Clarks Beach WWTP Options Study
Hydrodynamic Modelling

Watercare Services Limited

44800806/01

April 2016

The expert in **WATER ENVIRONMENTS**

This report has been prepared under the DHI Business Management System certified by Bureau Veritas to comply with ISO 9001 (Quality Management)

ISO 9001
Management System Certification
BUREAU VERITAS
Certification Denmark A/S

Clarks Beach WWTP Options Study
Hydrodynamic Modelling

Prepared for	Watercare Services Limited
Represented by	Tanvir Bhamji, Principal Planner

Clarks Beach, Manukau Harbour.

Project manager	John Oldman

Project number	44800806
Approval date	15-06-2106
Revision	Draft 0.4
Classification	Confidential

DHI Water and Environment Ltd• ecentre, Gate 5, Oaklands Road• Albany 0752 Auckland• New Zealand•
Telephone: +64 9 912 9638 • Telefax: • info.nz@dhigroup.com• www.dhigroup.com

CONTENTS

FIGURES

TABLES

Executive Summary

Watercare is in the process of developing a wastewater servicing programme for non-metropolitan areas of Auckland. This includes considering the implications of planned growth in Clarks Beach, Waiuku and Kingseat under the South-West Sub-Regional Wastewater Servicing Consent Project (the Project).

The anticipated population to be serviced by the proposed South-West sub-regional wastewater treatment plant (WWTP) ranges from 30,000 PE (population equivalent) to 50,000 PE.

This report gives details of modelling carried out to;

- Quantify the dynamics of the plume from a proposed outfall immediately offshore of the existing WWTP discharge site for current population levels,
- Assess the performance of this outfall for future growth scenarios for Clarks Beach,
- Carry out a high level review of potential alternative outfall locations within the south-west Manukau Harbour and a site discharging offshore to the Tasman Sea,
- Assess the potential changes in broader scale salinity that could be attributed to the proposed discharge.
- Quantify the relative impacts of the existing Mangere WWTP discharge and that of the proposed Clarks Beach outfall, and
- Determine the effects of inactivation processes for both microbial and viral contaminants at key sites in the south-west Manukau (used for a Public Health Risk Assessment process).

Clarks Beach 12th Green Mid-Channel Discharge

The focus of this modelling study has been on a discharge site within the Waiuku River directly offshore of the existing Clarks Beach WWTP. This discharge site is referred to as the Clarks Beach 12th Green Mid-Channel discharge site. For this site, an outfall 120 m long in around 9 m of water with forty 100 mm discharge ports would ensure that, under the majority of conditions that occur at the site, a treated wastewater plume would be fully mixed in the water column thus maximising the level of near-field dilution that could be achieved.

Such an outfall would therefore provide a good level of initial dilution for the discharge rates being considered up to the 50,000 PE Peak Wet Weather Flow (PWWF).

The range of dilutions achieved 200 m downstream of the outfall would be between 260-2800 depending on water depth, strength of the ambient tidal currents and discharge rate being considered.

Because the focus of this work was on the 30,000 and 50,000 PE discharge scenarios no further quantification of the dynamics of a treated wastewater plume for discharges beyond the 50,000 PE have been done.

Alternative Discharge Sites

In addition to a proposed outfall site directly offshore of the existing Clarks Beach discharge, a number of alternative discharge locations have been considered.

An outfall site offshore of the Awhitu Peninsula discharging to the Tasman Sea would provide the potential for much greater dilution than could be achieved at sites within the south-west Manukau. Quantification of the level of dilution that could be achieved and the potential impacts along the Awhitu Peninsula shoreline could only be done following full calibration of the existing model. This would require collection of at least 4-6 weeks of current data in the vicinity of any potential offshore outfall site.

The proposed discharge site directly offshore of the existing Clarks Beach WWTP provides a good level of near-field dilution. Other sites in the south-west Manukau provide either less initial dilution or may result in higher contaminant concentrations occurring at inter-tidal sites in and around Clarks Beach and Karaka Point.

Karaka Point Mid-Channel Discharge

During the early part of this study one option considered was combining the planned growth in Clarks Beach, Waiuku and Kingseat with planned growth in Pukekohe area (currently served by the Pukekohe WWTP). Such a scenario would result in a population equivalent of 100,000.

To accommodate such a discharge scenario a revised diffuser design would be required for the Clarks Beach 12th Green Mid-Channel Discharge site to ensure full mixing throughout the water column (and thus ensure maximum achievable dilution) or the effects of the reduced initial dilutions would need to be quantified with further modelling.

Alternatively, for a 100,000 PE discharge scenario another discharge location may need to be considered. A site immediately offshore of Karaka Point (to the north of the existing Clarks Beach WWTP) provides greater water depth, stronger tidal currents and more channel width to accommodate a diffuser compared to Clarks Beach 12th Green Mid-Channel Discharge site.

As such, a Karaka Point Mid-Channel site would provide the potential for more initial mixing but its proximity to the Clarks Beach inter-tidal area and camp ground at Karaka Point may mean that, at times, higher contaminant concentrations could occur in these areas.

Because the focus of this work was on the 30,000 and 50,000 PE discharge scenarios no further quantification of the dynamics of a treated wastewater plume have been carried out for the Karaka Point Mid-Channel site.

Harbour Wide Salinity Implications

Model predictions indicate that the effect of the proposed WWTP discharge on salinity levels in the Manukau Harbour would be very small. Reductions in salinity of less than 0.05 PSU are predicted to occur. This compares to the range of natural variation of salinity which varies between 0.5 – 3.0 PSU (depending on the actual location in the harbour).

At sites in the south-west corner of the Manukau, model predictions indicate that the proposed WWTP discharge would reduce salinities by less than 0.04 PSU. This compares to the range of natural variation of between 0.8 and 1.7 PSU that occurs in this area of the harbour.

This small decrease in salinity comes about due to the combination of the staging of the discharge (only occurring on the outgoing tide), the degree of mixing of the treated wastewater plume that occurs with more saline ambient harbour waters and the relative effect of the dynamics of the freshwater plumes of the Waiuku and Mauku rivers.

Cumulative Effects of Mangere and Clarks WWTP

Model simulations have been carried out with both the existing Mangere WWTP discharge and the proposed Clarks Beach WWTP discharge operating.

The model results indicate that;

- The contribution of the Mangere WWTP discharge on contaminant levels in the south-west corner of the harbour will be minimal, and
- The contribution of the proposed Clarks Beach WWTP discharge on contaminant levels in the middle and north-east sector of the harbour will be minimal.

Therefore, in terms of impacts and/or Public Health Risk of the proposed Clarks Beach discharge only contaminant levels in the south-west sector of the harbour need to be considered.

Viral and bacterial dilution

Annual simulations of the dynamics of the treated wastewater plume for the existing discharge onto the inter-tidal area near the existing Clarks Beach WWTP have been carried out for representative El Niño and La Niña conditions. This provides baseline estimates of the level of dilution that could be achieved for both viral and bacterial contaminants

Model results indicate that there is a very localised area where minimum dilutions of less than 1500 are achieved with an absolute minimum dilution of 35 achieved during the annual simulations. Once the discharged wastewater reaches the main channel of the Waiuku River significantly higher levels of dilution occur.

For the Clarks Beach 12th Green Mid-Channel Discharge site discharge scenarios for a 30,000 and 50,000 PE have been modelled. For the 30,000 PE discharge there is a very localised area in the immediate vicinity of the discharge point where a minimum dilution of between 500-1000 occurs and there is a narrow band directly to the north-west of the discharge point where a minimum dilution of less than 1500 occurs. The absolute minimum dilution achieved during the annual simulations is 265. For the 50,000 PE discharge there is a very localised area in the immediate vicinity of the discharge point where a minimum dilution < 500 occurs. There is a narrow band directly to the north-west of the discharge point where the minimum dilution of between 500-1000 occurs. The area where a minimum dilution of less than 1500 occurs now extends offshore of Karaka Point. The absolute minimum dilution achieved during the annual simulations is 160.

Moving the discharge location to the Clarks Beach 12th Green Mid-Channel site therefore improves the minimum level of dilution that is achieved at the discharge site. Away from the discharge site, improvements to the predicted level of viral and bacterial concentrations under the future discharge regimes will come about through improved levels of treatment at the plant, as discussed in detail in the Public Health Risk Assessment component of work (NIWA, 2016).

Key sites for the Public Health Risk Assessment process were identified as follows;

Recreational Sites

- Waiau Beach
- Karaka Point
- Clarks Beach West
- Clarks Beach East
- Matakawau Headland

Shellfish Sites

- Te Toro Road Settlement
- Te Toro Road Boat Ramp
- Matakawau Headland

Details of the level of total dilution and contaminant concentrations achieved for different levels of treatment are discussed in detail in the NIWA Public Health Risk Assessment report (xxxx, 2016).

For the Waiau Beach site (near the existing WWTP discharge point) mean dilutions of around 80,000 are currently achieved. This is due to the very low volume of treated wastewater that is currently being discharged. With the higher discharge rates being considered for the future options average dilutions of between 9,000 and 22,000 are achieved at this site.

Similarly, because of the small volume of treated wastewater currently being discharged the level of dilution achieved at the other Public Health Risk Assessment sites is very high.

For the future discharge regimes average dilutions at the Clarks Beach recreational sites range from 15,000 through to over 100,000.

At the Te Toro Road sites average dilutions range from 11,000 through to 31,000 for the future discharge regimes.

Because of the distance between the discharge point and the Matakawau Headland (> 4 km) average dilutions of at least 59,000 are achieved for the future discharge regimes.

Improvements to the predicted level of viral and bacterial concentrations under the future discharge regimes at the Public Health Risk Assessment sites will come about through improved levels of treatment at the plant, as discussed in detail in the Public Health Risk Assessment component of work (NIWA, 2016).

1 Introduction

Watercare Services Ltd (Watercare) is in the process of developing a wastewater servicing programme for non-metropolitan areas of Auckland. This includes considering the implications of planned growth in Clarks Beach, Waiuku and Kingseat under the South-West Sub-Regional Wastewater Servicing Consent Project (the Project).

This report gives details of modelling carried out to assess the potential effects of a proposed discharge of treated wastewater from a new sub-regional wastewater treatment plant (WWTP) at Clarks Beach.

Key components of the modelling exercise include:

- Quantification of the dynamics of the plume from a proposed outfall immediately offshore of the existing WWTP discharge site (Section 2),
- Assessment of the performance of this outfall for future growth scenarios for Clarks Beach (Section 2),
- A high level review of potential alternative outfall locations within the south-west Manukau and a site discharging offshore to the Tasman Sea (Section 3),
- Assessment of the proposed discharge in terms of potential broader scale salinity impacts (Section 4).
- Relative impacts of the existing Mangere WWTP discharge and that of the proposed discharge at Clarks Beach (Section 5), and
- Effects of inactivation processes for both microbial and viral contaminants at key sites in the south-west Manukau used for the Public Health Risk Assessment process (Section 6).

The work builds on earlier work carried out for Watercare (DHI, 2014) which assessed the effects of a proposed tidally staged and continuous discharge to the Waiuku River via an outfall immediately offshore of the existing Clarks Beach WWTP (Figure 1-1). This discharge site is referred to as the Clarks Beach 12th Green Mid-Channel site and is located approximately 70 m from low water on the northern side of the Waiuku channel some 900 m south-east of Karaka Point.

This earlier modelling (DHI, 2014) identified that there was a clear benefit of discharging only on the outgoing tide due to lower potential impacts on the Waiuku and Mauku river systems and the greater degree of dilution achieved when discharging when higher tidal currents occur. For this report it has been assumed that any proposed discharge of treated wastewater would only occur from High Water plus one hour for a period of four hours.

The anticipated population to be serviced by the proposed South-West sub-regional WWTP ranges from 30,000 PE (population equivalent) to 50,000 PE. Both these population scenarios have been considered in detail in the report along with higher and lower PE discharge regimes in relation to diffuser designs and alternative outfall locations.

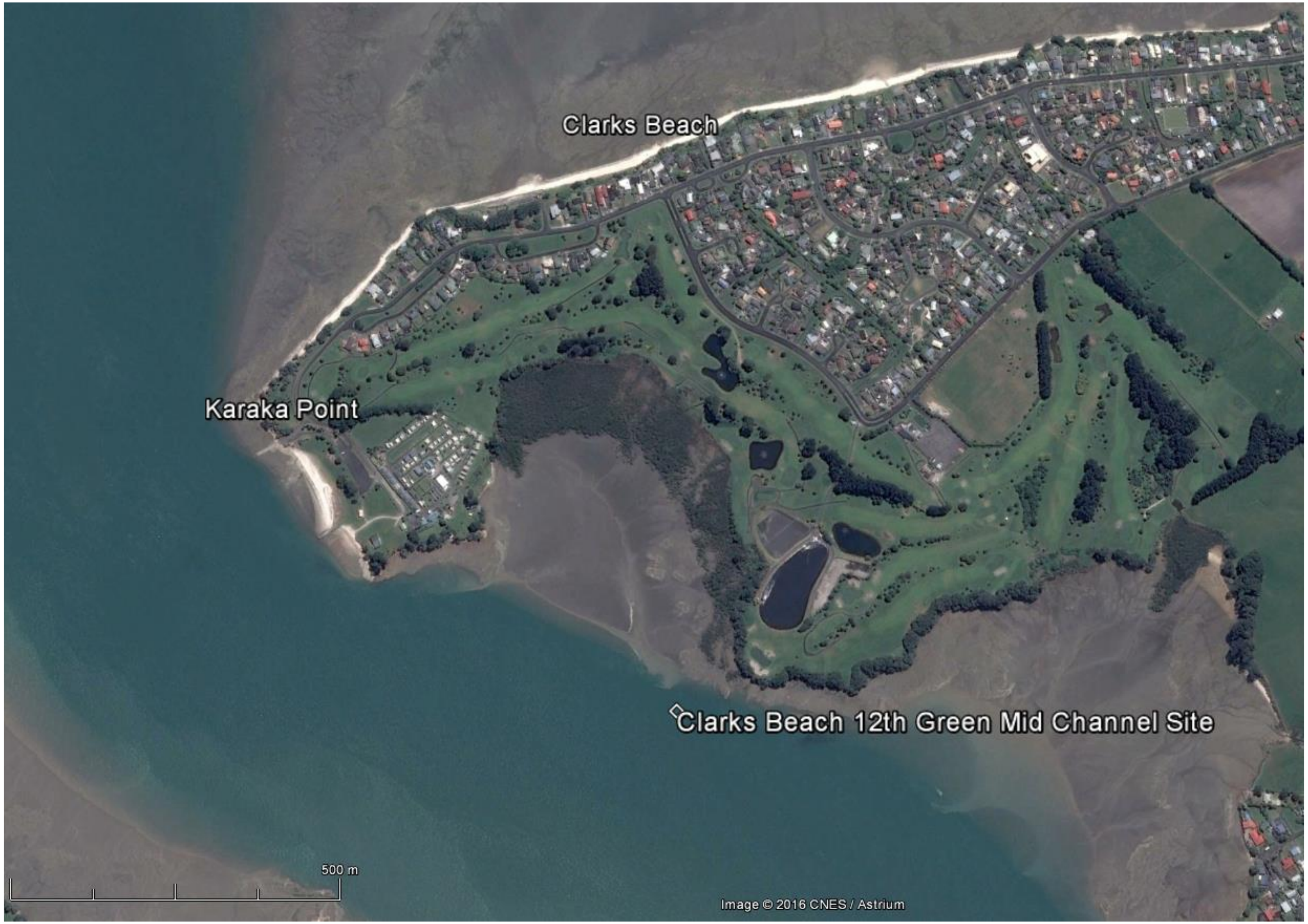

Figure 1-1 Aerial photo of Clarks Beach showing the location of the Clarks Beach 12th Green Discharge site located approximately 70 m from the low water line directly offshore of the existing Clarks Beach WWTP.

1.1 Discharge Scenarios Considered

Based on population estimates supplied by Watercare the data in Table 1-1 provides the range of Peak Wet Weather Flows (PWWF) and Average Dry Weather Flows (ADWF) considered during the initial phase of work. Note that Population Equivalents of greater than 50,000 would only eventuate if the planned growth in Pukekohe area (currently served by the Pukekohe WWTP) was to be serviced by the proposed South-West sub-regional WWTP.

During the course of this study it has been determined that the anticipated population growth to be serviced by the proposed South-West sub-regional WWTP would be just for Clarks Beach, Waiuku and Kingseat. As such, the 30,000 to 50,000 PE scenarios have been considered in detail in this report.

Table 1-1 ADWF and PWWF discharge rates for the range of population scenarios considered. Discharge is assumed to occur during a four hour window commencing at High Water plus one hour.

Population Equivalent (PE)	ADWF (m^3/s)	PWWF (m^3/s)
20,000	0.162	0.485
30,000	0.243	0.728
40,000	0.323	0.970
50,000	0.404	1.213
60,000	0.485	1.455
70,000	0.566	1.698
80,000	0.647	1.940
90,000	0.728	2.183
100,000	0.808	2.425

2 Near-Field Dilutions Assessment – Future Scenarios

Watercare have provided ADWF and PWWF for a number of potential scenarios of population that a Clarks Beach WWTP may service in the future (Table 1-1). For all scenarios it is assumed that the discharge will be staged, commencing one hour after high tide and terminating five hours after high tide (a four hour discharge window).

Detailed design of a diffuser suitable for these proposed flows was not part of the scope of this study. However to assess the dilutions for future options, DHI had to develop a conceptual diffuser design, to suitability assess the type of near field mixing that maybe achieved for each scenario.

Firstly, an initial diffuser design for the Clarks Beach 12th Green Mid-Channel site has been defined based on the discharges being considered up to the 50,000 PE scenario and various best practice design criteria discussed in detailed below.

During the initial phase of the study discharge rates beyond the 50,000 PE scenario were also considered. For a 100,000 PE discharge scenario the performance of the Clarks Beach 12th Green Mid-Channel are considered along with an alternative discharge location at Karaka Point.

2.1 Assessment of Near-Field Dilutions for up to 50,000 PE

It is not realistic to expect one diffuser design to service all population scenarios since the potential discharge rates vary significantly (Table 1-1). Instead the focus was placed on selecting a diffuser design that would provide adequate initial dilution for the discharge scenarios being considered in detail.

In this section of the report the performance of an outfall at the Clarks Beach 12th Green mid-channel site is assessed for both 20,000 and 50,000 PE discharge scenarios. The aim of this component of work was to ensure that an outfall at this site would perform well (in terms of providing maximum initial dilutions) up to the 50,000 PE PWWF discharge scenario.

Note that the conceptual diffuser design must be refined during a final design phase.

It should be noted that in the vicinity of Clarks Beach 12th Green Mid-Channel discharge site, the length of any potential diffuser is limited by the width of the main part of the channel, which is approximately 120 m (Figure 2-1).

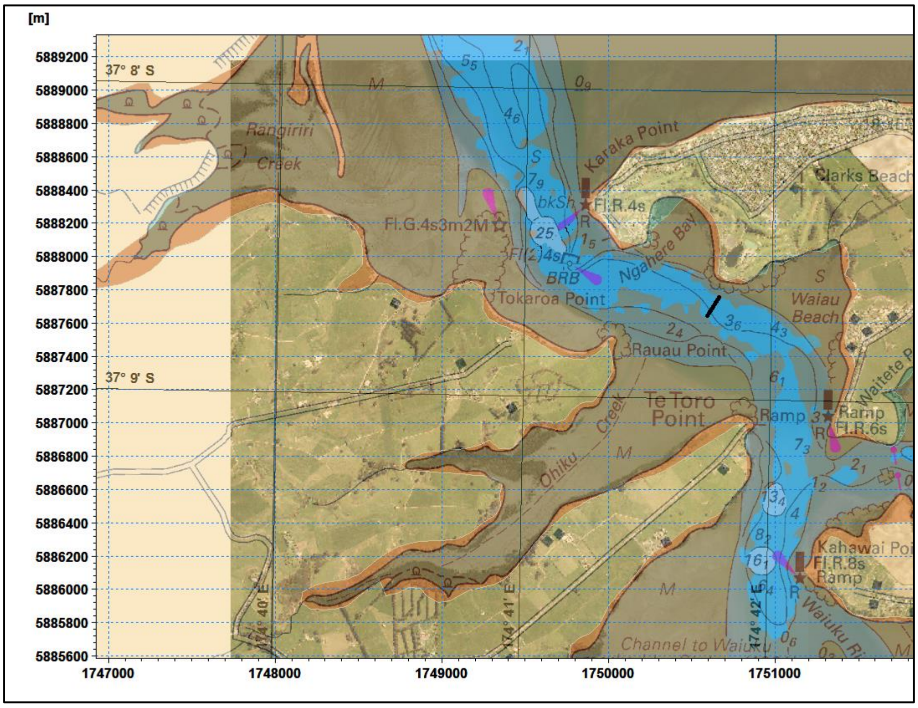

Figure 2-1 Indication of maximum possible diffuser length in vicinity of existing Clarks Beach 12th Green Mid-Channel discharge site. The blue shading indicates depths greater than 7 m (below chart datum) and the black line is 120m in length, providing an indication of the width of channel available for placement of an outfall. Coordinates are NZTM.

Similar to the previous conceptual design of the diffuser for the proposed outfall at Clarks Beach (DHI, 2014), the initial diffuser design for the Clarks Beach 12th Green Mid-Channel discharge site was established based on the range of discharges to be considered and the need to maintain adequate velocities in the diffuser pipe (to prevent deposition of material), ensuring that no sea water intrusion occurs and keeping the head loss reasonably small to minimise the requirement for pumping.

Criteria considered include the ASCE (1970) criteria of minimum of 0.5 m/s within the pipe (to prevent sediment build up) and maximum of 3.0 m/s within the pipe to avoid excessive head loss. There is a recommended ratio of port area to outfall pipe cross section of 70% (Williams, 1985). Also considered were the potential port velocities, which should be sufficiently high to not allow intrusion of receiving water back through the ports, but also keeping in mind the dimensions of the channel at the proposed location (Figure 2-1). Large port velocities could potentially generate significant turbulence within the channel. It is also recommended that the Froude number is greater than 1.0 but that the level of dilution is quantified using near-field modelling methods (ASCE, 1970).

Data in Table 2-1 gives the conceptual design parameters for the outfall based on the lowest PE initial considered (20,000 PE, Table 1-1) and the highest PE that has been studied in detail (50,000 PE, Table 1-1). The conceptual design consists of a 120 m diffuser, at a depth of approximately 9 m with a 0.8 m diameter pipe and 40 ports each with a diameter of 100 mm. The diffuser is aligned perpendicular to the main current direction (i.e. across channel). It is assumed that the ports will discharge horizontally (i.e. parallel to sea bed) with alternating directions.

Recent work carried out for the proposed Rehoboth ocean outfall (GHD, 2013) recommended that 7-10 m of diffuser is required for every 0.1 m^3/s of discharge[1]. Based on the highest peak

[1] Note the original reference uses 3-5 m of diffuser length for every Mega gallons per day discharge.

wet weather flows being considered an outfall length of up to 120 m maybe required which is the limit of the available width of channel at this site (Figure 2-1).

Table 2-1 Conceptual diffuser design based on ASCE (1970) and Williams (1985) criteria for minimum outfall flow and port to outfall area. Port discharge velocity also considered.

Design Parameters	20,000 PE ADWF	20,000 PE PWWF	50,000 PE ADWF	50,000 PE PWWF
Flow rate (m^3/s)	0.162	0.485	0.404	1.213
Diffuser length (m)	120	120	120	120
Pipe diameter (m)	0.800	0.800	0.800	0.800
Pipe area (m^2)	0.502	0.502	0.502	0.502
Pipe velocity (m/s)	0.322	0.965	0.804	2.414
Total port area (m^2)	0.314	0.314	0.314	0.314
Ratio port/pipe	0.625	0.625	0.625	0.625
Number ports	40	40	40	40
Single port area (m^2)	0.008	0.008	0.008	0.008
Single port radius (m)	0.050	0.050	0.050	0.050
Single port diameter (m)	0.100	0.100	0.100	0.100
Port discharge velocity (m/s)	0.516	1.545	1.287	3.863
Densimetric Froude number	3.007	9.004	7.500	22.518

The focus of the conceptual design of the diffuser was to determine design parameters that would produce an operational outfall as opposed to maximising the initial mixing of the wastewater. For the majority of the discharge scenarios, no matter what the number of ports, diameter of the ports or angle of the ports (all parameters that initial mixing of wastewater plumes are normally sensitive too), the individual jet plumes from each port interact very quickly after discharge, which results in the port characteristics having very little influence on the initial mixing of the wastewater plume. This is illustrated in Table 2-2, which presents CORMIX predictions of the wastewater plume behaviour 200 m from the outfall for different numbers of ports and 20,000 PWWF and a typical water depth and current speed condition previously modelled[2] - in this case a neap 95th percentile water depth of 10.8 m and corresponding current speed of 0.18 m/s. The only way to achieve additional initial mixing would be to increase the length of the diffuser, which for the current proposed outfall location would not be possible.

