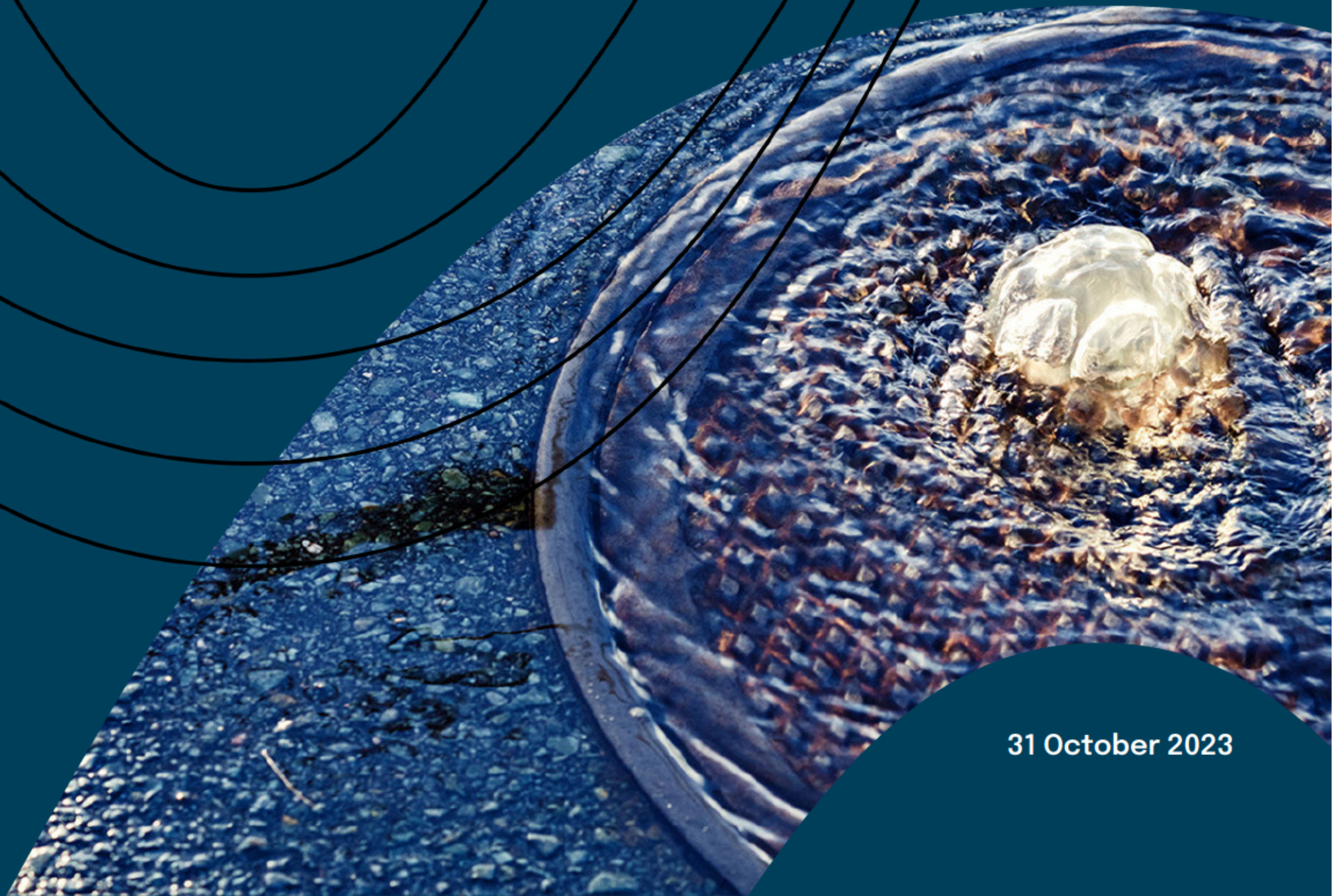
Exmouth Sea Outfall

Concept diffuser design and near field dispersion assessment



31 October 2023

Document information

Project name	Exmouth Sea Outfall
Report title	Concept diffuser design and near field dispersion assessment
Report date	31 October 2023

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1 Introduction

South West Water (SWW) is planning the construction of a new outfall at Straight Point near Exmouth, Devon (Figure 1.1). Galliford Try (GT) is the principal contractor and principal designer of the outfall and Pell Frischmann (PF) is supporting GT with various tasks associated with outfall. PF commissioned HR Wallingford to provide a near-field assessment to inform the design of the outfall diffuser.

Specifically, GT/PF require that the diffuser performance specification parameters are to be developed to a standard acceptable to the Environment Agency. The maximum flow through the diffuser will be comprised of 273 l/s UV-treated final effluent, plus 718 l/s settled stormwater, equalling 991 l/s in total. In addition, small amounts of effluent from a combined sewage outfall (CSO) may also be discharged through the outfall at times.

This report presents:

- Site conditions;
- Review of far-field modelling report;
- The model inputs and assumptions;
- Near-field and initial dilution assessment for current outfall;
- Outline concept design for the new diffuser, including results of near-field analysis;
- Conclusions and recommendations.

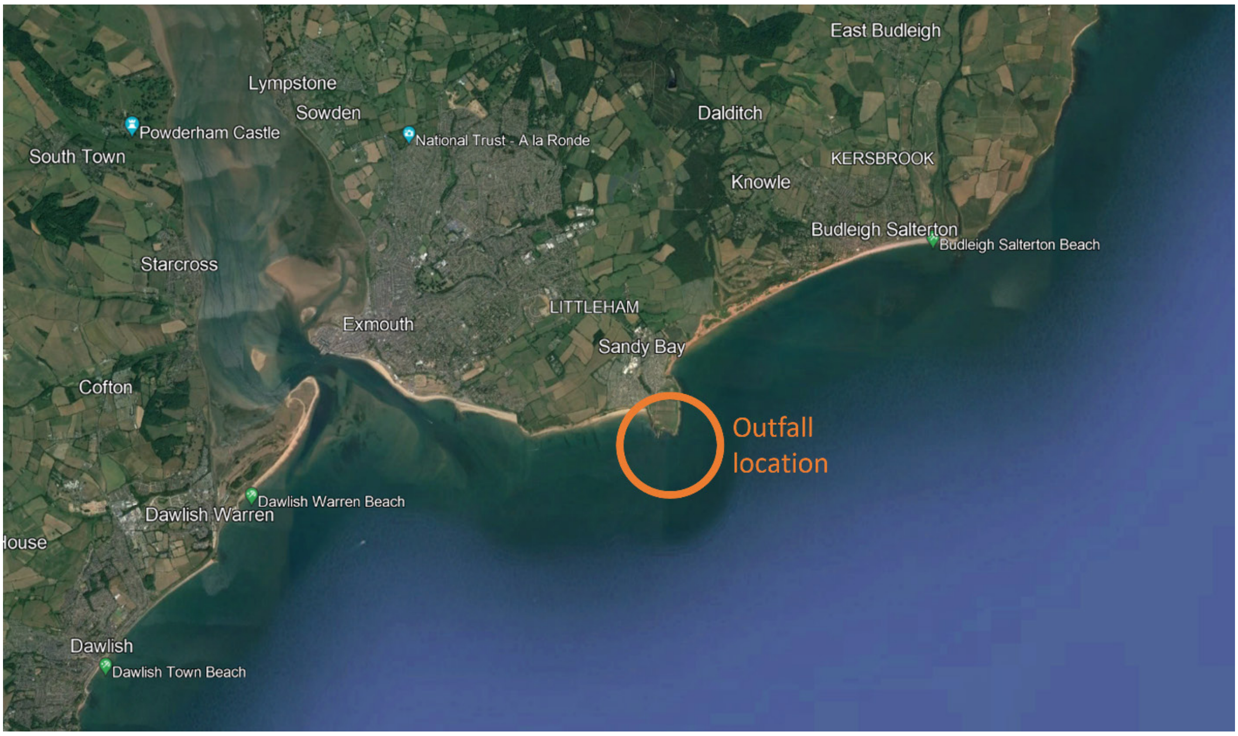


Figure 1.1: Project location

Source: Google Earth

2 Site conditions

2.1 Bathymetry

According to the provided survey reports, the seabed and bathymetry at the project location consists of an area of substantial boulders and possible rock outcrops protruding from the shore. The rock outcrop extends to the south east of the survey area. Depths in these areas are ranging from 1.2 metres above CD to 12.7 metres below CD. The remaining bathymetry to the west and south west of the area is predominantly flat and featureless with depths ranging from 5.3 metres below CD to 14 metres below CD.

There is a disparity for the exact location of the current outfall diffuser, with a two different sources stating the starting point of the diffuser with approximately 57 meters of lateral distance and 1 meter of water depth difference. For this study, the outfall location is assumed to be at the location, stated by SWW records, which starts at approximately 8 meters below CD.

A general view of the bathymetry is presented in Figure 2.1.

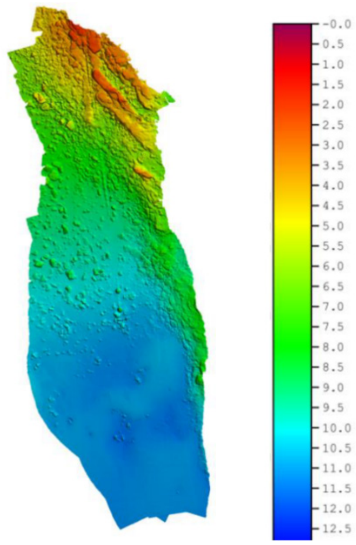


Figure 2.1: General bathymetry of the survey area

Source: *Titan Environmental Surveys Ltd., CS0608_Exmouth VMADCP_V1, 2021*

2.2 Currents

PF provided a survey report of Titan Environmental Surveys Ltd. which was appointed by SWW to conduct ADCP and bathymetric surveys at Exmouth and Straight point (outfall location). The surveys were undertaken between 23rd and 27th September 2021 using a vessel mounted ADCP, collecting data during one 12.5 hour full tide cycle at Straight Point.

At Straight Point prevailing current directions are 90˚ and 200˚, with minimum and maximum recorded current speeds of 0.04 m/s and 0.575 m/s respectively.

Averaged scatter plots of the current, and time series plot of current speed, direction and vectors are shown in Figure 2.2 and Figure 2.3.

