UNIVERSITY OF JOHANNESBURG

Faculty of Engineering and Built Environment

Department of Civil Engineering Technology

Water and Wastewater Engineering 3B

(WWWCIB3)

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GROUP 31

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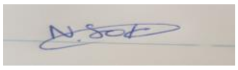
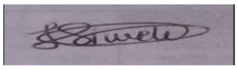
N.SOKASI	221004700	4,5 & 3	100%	
L.SIWELA	220000909	6,7 & 3	100%	

EXECUTIVE SUMMARY

This report presents a design of a primary treatment process for a wastewater treatment plant in the Free State province, Bothaville, Nala Local municipality. The Bothaville Wastewater Treatment Works (WWTW) currently serves the community of Bothaville and potentially surrounding rural areas within the municipality, thus it is the selected facility to work on. The proposed plant is designed to reach capacity of 35.4 ML/d and handle wastewater with Biochemical oxygen demand (BOD) of 230mg/L and Total suspended solids (TSS) of 336mg/L. Based on the available municipal documentations, the planning fundamentals and appropriate calculations are subjects to the available information from the Free State Provincial Government of South Africa. Municipal information is important for the design of the WWTP, as it is generally needed for estimating a population size, industrial activities, local geography, volume of wastewater, and other types of pollutants. The municipal data also includes regulatory requirements that must be addressed through the design and details of existing infrastructure to ensure that the legal standard is met and to allow easy integration into the municipal network.

Primary wastewater treatment focuses on the removal of large and solid materials that can either float or settle out by gravity in wastewater, and the process involves raw water screening, grit removal, primary sedimentation, scum and sludge removal processes. The key components of the design include centre-feed clarifiers with feed wells and energy dissipating units, suitable to enhance the sedimentation process efficiency. Calculations are crucial part of the WWTW primary design treatment for ensuring the system capability to deal with the amount and nature of wastewater that would be treated. This report provides correct calculations for the sizing of sedimentation tanks, determining the rate of flow, and finding out the removal efficiency of the suspended solids. This assignment will explore into detail the process of designing a primary treatment process for a wastewater treatment plant, providing an overview of the methodologies learnt in this module and to ensure that Group 13 members meets the Graduate attributes.

Wastewater treatment plants in South Africa are governed by several regulatory requirements that are in the best interest of environmental and public health concerns. Key regulations include the National Water Act, which requires control over water pollution and sustainable utilization of this resource. The Green Drop Programme, as part of the Department of Water and Sanitation's initiative, evaluates and certifies the performance of the wastewater treatment facilities on their compliance with the required effluent quality standards. This will also allow the municipalities to avoid possible litigation implications apart from securing public confidence.

ABBREVIATIONS

ADWF	Average Dry Weather Flow
AWWF	Average Wet Weather Flow
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
DM	District Municipality
DPW	Department of Public Works
DWAF	Department of Water and Sanitation
EIA	Environmental Impact Assessment
LM	Local Municipality
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
WWTP	Wastewater Treatment Plant
WWTW	Wastewater Treatment Works

UNITS

ML/d	Megalitres Per Day
m/s	Metres/second
l/c/d	Liters per capita per day
kg/m3	Kilogram Per Cubic Meter
°C	Degree Celsius

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CHAPTER 1: INTRODUCTION

1.1 BACKGROUND INFORNATION

The aim of this report is to conduct a detailed design review that meets the particular operational need in Bothaville WWTP and contributes to the sustainability of available water resources in the region. Group 31 was assigned the design of a primary treatment plant in Bothaville, Free State province, within the Nala Local municipality in the rural regions of the Free State Province. Wastewater treatment is highly instrumental in maintaining public health and ecological balance. Preliminary treatment is one of the preliminary processes that involve the removal of suspended solids or organic material through the process of sedimentation. This report presents the design of the primary treatment process for a WWTP with a capacity of 35.4 ML/d. Most concentration in this report has been given to the design of the primary clarifier, taking into consideration the South African design standards as presented by the Department of Water and Sanitation (2018).

The primary treatment captures the majority of the pollutant load that will flow into the succeeding stages of treatment due to simple settling by gravity of suspended solids. This process reduces the concentration of total suspended solids and biochemical oxygen demand in the influent. Given the influent characteristics of the Bothaville WWTP in the order of 230 mg/L BOD and 336 mg/L TSS, high removals are required by sedimentation. The design of the primary clarifiers has to make considered provision for hydraulic loading, retention time, and weir overflows while drawing appropriate correlation to ensure that effective performance is achieved with respect to requirements set by the National Water Quality Management Framework (Department of Water and Sanitation 2018).

In designing the primary treatment process, the design must adhere to the South African standards so that operational efficiency is achieved and that regulatory compliance has been met. The design should be incorporating principles outlined in the Civil Engineering Redbook and the guidelines provided by the Department of Public Works to ensure that sedimentation is effective to reduce environmental impacts and improve the treatment process

1.2 SOCIA-ECONOMIC ACTIVITY

The town hosts the head office of Grain South Africa and produces annually an average of 550 000 tons of maize. Bothaville serves mainly as a farming community in South Africa's Free State Province. With its rich soil and good climate, the place is suitable for crop growing, hence this area of the country being referred to as the "breadbasket." Its agricultural area contributes a great deal toward the livelihood of many citizens, apart from that of the national economy. Bothaville is home to the world-famous NAMPO Harvest Day Show. As this is the only big annual event in Bothaville, they have developed an intensive and progressive tourist development program to back it up.

Yet, Bothaville can boast of more other than its maize. Among others, the town is also known for its beautiful handmade crafts, stock farming, innovative agricultural and industrial undertakings, exporting vegetables and roses, and above all, its hospitality.

The primary economic sectors of Bothaville, which has a population of about 90 000, are game farming, fresh flower production, grain agriculture, and animal farming. The production of agricultural tools, small engineering projects and a Karet caravan manufacturing facility are examples of light industrial manufacturing. Government, tourism, light industry, and health and medical services are supporting sectors (https://www.bothaville.info/about-bothaville/).

1.3 SCOPE OF THE DETAILED DESIGN WORK

This assignment is primarily aimed at developing a design for a primary clarifier in the Free State Province of South Africa. The most prominent beneficiary of the study includes the Nala local Municipality; the design will serve the neighbouring areas within the Lejweleputswa District. The primary clarifier should be able to provide treatment to 35.4 ML of wastewater per day with strength of 336 mg/L of total suspended solids and 230 mg/L of biochemical oxygen demand. Thus, the primary clarifier will serve to eliminate all floating and settleable solid wastes that are still left over from the upstream operations, which have high oxygen demand on BOD. Therefore, this design will ensure that BOD is reduced up until it meets the requirements of the Department of Water Affairs and Forestry and the National Water Act (1998).

Through successive steps, the pollutants are removed to a level acceptable for disposal back to the environment. Finally, it is expected that, upon completion, the project will submit drawings of each clarifier in the facility and also a detailed design report of the main clarifier at the wastewater treatment plant in the Free State-Nala local municipality.

