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AAWDC Project: Summary of Brine Discharge Risk Assessment

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Glossary of Terms and Abbreviations

AA	Abu Alanda
AAWDC	Aqaba-Amman Water Desalination and Conveyance
AAWDCP	Aqaba-Amman Water Desalination and Conveyance Project
ADC	Aqaba Development Corporation
AoI	Area of Influence
ASEZA	Aqaba Special Economic Zone Authority
AW	Aqaba Water Company
AWDR	Aqaba Water Distribution Reservoir
BOT	Build-Operate-Transfer
BPS	Booster Pump Station
BPT	Break Pressure Tank
CAPEX	Capital Expenditure
CIP	Cleaning-in-Place
CO	Carbon Monoxide
DAF	Dissolved Air Flotation
DMF	Dual Media Filtration
EIB	European Investment Bank
ERI	Economic Resilience Initiative
ESIA	Environmental and Social Impact Assessment
EU	European Union
GRP	Glass Reinforced Plastic
HDPE	High Density Polyethylene
IPS	Intake Pumping Station
Km	Kilometre
MCM	Million Cubic Meters
MoEnv	Ministry of Environment
MoM	Minutes of Meeting
MWI	Ministry of Water and Irrigation
MF	Microfiltration
NO_2	Nitrogen Dioxide
O_3	Ozone
OD	Outside Diameter
O&M	Operation and Maintenance
OPEX	Operational Expenditure

PAP	Project Affected Person
PM10	Particulate Matter (diameter < 10 microns)
PS	Pumping Station
RGT	Regulating Tank
RO	Reverse Osmosis
RSDS	Red Sea Dead Sea
SMBS	Sodium Meta Bisulphite
SO_2	Sulphur Dioxide
SWRO	Sea Water Reverse Osmosis
TA	Technical Assistance (Referring to the team working on this project as part of a WYG-Led consortium under the ERI-ITA multi-facility contract)
TDS	Total Dissolved Solids
ToR	Terms of Reference
UAE	United Arab Emirates
UF	Ultrafiltration
USAID	United States Agency for International Development

1. Brine Discharge Risk Assessment

1.1. Overview of the Assessment and Proposed Mitigation

As mentioned previously in this ESIA study, the AAWDC Project is designed to deliver 300 MCM/year of desalinated water from abstracted seawater from the Gulf of Aqaba. Reverse Osmosis (RO) reject brine and the pretreatment backwash waste, after solids treatment, are planned to be discharged back into the marine environment.

The desalination facilities discharging brine into the Red Sea have been identified. There is approx. a 7 million m^3/d desalination capacity already in operation or in construction on the Red Sea. Currently, there are no large scale SWRO plants in the Gulf of Aqaba except from Egypt that has some smaller scale SWRO facilities on the Gulf of Aqaba with production sizes of 5,000 - 20,000 m^3/d.

The AAWDCP SWRO desalination plant will produce a reject brine with a salinity concentration of 1.7-1.8 times higher than the ambient seawater salinity. This brine needs to be discharged to the Gulf of Aqaba without causing significant damage to the marine environment; this disposal route cannot be avoided. The reject brine is proposed to be discharged into the sea at the new Industrial Port of Aqaba. The borders of three other nations share the Gulf of Aqaba within approximate distances of less than 15 km from the location of brine discharge, namely Saudi Arabia (1.5 km), Egypt (13 km) and Israel (14.5 km).

The Gulf of Aqaba is a unique environment, which contains some of the world's most important and potentially sensitive flora and fauna. Considering the Project baseline conditions, such an important marine environment demands that the best practice for brine clean-up and dispersion is achieved.

Desalination plants in many countries are regulated for brine discharges using mixing zones and end of pipe discharge limits to protect the flora and fauna from excessive salinity and chemicals. The internationally used mixing zones regulations require the brine to disperse to 2- 5% above ambient within 100-150 m from the diffusers. The Saudi Red Sea mixing zone requirement of salinity less than or equal to 2% above ambient seawater salinity at 100 m from the diffusers is among the most protective mixing zone regulations in the world, and is recommended to be adopted for this Project.

Brine dispersion modelling was carried out, which demonstrates that a well-designed outfall diffuser system can achieve brine dispersion to a salinity of 1.3 - 2% above the ambient seawater salinity at 100 m from the diffusers. It is anticipated that a dispersion of less than 2% should provide protection for the local flora and fauna outside of the mixing zone. It is, however, recommended that long term Whole Effluent Toxicity (WET) testing is carried out by the Project Developer during plant construction and early plant operation with real plant generated brine effluent to confirm the dilution needed to have no observable impact on the flora and fauna outside of the 100 m mixing zone.

SWRO results in a cleaner and an environmentally far less disruptive brine discharge than the brine generated by thermal desalination plants, as there is no large temperature increase of brine (only 0.5 to 1 ^{0}C), no discharge of heavy metals like copper from heat exchanger tubes, no antifoams and less antiscalants (since no calcium sulphate scale potential is anticipated by SWRO). The brine from SWRO plants themselves have also become cleaner over the past 20 years because of the increased experience in operating large scale SWRO facilities using polyamide spiral wound membranes. The average iron coagulant dosages typically used by SWRO plants in the region are lower at 0.5 mg/l -1 mg/l, acid dosing and polymer aids for coagulation are now rarely used, and real RO membrane antiscalant doses used are lower than antiscalant software predictions, chlorine used for intake fouling control is typically dosed in a shock manner and not used continuously or avoided completely with the use of intake pigging systems. Pre-treatment solids are generally not discharged with the brine in marine waters of environmental sensitivity.

Our study of the chemicals that could be discharged with the brine revealed two chemicals of particular concern, antiscalant and chlorine produced disinfection by-products (THMs).