Scenarios beyond the 50,000 population discharge scenarios for this location have not been considered, since not only would a new diffuser design be required to accommodate the increases in flow, preliminary predictions from CORMIX also indicate that the ability to fully mix the wastewater plume throughout the vertical may not occur under some conditions (See Section 2.2).

[2] See DHI, 2014 for derivation of this and other schematic current and water depth conditions used for assessing the near-field dilution using CORMIX.

Table 2-2 Sensitivity of CORMIX predicted wastewater plume behaviour 200 m from the outfall for different numbers of ports and 20,000 PWWF with a neap 95th percentile water depth.

Plume Characteristics	Number of Ports			
	10	20	40	60
Dilution (fold)	648	648	648	648
Plume Width (m)	217	217	217	217
Plume Thickness (m)	8.0*	8.0*	8.0*	8.0*

*Attached to the surface.

CORMIX predictions of the wastewater plume characteristics 200 m downstream from the outfall for a range of neap tide conditions and discharge scenarios are presented in Table 2-3 (again details of the derivation of these schematic conditions are outlined in DHI, 2014). Neap tide conditions have been considered since these produce the smallest current speeds when the least initial mixing of wastewater plume will occur. Except for 50,000 PWWF, with lower current speeds, it can be concluded that the wastewater plume will be essentially fully mixed throughout the vertical for whole window of the tide when discharge will occur.

Table 2-3 CORMIX predicted plume characteristics 200 m downstream from the outfall for a range of neap tide conditions and discharge scenarios.

	Neap 5th Percentile	Neap 50th Percentile	Neap 95th Percentile
Water Depth (m)	9.1	9.9	10.8
Mean Current Speed (m/s)	0.31	0.37	0.18
20,000 ADWF			
Dilution (fold)	2155	2793	1974
Plume Width (m)	124	124	170
Plume Thickness (m)	Fully mixed	Fully mixed	10.4*
20,000 PWWF			
Dilution (fold)	725	937	648
Plume Width (m)	124	124	217
Plume Thickness (m)	Fully mixed	Fully mixed	8.0*
50,000 ADWF			
Dilution (fold)	869	1124	781
Plume Width (m)	124	124	210
Plume Thickness (m)	Fully mixed	Fully mixed	8.4*

	Neap 5th Percentile	Neap 50th Percentile	Neap 95th Percentile
50,000 PWWF			
Dilution (fold)	409	456	262
Plume Width (m)	189	150	260
Plume Thickness (m)	8.5*	Fully mixed	6.8*

*Attached to the surface.

2.2 Assessment of Near-Field Dilutions for 100,000 PE

During the early part of this study one option considered was combining the planned growth in Clarks Beach, Waiuku and Kingseat with planned growth in Pukekohe area (currently served by the Pukekohe WWTP). Such a scenario would result in a population equivalent of 100,000.

For discharge scenarios beyond the 50,000 PE to achieve full mixing throughout the water column (and thereby maximise the initial dilution achieved at the discharge site) either a revised diffuser design would be required for the Clarks Beach 12th Green Mid-Channel discharge site or, an alternative discharge location may need to be considered.

A site immediately offshore of Karaka Point (Figure 2-2 and Figure 2-3) provides greater water depth, stronger tidal currents and greater channel width to accommodate a diffuser compared to the Clarks Beach 12th Green Mid-Channel discharge site (Figure 2-1).

A comparison of the CORMIX predicted plume behaviour for the 100,000 PE, PWWF scenario (the highest discharge scenario initial considered) 200 m downstream from an outfall (with conceptual diffuser design presented in Table 2-4) is shown in Table 2-5 for the Clarks Beach 12th Green Mid-Channel discharge site and an outfall offshore of Karaka Point. For the majority of the time the plume is fully mixed through the water column for the Karaka Point Mid-Channel site, unlike the Clarks Beach 12th Green Mid-Channel discharge site when the plume will often not be fully mixed for the 100,000 PE, PWWF scenario. Significantly more initial mixing and a higher dilution is achieved at the Karaka Point Mid-Channel site as a result of both the higher current speeds at this site and the ability to be able to design a longer diffuser, due to the wider channel dimensions at this location.

However, as discussed in detail in Section 3 (where alternative discharge sites are assessed), a discharge at the Karaka Point Mid-Channel site could result in higher concentration wastewater being transported across to the Clarks Beach inter-tidal area (directly east of the discharge point) and directly onshore to the area adjacent to the camp ground area off Karaka Point than for a similar discharge from the Clarks Beach 12th Green Mid-Channel site.

Figure 2-2 Aerial photo of Clarks Beach showing the location of a alternative outfall location off Karaka Point in relation to the Clarks Beach 12th Green Discharge site.

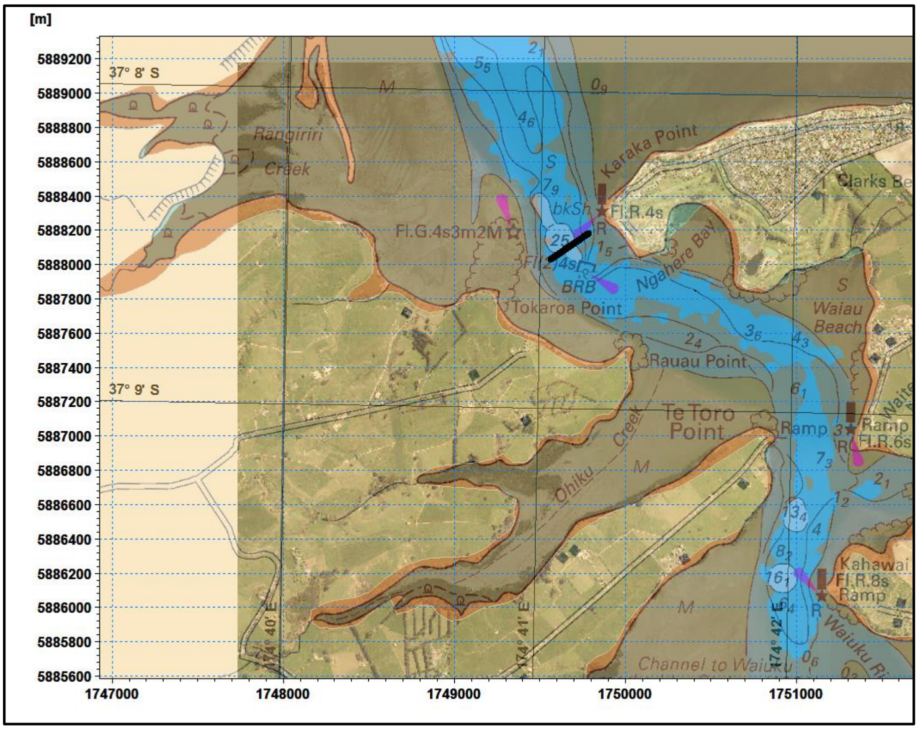

Figure 2-3 Indication of maximum possible diffuser length at the Karaka Point Mid-Channel discharge site. The blue shading indicates depths greater than 7 m below chart datum providing an indication of the width of channel available for placement of an outfall. The blue shading indicates depths greater than 7 m (below chart datum) and the black line is 180m in length, providing an indication of the width of channel available for placement of an outfall. Coordinates in NZTM.

Table 2-4 Conceptual diffuser design to accommodate 100,000 PE, PWWF at the Clarks Beach 12th Green and Karaka Point Mid-Channel sites based on ASCE (1970) and Williams (1985) criteria for minimum outfall flow and port to outfall area.

Design Parameters	Clarks Beach 12th Green Mid-Channel	Clarks Beach 12th Green Mid-Channel
Flow rate (m^3/s)	2.425	2.425
Diffuser length (m)	120	160
Pipe diameter (m)	1.200	1.200
Pipe area (m^2)	1.130	1.130
Pipe velocity (m/s)	2.145	2.145
Total port area (m^2)	0.628	0.628
Ratio port/pipe	0.556	0.556
Number ports	20	20
Single port area (m^2)	0.031	0.031
Single port radius (m)	0.100	0.100
Single port diameter (m)	0.200	0.200
Port discharge velocity (m/s)	3.861	3.861
Densimetric Froude number	15.916	15.916

Table 2-5 CORMIX predicted plume characteristics 200 m downstream from the outfall for a range of neap tide conditions and 100,000 PE, PWWF discharge scenario at the Clarks Beach 12th Green site and an alternative location offshore of Karaka Point.

	Clarks Beach 12th Green Mid-Channel			Karaka Point Mid-Channel		
	Neap 5th Percentile	Neap 50th Percentile	Neap 95th Percentile	Neap 5th Percentile	Neap 50th Percentile	Neap 95th Percentile
Water Depth (m)	9.1	9.9	10.8	12.5	13.4	14.2
Mean Current Speed (m/s)	0.31	0.37	0.18	0.41	0.51	0.31
Dilution (fold)	212	253	134	443	450	332
Plume Width (m)	192	193	284	208	164	242
Plume Thickness (m)	7.1*	8.6*	6.4*	Fully mixed	Fully mixed	10.8*

2.3 Conclusions – Near Field Dilution Assessment

This section of report provides an assessment of the potential for dilution in the immediate vicinity of a proposed outfall directly offshore of the existing Clarks Beach WWTP.

At the Clarks Beach 12th Green Mid-Channel site, an outfall 120 m long with forty 100 mm discharge ports would ensure that, under the majority of conditions that occur at the site, the wastewater plume becomes fully mixed in the water column thus maximising the achievable near-field dilution. Such an outfall would therefore provide a good level of initial dilution for the discharge rates being considered up to the 50,000 PE PWWF. Modelling shows that for lower discharge rates the number of operational ports could be reduced and a good level of dilution would still be achieved at the Clarks Beach 12th Green Mid-Channel site.

For the highest discharge rate being considered in detail (i.e. PWWF for a PE of 50,000) the wastewater plume at the Clarks Beach 12th Green Mid-Channel site may not be fully mixed in the vertical when tidal currents are lowest (i.e. just after the discharge commences and just before it ends). However, under such conditions reductions in contaminant concentrations come about due to the subsequent (far-field) dilution that occurs as the plume is transported away from the discharge site and into the Waiuku Channel in the south-west Manukau. The range of dilutions achieved 200 m downstream of the outfall would be between approximately 260-2800 depending on water depth, strength of the ambient tidal currents and discharge rate being considered.

For the highest discharge scenario initial considered (100,000 PE, PWWF) the initial dilution achieved at the Clarks Beach 12th Green Mid-Channel site is reduced due to the wastewater plume not being fully mixed in the water column for the majority of the time.

A discharge to the Karaka Point Mid-Channel would achieve better dilution for the 100,000 PE discharge scenario. However, because of the proximity of the discharge point to the Clarks Beach inter-tidal area (directly east of the discharge point) and to the shoreline adjacent to the camp ground area off Karaka Point, there is potential for higher contaminant concentrations in these areas compared to a similar discharge at the Clarks Beach 12th Green Mid-Channel site.

3 Assessment of Alternative Outfall Location

A number of alternative sites in both the south-west Manukau Harbour and a site offshore of the Awhitu Peninsula discharging to the Tasman Sea have been assessed.

The empirical formula for estimated initial dilution are only applicable for fully mixed plumes so the assessment of the alternative outfall locations has only been done for the lowest ADWF being considered (20,000 PE, ADWF, Table 1-1). For this discharge rate, typical diffuser designs at any of the alternative sites considered should provide full vertical mixing of the wastewater plume. This will therefore provide a valid comparison of the alternatives sites considered without the need for an in-depth assessment of diffuser designs at each of the sites.

Estimates of initial dilution that could be achieved at the alternative outfall sites using the empirical formula set out in the Appendix have been used to provide a comparative assessment of the potential alternative outfall sites.

It has been assumed that the same tidal staging of the discharges would occur at all alternate site within the south-west Manukau Harbour (i.e. High water plus 1 hours for four hours). For the offshore site it has been assumed that the discharge would not be tidally staged and would therefore consist of a continuous discharge of 0.052 m^3/s.

At each of the alternative sites, the predicted water depths and currents from the previously calibrated MIKE 21 model were extracted and used as input to the empirical formula set out in the Appendix.

3.1 South-West Manukau Harbour Sites

Time-series of predicted water depths and currents for the periods when a staged discharge would be occurring (High Water plus one hour for four hours) were extracted from the previously calibrated MIKE 21 hydrodynamic model. This data was then used in the empirical formula given in the Appendix to provide estimates of the range of dilutions that could be achieved at each of the south-west Manukau alternative sites (Figure 3-1).

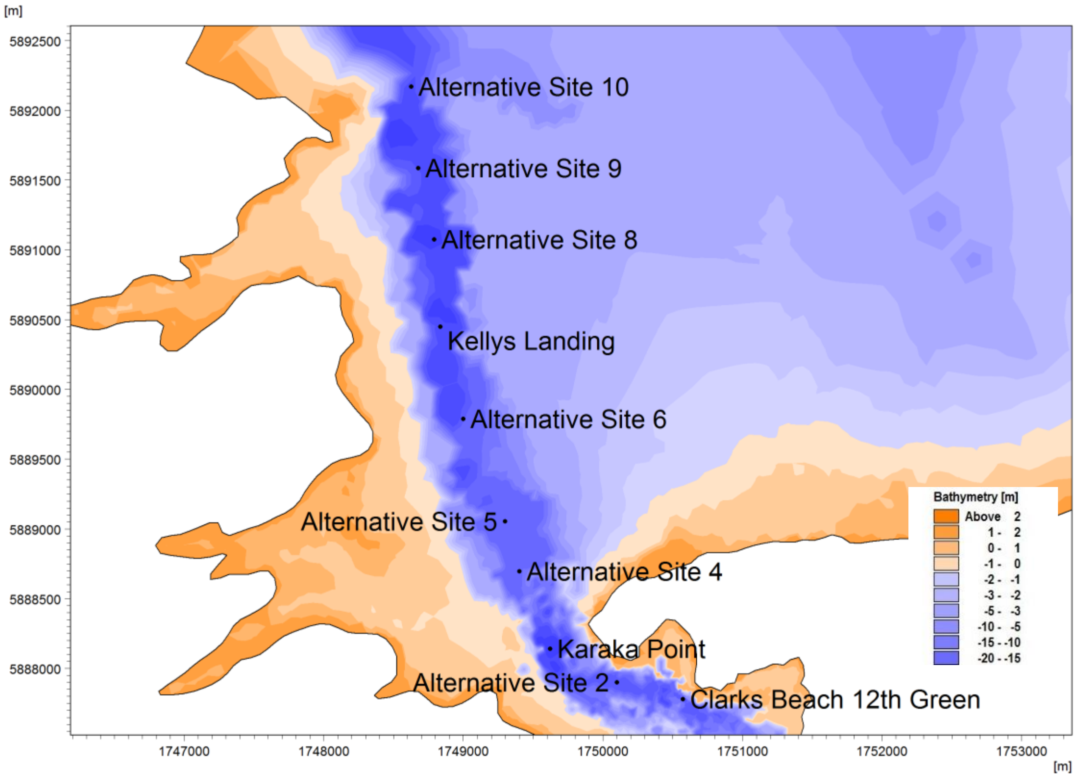

Figure 3-1 Potential alternative outfall sites within the south-west Manukau. The Clarks Beach 12th Green site is modelled in detail in other sections of this report. Coordinates are NZTM.

Table 3-1 shows the mean water depths, current speeds and estimated mean dilutions that could be achieved at each of these alternative outfall sites.

The following summarises the performance of each of the sites considered;

- The Clarks Beach 12th Green site and Site 2 provide very similar levels of dilution,
- The Karaka Point Site is deeper, has higher mean currents compared to the Clarks Beach 12th Green site and therefore provides greater dilution potential,
- Sites 4 and 5 have lower mean currents compared to the Clarks Beach 12th Green site which results in a corresponding reduction in dilution compared to the dilution achieved at the Clarks Beach 12th Green site, and
- Sites 6 through to 10 and the Kellys Landing site have significantly lower current speeds than the Clarks Beach 12th Green site and therefore provides less dilution potential (with best dilution achieved at the deeper of these sites).

Reruns of one of the previously modelled schematic hydrodynamics conditions (neap tide, no wind) were carried out to assess the potential wastewater plume footprints for Karaka Point, Alternative Site 4 and Kellys Point site compared to the same wastewater plume footprint for a discharge form the Clarks Beach 12th Green site. As for the previous study (DHI, 2014) the simulation assumes there are no decay, biological or chemical processes associated with the contaminant (i.e. contaminant behaves as a conservative tracer). This provides an indication of the relative extent of wastewater plume footprints at each of the sites considered.

Note that the empirical formula use a mean depth and current to estimate initial dilution while the model uses time-varying conditions. While no direct comparison should be made, the mean dilutions from the model runs provide similar levels of dilutions as those estimated by the empirical approach.

At the Karaka Point site, while the initial dilution is greater than at the Clarks Beach 12th Green site (Table 3-1), the stronger tidal current at this site produce a much longer zone where dilutions of less than ~500 are achieved compared to the Clarks Beach 12th Green site (Figure 3-2 compared to Figure 3-3). Because of this, there is potential for higher wastewater concentrations on the Clarks Beach inter-tidal area (directly east of the Karaka Point discharge point) compared to those that would occur for a discharge from the Clarks Beach 12th Green site. There is also potential for much higher concentrations to occur in the area immediately inshore from the Karaka Point discharge point adjacent to the camp ground area off Karaka Point.

Similarly, at Alternative Site 4 (Figure 3-4) because of the lower current speeds and shallower water depths the lower level of initial dilution achieved at this site could result in potential higher wastewater concentrations on the Clarks Beach inter-tidal area (directly east of the discharge point) compared to those that would occur for a discharge from the Clarks Beach 12th Green site.

For the Kellys Landing it can be seen that there is a relatively narrow band where dilutions of less than 300 are achieved (Figure 3-5). Because of the close proximity of this site to the Karaka Point headland and shoreline there is the potential (e.g. under north-westerly wind conditions) that higher concentration wastewater would reach the Clarks Beach inter-tidal area compared the concentrations that would occur under such conditions for a discharge from Clarks Beach 12th Green site.

The above analysis does not cover the full range of conditions that will occur at each of the alternative discharge sites. However, the model results do provide an indication of the relative impacts that the different discharge sites may have based on achievable initial dilutions and likely subsequent far-field dilutions and plume dynamics.

Table 3-1 Alternative outfall site data showing predicted mean water depths and mean current speeds during a staged 20,000 PE ADWF discharge and the predicted mean dilution achieved at each site based on empirical formula.

Alternative Site	Easting (NZTM)	Northing (NZTM)	Mean Depth for Staged Discharge	Mean Current Speed for Staged Discharge	Mean Near Field Dilution
Clarks Beach 12th Green	1750571	5887781	10.7	0.61	288
Alternative Site 2	1750100	5887900	11.4	0.52	285
Karaka Point	1749620	5888142	14.2	0.71	398
Alternative Site 4	1749400	5888698	9.7	0.46	171
Alternative Site 5	1749299	5889055	9.9	0.41	162
Alternative Site 6	1749000	5889789	11.6	0.24	127
Kellys Landing	1748834	5890448	13.9	0.20	146
Alternative Site 8	1748789	5891076	16.5	0.16	173
Alternative Site 9	1748675	5891585	12.9	0.19	123
Alternative Site 10	1748625	5892169	11.2	0.22	105

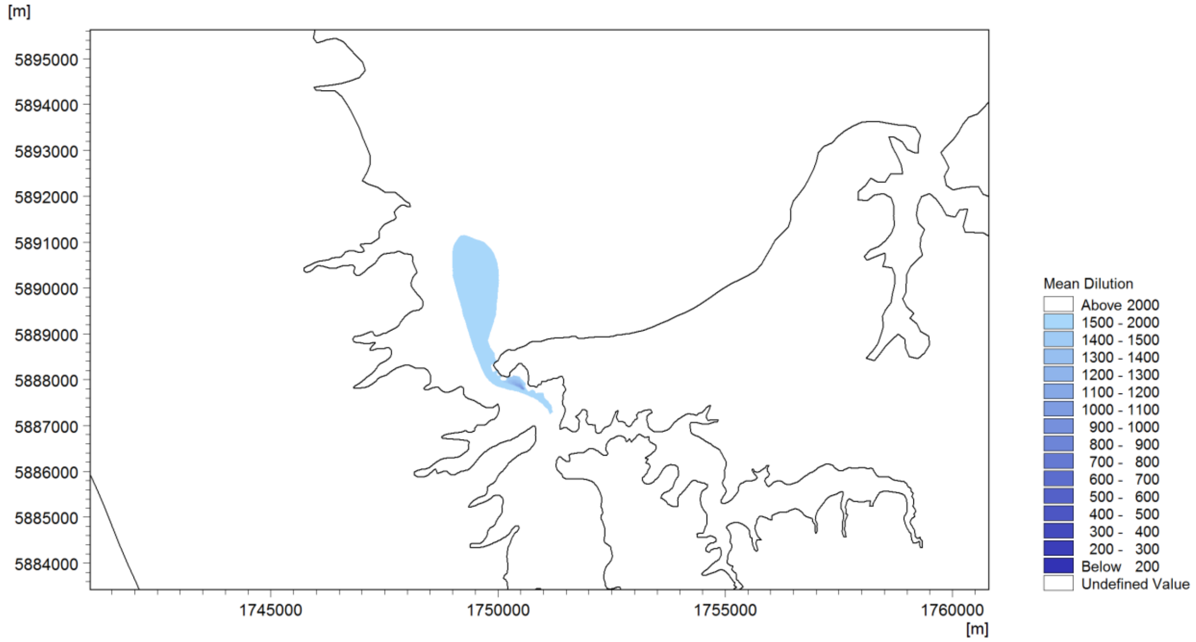

Figure 3-2 Mean predicted dilution for a conservative tracer, ADWF staged discharge of 0.162 m^3/s (20,000 PE) at the Clarks Beach 12th Green site (Figure 3-1). Simulation covers a 7 day period of neap tides with no winds. Coordinates are NZTM.

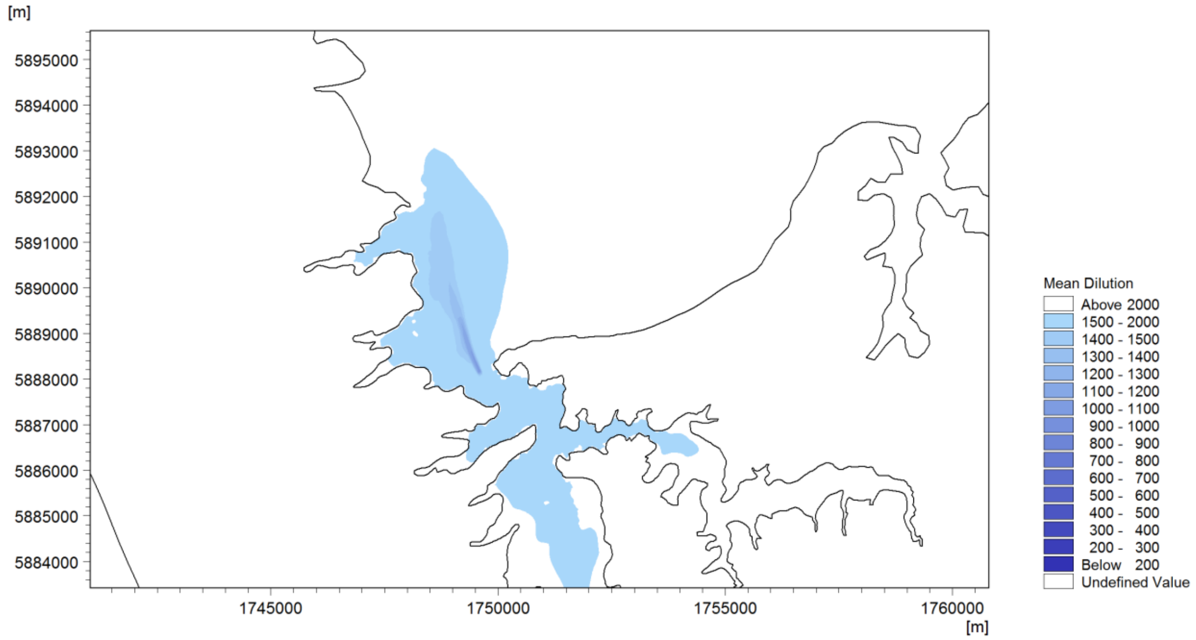

Figure 3-3 Mean predicted dilution for a conservative tracer, ADWF staged discharge of 0.162 m^3/s (20,000 PE) at the Karaka Point site (Figure 3-1) within the deepest section of the channel. Simulation covers a 7 day period of neap tides with no winds. Coordinates are NZTM.