In addition to the survey report, PF has provided an analysis of the ADCP data, to be used as the basis in the modelling, summarising hourly current speeds and directions within the tidal cycle, relative to the high water, as presented in Table 2.1 below.

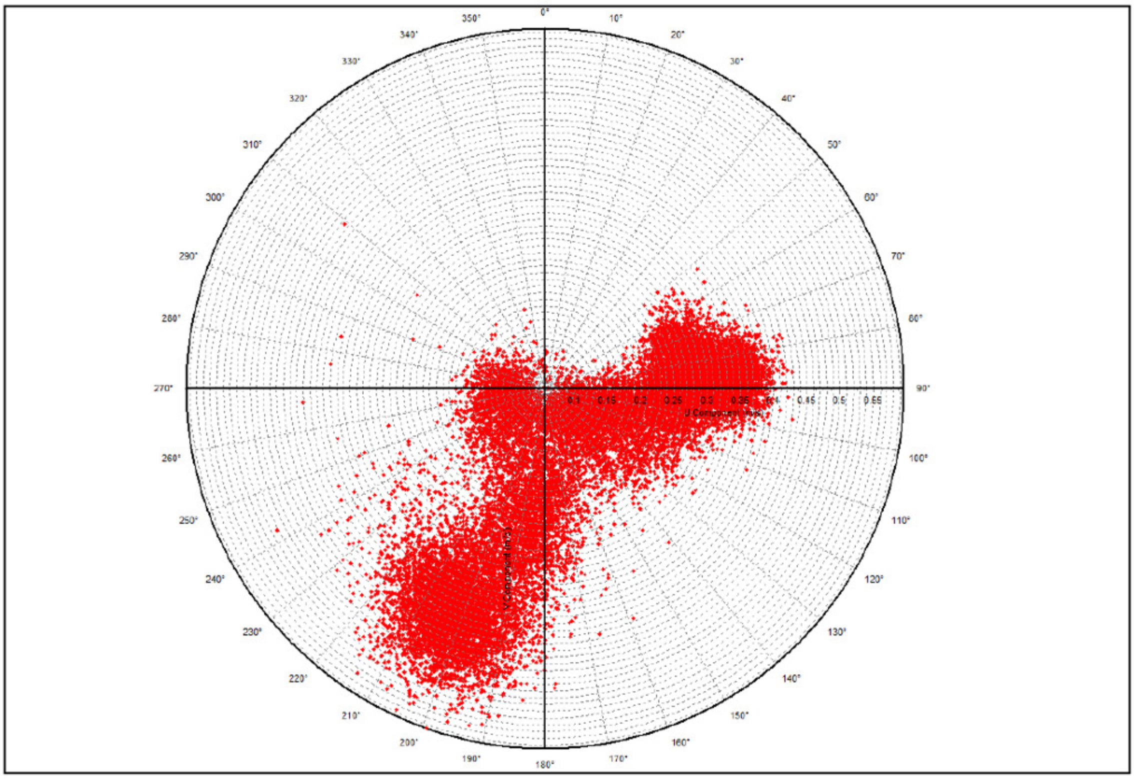


Figure 2.2: Averaged scatter plot displaying U and V current components

Source: Titan Environmental Surveys Ltd., CS0608_Exmouth VMADCP_V1, 2021

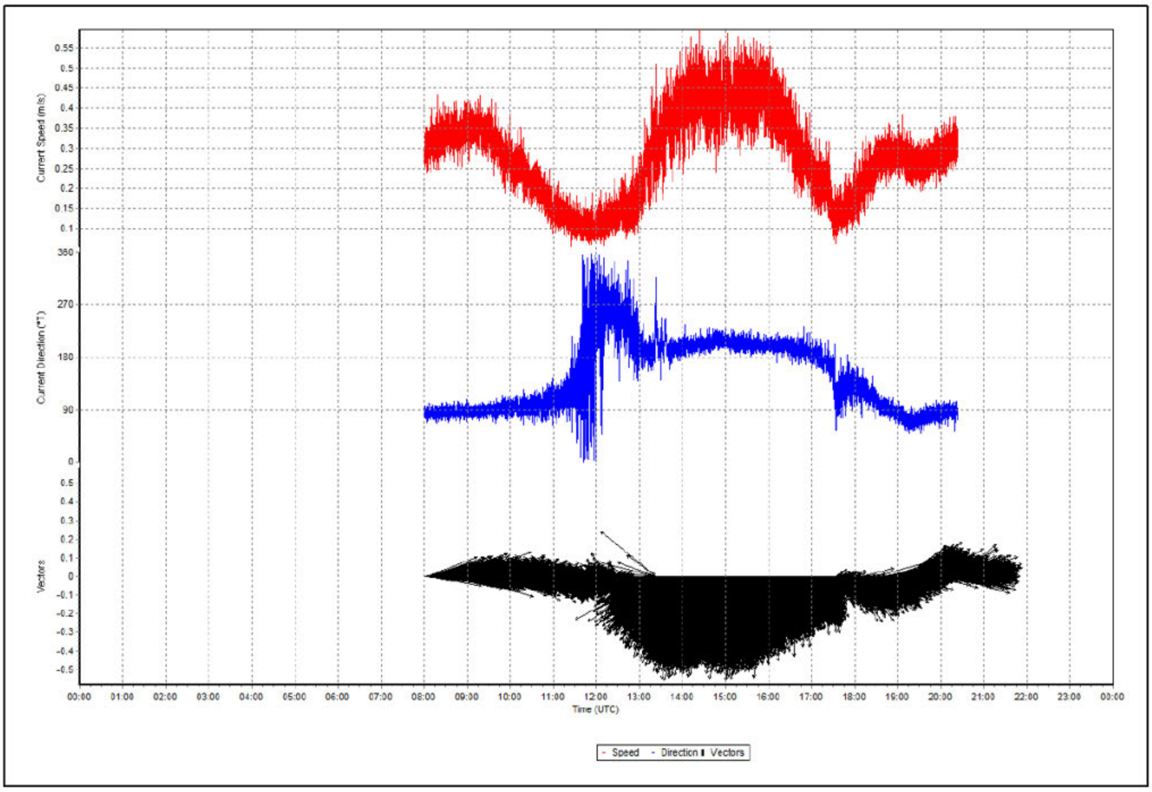


Figure 2.3: Averaged time series plot displaying current speed, current direction and current vectors

Source: Titan Environmental Surveys Ltd., CS0608_Exmouth VMADCP_V1, 2021

Table 2.1: Tidal Currents at the discharge location

Tidal Stage Relative to HW - hrs	Spring Tide (Tidal Range about 3.4 m) (Data taken to be same as for Mean Spring Tidal Range of 4.0 m)				Mean Neap Tide (Tidal Range 1.7 m) (Speed data scaled from Titan ADCP Spring tidal data by tidal range, i.e. by 0.5)			
	Current Speed m/s	Current Dir. °N	U (East) speed m/s	V (North) Speed m/s	Current Speed m/s	Current Dir. °N	U (East) Speed m/s	V (North) speed m/s
-6	0.42	204.4	-0.173	-0.381	0.21	204.4	-0.086	-0.191
-5	0.44	203.5	-0.174	-0.401	0.22	203.5	-0.087	-0.201
-4	0.35	196.4	-0.098	-0.333	0.17	196.4	-0.049	-0.167
-3	0.14	142.7	0.086	-0.113	0.07	142.7	0.043	-0.057
-2	0.27	105.8	0.257	-0.073	0.13	105.8	0.129	-0.036
-1	0.26	74.0	0.249	0.071	0.13	74.0	0.124	0.036
0	0.32	84.5	0.320	0.031	0.16	84.5	0.160	0.015
1	0.35	87.7	0.348	0.014	0.17	87.7	0.174	0.007
2	0.23	94.0	0.234	-0.016	0.12	94.0	0.117	-0.008
3	0.13	120.8	0.108	-0.064	0.06	120.8	0.054	-0.032
4	0.13	265.0	-0.129	-0.011	0.06	265.0	-0.064	-0.006
5	0.31	200.2	-0.106	-0.288	0.15	200.2	-0.053	-0.144
6	0.43	201.4	-0.157	-0.401	0.22	201.4	-0.078	-0.200

Note: PF defined / Titan Environmental Surveys Ltd., CS0608_Exmouth VMADCP_V1, 2021

2.3 Water quality

PF has provided a summary of water quality data at the project location to be used as background information. The provided background contaminant levels are presented in Table 2.2. These are based on data from various sources of data as listed in Table 2.3.

Table 2.2: Background contaminant levels

	SS 105`C Total - mg/l	Ammonia as N Total - mg/l	FC Conf or EC Conf - cfu/100ml	FS Conf or IE Conf - cfu/100ml
Average	7.9	0.022	71	83
Median	5.0	0.020	10	10
Geomean	5.9	0.020	17	14
Ranked 95th percentile	17.6	0.047	265	188

Source: PF analyses

Table 2.3: Source information of background contaminant levels

Contaminant	Data Source	Sampling Location	Eastings, Northings	Period Covered	Coverage through Year
Ammonia	EA WIMS Database	Exe Estuary at The Point	299430, 80589	2007 to 2022	All year
Suspended Solids	EA WIMS Database	Exe Estuary at The Point	299430, 80589	2007 to 2012	All year
Faecal Coliforms or EC Confirmed	EA WIMS Database	Sandy Bay Bathing Water	303300, 79800	2007 to 2022	May to September
Faecal Streptococci or IE Confirmed	EA WIMS Database	Sandy Bay Bathing Water	303300, 79800	2007 to 2022	May to September

3 Far-field modelling report review

Stantec UK Ltd. has conducted a far field modelling study for SWW in 2022, assessing the far-field behaviour of the plume discharged from the Straight Point outfall, and its effects on various sensitive receptors in the vicinity, including designated shellfish and bathing waters.

The main objectives of the study are given as:

1. Confirming the impact of the increased storm water discharges on the water quality at shellfish and bathing waters.
2. Verifying if compliance can be achieved without the need for storm water disinfection, or an extension of the outfall. If necessary, determining the length of the outfall extension.

Various bathing and shellfish waters were selected and assessed as sensitive receptors, with the results interpreted in accordance with the regulatory requirements of each.

The Mike 21 model was used in the study, utilizing the Flexible Mesh (FM) approach. The model is set-up with a domain of 20 km by 40 km (south to north and east to west directions, respectively) which can be considered suitable for the purpose of the analyses.

