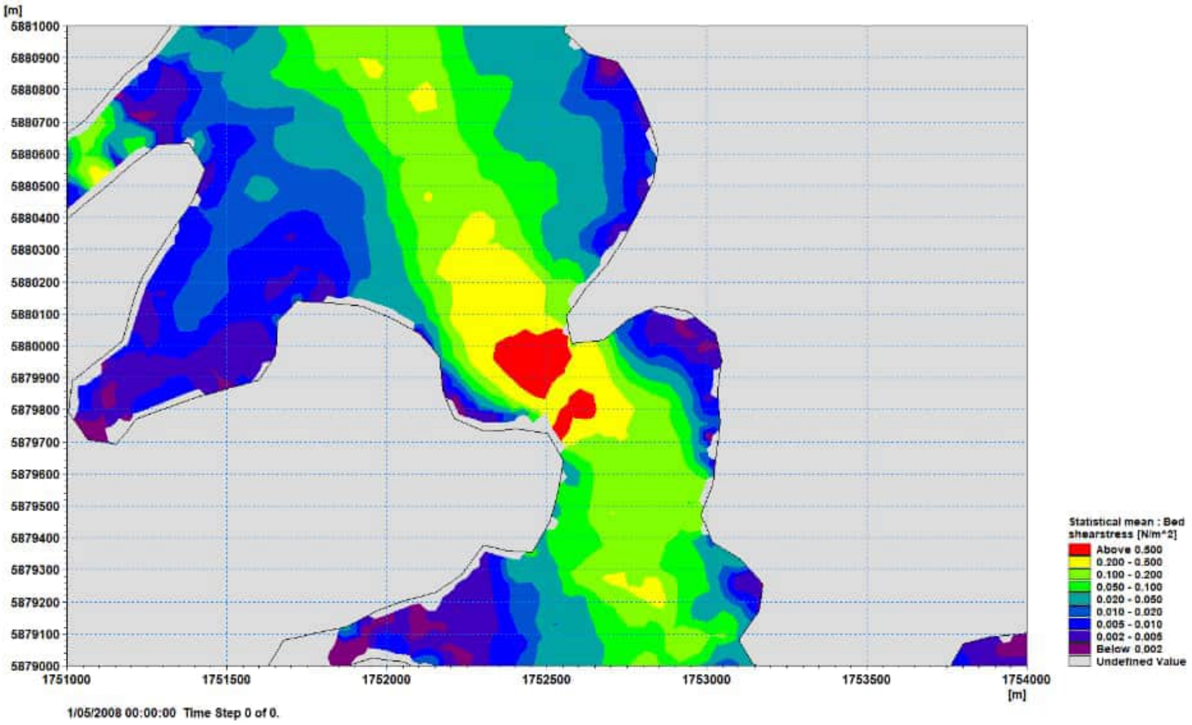

Figure E-1. Mean bed shear stress without waves for May 2008.

