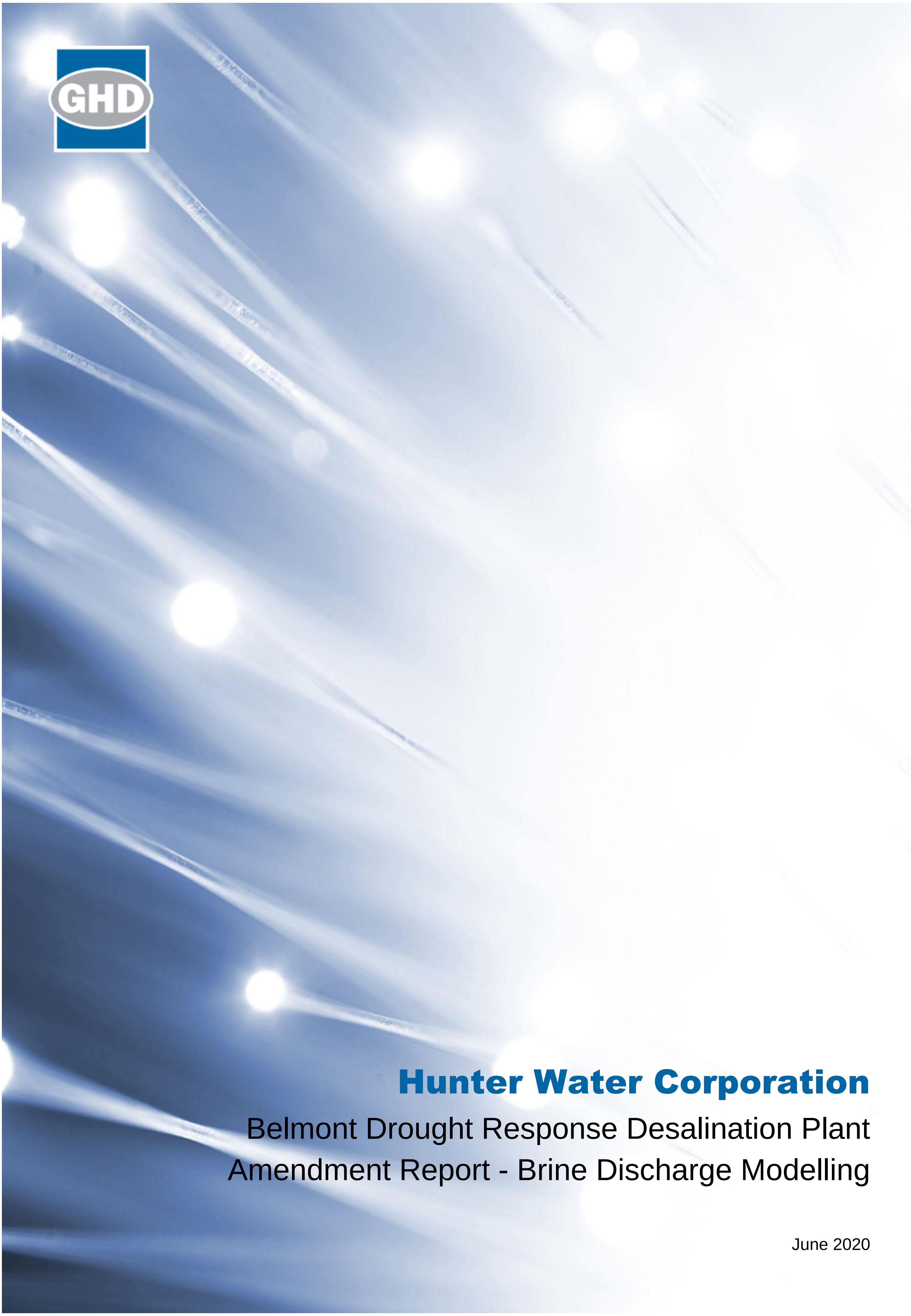
# **Appendix M** – Brine Discharge Modelling Report



# Hunter Water Corporation

## Belmont Drought Response Desalination Plant
## Amendment Report - Brine Discharge Modelling

June 2020

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# 1. Introduction

## 1.1 Background

Hunter Water Corporation (Hunter Water) is seeking approval to construct and operate a drought response desalination plant (the 'Project'), adjacent to the Belmont Wastewater Treatment Works (WWTW) in Belmont South, a suburb of Lake Macquarie Local Government Area (LGA) of New South Wales (NSW) (the 'Project area'); (see Figure 1-1).

Like much of NSW, the Lower Hunter region continues to experience ongoing drought conditions. In response to the drought, Hunter Water is rolling out a program of drought response measures as outlined in the 2014 Lower Hunter Water Plan (LHWP). Measures include the staged introduction of water restrictions, implementation of a broad range of water conservation and water loss initiatives as well as various operational measures. The 2014 LHWP identified the implementation of emergency desalination as a measure of last resort in response to a severe drought, and would only be implemented if water storage levels reached a critical point and all other measures have been implemented.

GHD Pty Ltd (GHD) were engaged by Hunter Water to prepare an Environmental Impact Statement (EIS) (GHD, 2019a) to support a development application for the Project as State Significant Infrastructure (SSI) under Part 5, Division 5.2 of the *Environmental Planning and Assessment Act 1979* (EP&A Act). The EIS was prepared in accordance with the provisions of the EP&A Act and the EP&A Regulation and addresses the Secretary's Environmental Assessment Requirements (SEARs) issued by the Department of Planning, Industry and Environment (DPIE) for the Project on 12 December 2017 and revised on 24 January 2018. The EIS was publicly exhibited by DPIE for 28 days from 21 November 2019 to 19 December 2019.

The Project described in the EIS included the construction and operation of a desalination plant, designed to produce up to 15 megalitres per day (ML/day) of potable water, with two sub-surface intake structures.

Since commencing this Project, Hunter Water has begun a major review of the 2014 LHWP, now referred to as the Lower Hunter Water Security Plan (LHWSP). The LHWSP seeks to determine the preferred portfolio of supply and demand side options to ensure a sustainable and resilient supply for the region, over the long term as well as during drought. This work indicates that a drought response portfolio including a desalination plant at Belmont with a nominal production capacity of up to 30 ML/day would provide the best balance of meeting the community's needs should a severe drought occur, while still providing value for money.

In addition to the proposed increase in plant capacity, further design development and assessment following completion of the EIS has identified that a direct ocean intake would perform considerably better than a sub-surface option across key criteria including, reliability, efficiency and scalability.

## 1.2 Purpose and structure of this report

This Report has been prepared as a supporting document to the Amendment Report and addresses the requirements for the SEARs in considering the revised impacts of the amended Project. The purpose of this report is to compare the change in marine impacts from an increased brine discharge associated with the amended nominal capacity 30 ML/day desalination plant from a 15 ML/day BDRDP.

This report should be read in conjunction with GHD reports titled: Belmont Drought Response Desalination Plant – Environmental Impact Statement (GHD, 2019a) and Belmont Drought Response Desalination Plant – Brine Modelling Assessment (GHD, 2019b).

This report considers the following two changes to the GHD (2019a,b) the amended Project in terms of marine impacts:

- A brine discharge of 56.6 ML/day (Amended design (nominal capacity 30 ML/day BDRDP)) is compared to the 28.2 ML/day brine discharge (EIS design (nominal capacity 15 ML/day BDRDP)).
- A brine salinity prior to comingling with the treated wastewater of 58.3 psu (Amended design (nominal capacity 30 ML/day BDRDP)) rather than 65 psu (EIS design (nominal capacity 15 ML/day BDRDP)).
- A seawater intake (Amended design) rather than a sub-surface seawater intake structure (EIS design).


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Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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**Hunter Water Corporation**
**Belmont Drought Response Desalination Plant**
**Brine Discharge Modelling Report**

Project No. **22-19573**
Revision No. **0**
Date **29/06/2020**

## Project Location

## Figure 1-1

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Data source: LPI: DTDB / DCDB, 2017; public_NSW_Imagery: © Department of Customer Service 2020. Created by: fmackay

# 2. Project changes

## 2.1 Overview

In addition to the proposed increase in plant capacity, the amended Project includes the following design changes:

- Seawater intake: Further design development and liaison with Hunter Water's construction partners following completion of the EIS identified reliability and construction risks with the proposed horizontal sub-surface intake system as described in the EIS. An assessment of the horizontal sub-surface intake system was undertaken against alternative intake options. This assessment found that a direct ocean intake would perform considerably better than a sub-surface option across key criteria including reliability, efficiency and scalability (see Section 2.2).
- Power supply: The EIS proposed to meet power requirements for the Project via a minor upgrade to the existing 11 kV power supply network in the vicinity of Hudson Street and Marriot Street. The amendment to the capacity of the water treatment process plant means this is now unfeasible, due to inability to meet energy requirements. Instead, the Project will connect to Ausgrid's 33 kV network in the vicinity of the Project (see Figure 2-1).