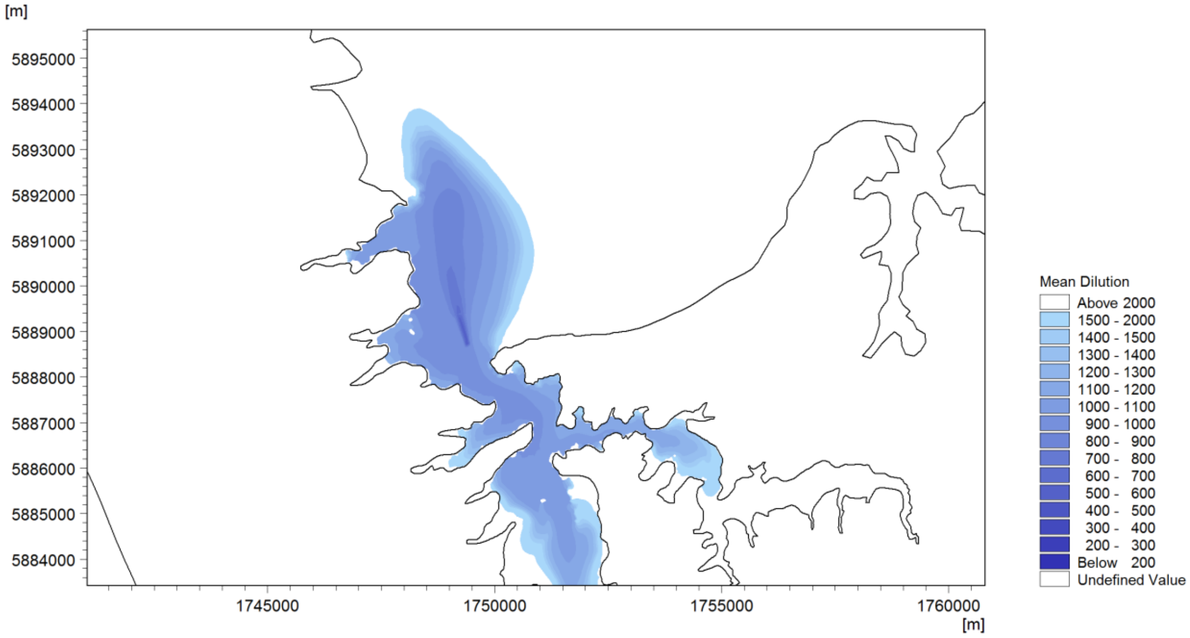

Figure 3-4 Mean predicted dilution for a conservative tracer, ADWF staged discharge of 0.162 m^3/s (20,000 PE) at Alternative Site 4 (Figure 3-1) just offshore of Clarks Beach. Simulation covers a 7 day period of neap tides with no winds. Coordinates are NZTM.

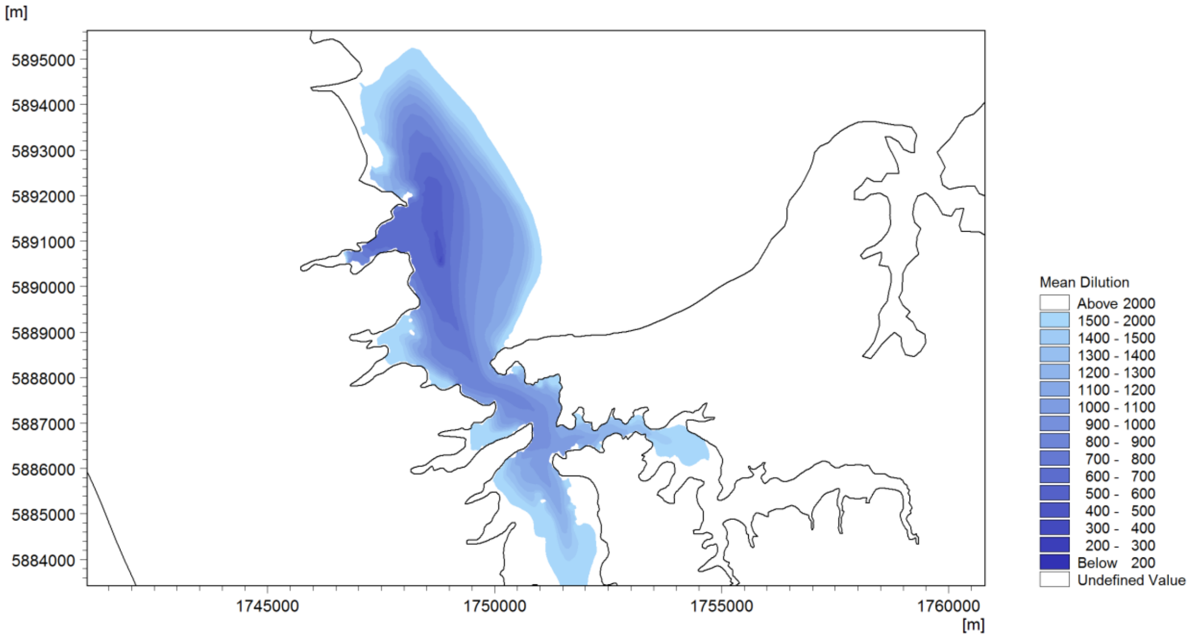

Figure 3-5 Mean predicted dilution for a conservative tracer, ADWF staged discharge of 0.162 m^3/s (20,000 PE) at Kellys Landing site (Figure 3-1). Simulation covers a 7 day period of neap tides with no winds. Coordinates are NZTM.

3.2 Offshore Site

For an alternative site offshore of the Awhitu Peninsula (Figure 3-6) three representative model locations in terms of water depth were chosen.

The calibrated MIKE 21 hydrodynamic model has been well calibrated within the Manukau Harbour and uses offshore tidal and global scale winds for boundary conditions. However no observations of currents have been made in the area offshore of the Awhitu Peninsula. Sutton & Bowen (2011) indicate that near-shore currents respond to wind forcing in a complex manner along the West coast of New Zealand and that mean longshore currents may be as low as 0.08 m/s. Data presented in Johnson and McComb (2010) indicate that at times there are relatively strong shore parallel currents offshore of the Manukau Heads.

Data extracted from the calibrated MIKE 21 hydrodynamic model at the mid-point of the transect shown in Figure 3-6 indicate that there are relatively weak tidal currents at the offshore site and wind driven currents can peak at over 0.4 m/s. The tidal current constituent amplitudes (i.e. peak tidal currents) are made up of M_2, S_2 and N_2 components of 0.17, 0.05, 0.03 m/s respectively. The distribution of the tidal and non-tidal components of currents are shown in Figure 3-7.

Such data should be viewed as very indicative of the current climate offshore of the Awhitu Peninsula and any further assessment of an alternative offshore site should include collection of current (and wave) data to validate the existing model in the offshore area of interest.

Based on the predicted currents offshore of the Awhitu Peninsula the empirical formula set out in the Appendix were used to quantify the potential near-field dilution that could be achieved for a number of different port configurations at each of the outfall depths being considered (Table 3-2). The mean dilution achieved for all of the port/outfall lengths considered is around 500 which is comparable with the best dilution achieved at the alternative sites in the south-west Manukau (Table 3-1). Given the distance offshore and the predominant westerly winds at the site (DHI, 2014) dilutions at sites immediate onshore of the outfall would be relatively high (of the order of 5,000). However, further work would be required to fully quantify potential impacts along the shoreline once the existing model had been validated in the offshore area of interest.

This data shows that the potential for dilution for an offshore site is relatively large due to 1) the opportunity for a continuous discharge 2) greater water depths than at some of the alternative sites in the south-west Manukau 3) no physical restrictions on outfall length and/or number of diffusers.

Figure 3-6 Location of transect for potential outfall sites offshore of the Awhitu Peninsula at water depths of 6, 8 and 10 m below Chart Datum.

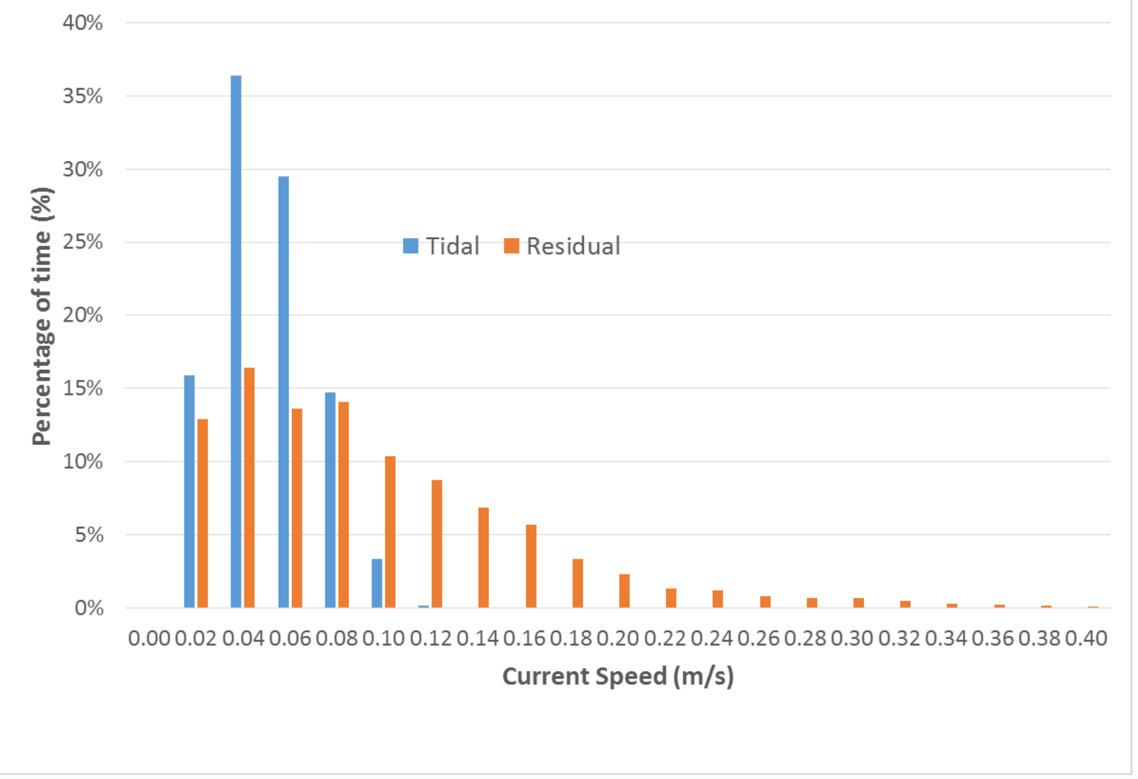

Figure 3-7 Distribution of tidal and non-tidal (residual) component of predicted currents offshore of the Awhitu Peninsula (Figure 3-6).

Table 3-2 Potential mean near field dilution for an offshore outfall site.

Water Depth (m, relative to Chart Datum)	Distance Offshore (m)	Number of Ports						
		8	10	12	14	16	18	20
6	800 m	159	198	240	281	309	360	394
8	1200 m	275	338	405	464	540	617	691
10	1500 m	404	507	628	720	813	926	1019

3.3 Conclusions – Alternative Sites

In addition to a proposed outfall site directly offshore of the existing Clarks Beach WWTP (the Clarks Beach 12th Green site) discharges to a number of alternative locations have been considered.

An outfall site offshore of the Awhitu Peninsula discharging to the Tasman Sea would provide the potential for much greater dilution than could be achieved at sites within the south-west Manukau.

The Clarks Beach 12th Green site provides a good level of near-field dilution. Other sites provide either less initial dilution or may lead to higher wastewater concentrations occurring at inter-tidal sites in and around Clarks Beach and Karaka Point.

4 Harbour Wide Freshwater Effects

To assess the potential effects of the proposed wastewater discharge on harbour wide salinities, the existing harbour wide model has been run with all the major freshwater inflows to the Manukau Harbour and the discharges from the existing Waiuku, Clarks Beach, Kingseat and Mangere WWTPs. This model has been calibrated against long-term salinity monitoring data at a number of sites around the harbour.

The calibrated model was then used to assess the effect that a future Average Dry Weather Flow (ADWF) treated wastewater discharge at Clarks Beach for a 50,000 population may have on salinity in the immediate vicinity of the discharge and also at a Harbour wide scale. This provides a worst case scenario in terms of assessing the potential effects of the proposed discharge on harbour wide salinities. Discharge rates less than the 50,000 PE discharge will have less of an effect.

4.1 Catchment Sources

For each of the catchments shown in Figure 4-1, a mean annual freshwater inflow was derived. For the gauged catchments (Waitangi, Mauku and Puhinui Streams) the mean inflow calculated from the available records were used (Table 4-1).

Freshwater inflows for the catchments identified during the South-East Manukau study (Green, 2008) were quantified using the TP108 approach (Auckland Regional Council, 1999), cross-correlated with the gauged mean annual flow for the Puhinui Stream.

The ratio of catchment area for the Waitangi catchment to the catchment area of the Awhitu and Clarks Beach catchments was used to scale the observed Waitangi mean annual flow to provide mean freshwater inflows for these catchments.

Catchments in the north-east section of the Harbour are limited in size and so the contribution of these to the overall salinities will be minor compared to the catchments to the south and east of the Harbour. As such, no freshwater inflow was assigned to the catchments from the airport through to Titirangi/Huia.

For the Titirangi/Huia catchments, it was assumed that the average freshwater yield (m^3/s/ha) from all the above catchments would be applicable. The freshwater inflow for these two catchment is then just the sum of the average freshwater yield (0.000048 m^3/s/ha) multiplied by this catchment area (9497 ha).

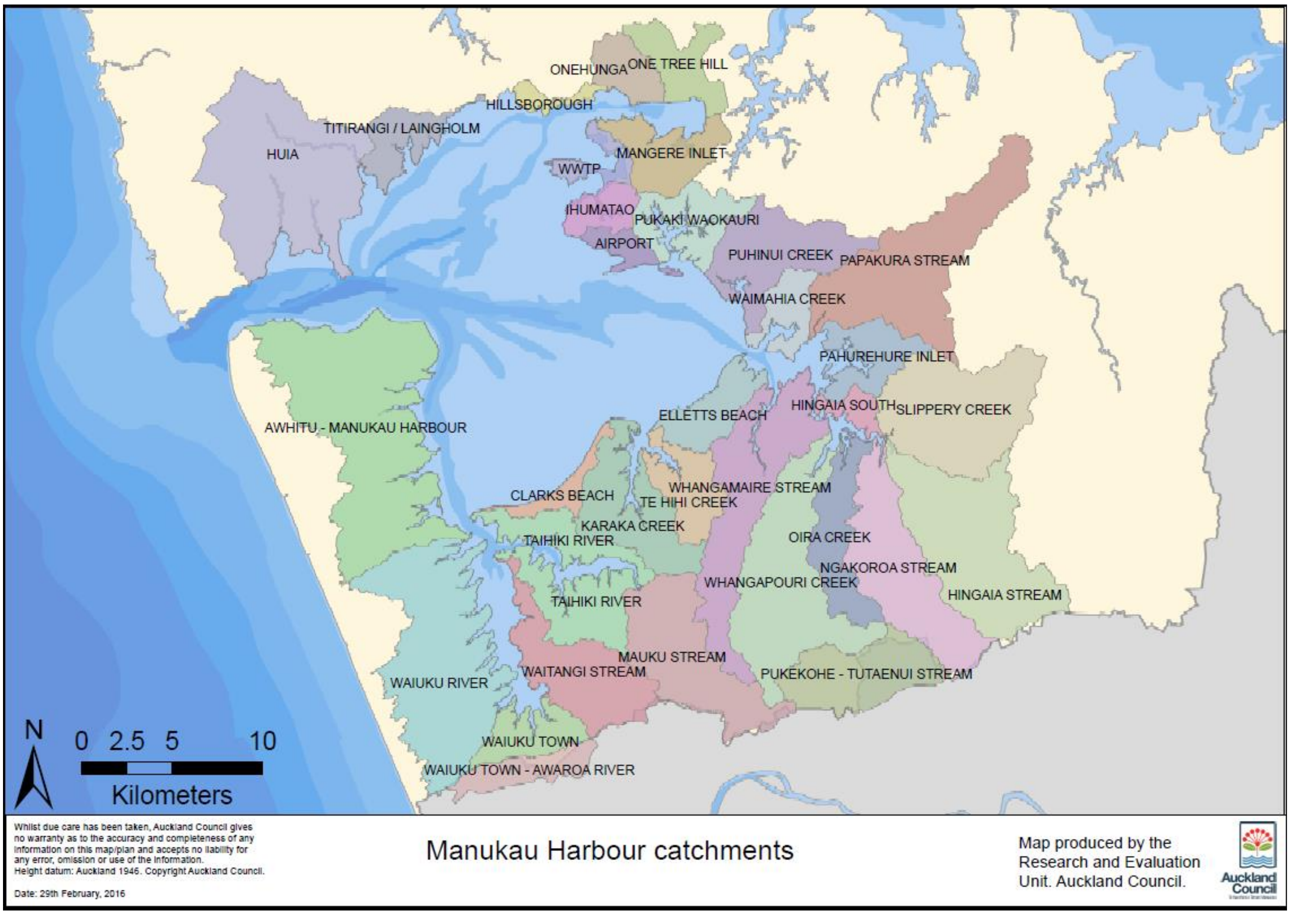

Figure 4-1 Manukau Harbour catchments (Auckland Council).

Table 4-1 Estimated mean annual freshwater inflows for the major sub-catchments of the Manukau Harbour.

Catchment (see Figure 4-1)	Method to derive mean annual freshwater inflow	Estimated Mean Annual Inflow (m^3/s)
Whangamarie Stream	TP108 from data in Green (2008)	0.103
Elletts Beach		0.026
Karaka Creek		0.131
Hingaia South, Whangapouri Creek, Oira Creek, Ngakoroa Stream, Hingaia Stream, Slippery Creek		0.932
Pahurehure Inlet,		0.077
Papakura Stream		0.961
Waimahia Creek		0.076
Puhinui Creek		0.200
Pukaki Waokauri		0.192
Awhitu	Based on catchment area and gauged flow from Waitangi catchment	0.555
Clarks Beach		0.051
Waitangi Stream/Waiuku Town & River	From Auckland Council Gauging data	0.240
Mauku Stream/Taihiki River		0.360
Puhinui Creek		0.200
Huia/Titirangi	Based on ratio of this catchment area to sum of all other catchment areas and predicted mean freshwater yield for above catchments	0.455

4.2 Existing Discharge at Clarks Beach

Using the freshwater inflows listed in Table 4-1 and the mean existing WWTP discharge values (supplied by Watercare) for Waiuku (tidally staged at 0.0943 m^3/s), Clarks Beach (continuous at 0.007 m^3/s), Kingseat (continuous at 0.0004 m^3/s) and Mangere (tidally staged at 15 m^3/s) an annual model run was carried out for 1991 using the existing calibrated hydrodynamic model (DHI, 2014). This year is representative of El Niño conditions when stronger persistent westerly winds results in more widespread movement of the treated wastewater across the southern area of the Manukau.

Results from this model run were compared to the long term salinity monitoring data from Auckland Council (Figure 4-2). These results show that, at the majority of the sites, the long term average salinity is well matched by the model. The root mean square error was 0.57 PSU[3]. The calibration shows that the mixing of freshwater sources is being well simulated by the model and that the model can therefore be used confidently, to predict the potential effects of the proposed WWTP discharge on salinities within the Harbour.

The predicted mean salinities across the south-west sector of the Harbour (Figure 4-3) show the relative influences of the catchments to the south-east, the higher salinities towards the mouth of the Harbour (influenced by the mixing of oceanic waters) and the relative effects of the Mauku and Waiuku freshwater discharges.

This data shows that the influence of the freshwater inflows from the Mauku and Waiuku Rivers and the exchange of more saline oceanic water (from towards the entrance) have a much greater influence on predicted salinities in the vicinity of the existing discharge location compared to the effect of the existing continuous discharge (which is minimal and very localised). If this was not the case, a localised 'hotspot' of low salinity at the discharge location would be noticeable.

[3] Note that in this report the term PSU (practical salinity units) is used. Often salinities are reported in part-per-thousand (ppt). Values of salinity in PSU and ppt are nearly equivalent.

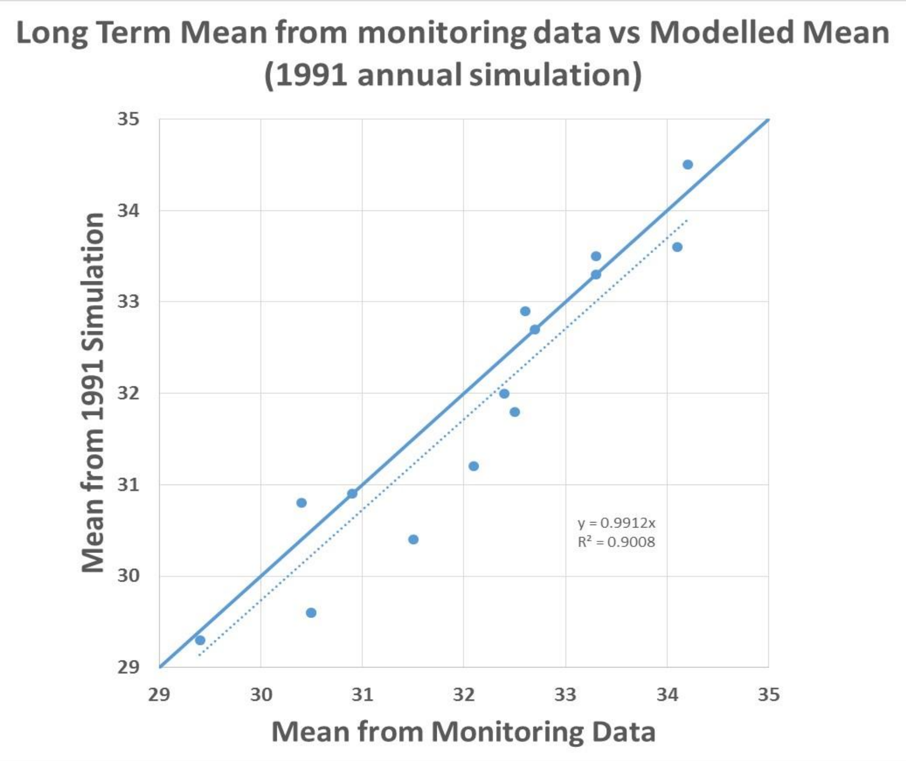

Figure 4-2 Comparison of long term Auckland Council monitoring data and results from the 1991 simulation with the mean annual catchment inflows for the Manukau Harbour (Table 4-1) and the existing Waiuku, Clarks Beach, Kingseat and Mangere WWTP discharges.