The hydrodynamic model was calibrated against measured data, including the Titan surveys at the discharge location, and the results are reported to be within acceptable limits defined by The Foundation for Water Research guidelines (FWR, 1993).

The discharge plume was modelled using the particle tracking module with default horizontal and vertical dispersion coefficients applied.

The modelling used a standard discharge for all scenarios, and the predicted concentrations were then factored during the post-processing stage.

Bacterial mortality was set to 20 hours (E.coli) and 40 hours (intestinal enterococci (IE)).

Three wind conditions with the directions of SW, S and SE were selected and modelled based on 10 years of wind data, as well as a no wind case. Only the winds towards land were reportedly considered in the modelling as these are the worst case scenarios, pushing the plume towards land and designated shellfish and bathing waters.

The reported modelling results have shown no impact for Exmouth, Sandy Bay, Dawlish Town And Dawlish Warren bathing waters.

For Budleigh Salterton Bathing Water, especially under Westerly winds, an impact of the outfall is reported, however, through some statistical analyses, it has been concluded and reported that this impact would be negligible.

For shellfish waters, the report states that if Sandy Bay Classified Shellfish Water get a future designation under the Shellfish Water Directive in the future, it would be 'Uncompliant' due to the discharge from Straight Point outfall.

The study also includes an investigation to assess the necessity of shifting the outfall location 250 metres offshore, with the conclusion that such shifting is not necessary, noting that there are currently no plans to seek designation of this site under the Shellfish Water Directive and there is no funding or regulatory requirement upon SWW to look to improve this receptor.

4 Assessment of the current outfall

4.1 Methodology and assumptions

The near-field assessments of both the existing and new outfall diffusers were made using CORMIX.

CORMIX is an internationally accepted software system for the analysis, prediction and design of aqueous toxic or conventional pollutant discharges into diverse water bodies. It incorporates an expert system that uses the characteristics of the discharge (flow rate and configuration) and of the receiving water (depth, width, current speed, etc) to determine a class for the discharge jet. It then calculates the centre-line trajectory and dilution rate of the jet to the edge of the near-field area.

CORMIX is a recommended analysis tool in many key guidance documents on the permitting of industrial, municipal, thermal, and other point source discharges to receiving waters.

CORMIX makes approximations for spatially-varying bathymetry, assuming uniform seawater current patterns and constant currents. It therefore is not normally used to predict the build-up of discharge constituents near the outfall, or further away at sensitive sites. It approximates the receiving water as a uniform environment, where the flow patterns are not significantly affected by the discharge that is introduced. Although CORMIX also has some capability for estimating the mid- and far-field dispersion of the effluent, it must be appreciated that it cannot represent detail such as spatially varying bathymetry or current patterns; it provides approximations for uniform environments. These types of approximation are well-suited to the current study as we are investigating the behaviour of the discharge only in the near-field.

CORMIX has three sub-systems:

- CORMIX1, for single-port discharges;
- CORMIX2, for submerged multi-port diffuser discharges;
- CORMIX3, for surface discharges.

As both the existing and proposed outfalls utilise multiport diffusers, CORMIX2 was selected for the present modelling. CORMIX1 was also used in the early stages of the study to investigate the behaviours and possible merging characteristics of individual jets from the rosettes of the existing diffuser.

CORMIX2 requires at least 3 risers (rosettes) to solve for a multiport diffuser. As the existing diffuser has only 2 risers, it cannot be defined into CORMIX as a multiport diffuser. To work around this limitation, an alternative approach was followed. In this approach, instead of a two riser configuration, a diffuser that has 3 rosettes (with 4 ports on each rosette) was defined with a proportional increase in diffuser length. The port diameters and jet velocities are the main factors affecting the dilution, therefore port geometry was kept constant while the flow was proportionally increased to achieve same jet velocities. In other words, the outfall was modelled as a 3 rosette/12 port diffuser with a 50% increase in discharge flow and diffuser length, whilst keeping the port diameters and jet velocities constant.

To assess the potential range of error in this approach, a sensitivity analysis was also performed, modelling diffusers with 3 to 8 rosettes (with 4 ports on each rosette), each with respective increases in discharged flow and diffuser lengths. Current velocities varying from the minimum of 0.06 m/s up to 0.44 m/s which represents the minimum and maximum current speeds at the diffuser location were also tested in this analysis. The results have shown that with the applied approach, the dilution predictions for the 3 rosette representative diffuser modelled, are likely to be reasonably representative of the dilutions for a 2 rosette diffuser for low current speeds, and slightly higher for higher currents. As the most critical (low dilution) condition is when the current speeds are low, this approach is found to be acceptable.

The existing diffuser has Tideflex Duckbill Valves (DBV) attached to the end of the ports of the rosettes. The DBVs have an elastic non-return valve, which open and close based on the differential pressure between the ambient and the effluent at that location. Therefore, the effective opening of the DBV varies with the flow passing through it. Tideflex suggests that the effective diameters, determined by a hydraulic analyses tool to be used to assess the initial dilution of a diffuser. To comply with this requirement, an initial investigation was conducted using CorHyd (Hydraulic tool of CORMIX package) for different flow conditions, and the resulting effective port diameters were used in near-field modelling with CORMIX. The results of hydraulic assessment are presented in Section 4.3.

The ambient data supplied by PF was used to define the current speeds, directions and water levels into CORMIX.

CORMIX solves for steady state conditions, therefore, to represent a typical tidal cycle, separate CORMIX runs were done using hourly averages of water depth, current speeds and relative angle between the currents and the diffuser, from -6 up to +6 hours with reference to high water time (0).

This series of computations were repeated for both spring and neap tides with FFT and peak flows. Resulting initial dilution predictions are presented as time-series with reference to high water level in Section 4.4.

4.2 Effluent flowrates and characteristics

Flowrates of the current outfall together with contaminant levels in the FFT and stormwater are provided by PF and presented in Table 4.1, Table 4.2 and Table 4.3.

Table 4.1: Flowrates for FFT, stormwater and combined flows of the current outfall

Flow	m3/day	l/s
Flows to Full Treatment (FFT)	23,587.0	273.0
Storm Flows	6,653.0	77.0
Total Flow through Outfall	30,240.0	350.0

Source: PF data

Table 4.2: Treated wastewater contaminant levels

	BOD 5 Day ATU Total - mg/l	SS 105`C Total - mg/l	Ammonia as N Total - mg/l	FC Pres or EC Pres - cfu/100 ml	FS Pres or IE Pres - cfu/100 ml
Average	8.8	8.0	28.5	10,329	4,049
Median	6.0	6.0	30.5	3,500	1,100
Geomean	6.9	5.8	26.1	2,846	876
Ranked 95th percentile	21.0	20.7	42.9	49,250	20,100

Source: PF data - SWW Operator Self-Monitoring Data for the period 2009 to 2023 for Sanitary Parameters and 2010 to 2023 for Bacterial Parameters. All Data taken as Face Value

Table 4.3: Storm water contaminant levels

	BOD 5 Day ATU Total - mg/l	SS 105`C Total - mg/l	Ammonia as N Total - mg/l	FC Pres or EC Pres - cfu/100 ml	FS Pres or IE Pres - cfu/100 ml
Range	75 - 125	350 - 400	6 - 10	1 - 10 x 10^6	1 - 6 x 10^5
Suggested Average	100	375	8		
Geomean				2.5 x 10^6	3.8 x 10^5

Source: PF Data - Ranges for Storm Sewage in a combined sewer system from WRc 1990. Design Guide for Marine Treatment Schemes. Vol. II. Environmental Design and Data Collection

The characteristics of the combined flow was calculated using the provided data, and presented below.

Table 4.4: Contaminant levels in FFT, stormwater and combined (peak) flow for the current outfall

	FFT	Stormwater flow	Combined Flow
Flow (l/s)	273.0	77	350.0
BOD5 (mg/l)	8.8	100	28.86
SS (mg/l)	8	375	88.74
Ammonia (mg/l)	28.5	8	23.99
FC or EC (cfu/100 ml)	2846	2.50E+06	5.52E+05
FS or IE (cfu/100 ml)	876	3.80E+05	8.43E+04

4.3 Hydraulic assessment and flow distribution

A hydraulic assessment using CorHyd was conducted to investigate the flow distribution between the risers (rosettes) and jet velocities. In addition, CorHyd includes the database of Tideflex Duckbill Valves (DBV), and can solve for their effective openings under the defined hydraulic conditions. Therefore the effective port diameters of the DBVs obtained in CorHyd computations were used in near-field assessment with CORMIX.

The complete diffuser geometry is defined in CorHyd including the pipe diameter reductions. A schematic view of the diffuser in CorHyd is presented below in Figure 4.1.

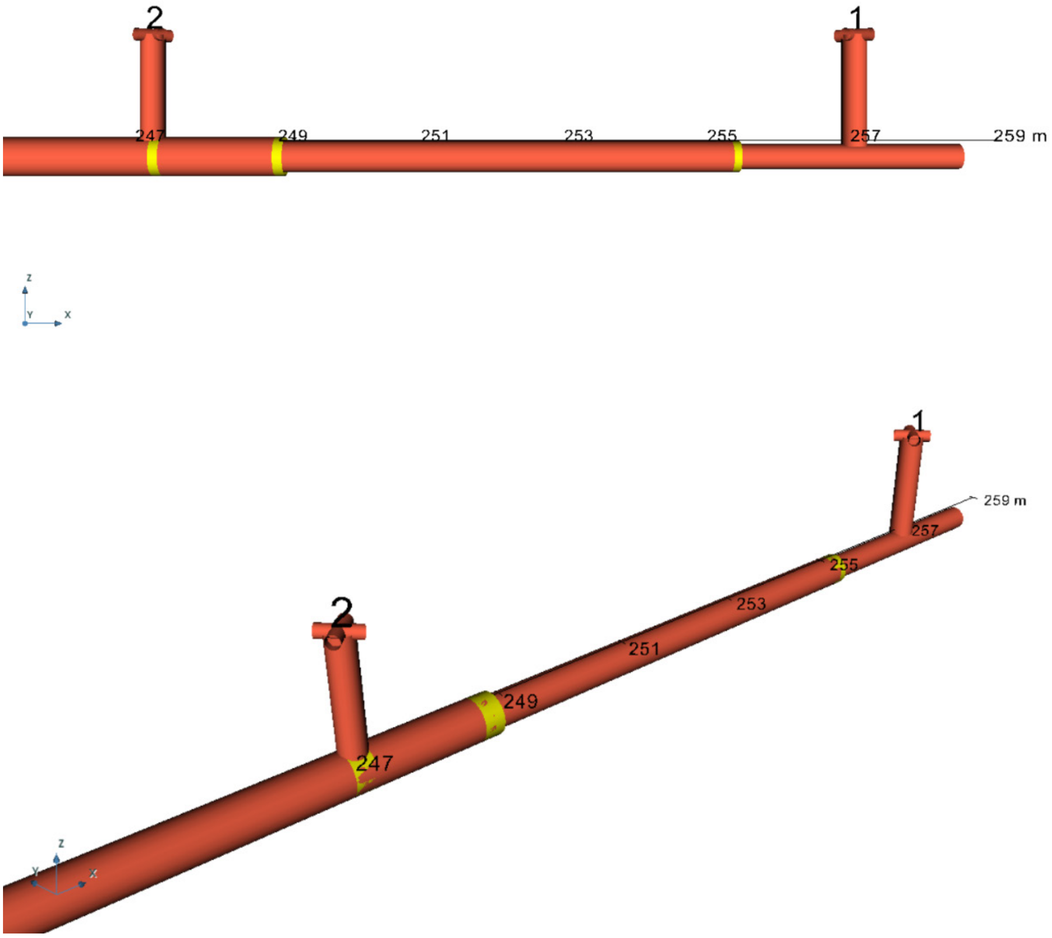


Figure 4.1: Elevation and isometric schematic views of the existing diffuser as defined in CorHyd