1.4 CONCLUSION

In conclusion, understanding the flow dynamics of wastewater in any given community, its flow trajectory towards treatment plants, and treating one economic activity or activities in a particular location is important in ensuring that the treatment designs are relevant. Given the domination of generations due to sources emanating from domestic and industrial origins in the Free State, such treated water should be returned for re-use by those very communities and industries, farming concerns. The population size that will be catered for, the site location of the proposed Bothaville wastewater treatment plant, and other key design aspects are elaborated in the subsequent chapter. Furthermore, applicable standards and quality control measures that are necessary for the efficiency of the primary treatments will also be looked into.

CHAPTER 2 DESIGN BASIS

2.1 LOCATION OF THE SEWERAGE FACILITIE

Figure 1: Sedibeng Water (Google Earth)

Figure 2: Free State Map (Google Earth)

2.2 SITE/SOIL CONDITIONS

Based from the reports, the general soil conditions of Bothaville are dominantly composed of clayey loam and sandy loam, which have different compactness and water retention abilities. In general, the clayey soils exhibit moderate to high plasticity, which can be quite problematic because the expansion and contraction of soil take place; this is expected especially during the wetting and drying cycles of the seasons. This carries risks of differential settlement and ground movement which, if the foundation of a primary treatment clarifier is being designed, would certainly need to be accounted for. Poor drainage is a possible problem with clay-rich soils due to their relatively low permeability can lead to ponding and reduced infiltration capacity. This therefore, needs for proper site preparation by compaction of the soil, grading, and probably installation of drainage systems to ensure that the clarifier remains stable and functional. Besides this, since Bothaville is semi-arid and the evaporation effects are high, the use of soil stabilizing methods such as lime treatment and geotextile reinforcement might be required to reduce settlement or erosion.

2.3 DESIGN CRITERIA/PARAMETERS OF WWTP

- Temperature of wastewater is 20°C.
- Gravity affects the wastewater flow.

2.3.1 POPULATION AND WASTEWATER FLOW

A. HOUSEHOULDS

Table 1: Settlement Demograohics (December 2017)

DM	LM	Settlements	Population	Households
Lejweleputswa	Nala	5	106981	29234

B. DEMAND

Table 2: Existing Sanitation Infrastracture

DM	LM	Number of WWTW'S	Capacity ML/d (AWWF)	Capacity ML/d (ADWF)	Hydraulic Capacity (ML/d) based on 24hr
Lejweleputswa	Nala	2	6.2	9.7	6.2

C. REQUIRED CAPACITY

- Capacity in Bothaville WWTW is 6.2 ML/d
- Proposed Capacity is 35.4 ML/d

2.3.2 WATER QUALITY

According to the standards for its use, the chemical, physical, and biological properties of water are referred to as its quality. It is most frequently used in reference to a set of standards which can be used to measure compliance, usually obtained by the treatment of water. The most utilized parameters of water quality are indicative of the status of the ecosystems, safety of direct human contact, magnitude of pollution, and quality of drinking water. Quality of drinking water because it greatly affects the water supply, and quite often the supply options themselves (Boyd, 2015).

Water has to undergo a number of water treatment processes in order for it to have acceptable standards, some primary characteristics to be used in the assessment of water quality:

- **Physical** are characteristics like color, turbidity, temperature, and taste or odour that are crucial in the assessment of water meant for domestic use.
- **Chemical** characteristics may include, for instance, reactions between hard water and soft water, which are usually not observable, in some instances-for instance, the oxidation of iron-it gives way to significant problems such as discolorations.
- **Microbiologica**l agents are of great importance regarding public health but can also affect the physical and chemical nature of water.
- **Radiological** aspects have to be taken into consideration in areas where water is in contact or has a possibility to be in contact with radioactive substances, since radioactivity can be dangerous to human health.

Water Quality Standards

- National Environmental Management Act (Act 107 of 1998);
- National Water Act (Act 36 of 1998);
- Water Services Act (Act 108 of 1997);
- National Building Regulations and building standards Act (Act 103 of 1977)
- Municipal By-laws, local policies and practices

2.4 DESIGN CONCEPT OF TREATMENT

According to Davis (2010), primary treatment is meant to remove the floating and settleable solid particles by gravity. In this process, several sequential steps are involved, which include screening, flow equalization, and grit removal. The screens used in this stage are mostly made of long, closely spaced metal bars with parallel or sloping elements either in fine or coarse form. They assist to intercept large floating debris like wood, rags, plastics, among others, which could clog up pipes and pumps. In modern plants, these screens are either manually or mechanically cleaned, and the resulting waste is usually buried immediately on-site. A combinatory may grind and shred the materials passing through the screens and sedimentation or flotation processes remove the shredded debris. Grit removal is conducted in large, narrow tanks called grit chambers where the velocity of wastewater is decreased enough to allow heavy particles, such as sand, coffee grounds, and eggshells, to be removed. Grit is highly abrasive because it causes severe wear on the pumps and mechanical equipment; hence, its removal is highly crucial, especially in the combined sewer systems that collect silt, sand, and gravel during storm events.

Suspended solids that pass through the screens and grit chambers are removed in sedimentation tanks - also called primary clarifiers - that provide roughly two hours of detention time for settling. As the wastewater flows slowly through the tanks, solids settle to the bottom as raw or primary sludge. Mechanical scrapers push this sludge toward a collection hopper. The sludge is removed by pumping and the floating materials like grease by mechanical surface-skimming devices.

2.6 CONCLUSION

The proposed primary treatment plant should treat the wastewater coming from domestic and industrial sources by gravity. The approach velocity for the plant shall be in the range of (0.6-1.2 m/s) according to the design standards, which shall protect and conserve the screens by removing large debris with coarse screens while fine screens take smaller particles. It cleans the screens mechanically, hence reducing manual labour and allowing staff to have time to perform other duties. The grit removal system is in place to reduce chances of equipment damage or blockages in the underground pipes. In addition, the primary treatment will be able to handle removing scum, which includes grease, oil, and all floatables that may enter the plant for optimal performance and reliability.

3.1 General - Primary Treatment Process

Primary treatment is the initial step in the wastewater treatment process, aiming to remove large solids and reduce the organic load on the system. This process primarily involves physical methods such as screening and sedimentation. The wastewater from both residential areas and agricultural runoff will be subjected to coarse screening to remove large debris like plastics, leaves, and other floating objects. After screening, the wastewater enters sedimentation tanks, where the flow slows down, and allowing heavier solids to settle at the bottom as sludge. Primary sedimentation can achieve a 30-40% reduction in BOD and a 50-70% reduction in TSS, depending on the detention time and flow characteristics. Lighter materials, such as oils and greases, are skimmed off the surface (Davis, 2010).

Given the rural and agricultural nature of the municipality, grit removal is particularly essential to eliminate sand, gravel, and other inorganic materials that could damage downstream equipment. This primary treatment step ensures that most of the suspended solids and floating materials are removed before secondary treatment, reducing the load on biological processes and protecting the plant's mechanical systems (Davis, 2010). The design of these systems is tailored to handle the specific wastewater characteristics of the area, with an emphasis on maximizing water recovery while maintaining operational efficiency.

