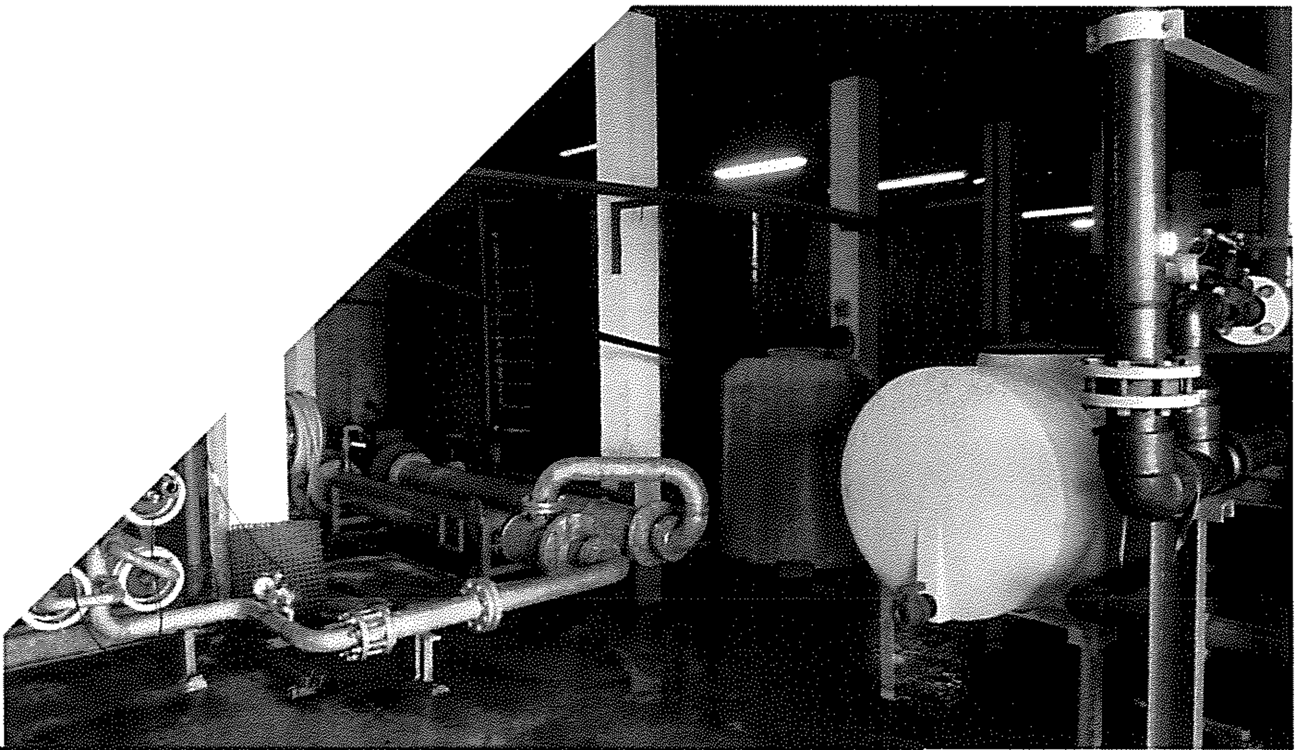
REPORT Nº 22213-02

ROBBEN ISLAND DESALINATION

PRELIMINARY DESIGN REPORT



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WSP | PARSONS BRINCKERHOFF

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PRELIMINARY DESIGN REPORT

Coega Development Corporation

Preliminary Design Report
FINAL
Project no: 22213
Date: 10 May 2017

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1 INTRODUCTION

1.1 APPOINTMENT

WSP|Parsons Brinckerhoff was appointed by Coega Development Cooperation (CDC) to design a new desalination plant to service all users and residents of Robben Island.

1.2 LOCALITY

The desalination plant is situated on Robben Island and for the layout indicating the desalination plant and associated infrastructure, please refer to Appendix A.

1.3 BRIEF AND SCOPE

Robben Island is currently being supplied with potable water from a reverse osmosis (RO) desalination plant situated on the island which was constructed in 1998. The desalination plant is currently the primary source of potable water on the island and during emergency situations when the plant is out of operation, bottled water is brought over with boat from the mainland.

The new desalination plant will have to be constructed while the existing plant remains in operation in order to ensure that residents have sufficient water during the construction phase.

The existing water treatment works (WTW) is outdated and is experiencing frequent replacement of membranes and therefore the need for the upgrade. In order not to delay the completion of the project, CDC requested that options must be considered which would not require an Environmental Impact Assessment (EIA), as this process will delay the completion of the project.

CDC also requested that the condition of the existing structure, housing the desalination plant, be assessed in term of life expectancy and safety. Should it be found that upgrading/refurbishment is in actual fact required, these upgrading/refurbishment requirements be included in the scope of work.

1.4 EXCLUSIONS FROM SCOPE

CDC has indicated that the appointment only covers the desalination plant itself and that ancillary facilities such as the following is excluded from the scope of works:

- Abstraction of seawater
- Seawater reservoir and fresh water reservoirs
- Reticulation network and pumps
- Disposal of brine

However, if during the investigations it is found that the some of these facilities require upgrading, WSP|Parsons Brinckerhoff will be highlight these requirements in their reports.

2 LIMITATIONS – ENVIRONMENTAL REQUIREMENTS

2.1 BACKGROUND

Due to its status as a UNESCO World Heritage Site any development on Robben Island is guided by a number of documents:

(i) The Robben Island Maintenance Plan (Department of Public Works, 1 November 2010) describes a framework which ensures that Robben Island Maintains its World Heritage Status and sets out various conservation principles.

(ii) The Integrated Conservation Management Plan (2002) and updated ICMP (2013 – 2018) outline Robben Island Museum's framework for achieving the Island's environmental objectives. Various management plans are included in the ICMP, which includes the Natural Environmental Management Plan (NEMP) among others. The NEMP was produced through a revision of the 2002 EMP compiled by the CSIR. The document provides the legal, institutional and procedural context for the more detailed management specifications set out to manage specific areas of intervention as well as, meeting legal and environmental management objectives

2.2 ENVIRONMENTAL

The National Environmental Management Act (Act No. 107 of 1998) (NEMA) provides the environmental legislative framework for South Africa and requires that activities be investigated that may have a potential impact on the environment, socio-economic conditions, and cultural heritage. The results of such investigation must be reported to the relevant authority. Procedures for the investigation and communication of the potential impact of activities are contained in Section 24(7) of the Act.

On the 4th December 2014 the minister responsible for Environmental Affairs promulgated new EIA Regulations (GNR 982) in terms of Chapter 5 of the NEMA. The EIA Regulations contain three listing notices (GNR 983, 984 and 985) which identify activities that are subject to either a Basic Assessment or Scoping and EIA in order to obtain an Environmental Authorisation (EA). A Basic Assessment must be completed if the proposed project triggers activities in GNR 983 (Listing Notice 1) or GNR 985 (Listing Notice 3) and Scoping and EIA process must be completed if the proposed project triggers activities in GNR 984 (Listing Notice 2).

All Beachfronts and Islands are seen as Coastal Public Property(CPP); thus the entire Robben Island is deemed CPP under NEMA. The EIA Regulations 2014, published in terms of NEMA, contains the following potential activities which require an Environmental Authorisation(EA) process. These are seen in Listing Notice 1 below:

15	The development of structures in the coastal public property where development footprint is bigger than 50 square meters, excluding - (i) the development of structure within existing ports or harbours that will not increase the development footprint of the port or harbour (ii) the development of the port or harbour, in which case activity 26 in Listing Notice 2 of 2014 applies; (iii) the development of temporary structures within the beach zone where such structure will be removed within 6 weeks of the commencement of development and where indigenous vegetation will not be cleared; or (iv) activities listed in activity 14 in Listing Notice 2 of 2014, in which case that activity applies.
16	The development and related operation of facilities for desalination of water with a design capacity to produce more than 100 cubic meters of treated water per day.

Table 2-1 Listing Notice 1

From the table above it be noted that any structure smaller than $50m^2$ will not require an EA Process.

The development of a new desalination plant however will trigger the need for an EA and a Basic Assessment process to be undertaken as the desalination plant will produce more than $100m^3$ treated water per day to cater for the demand on the island. However, "Development" is defined as follows within NEMA:

- "development" means the building, erection , construction or establishment of a facility, structure or infrastructure, including associated earthworks or borrow pits, that is necessary for the undertaking of a listed or specified activity, including any associated post development monitoring, but excludes any modification, alteration or expansion of such a facility, structure or infrastructure, including associated earthworks or borrow pits, and excluding redevelopment of the same facility in the same location, with the same capacity and footprint;

Thus, the redevelopment of a like-for-like facility in the same location with the same footprint and capacity is will be exempt from requiring an EA and Basic Assessment process.

3 WTW CAPACITY

3.1 FLOWS

From information received from the Facilities Manager of Robben Island Museum, the population of permanent residents on the island fluctuates between 110 and 200. All residents on the island are families of employees working for RIM or contracted on the island. Taking this into consideration there is a very low chance of increase in population figures on the island.

From the visitor information received, as indicated in Table 3-1, it can be seen that the peak is during December, where in 2015 almost 48 000 visitors were logged visiting Robben Island.

Table 3-1 Visitors per month

Visitors per month												
	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBE	DECEMBER
2 016				34 889	23 043	17 130	21 328	24 277	25 561			
2 015	40 590	35 998	38 060	28 356	16 699	12 461	20 418	23 880	24 462	39 306	35 846	47 945
2 014	34 964	28 399	31 061	36 742	16 416	11 099	17 252	22 868	27 455	34 891	31 222	33 447
2 013	36 794	27 868	32 845	20 933	12 341	12 903	19 330	17 481	22 072	30 136	32 130	36 893
2012	33 377	26 608	28 593	29 413	13 924	10 110	10 520	11 297	21 436	30 201	28 814	38 576

Working with the above figures, a peak of ±3200 visitors per day was derived by allowing for days where the boat could not reach the island as well as an increase of visitors over the weekend. This value was calculated by dividing the monthly visitors by 15 days in order to allow for the peaks.

Table 3-2 Water demand calculations

Description	l/c/d	No	Q (m³/d)	Losses (15%) (m³/d)	Q (m³/d)	Summer peak (200%) (m³/d)
Visitors	25	3 196	79.91	11.99	91.89	183.79
Permanent Residents	150	200	30.00	4.50	34.50	69
						252.79

Allowing for 15% losses and a conservative summer peak factor of 2, the total maximum demand per day is calculated to be 252.79m³/day.

3.2 CURRENT CAPACITY

The current plant's design capacity could not be confirmed as As-built information and Operations & Maintenance (O&M) manuals are not available. From inspections a process schematic has been compiled and is attached as Appendix B. The current Water and Wastewater Maintenance operator on Robben Island from Masisebenze indicated that the plant has been producing between 11 and 18m³/hr of treated water depending on membrane age and he further indicated that this flow has been sufficient to meet the island's demand.

A report on the existing desalination plants in South Africa indicated [1] the existing plant's design capacity at 20m³/hr. If operated for at 24 hours per day, this equates to a maximum 480m³/day.

From running hours and flowmeter readings acquired the flow production rate could be determined as an average of 169.63m³/day and an average running time of 9.57 hours per day.

Table 3-3 Water production readings

[illegible]			
Date	Clock	hrs	m³/day
2017/01/03	7707.36	20.49	363.36
2017/01/04	7727.85	20.88	370.28
2017/01/05	7748.73	15.32	271.68
2017/01/06	7764.05	11.6	205.71
2017/01/07	7775.65	16.5	292.60
2017/01/08	7792.15	9.56	169.53
2017/01/09	7801.71	10.84	192.23
2017/01/10	7812.55	11.32	200.74
2017/01/11	7823.87	6.77	120.06
2017/01/12	7830.64	9.33	165.45
2017/01/13	7839.97	9.17	162.62
2017/01/14	7849.14	0	0.00
2017/01/15	7849.14	0	0.00
2017/01/16	7849.14	0	0.00
2017/01/17	7849.14	17.36	307.85
2017/01/18	7866.5	21.69	384.64
2017/01/19	7888.19	16.59	294.20
2017/01/20	7904.78	3.45	61.18
2017/01/21	7908.23	0	0.00
2017/01/22	7908.23	0	0.00
2017/01/23	7908.23	0	0.00
Average		9.57	169.63

The current intake structure, comprises of two pumps located 500m southeast of the desalination plant which have reported flows of 75 and 120m³/hr respectively. With desalination, approximately 40% of the inflow can be produced as permeate (to be used as potable water), which means 25 and 40m³/hr, respectively for each of the raw water pump stations, can be theoretically be produced by a desalination plant being provided with this amount of seawater. The current intake structure's main disadvantage is that the pumps can only be operated when the tide is sufficiently high, which results in there being a few hours (2–5) each day when there is no seawater being delivered to the seawater reservoir. During spring tide, the amount of time the intake pumps are unable to operate is increased and can reportedly be as much as 8 hrs.

