TECHNICAL MEMORANDUM

City of Corpus Christi Desalination Study

Concentrate Modeling at La Quinta Channel

TPDES Permit No.: WQ0005290000

PREPARED BY	Ernest To, Ph.D., PE
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Table of Contents

List of Figures

List of Tables

LIST OF ABBREVIATONS

ADCP	Acoustic Doppler Current Profiler
EPA	United States Environmental Protection Agency
HHMZ	Human Health Mixing Zone
MGD	Million Gallons per Day
MZ	Mixing Zone
ppt	Parts per Thousand
RO	Reverse Osmosis
SOP	Standard Operating Procedures
SWQM	Surface Water Quality Monitoring
TCEQ	Texas Commission on Environmental Quality
TPDES	Texas Pollutant Discharge Elimination System
ZID	Zone of Initial Dilution

1 EXECUTIVE SUMMARY

As part of the Freese and Nichols, Inc. Project Team (Project Team), Plummer conducted a concentrate modeling study at the La Quinta site (Permit No.: WQ0005290000) to support Texas Pollutant Discharge Elimination System (TPDES) industrial wastewater discharge permit application for the potential desalination outfall location and diffuser configurations in the La Quinta channel. The CORMIX model software was utilized to evaluate the effluent percentages of the brine concentrate at the edges of the regulatory mixing zones: zone of initial dilution (ZID), aquatic life mixing zone (MZ), and Human Health Mixing Zone (HHMZ).

The model scenarios simulated 20 MGD, 30 MGD and 40 MGD desalination plant production capacities operating at the minimum and maximum RO recovery rates of 40% and 50%, as well as a range of ambient and discharge densities required by the Texas Commission on Environmental Quality (TCEQ) CORMIX Standard Operating Procedures (“SOP”). The CORMIX modeling also incorporated the background flow measured by an Acoustic Doppler Current Profiler (ADCP) monitoring data deployed at a nearby dock.

The proposed diffuser design is a multiport diffuser consisting of a 50-foot-long diffuser pipe with five risers – each containing two 8-inch diameter ports. This results in a total of 10 ports. When operating under the 30 MGD and 40 MGD phases, all the ports will be used to discharge the effluent. When operating under the 20 MGD phase, two ports will be closed resulting in eight ports opened to diffuse the effluent. This is to maintain sufficient port velocity to mix the effluent effectively. The diffuser would be placed at a depth of approximately 32 feet on private property near the east side of the navigation channel. The diffuser pipe would be aligned parallel to the channel while the diffuser ports would be directed towards the center of the channel. The diffuser ports would also be angled 60 degrees above the horizon. Since the diffuser is a multiport diffuser, rectangular mixing zones for the ZID, MZ and HHMZ were defined following SOP requirements. This resulted in the following rectangular dimensions:

- ZID: 100 ft x 78 ft centered around the diffuser pipe with the short side parallel to the pipe and long side perpendicular to the pipe;
- MZ: 400 ft x 314 ft centered around the diffuser pipe with the short side parallel to the pipe and long side perpendicular to the pipe; and,
- HHMZ: 800 ft x 628 ft centered around the diffuser pipe with the short side parallel to the pipe and long side perpendicular to the pipe.

The CORMIX model results were evaluated based on the following criteria:

1. Meeting critical dilutions at the edges of the ZID and MZ that are protective of aquatic life;
2. Achieving the CORMIX flow class of MNU8; and,
3. Meeting effluent velocity limits at the edges of the ZID and MZ that are protective of aquatic life.

Effluent percentages predicted by CORMIX at the edge of the ZID and the MZ mixing zones were compared with the critical dilutions proposed in the Corpus Christi Seawater Desalination Receiving Water Salinity Critical Dilutions White Paper ("White Paper") (FNI, 2020). The White Paper states the critical dilutions (expressed as percentage effluent) that are protective of aquatic life as follows:

- For the reverse osmosis (RO) recovery rate of 40%, the critical dilution for the ZID is 56% and the critical dilution for the MZ is 18%. These will produce salinities of 42 and 35 ppt respectively under average ambient salinity conditions.
- For the RO recovery rate of 50%, the critical dilution for the ZID is 38% and the critical dilution for the MZ is 13%. These will produce salinities of 42 and 35 ppt respectively under average ambient salinity conditions.

The flow class assigned by CORMIX was evaluated to ensure that the diffuser produces a properly dispersed plume. The CORMIX flow class of MNU8 represents a flow regime where "the discharge strength (measured by its momentum flux) is very high in relation to the layer depth and in relation to the stabilizing effect of the discharge buoyancy (measured by its buoyancy flux)". In other words, the predicted effluent has sufficient kinetic energy (characterized by port velocity) to engage and mix with the water column. In contrast, when the effluent has insufficient port velocity, it would flow to the bottom with little interaction with the ambient water. Therefore, the assignment of the flow class MNU8 is desired to ensure proper diffusion of the effluent plume.

To address concerns on aquatic life due to jet velocities in the vicinity of the discharge, effluent velocities at the edge of the ZID and the MZ were evaluated. Jet velocities less than 2 fps at the edge of the ZID and 0.5 fps at the edge of the MZ are considered safe. Effluent velocities along the plume centerline were calculated to ensure that the velocity limits were met.

Table 1 below provides the CORMIX results for the recommended diffuser design when the desalination plant is operating at RO 40% recovery rate for the production capacities of 30 MGD and 40 MGD. Results for each standard density scenario required are not shown separately because the predicted effluent percentages, velocities, and flow classes from CORMIX were identical. Table 1 shows that the recommended diffuser design meets all the criteria mentioned above for effluent percentage, CORMIX flow class and effluent velocity.

La Quinta

Table 1. Summary of CORMIX results for RO 40% recovery rate.

			ZID Results			MZ results			CORMIX Flow Classification	
Production Capacity (MGD)	RO Recovery Rate	Effluent Discharge (MGD)	Effluent Percentage (%)	Effluent Velocity (fps)	Evaluation	Effluent Percentage (%)	Effluent Velocity (fps)	Evaluation	Flow Class	Evaluation
20	40%	34.31	10.8	0.3	Meets critical dilution (<=56%) and velocity limit (<= 2 fps) for ZID.	7.7	0.2	Meets critical dilution (<=18%) and velocity limit (0.5 fps) for MZ.	MNU8	Meets desired flow class.
30	40%	51.47	12.0	0.3	Meets critical dilution (<=56%) and velocity limit (<= 2 fps) for ZID.	8.6	0.2	Meets critical dilution (<=18%) and velocity limit (0.5 fps) for MZ.	MNU8	Meets desired flow class.
40	40%	68.62	12.0	0.5	Meets critical dilution (<=56%) and velocity limit (<= 2 fps) for ZID.	8.5	0.3	Meets critical dilution (<=18%) and velocity limit (0.5 fps) for MZ.	MNU8	Meets desired flow class.

Table 2 below provides the CORMIX results for the recommended diffuser design when the desalination plant is operating at RO 50% recovery rate for the production capacities of 20 MGD, 30 MGD and 40 MGD. Results for each standard density scenario required are not shown separately because the predicted effluent percentages, velocities, and flow classes from CORMIX were identical. Table 2 shows that the recommended diffuser design meets all the criteria mentioned above for effluent percentage, CORMIX flow class and effluent velocity.

La Quinta

Table 2. Summary of CORMIX results for RO 50% recovery rate.

			ZID Results			MZ results			CORMIX Flow Classification	
Production Capacity (MGD)	RO Recovery Rate	Effluent Discharge (MGD)	Effluent Percentage (%)	Effluent Velocity (fps)	Evaluation	Effluent Percentage (%)	Effluent Velocity (fps)	Evaluation	Flow Class	Evaluation
20	50%	23.4	11.0	0.2	Meets critical dilution (<=38%) and velocity limit (<= 2 fps) for ZID.	7.9	0.1	Meets critical dilution (<=13%) and velocity limit (0.5 fps) for MZ.	MNU 8	Meets desired flow class.
30	50%	35.17	12.1	0.2	Meets critical dilution (<=38%) and velocity limit (<= 2 fps) for ZID.	8.6	0.2	Meets critical dilution (<=13%) and velocity limit (0.5 fps) for MZ.	MNU 8	Meets desired flow class.
40	50%	46.90	12.0	0.3	Meets critical dilution (<=38%) and velocity limit (<= 2 fps) for ZID.	8.6	0.2	Meets critical dilution (<=13%) and velocity limit (0.5 fps) for MZ.	MNU 8	Meets desired flow class.

Finally, it is noted that two other permittees (WQ0001651000 and WQ0003083000) are located near the proposed outfall window. A review was conducted on the CORMIX modeling reports of the two permittees to identify mixing zones, discharge depths and buoyancy characteristics of their respective effluent plumes. Based on this review, it is identified that truncation of the HHMZ of the proposed outfall may be necessary to prevent overlap with the mixing zones of Outfall 001 of WQ0001651000.

However, the truncation would not impact the CORMIX modeling results in this report (i.e., effluent percentages, CORMIX flow classification and velocities at the edges of the mixing zones) are still valid and the various assessment criteria are still met. This is because the truncated area would be located behind the diffuser in shallower area and not in the path of the proposed discharged effluent. Furthermore, the truncated area affects mostly the rear part of the HHMZ and with limited or no impact on the ZID and MZ.

For permitting purposes, since 40% and 50% recovery rates can result in different discharge rates even when the production rate is the same, it is recommended that the permits limits for average daily discharge volume be based on a 40% recovery rate (maximum anticipated discharge for each permit phase). The maximum daily discharge would be a factor of 1.20 times the average daily discharge volume.

2 INTRODUCTION

As part of the modeling study in support preparation of TPDES industrial wastewater discharge permit application, Plummer has performed a site-specific concentrate modeling for the La Quinta site using the CORMIX modeling software (Jirka, G. H., et. al, 1996) and the ADCP measured flow data. The goal of this study is to recommend a diffuser design and outfall location and to evaluate its performance based primarily on the effluent percentages of the desalination concentrate at the edges of the regulatory mixing zones to compare against the critical dilution defined in the Corpus Christi Seawater Desalination Receiving Water Salinity Critical Dilutions White Paper ("White Paper") (FNI, 2020). The White Paper critical dilutions are listed as follows:

- For reverse osmosis (RO) recovery rate of 40%, critical dilutions (as percentage effluent) of 56% at the ZID and 18% at the MZ; and,
- For the RO Recovery Rate of 50%, critical dilutions of 38% at the ZID and 13% at the MZ.

The desalination plant is expected to undergo three permit phases: an initial phase of 20 MGD plant production capacity, followed by an interim phase of 30 MGD production capacity, and then a final phase of 40 MGD production capacity. The plant is expected to operate at recovery rates ranging from 40% to 50%. CORMIX modeling was used to evaluate these ranges of operation and identify a feasible outfall location and diffuser design option that would satisfy the critical dilutions. In addition, the flow class assigned by CORMIX was evaluated to ensure that the proposed discharge would have the mixing characteristics of a properly diffused plume. Finally, CORMIX was used to evaluate effluent velocities to address concerns on aquatic life protection due to jet velocities.

3 DESCRIPTION OF OUTFALL LOCATION

3.1 DIFFUSER PLACEMENT

As per the permit application, the diffuser would be placed within the latitude/longitude window (“outfall window”) defined by the coordinates of 27.868°N, 97.245°W for the southeast corner and the coordinates of 27.872°N, 97.245°W at the northwest corner (Figure 1). The outfall window is near the Occidental Chemical Corporation dock and off the south bank of the La Quinta channel. The recommended diffuser design is a multiport diffuser consisting of a 50-foot-long diffuser pipe. The diffuser would be placed at a depth of approximately 32 feet on the north side of the navigation channel. The diffuser pipe would be aligned parallel to the channel while the diffuser ports would be directed towards the center of the channel.

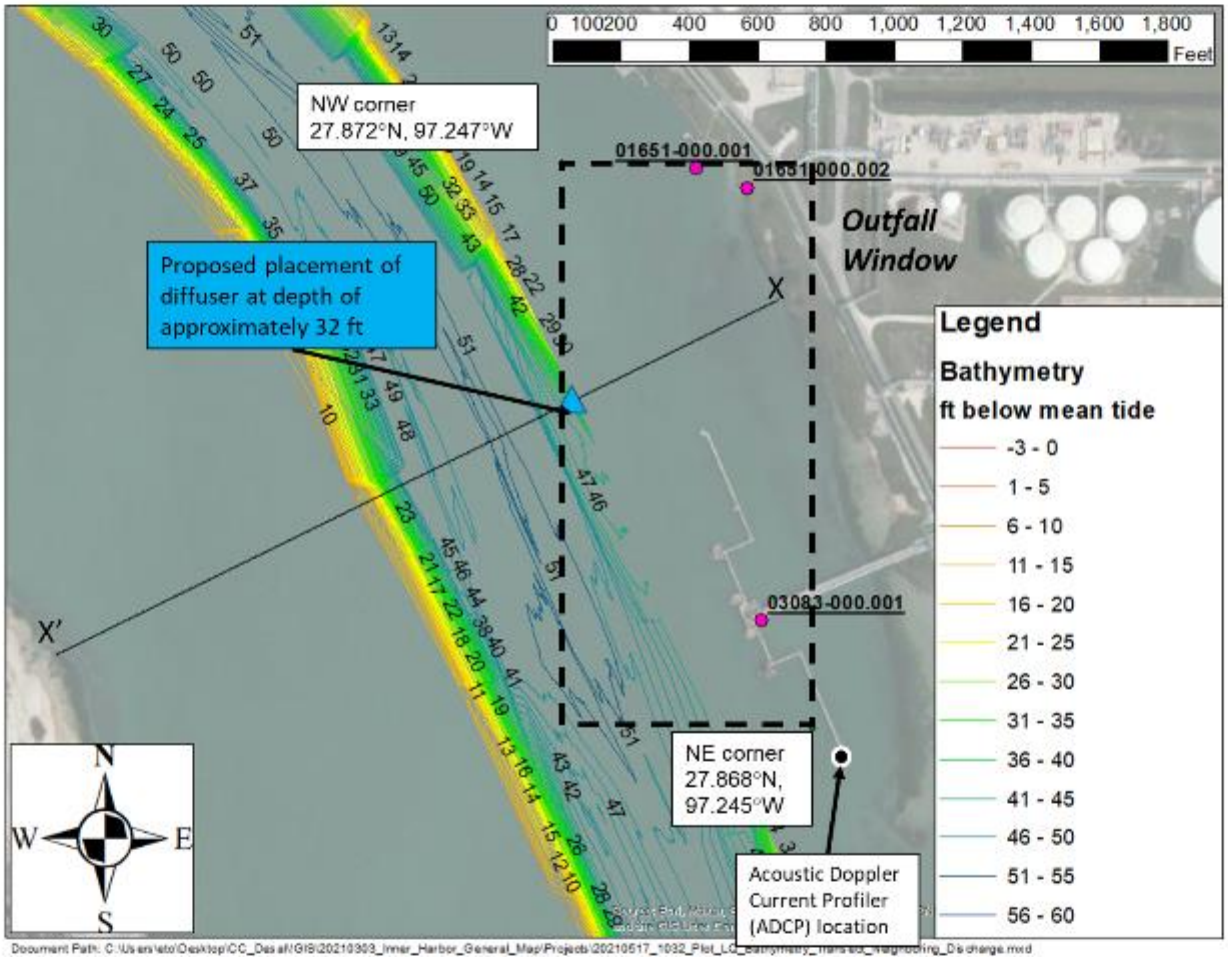

Figure 1. Map of the La Quinta outfall location.

Based on the bathymetry data collected in the La Quinta channel (see contour lines in Figure 1), a cross-sectional profile was plotted for the proposed outfall location (see Figure 2). The cross-sectional profile (see line X-X’) runs from La Quinta east shore (located at x = 0 ft in Figure 2) to the west shore (at x ~2350 ft) and the side view of the profile is provided in Figure 2. To model this profile in CORMIX, the cross section was approximated as a rectangle 768 ft wide x 42 ft deep or (234 m wide x 13 m deep). These dimensions reflect the width and average depth of the portion where the elevation data are available. The proposed diffuser would be located on provide property near navigational channel about 32 ft below the water surface and 20 ft from the eastern edge of the approximated rectangular cross-section.