1. First pass SWRO antiscalants are intended for calcium carbonate scale control and are used as a result of conservative membrane supplier warranty conditions. It may be possible for the Project Developer to eliminate the use of antiscalant due to low retention time relative the scale induction time. This should be

pilot tested during the construction of the SWRO desalination plant by the Project Developer. If antiscalant is determined to be essential, then it must be nitrogen free and biodegradable to prevent the addition of these nutrients to a very low nutrient and sensitive marine environment, where it is established that nitrogen is the limiting factor for primary productivity.

2. Shock dosing of chlorine is commonly used to control barnacle fouling on the sea intakes of SWRO plants and continuous/pulse chlorine dosing is very often used to protect the intakes of power stations from the same marine fouling. Although residual chlorine itself can be eliminated from the brine at the SWRO plant using dechlorination chemicals such as Sodium Bisulphite (SBS), the use of chlorine generates carcinogenic by-products, THMs, which cannot be eliminated from the brine with dechlorination and would end up discharged into the marine environment with the generated RO brine. Due to the very special and sensitive nature of the AAWDCP marine environment, the use of chlorine for RO pretreatment and intake system fouling control shall be avoided unless there is not a feasible technical alternative such as manual cleaning by divers and/or mechanical pigging.

3. In particular, the intake pipelines from the sea to the shore Intake Pump Station (IPS) must have a macrofouling strategy to enable sufficient seawater supply ensuring SWRO plant availability. The intake pipelines to the shore IPS are anticipated to be relative short, less than 200 m, and it should be possible to maintain hydraulic intake capacity in these short pipelines by the use of divers' cleaning or by the use of mechanical pigging without the use of chlorine.

4. However, two large diameter (> 2.3m) pipelines are anticipated to convey seawater from the IPS to the SWRO plant at a distance of approx. 3 km. If these pipes can be mechanically pigged, then chlorine dosing should not be needed for intake fouling control. However, if mechanical pigging is not technical feasible, then, the pipelines fouling control strategy will require the intake pipes to be manually cleaned, and the use of shock or continuous chlorination will likely be essential to reduce the frequency of manual pipe cleaning required and maintain the set plant availability.

It is considered that a precautionary principle is appropriate relative to the type of waste being generated by the SWRO process that could be allowed to be discharged to the sea taking also into account that the desalination facility must also be operable and maintain plant availability. This precautionary principle emanated from the detailed review and assessment of brine discharge impacts relative to the AAWDC Project, was supplemented by dispersion modelling in the near and far field and resulted to the following ESIA requirements for the Project:

- The high salinity reject brine shall be dispersed very rapidly in the ambient seawater in a small mixing zone. The salinity at a distance of 100 m from the diffusers shall be less than or equal to 2% above the ambient seawater salinity.
- The brine shall be chemically clean as practical. Chemicals or ions, that do not already exist in the local ambient seawater shall not be discharged to the Gulf of Aqaba unless there is no practical alternative for an operable SWRO desalination facility.
- No RO membrane spent cleaning chemicals that are organic, biocides, or phosphorus/nitrogen nutrient sources shall be discharged with the brine. Neutralised salts of simple acids and bases can be allowed to be discharged with the brine.
- Solids removed by the seawater pre-treatment, post treatment, and membrane cleaning shall be collected and treated by a solids treatment system with sludge thickening and dewatering for off-site disposal as a sludge cake. Due to their low volume, post treatment backwash waste can be sent to a buffering tank but the high solids content stream from the bottom of the buffering tank shall be sent to the solids treatment system and not to the brine chamber for direct outfall disposal.
- Appropriate end of pipe discharge limits for Iron, Chlorine Residual (zero), THMs, Turbidity, Dissolved Oxygen, and pH are set out as follows:
  - Dissolved oxygen shall be ≥ 3.5 mg/l
  - Turbidity shall be ≤ 5 NTU (90% ile) plus ambient intake seawater turbidity; and < 10 NTU (100% ile) plus ambient intake seawater turbidity
  - Total Iron shall be ≤ 0.3 mg/l on average, ≤ 0.5 mg/l maximum
  - Residual Chlorine shall be zero
  - Zero increase in THMs concentration above ambient, where the limit concentration for THMs will be the ambient measured THMs multiplied by the plant concentration factor (at overall recovery).
  - pH ≥ 7 and ≤ 9

- The use of chlorine for fouling control and RO pretreatment shall be avoided unless there is not technical alternative. If chlorine is used then THMs concentration in the brine before outfall disposal shall be monitored daily during operation.

Moreover, during the construction of the intake and outfalls, enhanced protection of marine environment is envisaged by including the following key measures:

- Minimise the excavation of the seabed to that required to ensure intake pipe and outfall pipe stability (i.e., minimum trench for gravel bed).
- Fully bury the intake and outfall pipes only in the surf zone.
- Use of silt curtains to minimise the turbidity impact of dredging.
- Relocation of corals that are located in the path of the intake and outfall pipelines where this is safe for divers to do so and by following an approved transplantation protocol.

Whereas during the operation of the SWRO desalination plant there shall be comprehensive monitoring and reporting of the combined brine flow and quality parameters and the sludge treatment liquors flow and turbidity, as set out in Section 2.11.2 'Marine Environmental Monitoring' of the ESMP.

. The true dispersion path and extent of the brine plume shall be mapped by Conductivity Temperature, Depth (CTD) profile investigation during the different seasons by the Project Developer. The long term condition of the marine environment in the path of the brine plume shall be monitored as part of the BOT Developer's responsibilities. The Project ESMP (Sections 2.9.2 to 2.9.5) comprises the detailed mitigation/management measures relative to brine discharge during the pre-construction, construction, and operation phases of the AAWDC Project. All these measures emanated from the parallel assessment undertaken by the ESIA team and presented to the EIB and the Project Promoter as a standalone report named 'Task 1.3 – Brine Discharge Risk Assessment'.