The resulting discharge deviation between the risers (rosettes) and the corresponding port and jet velocities are presented in Figure 4.2 and Figure 4.3 for peak and FFT flows respectively.

The discharge deviation plots present the flow distribution between the nozzles, and also marks the ±10% limits with red dashed lines. In both flow cases, the predicted deviation is within the limits, hence the diffuser can be considered as discharging the effluent uniformly into the ambient.

The port and jet velocities plots also provide the critical jet velocity limit as red dashed line, which shows the threshold of possible saline intrusion into the diffuser. In both cases, the jet velocities are predicted to be well above this threshold. These plots also present the effective port sizes for each of the risers, as a continuous black line, with the diameter shown on the vertical axis to the right of the plot.

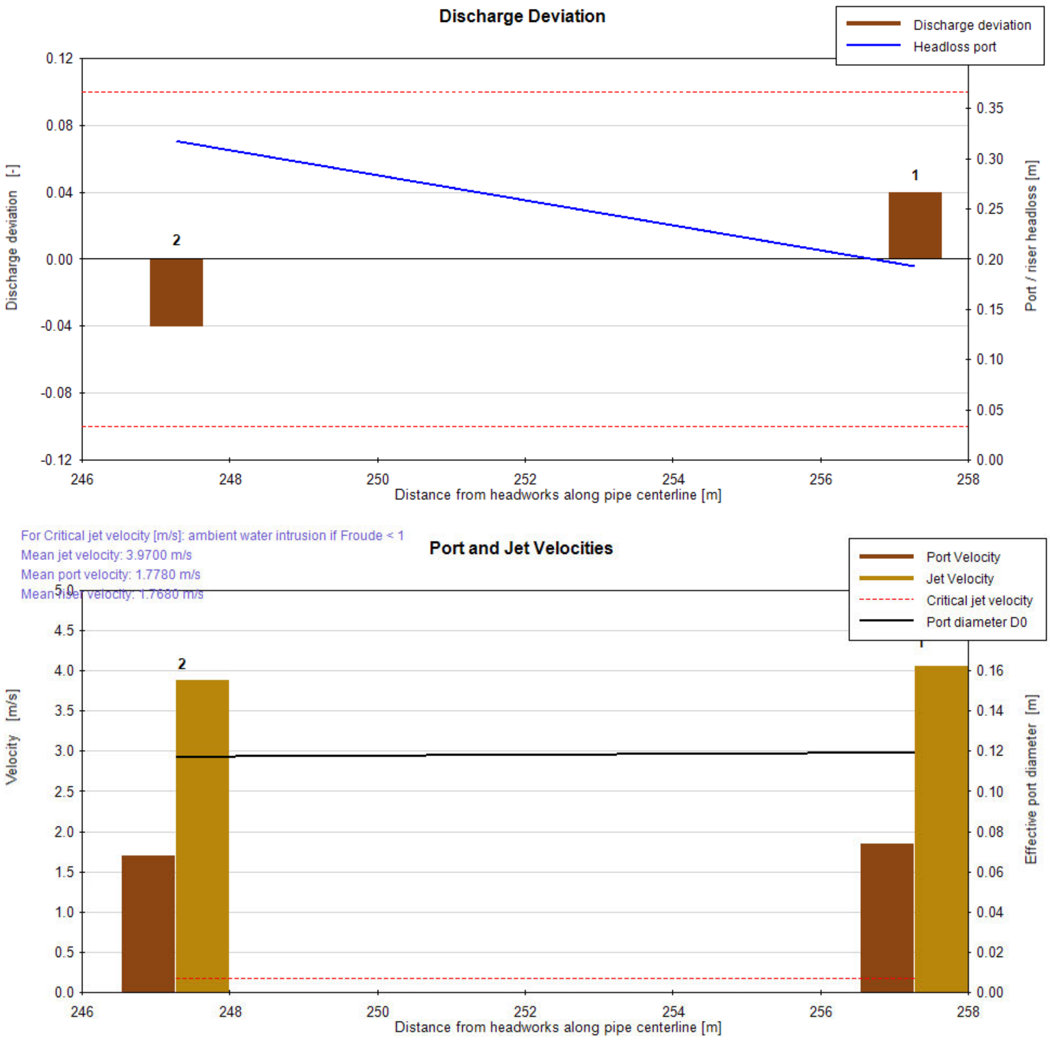


Figure 4.2: Discharge deviation and Port & Jet velocities of the existing diffuser (Peak flow)

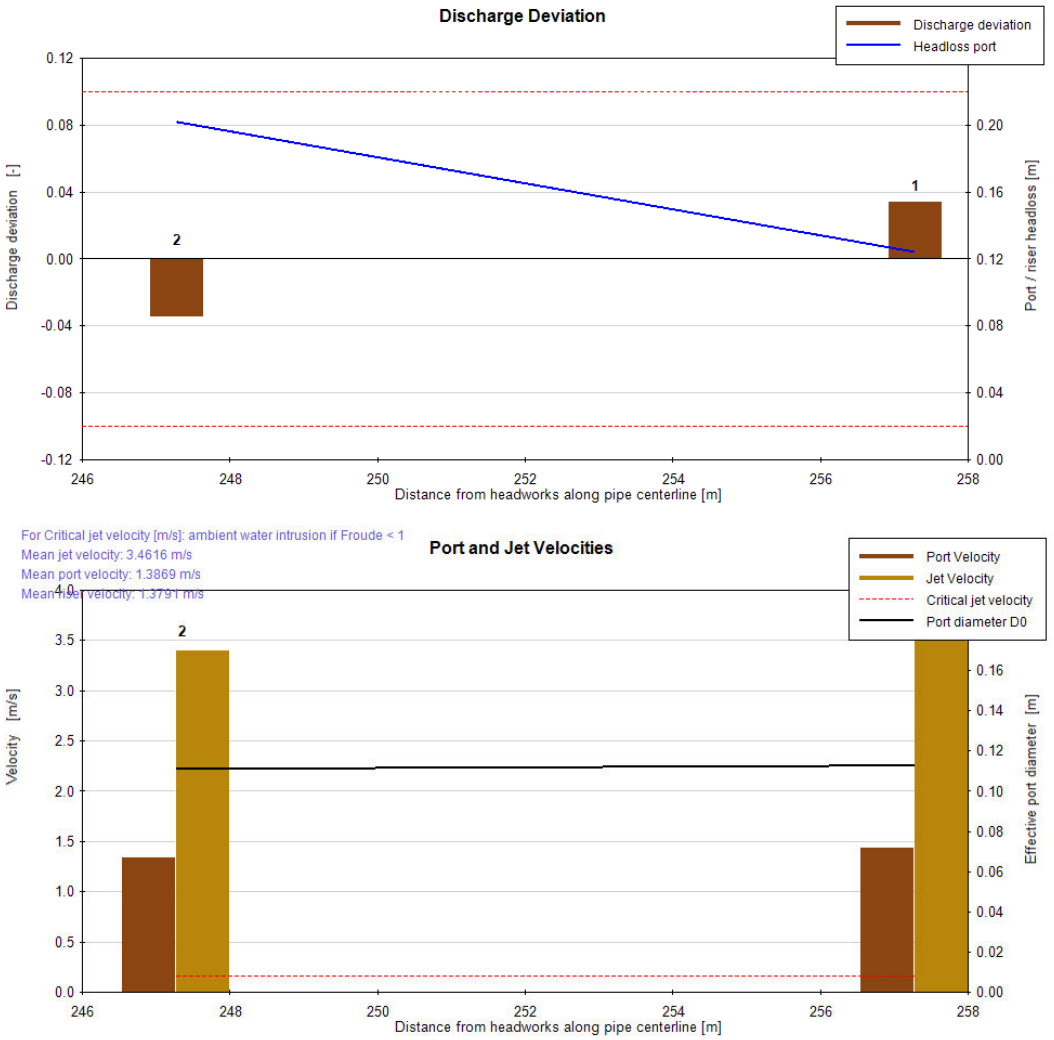


Figure 4.3: Discharge deviation and Port & Jet velocities of the existing diffuser (FFT)

4.4 Near-field assessment

Near-field assessment of the existing diffuser was done using CORMIX2, with the approach and assumptions as explained in Section 4.1.

The resulting initial dilution predictions for spring and neap tides, in both FFT and peak flow conditions are plotted together as timeseries, with reference to the time before or after high water, in Figure 4.4 below.

The FFT discharge in spring tide currents is predicted to have the highest dilutions, whereas the peak flow discharge during neap tide currents is the lowest. The flowrates of FFT and peak flow conditions are not too far apart, therefore the dilutions predicted for each are also not significantly different and the tidal current velocities are found to be the main factor affecting the dilution rates.

The minimum dilutions predicted are close to 20, and correspond to HW-3, HW+3 and HW+4 hours during neap tide, where the current speeds are slowest at 0.06 to 0.07 m/s.

