ADNOC PROJECT WAVE: COMPONENTS 1 & 2 – MIRFA SWTP AND DISTRIBUTION PIPELINE

SEAWATER INTAKE & OUTFALL: SUMMARY OF DESIGN CHANGES

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LIST OF ABBREVIATIONS

ADNOC	-	Abu Dhabi National Oil Company
ASME	-	American Society of Mechanical Engineers
°C	-	Centigrade
CO_2	-	Carbon Dioxide
Dome	-	Dome Oilfield Engineering & Services LLC
EAD	-	Environment Agency Abu Dhabi
EIA	-	Environmental Impact Assessment
EPC	-	Engineering, procurement, and Construction
GIS	-	Geographic Information System
HSE	-	Health, Safety and Environmental
in	-	Inch
km	-	Kilometer
m	-	Meter
MBWPD	-	Thousands Barrel of Water per Day
mg	-	Milligrams
MMBR	-	Marawah Marine Biosphere Reserve
NF	-	Nanofiltration
RO	-	Reverse Osmosis
SRP	-	Sulphate Reduction Plant
SWRO	-	Seawater Reverse Osmosis
SWTP	-	Seawater Treatment Plant
TDS	-	Total Dissolved Solids
TG	-	Technical Guidance
UF	-	Ultrafiltration
USEPA	-	United States Environmental Protection Agency
WHO	-	World Health Organization

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1 INTRODUCTION

1.1 Project Background

ADNOC Onshore is implementing Project Wave (the Project), which aims to utilize treated seawater as an alternative for the injection requirements on all ADNOC Onshore fields (BAB, Bu Hasa, NEB and Southeast). This Project Wave represents ADNOC ++ initiatives for ensuring an additional and more sustainable source of water for injection in ADNOC Onshore fields. The proposed Project Wave will include the following components (see Figure 1.1):

- Component-1: construction of a Seawater Treatment Plant (SWTP) at two locations (Mirfa and Nouf). Each consists of Seawater Intake, Outfall, Filtration and Sulphur Reduction Plant (SRP).
- Component-2: build a network of pipelines to transport treated, filtered, low-Sulphate seawater to all Onshore Fields (nine separate battery limits).
- Component-3: build a centralized pumping station and in-field distribution network to distribute treated water up to water injection wells.

The scope of the current Project is limited to Components 1 and 2 of the Mirfa SWTP (i.e., Component 3 is located within existing oilfields and is being implemented separately by ADNOC Onshore).

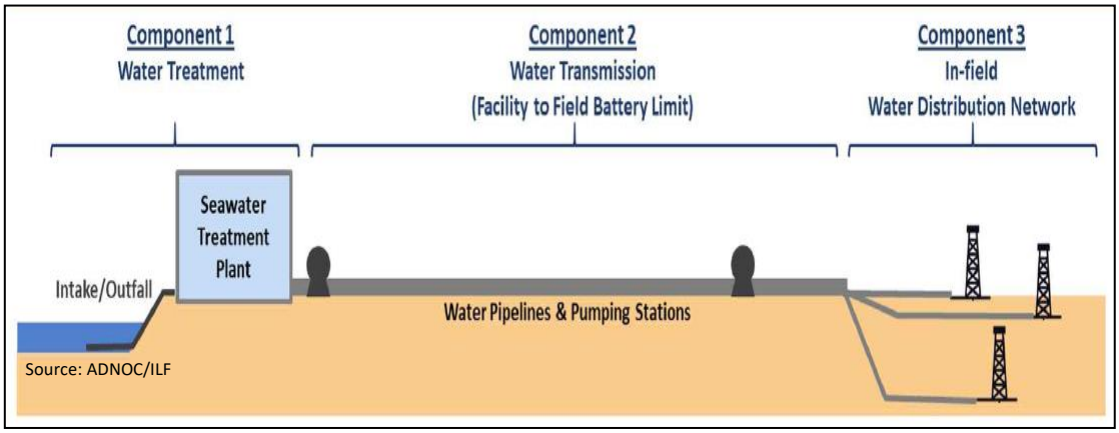


Figure 1.1 – Overall Project Wave Scope Schematic Diagram

1.2 Purpose of this Document

ADNOC and ADNOC Group Companies, by virtue of Article 94 of UAE Federal Law No. 24 of 1999 for the Protection and Development of the Environment, have been given self-regulatory status regarding environmental permitting. Nonetheless, considering that some components of this Project will be in a number of environmental protected areas (i.e., Mirfa STWP is within the Marawah Marine Biosphere Reserve, MMBR), a separate permit application with the Environment Agency Abu Dhabi (EAD) has been initiated. The EIA study for the Mirfa SWTP and associated facilities has been completed in October 2022 and was subsequently approved by EAD in December 2022 (Environmental Permit Number: DP-1418). This approval was based on the initial design of the SWTP, and associated facilities completed by ILF Consulting Engineers (Abu Dhabi), the Project Technical Advisor.

