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OSHAKATI TOWN COUNCIL
SEWAGE TREATMENT SITUATION

ASSESSMENT AND CONCEPTUAL DESIGN REPORT

No. 6 Newton Street | Unit no. 4 Philadelphia House
Maerua | Windhoek | Namibia

P.O. Box 698 | Windhoek | Namibia
Tel: +264 (61) 253 251 | Fax: +264 (61) 253 257

E-Mail: aquarius@aquarius.com.na

Web: www.aquarius.com.na

Member: Dr. G. G. Lempert & Mr T. Seifart

Project: 1802.001.OSH

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ASSESSMENT REPORT AND CONCEPTUAL DESIGN

REV	DATE	BY	COMMENTS
A	5 March 2018	TS	First draft - for Client's comments

Written & Compiled by: Thomas Seifart Revision: A

DISCLAIMER

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SECTION 1: BACKGROUND

1. INTRODUCTION

The current situation regarding sewage discharge and treatment at Oshakati Town was assessed during a visit undertaken during November 2017, by invitation of Engineering Services of this Town in conjunction with Aqua Utilities Corporation (Pty) Ltd.

Oshakati currently uses oxidation ponds (OxPonds) for treatment of all sewage collected. The sewage is transferred to two separate OxPonds, known as the "West Ponds" and the "East Ponds", each of which has had multiple extensions and upgrades over the years. From the map in Figure 1 it can be seen where these ponds are located. Various pump stations transfer sewage from the collection points and distribute it between the two OxPonds.

Figure 1. Google™ Map indicating location of the East and West Ponds at Oshakati

Oshakati has recently experienced significant development, with various residential extensions being serviced and connected up to the sewerage system. This has resulted in the OxPonds currently not being able to cope with excessive inflows, especially during the rainy season (see later) and they are therefore hydraulically overloaded. Also, both the current OxPonds systems have a final effluent that discharges into an adjacent oshona that is freely accessible to animals and humans, which does not fulfill the basic requirements as specified by the Department of Water Affairs and Forestry (DWAF) in their Guidelines for Pond Systems (DWAF, Code of Practice: Vol. 2, 2008). Furthermore, the population of Oshakati has grown to a number in excess of the size where OxPonds are permitted as the only treatment means. Its population is even expanding at an above-average growth rate, mainly due to urbanisation from the surrounding rural areas. These aspects will be elucidated on later in this report, but more background information on ponds systems needs to be given first.

Low-technology OxPonds have been the technology of choice for sewage treatment in Namibia in the past twenty to sixty years. It should, however be noted that DWAF has two basic requirements for communities that wish to make use of OxPonds as only treatment method for their sewage:

- No final effluent is allowed to be discharged into nature. Here, we wish to quote from the DWAF Guidelines (Code of Practice: Vol. 2, 2008): "*Generally, open ponds cannot produce a final effluent complying with the currently applicable Namibian standards for effluent discharge, viz the General Standard of Act No. 24 of 2004. Therefore, final effluent produced by a pond system will not be allowed for discharge into the environment*." This is not adhered to at Oshakati, where a large stream of insufficiently treated final effluent is discharged into the environment (see later) – this applies to both pond systems!
- All water treated in ponds must be completely evaporated because ponds are not able to produce a final effluent conforming to the General Standard. This requirement results in a good source of secondary water that is wasted instead of reused. Namibia is an arid country that needs to exploit its water resources more optimally and that is why DWAF does not allow use of ponds for larger communities. Again, we wish to quote from the DWAF Code of Practice (Vol. 2, 2008): "*Pond systems may only be considered if the ultimate load does not exceed 5 000 PE (population equivalents) or 800 kℓ/d*…", and further: "*Since water*

is a scarce commodity in Namibia, reuse thereof is strongly encouraged". The population of Oshakati exceeds latter figures by far, which requires the Town to implement more reuse projects to conserve potable water. However, this will require the final effluent that will be reused to conform at least to the General Standard, and will be elucidated on later.

The OxPonds at Oshakati are totally overloaded and especially during the rainy season, partly raw or, at best, hopelessly inadequately treated final effluent overflows into the environment. This causes a serious health hazard for humans as well as animals. Some of the fences at the ponds show signs of damage and cattle dung can be seen within the pond area and all over the pathways, which allows animals to drink such insufficiently treated water. Also, fish is harvested from the ponds, which poses a huge danger of humans developing diarrhea and even cholera when coming into contact with this effluent and/or eating the fish.

This report first addresses the existing situation prevailing at the Oshakati Sewage Treatment Plant (STP) and then gives a conceptual proposal for a proper treatment works incorporating technology that would be easiest to operate and maintain and therefore most appropriate to incorporate at this town. Also, reuse of the final effluent in line with DWAF's policies and to address future food security that will be greatly affected by the impact of climate change, is addressed. A cost estimate for a new treatment works and operating costs per cubic meter of sewage treated is also given.

2. OSHAKATI SEWAGE TREATMENT PLANT – CURRENT SITUATION

Typical problems normally associated with OxPond systems were also observed at the Oshakati OxPonds during the site visit, and will now be discussed in more detail. The two OxPonds will be addressed separately, as some observations are only applicable to one of the pond systems.

2.1 Oshakati West Ponds

General Condition. The West Pond system consists of a total of 8 ponds, some of which are still in a very good condition and have been recently constructed or refurbished. All ponds have either Hyson cell or concrete embankments and, as long as the entire pond floor area of each primary ponds is constructed similarly to the embankments, these ponds can be considered to be lined. DWAF (Vol. 2, 2008) requires specifically the anaerobic and primary ponds to be lined.

Some of the embankments and especially the primary ponds, however, show significant growth of weeds, reeds and bushes. The primary ponds are completely overgrown with dense vegetation to such an extent that the water surface is not even visible (Fig 2a and 2b). This is unacceptable and the complete area needs to be freed from all growth urgently. DWAF (Vol. 2, 2008) requires owners to keep the ponds and embankments free from growth at all times.

a) Primary ponds totally overgrown b) Large bushes even grow in the ponds

Figure 2. Oshakati West Ponds – Primary ponds overgrown.

While not as bad as at the primary ponds, the facultative and maturation ponds also show signs of vegetation (Fig. 3). These should also be cleaned and all vegetation removed. At a few places the embankments are damaged in these ponds, but not (yet) to such an extent that the water overflows out of the pond. However, these areas should be refurbished as soon as possible, to prevent further erosion and pond leakages.

b) Reed growth

b) Damaged embankment and growth

Figure 3. Oshakati West Ponds – Minor vegetation growth at facultative and maturation ponds.

We therefore recommended that the West Ponds are urgently cleaned by removing all grass and shrubs from inside the ponds as well as the embankments and surrounding, fenced-in area. In addition, the few areas where the embankments are damaged should be repaired.

<u>Final Effluent Discharge</u>. Despite low rainfall experienced in the summer of 2016/17, and the visit taking place in the dry season before the summer rainfalls of 2017/18 started, the ponds were found to discharge into an adjacent oshona (Fig 4a). This means that hazardous and not fully treated wastewater is discharged into an unfenced area where it can come into contact with people and where animals drink, which presents a severe health hazard to the community.

c) Final water discharged outside of the fence b) Cattle grazing and drinking
Figure 4. Oshakati West Ponds – Final water health hazards at the ponds

Fencing. Whereas a new, proper fence (Nato razor wire) was provided around the OxPonds, there is evidence of many repairs done to the fence after having been damaged by people. An area under the south-western gate has been dug out and a hole has been cut in the fence at the southern corner (Fig 5a), giving free access to humans inside the pond area. Also, evidence of fish being harvested was found at ponds (Fig 5b), which poses a huge danger of humans developing water-borne diseases such as diarrhea and even cholera when coming into contact with this effluent and/or eating the fish if not well cooked.

a) Southern corner fence damaged b) Fishing equipment at the ponds
Figure 5. Oshakati West Ponds – damaged fence and evidence of fishing activities

DWAF (Vol. 2, 2008) requires, as an absolute minimum, a 1.8 m high diamond mesh ("jakkalsproef") fence with locked, double-gate for access. Furthermore, the fence must completely enclose the whole treatment plant area and must ensure that all animals and people are kept out of the pond area at all times. We therefore recommend that the Town Council's continuous efforts to restore the fence and prevent access to the pond area are intensified to prevent further health hazards. Additional security guards should be employed to protect further removal of this fence or parts thereof and adequate warning signs in this regard should be put up.

2.2 Oshakati East Ponds

General Condition. The East Pond system consists of a total of 10 ponds and, as with the West Ponds, some are still in a very good condition and have been recently constructed or refurbished. In general the East Ponds appear in a slightly better overall condition as the West Ponds. All the ponds have either Hyson cell or concrete embankments and, as long as the entire pond floor area of the primary ponds are also constructed similarly to the embankments, the ponds can be considered to be lined, as required by DWAF (Vol. 2, 2008).

The general appearance of these ponds is good and the area is kept neat and tidy. Some of the embankments show minor growth of weeds, reeds and bushes, but in general much less than at the West Ponds. Pond embankments seem to be in a fair condition (Fig 6). At a few places the embankments are damaged in these ponds, but not (yet) to such an extent that the water overflows out of the pond. However, these areas should be refurbished as soon as possible, to prevent further erosion and pond leakages.


Figure 6. Oshakati East Ponds – Minor damage to embankments

The primary and large, facultative ponds are, however, very overgrown with reeds (Fig 7) and should be cleaned as a matter of urgency. As mentioned previously the complete area needs to be freed from all growth urgently, before it becomes a much bigger problem.


a) Reeds at primary pond b) Reeds at facultative pond

Figure 7. Oshakati East Ponds – Vegetation growth

We therefore recommended that the East Ponds are urgently cleaned by removing all grass and shrubs from inside the ponds as well as the embankments and surrounding, fenced-in area. In addition, the few areas where the embankments are damaged should be repaired.