1.2. Near Field Dispersion Modelling Results

The Brihne Model was used to assess the brine dispersion impact of the diffusers. The relative report and model results for near field modelling are appended to this ESIA study (Annex 1 refers).

The diffuser configuration for the Brihne Model was established using the Roberts Abessi equations. To ensure validity of the Roberts equations, the Froude number has to be greater than or equal to 20 to ensure the equations were valid.

Two scenarios are examined:

- Scenario 1 - Desalination Plant Recovery 45%
- Scenario 2 - Desalination Plant Recovery 42%

The key information obtained from the Model is presented below.

Scenario 1, SWRO overall plant recovery: 45%

- Inputs for the Brihne Model are as follows:
- Diffuser Port Diameter: 300 mm
- Number of Diffusers: 30 arranged as 15 diffuser pairs back to back
- Angle of the Diffusers: 60 deg. from the horizontal
- Velocity of Diffuser: 5.65 m/s
- Outfall pipe Manifold diameter: 2.5 m
- Diffuser height above Manifold: 1.0 m
- Diffuser height above seabed: 3.5 m
- Ambient Sea Water Salinity: 40.8 PSU
- Brine Discharge Salinity: 74.2 PSU
- Temperature of Seawater: 28 ^{0}C
- Temperature of Brine: 29 ^{0}C
- Density of Seawater: 1,026.55 kg/m^3
- Density of Brine: 1,051.68 kg/m^3

Near Field Brihne Model Results for 45% Recovery

A summary of the Brihne near field modelling results for this scenario is provided in Table 1, AND Figure 1-1 and Figure 1-2.

The most important findings from the near field modelling are as follows:

Confirmation of Mixing Zone 2% above Ambient @ 100m from diffusers is achievable.

A mixing zone requirement of achieving no more than 2% salinity above the ambient at 100m from the diffusers can be comfortably achieved at this location in the near field. The 2% above ambient salinity is shown to be achieved at a distance of 38 m from the diffusers (Figure 1-2 refers). The model indicated that at the end of the near field, i.e., at 56 m from the diffusers, the brine plume salinity concentration would be just 1.4 % above the ambient. These would all be excellent results for protecting the flora and fauna from brine elevated salinity.

Confirmation of Plume Height for 45% Recovery

The maximum plume height reached above the sea bed is 20.15 m using the Brihne model (Figure 1-1 refers). It is noted that the maximum plume height above seabed established by the Brihne model, is higher than that calculated using the Roberts/Abessi equation (2.25 x Froude x Do + 3.5) = 17.7 m. Allowing a margin of 5 m on Roberts/ Abessi maximum brine plume height gives a water depth of approx. 23 m, which should be sufficient to ensure that the brine plume does not reach the sea surface.

Spread Layer Height for 45% Recovery

The Brihne model indicated that the end of the near field will be at a distance of approx. 56 m from the diffusers. By this distance, the plume has hit the seabed and spread out as a layer and lost its forward momentum impacted by the diffusers. The brine plume spread layer thickness is established from the Brihne model as approx. 3.1 m. The top of brine plume spread layer has a salinity concentration of just 25% of the maximum concentration in the spread layer.

Until the end of the nearfield region is reached, brine plume dispersion has been caused by turbulent entrainment resulting from by the high velocity jet diffusers. After the end of near field distance of 56 m, the brine plume will flow as density current along the sea bed flowing the seabed bathymetry into deeper water. The brine plume will very gradually become more diluted to the local low ambient currents and by concentration diffusion. The path of brine plume and the further concentration reduction with distance will be established with the far field modelling.

Diffuser Manifold Length

The minimum required separation of the diffuser pairs is given by the Roberts Abessi equation

Minimum Separation = 2 x Froude *Do = 2x 21.1 * 0.3 = 12.7 m

The total length of the diffuser section would be = (15-1) *12.7 = 178 m.

Tables and Graph Outputs for 45% Recovery Scenario

Table 1-1:Brihne Model Near Field Brine Dispersion Result Summary

Symbol	Description	Measure	Units
Zm	Centerline peak of the jet trajectory (relative to the port nozzle)	12.57	m
Xm	Xm, horizontal location of the plume centerline peak height point	13.23	m
Zt Nozxle	Maximum plume rise height relative to the port nozzle	16.51	m
Zt ground	Maximum plume rise height relative to the bottom	17.51	m
Sm	Sm, centerline dilution at the jet maximum height (peak)	11.70	
Cm	Cm, centerline saline concentration at the jet maximum height (peak)	43.70	PSU
bm	Radius at the jet maximum height (radial distance from the centerline to where concentration is 50% of that at the centerline, C=50%Cc)	1.9	m
rm	Radius at the jet maximum height (radial distance from the centerline to where concentration is 25% of that at the centerline, C=25%Cc)	2.7	m

Symbol	Description	Measure	Units
Rm	Radius at the jet maximum height (radial distance from the centerline to where concentration is 6% of that at the centerline, C=6%Cc)	3.9	m
Xr	Centerline horizontal location of the return point (where the jet axis reaches the port height level)	20.87	m
Sr	Centerline dilution at the return point	33.5	
Cr	Centerline saline concentration at the return point	41.8	PSU
br	Jet radius at the return point (radial distance from the centerline to where concentration is 50% of that at the centerlinee, C=50%Cc)	3.4	m
rr	Jet radius at the return point (radial distance from the centerline to where concentration is 25% of that at the centerline, C=25%Cc)	4.9	m
Rr	Jet radius at the return point (radial distance from the centerline to where concentration is 6% of that at the centerline, C=6%Cc)	6.9	m
Xi	Centerline horizontal location of the impact with bottom point	23.4	m
Si	Centerline dilution at the impact point	29.7	
Ci	Centerline saline concentration at the impact point	41.9	PSU
Xn	Horizontal location of the spreading layer at the end of the near field region	56.9	m
hn	Thickness of the spreading layer at the end of the near field region	3.18	m
Sn	Centreline dilution of the spreading layer at the end of the near field region	56.9	
Cn	Centerline saline concentration of the spreading layer at the end of the near field region	41.4	PSU
Un	Centerline velocity of the spreading layer at the end of the near field region	0.10	m/s