3.2 Hydraulic Profile

The hydraulic profile is essential for determining how wastewater flows through the treatment plant, from the inlet to discharge, while accounting for head losses, changes in elevation, and maintaining gravity flow wherever possible. The goal is to minimize energy consumption by leveraging gravity, ensuring smooth flow through the plant. The hydraulic profile outlines the movement of wastewater through various components such as screens, sedimentation tanks, and clarifiers, ensuring that velocity is kept within an optimal range (Davis, 2010).

Given the plant's capacity of 35.4 ML/d (which converts to 0.41 m^3/s), the hydraulic design should maintain this flow rate without allowing velocity to drop below a point where solids remain suspended. A lower velocity might cause premature settling in pipes, leading to blockages, while a velocity too high could prevent adequate settling in sedimentation tank.

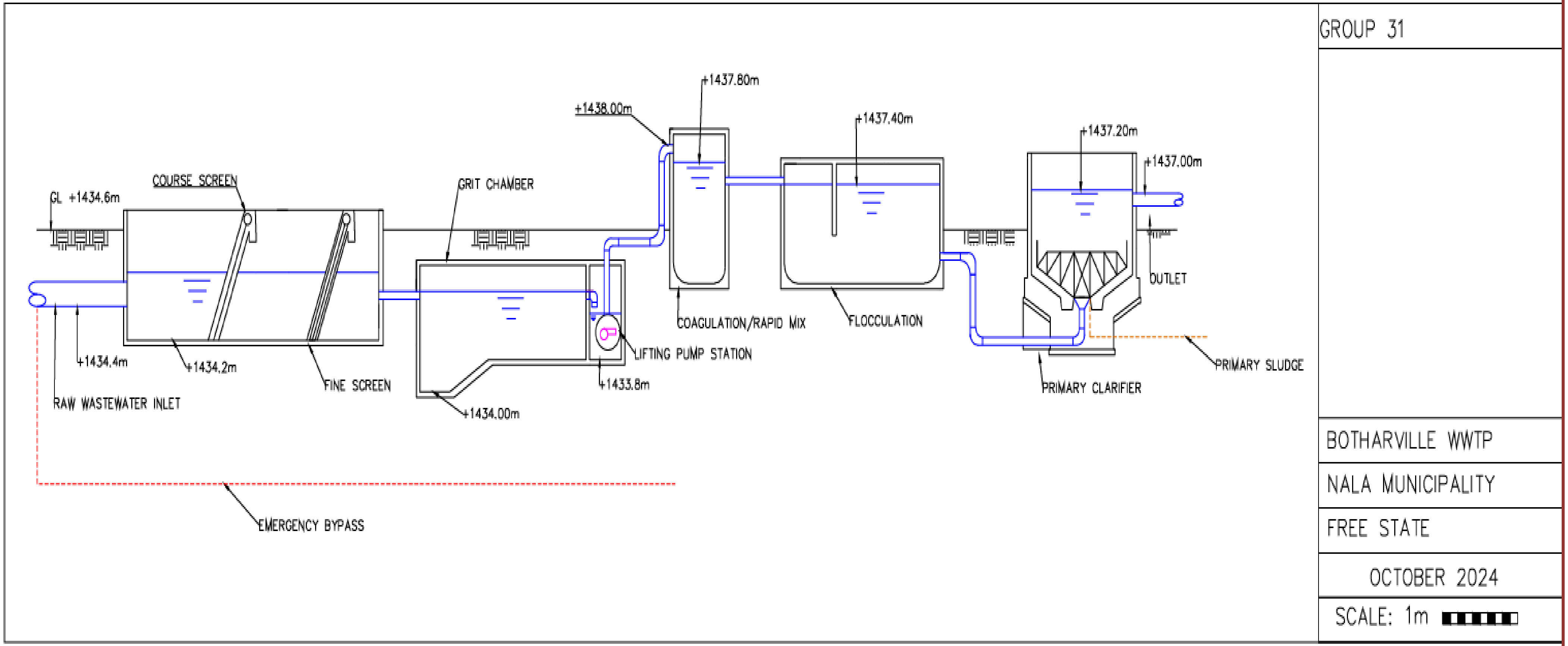


Figure 3: HYDRAULIC PROFILE OF BOTHARVILLE WWTP

3.3 Location of Mechanical Facilities

The location of mechanical facilities in the wastewater treatment plant is crucial for ensuring smooth operation, minimizing energy consumption, and protecting sensitive equipment. Mechanical components such as coarse screens and grit removal chambers must be positioned near the plant inlet to protect downstream equipment like pumps and sedimentation tanks from large debris.

In this WWTP, the coarse screens will be placed about 3 meters from the plant's inlet, followed by the grit chamber about 1 meter downstream. These facilities remove large debris and heavy inorganic materials, such as sand and gravel, from the wastewater before it enters the sedimentation tanks. By removing such materials early in the treatment process, the risk of damaging sensitive equipment downstream is minimized, and the efficiency of the primary treatment process is improved.

By minimizing the distance between the components, the plant can operate more efficiently and cost-effectively.

