UNIVERSITY OF CAPE TOWN
IYUNIVESITHI YASEKAPA • UNIVERSITEIT VAN KAAPSTAD

Case study of the implementation of a membrane bioreactor (MBR) package wastewater plant for treatment of domestic effluent in a remote location

Master of Engineering in Water Quality Engineering

Research Dissertation

Prepared by:
Johan Andries Kritzinger

Student nr:

KRTJOH013, 1622712

Supervisor
Dr David Ikumi

Department of Civil Engineering
Faculty of Engineering and the Built Environment
University of Cape Town

February 2022

Declarations

I, Johan Kritzinger, know the meaning of plagiarism and declare that all the work in the document, save for that which is properly acknowledged, is my own. This project has been submitted to the Turnitin module (or equivalent similarity and originality checking software) and I confirm that my supervisor has seen my report and any concerns revealed by such have been resolved with my supervisor.

Signed by candidate	14/02/2022
Johan Kritzinger	Date

Executive summary

The global population is more than it has ever been before; as it continues to grow, pressure on water resources increases due to the demand for the inalienable human right of access to basic services. Additionally, the detrimental impact of human activity on the environment has been realized and active measures to mitigate the threats posed by pollution (amongst other forms of environmental impact) are receiving high priority by numerous stakeholders and throughout the various parts of industry. These challenges all come into play in a unique manner when focusing on sanitation provision and wastewater treatment in rural areas. Rural communities are often disenfranchised by the lack of opportunities and services available to them and this is certainly compounded by the unique and challenging conditions for service provision and infrastructure implementation and management in these areas.

Decentralized wastewater treatment is an emerging approach that is well suited to meeting the needs of people in rural areas and as a result has attracted the interest of researchers and started to gain traction in industry. Principles of conventional technologies such as the Activated Sludge (AS) system are incorporated with newer technologies such as the membrane bioreactor (MBR) to come up with innovative solutions that have promising potential but must be designed and implemented to be fit for purpose. The stringent emission control that is now common in many countries and being applied in South Africa under the National Water Act (NWA) means that sewage and effluent need to be handled according to the highest quality requirements which will not be met in areas with insufficient infrastructure (such as many rural areas). As with all things, the cost of implementing and maintaining a solution could determine the feasibility thereof and thus understanding through quantifying and optimizing the cost would be prudent. Some researchers have found that MBR plants tend to cost more than conventional treatment systems, but that they do carry their own strategic advantages of which not least is the high-quality effluent that it produces.

This study provides a case study of a design and implementation of an MBR wastewater treatment plant (WWTP) on an agricultural farm in a rural area in the Western Cape of South Africa. The objectives were to (a) design the plant fit for purpose, using a scientifically accepted wastewater treatment process model, (b) evaluate the plant’s performance in terms of effluent/emissions produced and (c) perform the operation cost evaluation of the designed WWTP.

The AS model with biological nutrient removal (BNR) was developed in a Modified-Ludzack Ettinger (MLE) system adapted for MBR while using experimental raw water data as input. The outputs acquired from the model were used to size and design the practical implementation of the WWTP. The raw and treated effluent water and sludge quality data was obtained by experimental samples taken on site at the operational WWTP and tested by an analytical laboratory. The data was evaluated based on its trends, using statistical methods, using the effluent quality index for pollution and emissions, and using mass balances for verification. The operational costing was performed and evaluated according to the operational cost index.

The wastewater treatment plant was designed for 49.2 kl/day of wastewater in a bioreactor with MLSS of 12 000 mg/l and a sludge age of 25 days which yielded a reactor volume of 22 kilolitres. The minimum anoxic mass fraction was determined as 0.14 and then chosen as 0.24, but since it is an MBR plant the volume fraction of the anoxic was 0.27. The optimal a-recycle was determined as 3.5 and then chosen at 5. The total oxygen demand was found to be 28.6 kgO/day of which the membrane air scouring blower supplied 4.7 kgO/day and reduced the air supply required from the aeration blower to 23.8 kgO/day. To be conservative, two hundred membrane sheets were used which would operate

at a flux of 15.4 LMH. The reactor volume was also enlarged by a safety factor of 25% to 28 kilolitres. The small footprint of the WWTP comes at the cost of high energy usage. The model compared fairly well with the implemented WWTP particularly in terms of effluent ammonia and nitrate concentration.

The effluent water quality was good with all measured parameters on average being compliant with general limits for wastewater discharge. Particularly the removal of TSS (99%) and of COD (93.5%) was highly effective and there were less than 5 outlier results in total, which were for ammonia and nitrate. Out of the total number of parameters tested across all samples, 93% were compliant. The EQI for water was calculated as 12.1 with all contributions being positive while the EQI for sludge was 431.8 with one negative contribution from faecal coliforms amongst only positive contributions from the other parameters.

The operational cost was determined as R123 316 ex VAT per year of which more than 80% is attributed to energy usage. The aeration energy alone is 58% of the operational cost. The cost per kilolitre of treated effluent is R6.73 ex VAT, which for comparison is less nearly half the cost of what the local municipal rates for sanitation would be for the application and it is also less than the cost of irrigation water from the municipality which makes it an attractive prospect for reuse.

The conclusion from the study is that the WWTP design and implementation was accomplished by its cogent performance and reasonable operational cost. The objectives were achieved so that the design was developed and implemented with success, the effluent water quality was compliant, and the operational cost was understood and found to be feasible. The implications of the study are that decentralized sanitation service is being provided to a community that did not previously have access to this and that the wastewater produced by this community is now being adequately treated according to regulations, which ensures protection of the environment and advances public health.

Acknowledgements

I would like to thank my supervisor Prof. David Ikumi for mentoring and guiding me throughout my research project.

Many thanks to Alveo Water for the opportunity afforded to me to pursue my Master of Engineering Degree and in funding this research project.

I want to express my utmost gratitude and appreciation to my wife for all the support, patience, and understanding, especially in the last few months of the research project. It would not have been possible without you.

My family and friends are also thanked for their encouragement in seeing this out till the end.

Lastly, I would like to honour my Lord and Saviour who sustains me and to whom all glory is due.

Table of Contents

List of Abbreviations

AADY	annual average daily yield
ADWF	average dry weather flow
AE	aeration energy
ANO	autotrophic nitrifier organisms
AS	activated sludge
ASM	activated sludge model
BNR	biological nutrient removal
BNRAS	biological nutrient removal-activated sludge
BOD	biological oxygen demand
BSM	benchmark simulation modelling
CA	chemical addition
CAS	conventional activate sludge
CIP	clean-in-place
COD	Chemical oxygen demand
DO	dissolved oxygen
DWT	decentralized wastewater treatment
EQI	effluent quality index
FS	flatsheet
FSA	free and saline ammonia
HF	hollow fibre
HMI	Human-machine interface
iMBR	immersed membrane bioreactor
ISS	inorganic suspended solids
MBR	membrane bioreactor
ME	mixing energy
MLE	Modified-Ludzack Ettinger
MLSS	mixed liquor suspended solids
MT	multitube
NWA	National Water Act
O&M	operation and maintenance
OCI	Operational costing index
OEM	original equipment manufacturer
OHO	ordinary heterotrophic organism
P&ID	Process and Instrumentation Diagram
PAOs	phosphorous accumulating organisms
PE	person equivalent
PE	pumping energy
PLC	programmable logic controller
PPCP	pharmaceuticals and personal care products
PWWF	peak wet weather flow
RAS	return activated sludge
RAS	return activated sludge
RBCOD	readily biodegradable COD
SANAS	South African National Accredited System
sMBR	sidestream membrane bioreactor
SP	sludge production
SRT	solids retention time
TKN	total kjeldahl nitrogen
TMP	transmembrane pressure
TP	total phosphate

TSetS	total settleable solids
TSS	total suspended solids
VS	volatile solids
VSS	volatile suspended solids
WAS	waste activated sludge
WWTP	wastewater treatment plant

List of Figures

List of Tables

1. Chapter 1: Introduction

1.1 Background

In many regions of the world, the majority of the population are living in rural areas – regions with small settlements and low population density. Africa as a continent has a majority rural-based population and South Africa also has a significant portion of rural inhabitants (approximately 33% according to the latest estimates) (Statista, 2021).

In the rural landscape, access to basic services such as water and sanitation is not a straightforward assumption. Government municipalities have limited capability in serving areas outside of urban or peri-urban areas. Most often, farming communities are impacted by this shortfall in available services as agriculture is typically practiced on large areas of land in rural areas away from developed cities, towns, and other settlements. Sanitation services and subsequent sewage handling always remains one of the most important basic services that people require for reasons of public health, protecting the environment and human dignity. In certain rural locations, no municipal services are available and are unlikely to become available. Decentralized services, therefore, need to be considered. Furthermore, due to the way that surface water runoff flows with gravity and forms streams and rivers that become our water resources, the prevention of pollution and protection of the natural environment is of paramount importance. Untreated sewage that is allowed to flow or overflow without being properly handled, is a significant risk in that it will eventually reach natural watercourses and cause pollution. The world population has grown exponentially over the past century, placing more stress on nature while also escalating the predicament of delivering services to more people.

A growing school of thought is one that recognizes the value in implementing decentralized treatment of waste, as well as supply of other services such as drinking water. This is different from the traditional urban service provision in a centralized format and holds strategic advantages that are equipped towards bridging the gap to certain poorly serviced areas/peoples. Centralized systems certainly hold value in high-density city centres and have rightly been applied in this context in most cities. However, the importance of decentralized systems in expanding service delivery is being appreciated in recent research and it indicates a propensity to solve certain historic problems. In the United States of America, small, decentralized wastewater treatment plants are already providing sanitation and pollution control services to a quarter of the total national population (UNEP & Murdoch University, 2002).

A hurdle that decentralized servicing and modern technologies face, is that decision-makers are usually senior people who are used to doing things the way they have in the past and are less open to new ways of doing things. The mentality that business continues "as usual" can be the difference between an innovative solution and a persistent problem. There seems to be the need for human engagement in changing the perceptions of some who prevent the roll out and advancing of necessary projects.

Decentralized services hold within its development the principles of reuse and resource recovery. It is a concept that developed out of sustainability and to move away from waste-oriented approaches towards resource recovery (which includes water reuse). Resource recovery can be done on-site with the readily recycled resources of bioenergy and nutrients (such as nitrogen and phosphorus). The motivation for water reuse is self-evident in that water is a limited resource that is essential for human survival and activities. In the light of growing global population figures and climate change, efficiency and resilience are required to ensure that water does not run out for the many activities that it is used for and the multitude of life that it sustains.

The provision of sanitation and sewage services in rural locations remain a challenging field of engineering and is often poorly represented in research and applications. Sensible solutions need to be developed and implemented where mainstream urban services are not available to contribute to rural upliftment and sound environmental management.

1.2 Problem statement

Across the world, communities that are of relatively small size are subjected to the same uncompromising measures for wastewater discharge to the environment as large urban centres are, which is particularly problematic when not economically feasible to achieve. These rural areas are often not located close enough for local authorities or service providers to easily provide services and specifically sanitation. Membrane bioreactors are already becoming the new leading technology for wastewater treatment, both on large scale as well as smaller scale, but could turn out to be costly for applications in rural areas or small communities. The importance of effluent treatment for sustainable water management and environmental impact necessitates that solutions be developed that are geared towards the unique conditions that rural communities are faced with. The sustainability of any solution based on the factors of economic feasibility, consistent pollution prevention and being fit for purpose will conclude the success thereof. Finally, it is imperative that risks are properly assessed, and that health and safety is always a foremost priority as the nature of this kind of work contains certain risks that include health and safety related concerns. Risk assessments with mitigation strategies as well as a hazard and operability study (HAZOP) should be standard protocol of any study or work in the implementation realm.

1.3 Aim and objectives

The overarching aim of this study of wastewater treatment and environmental engineering is to provide a scientific approach to implementing and evaluating a decentralized package wastewater treatment plant in a remote location. Specifically, the three core objectives are detailed below:

- Design an appropriately sized package plant that is fit for a decentralized purpose and utilize a scientifically accepted wastewater treatment process model to provide an example of the design and sizing of a package wastewater treatment plant.
- Evaluate the implemented plant’s performance in terms of effluent quality and volume of treated effluent produced and the associated environmental impact.
- Perform the economic evaluation of the designed package wastewater treatment plant for the determination of operational costs.

1.4 Scope and limitations

The mathematical modelling of the wastewater treatment plant will be restricted to steady-state Microsoft Excel models. This is a simplified modelling approach where explicit steady-state equations are integrated to virtually replicate the conditions of the system. Some of the simplifications in this model include that constant flows and loads can be used and that system parameters do not have to be described comprehensively. These types of models are concerned with finding the design parameters that are necessary from a performance point of view. The applicability of using a simplified modelling approach will have to be evaluated based on the data and will be a factor in the success of the study.

The experimental work will be performed at the existing WWTP at High Noon farm, near the town of Villiersdorp, Western Cape, South Africa, that was implemented by an engineering contractor and paid for by an agricultural client. The cost and design of the WWTP were subject to approval from the stakeholders and as a result, certain budget and design decisions will have to be accepted and are out of the scope of this study.

A single sludge sample only was obtained for analysis as part of the experimental work which is limited due to the cost involved and the lead time for this analysis.

1.5 Outline & mind map

The thesis is structured according to a scientific procedure to achieve the research objectives. Different chapters are used to assemble the scientific approach in a stepwise manner and follow a rigorous research approach. The different chapters of the thesis are highlighted below, and the mind map shown.

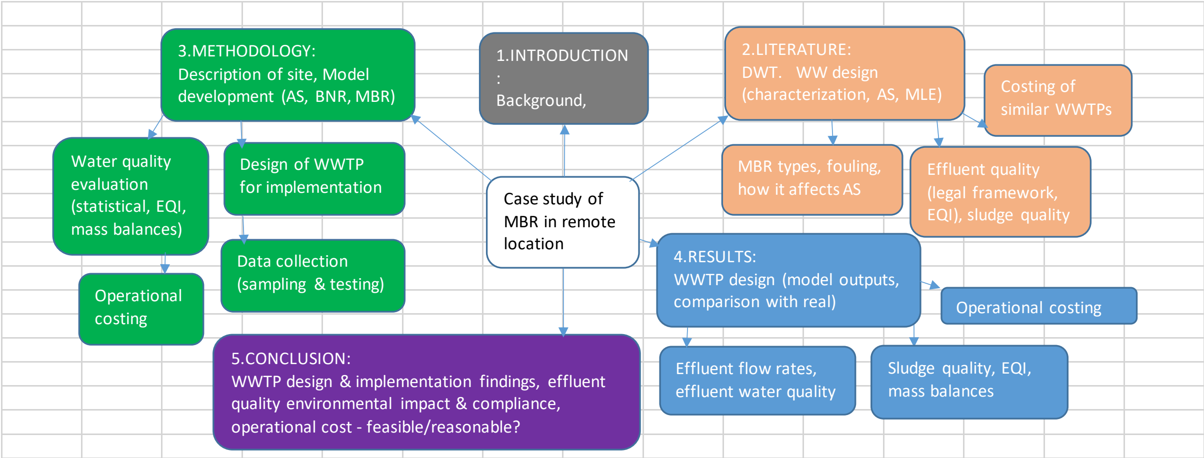
Chapter one is the introduction and the current chapter that provides context and motivation for the study.

Chapter two is the literature review that summarizes the current knowledge base and available models and data. It also offers overview of the relevant legal framework and tools for evaluation.

Chapter three is the methodology where the procedures for model development, plant design, data collection and data evaluation are discussed. Detailed information is given here in order to comprehend the work done and to be able to replicate this study if needed.

Chapter four is the results and discussions where the results are presented for the wastewater plant design, the plant performance, and the operational cost of the plant. Graphical representations are made together with tabulated information and statistical analyses that are analysed to come to the appropriate research findings.

Chapter five is the conclusion where the implications of the findings are summarized, and insight given into what the takeout should be for this specific study and how it can be utilized in future research and applications.


3.METHODOLOGY: Description of site, Model development (AS, BNR, MBR)
1.INTRODUCTION : Background,
2.LITERATURE: DWT. WW design (characterization, AS, MLE)
Costing of similar WWTPs
Water quality evaluation (statistical, EQI, mass balances)
Design of WWTP for implementation
Case study of MBR in remote location
MBR types, fouling, how it affects AS
Effluent quality (legal framework, EQI), sludge quality
Data collection (sampling & testing)
4.RESULTS: WWTP design (model outputs, comparison with real)
Operational costing
Operational costing
5.CONCLUSION: WWTP design & implementation findings, effluent quality environmental impact & compliance, operational cost - feasible/reasonable?
Effluent flow rates, effluent water quality
Sludge quality, EQI, mass balances

2. Chapter 2: Literature review

2.1 Decentralized wastewater treatment

Decentralized wastewater treatment for small communities can have the positive results of reducing pollution in the environment, improving public health, and increasing the reuse of wastewater (Capodaglio et al., 2017). However, deciding between centralized and decentralized systems should be done by an in-depth feasibility study considering not only financial implications, but also environmental and other supporting factors such as social acceptance and management strategies. Centralized wastewater treatment refers to the conventional treatment of a regional WWTP fed by central sewer systems which is commonplace across the world in major cities and many urban areas. Decentralized wastewater treatment (DWT) is different in that comparatively small volumes of wastewater are handled from groups of dwellings that are located close to each other (perhaps not more than a few kilometres as a general indication) and that treatment and disposal take place near the source. This could also apply to peri-urban developments that are not yet connected to a regional WWTP by a central sewer pipe network.

Decentralized wastewater treatment (DWT) naturally needs to have the sewage conveyed to the location of the treatment site, but this will be through shorter pipelines which are less costly than what is typically used in conventional centralized systems. The DWTs do need to be adequately designed and operated to attain the legal and feasibility requirements which would be the only way for them to be considered as an alternative to centralized systems. Taking the above into account, DWTs offer a feasible and sensible possibility that can benefit settlements of different sizes and demographics as well as at various levels of development. The financial benefit has been valued by Libralato *et al.* (2012) who found that in centralized systems, 80–90% of capital costs are related to the collection system itself, with some economy of scale in heavily populated areas. Additionally, the DWTs would treat and dispose of water within mostly the same watershed which can make reuse schemes in the local community an important possibility that can decrease improper demand for highly treated potable water.

Deciding on a technology of wastewater treatment is always directly linked to the application that it will be used for which can be further understood by considering the nature and climate of the location where it is required, the wastewater characteristics, the land area, and the applicable recycle/reuse requirements. The factors that are of importance for the DWT technologies are the economic feasibility, the O&M requirements, the specific treatment efficiency, the operational reliability, and the expansion options. An example where decentralization of sewage handling systems may be particularly valuable is for large block redevelopment in urban areas. Employing decentralized or local treatment in specific blocks will place less load on an old, failing, or overloaded existing sewer system. Decentralized wastewater treatment is commonly also referred to as package wastewater treatment plants. Key aspects that are targeted are robustness for remote locations, simplistic operation anticipating few or unskilled operational staff and management, designing conservatively to allow varying site conditions, and adding redundancy to accommodate certain equipment failures that take time to attend to in rural areas.

For scientists and/or engineers there can be a problem when a solution becomes purely technical, while the human component involved is being ignored. Social or public acceptance of any technology, infrastructure or programme that is being implemented on a broad scale can be the determining factor in the success of the endeavour. Even more so when the infrastructure or technology relates to a basic service such as sanitation. Since centralized wastewater treatment has been common in most urban areas and developed countries, this has become the status quo to many population groups, which is then accepted as “normal”. The acceptance is based on a general understanding that the authorities manage and control the centralized systems. For decentralized services, this is different, because it might require more involvement and awareness from local inhabitants, which is not always desirable to all. To gain community acceptance and operational involvement, public participation initiatives will be necessary. Capodaglio *et al.* (2017) found that in a few European countries, including Holland and Germany, there was a positive success in the implementation of 1000 PE decentralized systems in urban areas.

2.2 Wastewater treatment plant process design

2.2.1 Wastewater characterization

The first step in making any kind of progress with understanding wastewater and attempting to treat it, is to estimate the qualities and constituents that make up the wastewater itself.

A wastewater stream under consideration can be characterized as biodegradable, unbiodegradable, soluble and particulate based on the STOWA protocol (Hulsbeek et al., 2002).

2.2.2 Activated sludge (AS)

Activated sludge (AS) is a system that entails a specific reactor flow regime, several reactors in a specific configuration, recycle streams as well as some other elements that may be unintentional, deliberate or even just inevitable. Aerobic biological treatment is always developed in systems that have the same basis, be it aerated lagoons, extended aeration, trickling filters, Pasveer oxidation ditch or others. The difference is that the biological reactions take place in specific conditions that are constraining for the biology and chemistry to operate under, and which is commonly referred to as system constraints. The system constraints are essentially the environmental conditions within which the biological processes take place. This is the defining characteristic of the activated sludge system that biomass reacts according to their nature but are then also governed by optimally utilizing the known biological behaviour through physical features of how the AS treatment plant is designed. Following many years of research and implementation, AS systems have become the conventional technology for wastewater treatment worldwide and have been endorsed and validated by various researchers/practitioners and institutions (Marais & Ekama, 1976; Tchobanoglous et al., 2003).

2.2.3 Modified-Ludzack Ettinger (MLE)

Modified-Ludzack Ettinger is likely the most common biological process used for nutrient removal in MBR. A defining characteristic of the process is a recycle stream of the mixed liquor from the aerated membrane filtration zone to the anoxic zone. The recycle stream is implemented to utilize the nitrate produced in the aerated zone for the facultative bacteria as an oxygen source which coincides with the supply of raw wastewater in the anoxic zone. The nitrate-rich liquor arrives in a mixed state by aeration and is pumped into the anoxic zone also containing the sludge biomass while the incoming wastewater from primary treatment arrives in raw form and acts as a source of carbon for the organisms. The MLSS is typically made up of OHO's that are facultative bacteria, and these organisms rely on the nitrate as a source of oxygen and thus they perform the reaction of denitrification. Due to the inherent constraints of this specific process, complete denitrification cannot be reached in an MLE system (Tchobanoglous et al., 2003).

Furthermore, phosphorous removal is another aspect to discuss for a MLE system. Phosphorous removal is achieved by phosphorous accumulating organisms (PAOs) that are grown under a rotation of anaerobic and oxic conditions. In an aerobic environment, PAOs collect/accrue phosphorous which then provides the opportunity for the absorbed phosphorous to be removed from the reactor by wasting sludge. The lack of a dedicated anaerobic zone means that removal of TP will not be as effective as for some other treatment processes (Tchobanoglous et al., 2003).

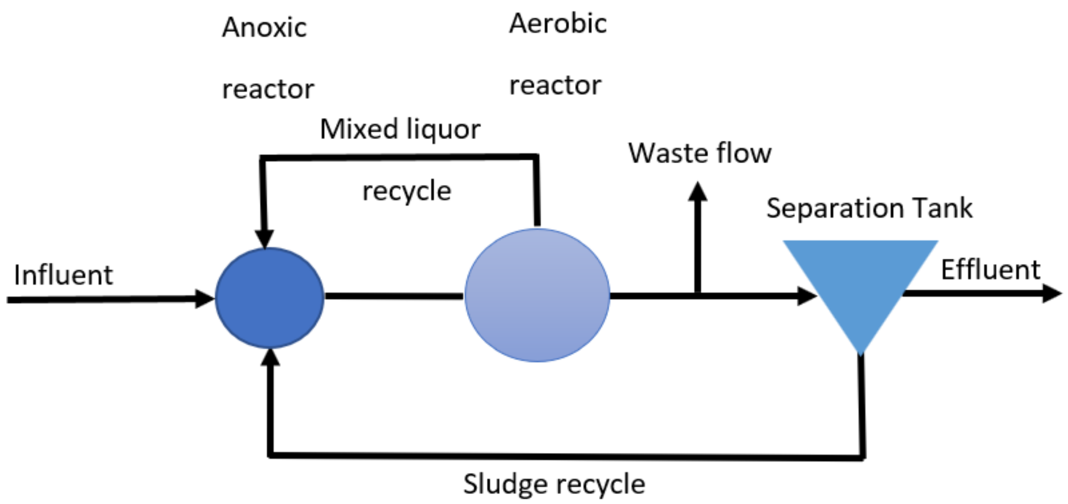


Figure 1: Schematic depicting the Modified-Ludzack Ettinger process system.

2.3 Membrane bioreactor (MBR)

Membrane technology was the subject of significant research and development through the second half of the 20th century and implementation thereof for wastewater treatment began on a commercial scale during the 1990s. In the 21st century, this technology has become relatively widespread and is now holding an important market share – reported in 2014 to be $426 million and $1.9 billion in 2019 based on different estimates (MarketsandMarkets, 2014; McWilliams, 2019). Furthermore, over the past decade global market growth rates have been above 10% as reported in various market analyses (Frost & Sullivan, 2013; Krzeminski et al., 2017) with the highest compound annual growth rates in Asia (17.6%) and North America (11.9%) with Europe following closely thereafter. In China alone, the cumulative capacity of wastewater treated by MBR more than doubled from 2014 to 2018 (Xiao et al., 2019). In a membrane bioreactor (MBR), the conventional wastewater treatment system is modified by combining the activated sludge process with membrane separation. The membrane separation unit that is implemented as a part of the biological treatment is used instead of the conventional process of sedimentation as separation in a settling tank. The advantages and disadvantages of implementing an MBR instead of a CAS system are weighed up in the remaining literature review below.

Membrane separation works on the principle of perm-selectivity where certain constituents can more freely pass through the membrane while other constituents based on the membrane's selectivity are not able to pass through and are left behind. The process stream that passes through the membrane is called the permeate and the process stream that is not able to pass through the membrane and is left behind is called the retentate (shown in the below schematic). The separation process is fundamentally limited in its capacity for separation and concurrent permeate production by the principle of a retentate being left behind. This limitation that exists on membrane separation holds a unique set of challenges that are to be navigated with care. Membrane fouling is probably the most common and problematic of occurrences when MBR's are used for wastewater treatment. The extensive research that has been done on the matter is indicative and in surveys of 186 different industry practitioners and researchers, the most identified problem (17%) was membrane fouling (Judd, 2015). The build-up of various foulants (organic, inorganic, reversible, irreversible) on the membranes decrease the capacity of the membrane for permeation due to clogging, blocking and cake filtration. Reversible fouling can be addressed via certain CIP (clean-in-place) and backflushing procedures that are performed periodically. Irreversible fouling can occur over time which leads to permanent "damage" to the membranes in the form of blocked pores that even with extensive recovery procedures do not show improvement and render the membranes with a decreased performance and eventually at some point needing (costly) replacement (Ramphao et al., 2005).

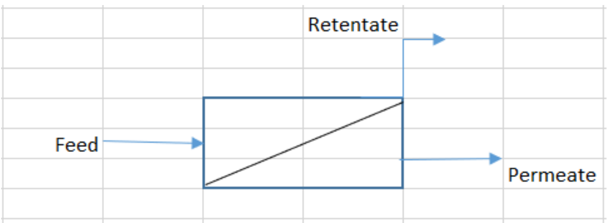


Figure 2: Figure indicating the basic separation principle of a membrane.

2.3.1 Different types of membranes and membrane systems

Membranes of different pore sizes are classified as different processes due to the different sizes of contaminants that are being separated and the different constraints and factors involved with these different processes. In bulk biological wastewater treatment such as required by national laws for environmental reasons, microfiltration and ultrafiltration are commonly used. Nanofiltration and reverse osmosis are used for more complex/specialized applications or where a higher quality effluent is desired and commonly also in the water treatment industry. This study will focus on the common applications of microfiltration (pore sizes approx. 0.05 to 10 μm) and/or ultrafiltration (pore sizes approx. 0.005 to 0.1 μm) within bulk biological wastewater treatment. The below figure from Verrecht *et al.* shows the operating range of the different membrane separation processes and where various contaminants fall within these ranges (Verrecht et al., 2012).

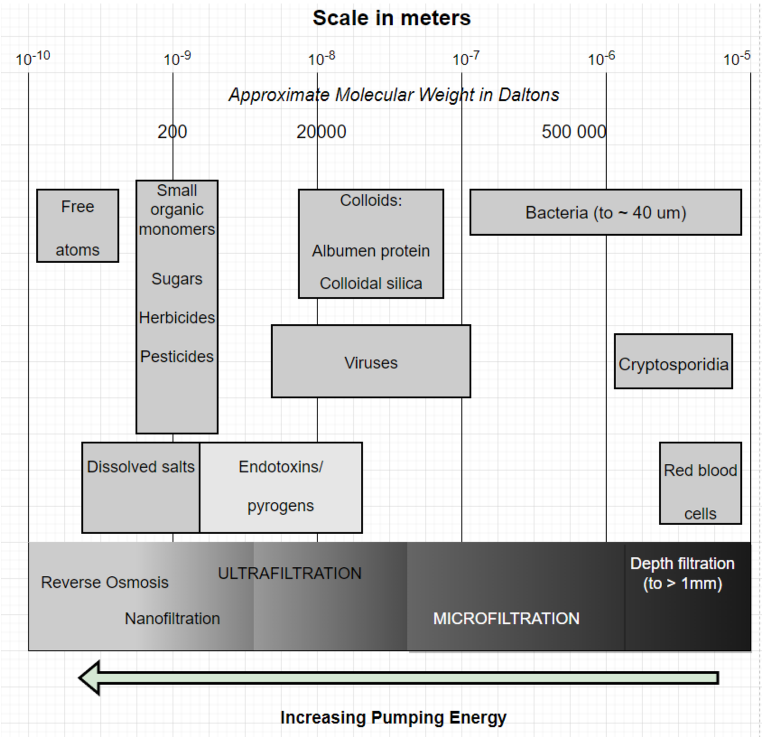


Figure 3: Figure explaining the different types of membrane separation processes.

A further important consideration in understanding the concept and application of MBR is the configuration of the membranes. This refers both to the geometry and installation of the membranes themselves as well as their orientation to the flow of water. These aspects have a substantial impact on the performance of the membranes and have been optimized over years of development. The first distinction that should be made when it comes to MBRs is whether the membranes are immersed within the bioreactor (abbreviated as iMBR) or installed in a separate sidestream (abbreviated as sMBR). The sidestream MBR is costlier since the membranes are installed in pressure vessels in a separate line that is pumped from the bioreactor. In practice, this installation of membranes has proved to be challenging and generally not worth the cost which has resulted in it being uncommon across the world (Le-Clech, Chen & Fane, 2006).

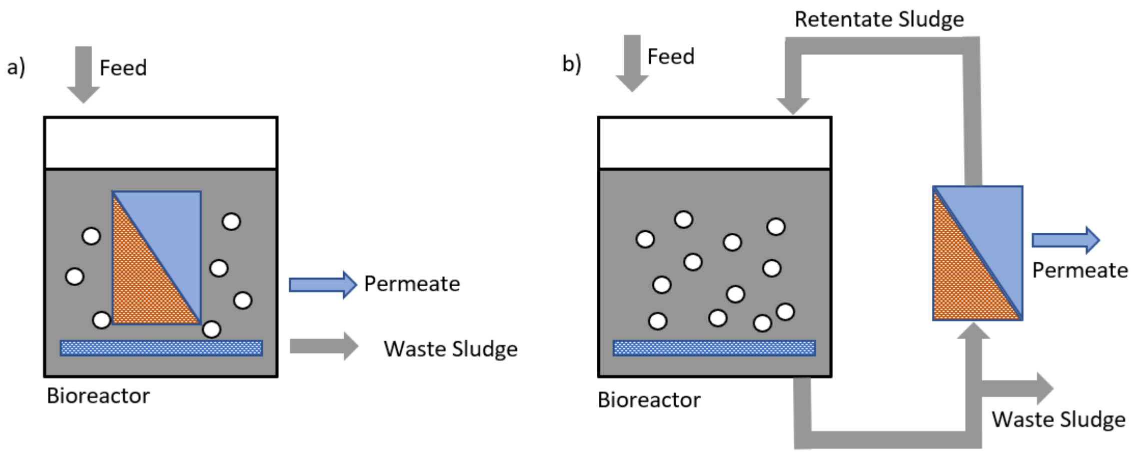


Figure 4: A schematic representation of the 2 types of membrane configurations.

The two different installations of membranes in MBRs also have the implication of different orientations to the flow of water as shown in the below diagram. The iMBR typically operates with the membranes orientated to the flow of water in a dead-end operation which means that feed is sent to the membrane tank and permeate is collected through the membranes, but no retentate is removed from the membrane tank. Of course, this excludes the minor amount of sludge that is being drawn off as the waste stream (which is infrequent and of small volume compared to the total volumetric flow). Circulation of the sludge does also take place, but this is within the bioreactor through the RAS recycle stream which still maintains the same water level and thus volume in the reactor tank and does not remove this activated sludge, because the bioreactor together with the immersed membranes therein is still viewed as one process unit where the feed enters and permeate leaves. No retentate is drawn off and thus essentially all the incoming water is treated as permeate, but sludge is wasted over time to maintain the sludge health and MLSS in the reactor. The sMBR typically operates with the membranes orientated to the flow of water in a crossflow operation where feed flows over the membrane surface, permeate is drawn through the membrane surface and retentate flows past and away from the membrane surface.

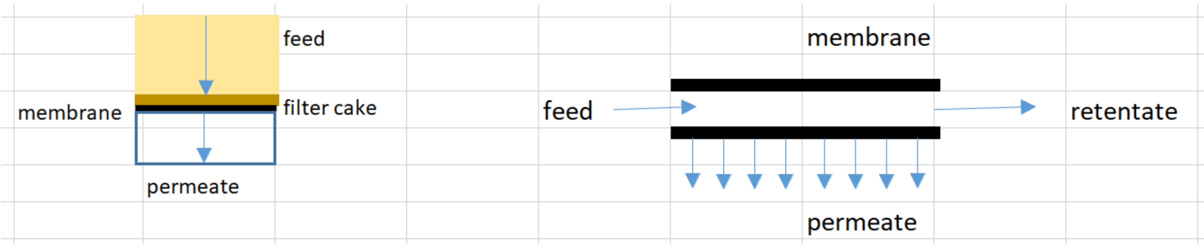


Figure 5: A schematic of dead-end operation (left) and crossflow operation (right).

Other than the installation of the membranes, the geometry thereof is also a crucial factor that typically comes down to 3 major options (2 of which are shown in Figure 6 below). Flatsheet (FS) membranes are rectangularly shaped membrane modules with two sheets of material over an internal frame allowing permeate flow perpendicular to the membrane sheet. The permeate flows enters the membrane material to the inside of the rectangular frame and is forced upwards to a collection outlet port while the retentate remains behind on the outside of the membranes in the tank. Hollow fiber (HF) membranes are made up of hundreds of straw-like tubes that are bundled together which creates a large surface area of membrane through which permeate can be collected and separated from the retentate. The permeate is collected by the tubes while the retentate flows outside over the membrane tubes. The third option of multitube (MT) membranes are similar to HF but differs in that the sludge flows through the tubes and the permeate is then collected when it flows through the sidewall of the tube into the module housing with the retentate continuing to flow through the tubes. MT membranes are only used for sMBR applications which makes up a minority of MBRs globally. The flow through the three different membrane geometries is depicted in Figure 6.

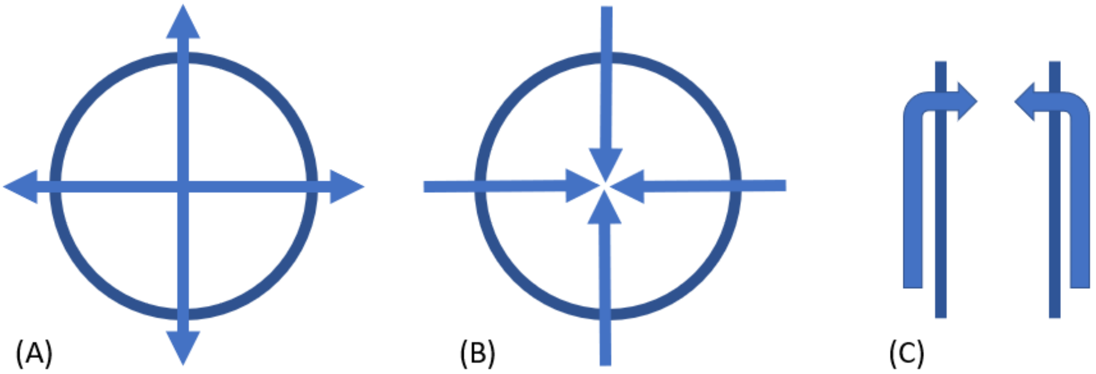


Figure 6: A schematic of the flow of water through the different membrane geometries (from left to right: multitube, hollow fibre and flatsheet).

In a global survey of various practitioners involved with all the different project phases in industry and development of MBR technology, only 18% of commercially implemented MBRs was of the sMBR installation and thus MT membranes (Judd, 2015). This study will focus on the commonly preferred iMBR installation which is operated as a dead-end process.

Figure 7: Pictures of flatsheet (left) and hollow fibre (right) membranes used in industry.

2.3.2 Membrane fouling

Since effluent water quality is consistent in an MBR particularly in terms of TSS, the operation of MBRs is chiefly concerned with the prevention and reduction of membrane fouling to maintain sustainable and long-term ability to treat the influent volume of wastewater. The first operating factor for an MBR to prevent membrane fouling is to operate at the correct flux that the membrane will allow without fouling. The flux (J) is the quantity of material passing through the area of the membrane over a period of time. In SI—units this would be expressed as m^3/m^2s, but the commonly applied non-SI unit parameter for flux is $L/m^2/h$ or LMH. MBRs generally operate at fluxes between 10 and 150 LMH. The other parameter of importance in operating an MBR is the transmembrane pressure (TMP). As the TMP increases, the flux should be reduced to prevent further fouling and reduction in membrane performance (Verrecht et al., 2012).

Membrane fouling is the phenomenon whereby the resistance to filtration through the membrane increases over time which leaves the membrane with a reduced capacity and performance to the detriment of the wastewater treatment process. Membrane fouling has been classified in 2 different ways as summarized by Meng et al., but essentially membrane fouling can be reversible either by physical or chemical cleaning methods or irreversible/irrecoverable which means that it eventually becomes impossible to recover the permeability of the membrane to sustain a desired flux (Meng et al., 2009). Fouling also occurs in different stages namely, conditioning fouling, steady fouling and the TMP pump, which is described by Judd in the MBR book and is based on the systematic reviews of Meng et al. and Le Clech et al. (Le-Clech, Chen & Fane, 2006; Meng et al., 2009, 2017). Various theories and models of membrane fouling have been proposed, but due to the complexity of the mechanisms and causes of membrane fouling, this remains a paramount area of research (Lesjean & Huisjes, 2008; Iorhemen, Hamza & Tay, 2016). Fouling can be of biological, organic or inorganic nature and the means to control fouling are pre-treatment of the feed, applying apt chemical or physical cleaning procedures, reducing the operating flux, increasing air scouring and chemical or biochemical modification of the mixer liquor. The significance of understanding membrane fouling and navigating the issue carefully is that it directly impacts the operating cost of the plant by energy use and chemical cost for treatment of reversible membrane fouling, but even more importantly it determines the replacement period of the membranes which is the major factor in determining the long-term profitability of a plant.

2.3.3 How MBR affects AS and BNR

When installing membranes in the aerobic zone of a nutrient removal system that consists of various zones of fixed volume, the recycle ratios can be used to vary the mass fractions between the different reactor zones. This provides an important advantage that MBR with biological nutrient removal (BNR) has over conventional activated sludge BNR system since the biological nitrogen and phosphorous removal can be optimized by adjusting the mass fractions to compensate for influent wastewater quality and meet required N and P concentrations in the effluent. (Ramphao, 2005)

In the case that peak wet weather flow (PWWF) is more than double the average dry weather flow (ADWF), the aerobic mass faction is less than 0.6 and the wastewater characteristic is a raw or high strength, the MBR BNR system would be operated as an extended aeration process. The reactor volume is significantly reduced compared to CAS BNR systems, but this is usually not enough of a reduction to offset the cost of membranes. An additional cost saving can also be factored in by eliminating the need for sludge treatment (such as digestion and thickening). If an equalization tank is used to balance the flow and primary settling is employed so that a settled and low strength wastewater characteristic is treated, then the ADWF can be doubled, but the cost of sludge treatment will have to be factored in.

Retention time in the MBR tank should be short enough to prevent an increase in the solids' concentration to a point that it could clog the membranes. The return activated sludge (RAS) usually then needs to be at least 3 times or more than the ADWF. This also contributes to a complication whereby the dissolved oxygen (DO) in the RAS is typically quite high which decreases the denitrification happening in the anoxic zone. This can be compensated for by recycling to the aerobic zone or by being conservative in the safety factor assumption of the anoxic reactor sizing (Ramphao et al., 2006; du Toit, Ramphao, et al., 2010).

For the case of MBRs with BNR the fraction of the concentration of TSS in the anoxic and aerobic zones over the bioreactor MLSS concentration is also the same as the sludge mass fraction as a fraction of the respective zone volume fractions (Parco, du Toit & Ekama, 2019). This is expressed by the below equations with $\overline{X_t}$ being the average TSS in the reactor, f_m as the sludge mass fraction and f_v as the sludge volume fraction.

$$\frac{X_{tanx}}{\overline{X_t}} = \frac{f_{manx}}{f_{vanx}} \qquad \text{Eq. 1}$$

$$\frac{X_{taer}}{\overline{X_t}} = \frac{f_{maer}}{f_{vaer}} \qquad \text{Eq. 2}$$

When membranes are installed in the aerobic zone, the distribution of the sludge mass is different throughout the bioreactor zone than in the CAS system. The effluent that is removed from the reactor by the membranes has a concentrating effect on the sludge in the aerobic zone. The recycle ratio thus plays an important part since it will determine the uniformity of sludge mass distribution through the system.

Studies have found that the specific denitrification rate by OHOs (K_{2OHO}) remains essentially the same in an MBR compared to what it is in a CAS system (du Toit, Parco, et al., 2010). Du Toit *et al*. (2010) and Parco *et al.* (2006) concluded that the BNRAS steady-state and kinetic models for a low VSS concentration can be applied to an MBR system. The exception is that the maximum specific growth rate of nitrifiers is lower in an MBR and thus needs to be calculated as below (Ramphao et al., 2005; du Toit, Parco, et al., 2010):

$$\mu_{nm20} = \frac{b_{n20}(\theta_b)^{T-20} + {}^{S_f}\!/_{R_s}}{f_{maer}(\theta_\mu)^{T-20}} \qquad \text{Eq. 3}$$

In 2006, however, Ramphao *et al.* (2006) found that the long SRT in an MBR for the high MLSS specified by membrane suppliers, makes it unlikely that nitrification will be insufficient.

Lastly, with regards to tailoring the system design for MBR, the kinetics $K_{2'T}$ for denitrification should be adjusted to 0.216 mgN/mgVSS/day at 20 °C (du Toit et al., 2007).

2.4 Effluent water quality and sludge

2.4.1 Legal framework for effluent water

Effluent water quality is in principle the most important part of wastewater treatment since it is the objective for development of wastewater treatment unit operations – the realization that certain wastewaters in their raw form are unsuitable for use or discharge into the environment and thus the need to treat and improve the quality of the wastewater. The effluent water quality that is required for environmental discharge in South Africa where this study is taking place, is regulated by the NWA of 1998 and the Gazette no. 169 of 2013 which contains the general limits for wastewater discharge. The general limits are shown in the below table. These are the current governing laws by which wastewater treatment in South Africa should abide.

Table 1: Table of the General Limits for wastewater discharge.