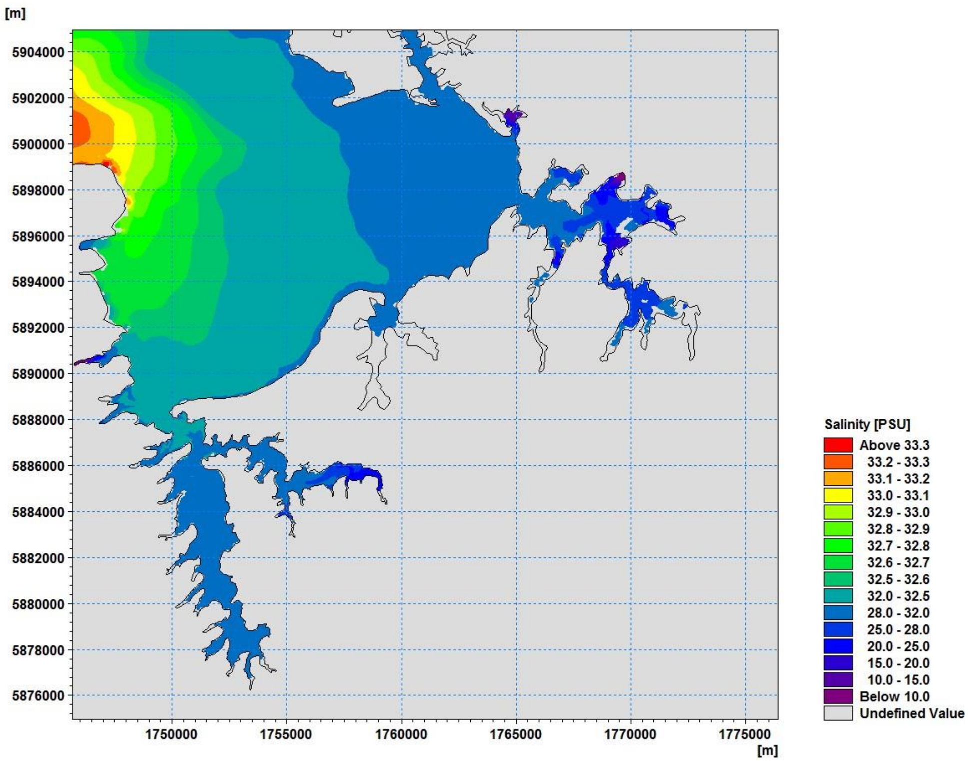

Figure 4-3 Predicted mean salinities for the 1991 simulation within the south-west sector of the Manukau Harbour with existing WWTP discharges (Mangere, Kingseat, Waiuku and Clarks) and mean catchment freshwater inflows. Note the non-linear salinity scale. Coordinates are NZTM.

4.3 Scenario with Proposed 50,000 PE ADWF

The calibrated model was re-run using the same catchment inflows, and the Mangere and Kingseat WWTP discharges of 15 m^3/s and 0.0004 m^3/s respectively. Note that the Kingseat freshwater inflow (of 0.103 m^3/s – see Table 4-1) was still included in the model run. The existing Waiuku and Clarks Beach WWTP discharges were removed from the simulation and a 50000 PE ADWF wastewater discharge was include at the Clarks Beach 12th Green discharge site. This simulation therefore provides a worst case scenario in terms of assessing the potential effects of the proposed discharge on harbour wide salinities. Discharges at lower rates will have less of an effect that the discharge modelled.

Data in Table 4-2 shows the predicted reductions in minimum, mean and maximum salinities at the Auckland Council salinity monitoring sites with the introduction of the proposed 50,000 PE ADWF.

It can be seen that at all sites (except for the Waiuku Town Basin), the predicted changes in salinities are all less than 0.01 PSU. At the Waiuku Town Basin site it is predicted that the minimum and maximum salinities will be lower by 0.02 PSU and the mean salinity at the site would be lowered by 0.05 PSU. Note that this site has the largest observed ranges of salinities in order of 28 - 31 PSU (Kelly and Sims-Smith, 2015).

Data in Table 4-3 shows the predicted salinities (minimum, mean and maximum) at sites in the immediate vicinity of the Clarks Beach 12th Green discharge site (Figure 4-4) for the simulation with the existing Clarks Beach WWTP discharge and the predicted reduction in salinity due to the introduction of the proposed 50,000 PE ADWF. The proposed discharge only occurs on the outgoing tide and there is no discharge occurring at low water, when salinities will be at their minimum. Therefore minimum salinities are predicted to be reduced by less than 0.01 PSU. The mean salinities at these sites are reduced by 0.01 PSU. This is due to the combination of the discharge only occurring for part of the tidal cycle and the fact that the plume will mix with ambient saline water as it rises through the water column. Maximum salinities are reduced by between 0.03 - 0.04 PSU. These changes in salinity need to be put in context of the ranges of salinities that are predicted to occur at this site – 31.40 - 32.21 PSU (range =0.81 PSU).

Data in Table 4-4 shows the predicted salinities (minimum, mean and maximum) at sites in Waiuku Channel north of the proposed outfall (Figure 4-5), for the simulation with the existing Clarks Beach WWTP discharge and the predicted reduction in salinity due to the introduction of the proposed 50,000 PE ADWF.

Minimum and mean salinities are reduced by less than 0.01 PSU while maximum salinities are predicted to be reduced by less than 0.03 PSU. These changes in salinity need to be put in context of the ranges of salinities that are predicted to occur at this site – 32.42 to 31.51 PSU (range = 0.91 PSU).

Data in Table 4-5 shows the predicted salinities (minimum, mean and maximum) at inter-tidal sites in the Mauku and Waiuku Rivers (Figure 4-6), for the simulation with the existing Clarks Beach WWTP discharge and the predicted reduction in salinity due to the introduction of the proposed 50,000 PE ADWF.

Minimum salinities are either not changed or are changed by less than 0.01 PSU. Mean salinities at these sites are reduced by less than 0.05 PSU and maximum salinities are reduced by less than 0.03 PSU. These changes in salinity need to be put in context of the predicted ranges of salinities that are predicted to occur at this site – 30.53 to 32.2 PSU (range = 1.67 PSU).

Data in Table 4-6 shows the predicted salinities (minimum, mean and maximum) at sites in Waiuku Channel north of the proposed outfall (Figure 4-7), for the simulation with the existing

Clarks Beach WWTP discharge and the predicted reduction in salinity due to the introduction of the proposed 50,000 PE ADWF.

Minimum salinities are either not changed or are changed by less than 0.01 PSU. Mean and maximum salinities at these sites are reduced by less than 0.02 PSU.

These changes in salinity need to be put in context of the predicted ranges of salinities that are predicted to occur at this site – 31.24 to 32.30 PSU (range = 1.06 PSU).

Table 4-2 Reductions in predicted minimum, mean and maximum salinities at Auckland Council monitoring sites due to a proposed 50000 PE, ADWF treated wastewater discharge at the Clarks Beach 12th Green discharge site and removal of Waiuku WWTP discharge compared to predictions with existing WWTP discharges (Waiuku, Clarks, Kingseat and Mangere) and mean catchment freshwater inflows.

Auckland Council Monitoring Site	Reduction In Minimum Salinity (PSU)	Reduction in Mean Salinity (PSU)	Reduction In Maximum Salinity (PSU)	Mean Salinity from Monitoring Data (PSU)
Harbour Mouth	<0.01	<0.01	<0.01	34.2
HWQ 70	0	<0.01	<0.01	34.1
HWQ 60	0	<0.01	<0.01	33.3
Grahams	0	0	<0.01	33.3
Clarks	<0.01	0.01	0.03	32.7
Titirangi	0	<0.01	<0.01	32.6
HWQ 30	0	<0.01	<0.01	32.5
HWQ80	0	0.01	<0.01	32.4
Nga kuia	<0.01	<0.01	<0.01	32.1
Puketutu	<0.01	<0.01	<0.01	31.5
Weymouth	0.005	0.01	<0.01	30.9
HWQ 10	0	0	<0.01	30.5
Wairopa	0	0	<0.01	30.5
HWQ 40	<0.01	<0.01	<0.01	30.4
Waiuku Town Basin	0.02	0.05	0.02	29.4

Table 4-3 Comparison of predicted minimum, mean and maximum salinities at sites near the proposed Clarks Beach outfall (Figure 4-4) with existing WWTP discharges (Waiuku, Clarks, Kingseat and Mangere) and mean catchment freshwater inflows and the change in salinity due to a proposed 50000 PE, ADWF treated wastewater discharge at the Clarks Beach 12th Green discharge site and removal of Waiuku WWTP discharge.

Site	Existing WWTP Discharges and Catchment Inputs			Mangere and Kingseat WWTP and Catchment Inputs 50000 PE, ADWF at Clarks		
	Minimum Salinity (PSU)	Mean Salinity (PSU)	Maximum Salinity (PSU)	Reduction in Minimum Salinity (PSU)	Reduction in Mean Salinity (PSU)	Reduction in Maximum Salinity (PSU)
Salinity Site 1 Clarks Beach 12th Green	31.53	32.72	32.19	<0.01	0.01	0.03
Salinity Site 2 Waiuku River	31.56	32.72	32.21	<0.01	0.01	0.03
Salinity Site 3 Waiuku River	31.40	32.73	32.07	<0.01	0.01	0.04
Salinity Site 4 Waiuku River	31.42	32.74	32.09	<0.01	0.01	0.04
Salinity Site 5 Waiuku River	31.43	32.74	32.11	<0.01	0.01	0.04
Salinity Site 6 Waiuku River	31.49	32.74	32.15	<0.01	0.01	0.04
Salinity Site 7 Waiuku River	31.48	32.75	32.17	<0.01	0.01	0.03

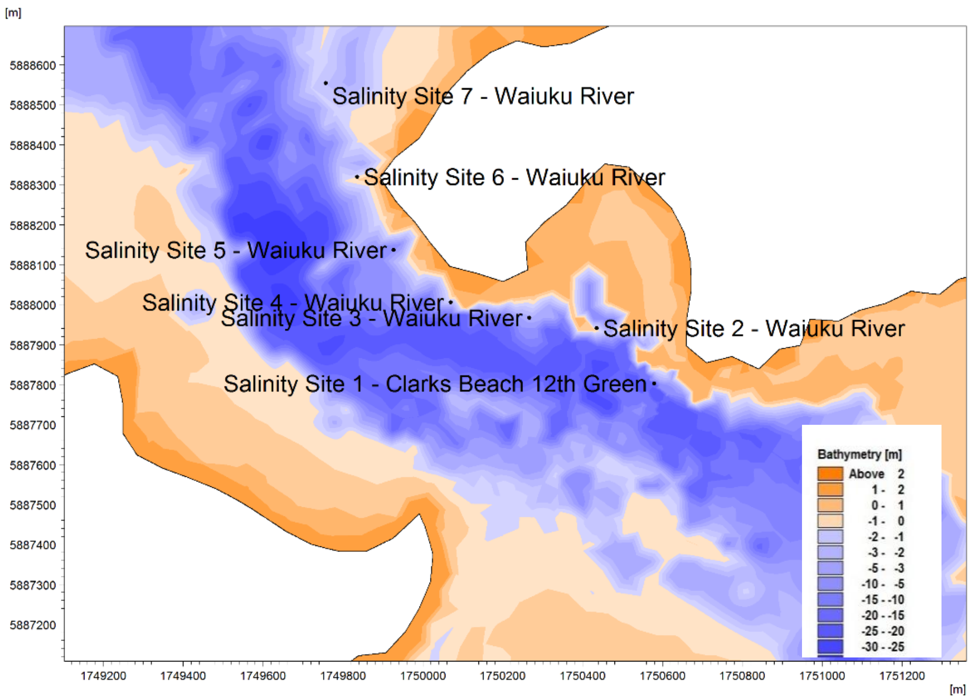

Figure 4-4 Salinity sites in the immediate vicinity of the Clarks Beach 12th Green discharge site.

Table 4-4 Comparison of predicted minimum, mean and maximum salinities in the Waiuku Channel north of the proposed Clarks Beach outfall (Figure 4-5) with existing WWTP discharges (Waiuku, Clarks, Kingseat and Mangere) and mean catchment freshwater inflows and the change in salinity due to a proposed 50000 PE, ADWF treated wastewater discharge at the Clarks Beach 12th Green discharge site and removal of Waiuku WWTP discharge.

Site	Existing WWTP Discharges and Catchment Inputs			Mangere and Kingseat WWTP and Catchment Inputs plus 50000 PE, ADWF at Clarks		
	Minimum Salinity (PSU)	Mean Salinity (PSU)	Maximum Salinity (PSU)	Reduction in Minimum Salinity (PSU)	Reduction in Mean Salinity (PSU)	Reduction in Maximum Salinity (PSU)
Salinity Site 1 Waiuku Channel	31.51	32.78	32.18	<0.01	<0.01	0.03
Salinity Site 2 Waiuku Channel	31.51	32.82	32.21	<0.01	<0.01	0.03
Salinity Site 3 Waiuku Channel	31.53	32.83	32.27	<0.01	<0.01	0.02
Salinity Site 4 Waiuku Channel	31.57	32.83	32.34	<0.01	<0.01	0.02
Salinity Site 5 Waiuku Channel	31.62	32.83	32.42	<0.01	<0.01	0.01

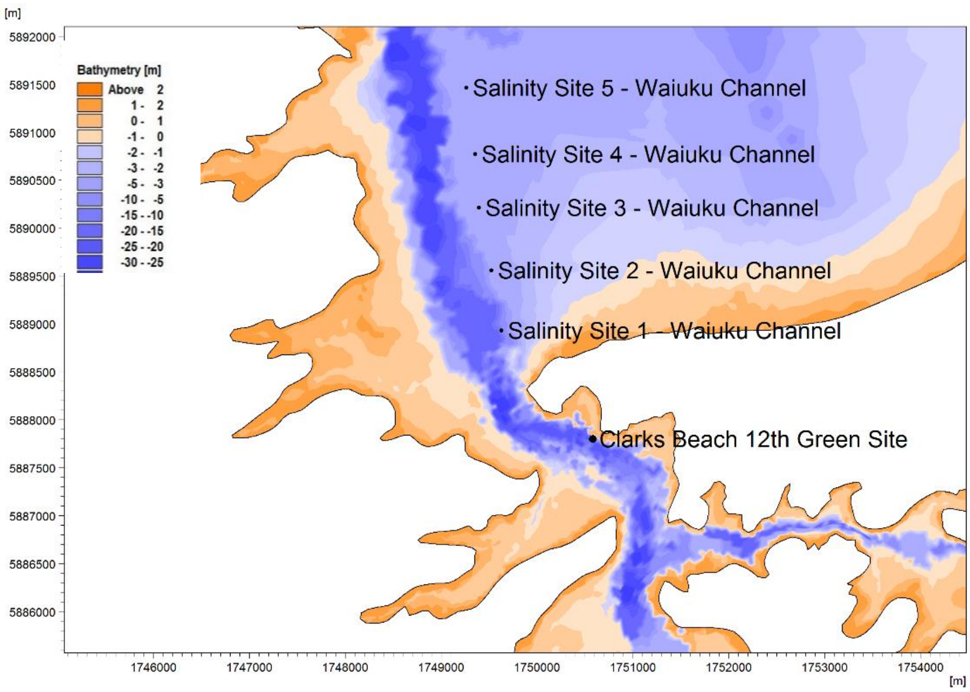

Figure 4-5 Salinity sites in the Waiuku Channel, north of Clarks Beach. Also shown location of the Clarks Beach 12th Green discharge site. Coordinates are NZTM.

Table 4-5 Comparison of predicted minimum, mean and maximum salinities at inter-tidal sites in the Mauku and Waiuku Rivers (Figure 4-6) with existing WWTP discharges (Waiuku, Clarks, Kingseat and Mangere) and mean catchment freshwater inflows and the change in salinity due to a proposed 50000 PE, ADWF treated wastewater discharge at the Clarks Beach 12th Green discharge site and removal of Waiuku WWTP discharge.

Site	Existing WWTP Discharges and Catchment Inputs			Mangere and Kingseat WWTP and Catchment Inputs plus 50000 PE, ADWF at Clarks		
	Minimum Salinity (PSU)	Mean Salinity (PSU)	Maximum Salinity (PSU)	Reduction in Minimum Salinity (PSU)	Reduction in Mean Salinity (PSU)	Reduction in Maximum Salinity (PSU)
Salinity Site 1 Waiuku inter-tidal	31.24	32.46	31.81	0	0.02	0.03
Salinity Site 2 Waiuku inter-tidal	31.41	32.42	31.74	0	0.05	0.02
Salinity Site 3 Waiuku inter-tidal	30.53	32.60	31.66	<0.01	0.03	0.03
Salinity Site 4 Waiuku inter-tidal	31.42	32.67	32.06	0	<0.01	0.03
Salinity Site 5 Waiuku inter-tidal	31.50	32.62	32.09	<0.01	0.03	0.03
Salinity Site 6 Waiuku inter-tidal	31.56	32.74	32.20	0	<0.01	0.02

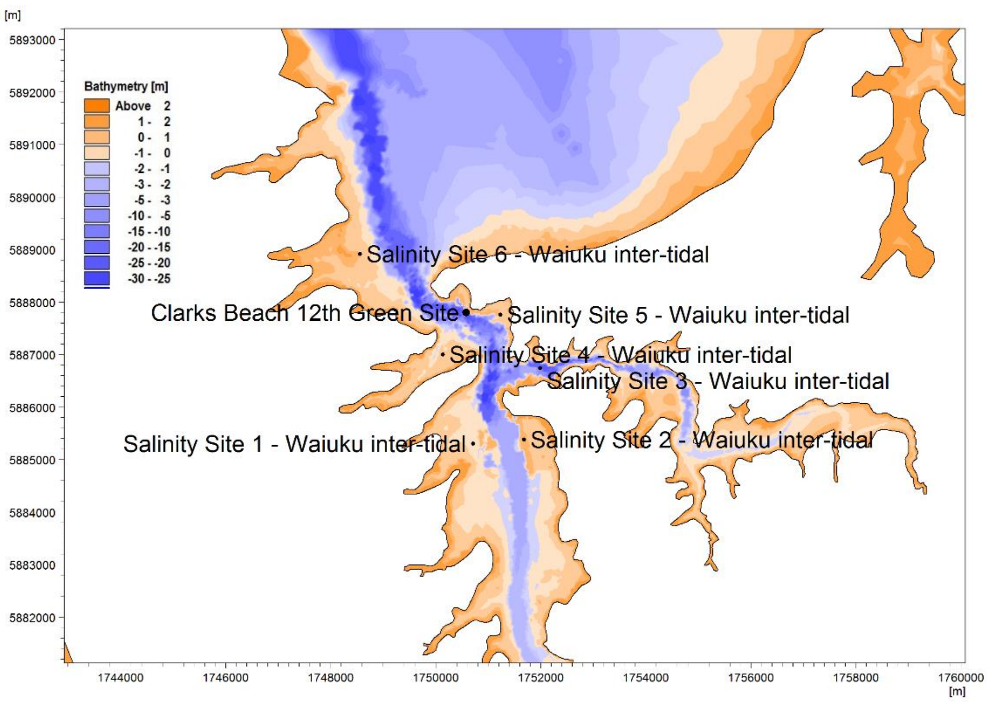

Figure 4-6 Salinity sites on intertidal areas within the Waiuku and Mauku Rivers. Also shown location of the Clarks Beach 12th Green discharge site. Coordinates are NZTM.

Table 4-6 Comparison of predicted minimum, mean and maximum salinities at site just offshore of Clarks Beach (Figure 4-7) with existing WWTP discharges (Waiuku, Clarks, Kingseat and Mangere) and mean catchment freshwater inflows and the change in salinity due to a proposed 50000 PE, ADWF treated wastewater discharge at the Clarks Beach 12th Green discharge site and removal of Waiuku WWTP discharge.

Site	Existing WWTP Discharges and Catchment Inputs			Mangere and Kingseat WWTP and Catchment Inputs plus 50000 PE, ADWF at Clarks		
	Minimum Salinity (PSU)	Mean Salinity (PSU)	Minimum Salinity (PSU)	Reduction in Minimum Salinity (PSU)	Reduction in Mean Salinity (PSU)	Reduction in Maximum Salinity (PSU)
Salinity Site 1 Clarks Beach	31.63	32.75	32.30	<0.01	0.01	0.02
Salinity Site 2 Clarks Beach	31.66	32.73	32.27	0	0.01	0.02
Salinity Site 3 Clarks Beach	31.65	32.74	32.26	0	0.01	0.02
Salinity Site 4 Clarks Beach	31.24	32.70	32.17	0	0.01	0.02
Salinity Site 5 Clarks Beach	31.52	32.60	32.18	0	0.02	0.02

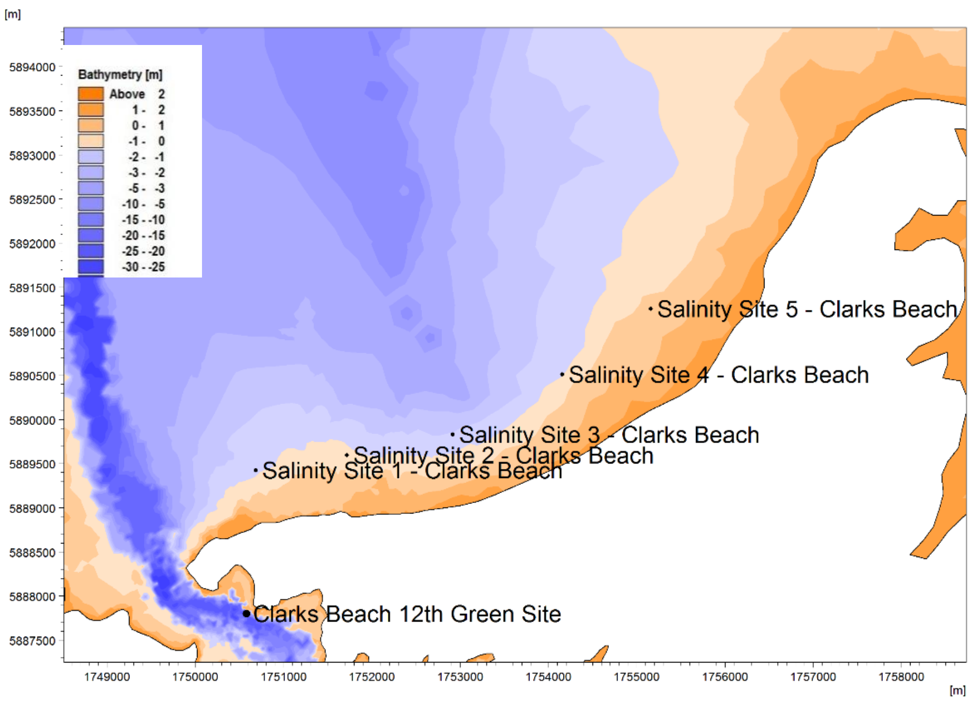

Figure 4-7 Salinity sites offshore of Clarks Beach. Also shown location of the Clarks Beach 12th Green discharge site. Coordinates are NZTM.

4.4 Conclusions – Harbour Wide Freshwater Effects

At the Auckland Council monitoring sites, predictions from the above simulations indicate that the effect of the proposed WWTP would be very small (i.e. reductions in salinity of less than 0.05 PSU) compared to the range of natural variation of salinity of ~0.5 - 3 PSU (depending on the site location).

At sites in the south-west corner of the Manukau, predictions from the above simulations indicate that the effect of the proposed WWTP would be very small (i.e. reductions in salinity of less than 0.04 PSU) compared to the range of natural variation of ~0.8 - 1.7 PSU (depending on the site location). This is due to a combination of the staging of the discharge (only occurring on the outgoing tide), the degree of mixing of the treated wastewater plume that occurs with more saline ambient harbour waters and the relative effect of the dynamics of the freshwater plumes from the Waiuku and Mauku rivers.

In terms of potential effects on ecology, such small changes in salinities lie well within the salinity tolerances for the majority of common benthic species in the Manukau Harbour (Kelly and Sims-Smith 2015). The predicted changes in salinity due to the discharge of treated wastewater at Clarks Beach are also well within the natural variability of salinities observed at Auckland Council monitoring sites and the salinity ranges predicted by the model at key sites in the south-west sector of the Manukau.

5 Cumulative Effects of Existing Mangere and Proposed Clarks WWTP Discharges

In this section of the report, the relative contribution of the existing Mangere WWTP discharge and the proposed Clarks Beach WWTP discharge are quantified in terms of harbour wide hydrodynamics and the mixing of both of the treated wastewater plumes within the Manukau Harbour.