This Document presents the Summary of Design Changes in the seawater intake and outfall structures based on the proposed design by the Consortium of Metito Utilities Limited and Orascom Construction (the Client), which has been selected as the developer and operator for the Project.

2 OVERVIEW OF THE EAD-APPROVED DESIGN

2.1 EAD-approved Project Location

The proposed Mirfa SWTP site is located within the fenced area in Mirfa with existing industrial installations (see Figure 2.1). It should be noted that the location has been selected based on a detailed site selection study that has been commissioned by ADNOC for the Project. The existing industrial facilities within this fenced area include the Mirfa IWP (water desalination/power plant), TRANSCO pumping station, and ADNOC Industrial Gases (Mirfa Plant) (see Figure 2.1). The site considered to be generally disturbed (i.e., review of publicly available satellite imagery showed that some part of the site has been used as laydown area during the construction of the ADNOC Industrial Gases (Mirfa Plant).

In terms of residential area, an accommodation camp/facility for the ADNOC Industrial Gases Mirfa Plant is present within the fenced area (see Figure 2.1). There are also a number of residential houses along the coastline of the Mirfa, adjacent to the proposed seawater intake and outfall line (see Figure 2.1). These houses primarily include vacation houses of locals (villas in large plots of land) and a few VVIP plots (see Figure 2.1). The town of Mirfa is located east of the proposed Mirfa SWTP site (the nearest residential area is about 4 km away, see Figure 2.1).