Parameter	General Limit	Special Limit
Faecal coliforms (per 100 ml)	1000	0
Chemical Oxygen Demand (mg/l)	75	30
pH	5.5-9.5	5.5-7.5
Ammonia (ionised & un-ionised) as Nitrogen (mg/l)	6	2
Nitrate/Nitrite as Nitrogen (mg/l)	15	1.5
Chlorine as Free Chlorine (mg/l)	0.25	0
Suspended Solids (mg/l)	25	10
Electrical Conductivity (mS/m)	70 mS/m above intake to a max of 150	50 mS/m above intake to a max of 100
Orthophosphate as phosphorous (mg/l)	10	1 (median) & 2.5 (max)
Fluoride (mg/l)	1	1
Soap, oil or grease (mg/l)	2.5	0
Arsenic and its compounds (mg/l)	0.02	0.01
Cadmium & its compounds (mg/l)	0.005	0.001
Chromium (IV) and its compounds (mg/l)	0.05	0.02
Copper and its compounds (mg/l)	0.01	0.002
Cyanide and its compounds (mg/l)	0.02	0.01
Iron (mg/l)	0.3	0.3
Lead & its compounds (mg/l)	0.01	0.006
Manganese & its compounds (mg/l)	0.1	0.1
Mercury & its compounds (mg/l)	0.005	0.001
Selenium & its compounds (mg/l)	0.02	0.02
Zinc & its compounds (mg/l)	0.1	0.04
Boron (mg/l)	1	0.5

The question could then be asked: if a wastewater treatment plant, be it CAS, MBR or other produces effluent of quality that is compliant with the general limits then should there be any further detailed study of the effluent water quality? This can be answered, by considering firstly, that not only one set of water quality parameters for compliance exist because there are special limits for endangered/protected areas and if this study is to be relevant and applicable on a global scale water quality should not simply be evaluated by South African law since other countries may have different requirements/laws. Furthermore, in the context of wastewater being reused, there is in general certainly more to gain with an effluent quality that is even better than the South African General Limits since it improves the water quality with positive effect for the reuse application. In a case where treated wastewater is being specifically reused for irrigation, residual ammonia, phosphate, and trace metals could be beneficial for its agricultural application as the crops that are grown require these inputs and thus the wastewater serves as a resource by providing nutrients for agriculture (Montwedi et al., 2020). Finally, even when only discharging to the environment according to the General Limits of South Africa, an improvement in effluent water quality means less pollution of the environment, such as less organic load and nutrient concentrations being fed into the water bodies. All of this necessitates the studious analysis of effluent water quality.

2.4.2 Water quality parameters of concern

Many contaminants are of interest, but for monitoring and analyses purposes it is necessary to understand the significance of the different parameters that are regulated in the general limits of wastewater discharge. Faecal coliforms are an indicator of a group of bacteria that is generally harmful to most forms of life and pose one of the primary problems associated with inadequately treated or untreated wastewater. In the absence of sufficient disinfection of which the efficiency is also dependent on the various other preceding treatment stages, bacteria will be present and grow to multiply in the water which can have severe health effects for most forms of life. It is in the interest of human health and development and environmental protection that wastewater is adequately disinfected to prevent harmful bacteria from multiplying and spreading throughout water courses.

Since the concentration of faecal coliforms in the water is related to other parameters in the water, these are also of importance in evaluating treatment efficiency and subsequent environmental impact. Total suspended solids (TSS) are important in that it indicates a possibility of bacterial presence (because bacteria can be shielded by solids), but it often also indicates organic or inorganic particulates that have not been treated by the system and thus are discharged with the effluent. TSS contributes to turbidity in the water.

Chemical oxygen demand (COD) is another of the important contaminants to be monitored and perhaps the most important. COD refers to all matter (mostly organic) that uses up oxygen in the water, limiting oxygen to plant root systems and resulting in an anaerobic environment which is non-ideal for most plant types. This is a wide indication of problematic pollutants that will be to the detriment of any watercourse that it is added to due to the reduction in oxygen content that it propagates. A healthy water body should have a negligibly low COD concentration because it is also a vector for the growth of bacteria and algae among other negative effects. Since treated effluent originates from high strength wastewater, simply having a COD of 0 is not always possible but keeping this as low as possible is one of the main aims. At the very least a concentration of less than 75 mg/l is required to comply with the General Limits for wastewater discharge.

Ammonia is also an important parameter in wastewater treatment due to its toxicity to aquatic life. Furthermore, nitrate and orthophosphate are nutrients that should not be present at high levels in any watercourse. These nutrients lead to growth of algae and other unwanted organisms in the water and must be reduced as low as possible. At high concentrations, both parameters can also be toxic to aquatic life.

2.4.3 MBR effluent quality

Effluent water quality from MBR has proved to be of high quality in comparison to other forms of wastewater treatment. Skoczko *et al.* (2020) found that their MBR improved TSS removal to 99% from 89% with a CAS SST previously amongst further minor improvements in COD, BOD, TKN and TP removal as well. Bertanza *et al.* (2017) also found an MBR yielded 50% better COD concentration in the effluent compared to CAS as well as an order of magnitude lower TSS. This is because the only contaminants that an MBR cannot reliably treat are, firstly, arduous particles that are smaller than the effective membrane pore size and, secondly, unbiodegradable soluble organics. The challenge of unbiodegradable soluble organics applies to all biological wastewater plants because the treatment of these materials is achieved by an affinity for biomass and by permselectivity (Verrecht et al., 2012). Most membranes have a pore size smaller than the size of bacteria (0.4 µm) which ensures the removal thereof. However, the interesting observation from the literature is that viruses, which are smaller than bacteria, are also mostly retained in the bioreactor and do not reach the permeate, because the bacteria mostly host the viruses (Shang, Wong & Chen, 2005). Removal of both metals and nitrates are dependent on the biological process design and metals are only removed when entrained or bound into the organics; thus, no significant difference between CAS and MBR can be observed in this case (Santos & Judd, 2010). When reviewing the literature on MBRs' performance in removing organic micropollutants it is evident that for the common pharmaceuticals (acetaminophen, ibuprofen, and paroxetine) it is similar to CAS, but certain pharmaceuticals and personal care products (PPCPs) are more removed in MBRs than in CAS which has been attributed to the longer SRT which is manageable in MBR operation (Cirja et al., 2007; Göbel, Dierkes & Coldewey, 2007; Sipma et al., 2010).

2.4.4 Effluent Quality Index (EQI)

Since treated effluent water quality is inherent in the process of wastewater treatment and of paramount importance because without treatment of wastewater the entire undertaking would be made void, the comparative evaluation of effluent quality, compliance and environmental impact should thus require considerable attention. A measure for evaluation and comparison is required so that the impact of the resulting effluent can be quantified. The effluent quality index (EQI) was developed by Jeppsson *et al*. (2007) for this exact purpose and then adapted by De Ketele *et al*. (2018) to be suitable for application to South Africa WWTP's.

The EQI analyses the 3 different forms of effluent from the WWTP, i.e., water, gas and sludge. The EQI for water was rewritten by Paleker *et al.* (2018) for a year to allow for seasonal variation. Finally, the weightings of different pollutants were revised in Verrecht *et al*. (2010) and Gernaey *et al*. (2014). The adaption by De Ketele *et al.* (2018), allowed for an EQI positive and EQI negative to be obtained because when a pollutant is below the emission limit (i.e., β*(Limit – pollutant(t))), its part in the equation will be positive. A poor effluent quality that is over the emission limit would reflect as a negative EQI. If T is defined as the evaluation period in days, β as the pollutant weighting factor and Q_e as the flow rate of the effluent, then the formula is given as below.

$$EQI = \frac{1}{Tx1000}\int_{t_0}^{t_{end}}(\beta_{TSS}(TSS_{limit} - TSS(t)) + \beta_{COD}(COD_{limit} - COD(t)) + \beta_{FSA}(FSA_{limit} - FSA(t)) + \beta_{NO}(NO_{limit} - NO(t)) + \beta_{OP}(OP_{limit} - OP(t)))Q_e(t)dt \quad \text{Eq. 4}$$

Finally, the sludge quality is also another form of pollution, and this is expressed once again by weightings that are factored for the mass of solids over the evaluation period as in Eq. 5. The term 38/x(t) is part of the axiom as the minimum reduction of VSS that represents the stability criterion for the waste sludge in solid form. To elaborate on this term, if the reduction in volatile solids is less than 38% this would mean that the sludge is classified as unstable, and this would contribute a factor by which the EQI is worsened.

$$EQI_{sludge} = \frac{1}{Tx1000}\int_{t_0}^{t_{end}}\frac{38}{x(t)}(\beta_{As}As(t) + \beta_{Cd}Cd(t) + \beta_{Cr}Cr(t) + \beta_{Cu}Cu(t) + \beta_{Pb}Pb(t) + \beta_{Hg}Hg + \beta_{Ni}Ni + \beta_{Zn}Zn + \beta_{CFU}CFU + \beta_{ova}ova)FSludge(t)dt \quad \text{Eq. 5}$$

2.5 Legal framework for sludge management

When it comes to the wastewater sludge, which is the other form of emission leaving the WWTP in a smaller volume, it still needs to be treated as a by-product or a potential form of pollution. The Sludge Guidelines are the regulatory framework that specifies the limits by which sludge must comply and the appropriate management options thereof (Snyman & Herselman, 2006a). The parameters that are regulated into 3 different classes of sludge management protocol are shown in the below table.

Table 2: Table of the limits for the classes of solid sludge waste classification.

	Class A limit	Class B limit	Class C limit
As (mg/kg)	<40	<75	>75
Cd (mg/kg)	<40	<85	>85
Cr (mg/kg)	<1200	<3000	>3000
Cu (mg/kg)	<1500	<4300	>4300
Pb (mg/kg)	<300	<840	>840
Hg (mg/kg)	<15	<55	>55
Ni (mg/kg)	<420	<420	>420
Zn (mg/kg)	<2800	<7500	>7500
Faecal coliforms (cfu/g)	<1000	<1000000	$>10^7$
Helminth ova (viable organisms/g)	0.25	<4	>4

Different tables are also given in the Sludge Guidelines that describe the management options and recommendations for sludge classified as Class A, B or C which would be on both a microbiological and a pollutant basis. The microbiological classification is based on the detection of faecal coliforms (common problematic pathogens found in wastewater including *E. coli*) and Helminth ova. Helminth ova or egg cells are a part of worm diseases in that they act as infective agents specifically for what is known as helminthiases. These are the eggs of cellular animals of a microscopic size which is found in wastewater and subsequently the waste sludge since they are excreted by infected individuals. The pollutant classification is based on the various heavy metals shown in the table that are high in density and can be toxic even at low concentrations.

There is, furthermore, the category of stability which can be classified as class 1, 2 or 3 and this considers the dewatering, reduction of volatile solids and vector attraction. Vector attraction refers to the fact that rodents, flies, mosquitos, and other organisms are attracted to certain characteristics in sewage sludge and that these organisms carry a risk because they transport infectious agents such as pathogens. Regulation requires that vector attraction is addressed by the reduction of the volatile solids in the sludge by treatment thereof to achieve at least 38% volatile solids reduction.

2.6 Costings of similar package wastewater plants

Bertanza *et al.* (2017) came to total costs (i.e., capex and opex) between 38% and 53% higher for MBR compared to CAS which varies due to dependency on market conditions. MBR proved to be significantly more expensive in terms of cost of construction and maintenance, but it did yield minor savings compared to CAS for sludge processing costs. (Singh *et al.*, 2018) and (Metcalf *et al.*, 2014) provided further examples of the costing of similar package wastewater treatment plants.

The operational cost of a wastewater plant is a critical design and feasibility consideration that should be evaluated on a standardized basis. For this reason, Jeppsson *et al.* (2007) originally developed the formulation of an operational costing index (OCI) and De Ketele *et al.* (2018) adapted it to yield the below equation. In equation 6 AE is aeration energy, PE is pumping energy, SP is sludge produced, EC is chemical addition, ME is mixing energy, MP is energy from methane produced and HE is total heat energy required by the anaerobic digester.

$$OCI = (AE + PE + ME + HE - MP).Energy\ cost + SP.Sludge\ disposal\ cost + CA.Chemical\ cost \quad \text{Eq. 6}$$

3. Chapter 3: Methodology

The methodology for performing this study included desktop study work as well as experimental work in the field. The 3 aims of the research each involve certain different means of achieving the objectives. A specific site was located and used for the study to provide context. A steady-state model was developed using activated sludge (AS) with biological nutrient removal (BNR) and in the Modified-Ludzack Ettinger (MLE) process system. The model was also modified for a membrane bioreactor and used within the relevant context of the studied location and conditions. The implementation of the WWTP was then described including the ADWF flow calculation and the process unit operations required. Experimental data was obtained from raw water, treated effluent and sludge samples that were tested according to analytical procedures and evaluated according to statistical methods, and mass balances. The system performance was evaluated according to the IWA benchmark simulation modelling (BSM) task group performance indices from section 2.4.4. Hence effluent quality was evaluated using the IWA effluent quality index and the operational costing was performed and evaluated using the operational cost index (OCI).

3.1 Description of site used for case study

The rural area within which this study takes place is in the Western Cape of South Africa close to the town of Villiersdorp. Approximately 15 km from Villiersdorp through a mountain pass the Elandskloof is reached where High Noon farm is the only commercial-scale farm in a valley in the Stettyns mountains. On High Noon fruit farm there is a settlement of farmworkers and their families with an approximate population of 750 people in total. This community, living in so-called Happy Valley for many years, is generally impoverished and cut off from service delivery and access to opportunities due to the rural location of the settlement. The community was identified by the farm management as needing an improved sanitation system. Furthermore, it was necessary to improve wastewater collection from the community to prevent environmental pollution. The site location and conditions were identified as being suitable to the aim and scope of this study.

An aerial view of the site is attached in Appendix A which shows farm dams, cultivated land, the general slope of the valley from West to East, the farmworker's houses and the access roads. A professional survey of the site is also attached which was used to determine the civil design of a sewer line to collect all of the wastewater produced. The average elevation of the site location is 580m above sea level with fairly steep gradients in certain areas. The site is accessed via the Elandskloof Road, approximately 2 kilometres outside of Villiersdorp, which ascends over a pass and into the Elandskloof valley. Within the valley, the Elandskloof river fed by the numerous surrounding mountains' streams flows into the Elandskloof dam, which is a municipal water dam that is used by the Theewaterskloof municipality. The average climate in Villiersdorp is summarized in the figure below as obtained from (Meteoblue, n.d.). Summers are hot, winters are cool, and the majority of rainfall takes place in the winter months.

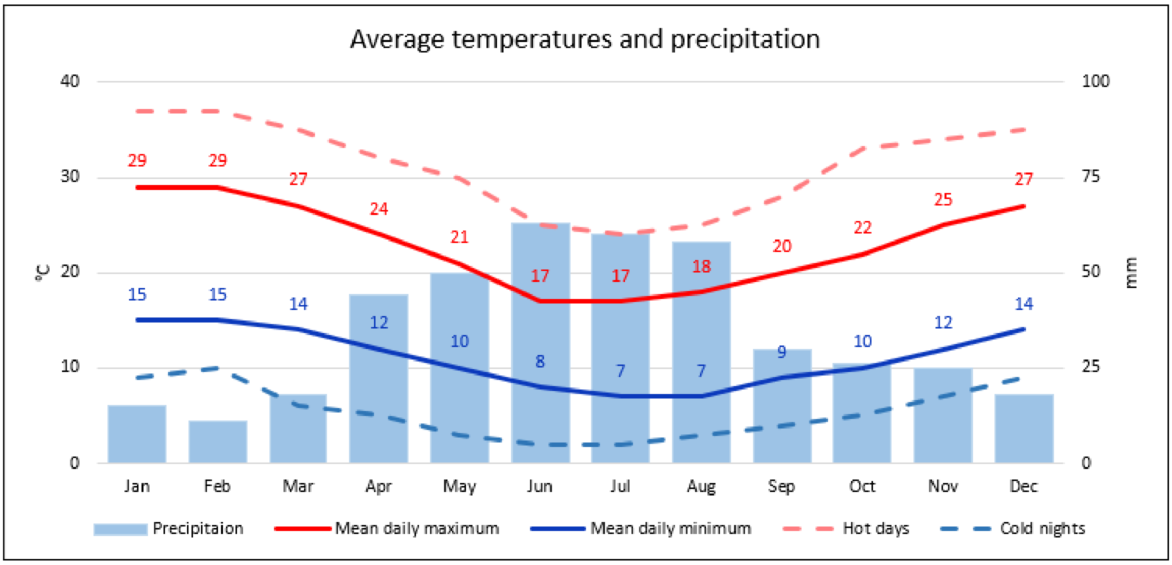


Figure 8: Figure of the average climate across the year in Villiersdorp.

Following the site survey that was performed of the site in 2020, the civil infrastructure was put in place with sewer reticulation systems from all of the old septic tanks of the houses to collect the wastewater for treatment. A sewer pipeline of approximately 1.2 km in total was constructed that is mostly fed by gravity except for a small section of 50 metres that is pumped. The sewer line leads to a buffer storage tank at a low point in the valley below all of the houses where the wastewater is to be treated. Drawings of the installed sewer collection system are attached in Appendix A.

3.2 Model description

3.2.1 AS system and BNR

To model organic removal, the accuracy and complexity of a dynamic model would not be required. By assuming constant flows and loads a model is simplified and a steady state is used to calculate organic removal. A steady-state model is aimed at determining the system design parameters that are of importance, but not the complete descriptions of the system parameters. By theoretically modelling reactors in the activated sludge model as completely mixed, the sludge only needs to be recycled fast enough to avoid a build-up in the settling tank (or membrane filtration tank). Furthermore, it is assumed based on previous experimental work that complete utilization of biodegradable organics takes place in the bioreactor (as long as a sludge age of more than about 3 or 4 days is used).

Based on the above model development it then follows that the incoming biodegradable COD is utilized to, firstly, grow new ordinary heterotrophic organisms (OHO) mass (X_{BH}) or, secondly, remain in the system as unbiodegradable and inert sludge mass (X_{EH} and X_I). The carbonaceous oxygen demand in the reactor and the mass of sludge produced are stoichiometric functions of the daily influent organic load. The total settleable solids (TSetS) is calculated as the total of the separately calculated volatile suspended solids (VSS) and inorganic suspended solids (ISS). Oxygen demand is then calculated using this information from where the important COD/VSS ratio of the sludge is also calculated (f_{CV}). Finally, the reactor volume and retention time is then also easily calculated. Knowing this the effluent COD concentration, the reactor TSS concentration and sludge age can be obtained. The design procedure is given by the set of equations that are followed in order and shown in Appendix B.

The growth and death of autotrophic nitrifying organisms (ANOs), known to mediate nitrification, is modelled using equation 7 (for ANO growth) and 8 (for ANO death) in Table 3. Importantly, the effluent ammonia concentration needs to be solved under a steady state to further understand the nitrification process. This is done by a mass balance on the change in nitrifier mass over the completely mixed system as given in Table 3 by equation 9 and simplified to equation 10, because $\Delta X_{BA}/\Delta t$ is zero under constant flow and load. Following the simplification described in Henze *et al.* (2019), the minimum sludge age is then solved using equation 11. These equations are then revised to include the unaerated fraction of the total sludge mass f_{xt} and reversed for a specified SRT including a safety factor S_f. (Henze et al., 2008)

Table 3: Table of the nitrogen removal by ANOs

$M\Delta X_{BA} = Y_A M \Delta N_a$	*Eq. 7*
$\dfrac{dX_{BA}}{dt} = -b_{AT} X_{BA}$	*Eq. 8*
$M\Delta X_{BA} = V_p \Delta X_{BA} = \dfrac{\mu_{AmT} N_a}{K_{nT} + N_a} X_{BA} V_p \Delta t - b_{AT} X_{BA} V_p \Delta t - X_{BA} Q_w \Delta t$	*Eq. 9*
$N_a = N_{ae} = \dfrac{K_{nT}(b_{AT} + \frac{1}{SRT})}{\mu_{AmT} - (b_{AT} + \frac{1}{SRT})}$	*Eq. 10*
$SRT_m = \dfrac{1}{\left(1 + \frac{K_{nT}}{N_{ai}}\right) \mu_{AmT} - b_{AT}}$	*Eq. 11*
$N_{ae} = \dfrac{K_{nT}(b_{AT} + \frac{1}{SRT})}{\mu_{AmT}(1 - f_{xt}) - (b_{AT} + \frac{1}{SRT})}$	*Eq. 12*
$SRT_m = \dfrac{1}{\mu_{AmT}(1 - f_{xt}) - b_{AT}}$	*Eq. 13*

Since all biological material is built on nitrogen and phosphorus, certain nutrient requirements are thus to be calculated for the organic sludge mass (VSS) which consists of the active organisms (X_{BH}), endogenous residue (X_{EH}) and unbiodegradable particulate organics (X_I). The amount of nutrients (in mass) used in the sludge mass is evaluated by a mass balance over the perfectly mixed activated sludge reactor under steady state conditions. The concentration of total nitrogen that is incorporated into the sludge mass (N_s), is also then wasted from the system via Q_w. The equations used to determine the N_s and from there the effluent TKN concentration (N_{te}), is equated in Table 4 below. Using equation A12 in Appendix B, the concentration of nitrogen per influent required for incorporation in the VSS is then equated below as the nitrogen content wasted in the VSS per day and divided by the influent flow. This is then further simplified by inputting Equation X and stating the N_s per S_{ti}. In the absence of nitrification, the effluent ammonia concentration is shown in Equation 17 (which is also the nitrification capacity) and the effluent TKN concentration by Equation 18 in Table 4. The MLE system does not include the growth of polyphosphate accumulating organisms, and the phosphorous (P) is mainly used as a growth nutrient for OHOs. The P is thus modelled in the same way N uptake for biomass nutrition.

Table 4: Table of the nutrient removal equations

$N_s = \frac{f_n M X_v}{Q_i SRT}$	*Eq. 14*
Nte = Nti – Ns	*Eq. 15*
$\frac{N_s}{S_{ti}} = f_n \left[\frac{(1 - f_{S'us} - f_{S'up}) Y_{Hv}}{1 + b_H SRT} (1 + f_H b_H SRT) + \frac{f_{S'up}}{f_{CV}} \right]$	*Eq. 16*
Nae = Nai + Nobsi + Nobpi – (Ns – Noupi)	*Eq. 17*
Nte = Nouse + Nae	*Eq. 18*

For the Modified Ludzack-Ettinger (MLE) system, an important concept to consider is the denitrification potential of the influent RBCOD in the anoxic reactor. This is acquired from the RBCOD portion of the influent biodegradable COD and by using the OHO yield of 0.45 mg VSS/mg COD and the oxygen equivalent of recovery from nitrate denitrified to N_2 gas. Equation 17 indicates the calculation of the denitrification potential ($D_{p1RBCOD}$).

$$D_{p1RBCOD} = f_{Sb's} S_{bi} (1 - f_{CV} Y_{Hv})/2.86 \qquad \textit{Eq. 19}$$

If the unaerated sludge mass fraction is allocated to equal the maximum anoxic sludge mass fraction available for denitrification, then the nitrate concentration exiting the anoxic reactor is zero and the nitrate concentration in the aerobic reactor is given by the below equation 20. Furthermore, the anoxic reactor equivalent nitrate load by the recycle streams (a and s) is as follows. This is then also the equation for the optimum denitrification since it is at the lowest effluent nitrate concentration. Substituting N_{ne} and N_{nar} yields:

Nne = Nnar = Nc/(a+s+1) *Eq. 20*

$$N_{nlp} = \left[N_{nar} + \frac{O_a}{2.86} \right] a + \left[N_{ne} + \frac{O_s}{2.86} \right] s \qquad \textit{Eq. 21}$$

$$D_{p1} = \left[\frac{N_c}{(a + s + 1)} + \frac{O_a}{2.86} \right] a + \left[\frac{N_c}{(a + s + 1)} + \frac{O_s}{2.86} \right] s \qquad \textit{Eq. 22}$$

And then solving for a, the optimum recycle ratio is obtained at which the anoxic reactor is loaded to its denitrification potential with nitrate and DO.

$$a_{opt} = \frac{-B + \sqrt{B^2 + 4AC}}{2A} \qquad \textit{Eq. 23}$$

Where A is Oa/2.86;

B is $N_c - D_{p1} + \frac{(s+1)O_a + sO_s}{2.86}$;

C is (s + 1)(Dpp – sOs/2.86) – sNc

When a ≤ aopt then the Nne is given by Equation 24 since no nitrate would leave the anoxic reactor.

$$N_{ne\ min} = N_{ne\ aopt} = \frac{N_c}{a_{opt} + s + 1} \qquad \text{Eq. 24}$$

For a > aopt the Nne is determined by a new equation which takes the equation below: the nitrification capacity Nc, plus the oxygen concentration nitrate equivalent and minus the denitrification potential.

$$N_{ne} = N_c + \frac{aO_a}{2.86} + \frac{sO_s}{2.86} - D_{p1} \qquad \text{Eq. 25}$$

The recycle ratio can be plotted against the effluent nitrate concentration to demonstrate how the change profile looks and at the point the effect of increasing the recycle ratio starts to yield a negligible or insignificant improvement in effluent nitrate concentration. A practical limit can be set to the recycle ratio and a safety factor can also be included to ensure that variations and deviations are accommodated.

The daily average total oxygen demand is then the sum of the oxygen required for degrading COD and nitrification, minus the oxygen recovered by denitrification. Denitrification recovers oxygen by a factor of 2.86 for the mass of nitrate that is denitrified which is calculated as in equation 26.

FOd = 2.86(Nc – Nne)Qi *Eq. 26*

Aeration requirements are determined according to the aeration tank design algorithm detailed in Henze *et al*. (2019), which implements calculation of $OTR_{required}$, guessing initial αSOTE, calculating Q_N and then by iteration coming to αSOTE and OTR_{actual} (Henze et al., 2019).

$$OTR = k_L a(DO - DO_{sat})V \qquad \text{Eq. 27}$$

3.2.2 Selecting a separation process

Following the bioprocess design, it is necessary to consider which separation process will be chosen and two options are commonly being considered across the world in recent times. The membrane bioreactor (MBR) as discussed before is a growing technology with proven success that uses membrane filtration (usually) in-situ in the bioreactor while the conventional activated sludge (CAS) system which has been the technology of choice for approximately a century is well-established and accepted worldwide and implements a secondary settling tank where sedimentation and clarification take place for separation. The generalized advantages (marked in dark grey) and disadvantages (marked in light grey) of each of the systems are summarized in Table 5 (Peck et al., 2012; Verrecht et al., 2012; Karim & James, 2017). Based on the advantages described an MBR system based on the MLE process was selected.

Table 5: Table summarizing the advantages and disadvantages of CAS and MBR

	CAS	**MBR**
Effluent quality	Good, but the risk of sludge carry-over	Very good and stable treatment
Energy usage	Moderate cost	High cost
Footprint	Large size	Small-medium size
Capex	Moderate cost	High cost
Opex	Moderate cost	Moderate
Operation	Simple operation	Complex operation
Sludge processing	High volumes	Moderate volumes
Expansion	Costly and not flexible	Modular, thus easy expansion

3.2.3 MBR design

Once having selected MBR as the preferred separation process, it is necessary to understand the procedure of how an iMBR system is designed. The average/peak flow, as well as the membrane flux, are used together to determine the necessary membrane area (A_m). The membrane flux can be selected based on the average sustainable or peak recommended flux by the manufacturer. Care should be taken to consider membrane fouling as discussed in section 2.3.2 and how flux affects membrane fouling and resulting performance. The membrane tank volume is then finally determined from the membrane area and the membrane packing density.

The minimum required area for membrane filtration is calculated in equation 28 using either the ADWF, PDWF or PWWF as the flow rate (Q) and J which is the permeate flux. The flow rate used will depend on how conservatively the process is designed and whether a balancing tank is included upfront.

$$A_m = \frac{Q}{J} \quad \text{Eq. 28}$$

The membrane packing density (φ_{tank}) is the area of the membranes packed into a certain volume. The packing density is determined by the way the manufacturer installs/manufactures the membrane cartridges and housings and is thus specific to each manufacturer. The packing density of most membranes ranges between 40-300 m^2/m^3. The minimum volume to house the membranes is then determined as follows.

$$V_{m,min} = \frac{A_m}{\varphi_{tank}} \quad \text{Eq. 29}$$

The 2 major types of membranes, flat-sheet and hollow-fibre, as discussed in section 2.3.1 are produced by a multitude of different original equipment manufacturers (OEMs). Since this study is not an exhaustive list of the different products on the market, only a few common options will be mentioned here. Suez Water Technologies is likely the largest supplier of MBR membranes, and these are in HF form. Mitsubishi Chemical and Koch Separation Solutions are other suppliers of HF MBR membranes. When it comes to FS MBR membranes, Kubota holds the largest market share while other options are produced by Membrane Solutions and Rising Sun. For this study, FS membranes supplied by Rising Sun were selected as the technology of choice by the client of the WWTP. The decision was made based on the cost of the membranes as well as the ease of installation and operation associated with flat-sheet membranes. Rising Sun are an OEM from China that price their products competitively in the market. The membrane packing density of these flatsheet membranes is defined by the supplier as 47.4 m^2/m^3. The recommended operating MLSS is allowable between 7 000-18 000 mg/l ("Flat sheet MBR / FMBR," n.d.).

The volume of the aerobic zone which is sufficient for biological treatment is known from the steady-state ASM calculations. The following equation is then used to come to the other defining bioreactor design parameters.

$$V_{aer} = \frac{MX_t f_{maer}}{X_{t,aer}} \quad \text{Eq. 30}$$

The wastewater characterization, kinetic and stoichiometric constants determine the solids mass (MX_t) while the aerobic mass fraction (f_{maer}) is naturally the reciprocal of the anoxic mass fraction (f_{anx}) required for nitrogen removal. The sludge age and MLSS concentration in the reactor are then the remaining unknown variables. The membrane suppliers do specify a minimum and a maximum MLSS concentration and thus an assumption can be made in this regard and the sludge age is calculated from there.

As explained in section 2.3.3, the recycle ratio is required high enough to ensure the sludge concentrations in the different zones are close to each other. The volume fractions of the total volume of the reactor for the different zones are expressed in terms of the mass fractions, the recycle ratios and the average bioreactor MLSS. The TSS concentrations of the aerobic and anoxic zones can also be expressed according to the same method (Parco, du Toit & Ekama, 2019).

$$f_{vanx} = \frac{1 - f_{maer}}{D} \quad \text{Eq. 31}$$

$$f_{vaer} = \frac{a f_{maer}}{(a+1)D} \quad \text{Eq. 32}$$

$$X_{tanx} = \overline{X_t} D \quad \text{Eq. 33}$$

$$X_{taer} = \overline{X_t}\frac{(a+1)D}{a} \quad \text{Eq. 34}$$

$$D = 1 - \frac{f_{maer}}{a+1} \quad \text{Eq. 35}$$

Aeration for air scouring is commonly implemented for the membrane permeation separation operation. Aeration for air scouring is expressed as the specific aeration demand as below and then the aeration demand per permeate product is also shown.

$$SAD_m = \frac{Q_A}{A} \quad \text{Eq. 36}$$

$$SAD_p = \frac{Q_A}{JA} \quad \text{Eq. 37}$$

The airflow required for scouring the membranes is based on the area of the membranes and is typically between 0.15 and 0.88 $Nm^3/(m^2.h)$ (Verrecht et al., 2008).

From Ramphao *et al*. (2005) and confirmed by the membrane supplier, the oxygen that will be needed by the membrane system is calculated as follows.

$$OTR_{mbr} = 0.3Q_{air}OTE_{mbr}\alpha V_{aer}100 \times 24 \quad \textit{Eq. 38}$$

For higher-strength wastewater the oxygen supplied for the membranes will typically be insufficient for the biological oxygen demand determined by the activated sludge BNR system. Additional fine bubble aeration is therefore used within the aerobic reactor volume, but not in the same volume area as where the membranes are situated (Ramphao et al., 2005).

3.3 Design of WWTP for implementation

The model used the experimental data for raw water quality as discussed in the following section to model site conditions and wastewater characteristics as closely as possible. This also enables a comparison of the results of the model to the results of the WWTP treated effluent quality.

The wet and dry weather flows that the WWTP would need to accommodate were calculated using information from site such as the number of houses, occupancy of the houses and the average water use and subsequent wastewater production per capita of the farm community. This information was provided by the engineering consultant to the farm who was responsible for the construction and monthly monitoring of the farm infrastructure (I Cunningham, email report 2020, 24 November) as shown in Table 6. The PWWF would be accommodated by the inclusion of an equalisation tank (also called buffer tank) and thus the reactor and membranes would only have to be designed for the average dry weather flow which ensured reduced infrastructure requirements and thus cost savings. A 15% infiltration is factored into the ADW flow for which the calculation is shown in Table 6 which reference to The Neighbourhood Planning and Design Guide (Council for Scientific and Industrial Research & Department of Human Settlements, 2019).

Table 6: Table of information received of resident numbers and wastewater production

Neighbourhood	**Houses**	**Capita per house**	**Wastewater production per capita (L/d/p)**
Happy Valley	18	5	80
New Happy Valley	39	5	80
Volcano	5	5	80
New Volcano	14	5	80
Green Valley	18	5	80
Valley View	7	5	80
Hostel	3	10	80

A Process and Instrumentation Diagram (P&ID) was drawn according to the MLE system and included the basic process units required to successfully implement the WWTP. A control philosophy was also developed based on the P&ID. The process units required were identified as below:

- Fine & Coarse screening
- Flow equalisation
- Primary settling
- AADY pumps
- Bioreactor with different tanks
- Anoxic mixing
- Chemical dosing
- Fine bubble diffused aeration
- RAS recycle pump
- Membrane filtration unit
- Permeate pumps
- BOD aeration blower
- Membrane air scouring blower
- Disinfection
- Membrane CIP system
- WAS pump
- Sludge thickening
- Drying beds
- Automated electrical control system

The equipment selection and design decisions were taken using best practice indicators from (Metcalf *et al.*, 2014) as well as supplier datasheets.

3.4 Water quality data collection

3.4.1 Sampling process

Raw and treated wastewater quality data was acquired through a partnership with a reputable wastewater treatment contractor at the existing WWTP at High Noon farm that was designed, built, and is operated by the contractor (Alveo Water).

Integrated samples were used by collecting 1-litre samples every 2 hours over 24 hours and then mixing all the individual samples to form an integrated composite that is representative of the water quality throughout a full 24-hour period. By determining the organic and nutrient load on the wastewater plant in this way, the samples and subsequent wastewater characterization is more accurate leading to an optimized reactor design than what it would be when simply taking a grab sample at an arbitrary time of day. All samples taken on site were at all times labelled immediately and clearly to indicate time, date, and location so that mistakes in the data are avoided. Only sterilized sample bottles were used to ensure no external contamination affects the water collected in the bottle. The sample bottles were sealed immediately and transported in a cooler box to the accredited laboratory so that no contamination could enter the samples or bacterial growth could take place in the sample (WRC, 2019). Samples were not taken during heavy rainfall which as per (O'Neill, 2004) has a dilution effect and does not represent the water quality well.

The treated water was tested for the profile of the general limits as shown in Table 1 in section 2.4. Since the treated effluent is in most cased (except for reuse) discharged to the environment, the general limits are the criteria for compliance used to regulate licenses to local and provincial authorities as legislated by the National Water Act (NWA) of 1998 (National Water Act, 1998).

Treated water samples were taken at sample point V-1-28 as shown in the P&ID plant drawing in Appendix C. This sample tap is located on the permeate line of the membrane unit following the disinfection unit (UV light) which represents biologically digested, membrane separated and then disinfected effluent that is discharged into the environment or collected for reuse.

3.4.2 Analytical methods

Sample analyses were performed at a South African National Accredited System (SANAS) laboratory (AL Abbott & Associates) according to industry best practice. Detailed and official water quality certificates and SANAS accreditation certificates are provided in Appendix D. The most important analytical methods used in the study are listed below, but not described since these are for reference and are readily available in the mentioned documents.

- Determination of chemical oxygen demand by titration is according to SANS 6048, ALA 2
- Determination of ammonia uses standard method 4500 NH3-C (1992), ALA 3
- Determination of electrical conductivity uses standard method 2510 A, ALA 9
- Determination of pH is according to SABS 11, ALA 19
- Determination of nitrate by colorimetric method – HACH 8039, ALA 4
- Determination of total suspended solids uses standard method 2540 D (1992), ALA 6A
- Determination of orthophosphate – HACH 8114, ALA 10
- Determination of Faecal Coliforms uses Colilert – 18/Quanti-Tray method for Faecal Coliforms, ALA 86

3.5 Other data collection

Sludge quality data were also acquired through a partnership with a reputable wastewater treatment contractor at the High Noon WWTP as with the water quality data. Three sludge samples were taken from each of the two drying beds on the same day and then mixed to form one composite sample. The sampling procedure was followed as described by Badza *et al.* (2020) and entails gathering a sample of 500 g dry sludge, placing it in a white plastic container that can be sealed, and transporting and storing it under a controlled temperature of approximately 4 °C until analyses were conducted. The physical removal of the sludge out of the drying bed was done by slicing down from the surface to the base of the sludge layer in the drying bed. By following this method, the sludge sample would be representative in terms of pollutant and bacterial contents as well as the moisture in the sludge. If a sample were to be taken only from the surface this could potentially misrepresent the sludge characteristics especially the bacteriological and moisture content since not the full distribution and range of sludge to be handled is tested. The profile that was analysed on the sludge samples was the parameters as required by the sludge guidelines and shown in Table 2 as well as the following parameters in Table 7 that are not part of sludge classification but are nevertheless required by regulation as minimum compulsory analyses.

Table 7: Table of the additional parameters for comprehensive sludge characterization.

Characteristic	Physical				Organic	Nutrient		
Parameter	pH	Tot Solids (TS)	Vol Solids (VS)	VFA	Poly-aromatic hydrocarbons (PAH)	TKN	TP	Potassium

Sample analyses were performed at the South African National Accredited System (SANAS) laboratory again as with the water quality samples. The official analysis certificate is in Appendix D. The analytical methods used for sludge sample analysis are listed below, but not described since these are for reference and are readily available in the mentioned documents.

- Determination of pH by direct measurement of pH on saturated paste or solution
- Determination of TS by Standard Method 2540B
- Determination of VS by Standard Method 2540E
- Determination of VFA by Adapted Standard Method as in Appendix 2 (Snyman & Herselman, 2006) adapted from American Public Health Association *et al*. (1998)
- Determination of TKN by Adapted Standard Method as in Appendix 2 (Snyman & Herselman, 2006) and Croll *et al.* (1985).
- Determination of TP by Adapted Standard Method as in Appendix 2 (Snyman & Herselman, 2006) and Zasoski *et al.* (2008).
- Determination of K by Adapted Standard Method as in Appendix 2 (Snyman & Herselman, 2006) (Sludge Guidelines) and Zasoski *et al.* (2008).
- Determination of metals based on *aqua regia* extraction and by ISO 11466: 1995 (E)
- Determination of PAH by EPA methods 3510C, 3540C and 3660B
- Determination of Faecal coliforms by EPA Method 1681
- Determination of Helminth ova as in Appendix 2 (Sludge Guidelines) adapted from US Environmental Protection Agency *et al.* (1999).

Unfortunately, the sample results for Helminth ova were not available at the time of writing due to the long lead time of minimum of 6 weeks for these analyses. The results of the faecal coliforms were used conservatively for the classification of the microbiological profile of the sludge. Routine analysis of PAH organics is not required for domestic waste and only applies to industrial waste, which is the reason that PAH was not tested for sludge characterisation.

The effluent flow rates were recorded on a daily basis using a water meter located on the permeate line to monitor the effluent discharge performance of the WWTP in terms of volumes of pollution produced. The water meter reading was recorded by hand at the same time of day every day for a 4-week period and a picture was taken of the water meter as well as further confirmation.

3.6 Water quality and sludge data evaluation

Eight data sets of water quality were acquired according to the data collection methodology described in section 3.4 and evaluated by statistical analysis, the effluent quality index and mass balances to determine any errors that are to be presented in the results and discussion.

3.6.1 Statistical analysis

The water quality and sludge data were evaluated according to a scientific approach based on standardised procedures and statistical methods. The raw water and treated water quality data points were analysed to determine the mean and standard deviation which are fundamental statistical methods to evaluate the data within the milieu of the whole dataset. The data trends were also plotted over time and with the general limits of wastewater discharge also indicated as a base for interpretation. The mean data then was used to calculate the percentage removal of each of the tested parameters from the raw water to the effluent. Furthermore, the percentage of parameters that were in line with the general limits were calculated to signify the percentage compliance of the effluent data. Finally, the percentage by which the effluent data deviated from the general limits was also calculated which indicates the exceedance or acceptable load of pollution by the effluent produced.

The sludge data was analysed in comparison to the sludge classifications by the national regulation for sludge management. The classification of the sludge according to the ranges within which the parameters were, then result in different sludge management protocols. The sludge could either be classified as suitable for unrestricted use, restricted use under specific conditions or unsuitable for most forms of use and then recommending further treatment or specific disposal measures.

The reduction of volatile solids (VS) in the sludge handling units of the WWTP can be calculated by O'Shaunessy's formula as described in Appendix 3 of the Sludge Guidelines and shown below (Snyman & Herselman, 2006):

$$VS\ reduction = \frac{V_i - V_0}{V_i - (V_i \times V_0)} \times 100 \qquad \textit{Eq. 39}$$

Where V_i is the feed sludge's volatile fraction and V_0 is the digested sludge's volatile fraction.

3.6.2 Effluent Quality Index (EQI)

The EQI is an important standardized procedure that evaluates the data by a common benchmark that can be applied across different plant's, operating conditions and legal requirements for comparison. It provides an understanding of what the data means without being severely affected by statistical outliers. The basis of the EQI theoretical development is provided in section 2.4.4. The Beta-values for the pollutant weighting factors are calculated by using the emission limit of COD as a basis and setting the other concerned emission limits as a ratio of the COD limit as shown below:

$$\beta = \frac{COD_{lim}}{Parameter\ of\ concern_{limit}} \qquad \textit{Eq. 40}$$

Where the parameter of concern will be the COD, TSS, FSA, NO and OP respectively.

Using the general limits in Table 1, which specify the relevant legislature for emissions applicable to the site of High Noon in the Elandskloof, the following table is then obtained for the pollutant weighting factors which is used to calculate the EQI of the effluent water.

Table 8: Pollutant weighting factors for EQI obtained from the general limits for wastewater discharge

Pollutant	Emission limit (mg/l)	Weighting factor (β)
COD	75	1
FSA	6	12.5
OP	10	7.5
NO	15	5
TSS	25	3

Even though recorded effluent flow rate data was available, the design flow rate, which is conservative, was used for the calculation of EQI as a worst-case indicator.

Similarly, following section 2.4.4 developing the theory of EQI for sludge, the Beta-values for the pollutant weighting factors are calculated by using the emission limit of Zn as a basis and setting the other concerned emission limits as a ratio of the Zn limit as shown below:

$$\beta = \frac{Zn_{lim}}{Parameter\ of\ concern_{limit}} \qquad \text{Eq. 41}$$

Where the parameter of concern will be all the other metals and the Faecal coliforms (CFU/g).

For sludge quality evaluation, Table 8 which specifies the relevant emission limits for sludge disposal, handling or reuse in the best-case scenario is used to obtain the weighting factors. These Beta-values below will then be used to calculate the EQI of the sludge.

Table 9: Pollutant weighting factors for EQI obtained from Sludge Guidelines (2006a)

Pollutant	Emission limit (mg/l)	Weighting Factor (β)
As	40	70
Cd	40	70
Cr	1200	2.33
Cu	1500	1.87
Pb	300	9.33
Hg	15	186.67
Ni	420	6.67
Zn	2800	1
FC (CFU/g)	10000	0.28

3.6.3 Mass balances

An additional important method of evaluating the experimental data is by applying mass balances over the system to verify the reliability of the experimental results. The principle of the conservation of mass promulgates that the mass flow going into a system would be equal to the mass flow going out of a system minus any change in mass. COD, N and P mass balances were performed on the system's experimental results for this purpose of data evaluation and verification.

The COD balance considers a single stream entering the system which is the raw water (through FS_{ti}), but there are multiple ways that the COD then exits the system. The WAS stream draws from the bioreactor where the total COD concentration (S_{ML}) is used. COD is further also used for denitrification

(FO_D), for biodegradable organic matter degradation (FO_C) and finally, the effluent (S_{te}) will also contain some COD. The COD mass balance equations are shown below.

$$FS_{ti} = S_{ti}Q_i \quad \text{Eq. 42}$$

$$FS_{out} = Q_w S_{ML} + FO_C + FO_D + Q_e S_{te} \quad \text{Eq. 43}$$

$$COD_{bal} = \frac{FS_{out}}{FS_{ti}} \times 100\% \quad \text{Eq. 44}$$

Similarly, the mass balance for conservation of nitrogen also follows, but instead of FO_C and FO_D, the mass of nitrate of denitrified ($\Delta FNO_{3,denitrif.}$) needs to be accounted for in the balance.

$$FN_{ti} = Q_i N_{ti} \quad \text{Eq. 45}$$

$$FN_{out} = Q_e N_{te} + Q_e NO_{3,effl.} + Q_w NO_{3,WAS} + Q_w N_{ML} + \Delta FNO_{3,dentrif.} \quad \text{Eq. 46}$$

$$N_{bal} = \frac{FN_{out}}{FN_{ti}} \times 100\% \quad \text{Eq. 47}$$

Thereafter, the phosphate balance is straightforward, and it is given in the below equations.

$$FP_{ti} = Q_i P_{ti} \quad \text{Eq. 48}$$

$$FP_{te} = (Q_e + Q_w)P_{te} \quad \text{Eq. 49}$$

$$P_{wasted} = P_{ML} Q_w \quad \text{Eq. 50}$$

$$P_{bal} = \frac{FP_{te} + P_{wasted}}{FP_{ti}} \times 100\% \quad \text{Eq. 51}$$

3.7 Operational costing of WWTP

The operational cost of the WWTP needs to be determined in a standardized and scientific approach that follows the IWA benchmark simulation modelling (BSM) task group's methodology. The Operational costing index (OCI) requires that aeration energy, pumping energy, mixing energy and heating energy are calculated in kWh/d. The heating energy and methane produced are not relevant to this WWTP since no heating is required and methane is not produced. Furthermore, the sludge produced would be required in kg TSS/d and the chemical addition in kl/d. The Eskom tariffs that apply at High Noon farm were obtained from Eskom (2021) and consist of two unit charges that are summed together to obtain the energy cost per unit. The energy charge in c/kWh is R142.19 ex VAT and the ancillary service charge is 0.55 c/kWh. The network capacity charge and service charge which are fixed connection costs are excluded since these are already payable by the farm since they have Eskom power supply.