Final Effluent Discharge. At the time of the assessment visit, there was no overflow of the final pond to the environment. However, the visit took place before the rain season commenced and there was clear evidence that there had previously been final water discharged from the ponds into the surrounding area, with signs of water erosion and a previously ponded area just outside the plant fence (Fig 8). This means that, during the rainy season, hazardous and not fully treated wastewater is discharged into an unfenced area where it can come into contact with people and where animals drink, which presents a severe health hazard to the community.

a) Soil erosion at the final pond outlet b) Area adjacent to final pond outlet - previous ponding

Figure 8. Oshakati East Ponds – Final water health hazards at the ponds

Fencing. The fence seems to be in a relatively good condition, although there is evidence of repairs having been done at several places. Unfortunately, there will always be people that try to gain access to the ponds to water their livestock or to do fishing at the pond. The Town Council is doing their utmost in repairing the fences as and when damaged and proper signage prohibiting fishing and grazing is also clearly visible (Fig 9). Whereas this sign is large, clearly visible and serves its purpose, we do not quite agree with the sign saying "ENTRY AT OWN RISK" – we would recommend this to be rather changed to "NO ENTRY FOR UNAUTHORIZED PERSONS".

Figure 9. Oshakati West Ponds – damaged fence and evidence of fishing activities

2.3 Treatment Capacity of Oxidation Ponds

We have calculated the actual treatment capacity of both the West and East Ponds to establish the current treatment capacity for comparison to the population of Oshakati.

<u>Capacity</u>. Due to uncertainties in the design capacity of these ponds, an assessment on site of the actual capacity of the OxPonds was made. The total pond area was approximately:

West Ponds:

- Anaerobic Ponds: 4 off, total area	=	47 500 m^2
- Primary Ponds: 2 off, total area	=	96 400 m^2
- Secondary (facultative) Ponds: 2 off, total area	=	54 000 m^2
SUB-TOTAL	**=**	**<u>197 900 m^2</u>**

East Ponds:

- Anaerobic Ponds: 8 off, total area	=	52 900 m^2
- Primary Ponds: 1 off, total area	=	85 100 m^2
- Secondary (facultative) Ponds: 1 off, total area	=	28 500 m^2
SUB-TOTAL	**=**	**<u>166 500 m^2</u>**

TOTAL COMBINED AREA = 364 400 m^2

When the DWAF Guidelines (Vol. 2, 2008) are followed, the total volume of effluent that can be treated in this plant would only serve approximately 10 000 people for the Oshakati West Ponds and 8 400 people for the East Ponds, for a combined total of 18 400 people. Latter figure compares badly with the current population estimated of approximately 40 000 - 45 000 for Oshakati, of which about 27 000 people are currently residing on erven that are already serviced, with a further 13 500 people's erven currently being serviced. This is based on the information given verbally by Mr Tomas Negongo of Oshakati Town Council (personal communication, 24 October 2017), who indicated that about 6 000 erven are currently serviced with another 3 000 in the process of being serviced. Since the town council and developers are currently driving services in order to connect up as many as possible existing and new households to the sewer system and also enforcing legislation to service and connect up households in future developments, additional treatment plant capacity is urgently required. Our estimate is that the capacity of the existing sewage treatment plant should now already cater for at least 30 000 people whose effluent currently already reaches the treatment plants. If the 3 000 erven currently being serviced are expected to be completed in the near future, the total treatment plant capacity to be provided now should be for 45 000 people. The population estimates are addressed further in Section 3.3.1 of this report.

3. UPGRADING AND EXTENDING EXISTING FACILITIES

From the above discussion it becomes clear that the existing pond systems for Oshakati are inadequate, require urgent attention and need to be upgraded, not only to cater for future growth, but also already to serve all existing users. Extending the existing ponds by adding additional ponds is not an option anymore and will now be further elucidated.

3.1 Upgrading the Existing Pond System

Extending the current oxidation ponds with bigger ponds (to evaporate all effluent produced) will **not** be an option, due to:

- DWAF not allowing oxidation and evaporation ponds to serve communities in excess of 5 000 people and discharging more than 800 m³/d, because reuse of the final effluent is propagated. The current population served and sewage reaching the treatment plant already far exceeds latter figures (Section 2.1.3);
- Evaporation ponds require large surface areas and open land is not readily available in the area. Just as an indication, to cater for the currently needed capacity of approximately 4 500 m³/d of effluent to be treated (45 000 people), will require approximately 893 000 m² of constructed ponds. Compared with the currently constructed 365 000 m² of ponds, it will mean that extensions totaling 2.4 times (!) the existing pond area are required! Even if this land would be available, it would be expensive and could be better utilized for further industrial and/or housing developments or for producing agricultural products;
- Potential health hazard. During times of excessive rains, oxidation ponds become flooded and spill over into the floodplains. This poses a serious health hazard to humans and animals living in and crossing the floodplains and consuming fish caught in the ponds;
- Difficulty to keep population and animals from reusing effluent. Especially during the dry season, the population will damage the fences to allow their animals to feed and drink in the pond area, as happens currently;

- Reliable source of secondary water with high nutritional value (for plants). This effluent, once properly treated, is an asset because it forms a reliable source of water, especially in the dry season. Also, all important nutrients needed for plants are still contained in the final water, necessitating no or very little fertilizer for continuous, sustainable agricultural produce. Thus, the final water can be reused for parks, sports fields, gardens and selected agricultural produce.

- Future food security and huge potential for community upliftment. The effect of climate change is already experienced in Namibia and can be expected to intensify in the near future. The large amount of a good quality of final water discharged reliably by this plant will make it attractive for community-based agricultural projects that want to address and implement poverty and upliftment programs. It will also contribute largely towards food security because a large, steady stream of water will be available daily for growing selected agricultural produce.

Therefore, a treatment process giving a final effluent that can be reused for agricultural purposes should be favored. Several advanced biological treatment processes, that treat raw sewage to the General Standard and thus produce a final effluent that can be reused for agricultural purposes are currently available on the market. The most familiar ones would be the activated sludge process, submerged membrane bioreactors, rotating disc reactors and trickling filters. We recommend new-generation trickling filter technology is used, because we have found it most applicable to local conditions and especially because it involves simple technology and is easy to operate and maintain.

3.2 New-Generation Trickling Filter Systems

New-Generation Trickling Filters (NGTF) effect advanced biological treatment of an effluent using attached-growth media technology to produce a high-quality final effluent. NGTF employ low-level mechanical technology in the form of submersible pumps, but latter require little service and maintenance. Generally, this technology is gaining increased acceptance throughout third world countries for the following reasons:

- Small footprint. To treat domestic effluent, NGTF need only ca 2-5% of the land area necessary for oxidation ponds (including evaporation);
- High quality final effluent. A final effluent exceeding the Namibian General Standard and WHO standards is produced. This will be safe for discharge even during periods of severe flooding of the area. Also, the final effluent can be reused for growing selected crops and aquaculture in line with WHO guidelines (WHO 2006a) or for gardening and lawns (e.g. sports fields and public parks) in the town.
- Simple technology. The only advanced mechanical equipment employed, are submersible pumps, which can be replaced without specific technical knowledge, and the drives for clarifier bridges (large plants only). Once commissioned, no further process control or adjustment to the process is required.
- Little mechanical equipment that can break. Under the latter, only the service/recycle pumps would be of concern, but designers always allow for duty and standby pumps.
- Little inspection, service and maintenance required. Only submersible pumps, which require periodic inspection and maintenance, are employed. However, the town will also need other pump stations to transfer sewage to the treatment plant and submersible pumps can therefore be regarded as standard mechanical equipment once a full reticulation system has been provided for the town.
- Low power requirements. NGTF use only ca 40 to 65% of the power required by other advanced treatment processes giving a comparable treated effluent, such as oxidation ditches or activated sludge processes. Not only will the continuous power demand be low, but standby power in the form of a standby generator can be provided at minimal costs.

For the specific conditions encountered at Oshakati, Trickling Filter Technology was therefore considered as most appropriate and most reliable technology to be employed. The next section will deal with the most important design parameters on which our design was based on.

3.3 Basic Design Figures

Our design relies on discharge figures currently observed plus expected growth due to more consumers installing flush toilets and being connected up to the sewer network, as well as future expected growth for the next ten years. Since it will take already approximately three to four years to secure funds from Central Government, do a detail design, tendering, construction and putting into operation the extensions to this plant, a ten year window is not very far into the future.

3.3.1 Population Estimate

Table 1 shows the population projection until 2028 (only 10 years from now!) based on actual population counts that were conducted by the NSA in 2001 and 2011. Three scenarios are given:

- Population grows further at 0.9 % as experienced in the Oshana Region from 2001 to 2011;
- Population grows further at 1.4% as per the national average from 2001 to 2011;
- Population grows further at 3.5% due to urbanisation.

Table 1: Population Projections for Oshakati – 2001 to 2028

YEAR	2001	2011	2018	2028
% Increase	Growth at 0.9% as experienced for Oshana Region between 2001 and 2011			
Population	28 255	36 541	38 906	42 553
% Increase	Growth at 1.4% as per current national growth rate between 2001 and 2011			
Population	28 255	36 541	40 276	46 283
% Increase	Growth at 3.5% due to urbanisation			
Population	28 255	36 541	46 490	65 579

While the 3.5% growth due to urbanisation over the next ten years may be a bit high, Oshakati Town can be expected to show growth-rates substantially above the national average. Looking at the above figures (Table 1), one should now already plan for serving ca 45 000 people, with another 15 000 additional inhabitants by 2028, ten years from now, thus 60 000 people in total. To serve latter amount of people will require treatment capacity to be provided of ca 4 500 m^3/d (at 100 l/p/d).