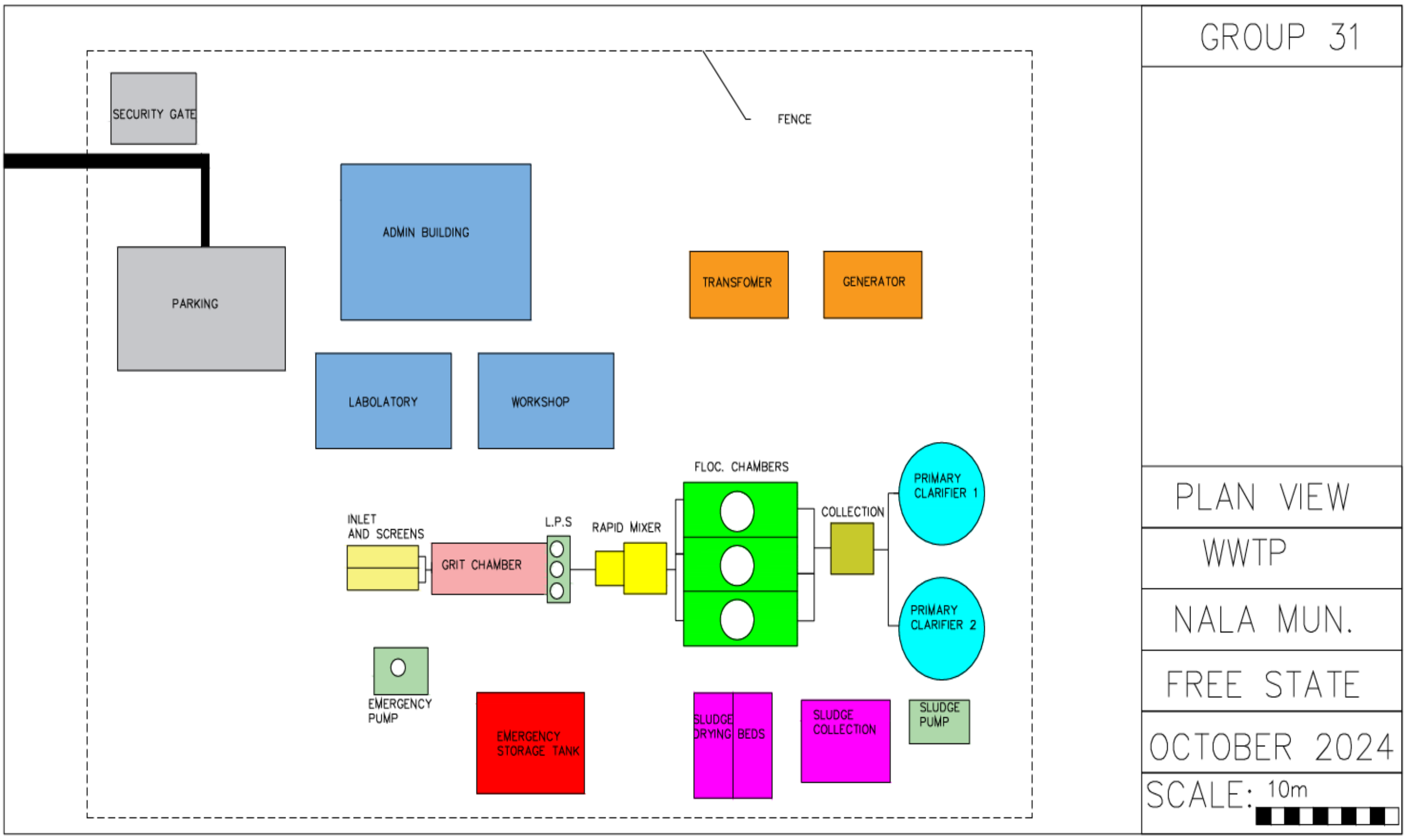


Figure 4: PLAN VIEW OF THE WWTP LAYOUT

3.4 Lifting Pump Station

The lifting pump station is designed to elevate wastewater when gravitational flow is insufficient. Submersible centrifugal pumps are commonly used for their reliability and efficiency in handling varying flow rates (Davis, 2010). The total power required for lifting is determined by the flow rate, head, and pump efficiency, as illustrated in your design calculations. Ensuring proper pump selection is key to reducing energy consumption and operational costs.

The lifting pump station is designed with the following specifications:

Main Pumps:

Type: Submersible centrifugal

- Number of units: 3 (2 duty + 1 standby)
- Capacity per pump: 1,844 m^3/h
- Total head: 12 m
- Motor rating: 90 kW
- Efficiency: 75%

3.5 Sewage Pump System

The sewage pumping system ensures the consistent movement of wastewater through the treatment plant. Dry pit centrifugal pumps are typically used for this purpose due to their durability and ability to handle large volumes of wastewater without clogging (Davis, 2010). The use of multiple pumps (duty and standby) ensures redundancy, enhancing system reliability.

The main sewage pumping system consists of:

- Pump type: Non-clog centrifugal
- Configuration: Dry pit installation
- Number of units: 4 (3 duty + 1 standby)
- Capacity per pump: 1,229 m^3/h
- Total head: 15 m
- Motor rating: 37 kW

3.6 Emergency Sewage Pump

Emergency pumps are crucial for maintaining system operation during power failures or other emergencies. Diesel-driven pumps are commonly used for their reliability and high capacity to handle peak flows (Davis, 2010). Fuel storage for 24-hour operation is essential to ensure continuous operation during extended power outages.

Emergency pumping system specifications:

- Type: Diesel-driven centrifugal

- Capacity: 3,688 m³/h
- Total head: 15 m
- Power rating: 90 Kw
- Fuel storage: 48-hour operation capacity (considering Eskom load shedding)

3.7 Inlet Gate for Lifting Pumping Station

The inlet gates are designed to control flow into the lifting pumping station. Electrically operated sluice gates with manual overrides are often used to provide operational flexibility and ensure proper sealing under high flow conditions (Davis, 2010). The use of stainless steel in construction ensures durability and resistance to corrosion.

Gates specifications:

- Type: Electrically operated sluice gate
- Number: 2
- Size: 1000mm × 1000mm
- Material: Stainless steel 316
- Actuator: Electric with manual override
- Sealing: EPDM rubber seals

3.8 Inlet Gate for Coarse Screen Channel

Manual sluice gates in the coarse screen channel are used to regulate flow through the screening system. The gates must be durable, made from stainless steel, and equipped with EPDM rubber seals for effective sealing (Davis, 2010).

Screen channel gates:

- Type: Manual sluice gate
- Number: 2 per channel
- Size: 800mm × 800mm
- Material: Stainless steel 316
- Operation: Manual handwheel
- Sealing: EPDM rubber seals

3.9 Coarse Screening System

The coarse screening system removes large debris to protect downstream equipment from damage. Mechanically cleaned bar screens with proper bar spacing ensure efficient removal of solids, while maintaining the necessary approach velocity to prevent overflow (Davis, 2010). The screen's angle plays a role in optimizing debris removal while minimizing head loss across the system.

Calculation and design assumptions

- Type: Mechanically cleaned bar screen
    - Number of units: 2 (1 duty + 1 standby)
    - Screen angle: 75° to horizontal

- Flow rate, QAV: 35.4 ML/d= 0.41 m³/s
- Peak hour factor: 2.5
- Width of channel, b: 1.43 m
- Depth of channel, D: 1.25 m
- Flow depth, y: 1.12 m
- Bar width: 10 mm
- Bar spacing: 25 mm
- Discharge coefficient: 0.6
- Screenings produced: 2 L/ML
- Screenings handling capacity: 70.8 L/d

Peak hour flow rate, Q_P

$$Q_P = 2.5 \times Q_{AV} = 2.5 \times 35.4 = \frac{88.5ML}{d} = 1.024\, m^3/s$$

Approach velocity, V_{ap}

$$A = W \times D = 1.43 \times 1.12 = 1.602\, m^2$$

$$V_{AP} = \frac{Q_{AV}}{A} = \frac{1.024}{1.602} = 0.64\, m/s$$

The approach velocity is above minimum of 0.4 m/s ($0.4<V_{ap}$)$\therefore\ ok$

Number of Bars Calculation

$$N = \frac{W - Bar\ spacing}{BarW + Bar\ spacing} = \frac{1430 - 25}{10 + 25} = 40.14 \approx 40$$

No. of spacings

$$N_{SP} = N_{bars} + 1 = 40 + 1 = 41$$

Velocity through the screen

$$b_{eff} = 25 \times 41 = 1025\, mm$$

$$A_{eff} = y \times b_{eff} = 1.12 \times 1.025 = 1.148\, m^2$$

$$A = W \times D = 0.48 \times 1.2 = 0.576\, m^2$$

$$V_{thru} = \frac{Q_P}{A_{eff}} = \frac{1.024}{1.148} = 0.892\, m/s$$

The velocity through the screen is less than 0.9 at peak hour ($V_{thru}<0.9$ m/s) $\therefore\ ok$

Head losses through the screen, h_L

$$h_L = \frac{1}{0.6}\left(\frac{V_{thru}^2 - V_{ap}^2}{2g}\right) = \frac{1}{0.6}\left(\frac{0.892^2 - 0.64^2}{2 \times 9.81}\right) = 0.033\ m = 33\ mm$$