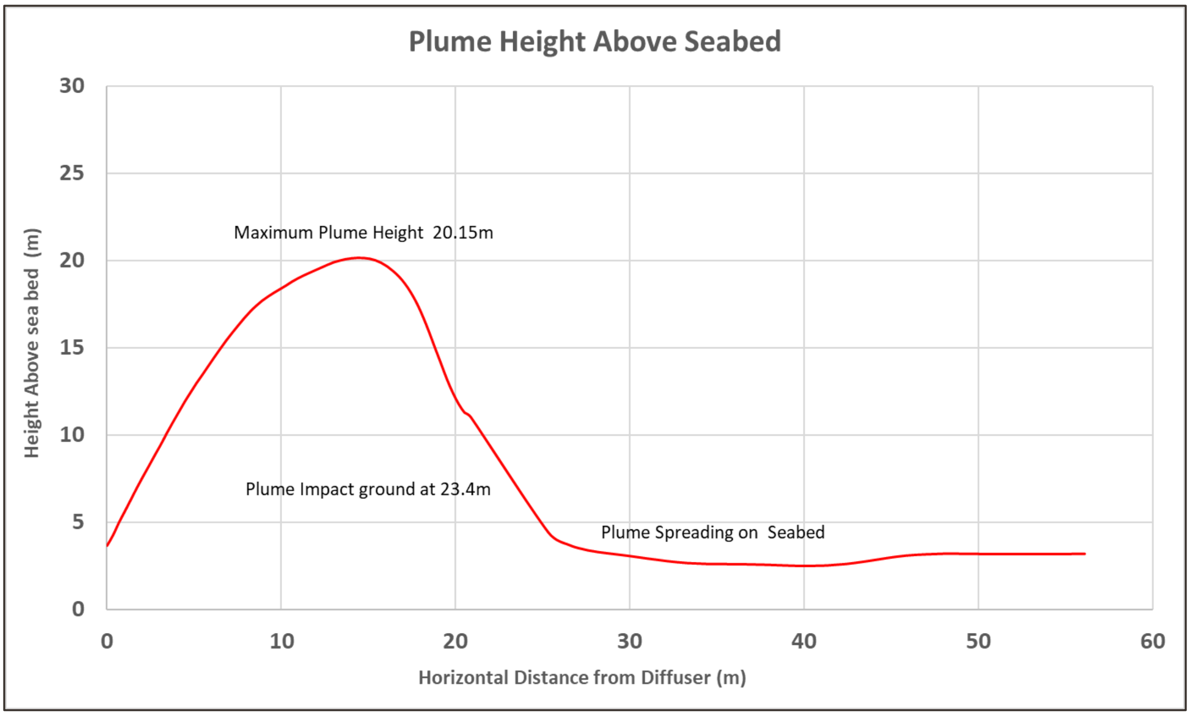

Figure 1-1: Plume Height with Distance from the Diffusers (45% Recovery)

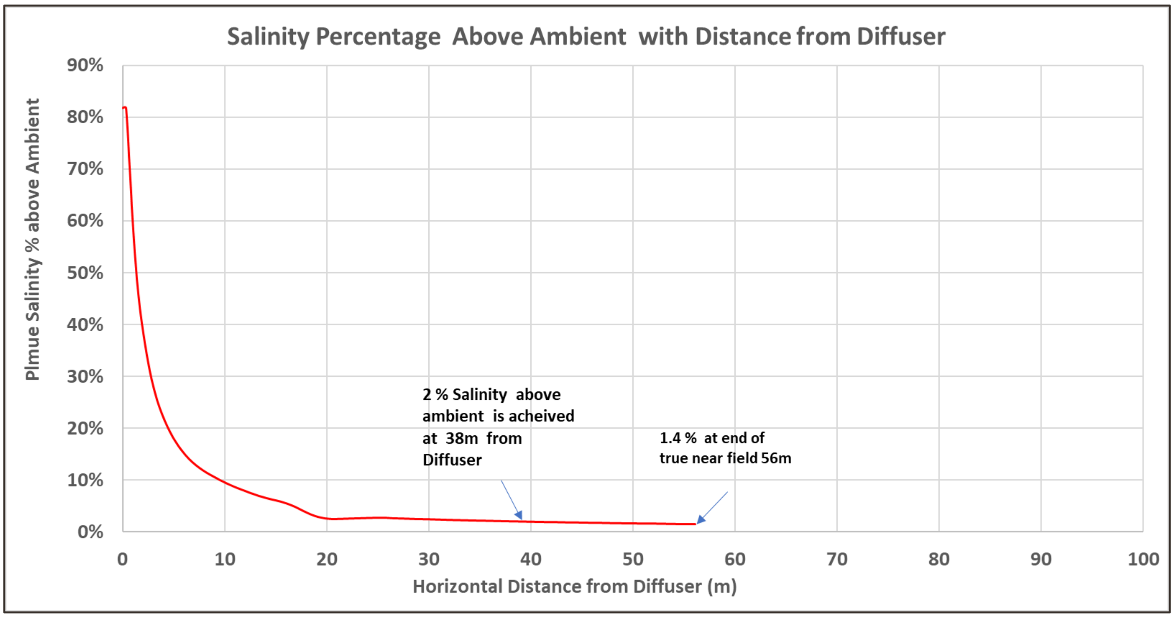

Figure 1-2: Salinity Percentage Above Ambient with Distance from Diffuser (45% Recovery)

Scenario 2, SWRO overall plant recovery: 42%

Inputs for the Brihne Model are as follows.