The aeration energy (AE) is based on the total power ratings of the aeration blower and the membrane scouring blower as well as their running hours and is shown in Table 10. The running hours was taken as the maximum possible running hours in a day as a conservative estimate of the maximum energy use of the plant.

Table 10: Table of all the blowers at the WWTP and their energy usage.

Pump name	Location	Type	kW	Running hours
Aeration blower	Equipment room (to aeration tank)	Busch Samos SB 0200 D2	3	23 hrs
Membrane blower	Equipment room (to membrane tank)	Busch Samos SB 0200 D2	3	22 hrs
Total				**135 kWh**

The pumping energy (PE) is based on the total power ratings of all the centrifugal and submersible pumps that are used in the WWTP as well as their running hours. The running hours was taken as the maximum possible running hours in a day as a conservative estimate of the maximum energy use of the plant. These are summarized in Table 11.

Table 11: Table of all the pumps at the WWTP and their energy usage.

Pump name	Qty	Location	Type	kW	Running hours
Buffer pumps	2	Buffer tank	Wilo JDSK-10	0.75	8 hrs
RAS pump	1	Membrane tank	Wilo JDS-10	0.75	18 hrs
Permeate pumps	2	Equipment room (from membrane tank)	Wilo MC 304	0.55	22 hrs
Dosing pump	1	Equipment room (to anoxic tank)	Grundfos DDE 6-10	0.019	8 hrs
Service pump	1	Equipment room	Wilo Hi-Peri 1-5	0.55	2 hrs
Total					**32.85 kWh**

The mixing energy (ME) is based on the total power ratings of the anoxic mixer and includes the rotary screw screen, the extractor fan for cooling of equipment and the UV light for disinfection as well as the respective running hours. The running hours was taken as the maximum possible running hours in a day as a conservative estimate of the maximum energy use of the plant. Table 12 below summarizes the mixing and other energy use at the WWTP.

Table 12: Table of all the mixers and other electrical equipment at the WWTP and their energy usage.

Pump name	Location	Type	kW	Running hours
Rotary screw screen motor	Buffer pump line	WAM CT-150	0.37	9 hrs
Anoxic mixer	Anoxic tank	Infin-8 mixer	0.75	23 hrs
Extraction fans	Equipment room	CFW FTAC40/4	0.22	12 hrs
UV sterilizer	Equipment room	Wonder HC-800	0.065	22 hrs
Total				**24.65 kWh**

Sludge production (SP) cost was taken as the cost of the primary sludge needing to be disposed of at the Villiersdorp municipal wastewater site. This was obtained from the municipal rates for disposal as well as the cost of transporting the sludge from the farm to the municipality (Theewaterskloof Municipality, 2021). The rates for transporting sludge via a vacuum truck were obtained from reputable service providers in the Western Cape that provide waste transport services (such as Immex and Junocorp). The waste activated sludge from the drying beds do not require disposal as a waste product due to the sludge classification which allows it to be reused and the location on a farm means its reuse can be done by the farm themselves on their own land. The cost of sewage disposal is R168.17 ex VAT per kiloliter and the transport thereof is R960 ex VAT per 6 kl load and R15/km of travelling.

For a 6 kl truckload which would be the most economical way to dispose of sludge in a full truckload, the disposal cost would be R1009.02 ex VAT, while the travel cost would be R450 ex VAT for the 30 km that the truck needs to travel from Villiersdorp to High Noon farm and back again. The volume and mass of sewage sludge to be disposed of were obtained from the steady-state model (T Venter, email quotation, 2021, 13 December; S Slabbert, email quotation, 2021, 9 December).

The chemical addition (CA) was taken as the cost of the volume of chemicals used monthly at the WWTP. The cost of chemicals is market-related and based on comparison from several reputable suppliers such as Protea Chemicals and Wet Chem. The chemical price used was R15.90/l. (D Terblanche, email quotation, 2022, 19 January; C Murphy, email quotation, 2022, 17 January)

Even though municipal sanitation services are not available in the area under consideration, it is still of interest to, using comparison, check the cost of the council fees for sewerage services against the price per kl of sewage treated. According to the newest tariff list (Theewaterskloof Municipality, 2021), residential premises are charged at R182 ex VAT straight fee for sewerage services irrespective of the number of toilets or water use. There are 104 farm workers' houses as determined in the Appendices and thus each of these houses would be charged the monthly sanitation provision fee.

4. Chapter 4: Results and discussion

4.1 Wastewater treatment plant design

4.1.1 Wastewater treatment model output

The design calculations based on information provided concluded that the WWTP design was to be for an ADWF flow of 49.22 kl/day as shown in Table 13. The peak wet weather flow component was accommodated by an equalisation tank up front before the reactor to be able to design the reactor and membrane units on the significantly lower value of Q_{ADWF} which also results in cost savings. At 49.22 kl/day the WWTP is classified as a small WWTP and though the economy of scale means that smaller WWTP's are less economical per kl of water treated, there is still a case for this WWTP's necessity. Equipment is sized and designed for implementation according to what is required at this small-scale wastewater treatment. Even though this WWTP receives a small flow rate it serves as many as 550 persons in the community it is situated in. This means it is comparable to the MBRs studied by (Capodaglio et al., 2017) with a 1000 P.E. in Germany and Netherlands that were successful.

Table 13: Table of wastewater flow calculation.

Site	**Wastewater production**
Happy Valley	7200
New Happy Valley	15600
Volcano	2000
New Volcano	5600
Green Valley	7200
Valley View	2800
Hostel	2400
Total Wastewater production (l/d)	42800
Infiltration (l/d)	6420
Total Wastewater production incl infiltration (l/d)	49220

Tables 14 and 15 display some of the primary important findings produced by the AS-BNR model that was implemented as described in section 3.2. The MLSS concentration was selected as 12000 mg/l which is within the membrane supplier's specification range of between 7000-18000 mg/l being acceptable. A smaller reactor volume can be achieved at a higher MLSS, but a quick review of the literature indicates that care must be taken to prevent membrane fouling conditions over the long term. A membrane might be able to sustain an acceptable performance for a few years at a high MLSS for the advantage of a small reactor, but the overall lifespan thereof could decrease which will contribute to additional costs for replacement as well as more frequent maintenance cleaning procedures.

Table 14: Table of solids and biomass concentrations, nitrates and oxygen rates.

Parameter	Unit	Result
TSS concentration	mg/l	12000
VSS concentration	mg/l	6218.9
ISS concentration	mg/l	5781.1
OHO concentration	mgCOD/l	640.5
NO3 denitrified	mgN/l	33.29
NO3 generated	mgN/l infl.	39.46

The minimum required reactor volume of 22 kl and HRT of under 1 hour is interesting compared to the daily flow rate which indicates the significant advantage that an MBR provides of a small footprint at the higher MLSS concentration. Du Toit (2007) found that under the same experimental conditions and at the same reactor size, an MBR plant could achieve 3 times the flow rate that a CAS plant could. This gives perspective on the size and footprint of an MBR system and how this can be beneficial for various reasons.

Table 15: Table of reaction volume, waste sludge & active fractions.

REACTOR VOLUME			
V	Reactor volume	22.06	m^3
Rh	Hydraulic retention time	10.76	h
SLUDGE WASTE			
Qw	Sludge volumetric waste flow rate	0.88	m^3/day
FXw	Sludge mass waste flow rate	10.59	kgTSS/day
ACTIVE FRACTIONS			
f_{av}	active fraction with respect to VSS	0.31	
fi	VSS to TSS ratio	0.52	
f_{at}	active fraction with respect to TSS	0.16	

The sludge age was chosen to be 25 days together with the 12 000 mg/l MLSS. Some important design assumptions that were made during the modelling process, are the underflow recycle ratio (which was selected as 0.4) and the dissolved oxygen in the 2 recycle streams (O_a and O_s). Since a DO of 1.5-2 mg/l is commonly targeted in practice, the DO in the a-recycle was assumed to be 2 mg/l. The membrane filtration unit uses high flow rates of air scouring for fouling prevention and maintaining the flux and this has been measured at higher DO’s than what the DO usually is in the main aerobic reactor. The O_s DO was assumed to be 4 mg/l (Henze et al., 2019).

Table 16: Table of nitrification calculations for the WWTP.

NITRIFICATION			
Nti	Total N in influent	62	mgN/l
Ns	Total N removed in sludge	22.30	mgN/l
fxm	maximum unaerated mass fraction	0.70	
fx1min	minimum primary anoxic sludge fraction	0.14	
fxt	Selected Primary anoxic sludge mass fraction	0.24	
Nae @ fxt	Effluent ammonia concentration	0.20	
Nc	Nitrification capacity	39.46	mgN/l

The nitrification and denitrification results shown in tables 16 and 17 were successful in that nitrification was able to take place as needed and the denitrification potential was sufficient to reduce the effluent nitrate concentration to an acceptable value within effluent discharge limits. Furthermore, optimal a recycle was calculated to less than the practical limit on a recycle. The a recycle was still chosen conservatively as 5, which is more than the optimum a recycle, because the membrane filtration unit requires a high return rate to prevent clogging. The reaction kinetics for ANO's are shown in the Appendix according to the literature described in section 2.3.3. Research has found that different kinetics apply for ANO's in MBR systems and thus the model was adapted in this regard to be as accurate to reality as possible. The selected mass fraction of anoxic in the reactor at 0.24 which is conservative for adequate denitrification is more than the minimum required anoxic sludge fraction. Importantly, this is not used directly to determine the anoxic reactor volume though, because of the research and methodology that indicates different sludge concentrations at different points in the reactor. The volume fraction of anoxic (0.27) was thus calculated as in Eq. 31 to determine the anoxic reactor volume of 6 kl and the aerobic reactor volume was the remaining 16 kl.

Table 17: Table of denitrification calculations for the WWTP.

DENITRIFICATION			
Dp1	Denitrification potential of the primary anoxic reactor	33.68	mgN/l
a,opt	optimum a recycle value	3.20	
a,prac	Practical limit on a recycle	6	
a	selected a recycle value	5	
Nne	effluent nitrate concentration	6.17	$mgNO_3/l$
Nte	Effluent TKN concentration	0.30	
	% N removal	91.15	%
fvanx	anoxic volume fraction	0.27	From Eq 29
fvaer	aerobic volume fraction	0.73	From Eq 30
Xtanx	anoxic TSS concentration	10480	From Eq 31
Xtaer	aerobic TSS concentration	12576	From Eq 32
Vano	Anoxic reactor volume	6.06	m^3
Vaer	Aerobic reactor volume	16.00	m^3

The biological oxygen demand shown in Table 18 is not much different than what it typically is for CAS systems. About a half of the nitrogenous oxygen demand is recovery by denitrification. Thus, the major contributor to oxygen required is naturally the carbonaceous oxygen demand. The total oxygen required of 28.58 kgO/day is in line with expectations for the design flow rate and wastewater characteristics.

Table 18: Table of the biological oxygen demand.

Biological oxygen demand			
FOc	Oxygen required for OHOs	24.41	kgO/day
FOn	Oxygen demand for nitrification	8.86	kgO/day
FOd	Oxygen recovery by denitrification	4.69	kgO/day
FOt	Total Oxygen required	28.58	kgO/day

Moving to the design specifically for MBR is twofold in that membrane filtration and membrane aeration needs to be modelled. This was done as described in section 3.2.3 and yielded the results as shown in Table 19 below. Membrane permeation is typically done intermittently to allow for flux recovery as based on many studies summarized in The MBR Book (Judd, 2010). Based on this a period of operation in 24 hours was assumed conservatively to allow for occasional maintenance and then the maximum design flux through membrane filtration was determined as 18 LMH. The area required for the membranes and the final design flux (15.4 LMH) based on equipment specifications was determined. Each SMU module demands 0.6 m^3/h for air scouring which comes to a total minimum air requirement of 120 m^3/h.

Table 19: Table of the membrane filtration & aeration design.

Membrane filtration & aeration design		
Daily on duration	20	hours
Daily flow to be treated	2.5	m^3/h
Max design flux	18	l/m^2/h
Membrane surface area per SMU module	0.8	m^2
Total Number of SMU module	200.00	
Am (area of membranes)	160.00	m^2
Calculated Design Flux per train	15.38	l/m^2/h
Minimum Aeration Requirement per SMU module	0.6	m^3/h
Total min Air requirement	120	m^3/h
SADm	0.75	m^3/m^2h
SADp	48.76	m^3/m^3
OTRmbr	4.74	kgO/day

The oxygen supplied by the membrane air scouring was deducted from the total oxygen demand requirement previously determined in the MLE model and thus a new air supply requirement for the aerobic reactor was found as 23.8 kgO_2/d as shown in Table 20. The final volumes for WWTP implementation were then decided on including a safety factor. The aerobic reactor volume was comfortably more than the minimum volume to house the membranes and was thus determined by the MLE modelling. The total reactor volume of 28 kl remains a small structure that should prove to be appropriate for installation even in severely constrained land areas. It is a significant plus point that an MBR plant can seemingly achieve what is required for legal and environmental needs in a compact structure that can fit into many small spaces and save on infrastructure and land use costs.

Table 20: Table of the implemented aeration design & reactor sizing.

Aeration design			
Aeration	Total Air supply required in the aerobic reactor	23.84	kgO_2/d
	Actual air supply	120	m^3 Air/h
	Actual O2 supply	35.81	kg O/h
	Actual O2 supply transferred	32.13	kg O/d
Reactor sizing			
Anoxic	Total required Volume	6	m^3
	Safety Factor	25%	
	Volume per reactor	**7.6**	m^3
	retention time	3.7	h

Aerobic	Min volume to house membranes	3.4	m^3
	Packing density	47.4	m^2/m^3
	Total Volume	16	m^3
	Safety Factor	25%	
	Volume per reactor	**20.00**	m^3
	retention time	10	h

4.1.2 Model and practical comparison

When comparing the model to the WWTP that is already located at High Noon farm certain similarities can be seen which indicates a good interaction and correspondence between the theoretical and practical sides of the wastewater treatment approach. A summary of certain key parameters is shown in Table 21. Some of the results included are from the results sections to follow where they are discussed in detail in each relevant section.

Table 21: Table for comparing the model and real WWTP outputs.

Parameter	Symbol	Unit	Model	WWTP
Effluent ammonia concentration	Nae	mg/l	0.2	0.1 for the majority of samples (some variation)
Effluent nitrate concentration	Nne	mg/l	6.2	Ranges between 0.8-14 for most samples
N removal	Nrem	%	91.2	85.4
Air supply (for biological demand)		kgO/h	23.8	32.1
Reactor volume	V	m^3	22	28

The effluent ammonia concentration corresponds well in general, although the WWTP effluent results do contain outliers which is an indication of dynamic conditions as well as other unforeseen inefficiencies or failures. The same can be said for the effluent nitrate concentration where the model predicts a value of 6.2 mg/l and the common range for the WWTP effluent results was around this range. There was however significant variation in the effluent nitrate concentration which once again indicates the need for dynamic modelling and the fact that site conditions are unpredictable with many factors that can influence the outcome which limits the ability of a model. The Nitrogen removal was close to being the same with a 6% difference which is an acceptable result for the model in predicting the actual WWPT.

Finally, certain practical differences are also present such as the air supply that requires about 24 kgO/h for the model, but in practice, the smallest commercial blower available in this size range supplied 32 kgO/h which is significantly more than what the model dictates. Blowers and pumps get manufactured in certain sizes and there are limitations in practical applications for how close to theoretical requirements an installation can be. VFD’s are used sometimes to operate blowers and pumps at specific frequencies to achieve a specific operating point. VFD’s however add cost to the capital of the project and even with additional measures such as throttling valves etc, there simply will be differences between the practical values such as oxygen supply and the theoretical model. The model remains helpful in prescribing a range or aim for the equipment. Finally, the safety factors that are included means that the WWTP reactors are slightly larger than the reactor predicted by the model. The difference is not major and thus the model was successful in this regard.

4.1.3 Implemented plant design evaluation

A Process and Instrumentation Diagram (P&ID) of the WWTP was produced for High Noon farm is attached in Appendix C and is described in this section to provide an overview of the process operation that was developed. The control philosophy of the WWTP is also attached in the Appendix.

The raw water that is collected by the sewer reticulation system as discussed in section 3.1 is coarse screened and then stored in a buffer tank with a 24-hour PWWF capacity, and then pumped over with 2 annual average daily yield (AADY) pumps (duty and standby) to the fine screen. The rotary screw screen with 2mm apertures is used to provide sufficient protection from particles for the membranes and following the screen, the water flows into the bioreactor. The bioreactor is equalized by gravity flow through the wall apertures and consists of the anoxic tank as well as 3 aerated tanks and the membrane filtration tank. A dual-purpose RAS/WAS pump is situated in the membrane filtration tank, and it returns activated sludge to the anoxic tank for denitrification as well as being manually manipulated to pump waste sludge to the sludge handling section. Two centrifugal permeate pumps (duty and standby) are situated in the control room that pump treated effluent out of the membranes and through an ultraviolet light for disinfection and out towards its discharge point where the water can go into a river or be reused for irrigation. The permeate pumps are critically monitored via instrumentation for suction pressure and flow rate to ensure the flux through the membranes is acceptable.

Chemical dosing is used to assist with phosphate removal in the anoxic reactor which is mixed by a slow mixing agitator. Fine bubble diffusers in the aeration reactors are fed by a side channel blower and another side channel blower supplies the membrane air scouring demands. A small pump and service tank filled with permeate water provides for when a CIP needs to be performed on the membranes or when foam control is required in the reactors. The CIP chemical tank is connected onto the permeate line and is manually opened to fill the membranes by gravity with a chemical solution when needed. The manually operated sludge handling system consists of 2 settling tanks to concentrate the sludge, where after the concentrated sludge is dried in 2 drying beds and the clarified water from the settling tanks joins the main process flow. All pumping is automated with level and pressure control as required and pump protection incorporated. The electrical equipment is controlled by a single central PLC and HMI that is programmed according to the control philosophy of the plant.

The WWTP was designed at an appropriate size and with durable equipment that is fairly simple to operate. The mobile reception in the area where the plant is located is poor and thus remote monitoring equipment was not used at the WWTP. Screenings were found to be excessive due to the lack of education of the residents as to what is allowed to flush down a toilet. Additional screening would be recommended for future applications. The WWTP was sufficiently automated to allow for minimal manual input or labour on the plant. The complexity of the process technology and the amount of labour required to clean screenings proved to be a challenge for local employees of the farm staff. Repeated training had to be provided both to farm managers and farmworkers at the plant so that the process inputs and checks were understood, and maintenance duties were performed. The WWTP infrastructure implementation was however viewed as a notable success by the residents as well as the local municipality and other involved stakeholders. The success is in that congruous basic service is being delivered to the community, the infrastructure is designed correctly and functioning as it should and the product from the WWTP is high-quality effluent that no longer pollutes the environment as previous methods of sewage handling for the community would have and is compliant with the relevant national legislation. This corresponds with what Singh and Kazmi (2018) found that MBR performed the best out of all of several different technologies that were trialled for DWT.

A final point of discussion is that the lack of a viable alternative in a rural, isolated, and underserviced area such as the Elandskloof where municipal services cannot easily extend through the mountain pass, means the solution of basic sanitation provision in this area is a noteworthy achievement of the plant. Since municipal sanitation services are not existing in this area and are unlikely to be provided in years to come due to the remote location and the significant lengths of piping that would have to be installed through mountainous areas, an alternative is needed. The economic activity of agriculture is continuing in this area which for one will maintain the community living in this area. Sanitation is a basic human right pertaining to human health and human dignity and thus the implementation of this plant is motivated. The rivers and streams in this valley lead to the Elandskloofdam which is a source of drinking water for the municipality, hence the further importance of sufficiently treated effluent water in this valley.

4.2 Plant performance

The performance of the WWTP at High Noon farm was evaluated primarily based on the quality and quantity of its emissions.

4.2.1 Effluent flow rates

The volumes of treated effluent produce on a daily basis are presented in Table 22. The importance of this data is that wastewater discharge permits are issued for a certain volume of allowable wastewater and further that higher flows of wastewater would lead to higher pollution contributions.

Table 22: Table of the treated effluent flow rates produce by the WWTP.

Date	16/11/21	17/11/21	18/11/21	19/11/21	20/11/21	21/11/21	**Avg**
Qe (kl/day)	33	39	40	41	48	45	41
Date	23/11/21	24/11/21	25/11/21	26/11/21	27/11/21	28/11/21	**Avg**
Qe (kl/day)	15	40	37	39	40	24	32.5
Date	29/11/21	30/11/21	01/12/21	02/12/21	03/12/21	04/12/21	**Avg**
Qe (kl/day)	30	31	25	36	49	47	36.3
Date	06/12/21	07/12/21	08/12/21	09/12/21	10/12/21	11/12/21	**Avg**
Qe (kl/day)	35	31	35	34	12	48	32.5

The volumes of treated effluent produced was on average less than the design flow rate which is a good indication meaning the WWTP was not overloaded, and pollution volumes were not being exceeded. Some high volumes in line with the design flow rate were recorded on Fridays and Saturdays, but for the rest of the week, the daily effluent flow rates were less than what the WWTP was designed for. In this regard the WWTP performance was successful.

4.2.2 Effluent water quality

The raw and treated effluent water quality data obtained according to the detailed methodology explained in section 3.4 is attached as a full table in Appendix D. Furthermore, the laboratory sample analysis certificates from the SANAS accredited laboratory AL Abbott & Associates are also attached. The data of some of the main parameters of concern is presented graphically with the emission limit also indicated for context.

The TSS in figure 9 is well below the general emission limit and remained approximately constant throughout the period under consideration. It is important to note that the reading of 4 mg/l which half of the data points are, is the lower limit of detection that the laboratory can quantify during their analytical procedure. The reading is in fact < 4 mg/l but is presented as 4 mg/l which is a conservative approach. The actual reading could be anything below 4 mg/l and even 0 mg/l. Moreover, the uncertainty of measurement (or precision) of the TSS readings reported by the laboratory is 18%. This means that it can safely be said that the TSS data obtained could at most be 7 mg/l if a 18% uncertainty is factored into the highest reading of 6 mg/l, but that variances of 1 mg/l such as between 4 and 5 mg/l should not be seen as telling since these 2 readings fall within the range of uncertainty of the other data point. All in all, the TSS is certainly at a low range that indicates a very good performance by the MBR system. As expected, the physical separation process of using a membrane is highly effective in removing solids and that is what the good TSS results prove. The MBR effluent TSS contributes sparingly to environmental emission, and it also reduces or removes any significant need for filtration or removal of solids when reusing the water.

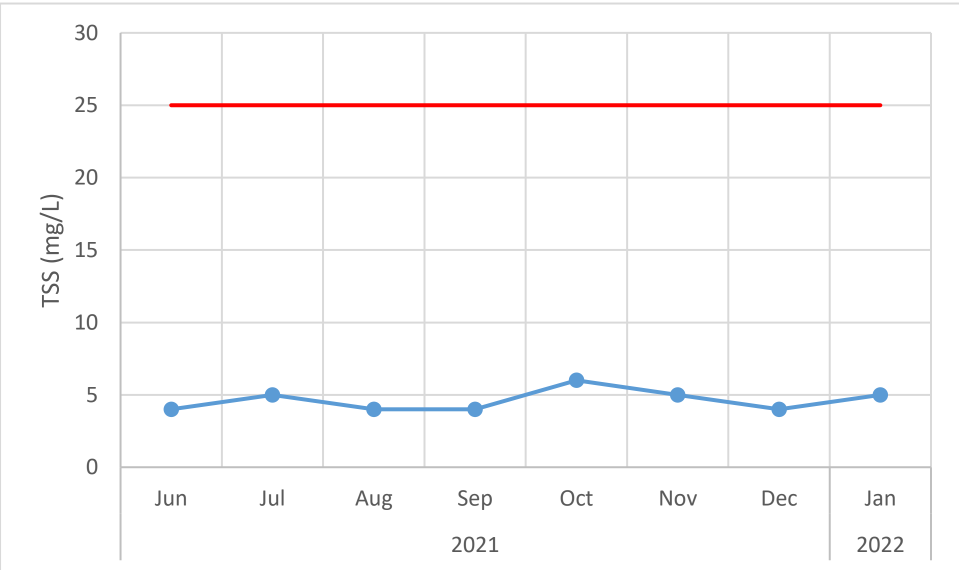


Figure 9: Graph of the Total Suspended Solids concentration measured over time and the general limit (in red).

The COD results of the treated effluent in Figure 10 indicated some variation with 2 samples reporting more than 57 mg/l while the other 6 samples were all at concentrations of less than 36 mg/l. The 2 samples at higher concentrations were consecutive which indicates some sort of seasonal variation or some reason in terms of the influent or perhaps the plant operation that occurred over 2 months, but thereafter improved. These were for November and December starting the summer season where wastewater characteristics and possibly plant operation could be slightly different than usual. Importantly, all measured results were within the general limits for wastewater discharge and thus the WWTP achieved full compliance for treating COD. The sample in December reached a value of 75 mg/l which is precisely on the limit, but still compliant since it is not over the limit and a 6.8% uncertainty in the laboratory measurements needs to be taken into consideration. The COD results indicate a good performance by the WWTP in treating COD and with some variations a consistency in achieving compliant effluent emissions.

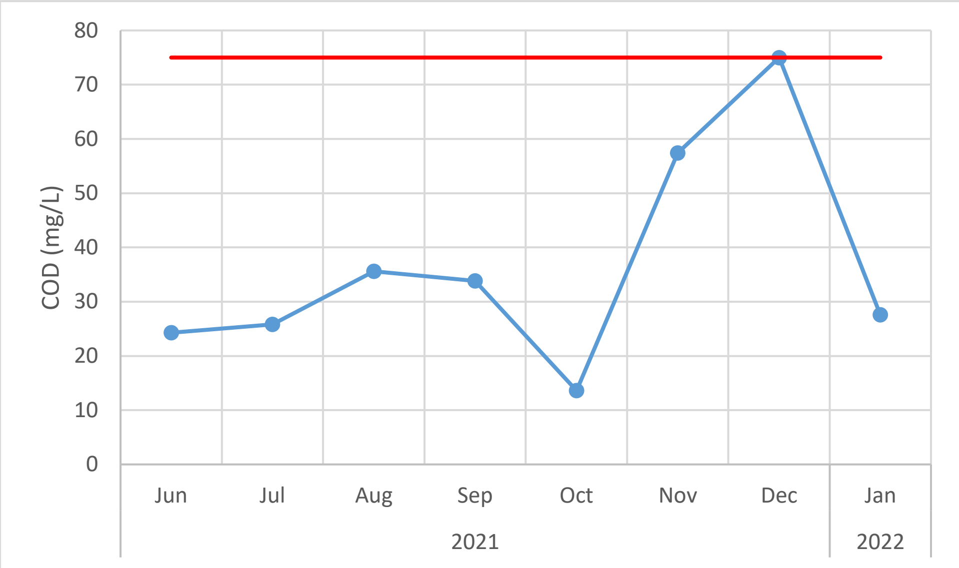


Figure 10: Graph of the Chemical Oxygen Demand concentration measured over time and the general limit (in red).

The FSA results shown in Figure 11 were stable for most samples, but there were also 2 outliers in the data. The general trend is that the effluent ammonia concentration is in the range of 0.1-0.2 mg/l for the majority of samples. Once again there is also an uncertainty with the precision of the laboratory measurements which in this case at 5.2% does not affect the trend of the data points in the low range. The four data points at 0.1 mg/l is in fact < 0.1 mg/l but reported as 0.1 mg/l to be conservative since 0.1 mg/l is the laboratory's lower limit of detection. The ammonia concentrations in the majority lower range are essentially negligibly low. The outliers are both fairly high at approximately 3 times the emission limit and in September and December. While the data points seem to corroborate since it happened more than once at a similar concentration, the explanation thereof is more uncertain. The available raw water data seems to indicate a higher than usual TKN entering the system in September at 74 mg/l, but unfortunately, raw water data for December is not available. Although these are still outliers, they cannot be ignored, but for lack of understanding could be ascribed to seasonal and system fluctuations. The overall performance of the system for treating ammonia is good although instances of non-compliance have also occurred.

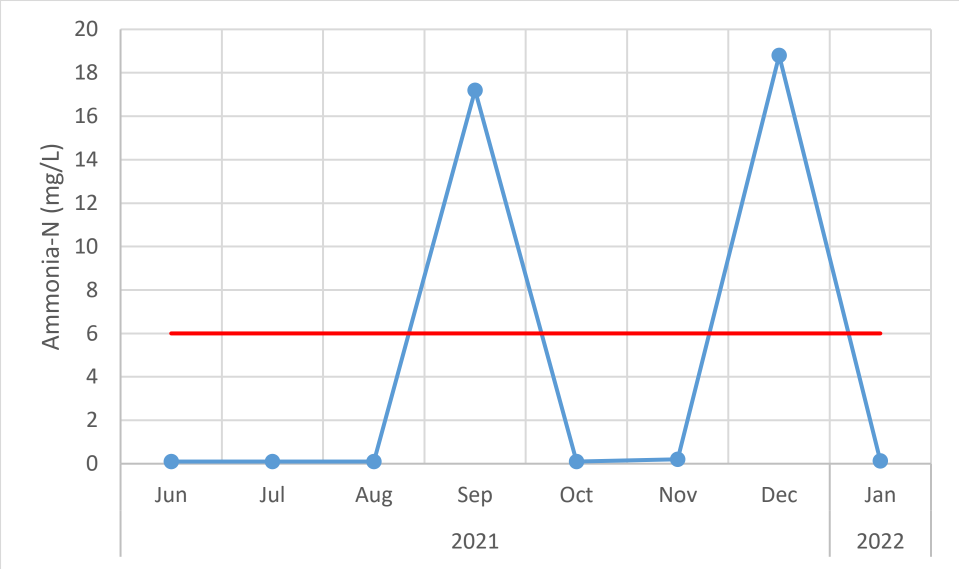


Figure 11: Graph of the Free and Saline Ammonia concentration measured over time and the general limit (in red).

When it comes to the results for nitrate concentration in the effluent in Figure 12, the trend is that there was initially a problem with the treatment of nitrates that led to 3 samples with fairly high readings, which thereafter improved to produce 5 samples with low nitrate concentrations. The first 3 sample results were in the range of 30 mg/l (with an uncertainty of 12.6% in the measurements) which indicates that these were not outliers and that there was a specific reason for these high readings which is approximately double the emission limit. From time spent on site, it is known that the recycle ratio was increased to improve the denitrification taking place in the bioreactor. This was optimized a few months after the WWTP had been commissioned which explains why the nitrate concentrations were initially high and then improved. From September to January all nitrate concentrations were compliant and below the emission limit. The readings continued to fluctuate over this period, but importantly the WWTP performed well and was successful in treating nitrate sufficiently for environmental discharge. Another interesting observation is that the lowest nitrate concentration of 0.77 mg/l in December coincides with the highest ammonia concentration. Once again, involvement with the WWTP operation and maintenance sheds light on this issue, because an equipment failure occurred during this period that prevented sufficient aeration from taking place effectively leaving a certain concentration of ammonia untreated and a significantly low concentration of nitrate resulting.

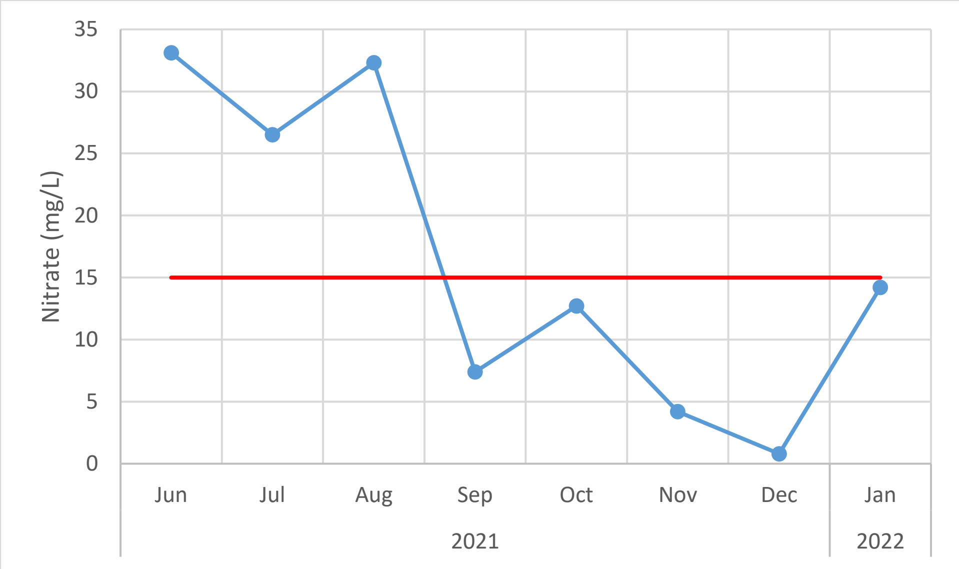


Figure 12: Graph of the Nitrate concentration measured over time and the general limit (in red).

The orthophosphate results in Figure 13 were relatively good and constant between 5-7 mg/l (at a 4.8% laboratory uncertainty of measurement) for 6 months where after a decrease to even lower concentrations below 1 mg/l was observed in the last 2 months. All readings were within the general limits for wastewater discharge which indicates the success of the WWTP in treating phosphate. This is important due to the environmental impact that phosphate has on water bodies as a nutrient and a major cause of algal blooms. The decrease in the last 2 months of the data evaluation is known to be due to increased sludge wasting which was possible following improvements to the sludge handling equipment.

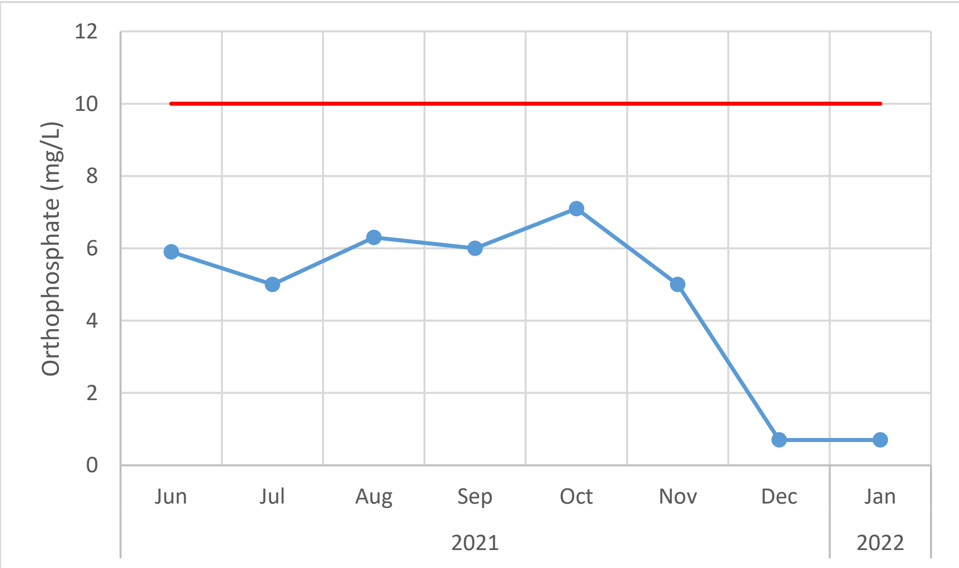


Figure 13: Graph of the Orthophosphate concentration measured over time and the general limit (in red).

The reliability of the results should be seen as good since at least 8 samples were used and these were taken according to a rigorous scientific approach described in section 3.4.1. Specifically, the samples were handled according to a standard protocol that follows best practice and all samples were composite samples collected over 24 hours. The veracity of the data cannot be doubted based on any observations made and thus the results and their interpretation do bear meaning.

The statistical analysis in Table 23 of all the water quality parameters tested by the laboratory indicates, firstly, that the mean of all of the parameters is within the applicable national limit for environmental discharge. The standard deviation of two of the parameters is, however, over the limit (ammonia and nitrate). This paints a picture of good and acceptable results in most samples, but that there are instances of unacceptable water quality in approximately a quarter of the samples for 2 specific parameters. This insight is further reinforced by the calculation of the number of compliant readings that were recorded across all the historic samples and for each individual parameter. While 7 of the 9 parameters were fully compliant for all samples taken, the ammonia readings were compliant 75% of the time and the nitrate readings were compliant 63% of the time. When the compliance of all the parameters is averaged a total compliance of 93% is achieved. This on its own is a significant indicator of the success of the MBR WWTP and attests to the design and construction of the plant as well as the sustained capability of an MBR system under the conditions implemented.

Table 23: Table of the statistical analysis of the treated water quality data.

	Mean	SD	Limit	Compliance	% of permissible emission
pH	7.2	0.39	5.5-9.5	100%	N/A
EC (mS/m)	68.0	12.87	150	100%	45%
TSS (mg/l)	4.6	0.74	25	100%	18%
Cl2 (free) (mg/l)	0.05	0.00	0.25	100%	20%
Ammonia-N (mg/l)	0.4	8.29	6	75%	7%
Nitrate-N (mg/l)	10.3	12.69	15	63%	68%
Ortho Phosphate (mg/l)	3.4	2.51	10	100%	34%
COD (mg/l)	32.4	19.98	75	100%	43%
Faecal coliforms (cfu/100 ml)	0.0	0.00	1000	100%	0%
Total				**93%**	**29%**

The mean of each parameter was taken as a ratio of the respective emission limit to calculate the percentage of the permissible emission limit that was being used by the effluent discharge. All but 1 of the parameters were at its mean using less than 50% of the permissible emissions which comes to an overall average of 29% of the permissible emissions used. The nitrate concentration was on average using 68% of the permissible emission. This also indicates the reasonably low pollution load that the WWTP has been contributing to the environment and that the impact of human activity has been limited through the effective treatment of wastewater.

Furthermore, when placing focus on additional parameters that were not presented in the graphical trends, it is of note that no faecal coliforms occurred in any of the samples. These pathogens are a health hazard to humans and aquatic life, and it is very important to limit exposure to these bacteria. The treatment of pathogens is thus successfully performed by the WWTP. The pH and EC of the treated effluent are both approximately in the middle of the acceptable range indicating healthy levels that are favourable for any water body that the water would be joining in. Specifically, the pH at 7.2 is well balanced and the free chlorine readings are also negligibly low which is important. Free chlorine is a corrosive substance that should be prevented from entering water bodies, because of its detrimental effect on natural organisms and plants. These parameters prove that the treated effluent will contribute to clean water resources and limits the impact of human activity on the environment. The results obtained are in line with what is expected from the literature. As discussed in section 2.4.3 MBR effluent quality has been proven to be of a high standard.

Another of evaluating the WWTP performance in terms of water quality is by the removal of each of the major contaminants from the influent. Table 24 shows that all parameters were removed from the influent with more than 80% efficiency. The TSS and COD were removed with more than 90% efficiency (99% and 93.5% respectively). These are high numbers for the percentage of removal from the influent and it puts the results into perspective of the success that the WWTP itself has proven to be and the major impact that it is making by treating the wastewater produced on High Noon farm.

Table 24: Table of the removal of each of the major contaminants.

Parameter		**Influent**	**Effluent**	**Efficiency**
Total Suspended Solids	mg/l	514.5	4.6	99.11%
Phosphate	mg/l as P	15.4	2.5	83.75%
Chemical Oxygen Demand	mg/l	501.3	32.4	93.53%
Total Kjeldahl Nitrogen	mg/l as N	73.0	10.7	85.40%

4.2.3 Sludge quality

The sludge quality is another important part of the emissions by the WWTP that are to be evaluated since it can also have an environmental impact. The readings obtained from the sludge sample that was analysed in the laboratory are shown in Table 25. All the parameters tested apart from 1 were within the class A limits which indicate the highest sludge quality that can be used for various purposes without restrictions.

The faecal coliforms reported a reading of 22000 cfu/g which falls within the class B limits. The maximum permissible limit for Class A sludge is 10 000 cfu/g and as a result, the microbiological characteristic of the sludge does not have some consideration when using the sludge. Since the result of the Helminth ova was unavailable, the faecal coliforms were taken as the defining microbiological characteristic by which the sludge is conservatively and definitively classified as class B sludge.

All the heavy metals readings were far below the limit for class A sludge classification which means that the result is favourable, and the sludge is acceptable for use. The heavy metals in the sludge are negligibly low. The pH, TKN and TP of the sludge were also found to be propitious for use as fertilizer because acidic pH is good for the soil and the high nitrogen and phosphorous values will impart rich nutrients where used.

The reliability of the results reported is not high since only 1 sample has been used. This is due to certain limitations in the scope of the study and thus the results and their interpretation need to be considered in this light. Specifically, the reported reading for faecal coliforms could be interrogated since all other parameters were comfortably within class A limits while the faecal coliforms are classified as class B. Sampling for bacteriological evaluation is a process that does contain inherent risks and thus needs to be executed to the highest order of precision and protocol adherence. The risk of contamination or incorrect handling or storage leading to skewed data is notable when it comes to measuring bacterial parameters and therefore this result can be treated with a dose of scepticism. The findings in this regard are not conclusive and additional sampling would be required to verify.

Table 25: Table of the sludge quality data.

	Reading	Class A limit
pH	5.8	
Tot Solids %	92.2	
Volatile Solids %	48.9	
Volatile Fraction %	53	
VFA %	0.02	
TKN (mg/kg)	28188	
TP (mg/kg)	4208	
K (mg/kg)	1835	
As (mg/kg)	0.042	<40
Cd (mg/kg)	0.64	<40
Cr (mg/kg)	7.1	<1200
Cu (mg/kg)	105	<1500
Pb (mg/kg)	16.8	<300
Hg (mg/kg)	0.004	<15
Ni (mg/kg)	6.3	<420
Zn (mg/kg)	375	<2800
Faecal coliforms (cfu/g)	22000	<1000

The stability classification of the sludge was determined by the O'Shaunessy formula as described in section 3.5 of the methodology. The stability classification is important for the reduction of vector attraction which is achieved by the reduction of volatile solids. The volatile solids reduction was calculated to be 78.5% based on equation 39 and the laboratory readings shown in Table 25. This places the stability of the sludge well and truly in the class 1 classification. The class 1 classification requires a minimum volatile solids reduction of 38% and thus the stability of this sludge sample achieved more than double the required reading. The sludge can be described as highly stable and fit for use without restrictions.

The implications of the sludge classification are evaluated according to Volume 2 of the Sludge Guidelines, which is focussed on the agricultural application which is of relevance for High Noon farm (Snyman & Herselman, 2006b). The pollutant class A means that the sludge is permissible for agricultural use without a soil analysis which would be required if the sludge achieved a worse classification. The stability class 1 similarly also allows agricultural use of the sludge with no restrictions. The microbiological class B allows for agricultural use, but with certain restrictions. The sludge should not be used in soil for growing vegetables that are consumed in their raw form. Certain additional site restrictions and management actions are also required. These are summarized well in the Sludge Guidelines for agriculture and can be viewed in full in the document that is freely available and not necessary to reproduce here. The measures relate to care that needs to be taken to prevent access for humans and livestock in the area in the immediate period (month) following the application of sludge as well as with crops where edible or harvested parts could be in contact with the soil/sludge and how certain waiting times would be needed before harvesting different types of crops from the soil where sludge was applied.

4.2.4 EQI results

Following all the statistical analyses performed, the EQI procedure is then used to evaluate the data according to a standardized, scientific procedure. The results of the EQI analysis are shown in Table 26 and Figure 14 below.

Table 26: Table of the EQI of the major pollutants.