Quality of screenings produced, q_{sc}

$$q_{sc} = 35.4 \times 2 = 50.8\ L/d\ \therefore ok$$

3.10 Odour Control System

Waste water treatment plants produce different types of odours like ammonia, hydrogen sulphide, mercaptans and amines. Not only is the production of these odours unpleasant but they tend to be toxic for the environment and they harm people's health. The Bothaville waste water treatment plant will be using a combination of both the liquid phase system and vapour phase system as the chosen odour control systems. The liquid phase system is a process where the water is treated with chemical like chlorine, calcium hydroxide and hydrogen peroxide etc to prevent the formation of odour. The vapour phase system is a process where the vapour gases released by the odour are captured using different methods like bio-filtration or scrubbing. Apart from the implementation of the liquid and vapour phase systems, there are other measures that can be put into place to control odour in the plant. The prevention of leaks and spillages from the waste water treatment plant may control odour as no odour water will be exposed into surroundings. Furthermore, the covering of the waste water tanks may be another measure to control odour as covering the tanks with a gastight cover may prevent the gases produced by the odour vapours from coming out of the tanks (ChemReady,2019).

3.11 Construction Method for Lifting Pump Station

In order to begin construction for the lifting pump station, materials and equipment need to be delivered to the site of the pump station. The construction site location is found to be near homes (surrounding residential areas) therefore, building temporary roads just for the transportation of the large equipment is ideal. This will make transportation easier while putting the safety of residents forward. This also means that the residents won't be inconvenienced through any means of travel. Secondly, grubbing the site removing any form of vegetation is the next step. This step is done in order to prepare the ground for construction. Next, the digging of trenches and the installation of the foundation for the pump station will be constructed where a reinforced concrete slab will be placed preparing for the walls that will be constructed. Once the foundation is set, the walls of the structure are built and the installation of the pipework, valves and earth bonding is done. After, the pipework has been installed, the installation of pumps and control equipment (including cables and power supply) should be installed as these are responsible for regulating how the system works. The final step would be to finish building the structure by installing the roof, doors, windows and floors making the structure complete (JICA).

3.12 Head-works

Head-works is the process where large objects and particles e.g. plastic and debris is blocked from going through into the waste treatment process. Bar screen chambers, grit chambers (responsible for removing sand and gravel) and flow measurement devices are all components of headworks.

Headworks are important since the downstream equipment is preserved from being damaged because of this process. Damage of the downstream equipment could easily hinder the waste water treatment process. This process prevents blockages and clogging significantly. Not only does it protect the equipment but it also allows efficient and effective operation minimising costs (Ecto, 2023).

3.13 Medium Screen

Screen has a spacing of usually 6-150mm. These types of screens collect larger particles and objects like branches, leave, small pieces of litter etc. Medium screens are responsible for protecting the downstream equipment like valves and weirs and reduce the presence of BOD and COD in the waste water. Course screens are easier to maintain and clean compared to fine screens. Medium screens are divided into two categories being hand cleaned and mechanically cleaned. Once the medium screen traps the large particles and objects from going through, the items are then collected by the trash rake and then disposed of into the trash bin (Ghangrekar & Kharagpur, 2011).

3.14 Grit Chamber

A grit chamber is a component used to remove all the grit materials found in the waste water. This is done by reducing the velocity of the water in such a way that the heavier materials and other inorganic materials (grit) settles while the light organic materials continue to flow with the rest of the water. The settled grit is then removed from the bottom and is disposed of into the bin. Grit chambers are important as they prevent the accumulation and cementation of inert material within the tanks. The equipment is less likely to be blocked or clogged meaning that the grit chambers also reduce the probability of the equipment to experience wears and tears (RACO, 2024).

Assumptions:

- Type- aerated grit chamber
- Detention time- 2 minuets
- Air flows- 0.45 m^3/min per meter of the tank length
- Depth- 4 m
- Diameter- 5m
- Headloss is negligible

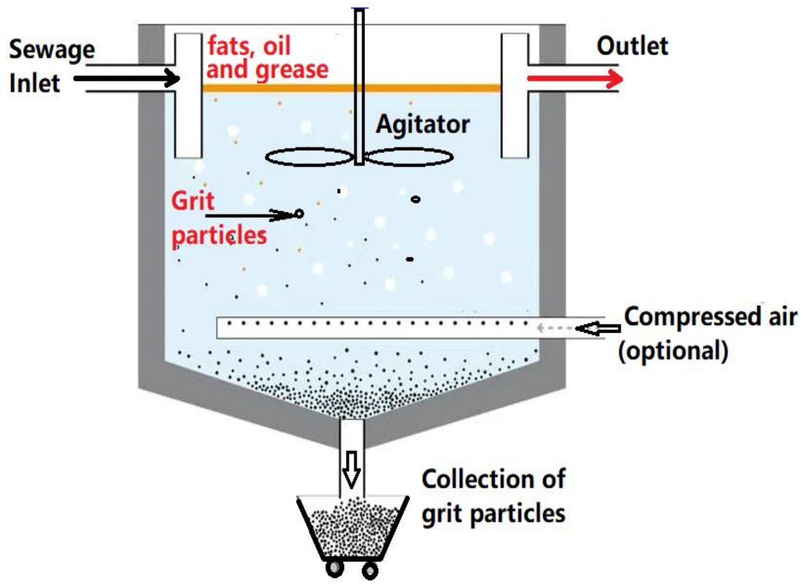


Figure 5: Grit Chamber

3.15 Aerated Grease Trap Chamber

The aerated grease trap chamber allows water to get in through the inlet. Once the water is in the chamber, the grease and oil are captured from the wastewater. Oxygen is then introduced into the chamber which is responsible for breaking down organic materials through biological processes. Once this is done the wastewater then leaves the chamber out the outlet leaving the grease and oil behind floating on top. This chamber reduces clogging that is grease or oil related by up to 99% which is very significant. Once the grease is left behind, it is skimmed and removed. The prevention of grease from going through will reduce odor, the attraction of pests and insects and the blocking of equipment (Veolia, 2024).

3.16 Fine Screen

Screen spacing is usually less than 6mm. These types of screens use closely spaced bars or woven wire cloths to trap particles. They are typically used in preliminary treatment (follows the course screen) where smaller particles like fine suspended solids are stopped from passing through to prevent clogging. Fine screens improve the effluent quality and protects most of the equipment located downstream. Fine screens are divided into three categories being static wedge wire, drum and step screens. Once the fine screen traps the fine suspended particles from going through, the items are then collected by the trash rake and then disposed of into the trash bin which is the same process that occurs during the medium screens (Ghangrekar & Kharagpur, 2011).

3.17 Odour Control System

- Increases safety of the environment and the health of people
- Odour control systems promote clean air and quality air
- Odour control systems decrease the chances of people complaining about the toxic and harmful smell they are exposed to

3.18 Sludge Treatment facility

The first step that will be implemented during the sludge treatment is thickening of the sludge. Once the sludge is thick, the overall mass of solids is reduced and any types of organisms and pathogens found in the sludge is then destroyed through a process of digestion. The third step of the sludge treatment would be to dewater the sludge. During this process, water is taken out of the sludge through evaporation leaving the sludge to dry up and turn into a solid. Once the sludge has turned into solids, it may be disposed of. The dried-up sludge will be used as a form of fertiliser for crops as it acts as a good soil conditioner. Also, the sludge will be used for biofuel means (Ambulkar & Nathanson, 2024).