The existing seawater reservoir's capacity is unknown and is reported to be approximately 250 m³. According to the current operator once it is not receiving seawater from Alpha 1, the reservoir is depleted in less than 2 hours, which means that its capacity is probably less than 2 hrs x 60 m³/hr = 120 m³.

3.3 PROPOSED CAPACITY

Indications are that the maximum design output capacity of the existing WTW is 20 m³/hr. The maximum demand for the island has been conservatively calculated to be 253 m³/day. Flow meter readings, taken during a three week period, have indicated the actual average daily production is 169.63 m³/day. However, it was also established during this period that the WTW only operates for an average period of approximately 10 hrs per day. That would imply that the WTW is actually producing approximately 17 m³/hr. This substantiates the theory that the WTW has a design capacity of 20 m³/hr, as the actual output capacity is dependent on a number of factors which could result in the loss of production. The condition of the membranes usually determine the output production to a large extend as the permeate produced is reduced with associated membrane fouling over a period of time.

Due to the inability of the intake to supply the WTW during low tide, it is unlikely that the WTW will be in operation all of the time and it is suspected to be the main reason that the output capacity exceeds the demand by a factor exceeding 2 (the WTW only operates for an average period of 10 hrs per day). The additional capacity will further allow for some downtime for maintenance such as membrane cleaning etc. This operation time is however lower than to be expected (usually 20 hrs per day for a conventional treatment works abstracting surface water).

As the development of a new desalination plant will trigger an EIA (as it will have to produce more than 100 m^3 treated water per day to cater for the demand on the island), it is proposed to replace the existing WTW with a WTW with the same capacity i.e 20 m^3/hr. An EIA process can be avoided if the "redevelopment of the same facility in the same location, with the same capacity and footprint" is undertaken. If the Client wishes to deviate from this requirement and wishes to have a desalination plant with a different capacity to be provided, this requirement is to be indicated as soon as possible.

4 PROPOSED WTW

4.1 PROPOSED PROCESS

SCOPE

The appointment is for the design and construction supervision of a desalination facility, and combined with the instruction not to trigger an EIA process (time constraints), other alternatives such as groundwater abstraction and pumping potable water from the mainland was not considered for the supply of potable water to the island.

DESALINATION

A variety of processes are available for the desalination of seawater. The paragraphs that follows discuss these.

Ion exchange is mostly considered a demineralisation technique, rather than a desalination technique, and was therefore not considered for this application. Demineralisation is normally applied where the feed water is well within the potable range (TDS<200 mg/l) which then results in a final water with a TDS<1 mg/l, such as is required for certain industrial applications for example boiler feed water.

The most popular desalination techniques can broadly be categorized in the following two groups:

- Distillation (evaporation & condensation) processes
- Membrane based processes

Various distillation processes such as multi-effect (MED), multi-stage flash (MSF) and vapour compression (VC) exist and will result in a final water with very low TDS. However, it has been shown [(1)] that distillation plants consume between 44 and 81 kWh/m^3. Only when the distillation process is combined with for example the waste stream of a power plant turbine, can the power consumption be reduced. This is however not the case for Robben Island and distillation processes' power requirements therefore exceeds the power requirements of for example a reverse osmosis (RO) membrane which is estimated at around 7 kWh/m^3, and even less if an energy recovery system is included. Power requirements play an important role in the process selection, especially if one considers that power to the treatment facility is being supplied by a diesel generator for which the diesel has to be shipped to the island at a significant additional cost.

Membrane based processes include the following:

- Electro-dialysis Reversal (EDR) – electro-potentially driven
- Reverse Osmosis (RO) - pressure driven
- Nano-filtration (NF) – pressure driven, partial desalination

It has been shown [1] that EDR is not economical when the TDS of the feed water exceeds 10 000 mg/l, which makes it an unfavourable process for this application, as west coast seawater has an average TDS of 36 000 mg/l. Furthermore, the EDR process is based on the removal of ions and therefore does and not remove colloidal, bacterial or non-ionized matter, which may be considered a notable disadvantage when compared to RO.

Both RO and NF are pressure driven membrane processes and are operated in a similar fashion. However, monovalent ions (such as Na^+ and Cl^- which constitute a large fraction of the TDS of seawater) pass through NF membranes with ease. Therefore, NF membranes are typically used for softening of water (Ca^{2+} and Mg^{2+} removal) and is not suitable for desalination of seawater to potable water standards.

The existing treatment facility comprise of a RO membrane facility (including pre-treatment) and ancillary facilities such as seawater abstraction and storage and brine discharge are already in place. The existing power supply is furthermore sufficient to operate a similar RO plant.

With the correct pre-treatment, RO will achieve the required potable water standards in the most cost-effective manner when compared to other desalination processes, and is therefore proposed. The existing infrastructure (abstraction/power/brine disposal) can furthermore be utilised if the existing RO plant is replaced with a similar RO plant. However, advances in RO membrane technology, alternative pre-treatment options as well as energy recovery devices will be investigated during the design of the complete desalination facility.

Sea water RO systems typically operate at a recovery around 40% to 50%, depending on the temperature, TDS and application. Therefore, a large portion of the feed water is discharged from the membrane unit as a saline concentrate at high pressure. It is standard practice to install energy recovery (discussed later in the report) units at sea water RO systems in order to minimise energy consumption.

Appendix C provides process flow diagrams (PFD) for the complete RO desalination WTW envisaged for this project. Please note that two options are provided for pre-treatment, the details of which are discussed later in the report. A recovery rate of 45% with 6 pressure vessels containing 6 membranes each at a flux of 15 lmh has preliminary been calculated for this project. The required feed pressure for this configuration is 65 m. Please refer to the PFD attached under Appendix C for details of the proposed system such as calculated flows, recoveries, etc.

It is envisaged that antiscalant will be continuously dosed before the RO membrane in order to prevent scale formation and subsequent membrane fouling.

RO membranes require CIP (clean-in-place) in order to remove fouling. NaOH, citric acid and EDTA may typically be used as cleaning chemicals during CIP. A common tank will be used for CIP and the tank must also be equipped with a heating coil to increase the CIP water temperature if required. A dedicated CIP/flush pump recycles water via a cartridge filter unit and the relevant RO unit, according to membrane cleaning/flushing requirements.

Each RO unit shall be fully equipped with, amongst other:

• Variable speed drive for flow control on high-pressure pump.

• Feed and permeate flow meter (to monitor and control recovery).

• Pressure sensors before after membranes (to monitor fouling).

• Conductivity meter (to monitor salt rejection and water quality).

• Brine valve for recovery control.

It is also recommended that critical spares (e.g. high-pressure pump, membranes, etc.) be kept in store near the site to cater for unforeseen breakdown events that cannot be fixed through normal maintenance and trouble-shooting exercises.

PRE-TREATMENT

An accumulation of one or more foreign substances on the surface of a membrane will result in a loss of flux (flow across a membrane). Higher operating pressures will then be required to maintain water production and quality and it will also lead to the early replacement of membranes. Membrane fouling generally occurs by one of the following mechanisms:

- precipitation of inorganic salts (scaling) due to supersaturation
- deposition of silt or other suspended solids
- interaction of organics with the membrane
- biological fouling caused by excessive microbial growth

The objective of proper pre-treatment is therefore to prevent membrane fouling. Suspended solids are removed by a combination of chemical pre-treatment (including coagulation), clarification and filtration. Although the existing desalination facility utilises sand filtration as filtration step, other alternatives such as membrane ultrafiltration (UF) are considered and discussed below. Biological fouling is generally prevented by the continuous or intermittent dosing of a disinfectant or biocide.

A full analysis of raw water is required in order to determine the site specific pre-treatment and membrane requirements. This information must also be provided to the tenderers in order for them to guarantee the process and equipment provided. No existing information on the raw water constituents could be obtained, which is concerning considering the amount of time the WTW has been in operation, and it was therefore required to do sampling and testing of the raw water. Ideally one would like to have tests result for a full year in order to have sufficient data available that represents all and any conditions including seasonal variations. Due to time constraints of the project it was proposed and accepted to undertake daily sampling and testing for a minimum period of three weeks. Although not sufficient to provide conclusive data for all maximum and minimum concentrations, it does provide usable data. However, should it be found that concentrations found during operation of the new WTW exceed the ones tested during this three-week period, WSP cannot be held liable. Appendix D contains all the test results received in a tabulated format and Table 4-1 below provides a summary of the average values. Two TDS results marked on Appendix D is not included in averages as the results are deemed to be incorrect.

Table 4-1 Summary of seawater analysis test results (average values)

SEAWATER CONSTITUENT AVERAGES				
Test	**Method**	**Units**	**LOD**	**AVERAGE**
Dissolved Aluminium	TM30/PM14	ug/l	<20	<20
Dissolved Barium	TM30/PM14	ug/l	<3	5.21
Dissolved Boron	TM30/PM14	ug/l	<12	3356.60
Dissolved Calcium	TM30/PM14	mg/l	<0.2	433.35
Total Dissolved Iron	TM30/PM14	ug/l	<20	<20
Dissolved Magnesium	TM30/PM14	mg/l	<0.1	1493.83
Dissolved Manganese	TM30/PM14	ug/l	<2	<2
Dissolved Potassium	TM30/PM14	mg/l	<0.1	419.32
Dissolved Sodium	TM30/PM14	mg/l	<0.1	11283.00
Dissolved Strontium	TM30/PM14	ug/l	<5	8992.25
Calcium Hardness Dissolved (as CaCO3)	TM30/PM14	mg/l	<0.5	1099.97
Magnesium Hardness Dissolved (as CaCO3)	TM30/PM14	mg/l	<0.5	5993.61
Total Hardness Dissolved (as CaCO3)	TM30/PM14	mg/l	<1	7289.43
Fats Oils and Grease	TM5/PM30	ug/l	<10	<10
Fluoride	TM173/PM0	mg/l	<0.3	1.36
Sulphate	TM38/PM0	mg/l	<0.5	2901.96
Chloride	TM38/PM0	mg/l	<0.3	19388.59
Nitrate as N	TM38/PM0	mg/l	<0.05	<0.05
Nitrite as N	TM38/PM0	mg/l	<0.006	<0.006
Total Alkalinity as CaCO3	TM75/PM0	mg/l	<1	126.60
Sulphide	TM106/PM0	mg/l	<0.01	<0.01
Dissolved Organic Carbon	TM60/PM0	mg/l	<2	<2
Electrical Conductivity @25C	TM76/PM0	uS/cm	<2	48726.15
pH	TM73/PM0	pH units	<0.01	7.91
Silica	TM52/PM0	mg/l	<0.01	0.94
Total Dissolved Solids	TM20/PM0	mg/l	<35	35602.94
Total Suspended Solids	TM37/PM0	mg/l	<10	163.11
Volatile Suspended Solids	TM37/PM0	mg/l	<10	34.53
Chlorophyll A*	Subcontracted	ug/l	<5	<5
Total Organic Carbon	TM60/PM0	mg/l	<2	<2
Turbidity	TM34/PM0	NTU	<0.1	8.83

Table 4-2 provides a general indication of the upper limit of parameters that may be put through a RO membrane. Please note that these values differ for different membrane manufacturers and is only provided for explanatory purposes. This implies that if any of the raw water constituents are above these limits, it has to be removed by pre-treatment prior to passing through the RO membranes.

Table 4-2 Typical water quality limits prior to RO

Parameter	Unit	Recommended limit (upstream of RO)
Iron	mg/l	0.05
Manganese	mg/l	0.02
Turbidity	mg/l	0.5
Suspended solids (TSS)	mg/l	1
SDI	mg/l	4
Chlorophyll	mg/l	0.002
DOC	mg/l	2
Hydrocarbons	mg/l	0.1

Each proposed treatment step is discussed in the paragraphs that follow and the reader is to note two filtration options are provided.

Prechlorination

The dosing of an oxidant, such as chlorine, is envisaged to control and minimise microbial growth, in order to avoid membrane biofouling. Instead of continuous dosing, chlorine is more and more applied periodically. This method is deemed more effective and also reduces the chlorine load to the RO membranes (chlorine damages most RO membranes). Sodium hypochlorite at shock dosages as high as 10 mg/l is anticipated. After shock dosing and before the system goes into operation again, all chlorine containing feed water it is to be rinsed out carefully and the absence of chlorine is to be verified.

The point of application is to be as soon as possible after seawater abstraction as this will also prevent any biofouling of the pipework and reservoirs prior the actual WTW. It is therefore proposed to install a manually initiated sodium hypochlorite dosing facility at the raw water pump station for this purpose.