EQI	
COD	2.09
FSA	3.43
OP	2.43
NO	1.16
TSS	3.00
Total	**12.11**

The EQI for the water proved to be good since all of the EQI ratings were positive indicating legal compliance. The implication is that no fines would be enforced on the WWTP and that this should be the aim for any WWTP operation. The incentive is clear to maintain a positive and acceptable EQI. Out of the different pollutants the EQI's for FSA and TSS were the best contributing to the low overall pollution rating that the plant achieved. The EQI for nitrate is closer to the value of zero than the others. Thus, nitrate is still compliant, but is the clearest risk factor out of the other pollutants and achieving sufficient denitrification at the plant should thus be a priority. The plant operators and management can implement systems to maintain the nitrate concentration to achieve a positive EQI. When taking in consideration the graphs in the previous section it is known that during the first 3 months nitrate removal was not optimal and thereafter it improved and thus this average value skews recent results that were even better.

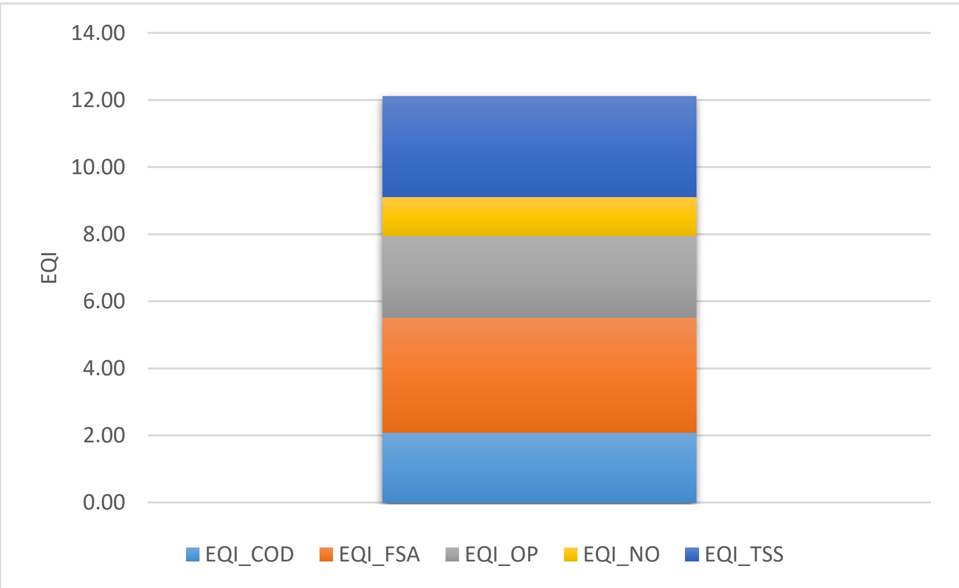


Figure 14: Graph of the EQI analysis of the major pollutants in the water.

The EQI for the sludge shown in Table 27 is also a positive value in total, however, there is an $EQI_{negative}$ which is caused by the faecal coliforms which was not compliant with the Class A classification for sludge. In terms of environmental pollution contribution, this does contribute negatively to the performance of the plant since these relatively high levels of faecal coliforms will enter the environment and be to the detriment. This is not a pollutant that can be fined in this range however since a Class B sludge classification is perfectly acceptable according to national regulation, but it just needs to be handled differently. The requirements for handling different classes of sludge are stipulated in the Guidelines for the utilization and disposal of wastewater sludge. (Snyman & Herselman, 2006b)

Table 27: Table of the EQI of the major pollutants in the sludge.

EQI	
As	66.3
Cd	65.4
Cr	66.0
Cu	61.8
Pb	62.7
Hg	66.4
Ni	65.4
Zn	57.5
FC (CFU)	-79.7
Total	**431.8**

The positive signs are that all other pollutants (heavy metals) were contributing an $EQI_{positive}$ to the plant environmental performance and evaluation. Heavy metals are toxic substances even at low concentrations and hence the importance of achieving a positive EQI in this regard. This furthermore indicates that the domestic origin of the wastewater as expected does not contribute significant amounts of heavy metals. The operational management of the WWTP should have clarity that improving faecal coliforms is the main aim in improving the environmental impact of the sludge. In other aspects the WWTP performs well and has a minimal environmental impact. The EQI results both of the sludge and the water are overall a significant success as displayed in Figure 15.

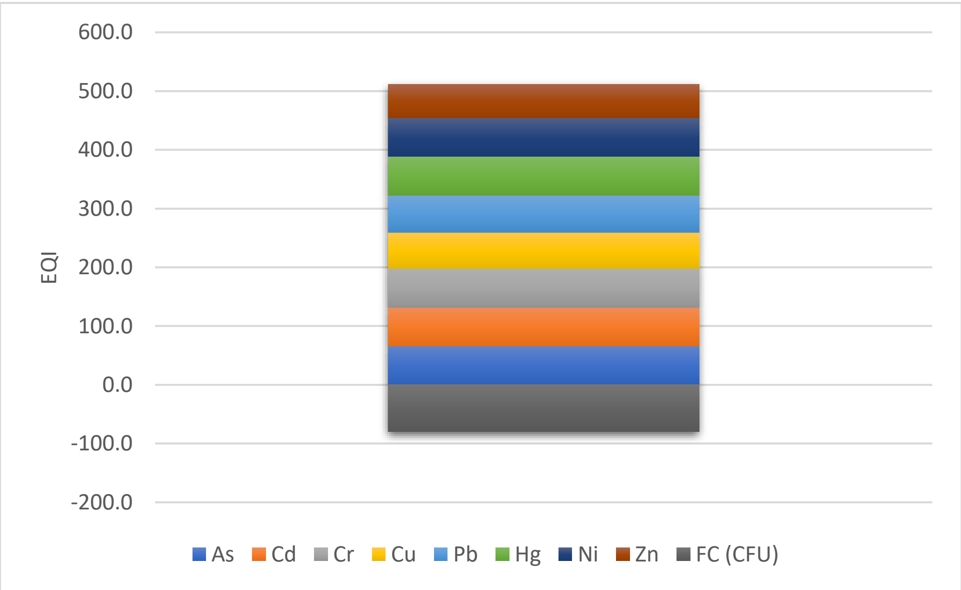


Figure 15: Graph of the EQI analysis of the major pollutants in the sludge.

4.2.5 Mass balances

Mass balances were performed according to the equations provided in 3.6.3 which are used to verify the data that has been produced. The principle of the conservation of mass dictates that over the reactor under consideration there should be a balance of mass going in, changing inside, and going out of the reactor. Using the raw water and treated effluent data collected on the same day of the 22/09/2021 as certified in report no. 5340 in Appendix D, the below mass balance was produced.

Table 28: Table of the mass balance for September data.

Fsti	41.28	kg/day
Fsout	34.94	kg/day
COD bal	**85%**	
FNti	3.64	kg/day
FNout	3.29	kg/day
N bal	**90.5%**	
FPti	0.36	kg/day
FPte	0.30	kg/day
Pwasted	0.15	kg/day
P bal	**121%**	

The COD mass balance was marginally close to 100% being 15% out from the fully conserved scientific principle. A tolerance of 10% is usually preferred as an aim for mass balances since this indicates that mass has mostly been conserved through the data and calculations as it should be. This result can be accepted since it is close to achieving the acceptable tolerance. The same tolerance that is applicable to the mass balance can also be applied to the data and the results. At 15% tolerance there could be some changes to the results, but not to the point that it would have an impact on the findings as results weren't evaluated based on being particularly close to any limits.

The N mass balance achieved a better result than the COD at 90.5% mass conserved. This is really the range of tolerance that is targeted when doing mass balances. Within 10% the results can be accepted and used as is with understanding that no model or experimental work is without uncertainty and designs are performed with safety factors being in place. As with the COD mass balance, but even more so for the nitrogen, the findings will not be impacted in any meaningful way by a marginal tolerance where results could be either slightly under or overreported. None of the findings are based on closely met compliance or on the verge of moving into a different category, classification, or performance evaluation. The experimental data for Nitrogenous parameters can be viewed as being fairly reliable.

The P mass balance was the worst of the 3 mass balances achieving a 121% of the influent P exiting the system. This is concerning since it means that the experimental readings for P could be quite far out from what they are being reported as. There could also be a build-up of phosphorous that is not being predicted by the model (pointing towards the nutrient ratios). Since the nutrient ratios are a well-established practice, it is more likely that the sample data is not accurate for some reason. This could be to do with the sampling method of the composite samples or the analytical methodology or simply human error in reading and reporting the data. The implication of this discrepancy in mass balance for P on the findings is not significant since this system was not designed for BEPR and all the effluent OP readings would still be well within acceptable limits even if adding a 20% error correction to the readings.

In general, the experimental data can be concluded to be moderately reliable with certain discrepancies noted which indicates a level of caution required when approaching the data and being conservative with the findings made. The findings from the experimental data still stands since any errors would not be significant enough to effect a change in the evaluation and classification of the WWTP performance.

4.3 Operational costing of the package wastewater plant

The operational costing analysed as the OCI in Table 29 and Figure 16 below indicates the cost of operating the WWTP day to day and throughout the year.

The rate of the different sources of energy usage is naturally the same since these are all supplied by the same electricity. The cost of AE, PE and ME are, however, vastly different since the quantity of energy used by each of these factors is not the same. AE uses the lion share of kWh units per day and thus contributes the most to energy cost while PE and ME are both significantly less energy-intensive and thus less costly. The cost of operating the aeration equipment is more than double the cost of the PE and ME combined is. The cost of PE is slightly more than the cost of ME, but these are both not major since the AE is the major cost factor in terms of energy usage, but also in terms of OCI.

Table 29: Table of the OCI for the WWTP.

		All ex VAT			
Parameter	**Quantity**	**Rate**	**Daily cost**	**Monthly cost**	**Annual cost**
AE (kWh)	135	R1.43	R193.05	R5 984.55	R71 814.60
PE (kWh)	32.85	R1.43	R46.98	R1 456.38	R17 476.56
ME (kWh)	24.65	R1.43	R35.25	R1 092.75	R13 113.00
SP (kg TSS)	14.8	R2 419.02	R40.32	R1 249.83	R14 997.92
CA (L)	1	R15.90	R15.90	R492.90	R5 914.80
OCI			**R331.50**	**R10 276.41**	**R123 316.88**

The rate for sludge production cost is the highest of all, but this is due to the methodology described in section 3.7 that specifies that primary sludge removal will be removed by a vacuum truck and transported to the nearest municipal waste works for disposal. The cost of particularly vacuum truck rental is high and therefore the high overall rate. This rate only must be applied approximately once in 2 months though because of the low volume of primary sludge produced which only gets removed once it has reached 6 kl which fills a vacuum truck for cost optimization. Consequently, the annual cost of sludge produced is in line with the pumping and mixing energy. The chemical addition for phosphate removal is the minor cost out of all the factors.

When viewing the percentages of each of the cost contributors shown in Figure 16, remarkably, the aeration energy contributes more than half of the total operational cost. This confirms the importance of optimizing the aeration regime and equipment. Thus, any optimization of the other cost contributors will make a minor difference compared to the majority contributor of AE. The PE, ME and SP all contribute similar minor costs to the total (11-14%) while the chemical addition cost is the smallest cost contributor of all at 5%. These results are in line with expectations due to the known high energy usage of MBR plants for biological oxygen demand as well as membrane air scouring.

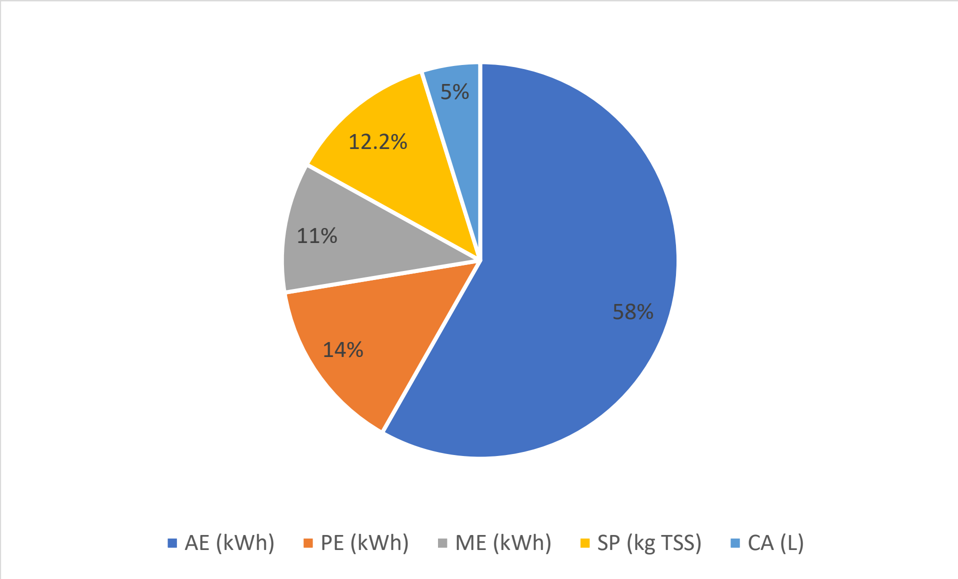


Figure 16: Graph of the OCI for the WWTP.

Looking at the bigger picture, the annual cost of R123 316 ex VAT for the operation of a plant that produces high-quality effluent that can be reused, prevents environmental pollution, and is legally required by the government, the plant implementation is viewed favourably. Taking the daily flow rate of sewage at 49.2 kl/day to determine the cost per kilolitre of wastewater treated then this is found to be R6.73/kl ex VAT. This seems a reasonable fee by all standards since services are not free – particularly not water or wastewater. Water has value to it and there is always a cost in providing water services to users.

From the municipal tariff list and the methodology followed in section 3.7, the 104 houses at High Noon farm would be charged R18 928 ex VAT to be provided by the municipality's sanitation service if it were available (irrespective of volumes). This is nearly double the monthly cost of the WWTP. There is thus a significant cost saving in using this package WWTP compared to using municipal services. This is because the package plant is fit for purpose for the application, quantity and volume of sewage and employs an effective treatment process without unnecessary units that are inefficient.

Furthermore, in terms of the reuse potential of the water, the cost of irrigation water from the municipality is quoted at R7.83 ex VAT per kl (Theewaterskloof Municipality, 2021). Even this is already more than the R6.73 per kl that it costs to produce treated effluent. From the plant performance, it can be seen that the effluent is of high quality suitable for many different non-potable reuse applications. Since the wastewater does need to be treated regardless of whether it's reused, the operational fee per kl for wastewater treatment can be discounted from the fee that is placed on the irrigation water. This places the operational costing of the package WWTP in a favourable light if it has not already been.

5. Chapter 6: Conclusion and recommendations

5.1 Conclusion

This study aimed to perform a case study on a decentralized package WWTP design, performance, and operational cost evaluation. This was done to provide an example of how a decentralized system can be implemented under unique rural conditions to meet the needs of remote communities (such as farmers in this case) and provide environmental protection at the same time. Access to basic services such as sanitation is limited in many rural areas in South Africa and simultaneously the environmental impact of domestic sewage must be mitigated not least to protect our valuable and scarce water resources. The motivation for treating wastewater is clear from a human rights perspective, for the advancing of public health, as well as the legislative requirement and the need to prevent pollution of the environment.

The model for wastewater design was successfully developed using MLE and adapting for MBR so that a design for the WWTP was available to be implemented. Experimental work was performed successfully to obtain raw and treated effluent water and sludge quality data. The treated water quality data (8 data sets over a period of more than 6 months) can be concluded to have been sufficient for the scope of the study and stood through the tests of reliability and repeatability with only minor flaws identified. The raw water data was used as input to the wastewater design model to simulate the specific conditions of the application. Only 1 sludge sample was available due to long analysis lead times which limited the extent and reliability of the findings on sludge quality. The operational cost data was obtained successfully for analysis of the OCI as described in section 3.7.

The wastewater treatment model provided the necessary output required for further design and implementation. The model dictated that a reactor volume of 22 kilolitres would be required with a minimum anoxic mass fraction of 0.14 but finalized at a 0.27 volume fraction and an optimal a-recycle rate of 3.2 (selected as 5 below the practical limit of 6). The effluent nitrate concentration was determined as 6 mg/l and the total oxygen demand 28.6 kgO/day. The membranes were chosen to operate at a design flux of 18 LMH which due to model sizes came to a membrane area of 160 m^2 and an instantaneous flux of 15.4 LMH. The membranes require 120 m^3/h of air scouring for fouling prevention which contributes 4.7 kgO/day and thus the total air supply required by the aerobic blower reduced to 23.8 kgO/d.

The model compared well to the practical side (the High Noon WWTP) since the effluent ammonia concentration was essentially the same while the effluent nitrate concentration was also in the same range. The model predicted Nitrogen removal of 91% whereas the WWTP achieved 85.4% which is plausible due to inefficiencies as well as inaccuracies in the real world. The reactor volume was selected as 28 kilolitres for the WWTP implementation compared to 22 kilolitres required in the model which differs for the reason of a 25% safety factor.

The WWTP received less influent wastewater (an average of 35.6 kl/day over a 4-week period) than the design flow rate of water which means that pollution contributions and effluent discharge licences were not exceeded. The mean water quality results for all the parameters tested were within the relevant limits and for 7 out of the 9 parameters all samples' results were also within limits. Ammonia and nitrates yielded 75% and 63% compliance respectively, but the ammonia discharged in the effluent was on average only 7% of the permissible emission. The effluent water quality produced by the WWTP can be concluded to be of high quality with near full compliance across the board which is a feat considering the harsh conditions and limited resources in the area that is located in. The high quality of the effluent water makes it an attractive option for reuse purposes. Drought conditions would be even more of a driving factor towards reuse and the effluent is well suited to reuse without treatment for many different non-potable applications.

The sludge quality was also acceptable for Class A (the highest class) use in all but one of the parameters (faecal coliforms) which dictates certain control measures that should be implemented when using for agriculture. The single sludge sample was however inconclusive and thus the findings in this regard would have to be verified by more sampling. From the mass balances for verification, it can be deduced that there is a degree of reliability in the results particularly for nitrogen and COD but that there is concern with the balance of phosphorous although this should not have a major impact because the phosphate readings recorded were far below the emission limits. The EQI of the water was positive at a value of 12 with all its components also registering positive contributions. The WWTP is successful in producing a minimal pollution load on the environment. Similarly, the EQI of the sludge was also positive at a value of 431.8.

The operational cost of the WWTP was determined as R10 276 ex VAT per month. The major contributor to operational cost was the aeration energy contributing 58%. Energy usage as a whole (including the PE and ME) contributed more than 80% of the total operational cost. When compared to the cost of sanitation service by the local municipality (although not available in this area), the WWTP outperforms the centralized services with an operational cost nearly half of what the municipal fee for the farm residents would be. Furthermore, the economic potential of reuse was also quantified by determining that the treated effluent costs R6.73 ex VAT per kilolitre to produce while irrigation water is sold by the municipality at R7.83 ex VAT per kilolitre.

The WWTP can be concluded to be performing well as it is providing an alternative water source, environmental protection, and the basic service of sanitation and that at an economically competitive and market related cost. These benefits were provided in an area where it was very much needed since sufficient sanitation was not a given for the farm community previously which leads to health concerns and the environment was being polluted by aging septic tanks which would have had an environmental impact not least on the Elandskloofdam (for public use) located downstream of the settlement. This study is an example of the potential that decentralized systems have in uplifting rural areas. Lastly, MBR technology is a judicious option when design and implementation is apposite to the application.

In closing, the design and implementation of the WWTP was successful and the objectives of the study were met.

5.2 Recommendations

Following the conclusion of this study, there is also an opportunity to make recommendations based on the way that this study was executed and what it achieved as well as any remaining or new questions that have arisen.

When sludge analyses are done more samples should be allowed for since a single sample might be insufficient to reliably characterize the sludge. Sludge analyses should be started with 3 months available due to the long lead time required for these results. Funding might need to be arranged depending on the number of samples, since it can be costly.

In addition to monthly water samples, there should also be sampling performed over a shorter period of evaluation such as weekly for a month, or each day for a week. This will provide an interesting insight into any outliers, the cause thereof and the environmental impact that it could have.

Raw water and treated water samples should always be taken together as to ensure mass balances can be performed to individually verify each data set of water quality results. Mass balances should also be done on each set of sample results as they become available to pre-empt any discrepancies and potentially investigate/rectify any issues.

For future studies a Life Cost Analysis could be a helpful indicator of evaluating the plant holistically and not just during design and implementation.

A future study could be performed doing a comprehensive capital cost comparison for a decentralized compared to a centralized solution for a rural location such as the farm under consideration, to set up an example of how decentralized (package plants) and centralized systems (sewer pipelines to municipal services) can be compared from a capital cost perspective.

6. References

APHA, AWWA & WEF. 1998. *Standard methods for the examination of water and wastewater*. 20th ed. 1998. ed. L.S. Clesceri, A.D. Eaton, A.E. Greenberg, & American Public Health Association, Eds. Washington DC: American Public Health Association.

Badza, T., Tesfamariam, E.H. & Cogger, C. 2020. Sludge stabilization process, drying depth and polymeric material addition: Implication on nitrogen content, selected chemical properties and land requirement in sand drying beds. *Energies*. 13(24). DOI: 10.3390/en13246753.

Bertanza, G., Canato, M., Laera, G., Vaccari, M., Svanström, M. & Heimersson, S. 2017. A comparison between two full-scale MBR and CAS municipal wastewater treatment plants: techno-economic-environmental assessment. *Environmental Science and Pollution Research*. 24(21):17383–17393. DOI: 10.1007/s11356-017-9409-3.

Capodaglio, A.G., Callegari, A., Cecconet, D. & Molognoni, D. 2017. Sustainability of decentralized wastewater treatment technologies. *Water Practice and Technology*. 12(2):463–477. DOI: 10.2166/wpt.2017.055.

Cirja, M., Ivashechkin, P., Schäffer, A. & Corvini, P.F.X. 2007. Factors affecting the removal of organic micropollutants from wastewater in conventional treatment plants (CTP) and membrane bioreactors (MBR). *Reviews in Environmental Science and Bio/Technology 2007 7:1*. 7(1):61–78. DOI: 10.1007/S11157-007-9121-8.

Council for Scientific and Industrial Research & Department of Human Settlements. 2019. *The Neighbourhood Planning and Design Guide - The Red Book*. CSIR, Ed. Pretoria. Available: https://www.ukesa.info/library/view/red-book [2022, February 13].

Croll, B.T., Tomlinson, T. & Whitfield, C.R.W. 1985. Determination of Kjeldahl nitrogen in sewage effluents, trade effluents and sewage sludges using a copper-titanium catalyst. *Analyst*. 110(7):861–866. DOI: 10.1039/AN9851000861.

Eskom. 2021. *Schedule of Standard Prices 2021/2022*.

Flat sheet MBR / FMBR. n.d. Available: https://www.risingsunmem.com/en/service.html?type=77 [2022, February 12].

Frost & Sullivan. 2013. *Global Membrane Bioreactor (MBR) Market*. Available: https://store.frost.com/global-membrane-bioreactor-mbr-market-9809.html [2022, January 31].

Gernaey, K. v, Jeppsson, U., Vanrolleghem, P.A. & Copp, J.B. 2014. Benchmarking of Control Strategies for Wastewater Treatment Plants. Available: http://iwaponline.com/ebooks/book-pdf/650794/wio9781780401171.pdf [2022, January 31].

Göbel, P., Dierkes, C. & Coldewey, W.G. 2007. Storm water runoff concentration matrix for urban areas. *Journal of Contaminant Hydrology*. 91(1–2):26–42. DOI: 10.1016/J.JCONHYD.2006.08.008.

Henze, M., van Loosdrecht, M.C.M., Ekama, G.A. & Brdjanovic, D. 2019. Biological Wastewater Treatment: Principles, Modeling and Design. *Biological Wastewater Treatment: Principles, Modeling and Design*. DOI: 10.2166/9781780408613.

Hulsbeek, J.J.W., Kruit, J., Roeleveld, P.J. & van Loosdrecht, M.C.M. 2002. A practical protocol for dynamic modelling of activated sludge systems. *Water Science and Technology*. 45(6):127–136. DOI: 10.2166/WST.2002.0100.

Iorhemen, O.T., Hamza, R.A. & Tay, J.H. 2016. DOI: 10.3390/membranes6020033.

Jeppsson, U., Pons, M.N., Nopens, I., Alex, J., Copp, J.B., Gernaey, K. v., Rosen, C., Steyer, J.P., et al. 2007. Benchmark simulation model no 2: general protocol and exploratory case studies. *Water Science and Technology*. 56(8):67–78. DOI: 10.2166/WST.2007.604.

Judd, S. 2010. *The MBR Book*. 2nd ed. S. Judd & C. Judd, Eds. Butterworth-Heinemann.

Judd, S.J. 2015. The status of industrial and municipal effluent treatment with membrane bioreactor technology. *Chemical Engineering Journal*. 305:37–45. DOI: 10.1016/j.cej.2015.08.141.

Karim, M. & James, M. 2017. A Preliminary Comparative Analysis of MBR and CAS Wastewater Treatment Systems. *International Journal of Water and Wastewater Treatment*. 3(2). DOI: 10.16966/2381-5299.138.

de Ketele, J., Davister, D. & Ikumi, D.S. 2018. Applying performance indices in plantwide modelling for a comparative study of wastewater treatment plant operational strategies. *Water SA*. 44(4):539–550. DOI: 10.4314/wsa.v44i4.3.

Krzeminski, P., Leverette, L., Malamis, S. & Katsou, E. 2017. DOI: 10.1016/j.memsci.2016.12.010.

Le-Clech, P., Chen, V. & Fane, T.A.G. 2006. Fouling in membrane bioreactors used in wastewater treatment. *Journal of Membrane Science*. 284(1–2):17–53. DOI: 10.1016/J.MEMSCI.2006.08.019.

Lesjean, B. & Huisjes, E.H. 2008. Survey of the European MBR market: trends and perspectives. *Desalination*. 231(1–3):71–81. DOI: 10.1016/j.desal.2007.10.022.

Libralato, G., Volpi Ghirardini, A. & Avezzù, F. 2012. To centralise or to decentralise: an overview of the most recent trends in wastewater treatment management. *Journal of environmental management*. 94(1):61–68. DOI: 10.1016/J.JENVMAN.2011.07.010.

Marais, G. & Ekama, G. 1976. The activated sludge process. Part 1 - Steady State Behaviour. *Water SA*. 2(4). Available: https://www.researchgate.net/publication/284774604_The_activated_sludge_process_Part_1_-_Steady_state_behaviour [2022, January 31].

MarketsandMarkets. 2014. *Membrane Bioreactor System Market by Application (Municipal Wastewater Treatment and Industrial Wastewater Treatment), by Type (Hollow Fiber, Flat Sheet, and Multi Tubular), by Configuration (Internal/ Submerged and External/Side stream), and by Region - Trends & Forecasts to 2019*.

McWilliams, A. 2019. *Membrane Bioreactors: Global Markets*. Available: https://www.bccresearch.com/market-research/membrane-and-separation-technology/membrane-bioreactors.html [2022, January 31].

Meng, F., Chae, S.R., Drews, A., Kraume, M., Shin, H.S. & Yang, F. 2009. DOI: 10.1016/j.watres.2008.12.044.

Meng, F., Zhang, S., Oh, Y., Zhou, Z., Shin, H.S. & Chae, S.R. 2017. DOI: 10.1016/j.watres.2017.02.006.

Meteoblue. n.d. *Simulated historical climate & weather data for Villiersdorp*. Available: https://www.meteoblue.com/en/weather/historyclimate/climatemodelled/villiersdorp_south-africa_3359957 [2022, February 09].

Montwedi, M., Munyaradzi, M., Pinoy, L., Dutta, A., Ikumi, D., Motoasca, E., Van der Bruggen, B. 2020. Resource recovery from and management of wastewater in rural South Africa: Possibilities and practices. *Journal of Water Process Engineering*. JWPE-D-20-01251R4.

National Water Act. 1998. Republic of South Africa.

Paleker, I., Ikumi, D. & Ekama, G. 2018. A Plant-wide Evaluation of the Benchmark Simulation Model No.2P (BSM2P) for Wastewater Treatment Systems - Part 1: Model Introduction. *WISA*. (June).

Parco, V., Wentzel, M. & Ekama, G. 2006. Kinetics of nitrogen removal in a MBR nutrient removal activated sludge system. *Desalination*. 199(1–3):89–91. DOI: 10.1016/J.DESAL.2006.03.149.

Parco, V., du Toit, G.J.G. & Ekama, G.A. 2019. Biological nutrient removal activated sludge systems with membranes. In *Advances in Wastewater Treatment*. G. Mannina, G. Ekama, H. Odegaard, & G. Olsson, Eds. IWA Publishing. DOI: 10.2166/9781780409719_0031.

Peck, S., Bartels, C., Jones, N., Pisarenko, A.N., Yan, D., Snyder, S.A., Freeman, B., Franks, R., et al. 2012. Optimizing Membrane Bioreactor/ Reverse Osmosis Performance for Municipal Wastewater Treatment. *IDA Journal of Desalination and Water Reuse*. 4(2):45–51. DOI: 10.1179/ida.2012.4.2.45.

Ramphao, M., Wentzel, M.C., Merritt, R., Ekama, G.A., Young, T. & Buckley, C.A. 2005. Impact of membrane solid-liquid separation on design of biological nutrient removal activated sludge systems. *Biotechnology and bioengineering*. 89(6):630–646. DOI: 10.1002/BIT.20311.

Ramphao, M.C., Wentzel, M.C., Ekama, G.A. & Alexander, W. v. 2006. A comparison of BNR activated sludge systems with membrane and settling tank solid–liquid separation. *Water Science and Technology*. 53(12):295–303. DOI: 10.2166/WST.2006.432.

Santos, A. & Judd, S. 2010. The Commercial Status of Membrane Bioreactors for Municipal Wastewater. *https://doi.org/10.1080/01496391003662337*. 45(7):850–857. DOI: 10.1080/01496391003662337.

Shang, C., Wong, H.M. & Chen, G. 2005. Bacteriophage MS-2 removal by submerged membrane bioreactor. *Water Research*. 39(17):4211–4219. DOI: 10.1016/J.WATRES.2005.08.003.

Singh, N.K. & Kazmi, A.A. 2018. Performance and Cost Analysis of Decentralized Wastewater Treatment Plants in Northern India: Case Study. *Journal of Water Resources Planning and Management*. 144(3):05017024. DOI: 10.1061/(asce)wr.1943-5452.0000886.

Sipma, J., Osuna, B., Collado, N., Monclús, H., Ferrero, G., Comas, J. & Rodriguez-Roda, I. 2010. Comparison of removal of pharmaceuticals in MBR and activated sludge systems. *Desalination*. 250(2):653–659. DOI: 10.1016/J.DESAL.2009.06.073.

Skoczko, I., Puzowski, P. & Szatyłowicz, E. 2020. Experience from the implementation and operation of the biological membrane reactor (MBR) at the modernized wastewater treatment plant in Wydminy. *Water*. 12(12):1–14. DOI: 10.3390/w12123410.

Snyman, H. & Herselman, J. 2006a. *Guidelines for the utilisation and disposal of wastewater sludge: Volume 1*. Available: www.wrc.org.za.

Snyman, H. & Herselman, J. 2006b. *Guidelines for the utilisation and disposal of wastewater sludge: volume 2*. Available: www.wrc.org.za.

Statista. 2021. *South Africa - urbanization 2010-2020*. Available: https://www.statista.com/statistics/455931/urbanization-in-south-africa/ [2022, January 31].

Tchobanoglous, G., Burton, F.L., Stensel, H.D., Metcalf & Eddy, Inc. 2003. *Wastewater engineering : treatment and reuse*. 4th ed. / ed. Boston: McGraw-Hill. Available: https://books.google.ca/books?id=L1MAXTAkl-QC [2022, January 31].

Theewaterskloof Municipality. 2021. *Theewaterskloof Municipality Tariff List Draft 2021/2022*.

du Toit, D., Parco, V., Ramphao, M., Wentzel, M., Lakay, M., Mafungwa, H. & Ekama, G. 2010. *The performance and kinetics of biological nitrogen and phosphorus removal with ultra-filtration membranes for solid-liquid separation*. Water Research Commission.

du Toit, G.J., Ramphao, M., Parco, V. & Wentzel, M. 2007. Design and performance of BNR activated sludge systems with flat sheet membranes for solid-liquid separation. *Water Science & Technology*. 56(6):105–113. DOI: 10.2166/wst.2007.643.

du Toit, G.J.G., Ramphao, M.C., Parco, V., Wentzel, M.C. & Ekama, G.A. 2010. The performance and kinetics of biological nitrogen and phosphorus removal with ultra-filtration membranes for solid-liquid separation. *undefined*. 56(6):105–113. DOI: 10.2166/WST.2007.643.

UNEP & Murdoch University. 2002. *Environmentally sound technologies for wastewater and stormwater management :* Osaka: UNEP, Division of Technology, Industry and Economics, International Environmental Technology Centre. Available: https://digitallibrary.un.org/record/477670 [2022, January 31].

US Environmental Protection Agency, US Office of Research and Development, US National Risk Management Research Laboratory & US Centre for Environmental Research Information. 1999. *Environmental regulations and technology: control of pathogens and vector attraction in sewage sludge (including domestic septage) EPA/625/R-92-013*. US Environmental Protection Agency.

Verrecht, B., Judd, S., Guglielmi, G., Brepols, C. & Mulder, J.W. 2008. An aeration energy model for an immersed membrane bioreactor. *Water research*. 42(19):4761–4770. DOI: 10.1016/J.WATRES.2008.09.013.

Verrecht, B., Maere, T., Nopens, I., Brepols, C. & Judd, S. 2010. The cost of a large-scale hollow fibre MBR. *Water Research*. 44(18):5274–5283. DOI: 10.1016/j.watres.2010.06.054.

Verrecht, B., James, C., Germain, E., Birks, R., Barugh, A., Pearce, P. & Judd, S. 2012. Economical Evaluation and Operating Experiences of a Small-Scale MBR for Nonpotable Reuse. *Journal of Environmental Engineering*. 138(5):594–600. DOI: 10.1061/(asce)ee.1943-7870.0000505.

Xiao, K., Liang, S., Wang, X., Chen, C. & Huang, X. 2019. DOI: 10.1016/j.biortech.2018.09.061.

Zasoski, R.J. & Burau, R.G. 2008. A rapid nitric-perchloric acid digestion method for multi-element tissue analysis. *http://dx.doi.org/10.1080/00103627709366735*. 8(5):425–436. DOI: 10.1080/00103627709366735.

Appendix A: Site layouts & drawings

An aerial/satellite view of the site of the WWTP close to Villiersdorp is attached to this appendix. The title block reference for the image is “20359_Fine Farms”. The surveyed site layout is also attached with title block reference “20359_Fine Farms”.

Civil engineering drawings of the design of the sewer reticulation system for the High Noon farm worker’s houses are attached to this appendix.

Appendix B: Model development

$FX_{Ivi} = QiX_{Ii}$ (mgVSS/d) Eq. A1

$FX_{Ivi} = Qif_{S'up}Sti/fcv$ (mgVSS/d) Eq. A2

$FX_{Ivi} = FStif_{S'up}/fcv$ (mgVSS/d) Eq. A3

$FX_{IOi} = QiX_{IOi}$ (mgISS/d) Eq. A4

FSti = QiSti (mgCOD/d) Eq. A5

FSbi = Qi ($S_{Si} + X_{Si}$) (mgCOD/d) Eq. A6

FSbi = QiSti (1– $f_{S'us}$ – $f_{S'up}$) (mgCOD/d) Eq. A7

FSbi = FSti (1– $f_{S'us}$ – $f_{S'up}$) (mgCOD/d) Eq. A8

$$MX_{BHv} = FS_{bi}\frac{Y_{Hv}SRT}{(1-b_H SRT)} = FS_{ti}\left(1 - f_{S'us} - f_{S'up}\right)\frac{Y_{Hv}SRT}{(1+b_H SRT)} \quad \text{Eq. A9}$$

$$MX_{EHv} = f_H b_H MX_{BHv}SRT = FS_{ti}(1 - f_{S'us} - f_{S'up})\frac{Y_{Hv}SRT}{(1+b_H SRT)} f_H b_H SRT \quad \text{Eq. A10}$$

$$MX_{Iv} = \frac{FX_{Ii}}{f_{CV}}SRT = FS_{ti}\frac{f_{S'up}}{f_{CV}}SRT \quad \text{Eq. A11}$$

$$MX_v = MX_{BHv} + MX_{Ev} + MX_{Iv}$$

$$= FS_{ti}\left[\frac{\left(1-f_{S'us}-f_{S'up}\right)Y_{Hv}SRT}{(1+b_H)SRT}(1 + f_H b_H SRT) + \frac{f_{S'up}}{f_{CV}}SRT\right] \quad \text{Eq. A12}$$

$$MX_{IO} = FX_{IOi}SRT + f_{iOHO}MX_{BHv} = FX_{IOi}SRT + f_{iOHO}f_{avOHO}MX_v \quad \text{Eq. A13}$$

MXt = MXv +MX_{IO} Eq. A14

$$FO_c = FS_{bi}\left[(1 - f_{CV}Y_{Hv}) + (1 - f_H)b_H\frac{Y_{Hv}f_{CV}SRT}{(1 + b_H SRT)}\right]$$

$$= FS_{ti}(1 - f_{S'us} - f_{S'up})\left[(1 - f_{CV}Y_{Hv}) + (1 - f_H)b_H\frac{Y_{Hv}f_{CV}SRT}{1+b_H SRT}\right] \quad \text{Eq. A15}$$

FOc = VpOc Eq. A16

Vp = MXt/Xt Eq. A17

HRTn = Vp/Qi Eq. A18

$$\frac{FX_t}{FS_{ti}} = \frac{1}{f_i}\left[\frac{\left(1-f_{S'us}-f_{S'up}\right)Y_{Hv}}{1+b_H SRT}(1 + f_H b_H SRT) + \frac{f_{S'u}}{f_{CV}}\right] \quad \text{Eq. A19}$$

Appendix C: WWTP implemented design documents

A P&ID of the WWTP at High Noon farm is attached to this appendix.

A control philosophy of the WWTP is attached to this appendix.

Appendix D: Water quality & sludge supporting docs

The SANAS accreditation certificate of the professional analytical laboratory used for sample testing is attached to this appendix.

Table of the raw water data in full.

	2021				
	Aug	**Sep**	**Nov--1**	**Nov--2**	**Nov--3**
pH	6.54		5.95	6.63	6.79
Electrical Conductivity	76.5		43	46	235
Total Suspended Solids	785		117	158	4830
Cl2 (free)	0.05		0.05	0.05	0.05
Ammonia-N	44		48.4	31.1	190
Nitrate-N	0.2		0.2	0.2	0.2
Ortho Phosphate	5.6	7.4	9.2	3.7	20.4
Chemical Oxygen Demand	1388	839	148	151	1217
Total Kjeldahl Nitrogen (mg/l)	66	74	49.9	33.8	252
Total Phosphate	16.5		10.1	8.5	41.8

Table of the treated effluent data in full.

	2021							2022
	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
pH	7.8	6.7	6.7	7.2	7.2	7.2	7.6	7.6
EC	82	70	71.5	85	72	48.5	72	52
TSS	4	5	4	4	6	5	4	5
Cl2 (free)	0.05	0.05	0.05	0.05	0.05	0.1	0.1	0.05
Ammonia-N	0.1	0.1	0.1	17.2	0.1	0.2	18.8	0.13
Nitrate-N	33.1	26.5	32.3	7.4	12.7	4.2	0.8	14.2
Orthophosphate	5.9	5	6.3	6	7.1	5	0.7	0.7
COD	24.3	25.8	35.6	33.8	13.6	57.4	75	27.6
Faecal coliforms	0	0	0	0	0	0	0	0

The laboratory sample analysis certificates from the SANAS accredited laboratory AL Abbott & Associates are attached to this appendix.