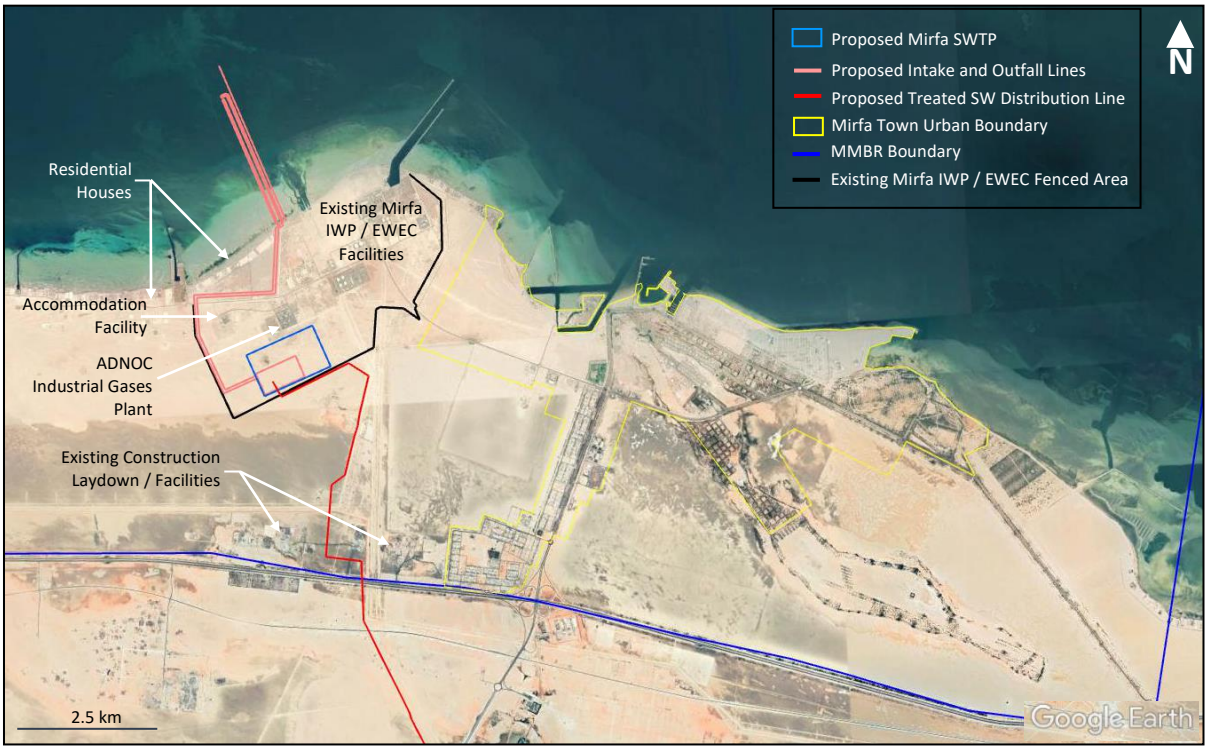


Figure 2.1 – EAD-Approved Project Location and Existing Land-uses

2.2 EAD-approved Plant Capacity and Design Parameters

The Mirfa SWTP has an EAD-approved design capacity of 2,840 MBWPD (which will be at peak by year 2029) and minimum capacity for turndown purposes is 1,606 MBWPD. The EAD-approved location and configuration of seawater intake and outfall structures of the SWTP are presented in Figure 2.2. The system is designed for a maximum of:

- Intake flowrate – 32,385 m^3/hr
- Outfall flow rate – 10,319 m^3/hr.

Table 2.1 presents the seawater design envelope for the SWTP (see Figure 2.3 for the design mass balance).

Table 2.1 – Seawater Design Envelope for the SWTP

Parameter	Unit	Design Envelope
Temperature	C	20 - 40
TDS	mg/l	39,000 – 55,000
TSS	mg/l	0-10
Sulphate	mg/l	0 - 4000

The proposed SWTP will have pre-filtration and Sulphate Reduction Plant (SRP). Prefiltration includes Coarse filtration and Ultra Filtration. After sulphate removal, the treated water will be deoxygenated in Vacuum Deaerator Tower and chemically deaerated. The following are quality requirements of the treated seawater for injection:

- Sulphates: 800 mg/l
- TSS: 0.1 mg/L (particle size: 95% separation ≥ 2 microns)
- Oxygen: 10 ppb for both Treatment Plants