Thus, three off treatment trains (=modules) need to be planned for now, each module serving 15 000 people and hydraulic capacity of 1 500 m^3/d. Additional module(s) of 1 500 m^3/d treatment capacity can then be added later, as the need arises and future growth-rate evolves. Table 2 shows our recommended design figures for a new STP plant for Oshakati that needs to be allowed for at this stage already. We recommend Phase 1 to consist of 3 off Modules for a total treatment capacity of 4 500 m^3/d and Phase 2 of an additional Module of 1 500 m^3/d to be provided within the next 10 years after construction of Phase 1.

Table 2: Population served and wastewater design volumes for Oshakati STP

DESIGN PARAMETER	UNITS	PLANT CAPACITY		
		Phase 1 now	Phase 2 future	TOTAL
Population served	PE	45 000	15 000	60 000
Sewage Discharged	m^3/d	4 500	1 500	6 000
Average Dry Weather Flow	m^3/h	187.5	62.5	250
Peak Flow	m^3/h	525	175	700

Based on the above figures, the corresponding organic loads for raw sewage discharged to the new works that need to be used for design purposes are shown in Table 3.

Table 3: Average Daily Design Wastewater Loads for new Oshakati STP

DESIGN PARAMETER		Basis	PLANT CAPACITY		
		Load (mg/l)	Phase 1 (kg/d)	Phase 2 (kg/d)	TOTAL (kg/d)
Chemical Oxygen Demand	(COD)	1 000	4 500	1 500	6 000
Biological Oxygen Demand	(COD)	500	2 250	750	3 000
Total Suspended Solids	(TSS)	400	1 800	600	2 400
Ammonia-Nitrogen	(NH_4-N as N)	35	157.5	52.5	210
Total Phosphates	(TP as P)	25	112.5	37.5	150

The location of the three modules for Phase 1 (1 500 m^3/d capacity each) can be finalised if and when the project goes ahead. Based on current inflow, we recommend that 2 x 1 500 m^3/d trains are constructed at the West Pond site and one 1 500 m^3/d train at the East Pond site, as the West Pond is currently the pond receiving more raw sewage inflow. The bulk of existing pump stations and pipework infrastructure could then be further used without requiring major changes. Our layout drawings that accompany this report (Drawing Number 1802.001.OSH-101A and -101B) are based on this preliminary recommendation. However, new residential extensions with corresponding pump stations can also be designed to transfer sewage to only one of the two current pond sites, or an entirely new site, if required. The final positions of the sewage treatment plants will need to be considered carefully in conjunction with the Town Engineer and the Town Planners.

The new sewage treatment plants will require only a small fraction of the land currently used for the pond systems. These ponds can then be dried out and the land used or sold for residential or agricultural purposes.

Final Effluent Quality. The final effluent will conform to the current Namibian General Standard (Appendix A) as per Namibian legislation for final effluents [Water Act, 1956 (Act No. 54 of 1956)] and will exceed European Standards (EC Directive 91/271/EHS) for plants of this size. Cognizance must also be taken of the new standards to be introduced by DWAF shortly, which are included in Appendix B.

Figure 10 depicts the proposed process schematics for the plant and unit processes. Latter are further elaborated on individually in this report (Appendix C).

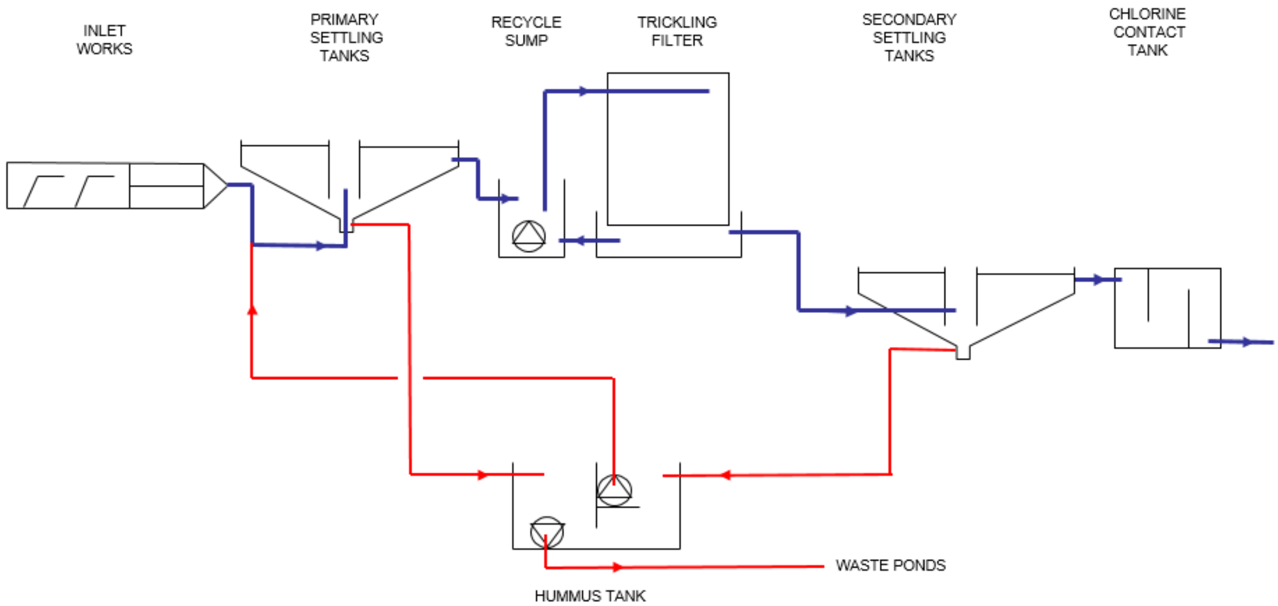

Figure 10: Process Schematic for Oshakati STP

The individual unit processes are discussed in detail in Appendix C in a similar order as the raw sewage flows through the plant and needs treatment. The discussion is supported by a basic process/piping and instrumentation diagram (P&ID, Drawing No 1802.001.OSH-001), which should be referred to as well. The description in Appendix C is for one 1 500 m^3/d train.

The final water produced by these plants will be excellent for reuse in gardens, parks and even selected agricultural produce. It is therefore proposed to discharge the final water in such a way that the existing maturation ponds will be used as a final water irrigation pond so that that the final treated water from the treatment plant is not discharged into the environment.

SECTION 2: COST ESTIMATE, PROJECT DURATION AND BENEFITS

A budget cost estimate of capital as well as operating costs was made for an envisaged plant for Oshakati based on the above-described design. Whereas total costs for a complete plant that includes also future extensions is given, only Phase 1 (3 modules of 1 500 m^3/d each) is relevant currently for construction purposes. Phase 2 will be an extension to be implemented when need arises, but is foreseen to be required within 10 years' time.

1 CAPITAL COSTS AND PROJECT REALISATION

Project Costs. It is estimated that the Total Project Costs for Phase 1, *viz*. to provide a new sewage treatment plant for Oshakati to serve 45 000 people and treat approximately 4 500 m^3/d of domestic effluent, will be approximately **N$176.3 m** (incl. V.A.T.), as reflected in Table 4 below.

Table 4. Estimated Project Cost for 4 500 m^3/d WWTP - Phase 1 only

ITEM	DESCRIPTION	COSTS (N$)
1	Professional Fees (Consultant)	13 300 000
2	Treatment Plant Cost:	
	• Civil Works	53 300 000
	• Mechanical Works	44 150 000
	• Electrical/Control	2 300 000
3	Peripheral Services Upgrade:	
	• Transformer and Electrical Feeder Upgrade	2 200 000
	• Boundary Wall, Gate & Guard Cubicle	2 100 000
	• 22 km Reuse Pipeline	22 000 000
	Sub-Total	139 350 000
	Add 10% Contingency	13 935 000
	Sub-Total	153 285 000
	Add 15% V.A.T.	22 992 750
	TOTAL	**176 277 750**

Implementation. Detail design, tendering and construction of Phase 1 of this project will take ca two years to complete, with another year that will be required to add Phase 2, thus in total a period of three years should be allowed for.

2 OPERATIONAL COSTS

The main annual operating costs for the trickling filter plants under consideration, includes the following:

- Manpower. Only one operator per plant is required to daily clean the linear screen, ensure chlorination is properly functioning, replace the chlorine cylinder when empty and ensure all pumps are functioning. Additional workers may be required periodically to empty the sludge drying beds;
- Chemicals. Chlorination of the final effluent is an environmental requirement (and mandatory by DWAF) irrespective of reuse of the final effluent or discharge to the environment. We have allowed for 2 mg/l chlorination, based on the capacity for the plant.
- Power Consumption. We have again assumed that the average daily flow will be maintained at the plant throughout the year. Average power consumption will be ca 45 kW per Module, therefore 135 kW for Phase 1 and another 45 kW for Phase 2.

The total annual operating costs based on typical Namibian costs for power, chemicals and operators have been estimated for the envisaged plant and are reflected in Table 5. An average of 4 500 m^3/d of sewage that has to be treated was used as basis for these annual operating costs (Phase 1), whereas an additional 1 500 m^3/d will be a future extension (Phase 2). The total annual operating costs based on early 2018 costs, are reflected in Table 5 below.