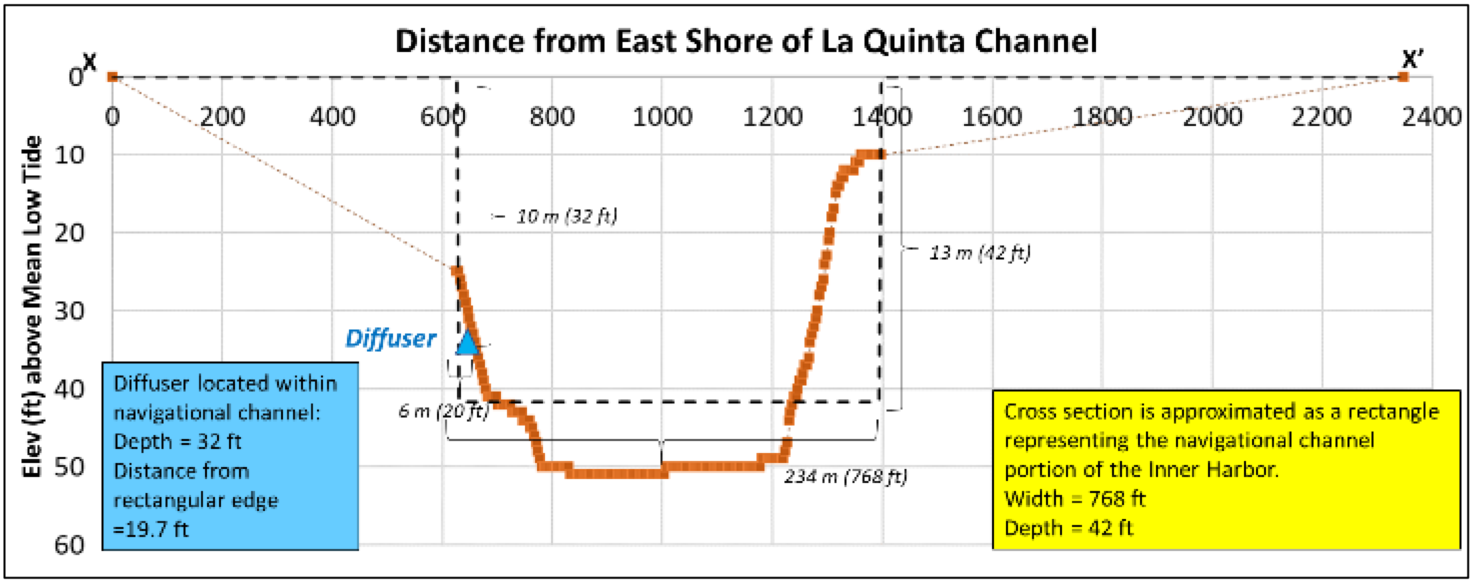

Figure 2. Cross-sectional profile at proposed diffuser location.

3.2 DIMENSIONS OF MIXING ZONES

Since the proposed diffuser will be a multiport diffuser, rectangular mixing zones for the ZID, MZ and Human Health Mixing Zone (HHMZ) were defined following SOP requirements. SOP require that the area of each rectangular mixing zone to be equal or less than the area of the corresponding circular mixing zone for the ZID, MZ and HHMZ. According to the TCEQ Implementation Procedures (TCEQ, 2010) the regulatory mixing distances in wide tidal rivers for the ZID, MZ and HHMZ are 50 ft, 200 ft and 400 ft respectively.

The following rectangular dimensions were defined for the proposed outfall:

- ZID: 100 ft x 78 ft centered around the diffuser pipe with the short side parallel to the pipe and long side perpendicular to the pipe.
- MZ: 400 ft x 314 ft centered around the diffuser pipe with the short side parallel to the pipe and long side perpendicular to the pipe; and,
- HHMZ: 800 ft x 628 ft centered around the diffuser pipe with the short side parallel to the pipe and long side perpendicular to the pipe.

A comparison between the areas of the rectangular mixing zones and the corresponding circular mixing zones is provided in Table 3.

Table 3. Comparison of areas of rectangular mixing zones and the corresponding circular mixing zones.

Regulatory Mixing Zone	Rectangular Dimensions	Rectangular Area	Corresponding circular mixing zone radius	Circular area
ZID	100 ft x 78 ft	7,800 sq. ft	50 ft	7,850 sq. ft
MZ	400 ft x 314 ft	125,600 sq. ft	200 ft	125,700 sq.ft
HHMZ	800 ft x 628 ft	502,400 sq. ft	400 ft	502,700 sq.ft

An illustration of the rectangular mixing zones in the vicinity of the outfall is shown in Figure 3. Note that the diffuser location is approximate and may be adjusted within the outfall window based on on-the-ground conditions. It is noted two other permittees have outfalls that are in the vicinity of the outfall window. A discussion of their impact on the mixing zones is provided in Section 8.

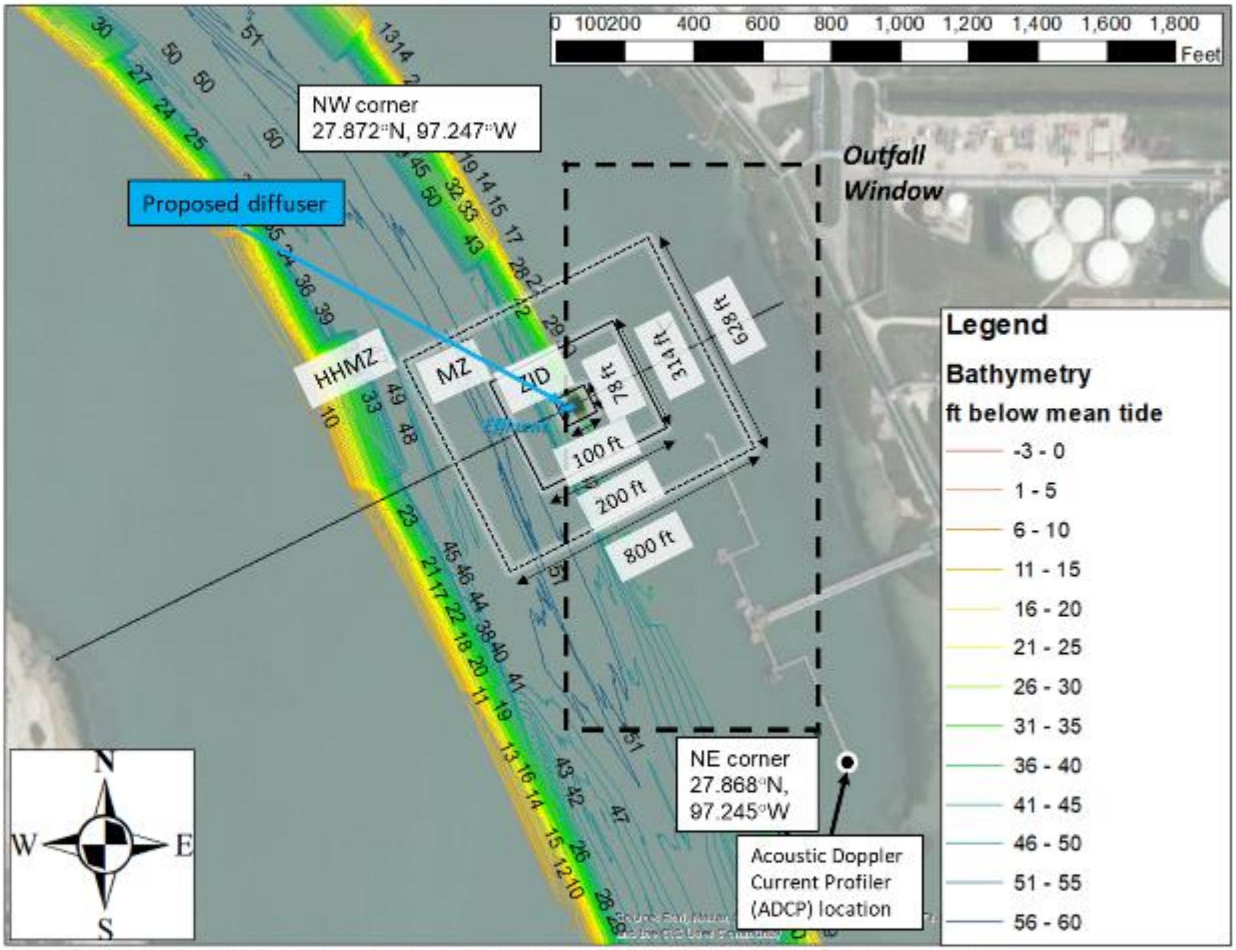

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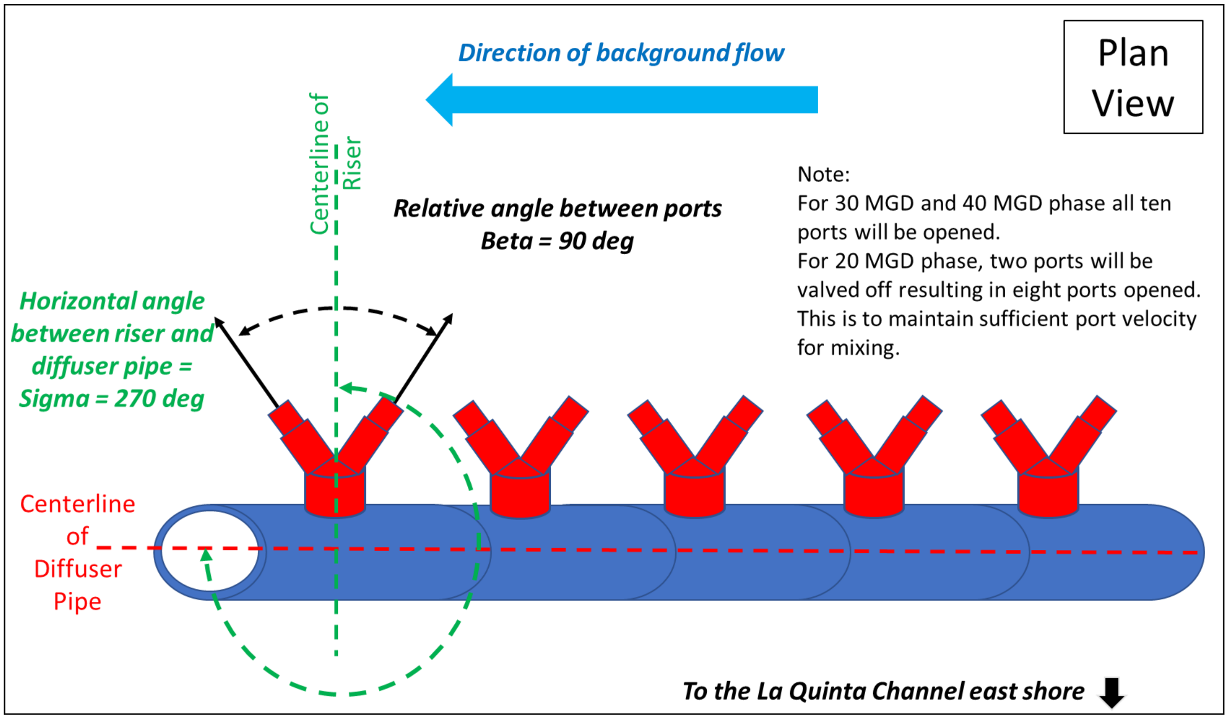
Figure 3. Illustration of rectangular regulatory mixing zones for the proposed diffuser.

4 DESCRIPTION OF PROPOSED DIFFUSER CONFIGURATION

The recommended diffuser design is a multiport diffuser consisting of a 50-foot-long diffuser pipe with five risers – each containing two 8-inch diameter ports (see Figure 4 for plan view of configuration). This results in a total of 10 ports. When operating under the 30 MGD and 40 MGD phase, all the ports will be used to discharge the effluent. When operating under the 20 MGD phase, two of these ports will be valved off resulting in eight ports opened to diffuse the effluent. This is to maintain sufficient port velocity to mix the effluent effectively.

The diffuser pipe will be aligned parallel to the channel while the risers will be perpendicular to the channel. The two diffuser ports on each riser will be angled at 90 degrees from each other. The diffuser would be placed at a depth of approximately 32 feet on the east side of the navigation channel (see Figure 5 for side view of configuration). The diffuser ports would also be angled 60 degrees upwards above the horizon to enhance mixing with the water column.



Note:
For 30 MGD and 40 MGD phase all ten ports will be opened.
For 20 MGD phase, two ports will be valved off resulting in eight ports opened. This is to maintain sufficient port velocity for mixing.

Figure 4. Diffuser array configuration concept (plan view, not to scale).

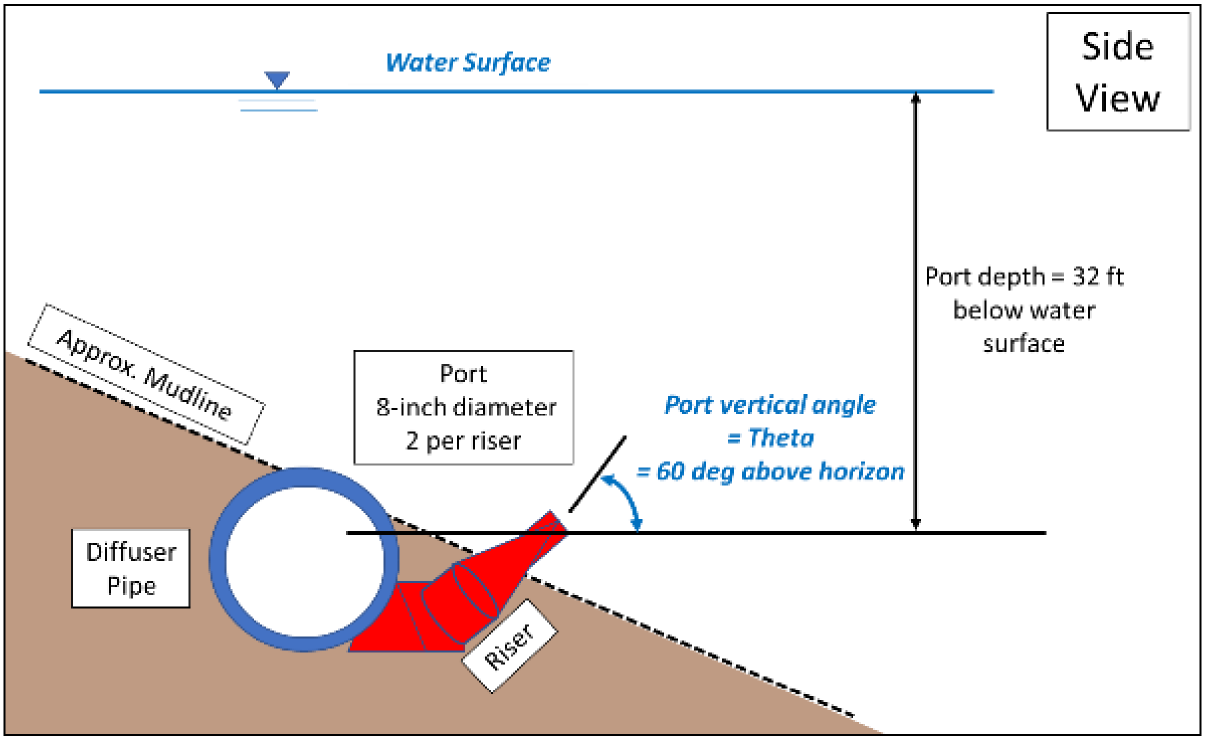
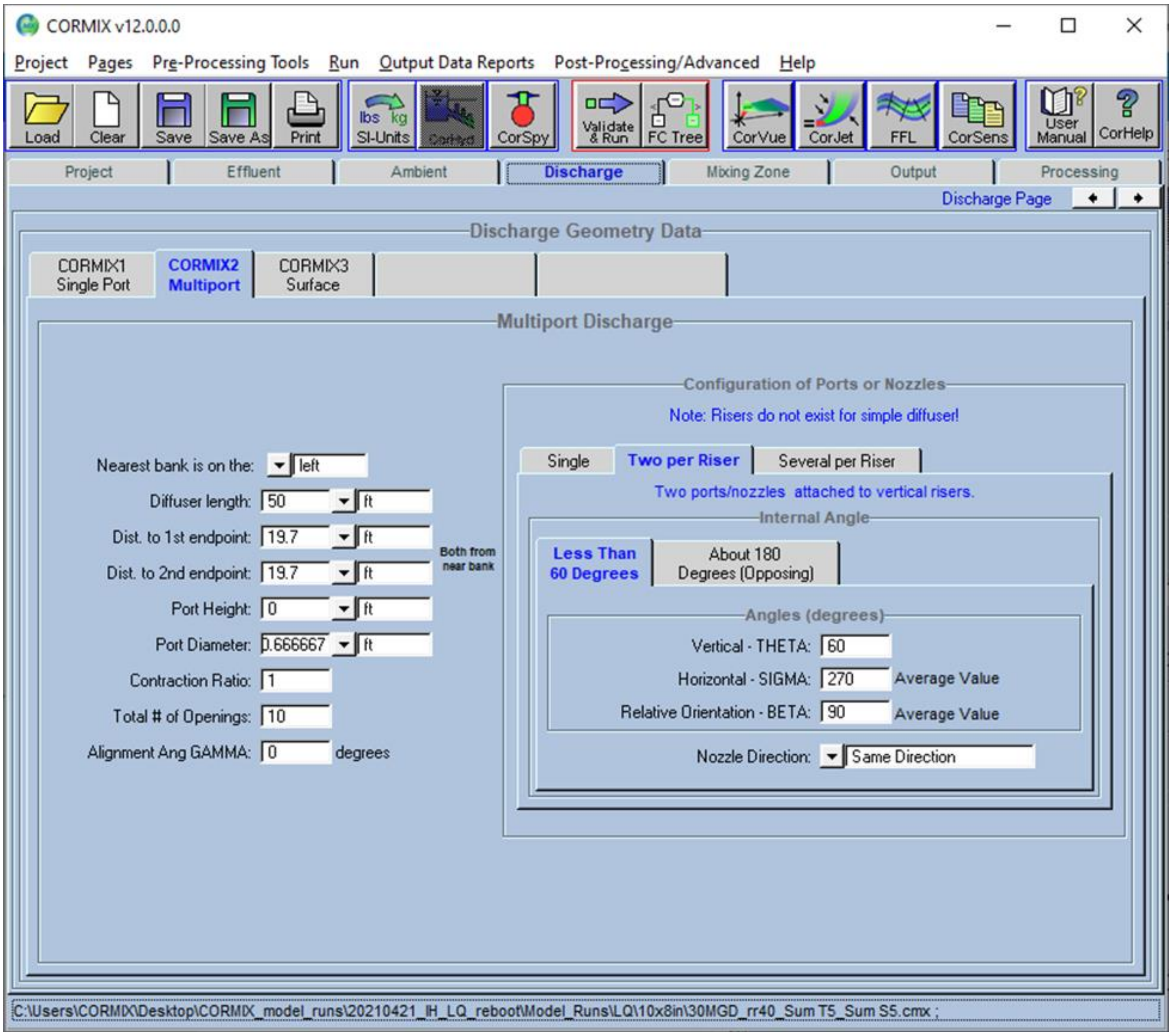


Figure 5. Diffuser array configuration concept (side view, not to scale).