Appendix E: Wastewater characterization

All in mg/l	**COD**	**TOC**	**TKN**	**FSA**	**TP**	**OP**	**TSS**	**ISS**
Unfiltered (Raw WW)	750.0	250.0	73.0		16.0		500.0	100.0
Supernatant (Settled WW)	375	150	62		14		200	40.0
0,45µm membrane filtered	300	62.5	53	44.0	13	8.0		

FLOW WEIGHTED AVERAGES FOR RAW WASTEWATER CONCENTRATIONS								
TIME	FLOW	COD	FSA	OP	TSetS	TSetS	ISuspS	TSuspS
	(m3/hr)	mg/l	mgN/L	mgP/L	ml/l	mg/l	mgISS/L	mgTSS/L
06:00	675	519	24.8	4.06	5.2	136.8	18.6	289
08:00	947	525	37.5	3.59	5.6	147.3	30.6	304
10:00	2813	988	58.3	8.33	10.1	265.6	42.5	557
12:00	3225	1358	68.1	11.97	14.1	370.8	63.8	771
14:00	2719	1531	75.6	13.22	15.8	415.5	69.1	866
16:00	2194	1568	81	13.85	16.3	428.7	74.5	891
18:00	1912	1728	67.5	15.31	17.9	470.8	79.8	980
20:00	2175	1605	62.1	13.54	16.5	434.0	69.1	905
22:00	1987	1481	55.6	12.39	15	394.5	58.5	830
00:00	1819	1420	43.2	11.35	14.3	376.1	53.2	792
02:00	1275	1296	40.5	10.93	13.1	344.5	47.9	723
04:00	825	864	32.9	7.29	8.6	226.2	29.3	479
06:00	675	519	24.8	4.06	5.2	136.8	18.6	289
MEAN (simpsons rule)	1875.06	1234.61	53.99	10.41	12.66	333.0	53.19	696.06
PEAK						0		
FLOW WEIGHTED AVERAGES		1345.10	59.99	11.46	363.65	58.92	759.33	
AADW	**2.05**	m3/hr	0.05	ML/day				

	COD	FSA	OP	TSetS	ISuspS	TSuspS
	kg/h	kg/h	kg/h	kg/h	kg/h	kg/h
	350.3	16.7	2.7	92.3	12.6	195.1
	497.2	35.5	3.4	139.46	29.0	287.9
	2779.2	164.0	23.4	747.2	119.6	1566.8
	4379.6	219.6	38.6	1195.9	205.8	2486.5
	4162.8	205.6	35.9	1129.8	187.9	2354.7
	3440.2	177.7	30.4	940.5	163.5	1954.9
	3303.9	129.1	29.3	900.1	152.6	1873.8
	3490.9	135.1	29.4	943.8	150.3	1968.4
	2942.7	110.5	24.6	783.8	116.2	1649.2
	2583.0	78.6	20.6	684.1	96.8	1440.6
	1652.4	51.6	13.9	439.2	61.1	921.8
	712.8	27.1	6.0	186.5	24.2	395.2
	350.3	16.7	2.7	92.3	12.6	195.1

Mean	**2522.1**	**112.5**	**21.5**	**681.9**	**110.5**	**1423.8**
Peak						

CONCENTRATIONS AND MASS RATIOS OF RAW AND SETTLED BPO			
Particulate organics	Units	BPO raw	BPO settled
COD	mgCOD/L	355.5	27.8
VSS	mgVSS/L	336.2	128.1
TOC	mgC/L	154.4	71.0
OrgN	mgN/L	7.50	2.927
OrgP	mgP/L	1.445	0.642
fcv	mgCOD/mgVSS	1.057	0.217
fc	mgC/mgVSS	0.459	0.554
fn	mgN/mgVSS	0.022	0.023
fp	mgP/mgVSS	0.004	0.005

CONCENTRATIONS AND MASS RATIOS OF DISSOLVED ORGANICS IN RAW WW					
Soluble organics	Units	SO	USO	VFA	FBSO
COD	mgCOD/L	300.0	15.0	0	285
VSS	mgVSS/L	206.6	10.0	0	196.6
TOC	mgC/L	62.5	0.50	0	62
OrgN	mgN/L	8.74	0.10		8.6425
OrgP	mgP/L	4.96	0.10		4.86
fcv	mgCOD/mgVSS	1.452	1.50	0	1.45
fc	mgC/mgVSS	0.303	0.050	0.000	0.315
fn	mgN/mgVSS	0.042	0.010		0.044
fp	mgP/mgVSS	0.024	0.000		0.0247

	UPO	**Biomass (XBH & XEH)**
fcv	1.481	1.481
fc	0.518	0.518
fn	0.2	0.1
fp	0.025	0.025

	RAW	Settled
Fs'up	0.126	0.023

PHASE 2	Raw WW		Settled WW		Underflow	
Flow - Ml/day	**49.22**	m3/d	**49.12**	m3/d	**0.1**	m3/d
	Conc	Flux	Conc	Flux	Conc	Flux
Units	mg/l	kg/d	mg/l	kg/d	mg/l	kg/d
COD	750	36.92	375	18.42	184950.0	18.50
UPO (COD)	94.5	4.65	47.25	2.32	23303.7	2.33
TOC	250	12.31	150	7.37	49370.0	4.94
FSA	44	2.17	44.0	2.16	44.0	0.00

TKN	73	3.59	62	3.05	5451.6	0.55
OP	8	0.39	8.00	0.39	8.0	0.00
TP	16	0.79	14	0.71	801.9	0.08
VSS	400.0	19.69	160.0	7.86	118288.0	11.83
ISS	100	4.92	40.00	1.96	29572.0	2.96
TSS	500	24.61	200.0	9.82	147860.0	14.79

Appendix F: Nutrient fractionation

NUTRIENT FRACTIONATION: RAW WASTEWATER							
COD							
	Total COD(S_{ti}):	**750**	mgCOD/L				
BSO (S_{bsi})	**285**		USO (S_{usi})	**15**		Total Soluble:	**300**
VFA (S_{bsai})	0						
FBSO(S_{bsfi})	285						
BPO (S_{bpi})	**355,5**		UPO (S_{upi})	**94,5**		Total Particulate:	**450**
Total Biodegradable:	**640,50**		Total UnBiodegradable:	**109,5**			
TOC							
	Total TOC (C_{ti}):	**250**	mgTOC/L				
BSO (C_{bsi})	**62**		USO (C_{usi})	**0,5**		Total Soluble:	**62,5**
VFA (C_{bsai})	0						
FBSO(C_{bsfi})	62						
BPO (C_{bpi})	**154,4**		UPO (C_{upi})	**33,1**		Total Particulate:	**187,5**
Total Biodegradable:	**216,4**		Total UnBiodegradable:	**33,6**			

TKN							
	Total TKN (N_{ti}):	**73**	mgN/L				
		OrgN (N_{obi})	**29,0**				
FSA (N_{ai})	**44,0**					Total Soluble:	**52,7425**
FBSOrgN (N_{obsfi})	**8,6**		USOrgN (N_{ousi})	**0,1**			
BPOrgN (N_{obpi})	**7,5**		UPOrgN (N_{oupi})	**12,8**		Total Particulate:	**20,2575**
Total Biodegradable:	**60,1**		Total UnBiodegradable:	**12,9**			

TP							
	Total P (P_{ti}):	**16**	mgP/L				
		OrgP (P_{obi})	**8**				
OP (P_{si})	**8**					Total Soluble:	**12,96**
FBSOrgP (P_{obsfi})	**4,86**		USOrgP (P_{ousi})	**0,1**			
BPOrgP (P_{obpi})	**1,4**		UPOrgP (P_{oupi})	**1,6**		Total Particulate:	**3,04**
Total Biodegradable:	**14,3**		Total UnBiodegradable:	**1,7**			

NUTRIENT FRACTIONATION: SETTLED WASTEWATER							
COD							
	Total COD(S_{ti}):	**375**	mgCOD/L				
BSO (S_{bsi})	**285**		USO (S_{usi})	**15**		Total Soluble:	**300**
VFA (S_{bsai})	0,2						
FBSO(S_{bsfi})	284,8						
BPO (S_{bpi})	**27,75**		UPO (S_{upi})	**47,25**		Total Particulate:	**75**
Total Biodegradable:	**312,75**		Total UnBiodegradable:	**62,25**			
TOC							
	Total TOC (C_{ti}):	**150**	mgTOC/L				
BSO (C_{bsi})	**62**		USO (C_{usi})	**0,5**		Total Soluble:	**62,50**
VFA (C_{bsai})	0,2						
FBSO(C_{bsfi})	61,8						
BPO (C_{bpi})	**71,0**		UPO (C_{upi})	**16,5**		Total Particulate:	**87,50**
Total Biodegradable:	**133,0**		Total UnBiodegradable:	**17,0**			

TKN							
	Total TKN (N_{ti}):	**62**	mgN/L				
		OrgN (N_{obi})	**18,05**				
FSA (N_{ai})	**44,00**					Total Soluble:	**53**
FBSOrgN (N_{obsfi})	**8,6425**		USOrgN (N_{ousi})	**0,1**			
BPOrgN (N_{obpi})	**2,9**		UPOrgN (N_{oupi})	**6,4**		Total Particulate:	**9,3075**
Total Biodegradable:	**55,6**		Total UnBiodegradable:	**6,5**			

TP							
	Total P (P_{ti}):	**14**	mgP/L				
		OrgP (P_{obi})	**6,4**				
OP (P_{si})	**8,00**					Total Soluble:	**13**
FBSOrgP (P_{obsfi})	**4,96**		USOrgP (P_{ousi})	**0**			
BPOrgP (P_{obpi})	**0,6**		UPOrgP (P_{oupi})	**0,8**		Total Particulate:	**1,44**
Total Biodegradable:	**13,6**		Total UnBiodegradable:	**0,8**			

Appendix G: Reaction kinetics

REACTION KINETICS -ANO's			
Tmin	minimum temperature	12.5	°C
Tmax	maximum temperature	20	°C
µAm20	max specific growth rate of nitrifiers @ 20°C	0.45	day-1
µAmT	max specific growth rate of nitrifiers @ T°C	0.30	day-1
YH,n	Yield coefficient for nitrifiers	0.1	mgVSS/mgFSA
SF	Factor of safety on nitrification	1.25	
Kn20	Half saturation constant for nitrifiers @ 20°C	1	mgN/l
KnT	Half saturation constant for nitrifiers @ T°C	0.42	mgN/l
bA20	endogenous respiration rate of nitrifiers @ 20°C	0.04	day-1
bAT	endogenous respiration rate of nitrifiers @ T°C	0.03	day-1
K1,20	K1 denitrification rate at 20°C (RBCOD)	0.72	
K1,T	K1 denitrification rate at T°C (RBCOD)	0.18	
K2,20	K2 denitrification rate at 20°C (SBCOD)	0.216	
K2,T	K2 denitrification rate at T°C (SBCOD)	0.12	
$(Y_A Rs)/(1+bAT*Rs)$		1.38	

REACTION KINETICS -OHO's			
Tmin	minimum temperature	12.5	°C
Tmax	maximum temperature	20	°C
Y_H	Yield Coefficient	0.67	mgCOD/mgCOD
Y_{hv}	specific yield coefficient	0.45	mgVSS/mgCOD
$b_{H\ @\ Tmin}$	Endogenous respiration rate at Tmin	0.19	day-1
$b_{H\ @\ Tmax}$	Endogenous respiration rate at Tmax	0.24	day-1
f_H	Endogenous residue fraction	0.2	
fi_{OHO}	ISS content of OHOs	0.15	
fcv	COD/VSS ratio of UPO	1.481	
$(Y_H Rs)/(1+bhT*Rs)$		1.94	day

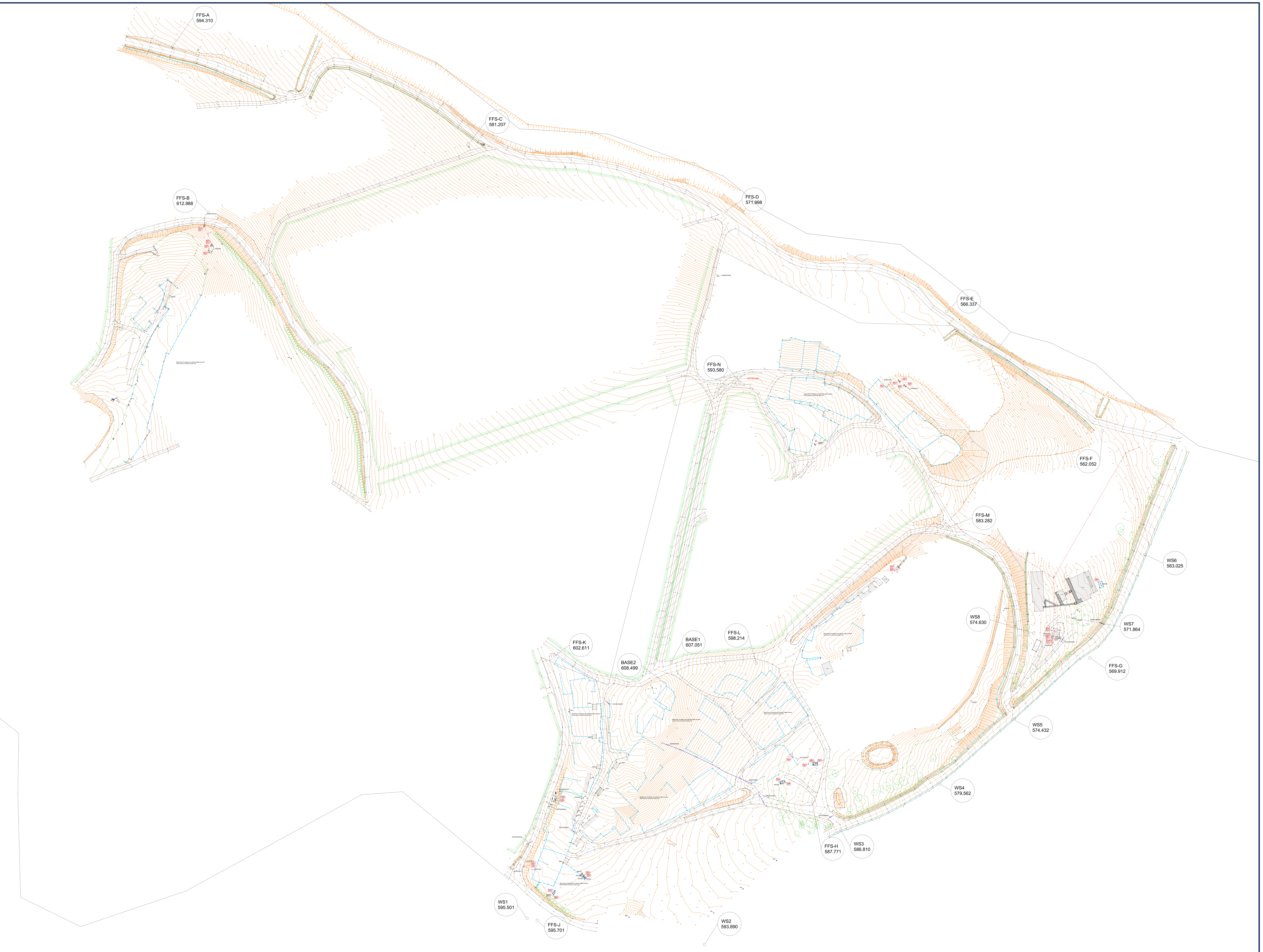
Appendix H: Reactor design

FLUXES			
FSi	flux of total influent COD to reactor	36.92	kgCOD/day
FSbi	flux of total biodegradable COD to reactor	31.53	kgCOD/day
FXupi	flux of total un-bio particulate VSS to reactor	3.14	KgVSS/day
Fxii	flux of total un-bio particulate ISS to reactor	4.92	KgISS/day
REACTOR SLUDGE MASSES			
Mbh	biomass in reactor	29.80	kgVSS
Mxeh	endogenous residue in reactor	28.86	kgVSS
MXI	unbiodegradable particulates in reactor	78.52	kgVSS
MXv	Total VSS in reactor	137.18	kgVSS
MXIO	Total ISS in reactor	127.52	kgISS
MXt	Total TSS in reactor	264.70	kgTSS

Control Points (WGS84/19)

#	Name	Y Coordinate	X Coordinate	Elevation (msl)	Description
	BASE1	-25 441.656	+3 754 849.921	607.051	10MM IRON PEG IN GROUND
	BASE2	-25 436.387	+3 754 865.449	608.499	10MM IRON PEG IN GROUND
	FFS-A	-25 060.686	+3 754 378.993	594.310	12MM IRON PEG IN CONCRETE
	FFS-B	-25 088.072	+3 754 506.007	612.988	12MM IRON PEG IN CONCRETE
	FFS-C	-25 286.420	+3 754 454.502	581.207	12MM IRON PEG IN CONCRETE
	FFS-D	-25 483.930	+3 754 504.808	571.998	12MM IRON PEG IN CONCRETE
	FFS-E	-25 652.390	+3 754 581.783	566.337	12MM IRON PEG IN CONCRETE
	FFS-F	-25 771.390	+3 754 672.899	562.052	12MM IRON PEG IN CONCRETE
	FFS-G	-25 761.782	+3 754 846.480	569.912	12MM IRON PEG IN CONCRETE
	FFS-H	-25 549.548	+3 754 956.670	587.771	12MM IRON PEG IN CONCRETE
	FFS-J	-25 339.414	+3 755 047.060	595.701	12MM IRON PEG IN CONCRETE
	FFS-K	-25 352.841	+3 754 844.991	602.611	12MM IRON PEG IN CONCRETE
	FFS-L	-25 506.785	+3 754 850.596	598.214	12MM IRON PEG IN CONCRETE
	FFS-M	-25 652.598	+3 754 747.111	583.282	12MM IRON PEG IN CONCRETE
	FFS-N	-25 494.207	+3 754 635.526	593.580	12MM IRON PEG IN CONCRETE
	WS1	-25 331.644	+3 755 045.529	595.501	10MM IRON PEG IN GROUND
	WS2	-25 467.119	+3 755 065.740	593.890	10MM IRON PEG IN GROUND
	WS3	-25 571.510	+3 754 978.174	586.810	10MM IRON PEG IN GROUND
	WS4	-25 647.162	+3 754 942.880	579.562	10MM IRON PEG IN GROUND
	WS5	-25 702.745	+3 754 893.386	574.432	10MM IRON PEG IN GROUND
	WS6	-25 803.722	+3 754 767.479	563.025	10MM IRON PEG IN GROUND
	WS7	-25 745.036	+3 754 815.330	571.864	10MM IRON PEG IN GROUND
	WS8	-25 718.931	+3 754 827.761	574.630	10MM IRON PEG IN GROUND

NORTH



JOUBERT & BRINK SURVEYS

TOPOGRAPHIC, ENGINEERING & CONSTRUCTION SURVEY SOLUTIONS

14 DELWYN CRESCENT
STELLENBERG, 7550
WESTERN CAPE
SOUTH AFRICA

SAGC REGISTERED SURVEYORS

+27 (0)21-910-2934
+27 (0)83-273-8266
jbsur@mweb.co.za
CK1996/001136/23

PLEASE NOTE

1. Only use our tabled control points. No other control points shall be used without consulting the surveyor.
2. All spot heights and positions are single measurement elements and are therefore subject to error - any critical design points, especially services, should be discussed with the surveyor so that the appropriate survey methods can be used.
3. This survey includes only visible services which can be opened with hand tools and should be checked against local authority as built plans. Services which are blocked or unable to be opened should be referred to the local authority. Invert levels deeper than 5 metres are approximate unless otherwise discussed before the survey commences.
4. Boundary reconstructions from Surveyor General diagrams can sometimes be a time-consuming process. To save costs and time, a checked GIS overlay for information purposes are generally used, unless otherwise required.
5. This survey information is always sent as a zipped data package which includes this drawing in DWG and PDF format; the raw data in ASCII format; a digital terrain model in XML, TOT, BOT and CDM format; Survey codes and descriptions. If there are any queries or requests regarding these files, please send us an email at jbsur@mweb.co.za.

HORIZONTAL CONTROL BASED ON PRD5			
VERTICAL CONTROL BASED ON PRD5			
SURVEY LEADER D.SNYMAN	DRAWN BY C.STRYDOM	CHECKED BY H.V.D.SANDT	SURVEY DATE NOV 2020
REFERENCE ELLIPSOID WGS84	SURVEY PROJECTION WG19	HEIGHT DATUM HART94	SURVEY HEIGHTS MAMSL
ALLOTMENT AREA STERFONTEIN		ADMINISTRATIVE DISTRICT ELANDSKLOOF	

PROJECT DESCRIPTION

NEW SEWER RETICULATION AND WWTW FINE FARM, VILLIERSDORP

CLIENT ALVEO WATER: JEANDRE KRITZINGER	PLOT SCALE 1:1000 (A0)
DRAWING NAME **20359_FINEFARMS**	SHEET 1 of 1

JOUBERT & BRINK SURVEYS

TOPOGRAPHIC, ENGINEERING & CONSTRUCTION SURVEY SOLUTIONS

14 DELWYN CRESCENT
STELLENBERG, 7550
WESTERN CAPE
SOUTH AFRICA

SAGC REGISTERED SURVEYORS

+27 (0)21-910-2934
+27 (0)83-273-8266
jbsur@mweb.co.za
CK1996/001136/23

PLEASE NOTE

1. Only use our tabled control points. No other control points shall be used without consulting the surveyor.
2. All spot heights and positions are single measurement elements and are therefore subject to error - any critical design points, especially services, should be discussed with the surveyor so that the appropriate survey methods can be used.
3. This survey includes only visible services which can be opened with hand tools and should be checked against local authority as built plans. Services which are blocked or unable to be opened should be referred to the local authority. Invert levels deeper than 5 metres are approximate unless otherwise discussed before the survey commences.
4. Boundary reconstructions from Surveyor General diagrams can sometimes be a time-consuming process. To save costs and time, a checked GIS overlay for information purposes are generally used, unless otherwise required.
5. This survey information is always sent as a zipped data package which includes this drawing in DWG and PDF format; the raw data in ASCII format; a digital terrain model in XML, TOT, BOT and CDM format; Survey codes and descriptions. If there are any queries or requests regarding these files, please send us an email at jbsur@mweb.co.za.

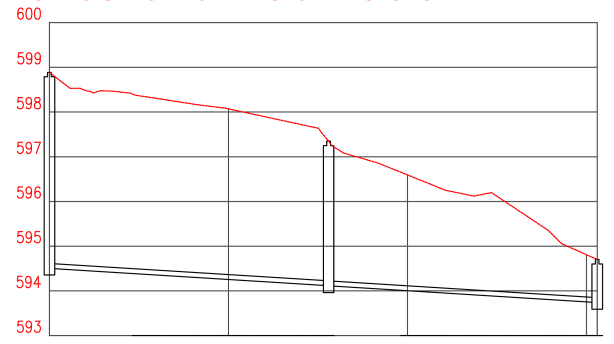
HORIZONTAL CONTROL BASED ON ----			
VERTICAL CONTROL BASED ON ----			
SURVEY LEADER D.SNYMAN	DRAWN BY C.STRYDOM	CHECKED BY ----	SURVEY DATE NOV 2020
REFERENCE ELLIPSOID WGS84	SURVEY PROJECTION WG19	HEIGHT DATUM HART94	SURVEY HEIGHTS MAMSL
ALLOTMENT AREA ----		ADMINISTRATIVE DISTRICT ----	

PROJECT DESCRIPTION

NEW SEWER RETICULATION AND WWTW FINE FARM, VILLIERSDORP

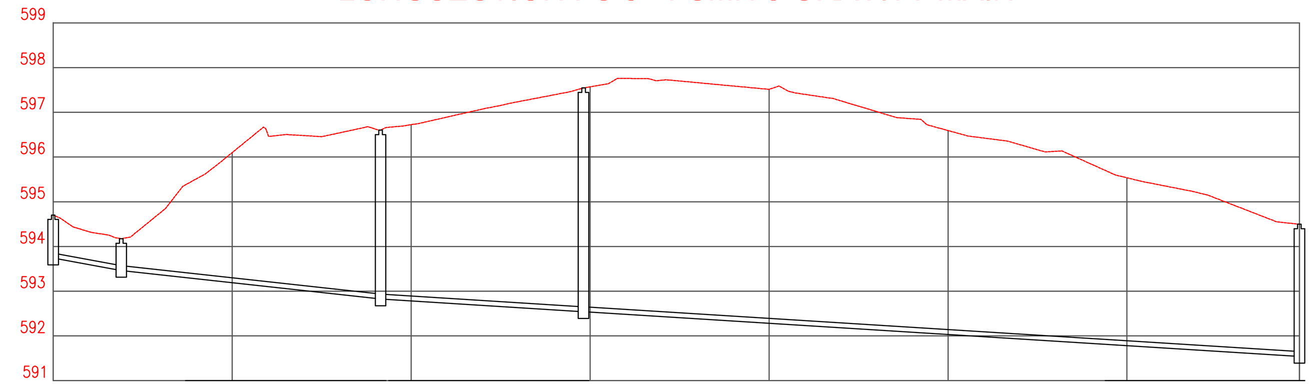
CLIENT ----	PLOT SCALE 1:1000 (A0)
DRAWING NAME 20359_FINEFARMS	SHEET 1 of 1

LONGSECTION FS 9 - FS 3 GRAVITY MAIN



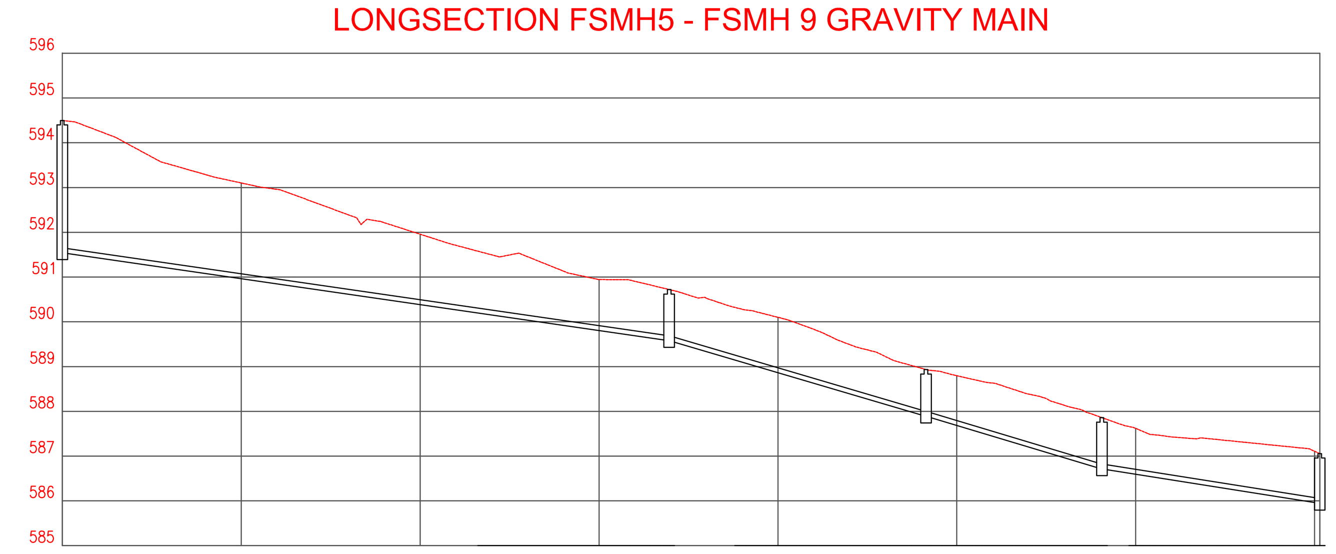
Name	FS 9		FSMH 1		FS 3
Chainage	0.000		31.192		61.192
Ground Level	598.888		597.350		594.703
Rim Elevations	598.888		597.350		594.703
Pipe Size / Pipe Type:		110 mm uPVC Class 4 Pressure Pipe		110 mm uPVC Class 4 Pressure Pipe	
Invert Elevations	594.505		594.115 / 594.115		593.740
Pipe Length & Gradient		1:80 31.195		1:80 30.002	

LONGSECTION FS 3 - FSMH 5 GRAVITY MAIN



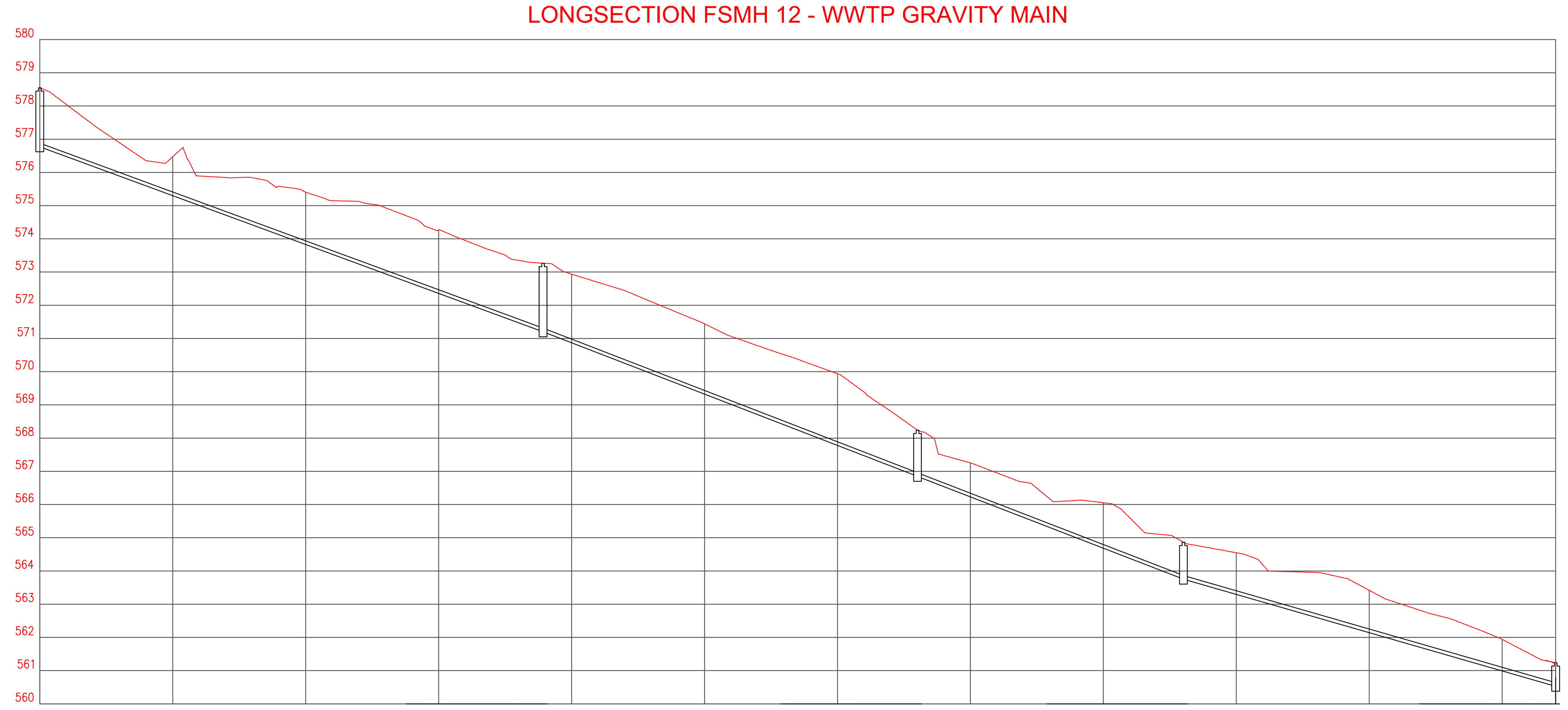
Name	FS 3		FSMH 2		FSMH 3		FSMH 4		FSMH 5
Chainage	0.000		7.611		36.583		59.267		139.267
Ground Level	594.703		594.173		596.602		597.546		594.497
Rim Elevations	594.703		594.173		596.602		597.546		594.497
Pipe Size / Pipe Type:		110 mm uPVC Class 4 Pressure Pipe		110 mm uPVC Class 4 Pressure Pipe		110 mm uPVC Class 4 Pressure Pipe		110 mm uPVC Class 4 Pressure Pipe	
Invert Elevations	593.740		593.463 / 593.463		592.825 / 592.825		592.541 / 592.541		591.541
Pipe Length & Gradient		1:27 7.616		1:45 28.979		1:80 22.686		1:80 80.006	

LONGSECTION FSMH5 - FSMH 9 GRAVITY MAIN



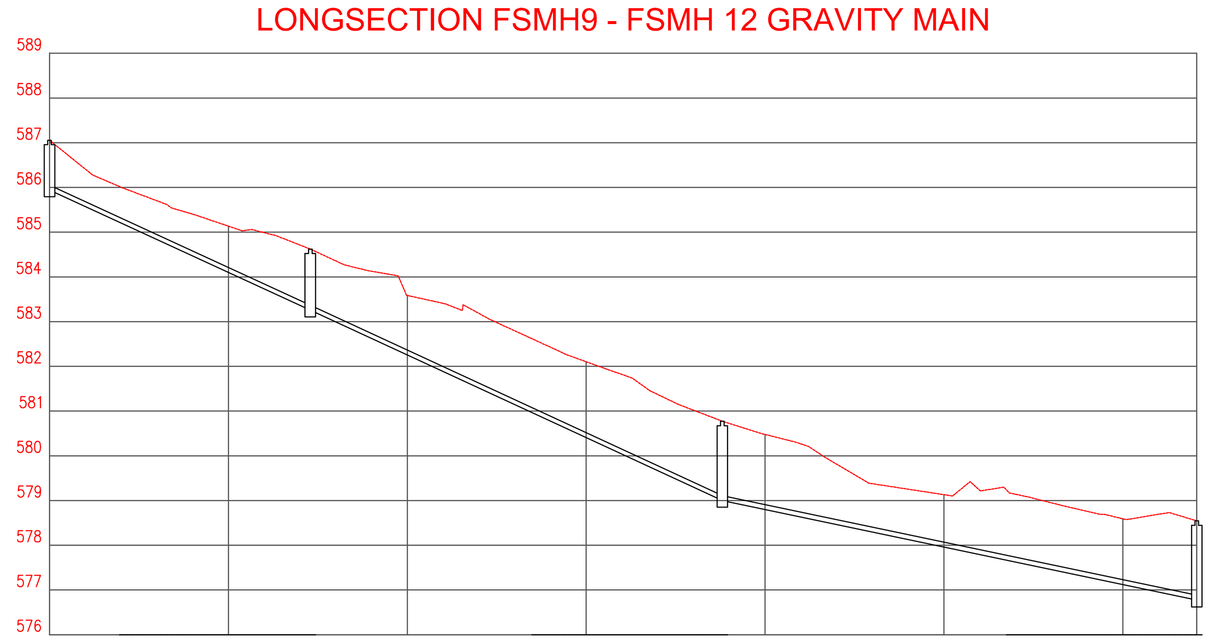
Name	FSMH 5		FSMH 6		FSMH 7		FSMH 8		FSMH 9
Chainage	0.000		67.846		96.557		116.221		140.580
Ground Level	594.497		590.721		588.935		587.859		587.056
Rim Elevations	594.497		590.721		588.935		587.859		587.056
Pipe Size / Pipe Type:		110 mm uPVC Class 4 Pressure Pipe		110 mm uPVC Class 4 Pressure Pipe		110 mm uPVC Class 4 Pressure Pipe		110 mm uPVC Class 4 Pressure Pipe	
Invert Elevations	591.541		589.578 / 589.578		587.889 / 587.889		586.712 / 586.712		585.942
Pipe Length & Gradient		1:35 67.875		1:17 28.760		1:17 19.699		1:32 24.371	

LONGSECTION FSMH 12 - WWTP GRAVITY MAIN



Name	FSMH 12		FSMH 13		FSMH 14		FSMH 15		WWTP
Chainage	0.000		75.710		132.046		172.046		228.046
Ground Level	578.546		573.264		568.238		564.864		561.238
Rim Elevations	578.546		573.264		568.238		564.864		561.238
Pipe Size / Pipe Type:		110 mm uPVC Class 4 Pressure Pipe		110 mm uPVC Class 4 Pressure Pipe		110 mm uPVC Class 4 Pressure Pipe		110 mm uPVC Class 4 Pressure Pipe	
Invert Elevations	576.772		571.201 / 571.201		566.848 / 566.848		563.752 / 563.752		560.528
Pipe Length & Gradient		1:14 75.915		1:13 56.503		1:13 40.120		1:17 56.093	

LONGSECTION FSMH9 - FSMH 12 GRAVITY MAIN



Name	FSMH 9		FSMH 10		FSMH 11		FSMH 12
Chainage	0.000		29.159		75.222		128.261
Ground Level	587.056		584.623		580.772		578.546
Rim Elevations	587.056		584.623		580.772		578.546
Pipe Size / Pipe Type:		110 mm uPVC Class 4 Pressure Pipe		110 mm uPVC Class 4 Pressure Pipe		110 mm uPVC Class 4 Pressure Pipe	
Invert Elevations	585.942		583.257 / 583.257		579.000 / 579.000		576.772
Pipe Length & Gradient		1:11 29.283		1:11 46.259		1:24 53.086	

HIGH NOON GRAVITY MAIN & RISING MAIN LONG SECTIONS

SCALE 1:500

GENERAL:

- ALL WORK MUST BE DONE IN ACCORDANCE WITH THE STANDARD SPECIFICATION SANS 1200 AND THE GENERAL CONDITIONS OF CONTRACT FOR CONSTRUCTION WORKS (GCC) THIRD EDITION 2015.
- CO-ORDINATES ARE BASED ON THE WGS84 Lo19 SYSTEM
- THE CONTRACTOR TO SUBMIT RECORD INFORMATION OF ALL CIVIL SERVICE INFRASTRUCTURE AS WELL AS INVERT AND FINAL COVER LEVELS OF ALL CIVIL SERVICES STRUCTURES.
- THE CONTRACTOR HAS TO CHECK ALL SETTING OUT INFORMATION ON SITE AND NOTIFY ENGINEER OF ANY IRREGULARITIES PRIOR CONSTRUCTION
- ALL MODIFICATIONS TO EXISTING SERVICES AND DEVIATIONS FROM THE DESIGN TO BE AS PER INSTRUCTION FROM THE ENGINEER ONLY.
- POSITIONS OF EXISTING SERVICES ARE GIVEN IN GOOD FAITH BUT CONTRACTOR IS RESPONSIBLE FOR LOCATING AND PROTECTING SERVICES. LOCATING OF EXISTING SERVICE MUST BE DONE BY HAND, NO MACHINERY IS ALLOWED.
- THE CONTRACTOR SHALL LIAISE WITH RELEVANT LOCAL AUTHORITIES FOR POINTING OUT UNKNOWN EXISTING SERVICES AND OBTAIN NECESSARY APPROVALS AND WAY LEAVES IN WRITING PRIOR TO CONSTRUCTION AND SUBMIT TO THE ENGINEER
- ALL PIPELINES TO BE INSTALLED TO HAVE A MINIMUM COVER OF 1000mm UNDER ROADWAYS, 800mm UNDER ROAD RESERVE AND 600MM UNDER SERVITUDE AND PUBLIC OPEN SPACES.
- ALL EXISTING FENCES, OVERHEAD ELECTRICAL/COMMUNICATION CABLES AND EXISTING STRUCTURES SHOULD BE PROTECTED DURING CONSTRUCTION ALONG PIPE ROUTES.
- CONTRACTOR TO REPAIR AND REINSTATE EXISTING SURFACES COMPLETE WITH LAYERWORKS TO MATCH EXISTING.
- ALL COVERS AND FRAMES ON PROPOSED MANHOLES MUST BE NEW. OLD MANHOLE COVERS AND FRAMES REMOVED FROM OLD CHAMBERS MAY NOT BE RE-USED AND MUST BE SUBMITTED TO THE CLIENT
- CONTRACTOR WILL RECEIVE COMPLETION CERTIFICATE ONLY ONCE ALL AS-BUILT INFORMATION HAS BEEN SUBMITTED BY THE ENGINEER

LEGEND
LEGENDE

PLAN VIEW LEGEND

- BUILDING
- OVERHEAD POWER LINE
- PROPERTY BOUNDARY LINE
- EXISTING FENCE
- EXISTING FOUL SEWER PIPELINE
- BENCHMARK (peg in concrete)
- TREE
- ORCHARDS
- EXISTING WATER PIPELINE
- EXISTING WATER VALVE
- EXISTING WATER MANHOLE CHAMBER
- EXISTING TELEPHONE LINE
- 490.0 CONTOUR
- FLOODLINE
- PROPOSED FOUL SEWER GRAVITY MAIN
- PROPOSED FOUL SEWER MANHOLE
- EXISTING FOUL SEWER MANHOLE
- EXISTING SEPTIC TANK
- PROPOSED FOUL SEWER RISING MAIN
- MARKER POST FOR 90°BENDS IN FOUL SEWER
- MARKER POST FOR 11.25° BENDS IN FOUL SEWER RISING MAIN
- PROPOSED RISING MAIN AIR RELEASE VALVE

LONGSECTION LEGEND

- GROUND LEVEL
- FLOODLINE
- PROPOSED FOUL SEWER GRAVITY MAIN
- PROPOSED FOUL SEWER RISING MAIN
- PROPOSED FOUL SEWER MANHOLE
- PROPOSED RISING MAIN AIR RELEASE VALVE

No.	REVISION	DATE	AUTHOR
A	FOR DISCUSSION	11/12/2020	E.RICHARDS
B	FOR DISCUSSION	22/12/2020	E.RICHARDS
0	FOR CONSTRUCTION	13/01/2020	E.RICHARDS
1	WWTP LOCATION REVISED	21/01/2020	E.RICHARDS

CLIENT: **HIGH NOON FARM**

CONSULTANT: ALVEO WATER

CONTRACTOR: BUILD CORP CONSTRUCTION

DESIGNED BY:	DRAWN BY:	CHECKED BY:
E.RICHARDS	E.RICHARDS	M. DE VILLIERS

APPROVED BY: E. RICHARDS
SIGNATURE:
APPROVAL DATE: 21/01/2021
PROF. REG. NO: 201670022

PROJECT STATUS: **FOR CONSTRUCTION**

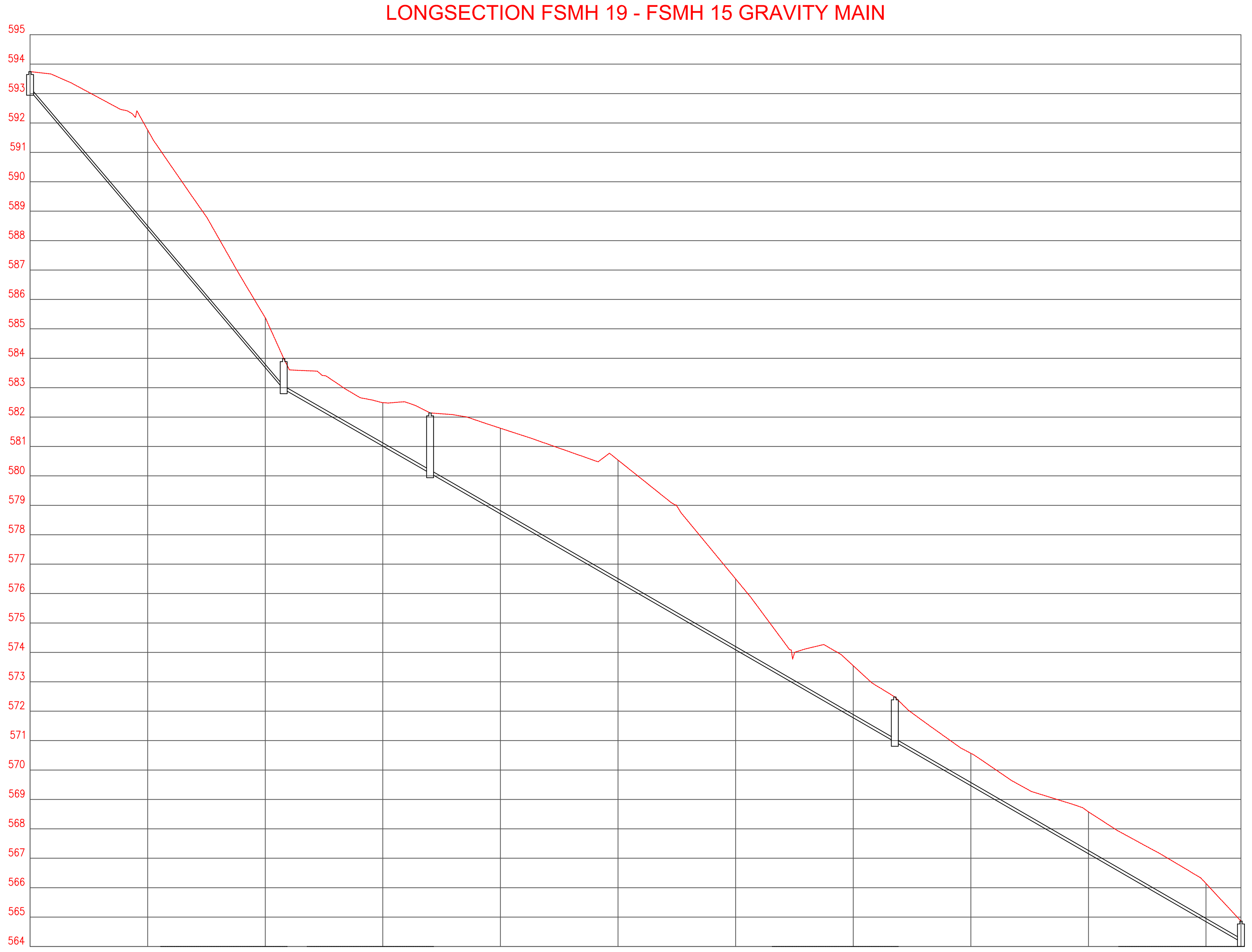
PROJECT: **HIGH NOON FARM WASTEWATER TREATMENT WORKS**

DRAWING TITLE: **LONG SECTIONS OF GRAVITY MAINS AND RISING MAINS**

SCALE: AS SHOWN @ A0
DATE: 21/01/2021

DRAWING NUMBER: (PROJECT NO: / INITIATOR: / SHEET:) 2028 - ALV - C0002
REVISION: 1

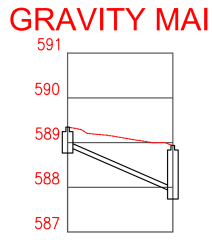
LONGSECTION FSMH 19 - FSMH 15 GRAVITY MAIN



Name	FSMH 19	FSMH 20	FSMH 21	FSMH 22	FSMH 15
Chainage	0.000	43.142	68.033	147.075	205.943
Ground Level	593.746	583.996	582.142	572.484	564.864
Rim Elevations	593.746	583.985	582.142	572.484	564.864
Invert Elevations	593.095	582.946 582.946	580.092 580.092	570.958 570.958	564.154

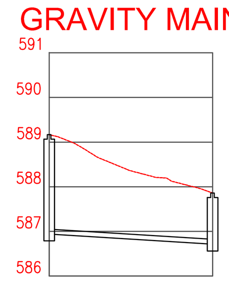
Pipe Size / Pipe Type:	110 mm uPVC Class 4 Pressure Pipe	110 mm uPVC Class 4 Pressure Pipe	110 mm uPVC Class 4 Pressure Pipe	110 mm uPVC Class 4 Pressure Pipe
Pipe Length & Gradient	1:4 44.320	1:9 25.053	1:9 79.569	1:9 59.259

LONGSECTION FSMH 17 - FSMH 7 GRAVITY MAIN



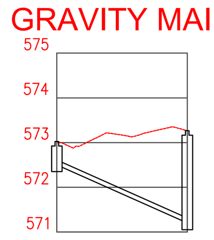
Name	FSMH 17	FSMH 7
Chainage	0.000	11.764
Ground Level	589.347	588.935
Rim Elevations	589.347	588.935
Pipe Size / Pipe Type:	110 mm uPVC Class 4 Pressure Pipe	
Invert Elevations	588.915	587.889
Pipe Length & Gradient	1:11 11.809	

LONGSECTION FS 5 - FSMH 8 GRAVITY MAIN



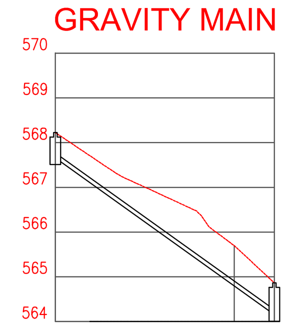
Name	FS 5	FSMH 8
Chainage	0.000	18.268
Ground Level	589.166	587.859
Rim Elevations	589.166	587.859
Pipe Size / Pipe Type:	110 mm uPVC Class 4 Pressure Pipe	
Invert Elevations	586.940	586.712
Pipe Length & Gradient	1:80 18.269	

LONGSECTION FS 8 - FSMH 13 GRAVITY MAIN



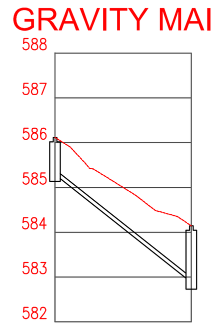
Name	FS 8	FSMH 13
Chainage	0.000	14.548
Ground Level	573.023	573.264
Rim Elevations	573.023	573.264
Pipe Size / Pipe Type:	110 mm uPVC Class 4 Pressure Pipe	
Invert Elevations	572.500	571.201
Pipe Length & Gradient	1:11 14.606	