Table 5. Estimated Annual Operational Cost (excl. V.A.T.) for 4 500 m³/d plant

Item No.	DESCRIPTION	ANNUAL COSTS (N$ - 2018)
2	Chemicals and Consumables	180 000
4	Personnel and Supervision	221 000
5	Power Consumption (135 kW @ N$1.65/kW.h)	1 951 290
6	Annual Service and Maintenance costs	1 200 000
	TOTAL (excl. V.A.T.)	**3 151 691**
	Unit operating costs, based on 4 500 m³/d (N$ per m³ effluent)	N$1.92/m³

The above unit operating costs make it very attractive to reuse this final effluent, which will be highly nutritious for plants, for selected agricultural production, if compared to current potable water unit prices. Also, when sports facilities with grass fields need to be provided with irrigation water, this reclaimed water will replace the potable water required and will thus be at a fraction of the cost of potable water (ca N$10,- as currently provided by NamWater).

3 JOB CREATION AND LONG TERM BENEFITS

The project will greatly benefit the community, not only during the construction phase when many local workers will be required for the building works, but long thereafter as well. This is because a good quality of final effluent will be produced that can/should be reused for agricultural purposes, and latter aspect will be promoted. With the final, reusable effluent estimated at 4 200 m³/d for Phase 1 and a further 1 400 m³/d for Phase 2 on a sustainable basis, large agricultural developments can be undertaken and should be encouraged by Oshakati Town Council to be undertaken by the local communities in the adjacent areas. Table 6 indicates the envisaged short and long term jobs that this project is envisaged to create for the community

Table 6 – Estimated Jobs Created by this Project

DESCRIPTION	Phase 1		Phase 2	
	Temporary (construct.)	**Permanent** (agriculture)	**Temporary** (construct.)	**Permanent** (agriculture)
During Construction Phase	120		85	
After Construction (agriculture)		85		45

Thus, there will be in total 205 temporary employed persons during the construction phase and afterwards 130 permanently employed people that will benefit from this sewage treatment plant.

4 PUBLIC-PRIVATE-PARTNERSHIP (PPP)

The need to implement proper sewage treatment facilities is high and should be seen as a matter of urgency, since the current situation is unacceptable, not only from an environmental point of view, but also because it creates a health (and safety) hazard, endangering lives.

Funding from Central Government for new capital projects have been put on hold for at least two years and the Finance Ministry indicated that funds for new projects will be limited for a long time in future. For a project of this magnitude, requiring at least N$175 m (incl. contingencies and V.A.T.), an alternative way of financing the capital costs will be needed. Also, town councils are progressively struggling to attract suitably qualified personnel with adequate technical skills to operate treatment plants, despite the proposed technology being simple. The private sector could assist with both these needs and many public-private-partnerships (PPPs) have been implemented all over the world to the benefit of all parties involved. Where such contracts have been implemented they are commonly called concession, BOO (build-own-operate) or BOT (build-own-transfer) contracts, latter two are also often referred to as BOOT contracts. Figure 11 is a simple, schematic drawing showing only the main parties involved in a typical BOOT contract.

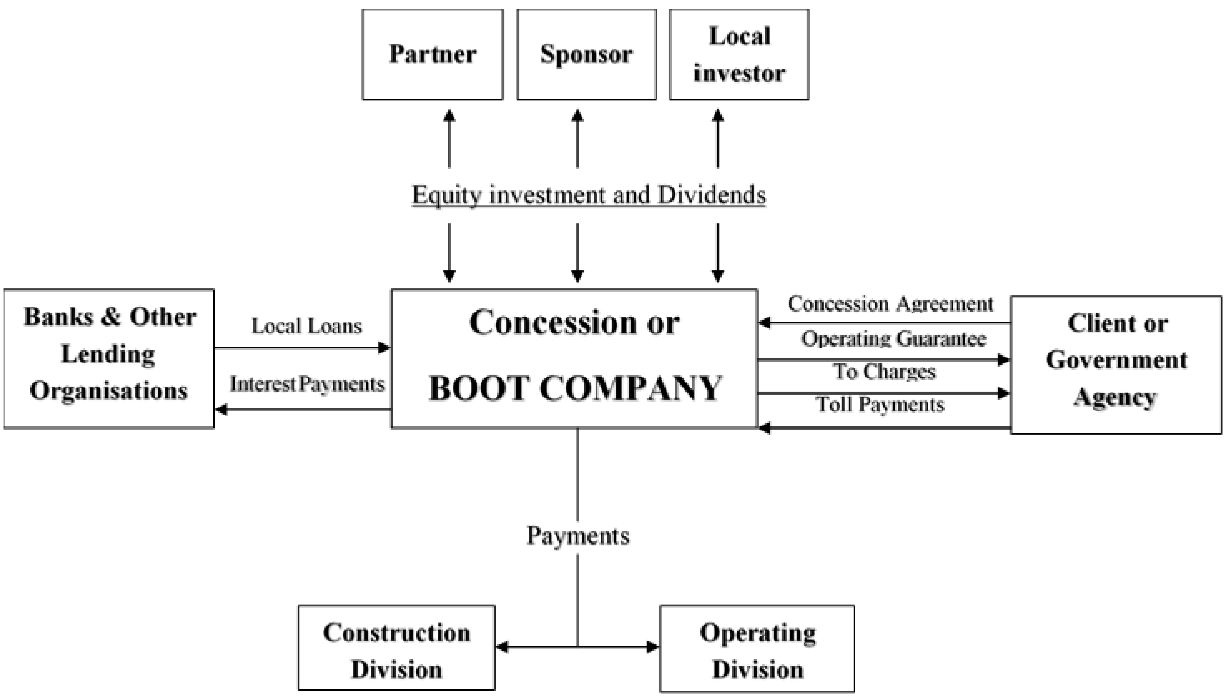

Figure 11. Schematics of a basic concession (BOOT) contract with main parties involved.

Many different types of PPPs can be established. Partnership options range from projects where the private sector fully finances the capital costs and operates the facilities for the public sector for an extended period of time, typically 10 to 25 years, to projects where the private sector only operates or maintains the facilities for a long-term period, typically 20 to 25 years. Whereas endless different options can be established for a meaningful PPP, it is also possible to create a PPP for only part of the project value. For example, 50% of the capital costs could be funded from central government and the remaining 50% from private sector or donor organisations.

SECTION 3: CONCLUSIONS

An assessment of the current situation with regards to sewage discharge and treatment at both the Oshakati West and East Ponds was undertaken. It was found that:

- Both plants were provided with pond systems, which are already highly overloaded with regard to sewage volumes and organic loading reaching the sewage works;
- Future population influx and above-average growth, coupled with an increase in households with flushing toilets being connected up to the reticulation system, will result in an exponential growth with regards to effluent being discharged into the treatment plants;
- Both the existing pond systems are already overflowing and will not be able to cope with any future growth;
- Overflowing of the ponds creates a serious health risk and environmental hazard;
- New sewage treatment plants, based on advanced biological treatment systems, are urgently required for both towns.

A conceptual design for a new sewage treatment plant for Oshakati was undertaken, based on most appropriate technology for the Oshona Region:

- New-Generation Trickling Filter technology was selected as most appropriate process for sewage treatment at Oshakati;
- The respective design capacities for Phase 1 (urgent) are 4 500 m^3/d and 1 500 m^3/d for Phase 2 within the next 10 years;
- The final water will be of a standard that conforms to the current and future Namibian General Standard and will be suitable for reuse in gardens, lawns (e.g. sports fields) and selective agricultural growth;
- The approximate capital costs for the new plants (Phase 1) will be N$176.3 m (contingencies & V.A.T. included);
- The project will be undertaken over three financial years;

- The unit operating and maintenance costs will be below N$2.00 per m³, which makes the final water attractive for reuse, especially if it can be used to replace fresh water, where latter would have to be supplied by NamWater;
- The project (both Phases combined) will result in at least 205 temporary jobs created and 130 permanent jobs.

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APPENDICES

Appendix A: Current Water Quality Standards for Effluents

Appendix B: Envisaged Future Water Quality Standards for Effluents

Appendix C: Typical Trickling Filter Plant Description

Appendix D: Drawings

APPENDIX A: Currently Applicable Standards for Wastewater Discharge

Parameter	Unit	General*	Special*
Colour, odor, taste		No substance that will produce color, odor, taste	No substance that will produce color, odor, taste
Faecal coliforms	per 100 mL	Nil	Nil
Chemical Oxygen Demand (mg/L)	mg/L	75	30
pH		5.5 - 9.5	5.5 - 7.5
Dissolved Oxygen	% satur.	75	75
Temperature	°C	≤ 35	≤ 35
Oxygen Absorbed (N/80/4h)	mg/L	10	5
TDS	mg/L	increase in TDS ≤ 500 over intake water conc.	increase in TDS ≤ 15% over intake water conc.
Ammonia as N	mg/L	10	1
Nitrate/Nitrite as N	mg/L	NS	1.5
Chlorine as Free Chlorine	mg/L	0.1	Nil
Suspended Solids	mg/L	25	10
Electrical Conductivity	mS/m	NS	≤70 mS/m above, max 150 mS/m
Soap, oil or grease	mg/L	≤ 2.5	Nil
Arsenic (as As)	mg/L	0.5	0.1
Boron (as B)	mg/L	1	0.5
Cadmium (as Cd)	mg/L	NS	0.05
Hexavalent chromium (as Cr)	mg/L	0.05	NS
Total chromium (as Cr)	mg/L	0.5	0.05
Copper (as Cu)	mg/L	1	0.02
Cyanide (as CN)	mg/L	0.5	0.5
Fluoride (as F)	mg/L	1	1
Iron (as Fe)	mg/L	NS	0.3
Lead (as Pb)	mg/L	1	0.1
Manganese (as Mn)	mg/L	NS	0.1
Ortho-Phosphate (as P)	mg/L	NS	1.0
Total Phosphates (as P)	mg/L	NS	2.0
Sodium (as Na)	mg/L	≤ 50 over intake conc.	≤ 50 over intake water conc.
Sulphides (as S)	mg/L	1	0.05
Zinc (as Zn)	mg/L	5	0.3