## 2.2 Key features of the amended Project

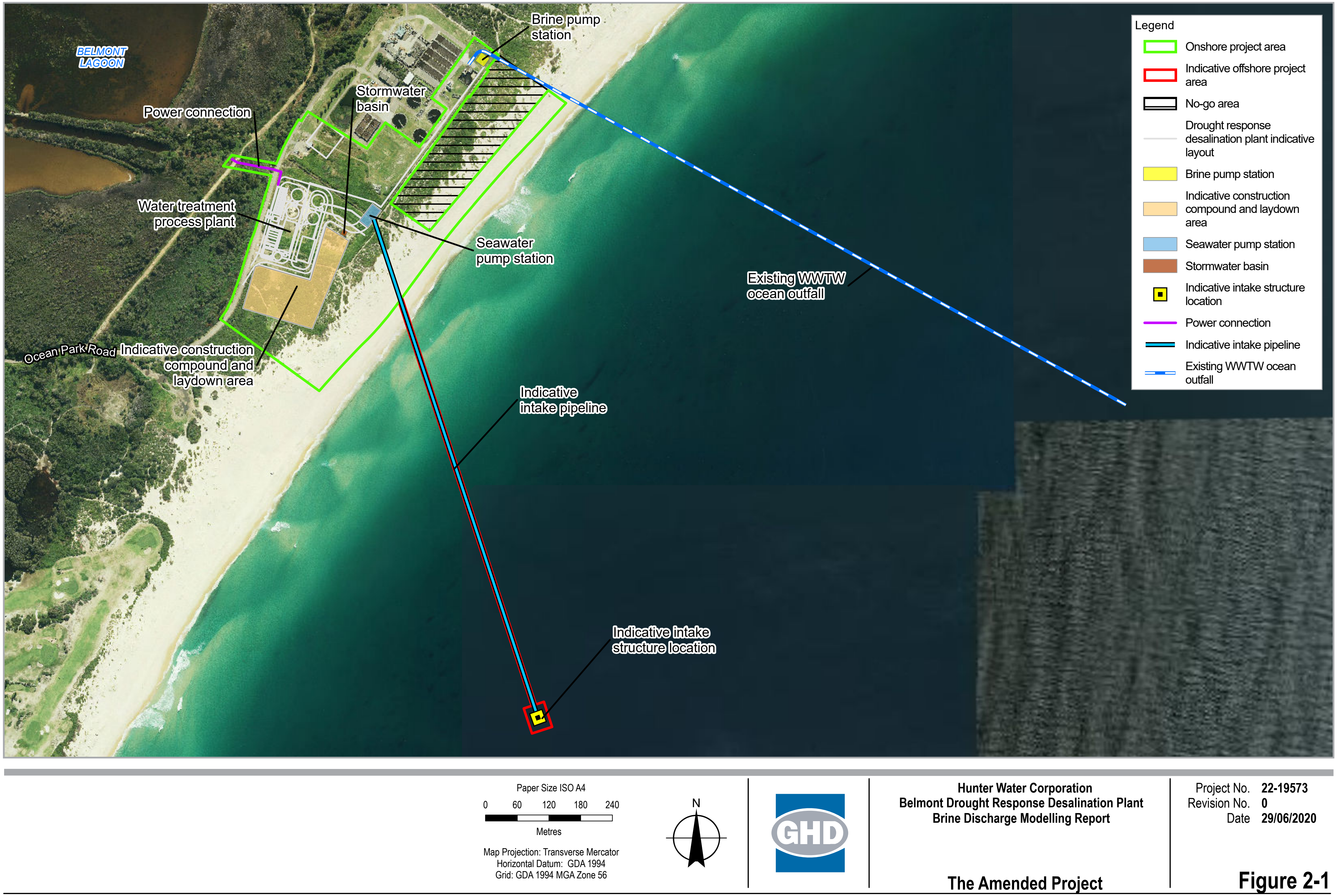
The amended Project for the construction and operation of a drought response desalination plant, designed to produce up to 30 ML/d of potable water, includes the following key components (as shown in Figure 2-1):

- **Direct ocean intake** – To ensure provision of sufficient quantities of raw feed water for the water treatment process plant, a direct ocean intake is proposed as part of the amended Project, as follows:
  - *Sea Water Pump Station (On-shore), including a central well, screening and pump housing*, proposed to be a concrete structure (referred to as a wet well) of approximately nine to 11 m diameter, installed to a depth up to 20 m below existing surface levels.
  - *Intake pipeline,* the indicative pipeline alignment is approximately 1000 m in length, extending outwards from the central housing to the off-shore intake structure. Construction of the intake pipeline would be determined during detailed design; however, the following construction methodologies/ considered and assessed included Construction method 1 (CM1) Horizontal directional drilling (HDD) and (CM2) Pipejacking/micro-tunnelling.
  - *Intake structure (Off-shore)*, the intake structure would be in the form of a horizontal intake with a velocity cap structure and low through-screen velocity to minimise impacts on marine species and habitat. The intake structure would be 5 m in diameter, have a minimum of 5 m clearance from the seabed and a depth of approximately 18 m of water.

- **Water treatment process plant** – The water treatment process plant would not significantly change from that described in the EIS. The inclusion of buildings to house equipment rather than the installation of containerised equipment is the primary change. The buildings would be placed above ground level and located to allow incremental installation, if required. Services to and from the process equipment (e.g. power, communications, and raw feed water (seawater)) would comprise a mix of buried and overhead methods. The general components of the water treatment process would comprise:
  - *Pre-treatment:* a pre-treatment system is required to remove micro-organisms, sediment, and organic material from the raw feed water.
  - *Desalination:* a reverse osmosis (RO) desalination system made up of pressurising pumps and membranes. These would be comprised of modular components. In addition, a number of tanks and internal pipework would be required.
  - *Post treatment:* desalinated water would be treated to drinking water standards and stored prior to pumping to the potable water supply network.
- **Brine disposal system** – The desalination process would produce up to 56 ML/d of wastewater, comprising predominantly brine, as well as a small amount of pre-treatment and RO membrane cleaning waste. The waste brine from the desalination process would be transferred via a pipeline to a brine pump station at the Belmont WWTW for disposal via the existing ocean outfall pipe.
- **Power supply** – Power requirements of the amended water treatment process plant would require connection to Ausgrid's 33 kV line to the north-west of the water treatment process plant site, with new private power line connecting to a substation within the plant site.
- **Ancillary facilities** – including a tank farm, equipment housing buildings, chemical storage and dosing, hardstand areas, stormwater and cross drainage, access roads, parking areas, and fencing, signage and lighting.

Each of these elements are described further in Appendix C of the Amendment Report.

The desalination plant would be connected to Hunter Water's potable water network via a potable water pipeline proposed to be constructed to augment the existing water network. The pipeline does not form part of the Project and would be part of a separate design and approvals process.




Hunter Water Corporation
Belmont Drought Response Desalination Plant
Brine Discharge Modelling Report

Project No. 22-19573
Revision No. 0
Date 29/06/2020

**The Amended Project**

**Figure 2-1**

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Data source: HWC: Aerial Imagery, Existing outfall: 2019; LPI: DTDB / DCDB, 2017; public_NSW_Imagery: © Department of Customer Service 2020. Created by: fmackay

# 3. Methodology

The scope of the GHD (2019b) Brine Discharge Modelling report was to predict the potential water quality impacts from the discharge of brine during the operation of a nominal capacity 15 ML/day BDRDP that is co-mingled with the Belmont Wastewater Treatment Works (WWTW) treated wastewater via the following tasks:

1. Develop water quality objectives (WQOs) for key parameters of concern for the co-mingled brine-treated wastewater discharge.
2. Confirm the existing Belmont WWTW outfall diffuser can accommodate the additional brine flow from the BDRDP from a near-field dilution perspective when co-mingled with the treated wastewater.
3. Develop a calibrated and validated three-dimensional (3D) hydrodynamic model.
4. Simulate dispersion of the co-mingled brine-treated wastewater discharge for a range of WWTW flow conditions and a constant brine discharge of 28.2 ML/day from a 15 ML/day BDRDP (EIS design) over a range of receiving marine water conditions (i.e. tides, stratification).

In this Amendment Report, tasks 1, 2 and 4 are carried out for a brine discharge of 56.6 ML/day for a potable water production capacity of 30 ML/day. The 3D model has already undergone calibration and validation (task 3) as reported in the EIS and did not have to be redone as the previous calibration covered the range of flows for the amended Project also. Comparisons between these three tasks are reported here. Additionally, the degree of recirculation of the co-mingled discharge from the diffuser is evaluated at the amended proposal's seawater intake.

Refer to the GHD (2019b) Brine Discharge Modelling Report for the following:

- Detailed methodology to define the WQOs and to carry out the near-field and 3D modelling (Section 2 of GHD (2019b)). WQOs are expressed as a required dilution factor of the treated wastewater-brine mixture by the ambient marine waters to meet the relevant guideline or trigger values (Table 3-1).
- The model domain, bathymetry and mesh used in the simulations (Section 3.1 of GHD (2019b)).
- The available data and information that served to define model inputs for environmental forcing (meteorology, river discharge, open ocean boundaries (water level, currents, temperature, salinity), diffuser discharges (treated wastewater discharge and salinity, brine water quality estimates, discharge of comingled treated wastewater-brine) and model validation data for currents (Sections 3.2 and 3.3 of GHD (2019b)).

**Table 3-1 Summary of guideline and trigger values**[1]

| Parameter | DS (psu) | $NH_x$ (mg/L) | $NO_x$ (mg/L) | TN (mg/L) | TP (mg/L) | Entero (MPN)/ 100mL) | Cu (mg/L) | Pb (mg/L) | Zn (mg/L) | Turbidity (NTU) |
|---|---|---|---|---|---|---|---|---|---|---|
| Marine Toxicity | | 0.91 | | | | | 0.0013 | 0.0044 | 0.015 | |
| Marine Ecosystem | 1.0 | 0.009 | 0.049 | 0.334 | 0.012 | | | | | 2.7 |
| Human health | | | | | | 35 | | | | |

[1] Refer to GHD (2019b) for further explanation of acronyms and source of values.

# 4. Impact assessment – brine discharge

## 4.1 Diffuser discharge, salinity and temperature inputs

Estimates of the diffuser discharge, salinity and temperature of the existing treated wastewater and proposed 15 ML/day nominal capacity BDRDP scenarios were provided in Section 3.3.5 of GHD (2019b). GHD (2019b) utilised a conservative brine salinity of 65 psu prior to co-mingling with the treated effluent. In the amended scenario for the 30 ML/day nominal capacity DRPR, a more realistic brine salinity of 58.3 psu was used that assumed 40% recovery. This is summarised in Table 4-1.

Figure 4-1, Figure 4-2 and Figure 4-3 illustrate the diffuser discharge, salinity and temperature, respectively, for the three scenarios (existing treated wastewater, proposal, amendment) that served as model inputs. For the proposal and amendment scenarios, the treated wastewater-brine discharge, salinity and temperature were estimated on the basis of volume, mass and heat balances of the time varying (discharge, temperature) and constant (salinity) properties of the WWTW treated wastewater, and the average estimates of the BDRDP brine properties (discharge, temperature and salinity). The following observations are noted:

- The median outlet (diffuser) discharge of the amended 30 ML/day scenario (1.27 $m^3/s$) is approximately twice the existing treated effluent scenario (0.61 $m^3/s$) and approximately a third greater than the proposed 15 ML/day scenario (0.94 $m^3/s$).
- The salinity range between the 10$^{th}$ and 90$^{th}$ percentiles of salinity for the amendment scenario (26 to 43 psu) indicates that a greater proportion of the co-mingled treated wastewater-brine salinity results in negatively buoyant (sinking) plumes (outlet salinity >35 psu) relative to the proposal scenario (20 to 38 psu).
- Estimated variations in the outlet (diffuser) water temperatures between the three scenarios are minimal.