Figure 6 provides a screenshot of the CORMIX Discharge which summarizes the dimensions and orientation of the proposed diffused configuration for 30 MGD and 40 MGD phase. For the 20 MGD phase, “Total # of openings” is reduced from 10 to 8.



Note: Risers do not exist for simple diffuser!

Two ports/nozzles attached to vertical risers.

Nearest bank is on the: left
Diffuser length: 50 ft
Dist. to 1st endpoint: 19.7 ft
Dist. to 2nd endpoint: 19.7 ft
Both from near bank
Port Height: 0 ft
Port Diameter: 0.666667 ft
Contraction Ratio: 1
Total # of Openings: 10
Alignment Ang GAMMA: 0 degrees

Vertical - THETA: 60
Horizontal - SIGMA: 270 Average Value
Relative Orientation - BETA: 90 Average Value
Nozzle Direction: Same Direction

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Figure 6. Screenshot of CORMIX Discharge page showing dimensions and orientation of the proposed diffused configuration for the 30 MGD and 40 MGD phase. (For the 20 MGD phase, "Total # of openings" is reduced from 10 to 8).

5 DESCRIPTION OF AMBIENT CONDITIONS

5.1 BACKGROUND FLOW

The background velocity at the La Quinta site was derived from the Acoustic Doppler Current Profiler (ADCP) data. The ADCP was deployed at a dock near the Occidental Chemical property for a six-month period from November 13, 2019 to May 13, 2020 and collected data at 15-minute intervals. Because CORMIX is a steady-state model, it only accepts one value for background velocity. The background velocity of 0.020 m/s for the La Quinta was calculated from the long-term net average of the ADCP velocities. For details of the calculation methodology please see Appendix A.

5.2 BRINE ACCUMULATION

Apart from being used as a CORMIX input, the long-term net average background velocity was also used to evaluate the potential for brine accumulation. Because the outfall is located in a tidal zone, background flows can reverse throughout the course of the day. Tidal flows during one part of the day may temporarily move the dispersed effluent away from the outfall but can move it back when the tide changes. The long-term net average background velocity averages over transient tidal effects, thereby accounting for the net background flow available to transport the dispersed effluent away from the outfall. A non-zero long-term net average background velocity (0.020 m/s – in this case) would indicate net transport of the dispersed effluent away from the outfall, thereby preventing long-term brine accumulation.

5.3 AMBIENT DENSITY SCENARIOS

According to the SOP, the CORMIX evaluations must be performed on a range of scenarios that capture the ambient densities associated with the 5th and 95th percentile of water salinity and temperature. Per TCEQ staff guidance, eight standard density scenarios were defined as follows:

Summer: $\rho(T_5, S_5),\ \rho(T_5, S_{95}),\ \rho(T_{95}, S_5),\ \rho(T_{95}, S_{95})$

Winter: $\rho(T_5, S_5),\ \rho(T_5, S_{95}),\ \rho(T_{95}, S_5),\ \rho(T_{95}, S_{95})$

where the density ρ (kg/m^3) is a function of temperature, T (℃) and salinity, S (ppt) as shown in Equation 1:

$$\rho_{s,t,0} = [1 + \left(0.001\left((28.14 - 0.0735T - 0.00469T^2) + (0.802 - 0.002T)(S - 35)\right)\right)] \times 1000.$$

(Equation 1)

The subscripts 5 and 95 for the four standard density cases represent the 5th and 95th percentiles. The salinity and temperature data for the La Quinta channel are available at SWQM station 13409 from 1985 to 2017. Table 4 provides the 5th and 95th percentile temperature and salinity values for the summer months

(April through September) and winter months (October through March). Table 4 also contains the corresponding ambient densities calculated from Equation 1 for the eight standard density scenarios.

Table 4 Ambient temperature and salinity conditions at La Quinta channel

Season	Density Scenario	Temperature Statistic	Ambient Temperature ℃ (℃)	Salinity Statistic	Ambient Salinity (ppt)	Ambient Density (kg/m3)
Summer	$\rho(T_5, S_5)$	T_5	21.9	S_5	25.0	1016.7
	$\rho(T_{95}, S_5)$	T_{95}	31.0	S_5	25.0	1013.9
	$\rho(T_5, S_{95})$	T_5	21.9	S_{95}	38.8	1027.2
	$\rho(T_{95}, S_{95})$	T_{95}	31.0	S_{95}	38.8	1024.2
Winter	$\rho(T_5, S_5)$	T_5	11.4	S_5	27.1	1020.5
	$\rho(T_{95}, S_5)$	T_{95}	27.1	S_5	27.1	1016.8
	$\rho(T_5, S_{95})$	T_5	11.4	S_{95}	32.6	1024.8
	$\rho(T_{95}, S_{95})$	T_{95}	27.1	S_{95}	32.6	1020.9

5.4 STRATIFICATION

According to the SOP, if stratification is determined to be a routine characteristic of the receiving waters, another model scenario must be modeled to capture the impacts on mixing. Density stratification is defined when the density difference from surface to bottom is more than 0.1 kilograms per cubic meter (kg/m^3). Using temperature, salinity and conductivity depth profiles from SWQM station 13409 the median density difference for data analyzed for the La Quinta Channel was 0.3 kg/m^3. Following the SOP, this density difference was used to develop stratification cases for the most critical two cases -Winter $\rho(T_5, S_{95})$ and Summer $\rho(T_5, S_{95})$ as shown in Table 5.

Table 5 Stratification cases for the La Quinta channel

Season	**Density Scenario**	**Ambient Density (kg/m3)**	**Surface Density (kg/m3)** *(Ambient density – 0.5*0.3 kg/m^3)*	**Bottom Density (kg/m3)** *(Ambient density + 0.5* 0.3 kg/m^3)*
Summer	$\rho(T_5, S_{95})$ – stratification	1027.2	1027.0	1027.3
Winter	$\rho(T_5, S_{95})$ - stratification	1024.8	1024.7	1025.0

6 DESCRIPTION OF EFFLUENT SCENARIOS

The model scenarios simulated 30 MGD and 40 MGD desalination plant production capacities operating at the minimum and maximum RO recovery rates of 40% and 50%. The effluent discharge associated with each of the six combinations of production capacity and recovery rate ("combination") is provided in Table 6.

Table 6 Effluent discharges associated with proposed production capacities and recovery rates.

Production Capacity	Recovery Rate	Effluent Discharge
20 MGD	50%	23.4 MGD
	40%	34.3 MGD
30 MGD	50%	35.2 MGD
	40%	51.5 MGD
40 MGD	50%	46.9 MGD
	40%	68.6 MGD

It is expected that the salinity of the effluent discharge would increase with the RO recovery rate and the salinity of the source water. It is also expected that heat from the desalination process would raise the temperature of the effluent discharge slightly higher than the ambient water (by less than 1.5 ^{o}F). Since the temperature and salinity of the effluent depend on those of the source water, the effluent density is expected to vary with the ambient density and therefore need to be calculated for each of the ten density scenarios. Table 7 and Table 8 provides the effluent densities for the ten density scenarios (eight unstratified + two stratified) under each of the two RO recovery rates (40% and 50%) and three production capacities. The tables provide densities for in a total of 60 scenarios evaluated for the proposed diffuser configuration.

La Quinta

Table 7. Effluent Densities for Various Production Capacities and 40% RO Recovery Rate Scenarios.

				Scenario		Ambient			Effluent		
Production Capacity	**Recovery Rate**	**Effluent Discharge**	**Season**	**Temp stat**	**Sal stat**	**T (°C)**	**S (ppt)**	**Density (kg/m3)**	**T (°C)**	**S (ppt)**	**Density (kg/m3)**
20 MGD/ 30 MGD/ 40 MGD	40%	34.3 MGD/ 51.5 MGD/ 68.6 MGD	Summer	T5	S5	21.9	25.0	1016.7	22.8	39.5	1027.4
				T5	S95	21.9	38.8	1027.2	22.8	61.3	1043.9
				T95	S5	31.0	25.0	1013.9	31.8	39.5	1024.4
				T95	S95	31.0	38.8	1024.2	31.8	61.3	1040.5
			Summer Strat-ification	T5	S95	21.9	38.8	Top: 1027.0 Bottom: 1027.3	22.8	61.3	1043.9
			Winter	T5	S5	11.4	27.1	1020.5	12.3	42.8	1032.6
				T5	S95	11.4	32.6	1024.8	12.3	51.5	1039.4
				T95	S5	27.1	27.1	1016.8	28.0	42.8	1028.2
				T95	S95	27.1	32.6	1020.9	28.0	51.5	1034.7
			Winter Strat-ification	T5	S95	11.4	32.6	Top: 1024.7 Bottom: 1025.0	12.3	51.5	1039.4

Table 8. Effluent Densities for Various Production Capacities and 50% RO Recovery Rate Scenarios.

				Scenario		Ambient			Effluent		
Production Capacity	**Recovery Rate**	**Effluent Discharge**	**Season**	**Temp stat**	**Sal stat**	**T (°C)**	**S (ppt)**	**Density (kg/m3)**	**T (°C)**	**S (ppt)**	**Density (kg/m3)**
20 MGD/ 30 MGD/ 40 MGD	50%	23.4 MGD/ 35.2 MGD/ 46.8 MGD	Summer	T5	S5	21.9	25.0	1016.7	22.8	46.2	1032.5
				T5	S95	21.9	38.8	1027.2	22.8	71.7	1051.8
				T95	S5	31.0	25.0	1013.9	31.8	46.2	1029.3
				T95	S95	31.0	38.8	1024.2	31.8	71.7	1048.2
			Summer Strat-ification	T5	S95	21.9	38.8	Top: 1027.0 Bottom: 1027.3	22.8	71.7	1051.8
			Winter	T5	S5	11.4	27.1	1020.5	12.3	50.1	1038.3
				T5	S95	11.4	32.6	1024.8	12.3	60.3	1046.2
				T95	S5	27.1	27.1	1016.8	28.0	50.1	1033.7
				T95	S95	27.1	32.6	1020.9	28.0	60.3	1041.3
			Winter Strat-ification	T5	S95	11.4	32.6	Top: 1024.7 Bottom: 1025.0	12.3	60.3	1046.2

7 EVALUATION CRITERIA AND RESULTS

CORMIX was used to simulate the performance of the diffuser configuration by incorporating the information about outfall location, proposed diffuser configuration, background flow, ambient and effluent density scenarios. CORMIX results from each of the 40 scenarios were evaluated based on three criteria:

1. Effluent percentages at the MZ and ZID;
2. CORMIX-assigned flow class; and,
3. Effluent velocities at the MZ and ZID.

Detailed descriptions of each criteria are provided in the following subsections.

7.1 EFFLUENT PERCENTAGES AT THE ZONE OF INITIAL DILUTION AND MIXING ZONE

Effluent percentages predicted by CORMIX at the edge of the ZID and the MZ mixing zones were compared with the critical dilutions proposed in the Corpus Christi Seawater Desalination Receiving Water Salinity Critical Dilutions White Paper ("White Paper") (FNI, 2020). The White Paper states the critical dilutions (expressed as percentage effluent) that are protective of aquatic life as follows:

- For the reverse osmosis (RO) recovery rate of 40%, the critical dilution for the ZID is 56% and the critical dilution for the MZ is 18%.
- For the RO recovery rate of 50%, the critical dilution for the ZID is 38% and the critical dilution for the MZ is 13%.

7.1.1 Considering the Limiting Effluent Percentage

It is necessary to consider the Limiting Effluent Percentage (LE) when interpreting the numerical predictions of effluent percentages from CORMIX. The LE represents the lowest physically achievable effluent percentage after mixing within a system. Because the effluent is discharged into a channel, the ability to dilute with ambient water is constrained by background flow passing through the channel. LE is inversely related to the Limiting Dilution, which is a limit established by CORMIX. The limiting dilution is based on mass balance of the concentrate discharge flow and the background flow as shown in Equation 2:

$$Limiting\ Dilution = QA/Q0 + 1.0, \qquad \text{(Equation 2)}$$

where QA is the background flow rate and $Q0$ is the effluent discharge flow rate.

If the predictions of effluent dilution (i.e., the inverse of the effluent percentage) exceed the limiting dilution, the CORMIX software would provide a note stating that those predictions that exceed would be unreliable. Since evaluations are based on effluent percentage, instead of dilutions, Effluent Percentage (LE) is therefore calculated from the limiting dilution by taking the inverse of Equation 2:

$$LE = \mathit{Limiting\ Effluent\ Percentage}$$

$$= \frac{1}{\mathit{Limiting\ Dilution}} x\ 100\%$$

$$= \frac{1}{\frac{QA}{Q0} + 1} x\ 100\%$$

$$= \frac{Q0}{QA + Q0} x\ 100\%$$

(Equation 3)

Because the LE constrains the effluent percentage value, consequently, in the interpretation of the CORMIX model results, any predicted effluent percentage value less than the LE was set to the value of the LE.

The LE is different for each combination because the effluent discharge, $Q0$, depends on production capacity and RO recovery rate. Table 9 summarizes the LE calculated for each combination.

The background flow, QA, is calculated based on the net average background velocity of 0.02 m/s (see Appendix A) and the rectangular channel dimensions of 234 m wide x 13 m deep (see Section 3). Therefore QA = 0.02 x 234 x 13 = 60.5 m^3/s (or 1382 MGD).

Table 9. Summary of limiting effluent percentages (LE) for proposed production rate/RO recovery rate combinations.

Production Rate	RO Recovery Rate	Effluent Discharge	Background Flow	Limiting Effluent Percentage
20 MGD production	40%	34.3 MGD	1382 MGD	2.42%
30 MGD production		51.5 MGD		3.59%
40 MGD production		68.6 MGD		4.73%
20 MGD production	50%	23.4 MGD		1.67%
30 MGD production		35.2 MGD		2.48%
40 MGD production		46.9 MGD		3.28%

7.1.2 Evaluation of Effluent Percentage Results

Graphs of the effluent percentages along the direction of discharge (i.e., the long side of the rectangular mixing zones – recall Figure 3) are provided in Figure 7 to Figure 12 for the six production rate/RO recovery rate combinations. Tables comparing the effluent percentages with the critical dilution at the ZID and the MZ are provided in Table 10 to Table 15. It can be observed that within each combination, the effluent percentages predicted for the ten density scenarios were identical. The proposed diffuser configuration met the critical dilutions under all six combinations of production rate/RO recovery rate.

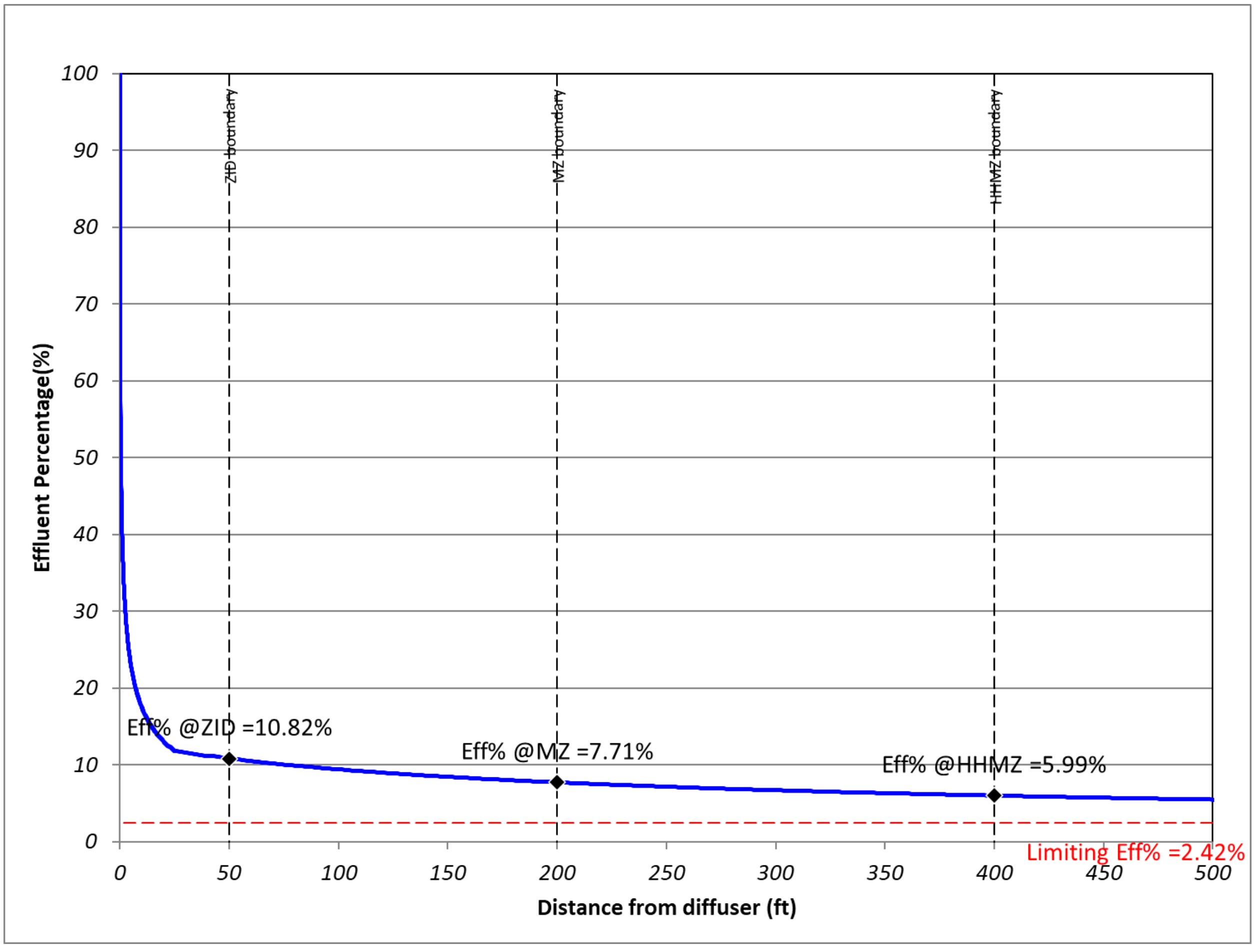

Figure 7. Graph of effluent percentages predicted for 20 MGD x 40% RO Recovery Rate along direction of effluent discharge.