* as per Regional Effluent Standard: R553 of 15 April 1962 and amendments (Water Act, 1956)
NS = not specified

APPENDIX B: Envisaged Future Standards for Wastewater Discharge

Effluent to be discharged or disposed of in areas with potential for drinking water source contamination; international rivers and dams and in water management and other areas				
			Special Standard	General Standard
DETERMINANTS	**UNIT**	**FORMAT**	**95 percentile requirements**	
PHYSICAL REQUIREMENTS				
Temperature	° C		Not more than 10^0C higher than the recipient water body	
Turbidity	NTU		< 5	< 12
pH			6.5-9.5	6.5-9.5
Colour	mg/litre Pt		< 10	< 15
Smell			No offensive smell	
Electric conductivity 25 °C	mS/m		< 75 mS/m above the intake potable water quality	
Total Dissolved Solids	mg/litre		< 500 mg/litre above the intake potable water quality	
Total Suspended Solids	mg/litre		< 40	< 100
Dissolved oxygen	% saturation		>75	>75
Radioactivity	units		below ambient water quality of the recipient water body	
ORGANIC REQUIREMENTS				
Biological Oxygen Demand	mg/litre	BOD	< 10	< 30
Chemical Oxygen Demand	mg/litre	COD	< 55	< 100
Detergents (soap)	mg/litre		< 0.2	< 3
Fat, oil & grease, individual	mg/litre	FOG	< 1.0	< 3.0
Phenolic compounds	mg/litre	as phenol	< 0.01	< 0.10
Aldehyde	µg/litre		< 50	< 100
Adsorbable Organic Halogen	µg/litre	AOX	< 50	< 100
INORGANIC MACRO DETERMINANTS				
Ammonia (NH_4 – N)	mg/litre	N	< 1	< 10
Nitrate (NO_3 - N)	mg/litre	N	< 15	< 20
Nitrite (NO_2 - N)	mg/litre	N	< 2	< 3
Total Kjeldahl Nitrogen (TKN)	mg/litre	N	< 5.0	< 33
Chloride	mg/litre	Cl	< 40 mg/litre above the intake potable water quality	< 70 mg/litre above the intake potable water quality
Sodium	mg/litre	N	< 50 mg/litre above the intake potable water quality	<90 mg/litre above the intake potable water quality
Sulphate	mg/litre	SO_4	< 20 mg/litre above the intake potable water quality	< 40 mg/litre above the intake potable water quality
Sulphide	mg/litre	S	< 0.05	< 0.5

Effluent to be discharged or disposed of in areas with potential for drinking water source contamination; international rivers and dams and in water management and other areas				
			Special Standard	General Standard
DETERMINANTS	UNIT	FORMAT	95 percentile requirements	
Fluoride	mg/litre	F	1.0	2.0
Cyanide (Free)	µg/litre	CN	< 30	< 100
Cyanide (recoverable)	µg/litre	CN	< 70	< 200
Soluble Ortho phosphate	mg/litre	P	< 1.0	< 15
Zinc*	mg/litre	Zn	1	5

Effluent to be discharged or disposed of in areas with potential for drinking water source contamination; international rivers and dams and in water management and other areas				
			Special Standard	General Standard
DETERMINANTS	UNIT	FORMAT	95 percentile requirements	
INORGANIC MICRO DETERMINANTS				
Aluminium	µg/litre	Al	< 25	< 200
Antimony	µg/litre	Sb	< 5	< 50
Arsenic	µg/litre	As	< 50	< 150
Barium	µg/litre	Ba	< 50	< 200
Boron	µg/litre	B	< 500	< 1000
Cadmium*	µg/litre	Cd	< 5	< 50
Chromium, (hexavalent)	µg/litre	Cr	< 10	< 50
Chromium, Total*	µg/litre	Cr	< 50	< 1000
Copper*	µg/litre	Cu	< 500	< 2000
Iron	µg/litre	Fe	< 200	< 1000
Lead*	µg/litre	Pb	< 10	< 100
Manganese	µg/litre	Mn	< 100	< 400
Mercury*	µg/litre	Hg	< 1	< 2
Nickel	µg/litre	Ni	< 100	< 300
Selenium	µg/litre	Se	< 10	< 50
Strontium*	µg/litre	Sr	< 100	< 100
Thallium	µg/litre	Ti	< 5	< 10
Tin*	µg/litre	Sn	< 100	< 400
Titanium	µg/litre	Ti	< 100	< 300
Uranium*	µg/litre	U	< 15	< 500
*Total for Heavy Metals (Sum of Cd,Cr,Cu,Hg,Pb	µg/litre	Cd,Cr,Cu, Hg & Pb	< 200	< 500

No. 6 Newton Street | Unit no. 4 Philadelphia House
Maerua | Windhoek | Namibia

P.O. Box 698 | Windhoek | Namibia
Tel: +264 (61) 253 251 | Fax: +264 (61) 253 257

E-Mail: aquarius@aquarius.com.na

Web: www.aquarius.com.na

Member: Dr. G. G. Lempert & Mr T. Seifart

UNSPECIFIED COMPOUNDS FROM ANTHROPOGENIC ACTIVITIES				
Agricultural chemical compounds	µg/litre		Any in-/organic compound recognized as an agro-chemical is to be avoided or reduced as far as possible. Maximum acceptable contaminant levels will be site specific, dependent on chemical usage and based the water quality of the recipient water body	
Industrial and mining chemical compounds, including unlisted metals and persistent organic pollutants	µg/litre		Any in-/ organic compound recognized as an industrial chemical including unlisted metals is to be avoided or reduced as far as possible. Maximum acceptable contaminant levels will be site specific dependent on chemical usage and based the water quality of the recipient water body	
Endocrine Disruptive Compounds (EDC)	µg/litre		Any chemical compound that is suspected of having endocrine disruptive effects is to be avoided as far as is possible. Maximum acceptable contaminant levels will be site specific dependent on chemical usage and based the water quality of the recipient water body.	
Hydrocarbons (Benzene, Ethyl Benzene, Toluene and Xylene	µg/litre		Below detection level	Below detection level
Organo-metallic compounds: methyl mercury, tributyl tin (TBT), etc.	µg/litre		Below detection level	Below detection level
DISINFECTION				
Residual chlorine	mg/litre		1 Dependent on recipient water body (at retention time 3 hours)	3 Dependent on recipient water body (at retention time 5 hours)

Effluent to be discharged or disposed of in areas with potential for drinking water source contamination; international rivers and dams and in water management and other areas				
			Special Standard	**General Standard**
DETERMINANTS	**UNIT**	**FORMAT**		
BIOLOGICAL REQUIREMENTS (Algae and parasites)				
Further treatment of the effluent dependent on: 1. the water quality of the recipient water body if any 2. the distance from any point of potable water abstraction 3. an acceptable maximum contaminant level downstream of the point of discharge 4. the exposure to human and animal consumption downstream of the point of discharge 5. any reuse option that may be implemented.				
MICROBIOLOGY				
Further treatment of the effluent are dependent on: 1. the water quality of the recipient water body if any 2. the distance from any point of potable water abstraction 3. an acceptable maximum contaminant level downstream of the point of discharge 4. the exposure to human and animal consumption downstream of the point of discharge 5 any water reuse option that may be implemented.				

APPENDIX C: TRICKLING FILTER PLANT DESCRIPTION

Our design relies on discharge figures currently observed plus expected growth due to more consumers installing flush toilets and being connected up to the sewer network, as well as future expected growth for the next ten years. Since it will take already approximately three to four years to secure funds from Central Government, do a detail design, tendering, construction and putting into operation the extensions to this plant, a ten year window is not very far into the future.

C.1 Population Estimate

Table 1 shows the population projection until 2028 (only 10 years from now!) based on actual population counts that were conducted by the NSA in 2001 and 2011. Three scenarios are given:

- Population grows further at 0.9 % as experienced in the Oshana Region from 2001 to 2011;
- Population grows further at 1.4% as per the national average from 2001 to 2011;
- Population grows further at 3.5% due to urbanisation.

Table C1: Population Projections for Oshakati – 2001 to 2028

YEAR	2001	2011	2018	2028
% Increase	Growth at 0.9% as experienced for Oshana Region between 2001 and 2011			
Population	28 255	36 541	38 906	42 553
% Increase	Growth at 1.4% as per current national growth rate between 2001 and 2011			
Population	28 255	36 541	40 276	46 283
% Increase	Growth at 3.5% due to urbanisation			
Population	28 255	36 541	46 490	65 579

While the 3.5% growth due to urbanisation over the next ten years may be a bit high, Oshakati Town can be expected to show growth-rates substantially above the national average. Looking at the above figures (Table 1), one should now already plan for serving ca 45 000 people, with another 15 000 additional inhabitants by 2028, ten years from now, thus 60 000 people in total. To serve latter amount of people will require treatment capacity to be provided of ca 4 500 m³/d (at 100 l/p/d).

Thus, three off treatment trains (=modules) need to be planned for now, each module serving 15 000 people and hydraulic capacity of 1 500 m³/d. Additional module(s) of 1 500 m³/d treatment capacity can then be added later, as the need arises and future growth-rate evolves. Table 2 shows our recommended design figures for a new STP plant for Oshakati that needs to be allowed for at this stage already. We recommend Phase 1 to consist of 3 off Modules for a total treatment capacity of 4 500 m^3/d and Phase 2 of an additional Module of 1 500 m^3/d to be provided within the next 10 years after construction of Phase 1.