LONGSECTION FSMH 18 - FSMH 15 GRAVITY MAIN



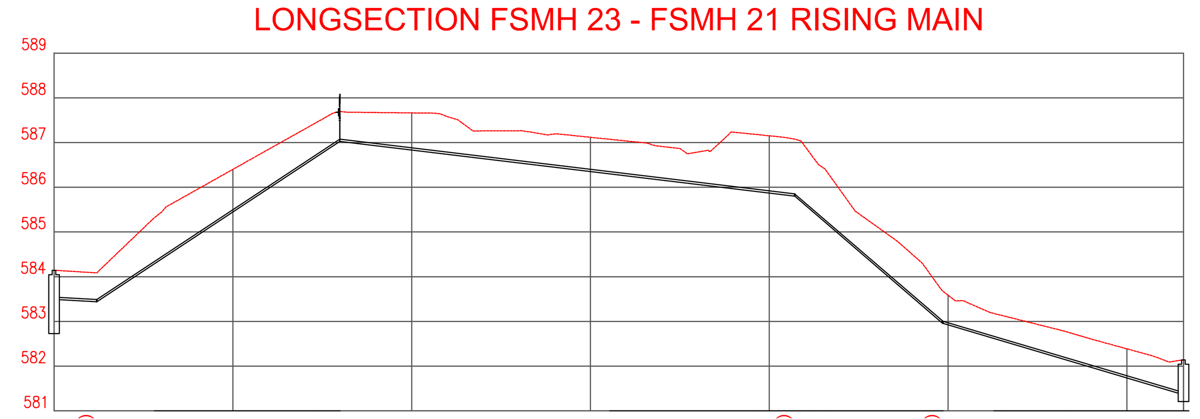
Name	FSMH 18	FSMH 15
Chainage	0.000	24.483
Ground Level	568.225	564.864
Rim Elevations	568.225	564.864
Pipe Size / Pipe Type:	110 mm uPVC Class 34	
Invert Elevations	567.660	564.154
Pipe Length & Gradient	1:7 24.733	

LONGSECTION FS 2 - FSMH 23 GRAVITY MAIN



Name	FS 2	FSMH 23
Chainage	0.000	15.242
Ground Level	586.117	584.144
Rim Elevations	586.117	584.144
Pipe Size / Pipe Type:	110 mm uPVC Class 4 Pressure Pipe	
Invert Elevations	585.290	582.880
Pipe Length & Gradient	1:6 15.431	

LONGSECTION FSMH 23 - FSMH 21 RISING MAIN



Name	FSMH 23	Structure - (41)	AV 1	Structure - (43)	Structure - (67)	FSMH 21
Chainage	0.000	4.779	31.958	82.841	99.408	126.324
Ground Level	584.144	584.086	587.697	587.078	583.679	582.142
Rim Elevations	584.144	583.494	587.081	585.855	583.010	582.142
Invert Elevations	583.494	583.439 583.439	587.027 587.027	585.801 585.801	582.956 582.956	581.359

Pipe Size / Pipe Type:	50 mm uPVC Class 9 Pressure Pipe	50 mm uPVC Class 9 Pressure Pipe	50 mm uPVC Class 9 Pressure Pipe	50 mm uPVC Class 9 Pressure Pipe	50 mm uPVC Class 9 Pressure Pipe
Pipe Length & Gradient	1:88 4.779	-1:8 27.415	1:42 50.899	1:6 16.810	1:17 26.963

HIGH NOON GRAVITY MAIN & RISING MAIN LONG SECTIONS

SCALE 1:500

GENERAL:

- ALL WORK MUST BE DONE IN ACCORDANCE WITH THE STANDARD SPECIFICATION SANS 1200 AND THE GENERAL CONDITIONS OF CONTRACT FOR CONSTRUCTION WORKS (GCC) THIRD EDITION 2015.
- CO-ORDINATES ARE BASED ON THE WGS84 Lo19 SYSTEM
- THE CONTRACTOR TO SUBMIT RECORD INFORMATION OF ALL CIVIL SERVICE INFRASTRUCTURE AS WELL AS INVERT AND FINAL COVER LEVELS OF ALL CIVIL SERVICES STRUCTURES.
- THE CONTRACTOR HAS TO CHECK ALL SETTING OUT INFORMATION ON SITE AND NOTIFY ENGINEER OF ANY IRREGULARITIES PRIOR CONSTRUCTION
- ALL MODIFICATIONS TO EXISTING SERVICES AND DEVIATIONS FROM THE DESIGN TO BE AS PER INSTRUCTION FROM THE ENGINEER ONLY.
- POSITIONS OF EXISTING SERVICES ARE GIVEN IN GOOD FAITH BUT CONTRACTOR IS RESPONSIBLE FOR LOCATING AND PROTECTING SERVICES. LOCATING OF EXISTING SERVICE MUST BE DONE BY HAND, NO MACHINERY IS ALLOWED.
- THE CONTRACTOR SHALL LIAISE WITH RELEVANT LOCAL AUTHORITIES FOR POINTING OUT UNKNOWN EXISTING SERVICES AND OBTAIN NECESSARY APPROVALS AND WAY LEAVES IN WRITING PRIOR TO CONSTRUCTION AND SUBMIT TO THE ENGINEER
- ALL PIPELINES TO BE INSTALLED TO HAVE A MINIMUM COVER OF 1000mm UNDER ROADWAYS, 800mm UNDER ROAD RESERVE AND 600MM UNDER SERVITUDE AND PUBLIC OPEN SPACES.
- ALL EXISTING FENCES, OVERHEAD ELECTRICAL/COMMUNICATION CABLES AND EXISTING STRUCTURES SHOULD BE PROTECTED DURING CONSTRUCTION ALONG PIPE ROUTES.
- CONTRACTOR TO REPAIR AND REINSTATE EXISTING SURFACES COMPLETE WITH LAYERWORKS TO MATCH EXISTING.
- ALL COVERS AND FRAMES ON PROPOSED MANHOLES MUST BE NEW. OLD MANHOLE COVERS AND FRAMES REMOVED FROM OLD CHAMBERS MAY NOT BE RE-USED AND MUST BE SUBMITTED TO THE CLIENT
- CONTRACTOR WILL RECEIVE COMPLETION CERTIFICATE ONLY ONCE ALL AS-BUILT INFORMATION HAS BEEN SUBMITTED BY THE ENGINEER

LEGEND
LEGENDE

PLAN VIEW LEGEND

- BUILDING
- OVERHEAD POWER LINE
- PROPERTY BOUNDARY LINE
- EXISTING FENCE
- EXISTING FOUL SEWER PIPELINE
- BENCHMARK (peg in concrete)
- TREE
- ORCHARDS
- EXISTING WATER PIPELINE
- EXISTING WATER VALVE
- EXISTING WATER MANHOLE CHAMBER
- EXISTING TELEPHONE LINE
- 490.0 CONTOUR
- FLOODLINE
- PROPOSED FOUL SEWER GRAVITY MAIN
- PROPOSED FOUL SEWER MANHOLE
- EXISTING FOUL SEWER MANHOLE
- EXISTING SEPTIC TANK
- PROPOSED FOUL SEWER RISING MAIN
- MARKER POST FOR 90°BENDS IN FOUL SEWER
- MARKER POST FOR 11.25° BENDS IN FOUL SEWER RISING MAIN
- PROPOSED RISING MAIN AIR RELEASE VALVE

LONGSECTION LEGEND

- GROUND LEVEL
- FLOODLINE
- PROPOSED FOUL SEWER GRAVITY MAIN
- PROPOSED FOUL SEWER RISING MAIN
- PROPOSED FOUL SEWER MANHOLE
- PROPOSED RISING MAIN AIR RELEASE VALVE

No.	REVISION	DATE	AUTHOR
A	FOR DISCUSSION	11/12/2020	E.RICHARDS
B	FOR DISCUSSION	22/12/2020	E.RICHARDS
0	FOR CONSTRUCTION	13/01/2020	E.RICHARDS
1	WWTP LOCATION REVISED	21/01/2020	E.RICHARDS

CLIENT:
HIGH NOON FARM

CONSULTANT:
ALVEO WATER

CONTRACTOR:
BUILD CORP CONSTRUCTION

DESIGNED BY:	DRAWN BY:	CHECKED BY:
E.RICHARDS	E.RICHARDS	M. DE VILLIERS

APPROVED BY: E. RICHARDS
SIGNATURE:
APPROVAL DATE: 21/01/2021
PROF. REG. NO: 201670022

PROJECT STATUS:
FOR CONSTRUCTION

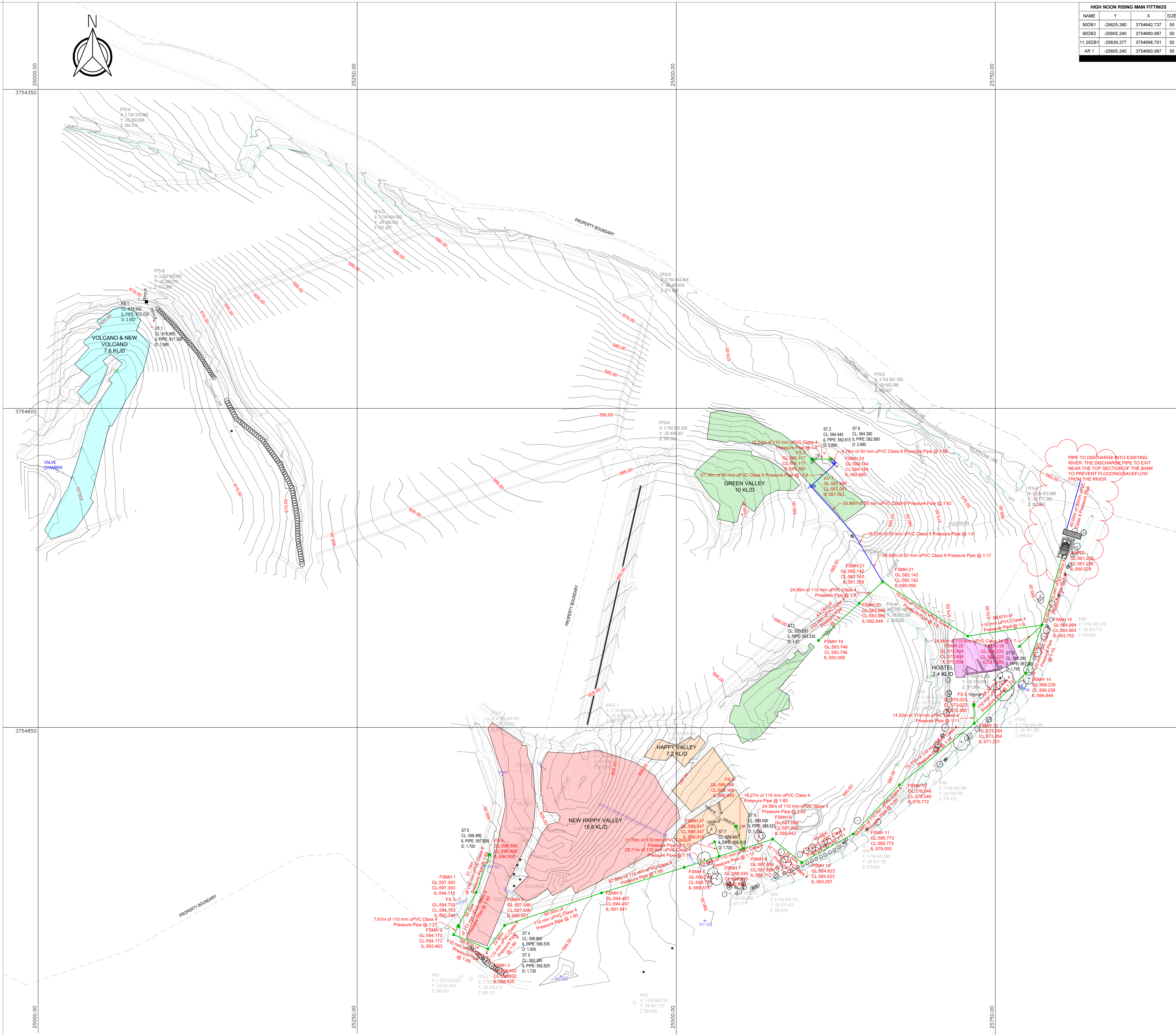
PROJECT:
HIGH NOON FARM WASTEWATER TREATMENT WORKS

DRAWING TITLE:
LONG SECTIONS OF GRAVITY MAINS AND RISING MAINS

SCALE: AS SHOWN @ A0
DATE: 21/01/2021

DRAWING NUMBER: PROJECT NO: INITIATOR: SHEET:
2028 - ALV - C0003

REVISION: 1



HIGH NOON WASTEWATER TREATMENT WORKS, GRAVITY MAIN & RISING MAIN PLAN VIEW

SCALE 1:1000

HIGH NOON RISING MAIN FITTINGS

NAME	Y	X	SIZE
90DB1	-25625,380	3754642,737	50
90DB2	-25605,240	3754660,987	50
11,25DB1	-25639,377	3754698,701	50
AR 1	-25605,240	3754660,987	50

HIGH NOON SEWER GRAVITY MAIN

NAME	Y	X	IL	CL	DIST (m)	GRADE (1:)	DIAMETER (mm)
FS 9	-25 353,573	3 754 949,844	594,505	598,888	31,190	80,000	110,000
FSMH 1	-25 343,292	3 754 979,294	594,115	597,350	30,000	80,000	110,000
FS 3	-25 329,170	3 755 005,762	593,740	594,703	7,610	27,000	110,000
FSMH 2	-25 325,587	3 755 012,477	593,463	594,173	28,970	45,000	110,000
FSMH 3	-25 352,361	3 755 023,547	592,825	596,602	22,680	80,000	110,000
FSMH 4	-25 365,583	3 755 005,115	592,541	597,546	80,000	80,000	110,000
FSMH 5	-25 441,434	3 754 979,687	591,541	594,497	67,850	35,000	110,000
FSMH 6	-25 506,274	3 754 959,712	589,578	590,721	28,710	17,000	110,000
FSMH 7	-25 533,621	3 754 950,970	587,889	588,935	19,660	17,000	110,000
FSMH 8	-25 552,351	3 754 944,983	586,712	587,859	24,360	32,000	110,000
FSMH 9	-25 575,554	3 754 937,566	585,942	587,056	29,160	11,000	110,000
FSMH 10	-25 598,267	3 754 955,851	583,257	584,623	46,060	11,000	110,000
FSMH 11	-25 638,574	3 754 933,554	579,000	580,772	53,040	24,000	110,000
FSMH 12	-25 674,933	3 754 894,939	576,772	578,546	75,710	14,000	110,000
FSMH 13	-25 733,463	3 754 846,915	571,201	573,264	56,340	13,000	110,000
FSMH 14	-25 773,739	3 754 807,526	566,848	568,238	40,000	13,000	110,000
FSMH 15	-25 786,588	3 754 769,646	563,752	564,864	56,000	17,000	110,000
WWTP	-25 802,447	3 754 715,938	560,528	561,238			
FSMH 17	-25 530,039	3 754 939,764	588,915	589,427	11,760	11,000	110,000
FSMH 7	-25 533,621	3 754 950,970	587,889	588,935			
FS 5	-25 546,789	3 754 927,582	586,940	589,166	18,270	80,000	110,000
FSMH 8	-25 552,351	3 754 944,983	586,712	587,859			
FS 8	-25 733,168	3 754 832,370	572,500	573,023	14,550	11,000	110,000
FSMH 13	-25 733,463	3 754 846,915	571,201	573,264			
FSMH 18	-25 768,886	3 754 786,559	567,658	568,225	24,480	7,000	110,000
FSMH 15	-25 786,588	3 754 769,646	564,154	564,864			
FSMH 19	-25 611,479	3 754 781,899	593,095	593,746	43,140	4,000	110,000
FSMH 20	-25 643,321	3 754 752,809	582,946	583,985	24,890	9,000	110,000
FSMH 21	-25 661,707	3 754 736,012	580,090	582,142	79,040	9,000	110,000
FSMH 22	-25 728,385	3 754 778,461	570,958	572,484	58,870	9,000	110,000
FSMH 15	-25 786,588	3 754 769,646	564,154	564,864			
FS 2	-25 805,019	3 754 707,251	585,290	586,472	15,240	6,000	110,000
FSMH 22	-25 606,469	3 754 639,781	582,880	584,144			

SEPTIC TANKS ST 6, 7 & 9 SHALL BE DEMOLISHED BY THE CLIENT. THE CONTRACTOR SHALL DIVERT THE INFLOW OF THE SEPTIC TANK TO THE NEAREST MANHOLE.

PLEASE NOTE:

GENERAL:

- ALL WORK MUST BE DONE IN ACCORDANCE WITH THE STANDARD SPECIFICATION SANS 1200 AND THE GENERAL CONDITIONS OF CONTRACT FOR CONSTRUCTION WORKS (GCC) THIRD EDITION 2015.
- CO-ORDINATES ARE BASED ON THE WGS84 Lo19 SYSTEM
- THE CONTRACTOR TO SUBMIT RECORD INFORMATION OF ALL CIVIL SERVICE INFRASTRUCTURE AS WELL AS INVERT AND FINAL COVER LEVELS OF ALL CIVIL SERVICES STRUCTURES.
- THE CONTRACTOR HAS TO CHECK ALL SETTING OUT INFORMATION ON SITE AND NOTIFY ENGINEER OF ANY IRREGULARITIES PRIOR CONSTRUCTION
- ALL MODIFICATIONS TO EXISTING SERVICES AND DEVIATIONS FROM THE DESIGN TO BE AS PER INSTRUCTION FROM THE ENGINEER ONLY.
- POSITIONS OF EXISTING SERVICES ARE GIVEN IN GOOD FAITH BUT CONTRACTOR IS RESPONSIBLE FOR LOCATING AND PROTECTING SERVICES. LOCATING OF EXISTING SERVICE MUST BE DONE BY HAND, NO MACHINERY IS ALLOWED.
- THE CONTRACTOR SHALL LIAISE WITH RELEVANT LOCAL AUTHORITIES FOR POINTING OUT UNKNOWN EXISTING SERVICES AND OBTAIN NECESSARY APPROVALS AND WAY LEAVES IN WRITING PRIOR TO CONSTRUCTION AND SUBMIT TO THE ENGINEER
- ALL PIPELINES TO BE INSTALLED TO HAVE A MINIMUM COVER OF 1000mm UNDER ROADWAYS, 800mm UNDER ROAD RESERVE AND 600MM UNDER SERVITUDE AND PUBLIC OPEN SPACES.
- ALL EXISTING FENCES, OVERHEAD ELECTRICAL/COMMUNICATION CABLES AND EXISTING STRUCTURES SHOULD BE PROTECTED DURING CONSTRUCTION ALONG PIPE ROUTES.
- CONTRACTOR TO REPAIR AND REINSTATE EXISTING SURFACES COMPLETE WITH LAYERWORKS TO MATCH EXISTING.
- ALL COVERS AND FRAMES ON PROPOSED MANHOLES MUST BE NEW. OLD MANHOLE COVERS AND FRAMES REMOVED FROM OLD CHAMBERS MAY NOT BE RE-USED AND MUST BE SUBMITTED TO THE CLIENT
- CONTRACTOR WILL RECEIVE COMPLETION CERTIFICATE ONLY ONCE ALL AS-BUILT INFORMATION HAS BEEN SUBMITTED BY THE ENGINEER

LEGEND
LEGENDE

PLAN VIEW LEGEND

- BUILDING
- OVERHEAD POWER LINE
- PROPERTY BOUNDARY LINE
- EXISTING FENCE
- EXISTING FOUL SEWER PIPELINE
- BENCHMARK (peg in concrete)
- TREE
- ORCHARDS
- EXISTING WATER PIPELINE
- EXISTING WATER VALVE
- EXISTING WATER MANHOLE CHAMBER
- EXISTING TELEPHONE LINE
- CONTOUR
- FLOODLINE
- PROPOSED FOUL SEWER GRAVITY MAIN
- PROPOSED FOUL SEWER MANHOLE
- EXISTING FOUL SEWER MANHOLE
- EXISTING SEPTIC TANK
- PROPOSED FOUL SEWER RISING MAIN
- MARKER POST FOR 90°BENDS IN FOUL SEWER
- MARKER POST FOR 11.25° BENDS IN FOUL SEWER RISING MAIN
- PROPOSED RISING MAIN AIR RELEASE VALVE

LONGSECTION LEGEND

- GROUND LEVEL
- FLOODLINE
- PROPOSED FOUL SEWER GRAVITY MAIN
- PROPOSED FOUL SEWER RISING MAIN
- PROPOSED FOUL SEWER MANHOLE
- PROPOSED RISING MAIN AIR RELEASE VALVE

No.	REVISION	DATE	AUTHOR
A	FOR DISCUSSION	11/12/2020	E.RICHARDS
B	FOR DISCUSSION	22/12/2020	E.RICHARDS
0	FOR CONSTRUCTION	13/01/2020	E.RICHARDS
1	WWTP LOCATION REVISED	21/01/2020	E.RICHARDS
2	CONCRETE PLATFORM LOCATION REVISED	04/02/2020	E.RICHARDS

CLIENT:

HIGH NOON FARM

CONSULTANT: ALVEO WATER

CONTRACTOR: BUILD CORP CONSTRUCTION

DESIGNED BY:	DRAWN BY:	CHECKED BY:
E.RICHARDS	E.RICHARDS	M. DE VILLIERS

APPROVED BY: E. RICHARDS

SIGNATURE:

APPROVAL DATE: 04/02/2021

PROF. REG. NO: 201670022

PROJECT STATUS:

FOR CONSTRUCTION

PROJECT:

HIGH NOON FARM WASTEWATER TREATMENT WORKS

DRAWING TITLE:

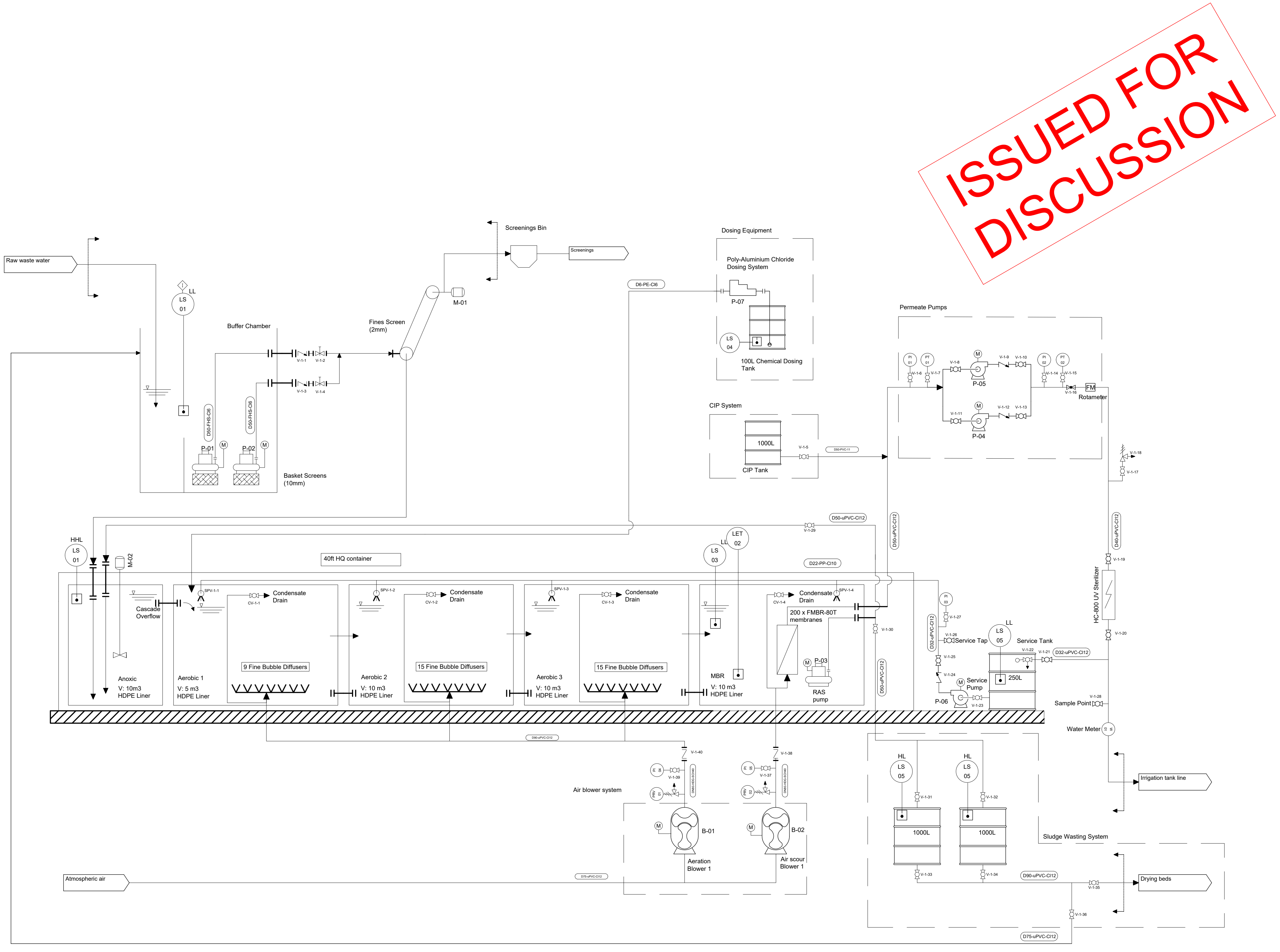
PLAN VIEW OF GRAVITY MAINS AND RISING MAINS

SCALE: AS SHOWN @ A0

DATE: 04/02/2021

DRAWING NUMBER: (PROJECT NO: / INITIATOR: / SHEET:) 2028 - ALV - C0001

REVISION: 2



GENERAL NOTES:

PLEASE NOTE:
THIS DRAWING HAS BEEN PREPARED BY ALVEO WATER AND IS THE SOLE PROPERTY OF ALVEO WATER. NO LOGO OF THE CONTRACTOR SHALL APPEAR ON THE DRAWING BUT MAY BEAR THE WORDS PREPARED BY: "CONTRACTORS NAME". ALVEO WATER RESERVES THE RIGHT WITH REGARD TO COPYRIGHT AND THIS DRAWING MAY NOT BE COPIED, USED OR REPRODUCED IN ANY MANNER WITHOUT PRIOR WRITTEN CONSENT OF ALVEO WATER.

No.	REVISION	DATE	AUTHOR
A	ISSUED FOR DISCUSSION	18/11/2020	B.MEINTJES

CLIENT:

CONSULTANT:

CONTRACTOR:

ALVEO WATER

DESIGNED BY:	DRAWN BY:	CHECKED BY:
J.KRITZINGER	B.MEINTJES	J.KRITZINGER

APPROVED BY:	SIGNATURE:
APPROVAL DATE:	PROF. REG. NO:

PROJECT STATUS:
FOR DISCUSSION

PROJECT:
FINE FARMS HIGH NOON WWTP

DRAWING TITLE:
PROCESS AND INSTRUMENTATION DIAGRAM

SCALE: AS SHOWN @ A3

DATE: 18/11/2020

DRAWING NUMBER: 2028-ALV-A10P0001

REVISION: A

Last saved date: 2020-11-19 14:55:16 Last saved by: Brendan Plot date: 2020-11-19 14:58:49

Date:	2020/11/19
Project Name:	High Noon WWTP
Project Commission Date:	2021/02/20
Design Engineer:	Jeandré Kritzinger
Project Manager:	Jeandré Kritzinger

Pumps / Mixers / Blower

Item #	Name	Qty	Location	Type	Start Method	kW	Amps	3ph/1ph
P-01/P-02	Buffer pumps (2 x duty rotate)	2	Buffer chamber	JDSK-10	DOL	0.75	1.8	3
B-01	Aeration blower	1	Equipment room	SAMOS SB 0200 D2	DOL	3	7.2	3
P-03	RAS pump	1	MBR liner	JDS-10	DOL	0.75	1.8	3
P-04/P05	Permeate pumps (2 x duty rotate)	2	Equipment room	Wilo MC 304	DOL	0.55	1.56	3
B-02	MBR blower	1	Equipment room	SAMOS SB 0200 D2	DOL	3	7.2	3
M-01	Screen Motor	1	Before Anoxic liner	CT-150	DOL	0.37	1.06	3
M-02	Anoxic Agitator	1	Anoxic liner	Infin-8 top entry mixer	DOL	0.75	1.4	3
N/A	Extraction Fans x 1	1	Equipment room	FTAC40/4	DOL	0.22	0.45	3
P-07	PAC dosing pump	1	Equipment room	Grundfos DDE 6-10	Run CMND	0.019	25 (Inrush)	1
P-06	Service Pump	1	Equipment room	Hi-Peri 1-5	DOL	0.55		1
N/A	UV Sterilizer	1	Equipment room	HC-800	TIMER	0.065		1

Floats / Sensors / Other

Item #	Name		Location	Type	Other
LS-01	Buffer low level	1	Buffer Tank	Float	
LS-02	MBR critical low level	1	MBR chamber	Float	
LS-03	Anoxic high high level	1	MBR chamber	Float	
LET-01	MBR Level	1	MBR chamber	Hydrostatic Level sensor	
LS-04	PAC dosing tank low level	1	PAC dosing tank	Float	
PET-01	Permeate pumps suction pressure sensor	1	Permeate pumps suction	Pressure transducer	
PET-02	Permeate pumps discharge pressure sensor	1	Permeate pumps discharge	Pressure transducer	
LS-05	Service tank low level	1	Service tank	Float	
LS-06	Sludge tank1 low level	1	Sludge tank1	Float	
LS-07	Sludge tank2 low level	1	Sludge tank2	Float	

Control Philosophy

Description	Sign-off: Programming Team	Sign-off: Process Team

LEGEND
ABC - information displayed on the HMI
EFG - setting that can be changed on the setting list

Buffer pumps
The buffer pump operates on a duty/standby cycle. The Buffer Pump Duty Cycle is set on the HMI (password protected).
The buffer pump runs according to the MBR High Level Setpoint (password protected). The buffer pump is also switched off immediately by the anoxic high high level float.
The buffer chamber low level float stops the buffer pump to prevent dry running.
If the MBR high level or the anoxic high high is activated the duty buffer pump stops and will only resume once both the conditions are removed.

Mechanical Screen
The mechanical screen operates with the buffer pump and for a cool down duration after the buffer pump stopped.
If the duty buffer pump has run and stopped, then the screen will continue operating for a Screen Cool Down Duration, then the mechanical screen stops. As soon as the buffer pump starts again the screen starts as well and the Screen Cool Down time is reset.

Aeration blower
Aeration blower runs continually, the MBR critical low level float stops the blower
The aeration blower will rest for a timed period every day. When the Aeration Blower Rest Time is reached the blower stops.
When the Aeration Blower Restart Time is reached the blower starts up again

RAS pump
The RAS pump runs to achieve a number of cycles, the MBR Low Level Setpoint stops the RAS pump, the anoxic high high level also stops the RAS pump.
The RAS pump runs for the RAS Run Duration, then stops for the RAS Rest Duration, This cycle continues 24/7.
See CIP Procedure below for when RAS pump is to be kept off.

Permeate pumps
The MBR Level is measured by the hydrostatic and displayed on the HMI.
The permeate pump operates on a duty/standby cycle. The Permeate Pump Duty Cycle is set on the HMI.
Pump to stop on MBR Low Level Setpoint. Pump to start once this condition is removed.
Refer to MBR Blowers section for pump start-up after the blowers start.
Permeate Pumps to operate for Permeate Pump Run duration and stop for Permeate Pump Rest duration. This cycle continues 24/7.
Permeate pumps not to operate if CIP Procedure Active is active.
Permeate pumps not to operate ever if MBR blower not operating. Please interlock.
Permeate pump stops and trips on Permeate High Discharge Pressure as measured by the Permeate Pump Discharge Pressure.
If the measured permeate pump suction pressure is lower or equal to the Low Suction Pressure setpoint for a period greater than the Low Pressure Delay period, then the CIP Required alarm is activated but the permeate pump continues to operate. This notification should not block any buttons on the HMI display.

Permeate pumps **critical low suction pressure** sequence:
1. If the measured permeate pump suction pressure is lower or equal to the Critical Low Suction Pressure setpoint for a period greater than the Critical Low Pressure Delay period, then permeate pumps immediately stop.
2. CIP Required Alarm to be activated immediately at critical low suction pressure. Permeate pumps only to operate again following a CIP Procedure Active cycle.

CIP
When CIP Procedure Active is activated on HMI, the MBR blower, RAS pump and permeate pumps are stopped.
This allows the operator to carry out a manual CIP procedure without any equipment starting.
After the CIP procedure is completed, the operator must deactivate the CIP Procedure Active and this will allow the plant to operate again. The RAS pump will remain off for 1400 mins after the CIP Procedure Active was deactivated.

MBR blowers
MBR blower to stop at MBR Blower & UV Rest Time restart at MBR Blower & UV Restart Time.
The MBR critical low level float stops the MBR Blower from running.
After the MBR blower has restarted, the Permeate pump will only restart after the Permeate Pump Scour Delay period has lapsed.

Service Pump
Service Pump to operate for Service Pump Run duration and stop for Service Pump Rest duration.
The Service tank low level float stops the Service pump from running and will only operate again once the condition is removed.

PAC Dosing pump
The PAC dosing pump runs along with the buffer pump.
If the dosing tank low level switch is activated, the dosing pump stops and will resume pumping when the level alarm is removed by topping up the dosing tank.

UV Sterilizer
The UV Sterilizer runs continually and rests at the same time as the MBR Blower.

Trip events
Externally mounted strobe light to accompany any equipment trips
Fault siren to be installed

Parameter List

#	Description	UOM	Value
1	Buffer Pump Duty Cycle	hr	1--48
2	MBR High Level Setpoint	mm	1900-2100
3	MBR Low Level Setpoint	mm	1700-1900
4	MBR Critical Low Level Setpoint	mm	1600-1900
5	Screen Cool-Down Duration	min	1 -- 30
6	Aeration Blower Rest Time	hh:mm	22:00 - 23:00
7	Aeration Blower Restart Time	hh:mm	23:00 - 00:00
8	RAS Run Duration	min	0 -- 50
9	RAS Rest Duration	min	0 -- 20
10	Permeate Pump Duty Cycle	hr	1--48
11	Permeate Pump Run	min	5--10
12	Permeate Pump Rest	min	1--3
13	Permeate High Discharge Pressure	bar	1--5
14	Low Suction Pressure	bar	0.1 to -0.3bar
15	Low Suction Delay	sec	0 - 60
16	Critical Low Suction Pressure	bar	0.1 to -0.5bar
17	Critical Low Suction Delay	sec	0 - 60
18	MBR Blower Rest Time	min	23:00 - 00:00
19	MBR Blower Restart Time	min	00:00 - 01:00
20	Service Pump Run	min	0-30
21	Service Pump Rest	min	0-30
22	Permeate Pump Scour Delay	min	1-10

Other

Panel Location:	Inside container on container wall.
Possible Future Extra's:	
Other Notes:	

sanas
South African National
Accreditation System

CERTIFICATE OF ACCREDITATION

In terms of section 22(2) (b) of the Accreditation for Conformity Assessment, Calibration and Good Laboratory Practice Act, 2006 (Act 19 of 2006), read with sections 23(1), (2) and (3) of the said Act, I hereby certify that:-

A L ABBOTT AND ASSOCIATES (PTY) LTD
Co. Reg. No.: 1982/004379/07

Facility Accreditation Number: **T0276**

is a South African National Accreditation System accredited facility
provided that all conditions and requirements are complied with

This certificate is valid as per the scope as stated in the accompanying schedule of accreditation, Annexure "A", bearing the above accreditation number for

CHEMICAL AND MICROBIOLOGICAL ANALYSIS

The facility is accredited in accordance with the recognised International Standard

ISO/IEC 17025:2017

The accreditation demonstrates technical competency for a defined scope and the operation of a quality management system

While this certificate remains valid, the Accredited Facility named above is authorised to use the relevant accreditation symbol to issue facility reports and/or certificates

Mr M Phaloane
Acting Chief Executive Officer

Effective Date: 30 July 2020
Certificate Expires: 28 May 2025

ANNEXURE A

SCHEDULE OF ACCREDITATION

Facility Number: **T0276**

Permanent Address of Laboratory:
A L Abbott and Associates (Pty) Ltd
1 Vine Park
Vine Road
Woodstock
7925

Technical Signatories:
Mrs N van Binsbergen (All Methods)
Mr JL da Silva (All Methods)
Ms L Schuller [All Chemistry methods]

Postal Address:
P O Box 483
Woodstock, Cape Town
7915

Nominated Representative:
Mrs N van Binsbergen

Tel: 021 448-6340
Fax: 021 448-6342
E-mail: info@alabbott.co.za

Issue No.: 13
Date of Issue: 30 July 2020
Expiry Date: 28 May 2025

Material or Products Tested	Type of Tests/ Properties Measured, Range of Measurement	Standard Specifications, Techniques / Equipment Used
CHEMICAL		
Raw water, Potable water, Domestic water, Industrial water, Saline water, water for Irrigation, Borehole water, Sea water and Waste water	Determination of Chemical oxygen demand by titration	SANS 6048, ALA 2
	Determination of Ammonia	STD Method 4500 NH3-C (1992), ALA 3
	Determination of Electrical Conductivity	STD Method 2510 A, ALA 9
	Determination of pH	SABS 11, ALA 19
	Determination of Chloride by titration	SABS 202, ALA 25
	Determination of Sulphate by colorimetric method	HACH 8051, ALA 24
	Determination of Nitrate by colorimetric method	HACH 8039, ALA 4
	Determination of Turbidity by colorimetric method	HACH 8237, ALA 27
	Determination of Fluoride by colorimetric method	HACH 8029, ALA 29
	Determination of Nitrite by colorimetric method	GRIESS - ILOSVAY'S Reagent, ALA 5
	Determination of Nitrate and Nitrite	Brucine: Method 4B, ALA 4B

Raw water, Potable water, Domestic water, Industrial water, Saline water, water for Irrigation, Borehole water, Sea water and Waste water	Determination of Total Suspended Solids (Mg/l)	STD Method 2540 D (1992), ALA 6A
	Determination of Ortho Phosphate (mg/l)	HACH 8114, ALA 10
	The determination of metal by ICP: Calcium, Magnesium, Sodium, Potassium, Silica, Strontium, Antimony, Tin, Barium, Molybdenum, Zinc, Aluminium, Arsenic, Beryllium, Copper, Chromium, Iron, Manganese, Lead, Nickel, Cobalt, Cadmium, Selenium, Vanadium, Boron	Based on SANS 11885:2008, ALA Method 929
	CALCULATIONS:	
	Determination of Calcium Hardness	Standard Methods (18th Edition, 1992) For the Examination of Water and Waste Water
	Determination of Magnesium Hardness	Standard Methods (18th Edition, 1992) For the Examination of Water and Waste Water
	Determination of Total Hardness	Standard Methods (18th Edition, 1992) For the Examination of Water and Waste Water
	Determination of % Sodium	Standard Methods (20th Edition) For the Examination of Water and Waste Water
	Determination of Corrosivity Ratio	Standard Methods (20th Edition) For the Examination of Water and Waste Water
	Determination of pHs	Standard Methods (20th Edition) For the Examination of Water and Waste Water
	Determination of Ryznar Stability Index	Cooling-Water – Towers/ Ryznar.htm
	Determination of Langelier Saturation Index	Cooling-Water – Towers/ Ryznar.htm
	Discrete Analysis (Gallery):	
	Determination of Total Alkalinity	A.L.A Method 94
	Determination of Ammonia	A.L.A Method 95
	Determination of Chloride	A.L.A Method 96
	Determination of Colour	A.L.A Method 97
	Determination of Fluoride	A.L.A Method 98
	Determination of Nitrite	A.L.A Method 99
	Determination of Nitrate	A.L.A Method 100
	Determination of Ortho Phosphate	A.L.A Method 101
	Determination of Sulphate	A.L.A Method 102
MICROBIOLOGY		
Raw water, Potable water, Domestic water, Industrial water, Saline water, water for Irrigation, Borehole water, Sea water and Waste water	*Escherichia coli*	Colilert - 18/Quanti-Tray method for Escherichia coli, ALA 84
	Total Coliforms	Colilert - 18/Quanti-Tray method for ToT. Coliform, ALA 85

Raw water, Potable water, Domestic water, Industrial water, Saline water, water for Irrigation, Borehole water, Sea water and Waste water	Faecal Coliforms	Colilert - 18/Quanti-Tray method for Faecal Coliforms, ALA 86
	Heterotrophic Plate Count	MC-Media Pad
	Enterococci (Entrolert - E)	Entrolert - 24/Quanti-Tray method for enterococci, ALA 87

Original Date of Accreditation: 29 May 2005

ISSUED BY THE SOUTH AFRICAN NATIONAL ACCREDITATION SYSTEM

Accreditation Manager

A. L. ABBOTT & ASSOCIATES (PTY) LTD
Reg. No. 1982/004379/07
Established 1964
THE WATER & WASTE WATER SPECIALISTS

Consulting Analytical & Industrial Chemists
Specialists in Water & Waste Water Treatment
Telephone (021)448 6340/1
After Hours (083-3263887)
e-Mail Address :
info@alabbott.co.za

No. 1, Vine Park
Vine Road
7925
P.O. Box 483
WOODSTOCK, CAPE
7915

sanas Testing Laboratory T0276

Certificate of Analysis

ALVEO WATER

ANALYSES

HIGH NOON WWTP

DATE SAMPLED : 2021/06/09

Order Number : JK 2067

DATE RECEIVED : 2021/06/10

OUR REF. : 2021/06/09/15771

DATE ANALYSIS COMMENCED : 2021/06/10

REPORT NO . : 3240

	Sample Number	15771		
Mthd ALA No.	**Analyses**	**Results**	**LIMIT**	**% Uncertainty of Measurement**
19	pH (at 25 ºC)	7.80	5.0 – 9.5	1.5
9	Conductivity (mS/m) (at 25 ºC)	82.0	170	4.5
6A	Total Suspended Solids (mg/l)	<4	25	18
95	Ammonia Nitrogen (mg/l as N)	<0.10	6.0	5.2
100	Nitrate Nitrogen. (mg/l as N)	33.1	15.0	12.6
99	Nitrite Nitrogen (mg/l as N)	<0.20	-	4
66	Free Chlorine (mg/l)	<0.05	0.25	-
101	Ortho Phosphate (mg/l as P)	5.9	10.0	4.8
2	Chemical Oxygen Demand (mg/l)	24.3	75.0	6.8
86	Faecal Coliforms (count per 100 ml)	<1	1000	0.11

Notes:

1. Test marked with an asterisk (*) on attached Appendix 1 (Doc. 7.8#3) are SANAS Accredited and are included in the SANAS Schedule of Accreditation for this laboratory.
2. Schedule of Accreditation excludes sampling. Where applicable pH and Free & Total Chlorine Residual results are supplied by the sampling officer and will be indicated on the Certificate of Analysis. This is marked as "Field".
3. Sampling plans are as requested by the customer. Sampling is done according to A.L. Abbott and Associates (Pty) Ltd sampling procedures which are available on request.
4. Uncertainty of Measurement and Method Description will be provided upon request.
5. Results are reported at the 95% Confidence Interval with a Coverage Factor K = 2.
6. The laboratory does not normally issue any statement of conformity, unless by prior arrangement.
   Decision Rule: Results reflecting on the Certificate of Analysis are actual results as obtained at the time of testing and do not include any uncertainty consideration.
7. The quality and integrity of samples submitted has a direct correlation on the results reported. Results reflected on this report therefore relate only to the sample as received.
8. In the absence of customer specified limits, SANS 241-1:2015 or General Limits will appear, as applicable.
9. This report may not be reproduced, except in full, without the prior written approval of the laboratory.
10. Opinions and interpretations are not included in the Certificate of Analysis.

Sampler : CUSTOMER (PHILASANDE)

A. L. ABBOTT & ASSOCIATES (PTY) LTD
Reg. No. 1982/004379/07
Established 1964
THE WATER & WASTE WATER SPECIALISTS

Consulting Analytical & Industrial Chemists
Specialists in Water & Waste Water Treatment
Telephone (021)448 6340/1
After Hours (083-3263887)
e-Mail Address :
info@alabbott.co.za

No. 1, Vine Park
Vine Road
7925
P.O. Box 483
WOODSTOCK, CAPE
7915

Doc.No. 7.8 # 1 Rev.4

sanas Testing Laboratory
T0276

Certificate of Analysis

ALVEO WATER

ANALYSES

HIGH NOON WWTP

DATE SAMPLED : 2021/06/09

DATE RECEIVED : 2021/06/10

DATE ANALYSIS COMMENCED : 2021/06/10

OUR REF. : 2021/06/09/15771

REPORT NO . : 3240

José Luis da Silva
Digitally signed by José Luis da Silva
Date: 2021.06.25 09:13:30 +02'00'

J.L. DA SILVA (Cert.Sci.Nat.)
TECHNICAL MANAGER
24 June 2021

TO: ALVEO WATER
9 van Zyl Street
Strand
Cape Town, South Africa
Att: service@alveowater.co.za

Sampler : CUSTOMER (PHILASANDE)

This report relates only to the samples tested and is issued subject to the company's standard terms and conditions of business.