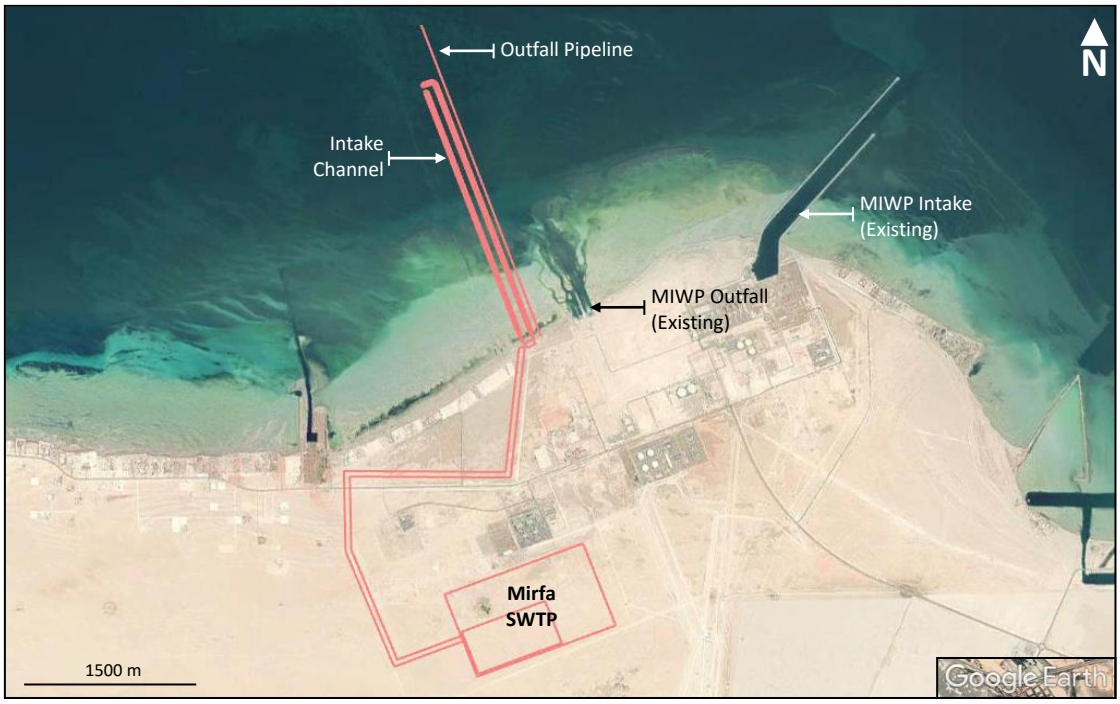


Figure 2.2 – EAD-Approved Mirfa SWTP and Intake/Outfall Configuration

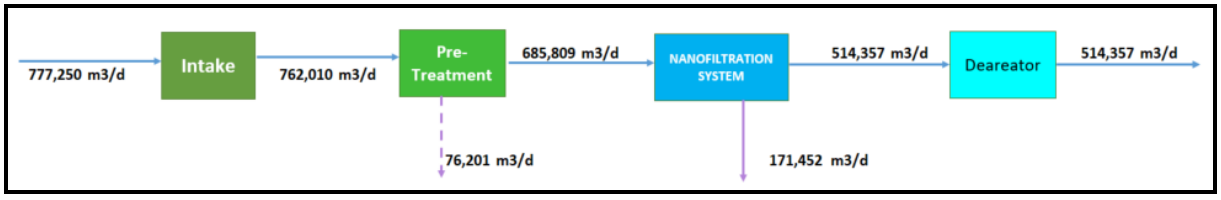


Figure 2.3 – EAD-Approved Mirfa SWTP Design Mass Balance

3 OVERVIEW OF DESIGN CHANGES

3.1 SWTP Location

The proposed design by the consortium of Metito Utilities Limited and Orascom Construction has considered a new location for the proposed SWTP (see Figure 3.1). This new location is situated at the northwest corner of the existing fenced area, about 350 m west of the existing ADNOC Industrial Gases Plant. Based on the Project information, the existing accommodation facility within the new site is already planned to be demolished. Based on this and considering that the new proposed location is located within the existing fenced area (i.e., intended for industrial development), it is not expected to result in any significant land-use issue.