**Table 4-1 Model inputs for diffuser discharge, salinity and temperature for the existing treated wastewater and co-mingled brine-treated wastewater scenarios**

| Parameter | Existing Treated Wastewater | EIS Design Treated Wastewater-Brine | Amended Design Treated Wastewater-Brine | Justification |
|---|---|---|---|---|
| Operating Hours (hrs/day) | 24 | | | Plant to operate continuously (GHD 2019a). |
| Discharge ($m^3/s$) | Figure 4-1 (black) | Figure 4-1 (red) | Figure 4-1 (green) | Brine discharges of 28.2 and 56.6 ML/day comingled with treated wastewater for EIS and amended designs, respectively. |
| Salinity (psu) | Figure 4-2 (black) | Figure 4-2 (red) | Figure 4-2 (green) | Brine salinities of 65 and 58.3 psu comingled with treated wastewater median of 4.1 psu for EIS and amended designs, respectively. |
| Temperature (°C) | Figure 4-3 (black) | Figure 4-3 (red) | Figure 4-3 (green) | Characteristic brine temperature of 20°C comingled with treated wastewater for EIS and amended designs, respectively. |


**Figure 4-1 Diffuser discharge over entire simulation period (top) and over the last 2 months (bottom) of the three scenarios**

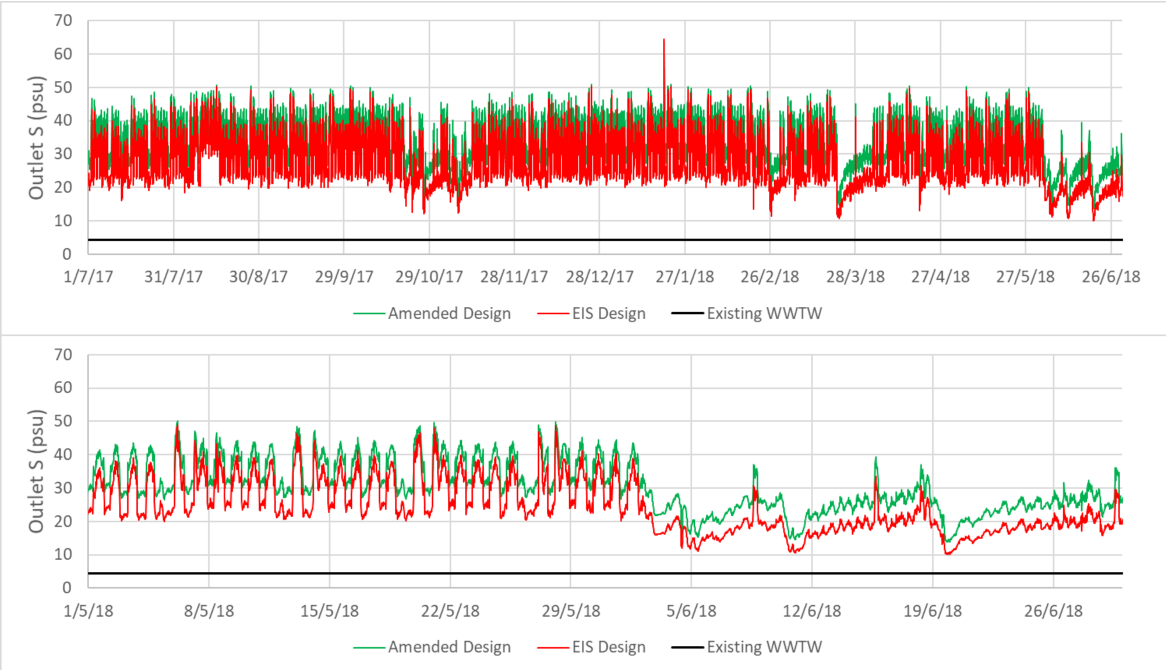


**Figure 4-2 As Figure 4-1 for salinity**


**Figure 4-3 As Figure 4-2 for temperature**

### 4.1.1 Changes in model inputs of the amendment relative to the proposal

The changes in the model inputs for the diffuser discharge, temperature and salinity for the amendment scenario relative to the proposal scenario include:

- Approximately a one third increase in the treated wastewater-brine discharge through the diffuser.
- A 13%, 27% and 33% salinity increase in the comingled treated wastewater-brine for the $10^{th}$, $50^{th}$ and $90^{th}$ percentiles, respectively.
- Extraction of seawater from an intake structure (Figure 2-1).

## 4.2 WQO dilution estimates

The WQOs at the edge of the mixing zone for key parameters of concern of the existing treated wastewater and the two treated wastewater-brine mixture scenarios (i.e. 15 and 30 ML/day nominal capacity BDRDPs) are expressed as a dilution factor to meet the relevant guideline or trigger values. The dilution factor of the treated wastewater (existing scenario) or treated wastewater-brine mixture (EIS and amended design scenarios) by the ambient marine waters is simulated with a conservative tracer via 3D hydrodynamic modelling (Section 4.4). The dilution factor is used to evaluate the spatial extent of the existing WWTW's treated wastewater mixing zone and to predict the spatial extent of the treated wastewater-brine mixing zone during operation of the BDRDP (Section 4.4).

The dilution factor for salinity effects for the EIS and amended design scenarios was modified from GHD (2019b) as follows:

- In GHD (2019b) a mass balance was used to estimate a characteristic salinity from the constant salinities of the brine (proposal 65 psu) and treated wastewater (4.3 psu), and the average diffuser discharge during the selected dry (April 21-May 18, 2018) and wet (June 2-29, 2018) periods. This characteristic salinity was used to estimate the dilution factor at the surface for these two periods. The maximum salinity of the comingled treated wastewater-brine salinity model inputs was used to estimate the dilution factor at the seabed.

- In this amendment report, the 1st and 99th percentiles of the comingled treated wastewater-brine salinity model inputs (Section 4.1) were used to estimate the dilution factors at the surface and seabed, respectively, irrespective of seasonality. This approach bounds the range of dilution factors to define the edge of the mixing zone on a statistical basis.

Table 4-2 summarises the dilution factors of the WQOs (human health, marine toxicity, marine ecosystem, and near surface and near seabed salinity) for the EIS and amended designs. Table 4-3 provides greater detail in the information used to estimate these dilution factors across the analytes with sufficient data for this analysis.

**Table 4-2 WQOs expressed as dilution factors to define area of impact (or effect) for human health, marine toxicity, marine ecosystem and ambient salinity**

| WQO | Analyte | Dry Exist | Dry Propose | Dry Amend | Wet Exist | Wet Propose | Wet Amend |
|---|---|---|---|---|---|---|---|
| Human Health | Enterococci | 47 | 29 | 22 | 22 | 18 | 15 |
| Marine Toxicity | $NH_X$ | 0.8 | 0.7 | 0.6 | 0.0 | 0.1 | 0.2 |
| Marine Ecosystem | $NO_X$ | 234 | 203 | 189 | 142 | 144 | 146 |
| Salinity (Near Surface $S_{Diffuser}$ <35 psu) | DS | 31 | 22 (8)[2] | 18 | 31 | 22 (18) | 18 |
| Salinity (Near Seabed $S_{Diffuser}$ >35 psu) | DS | NA | 11 (14) | 13 | NA | 11 (NA) | 13 |

### 4.2.1 Changes in WQOs of the amendment relative to the proposal

The changes in the WQOs for the amendment scenario relative to the EIS design scenario include:

- Because of greater pre-dilution of the treated wastewater by the higher brine discharge, the dilution factors at the edge of the near surface mixing zone for human health decreased from 29 to 22 and 18 to 15 for the dry and wet periods, respectively.
- Marine toxicity dilution factors remain very low for both scenarios.
- The marine ecosystem dilution factor decreases by ~5% over dry period, and does not materially change for wet period.
- The dilution factor for salinity near the:
  - Surface for the proposal scenario increased to 22 with the statistical approach (99th percentile of proposal comingled salinities) relative to the GHD (2019b) values of 8 and 18 for the dry and wet seasons, respectively.
  - Seabed for the proposal scenario was 11 for both dry and wet seasons relative to the GHD (2019b) value of 14 for the dry season.
  - Surface decreases from 22 for the proposal scenario to 18 for the amendment scenario because of the higher salinities of the amended design.
  - Seabed increases from 11 for the proposal scenario to 13 for the amendment scenario because of the higher salinities of the amended design.

[2] Values in parentheses reported in GHD (2019b), but have been updated here.