The key objective of this component of work was to determine if the effect of the proposed Clarks Beach discharge on contaminant levels in the north-east sector of the harbour need to be considered in the context of the current Mangere WWTP discharge.

It is unlikely that the 50,000 PE Clarks discharge scenario would be operational without a concurrent increase in the Mangere WWTP discharge. As such, the current Mangere WWTP discharge (tidally staged at of 15.9 m^3/s) and the 30,000 PE Clarks Beach discharge scenario have been considered for this component of work.

The wastewater concentration for both discharges was set to a value of 1.0 – all results are therefore in terms of relative concentrations. The simulation assumes there are no decay, biological or chemical processes associated with the contaminant (i.e. the contaminant behaves as a conservative tracer). Model predictions at sites away from the discharge point are representative of worse case concentrations of contaminants. Decay processes for contaminants such as viruses, enterococci or nutrients will result in concentrations much lower than those predicted by this model. However, the model results still provide good estimates of the relative contribution that the Mangere WWTP discharge and proposed WWTP discharge at Clarks Beach may have on harbour wide contaminant levels.

Figure 5-1 shows the predicted mean relative concentration for the simulation. The mean relative concentration at the Clarks Beach site is 0.0029 which equates to a dilution of around 350 (consistent with the initial dilution estimates discussed in Section 2). For the Mangere discharge the mean relative concentration is 0.294 which equates to a dilution of around 3.5 consistent with data presented in Black et al. (1995) who modelled the diffuse shoreline discharge for a range of proposed discharge regimes and tide and wind conditions.

Elsewhere in the harbour, relative concentrations are very low (< 0.002), except for the channel running south-west of the Mangere discharge where it can be seen that concentrations reduce with distance from the discharge from 0.05 immediately west of the Mangere discharge point through to 0.008 some 4 km from the Mangere discharge point.

Figure 5-2 shows the relative contribution that the Mangere WWTP discharge has to the overall contaminant levels within the Manukau Harbour. It can be seen that in the northern half of the harbour, it is the Mangere discharge which is the major contributor to predicted conservative contaminant levels. Moving towards the proposed Clarks Beach site the contribution of the Mangere discharge in terms of the predicted conservative contaminant levels drops off along the Waiuku Channel to less than 3% at the proposed Clarks Beach site.

Figure 5-3 shows the relative contribution that the Clarks Beach WWTP discharge has to the overall contaminant levels within the Manukau Harbour. It can be seen that in the Waiuku Channel the proposed Clarks Beach discharge contributes to the majority of the predicted conservative contaminant levels. Also, within the middle section of the harbour the Clarks Beach discharge contributes up to 25% of the predicted conservative contaminant levels (which are however very low, see Figure 5-1).

In summary, the model predictions indicate that;

- The contribution of the Mangere WWTP discharge on contaminant levels in the south-west corner of the harbour will be minimal,
- The contribution of the proposed Clarks Beach WWTP discharge on contaminant levels in the middle and north-east sector of the harbour will be minimal, and
- Therefore, in terms of impacts and/or Public Health Risk of the proposed Clarks Beach discharge only contaminant levels in the south-west sector of the harbour need to be considered.

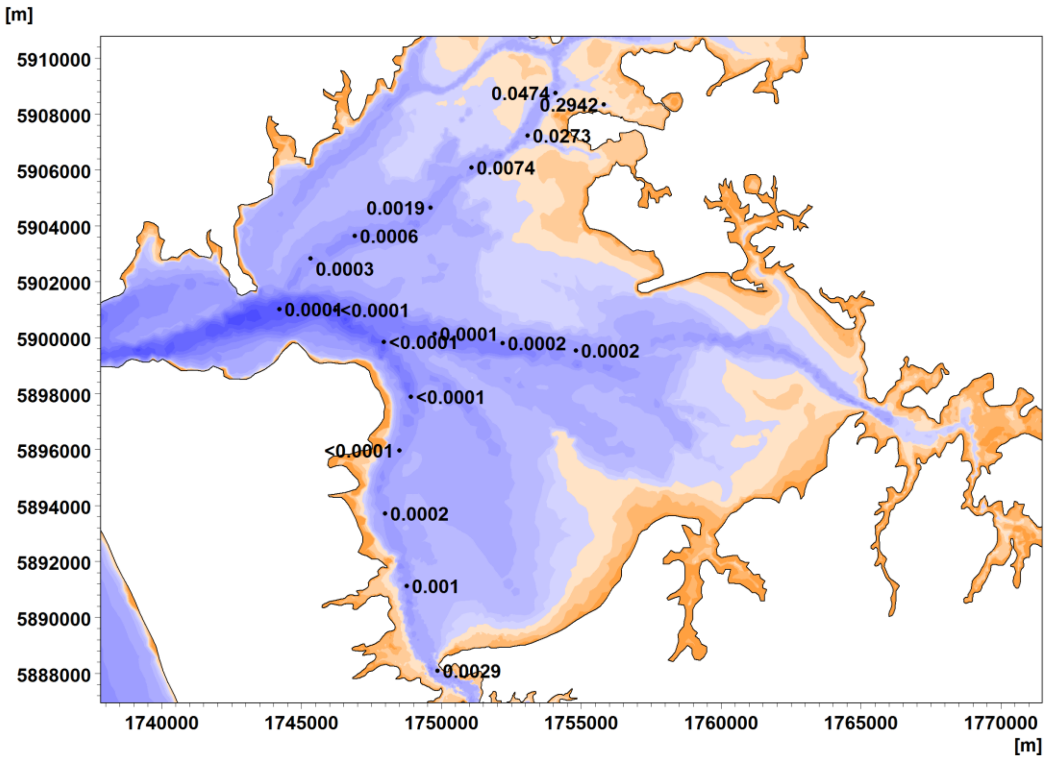

Figure 5-1 Combined relative concentration for the existing Mangere WWTP staged discharge of 15.0 m^3/s and the proposed 30,000 PE staged discharge at the Clarks Beach site of 0.243 m^3/s. Results are for a conservative contaminant. Coordinates are NZTM.

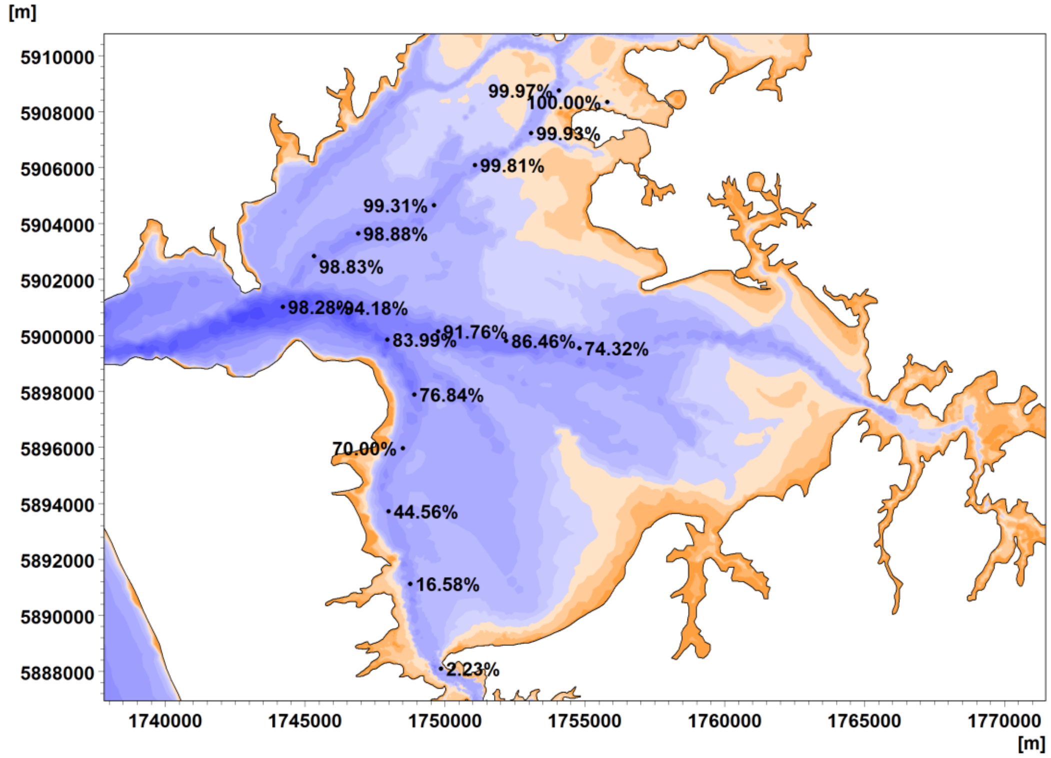

Figure 5-2 Relative contribution of the Mangere discharge to the overall contaminant levels in the Manukau Harbour shown in Figure 5-1. Coordinates are NZTM.

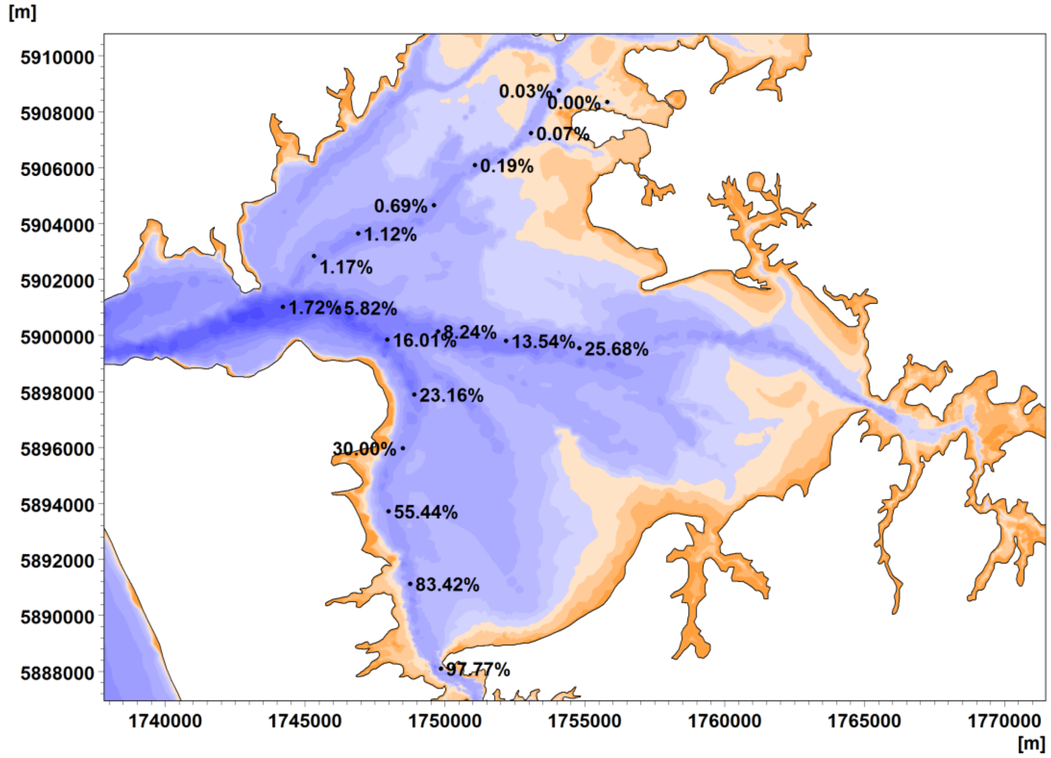

Figure 5-3 Relative contribution of the proposed Clarks Beach discharge to the overall contaminant levels in the Manukau Harbour shown in Figure 5-1. Coordinates are NZTM.

6 Assessment of Dilutions for Viruses and Enterococci

In this section of the report, details of the modelling of both viral and enterococci contaminants from the Clarks Beach 12th Green Mid-Channel site are presented.

Three discharge regimes are considered as follows:

1. Existing ADWF – continuous discharge of 0.007 m^3/s across the inter-tidal area near the WWTP. The discharge volume is based on most recent monitoring data.
2. Proposed staged ADWF for 30,000 population scenario – 0.242 m^3/s during a four hour discharge window commencing one hour after high water.
3. Proposed staged ADWF for 50,000 population scenario – 0.404 m^3/s during a four hour discharge window commencing one hour after high water.

For each of these discharge scenarios, annual simulations were carried out for 1991 and 1999 using time-varying inactivation rates for both viruses and enterococci.

These two years were chosen as being representative of El Niño conditions (1991) when the Southern Oscillation Index was negative and La Niña conditions (1999) when the Southern Oscillation Index was positive. Wind data indicates that there are periods of stronger persistent south-westerly winds during 1991 compared to 1999. As such, wind driven residual currents (at times) will play an important role in terms of the wastewater plume dynamics in 1991 compared to 1999.

Note that the Total Dilution referred to in this section of the report includes the combination of the near-field and far-field dilution plus the effects of inactivation.

6.1 Inactivation Rates

Viruses were modelled assuming worst case dark (night time) inactivation coefficients for summer and winter of 0.044 h^{-1} and 0.015 h^{-1} respectively, while the daytime coefficients were assumed to be 0.33 h^{-1} and 0.045 h^{-1} for summer and winter respectively. These inactivation coefficients were derived from data presented in Sinton et. al (1994) and Noble et. al (1994).

For enterococci, the dark inactivation coefficients for summer and winter were assumed to be 0.020 h^{-1} and 0.013 h^{-1} respectively, while the daytime coefficients were assumed to be 0.36 h^{-1} and 0.19 h^{-1} for summer and winter respectively. These inactivation coefficients were derived from data presented in Noble et. al (1999).

The seasonal and daily variation for inactivation rates for both viruses and enterococci were derived based on the above dark and light inactivation rates. The seasonal variation in the maximum dark and light rates were derived using a sigmoidal variation based on the number of days to and from winter solstice as follows;

$$k_{DayNumber} = k_{winter} + \left(\frac{k_{summer} + k_{winter}}{1 + exp^{(6-12*DayNumber/182)}}\right) \quad (6.1)$$

Where k_{summer} or k_{winter} are the dark (or light) inactivation rates (as above) and $k_{DayNumber}$ is the daily maximum dark (or light) inactivation rate for the day of year being considered – where *Day Number* is defined as the time to or from the winter solstice;

$$DayNumber = \mathrm{abs}(Day\ of\ the\ Year - 182) \quad (6.2)$$

Figure 6-1 shows the maximum daily inactivation rates (dark and light combined) as a function of the day of the year based on the above summer and winter dark and light inactivation rates and day of year.

Lastly, the light inactivation rate was modulated on an hourly basis based on the observed solar radiation. The actual inactivation rate was assumed to be the predicted maximum daily inactivation rate (Figure 6-1) multiplied by the ratio of the observed hourly solar radiation to the maximum clear sky solar radiation for the day being considered.

Figure 6-2 and Figure 6-3 show the derived inactivation rates for 1991 and 1999 for enterococci and viruses respectively. Figure 6-4 shows a detailed view of a selected 50 day period of inactivation rates for enterococci in 1999 showing the hourly variation relating to observed solar radiation.

Using these derived inactivation rates for enterococci and viruses, simulations for 1991 and 1999 were carried out for the three discharge regimes being considered.

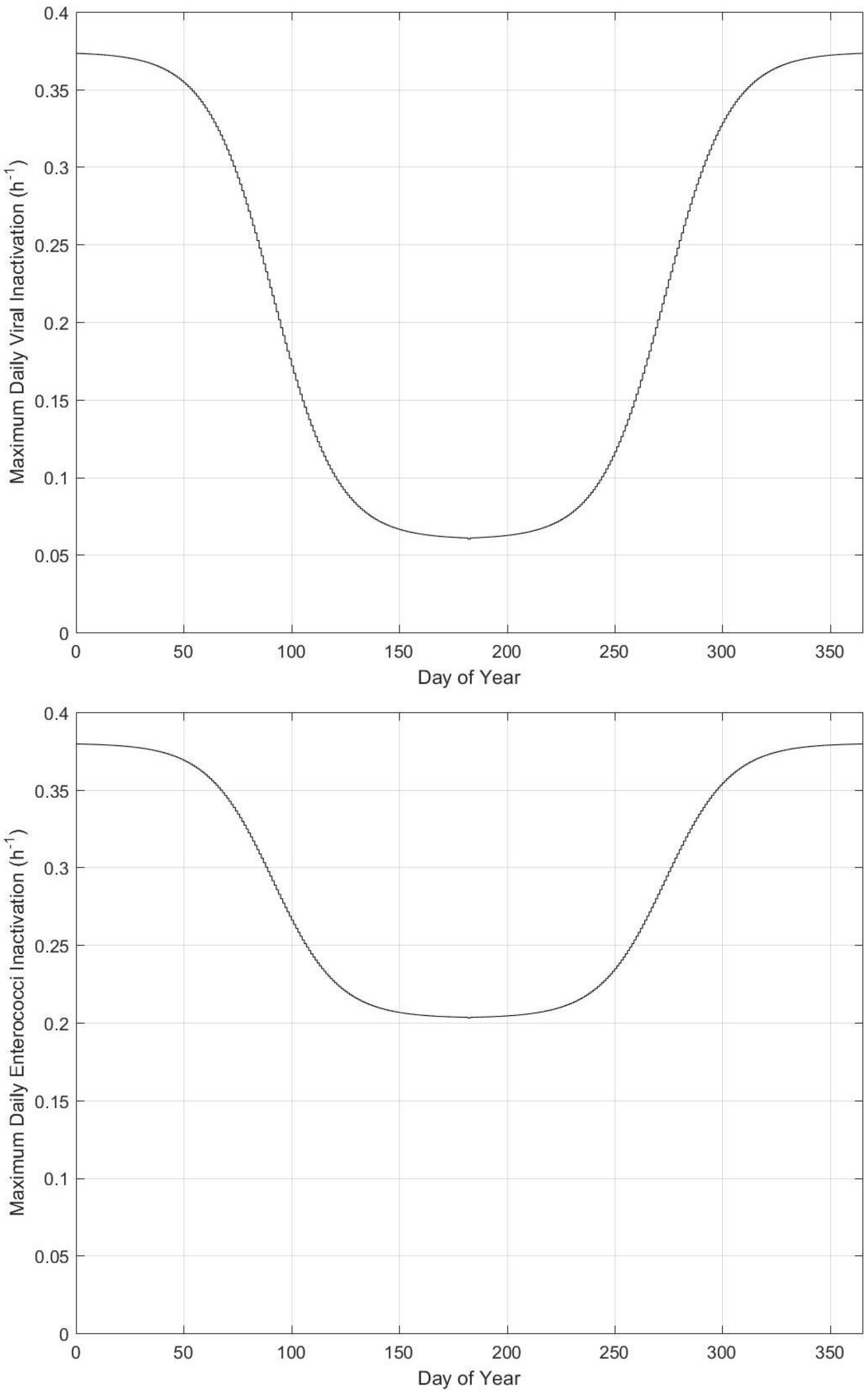

Figure 6-1 Maximum daily inactivation rates (sum of dark and light inactivation rates) based sigmoidal variation of specified summer and winter dark and light inactivation rates and time to or from winter solstice for viruses (top panel) and enterococci (bottom panel).

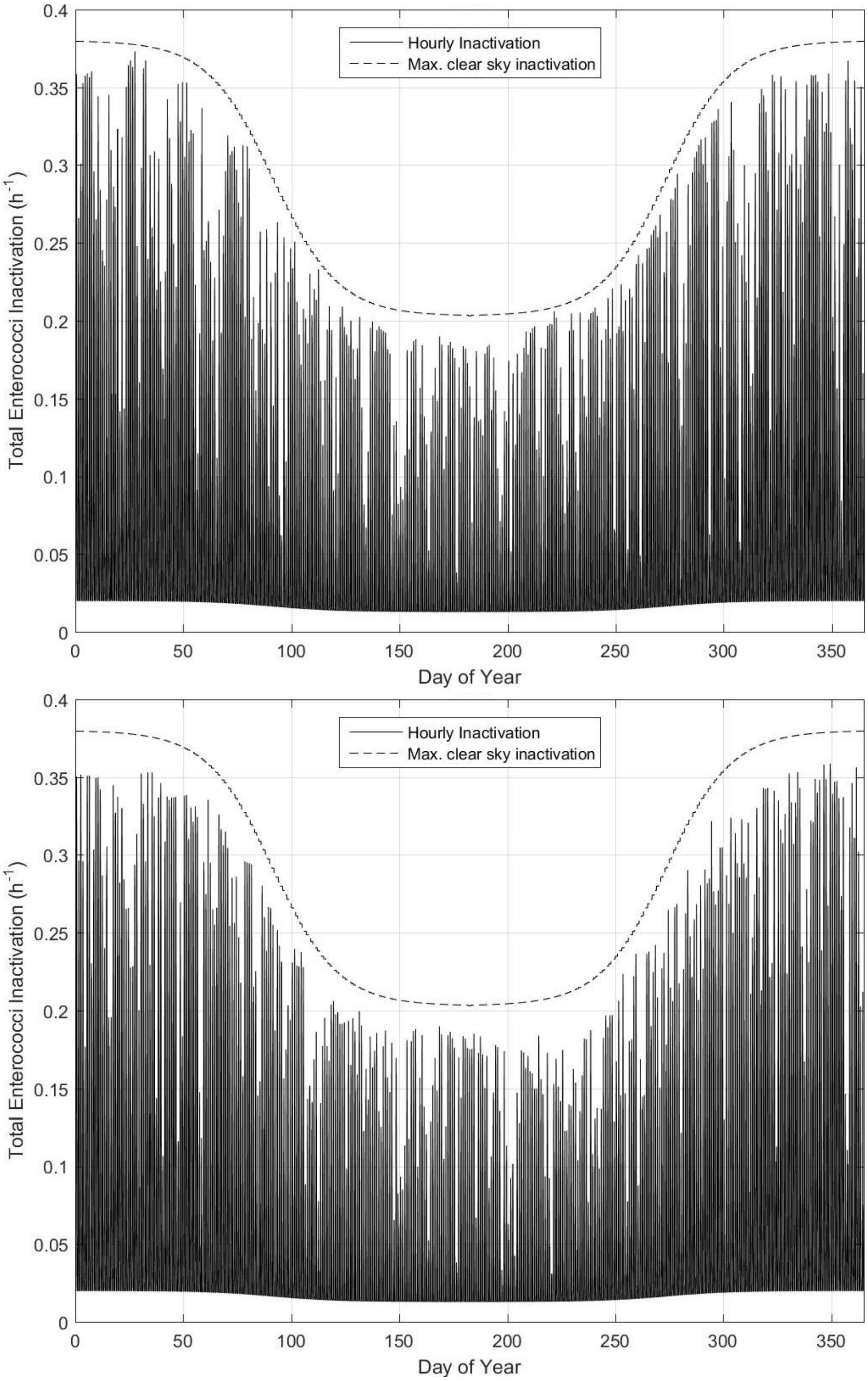

Figure 6-2 Hourly variation of enterococci inactivation rates (sum of dark and light inactivation rates) based on maximum daily inactivation (Figure 6-1) and based on observed solar radiation for 1991 (top panel) and 1999 (bottom panel).