- Diffuser Port Diameter: 300 mm
- Number of Diffusers: 15
- Angle of the Diffusers: 60 deg. from the horizontal
- Velocity of Diffuser: 6.4 m/s
- Outfall pipe Manifold diameter: 2.5 m
- Diffuser height above Manifold: 1.0 m
- Diffuser height above seabed: 3.5 m
- Ambient Sea Water Salinity: 40.8 PSU
- Brine Discharge Salinity: 70.345 PSU
- Temperature of Seawater: 28 ^{0}C
- Temperature of Brine: 29 ^{0}C
- Density of Seawater: 1,026.55 kg/m^3
- Density of Brine: 1,048.73 kg/m^3

Near Field Brihne Model Results for 42% Recovery

A summary of the Brihne near field modelling results for this scenario is provided in Table 1-2 and Figure 1-3 Figure 1-4 below.

The most important findings from the near field modelling for this scenario are as follows:

Confirmation of Mixing Zone 2% above Ambient @ 100m from diffusers is achievable.

A mixing zone requirement of achieving nor more than 2% salinity above the ambient at 100 m from the diffusers can be comfortably achieved this location in the near field. The 2% above ambient salinity is shown to be achieved at a distance of 23.5 m from the diffusers (Figure 1-4 refers). The model indicated that at the end of the near field, at 69 m from the diffusers, the brine plume salinity concentration would be just 1.3 % above the ambient seawater salinity. These would all be excellent results for protecting the flora and fauna from elevated salinity.

Confirmation of Plume Height for 42% Recovery

The maximum plume height reached above the sea bed is 23.45 m using the Brihne model (Figure 1-3 refers). It is noted that the maximum plume height above sea bed established by the Brihne model, is higher than that calculated using the Roberts/Abessi equation (2.25 x Froude x Do + 3.5) = 20.7 m. Allowing a margin of 5 m on Roberts/ Abessi maximum plume height gives a water depth of approx. 25.5 m which should be sufficient to ensure that the brine plume does not reach the sea surface.

Spread Layer Height for 42% Recovery

The Brihne model indicated that the end of the near field will be at a distance of approx. 69 m from the diffusers. By this distance, the plume has hit the sea bed and spread out as a layer and lost its forward momentum impacted by the diffusers. The brine plume spread layer thickness is established from the Brihne model as approx. 3.8 m. The top of brine plume spread layer has concentration of just 25% of the maximum concentration in the spread layer.

Until the end of the nearfield region is reached brine plume dispersion has been caused by turbulent entrainment resulting from by the high velocity jet diffusers. After the end of near field distance of 69 m the brine plume will flow as density current along the sea bed flowing the seabed bathymetry into deeper water. The brine plume will very gradually become more diluted to the local low ambient currents and by concentration diffusion. The path of brine plume and the further concentration reduction with distance will be established with the far field modelling.

Diffuser Manifold Length

The minimum required separation of the diffuser pairs is given by the Roberts Abessi equation:

Minimum Separation = 2 x Froude *Do = 2x 25.5 * 0.3 = 15.3 m

The total length of the diffuser section would be = (15-1) *12.7 = 214 m.

Tables and Graph Outputs for 42% Recovery Scenario

Table 1-2:Brihne Near Field Brine Dispersion Modelling Result Summary

Symbol	Description	Measure	Units
Zm	Centerline peak of the jet trajectory (relative to the port nozzle)	15.16	m
Xm	Xm, horizontal location of the plume centerline peak height point	15.96	m
Zt Nozxle	Maximum plume rise height relative to the port nozzle	19.90	m
Zt ground	Maximum plume rise height relative to the bottom	20.90	m
Sm	Sm, centerline dilution at the jet maximum height (peak)	14.10	
Cm	Cm, centerline saline concentration at the jet maximum height (peak)	42.90	PSU
bm	Radius at the jet maximum height (radial distance from the centerline to where concentration is 50% of that at the centerline, C=50%Cc)	2.3	m
rm	Radius at the jet maximum height (radial distance from the centerline to where concentration is 25% of that at the centerline, C=25%Cc)	3.3	m
Rm	Radius at the jet maximum height (radial distance from the centerline to where concentration is 6% of that at the centerline, C=6%Cc)	4.7	m
Xr	Centerline horizontal location of the return point (where the jet axis reaches the port height level)	25.17	m
Sr	Centerline dilution at the return point	40.4	
Cr	Centerline saline concentration at the return point	41.5	PSU
br	Jet radius at the return point (radial distance from the centerline to where concentration is 50% of that at the centerlinee, C=50%Cc)	4.2	m
rr	Jet radius at the return point (radial distance from the centerline to where concentration is 25% of that at the centerline, C=25%Cc)	5.9	m
Rr	Jet radius at the return point (radial distance from the centerline to where concentration is 6% of that at the centerline, C=6%Cc)	8.3	m
Xi	Centerline horizontal location of the impact with bottom point	28.2	m
Si	Centerline dilution at the impact point	35.8	
Ci	Centerline saline concentration at the impact point	41.6	PSU
Xn	Horizontal location of the spreading layer at the end of the near field region	68.6	m
hn	Thickness of the spreading layer at the end of the near field region	3.83	m
Sn	Centreline dilution of the spreading layer at the end of the near field region	68.6	
Cn	Centerline saline concentration of the spreading layer at the end of the near field region	41.2	PSU
Un	Centerline velocity of the spreading layer at the end of the near field region	0.10	m/s