**Table 4-3 Estimation of dilution factors for existing, proposed and amended scenarios to meet marine ecosystem, ecotoxicity, salinity and human health WQOs**

| Parameter | $NH_X$ | $NO_X$ | TN | TP | E | Cu | Pb | Zn | TSS | $S_{Surface}$ | $S_{Seabed}$ | References and Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $C_A$: Ambient (mg/L, cfu/100 ml, psu) | 0.0025 | 0.005 | 0.121 | 0.005 | 0.5 | 0.0005 | 0.0001 | 0.0025 | 0.5 | 35 | 35 | Section 3.2.4 of GHD (2019b), median of reference sites |
| $C_B$: Design brine concentration (mg/L, cfu/100 ml, psu) | 0.44 | 6.7 | ND[3] | ND | 0 | ND | ND | ND | 0 | 65 (EIS) 58.3 (Amend) | 65 (EIS) 58.3 (Amend) | Sections 3.2.3 and 3.3.1 of GHD (2019b); proposal and amendment salinities of 65 and 58.3 psu, respectively; assume desalination process removes all TSS and enterococci. |
| $C_V$: Marine Ecosystem SSTV (mg/L) | 0.009 | 0.049 | 0.334 | 0.012 | | | | | 2.7 | | | Section 2.1.1 of GHD (2019b) |
| $C_V$: Marine Toxicity MMTV (mg/L) | 0.91 | | | | | 0.0013 | 0.0044 | 0.015 | | | | |
| $C_V$: Human Health RPCGV (cfu/100 ml) | | | | | 35 | | | | | | | |
| $C_V$: Salinity Trigger Value (psu) | | | | | | | | | | 34 | 36 | |
| **Dry Weather EXISTING Scenario (Treated Wastewater) – Low WWTW Discharge** | | | | | | | | | | | | |
| $C_O$: Treated Wastewater (mg/L, cfu/100 ml, psu) | 0.76 | 10.4 | 13.3 | 3.5 | 1,622 | 0.0040 | 0.0006 | 0.0572 | 21 | 4.3 | 4.3 | Section 3.2.2 of GHD (2019b), 90th percentile except for median salinity |
| Marine Ecosystem Dilution Factor | 116 | 234 | 62 | 485 | | | | | 9.3 | | | Calculated as per equation in Section 2.1 of GHD (2019b) |
| Marine Toxicity Dilution Factor | 0.8 | | | | | 4.3 | 0.1 | 4.4 | | | | |
| Human Health Dilution Factor | | | | | 47.0 | | | | | | | |
| Salinity Dilution Factor | | | | | | | | | | 30.7 | | |
| **Dry Weather PROPOSAL Scenario (Comingled Treated Wastewater-Brine) – Low WWTW Discharge** | | | | | | | | | | | | |
| $Q_W$: Treated Wastewater Discharge ($m^3/s$) | 0.54 | | | | | | | | | | | Section 3.2.1 of GHD (2019b), average discharge over dry weather period |
| $Q_B$: EIS design - 15 ML/day BDRDP Brine Discharge ($m^3/s$) | 0.326 | | | | | | | | | | | Section 2.3. of GHD (2019b), average discharge |
| $C_O$: Treated Wastewater -Brine (mg/L, cfu/100 ml, psu) | 0.64 | 9.0 | | | 1,011 | | | | 13.1 | 12.9 | 45.4 | $C_O=(Q_B \times C_B+Q_W \times C_W)/(Q_B+Q_W)$ except $S_{Surface}$ and $S_{Seabed}$ are 1st and 99th percentiles from Section 4.1 inputs, respectively |
| Marine Ecosystem Dilution Factor | 98 | 203 | | | | | | | 5.7 | | | Calculated as per Section 2.1 of GHD (2019b) |
| Marine Toxicity Dilution Factor | 0.7 | | | | | | | | | | | |
| Human Health Dilution Factor | | | | | 29.3 | | | | | | | |
| Salinity Dilution Factor | | | | | | | | | | 22.1 | 10.4 | |
| **Dry Weather AMENDED Scenario (Comingled Treated Wastewater-Brine) – Low WWTW Discharge** | | | | | | | | | | | | |
| $Q_W$: Treated Wastewater Discharge ($m^3/s$) | 0.54 | | | | | | | | | | | Section 3.2.1 of GHD (2019b), average discharge over dry weather period |
| $Q_B$: Amended design - 30 ML/day BDRDP Brine Discharge ($m^3/s$) | 0.655 | | | | | | | | | | | Estimated for this report |
| $C_O$: Treated Wastewater - Brine (mg/L, cfu/100 ml, psu) | 0.58 | 8.3 | | | 723.9 | | | | 9.5 | 17.7 | 47.9 | $C_O=(Q_B \times C_B+Q_W \times C_W)/(Q_B+Q_W)$ except $S_{Surface}$ and $S_{Seabed}$ are 1st and 99th percentiles from Section 4.1 inputs, respectively |
| Marine Ecosystem Dilution Factor | 89 | 189 | | | | | | | 4.1 | | | Calculated as per Section 2.1 of GHD (2019b) |
| Marine Toxicity Dilution Factor | 0.6 | | | | | | | | | | | |
| Human Health Dilution Factor | | | | | 21.2 | | | | | | | |
| Salinity Dilution Factor | | | | | | | | | | 17.3 | 12.9 | |
| **Wet Weather EXISTING Scenario (Treated Wastewater) – High WWTW Discharge** | | | | | | | | | | | | |
| $C_O$: Treated Wastewater (mg/L, cfu/100 ml, psu) | 0.02 | 6.3 | 7.8 | 1.9 | 761 | 0.0012 | 0.0001 | 0.0276 | 5 | 4.3 | 4.3 | Section 3.2.2 of GHD (2019b), 20th percentile except for median salinity |
| Marine Ecosystem Dilution Factor | 3 | 142 | 36 | 263 | | | | | 2 | | | Calculated as per Section 2.1 of GHD (2019b) |
| Marine Toxicity Dilution Factor | 0.0 | | | | | 0.9 | 0.0 | 2.0 | | | | |
| Human Health Dilution Factor | | | | | 22.0 | | | | | | | |
| Salinity Dilution Factor | | | | | | | | | | 30.7 | | |
| **Wet Weather PROPOSAL Scenario (Comingled Treated Wastewater-Brine) – High WWTW Discharge** | | | | | | | | | | | | |
| $Q_W$: Treated Wastewater Discharge ($m^3/s$) | 1.25 | | | | | | | | | | | Section 3.2.1 of GHD (2019b), average discharge over wet weather period |
| $Q_B$: EIS design - 15 ML/day BDRDP Brine Discharge ($m^3/s$) | 0.326 | | | | | | | | | | | Section 2.3. of GHD (2019b), average discharge |
| $C_O$: Treated Wastewater - Brine (mg/L, cfu/100 ml, psu) | 0.11 | 6.4 | | | 604 | | | | 4.0 | 12.9 | 45.4 | $C_O=(Q_B \times C_B+Q_W \times C_W)/(Q_B+Q_W)$ except $S_{Surface}$ and $S_{Seabed}$ are 1st and 99th percentiles from Section 4.1 inputs, respectively |
| Marine Ecosystem Dilution Factor | 16 | 144 | | | | | | | 1.6 | | | Calculated as per Section 2.1 of GHD (2019b) |
| Marine Toxicity Dilution Factor | 0.1 | | | | | | | | | | | |
| Human Health Dilution Factor | | | | | 17.5 | | | | | | | |
| Salinity Dilution Factor | | | | | | | | | | 22.1 | 10.4 | |
| **Wet Weather AMENDED Scenario (Comingled Treated Wastewater-Brine) – High Effluent Discharge** | | | | | | | | | | | | |
| $Q_W$: Treated Wastewater Discharge ($m^3/s$) | 1.25 | | | | | | | | | | | Section 3.2.1 of GHD (2019b), average discharge over wet weather period |
| $Q_B$: Amended design - 30 ML/day BDRDP Brine Discharge ($m^3/s$) | 0.655 | | | | | | | | | | | Estimated for this report. |
| $C_O$: Treated Wastewater - Brine (mg/L, cfu/100 ml, psu) | 0.16 | 6.4 | | | 500 | | | | 3.3 | 17.7 | 47.9 | $C_O=(Q_B \times C_B+Q_W \times C_W)/(Q_B+Q_W)$ except $S_{Surface}$ and $S_{Seabed}$ are 1st and 99th percentiles from Section 4.1 inputs, respectively |
| Marine Ecosystem Dilution Factor | 25 | 146 | | | | | | | 1.3 | | | Calculated as per Section 2.1 of GHD (2019b) |
| Marine Toxicity Dilution Factor | 0.2 | | | | | | | | | | | |
| Human Health Dilution Factor | | | | | 14.5 | | | | | | | |
| Salinity Dilution Factor | | | | | | | | | | 17.7 | 12.9 | |

*Light orange shading identifies maximum dilution factors that are reported in* Table 4-2*, whereas light yellow shading is the highest dilution factor, but not used as only an estimate for the existing case and not the proposed or amended cases.*

[3] No data.

## 4.3 Near-field modelling

Near-field modelling was carried out by GHD (2019b) to confirm that the existing diffuser can accommodate the additional brine discharge from operation of the EIS design scenario (nominal BDRDP capacity of 15 ML/day). Refer to Sections 2.2 and 4.2 of GHD (2019b) for details on the methodology and inputs, respectively. The same diffuser specifications and ambient marine conditions were run for the amended design scenario (nominal BDRDP capacity of 30 ML/day) with appropriate values for the comingled discharges and salinities as summarised in Table 4-4.

### Table 4-4 Diffuser and outlet discharge inputs for near-field modelling

| Parameter | Original Diffuser (1992) | Augmented Diffuser (2004) | Justification |
|---|---|---|---|
| % of Total Outlet Discharge (Q) | 33.3% | 66.7% | Total outlet diffuser flow for the two diffuser segments proportional to the number of ports |
| High Existing Scenario Q ($m^3$/s) | 0.321 | 0.643 | 90th (high) and 10th (low) percentiles of WWTW discharge measurements |
| Low Existing Scenario Q ($m^3$/s) | 0.087 | 0.175 | |
| High Proposal Scenario Q ($m^3$/s) | 0.430 | 0.860 | 90th (high) and 10th (low) percentiles of treated wastewater-brine discharge model inputs for proposal scenario (15 ML/day) in Section 4.1 |
| Low Proposal Scenario Q ($m^3$/s) | 0.196 | 0.382 | |
| High Amendment Scenario Q ($m^3$/s) | 0.540 | 1.080 | 90th (high) and 10th (low) percentiles of treated wastewater-brine discharge model inputs for amendment scenario (30 ML/day) in Section 4.1 |
| Low Amendment Scenario Q ($m^3$/s) | 0.306 | 0.611 | |
| WWTW Baseline Salinity (S) (psu) | 4.3 | | Median salinity of treated wastewater |
| High Proposal Scenario S (psu) | 38.0 | | 90th (high) and 10th (low) percentiles of treated wastewater-brine discharge model inputs for proposal scenario (15 ML/day) in Section 4.1 |
| Low Proposal Scenario S (psu) | 19.7 | | |
| High Amendment Scenario S (psu) | 42.9 | | 90th (high) and 10th (low) percentiles of treated wastewater-brine discharge model inputs for amendment scenario (30 ML/day) in Section 4.1 |
| Low Amendment Scenario S (psu) | 26.1 | | |

The exit velocities from the diffuser nozzles are very low for the 90th (0.61, 0.78 and 1.03 m/s for the existing, proposal and amendment scenarios, respectively) and 10th (0.17, 0.35 and 0.59 m/s for the existing, proposal and amendment scenarios, respectively) percentile outlet discharges. Clearly, the diffusers have been designed primarily to rely on positive buoyancy-driven plume mixing (i.e. rising plumes), and not jet-induced mixing (i.e. typically exit velocities of ~5 m/s yield effective jet-induced mixing). Given the median treated wastewater salinity of 4.3 psu relative to the seawater salinity of ~35 psu, this is an effective mechanism for the existing scenario that only discharges treated wastewater. The simulated near-field dilution factors of the three scenarios are illustrated in Figure 4-4 and are summarised in Table 4-5.