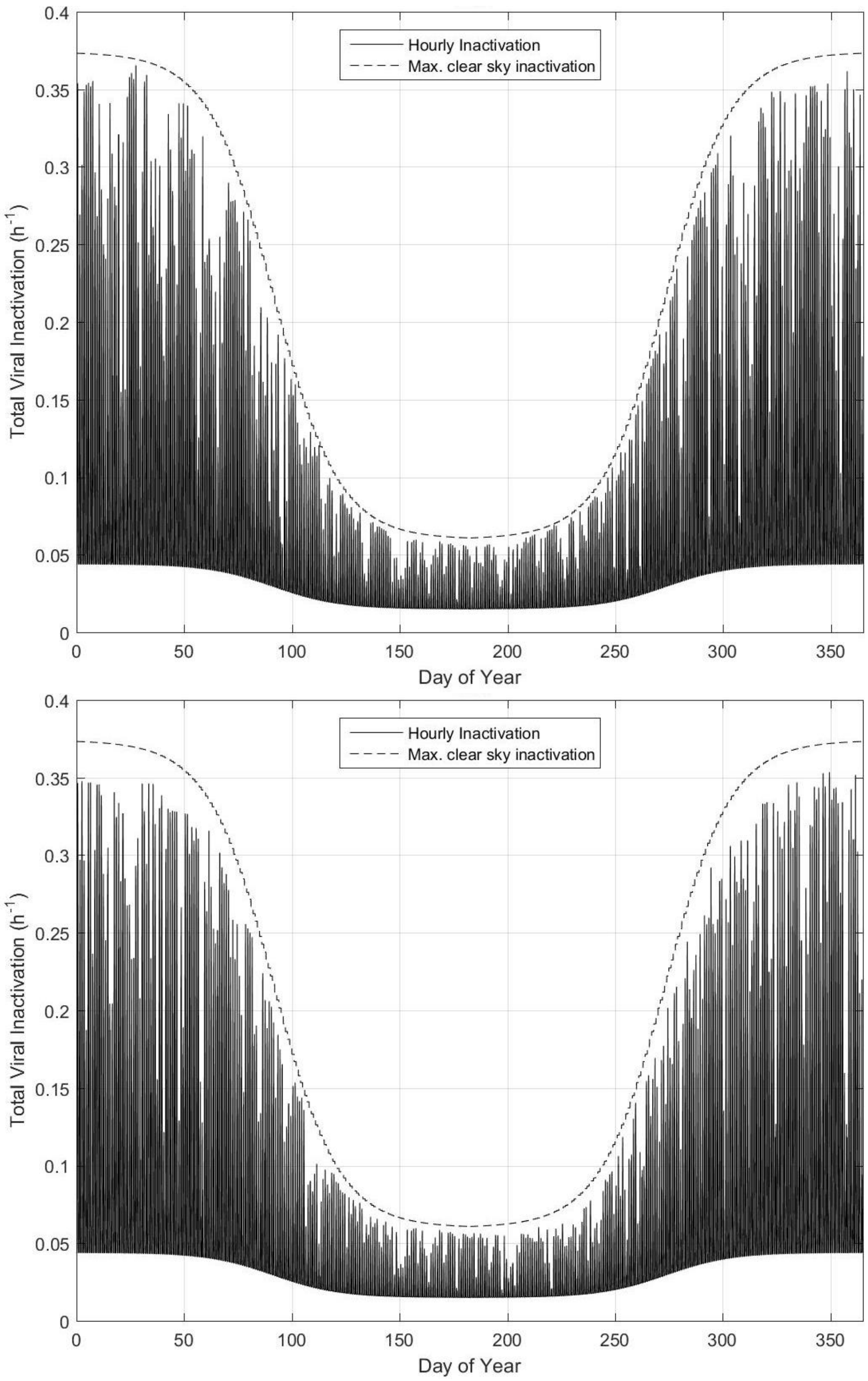

Figure 6-3 Hourly variation of viral inactivation rates (sum of dark and light inactivation rates) based on maximum daily inactivation (Figure 6-1) and based on observed solar radiation for 1991 (top panel) and 1999 (bottom panel).

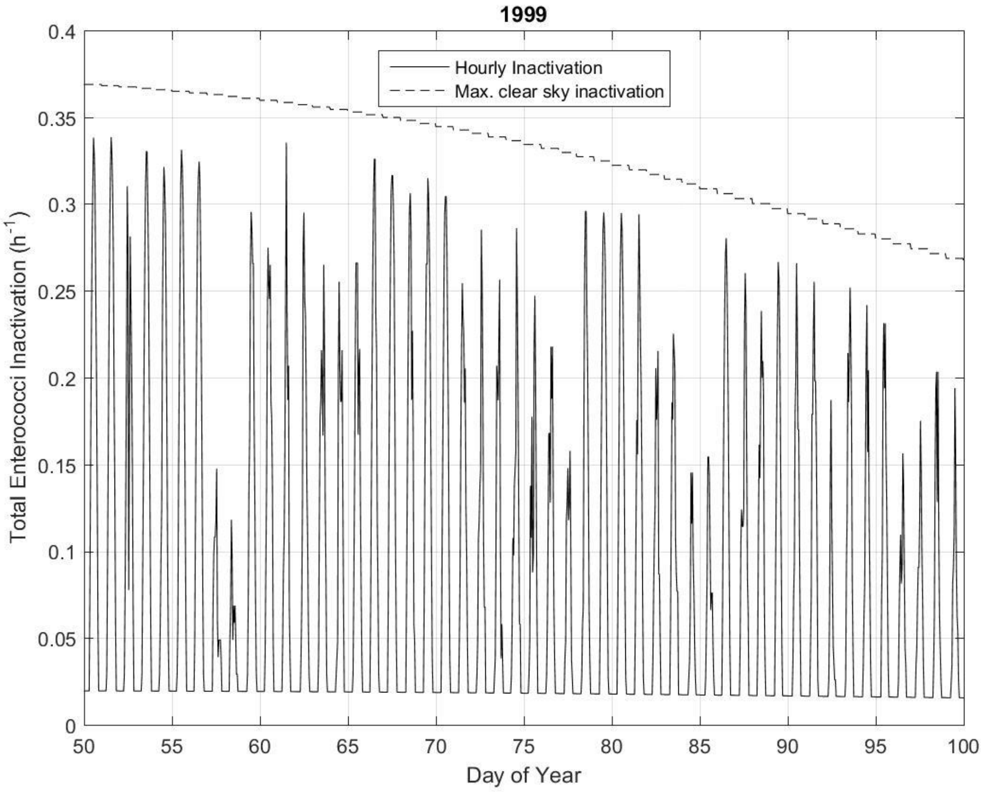

Figure 6-4 Hourly variation in inactivation rate based on observed incoming solar radiation and maximum clear sky inactivation rates for enterococci Days 50-100 in 1999.

6.2 Spatial Plots of Minimum Total Dilutions Achieved

In this section of the report, the minimum total dilution achieved during one of the annual simulations is presented for each of the discharge scenarios being considered. Note that the total dilution is a combination of physical dilution (near-field and far-field) plus the effects of inactivation on contaminant levels.

Model results show that the choice of year or contaminant make little difference to the minimum total dilutions achieved in the immediate vicinity of the discharge. Results for the 1991 simulation of enterococci are therefore given below.

The minimum total dilution achieved for each of the discharge scenarios being considered for the 1991, enterococci simulation are given in (Figure 6-5, Existing discharge), (Figure 6-6, 30,000 PE discharge) and (Figure 6-7, 50,000 PE discharge). Note, that these plots show the minimum total dilution achieved at **any time** during the 1991 simulation.

For the existing discharge across the inter-tidal area (Figure 6-5) there is a very localised area where minimum total dilutions of less than 1500 are achieved with an absolute minimum total dilution of 35 achieved during the annual simulations. Once the discharged wastewater reaches the main channel of the Waiuku River or mixes with ambient Waiuku River waters in the Waiau Beach area significantly higher levels of total dilution occurs.

For the 30,000 PE discharge (Figure 6-6) there is a very localised area in the immediate vicinity of the discharge point where a minimum total dilution of between 500-1000 occurs with an absolute minimum total dilution of 265 achieved during the annual simulations. There is a narrow band directly to the north-west of the discharge point where a minimum total dilution of less than 1500 occurs.

For the 50,000 PE discharge (Figure 6-7) there is a very localised area in the immediate vicinity of the discharge point where a minimum total dilution of <500 occurs with an absolute minimum total dilution of 160 achieved during the annual simulations. There is a narrow band directly to the north-west of the discharge point where the minimum total dilution of between 500-1000 occurs. The area where a minimum total dilution of less than 1500 occurs now extends towards and offshore of Karaka Point.

These plots give an indication of the relative areas of the so called zone of initial dilution or edge of mixing zone. Outside such areas, the aim is that specific water quality criteria will always be met. However for such a mixing zone to be absolutely defined, not only must the minimum achievable dilution be known but the quality of the wastewater being discharged needs to be specified and put in context of relevant receiving environment water quality standards.

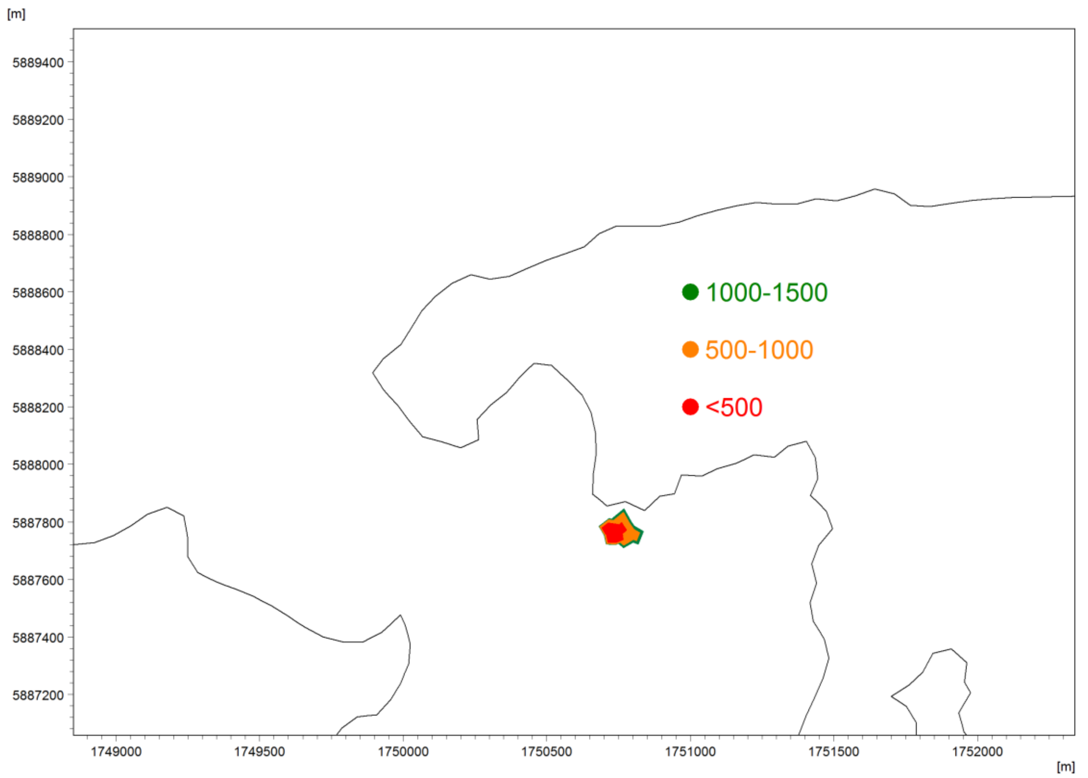

Figure 6-5 Minimum total dilution achieved during 1991 for the existing Clarks Beach WWTP discharge across the inter-tidal area for enterococci. Note that total dilutions of greater than 1500 are not shown. Coordinates are NZTM.

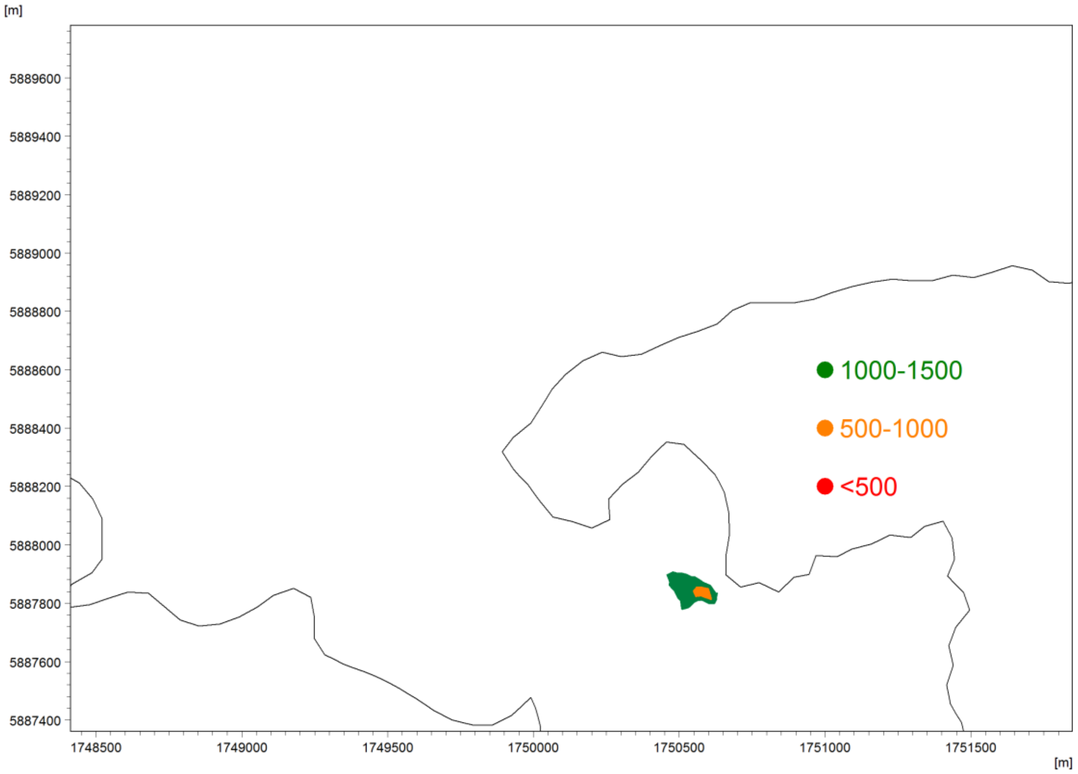

Figure 6-6 Minimum total dilution achieved during 1991 for the 30,000 PE discharge at the Clarks Beach 12th Green site for enterococci. Note that total dilutions of greater than 1500 are not shown. Coordinates are NZTM.

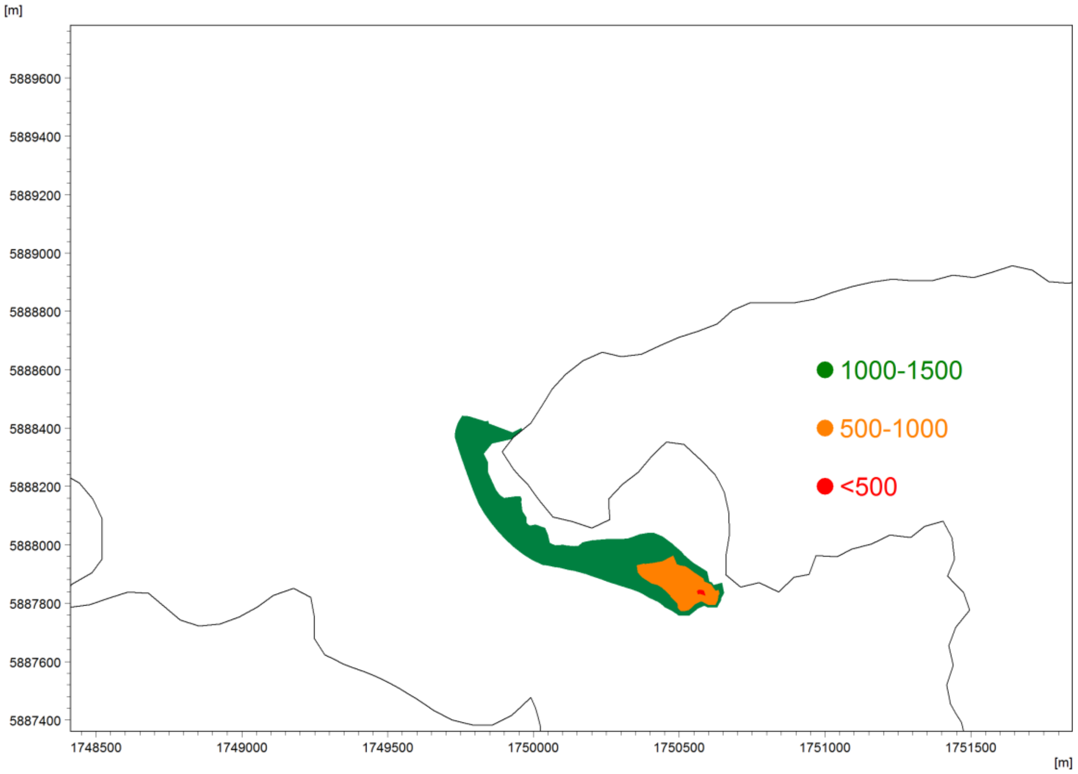

Figure 6-7 Minimum total dilution achieved during 1991 for the 50,000 PE at the Clarks Beach 12th Green site for enterococci. Note that total dilutions of greater than 1500 are not shown. Coordinates are NZTM.

6.3 Spatial Plots of Average Total dilutions

The following section of the report gives an overview of the average total dilutions that are achieved in the south-west sector of the Manukau Harbour for the discharge regimes and contaminants being considered.

As discussed in the previous section the wastewater plume footprint for the existing discharge is very small since:

1. the volume being discharged is small; and
2. once the wastewater plume mixes with water within the main channel of the Waiuku River, high levels of total dilution are achieved.

Figures 6-8 to 6-11 how the predicted mean annual total dilution achieved for enterococci and viruses during 1991 and 1999. It can be seen that (as for the minimum total dilutions) there is a small area where average total dilutions of less than 25,000 are achieved at the discharge site.

Elsewhere, the plume footprint extends into Waiau Beach but (as discussed below) average total dilutions are very high (>50,000) since:

1. the low frequency with which the plume is transported towards into this beach; and
2. the high degree of mixing of ambient Waiuku River water and the wastewater plume.

Because of the proximity of Waiau Beach to the discharge site there is very little opportunity for inactivation and the effects of wider scale wind driven circulation are minimal so there is very little difference between the predicted enterococci and viral total dilutions achieved in both years.

For the 30,000 PE discharge (Figures 6-12 to 6-15) the treated wastewater plume footprint extends along the middle of the Waiuku River channel (where average total dilution ranges between 2,000 and 5,000) and into the south-west corner of the Manukau. Because of the lower inactivation rates for viruses the area where average total dilutions of between 5,000 and 20,000 is achieved (shaded green) covers a slightly larger area of the harbour than the same zone for the enterococci.

As for the 30,000 PE discharge the treated wastewater plume footprint extends along the middle of the Waiuku River channel and into the south-west corner of the Manukau for the 50,000 PE discharge (Figures 6-16 to 6-19). There is now a small zone where average total dilutions are less than 2,000 which (for the viruses) extends towards Karaka Point. The zone where average total dilutions of between 2,000 and 5,000 are achieved now extents out in to the south-west corner of the Manukau. As for the 30,000 PE discharge regime, because of the lower inactivation rates for viruses the area where average total dilutions of between 5,000 and 20,000 is achieved (shaded green) covers a slightly larger area of the harbour than the same zone for the enterococci.

There is a slight evidence of the migration of the plume footprint towards the east for the 1991 El Niño conditions.

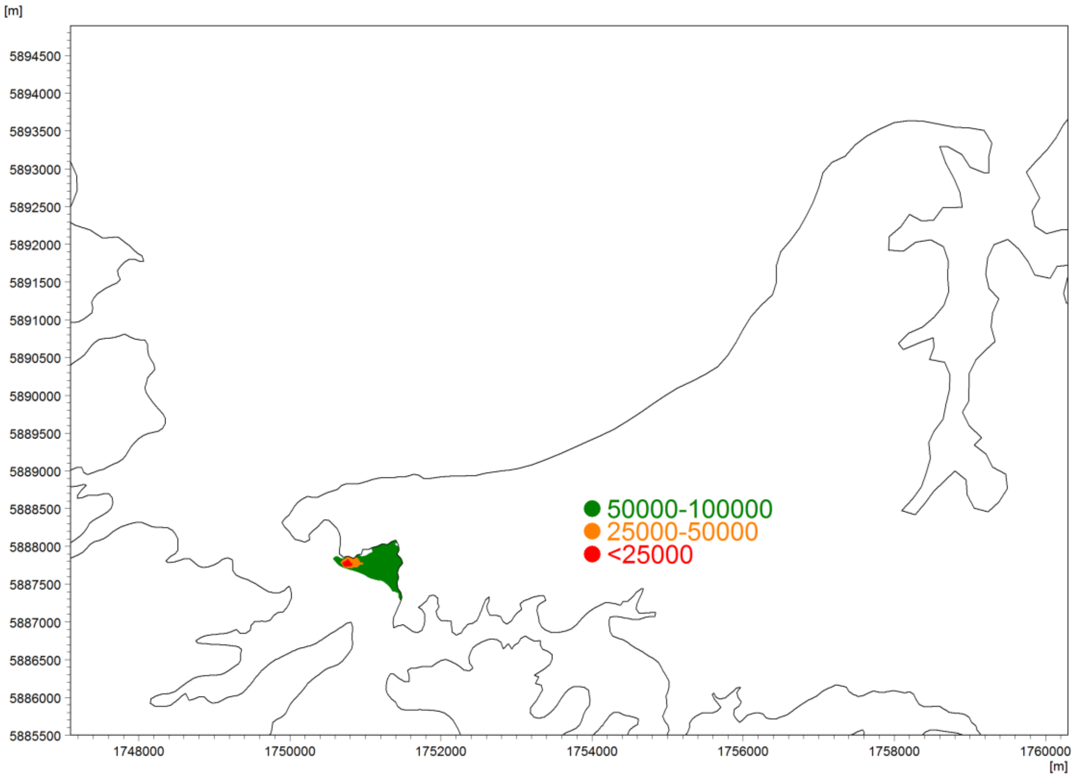

Figure 6-8 Annual average total dilution for enterococci achieved during 1991 for the existing Clarks Beach WWTP discharge across the inter-tidal area. Note that areas where average total dilutions of greater than 100,000 are achieved are not shown. Coordinates are NZTM.

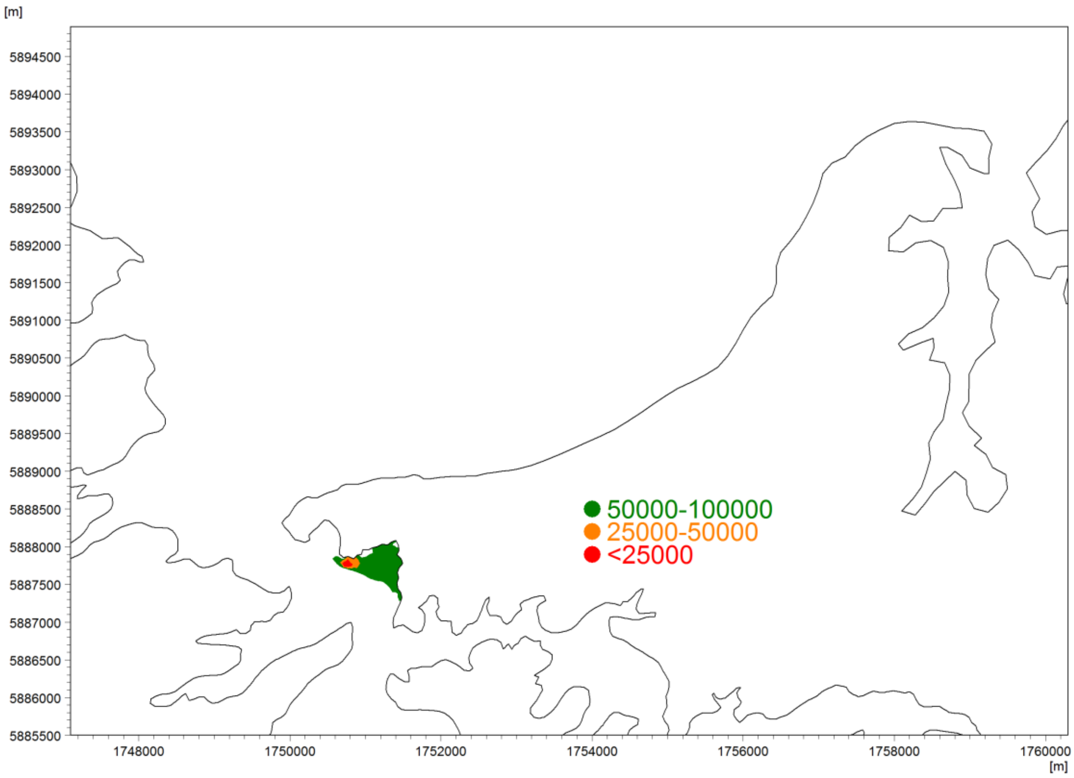

Figure 6-9 Annual average total dilution for enterococci achieved during 1999 for the existing Clarks Beach WWTP discharge across the inter-tidal area. Note that areas where average total dilutions of greater than 100,000 are achieved are not shown. Coordinates are NZTM.