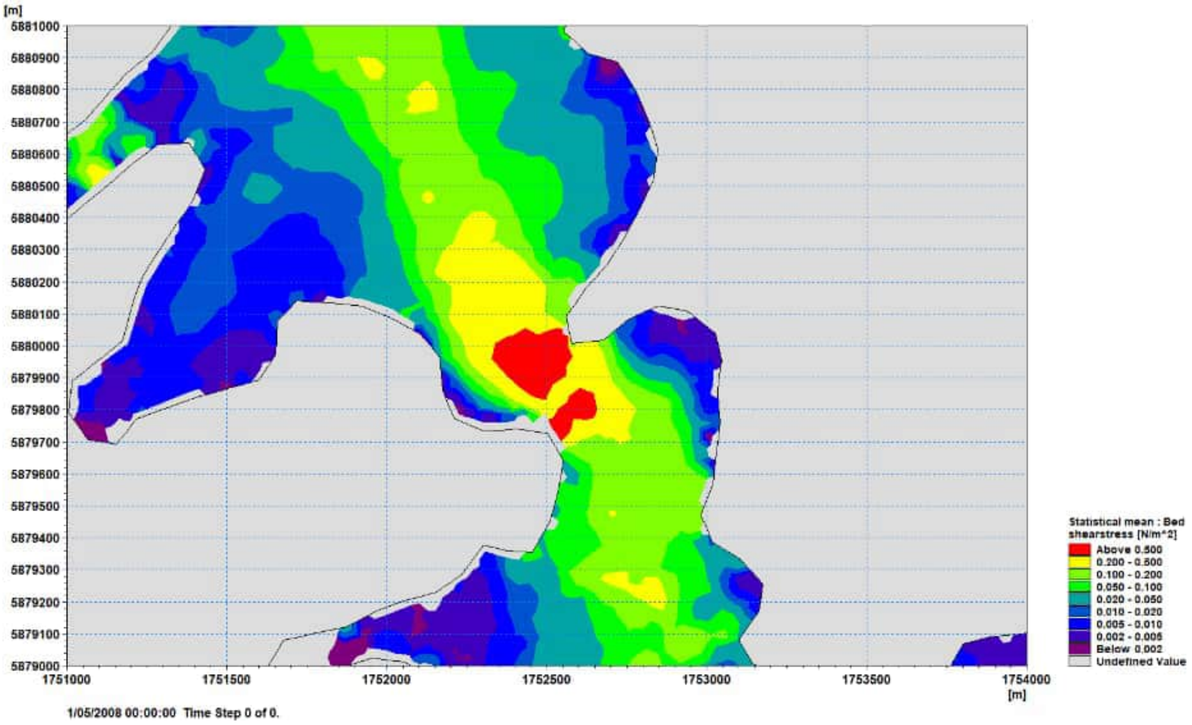

Figure E-2. Mean bed shear stress with schematic waves for May 2008.

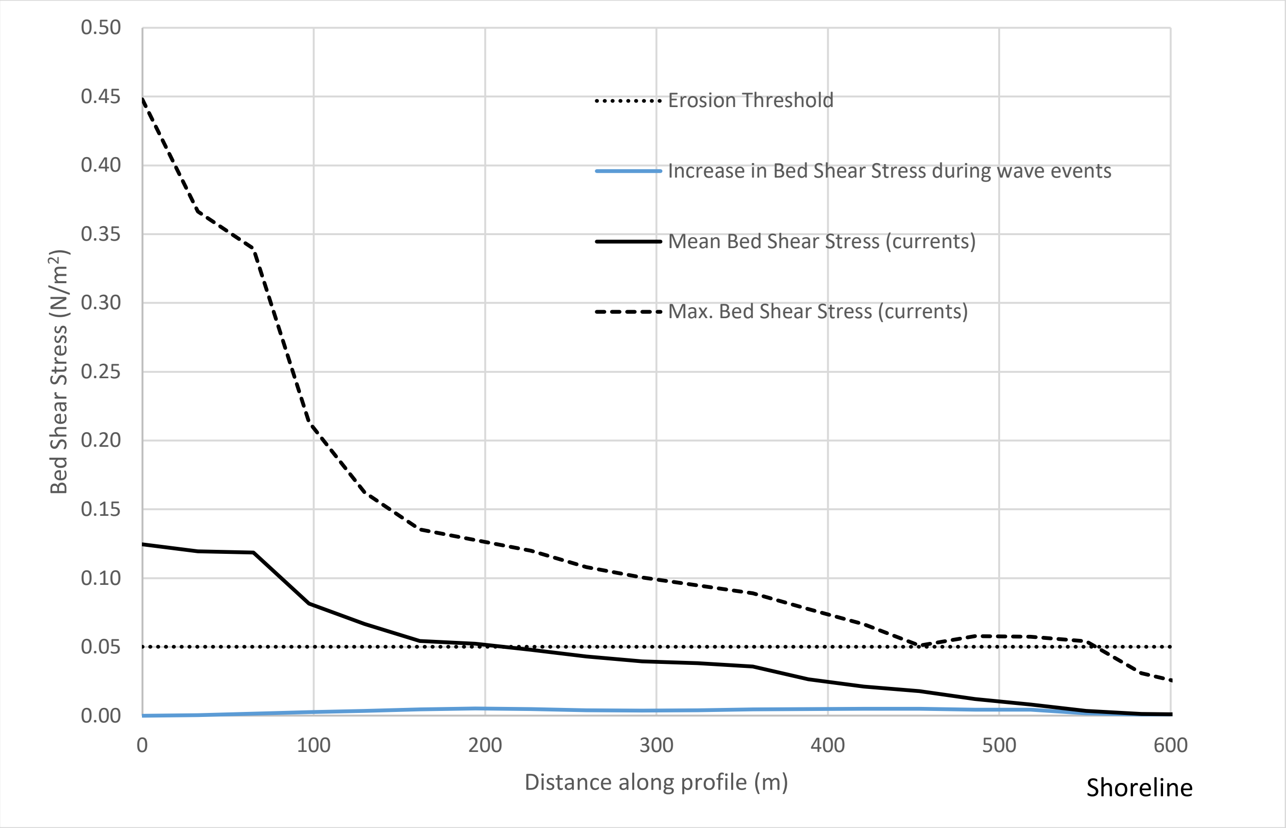

Figure E-3. Average increase in bed shear stress during schematic wave events and the mean and maximum bed shear stress values due to tides and winds driven currents.