In-line coagulation

In order to remove smaller colloidal inorganic and organic particles coagulation/flocculation is envisaged. This causes the smaller particles to form bigger particles that can be readily removed by the filtration step that follows it. In addition to the dosing of a coagulant such as ferric chloride, pH adjustment will probably also be required as coagulation is pH dependant.

Dual media sand filtration (option 1)

The most common pre-treatment for open seawater is multimedia filtration. Dual media pressure filtration (sand and anthracite), with a hydraulic loading rate not exceeding 8 m/hr is usually employed. The preliminary design conducted for this report included for three 2,5m diameter dual media filters at a hydraulic loading rate of 5 m/hr. Backwashing will be allowed for and will include a separate pump for backwashing as well as an air scour facility. Backwashing of each of the pressure filters will typically occur once every 24 hrs. Each filter will be equipped with five actuated valves (inlet, outlet, water backwash in, air backwash in & backwash water out) and the complete backwash sequence will be automated. Up-stream and down-stream pressure sensors will be provided in order to indicate the pressure drop across the filter bank, and when this value exceeds a pre-set value, an alarm on the SCADA will indicate that a backwash sequence is required.

Filtered water will be collected in a separate backwash tank before overflowing into the clean water tank in order to ensure that there is always sufficient water available for backwash purposes.

An on-line turbidity meter, installed after filtration, shall provide real time indication of the process performance of the filters.

Ultrafiltration (option 2)

Ultrafiltration (UF) pre-treatment involves forcing seawater through a membrane with very fine pores. Particles larger than the pores are filtered out. It is understood that UF membranes usually reject particles larger than 0.05 micron, where media filtration only capture particles larger than about 10 micron. The obvious advantage of UF is that the smaller particle rejection will result in an increased RO membrane life expectancy. However, UF has the following disadvantages:

- In addition to frequent normal backwashes, UF requires chemical backwashing from time to time to remove fouling on the membrane.
- As with other membranes, UF membranes need to be replaced after a number of years depending on the manner in which it is operated (7 years is sometimes used for indicative purposes).
- UF membranes have pressure drop across that must be overcome by pumping the seawater through it at a pressure of approximately 1.5 bar (this is however similar to the pressure drop for media filtration)

24 x polyethersulfane (PES) UF membranes, each with an area if 40m^2, at a flux of 60 lmh, have preliminary been sized for this project.

Sedimentation / Dissolved Air Flotation (DAF)

The test results for total suspended solids (TSS) of the seawater samples are higher than what was expected and is of concern. Two additional samples have been taken and will be send to a different laboratory for confirmation. TSS provides one with an indication of the amount of solids or "dirt" in the water that needs to be removed. Another test used for the same purpose is the turbidity rest. For some of the same samples tested, the TSS value was much higher than expected whereas the turbidity test result was much lower. For these TSS values (some were in excess of 200 mg/l), an additional phase separation process (such as DAF or sedimentation) will be required prior to the sand filters / UF membranes. However, for the same sample, the turbidity test result values would indicate that the water might be put directly onto the sand filters / UF membranes.

The current installation does not include for sedimentation or DAF step in the process train prior to sand filtration and at this stage, allowance has not been made for any of these additional processes. Once the additional samples have been analysed and the test results have been received, further comment will be made on the matter. It must be noted that there is not space available inside the existing building for these additional processes (which is a requirement) and that the estimated cost for a DAF unit (occupies less space than a settling tank) is expected to be in excess of R2,5 mil.

POST TREATMENT

Post treatment of desalinated water entails the stabilisation and disinfection of the water. Stabilisation is required as desalinated water is corrosive as it contains negligible concentrations of calcium, magnesium and carbonate. Stabilisation is achieved by the recarbonation of the water to ensure a positive calcium carbonate precipitation potential (CCPP). This can be achieved by dosing chemicals such as lime, CO_2, calcium carbonate, soda ash (sodium carbonate), caustic soda, sodium bicarbonate and calcium chloride. Dosing a combination of sodium bicarbonate (to provide the carbonate species) and calcium chloride (to provide the calcium) is envisaged for this project. Although possibly not most cost effective in terms of operational costs, it will be relatively easy to get these chemicals on the island and the dosing systems for these chemicals are relatively simple when compared to lime dosing or the provision of calcium carbonate filters.

As is the case with most conventional WTWs, the final water needs to be disinfected to prevent biological growth in the downstream distribution system. Chlorine is usually used for this purpose and can be dosed in various forms (gas/sodium hypochlorite/calcium hypochlorite), with calcium hypochlorite being proposed for this application, considering the size and the location of the WTW.

4.2 ENERGY RECOVERY

The majority of the energy required in a desalination plant is for the pressure pump to "drive" the water through the RO membrane. The current plant does not utilise any form of energy recovery and only has an orifice plate which breaks this pressure to create the necessary backpressure. Technologies exist today that incorporate energy recovery through pressure exchange and boosting by using the pressurized brine and transferring energy into the influent seawater.

Currently, two reliable energy recovery systems are available, viz. pelton-type turbines and pressure exchangers. Pressure exchangers are gaining popularity due to their better efficiencies and independent operation. The preliminary design included in this report allows for an isobaric pressure-exchanger energy recovery system as detailed in Figure 4-1 below. A booster pump must be installed for the exchanger in order to recover the pressure losses over the RO system (brine side) and over the pressure exchangers. This pump must be able to boost the pressure by approximately 26 m.

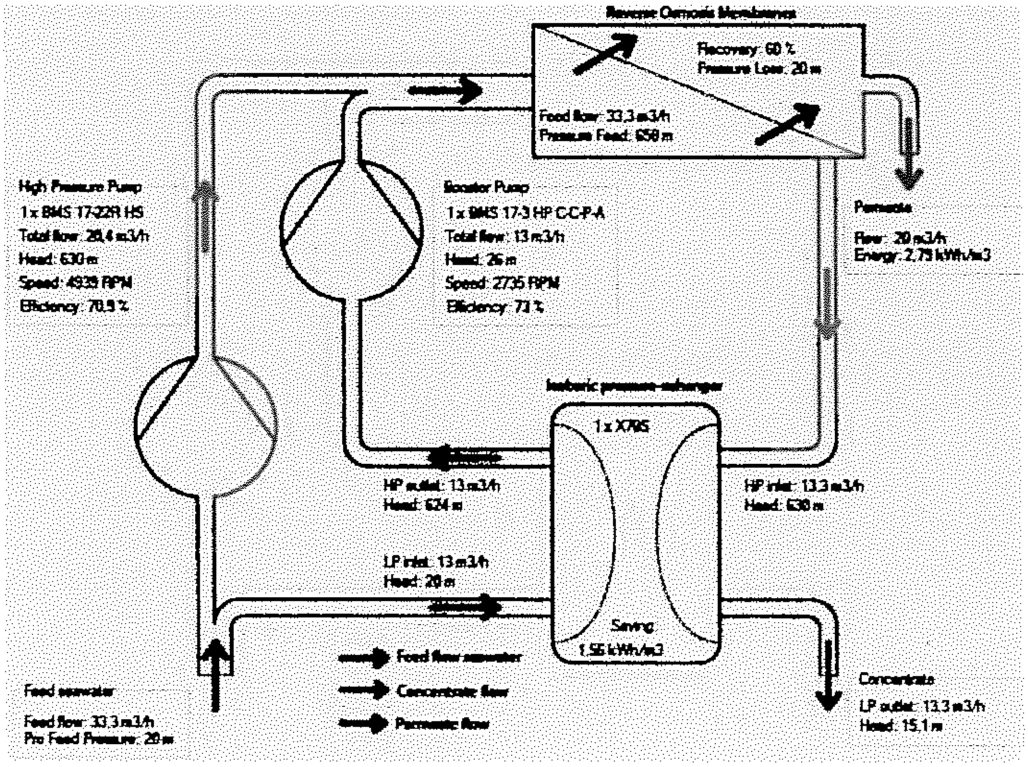


Figure 4-1 Isobaric pressure exchanger

4.3 AUTOMATION

Although the majority of the existing plant is currently operated manually, it is proposed to install a completely automated facility and SCADA system where for example backwashing of filters and the chemical cleaning of membranes will be initiated by the push of a button. It is proposed to provide on-line measurement of for example conductivity and combining it with an alarm to warn the operator that a pre-set value is being exceeded.

Depending on the needs of the Client, a telemetry system can be installed where the levels of the reservoirs can be indicated on the SCADA and the WTW data such as flows, conductivity or alarms can be provided to an off-site location.

5 EXISTING INFRASTRUCTURE (OTHER THAN ACTUAL DESALINATION PLANT)

5.1 BUILDINGS

The existing plant is housed in a covered stone and concrete structure which used to be a water reservoir. The structure is divided into two equal sections, one for the plant and storeroom and the other half serves as a reticulation reservoir for the permeate from the desalination plant. The structure is 30 x 15m in total, with 300 x 300mm concrete columns spaced at 2.75m c/c over the length and at 6.8m c/c over the width. The condition of this structure is discussed in detail under Paragraph 5.6.

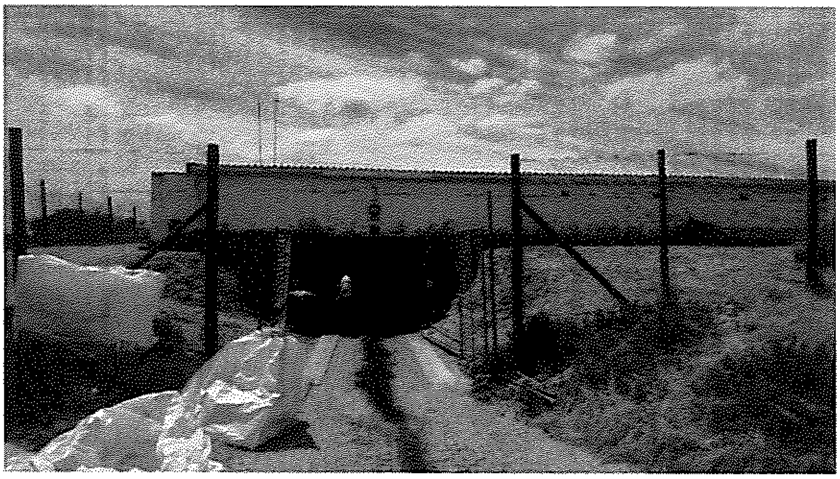


Figure 5-1 Desalination building below NGL

5.2 RESERVOIRS

There are three 1.2Ml treated water reservoirs around the desalination plant. Two are currently in use and these two reservoirs are situated lower than the reservoir which is in the same structure as the current desalination plant. This causes lower pressures to be experienced at residents' houses on the island.

The higher reservoir connected to the desalination plant was reportedly in use until the leakage worsened to such an extent that the reservoir was decommissioned. This reservoir has a rubber/bituminous waterproofing coating.

5.3 POWER

The plant runs off the power from the main power generating facility of the island. There is also a backup generator specifically for the WTW, which is operated by RIM.

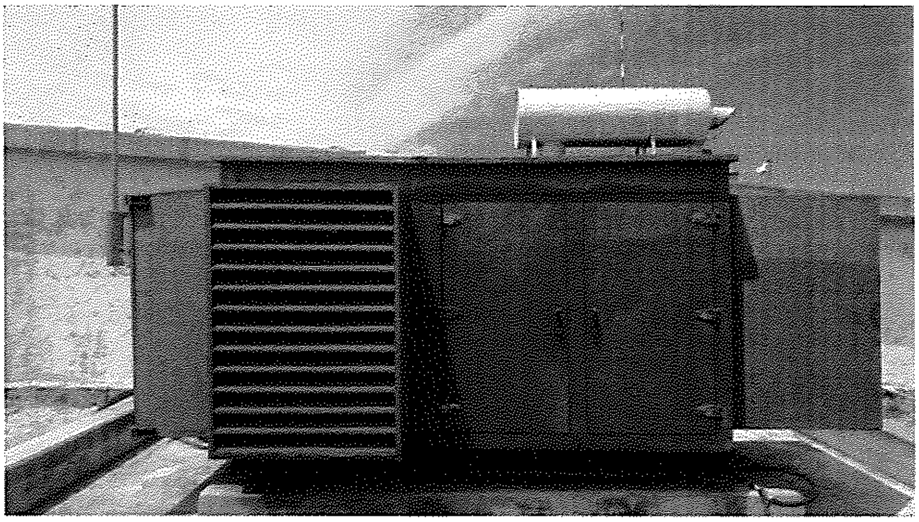


Figure 5-2 Desalination plant backup generator

5.4 INTAKE STRUCTURE

The seawater intake structure, called Alpha 1, has two pumps located on either end of a convenience store and look out point on the southeast side of the island.

One intake is a concrete sump with a 30kW submersible pump with a capacity of 120m^3/hr, pumping seawater to the seawater reservoir. The structure has screens which prevents larger particles from entering the sump from the ocean. The sump is completely submerged during high tides and can only be worked on/accessed during low tides.