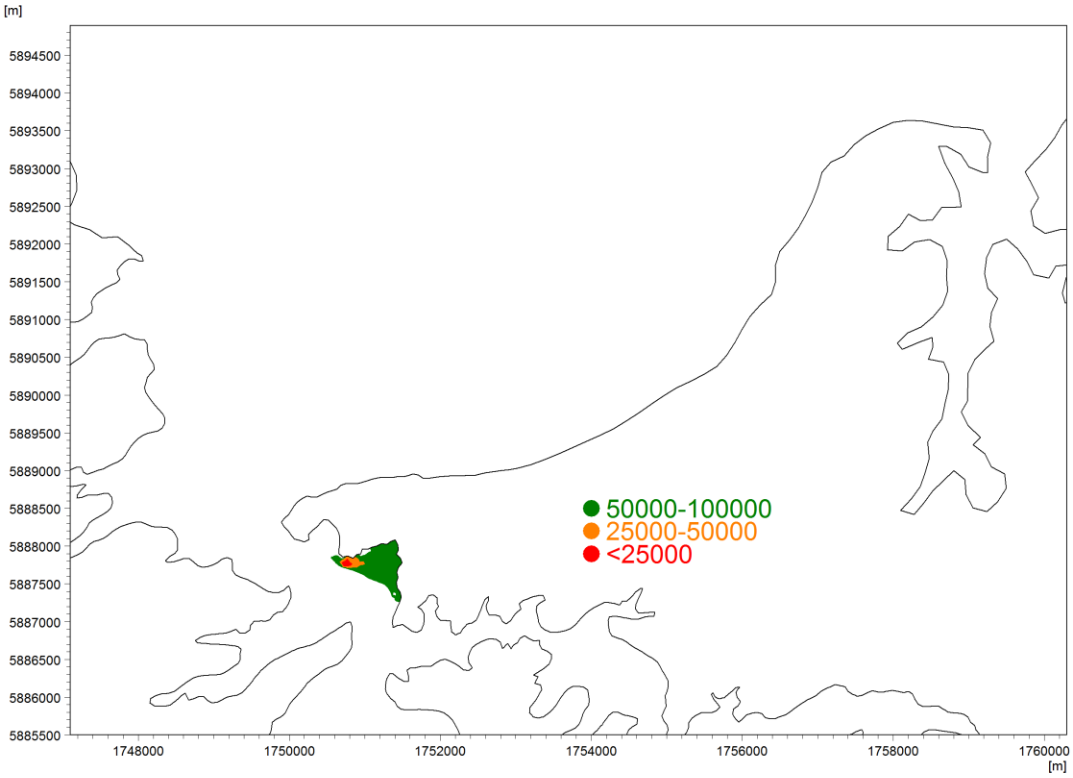

Figure 6-10 Annual average total dilution for Viruses achieved during 1991 for the existing Clarks Beach WWTP discharge across the inter-tidal area. Note that areas where average total dilutions of greater than 100,000 are achieved are not shown. Coordinates are NZTM.

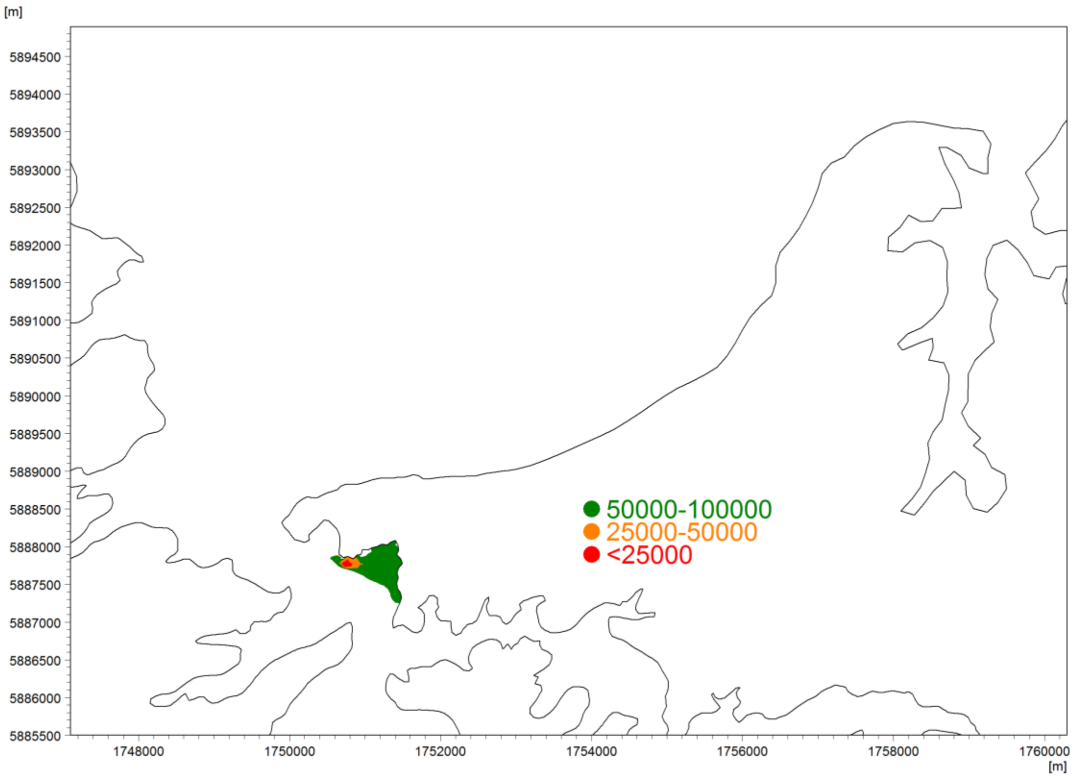

Figure 6-11 Annual average total dilution for Viruses achieved during 1991 for the existing Clarks Beach WWTP discharge across the inter-tidal area. Note that areas where average total dilutions of greater than 100,000 are achieved are not shown. Coordinates are NZTM.

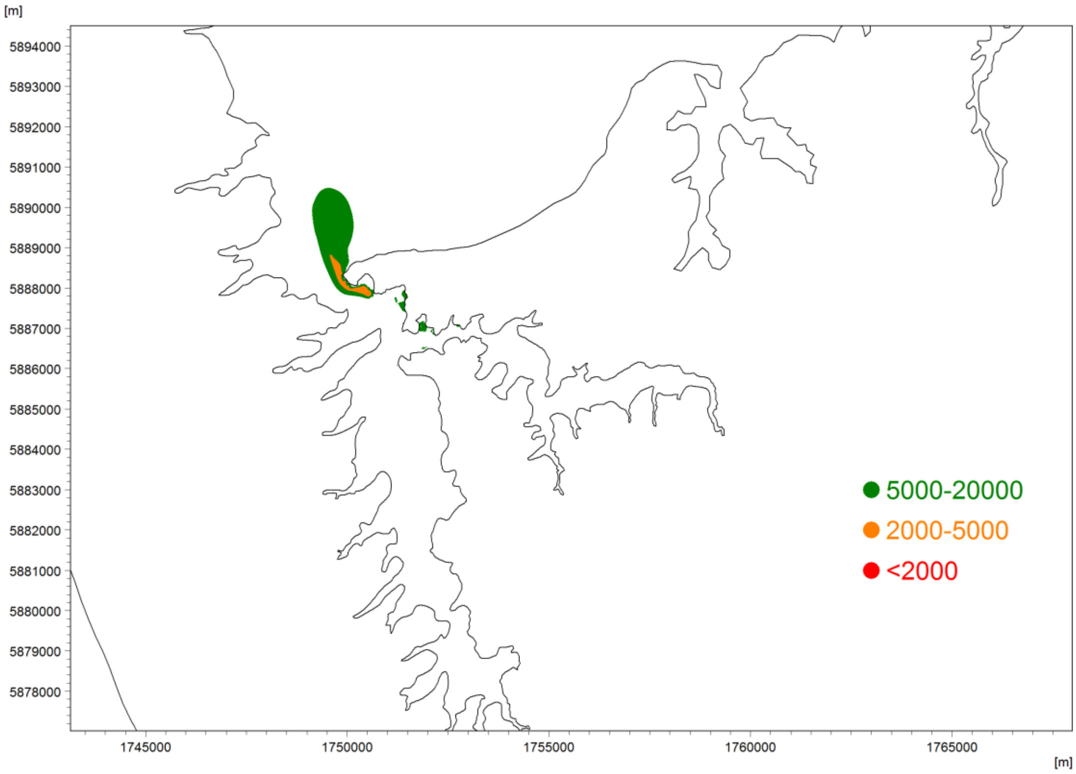

Figure 6-12 Annual average total dilution for enterococci achieved during 1991 for the 30,000 PE discharge at the Clarks Beach 12th Green site. Note that areas where average total dilutions of greater than 20,000 are achieved are not shown. Coordinates are NZTM.

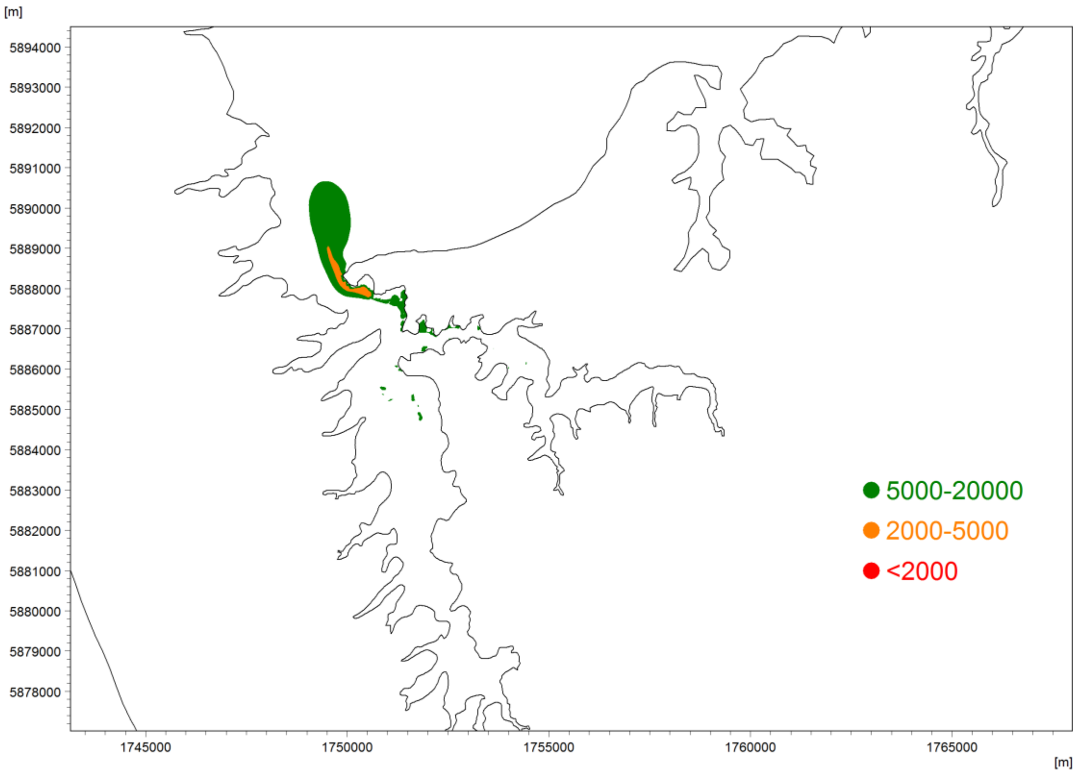

Figure 6-13 Annual average total dilution for enterococci achieved during 1999 for the 30,000 PE discharge at the Clarks Beach 12th Green site. Note that areas where average total dilutions of greater than 20,000 are achieved are not shown. Coordinates are NZTM.

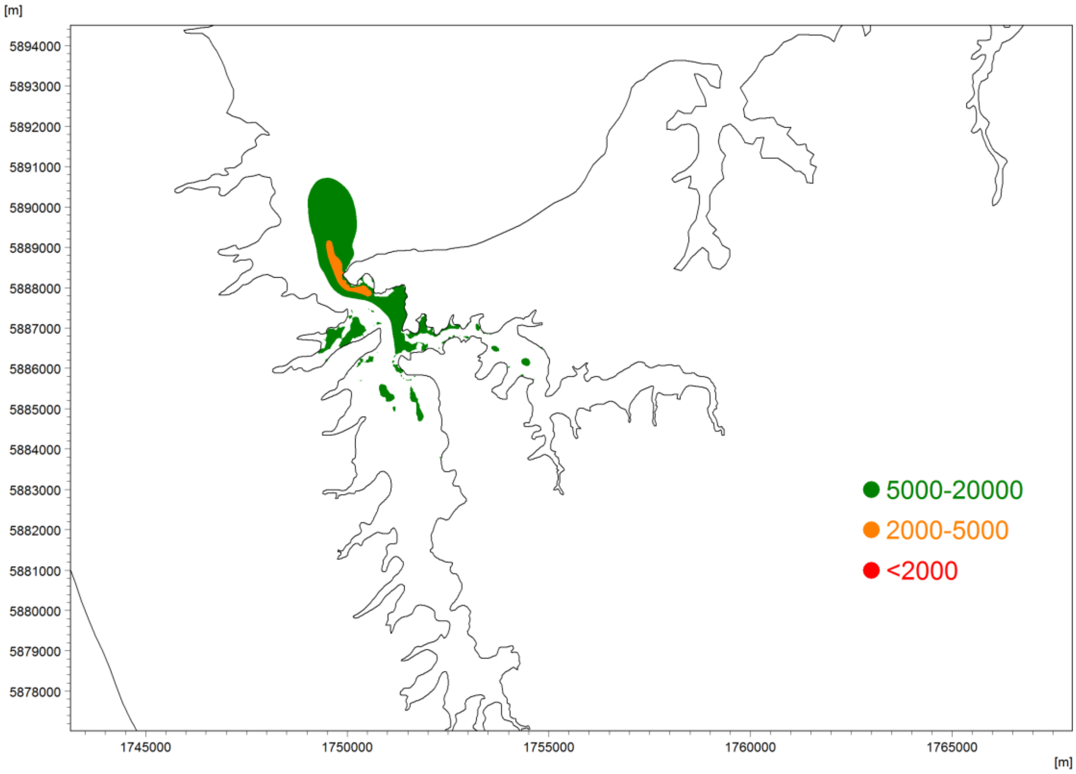

Figure 6-14 Annual average total dilution for Viruses achieved during 1991 for the 30,000 PE discharge at the Clarks Beach 12th Green site. Note that areas where average total dilutions of greater than 20,000 are achieved are not shown. Coordinates are NZTM.

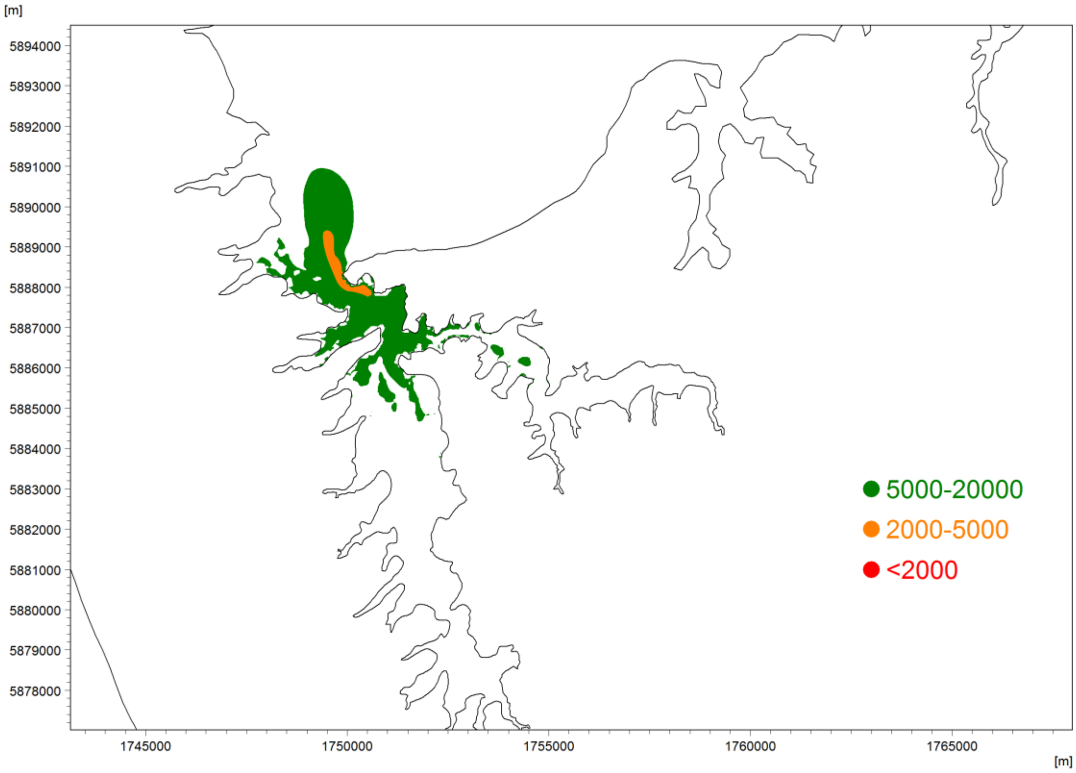

Figure 6-15 Annual average total dilution for Viruses achieved during 1999 for the 30,000 PE discharge at the Clarks Beach 12th Green site. Note that areas where average total dilutions of greater than 20,000 are achieved are not shown. Coordinates are NZTM.

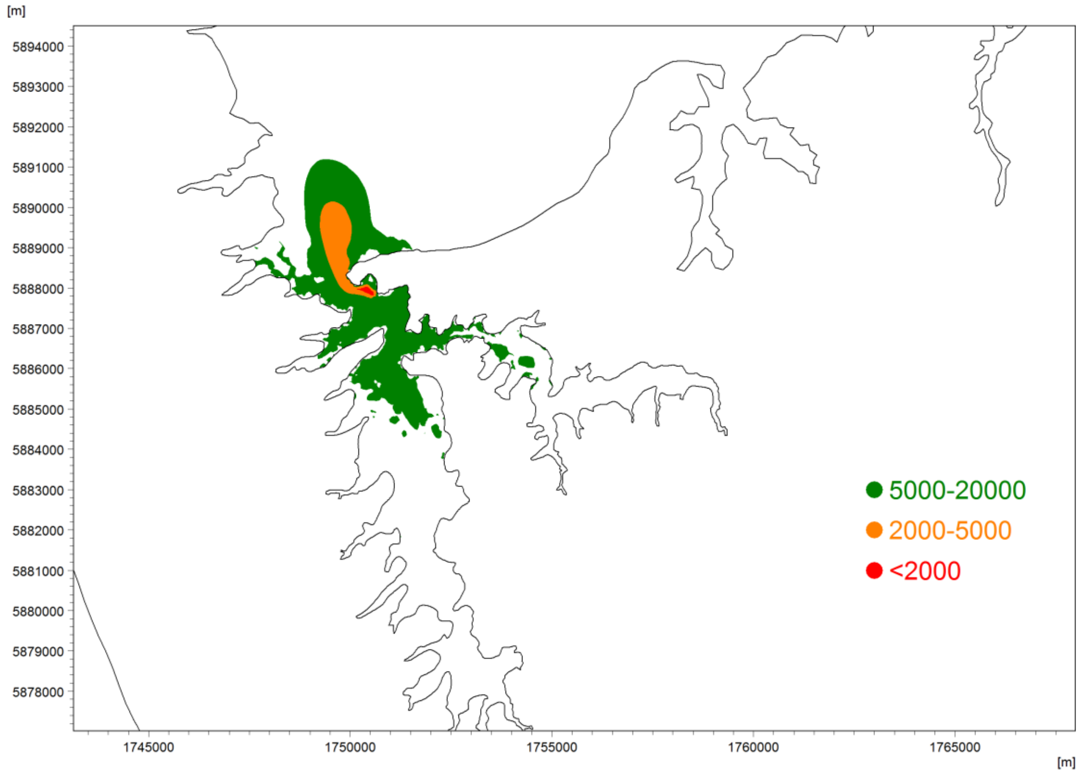

Figure 6-16 Annual average total dilution for enterococci achieved during 1991 for the 50,000 PE discharge at the Clarks Beach 12th Green site. Note that areas where average total dilutions of greater than 20,000 are achieved are not shown. Coordinates are NZTM.

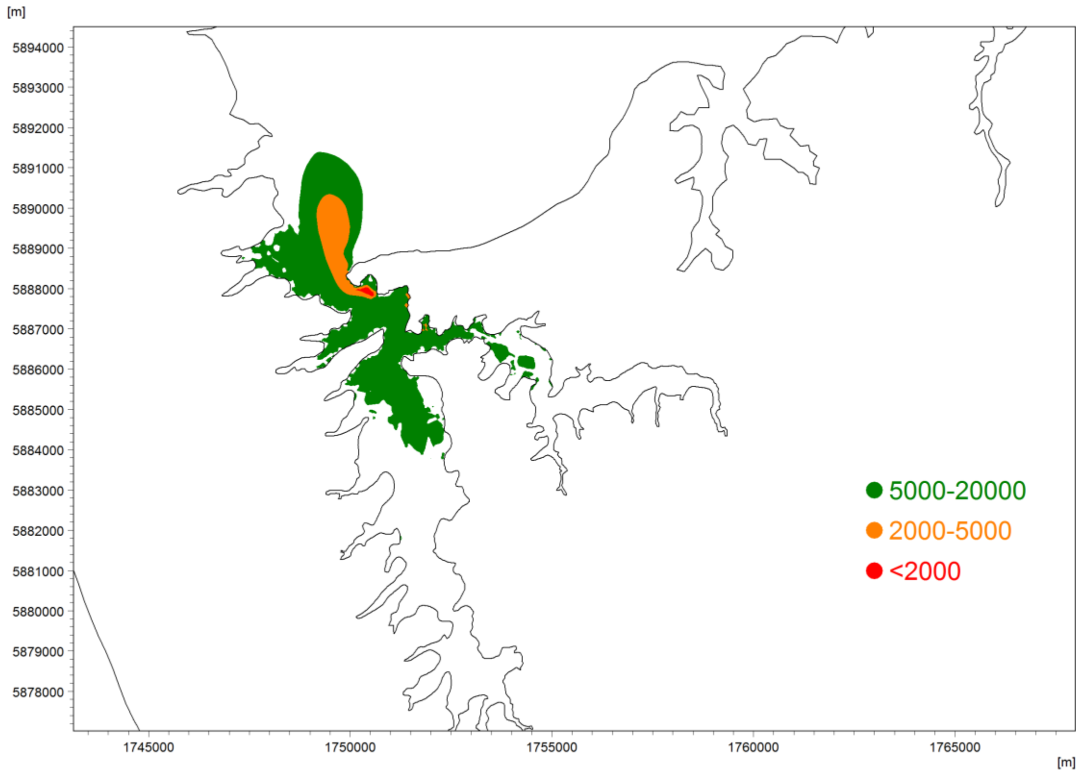

Figure 6-17 Annual average total dilution for enterococci achieved during 1999 for the 50,000 PE discharge at the Clarks Beach 12th Green site. Note that areas where average total dilutions of greater than 20,000 are achieved are not shown. Coordinates are NZTM.