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Table 10. Comparison of effluent percentages for 20 MGD x 40% RO Recovery Rate with critical dilutions.

				ZID Results		MZ results		HHMZ
Production Rate (MGD)	**Recovery Rate**	**Effluent Discharge (MGD)**	**Density Scenario**	**Effluent Percentage (%)**	**Evaluation (<=56%?)**	**Effluent Percentage (%)**	**Evaluation (<=18%?)**	**Effluent Percentage (%)**
20	40%	34.3	Summer (T5, S5)	10.8	Yes	7.7	Yes	6.0
			Summer (T5, S95)	10.8	Yes	7.7	Yes	6.0
			Summer (T95, S5)	10.8	Yes	7.7	Yes	6.0
			Summer (T95, S95)	10.8	Yes	7.7	Yes	6.0
			Winter (T5, S5)	10.8	Yes	7.7	Yes	6.0
			Winter (T5, S95)	10.8	Yes	7.7	Yes	6.0
			Winter (T95, S5)	10.8	Yes	7.7	Yes	6.0
			Winter (T95, S95)	10.8	Yes	7.7	Yes	6.0
			Summer* stratified (T5, S95)	10.8	Yes	7.7	Yes	6.0
			Winter* stratified (T5, S95)	10.8	Yes	7.7	Yes	6.0

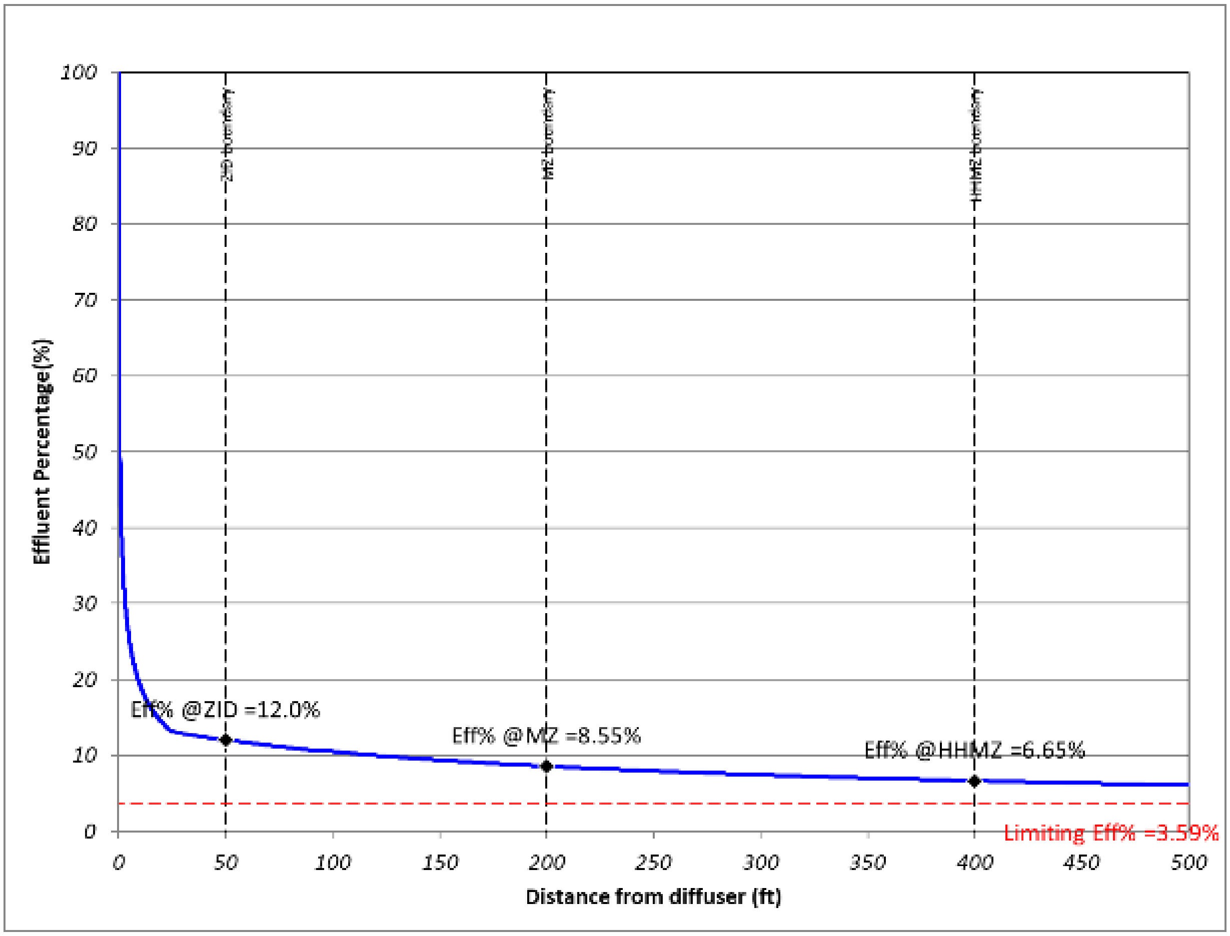

Figure 8. Graph of effluent percentages predicted for 30 MGD x 40% RO Recovery Rate along direction of effluent discharge.

Table 11. Comparison of effluent percentages for 30 MGD x 40% RO Recovery Rate with critical dilutions.

				ZID Results		MZ results		HHMZ
Production Rate (MGD)	Recovery Rate	Effluent Discharge (MGD)	Density Scenario	Effluent Percentage (%)	Evaluation (<=56%?)	Effluent Percentage (%)	Evaluation (<=18%?)	Effluent Percentage (%)
30	40%	51.5	Summer (T5, S5)	12.0	Yes	8.6	Yes	6.7
			Summer (T5, S95)	12.0	Yes	8.6	Yes	6.7
			Summer (T95, S5)	12.0	Yes	8.6	Yes	6.7
			Summer (T95, S95)	12.0	Yes	8.6	Yes	6.7
			Winter (T5, S5)	12.0	Yes	8.6	Yes	6.7
			Winter (T5, S95)	12.0	Yes	8.6	Yes	6.7
			Winter (T95, S5)	12.0	Yes	8.6	Yes	6.7
			Winter (T95, S95)	12.0	Yes	8.6	Yes	6.7
			Summer stratified (T5, S95)	12.0	Yes	8.6	Yes	6.7
			Winter stratified (T5, S95)	12.0	Yes	8.6	Yes	6.7

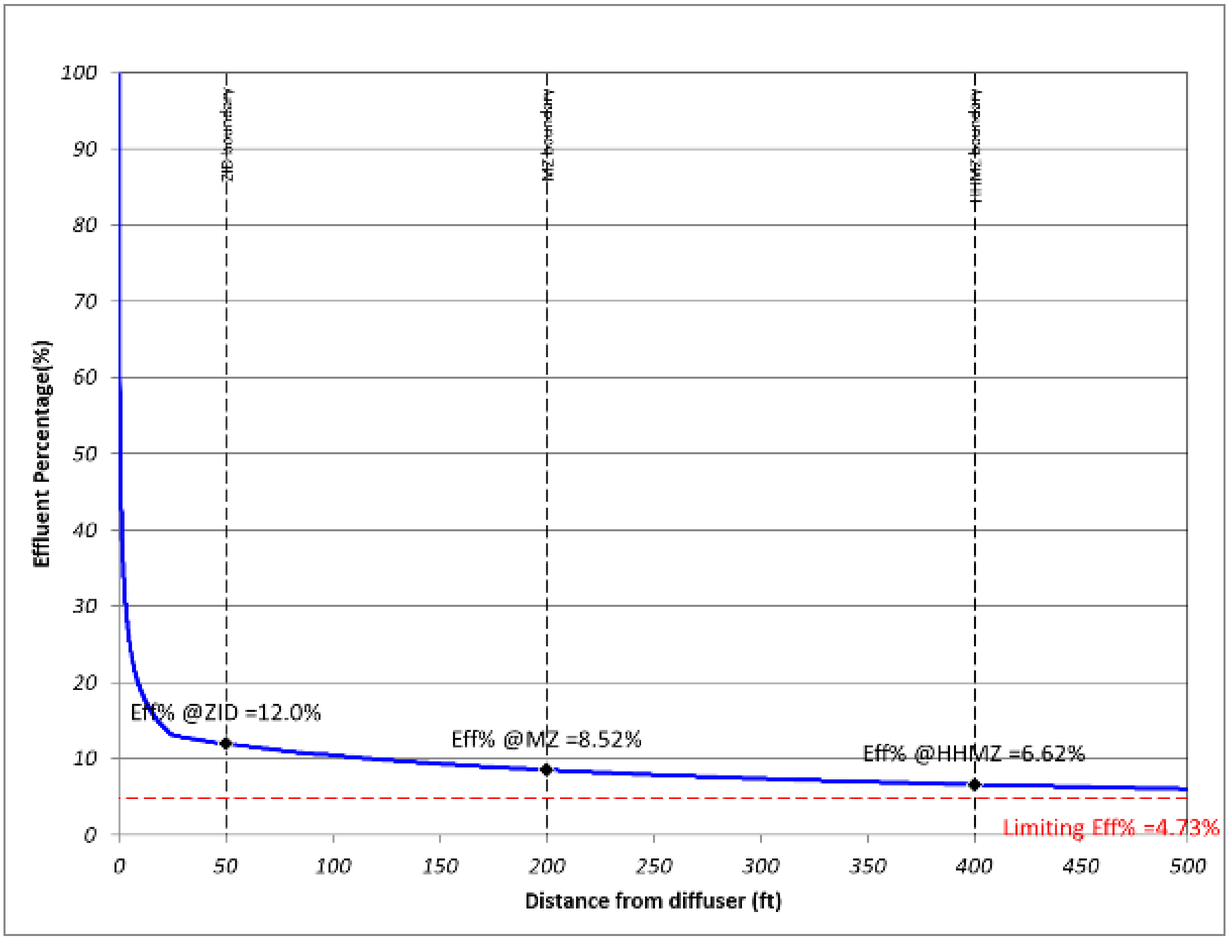

Figure 9. Graph of effluent percentages predicted for 40 MGD x 40% RO Recovery Rate along direction of discharge.

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Table 12. Comparison of effluent percentages for 40 MGD x 40% RO Recovery Rate with critical dilutions.

				ZID Results		MZ results		HHMZ
Production Rate (MGD)	Recovery Rate	Effluent Discharge (MGD)	Density Scenario	Effluent Percentage (%)	Evaluation (<=56%?)	Effluent Percentage (%)	Evaluation (<=18%?)	Effluent Percentage (%)
40	40%	68.6	Summer (T5, S5)	12.0	Yes	8.5	Yes	6.6
			Summer (T5, S95)	12.0	Yes	8.5	Yes	6.6
			Summer (T95, S5)	12.0	Yes	8.5	Yes	6.6
			Summer (T95, S95)	12.0	Yes	8.5	Yes	6.6
			Winter (T5, S5)	12.0	Yes	8.5	Yes	6.6
			Winter (T5, S95)	12.0	Yes	8.5	Yes	6.6
			Winter (T95, S5)	12.0	Yes	8.5	Yes	6.6
			Winter (T95, S95)	12.0	Yes	8.5	Yes	6.6
			Summer stratified (T5, S95)	12.0	Yes	8.5	Yes	6.6
			Winter stratified (T5, S95)	12.0	Yes	8.5	Yes	6.6

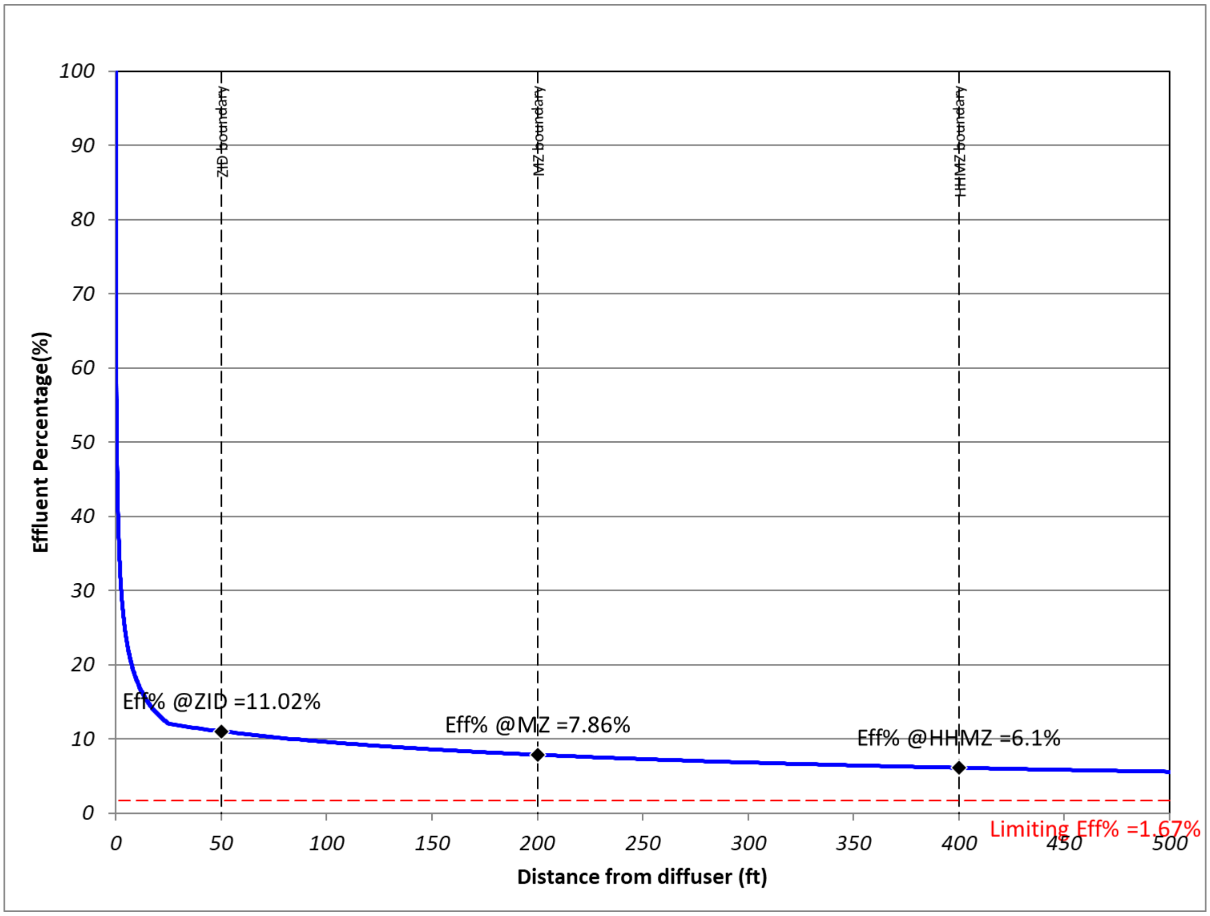

Figure 10. Graph of effluent percentages predicted for 20 MGD x 50% RO Recovery Rate along direction of effluent discharge.

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Table 13. Comparison of effluent percentages for 20 MGD x 50% RO Recovery Rate with critical dilutions.