3.19 Waste Sludge Feeding Pump

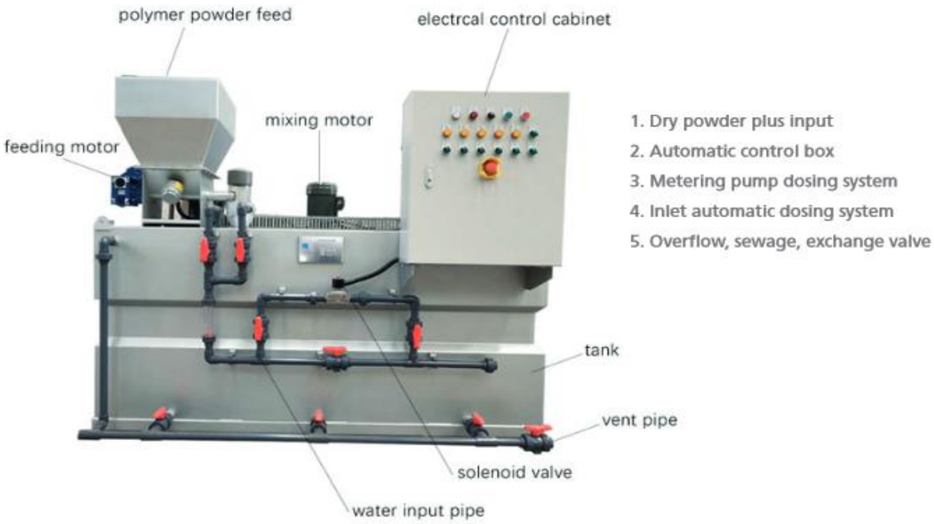
The main purpose of a waste sludge feeding pump is to transfer high solid waste fluids from one stage of the treatment process to the other. Due to the presence of sludge feeding pumps, the flow of the sludge is well controlled maximising consistent flow management. It is essential to understand the sludge characteristics before selecting the type of waste sludge feeding pump you want (MaltoTec, 2024).

Characteristics that need to be looked at:

- Sludge viscosity
- Concentration of solids
- Particles and their sizes

3.20 Polymer Dissolving System

Figure 6: Polymer Dissolving System



Assumptions:

- Optimum composite polymer dosage 2.7mg/L
- Optimum pH 7.6

- Concentration of polymer is 0.7%
- Water temperature 20 degrees Celsius

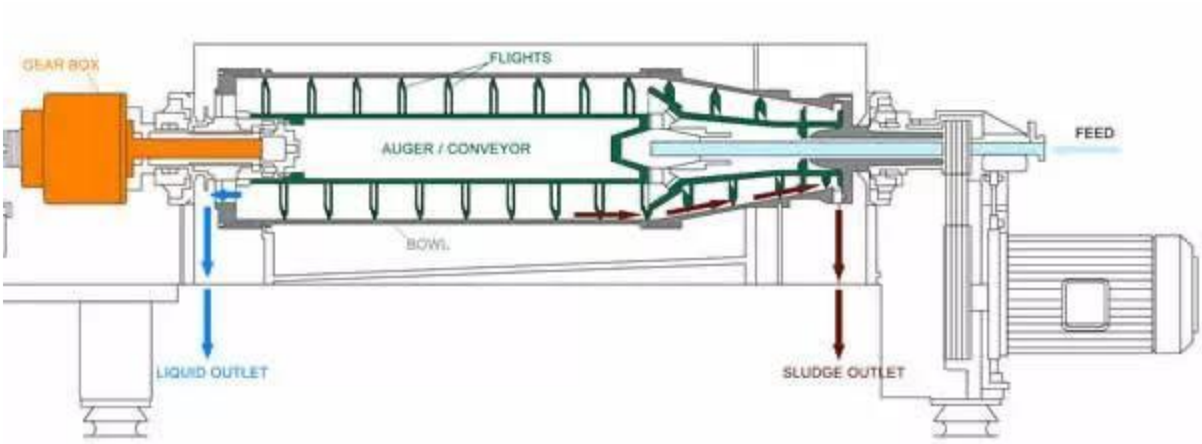
3.21 Polymer Dosage Pump

Figure 7: polymer preparation unit

3.22 Sludge Dewatering Machine

This machine is responsible for significantly reducing the volume of sludge by removing the water content in the sludge. This step of the waste water treatment is usually done after removing all the harmful gases, toxins and byproducts right before final disposal. The method implemented for our sludge dewatering process is centrifugation (Amcon, 2024).

Figure 8: Sludge Dewatering Machine



Steps of process:

- Sludge enters the machine
- Centrifugal forces separate liquid from solids
- Liquid is expelled from liquid outlet
- Dry solids are then expelled out the machine through its outlet

3.23 Sludge Cake Conveyor

The Sludge cake conveyors as essential as they handle the dewatered sludge. They transport the dewatered sludge from the sludge dewatering machine through means of either a closed or open system to storage hoppers. The type of system used for our waste water treatment plant is an open system. This system uses conveyor belts that are inclined at an angle to transport the sludge cake. Though this system works efficiently and effectively, open systems do have disadvantages to them. Open systems release odours into the atmosphere, cause a contamination hazard and the machines produce a lot of noise which might contribute to noise pollution (Netzsch, 2022).

3.24 Sludge Cake Hopper

This device collects, stores and handles the dewatered sludge that comes from the sludge cake conveyor (for short term). The machines do come in 8 different types therefore it is vital to consider factors like the volume of the sludge and space constraints before selecting the type of hopper to be used for sludge handling. Not only do sludge hoppers help with the efficient management of dewatered sludge but they highlight operational efficiency, help with the protection of environmental standards. To maximise the advantages of sludge cake hoppers, these machines need to be designed well with all characteristics taken into account and the machines should be regularly maintained (MYEP, 2016).

3.25 Conclusion on the primary treatment process

Designing a waste water treatment facility is a long and complex process that requires careful decision making for each of the equipment selected looking at all characteristics and factors. Each machine selected needs to meet the required standards and contribute towards the waste water plant treatment goals. Preliminary treatment is vital in waste water treatment processes because it protects the equipment, increases the efficiency (enhance operations) of the system.