Figure 4-4 and Table 4-5 can be readily interpreted by considering the following from GHD (2019b):

- The spacing between adjacent ports is the primary mechanism for the decreased dilution of the augmented diffuser section (0.55 m spacing between ports) relative to the original diffuser (2.2 m spacing between ports). Shorter spacing between ports results in the merging of adjacent plumes more rapidly for the augmented section than the original portion of the diffuser, thereby decreasing dilution efficiency. One measure to improve the near-field dilution of the augmented diffuser section is to cap some of the diffuser ports (nozzles). For example, if four adjacent ports were capped with every fourth port remaining uncapped, then an equivalent port spacing of 2.2 m as the original diffuser would result in improved near-field dilution via two mechanisms:
  - Delay in the merging of plumes and thereby greater mixing efficiency during the plumes rising.
  - Increased port exit velocities thereby increasing jet-induced mixing when discharged into the ambient waters, which is very low currently.
- Dilution increases with higher ambient current speeds. This is caused by the interaction between shear mixing (mixing caused by the currents of the ambient marine waters) and buoyancy driven mixing (mixing induced as the plume of lower density rises through the ambient waters).
- Because jet-induced mixing is low for all three scenarios due to the low exit velocities from the diffuser ports, lower discharges (e.g. 10th percentile) yield greater dilution than higher flow rates (e.g. 90th percentile). This is primarily due to the smaller plume diameters that occur during lower discharge rates with greater concomitant entrainment efficiency of ambient waters into the interior of the plume than for larger plume diameters with higher flow rates.
- The high salinity cases that are evaluated with the near-field modelling for the proposal and amendment scenarios have values that are greater than ambient seawater (~35 psu) and therefore fall to seabed after exiting the diffuser ports. Hence, near-field dilution is low as the falling plumes only travel a short distance before striking the seabed.

**Table 4-5 Summary of simulated near-field dilution factors**

| Parameter | Existing Scenario | Proposal Scenario | Amendment Scenario | Comment |
|---|---|---|---|---|
| Dilution (D) for low currents (v), high salinity (S), low discharge (Q), original diffuser | 970 | 12 (21)[4] | 11 | Proposal and amendment scenarios strike seabed at ~2 m due to the higher salinities of the proposal and amendment scenarios with resultant low near-field dilution of ~10 relative to the existing scenario with rising plumes (325-970 fold). |
| D: low v, high S, low Q, augmented diffuser | 325 | 10 (14) | 9 | |
| D: high v, high S, low Q, augmented diffuser | 3,900 | 64 (45) | 36 | Proposal and amendment plumes strike seabed at ~5-6 and ~3-4 m, respectively. Higher dilution than low currents for proposal and amendment scenarios because higher current speeds increase shear mixing prior to striking the seabed. |
| D: high v, high S, low Q, augmented diffuser | 1,000 | 35 (31) | 24 | |

[4] Values in parentheses report in GHD (2019), but refined here on basis of improved interrogation of seabed strike from simulations.

| Parameter | Existing Scenario | Proposal Scenario | Amendment Scenario | Comment |
|---|---|---|---|---|
| D: low v, low S, high Q, original diffuser | 340 | 245 | 197 | For this case all three scenarios have rising buoyant plumes that reach the surface. Relatively high dilution is achieved for all three cases with the original diffuser segment with a substantive reduction for plumes from the augmentation diffuser segment due to merging. |
| D: low v, low S, high Q, augmented diffuser | 120 | 85 | 68 | |
| D: high v, low S, high Q, original diffuser | 1,075 | 810 | 630 | Similar findings to model runs with low currents except dilution is much greater due to enhanced mixing of the plume from shear mixing by the elevated ambient currents. |
| D: high v, low S, high Q, augmented diffuser | 300 | 220 | 170 | |

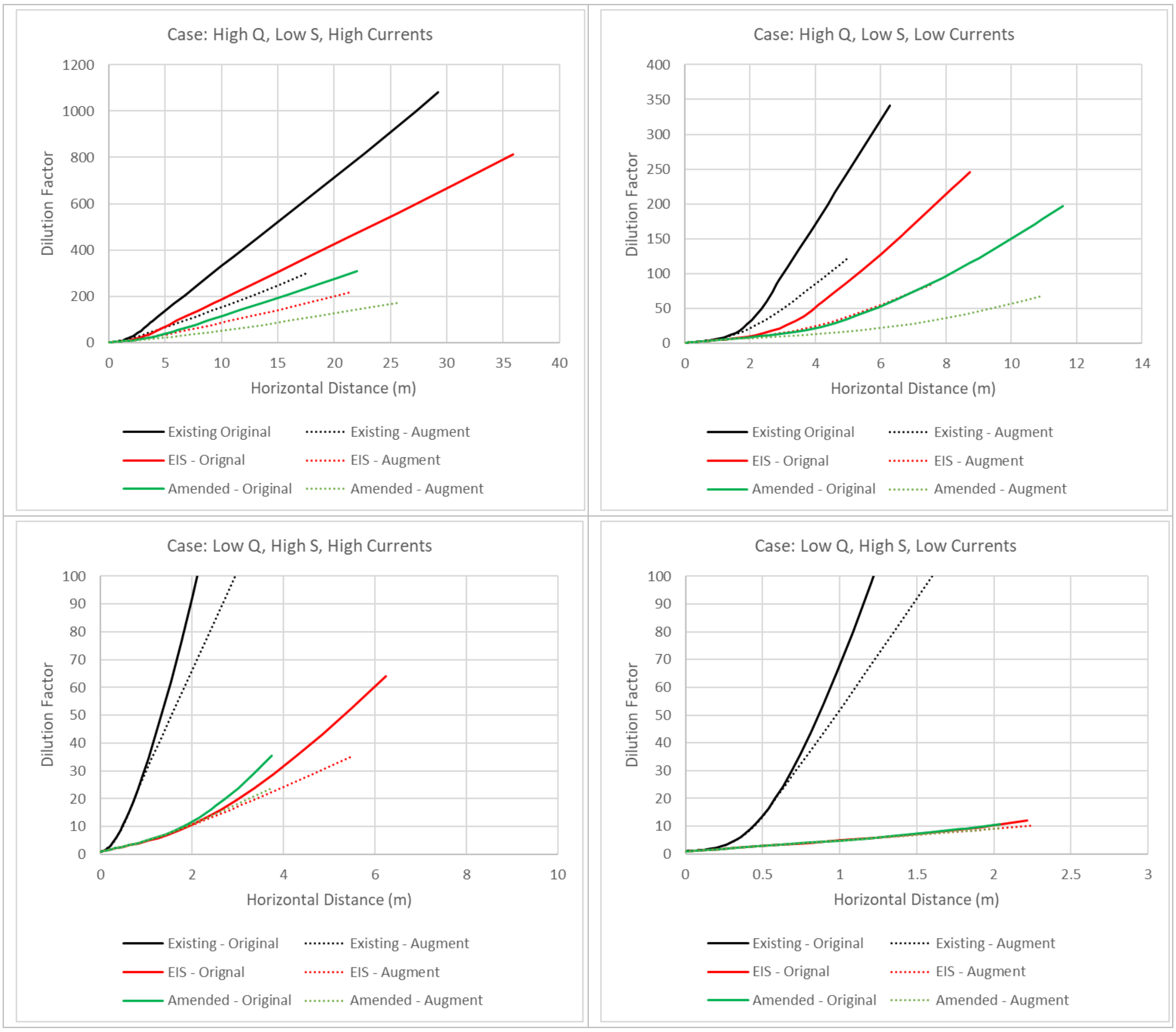


**Figure 4-4 Simulated near-field dilution factors of original and augmented diffuser segments of the three scenarios over four cases**

### 4.3.1 Changes in near-field dilution factors of the amended design relative to the EIS design

The changes in the simulated near-field dilution factors for the amendment scenario relative to the proposal scenario include:

- Because of the higher salinities of the amended design scenario, positively buoyant (rising) plume mixing is less vigorous, and so dilution factors are lower than the proposal scenario (upper two panels of Figure 4-4). However, the near-field dilution factors for the amendment scenario (68-310) are still substantially greater than the WQOs for human health (22 dry season, 15 wet season) and near-surface salinity (18) (Section 4.2).
- Dilution factors are similar between the amended and EIS scenarios over the short horizontal distance that negatively buoyant (sinking) plumes are transported prior to striking the seabed (lower two panels of Figure 4-4). The near-field dilution factors for the amend design scenario are substantially greater for higher currents (24-36) or similar during low currents (9-11) relative to the WQO for near-seabed salinity (13) (Section 4.2).

## 4.4 3D modelling scenarios

### 4.4.1 Changes in the far-field dilution factors of the amended design relative to the EIS design

The spatial extent of impacts (or effects) on the basis of the dilution factors for the near-surface salinity, human health and ecosystem productivity WQOs (Section 4.2) are presented as probability exceedance contours for the representative dry (21 April to 18 May 2018) and wet (2-29 June 2018) weather periods over two neap-spring tidal cycles in Figure 4-5 to Figure 4-10.

#### *Human health WQO*

The amended design scenario has substantially reduced predicted mixing zones during both the dry (Figure 4-5) and wet (Figure 4-8) periods relative to the EIS design scenario for the human health WQO because:

- There is greater pre-dilution of the treated wastewater enterococci loads by the brine, which reduces the dilution factor of the amendment co-mingled discharge for the human health WQO relative to the EIS design scenario (Section 4.2.1).
- The higher salinities of the amended design co-mingled discharge results in greater mixing of the plume through the water column for the amended design relative to the EIS design scenarios.