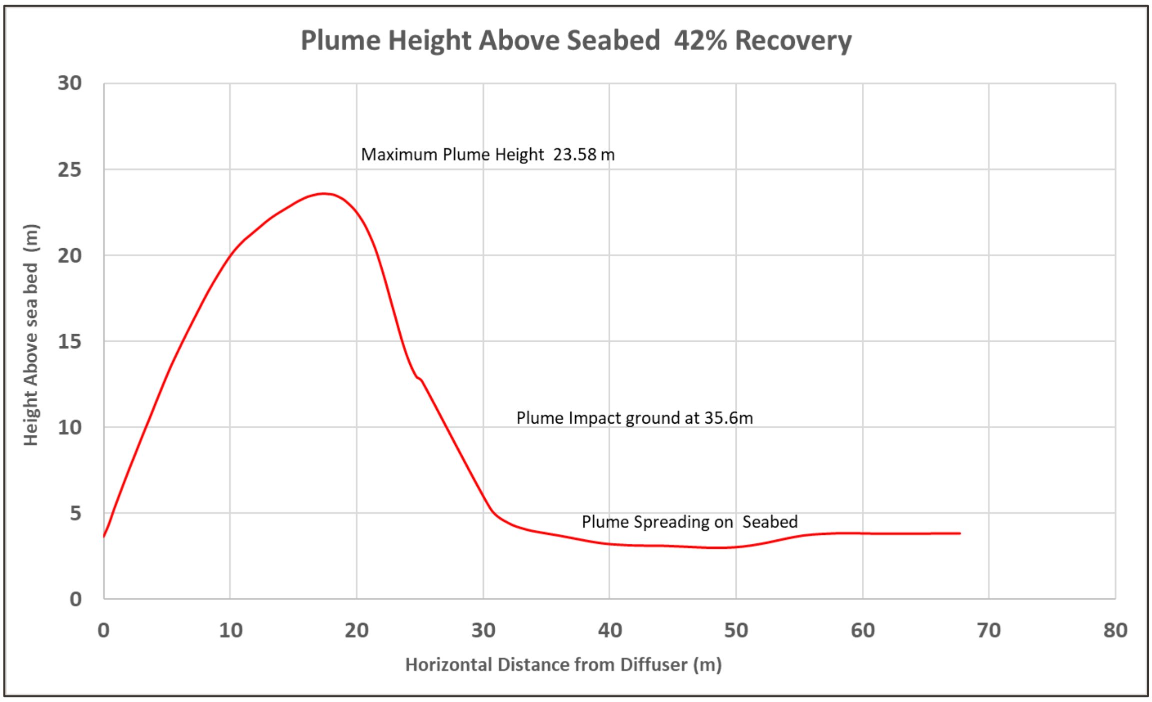

Figure 1-3: Plume Height with Distance from the Diffusers (42% Recovery)

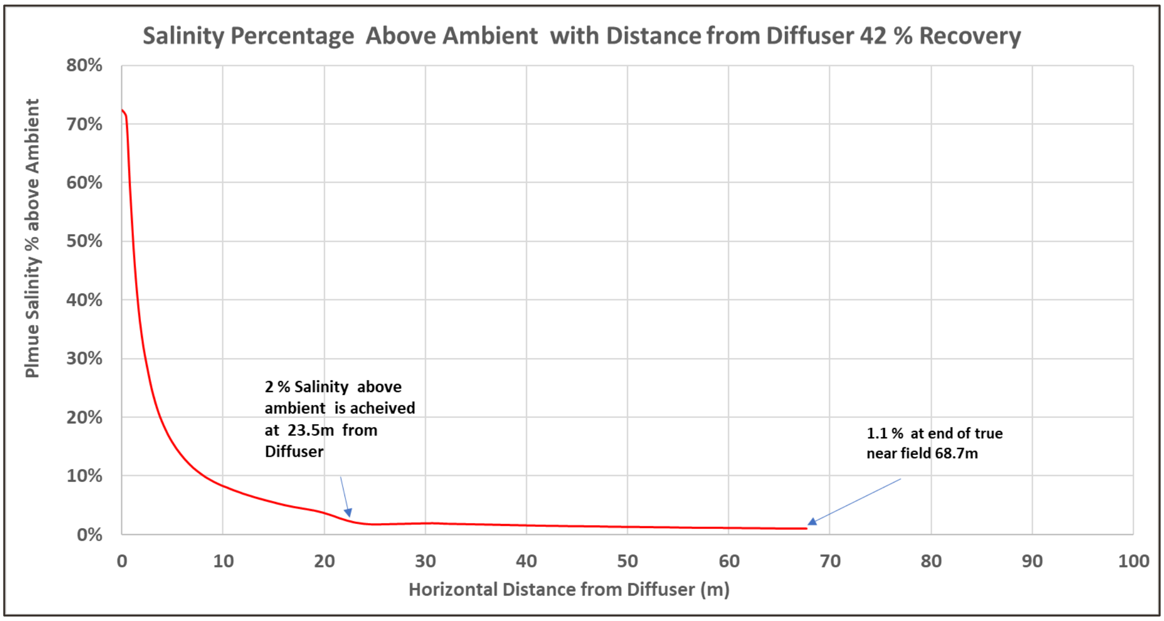

Figure 1-4: Salinity Percentage Above Ambient with Distance from Diffuser (42% Recovery)

Indicative Outfall Diffuser Manifold

The Brihne near field modelling provided the area of the true near field mixing zone and the brine plume maximum heights requiring a water depth of approx. 25 m to 29 m.

Figure 1-5 below shows a potential 200m diffuser manifold in (green) starting at a water depth of approx. 25 - 30 m.