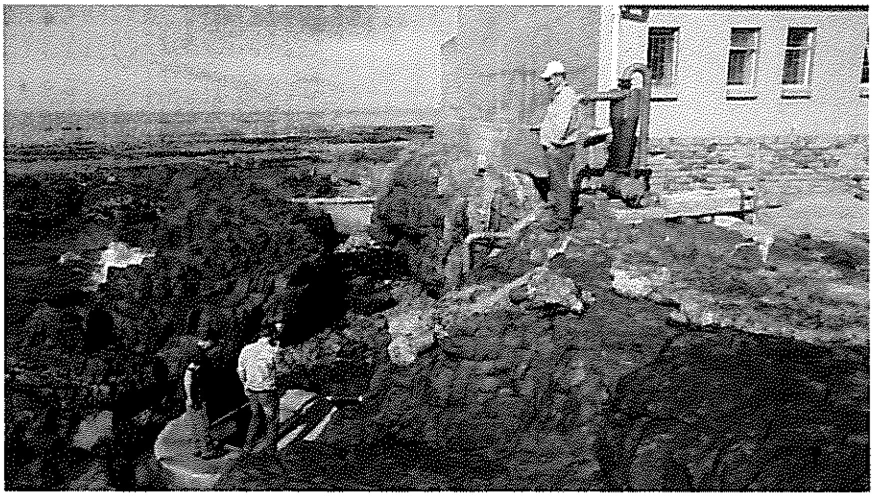


Figure 5-3 Submersible seawater pump

The other intake has an 18.5kW centrifugal pump capable of pumping 75m³/hr. This pump needs to be primed manually as it is situated above ground (and sea level) with a suction pipe which runs into the ocean below. This pump does not switch off automatically when the seawater reservoir is filled and this causes the reservoir to overflow.

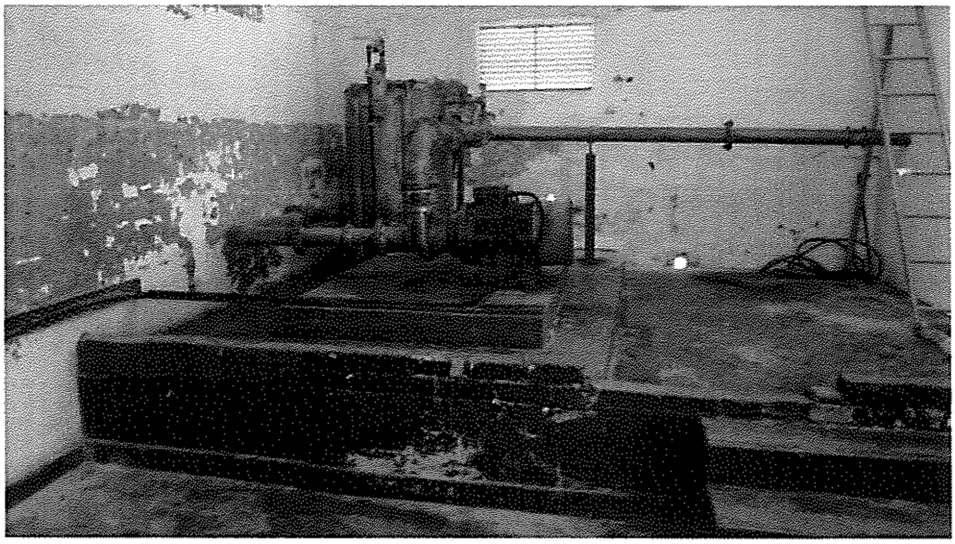


Figure 5-4 Centrifugal seawater pump

Figure 5-5 Seawater reservoir overflowing

5.5 BRINE DISPOSAL PIPELINE

Currently all brine from the desalination plant is disposed of into a separate pipeline which flows to the old jetty and is disposed of in the ocean. There are connections from this brine pipeline to the existing wastewater system.

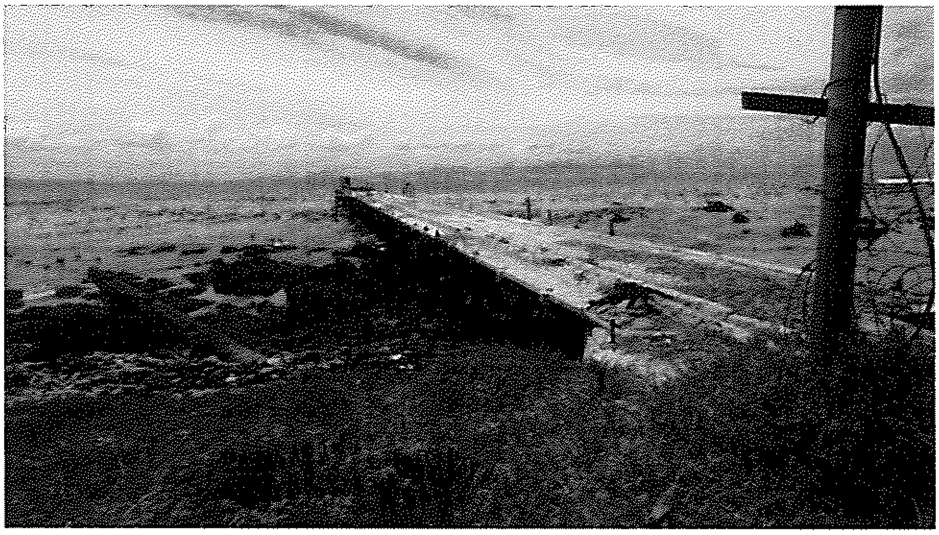


Figure 5-6 Brine disposal pipeline runs below jetty

5.6 UPGRADING OF EXISTING INFRASTRUCTURE

BUILDINGS

Upgrading/refurbishment of the building housing the desalination plant falls within the scope of project.

DESALINATION BUILDING

The existing desalination plant is housed within a structure that also houses a reservoir that is not in operation as it is reportedly leaking. Please refer to Figure 5-7 and Figure 5-8 below for a photograph depicting the outside of the structure. Annexure A contains a layout plan of the complete structure. Figure 5-9 to Figure 5-15 depict the condition of various element of this structure. The outside wall of the structure acts as a retaining wall and encloses the complete desalination plant (including storage area) as well as the reservoir. A portion of the wall was removed in order to install the door to the desalination plant (please refer Figure 5-15 below) and from this it can be seen that up to the top of the door level, the wall is constructed of what seems to be stones and cement. Figure 5-16 below depicts the anticipated materials of construction of the complete retaining wall. This stone retaining wall also seems much older than the remainder of the structure. On top of this is what seems to be a ringbeam of approximately 1,0m high. The whole structure is covered by a roof consisting of AC roof tiles supported on wooden trusses, which are in turn supported on the ringbeam on top of the retaining wall on the outer perimeter as well as four rows of concrete columns on the inside.

The existing reinforced concrete columns show signs of rutting and steel is exposed in places.

Although the floor shows no obvious signs of structural faults, it is very uneven and has no clear drainage point. There is a temporary sump cut into the concrete floor, which has a submersible pump to drain the building in case of flooding.

The existing structure's asbestos roof sheets are worn and is leaking. The existing trusses, bargeboards, rake verges and facia boards of the desalination building and seawater reservoir are not in an acceptable condition and will be need to be replaced.

The structural integrity of the retaining wall does not seem to be compromised as a visual inspection on the inside (outside is covered by soil) did not show deflections or signs of excessive cracking that might be cause of concern for structural failure. However, light cracking was observed and this could result in operational problems such as the ingress of water and the subsequent moisture problems such as the peeling of paint that is currently being experienced. Although it is unlikely that this retaining wall will fail, the structural integrity cannot be guaranteed and an option for the replacement of the complete structure is also provided. The condition of the brick wall on top of the retaining wall is however questionable as it is showing signs of cracking. Two options with regards to the structure housing the desalination facility is therefore available viz. replacing the top structure on top of the retaining wall only and replacing the complete structure. A further option for re-constructing the reservoir within the structure is also provided (complete re-construction of building including reservoir).

For the option of replacing the top structure only, it can be achieved by first replacing the roof and ringbeam on the side where the storage facility is. Once this has been completed, the new desalination facility can be installed inside the already refurbished area, after which the roof and ringbeam of the area which houses the current desalination facility can be replaced. For the replacement of the complete structure, it is envisaged that a reinforced concrete retaining wall will replace the existing stone retaining wall. This will entail removal of the soil around the structure and stockpiling it, for the duration of construction before replacing it after completion.

The following further needs to be taken into consideration with regards to the replacement of the complete structure including retaining wall:

- The removal of the retaining wall will require a heritage impact assessment (HIA) and the issue of a license for the removal of it. The expected timeframe of the HIA is approximately three months, but the issue of a license cannot be guaranteed. It will therefore only be known whether this option is available once the HIA has been completed and a license requested.

- Large amounts of building rubble will have to be disposed of; the expected cost of which will be substantial, especially if it is required to be removed from the island.
- A temporary structure around the existing desalination plant will have to be constructed to protect it while construction is in progress. This will be difficult to achieve and will therefore also be very costly.
- Once the existing stone wall has been removed, the founding conditions will have to assessed and a possible geotechnical investigation will be required to obtain the information required in order to design the new reinforced concrete retaining wall.