				ZID Results		MZ results		HHMZ
Production Rate (MGD)	**Recovery Rate**	**Effluent Discharge (MGD)**	**Density Scenario**	**Effluent Percentage (%)**	**Evaluation (<=56%?)**	**Effluent Percentage (%)**	**Evaluation (<=18%?)**	**Effluent Percentage (%)**
20	50%	23.4	Summer (T5, S5)	11.0	Yes	7.9	Yes	6.1
			Summer (T5, S95)	11.0	Yes	7.9	Yes	6.1
			Summer (T95, S5)	11.0	Yes	7.9	Yes	6.1
			Summer (T95, S95)	11.0	Yes	7.9	Yes	6.1
			Winter (T5, S5)	11.0	Yes	7.9	Yes	6.1
			Winter (T5, S95)	11.0	Yes	7.9	Yes	6.1
			Winter (T95, S5)	11.0	Yes	7.9	Yes	6.1
			Winter (T95, S95)	11.0	Yes	7.9	Yes	6.1
			Summer stratified (T5, S95)	11.0	Yes	7.9	Yes	6.1
			Winter stratified (T5, S95)	11.0	Yes	7.9	Yes	6.1

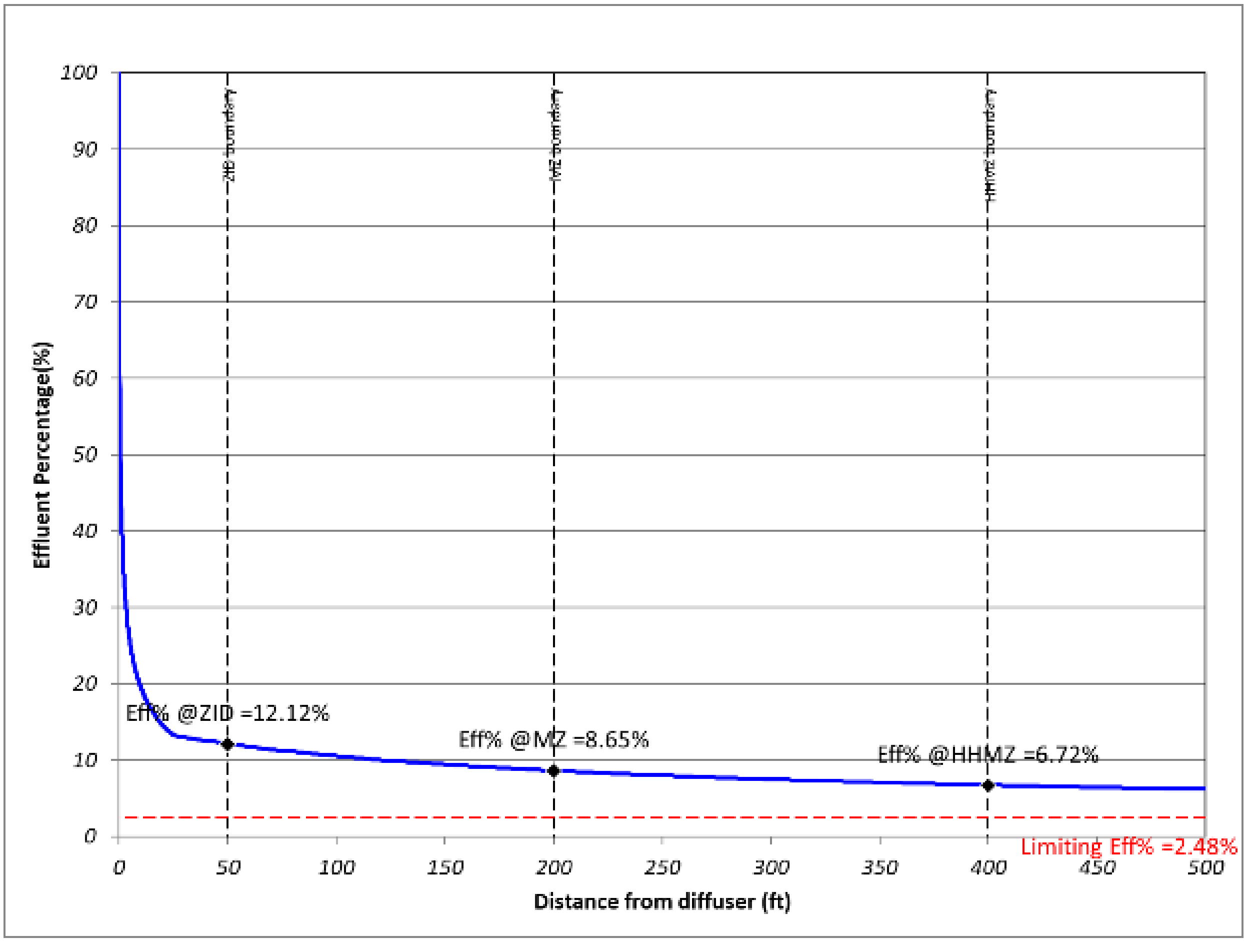

Figure 11. Graph of effluent percentages predicted for 30 MGD x 50% RO Recovery Rate along direction of discharge.

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Table 14. Comparison of effluent percentages for 30 MGD x 50% RO Recovery Rate with critical dilutions.

				ZID Results		MZ results		HHMZ
Production Rate (MGD)	**Recovery Rate**	**Effluent Discharge (MGD)**	**Density Scenario**	**Effluent Percentage (%)**	**Evaluation (<=38%?)**	**Effluent Percentage (%)**	**Evaluation (<=13%?)**	**Effluent Percentage (%)**
30	50%	35.2	Summer (T5, S5)	12.1	Yes	8.7	Yes	6.7
			Summer (T5, S95)	12.1	Yes	8.7	Yes	6.7
			Summer (T95, S5)	12.1	Yes	8.7	Yes	6.7
			Summer (T95, S95)	12.1	Yes	8.7	Yes	6.7
			Winter (T5, S5)	12.1	Yes	8.7	Yes	6.7
			Winter (T5, S95)	12.1	Yes	8.7	Yes	6.7
			Winter (T95, S5)	12.1	Yes	8.7	Yes	6.7
			Winter (T95, S95)	12.1	Yes	8.7	Yes	6.7
			Summer stratified (T5, S95)	12.1	Yes	8.7	Yes	6.7
			Winter stratified (T5, S95)	12.1	Yes	8.7	Yes	6.7

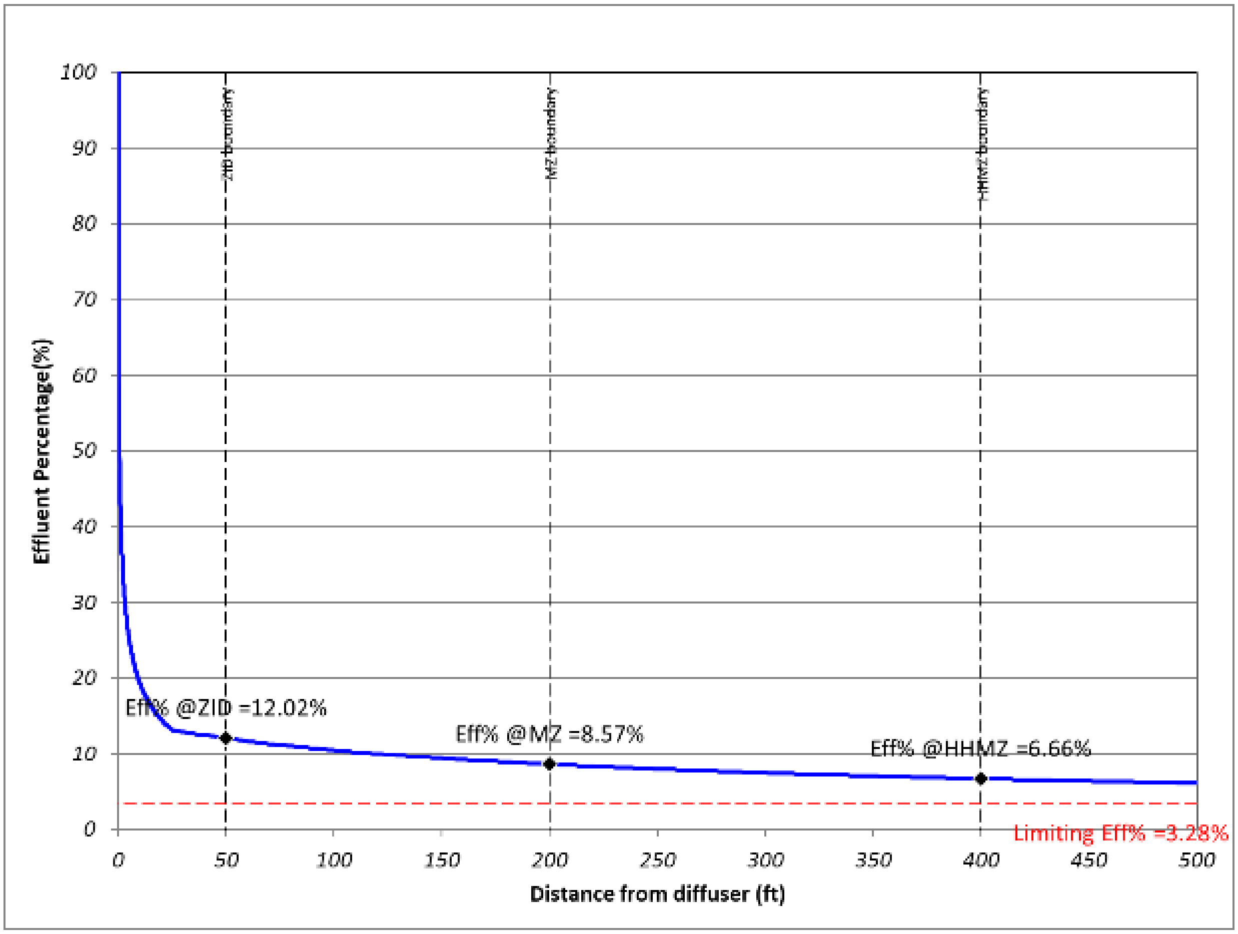

Figure 12. Graph of effluent percentages predicted for 40 MGD x 50% RO Recovery Rate along direction of discharge.

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Table 15. Comparison of effluent percentages for 40 MGD x 50% RO Recovery Rate with critical dilutions.

				ZID Results		MZ results		HHMZ
Production Rate (MGD)	**Recovery Rate**	**Effluent Discharge (MGD)**	**Density Scenario**	**Effluent Percentage (%)**	**Evaluation (<=38%?)**	**Effluent Percentage (%)**	**Evaluation (<=13%?)**	**Effluent Percentage (%)**
40	50%	46.9	Summer (T5, S5)	12.0	Yes	8.6	Yes	6.7
			Summer (T5, S95)	12.0	Yes	8.6	Yes	6.7
			Summer (T95, S5)	12.0	Yes	8.6	Yes	6.7
			Summer (T95, S95)	12.0	Yes	8.6	Yes	6.7
			Winter (T5, S5)	12.0	Yes	8.6	Yes	6.7
			Winter (T5, S95)	12.0	Yes	8.6	Yes	6.7
			Winter (T95, S5)	12.0	Yes	8.6	Yes	6.7
			Winter (T95, S95)	12.0	Yes	8.6	Yes	6.7
			Summer stratified (T5, S95)	12.0	Yes	8.6	Yes	6.7
			Winter stratified (T5, S95)	12.0	Yes	8.6	Yes	6.7

7.2 CORMIX ASSIGNED FLOW CLASS

In addition to the effluent percentage, the performance of the diffuser in CORMIX was evaluated in terms of flow class. The CORMIX flow classification scheme categorizes the discharge/environment interaction into one of many flow classes with distinct hydrodynamic features and accounts for factors such as ambient conditions, effluent conditions and the diffuser design (Jirka, et.al., 1996). Once a flow class has been assigned, a specific modeling procedure unique to the flow class is utilized by CORMIX to simulate the interaction of the discharge with the receiving water.

In the process of identifying the proposed diffuser configuration, different port sizes, port numbers and other diffuser parameters were tested using CORMIX. It was observed that CORMIX assigned either one of two flow classes MNU8 or MNU3 to the resulting flow regime. These two classifications are explained in further detail below.

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According to the CORMIX prediction file, MNU is a family of flow classes for “deeply submerged negatively buoyant multiport diffuser discharge” and MNU8 represents a situation where “the discharge strength (measured by its momentum flux) is very high in relation to the layer depth and in relation to the stabilizing effect of the discharge buoyancy (measured by its buoyancy flux)”. For the flow class of MNU8, the predicted effluent discharges upwards and engages the water column before falling to the bottom (Figure 13). This flow class represents a behavior desirable for a diffuser and is preferred for the purpose of diffuser design. MNU8 is usually assigned by CORMIX to diffuser configurations with smaller port diameters or smaller number of ports because they result in higher port velocities that provide more kinetic energy for mixing. MNU8 is also more common for density scenarios where ambient and effluent densities are more similar and it takes less energy to mix the two fluids.

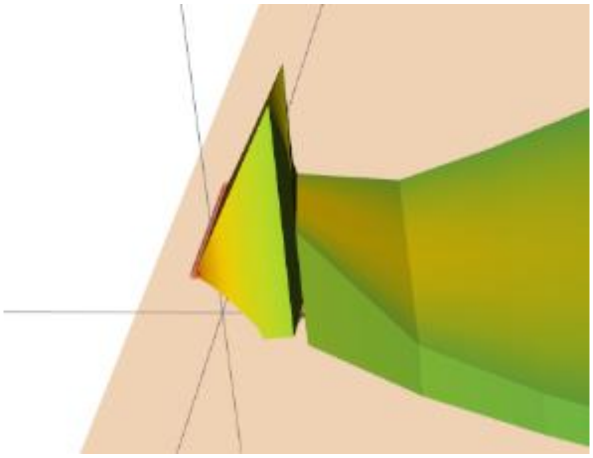

Figure 13 CORMIX-predicted plume under flow class MNU8.

On the other hand, MNU3 represents a situation where “the discharge strength (measured by its momentum flux) is weak in relation to the layer depth and in relation to the stabilizing effect of the negative discharge buoyancy (measured by its buoyancy flux)”. The predicted effluent flows out onto the bottom with limited engagement with the water column (Figure 14). This flow class represents a less desirable behavior for a diffuser. MNU3 is usually assigned by CORMIX to diffuser configurations with larger port diameters or larger number of ports since they result in lower port velocities that provide less kinetic energy for mixing. MNU3 is also more common for density scenarios where the difference between ambient and effluent densities are larger and it takes more energy to mix the two.

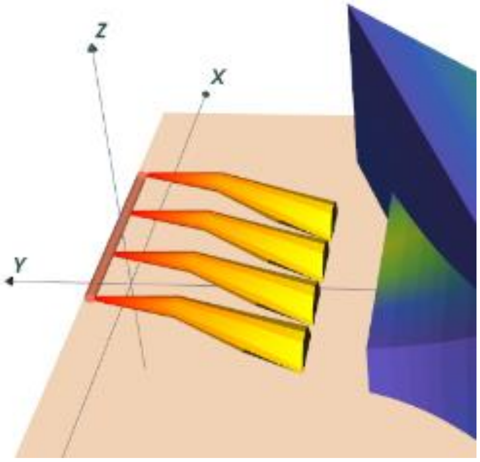

Figure 14 CORMIX-predicted plume under flow class MNU3.

In this modeling study, the diffuser port has been tested with various sizes. The port diameter of 8 inches is deemed optimal in that allows the diffuser to maintain high discharge velocities that result in sufficient dilution. The resulting flow class is MNU8 for 8-inch scenarios.

In contrast, increasing the port diameter from 8 inches to 12 inches reduces the discharge velocities and can result in a flow classification of MNU3 when the effluent discharge rates are the lowest and salinities are highest. Table 16 to Table 18 provides comparison in CORMIX assigned flow class between the 8-inch port diameter (proposed configuration) and 12-inch diameter configurations for 20 MGD, 30 MGD and 40 MGD. The flow classification of MNU3 occurs in scenarios where production/recovery rates that entail low discharge rates and high salinities (i.e., 20 MGD x 50% recovery rate and 30 MGD x 50% recovery rate.)

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Table 16. Comparison of CORMIX flow classes between 8x8” and 8x12” diffuser configurations (20 MGD x 40% and 20 MGD 50% RO Recovery scenarios).

				CORMIX Flow Class	
Production Rate (MGD)	**Recovery Rate**	**Effluent Discharge (MGD)**	**Density Scenario**	**8x8" (proposed configuration)**	**8x12" (for comparison)**
20	40%	34.3	Summer (T5, S5)	MNU8	MNU8
			Summer (T5, S95)	MNU8	MNU8
			Summer (T95, S5)	MNU8	MNU8
			Summer (T95, S95)	MNU8	MNU8
			Winter (T5, S5)	MNU8	MNU8
			Winter (T5, S95)	MNU8	MNU8
			Winter (T95, S5)	MNU8	MNU8
			Winter (T95, S95)	MNU8	MNU8
	50%	23.4	Summer (T5, S5)	MNU8	MNU3
			Summer (T5, S95)	MNU8	MNU3
			Summer (T95, S5)	MNU8	MNU3
			Summer (T95, S95)	MNU8	MNU3
			Winter (T5, S5)	MNU8	MNU3
			Winter (T5, S95)	MNU8	MNU3
			Winter (T95, S5)	MNU8	MNU3
			Winter (T95, S95)	MNU8	MNU3

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Table 17. Comparison of CORMIX flow classes between 10x8” and 10x12” diffuser configurations (30 MGD x 40% and 30 MGD 50% RO Recovery scenarios).