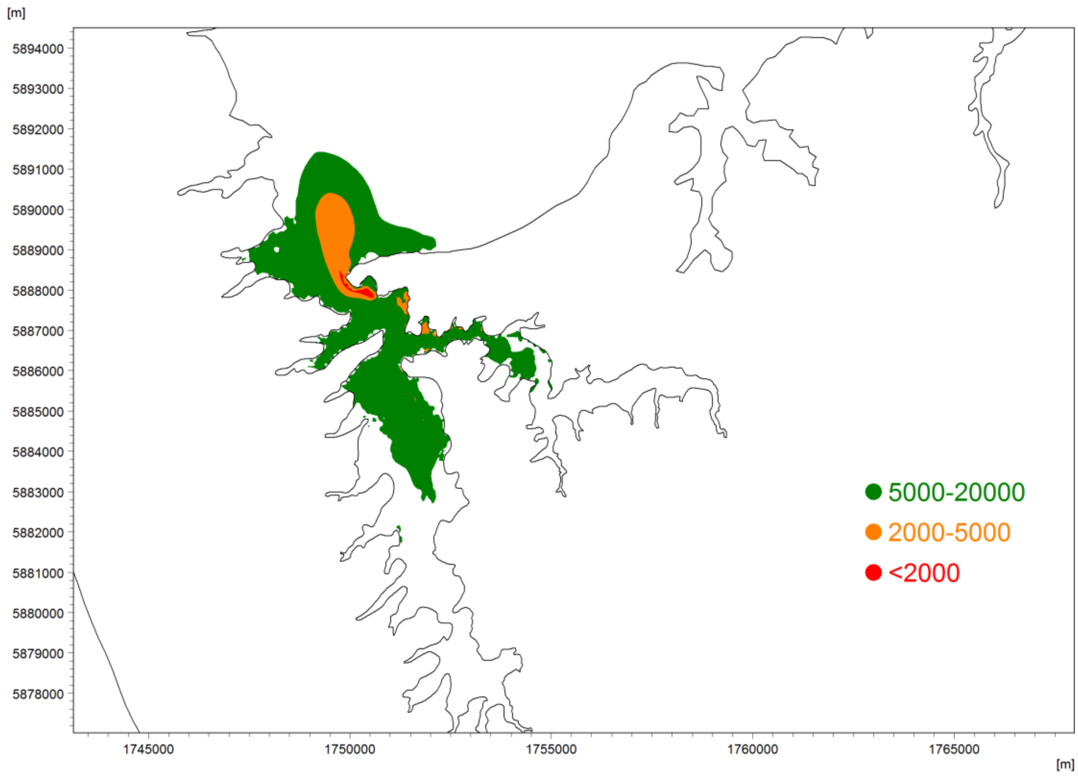

Figure 6-18 Annual average total dilution for Viruses achieved during 1991 for the 50,000 PE discharge at the Clarks Beach 12th Green site. Note that areas where average total dilutions of greater than 20,000 are achieved are not shown. Coordinates are NZTM.

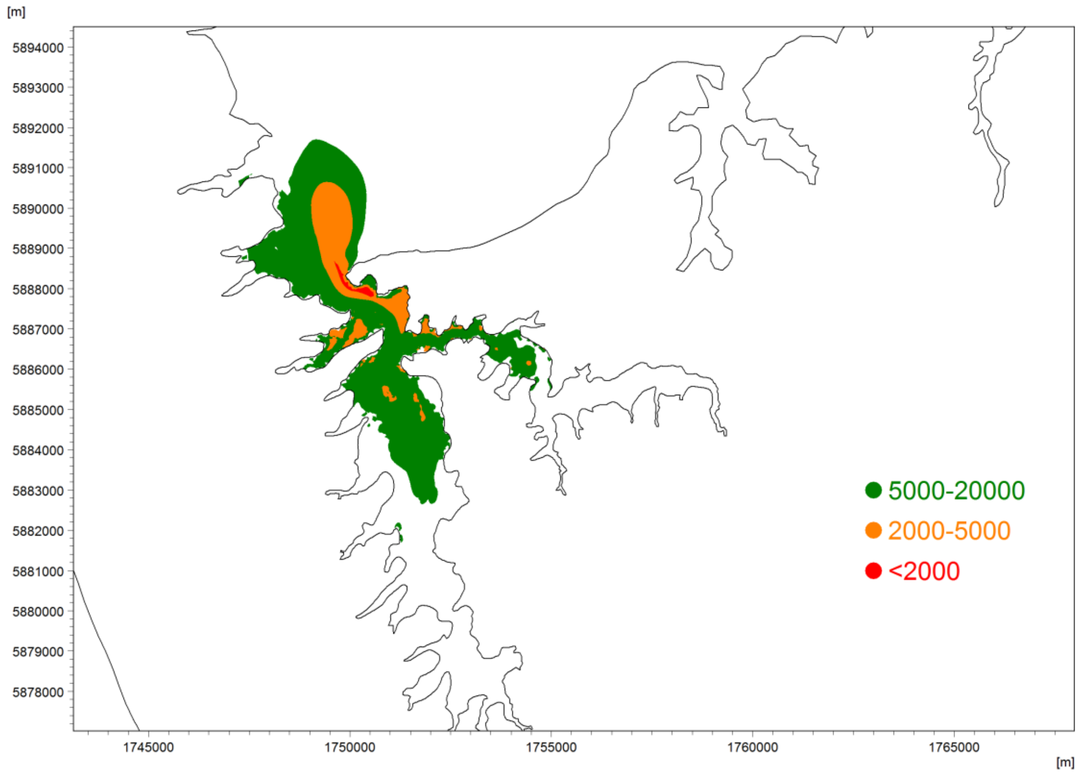

Figure 6-19 Annual average total dilution for Viruses achieved during 1999 for the 50,000 PE discharge at the Clarks Beach 12th Green site. Note that areas where average total dilutions of greater than 20,000 are achieved are not shown. Coordinates are NZTM.

6.4 Summary of Predictions at Public Health Risk Assessment process Sites

Based on discussions with Watercare, NIWA and Aquatic Environmental Sciences, four recreational and three shellfish sites were chosen for the Public Health Risk Assessment process as follows and as shown in Figure 6-20 and Figure 6-21;

Recreational Sites

- Waiau Beach
- Clarks Beach West
- Clarks Beach East
- Matakawau Headland

Shellfish Sites

- Te Toro Road Settlement
- Te Toro Road Boat Ramp
- Matakawau Headland

The time-series of predicted viral and enterococci concentrations were extracted from the model, at the sites shown above for both of the annual simulations and supplied to NIWA for input to the Public Health Risk Assessment process.

Average annual total dilutions achieved (to the nearest 1,000) at these sites for the enterococci and viruses are shown in Table 6-1 and Table 6-2 respectively.

A full summary of the predicted distribution of concentrations at each of the sites for a range of potential wastewater treatments will form part of the Public Health Risk Assessment process.

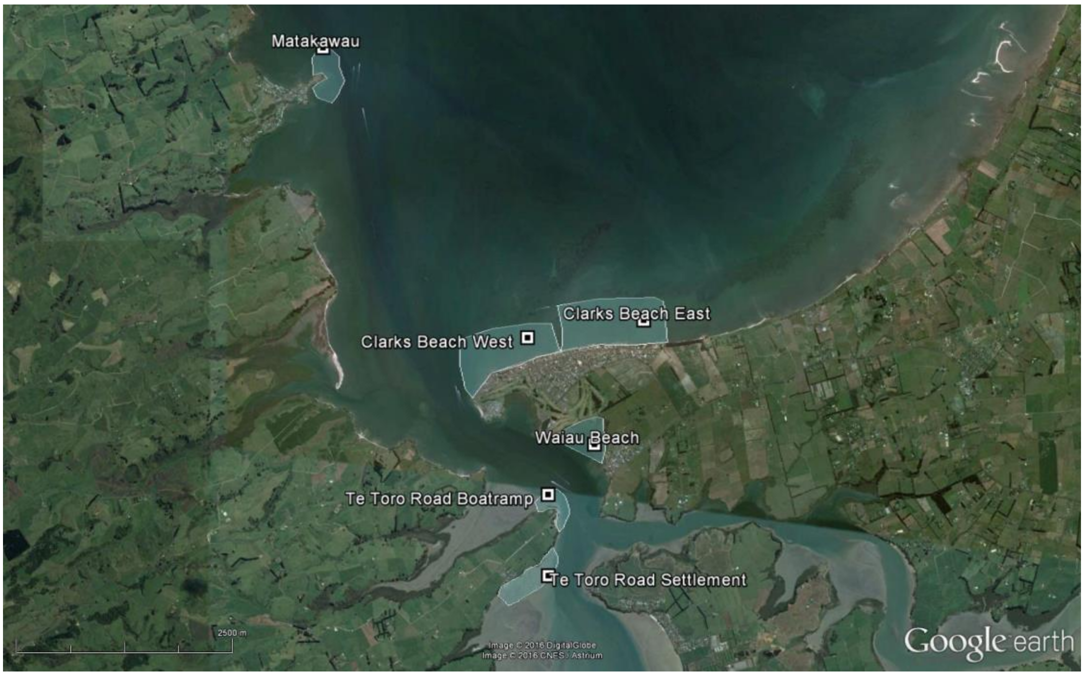

Figure 6-20 General locations of the sites selected for the Public Health Risk Assessment process.

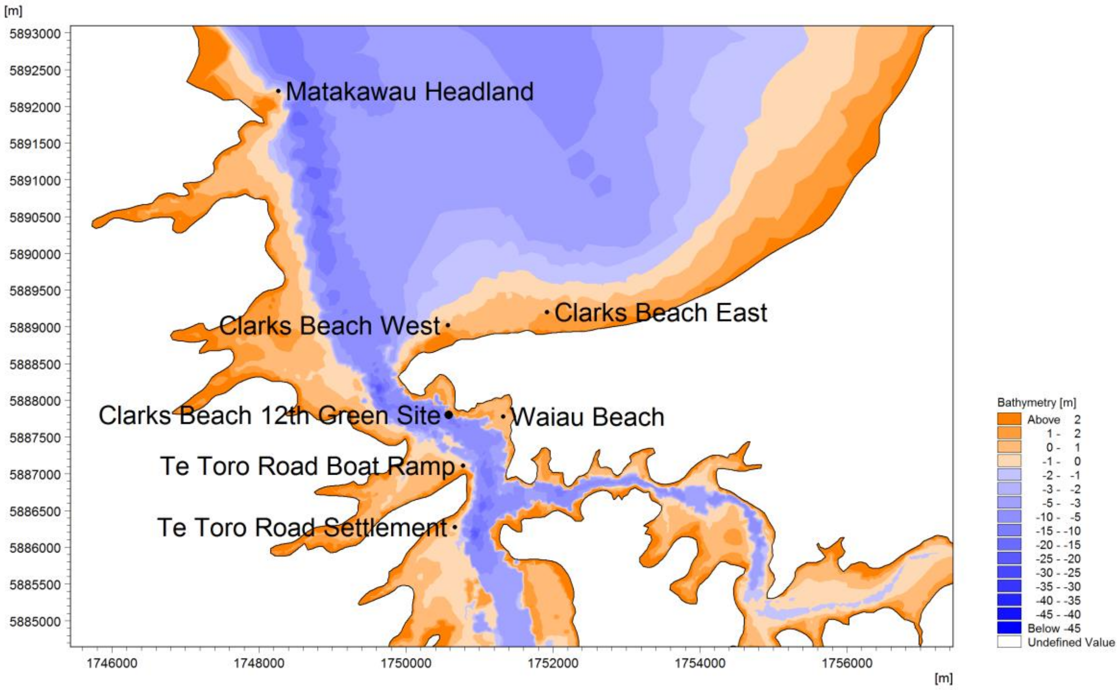

Figure 6-21 Public Health Risk Assessment sites within the Manukau Harbour model domain. Also shown location of the Clarks Beach 12th Green discharge site. Coordinates are NZTM.

Table 6-1 Average total dilutions (to the nearest 1,000) for enterococci at the Public Health Risk Assessment sites.

Scenario	Waiau Beach	Clarks West	Clarks East	Te Toro Road Settlement	Te Toro Road Boat Ramp	Matakawau Headland
1991 (Existing)	82,000	> 100,000	> 100,000	> 100,000	> 100,000	> 100,000
1999 (Existing)	82,000	> 100,000	> 100,000	> 100,000	> 100,000	> 100,000
1991 (30,000 PE)	22,000	29,000	38,000	31,000	29,000	> 100,000
1999 (30,000 PE)	20,000	58,000	> 100,000	27,000	25,000	> 100,000
1991 (50,000 PE)	13,000	17,000	23,000	19,000	17,000	> 100,000
1999 (50,000 PE)	12,000	35,000	63,000	16,000	15,000	97,000

Table 6-2 Average total dilutions (to the nearest 1,000) for viruses at the Public Health Risk Assessment sites.

Scenario	Waiau Beach	Clarks West	Clarks East	Te Toro Road Settlement	Te Toro Road Boat Ramp	Matakawau Headland
1991 (Existing)	75,000	> 100,000	> 100,000	> 100,000	> 100,000	> 100,000
1999 (Existing)	75,000	> 100,000	> 100,000	> 100,000	> 100,000	> 100,000
1991 (30,000 PE)	17,000	24,000	31,000	23,000	21,000	> 100,000
1999 (30,000 PE)	15,000	46,000	83,000	20,000	18,000	98,000
1991 (50,000 PE)	10,000	15,000	18,000	14,000	13,000	84,000
1999 (50,000 PE)	9,000	28,000	50,000	12,000	11,000	59,000

7 Glossary

Average Dry Weather Flow (ADWF). The average daily volume of wastewater discharged from a sewage treatment plant in dry weather.

Buoyancy. The tendency for a submerged object to rise in a liquid.

Buoyant. An object with a bulk specific gravity less than that of the liquid within which it is immersed.

Conservative contaminants. Contaminants whose concentration is only effected by physical mixing processes. Such contaminants can be considered to be chemically/biologically inactive.

Non-Conservative contaminants. Contaminants that undergo biological uptake, chemical reactions, exchange with sediments or decay processes that result in a changes in contaminant mass with time.

Diffuser. Structure designed to enhance the dispersion of the wastewater as it is discharged into the receiving environment.

Far-field. The area that is not in the immediate vicinity of the discharge being considered.

Froude number. Dimensionless fluid mechanics parameter involving the ratio of inertia force and gravity force.

Mixing zone. Zone in which mixing of the wastewater discharge takes place in the receiving environment. An allowance for reasonable mixing is made in the RMA (1991) (S 69, 70, Schedule 3) before water quality standards are required to be met.

Neap Tide. A tide that occurs at the first or last quarter of the moon when the tide-generating forces of the sun and moon oppose each other, producing the smallest rise and fall in tidal level.

Non-compliance zone. A zone around a discharge where water quality standards or guidelines are not likely to be met.

Population Equivalent (PE). Refers to the effective population level to be serviced by a WWTP (including both industrial and domestic loadings). Industrial inputs are assigned an equivalent load in terms of per capita loading.

Peak Wet Weather Flow (PWWF). The maximum volumes of water discharged from a sewage treatment plant during or soon after a period of heavy rainfall.

Percentile. The value of a variable that is not exceeded for a stated percentage of an assessment period.

Reasonable mixing. The term used in Sections 69, 70, 107 and Schedule 3 of the RMA (1991) to define the area beyond which a range of minimum standards must be met. The boundaries of the area of 'reasonable mixing' is not synonymous with the 'mixing zone'.

Salinity. A measure of the concentration of dissolved salts in water. Salinity is described in terms practical salinity units (PSU). Freshwater is regarded having a PSU of less than 0.5 while seawater generally has a PSU of greater than 30.

Zone of initial dilution. Zone in which the initial dilution of the wastewater wastewater discharge takes place.

8 References

/1/ Agg, A.R. (1978a) *Application of Coastal Pollution Research 3 Initial Dilution* WRC Technical Report TR 92.

/2/ Agg, A.R. (1978b) *Investigations of Sewage Discharges to some British Coastal Waters*, *Chapter 6 Initial Dilution.* WRC Technical Report TR 99.

/3/ ASCE (1970) *Design and Construction of Sanitary and Storm Sewers*. ASCE manuals and reports on engineering practice, No. 37.

/4/ Auckland Regional Council 1999. Guidelines for stormwater runoff modelling in the Auckland Region. Auckland Regional Council, Technical Publication No. 108.

/5/ Bennett, N.J. (1983) *Design of sea outfalls. The lower limit concept of Initial Dilution.* Technical Note 354, Proc. Institute of Civil Engineers, 75, Part 2, 113-121.

/6/ Bettess, R. and Munro, D. (1981) *Field Measurement of Initial Dilution at a Sea Outfall*, WRC. Technical Report TR 161.

/7/ Black, K. P.; Bell, R. G.; Oldman, J. W.; Gorman, R. M.; Oulton, D. 1995. Numerical modelling of a future diffuse shoreline discharge option for the Mangere Wastewater Treatment Plant. Report for Watercare Services Ltd, Auckland. NIWA

/8/ Cederwall, K. (1968) *Hydraulics of marine waste water disposal.* Report 42. Chalmers Institute of Technology. Goteborg.

/9/ DHI (2011): MIKE 21 Flow Model FM, Hydrodynamic Module, User Guide, DHI Water & Environment.

/10/ DHI 2014. Clarks Beach - Marine Outfall Dilution and Dispersion Modelling. Report prepared for MWH and Watercare

/11/ Dolphin, T. J. and Green, M. O. (2009) *Patterns of wave-orbital speed and skin-friction under estuarine (fetch-limited) waves*. Journal of Coastal Research, SI56 178-182.

/12/ Doneker, R.L and G.H Jirka (2007): *CORMIX User Manual: A Hydrodynamic Mixing Zone Model and Decision Support System for Pollutant Discharges into Surface Waters.* U.S. Environmental Protection Agency.

/13/ GHD 2013. City of Rehoboth Beach Wastewater Treatment Plant Ocean Outfall Project. Environmental Impact Statement. Report prepared for City of Delaware.

/14/ 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.

/15/ Johnson D and McComb P 2010. Coastal and Shelf Currents around New Zealand. New Zealand Coastal Society Conference Proceedings.

/16/ Kelly, S. and C Sims-Smith C. 2015. Effects of Mangere Wastewater Discharge on Manukau Harbour Salinity. Report prepared for Watercare.

/17/ Noble, R.T., Lee, I.M. and Schiff, K.C. 1994. Inactivation of indicator micro-organisms from various sources of faecal contamination in seawater and freshwater. Journal of Applied Microbiology 2004, 96, 464–472

/18/ NIWA (2016). Quantitative Microbial Risk Assessment for the discharge of treated wastewater. Proposed sub-regional wastewater treatment facility at Clarks Beach, South Manukau. NIWA Client Report HAM2016-018.

/19/ Sinton, L.W., Davies-Colley, R.J., and Bell, R.G. (1994). Inactivation of enterococci and fecal coliforms from from sewage and meatworks effluents in seawater chambers. Applied and Environmental Microbiology 2040–2048.

/20/ Sinton, L.W., Finlay, R.K., and Lynch, P.A. (1999). Sunlight inactivation of fecal bacteriophages and bacteria in sewage-polluted seawater. Applied and Environmental Microbiology 3605–3613. Singh, A and T. Aung (2005); Effect of Barometric Pressure on Sea Level Variations in the Pacific Region. The South Pacific Journal of Natural Science, Volume 23.

/21/ Sutton, PJH; Bowen, MM 2014. Currents off the west coast of Northland, New Zealand. New Zealand Journal of Marine and Freshwater Research 45(4) 609-624.

/22/ Williams (1985) *Ocean outfall handbook: a manual for the planning, investigation, design and monitoring of ocean outfalls to comply with water quality management objectives*. Water and Soil Misc. Publication, 76, Ministry of Works & Development.

/23/ WRC (1990) *Design guide for marine treatment schemes*. Water Research Centre Report UM 1009. Swindon, UK.

APPENDIX – Modelling Methodology

Modelling has been carried out to assess the level of mixing that occurs within the near-field (the zone of initial dilution) and the subsequent dilution that occurs away from the diffuser site (the far-field).

For the near-field modelling, a combination of empirically based near-field mixing estimates and CORMIX modelling has been carried out.

For the far-field modelling the MIKE 21 hydrodynamic model (DHI, 2011), which had been previously calibrated, has been used to simulate a range of tidal and wind conditions and the dynamics of the treated wastewater plume for the range of discharges being considered. Details of the calibration of the model, model grid and boundary conditions used are provided in the original Clarks Beach Outfall report (DHI, 2014).

Empirical Near Field Modelling

Initial dilution estimates were quantified using equations from the Water Research Centre Design Guide for Marine Treatment Schemes (WRC, 1990). These design methods have been incorporated into the regulations and guidelines covering discharges into tidal waters.

The equations assumed a non-stratified water column and a number of equally spaced uniform diffuser ports. The methodology considers buoyancy effects where weak tidal currents occur when mixing is primarily driven by density differences. The effect of increasing ambient currents (when buoyancy effects become negligible) is to create forced entrainment of the treated wastewater in the sea water which leads to increased dilution. The most commonly used prediction for initial dilution are based on early work by Agg (1978a,b) and Cederwall (1968) which are based on results from field experiments where initial dilutions were measured under a variety of tidal conditions. Subsequent work by Bennett (1983) and Bettess and Munro (1981) were used to update the earlier formula of Agg into the standard equations that have been applied for this study.

The flow per port (P_f) is defined as the total treated wastewater flow rate divided by the number of ports. The velocity at the port (P_v) is defined as the flow per port (P_f) divided by the port area $\pi\left(\frac{D}{2}\right)^2$ where D is the port diameter.

The densimetric Froude Number (F) is defined as

$$F = \frac{P_v}{\sqrt{\left[\frac{(\rho_a - \rho_e)}{\rho_e}\right] gD}} \qquad \text{(A.1)}$$

where g is gravity, ρ_e is wastewater density and ρ_a is ambient water density.

The Buoyancy Flux (B) is defined as

$$B = \left[\frac{(\rho_a - \rho_e)}{\rho_e}\right] gP_f \qquad \text{(A.2)}$$

The treated wastewater plume width is defined as 0.76 times W_d. The treated wastewater plume depth is defined as 0.37 times W_d. The minimum water depth over the diffuser is assumed to occur at Mean Low Water Spring (MLWS). The minimum still water depth over the diffuser (W_{dmin}) is the water depth at the outfall site at MLWS minus the Port Height (P_h). The minimum still water plume width is defined as 0.26 times W_{dmin}. The minimum still water plume depth is defined as 0.13 times W_{dmin}.

The still water initial dilution is defined using the Cederwall (1968) formula

$$S_s = 0.54 * F * \left(\left[\frac{0.38 * W_{dmin}}{D * F}\right] + 0.66\right)^{\frac{5}{3}} \quad \text{(A.3)}$$

The minimum port separation (P_s) is defined as

$$Ps = W_d \left(0.3 + 0.4\sqrt{\frac{U}{P_v}}\right) \quad \text{(0.4)}$$

The moving water dilution (ID) is defined for two cases. If the velocity over the port (U) is zero or the water depth (W_d) is less than $\left(\frac{5*B}{U^3}\right)$ then

$$ID = \frac{0.27\, B^{\frac{1}{3}}\, W^{\frac{5}{3}}}{P_f} \quad \text{(A.5)}$$

for all other cases

$$ID = \frac{0.27\, U\, W^{\frac{5}{3}}}{P_f} \quad \text{(A.6)}$$

CORMIX Near-Field Modelling

CORMIX v.6.0 has been used to predict the behaviour of the wastewater plume within the near-field mixing zone, where the mixing behaviour of the plume is driven by the geometry of the outfall, along with the momentum and buoyancy of the wastewater plume. For further details of near-field model see CORMIX User Manual (Doneker and Jirka, 2007).

Inputs for the model include properties of the wastewater (i.e. temperature and salinity), the wastewater discharge rate, the geometry of the outfall and the properties of the receiving water body (i.e. current speed, temperature and salinity) and its dimensions. The model then calculates the mixing behaviour of the wastewater as it is discharged from the outfall and as it interacts with the receiving water body, which is assumed to be stationary in time and spatially uniform.

Far-Field Modelling

Previously, the focus of the modelling was on predicting the level of dilution that could be achieved based on short-term simulations and assuming no decay processes associated with the wastewater contaminant. This provided quantification of the likely envelop of dilutions that a particular outfall design and discharge regime could provide.

Using such an approach is considered conservative and over predicts non-conservative tracer concentrations (such as nutrients, viruses and microbial contaminants) at sites away from the immediate vicinity of an outfall and does not adequately quantify the true distribution of contaminant concentrations that may occur at particular sites of interest.

The Public Health Risk Assessment work to be carried out requires a good understanding of the distribution of microbial and viral concentrations that could occur at sites well away from the outfall location.

As such, annual simulations which include appropriate decay processes have been carried out for representative El Niño and La Niña conditions. The inactivation rates have been derived by NIWA based on an extensive literature review.