A. L. ABBOTT & ASSOCIATES (PTY) LTD
Reg. No. 1982/004379/07
Established 1964
THE WATER & WASTE WATER SPECIALISTS

Consulting Analytical & Industrial Chemists
Specialists in Water & Waste Water Treatment
Telephone (021)448 6340/1
After Hours (083-3263887)
e-Mail Address :
info@alabbott.co.za

No. 1, Vine Park
Vine Road
7925
P.O. Box 483
WOODSTOCK, CAPE
7915

Doc.No. 7.8 # 1 Rev.4

sanas Testing Laboratory T0276

Certificate of Analysis

ALVEO WATER

ANALYSES

HIGH NOON WWTP

DATE SAMPLED : **2021/07/12** **Order Number : JK 2137**

DATE RECEIVED : **2021/07/13** **OUR REF. :** **2021/07/12/19028**

DATE ANALYSIS COMMENCED : **2021/07/13** **REPORT NO . :** **3883**

	Sample Number	19028		
Mthd ALA No.	**Analyses**	**Results**	**LIMIT**	**% Uncertainty of Measurement**
19	pH (at 25 ºC)	6.74	5.0 – 9.5	1.5
9	Conductivity (mS/m) (at 25 ºC)	70.0	170	4.5
6A	Total Suspended Solids (mg/l)	5	25	18
95	Ammonia Nitrogen (mg/l as N)	<0.10	6.0	5.2
100	Nitrate Nitrogen. (mg/l as N)	26.5	15.0	12.6
99	Nitrite Nitrogen (mg/l as N)	<0.20	-	4
66	Free Chlorine (mg/l)	<0.05	0.25	-
101	Ortho Phosphate (mg/l as P)	5.0	10.0	4.8
2	Chemical Oxygen Demand (mg/l)	25.8	75.0	6.8
86	Faecal Coliforms (count per 100 ml)	<1	1000	0.11

Notes:
1. Test marked with an asterisk (*) on attached Appendix 1 (Doc. 7.8#3) are SANAS Accredited and are included in the SANAS Schedule of Accreditation for this laboratory.
2. Schedule of Accreditation excludes sampling. Where applicable pH and Free & Total Chlorine Residual results are supplied by the sampling officer and will be indicated on the Certificate of Analysis. This is marked as "Field".
3. Sampling plans are as requested by the customer. Sampling is done according to A.L. Abbott and Associates (Pty) Ltd sampling procedures which are available on request.
4. Uncertainty of Measurement and Method Description will be provided upon request.
5. Results are reported at the 95% Confidence Interval with a Coverage Factor K = 2.
6. The laboratory does not normally issue any statement of conformity, unless by prior arrangement.
   Decision Rule: Results reflecting on the Certificate of Analysis are actual results as obtained at the time of testing and do not include any uncertainty consideration.
7. The quality and integrity of samples submitted has a direct correlation on the results reported. Results reflected on this report therefore relate only to the sample as received.
8. In the absence of customer specified limits, SANS 241-1:2015 or General Limits will appear, as applicable.
9. This report may not be reproduced, except in full, without the prior written approval of the laboratory.
10. Opinions and interpretations are not included in the Certificate of Analysis.

Sampler : CUSTOMER (GILBERT)

A. L. ABBOTT & ASSOCIATES (PTY) LTD
Reg. No. 1982/004379/07
Established 1964
THE WATER & WASTE WATER SPECIALISTS

Consulting Analytical & Industrial Chemists
Specialists in Water & Waste Water Treatment
Telephone (021)448 6340/1
After Hours (083-3263887)
e-Mail Address :
info@alabbott.co.za

Doc.No. 7.8 # 1 Rev.4

sanas Testing Laboratory
T0276

No. 1, Vine Park
Vine Road
7925
P.O. Box 483
WOODSTOCK, CAPE
7915

Certificate of Analysis

ALVEO WATER

ANALYSES

HIGH NOON WWTP

DATE SAMPLED : 2021/07/12

DATE RECEIVED : 2021/07/13

DATE ANALYSIS COMMENCED : 2021/07/13

OUR REF. : 2021/07/12/19028

REPORT NO . : 3883

Natasia van Binsbergen — Digitally signed by Natasia van Binsbergen Date: 2021.07.26 12:38:53 +02'00'

N. VAN BINSBERGEN (Pr.Sci.Nat.)
DIRECTOR
26 July 2021

TO: ALVEO WATER
9 van Zyl Street
Strand
Cape Town, South Africa
Att: service@alveowater.co.za

Sampler : CUSTOMER (GILBERT)

This report relates only to the samples tested and is issued subject to the company's standard terms and conditions of business.

A. L. ABBOTT & ASSOCIATES (PTY) LTD
Reg. No. 1982/004379/07
Established 1964
THE WATER & WASTE WATER SPECIALISTS

Consulting Analytical & Industrial Chemists
Specialists in Water & Waste Water Treatment
Telephone (021)448 6340/1
After Hours (083-3263887)
e-Mail Address :
info@alabbott.co.za

sanas Testing Laboratory
T0276

No. 1, Vine Park
Vine Road
7925
P.O. Box 483
WOODSTOCK, CAPE
7915

Certificate of Analysis

ALVEO WATER

ANALYSES

HIGH NOON WWTP

DATE SAMPLED : 2021/08/03

Order Number : JK 2196

DATE RECEIVED : 2021/08/04

OUR REF. : 2021/08/03/20918

DATE ANALYSIS COMMENCED : 2021/08/04

REPORT NO . : 4287

	Sample Number	20918		
Mthd ALA No.	**Analyses**	**Results**	**LIMIT**	**% Uncertainty of Measurement**
19	pH (at 25 ºC)	6.70	5.5-9.5	1.5
9	Conductivity (mS/m) (at 25 ºC)	71.5	170	4.5
6A	Total Suspended Solids (mg/l)	<4	25	18
95	Ammonia Nitrogen (mg/l as N)	<0.10	6.0	5.2
100	Nitrate Nitrogen. (mg/l as N)	32.3	15.0	12.6
99	Nitrite Nitrogen (mg/l as N)	<0.20	-	4
66	Free Chlorine (mg/l)	<0.05	0.25	-
101	Ortho Phosphate (mg/l as P)	6.3	10.0	4.8
2	Chemical Oxygen Demand (mg/l)	35.6	75.0	6.8
86	Faecal Coliforms (count per 100 ml)	<1	1000	0.11

Notes:

1. Test marked with an asterisk (*) on attached Appendix 1 (Doc. 7.8#3) are SANAS Accredited and are included in the SANAS Schedule of Accreditation for this laboratory.
2. Schedule of Accreditation excludes sampling. Where applicable pH and Free & Total Chlorine Residual results are supplied by the sampling officer and will be indicated on the Certificate of Analysis. This is marked as "Field".
3. Sampling plans are as requested by the customer. Sampling is done according to A.L. Abbott and Associates (Pty) Ltd sampling procedures which are available on request.
4. Uncertainty of Measurement and Method Description will be provided upon request.
5. Results are reported at the 95% Confidence Interval with a Coverage Factor K = 2.
6. The laboratory does not normally issue any statement of conformity, unless by prior arrangement.
   Decision Rule: Results reflecting on the Certificate of Analysis are actual results as obtained at the time of testing and do not include any uncertainty consideration.
7. The quality and integrity of samples submitted has a direct correlation on the results reported. Results reflected on this report therefore relate only to the sample as received.
8. In the absence of customer specified limits, SANS 241-1:2015 or General Limits will appear, as applicable.
9. This report may not be reproduced, except in full, without the prior written approval of the laboratory.
10. Opinions and interpretations are not included in the Certificate of Analysis.

Sampler : CUSTOMER (JEAN)

A. L. ABBOTT & ASSOCIATES (PTY) LTD
Reg. No. 1982/004379/07
Established 1964
THE WATER & WASTE WATER SPECIALISTS
Consulting Analytical & Industrial Chemists
Specialists in Water & Waste Water Treatment
Telephone (021)448 6340/1
After Hours (083-3263887)
e-Mail Address :
info@alabbott.co.za

Doc.No. 7.8 # 1 Rev.4

sanas Testing Laboratory
T0276

No. 1, Vine Park
Vine Road
7925
P.O. Box 483
WOODSTOCK, CAPE
7915

Certificate of Analysis

ALVEO WATER

ANALYSES

HIGH NOON WWTP

DATE SAMPLED :	**2021/08/03**		
DATE RECEIVED :	**2021/08/04**	**OUR REF. :**	**2021/08/03/20918**
DATE ANALYSIS COMMENCED :	**2021/08/04**	**REPORT NO . :**	**4287**

Natasia van Binsbergen
Digitally signed by Natasia van Binsbergen
Date: 2021.08.16 12:56:31 +02'00'

N. VAN BINSBERGEN (Pr.Sci.Nat.)
DIRECTOR
16 August 2021

TO: ALVEO WATER
9 van Zyl Street
Strand
Cape Town, South Africa
Att: service@alveowater.co.za

Sampler : CUSTOMER (JEAN)

This report relates only to the samples tested and is issued subject to the company's standard terms and conditions of business.

A. L. ABBOTT & ASSOCIATES (PTY) LTD
Reg. No. 1982/004379/07
Established 1964
THE WATER & WASTE WATER SPECIALISTS

Consulting Analytical & Industrial Chemists
Specialists in Water & Waste Water Treatment
Telephone (021)448 6340/1
After Hours (083-3263887)
e-Mail Address :
info@alabbott.co.za

No. 1, Vine Park
Vine Road
7925
P.O. Box 483
WOODSTOCK, CAPE
7915

sanas Testing Laboratory
T0276

Certificate of Analysis

ALVEO WATER

Order Number : JK 2286

DATE SAMPLED: 2021/09/21 **DATE RECEIVED: 2021/09/22** **DATE ANALYSIS COMMENCED: 2021/09/22** **REPORT NO.: 5340**

SAMPLE	Mthd ALA No.	HIGH NOON WWTP Sample 26056	HIGHNOON WWTP-RAW BUFFER Sample 26057	HIGHNOON WWTP-RAW SEWER Sample 26058	LIMIT	% Uncertainty of Measurement
pH (at 25 ºC)	19	7.15	-	-	5.5-9.5	1.5
Conductivity (mS/m) (at 25 ºC)	9	85.0	-	-	150	4.5
Total Suspended Solids (mg/l)	6A	<4	-	-	25	18
Total Kjeldahl Nitrogen (mg/l as N)	15	-	74.0	29.9	-	N/A
Ammonia Nitrogen (mg/l as N)	95	17.2	-	-	6.0	5.2
Free Chlorine (mg/l)	66	<0.05	-	-	0.25	N/A
Chemical Oxygen Demand (mg/l)	2	33.8	839	272	75.0	6.8
Total Phosphate (mg/l as P)	11	-	7.4	2.0	-	N/A
Ortho Phosphate (mg/l as P)	101	6.0	-	-	10.0	4.8
Nitrite Nitrogen (mg/l as N)	100	2.2	-	-	-	10.2
Faecal Coliforms (count per 100 ml)	86	<1	-	-	1000	0.11
Nitrate Nitrogen. (mg/l as N)	N/A	7.4	-	-	15.0	N/A

Sampler : CUSTOMER (SELASSIE)

A. L. ABBOTT & ASSOCIATES (PTY) LTD
Reg. No. 1982/004379/07
Established 1964
THE WATER & WASTE WATER SPECIALISTS

Consulting Analytical & Industrial Chemists
Specialists in Water & Waste Water Treatment
Telephone (021)448 6340/1
After Hours (083-3263887)
e-Mail Address :
info@alabbott.co.za

No. 1, Vine Park
Vine Road
7925
P.O. Box 483
WOODSTOCK, CAPE
7915

sanas Testing Laboratory
T0276

Certificate of Analysis

ALVEO WATER

Order Number : JK 2286

Notes:

1. Test marked with an asterisk (*) on attached Appendix 1 (Doc. 7.8#3) are SANAS Accredited and are included in the SANAS Schedule of Accreditation for this laboratory.
2. Schedule of Accreditation excludes sampling. Where applicable pH and Free & Total Chlorine Residual results are supplied by the sampling officer and will be indicated on the Certificate of Analysis. This is marked as “Field”.
3. Sampling plans are as requested by the customer. Sampling is done according to A.L. Abbott and Associates (Pty) Ltd sampling procedures which are available on request.
4. Uncertainty of Measurement and Method Description will be provided upon request.
5. Results are reported at the 95% Confidence Interval with a Coverage Factor K = 2.
6. The laboratory does not normally issue any statement of conformity, unless by prior arrangement.
   Decision Rule: Results reflecting on the Certificate of Analysis are actual results as obtained at the time of testing and do not include any uncertainty consideration.
7. The quality and integrity of samples submitted has a direct correlation on the results reported. Results reflected on this report therefore relate only to the sample as received.
8. In the absence of customer specified limits, SANS 241-1:2015 or General Limits will appear, as applicable.
9. This report may not be reproduced, except in full, without the prior written approval of the laboratory.
10. Opinions and interpretations are not included in the Certificate of Analysis.

Natasia van Binsbergen
Digitally signed by Natasia van Binsbergen
Date: 2021.10.04 08:59:43 +02'00'

N. VAN BINSBERGEN (Pr.Sci.Nat.)
DIRECTOR
01 October 2021

TO: ALVEO WATER
9 van Zyl Street
Strand
Cape Town, South Africa
Att: service@alveowater.co.za

Sampler : CUSTOMER (SELASSIE)

This report relates only to the samples tested and is issued subject to the company’s standard terms and conditions of business.

A. L. ABBOTT & ASSOCIATES (PTY) LTD
Reg. No. 1982/004379/07
Established 1964
THE WATER & WASTE WATER SPECIALISTS
Consulting Analytical & Industrial Chemists
Specialists in Water & Waste Water Treatment
Telephone (021)448 6340/1
After Hours (083-3263887)
e-Mail Address :
info@alabbott.co.za

Doc.No. 7.8 # 1 Rev.4

No. 1, Vine Park
Vine Road
7925
P.O. Box 483
WOODSTOCK, CAPE
7915

sanas Testing Laboratory
T0276

Certificate of Analysis

ALVEO WATER

ANALYSES

HIGH NOON PERMEATE

DATE SAMPLED : **2021/10/12**

Order Number : JK 2331

DATE RECEIVED : **2021/10/13**

OUR REF. : **2021/10/12/28131**

DATE ANALYSIS COMMENCED : **2021/10/13**

REPORT NO . : **5760**

	Sample Number	28131		
Mthd ALA No.	**Analyses**	**Results**	**LIMITS**	**% Uncertainty of Measurement**
19	pH (at 25 ºC)	7.21	5.5 – 9.5	1.5
9	Conductivity (mS/m) (at 25 ºC)	72.0	150	4.5
6A	Total Suspended Solids (mg/l)	6	25	18
95	Ammonia Nitrogen (mg/l as N)	<0.10	6.0	5.2
100	Nitrate Nitrogen. (mg/l as N)	12.7	15.0	12.6
99	Nitrite Nitrogen (mg/l as N)	<0.20	-	4
66	Free Chlorine (mg/l)	<0.05	0.25	-
101	Ortho Phosphate (mg/l as P)	7.1	10.0	4.8
2	Chemical Oxygen Demand (mg/l)	13.6	75.0	6.8
86	Faecal Coliforms (count per 100 ml)	<1	1000	7

Notes:
1. Test marked with an asterisk (*) on attached Appendix 1 (Doc. 7.8#3) are SANAS Accredited and are included in the SANAS Schedule of Accreditation for this laboratory.
2. Schedule of Accreditation excludes sampling. Where applicable pH and Free & Total Chlorine Residual results are supplied by the sampling officer and will be indicated on the Certificate of Analysis. This is marked as "Field".
3. Sampling plans are as requested by the customer. Sampling is done according to A.L. Abbott and Associates (Pty) Ltd sampling procedures which are available on request.
4. Uncertainty of Measurement and Method Description will be provided upon request.
5. Results are reported at the 95% Confidence Interval with a Coverage Factor K = 2.
6. The laboratory does not normally issue any statement of conformity, unless by prior arrangement.
   Decision Rule: Results reflecting on the Certificate of Analysis are actual results as obtained at the time of testing and do not include any uncertainty consideration.
7. The quality and integrity of samples submitted has a direct correlation on the results reported. Results reflected on this report therefore relate only to the sample as received.
8. In the absence of customer specified limits, SANS 241-1:2015 or General Limits will appear, as applicable.
9. This report may not be reproduced, except in full, without the prior written approval of the laboratory.
10. Opinions and interpretations are not included in the Certificate of Analysis.

Sampler : CUSTOMER (JEAN)

This report relates only to the samples tested and is issued subject to the company's standard terms and conditions of business.

A. L. ABBOTT & ASSOCIATES (PTY) LTD
Reg. No. 1982/004379/07
Established 1964
THE WATER & WASTE WATER SPECIALISTS

Consulting Analytical & Industrial Chemists
Specialists in Water & Waste Water Treatment
Telephone (021)448 6340/1
After Hours (083-3263887)
e-Mail Address :
info@alabbott.co.za

No. 1, Vine Park
Vine Road
7925
P.O. Box 483
WOODSTOCK, CAPE
7915

Doc.No. 7.8 # 1 Rev.4

sanas Testing Laboratory
T0276

Certificate of Analysis

ALVEO WATER

ANALYSES

HIGH NOON PERMEATE

DATE SAMPLED :	**2021/10/12**
DATE RECEIVED :	**2021/10/13**
DATE ANALYSIS COMMENCED :	**2021/10/13**

OUR REF. : **2021/10/12/28131**
REPORT NO . : **5760**

José Luis da Silva
Digitally signed by José Luis da Silva
Date: 2021.10.21 14:07:57 +02'00'

J.L. DA SILVA (Cert.Sci.Nat.)
TECHNICAL MANAGER
21 October 2021

TO: ALVEO WATER
9 van Zyl Street
Strand
Cape Town, South Africa
Att: service@alveowater.co.za

Sampler : CUSTOMER (JEAN)

This report relates only to the samples tested and is issued subject to the company's standard terms and conditions of business.

A. L. ABBOTT & ASSOCIATES (PTY) LTD
Reg. No. 1982/004379/07
Established 1964
THE WATER & WASTE WATER SPECIALISTS

Consulting Analytical & Industrial Chemists
Specialists in Water & Waste Water Treatment
Telephone (021)448 6340/1
After Hours (083-3263887)
e-Mail Address :
info@alabbott.co.za

No. 1, Vine Park
Vine Road
7925
P.O. Box 483
WOODSTOCK, CAPE
7915

sanas Testing Laboratory
T0276

Certificate of Analysis

ALVEO WATER

ANALYSES

HIGH NOON WWTP

DATE SAMPLED : 2021/11/09

Order Number : JK 2359

DATE RECEIVED : 2021/11/10

OUR REF. : 2021/11/09/30729

DATE ANALYSIS COMMENCED : 2021/11/10

REPORT NO . : 6311

	Sample Number	30729		
Mthd ALA No.	**Analyses**	**Results**	**LIMITS**	**% Uncertainty of Measurement**
19	pH (at 25 ºC)	7.22	5.5 – 9.5	1.5
9	Conductivity (mS/m) (at 25 ºC)	48.5	150	4.5
6A	Total Suspended Solids (mg/l)	5	25	18
95	Ammonia Nitrogen (mg/l as N)	0.18	6.0	5.2
100	Nitrate Nitrogen. (mg/l as N)	4.2	15.0	12.6
99	Nitrite Nitrogen (mg/l as N)	<0.20	-	4
66	Free Chlorine (mg/l)	<0.05	0.25	-
101	Ortho Phosphate (mg/l as P)	5.0	10.0	4.8
2	Chemical Oxygen Demand (mg/l)	57.4	75.0	6.8
86	Faecal Coliforms (count per 100 ml)	<1	1000	7

Notes:

1. Test marked with an asterisk (*) on attached Appendix 1 (Doc. 7.8#3) are SANAS Accredited and are included in the SANAS Schedule of Accreditation for this laboratory.
2. Schedule of Accreditation excludes sampling. Where applicable pH and Free & Total Chlorine Residual results are supplied by the sampling officer and will be indicated on the Certificate of Analysis. This is marked as “Field”.
3. Sampling plans are as requested by the customer. Sampling is done according to A.L. Abbott and Associates (Pty) Ltd sampling procedures which are available on request.
4. Uncertainty of Measurement and Method Description will be provided upon request.
5. Results are reported at the 95% Confidence Interval with a Coverage Factor K = 2.
6. The laboratory does not normally issue any statement of conformity, unless by prior arrangement.
   Decision Rule: Results reflecting on the Certificate of Analysis are actual results as obtained at the time of testing and do not include any uncertainty consideration.
7. The quality and integrity of samples submitted has a direct correlation on the results reported. Results reflected on this report therefore relate only to the sample as received.
8. In the absence of customer specified limits, SANS 241-1:2015 or General Limits will appear, as applicable.
9. This report may not be reproduced, except in full, without the prior written approval of the laboratory.
10. Opinions and interpretations are not included in the Certificate of Analysis.

Sampler : CUSTOMER (NICO SWART)

A. L. ABBOTT & ASSOCIATES (PTY) LTD
Reg. No. 1982/004379/07
Established 1964
THE WATER & WASTE WATER SPECIALISTS
Consulting Analytical & Industrial Chemists
Specialists in Water & Waste Water Treatment
Telephone (021)448 6340/1
After Hours (083-3263887)
e-Mail Address :
info@alabbott.co.za

Doc.No. 7.8 # 1 Rev.4

sanas Testing Laboratory
T0276

No. 1, Vine Park
Vine Road
7925
P.O. Box 483
WOODSTOCK, CAPE
7915

Certificate of Analysis

ALVEO WATER

ANALYSES

HIGH NOON WWTP

DATE SAMPLED : **2021/11/09**

DATE RECEIVED : **2021/11/10**

OUR REF. : **2021/11/09/30729**

DATE ANALYSIS COMMENCED : **2021/11/10**

REPORT NO . : **6311**

Natasia van Binsbergen
Digitally signed by Natasia van Binsbergen
Date: 2021.11.17 10:54:22 +02'00'

N. VAN BINSBERGEN (Pr.Sci.Nat.)
DIRECTOR
17 November 2021

TO: ALVEO WATER
9 van Zyl Street
Strand
Cape Town, South Africa

Att: service@alveowater.co.za

Sampler : CUSTOMER (NICO SWART)

This report relates only to the samples tested and is issued subject to the company's standard terms and conditions of business.

A. L. ABBOTT & ASSOCIATES (PTY) LTD
Reg. No. 1982/004379/07
Established 1964
THE WATER & WASTE WATER SPECIALISTS

Consulting Analytical & Industrial Chemists
Specialists in Water & Waste Water Treatment
Telephone (021)448 6340/1
After Hours (083-3263887)
e-Mail Address :
info@alabbott.co.za

No. 1, Vine Park
Vine Road
7925
P.O. Box 483
WOODSTOCK, CAPE
7915

sanas Testing Laboratory
T0276

Certificate of Analysis

ALVEO WATER

ANALYSES

HIGH NOON WWTP

DATE SAMPLED : 2021/12/15

Order Number : JK 2407

DATE RECEIVED : 2021/12/15

OUR REF. : 2021/12/15/34944

DATE ANALYSIS COMMENCED : 2021/12/15

REPORT NO . : 7152

	Sample Number	34944		
Mthd ALA No.	**Analyses**	**Results**	**LIMITS**	**% Uncertainty of Measurement**
19	pH (at 25 ºC)	7.55	5.5 – 9.5	1.5
9	Conductivity (mS/m) (at 25 ºC)	72.0	150	4.5
6A	Total Suspended Solids (mg/l)	<4	25	18
95	Ammonia Nitrogen (mg/l as N)	18.8	6.0	5.2
100	Nitrate Nitrogen. (mg/l as N)	0.77	15.0	12.6
99	Nitrite Nitrogen (mg/l as N)	<0.20	-	4
66	Free Chlorine (mg/l)	<0.05	0.25	-
10	Ortho Phosphate (mg/l as P)	0.65	10.0	4
2	Chemical Oxygen Demand (mg/l)	75.1	75.0	6.8
86	Faecal Coliforms (count per 100 ml)	<1	1000	7

Notes:

1. Test marked with an asterisk (*) on attached Appendix 1 (Doc. 7.8#3) are SANAS Accredited and are included in the SANAS Schedule of Accreditation for this laboratory.
2. Schedule of Accreditation excludes sampling. Where applicable pH and Free & Total Chlorine Residual results are supplied by the sampling officer and will be indicated on the Certificate of Analysis. This is marked as "Field".
3. Sampling plans are as requested by the customer. Sampling is done according to A.L. Abbott and Associates (Pty) Ltd sampling procedures which are available on request.
4. Uncertainty of Measurement and Method Description will be provided upon request.
5. Results are reported at the 95% Confidence Interval with a Coverage Factor K = 2.
6. The laboratory does not normally issue any statement of conformity, unless by prior arrangement.
   Decision Rule: Results reflecting on the Certificate of Analysis are actual results as obtained at the time of testing and do not include any uncertainty consideration.
7. The quality and integrity of samples submitted has a direct correlation on the results reported. Results reflected on this report therefore relate only to the sample as received.
8. In the absence of customer specified limits, SANS 241-1:2015 or General Limits will appear, as applicable.
9. This report may not be reproduced, except in full, without the prior written approval of the laboratory.
10. Opinions and interpretations are not included in the Certificate of Analysis.

Sampler : CUSTOMER (PHILA)

A. L. ABBOTT & ASSOCIATES (PTY) LTD
Reg. No. 1982/004379/07
Established 1964
THE WATER & WASTE WATER SPECIALISTS
Consulting Analytical & Industrial Chemists
Specialists in Water & Waste Water Treatment
Telephone (021)448 6340/1
After Hours (083-3263887)
e-Mail Address :
info@alabbott.co.za

Doc.No. 7.8 # 1 Rev.4

sanas Testing Laboratory
T0276

No. 1, Vine Park
Vine Road
7925
P.O. Box 483
WOODSTOCK, CAPE
7915

Certificate of Analysis

ALVEO WATER

ANALYSES

HIGH NOON WWTP

DATE SAMPLED : **2021/12/15**

DATE RECEIVED : **2021/12/15**

DATE ANALYSIS COMMENCED : **2021/12/15**

OUR REF. : **2021/12/15/34944**

REPORT NO . : **7152**

Natasia van Binsbergen
Digitally signed by Natasia van Binsbergen
Date: 2021.12.21 12:53:34 +02'00'

N. VAN BINSBERGEN (Pr.Sci.Nat.)
DIRECTOR
21 December 2021

TO: ALVEO WATER
9 van Zyl Street
Strand
Cape Town, South Africa

Att: service@alveowater.co.za

Sampler : CUSTOMER (PHILA)

This report relates only to the samples tested and is issued subject to the company's standard terms and conditions of business.

A. L. ABBOTT & ASSOCIATES (PTY) LTD
Reg. No. 1982/004379/07
Established 1964
THE WATER & WASTE WATER SPECIALISTS

Consulting Analytical & Industrial Chemists
Specialists in Water & Waste Water Treatment
Telephone (021)448 6340/1
After Hours (083-3263887)
e-Mail Address :
info@alabbott.co.za

No. 1, Vine Park
Vine Road
7925
P.O. Box 483
WOODSTOCK, CAPE
7915

Doc.No. 7.8 # 1 Rev.4

sanas Testing Laboratory
T0276

Certificate of Analysis

ALVEO WATER

ANALYSES

HIGH NOON WWTP

DATE SAMPLED : **2022/01/28** **Order Number : JK 2452**

DATE RECEIVED : **2022/01/28** **OUR REF. :** **2022/01/28/2917**

DATE ANALYSIS COMMENCED : **2022/01/28** **REPORT NO . :** **557**

	Sample Number	2917		
Mthd ALA No.	**Analyses**	**Results**	**LIMITS**	**% Uncertainty of Measurement**
19	pH (at 25 ºC)	6.14	5.0 - 9.5	1.5
9	Conductivity (mS/m) (at 25 ºC)	56.5	170 mS/m	4.5
6A	Total Suspended Solids (mg/l)	5	25 mg/l	18
95	Ammonia Nitrogen (mg/l as N)	0.30	6 mg/l	5.2
100	Nitrate Nitrogen. (mg/l as N)	35.1	15 mg/l	12.6
99	Nitrite Nitrogen (mg/l as N)	<0.20	15 mg/l	4
66	Free Chlorine (mg/l)	<0.05	0.25 mg/l	-
101	Ortho Phosphate (mg/l as P)	8.0	10 mg/l	4.8
2	Chemical Oxygen Demand (mg/l)	21.2	75 mg/l	6.8
86	Faecal Coliforms (count per 100 ml)	<1	1000 cfu/100 ml	7

Sampler : CUSTOMER (PAUL)

A. L. ABBOTT & ASSOCIATES (PTY) LTD
Reg. No. 1982/004379/07
Established 1964
THE WATER & WASTE WATER SPECIALISTS

Doc.No. 7.8 # 1 Rev.4

Consulting Analytical & Industrial Chemists
Specialists in Water & Waste Water Treatment
Telephone (021)448 6340/1
After Hours (083-3263887)
e-Mail Address :
info@alabbott.co.za

sanas Testing Laboratory
T0276

No. 1, Vine Park
Vine Road
7925
P.O. Box 483
WOODSTOCK, CAPE
7915

Certificate of Analysis

ALVEO WATER

ANALYSES

HIGH NOON WWTP

DATE SAMPLED :	**2022/01/28**		
DATE RECEIVED :	**2022/01/28**	**OUR REF. :**	**2022/01/28/2917**
DATE ANALYSIS COMMENCED :	**2022/01/28**	**REPORT NO . :**	**557**

Notes:

1. Test marked with an asterisk (*) on attached Appendix 1 (Doc. 7.8#3) are SANAS Accredited and are included in the SANAS Schedule of Accreditation for this laboratory.
2. Schedule of Accreditation excludes sampling. Where applicable pH and Free & Total Chlorine Residual results are supplied by the sampling officer and will be indicated on the Certificate of Analysis. This is marked as “Field”.
3. Sampling plans are as requested by the customer. Sampling is done according to A.L. Abbott and Associates (Pty) Ltd sampling procedures which are available on request.
4. Uncertainty of Measurement and Method Description will be provided upon request.
5. Results are reported at the 95% Confidence Interval with a Coverage Factor K = 2.
6. The laboratory does not normally issue any statement of conformity, unless by prior arrangement.
   Decision Rule: Results reflecting on the Certificate of Analysis are actual results as obtained at the time of testing and do not include any uncertainty consideration.
7. The quality and integrity of samples submitted has a direct correlation on the results reported. Results reflected on this report therefore relate only to the sample as received.
8. In the absence of customer specified limits, SANS 241-1:2015 or General Limits will appear, as applicable.
9. This report may not be reproduced, except in full, without the prior written approval of the laboratory.
10. Opinions and interpretations are not included in the Certificate of Analysis.

José Luis da Silva
Digitally signed by José Luis da Silva
Date: 2022.02.07 09:35:37 +02'00'

J.L. DA SILVA (Cert.Sci.Nat.)
TECHNICAL MANAGER
07 February 2022

TO: ALVEO WATER
9 van Zyl Street
Strand
Cape Town, South Africa
Att: service@alveowater.co.za

Sampler : CUSTOMER (PAUL)

This report relates only to the samples tested and is issued subject to the company’s standard terms and conditions of business.

A. L. ABBOTT & ASSOCIATES (PTY) LTD
Reg. No. 1982/004379/07
Established 1964
THE WATER & WASTE WATER SPECIALISTS

No.1, Vine Park
Vine Road
7925
P.O. Box 483
WOODSTOCK, CAPE
7915
SOUTH AFRICA
Telephone: (021) 448 6340/1
After Hours: 083-3263887
E-Mail Address: info@alabbott.co.za

22/583

11 February 2022

ALVEO WATER
9 Van Zyl Street,
Gants Plaza
STRAND
7140

Dear Sir,

<u>CLASSIFICATION OF SLUDGE : HIGH NOON (JK 2445)</u>

We attach our classification of sludge from High Noon, received on 28th January 2022.

Disposal options are included.

Yours faithfully,

....

N. VAN BINSBERGEN Pr.Sci.Nat.
DIRECTOR

A. L. ABBOTT & ASSOCIATES (PTY) LTD
Reg. No. 1982/004379/07
Established 1964
THE WATER & WASTE WATER SPECIALISTS

Doc.No. 7.8 # 1 Rev.4

sanas Testing Laboratory
(No. T0276)

No.1, Vine Park
Vine Road
7925
P.O. Box 483
WOODSTOCK, CAPE
7915
SOUTH AFRICA
Telephone: (021) 448 6340/1
After Hours: 083-3263887
E-Mail Address: info@alabbott.co.za

Certificate of Analysis

ALVEO WATER

Sample : **One Sample of Sludge (ex High Noon)**

Date Received : **28 January 2022** **Lab. Data Sheet No.: 22/583**

Your Ref. : **JK 2445**

Our Ref. : **bm/583**
11 February 2022

		HIGH NOON
Physical Characteristics :	pH	5.80
	Total Solids (%)	92.2
	Volatile Solids (%)	48.9
	Volatile Fraction (%)	53.0
	Volatile Fatty Acids (%)	0.02

		HIGH NOON
Nutrients :	Total Kjeldahl Nitrogen (mg/kg as N)	28188
	Total Phosphate (mg/kg as P)	4208
	Potassium (mg/kg as K)	1835

		HIGH NOON	Classification
Metal Limits and Micro Elements :	**Metal Limits :**		
	Arsenic (mg/kg as As)	0.042	**a**
	Cadmium (mg/kg as Cd)	0.64	**a**
	Chromium (mg/kg as Cr)	7.1	**a**
	Copper (mg/kg as Cu)	105	**a**
	Lead (mg/kg as Pb)	16.8	**a**
	Mercury (mg/kg as Hg)	0.004	**a**
	Nickel (mg/kg as Ni)	6.3	**a**
	Zinc (mg/kg as Zn)	375	**a**

		HIGH NOON	Classification
Microbiological Quality :	Faecal Coliforms (organisms per g)	22000	**B**
	Total Viable Helminth Ova (ova/4 g)	**To Follow**	**To Follow**

NOTES:	1.	Routine analysis of organic pollutants is not required for domestic sludge.
	2.	According to O'Shaunessy's formula, the volatile solids reduction was 78.5% = Stability Class 1

CHARACTERISATION AND PRELIMINARY CLASSIFICATION OF SLUDGE FROM HIGH NOON

	HIGH NOON SLUDGE
Sludge Type	Sludge
Sampling Point	Unknown
Microbiological Parameters	To Follow
Vector Attraction Reduction Options Applied	1
Pollutant Class	a
Classification	To Follow

....
N. VAN BINSBERGEN Pr.Sci.Nat.
DIRECTOR

bm/583
11 February 2022

TO: ALVEO WATER
9 Van Zyl Street
Gants Plaza
STRAND
7140

TABLE 8: USING THE PRELIMINARY MICROBIOLOGICAL CLASSIFICATION TO ASSESS THE APPROPRIATENESS OF A MANAGEMENT OPTION

Class	Management option	Appropriate Sludge Guideline	Appropriateness of this option?	What are the major restrictions in terms of the Microbiological class?
Microbiological class A	Agricultural use at agronomic rates	Volume 2	Yes (i)	None.
	On-site or off-site disposal	Volume 3	May be (iii)	It is an inappropriate option for the disposal of a disinfected sludge. Disinfection technologies are costly and this management option therefore represents wasting of potential resource recovery.
	Beneficial use (other than agricultural use at agronomic rates)	Volume 4	Yes (i)	None pertain to this Microbiological class.
	Thermal treatment methods	Volume 5	No (v)	It is not recommended to use thermal methods, such as incineration to manage a Microbiological class A sludge, as it was costly to achieve this classification in the first place.
	Produce saleable products	Volume 5	Yes (i)	Most saleable products will require disinfection process.
Microbiological class B	Agricultural use at agronomic rates	Volume 2	Qualified yes (ii)	May not be appropriate for some crops with edible parts below the soil surface.
	On-site or off-site disposal	Volume 3	May be (iii)	It could potentially be used beneficially, as this is a partially disinfected product.
	Beneficial use (other than agricultural use at agronomic rates)	Volume 4	May be (iii)	Due to the incomplete disinfection process it could affect the beneficial use depending on the application.
	Thermal treatment methods	Volume 5	Qualified no (iv)	It is not recommended to use thermal methods, such as incineration to manage a Microbiological class B sludge, as it was costly to achieve this classification.
	Produce saleable products	Volume 5	Qualified no (iv)	Due to the incomplete disinfection process it could influence the quality of the product.
Microbiological class C	Agricultural use at agronomic rates	Volume 2	Qualified no (iv)	Microbiological class C sludge can only be used if stability class 1 or 2 is achieved. Restrictions to crop types also apply.
	On-site or off-site disposal	Volume 3	Yes (i)	None.
	Beneficial use (other than agricultural use at agronomic rates)	Volume 4	Qualified no (iv)	Care should be taken not to expose the public and workers to pathogens.
	Thermal treatment methods	Volume 5	Yes (i)	Thermal process is an appropriate technology for this microbiological class.
	Produce saleable products	Volume 5	No (v)	Risk of infection is unacceptable.

TABLE 9: USING THE PRELIMINARY STABILITY CLASSIFICATION TO ASSESS THE APPROPRIATENESS OF A MANAGEMENT OPTION

Class	Management option	Appropriate Sludge Guideline	Appropriateness of this option?	What are the major restrictions in terms of the Stability class?
Stability class 1	Agricultural use at agronomic rates	Volume 2	Yes (i)	None.
	On-site or off-site disposal	Volume 3	Yes (i)	None. Note that vector attraction reduction options 9 and 10 do not apply.
	Beneficial use (other than agricultural use at agronomic rates)	Volume 4	Qualified yes (ii)	Vector attraction reduction options 1 to 8 would be appropriate.
	Thermal treatment methods	Volume 5	May be (iii)	Vector attraction reduction options 7 and 8 or an appropriate dewatering step should be applied as a pre-treatment step before thermal treatment.
	Produce saleable products	Volume 5	Yes (i)	Long-term stability would be required for saleable products.
Stability class 2	Agricultural use at agronomic rates	Volume 2	Qualified yes (ii)	Due to the reliability of the vector attraction reduction measures implemented, additional management systems may be required.
	On-site or off-site disposal	Volume 3	Qualified yes (ii)	Vector attraction options 9 and 10 do not apply. Make sure that the vector reduction processes are reliable to prevent odours or other nuisances.
	Beneficial use (other than agricultural use at agronomic rates)	Volume 4	May be (iii)	This will depend on the beneficial use selected
	Thermal treatment methods	Volume 5	Qualified yes (ii)	Vector attraction reduction options 7 and 8 or an appropriate dewatering step should be applied as a pre-treatment step before thermal treatment.
	Produce saleable products	Volume 5	Qualified no (iv)	Long-term stability is required for saleable products and the reliability of this Stability class may not be appropriate.
Stability class 3	Agricultural use at agronomic rates	Volume 2	No (v)	At least one vector attraction reduction option should be implemented.
	On-site or off-site disposal	Volume 3	Qualified no (iv)	Unstable sludges such as raw/primary sludge may not be accepted at landfill sites.
	Beneficial use (other than agricultural use at agronomic rates)	Volume 4	Qualified no (iv)	Care should be taken not to expose the public and workers to unstable sludge.
	Thermal treatment methods	Volume 5	Yes (i)	Vector attraction options 9 and 10 do not apply. Make sure that the vector reduction processes are reliable to prevent odours or other nuisances.
	Produce saleable products	Volume 5	No (v)	The product is not stable and the public will find this unacceptable.

TABLE 10: USING THE PRELIMINARY POLLUTANT CLASSIFICATION TO ASSESS THE APPROPRIATENESS OF A MANAGEMENT OPTION

Class	Management option	Appropriate Sludge Guideline	Appropriateness of this option?	What are the major restrictions in terms of the Pollutant class?
Pollutant class a	Agricultural use at agronomic rates	Volume 2	Yes (i)	No limitations apart from the sludge application rate should not exceed agronomic rates.
	On-site or off-site disposal	Volume 3	Qualified no (iv)	This sludge should not be disposed off as it is a high quality product that should be used beneficially.
	Beneficial use (other than agricultural use at agronomic rates)	Volume 4	Yes (i)	No limitations with regard to the pollutant class, for the beneficial uses identified in this Volume.
	Thermal treatment methods	Volume 5	Yes (i)	Thermal process will have limited environmental impacts in respect of the metals.
	Produce saleable products	Volume 5	Yes (i)	No limitations with regard to the Pollutant class. (This excludes the production of edible products from sludge).
Pollutant class b	Agricultural use at agronomic rates	Volume 2	Qualified yes (ii)	Additional analyses will be required to assess whether the receiving soil can accommodate the load.
	On-site or off-site disposal	Volume 3	May be (iii)	Delisting according to the Minimum Requirements will be required.
	Beneficial use (other than agricultural use at agronomic rates)	Volume 4	May be (iii)	High rate application of this sludge could cause long-term effects and source control should be implemented.
	Thermal treatment methods	Volume 5	Qualified yes (ii)	Emissions of gaseous contaminants and the ash should be monitored and managed.
	Produce saleable products	Volume 5	May be (iii)	This depends on the product.
Pollutant class c	Agricultural use at agronomic rates	Volume 2	No (v)	The sludge metal content is too high for agricultural use. Source control should be implemented.
	On-site or off-site disposal	Volume 3	May be (iii)	Delisting according to the Minimum Requirements will be required.
	Beneficial use (other than agricultural use at agronomic rates)	Volume 4	Qualified no (iv)	High rate application of this sludge could cause long-term effects and source control should be implemented.
	Thermal treatment methods	Volume 5	Qualified yes (ii)	Emissions of gaseous contaminants and the ash should be monitored and managed.
	Produce saleable products	Volume 5	May be (iii)	This depends on the product.

Doc.No. 7.8 # 1 Rev.4

A. L. ABBOTT & ASSOCIATES (PTY) LTD
Reg. No. 1982/004379/07
Established 1964
THE WATER & WASTE WATER SPECIALISTS

Consulting Analytical & Industrial Chemists
Specialists in Water & Waste Water Treatment
Telephone (021)448 6340/1
After Hours (083-3263887)
e-Mail Address :
info@alabbott.co.za

No. 1, Vine Park
Vine Road
7925
P.O. Box 483
WOODSTOCK, CAPE
7915

sanas Testing Laboratory
T0276

Certificate of Analysis

ALVEO WATER

Order Number : JK 2197

DATE SAMPLED: 2021/08/03 **DATE RECEIVED: 2021/08/04** **DATE ANALYSIS COMMENCED: 2021/08/04** **REPORT NO.: 4288**

SAMPLE	Mthd ALA No.	HIGHNOON BEFORE ANOXIC Sample 20919	HIGHNOON RAW Sample 20920	LIMIT	% Uncertainty of Measurement
pH (at 25 ºC)	19	6.76	6.54	5.0 – 9.5	1.5
Conductivity (mS/m) (at 25 ºC)	9	98.5	76.5	170	4.5
Total Suspended Solids (mg/l)	6A	160	785	25	18
Total Kjeldahl Nitrogen (mg/l as N)	15	-	66.0	-	N/A
Ammonia Nitrogen (mg/l as N)	95	58.3	44.0	6.0	5.2
Free Chlorine (mg/l)	66	<0.05	<0.05	0.25	N/A
Chemical Oxygen Demand (mg/l)	2	494	1388	75.0	6.8
Total Phosphate (mg/l as P)	11	-	16.5	-	N/A
Ortho Phosphate (mg/l as P)	101	5.7	5.6	10.0	4.8
Nitrite Nitrogen (mg/l as N)	100	<0.20	<0.20	-	10.2
Nitrate Nitrogen. (mg/l as N)	N/A	0.59	<0.20	15.0	N/A

Sampler : CUSTOMER (JEAN)

A. L. ABBOTT & ASSOCIATES (PTY) LTD
Reg. No. 1982/004379/07
Established 1964
THE WATER & WASTE WATER SPECIALISTS

Consulting Analytical & Industrial Chemists
Specialists in Water & Waste Water Treatment
Telephone (021)448 6340/1
After Hours (083-3263887)
e-Mail Address :
info@alabbott.co.za

sanas Testing Laboratory
T0276

No. 1, Vine Park
Vine Road
7925
P.O. Box 483
WOODSTOCK, CAPE
7915

Certificate of Analysis

ALVEO WATER

Order Number : JK 2197

Notes:

1. Test marked with an asterisk (*) on attached Appendix 1 (Doc. 7.8#3) are SANAS Accredited and are included in the SANAS Schedule of Accreditation for this laboratory.
2. Schedule of Accreditation excludes sampling. Where applicable pH and Free & Total Chlorine Residual results are supplied by the sampling officer and will be indicated on the Certificate of Analysis. This is marked as “Field”.
3. Sampling plans are as requested by the customer. Sampling is done according to A.L. Abbott and Associates (Pty) Ltd sampling procedures which are available on request.
4. Uncertainty of Measurement and Method Description will be provided upon request.
5. Results are reported at the 95% Confidence Interval with a Coverage Factor K = 2.
6. The laboratory does not normally issue any statement of conformity, unless by prior arrangement.
   Decision Rule: Results reflecting on the Certificate of Analysis are actual results as obtained at the time of testing and do not include any uncertainty consideration.
7. The quality and integrity of samples submitted has a direct correlation on the results reported. Results reflected on this report therefore relate only to the sample as received.
8. In the absence of customer specified limits, SANS 241-1:2015 or General Limits will appear, as applicable.
9. This report may not be reproduced, except in full, without the prior written approval of the laboratory.
10. Opinions and interpretations are not included in the Certificate of Analysis.