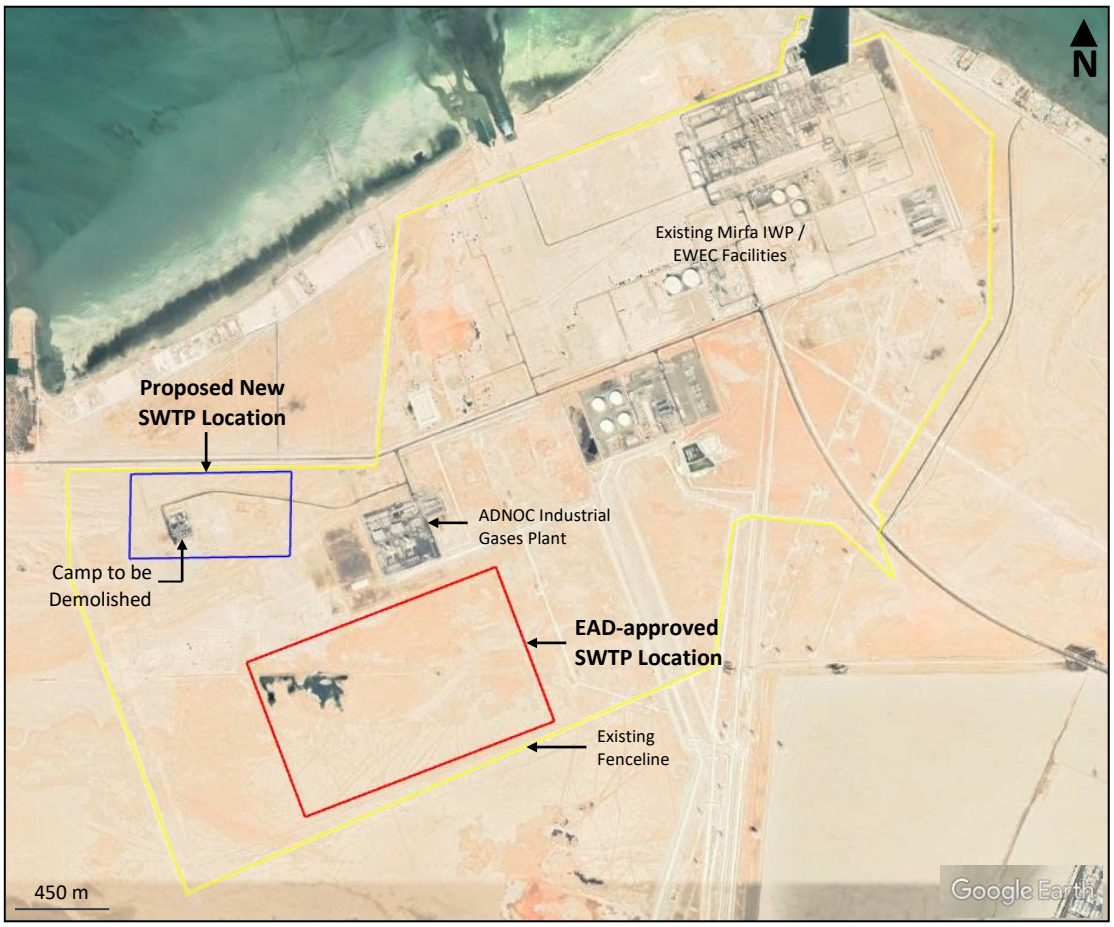


Figure 3.1 – Proposed New Location of the Mirfa SWTP

3.2 Intake and Outfall Configuration

The proposed design by the consortium of Metito Utilities Limited and Orascom Construction has generally adopted the EAD-approved seawater intake and outfall design (see Figure 3.2). For the seawater intake structure, some adjustments were made at the shoreline approach of the structure, but the previously defined intake point was maintained. In regard to the outfall pipeline, the new design considered a pipeline running within the intake channel, however, the previously defined outfall point (i.e., Option 2 outfall in the EAD-approved EIA Report) was also maintained.