				CORMIX Flow Class	
Production Rate (MGD)	**Recovery Rate**	**Effluent Discharge (MGD)**	**Density Scenario**	**10x8" (proposed configuration)**	**10x12" (for comparison)**
30	40%	51.5	Summer (T5, S5)	MNU8	MNU8
			Summer (T5, S95)	MNU8	MNU8
			Summer (T95, S5)	MNU8	MNU8
			Summer (T95, S95)	MNU8	MNU8
			Winter (T5, S5)	MNU8	MNU8
			Winter (T5, S95)	MNU8	MNU8
			Winter (T95, S5)	MNU8	MNU8
			Winter (T95, S95)	MNU8	MNU8
	50%	35.2	Summer (T5, S5)	MNU8	MNU3
			Summer (T5, S95)	MNU8	MNU3
			Summer (T95, S5)	MNU8	MNU3
			Summer (T95, S95)	MNU8	MNU3
			Winter (T5, S5)	MNU8	MNU3
			Winter (T5, S95)	MNU8	MNU3
			Winter (T95, S5)	MNU8	MNU3
			Winter (T95, S95)	MNU8	MNU3

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Table 18. Comparison of CORMIX flow classes between 10x8” and 10x12” diffuser configurations (40 MGD x 40% and 40 MGD 50% RO Recovery scenarios).

				CORMIX Flow Class	
Production Rate (MGD)	Recovery Rate	Effluent Discharge (MGD)	Density Scenario	10x8" (proposed configuration)	10x12" (for comparison)
40	40%	68.6	Summer (T5, S5)	MNU8	MNU8
			Summer (T5, S95)	MNU8	MNU8
			Summer (T95, S5)	MNU8	MNU8
			Summer (T95, S95)	MNU8	MNU8
			Winter (T5, S5)	MNU8	MNU8
			Winter (T5, S95)	MNU8	MNU8
			Winter (T95, S5)	MNU8	MNU8
			Winter (T95, S95)	MNU8	MNU8
	50%	46.9	Summer (T5, S5)	MNU8	MNU8
			Summer (T5, S95)	MNU8	MNU8
			Summer (T95, S5)	MNU8	MNU8
			Summer (T95, S95)	MNU8	MNU8
			Winter (T5, S5)	MNU8	MNU8
			Winter (T5, S95)	MNU8	MNU8
			Winter (T95, S5)	MNU8	MNU8
			Winter (T95, S95)	MNU8	MNU8

7.3 EFFLUENT VELOCITIES AT THE MZ AND ZID

The jet velocities of the diffuser have also been evaluated at the edges of ZID and MZ, as high velocities can cause concerns regarding the aquatic life protection in the mixing zones.

The jet velocities were calculated using the CORMIX-predicted travel times and distances along the plume centerline. The centerline velocities ($v_{centerline}$) can be estimated by dividing the incremental increase in cumulative travel distance ($\Delta Distance$) by the incremental increase in cumulative travel time ($\Delta Travel\ Time$). The $Distance$ value is calculated using the Pythagoras equation on the X, Y, Z distances between the plume centerline and the diffuser location along the axes (see Figure 8) (Equation 5).

$$v_{centerline} = \Delta Distance/\Delta Travel\ Time, \qquad \text{(Equation 4)}$$

$$Distance = \left(\sqrt{X^2 + Y^2 + Z^2}\right) \quad . \qquad \text{(Equation 5)}$$

Graphs of the effluent velocities along the direction of discharge (i.e., the long side of the rectangular mixing zones – recall Figure 3) are provided in Figure 15 to Figure 20 for the six production rate/RO recovery rate combinations. Tables comparing the effluent velocities with the critical dilution at the ZID and the MZ are provided in Table 19 to Table 24. It was noted that, within each combination, the effluent velocities predicted for the ten density scenarios are essentially identical. The proposed diffuser configuration met the velocity limits under all 6 production rate/RO recovery rate combinations.

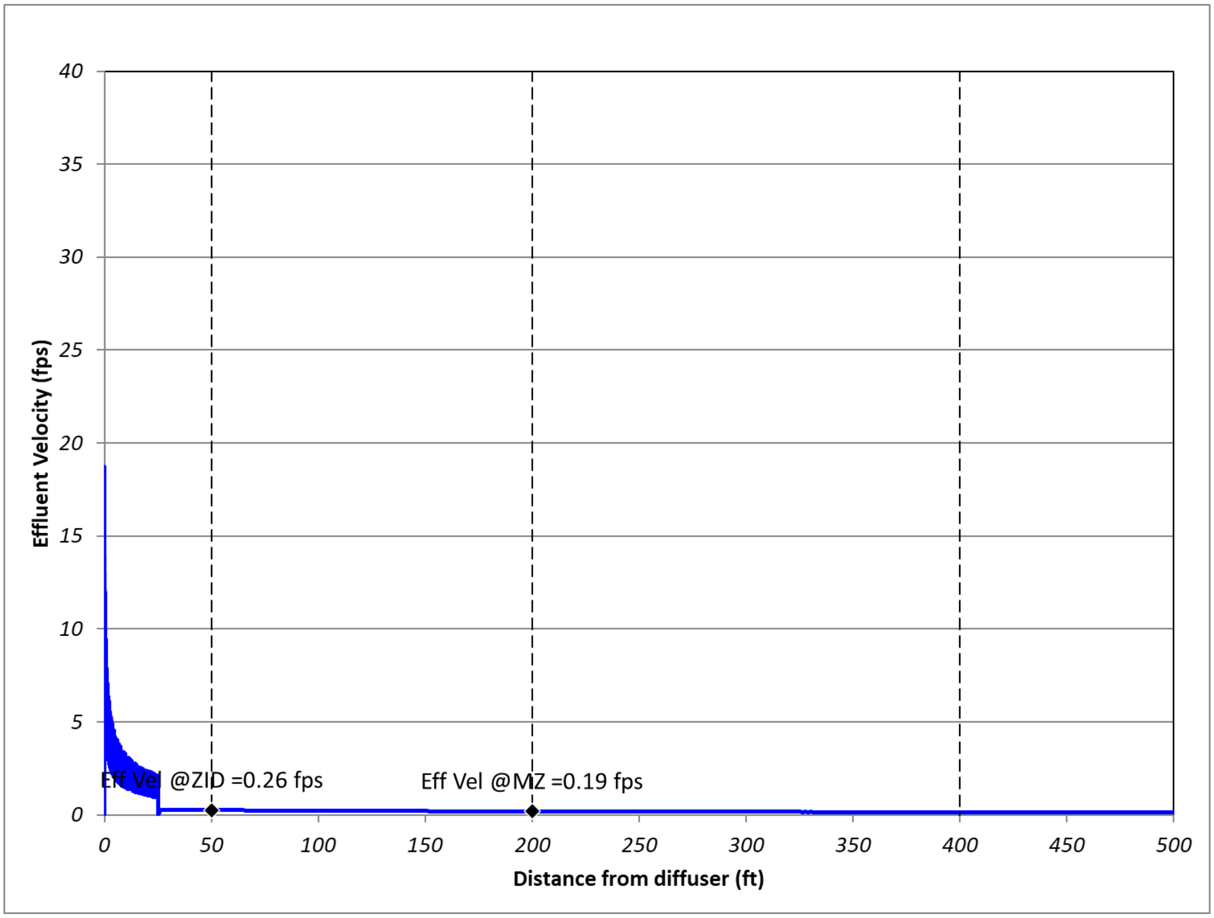

Figure 15. Graph of effluent velocities predicted for 20 MGD x 40% RO Recovery Rate along direction of effluent discharge.

Table 19. Comparison of effluent velocities for 20 MGD x 40% RO Recovery Rate with velocity limits.

				ZID Results		MZ results	
Production Rate (MGD)	Recovery Rate	Effluent Discharge (MGD)	Density Scenario	Effluent Velocity (fps)	Evaluation (<=2 fps?)	Effluent Velocity (fps)	Evaluation (<=0.5 fps?)
20	40%	34.3	Summer (T5, S5)	0.26	Yes	0.19	Yes
			Summer (T5, S95)	0.26	Yes	0.19	Yes
			Summer (T95, S5)	0.26	Yes	0.19	Yes
			Summer (T95, S95)	0.26	Yes	0.19	Yes
			Winter (T5, S5)	0.26	Yes	0.19	Yes
			Winter (T5, S95)	0.26	Yes	0.19	Yes
			Winter (T95, S5)	0.26	Yes	0.19	Yes
			Winter (T95, S95)	0.26	Yes	0.19	Yes
			Summer Stratified (T5, S95)	0.26	Yes	0.19	Yes
			Winter Stratified (T5, S95)	0.26	Yes	0.19	Yes

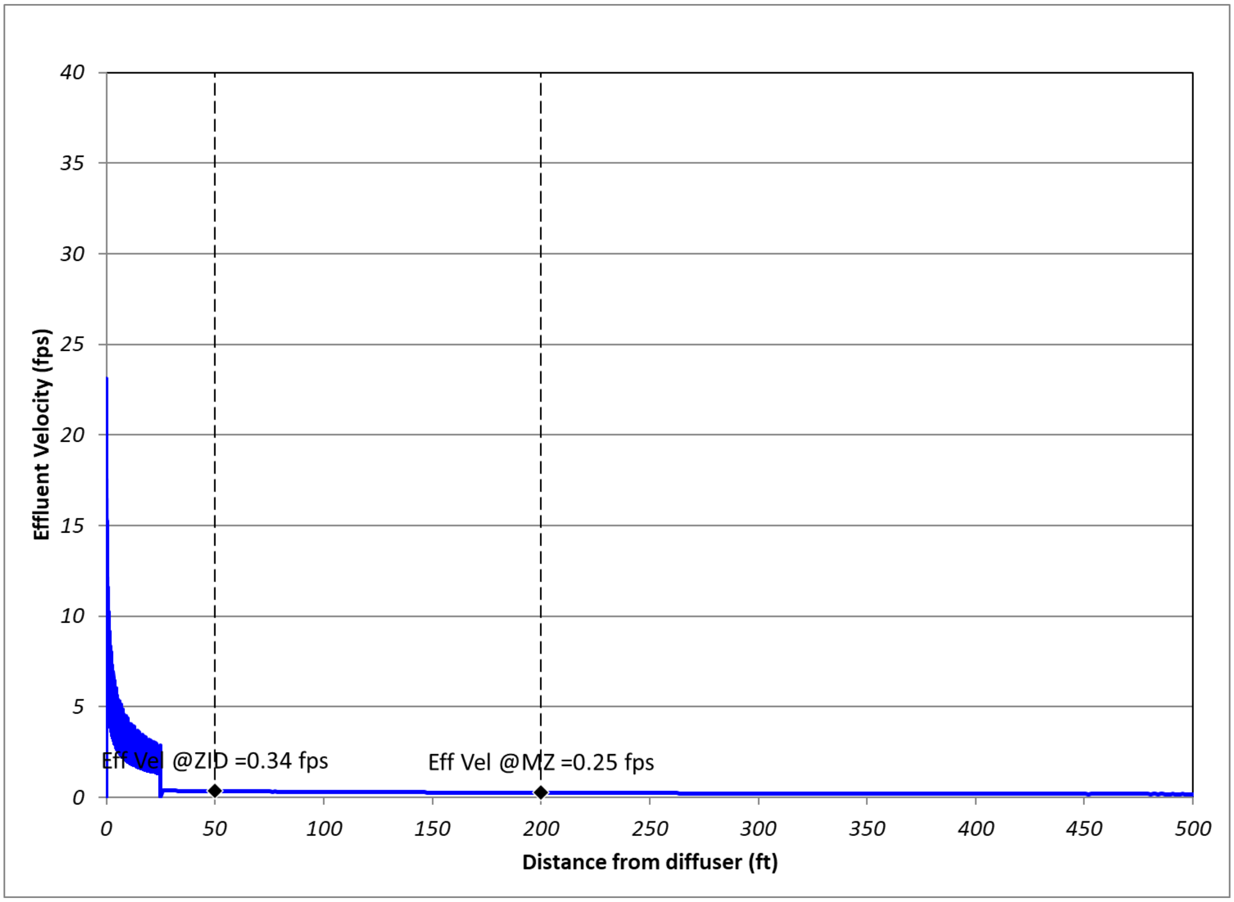

Figure 16. Graph of effluent velocities predicted for 30 MGD x 40% RO Recovery Rate along direction of effluent discharge.

Table 20. Comparison of effluent velocities for 30 MGD x 40% RO Recovery Rate with velocity limits.

				ZID Results		MZ results	
Production Rate (MGD)	**Recovery Rate**	**Effluent Discharge (MGD)**	**Density Scenario**	**Effluent Velocity (fps)**	**Evaluation (<=2 fps?)**	**Effluent Velocity (fps)**	**Evaluation (<=0.5 fps?)**
30	40%	51.5	Summer (T5, S5)	0.34	Yes	0.25	Yes
			Summer (T5, S95)	0.34	Yes	0.25	Yes
			Summer (T95, S5)	0.34	Yes	0.25	Yes
			Summer (T95, S95)	0.34	Yes	0.25	Yes
			Winter (T5, S5)	0.34	Yes	0.25	Yes
			Winter (T5, S95)	0.34	Yes	0.25	Yes
			Winter (T95, S5)	0.34	Yes	0.25	Yes
			Winter (T95, S95)	0.34	Yes	0.25	Yes
			Summer Stratified (T5, S95)	0.34	Yes	0.25	Yes
			Winter Stratified (T5, S95)	0.34	Yes	0.25	Yes

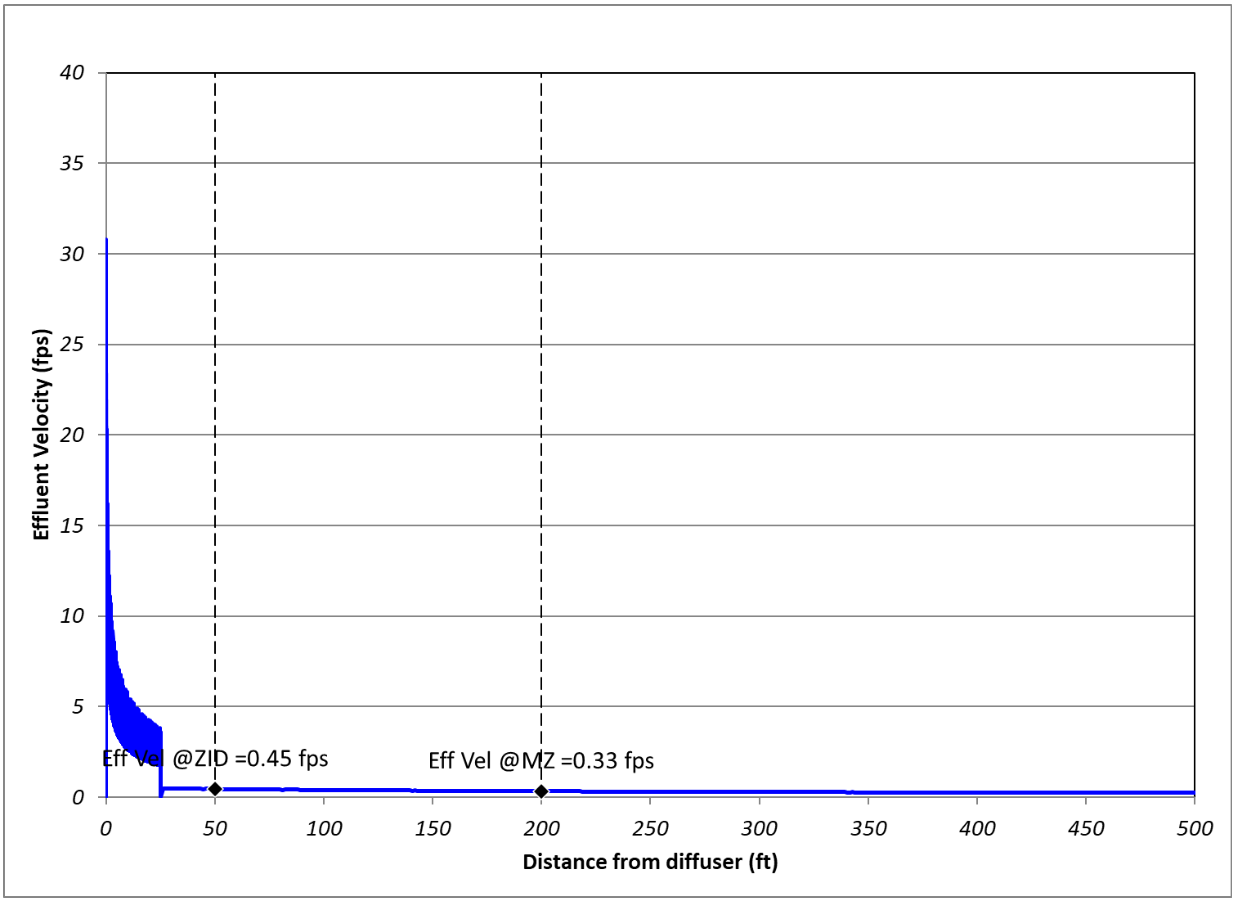

Figure 17. Graph of effluent velocities predicted for 40 MGD x 40% RO Recovery Rate (all density scenarios).

Table 21. Comparison of effluent velocities for 40 MGD x 40% RO Recovery Rate with velocity limits.