The near-field in these low current speed conditions are predicted to have rather large upstream intrusion zones and takes much longer time to form, in comparison to a typical near field mixing zone. As noted earlier, CORMIX assumes a steady state condition, however in reality, these periods of low current speeds are transient conditions when the currents are changing directions. Therefore, the predictions may not represent the actual dilutions in these conditions.

As this study aims to set out the performance of the existing diffuser to use it as a basis for target dilutions of the new proposed diffuser designs, this limitation is not expected to affect the end result.

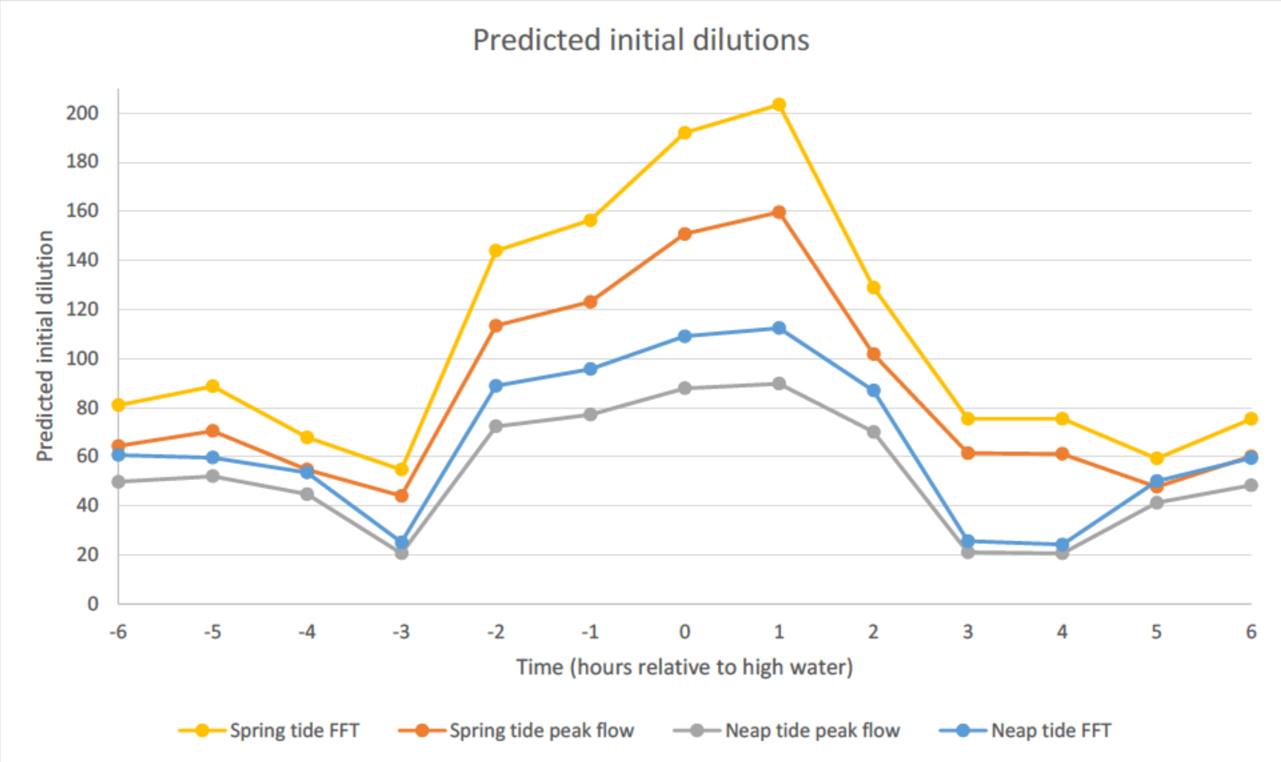


Figure 4.4: Predicted initial dilution on the existing diffuser in different flow and ambient conditions

5 Concept design of the new diffuser

5.1 Proposed flows and effluent characteristics

The new proposed outfall is required to discharge the combination of FFT and overflows of three different STPs. Thus while the FFT conditions are same as the existing outfall, the peak flow is expected to increase nearly three times. The provided flow rates are presented below in Table 5.1.

Table 5.1: Flowrates for FFT, stormwater and combined flows of the proposed new outfall

Flow	m^3/day	l/s
Flows to Full Treatment (FFT)	23,587.0	273.0
Storm Flows	62,035.2	718.0
Total Flow through Outfall	85,622.2	991.0

Source: PF data

Table 5.2: Contaminant levels in FFT, stormwater and combined (peak) flow for the proposed new outfall

	FFT	Stormwater flow	Combined (peak) flow
Flow (l/s)	273.0	718.0	991.0
BOD5 (mg/l)	8.8	100	75
SS (mg/l)	8	375	274
Ammonia (mg/l)	28.5	8	13.7
FC or EC (cfu/100 ml)	2846	2.50E+06	1.81E+06
FS or IE (cfu/100 ml)	876	3.80E+05	2.76E+05

5.2 Alternative diffuser types and proposed diffuser characteristics

According to the survey data, the current directions at the outfall location are mostly towards the east or south-west, with a wide range of scatter in between. With such varying current conditions, a unidirectional port diffuser is not expected to perform well. Instead, a diffuser that is able to distribute the flow towards both sides of the diffuser axis typically performs better in these current conditions. A rosette type diffuser, as in the existing configuration, is well suited for these conditions. Similarly, alternating, or twin port (per riser) diffuser configurations may also perform well. For this study both a rosette type, and a twin port per riser type diffuser configurations were investigated and their respective near-field assessments were done.

Schematic views of a 4 port rosette (as in the existing diffuser) and a riser with two opposing ports are shown in Figure 5.1 and Figure 5.2 as example.

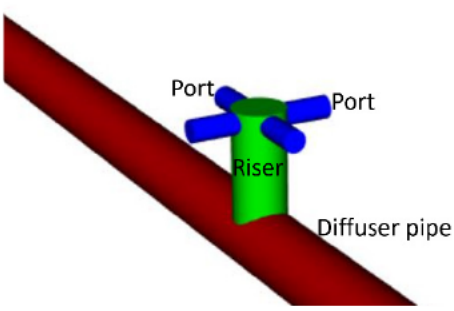


Figure 5.1: Schematic view of a 4 port rosette

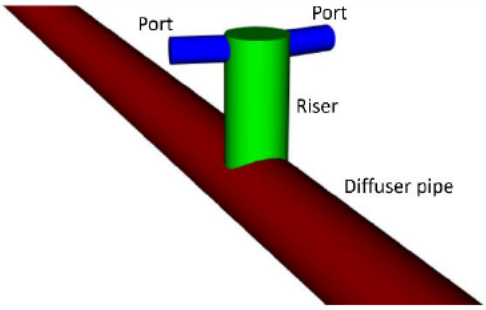


Figure 5.2: Schematic view of a 2 port riser

For the rosette type diffuser, 4 and 5 riser (16 and 20 port respectively) configurations were assessed. For the two ports per riser configuration, 8 risers (16 ports) configuration was modelled and assessed. Table 5.3 below summarises the main characteristics of the 4 rosette and two port per riser diffuser configurations modelled. Both diffusers are modelled with their starting points at the location marked as the “outfall location” in the provided drawings (NGR 303947.6730, 79190.6630). Pipe sizes given in the table refer to SDR17, PE100 HDPE pipes, to be consistent with the design drawings provided by PF.

Table 5.3: Main characteristics of the proposed diffusers

	4 rosette configuration	Two port per riser configuration
Number of ports	16	16
Port diameter	ø 200 mm	ø 200 mm
Number of risers	4	8
Riser diameter	ø 450 mm	~ ø 300 mm
Spacing between risers	10 m	4.3 m
Diffuser length	30 m	30 m

5.3 Hydraulic assessment and flow distribution

A hydraulic assessment of the proposed 4 rosette diffuser was undertaken, similar for the assessment of the existing diffuser, with the aim of verifying the flow distribution between the ports and obtaining effective port diameters of the DBVs.

The complete diffuser geometry is defined in CorHyd including the pipe diameter reductions as per the draft drawings provided by PF. A schematic view of the diffuser in CorHyd is presented below in Figure 5.3.

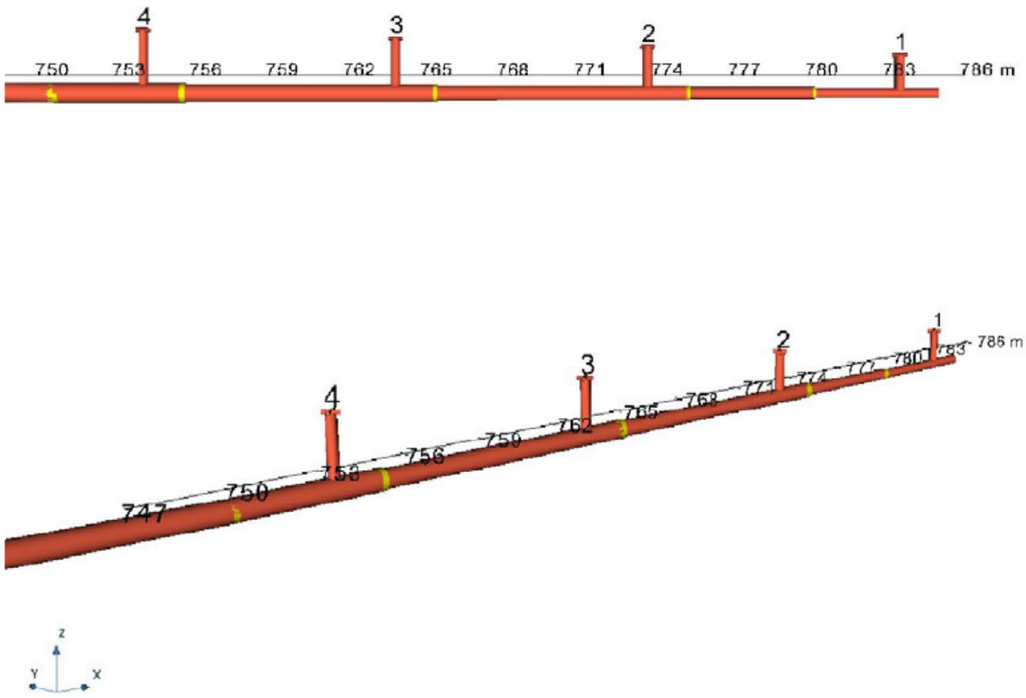


Figure 5.3: Elevation and isometric schematic views of the proposed 4 rosette diffuser as defined in CorHyd

The resulting discharge deviation between the risers (rosettes) and the corresponding port and jet velocities are presented in Figure 5.4 and Figure 5.5 for peak and FFT flows respectively.