As noted in GHD (2019b) for the existing and EIS design scenarios, the amended design scenario is also predicted to achieve the human health WQO in closer proximity to the longer (121 m) original diffuser segment (~2 m spacing between 55 ports) than the shorter (61 m) augmented diffuser segment (~0.5 m spacing between 110 ports) because of greater dilution efficiency due to delayed plume merging, in agreement with the near-field modelling in Section 4.3.

#### *Ambient Salinity WQO*

The amended design scenario has substantially reduced predicted mixing zones during both the dry (Figure 4-6) and wet (Figure 4-9) periods relative to the EIS design scenario for the near surface salinity WQO because:

- The higher salinities of the amended design co-mingled discharge reduces the dilution factor for the near surface salinity WQO (Section 4.2.1).

- The higher salinities of the amended design co-mingled discharge results in greater mixing of the plume through the water column for the amended design relative to the EIS design scenarios.

As with the human health WQO above, the near surface salinity WQO is predicted to be achieved in closer proximity to the longer (121 m) original diffuser segment (~2 m spacing between 55 ports) than the shorter (61 m) augmented diffuser segment (~0.5 m spacing between 110 ports) because of greater dilution efficiency due to delayed plume merging, in agreement with the near-field modelling in Section 4.3.

A dilution factor of 13 for the near-seabed salinity WQO of the amended design is met within 5 m of the diffuser as demonstrated by the near-field modelling (Section 4.3), the same finding as the GHD (2019b) prediction for the EIS design comingled discharge scenario.

#### *Marine Ecosystem WQO*

The amended design scenario has similar sized predicted mixing zones during both the dry (Figure 4-7) and wet (Figure 4-10) periods relative to the EIS design scenario for the ecosystem productivity WQO because:

- There is a slight reduction in the dry weather dilution factor for the ecosystem productivity due to pre-dilution for the amended design comingled discharge, but no material change in the dilution factor for the wet period (Section 4.2.1).
- Because of the relatively high dilution factors that define the ecosystem productivity WQO (142-146 in wet season, 189-234 in dry season), far-field (natural) mixing processes become an important mechanism for all three scenarios, and thereby yield similar spatial extents for the representative dry and wet periods.

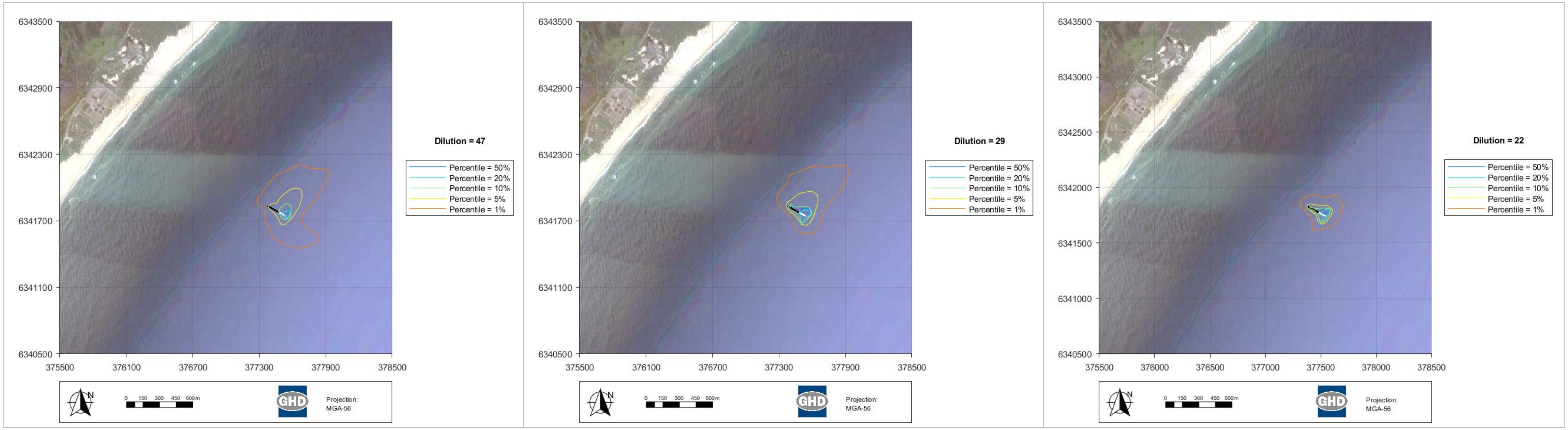


**Figure 4-5 1%, 5%, 10%, 20% and 50% percentile probability exceedance contours of the human health WQO dilution factors over the wet weather period (21 April-18 May 2018) for the existing (left), and EIS (middle) and amended (right) design scenarios**

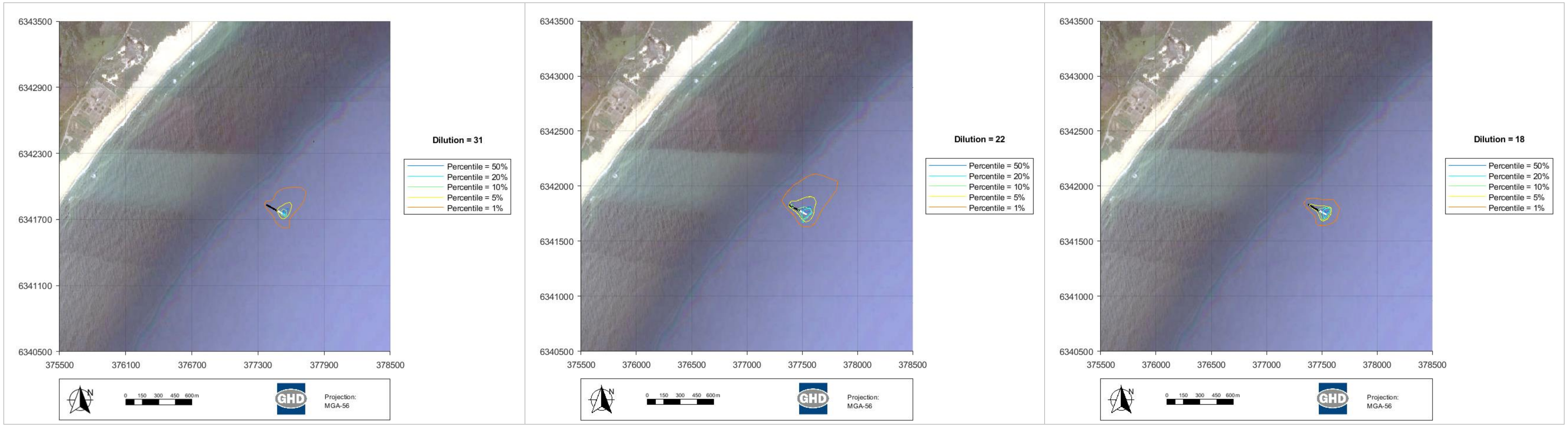


**Figure 4-6 As Figure 4-5 for the near-surface salinity WQO dilution factors**

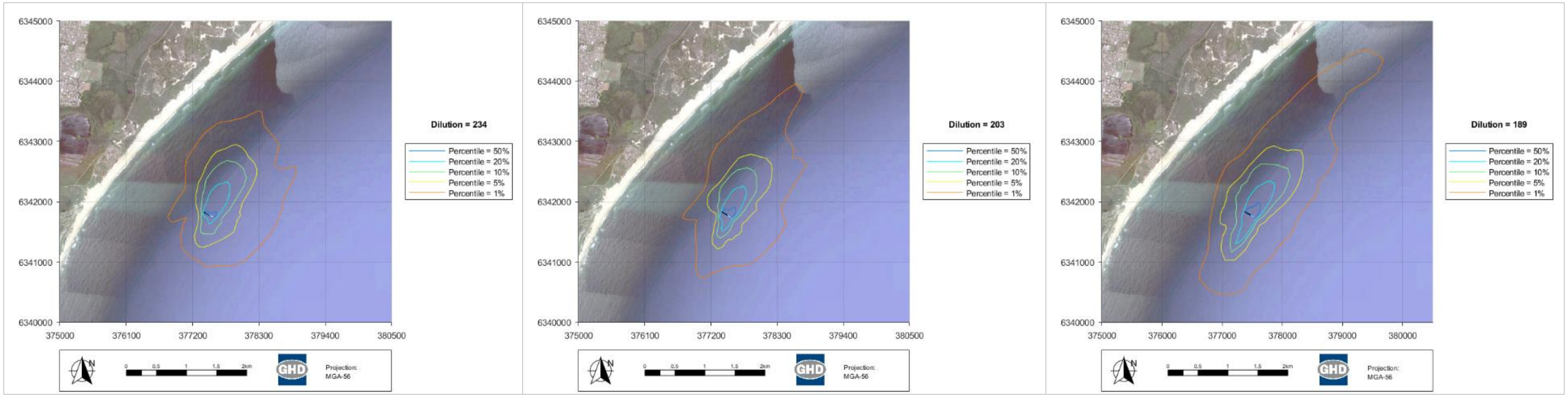


**Figure 4-7 As Figure 4-5 for the ecosystem productivity WQO dilution factors**

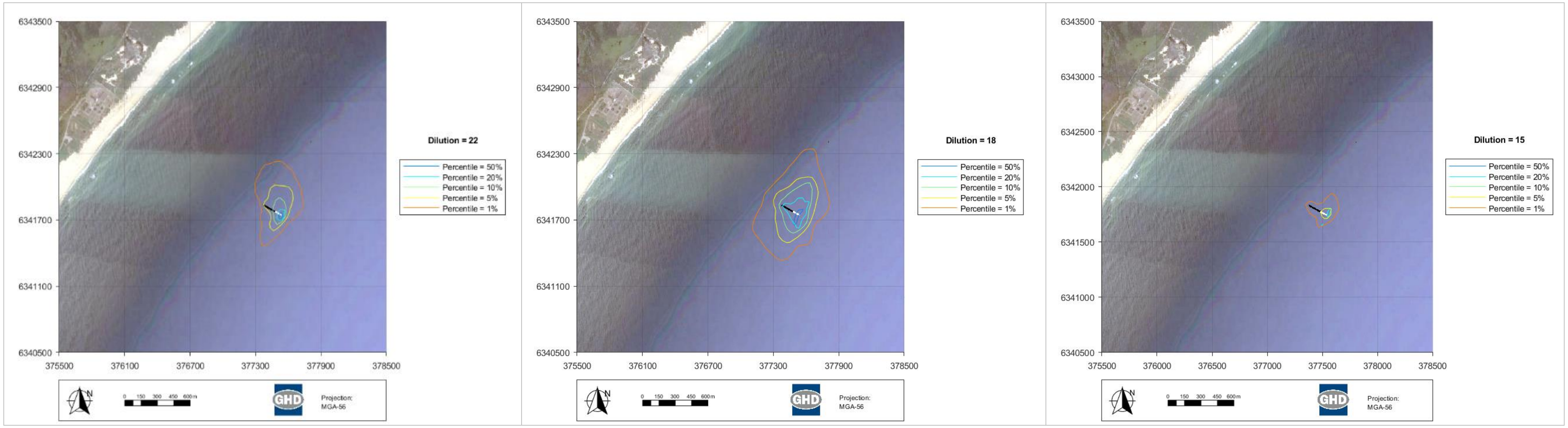


**Figure 4-8 1%, 5%, 10%, 20% and 50% percentile probability exceedance contours of the human health WQO dilution factors over the wet weather period (2-29 June 2018) for the existing (left), and EIS (middle) and amended (right) design scenarios**