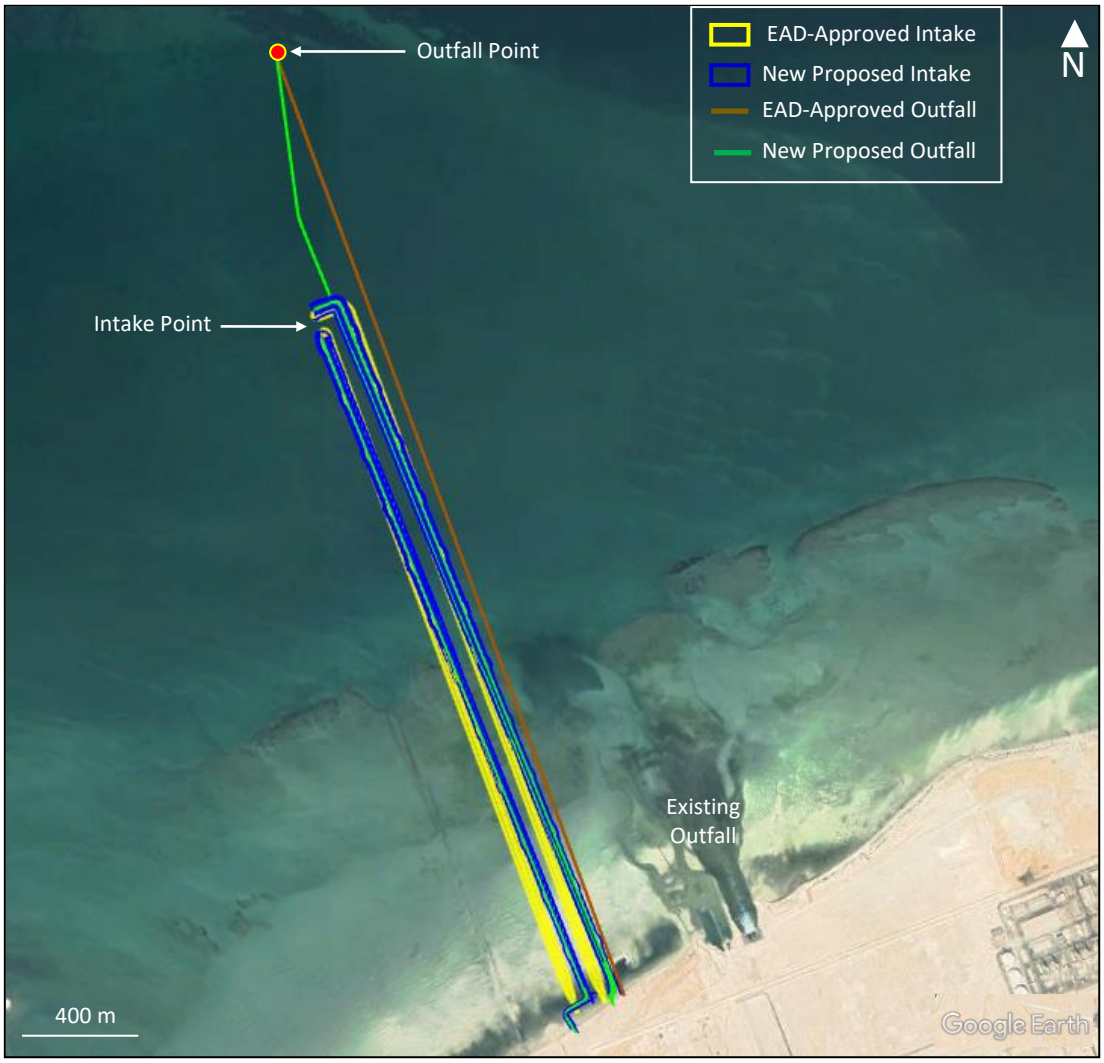


Figure 3.2 – Proposed Seawater Intake and Outfall Structures for the Mirfa SWTP

3.3 Plant Capacity and Design Parameters

Table 3.1 provides the summary of changes in the design capacity of the proposed Mirfa SWTP. The new design data shows an increase in net capacity of about 16% from the original design. Nonetheless, it should be noted that the new design will have a lower intake flowrate (i.e., reduced by about 1,885 m^3/hr or about 6% from the original). This is similar for the return water or brine outfall flowrate, which has been reduced by about 3,565 m^3/hr or about 35% from the original.

In terms of the pant design envelope, the new proposed design considered the data as presented in Table 2.1, except for TDS (i.e., a background level of 42,000 mg/l was adopted).

Table 3.1 – Summary of Changes in Design Capacity

Parameter	EAD-Approved Design Details	New Proposed Design Details
Net Production Capacity	451,524 m^3/day	522,800 m^3/day
Minimum Production Capacity	255,336 m^3/day	125,500 m^3/day
Intake Flowrate (maximum)	32,385 m3/hr	30,500 m3/hr
Outfall Flowrate (maximum)	10,319 m3/hr	6,754 m3/hr

The new SWTP design also shows reduced concentrations of key pollutants associated with the seawater return (brine) that will be discharged into the marine environment (see Table 3.2. For instance, the temperature of the proposed discharge has been reduced by about 29% from the original value considered in the EAD-approved EIA Report. This is similar for the values of TDS, sulphate, and chloride, which have been reduced by about 4% to 18% from the original values considered in the EAD-approved EIA Report.

In terms of the outfall diffuser design, the new design will include a higher number of ports (i.e., from 3 to 12) over a 30m diffuser stretch (see Table 3.2 and Figure 3.3).

Table 3.2 – Properties of Seawater Return (Brine) Discharge

Design Aspects	EAD-Approved Design Details	New Proposed Design Details
Temperature of discharge waters	<42 degrees	30 degrees (from Annex 1 of B3.1 Document)
Salinity of brine discharge waters	< 75 ppt (parts per thousand)	65.50 psu (from Annex 1 of B3.1 Document)
TDS	75,000 mg/l	68.052 mg/l
Sulphate	14,500 mg/l	13,848 mg/l
Chloride	39,000 mg/l	31,821 mg/l
Outfall pipe diffuser configuration	3 diffusers at right angles to the outfall pipe, 10m apart, at 15 degrees to horizontal on alternate sides of the pipe (2 on opposite side to sea water intake).	Consist of 6 risers pipe OD 600 mm SDR26, with two outlet ports per riser (12 in total) OD 280 mm SDR26. Risers are spaced every 6 m. The total diffuser length is 30 m. The discharge angle (respect the horizontal line) is 15 º. [data from B3.1.1 Document)