The predictions show that the diffuser is able to distribute the discharge within acceptable limits, and jet velocities for FFT and peak flows are above the threshold for the saline intrusion, hence the proposed diffuser is hydraulically suitable.

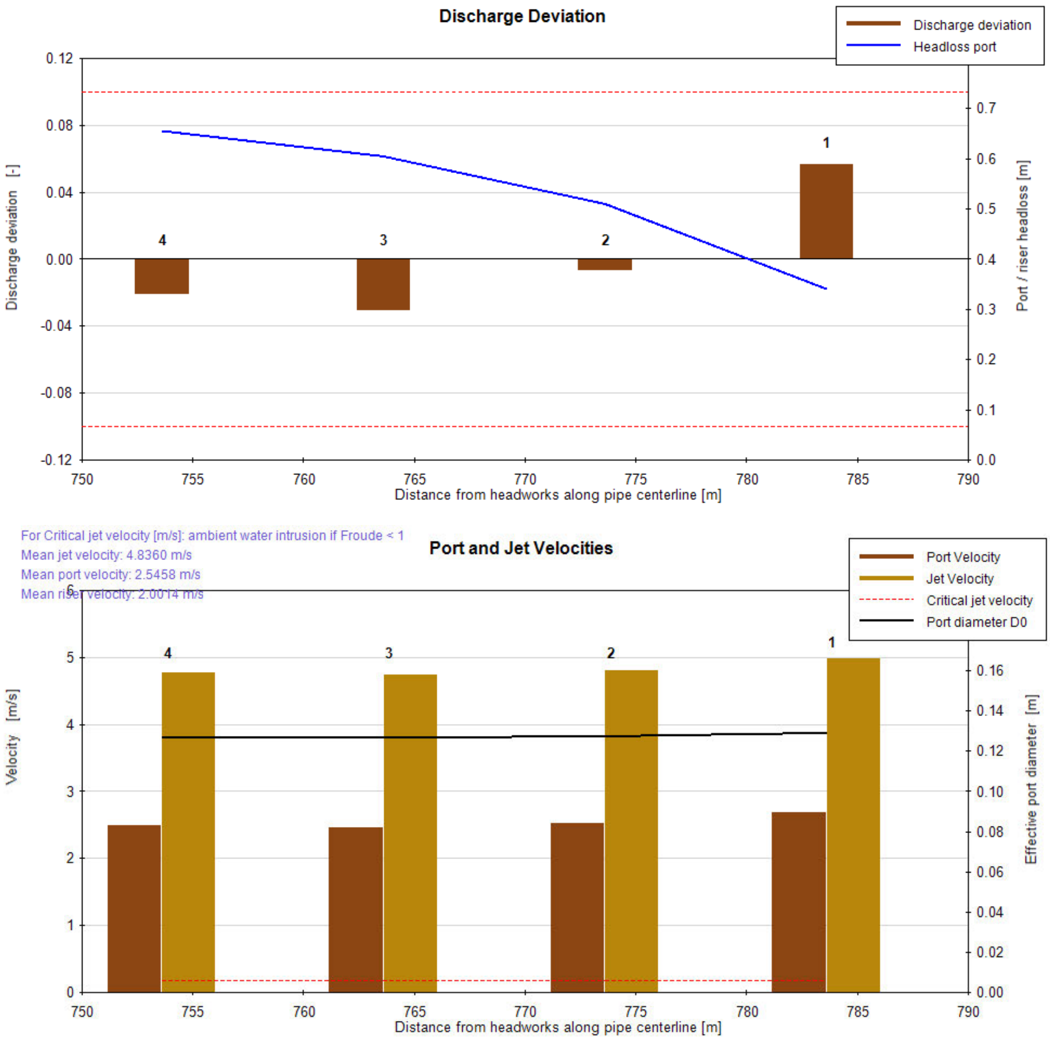


Figure 5.4: Discharge deviation and Port & Jet velocities of the proposed 4 rosette diffuser (Peak flow)

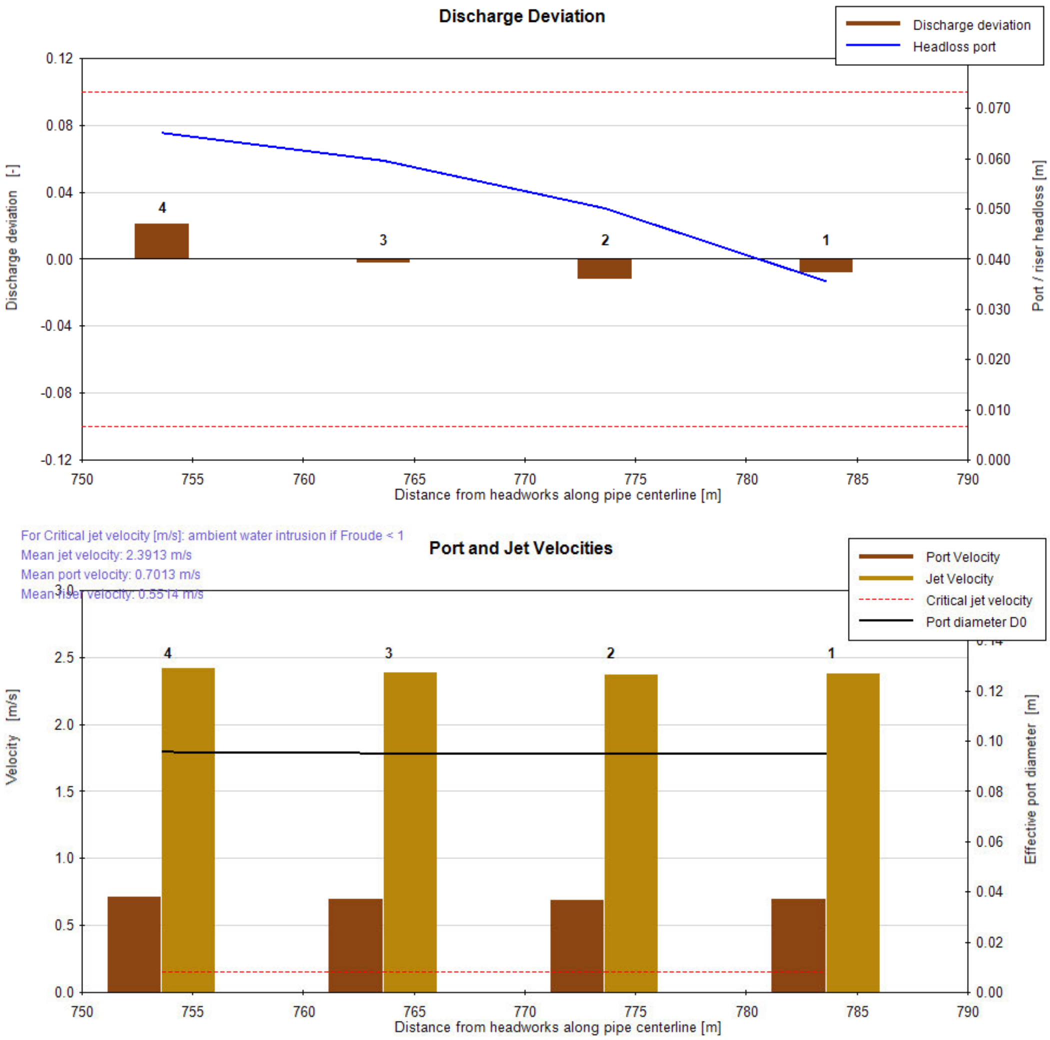


Figure 5.5: Discharge deviation and Port & Jet velocities of the proposed 4 rosette diffuser (FFT)

5.4 Near-field assessment

The initial dilution of the proposed diffusers were computed following the same approach as described in of the existing diffuser was applied to the proposed new diffusers.

Dilution computations with CORMIX were made for both the rosette and two port per riser configurations, and the resulting initial dilutions are plotted in Figure 5.6 below. The performance of both proposed diffusers are very close, therefore, to provide a clear image, only the rosette type diffuser results are presented. In the case of FFT, the vertical axis (initial dilution values) is capped at 250, to be able to present the lower dilution ranges better. The dilutions of FFT discharge in spring tide current conditions is predicted to peak at 450.

The minimum dilutions predicted are as low as 16, and correspond to HW-3, HW+3 and HW+4 hours during neap tide, where the current speeds are slowest at 0.06 to 0.07 m/s.

Similar to the existing diffuser, but in a larger effect, the near-field in these low current speed conditions are predicted to have large upstream intrusion zones and takes longer time to form. As the amount of water discharged in peak flow is nearly three times more than the peak flow of the existing diffuser, the near field boundaries are also expanding significantly, with shore contact (within the near field) predicted by CORMIX. As noted earlier, CORMIX assumes a steady state condition, however in reality, these periods of low current speeds are transient conditions when the currents are changing directions. Therefore, the shoreline contact prediction may not be accurate and changing current speeds might disperse the plume before can fully develop as predicted by CORMIX. It should also be noted this adverse condition only happens in peak flow and neap tide conditions, and the joint probability of these events happening at the same time is expected to be relatively small. Moreover, CORMIX predicts this shore contact at the nearest point to the outfall location, which in reality is the tip of the Straight Point. Since the beaches on both sides of Straight Point are further away from the outfall location, this predicted shoreline contact does not refer to a contact at the beaches. Nevertheless, other environmental factors, especially the southerly winds might push the plume towards the land, thus, the possibility of a shoreline contact should not be entirely dismissed.