Natasia van Binsbergen

Digitally signed by Natasia van Binsbergen
Date: 2021.08.16 13:02:24 +02'00'

N. VAN BINSBERGEN (Pr.Sci.Nat.)
DIRECTOR
16 August 2021

TO: ALVEO WATER
9 van Zyl Street
Strand
Cape Town, South Africa
Att: service@alveowater.co.za

Sampler : CUSTOMER (JEAN)

This report relates only to the samples tested and is issued subject to the company’s standard terms and conditions of business.

A. L. ABBOTT & ASSOCIATES (PTY) LTD
Reg. No. 1982/004379/07 Established 1964
THE WATER & WASTE WATER SPECIALISTS

Report: 5340

Doc.No. 7.8 # 1 Rev.4

Consulting Analytical & Industrial Chemists
Specialists in Water & Waste Water Treatment
Telephone (021)448 6340/1
After Hours (083-3263887)
e-Mail Address :
info@alabbott.co.za

No. 1, Vine Park
Vine Road
7925
P.O. Box 483
WOODSTOCK, CAPE
7915

sanas Testing Laboratory
T0276

Certificate of Analysis

ALVEO WATER

Order Number : JK 2286

DATE SAMPLED: 2021/09/21 **DATE RECEIVED: 2021/09/22** **DATE ANALYSIS COMMENCED: 2021/09/22** **REPORT NO.: 5340**

SAMPLE	Mthd ALA No.	HIGH NOON WWTP Sample 26056	HIGHNOON WWTP-RAW BUFFER Sample 26057	HIGHNOON WWTP-RAW SEWER Sample 26058	LIMIT	% Uncertainty of Measurement
pH (at 25 ºC)	19	7.15	-	-	5.5-9.5	1.5
Conductivity (mS/m) (at 25 ºC)	9	85.0	-	-	150	4.5
Total Suspended Solids (mg/l)	6A	<4	-	-	25	18
Total Kjeldahl Nitrogen (mg/l as N)	15	-	74.0	29.9	-	N/A
Ammonia Nitrogen (mg/l as N)	95	17.2	-	-	6.0	5.2
Free Chlorine (mg/l)	66	<0.05	-	-	0.25	N/A
Chemical Oxygen Demand (mg/l)	2	33.8	839	272	75.0	6.8
Total Phosphate (mg/l as P)	11	-	7.4	2.0	-	N/A
Ortho Phosphate (mg/l as P)	101	6.0	-	-	10.0	4.8
Nitrite Nitrogen (mg/l as N)	100	2.2	-	-	-	10.2
Faecal Coliforms (count per 100 ml)	86	<1	-	-	1000	0.11
Nitrate Nitrogen. (mg/l as N)	N/A	7.4	-	-	15.0	N/A

Sampler : CUSTOMER (SELASSIE)

A. L. ABBOTT & ASSOCIATES (PTY) LTD
Reg. No. 1982/004379/07
Established 1964
THE WATER & WASTE WATER SPECIALISTS

Report: 5340

Doc.No. 7.8 # 1 Rev.4

Consulting Analytical & Industrial Chemists
Specialists in Water & Waste Water Treatment
Telephone (021)448 6340/1
After Hours (083-3263887)
e-Mail Address :
info@alabbott.co.za

sanas Testing Laboratory
T0276

No. 1, Vine Park
Vine Road
7925
P.O. Box 483
WOODSTOCK, CAPE
7915

Certificate of Analysis

ALVEO WATER

Order Number : JK 2286

Notes:

1. Test marked with an asterisk (*) on attached Appendix 1 (Doc. 7.8#3) are SANAS Accredited and are included in the SANAS Schedule of Accreditation for this laboratory.
2. Schedule of Accreditation excludes sampling. Where applicable pH and Free & Total Chlorine Residual results are supplied by the sampling officer and will be indicated on the Certificate of Analysis. This is marked as “Field”.
3. Sampling plans are as requested by the customer. Sampling is done according to A.L. Abbott and Associates (Pty) Ltd sampling procedures which are available on request.
4. Uncertainty of Measurement and Method Description will be provided upon request.
5. Results are reported at the 95% Confidence Interval with a Coverage Factor K = 2.
6. The laboratory does not normally issue any statement of conformity, unless by prior arrangement.
   Decision Rule: Results reflecting on the Certificate of Analysis are actual results as obtained at the time of testing and do not include any uncertainty consideration.
7. The quality and integrity of samples submitted has a direct correlation on the results reported. Results reflected on this report therefore relate only to the sample as received.
8. In the absence of customer specified limits, SANS 241-1:2015 or General Limits will appear, as applicable.
9. This report may not be reproduced, except in full, without the prior written approval of the laboratory.
10. Opinions and interpretations are not included in the Certificate of Analysis.

Natasia van Binsbergen
Digitally signed by Natasia van Binsbergen
Date: 2021.10.04 08:59:43 +02'00'

N. VAN BINSBERGEN (Pr.Sci.Nat.)
DIRECTOR
01 October 2021

TO: ALVEO WATER
9 van Zyl Street
Strand
Cape Town, South Africa
Att: service@alveowater.co.za

Sampler : CUSTOMER (SELASSIE)

This report relates only to the samples tested and is issued subject to the company’s standard terms and conditions of business.

A. L. ABBOTT & ASSOCIATES (PTY) LTD
Reg. No. 1982/004379/07
Established 1964
THE WATER & WASTE WATER SPECIALISTS
Consulting Analytical & Industrial Chemists
Specialists in Water & Waste Water Treatment
Telephone (021)448 6340/1
After Hours (083-3263887)
e-Mail Address :
info@alabbott.co.za

Doc.No. 7.8 # 1 Rev.4

sanas Testing Laboratory
T0276

No. 1, Vine Park
Vine Road
7925
P.O. Box 483
WOODSTOCK, CAPE
7915

Certificate of Analysis

ALVEO WATER

ANALYSES

HIGH NOON SEPTIC TANK 1

DATE SAMPLED : 2020/11/13

Order Number : JK 1405

DATE RECEIVED : 2020/11/13

OUR REF. : 2020/11/13/28344

DATE ANALYSIS COMMENCED : 2020/11/13

REPORT NO . : 5850

	Sample Number	28344		
Mthd ALA No.	**Analyses**	**Results**	**LIMITS**	**% Uncertainty of Measurement**
19	pH (at 25 ºC)	5.95	5.0 – 9.5	1.5
9	Conductivity (mS/m) (at 25 ºC)	43.0	170	4.5
6A	Total Suspended Solids (mg/l)	117	25	18
95	Ammonia Nitrogen (mg/l as N)	48.4	6.0	5.2
100	Nitrate Nitrogen. (mg/l as N)	<0.20	15.0	12.6
99	Nitrite Nitrogen (mg/l as N)	<0.20	-	4
66	Free Chlorine (mg/l)	<0.05	0.25	-
101	Ortho Phosphate (mg/l as P)	9.2	10.0	4.8
2	Chemical Oxygen Demand (mg/l)	219	75.0	6.8
86	Faecal Coliforms (count per 100 ml)	>2419	1000	0.11
11	Total Phosphate (mg/l as P)	10.1	-	-
2	Chemical Oxygen Demand (Filtered) (mg/l)	148	75.0	6.8
105	Total Organic Carbon (mg/l as C)	48.0	-	0.07
105	Dissolved Organic Carbon (mg/l as C)	41.1	-	-
15	Total Kjeldahl Nitrogen (mg/l as N)	49.9	-	-

Sampler : CUSTOMER (PHILASANDE)

This report relates only to the samples tested and is issued subject to the company's standard terms and conditions of business.

A. L. ABBOTT & ASSOCIATES (PTY) LTD
Reg. No. 1982/004379/07
Established 1964
THE WATER & WASTE WATER SPECIALISTS

Consulting Analytical & Industrial Chemists
Specialists in Water & Waste Water Treatment
Telephone (021)448 6340/1
After Hours (083-3263887)
e-Mail Address :
info@alabbott.co.za

No. 1, Vine Park
Vine Road
7925
P.O. Box 483
WOODSTOCK, CAPE
7915

Doc.No. 7.8 # 1 Rev.4

sanas Testing Laboratory
T0276

Certificate of Analysis

ALVEO WATER

ANALYSES

HIGH NOON SEPTIC TANK 1

DATE SAMPLED :	**2020/11/13**		
DATE RECEIVED :	**2020/11/13**	**OUR REF. :**	**2020/11/13/28344**
DATE ANALYSIS COMMENCED :	**2020/11/13**	**REPORT NO . :**	**5850**

Notes:

1. Test marked with an asterisk (*) on attached Appendix 1 (Doc. 7.8#3) are SANAS Accredited and are included in the SANAS Schedule of Accreditation for this laboratory.
2. Schedule of Accreditation excludes sampling. Where applicable pH and Free & Total Chlorine Residual results are supplied by the sampling officer and will be indicated on the Certificate of Analysis. This is marked as "Field".
3. Sampling plans are as requested by the customer. Sampling is done according to A.L. Abbott and Associates (Pty) Ltd sampling procedures which are available on request.
4. Uncertainty of Measurement and Method Description will be provided upon request.
5. Results are reported at the 95% Confidence Interval with a Coverage Factor K = 2.
6. The laboratory does not normally issue any statement of conformity, unless by prior arrangement.
   Decision Rule: Results reflecting on the Certificate of Analysis are actual results as obtained at the time of testing and do not include any uncertainty consideration.
7. The quality and integrity of samples submitted has a direct correlation on the results reported. Results reflected on this report therefore relate only to the sample as received.
8. In the absence of customer specified limits, SANS 241-1:2015 or General Limits will appear, as applicable.
9. This report may not be reproduced, except in full, without the prior written approval of the laboratory.
10. Opinions and interpretations are not included in the Certificate of Analysis.

Natasia Van Binsbergen
Digitally signed by Natasia Van Binsbergen
Date: 2020.11.19 12:09:44 +02'00'

N. VAN BINSBERGEN (Pr.Sci.Nat.)
DIRECTOR
19 November 2020

TO: ALVEO WATER
9 van Zyl Street
Strand
Cape Town, South Africa
Att: service@alveowater.co.za

Sampler : CUSTOMER (PHILASANDE)

A. L. ABBOTT & ASSOCIATES (PTY) LTD
Reg. No. 1982/004379/07
Established 1964
THE WATER & WASTE WATER SPECIALISTS
Consulting Analytical & Industrial Chemists
Specialists in Water & Waste Water Treatment
Telephone (021)448 6340/1
After Hours (083-3263887)
e-Mail Address :
info@alabbott.co.za

Doc.No. 7.8 # 1 Rev.4

sanas Testing Laboratory
T0276

No. 1, Vine Park
Vine Road
7925
P.O. Box 483
WOODSTOCK, CAPE
7915

Certificate of Analysis

ALVEO WATER

ANALYSES

HIGH NOON SEPTIC TANK 2

DATE SAMPLED : 2020/11/13 **Order Number : JK 1405**

DATE RECEIVED : 2020/11/13 **OUR REF. :** 2020/11/13/28345

DATE ANALYSIS COMMENCED : 2020/11/13 **REPORT NO . :** 5850

	Sample Number	28345		
Mthd ALA No.	**Analyses**	**Results**	**LIMITS**	**% Uncertainty of Measurement**
19	pH (at 25 ºC)	6.63	5.0 – 9.5	1.5
9	Conductivity (mS/m) (at 25 ºC)	46.0	170	4.5
6A	Total Suspended Solids (mg/l)	158	25	18
95	Ammonia Nitrogen (mg/l as N)	31.1	6.0	5.2
100	Nitrate Nitrogen. (mg/l as N)	<0.20	15.0	12.6
99	Nitrite Nitrogen (mg/l as N)	<0.20	-	4
66	Free Chlorine (mg/l)	<0.05	0.25	-
101	Ortho Phosphate (mg/l as P)	3.7	10.0	4.8
2	Chemical Oxygen Demand (mg/l)	255	75.0	6.8
86	Faecal Coliforms (count per 100 ml)	>2419	1000	0.11
11	Total Phosphate (mg/l as P)	8.5	-	-
2	Chemical Oxygen Demand (Filtered) (mg/l)	151	75.0	6.8
105	Total Organic Carbon (mg/l as C)	61.1	-	0.07
105	Dissolved Organic Carbon (mg/l as C)	56.9	-	-
15	Total Kjeldahl Nitrogen (mg/l as N)	33.8	-	-

Sampler : CUSTOMER (PHILASANDE)

This report relates only to the samples tested and is issued subject to the company's standard terms and conditions of business.

A. L. ABBOTT & ASSOCIATES (PTY) LTD
Reg. No. 1982/004379/07
Established 1964
THE WATER & WASTE WATER SPECIALISTS

Doc.No. 7.8 # 1 Rev.4

Consulting Analytical & Industrial Chemists
Specialists in Water & Waste Water Treatment
Telephone (021)448 6340/1
After Hours (083-3263887)
e-Mail Address :
info@alabbott.co.za

sanas Testing Laboratory
T0276

No. 1, Vine Park
Vine Road
7925
P.O. Box 483
WOODSTOCK, CAPE
7915

Certificate of Analysis

ALVEO WATER

ANALYSES

HIGH NOON SEPTIC TANK 2

DATE SAMPLED : **2020/11/13**

DATE RECEIVED : **2020/11/13**

DATE ANALYSIS COMMENCED : **2020/11/13**

OUR REF. : **2020/11/13/28345**

REPORT NO . : **5850**

Notes:

1. Test marked with an asterisk (*) on attached Appendix 1 (Doc. 7.8#3) are SANAS Accredited and are included in the SANAS Schedule of Accreditation for this laboratory.
2. Schedule of Accreditation excludes sampling. Where applicable pH and Free & Total Chlorine Residual results are supplied by the sampling officer and will be indicated on the Certificate of Analysis. This is marked as “Field”.
3. Sampling plans are as requested by the customer. Sampling is done according to A.L. Abbott and Associates (Pty) Ltd sampling procedures which are available on request.
4. Uncertainty of Measurement and Method Description will be provided upon request.
5. Results are reported at the 95% Confidence Interval with a Coverage Factor K = 2.
6. The laboratory does not normally issue any statement of conformity, unless by prior arrangement.
   Decision Rule: Results reflecting on the Certificate of Analysis are actual results as obtained at the time of testing and do not include any uncertainty consideration.
7. The quality and integrity of samples submitted has a direct correlation on the results reported. Results reflected on this report therefore relate only to the sample as received.
8. In the absence of customer specified limits, SANS 241-1:2015 or General Limits will appear, as applicable.
9. This report may not be reproduced, except in full, without the prior written approval of the laboratory.
10. Opinions and interpretations are not included in the Certificate of Analysis.

Natasia Van Binsbergen
Digitally signed by Natasia Van Binsbergen
Date: 2020.11.19 12:10:28 +02'00'

N. VAN BINSBERGEN (Pr.Sci.Nat.)
DIRECTOR
19 November 2020

TO: ALVEO WATER
9 van Zyl Street
Strand
Cape Town, South Africa
Att: service@alveowater.co.za

Sampler : CUSTOMER (PHILASANDE)

This report relates only to the samples tested and is issued subject to the company’s standard terms and conditions of business.

A. L. ABBOTT & ASSOCIATES (PTY) LTD
Reg. No. 1982/004379/07
Established 1964
THE WATER & WASTE WATER SPECIALISTS
Consulting Analytical & Industrial Chemists
Specialists in Water & Waste Water Treatment
Telephone (021)448 6340/1
After Hours (083-3263887)
e-Mail Address :
info@alabbott.co.za

Doc.No. 7.8 # 1 Rev.4

sanas Testing Laboratory
T0276

No. 1, Vine Park
Vine Road
7925
P.O. Box 483
WOODSTOCK, CAPE
7915

Certificate of Analysis

ALVEO WATER

ANALYSES

HIGH NOON SEPTIC TANK 3

DATE SAMPLED : 2020/11/13 **Order Number : JK 1405**

DATE RECEIVED : 2020/11/13 **OUR REF. :** 2020/11/13/28346

DATE ANALYSIS COMMENCED : 2020/11/13 **REPORT NO . :** 5850

	Sample Number	28346		
Mthd ALA No.	**Analyses**	**Results**	**LIMITS**	**% Uncertainty of Measurement**
19	pH (at 25 ºC)	6.79	5.0 – 9.5	1.5
9	Conductivity (mS/m) (at 25 ºC)	235	170	4.5
6A	Total Suspended Solids (mg/l)	4830	25	18
95	Ammonia Nitrogen (mg/l as N)	190	6.0	5.2
100	Nitrate Nitrogen. (mg/l as N)	<0.20	15.0	12.6
99	Nitrite Nitrogen (mg/l as N)	<0.20	-	4
66	Free Chlorine (mg/l)	<0.05	0.25	-
101	Ortho Phosphate (mg/l as P)	20.4	10.0	4.8
2	Chemical Oxygen Demand (mg/l)	5556	75.0	6.8
86	Faecal Coliforms (count per 100 ml)	>2419	1000	0.11
11	Total Phosphate (mg/l as P)	41.8	-	-
2	Chemical Oxygen Demand (Filtered) (mg/l)	1217	75.0	6.8
105	Total Organic Carbon (mg/l as C)	998	-	0.07
105	Dissolved Organic Carbon (mg/l as C)	449	-	-
15	Total Kjeldahl Nitrogen (mg/l as N)	252	-	-

Sampler : CUSTOMER (PHILASANDE)

This report relates only to the samples tested and is issued subject to the company's standard terms and conditions of business.

A. L. ABBOTT & ASSOCIATES (PTY) LTD
Reg. No. 1982/004379/07
Established 1964
THE WATER & WASTE WATER SPECIALISTS
Consulting Analytical & Industrial Chemists
Specialists in Water & Waste Water Treatment
Telephone (021)448 6340/1
After Hours (083-3263887)
e-Mail Address :
info@alabbott.co.za

No. 1, Vine Park
Vine Road
7925
P.O. Box 483
WOODSTOCK, CAPE
7915

sanas Testing Laboratory
T0276

Certificate of Analysis

ALVEO WATER

ANALYSES

HIGH NOON SEPTIC TANK 3

DATE SAMPLED : 2020/11/13

DATE RECEIVED : 2020/11/13

DATE ANALYSIS COMMENCED : 2020/11/13

OUR REF. : 2020/11/13/28346

REPORT NO . : 5850

Notes:
1. Test marked with an asterisk (*) on attached Appendix 1 (Doc. 7.8#3) are SANAS Accredited and are included in the SANAS Schedule of Accreditation for this laboratory.
2. Schedule of Accreditation excludes sampling. Where applicable pH and Free & Total Chlorine Residual results are supplied by the sampling officer and will be indicated on the Certificate of Analysis. This is marked as “Field”.
3. Sampling plans are as requested by the customer. Sampling is done according to A.L. Abbott and Associates (Pty) Ltd sampling procedures which are available on request.
4. Uncertainty of Measurement and Method Description will be provided upon request.
5. Results are reported at the 95% Confidence Interval with a Coverage Factor K = 2.
6. The laboratory does not normally issue any statement of conformity, unless by prior arrangement.
   Decision Rule: Results reflecting on the Certificate of Analysis are actual results as obtained at the time of testing and do not include any uncertainty consideration.
7. The quality and integrity of samples submitted has a direct correlation on the results reported. Results reflected on this report therefore relate only to the sample as received.
8. In the absence of customer specified limits, SANS 241-1:2015 or General Limits will appear, as applicable.
9. This report may not be reproduced, except in full, without the prior written approval of the laboratory.
10. Opinions and interpretations are not included in the Certificate of Analysis.

Natasia Van Binsbergen
Digitally signed by Natasia Van Binsbergen
Date: 2020.11.19 12:11:52 +02'00'

N. VAN BINSBERGEN (Pr.Sci.Nat.)
DIRECTOR
19 November 2020

TO: ALVEO WATER
9 van Zyl Street
Strand
Cape Town, South Africa
Att: service@alveowater.co.za

Sampler : CUSTOMER (PHILASANDE)

This report relates only to the samples tested and is issued subject to the company’s standard terms and conditions of business.

A. L. ABBOTT & ASSOCIATES (PTY) LTD
Reg. No. 1982/004379/07
Established 1964
THE WATER & WASTE WATER SPECIALISTS

Report: 4288

Doc.No. 7.8 # 1 Rev.4

Consulting Analytical & Industrial Chemists
Specialists in Water & Waste Water Treatment
Telephone (021)448 6340/1
After Hours (083-3263887)
e-Mail Address :
info@alabbott.co.za

No. 1, Vine Park
Vine Road
7925
P.O. Box 483
WOODSTOCK, CAPE
7915

sanas Testing Laboratory
T0276

Certificate of Analysis

ALVEO WATER

Order Number : JK 2197

DATE SAMPLED: 2021/08/03 **DATE RECEIVED: 2021/08/04** **DATE ANALYSIS COMMENCED: 2021/08/04** **REPORT NO.: 4288**

SAMPLE	Mthd ALA No.	HIGHNOON BEFORE ANOXIC Sample 20919	HIGHNOON RAW Sample 20920	LIMIT	% Uncertainty of Measurement
pH (at 25 ºC)	19	6.76	6.54	5.0 – 9.5	1.5
Conductivity (mS/m) (at 25 ºC)	9	98.5	76.5	170	4.5
Total Suspended Solids (mg/l)	6A	160	785	25	18
Total Kjeldahl Nitrogen (mg/l as N)	15	-	66.0	-	N/A
Ammonia Nitrogen (mg/l as N)	95	58.3	44.0	6.0	5.2
Free Chlorine (mg/l)	66	<0.05	<0.05	0.25	N/A
Chemical Oxygen Demand (mg/l)	2	494	1388	75.0	6.8
Total Phosphate (mg/l as P)	11	-	16.5	-	N/A
Ortho Phosphate (mg/l as P)	101	5.7	5.6	10.0	4.8
Nitrite Nitrogen (mg/l as N)	100	<0.20	<0.20	-	10.2
Nitrate Nitrogen. (mg/l as N)	N/A	0.59	<0.20	15.0	N/A

Sampler : CUSTOMER (JEAN)

This report relates only to the samples tested and is issued subject to the company's standard terms and conditions of business.

A. L. ABBOTT & ASSOCIATES (PTY) LTD
Reg. No. 1982/004379/07
Established 1964
THE WATER & WASTE WATER SPECIALISTS

Consulting Analytical & Industrial Chemists
Specialists in Water & Waste Water Treatment
Telephone (021)448 6340/1
After Hours (083-3263887)
e-Mail Address :
info@alabbott.co.za

No. 1, Vine Park
Vine Road
7925
P.O. Box 483
WOODSTOCK, CAPE
7915

sanas Testing Laboratory
T0276

Certificate of Analysis

ALVEO WATER

Order Number : JK 2197

Notes:

1. Test marked with an asterisk (*) on attached Appendix 1 (Doc. 7.8#3) are SANAS Accredited and are included in the SANAS Schedule of Accreditation for this laboratory.
2. Schedule of Accreditation excludes sampling. Where applicable pH and Free & Total Chlorine Residual results are supplied by the sampling officer and will be indicated on the Certificate of Analysis. This is marked as “Field”.
3. Sampling plans are as requested by the customer. Sampling is done according to A.L. Abbott and Associates (Pty) Ltd sampling procedures which are available on request.
4. Uncertainty of Measurement and Method Description will be provided upon request.
5. Results are reported at the 95% Confidence Interval with a Coverage Factor K = 2.
6. The laboratory does not normally issue any statement of conformity, unless by prior arrangement.
   Decision Rule: Results reflecting on the Certificate of Analysis are actual results as obtained at the time of testing and do not include any uncertainty consideration.
7. The quality and integrity of samples submitted has a direct correlation on the results reported. Results reflected on this report therefore relate only to the sample as received.
8. In the absence of customer specified limits, SANS 241-1:2015 or General Limits will appear, as applicable.
9. This report may not be reproduced, except in full, without the prior written approval of the laboratory.
10. Opinions and interpretations are not included in the Certificate of Analysis.

Natasia van Binsbergen

Digitally signed by Natasia van Binsbergen
Date: 2021.08.16 13:02:24 +02'00'

N. VAN BINSBERGEN (Pr.Sci.Nat.)
DIRECTOR
16 August 2021

TO: ALVEO WATER
9 van Zyl Street
Strand
Cape Town, South Africa
Att: service@alveowater.co.za

Sampler : CUSTOMER (JEAN)

A. L. ABBOTT & ASSOCIATES (PTY) LTD
Reg. No. 1982/004379/07
Established 1964
THE WATER & WASTE WATER SPECIALISTS

Consulting Analytical & Industrial Chemists
Specialists in Water & Waste Water Treatment
Telephone (021)448 6340/1
After Hours (083-3263887)
e-Mail Address :
info@alabbott.co.za

No. 1, Vine Park
Vine Road
7925
P.O. Box 483
WOODSTOCK, CAPE
7915

sanas Testing Laboratory
T0276

Certificate of Analysis

ALVEO WATER

Order Number : JK 2286

DATE SAMPLED: 2021/09/21 **DATE RECEIVED: 2021/09/22** **DATE ANALYSIS COMMENCED: 2021/09/22** **REPORT NO.: 5340**

SAMPLE	Mthd ALA No.	HIGH NOON WWTP Sample 26056	HIGHNOON WWTP-RAW BUFFER Sample 26057	HIGHNOON WWTP-RAW SEWER Sample 26058	LIMIT	% Uncertainty of Measurement
pH (at 25 ºC)	19	7.15	-	-	5.5-9.5	1.5
Conductivity (mS/m) (at 25 ºC)	9	85.0	-	-	150	4.5
Total Suspended Solids (mg/l)	6A	<4	-	-	25	18
Total Kjeldahl Nitrogen (mg/l as N)	15	-	74.0	29.9	-	N/A
Ammonia Nitrogen (mg/l as N)	95	17.2	-	-	6.0	5.2
Free Chlorine (mg/l)	66	<0.05	-	-	0.25	N/A
Chemical Oxygen Demand (mg/l)	2	33.8	839	272	75.0	6.8
Total Phosphate (mg/l as P)	11	-	7.4	2.0	-	N/A
Ortho Phosphate (mg/l as P)	101	6.0	-	-	10.0	4.8
Nitrite Nitrogen (mg/l as N)	100	2.2	-	-	-	10.2
Faecal Coliforms (count per 100 ml)	86	<1	-	-	1000	0.11
Nitrate Nitrogen. (mg/l as N)	N/A	7.4	-	-	15.0	N/A

Sampler : CUSTOMER (SELASSIE)

A. L. ABBOTT & ASSOCIATES (PTY) LTD
Reg. No. 1982/004379/07
Established 1964
THE WATER & WASTE WATER SPECIALISTS

Consulting Analytical & Industrial Chemists
Specialists in Water & Waste Water Treatment
Telephone (021)448 6340/1
After Hours (083-3263887)
e-Mail Address :
info@alabbott.co.za

No. 1, Vine Park
Vine Road
7925
P.O. Box 483
WOODSTOCK, CAPE
7915

T0276

Certificate of Analysis

ALVEO WATER

Order Number : JK 2286

Notes:

1. Test marked with an asterisk (*) on attached Appendix 1 (Doc. 7.8#3) are SANAS Accredited and are included in the SANAS Schedule of Accreditation for this laboratory.
2. Schedule of Accreditation excludes sampling. Where applicable pH and Free & Total Chlorine Residual results are supplied by the sampling officer and will be indicated on the Certificate of Analysis. This is marked as "Field".
3. Sampling plans are as requested by the customer. Sampling is done according to A.L. Abbott and Associates (Pty) Ltd sampling procedures which are available on request.
4. Uncertainty of Measurement and Method Description will be provided upon request.
5. Results are reported at the 95% Confidence Interval with a Coverage Factor K = 2.
6. The laboratory does not normally issue any statement of conformity, unless by prior arrangement.
   Decision Rule: Results reflecting on the Certificate of Analysis are actual results as obtained at the time of testing and do not include any uncertainty consideration.
7. The quality and integrity of samples submitted has a direct correlation on the results reported. Results reflected on this report therefore relate only to the sample as received.
8. In the absence of customer specified limits, SANS 241-1:2015 or General Limits will appear, as applicable.
9. This report may not be reproduced, except in full, without the prior written approval of the laboratory.
10. Opinions and interpretations are not included in the Certificate of Analysis.

Natasia van Binsbergen

Digitally signed by Natasia van Binsbergen
Date: 2021.10.04 08:59:43 +02'00'

N. VAN BINSBERGEN (Pr.Sci.Nat.)
DIRECTOR
01 October 2021

TO: ALVEO WATER
9 van Zyl Street
Strand
Cape Town, South Africa
Att: service@alveowater.co.za

Sampler : CUSTOMER (SELASSIE)

This report relates only to the samples tested and is issued subject to the company's standard terms and conditions of business.

A. L. ABBOTT & ASSOCIATES (PTY) LTD
Reg. No. 1982/004379/07
Established 1964
THE WATER & WASTE WATER SPECIALISTS

Consulting Analytical & Industrial Chemists
Specialists in Water & Waste Water Treatment
Telephone (021)448 6340/1
After Hours (083-3263887)
e-Mail Address :
info@alabbott.co.za

No. 1, Vine Park
Vine Road
7925
P.O. Box 483
WOODSTOCK, CAPE
7915

Doc.No. 7.8 # 1 Rev.4

sanas Testing Laboratory
T0276

Certificate of Analysis

ALVEO WATER

ANALYSES

HIGH NOON SEPTIC TANK 1

DATE SAMPLED : **2020/11/13** **Order Number : JK 1405**

DATE RECEIVED : **2020/11/13** **OUR REF. :** **2020/11/13/28344**

DATE ANALYSIS COMMENCED : **2020/11/13** **REPORT NO . :** **5850**

	Sample Number	28344		
Mthd ALA No.	**Analyses**	**Results**	**LIMITS**	**% Uncertainty of Measurement**
19	pH (at 25 ºC)	5.95	5.0 – 9.5	1.5
9	Conductivity (mS/m) (at 25 ºC)	43.0	170	4.5
6A	Total Suspended Solids (mg/l)	117	25	18
95	Ammonia Nitrogen (mg/l as N)	48.4	6.0	5.2
100	Nitrate Nitrogen. (mg/l as N)	<0.20	15.0	12.6
99	Nitrite Nitrogen (mg/l as N)	<0.20	-	4
66	Free Chlorine (mg/l)	<0.05	0.25	-
101	Ortho Phosphate (mg/l as P)	9.2	10.0	4.8
2	Chemical Oxygen Demand (mg/l)	219	75.0	6.8
86	Faecal Coliforms (count per 100 ml)	>2419	1000	0.11
11	Total Phosphate (mg/l as P)	10.1	-	-
2	Chemical Oxygen Demand (Filtered) (mg/l)	148	75.0	6.8
105	Total Organic Carbon (mg/l as C)	48.0	-	0.07
105	Dissolved Organic Carbon (mg/l as C)	41.1	-	-
15	Total Kjeldahl Nitrogen (mg/l as N)	49.9	-	-

Sampler : CUSTOMER (PHILASANDE)

This report relates only to the samples tested and is issued subject to the company's standard terms and conditions of business.

A. L. ABBOTT & ASSOCIATES (PTY) LTD
Reg. No. 1982/004379/07
Established 1964
THE WATER & WASTE WATER SPECIALISTS

Consulting Analytical & Industrial Chemists
Specialists in Water & Waste Water Treatment
Telephone (021)448 6340/1
After Hours (083-3263887)
e-Mail Address :
info@alabbott.co.za

No. 1, Vine Park
Vine Road
7925
P.O. Box 483
WOODSTOCK, CAPE
7915

sanas Testing Laboratory
T0276

Certificate of Analysis

ALVEO WATER

ANALYSES

HIGH NOON SEPTIC TANK 1

DATE SAMPLED :	**2020/11/13**		
DATE RECEIVED :	**2020/11/13**	**OUR REF. :**	**2020/11/13/28344**
DATE ANALYSIS COMMENCED :	**2020/11/13**	**REPORT NO . :**	**5850**

Notes:

1. Test marked with an asterisk (*) on attached Appendix 1 (Doc. 7.8#3) are SANAS Accredited and are included in the SANAS Schedule of Accreditation for this laboratory.
2. Schedule of Accreditation excludes sampling. Where applicable pH and Free & Total Chlorine Residual results are supplied by the sampling officer and will be indicated on the Certificate of Analysis. This is marked as "Field".
3. Sampling plans are as requested by the customer. Sampling is done according to A.L. Abbott and Associates (Pty) Ltd sampling procedures which are available on request.
4. Uncertainty of Measurement and Method Description will be provided upon request.
5. Results are reported at the 95% Confidence Interval with a Coverage Factor K = 2.
6. The laboratory does not normally issue any statement of conformity, unless by prior arrangement.
   Decision Rule: Results reflecting on the Certificate of Analysis are actual results as obtained at the time of testing and do not include any uncertainty consideration.
7. The quality and integrity of samples submitted has a direct correlation on the results reported. Results reflected on this report therefore relate only to the sample as received.
8. In the absence of customer specified limits, SANS 241-1:2015 or General Limits will appear, as applicable.
9. This report may not be reproduced, except in full, without the prior written approval of the laboratory.
10. Opinions and interpretations are not included in the Certificate of Analysis.

Natasia Van Binsbergen
Digitally signed by Natasia Van Binsbergen
Date: 2020.11.19 12:09:44 +02'00'

N. VAN BINSBERGEN (Pr.Sci.Nat.)
DIRECTOR
19 November 2020

TO: ALVEO WATER
9 van Zyl Street
Strand
Cape Town, South Africa
Att: service@alveowater.co.za

Sampler : CUSTOMER (PHILASANDE)

This report relates only to the samples tested and is issued subject to the company's standard terms and conditions of business.

A. L. ABBOTT & ASSOCIATES (PTY) LTD
Reg. No. 1982/004379/07
Established 1964
THE WATER & WASTE WATER SPECIALISTS

Doc.No. 7.8 # 1 Rev.4

Consulting Analytical & Industrial Chemists
Specialists in Water & Waste Water Treatment
Telephone (021)448 6340/1
After Hours (083-3263887)
e-Mail Address :
info@alabbott.co.za

No. 1, Vine Park
Vine Road
7925
P.O. Box 483
WOODSTOCK, CAPE
7915

sanas Testing Laboratory
T0276

Certificate of Analysis

ALVEO WATER

ANALYSES

HIGH NOON SEPTIC TANK 2

DATE SAMPLED : 2020/11/13 **Order Number : JK 1405**

DATE RECEIVED : 2020/11/13 **OUR REF. :** 2020/11/13/28345

DATE ANALYSIS COMMENCED : 2020/11/13 **REPORT NO . :** 5850

	Sample Number	28345		
Mthd ALA No.	**Analyses**	**Results**	**LIMITS**	**% Uncertainty of Measurement**
19	pH (at 25 ºC)	6.63	5.0 – 9.5	1.5
9	Conductivity (mS/m) (at 25 ºC)	46.0	170	4.5
6A	Total Suspended Solids (mg/l)	158	25	18
95	Ammonia Nitrogen (mg/l as N)	31.1	6.0	5.2
100	Nitrate Nitrogen. (mg/l as N)	<0.20	15.0	12.6
99	Nitrite Nitrogen (mg/l as N)	<0.20	-	4
66	Free Chlorine (mg/l)	<0.05	0.25	-
101	Ortho Phosphate (mg/l as P)	3.7	10.0	4.8
2	Chemical Oxygen Demand (mg/l)	255	75.0	6.8
86	Faecal Coliforms (count per 100 ml)	>2419	1000	0.11
11	Total Phosphate (mg/l as P)	8.5	-	-
2	Chemical Oxygen Demand (Filtered) (mg/l)	151	75.0	6.8
105	Total Organic Carbon (mg/l as C)	61.1	-	0.07
105	Dissolved Organic Carbon (mg/l as C)	56.9	-	-
15	Total Kjeldahl Nitrogen (mg/l as N)	33.8	-	-

Sampler : CUSTOMER (PHILASANDE)

This report relates only to the samples tested and is issued subject to the company's standard terms and conditions of business.

A. L. ABBOTT & ASSOCIATES (PTY) LTD
Reg. No. 1982/004379/07
Established 1964
THE WATER & WASTE WATER SPECIALISTS

Doc.No. 7.8 # 1 Rev.4

Consulting Analytical & Industrial Chemists
Specialists in Water & Waste Water Treatment
Telephone (021)448 6340/1
After Hours (083-3263887)
e-Mail Address :
info@alabbott.co.za

sanas Testing Laboratory
T0276

No. 1, Vine Park
Vine Road
7925
P.O. Box 483
WOODSTOCK, CAPE
7915

Certificate of Analysis

ALVEO WATER

ANALYSES

HIGH NOON SEPTIC TANK 2

DATE SAMPLED : **2020/11/13**

DATE RECEIVED : **2020/11/13**

DATE ANALYSIS COMMENCED : **2020/11/13**

OUR REF. : **2020/11/13/28345**

REPORT NO . : **5850**

Notes:

1. Test marked with an asterisk (*) on attached Appendix 1 (Doc. 7.8#3) are SANAS Accredited and are included in the SANAS Schedule of Accreditation for this laboratory.
2. Schedule of Accreditation excludes sampling. Where applicable pH and Free & Total Chlorine Residual results are supplied by the sampling officer and will be indicated on the Certificate of Analysis. This is marked as “Field”.
3. Sampling plans are as requested by the customer. Sampling is done according to A.L. Abbott and Associates (Pty) Ltd sampling procedures which are available on request.
4. Uncertainty of Measurement and Method Description will be provided upon request.
5. Results are reported at the 95% Confidence Interval with a Coverage Factor K = 2.
6. The laboratory does not normally issue any statement of conformity, unless by prior arrangement.
   Decision Rule: Results reflecting on the Certificate of Analysis are actual results as obtained at the time of testing and do not include any uncertainty consideration.
7. The quality and integrity of samples submitted has a direct correlation on the results reported. Results reflected on this report therefore relate only to the sample as received.
8. In the absence of customer specified limits, SANS 241-1:2015 or General Limits will appear, as applicable.
9. This report may not be reproduced, except in full, without the prior written approval of the laboratory.
10. Opinions and interpretations are not included in the Certificate of Analysis.

Natasia Van Binsbergen
Digitally signed by Natasia Van Binsbergen
Date: 2020.11.19 12:10:28 +02'00'

N. VAN BINSBERGEN (Pr.Sci.Nat.)
DIRECTOR
19 November 2020

TO: ALVEO WATER
9 van Zyl Street
Strand
Cape Town, South Africa
Att: service@alveowater.co.za

Sampler : CUSTOMER (PHILASANDE)

This report relates only to the samples tested and is issued subject to the company’s standard terms and conditions of business.

A. L. ABBOTT & ASSOCIATES (PTY) LTD
Reg. No. 1982/004379/07
Established 1964
THE WATER & WASTE WATER SPECIALISTS

Doc.No. 7.8 # 1 Rev.4

Consulting Analytical & Industrial Chemists
Specialists in Water & Waste Water Treatment
Telephone (021)448 6340/1
After Hours (083-3263887)
e-Mail Address :
info@alabbott.co.za

No. 1, Vine Park
Vine Road
7925
P.O. Box 483
WOODSTOCK, CAPE
7915

sanas Testing Laboratory
T0276

Certificate of Analysis

ALVEO WATER

ANALYSES

HIGH NOON SEPTIC TANK 3

DATE SAMPLED : 2020/11/13 **Order Number : JK 1405**

DATE RECEIVED : 2020/11/13 **OUR REF. :** 2020/11/13/28346

DATE ANALYSIS COMMENCED : 2020/11/13 **REPORT NO . :** 5850

	Sample Number	28346		
Mthd ALA No.	**Analyses**	**Results**	**LIMITS**	**% Uncertainty of Measurement**
19	pH (at 25 ºC)	6.79	5.0 – 9.5	1.5
9	Conductivity (mS/m) (at 25 ºC)	235	170	4.5
6A	Total Suspended Solids (mg/l)	4830	25	18
95	Ammonia Nitrogen (mg/l as N)	190	6.0	5.2
100	Nitrate Nitrogen. (mg/l as N)	<0.20	15.0	12.6
99	Nitrite Nitrogen (mg/l as N)	<0.20	-	4
66	Free Chlorine (mg/l)	<0.05	0.25	-
101	Ortho Phosphate (mg/l as P)	20.4	10.0	4.8
2	Chemical Oxygen Demand (mg/l)	5556	75.0	6.8
86	Faecal Coliforms (count per 100 ml)	>2419	1000	0.11
11	Total Phosphate (mg/l as P)	41.8	-	-
2	Chemical Oxygen Demand (Filtered) (mg/l)	1217	75.0	6.8
105	Total Organic Carbon (mg/l as C)	998	-	0.07
105	Dissolved Organic Carbon (mg/l as C)	449	-	-
15	Total Kjeldahl Nitrogen (mg/l as N)	252	-	-

Sampler : CUSTOMER (PHILASANDE)

This report relates only to the samples tested and is issued subject to the company's standard terms and conditions of business.

A. L. ABBOTT & ASSOCIATES (PTY) LTD
Reg. No. 1982/004379/07
Established 1964
THE WATER & WASTE WATER SPECIALISTS

Doc.No. 7.8 # 1 Rev.4

Consulting Analytical & Industrial Chemists
Specialists in Water & Waste Water Treatment
Telephone (021)448 6340/1
After Hours (083-3263887)
e-Mail Address :
info@alabbott.co.za

sanas Testing Laboratory
T0276

No. 1, Vine Park
Vine Road
7925
P.O. Box 483
WOODSTOCK, CAPE
7915

Certificate of Analysis

ALVEO WATER

ANALYSES

HIGH NOON SEPTIC TANK 3

DATE SAMPLED : **2020/11/13**

DATE RECEIVED : **2020/11/13**

DATE ANALYSIS COMMENCED : **2020/11/13**

OUR REF. : **2020/11/13/28346**

REPORT NO . : **5850**

Notes:

1. Test marked with an asterisk (*) on attached Appendix 1 (Doc. 7.8#3) are SANAS Accredited and are included in the SANAS Schedule of Accreditation for this laboratory.
2. Schedule of Accreditation excludes sampling. Where applicable pH and Free & Total Chlorine Residual results are supplied by the sampling officer and will be indicated on the Certificate of Analysis. This is marked as “Field”.
3. Sampling plans are as requested by the customer. Sampling is done according to A.L. Abbott and Associates (Pty) Ltd sampling procedures which are available on request.
4. Uncertainty of Measurement and Method Description will be provided upon request.
5. Results are reported at the 95% Confidence Interval with a Coverage Factor K = 2.
6. The laboratory does not normally issue any statement of conformity, unless by prior arrangement.
   Decision Rule: Results reflecting on the Certificate of Analysis are actual results as obtained at the time of testing and do not include any uncertainty consideration.
7. The quality and integrity of samples submitted has a direct correlation on the results reported. Results reflected on this report therefore relate only to the sample as received.
8. In the absence of customer specified limits, SANS 241-1:2015 or General Limits will appear, as applicable.
9. This report may not be reproduced, except in full, without the prior written approval of the laboratory.
10. Opinions and interpretations are not included in the Certificate of Analysis.

Natasia Van Binsbergen
Digitally signed by Natasia Van Binsbergen
Date: 2020.11.19 12:11:52 +02'00'

N. VAN BINSBERGEN (Pr.Sci.Nat.)
DIRECTOR
19 November 2020

TO: ALVEO WATER
9 van Zyl Street
Strand
Cape Town, South Africa
Att: service@alveowater.co.za

Sampler : CUSTOMER (PHILASANDE)

This report relates only to the samples tested and is issued subject to the company’s standard terms and conditions of business.