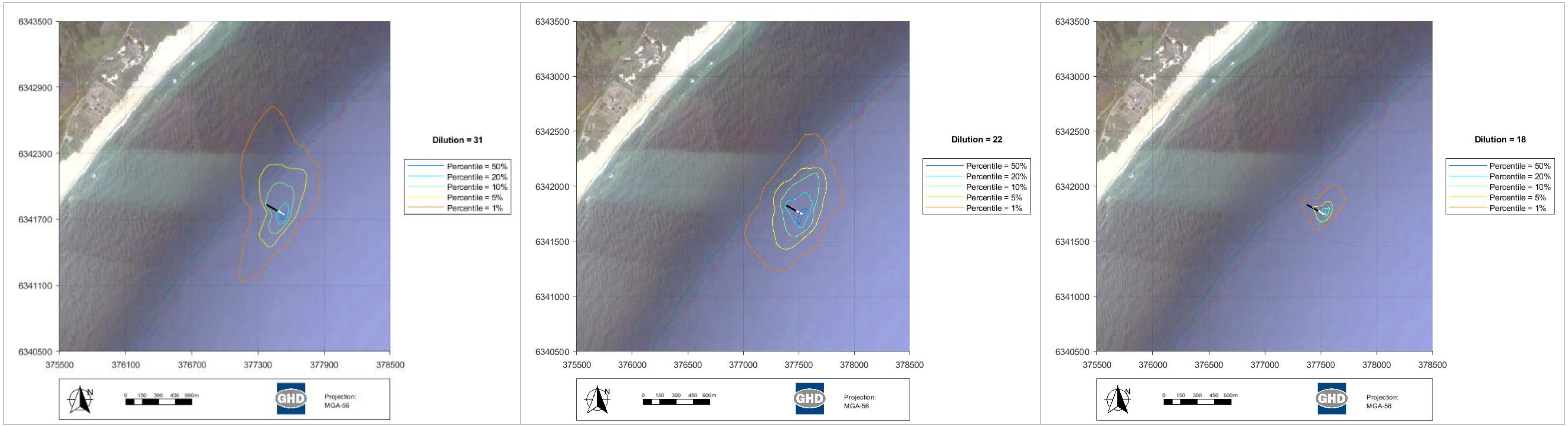


**Figure 4-9 As Figure 4-8 for the near-surface salinity WQO dilution factors**

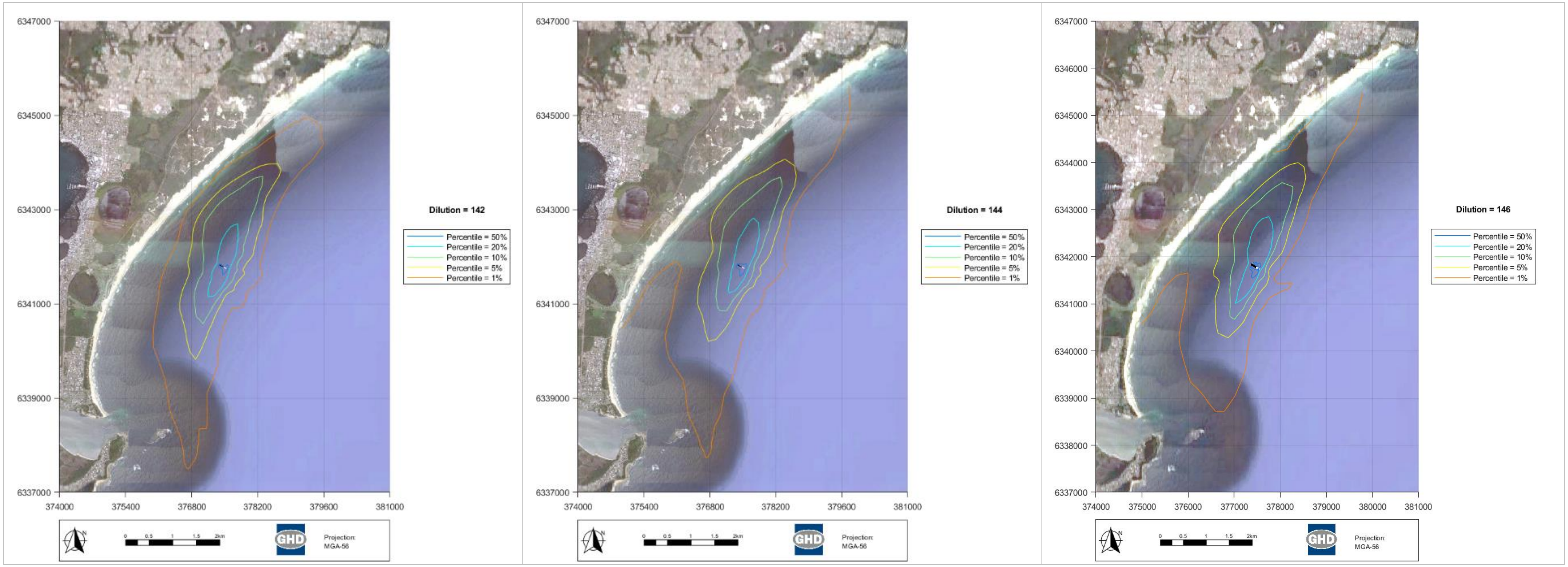


**Figure 4-10 As Figure 4-8 for the ecosystem productivity WQO dilution factors**

### 4.4.2 Operational risk or recirculation of diffuser discharge to the seawater intake

The operational risk of recirculation of co-mingled discharge from the diffuser to the seawater intake is considered here for the amended design.

The predicted temporal percentile contours (90%, 95%, 99%, 99.5%, 99.9%) that enclose the area in which seawater at the level of the intake structure has a 1% or greater composition of co-mingled discharge from the diffuser is illustrated in Figure 4-11 over representative dry (21 April-18 May 2018) and wet (2-29 June 2018) periods. The 1% threshold for the proportion of co-mingled discharge in seawater is a preliminary indicator of the risk of treated effluent recirculation into the seawater intake. In fact, the 99$^{th}$, 99.5$^{th}$ and 99.9$^{th}$ percentiles over the representative dry season period to the west of the diffuser do not occur within 500 m of the intake structure, in part due to the upward seabed slope between the diffuser (~23 m depth) and the intake (~15 to 18 m depth). Additionally, the simulated areal extent of seawater with 1% co-mingled water is substantially smaller for the representative wet weather period than the dry weather period. During the wet weather period the co-mingled discharge salinities are generally lower than the ambient seawater and thereby tend to rise to the surface upon exiting the diffuser, and therefore are less likely to recirculate to the depth of the intake structure.

The proportion of treated effluent in the comingled discharge that is injected into the surrounding waters via the diffuser for the amended design typically ranges between 20-60% during dry periods and 50-80% during wet periods (top panel of Figure 4-12). The proportion of treated effluent withdrawn by the intake structure (i.e. degree of recirculation) was simulated with a conservative tracer (i.e. no microbial pathogen decay/die-off during transport from diffuser to intake structure). The simulated range of treated effluent at the intake was 0-0.35% (middle panel of Figure 4-12). Assuming a constant enterococci concentration of the treated effluent equivalent to the median (938 MPN/100 ml) and 99$^{th}$ percentile (2,048 MPN/100 ml) of measurements from January 2014 to November 2018, and assuming no die-off or decay of enterococci during transport from the diffuser to the intake structure, then the enterococci concentrations of source waters from the intake are predicted be <7.5 MPN/100 ml for a continuous 99$^{th}$ percentile treated effluent concentration and <3.5 MPN/100 ml for a continuous median treated effluent concentration (bottom panel of Figure 4-12).

The predicted percentile distribution of enterococci concentrations at the intake for the continuous median and 99$^{th}$ percentile treated effluent concentrations are illustrated in Figure 4-13, which show that for 90% of the time the concentrations are <0.7 MPN/100 ml and <1.6 MPN/100 ml, respectively.