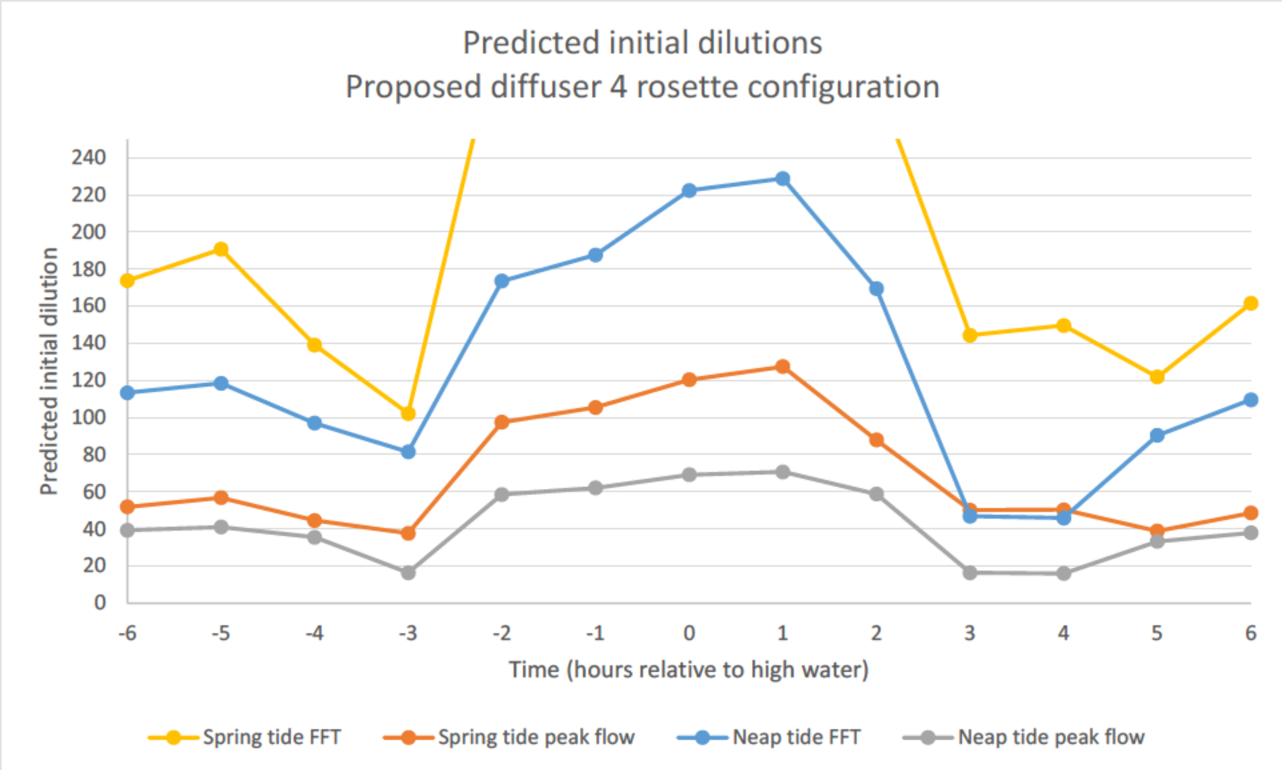


Figure 5.6: Predicted dilutions along the tidal cycles for FFT and peak flows

5.4.1 Comparison of initial dilutions

In addition to the initial dilution predictions, a comparison between the existing and proposed new diffusers is presented in Figure 5.7 and Figure 5.8 for both FFT and peak flows, during neap and spring tide current conditions.

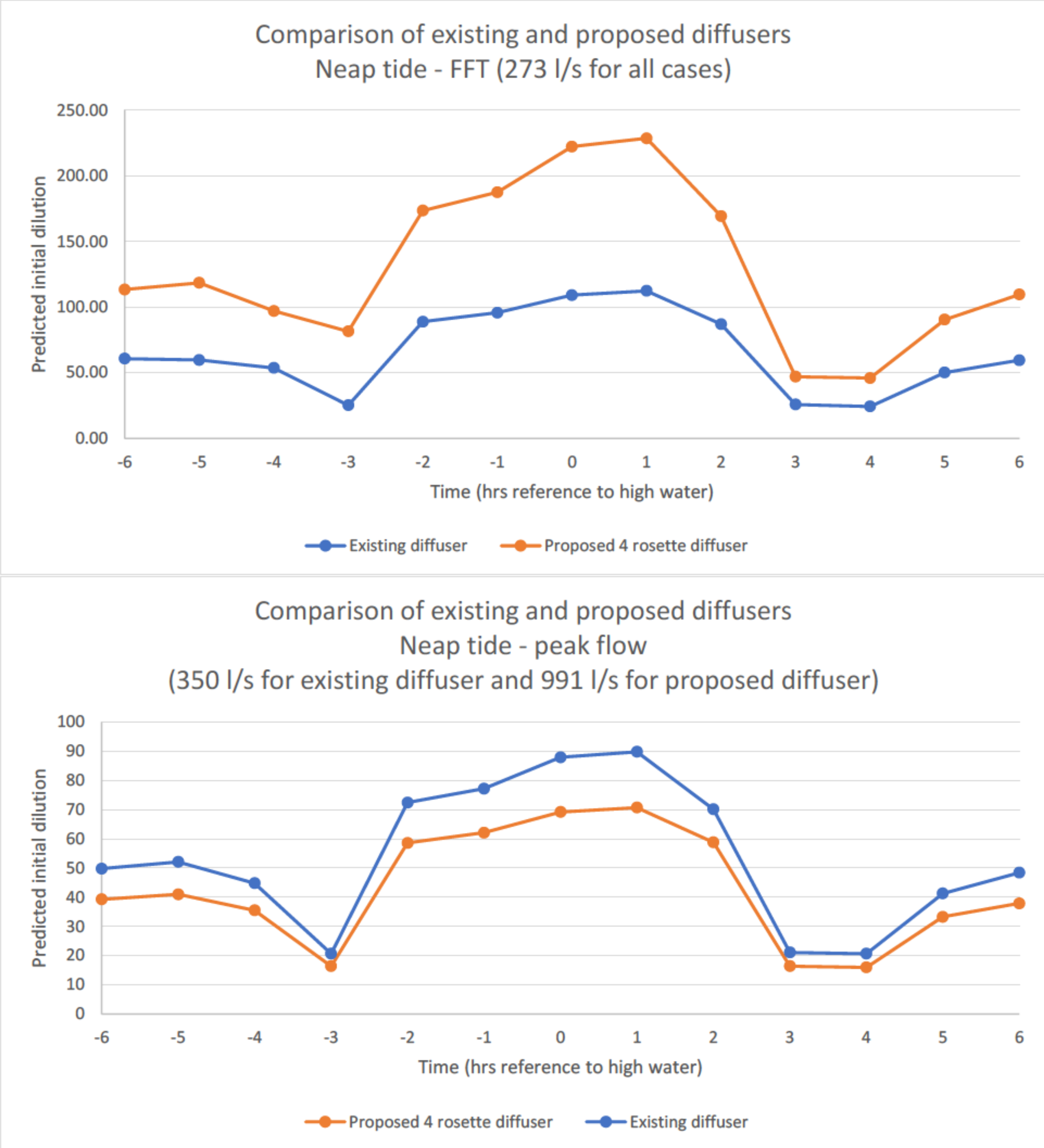
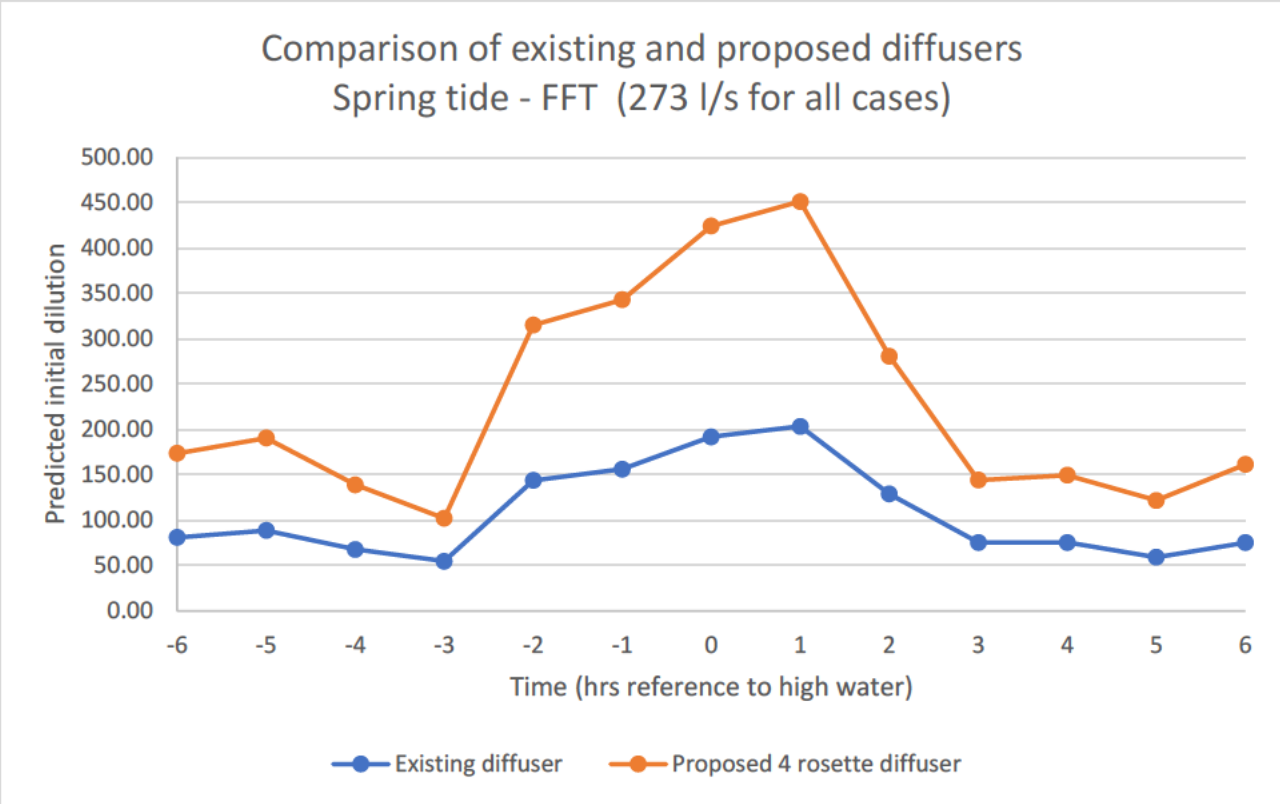


Figure 5.7: Comparison of dilution performance of the existing diffuser and proposed diffusers in neap tide