Table C2: Population served and wastewater design volumes for Oshakati STP

DESIGN PARAMETER	UNITS	PLANT CAPACITY		
		Phase 1 now	Phase 2 future	TOTAL
Population served	PE	45 000	15 000	60 000
Sewage Discharged	m³/d	4 500	1 500	6 000
Average Dry Weather Flow	m³/h	187.5	62.5	250
Peak Flow	m³/h	525	175	700

Based on the above figures, the corresponding organic loads for raw sewage discharged to the new works that need to be used for design purposes are shown in Table 3.

Table C3: Average Daily Design Wastewater Loads for new Oshakati STP

DESIGN PARAMETER		Basis	PLANT CAPACITY		
		Load (mg/l)	Phase 1 (kg/d)	Phase 2 (kg/d)	TOTAL (kg/d)
Chemical Oxygen Demand	(COD)	1 000	4 500	1 500	6 000
Biological Oxygen Demand	(COD)	500	2 250	750	3 000
Total Suspended Solids	(TSS)	400	1 800	600	2 400
Ammonia-Nitrogen	(NH_4-N as N)	35	157.5	52.5	210
Total Phosphates	(TP as P)	25	112.5	37.5	150

The location of the three modules for Phase 1 (1 500 m^3/d capacity each) can be finalised if and when the project goes ahead. Based on current inflow, we recommend that 2 x 1 500 m^3/d trains are constructed at the West Pond site and one 1 500 m^3/d train at the East Pond site, as the West Pond is currently the pond receiving more raw sewage inflow. The bulk of existing pump stations and pipework infrastructure could then be further used without requiring major changes. Our layout drawings that accompany this report (Drawing Number 1802.001.OSH-101A and -101B) are based on this preliminary recommendation. However, new residential extensions with corresponding pump stations can also be designed to transfer sewage to only one of the two current pond sites, or an entirely new site, if required. The final positions of the sewage treatment plants will need to be considered carefully in conjunction with the Town Engineer and the Town Planners.

The new sewage treatment plants will require only a small fraction of the land currently used for the pond systems. These ponds can then be dried out and the land used or sold for residential or agricultural purposes.

Final Effluent Quality. The final effluent will conform to the current Namibian General Standard (Appendix A) as per Namibian legislation for final effluents [Water Act, 1956 (Act No. 54 of 1956)] and will exceed European Standards (EC Directive 91/271/EHS) for plants of this size. Cognizance must also be taken of the new standards to be introduced by DWAF shortly, which are included in Appendix B.

C.2 Selected Treatment Processes & Technology

Advanced biological treatment utilizing Trickling Filter (TF) technology as envisaged for Oshakati will incorporate the following unit treatment processes:

- Inlet works with screening and grit removal in a grid channel;
- Suspended solids removal and anaerobic digestion in existing ponds;
- Aerobic, biological carbonaceous material removal and nitrification in biofilters (trickling filters);
- Biomass removal in secondary clarifier;

- Disinfection using chlorine gas;
- Desludging to and sludge drying in drying beds.

Figure C1 depicts the proposed process schematics for the plant and unit processes. Latter are further elaborated on individually in this report.

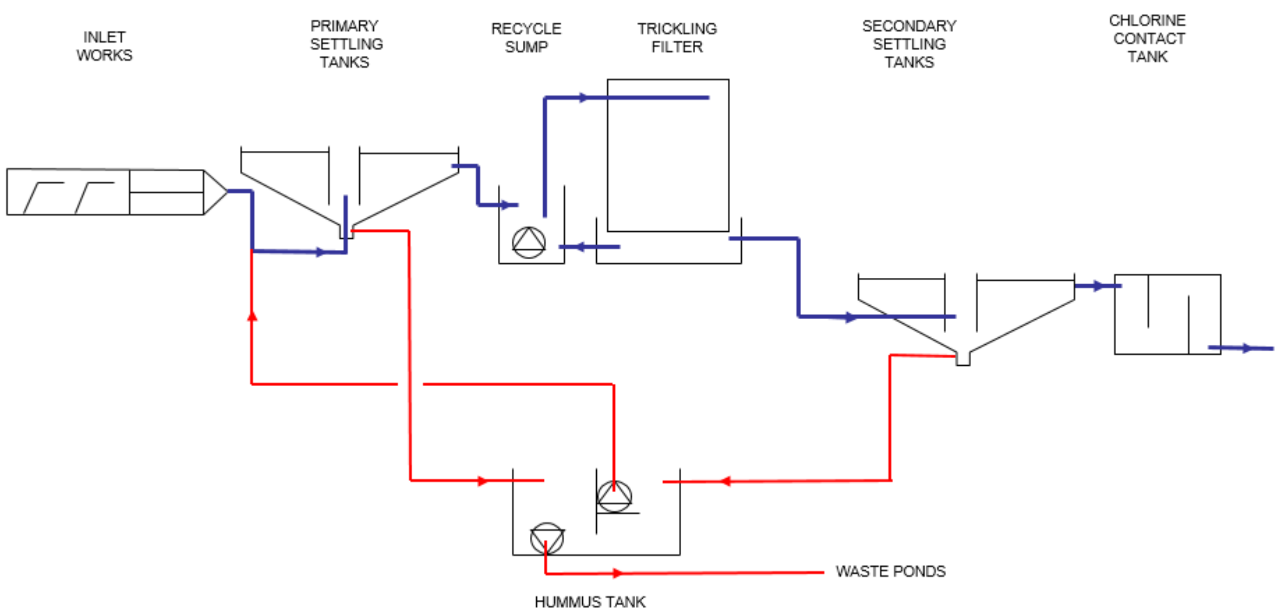


Figure C1: Process Schematic for Oshakati STP

The individual unit processes will now be discussed in a similar order as the raw sewage flows through the plant and needs treatment. The discussion is supported by a basic process/piping and instrumentation diagram (P&ID, Drawing No 1802.001.OSH-001), which should be referred to as well. The description below is for one 1 500 m^3/d train.

C.2.1 Inlet Works (CT01). A typical inlet works structure will serve two off trains, each sized for 1 500 m³/d ADWF. Large objects such as plastic bags, bottles, rags and other, generally non-biodegradable material will be caught by a set (two off) of screens in series at the inlet to the treatment plant. Thee screens consist of static, parallel bars at a 45° angle with spacing between the bars of 25 mm for the first screen, followed by 10 mm for the second screen. The screens will be manually cleaned (raked) and the screenings collected and disposed of in a waste-bin that will be placed next to the screens. Final disposal of the screenings will be to the municipal solid-waste dump site.

After screening a set of grit removal channels (see Figure. C2) will ensure that the bulk of sand and grid can be removed from the sewage before further treatment. During normal operation both channels are in operation and heavy, mostly inorganic particles settle in these channels. During times of low inflow to the works, one channel is taken out of operation by inserting manual sluice gates on either side thereof and draining the water from it. The grit is then manually removed by an operator from the bottom of the channel and left to drip off and dry out on a ledge at the top of the channel.

Figure C2: Proposed Inlet works with Grit Removal Channel

Although requiring manual intervention to clean the screens and grit channels, we recommend that this method be used and that no electro-mechanical screen will be provided. This is because latter need frequent service and maintenance and, from practical experience, we found them to often break down due to a revolving chain employed. The necessary expertise to repair such a mechanical screen is not available in close proximity of the plants.

After passing through the grid channels, the inflow will be split to feed two trains, thus to the inlet of the existing primary ponds (CT02). A flowmeter (FM01/02) will be provided to measure inlet flows to each primary pond.

C.2.2 Primary clarifier (CT02). Primary settlers are employed to remove 60% to 70% of suspended solids and 40% of COD in the raw sewage. One primary settler (CT01) will be provided per train with main dimensions as follows:

- Diameter = 16,0 m
- Water depth (sidewall) = 3,5 m

The settler will be fitted with a central, stilling well to equally distribute the inflow, with the following dimensions:

- Diameter = 1,2 m
- Water depth (sidewall) = 2,5 m

Peripheral overflow weirs (V-notch) with a 500 mm wide Stamford baffle should be installed to prevent density currents and ensure equal draw-off of clarified effluent.

Rotating bridge. The settler is fitted with a rotating (travelling) bridge driven by a peripheral bridge-drive (MM01) and scum and sludge-scraping mechanism at a peripheral speed between 1.5 and 2 m per minute. The peripheral drive runs on the outside wall of the clarifier and the sludge is moved towards the central sludge hopper for periodic sludge withdrawal. Sludge and scum is withdrawn by opening the desludge valve (mechanically when the bridge passes over the desludge valve opening mechanism).

C.2.3 Trickling Filter System. The trickling filter system consists of a feed/recycle sump (CT03), which is sized for and acts as anoxic reactor for denitrification, the trickling filter tower (MT01) and trickling filter basin (CT04):

3.2.3.1 Trickling Filter Feed Sump (CT03). After primary treatment, the overflow from the primary settler, is discharged into a pump sump, from where it is recirculated by open impellor submersible pumps (2 duty, 1 standby) through the trickling filter. This sump is sized with a hydraulic retention time that allows anoxic conditions to prevail.

Control System. The pumps will be fitted with a low-level protection switch. If the period of non-inflow to the plant is very long, it can be expected that water will be lost through evaporation and the level in this sump will drop. To then prevent the pump(s) from running dry, they will be switched off at a certain low-level. Should the plant receive inflow again, the level in the sump will rise and the level switch will switch the pump(s) on automatically. This also ensures that no operator will be required to ever switch the plant on or off.