3.26 Calculations

- Clarifier design
- Design parameters

- Flow rate, Q: 35.4 ML/d = 35 400 m^3/d
- Overflow rate, V_o: 30 $m^3/d/m^2$
- Side Water Depth, (SWD): 4 m
- Feed well depth: 50% of SWD
- Feed well diameter: 12% of clarifier diameter
- EDI depth: 30% of SWD
- EDI diameter: 10% of clarifier diameter
- We assume 3% (30 000 mg/L) for solids in sludge.
- Sludge hopper volume: 1 m^3
- BOD: 230 mg/L
- TSS: 336 mg/L
- Clarifiers in use: 1 out of 2
- Clarifier type: Centre-feed circular clarifier with energy-dissipating inlets (EDIs)

Clarifier surface area, A_S

$$A_S = \frac{Q}{V_O} = \frac{35\ 400}{30} = 1\ 180\ m^2$$

Clarifier diameter, D

$$A_S = \frac{\pi D^2}{4}$$

$$1\ 180 = \sqrt{\frac{1180 \times 4}{\pi}} = 38.76\ m = 39\ m$$

<u>Feed well design:</u>

Feed well depth, d_{fw}

$$d_{fw} = 0.5 \times 4 = 2\ m$$

Feed well diameter, D_{fw}

$$0.12 \times 39 = 4.68\ m$$

Feed well detention, t_{fw}

$$t_{fw} = \frac{\forall}{Q} = \frac{\left(\frac{\pi 4.68^2}{4}\right) \times 2 \times 24 \times 60}{35\ 400} = 1.399 \approx 1.4\ min$$

EDI design

EDI depth, d_{EDI}

$$d_{EDI} = 0.3 \times 4 = 1.2\ m$$

EDI diameter, D_{EDI}

$$D_{EDI} = 0.1 \times 39 = 3.9 \approx 4\ m$$

EDI detention time, t_{EDI}

$$t_{EDI} = \frac{\forall}{Q} = \frac{\left(\frac{\pi \times 4^2}{4}\right) \times 1.2 \times 24 \times 60}{35\ 400} = 0.583 = 35\ sec$$

Weir loading

Weir length, L

$$L = \pi \times D = \pi \times 39 = 122.52\ m$$

Weir loading, WL

$$WL = \frac{Q}{L} = \frac{35\ 400}{122.52} = 288.93 \approx 289\ m^2/d/m$$

Sludge production

Total suspended solid, TSS

$$TSS\ load = Q \times TSS\ concentration = 35\ 400 \times 11\ 894\ 400\ g/d = 11\ 894.4\ kg/d$$

Sludge volume, $\forall_{sludge}$

$$sludge\ volume = \frac{11\ 894}{30\ 000 \times 10^{-3}} = 396.48\ m^3/d$$

Checking sludge hopper capacity

$$sludge\ removal\ freq. = \frac{sludge\ volume}{hopper\ volume} = \frac{396.48}{1} = 396.48\ removal/d$$

$$time\ between\ removals = \frac{24 \times 60}{396.48} = 3.63\ min/removal$$

$$\therefore continous\ sludge\ removal\ system\ to\ be\ used.$$

Tank detention time, td

$$t_d = \frac{\forall}{Q} = \frac{\left(\frac{\pi \times 39^2}{4}\right) \times 4 \times 24}{35\ 400} = 3.24\ hrs$$

BOD % removal

$$P = \frac{t}{a + bt} = \frac{3.24}{0.018 + 0.02 \times 3.24} = 39.13\% \approx 39\%$$

$$P_{eff} = 100 - 39 = 61\%$$

$$BOD = 61\% \times 230 = 140.3\ mg/L$$

TSS % removal

$$P = \frac{t}{a + bt} = \frac{3.24}{0.0075 + 0.014 \times 3.24} = 61.3\% \approx 61\%$$

$$P_{eff} = 100 - 61 = 39\%$$

$$TSS_{eff} = 39\% \times TSS = 39\% \times 336 = 131.04\ mg/L$$

3.25. CALCULATIONS

- Clarifier design

- Design parameters

- Flow rate, Q: 35.4 ML/d = 35 400 m^3/d
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EDI diameter, D_{EDI}

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Weir length, L

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Total suspended solid, TSS

$$TSS\ load = Q \times TSS\ concentration = 35\,400 \times 11\,894\,400\,g/d = 11\,894.4\,kg/d$$

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Chapter 4: RISK ANALYSIS

4.1 General Theory of EIA/ESIA

The Environmental Impact Assessment (EIA) is a systematic process that evaluates the potential environmental effects of a proposed project, both positive and negative. The primary objective is to provide decision-makers with the necessary information to make informed decisions and to design strategies to mitigate environmental damage before the project begins. According to the United Nations Environment Programme (UNEP), EIA is essential for sustainable development, ensuring projects are socially equitable and environmentally responsible (UNEP, 2023).

The Environmental and Social Impact Assessment (ESIA) goes a step further, incorporating the social and economic implications of the project. It assesses how the project might affect local communities and human health. This process ensures that the project will bring benefits without disproportionately harming the environment or local populations (Davis, 2010).

4.2 Considerations Taken for Environmental Impact Assessment (EIA)

For Nala Local Municipality, the environmental impact assessment must focus on its primary agricultural activities, natural resources, and community health. The following are key environmental considerations:

Negative Impacts:

- **Soil and Water Contamination**: The project could lead to contamination of the region's soil and water sources if wastewater is not properly treated. Since the Nala Municipality relies heavily on agriculture, any pollution could impact both crop production and groundwater quality.
    - Mitigation: Use advanced filtration systems to treat wastewater effectively before discharging it into local water bodies (Davis, 2010).
- **Loss of Biodiversity**: Construction activities could lead to the displacement of local flora and fauna, especially in areas used for grazing or crop production.
    - Mitigation: Ensure that construction is planned away from sensitive ecosystems and minimize habitat disruption (UNEP, 2022).
- **Increased Carbon Emissions**: The use of heavy machinery during construction will contribute to greenhouse gas emissions, which may affect air quality in the region.
    - Mitigation: Adopt low-emission machinery and offset carbon emissions by planting trees in affected areas (Green Drop, 2021).

Positive Impacts:

- **Improved Water Quality**: The construction of a wastewater treatment plant will significantly improve water quality in the municipality, reducing the risks of waterborne diseases and protecting the local ecosystem (Davis, 2010).

- **Support for Agricultural Activities**: Treated water can be repurposed for agricultural irrigation, reducing the stress on freshwater resources, which are critical for farming in the area (Department of Water and Sanitation, 2021).
- **Conservation of Natural Resources**: The project will help reduce the overuse of local rivers and groundwater sources for irrigation by introducing recycled water into the agricultural cycle, aiding in water conservation efforts (Green Drop, 2021).

4.3 Considerations Taken for Social Impact Assessment (ESIA)

In Nala Municipality, the social impact of the wastewater treatment project will primarily affect the local communities involved in agriculture and those living in close proximity to the construction site.

Negative Impacts:

- **Health and Safety Risks**: Construction activities pose risks such as accidents and potential exposure to harmful materials. Local residents working near the site might face increased health and safety concerns.
    - Mitigation: Implement strict safety protocols, including providing personal protective equipment (PPE) and regular health and safety training for workers and local residents (ILO, 2021).
- **Temporary Disruption of Agricultural Activities:** Construction could lead to disruptions in farming activities, such as restricted access to fields and increased dust pollution affecting crop growth.
    - Mitigation: Schedule construction activities outside of key planting and harvesting periods, and establish dust control measures, such as watering roads and covering trucks (UNEP, 2022).