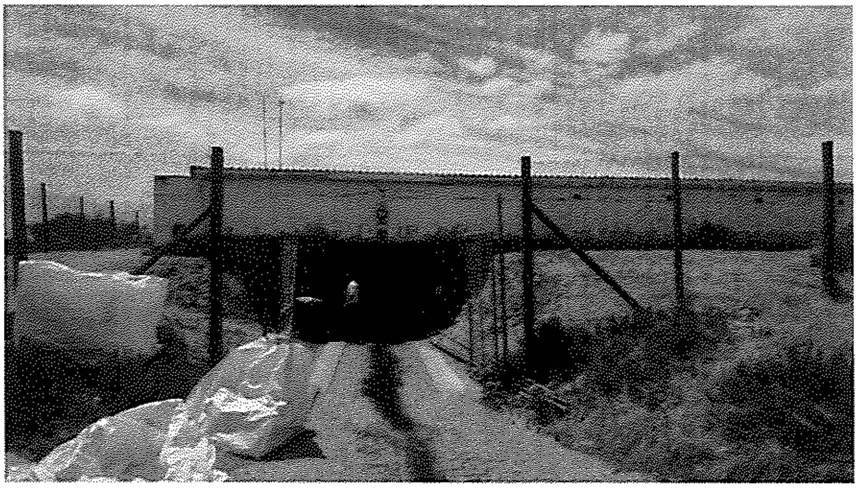


Figure 5-7 South Western Elevation of the Desalination Building

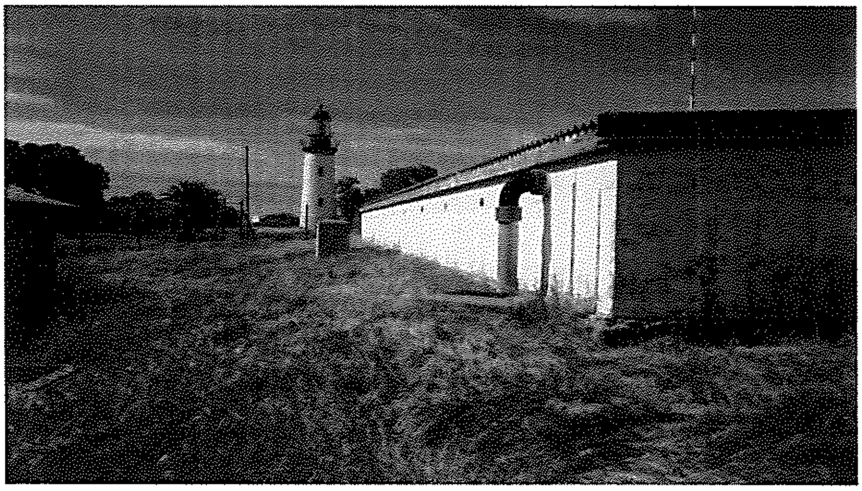


Figure 5-8 North Eastern Elevation of the Desalination Building

Figure 5-9 Exposed reinforcement on columns

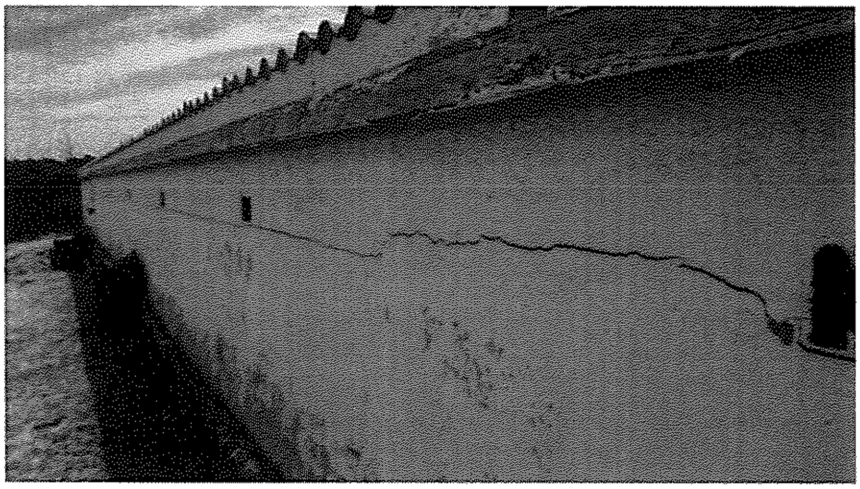


Figure 5-10 Cracks between concrete wall and brickwork

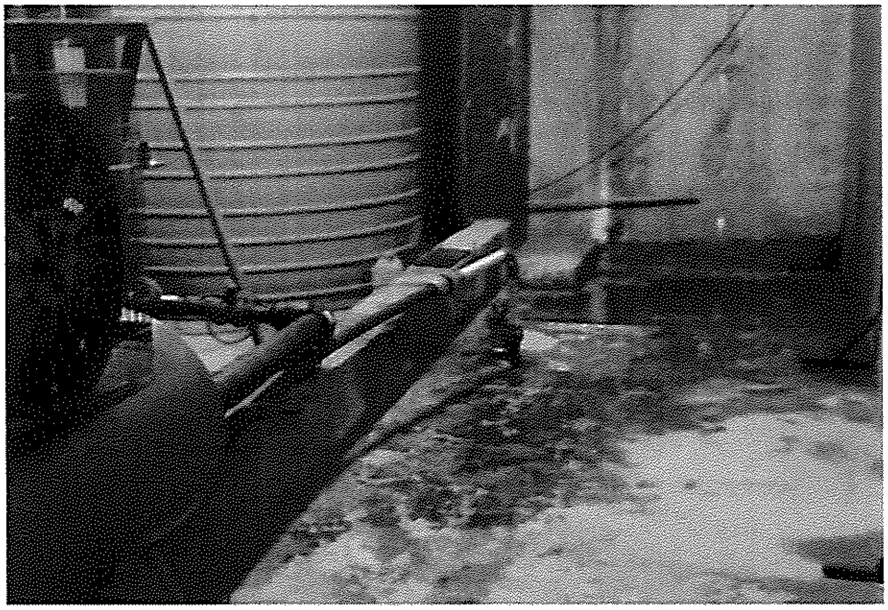


Figure 5-11 Submersible pump in temporary drainage sump

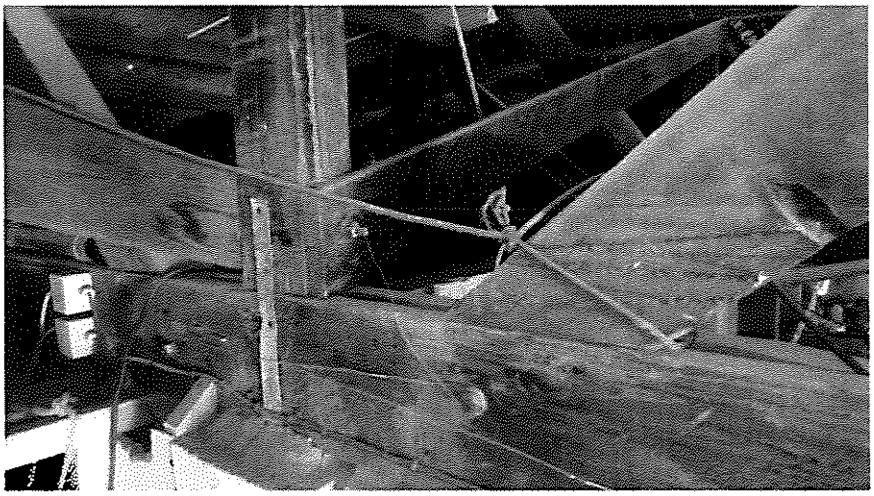


Figure 5-12 Trusses with rusted bolts and nuts

Figure 5-13 Existing roofsheets of seawater reservoir

Figure 5-14 Openings through roofsheets

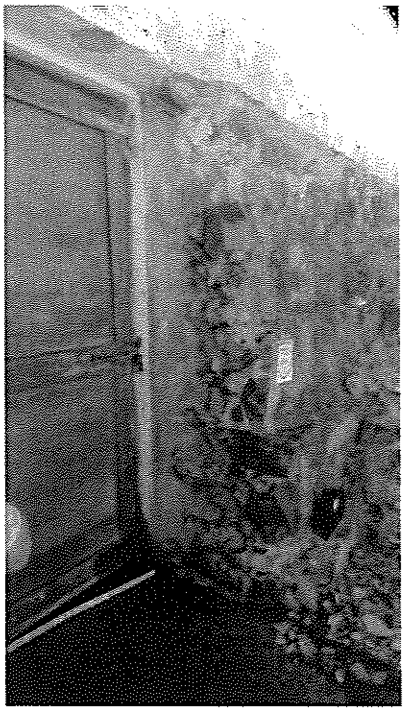


Figure 5-15 Photograph depicting outer retaining wall of Desalination Building

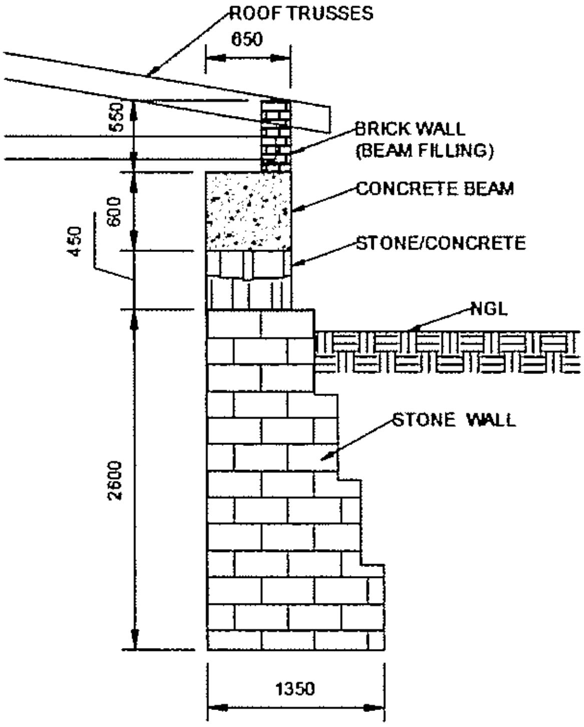


Figure 5-16 Sketch depicting outer retaining wall of Desalination Building

COSTING

Due to various options available for the refurbishment of the existing desalination plant building, 3 costing options have been provided. Each of these options are discussed below. Where applicable, the costing of the options exclude the following, as they could not be priced for at this stage:

- Allowance for hard rock in excavation other than removal of existing foundations.
- Any additional work required over and above typical foundations as may be required by the geotechnical assessment.
- Specialist studies/assessments required, such as heritage impact assessment, environmental impact assessment and geotechnical foundation assessment.
- Additional transporting costs for large trusses to the island.
- Area for disposal of soil and building rubble (stone wall), if allowed, needs to be confirmed by Client.
- Temporary building around desalination equipment for protection during civil construction.
- Relocation of existing services (not known).
- Additional cost for the phasing of the works, to ensure existing plant remains in operation.
- Relocation of the desalination plant generator.

OPTION 1:

Option 1 is the least costly option which does not allow for the demolition of the existing stone wall completely. It does include for the demolition of the existing 1.6m of concrete ring beam and beam filling which currently shows signs of cracking, and replacing it with reinforced concrete walls and new brickwork.

This option allows for the existing roof trusses to be removed and replaced with new trusses. A complete new roof covering, consisting of 0.8mm galvanised epoxy finished roof sheets, has also been allowed for.

The existing floor and walls will be cleaned and refurbished by means of concrete repairs. The storage area floor will be filled with mass concrete to level the area and allow for drainage prior to the installation of the new desalination equipment. The entire floor will be painted with self-levelling polyurethane floor coating.

Allowance has been made for the existing columns to be repaired by a specialist concrete repairer who will by means of a hammer test remove all spalling concrete which has been affected by corrosion of steel. Diameter of corroded reinforcement will be measured to ensure they do not require replacing. A corrosion inhibitor will be applied once it is determined that steel does not require replacing. A concrete repair mortar will be applied to reinstate columns. Finally all columns will be repainted.

Refer to Table 5-1 for Option 1 civil cost estimates.

Table 5-1 Civil construction cost estimates Option 1

Robben Island Desalination plant Civil Summary OPTION 1			
Section	Description	Amount	On Island (Civil+40% M&E+20%)
A	Preliminary & General - Civils 20%	R 504 996.90	R 700 947.66
B	WWTW Civil & Structural	R 0.00	R 0.00
	Demolition of walls	R 21 600.00	R 30 240.00
	Concrete works	R 402 264.50	R 563 170.30
	Painting	R 332 700.00	R 465 780.00
	Roof	R 1 768 420.00	R 2 475 788.00
	CIVILS TOTAL	R 3 029 981.40	R 4 235 925.96

OPTION 2:

Option 2 further allows for the demolition and rebuilding of existing retaining walls (exterior walls). Preliminary construction and project cost estimates, as detailed in Table 7-1, as well as the project programme attached as Appendix E, are based on this option.

In addition to the work proposed for option 1, option 2 further includes the following:

- Excavation (and backfill) of soil for 1m working space around structure.
- Demolition and removal of existing stone retaining wall.
- Construction of a new reinforced concrete retaining wall.

Refer to Table 5-1 for Option 2 civil cost estimates.

Table 5-2 Civil construction cost estimates Option 2

Robben Island Desalination plant Civil Summary OPTION 2			
Section	Description	Amount	On Island (Civil+40% M&E+20%)
A	Preliminary & General - Civils 20%	R 666 678.90	R 857 750.46
B	WWTW Civil & Structural	R 0.00	R 0.00
	Earthworks	R 123 000.00	R 172 200.00
	Demolition of walls	R 147 000.00	R 205 800.00
	Concrete works	R 962 274.50	R 1 347 184.30
	Painting	R 332 700.00	R 465 780.00
	Roof	R 1 768 420.00	R 2 475 788.00
	CIVILS TOTAL	R 4 000 073.40	R 5 524 502.76

OPTION 3:

Option 3 allows for the demolition of the entire structure and rebuilding thereof.
This includes all works as mentioned in option 2, but also includes the removal of existing floor slab and columns. Where requires, a new water retaining floor slab and wall will be constructed which will allow half of the structure to be used as a reservoir.
Refer to Table 5-3 for Option 3 civil cost estimates.

Table 5-3 Civil construction cost estimates Option 3

Robben Island Desalination plant Civil Summary OPTION 3				
Section	**Description**		**Amount**	**On Island (Civil+40% M&E+20%)**
A	Preliminary & General - Civils	20%	R 859 066.70	R 1 110 993.55
B	WWTW Civil & Structural		R 0.00	R 0.00
	Earthworks		R 90 200.00	R 126 280.00
	Demolition of walls		R 237 299.40	R 332 219.16
	Concrete works		R 1 866 714.10	R 2 613 399.74
	Painting		R 332 700.00	R 465 780.00
	Roof		R 1 768 420.00	R 2 475 788.00
	CIVILS TOTAL		R 5 154 400.20	R 7 124 460.45

RESERVOIRS

Upgrading/refurbishment of the existing reservoirs falls outside the scope of this project. The one reservoir is reportedly leaking and if the Client wishes WSP PB to investigate this matter further, they are to advise accordingly.

POWER

Upgrading the power supply falls outside the scope of this project. It is anticipated that new desalination facility will have a power requirement not exceeding the power requirement of the existing facility, and therefore additional power capacity will not be required. Although additional infrastructure such as prechlorination and recarbonation is now provided (which was not provided for the original WTW), the total power demand of the WTW will not increase as an energy recovery system is proposed for the high pressure RO feed pumps.

INTAKE STRUCTURE

Upgrading/refurbishment of the existing intake structure falls outside the scope of this project. It was however noted that the mechanical/electrical equipment is old and in need of replacement. Integrating the raw water intake into the SCADA/control system of the desalination plant is an option and the Client's requirements in this regard needs to be indicated, but is considered to be outside the current scope unless indicated differently.

BRINE DISPOSAL

Upgrading/refurbishment of the existing brine disposal pipeline falls outside the scope of this project. It is however suspected that the pipeline is old and in need of repair/replacement and CDC is to indicate if further investigation in this regard is to be undertaken.

6 TIMEFRAMES

6.1 PROGRAMME

A preliminary programme, indicating the expected timeframes, is attached as Appendix E to the report. Please note that the exact timeline for possible HIA and Geotechnical assessments cannot be determine at this stage, the time allowed for these activities are estimated at this stage.