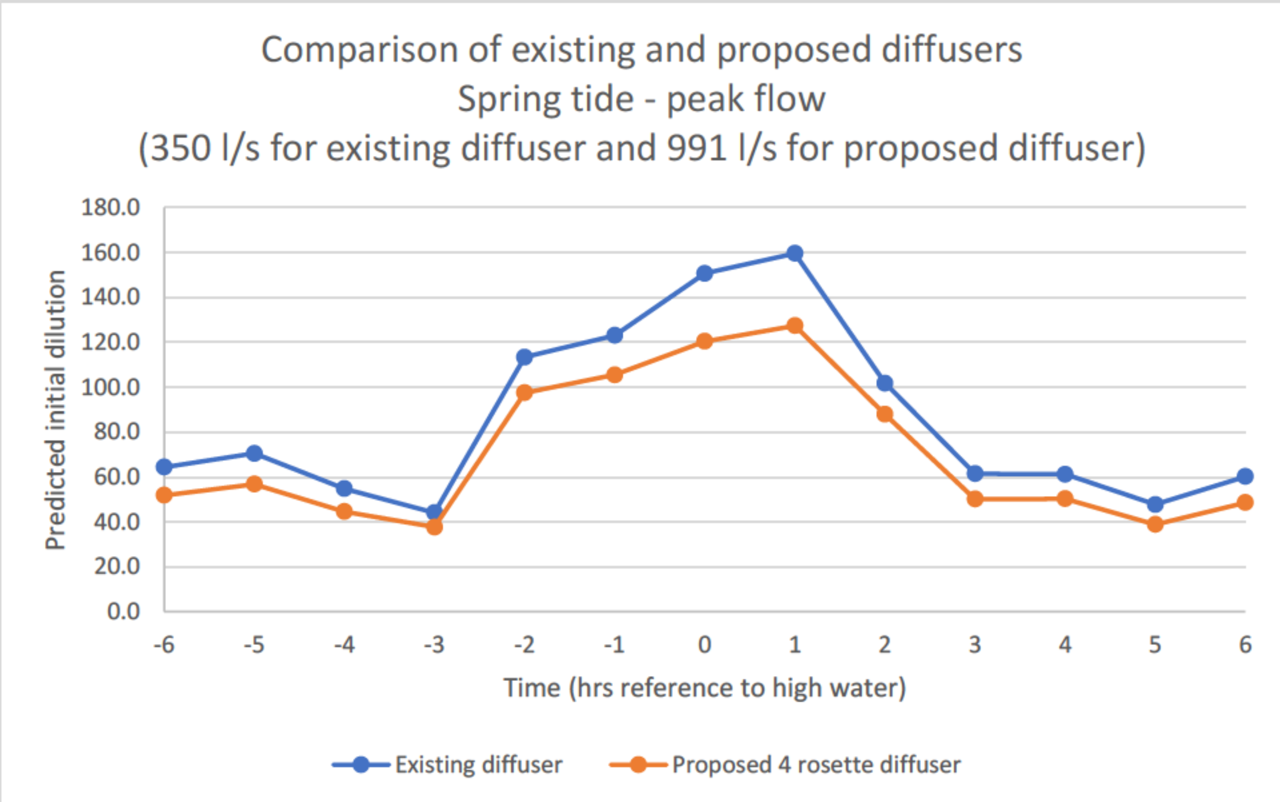


Figure 5.8: Comparison of dilution performance of the existing diffuser and proposed diffusers in spring tide

Table 5.4 below present a summary of various comparisons of the predicted dilutions and near-field concentrations of the existing and proposed new diffusers. It can clearly be seen that overall the new diffuser is providing higher average dilutions because the dilutions for FFT are significantly improved. On the other hand, the averages in peak flow conditions show that the dilution performance of the new diffuser is falling slightly behind the existing one.

In terms of concentrations, it can be concluded that the new proposed diffuser is performing very close to the existing in overall and FFT conditions. However, during the peak flow conditions, the effluent contaminant concentrations are likely to be increased (except for Ammonia) and as the ratio of stormwater flow and treated wastewater will increase for the proposed new outfall, the combined flow contaminant concentrations are also higher in the new outfall combined (peak) flow in comparison to the combined (peak) flow of the existing outfall. In addition, the lower dilution capacity in these conditions is resulting with increased concentrations at the end of near field.

If sufficient data is available, an analyses on the duration and frequency of the peak flows is recommended to investigate the risks due to this slightly lower dilutions in peak flow conditions. In addition, a joint probability analysis of the peak flows and neap tide calm seas would be beneficial to further quantify this risk of increased concentrations and possible shore contact of the plume.

The concentrations presented in the Table 5.4 are aiming to provide a comparison between the performances of the existing and new proposed diffusers, they should not be considered as definitive values.

Table 5.4: Comparison of the existing and proposed new (4 rosette type) diffusers dilutions and end of near-field concentrations

	Dilution		BOD_5 (mg/l)*		SS (mg/l)		Ammonia (mg/l)		FC or EC (cfu/100 ml)		FS or IE (cfu/100 ml)	
	Existing	New	Existing	New	Existing	New	Existing	New	Existing	New	Existing	New
Overall average	78	118	<2	<2	6.4	7.0	0.36	0.20	3.57E+03	7.71E+03	5.60E+02	1.19E+03
FFT Average	87	180	<2	<2	5.9	5.9	0.35	0.18	4.95E+01	3.27E+01	2.39E+01	1.88E+01
Peak flow average	70	57	<2	2	7.1	10.6	0.36	0.26	7.91E+03	3.18E+04	1.22E+03	4.85E+03
FFT spring tide average	108	230	<2	<2	5.9	5.9	0.28	0.14	4.32E+01	2.93E+01	2.20E+01	1.77E+01
Peak flow spring tide average	86	71	<2	2	6.9	9.7	0.30	0.21	6.44E+03	2.55E+04	9.94E+02	3.89E+03
FFT neap tide average	66	130	<2	<2	5.9	5.9	0.45	0.24	5.99E+01	3.88E+01	2.71E+01	2.06E+01
Peak flow neap tide average	54	43	2	3	7.4	12.1	0.46	0.34	1.02E+04	4.22E+04	1.57E+03	6.42E+03
Minimum predicted dilution (FFT)	24	46	<2	<2	6.0	5.9	1.21	0.64	1.35E+02	7.85E+01	4.99E+01	3.27E+01
Minimum predicted dilution (peak flow)	21	16	2	6	9.8	22.6	1.16	0.87	2.63E+04	1.13E+05	4.03E+03	1.72E+04

**BOD_5 background concentrations are assumed as 1 mg/l in the calculations*

6 Conclusions and recommendations

A combined hydraulic and near-field assessment was conducted on the existing diffuser, aiming to set the performance target for the design of the diffuser of the new outfall.

As a result, it is predicted that the existing diffuser will have the highest dilution performance during FFT discharge in spring tide currents, compared to peak flow discharge during neap tide currents, where the dilution is predicted to be the lowest. The minimum dilutions predicted are close to 20, and correspond to HW-3, HW+3 and HW+4 hours during neap tide, where the current speeds are slowest at 0.06 to 0.07 m/s.

For the new outfall diffuser, a 4 rosette (riser) configuration is proposed, which has total of 16 ports with duckbill valves.

As an alternative to the rosette type diffuser, a two port per riser – 8 riser diffuser configuration with same port diameters have been tested, resulting in very similar dilution performance. Therefore this diffuser may be considered if it is considered to be easier to manufacture and install.

The proposed 4 rosette type diffuser is predicted to have better dilution performance in overall average of the cases modelled, and especially in FFT conditions.

However, in peak flow, due to the significant increase of stormwater, the dilution performance of the new diffuser is predicted to be slightly lower than the existing diffuser.

The stormwater flow has higher contaminant levels (except for Ammonia) than the treatment plant effluent (FFT). As the ratio of stormwater flow and treated wastewater are also increasing for the proposed new outfall, the combined flow contaminant concentrations are also higher in the new outfall combined (peak) flow in comparison to the combined (peak) flow of the existing outfall. Therefore resulting concentrations at the end of near field are also predicted to be higher than the existing conditions.

If sufficient data is available, an analyses on the duration and frequency of the peak flows is recommended to investigate the risks due to this slightly lower dilutions in peak flow conditions. In addition, a joint probability analysis of the peak flows and neap tide calm seas would be beneficial to further quantify this risk of increased plume concentrations and possible shore contact.

If these risks are found to be significant it is required to match the performance of the existing diffuser in the peak flow conditions, then either a longer diffuser with more ports or shifting the outfall further offshore has to be considered. To give an indication, a 5 rosette diffuser in the same port configuration is predicted to increase the minimum initial dilution from 16 to 19. As an alternative, an increase in discharge depth would also improve dilutions. It is predicted that, if the diffuser is moved further offshore where the water is one meter deeper, the minimum initial dilution would increase to 19, matching the 5 rosette diffuser performance. Further move offshore, increasing the water depth by 1.5 m in total, is predicted to provide a minimum initial dilution of 21, matching the minimum dilution of the existing diffuser.

7 References

Michael J. Duer(2016), “Duckbill Nozzle Knowledge Base for Inland and Marine Outfall Diffuser Designers and Modelers”, IAHR-IWA Joint Committee on Marine Outfall Systems May 10th-13th, 2016, Ottawa, Canada.

Shoreline Surveys Ltd. (2022), “Multibeam, backscatter, sub-bottom profiler and lidar surveys report, outfall survey” 2022.

Stantec (2022), “Exe Estuary, Coastal Modelling Report”.

Titan Environmental Surveys Ltd. (2021), “CS0608_Exmouth VMADCP_V1”.

Appendix

A Construction Design and Management Regulations (CDM 2015)

The Construction (Design and Management) Regulations 2015 (CDM 2015) require a designer to avoid foreseeable risks to those involved in construction and future use of the structure, and in doing so, they should eliminate hazards (so far as is reasonably practicable, taking into account other design considerations) and reduce and control risks associated with those hazards which remain. It is essential that, where required to do so, a principal designer and principal contractor are appointed to fulfil their respective duties under the CDM 2015. It is also essential to highlight and record the impacts of the works on health, safety and welfare which should feed into the Health and Safety File (if required). Further details of the requirements of CDM 2015 can be found on:

http://www.hse.gov.uk/construction/cdm/2015/index.htm

This project consists of desk assessments and modelling work which may be used by others in the design process. No design work, as defined in the CDM 2015, has been undertaken by HR Wallingford and we have not identified any particular issues that should be drawn to the attention of the principal designer and principal contractor in any ultimate construction work which may be undertaken. It is assumed that the appointed principal designer will review the information produced in this study when discharging their duties under the CDM 2015.

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