				ZID Results		MZ results	
Production Rate (MGD)	Recovery Rate	Effluent Discharge (MGD)	Density Scenario	Effluent Velocity (fps)	Evaluation (<=2 fps?)	Effluent Velocity (fps)	Evaluation (<=0.5 fps?)
40	40%	68.6	Summer (T5, S5)	0.45	Yes	0.33	Yes
			Summer (T5, S95)	0.45	Yes	0.33	Yes
			Summer (T95, S5)	0.45	Yes	0.33	Yes
			Summer (T95, S95)	0.45	Yes	0.33	Yes
			Winter (T5, S5)	0.45	Yes	0.33	Yes
			Winter (T5, S95)	0.45	Yes	0.33	Yes
			Winter (T95, S5)	0.45	Yes	0.33	Yes
			Winter (T95, S95)	0.45	Yes	0.33	Yes
			Summer stratified (T5, S95)	0.45	Yes	0.33	Yes
			Winter stratified (T5, S95)	0.45	Yes	0.33	Yes

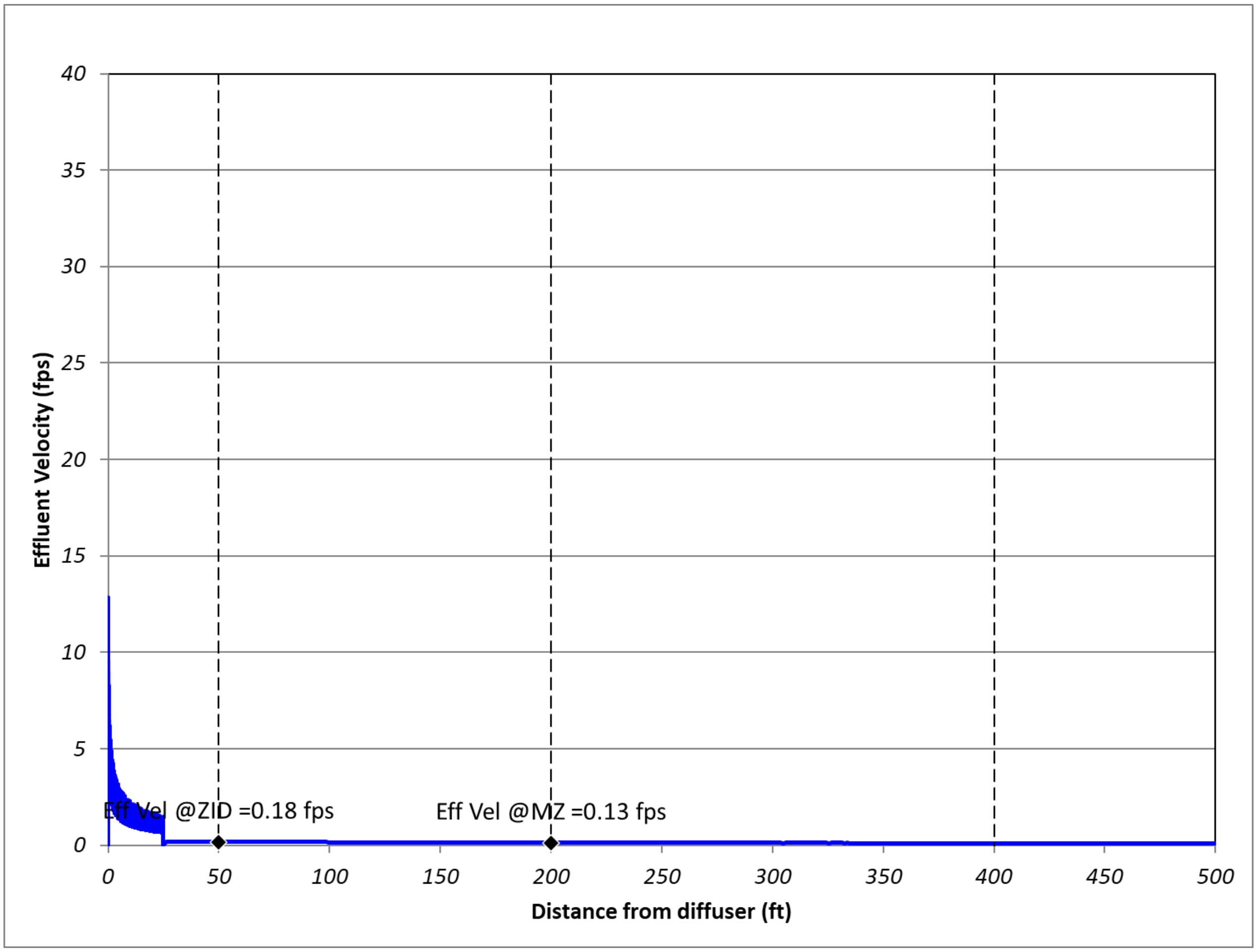

Figure 18. Graph of effluent velocities predicted for 20 MGD x 50% RO Recovery Rate (all density scenarios).

La Quinta

Table 22. Comparison of effluent velocities for 20 MGD x 50% RO Recovery Rate with velocity limits.

				ZID Results		MZ results	
Production Rate (MGD)	**Recovery Rate**	**Effluent Discharge (MGD)**	**Density Scenario**	**Effluent Velocity (fps)**	**Evaluation (<=2 fps?)**	**Effluent Velocity (fps)**	**Evaluation (<=0.5 fps?)**
20	50%	23.4	Summer (T5, S5)	0.18	Yes	0.13	Yes
			Summer (T5, S95)	0.18	Yes	0.13	Yes
			Summer (T95, S5)	0.18	Yes	0.13	Yes
			Summer (T95, S95)	0.18	Yes	0.13	Yes
			Winter (T5, S5)	0.18	Yes	0.13	Yes
			Winter (T5, S95)	0.18	Yes	0.13	Yes
			Winter (T95, S5)	0.18	Yes	0.13	Yes
			Winter (T95, S95)	0.18	Yes	0.13	Yes
			Summer stratified (T5, S95)	0.18	Yes	0.13	Yes
			Winter stratified (T5, S95)	0.18	Yes	0.13	Yes

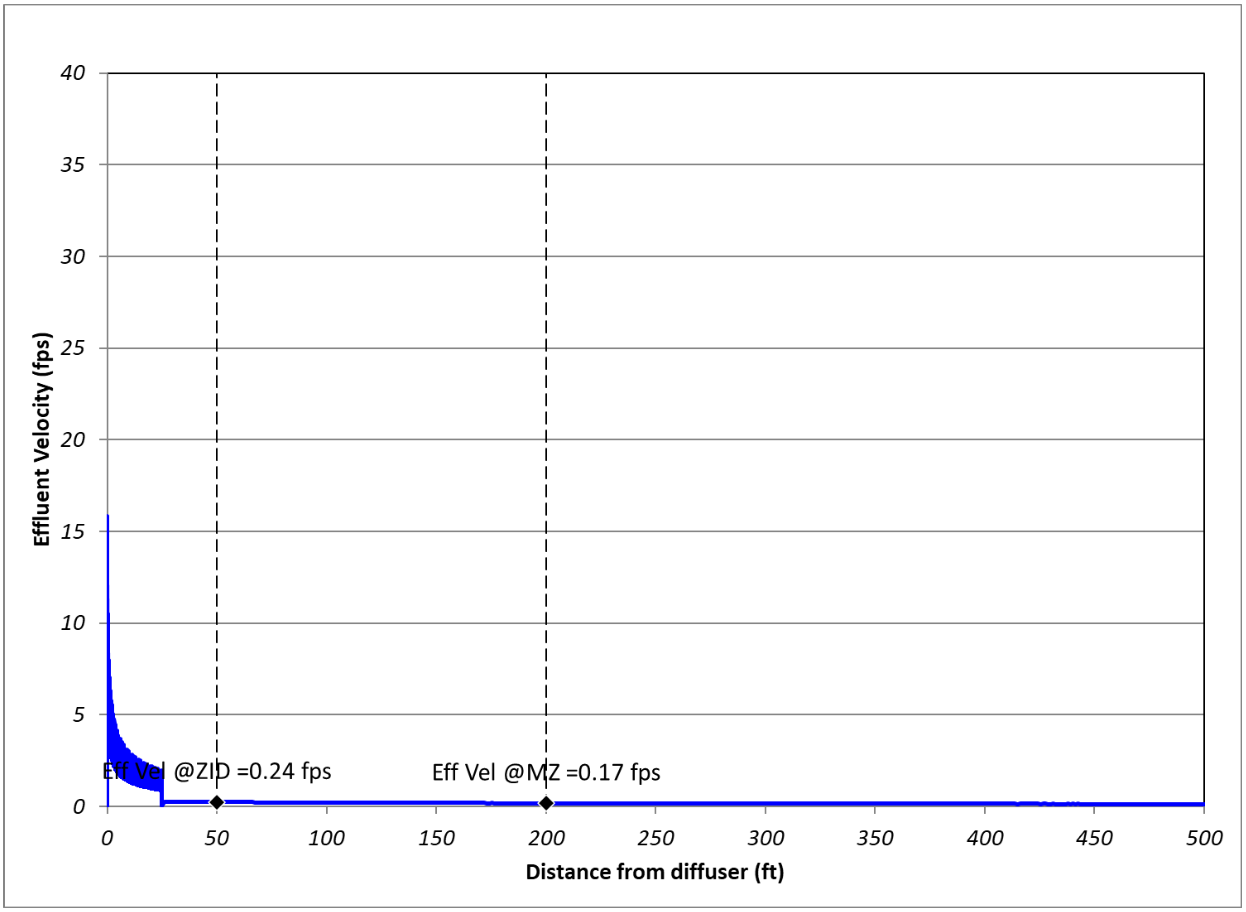

Figure 19. Graph of effluent velocities predicted for 30 MGD x 50% RO Recovery Rate (all density scenarios).

Table 23. Comparison of effluent velocities for 30 MGD x 50% RO Recovery Rate with velocity limits.

				ZID Results		MZ results	
Production Rate (MGD)	**Recovery Rate**	**Effluent Discharge (MGD)**	**Density Scenario**	**Effluent Velocity (fps)**	**Evaluation (<=2 fps?)**	**Effluent Velocity (fps)**	**Evaluation (<=0.5 fps?)**
30	50%	35.2	Summer (T5, S5)	0.24	Yes	0.17	Yes
			Summer (T5, S95)	0.24	Yes	0.17	Yes
			Summer (T95, S5)	0.24	Yes	0.17	Yes
			Summer (T95, S95)	0.24	Yes	0.17	Yes
			Winter (T5, S5)	0.24	Yes	0.17	Yes
			Winter (T5, S95)	0.24	Yes	0.17	Yes
			Winter (T95, S5)	0.24	Yes	0.17	Yes
			Winter (T95, S95)	0.24	Yes	0.17	Yes
			Summer stratified (T5, S95)	0.24	Yes	0.17	Yes
			Winter stratified (T5, S95)	0.24	Yes	0.17	Yes

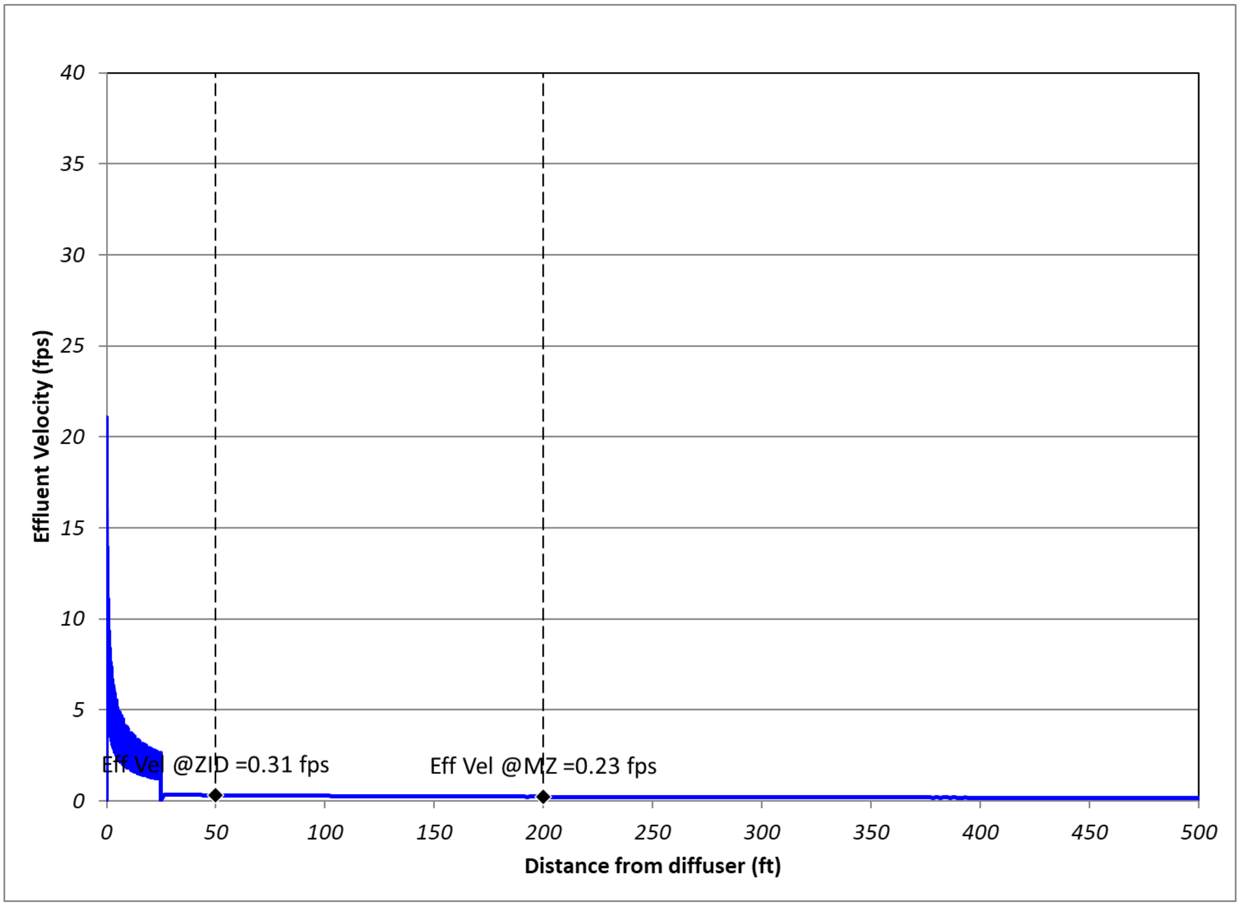

Figure 20. Graph of effluent velocities predicted for 40 MGD x 50% RO Recovery Rate (all density scenarios).

Table 24. Comparison of effluent velocities for 40 MGD x 50% RO Recovery Rate with velocity limits.

				ZID Results		MZ results	
Production Rate (MGD)	**Recovery Rate**	**Effluent Discharge (MGD)**	**Density Scenario**	**Effluent Velocity (fps)**	**Evaluation (<=2 fps?)**	**Effluent Velocity (fps)**	**Evaluation (<=0.5 fps?)**
40	50%	46.9	Summer (T5, S5)	0.31	Yes	0.23	Yes
			Summer (T5, S95)	0.31	Yes	0.23	Yes
			Summer (T95, S5)	0.31	Yes	0.23	Yes
			Summer (T95, S95)	0.31	Yes	0.23	Yes
			Winter (T5, S5)	0.31	Yes	0.23	Yes
			Winter (T5, S95)	0.31	Yes	0.23	Yes
			Winter (T95, S5)	0.31	Yes	0.23	Yes
			Winter (T95, S95)	0.31	Yes	0.23	Yes
			Summer Stratified (T5, S95)	0.31	Yes	0.23	Yes
			Winter Stratified (T5, S95)	0.31	Yes	0.23	Yes

7.4 CONCLUSIONS ON CORMIX RESULTS

CORMIX was used to evaluate the proposed diffuser configuration for 60 scenarios – which encompass 3 proposed production capacities x 2 recovery rates x 10 density scenarios (8 unstratified + 2 stratified). Results from each of the 40 scenarios were evaluated based on three criteria:

1. Effluent percentages at the MZ and ZID;
2. CORMIX-assigned flow class; and,
3. Effluent velocities at the MZ and ZID.

Results showed the proposed diffuser configuration met all the three criteria and is a feasible design for the La Quinta desalination plant outfall.

8 INTERACTION WITH NEIGHBORING DISCHARGERS

It is noted that two other permittees (WQ0001651000 and WQ0003083000) are located in the vicinity of the proposed outfall window. WQ0001651000 has two outfalls: 001 and 002. Based on information contained in the WQ0001651000 permit, Outfall 001 has a diffuser installed while Outfall 002 is a stormwater outfall that does not have mixing zones. WQ0003083000 has one outfall (Outfall 001) that is in the vicinity of the proposed outfall window and is also installed with a diffuser. Figure 21 shows the location of the three neighboring outfalls in relation to the proposed diffuser.