7 COSTING

Please refer Table 7-1 below for an estimated of the expected construction costs. Please note that the costing allows for the UF option as discussed earlier in the report. For preliminary costing a conservative "island factor" allowance of 40% extra for civil works and 20% extra for mechanical works was allowed for due to the nature of working on Robben Island.

This additional cost factor is to make allowance for the following:

- Uncertainty of whether access will be allowed to the island.
- Accommodation on the island.
- Extra time allowance for specialists to visit island.
- Transport of materials to island.
- Availability of parts for machinery on island.

Table 7-1 Preliminary construction cost estimates

Robben Island Desalination plant BoQ Summary				
Section	Description		Amount	On Island (Civil+40% M&E+20%)
A	Preliminary & General - Civils	20%	R 666 678.90	R 857 750.46
B	WWTW Civil & Structural			
	Earthworks		R 123 000.00	R 172 200.00
	Demolition of walls and footings		R 147 000.00	R 205 800.00
	Concrete works		R 962 274.50	R 1 347 184.30
	Painting		R 332 700.00	R 465 780.00
	Roof		R 1 768 420.00	R 2 475 788.00
C	MECHANICAL			
	Preliminary & General		R 605 000.00	R 726 000.00
	ULTRAFILTATION			
	UF feed pumps x 2		R 204 000.00	R 244 800.00
	UF skid		R 2 210 000.00	R 2 652 000.00
	Buffer tank 20m³		R 34 000.00	R 40 800.00
	REVERSE OSMOSIS			
	RO LP pumps		R 204 000.00	R 244 800.00
	RO HP pump and energy recovery		R 975 000.00	R 1 170 000.00
	RO skid		R 1 530 000.00	R 1 836 000.00
	CIP			
	CIP pump		R 136 000.00	R 163 200.00
	CIP tank 2m³		R 8 500.00	R 10 200.00
	Installation		R 371 025.00	R 445 230.00
	Commissioning		R 247 350.00	R 296 820.00
D	Electrical + Electronic			
	Automation		R 510 000.00	R 612 000.00
	MCC		R 442 000.00	R 530 400.00
	Sub Total		**R 11 476 948.40**	**R 14 496 752.76**
	Contingencies	10%	R 1 147 694.84	R 1 449 675.28
	Sub Total		**R 12 624 643.24**	**R 15 946 428.04**
	VAT	14%	R 1 767 450.05	R 2 232 499.93
	Total		**R 14 392 093.29**	**R 18 178 927.96**

<u>NOTE:</u> Stripping, decommissioning and removal/selling of the existing desalination equipment is not included in the pricing table below. Client preference will determine whether this will be a cost included or will be sold off and removed in a separate contract and need to be discussed.

8 RECOMMENDATIONS

The preliminary design included in this report allowed for two separate pre-treatment options viz. media filtration and ultrafiltration (UF). Although it is generally believed that UF is the more capital expensive of the two, it has been found that once a proper automated backwash system is provided and when acceptable hydraulic loading rates are not exceeded, the costs are similar to that of UF. It is understood that UF membranes usually reject particles larger than 0.05 micron, where media filtration only capture particles larger than about 10 micron. The obvious advantage of UF is that the smaller particle rejection will result in an increased RO membrane life expectancy. However, UF has the following disadvantages:

- In addition to frequent normal backwashes, UF requires chemical backwashing from time to time to remove fouling on the membrane.
- As with other membranes, UF membranes need to be replaced after a number of years depending on the manner in which it is operated (7 years is sometimes used for indicative purposes).
- UF membranes have pressure drop across that must be overcome by pumping the seawater through it at a pressure of approximately 1.5 bar (this is however similar to the pressure drop for media filtration)

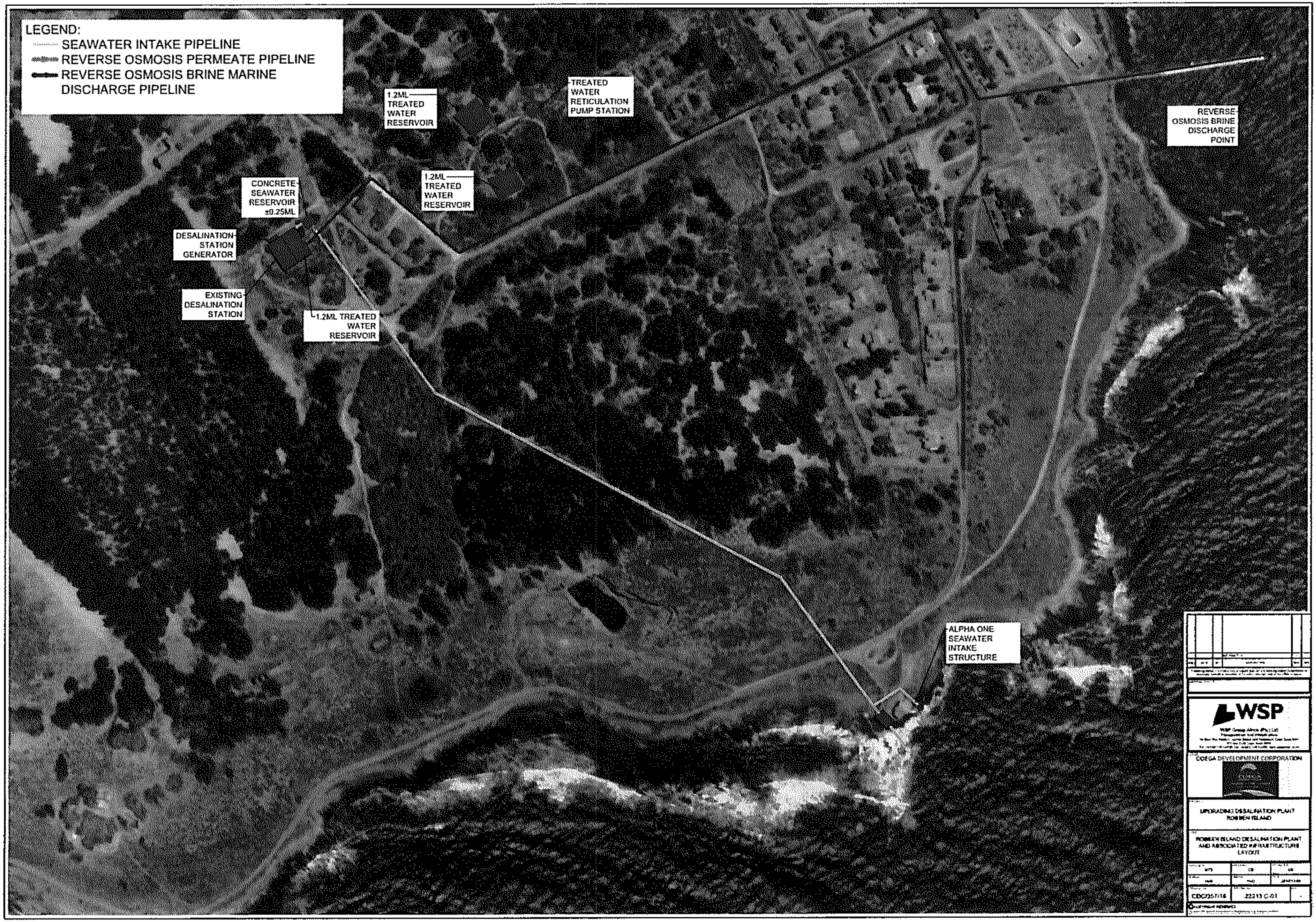
Due to the nature of the equipment being supplied for the desalination plant, it is envisaged and planned to procure a Contractor on a design-build (Fidic Yellow Book) type Contract. The reason being that equipment such as membranes are propriety items and the design values for each manufacturer are different. The specifications will therefore include water quality criteria to be met (performance specification), maximum power usage (and other operating costs), minimum membrane life expectancy (and other life cycle costs), etc., but will not specify exact equipment to be provided. The implication of this is that the process to be employed by the Contractor can not be dictated and it is therefore unsure whether dual media sand filtration or UF will be proposed. However, one of the requirements will be to remain within the storage area of the existing building (the footprint of the building can not be increased and the existing WTW has to remain in operation), and it is therefore anticipated that ultrafiltration will be more likely due to its smaller footprint.

BIBLIOGRAPHY

→ 1.JA du Plessis, AJ Burger, CD Swartz and N Musee (July 2006), A Desalination Guide for South African Municipal Engineers, Department of Water Affairs and Forestry, Water Research Commission

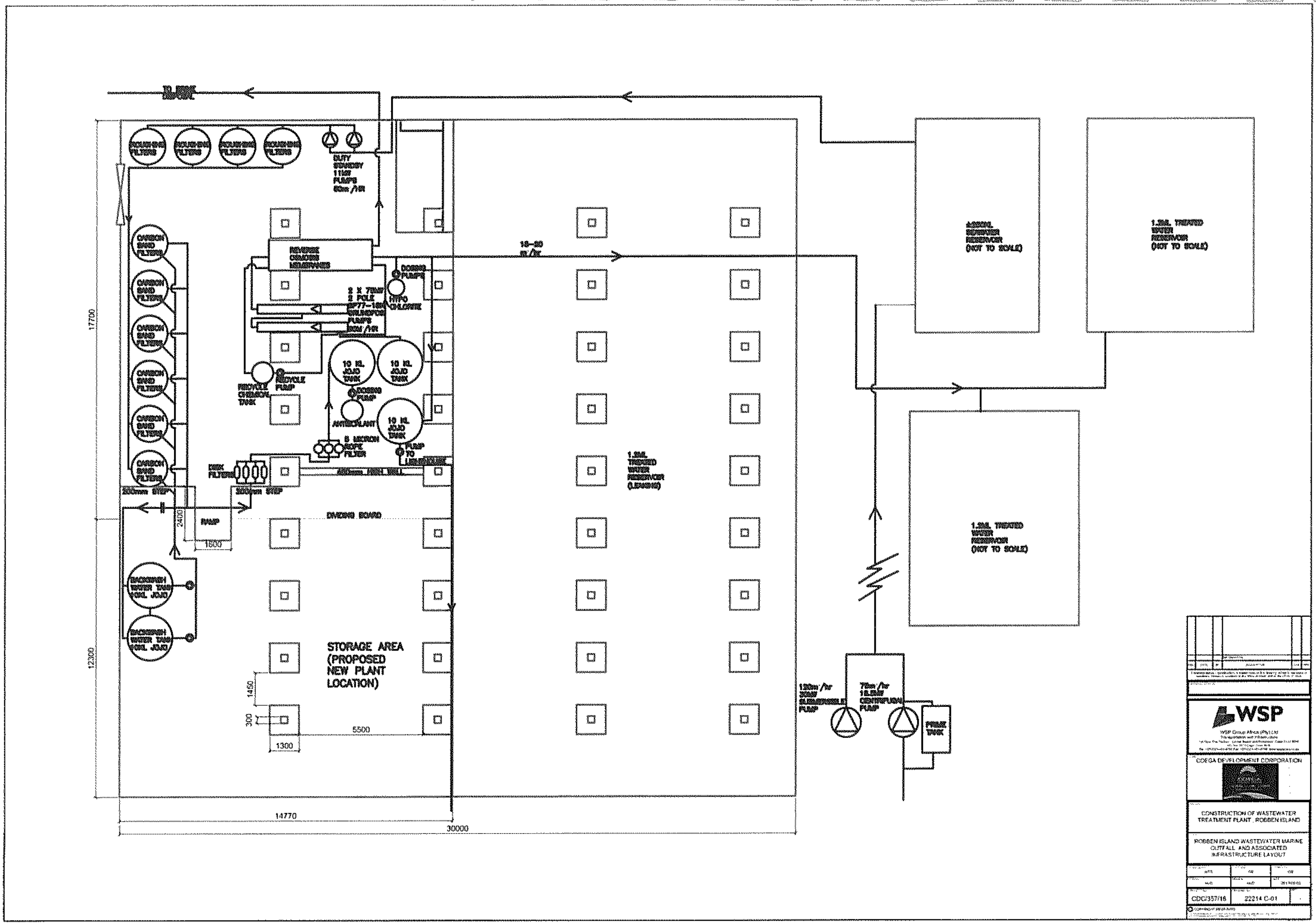
Appendix A

LAYOUT OF DESALINATION PLANT AND ASSOCIATED INFRASTRUCTURE


LEGEND:
SEAWATER INTAKE PIPELINE
REVERSE OSMOSIS PERMEATE PIPELINE
REVERSE OSMOSIS BRINE MARINE DISCHARGE PIPELINE
1.2ML TREATED WATER RESERVOIR
TREATED WATER RETICULATION PUMP STATION
REVERSE OSMOSIS BRINE DISCHARGE POINT
CONCRETE SEAWATER RESERVOIR ±0.25ML
1.2ML TREATED WATER RESERVOIR
DESALINATION STATION GENERATOR
EXISTING DESALINATION STATION
1.2ML TREATED WATER RESERVOIR
ALPHA ONE SEAWATER INTAKE STRUCTURE
WSP
COEGA DEVELOPMENT CORPORATION
UPGRADING DESALINATION PLANT ROBBEN ISLAND
ROBBEN ISLAND DESALINATION PLANT AND ASSOCIATED INFRASTRUCTURE LAYOUT
CDC/257/18
22313 C-01