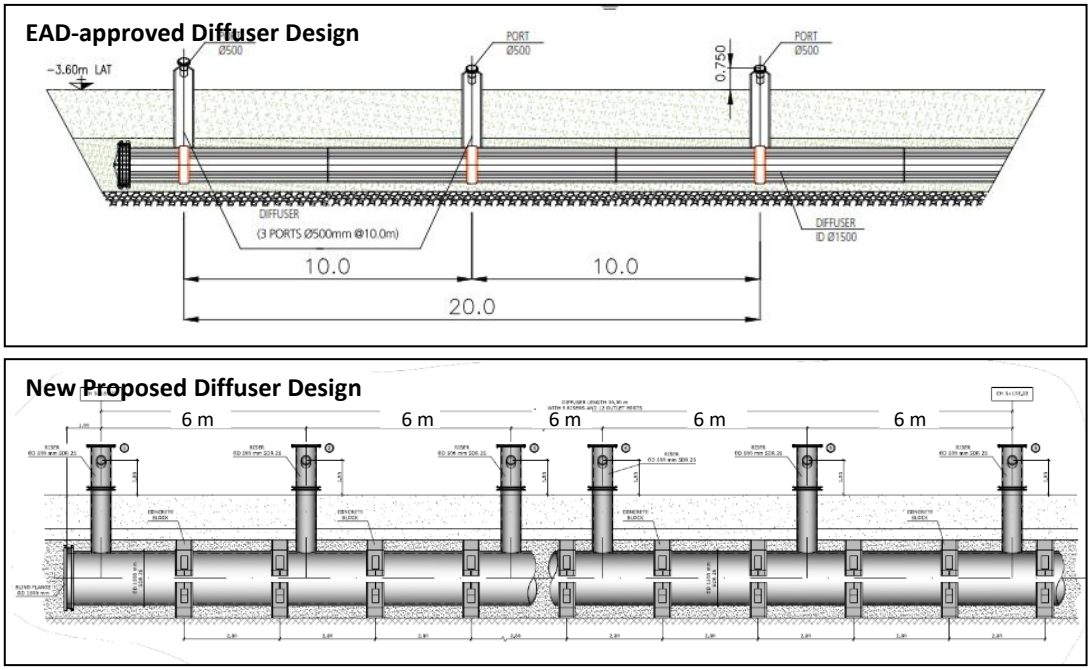


Figure 3.3 – Proposed Seawater Return (Brine) Outfall Diffusers for the Mirfa SWTP

3.4 New Seawater Reverse Osmosis (SWRO) Plant

The new auxiliary reverse osmosis system (SWRO) is sized to produce clean water for ancillary utilizers, such as firefighting, chemical preparation, potable water, as well as for the cleaning and flushing systems related to UF and NF (i.e., for internal potable water requirements of the SWTP).

The capacity of the RO plant is able to produce in less than 24 hrs the required water for the NF flushing tank (for total NF plant flushing capacity), NF and UF CIP system, chemical preparation and safety showers (see Table 3.3). The SWRO will have a seawater feed rate of about 76 m^3/hr and brine discharge of about 41 m^3/hr, which will be directed in the common outfall system of the SWTP (to be discharged as part of the SWTP seawater return effluent).

Table 3.3 – New Auxiliary SWRO Design Capacity

Parameters	Unit	Value
NF Flushing	m^3	686
Volume of CIP Filling	m^3	65
Daily Potable Consumption	m^3	8
UF CIP	m^3	13.5
Chemical Preparation – Safety Showers	m^3	10
Net Volume	m^3	783
Adopted Volume	m^3	800
Flow Filling in 24 hr (SWRO Capacity)	m^3/hr	33.3

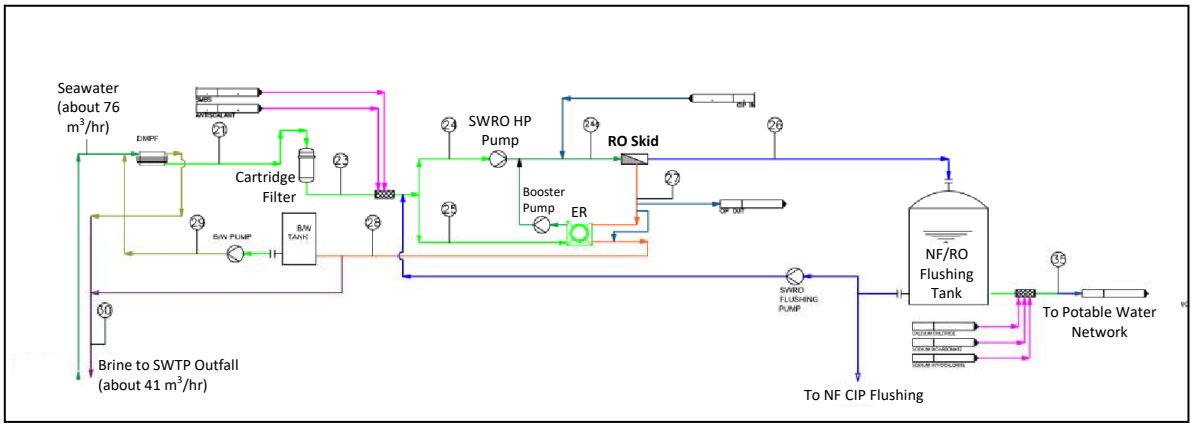


Figure 3.4 – Process Flow Diagram of the Proposed SWRO

The auxiliary SWRO takes the clarified water after the DAF and will be supplied by the UF Feed Pumps. The plant consists of main systems:

- Pretreatment, performed with Pressurized Dual Media Filter – After the clarification phase, filtration is the key treatment step in water treatment plants for the removal of suspended solids to meet the RO feed water requirements. Clarified sea water stored in clarified water storage tank is then pumped to dual media filtration units (1 working +1 stand by) with the help of DMF feed pumps for further filtration of sea water. Filtration units consist of sand and anthracite as the filtering media supported on gravel. When the pressure drop across the filter exceeds the preset limit, the filter media is required to be cleaned to remove dust and dirt. Cleaning operation of filtration units shall be performed in three steps, including air scouring, backwash and rinse.
- Cartridge Filter – After filtration process in dual media filter units, filtered water is then fed to cartridge filter units with help of DMF feed pumps. Cartridge filtration of 5-micron ratings shall be provided ahead of the RO stage and shall be working to safeguard the RO membranes from the impurities not as a screening device. The Cartridge units (1 working + 1 stand by) shall have replaceable type polypropylene wound cartridge elements. Anti-scalant shall be dosed upstream of cartridge filter units to prevent scaling in RO membrane. Sodium meta-bisulphite shall also be dosed upstream of cartridge filters for removal of residual chlorine available in water.

- Single Pass RO Train – The feed water coming out of cartridge filter is boosted by high pressure pump (1 working + 1 stand by) to feed at required pressure to first pass Reverse Osmosis membranes. The reverse osmosis streams shall be equipped with 8-inch, spiral wound, thin film composite reverse osmosis membranes. The product water shall be stored in a Permeate Water storage tank. Each reverse osmosis stream shall be equipped with a dedicated energy recovery device. The reject water from SWRO will pass through Energy recovery device (ERD) for recovery of reject water pressure. This ERD will transfer pressure energy from the reject side to part of SWRO feed water to minimize the auxiliary power requirement of high-pressure pumps. The reject water after ERD is transferred to outfall discharge (as part of the SWTP discharge). Part of this reject water is stored in separate backwash water tank and used for backwashing of dual media filters. Filter backwash water pumps will take suction from this backwash water tank for backwashing of dual media filter units.
- Remineralization dosing System – the post treatment / Remineralization system shall be provided to treat the required quantity of permeate making suitable for drinking and sanitary purposes. The system shall comprise inline dosing of chemicals - namely Calcium chloride, Sodium Bicarbonate, and Sodium hypochlorite to raise the levels of dissolved solids and pH levels in order to make the water suitable for drinking purposes. In this system, Potable water plant supply pumps are provided to take suction from service water / fire water storage tank and chemicals are being dosed at discharge header of potable water plant supply pumps. Remineralized water after mixing with chemicals is then be stored in Potable water storage tank for further usage of water for drinking and sanitary purposes.

4 CONCLUSIONS

The following conclusions are drawn from the analysis of the proposed seawater intake and outfall design by the consortium of Metito Utilities Limited and Orascom Construction:

- SWTP Location – the location of the proposed SWTP was moved to a different location within the existing fenced area of Mirfa IWP and ADNOC Industrial Gases Plant. This change in location of the plant is not expected to result in any land use issue (considering its location in the same industrialized area) and will not have any direct effect on the seawater intake and outfall facilities.
- Plant Capacity and Design – a more efficient design has been adopted, which resulted in an increased net production capacity with lower intake and brine discharge flow rates. For instance, the brine discharge flowrate was reduced by about 35% from the value considered in the EAD-approved EIA Report.
- Brine Discharge Pollutants Concentrations – the new design shows a significant reduction in the concentrations of key water quality pollutants associated with the brine discharge.
- Seawater Intake and Outfall Configuration – the EAD-approved intake and outfall points were adopted/retained and there are no significant changes on the intake and outfall layout.
- Outfall Diffusers – the number of diffuser ports increased from three (3) ports in the EAD-approved EIA Report to twelve (12), including an increase in the diffuser stretch from 20m to 30m.
- New Auxiliary SWRO – the brine discharge from the new SWRO is minimal (i.e., 41 m3/hr) and will be discharged as part of the SWTP discharge (common outfall). It should be noted that the overall marine discharge of the new design (i.e., SWTP + SWRO brine) is still lower than the EAD-approved discharge volume.

Overall, the changes in the design are expected to result in positive environmental effect. For instance, the new proposed outfall pipeline layout, which moved the outfall pipeline within the intake channel, will reduce coastal and marine habitat disturbance. Furthermore, the reduced brine discharge flowrate and lower pollutants concentrations are expected to reduce the overall magnitude of impact and a much smaller area of impact. The improved outfall diffusers design is also expected to result in better near-field dilution, which will further reduce the magnitude of marine water and ecological impact of the brine discharge. It should be noted that an updated modeling study has been carried out for the brine discharge based on the new design details and configuration.

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Description of Major Equipment and Systems including theior Auxiliaries: Main Report (Document No.: B3.1.1).

General Description of Treatment Facilities and the Transportation Facilities (Document No.: B1.4).

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