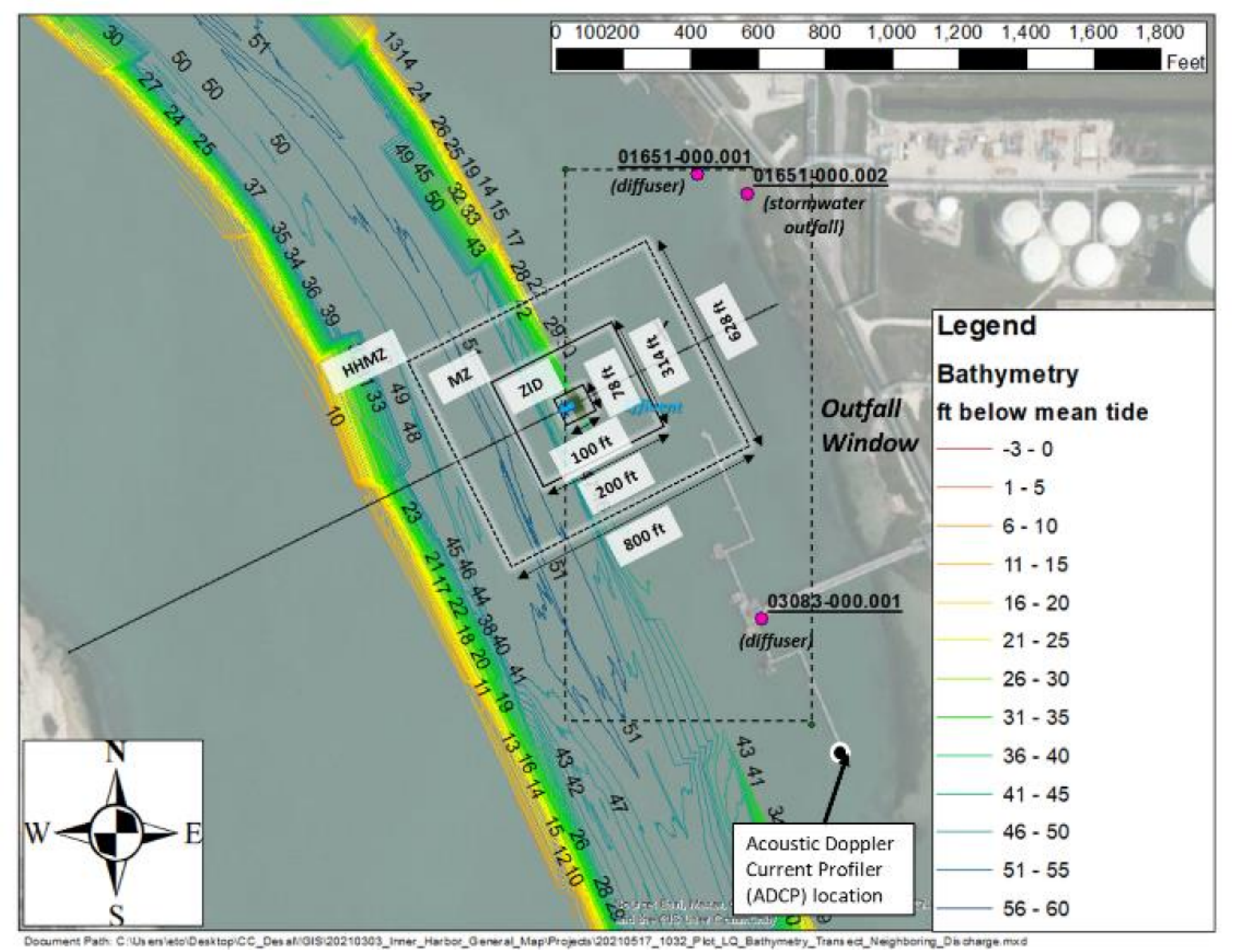

Figure 21. Location of neighboring diffusers in vicinity of proposed outfall.

Based on the CORMIX analyses performed by TCEQ for WQ0001651000 (TCEQ, 2020) and WQ0003083000 (TCEQ, 2019), the HHMZs zones of neighboring two outfalls are mapped along with the mixing zones of the proposed outfall in Figure 22.

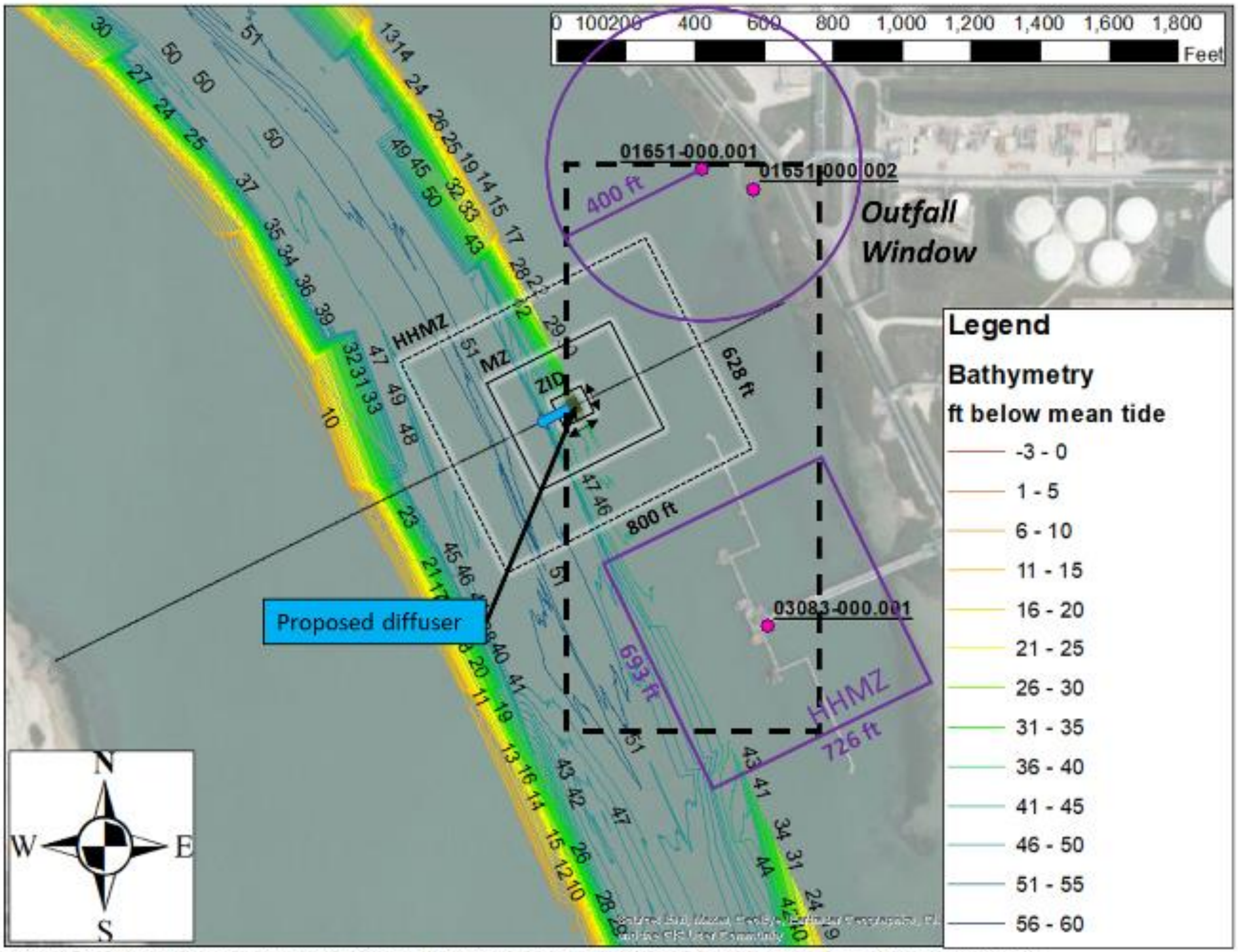

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Figure 22. Mixing zones of neighboring diffusers in vicinity of proposed outfall.

It can be observed that the HHMZ of the proposed outfall only overlaps with the HHMZ of WQ0001651000 Outfall 001. Typically, when there is horizontal overlap between two discharges, further analysis is conducted to see if there would be meaningful vertical overlap between the discharge plumes and if truncation of the mixing zones would be needed. This analysis involves reviewing the discharge depths and buoyancy characteristics of the plumes.

From the CORMIX analysis conducted by TCEQ for WQ0001651000 Outfall 001 (TCEQ, 2020), the discharge depth is 15 ft (4.57 m). While this depth is shallower than the depth of 32 ft (10 m) for the proposed diffuser, the effluent for WQ0001651000 is negatively buoyant under all standard density scenarios. Since the effluent for the proposed discharge is also negatively buoyant under all standard density scenarios (see Table 7), it cannot be established that there would be no meaningful vertical overlap between the two effluent plumes.

Therefore, it is anticipated that the mixing zone of the proposed diffuser maybe potentially truncated to avoid interaction between the plume from the proposed outfall and from the neighboring outfalls. Based on the geometries of the overlapping mixing zones, the estimated truncated area shown in Figure 23.

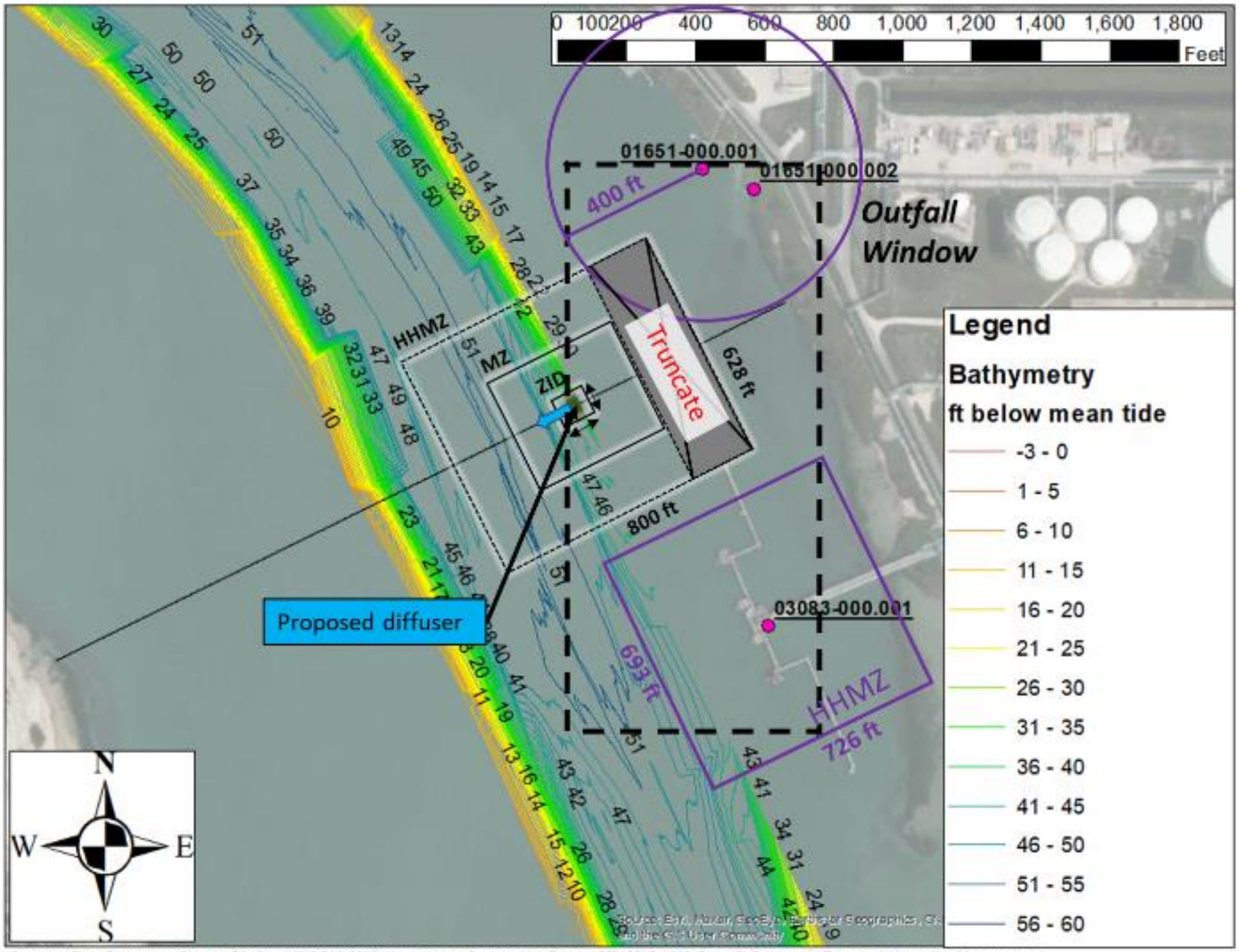

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Figure 23. Potential truncation of mixing zones of proposed diffuser.

It can be observed that the area truncated would be located behind the diffuser in shallower area and not in the trajectory of the proposed discharged effluent. Furthermore, truncation is expected to affect mostly the rear part of the HHMZ, with limited or no impact on the MZ and the ZID. For these reasons, the CORMIX modeling results in this report (i.e., effluent percentages, CORMIX flow classification and velocities at the edges of the mixing zones) remain valid and the various criteria for assessment are still met.

9 CONCLUSIONS

This technical memorandum describes the concentrate modeling study at the La Quinta site. The modeling activities have been performed for the desalination plant operating at 20 MGD, 30 MGD and 40 MGD productions with the RO recovery rates of 40% and 50% under different ambient density conditions (represented by combinations of salinity and temperature extremes) and stratifications.

The proposed diffuser design is a multiport diffuser consisting of a 50-foot-long diffuser pipe with five risers – each containing two 8-inch diameter ports. This results in a total of 10 ports. When operating under the 30 MGD and 40 MGD phase, all the ports will be opened to discharge the effluent. When operating under the 20 MGD phase, two of these ports will be valved off resulting in eight ports open to diffuse the effluent. This is to maintain sufficient port velocity to mix the effluent effectively under lower permitted discharges.

The diffuser would be placed at a depth of approximately 32 feet on the south side of the navigation channel. The diffuser pipe would be aligned parallel to the channel while the diffuser ports would be directed towards the center of the channel. The diffuser ports would also be angled 60 degrees above the horizon. Since the diffuser is a multiport diffuser, rectangular mixing zones for the ZID and MZ were defined following SOP requirements. This resulted in the following rectangular dimensions:

- ZID: 100 ft x 78 ft centered around the diffuser pipe with the short side parallel to the pipe and long side perpendicular to the pipe;
- MZ: 400 ft x 314 ft centered around the diffuser pipe with the short side parallel to the pipe and long side perpendicular to the pipe; and,
- HHMZ: 800 ft x 628 ft centered around the diffuser pipe with the short side parallel to the pipe and long side perpendicular to the pipe.

The CORMIX model results were evaluated based on the following criteria:

1. Meeting critical dilutions proposed in the White Paper at the edges of the ZID and MZ that are protective of aquatic life;
2. Achieving the CORMIX flow class of MNU8; and,
3. Meeting effluent velocity limits at the edges of the ZID and MZ that are protective of aquatic life.

Table 25 below provides the CORMIX results for the recommended diffuser design when the desalination plant is operating at RO 40% and 50% recovery rates for the production capacities of 20 MGD and 30 MGD. The recommended diffuser design meets all the criteria mentioned above for effluent percentage, CORMIX flow class and effluent velocity.

La Quinta

Table 25. Summary of CORMIX results for proposed diffuser configuration.

			ZID Results			MZ results			CORMIX Flow Classification	
Production Capacity (MGD)	RO Recovery Rate	Effluent Discharge (MGD)	Effluent Percentage (%)	Effluent Velocity (fps)	Evaluation	Effluent Percentage (%)	Effluent Velocity (fps)	Evaluation	Flow Class	Evaluation
20	40%	34.31	10.8	0.3	Meets critical dilution (<=56%) and velocity limit (<= 2 fps) for ZID.	7.7	0.2	Meets critical dilution (<=18%) and velocity limit (0.5 fps) for MZ.	MNU8	Meets desired flow class (MNU8).
30	40%	51.47	12.0	0.3	Meets critical dilution (<=56%) and velocity limit (<= 2 fps) for ZID.	8.6	0.2	Meets critical dilution (<=18%) and velocity limit (0.5 fps) for MZ.	MNU8	Meets desired flow class (MNU8).
40	40%	68.62	12.0	0.5	Meets critical dilution (<=56%) and velocity limit (<= 2 fps) for ZID.	8.5	0.3	Meets critical dilution (<=18%) and velocity limit (0.5 fps) for MZ.	MNU8	Meets desired flow class (MNU8).
20	50%	23.4	11.0	0.2	Meets critical dilution (<=38%) and velocity limit (<= 2 fps) for ZID.	7.9	0.1	Meets critical dilution (<=13%) and velocity limit (0.5 fps) for MZ.	MNU8	Meets desired flow class (MNU8).
30	50%	35.17	12.1	0.2	Meets critical dilution (<=38%) and velocity limit (<= 2 fps) for ZID.	8.6	0.2	Meets critical dilution (<=13%) and velocity limit (0.5 fps) for MZ.	MNU8	Meets desired flow class (MNU8)
40	50%	46.90	12.0	0.3	Meets critical dilution (<=38%) and velocity limit (<= 2 fps) for ZID.	8.6	0.2	Meets critical dilution (<=13%) and velocity limit (0.5 fps) for MZ.	MNU8	Meets desired flow class (MNU8)

Finally, it is noted that two other permittees (WQ0001651000 and WQ0003083000) are located near the proposed outfall window. A review was conducted on the CORMIX modeling reports of the two permittees to identify mixing zones, discharge depths and buoyancy characteristics of their respective effluent plumes.

Based on the review, it is noted that truncation of the HHMZ of the proposed outfall may be necessary to prevent overlap with the mixing zones of Outfall 001 of WQ0001651000.

However, the area truncated would be located behind the diffuser in shallower area and not in the path of the proposed discharged effluent. Furthermore, the truncation is expected to impact only the rear part of the HHMZ and with limited or no impact on the ZID or MZ. As such, CORMIX modeling results in this report (i.e. effluent percentages, CORMIX flow classification and velocities at the edges of the mixing zones) are still valid and the various assessment criteria are still met even after truncation.

For permitting purposes, since 40% and 50% recovery rates can result in different discharge rates even when the production rate is the same, it is recommended that the permits limits for average daily discharge volume be based on a 40% recovery rate (maximum anticipated discharge for each permit phase). The maximum daily discharge would be a factor of 1.20 times the average daily discharge volume.

10 REFERENCES

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