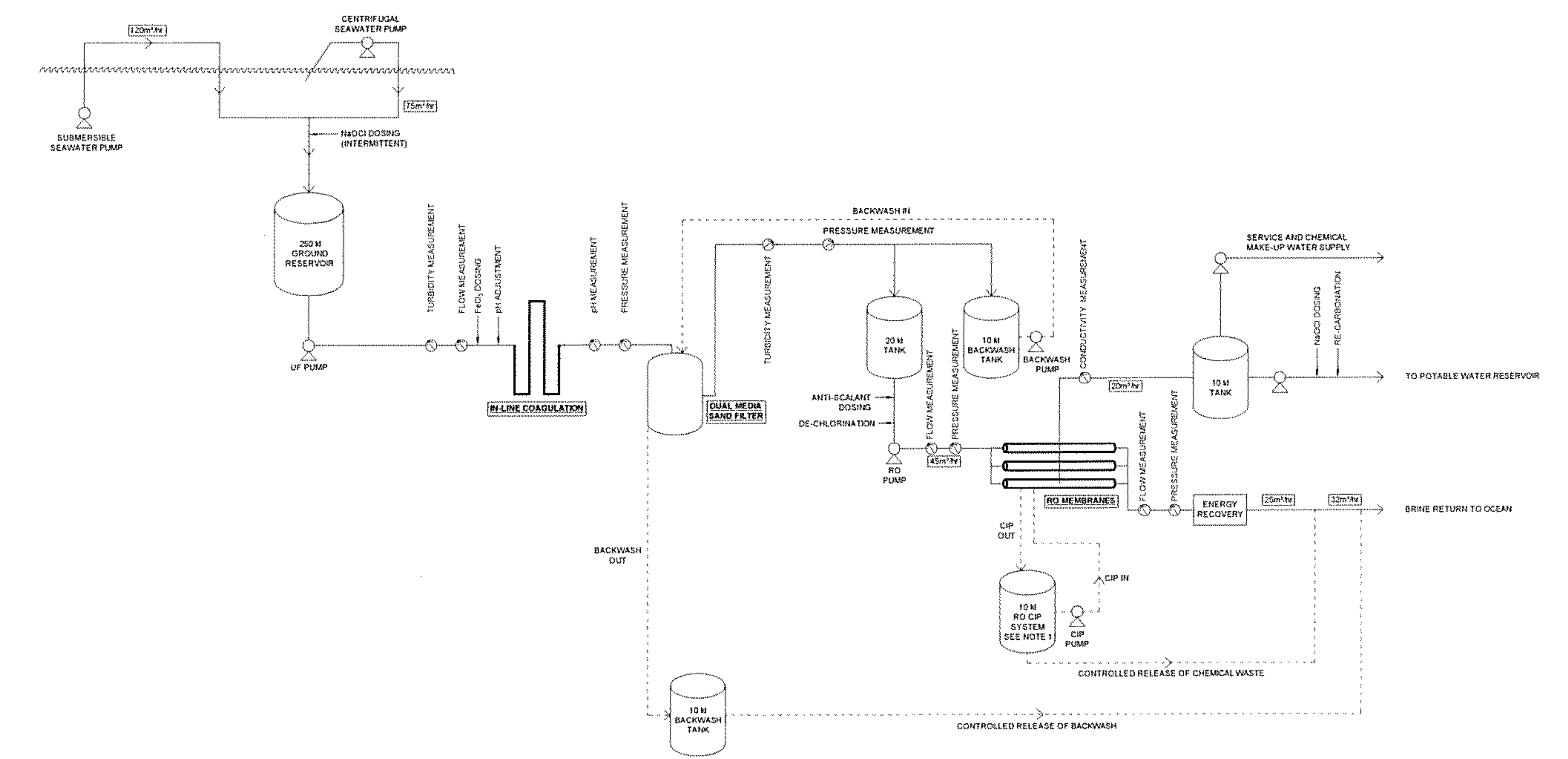
Appendix B

DESALINATION PROCESS SCHEMATIC


ROUGHING FILTERS
CARBON SAND FILTERS
REVERSE OSMOSIS MEMBRANES
DOSING PUMPS
HYPO CHLORITE
10 KL JOJO TANK
RECYCLE PUMP
DOSING PUMP
ANTISCALANT
5 MICRON ROPE FILTER
DISK FILTERS
200mm STEP
RAMP
2400
1600
DIVIDING BOARD
STORAGE AREA (PROPOSED NEW PLANT LOCATION)
1450
300
1300
5500
14770
30000
17700
12300
16-20 m³/hr
1.2ML TREATED WATER RESERVOIR (LEAKING)
1.2ML TREATED WATER RESERVOIR (NOT TO SCALE)
PRIME TANK
WSP
COEGA DEVELOPMENT CORPORATION
CONSTRUCTION OF WASTEWATER TREATMENT PLANT, ROBBEN ISLAND
ROBBEN ISLAND WASTEWATER MARINE OUTFALL AND ASSOCIATED INFRASTRUCTURE LAYOUT
CDC/357/16
22214 C-01

Appendix C

PROCESS FLOW DIAGRAMS



* NOTE 1:
- NaOH DOSING
- H_2SO_4 DOSING
- NaOCl DOSING

REV	DATE	BY	DESCRIPTION	CHK	APD
A	-	-	INITIAL ISSUE	-	-

DRAWING STATUS: PRELIMINARY

If drawing status = construction, a signed copy of this drawing (either in hardcopy or electronic format) is available at the office of origin and at the office of issue.

CLIENT:

WSP | PARSONS BRINCKERHOFF

WSP Group Africa (Pty) Ltd
Development, Transportation and Infrastructure
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Cape Town 8001, South Africa
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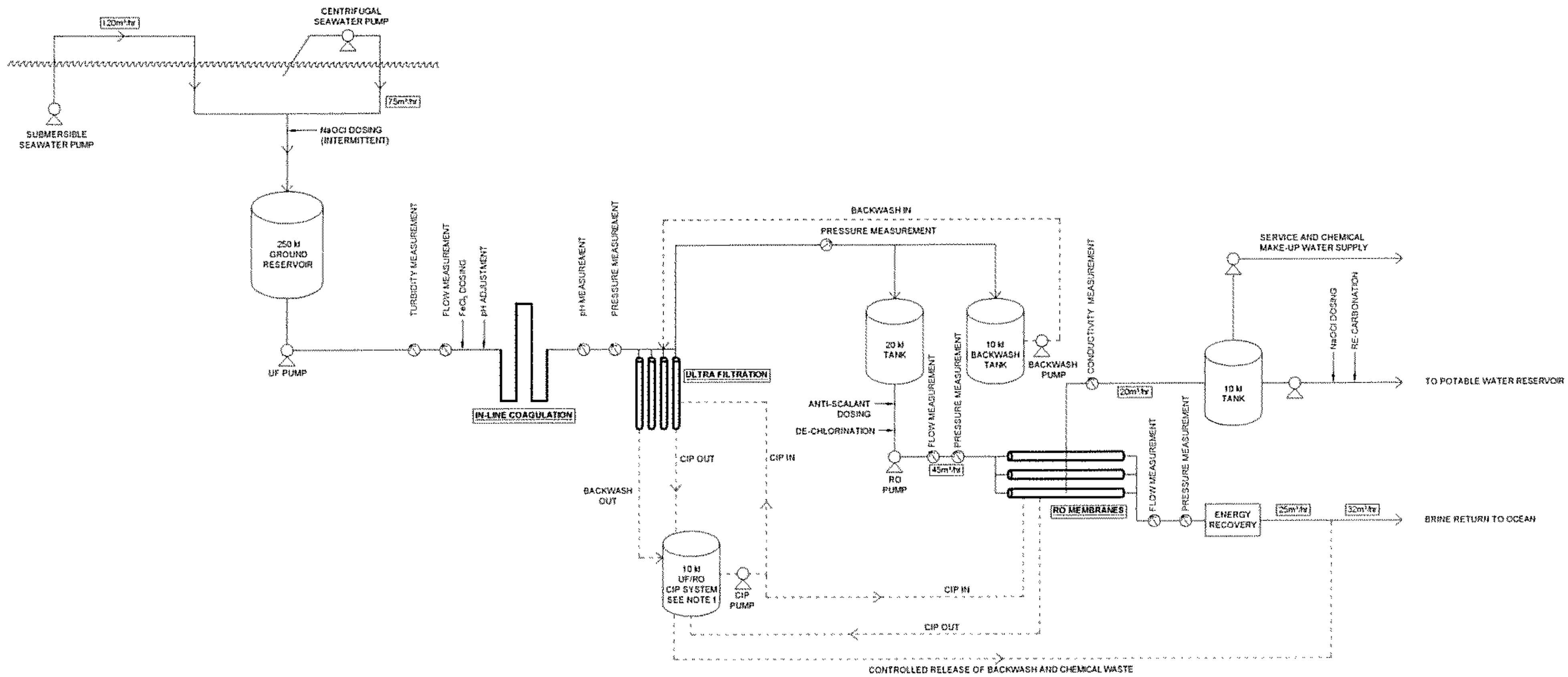
PROJECT: CDC RI DESALINATION

TITLE: PROCESS FLOW DIAGRAM (SAND FILTER OPTION)

SCALE	CHECKED	APPROVED
1:1000	G.B	G.B
DESIGN: G.B	DRAWN: B.T.B	DATE: 2017/03/09
PROJECT No: 22213	DRAWING No: C1100	REV: 0

CESA

TEMPLATE VERSION 1.1



* NOTE 1:
- NaOH DOSING
- H_2SO_4 DOSING
- NaOCl DOSING

REV	DATE	BY	DESCRIPTION	CHK	APD
A	-	-	INITIAL ISSUE	-	-

CLIENT: -

DRAWING STATUS: PRELIMINARY

If drawing status = construction, a signed copy of this drawing (either in hardcopy or electronic format) is available at the office of origin and at the office of issue.

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PROJECT: CDC RI DESALINATION

TITLE: PROCESS FLOW DIAGRAM (UF OPTION)

SCALE: 1:1000	CHECKED: G.B	APPROVED: G.B
DESIGN: G.B	DRAWN: B.T.B	DATE: 2017/03/09
PROJECT No: 22213	DRAWING No: C1000	REV: 0