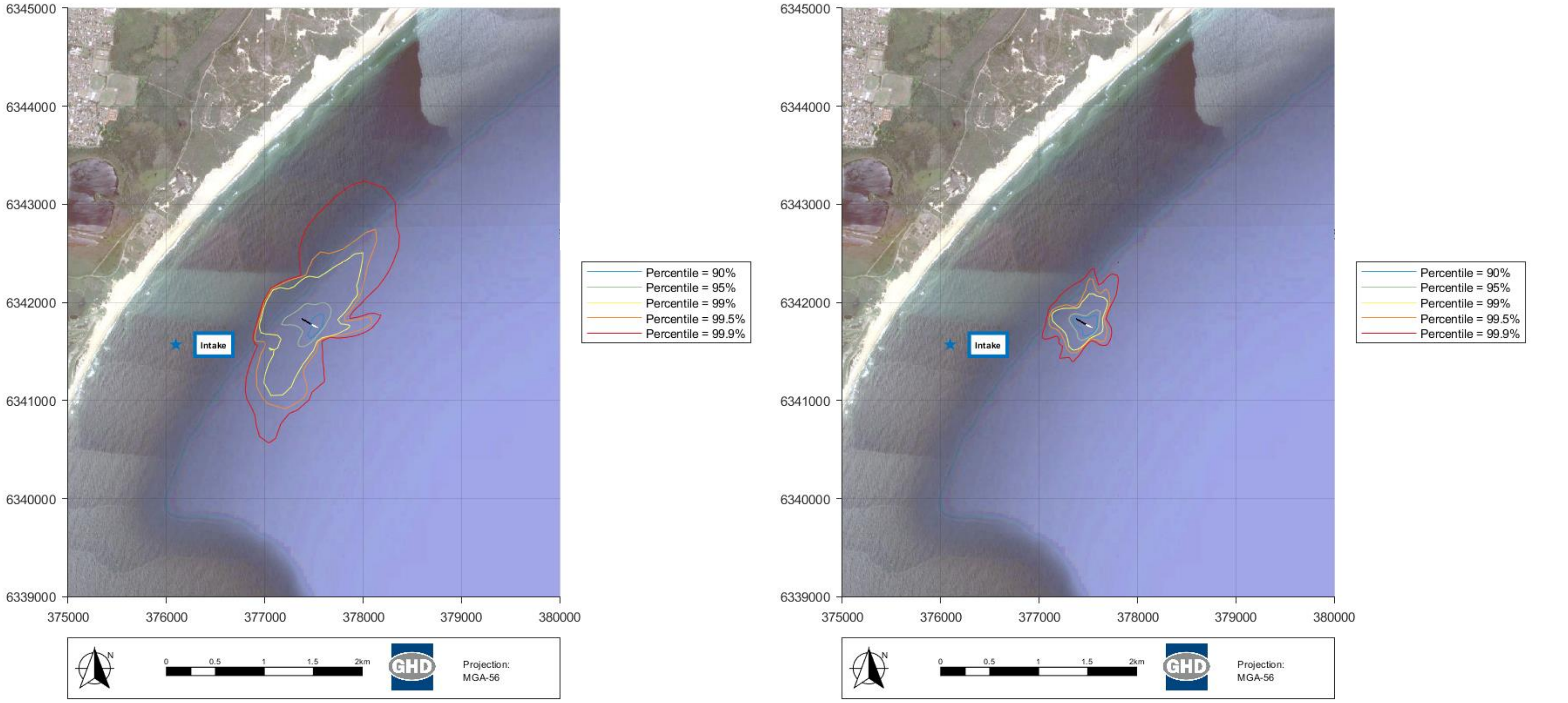


**Figure 4-11 Contours of 1% of co-mingled discharge in seawater at the intake structure level for the amended design over the representative dry (top) and wet (bottom) periods**

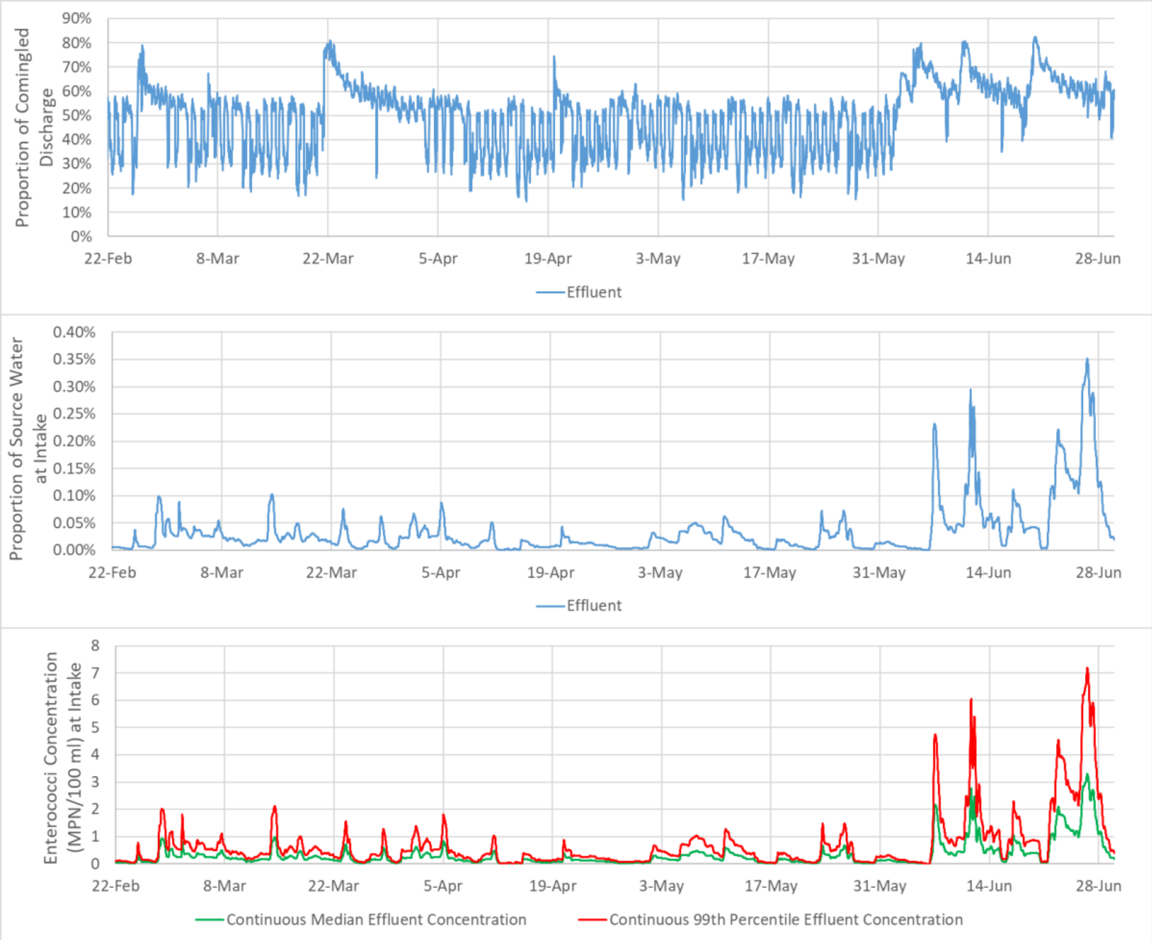


**Figure 4-12 Proportion of effluent in comingled discharge from diffuser (top), proportion of effluent in source waters from intake (middle) and estimated enterococci concentration at intake for continuous median and 99th percentile treated effluent concentrations**

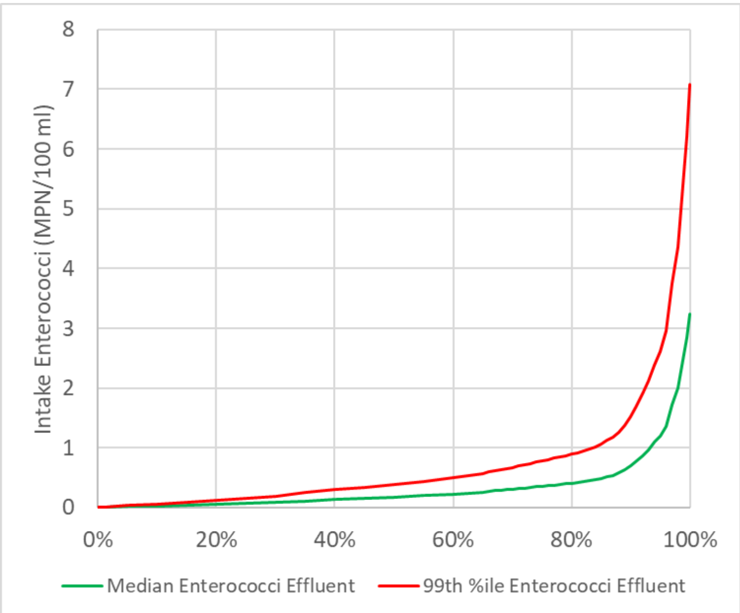


**Figure 4-13 Percentile distributions of enterococci at the intake due to recirculation of comingled discharge for continuous median and 99th percentile treated effluent concentrations**

# 5. Summary of revised mitigation measures

All mitigation measures identified in the EIS (GHD 2019) to manage potential impacts associated with brine discharge are relevant and appropriate to manage the potential impacts of the amended design.

# 6. Conclusion

The key conclusions in regards to the water quality impacts (effects) of the release of the amendment versus proposal co-mingled discharges into the marine environment via the existing diffuser include:

- For both scenarios the marine toxicity WQO is met within ~1 m of the diffuser because of the low required dilution factor of <1. UM3 near-field modelling predicts this dilution factor is met immediately upon release into the marine environment.
- The spatial area to meet the human health WQO dilution factor is predicted to decrease because of pre-dilution of the treated wastewater by the increased brine discharge. Exceedances of the human health WQO occur at a distance greater than ~1 km from the nearest beach, and thereby do not pose a material primary contact risk.
- The spatial area to meet the near-surface salinity WQO is predicted to be substantially smaller for the amended design relative to the EIS design.
- The dilution factor for the near-seabed salinity WQO is readily met within 5 m of the diffuser.
- The spatial area of effect of the marine ecosystem WQO is predicted to be similar across dry and wet season periods for the EIS and amended design scenarios.

Because of the increased potable water generation capacity of the amended design from 15 ML/day to 30 ML/day, a seawater intake is required as the sub-surface seawater intake structure of the EIS design cannot supply sufficient source water. The operational risk of recirculation of microbial pathogens from the treated effluent discharged via the diffuser into the BDRDP intake structure is low as:

- For a continuous 99$^{th}$ percentile effluent concentration prior to dilution with the BDRDP brine, the maximum enterococci concentration at the intake is <7.5 MPN/100 ml.
- For a continuous median effluent concentration prior to dilution with the BDRDP brine, the maximum enterococci concentration at the intake is <3.5 MPN/100 ml.

For 90% of the time, the continuous 99$^{th}$ percentile and median effluent concentrations are <1.6 and <0.7 MPN/100 ml in the source waters from the intake structure.

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