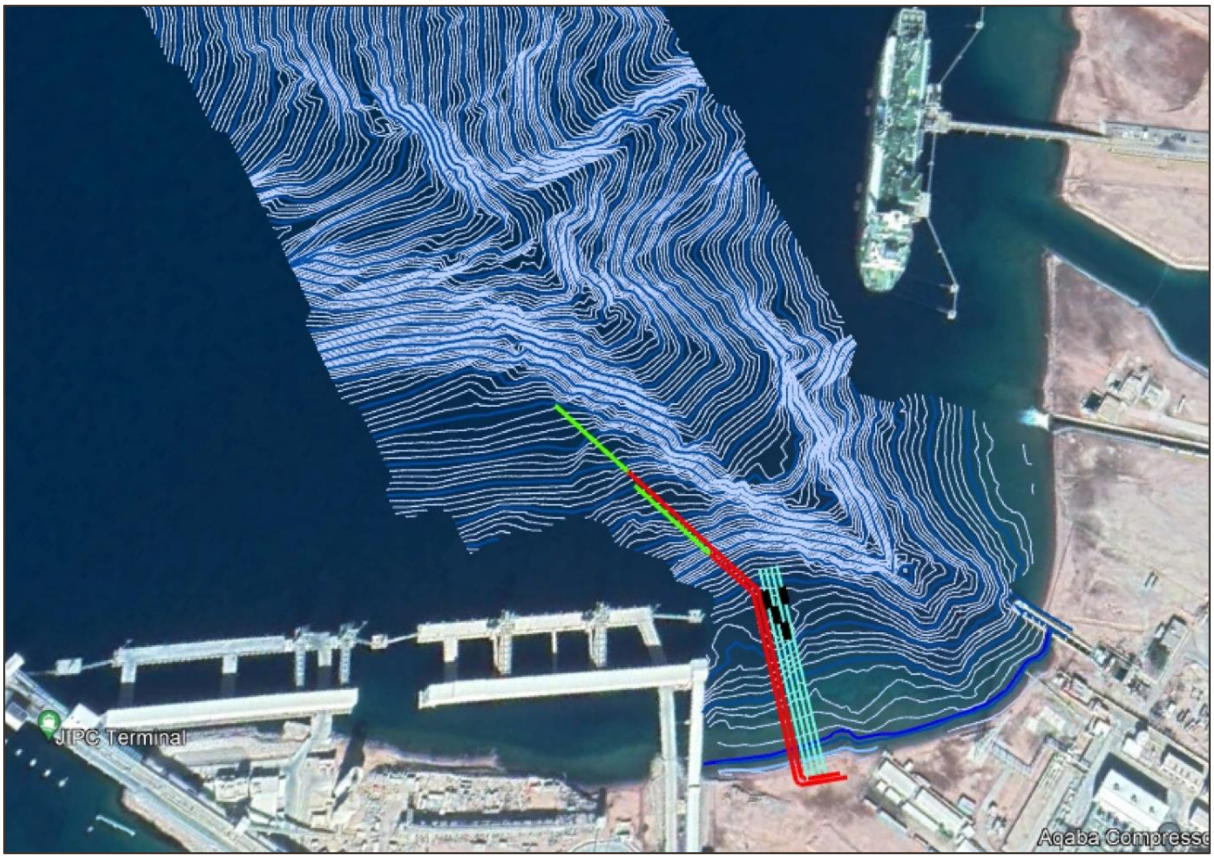

Figure 1-5: 200m Outfall Diffusers Manifold at 25m water depth

1.3. Far Field Dispersion Modelling Results

The near field modelling results indicated that brine salinity will be diluted to less than 2% above the ambient salinity within 100 m from the diffusers, this should already provide the greatest protection for the marine flora and fauna in the far field region beyond 100 m from the diffusers.

Far Field modelling was carried out by using the Mohid far field model. The respective report and calculations are appended to this ESIA study (**Annex 1** refers).

The expected far field brine plume dispersion for the scenario of 45% recovery RO plant is presented in Figure 1-6. The figure shows that the brine plume starting at ≤ 2% above ambient salinity will slowly become more diluted over several kilometres by underwater currents, brine rolling downslope under gravity and concentration diffusion. The brine plume will travel as density current, following the bathymetry under gravity to deeper waters.

Table 1-3 shows the concentration of brine at different distances from the diffusers. It can be observed from the table that the brine concentration continues to be diluted in the far field. At distances of approx. 1.5 km from the diffusers it would be difficult to observe the brine plume because the salinity concentration is less than 0.1 PSU above the ambient salinity, which is the sensitivity of many CTD instruments used to monitor brine plumes.