CESA

TEMPLATE VERSION 1.1

Appendix D

LAB TESTING RESULTS

ROBBEN ISLAND SEAWATER ANALYISIS

Test	Method	Units	LOD	09/01/ 2017	10/01/ 2017	11/01/ 2017	12/01/ 2017	12/01/ 2017	13/01/ 2017	16/01/ 2017	17/01/ 2017	18/01/ 2017	19/01/ 2017	20/01/ 2017	20/01/ 2017	23/01/ 2017	24/01/ 2017
Dissolved Aluminium	TM30/PM14	ug/l	<20	<20	<20	<20	<20	-	<20	<20	<20	<20	<20	<20	-	<20	<20
Dissolved Barium	TM30/PM14	ug/l	<3	4	4	4	4	-	5	5	5	5	5	5	-	6	5
Dissolved Boron	TM30/PM14	ug/l	<12	3383	3390	3345	3465	-	3430	3314	3407	3364	3539	3461	-	3453	3376
Dissolved Calcium	TM30/PM14	mg/l	<0.2	524.5	456.9	486.1	471.4	-	432.3	434.9	413	413.9	458	431.4	-	438.4	401.3
Total Dissolved Iron	TM30/PM14	ug/l	<20	<20	<20	<20	<20	-	<20	<20	<20	<20	<20	<20	-	<20	<20
Dissolved Magnesium	TM30/PM14	mg/l	<0.1	-	-	-	-	-	1344	1409	1533	1491	1571	1615	-	-	-
Dissolved Manganese	TM30/PM14	ug/l	<2	<2	<2	<2	<2	-	<2	<2	<2	<2	<2	<2	-	<2	<2
Dissolved Potassium	TM30/PM14	mg/l	<0.1	450.5	463	490.1	476.3	-	423.3	423.6	387.6	378.6	428.1	396.4	-	427.2	390.3
Dissolved Sodium	TM30/PM14	mg/l	<0.1	11680	12080	11160	11720	-	11460	11660	11580	11430	11310	11200	-	11460	11110
Dissolved Strontium	TM30/PM14	ug/l	<5	9325	8693	8455	9009	-	9397	9422	8491	8703	8734	9041	-	7972	7728
Calcium Hardness Dissolved (as CaCO3)	TM30/PM14	mg/l	<0.5	1190	1184.8	1221.8	1045.5	-	1080.8	1087.3	1032.5	1034.8	1145	1078.5	-	1102.5	1124.5
Magnesium Hardness Dissolved (as CaCO3)	TM30/PM14	mg/l	<0.5	6207.6	6329.4	6287.4	6123.6	-	5644.8	5917.8	6438.6	6262.2	6598.2	6783	-	6186.6	5850.6
Total Hardness Dissolved (as CaCO3)	TM30/PM14	mg/l	<1	7132	7778	7276	7365	-	6726	7005	7471	7297	7743	7862	-	7010	7375
Fats Oils and Grease	TM5/PM30	ug/l	<10	-	<10	<10	<10	-	<10	<10	<10	<10	<10	<10	-	<10	<10
Fluoride	TM173/PM0	mg/l	<0.3	1.7	1.7	1.7	1.7	-	1.2	1.2	1.3	1.2	1.3	1.3	-	1.2	1.3
Sulphate	TM38/PM0	mg/l	<0.5	2810.4	2970.2	2983	2856.6	-	2938.6	2966.1	2908.3	2929.6	2895.9	2917.2	-	2904.4	2874.9
Chloride	TM38/PM0	mg/l	<0.3	20048.2	20057.8	19499.9	19422.4	-	18134.5	18045.3	18863.9	18270.4	18280.8	17851.8	-	20446.1	20342
Nitrate as N	TM38/PM0	mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-	<0.05	<0.05
Nitrite as N	TM38/PM0	mg/l	<0.006	<0.006	<0.006	<0.006	<0.006	-	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	-	<0.006	<0.006
Total Alkalinity as CaCO3	TM75/PM0	mg/l	<1	126	118	130	126	-	122	122	126	124	124	120	-	136	126
Sulphide	TM106/PM0	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Dissolved Organic Carbon	TM60/PM0	mg/l	<2	<2	<2	<2	<2	-	<2	<2	<2	<2	<2	<2	-	<2	<2
Electrical Conductivity @25C	TM76/PM0	uS/cm	<2	50538	50217	50284	49318	-	48570	47283	47599	47592	47026	47427	-	49168	44658
pH	TM73/PM0	pH units	<0.01	8	7.54	7.72	7.82	-	7.94	7.05	7.43	7.64	7.56	7.46	-	8.15	8.1
Silica	TM52/PM0	mg/l	<0.01	0.6	0.1	0.3	0.7	-	1.4	2	1.1	1.6	1.7	1.6	-	<0.01	<0.01
Total Dissolved Solids	TM20/PM0	mg/l	<35	-	57029	57446	36251	-	34196	36776	36093	35016	35557	34950	-	36262	35333
Total Suspended Solids	TM37/PM0	mg/l	<10	-	112	133	142	-	212	184	169	169	193	39	-	91	70
Volatile Suspended Solids	TM37/PM0	mg/l	<10	-	21	32	29	-	35	39	31	27	32	29	-	24	13

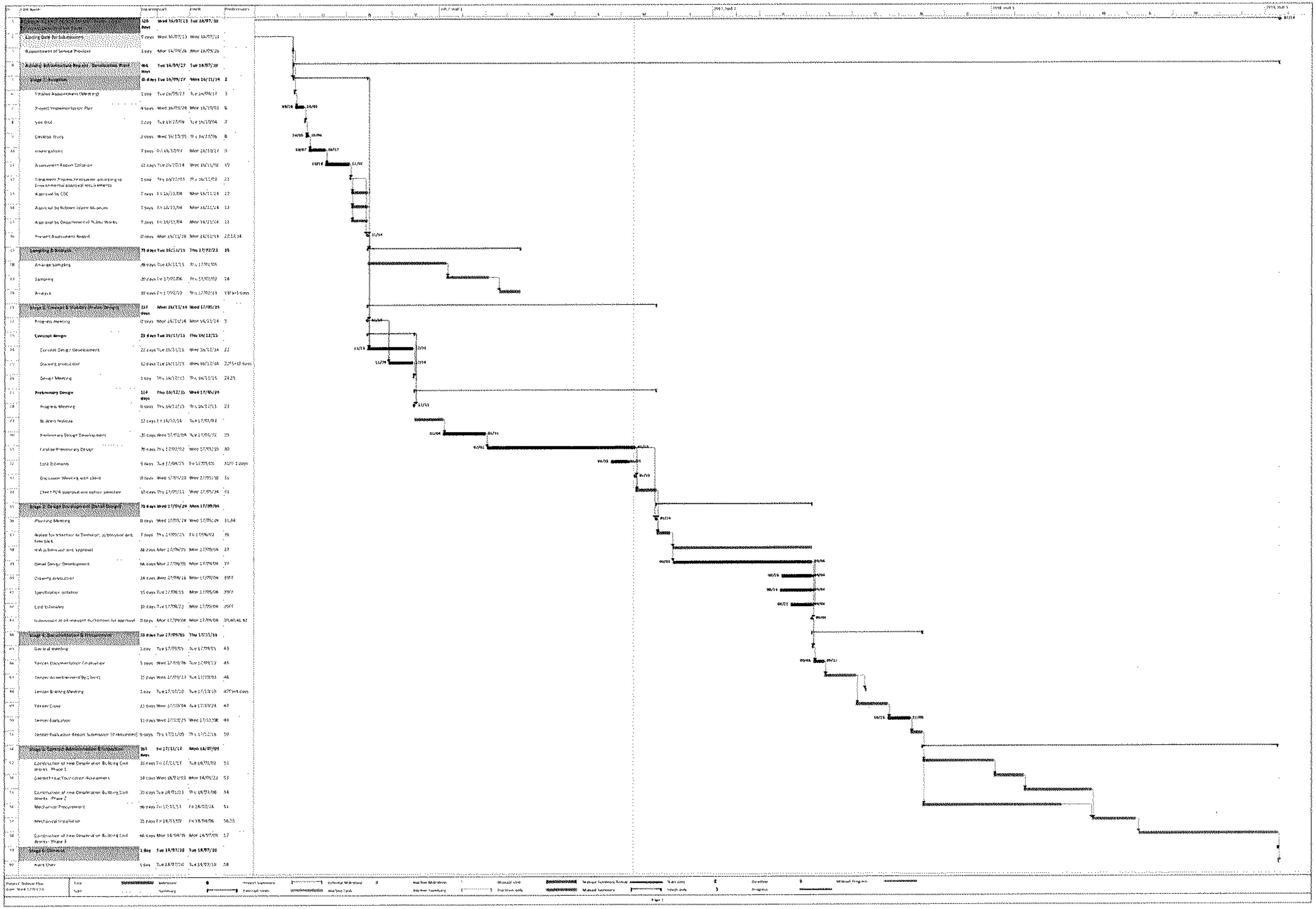
(shaded) Values not used to determine average

ROBBEN ISLAND SEAWATER ANALYISIS

Test	Method	Units	LOD	25/01/ 2017	26/01/ 2017	26/01/ 2017	20/01/ 2017	24/01/ 2017	27/01/ 2017	30/01/ 2017	31/01/ 2017	01/02/ 2017	02/02/ 2017	03/02/ 2017	03/02/ 2017	03/02/ 2017
Dissolved Aluminium	TM30/PM14	ug/l	<20	<20	<20	-	-	-	<20	<20	<20	<20	<20	<20	-	-
Dissolved Barium	TM30/PM14	ug/l	<3	6	5	-	-	-	3	3	<3	3	12	10	-	-
Dissolved Boron	TM30/PM14	ug/l	<12	3598	3432	-	-	-	3089	3072	3131	3169	3218	3496	-	-
Dissolved Calcium	TM30/PM14	mg/l	<0.2	399.8	403.4	-	-	-	410.1	395.7	409.8	426.4	446.7	412.9	-	-
Total Dissolved Iron	TM30/PM14	ug/l	<20	<20	<20	-	-	-	<20	<20	<20	<20	<20	<20	-	-
Dissolved Magnesium	TM30/PM14	mg/l	<0.1	-	-	-	-	-								
Dissolved Manganese	TM30/PM14	ug/l	<2	<2	<2	-	-	-	<2	<2	<2	<2	<2	<2	-	-
Dissolved Potassium	TM30/PM14	mg/l	<0.1	391.4	397	-	-	-	403	389.2	405.2	420.1	440.4	405.1	-	-
Dissolved Sodium	TM30/PM14	mg/l	<0.1	11050	11320	-	-	-	10740	10870	10840	11150	10890	10950	-	-
Dissolved Strontium	TM30/PM14	ug/l	<5	8366	7319	-	-	-	9620	9752	10190	9739	9429	10460	-	-
Calcium Hardness Dissolved (as CaCO3)	TM30/PM14	mg/l	<0.5	1108.8	1065	-	-	-	1027	1022.8	1038.8	1047.5	1117	1244.5	-	-
Magnesium Hardness Dissolved (as CaCO3)	TM30/PM14	mg/l	<0.5	5670	6518.4	-	-	-	5363.4	5523	5493.6	5317.2	5850.6	5506.2	-	-
Total Hardness Dissolved (as CaCO3)	TM30/PM14	mg/l	<1	7178	6834	-	-	-	-	-	-	-	-	-	-	-
Fats Oils and Grease	TM5/PM30	ug/l	<10	<10	<10	-	-	-	<10	<10	<10	<10	<10	<10	-	-
Fluoride	TM173/PM0	mg/l	<0.3	1.3	1.3	-	-	-	1.3	1.2	1.3	1.3	1.3	1.3	-	-
Sulphate	TM38/PM0	mg/l	<0.5	2947.9	2926.1	-	-	-	2872.1	2883.7	2858.9	2820.5	2867.5	2907.2	-	-
Chloride	TM38/PM0	mg/l	<0.3	20564.3	20487.3	-	-	-	19753.1	19807	19833.7	19953.1	18792.8	19317.3	-	-
Nitrate as N	TM38/PM0	mg/l	<0.05	<0.05	<0.05	-	-	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-	-
Nitrite as N	TM38/PM0	mg/l	<0.006	<0.006	<0.006	-	-	-	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	-	-
Total Alkalinity as CaCO3	TM75/PM0	mg/l	<1	122	124	-	-	-	142	124	122	128	134	136	-	-
Sulphide	TM106/PM0	mg/l	<0.01	<0.01	<0.01	<0.01	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-
Dissolved Organic Carbon	TM60/PM0	mg/l	<2	<2	<2	-	-	-	<2	<2	<2	<2	<2	<2	-	-
Electrical Conductivity @25C	TM76/PM0	uS/cm	<2	46426	46898	-	-	-	50507	51305	50763	49556	50226	49162	-	-
pH	TM73/PM0	pH units	<0.01	8.2	8.21	-	-	-	8.14	8.24	8.3	8.29	8.3	8.04	-	-
Silica	TM52/PM0	mg/l	<0.01	<0.01	<0.01	-	-	-	0.9	0.8	0.7	0.5	0.5	0.5	-	-
Total Dissolved Solids	TM20/PM0	mg/l	<35	37310	35175	-	-	-	35839	36528	35850	32388	35374	36352	-	-
Total Suspended Solids	TM37/PM0	mg/l	<10	102	152	-	-	-	271	184	198	222	230	226	-	-
Volatile Suspended Solids	TM37/PM0	mg/l	<10	33	80	-	-	-	47	36	37	41	36	34	-	-
Chlorophyll A*	Subcontracted	ug/l	<5	-	-	-	<5	<5	-	-	-	-	-	-	-	-
Total Organic Carbon	TM60/PM0	mg/l	<2						<2	<2	<2	<2	<2	<2	-	<5
Turbidity	TM34/PM0	NTU	<0.1						2.3	4.4	2.8	4.1	3.8	35.6	-	-

Appendix E

UPDATED PROGRAMME



Closing Date for Submissions
Appointment of Service Provider
Stage 1: Inception
Project Implementation Plan
Site Visit
Investigations
Approval by CSC
Project Assessment Report
Sampling & Analysis
Sampling
Analysis
Progress Meeting
Concept Design
Concept Design Development
Drawing production
Design Meeting
Preliminary Design
Progress Meeting
Preliminary Design Development
Finalise Preliminary Design
Cost Estimates
Discussion Meeting with client
Planning Meeting
Detail Design Development
Drawing production
Specification collation
Cost Estimates
General Meeting
Tender Documentation Compilation
Tender Briefing Meeting
Tender Close
Tender Evaluation
Construction of new Desalination Building Civil Works - Phase 1
Construction of new Desalination Building Civil Works - Phase 2
Mechanical Procurement
Mechanical Installation
Construction of new Desalination Building Civil Works - Phase 3