Trickling Filter Tower (MT01). The trickling filter itself consists of tower stacked with a bed of highly permeable medium (Figure C3a), which serves as host for micro-organisms to attach to and grow on, to form a biological film. Organic material in the wastewater is absorbed by micro-organisms growing as a biological film on the media. In the outer portion of the film, aerobic organisms degrade organic material, whereas anaerobic organisms exist deeper into the biological film, i.e. near the surface of the media (Figure C3b).

Figure C3a): Packing in trickling filter.

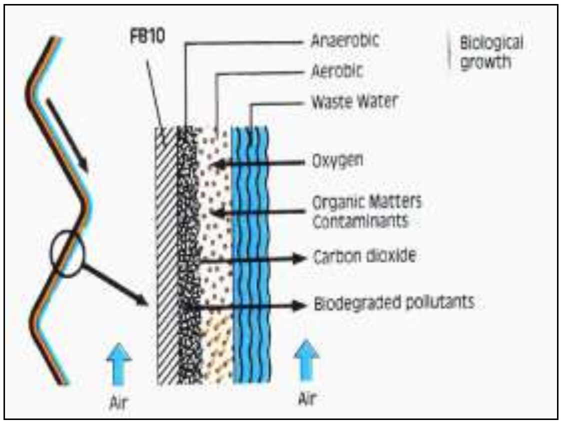


Figure C3b): Biofilm growth on media.

Figure C3: Trickling Filter Media and Wetting (Spray Nozzles)

The filter media will be manufactured from robust, weatherproof and UV-stabilised plastic material with self-supporting structure and is stacked inside a tower, 6 m high (Figure C4a). The wastewater is sprayed over and percolates through the media. A simple system of non-clogging, open nozzles will be used to distribute the water evenly over the top of the media (Figure C4b). The media will allow for carbonaceous material removal as well as nitrification to take place inside the trickling filter. The packing will have a high void ratio (>97%) to reduce the risk of clogging and to maximize ventilation throughout the filter. Efficient mixing and wetting is essential and media with a cross-flow pattern for the even distribution of water throughout the filter bed will be provided.

Figure C4a): Trickling filter tower

Figure C4b): Water distribution on top.

Figure C4: Trickling Tower with Wetting (Spray Nozzles) on Top

The water, after percolating through the media, is collected in the trickling filter basin. Biological solids that have become detached from the packing media have to be removed before the effluent is disinfected and can be finally discharged. Removal of the biomass is achieved in a conventional, secondary settler/clarifier.

C.2.4 Secondary Clarifier (CT05). Treated effluent from the trickling filter is discharged into the settling tank (Fig C5), where the suspended solids settle out and clear water is drawn off via V-notch weirs that discharge into a peripheral channel at the top of the clarifier. The sludge is scraped by a rotating bridge to the centre of the tank, where it is collected in a desludge hopper. The settler will be fitted with a central, stilling well to equally distribute the inflow.

Rotating bridge. The settler will be fitted with a rotating (travelling) bridge driven by an electric motor (MM02) with speed reducer to obtain a peripheral speed between 1.5 and 2 m per minute. The peripheral drive runs on the outside wall of the clarifier and the sludge is moved towards the central sludge hopper for periodic sludge withdrawal. The clarifier is fitted with a desludge pipe with an electrically actuated valve so that the desludge process can occur fully automatic.

Figure C5: Clarifier with Rotating Bridge

C.2.5 Sludge Handling - Humus Tank (CT08). Sludge from the secondary clarifier is collected in the humus tank, which also serves as sludge return sump. The humus tank is fitted with two sets of submersible sludge pumps: Two off (PS02 A/B; duty/standby) pumps for periodic desludging of settled, thickened sludge to the sludge drying beds (see Section C.2.7); and two off (PS03 A/B; duty/standby) sludge pumps to continuously return anaerobic sludge back to the primary clarifier for anaerobic digestion of the inflow COD/BOD.

C.2.6 Disinfection – Chlorine Contact Tank (CT06). It is a requirement by DWAF that all final effluent produced in sewage treatment plants **must** be disinfected properly, even if only discarded to the environment.

The effluent will be disinfected utilising chlorine gas. The disinfection plant will consist of 2 off 68 kg chlorine gas cylinders (on hire by client), each of which is fitted with a gas chlorinator (Fig C6). The dosing rate of the chlorinator can be manually adjusted to provide the necessary dosage for disinfecting the final effluent before discharge. An automatic switch-over unit will ensure that, when the cylinder in operation is empty, the system will switch over to a new, full bottle.

Figure C6: Typical medium-scale chlorine gas disinfection system (Hydramet)

Water for the booster bump stream is obtained from the municipal (potable) water supply. The chlorinated, recycle stream discharges into the inlet to the chlorine contact tank (CT06), which is sized to provide at least 20 min contact time at peak flow for proper disinfection.

<u>C.2.7 Sludge Disposal – Sludge Drying Beds (CT07)</u>. 20 off Sludge drying beds, each with a surface area of 10 m², will be supplied per 1 500 m^3/d train. Sludge is periodically (ca once per week) removed from the humus tank as described in Section C.2.5 and pumped to the drying beds. The operators will select which drying bed to fill by switching the isolating valves such that these pumps discharge only into the selected sludge drying bed(s). The sludge is then left to dry and can then be manually removed from the sludge drying beds and reused as compost, typically for gardening purposes.

C.2.8 Final Water Reuse. The final water produced by these plants will be excellent for reuse in gardens, parks and even selected agricultural produce. It is therefore proposed to discharge the final water as follows:

The existing maturation ponds will be used as a final water irrigation pond so that that the final treated water from the treatment plant is not discharged into the environment.

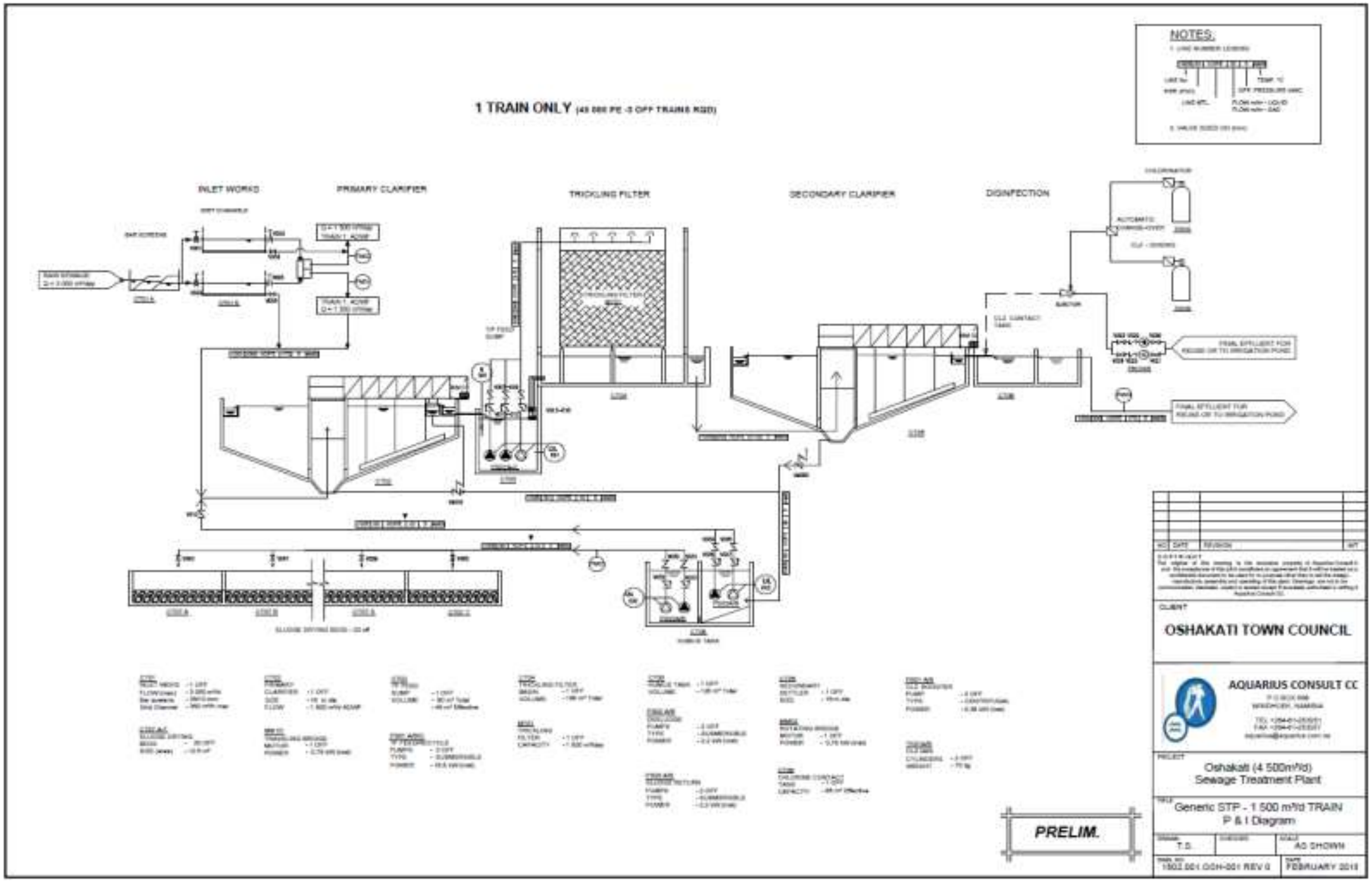
C.3 Power Supply, Electrical Board, Control and Monitoring

Total, continuous power consumption for one train serving 15 000 people will be not more than 45 kW. Therefore, a total of 135 kW will be drawn for the proposed Phase 1 of the project, with a further 45 kW needed later. The positions of the plant(s) will determine how much power will be required at which location.