Positive Impacts:

- **Job Creation**: The construction and operation phases of the project will create employment opportunities for the local population. This will directly benefit the local economy by providing income for families and improving living standards (World Bank, 2021).
- **Health Improvements**: With improved water treatment, there will be fewer cases of waterborne diseases such as cholera and diarrhoea, which are common in areas with poor sanitation. This will lead to better overall community health and reduced healthcare costs (WHO, 2021).
- **Sustainability for Farmers**: The treated wastewater can be reused in irrigation, offering farmers a sustainable water source, especially in periods of drought, which are common in the Free State (Development Bank of South Africa, 2021).

4.4 Environmental and Social Risk Analysis Table

Table 4: Environmental and Social Risk Analysis Table

Impact	Affected Parties	Magnitude	Duration	Likelihood	Mitigation/Comments
Soil and Water Contamination	Farmers, local water sources	High	Long-term	Medium	Advanced filtration systems and regular monitoring
Loss of Biodiversity	Local ecosystems	Medium	Short-term	Medium	Minimize habitat disruption and replant vegetation
Carbon Emissions	Local population, environment	Medium	Short-term	High	Use low-emission machinery, plant trees
Job Creation	Local population	High	Long-term	High	Employment during construction and operations
Water Quality Improvement	Local communities, farmers	High	Long-term	High	Treated water will improve irrigation and health
Health and Safety Risks	Workers, nearby residents	Medium	Short-term	High	Strict safety protocols and training
Temporary Agricultural Disruption	Farmers	Medium	Short-term	Medium	Schedule work outside planting/harvesting seasons

4.5 CONCLUSION

While construction may temporarily disrupt agriculture and pose risks like noise, dust, and soil contamination, these can be mitigated through proper planning and sustainable practices. The project's long-term benefits, including improved water quality, job creation, and enhanced infrastructure, will significantly boost local agriculture and reduce waterborne diseases. By reusing treated wastewater for irrigation, the project supports farmers, especially during droughts, ensuring resource sustainability. Ultimately, the positive environmental and social outcomes far outweigh the temporary disruptions, contributing to the region's long-term development.

5. Operation and Maintenance

Effective operation and maintenance (O&M) of the wastewater treatment plant (WWTP) in Nala Local Municipality is crucial for ensuring that the plant meets water quality standards while supporting the local community's domestic and agricultural needs. The plant must handle significant fluctuations in inflows, especially during rainy seasons when agricultural runoff increases. Proper O&M helps minimize downtime, extend equipment lifespan, and ensure continuous service.

Operation

- Screening: Removes large debris like plastics and agricultural waste, protecting downstream equipment.
- Grit Removal: Essential for removing sand and grit from soil erosion and stormwater, preventing damage to pumps and machinery.
- Sedimentation: Settles suspended solids to the bottom of tanks, forming sludge.
- Sludge Pumping: Periodic removal of sludge ensures continuous plant operation, particularly during periods of high inflow.

The operation must focus on managing variable inflows, with attention to balancing sedimentation and ensuring proper sludge management during peak seasons.

Maintenance

- Preventive Maintenance: Regular cleaning and inspections of tanks, pumps, and pipelines. This reduces blockages from agricultural debris and ensures the system handles the solid load effectively.
- Corrective Maintenance: Quick repairs during peak agricultural periods to avoid service interruptions. Critical equipment like pumps should be replaced or repaired promptly when needed.
- Predictive Maintenance: Monitoring systems identify potential failures in critical components like sludge pumps, allowing for pre-emptive repairs.

Maintenance must be adaptive to seasonal changes and increased inflows from agriculture, reducing system stress during critical periods.

The WWTP requires 23 staff members, including a Plant Manager, Operations and Maintenance Supervisors, Operators, Lab Technicians, and General Workers. Regular staff training ensures compliance with environmental regulations and operational efficiency during peak periods.

Operation costs are estimated at R500,000 to R750,000 annually, covering labour, energy, and chemicals. Maintenance costs range from R150,000 to R200,000 for preventive maintenance, and R250,000 to R400,000 for corrective maintenance, ensuring the longevity and efficiency of the plant.

6. Project duration: 3 months (5 days a week and 8 hours/working day as per South African Basic

Description	Units	Quantity	Price/Quantity	Total amount
MATERIALS				
Clarifiers	-	2	R250000	R500000
Industrial valves	-	16	R1800	R28800
Pipes	m	65	R450/m	R29250
Pumps	-	2	R790	R1580
Electrical panels	-	2	R3700	R7400
Vessels	-	3	R4000	R12000
CONSTRUCTION				
Gravel	m^3	600	R200/m^3	R120000
Sand	m^3	550	R230/m^3	R126500
Water	L	3500	R20/l	R70000
Cement	kg Bags	400	R100/bag	R40000
Reinforcement bars	m	500 Y24 bars	R35/1m bar	R17500
Earthworks	m^3	3220	R55/m^3	R177100
Aggregates	Kg	200	R100	R20000
Bricks	-	600	R3/brick	R1800
MACHINES AND EQUIPTMENT (used for 1 month only)				
Excavator	-	2	R70/hr	R22400
Loaders	-	3	R50/hr	R24000
Dump trucks	-	1	R85/hr	R136000
Compactors	-	1	R50/hr	R8000
Power shovel	-	1	R90/hr	R14400
LABOUR (full 3 months)				
Wastewater engineer	-	1	R180/hr	R86400
Civil engineer	-	1	R160/hr	R76800
General workers	-	15	R90/hr	R648000
Technicians	-	2	R120/hr	R115200
Inspectors	-	2	R100/hr	R96000
TOTAL INCL. TAX				**R 1 731 130**

Conditions of Employment Act)

Conclusion

The main aim of this project was to provide an appraisal for the primary treatment in the Free State, Bothaville. This report briefly explains the design basis, provides in depth information regarding waste water processes and equipment that was used. Furthermore, the report carefully describes the risk analysis methods that will be implemented through the project. Lastly, a thorough bill of quantities is provided to show the materials needed for the project including the prices of the items and the overall estimated price.

Implementing wastewater treatment plants is vital for protecting public health, preserving the environment, conserving resources, and promoting sustainable economic growth.
Their role in managing wastewater effectively is essential for healthy and resilient communities.

7. Recommendations

Sludge treatment is important to manage in wastewater because it significantly decreases its impacts onto the environment and people. The microorganisms found in sludge can be very dangerous when in contact with humans hence the need to treat the sludge. A way of preventing the sludge from releasing harmful toxins into the environment is by stabilising it. Below are a few recommendations that will be used for the preliminary treatment process for the waste water treatment plant in the Free State, Bothaville.

- Thickening: mechanical thickening
- Stabilization: Aerobic digestion
- Dewatering: usage of centrifuges
- Disposal: the waste will be disposed of at landfills

Technology selection It is recommended to use the following factors before beginning with the technology selection process for the waste water plant:

- How complex the plant will be
- The size of the location where the treatment plant will be situated
- The environmental characteristics of where the waste water plant is situated will determine the type of equipment to use.

General recommendations:

- Regular monitoring of all equipment and request inspections/ maintenance
- Always opt for advanced and energy efficiency systems
- Invest in the implementation of biogas utilisation systems (this method turns waste into energy) to promote sustainability

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