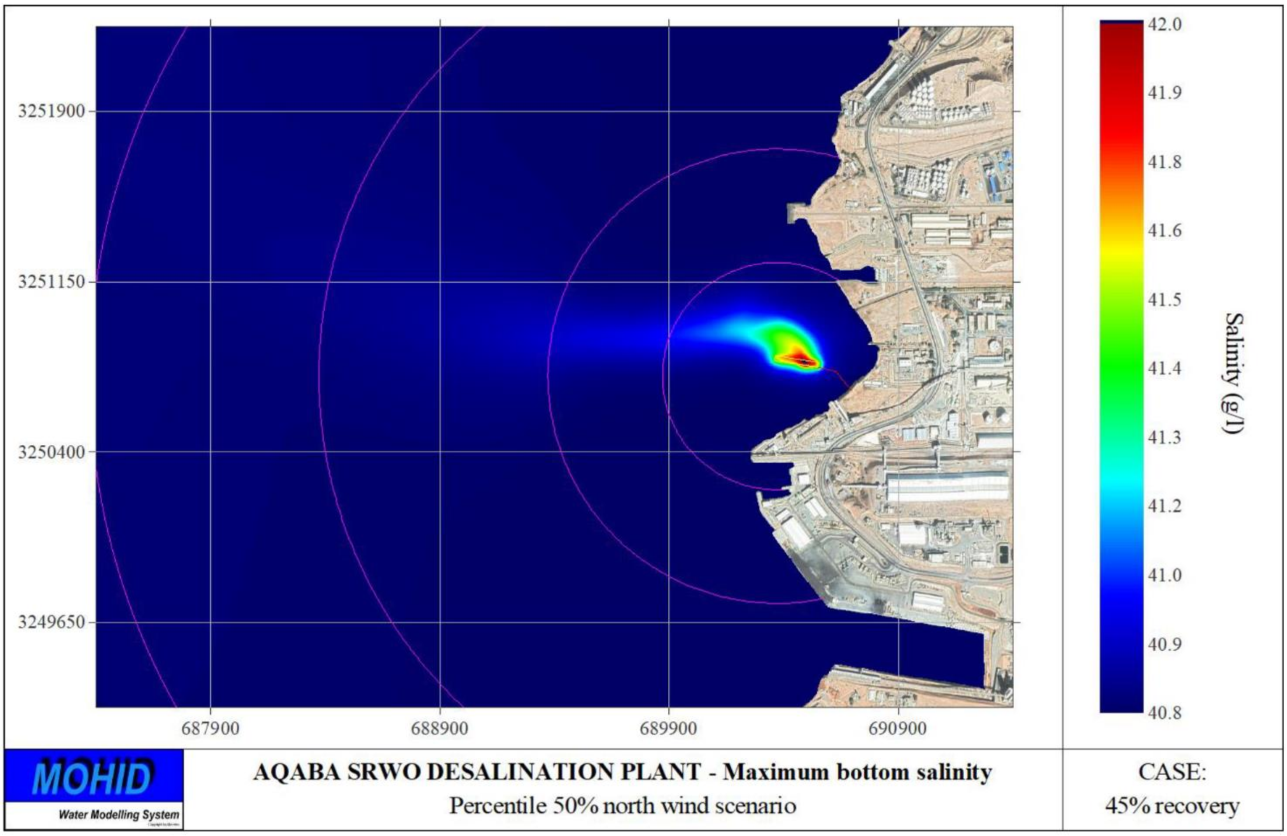

Figure 1-6: Far Field Brine Dispersion 45% recovery (note: ambient salinity 40.8 PSU)

Table 1-3: Far Field Brine Salinity Concentration with Distance from Diffusers (Note: Ambient Salinity 40.8 PSU)

Scenario	Maximum Salinity (PSU) from the Diffusers			
	500m	1000m	2000m	3000m
Mean Wind North	41.02	40.94	40.85	40.84
90th Percentile Wind North	41.02	40.93	40.85	40.84
90th Percentile Wind South	41.02	40.93	40.85	40.84

Impact of the brine plume on Intake salinity

Because the brine plume is slightly denser than the seawater in the far field region it will therefore travel downslope as a density current to deeper waters, very little of brine plume can recirculate to the desalination plant intake towers provided that those intake towers are located in shallower depths than the outfall diffusers. Figure 1-7 shows the results of the Mohid far field model for the impact of salinity on the intake towers. The ambient salinity was taken as 40.8 PSU, and the salinity elevation due to the brine is less than 0.012 PSU. Therefore, the salinity increase caused by recirculation brine to the intake can be considered as negligible.

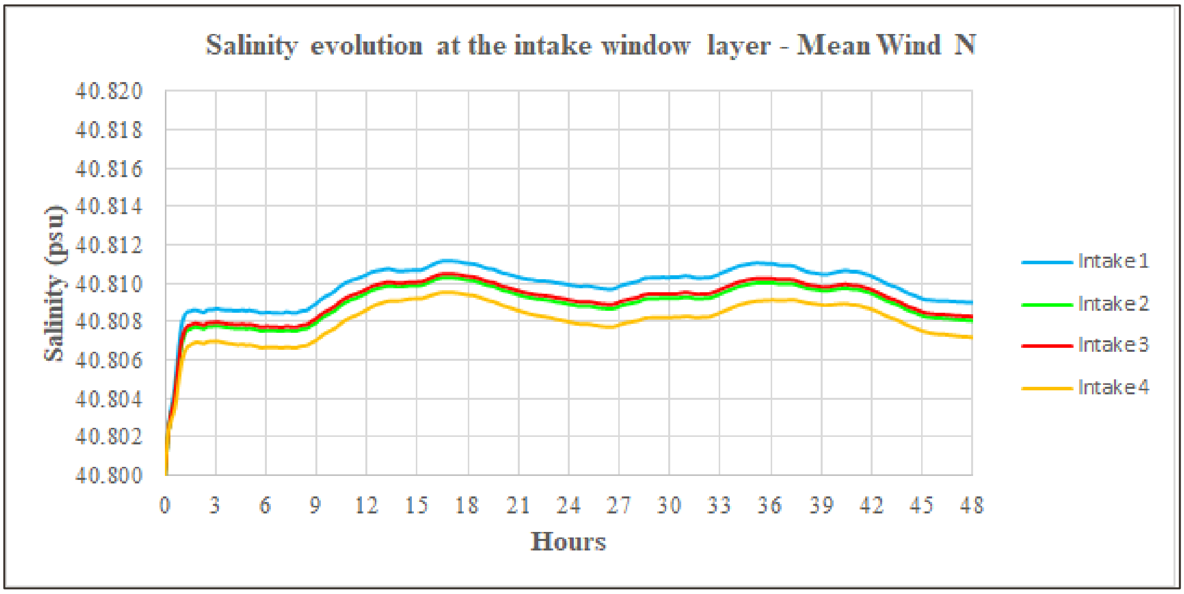

Figure 1-7: Salinity Concentration Recirculation to the Intake Towers from Brine