The plant will be fitted with very basic control:

- Automatic duty/standby rotation every 12 h of all pumps sets;
- Two indication lights (running/trip) for every pump are required;
- An alarm signal light (similar to a break-down truck) on top of the control board will be provided. Latter will be activated if any pump trips and will be switched off when all signals are healthy again. Thus, an operator will be able to already see from a considerable distance from the plant, if any motor has tripped.

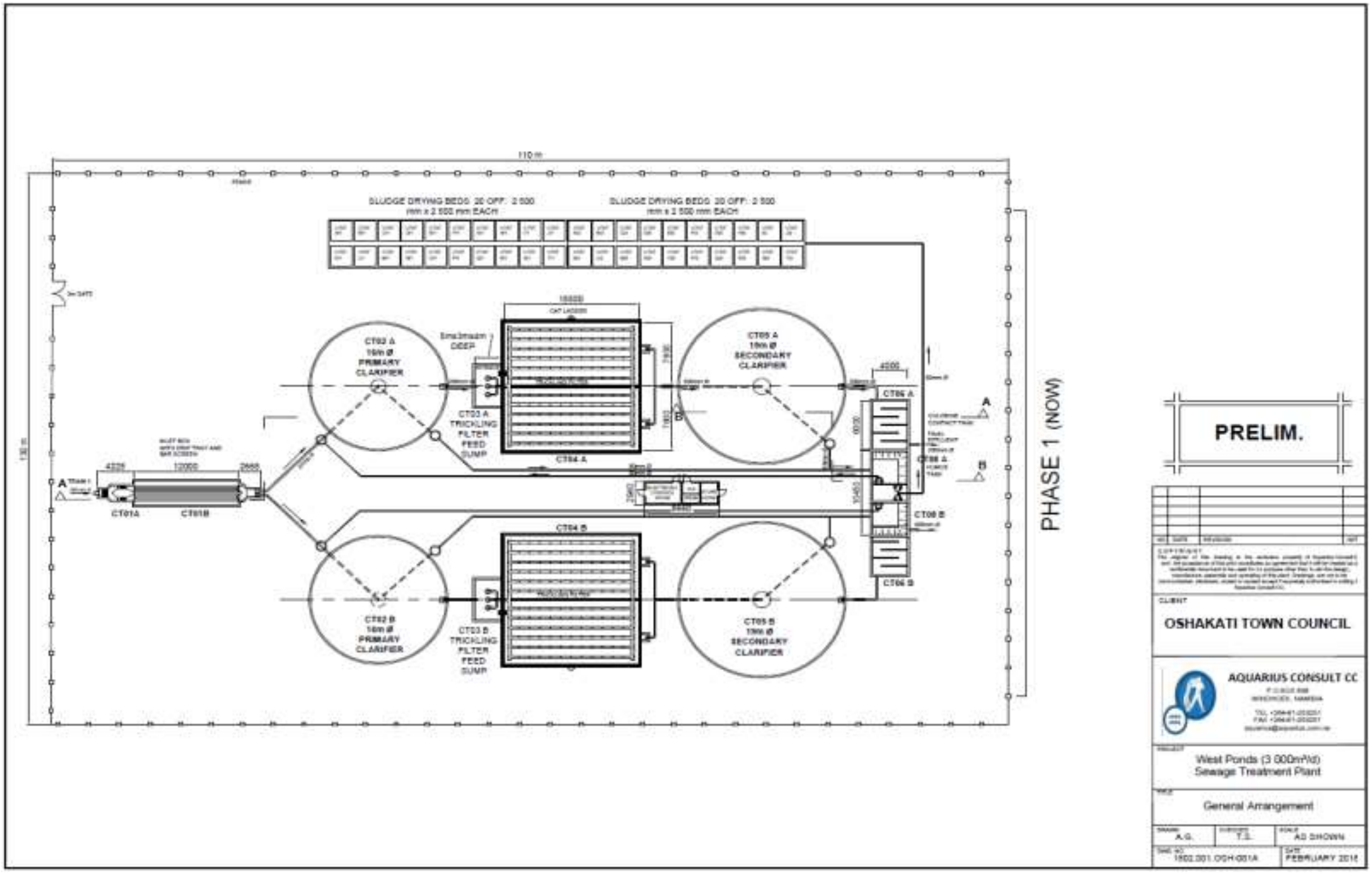
APPENDIX D: TYPICAL DRAWINGS



1 TRAIN ONLY
INLET WORKS
PRIMARY CLARIFIER
TRICKLING FILTER
SECONDARY CLARIFIER
DISINFECTION
NOTES:
OSHAKATI TOWN COUNCIL
AQUARIUS CONSULT CC
Oshakati (4 500m³/d) Sewage Treatment Plant
Generic STP - 1 500 m³/d TRAIN P & I Diagram
PRELIM.
AS SHOWN

AQUARIUS CONSULT CC

Reg. No.: CC/2010/3052



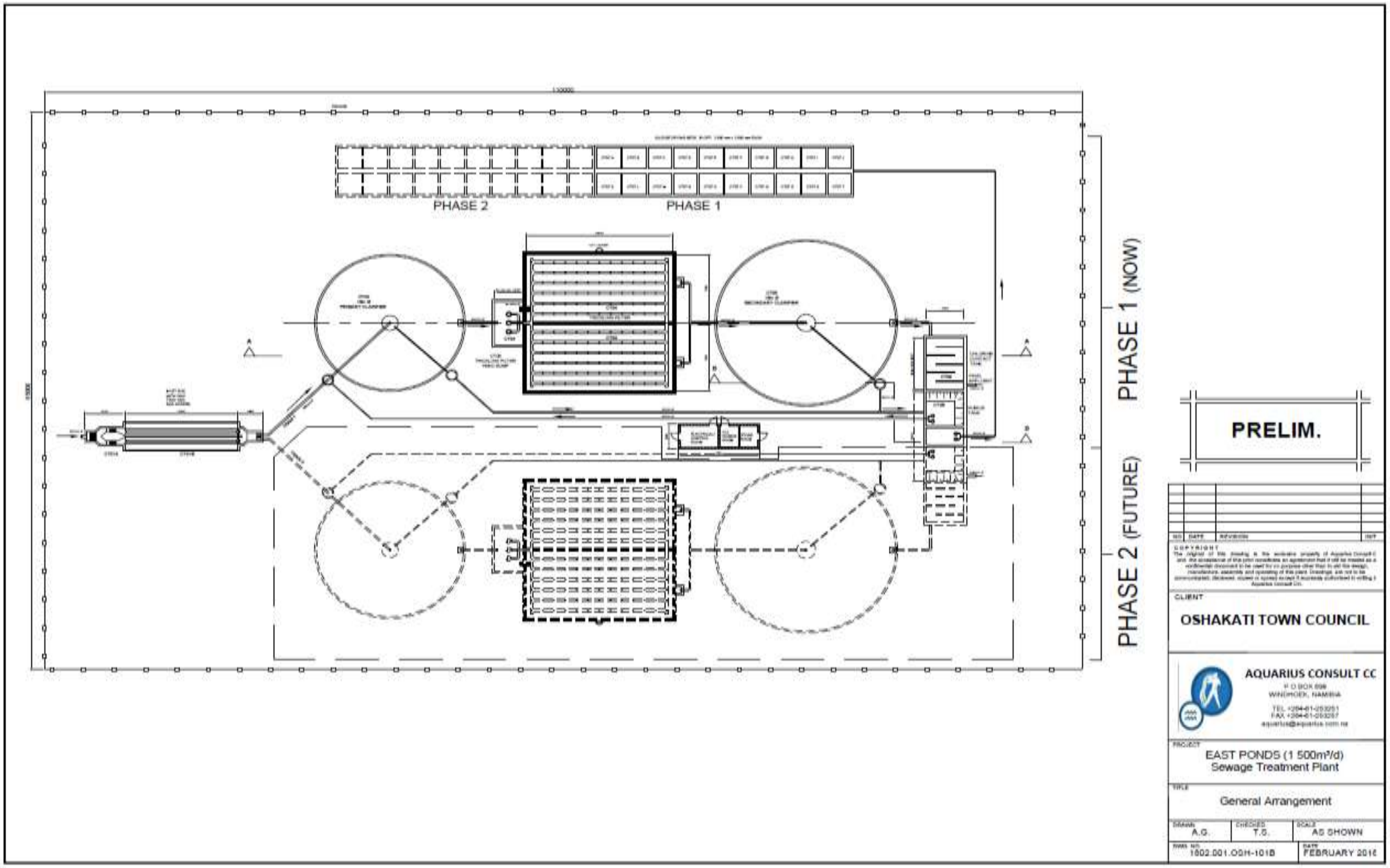
No. 6 Newton Street | Unit no. 4 Philadelphia House
Maerua | Windhoek | Namibia

P.O. Box 698 | Windhoek | Namibia
Tel: +264 (61) 253 251 | Fax: +264 (61) 253 257

E-Mail: aquarius@aquarius.com.na

Web: www.aquarius.com.na

Member: Dr. G. G. Lempert & Mr T. Seifart



PHASE 2
PHASE 1
PHASE 1 (NOW)
PHASE 2 (FUTURE)
PRELIM.
OSHAKATI TOWN COUNCIL
AQUARIUS CONSULT CC
EAST PONDS (1 500m³/d)
Sewage Treatment Plant
General Arrangement
A.G.
T.S.
AS SHOWN
FEBRUARY 2016