Report Number: P WMA 06/D00/00/3423/2

water & sanitation

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Water and Sanitation
REPUBLIC OF SOUTH AFRICA

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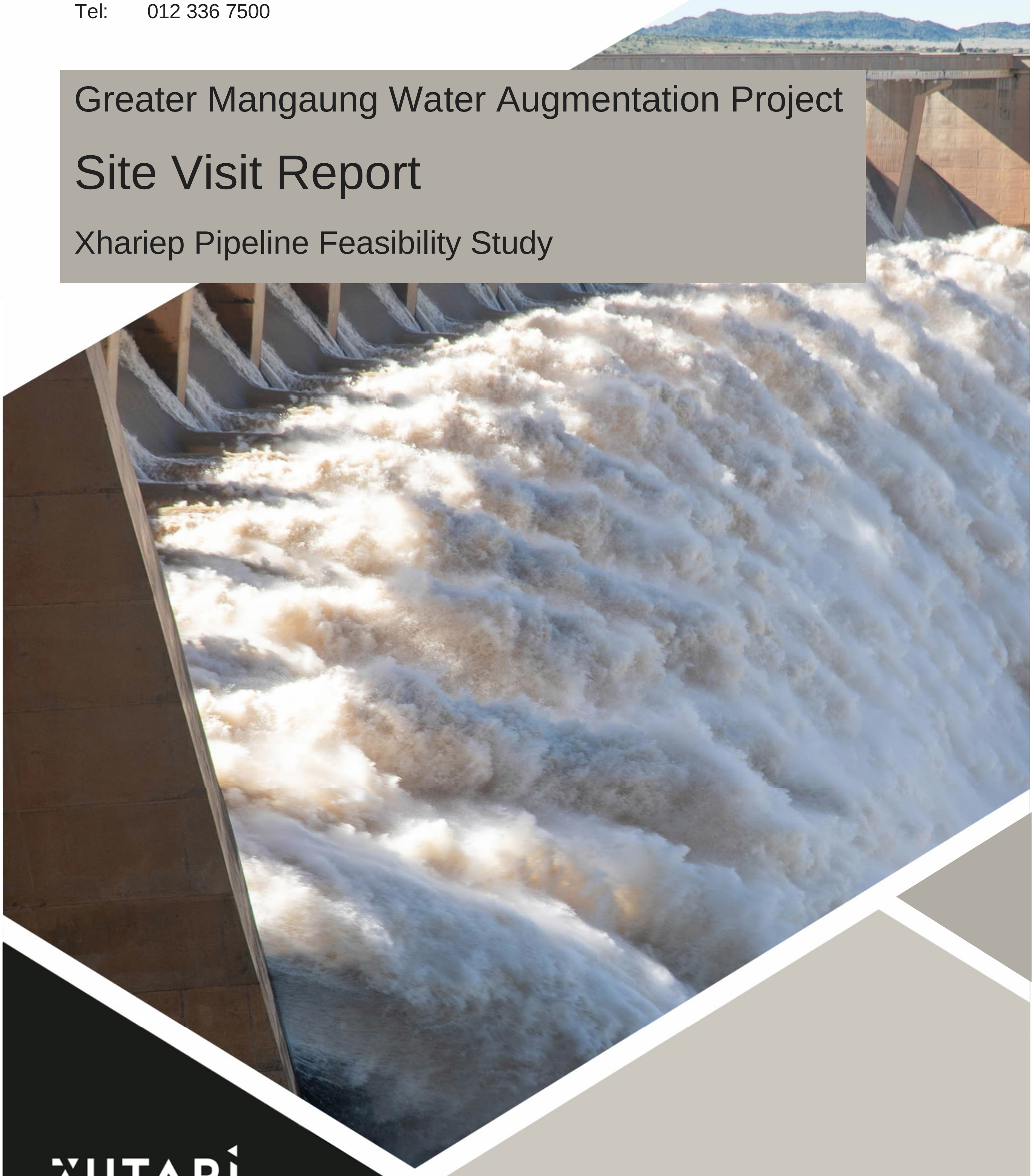
Greater Mangaung Water Augmentation Project

Site Visit Report

Xhariep Pipeline Feasibility Study



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REPUBLIC OF SOUTH AFRICA

Directorate Water Resource Development Planning

Site Visit Report

APPROVAL

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Consultants	:	Zutari (Pty) Ltd
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Author signature		Approver signature	
Name	Frances A'Bear	Name	Stephan Kleynhans
Title	Professional Engineer	Title	Design Director

Report Structure

This report forms part of the following suite for the study:

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9	Feasibility Design Report - Pipeline, Pump Stations & Reservoirs	P WMA 06/D00/00/3423/9
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Editor’s Note

During the drafting of this report, an important update was released in the Government Gazette 48954 on 13 July 2023, confirming the change of name from “Bloem Water” to “Vaal Central Water Board”. Throughout this document, the term “Bloem Water” was used, which should be understood to be synonymous with the new name, “Vaal Central Water Board”. Subsequent reports in this study will refer to the entity as Vaal Central Water Board for consistency.

Reference

This report is to be referred to in bibliographies as:

Department of Water and Sanitation, South Africa. 2023. *Greater Mangaung Water Augmentation Project – Xhariep Pipeline Feasibility Study: Site Visit Report*.

DWS Report Number: P WMA 06/D00/00/3423/2

Prepared by Zutari (Pty) Ltd

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Abbreviations

Acronyms

Acronym	Description
AADD	Average Annual Daily Demand
BW	Bloem Water
CBD	Central business district
DWS	Department of Water & Sanitation
EFR	Environmental flow requirements
EIA	Environmental Impact Assessment
GIS	Geographical information systems
IDP	Integrated Development Plan
ISP	Internal Strategic Perspective
MMM	Mangaung Metropolitan Municipality
NWRP	DWA Directorate: National Water Resource Planning
P/s	Pumpstation
PRV	Pressure reducing valve
RDP	Reconstruction and Development Programme
RO	Reverse osmosis
RPST	Reconciliation Planning Support Tool
SANS 241	South African National Standard for Drinking Water Quality
SDF	Spatial Development Plan
SMC	Study Management Committee
UAW	Unaccounted for Water
URV	Unit Reference Values
WARMS	Water Authorisation and Registration Management System
WC/WDM	Water Conservation and Water Demand Management
WMA	Water Management Area
WSDP	Water Service Development Plan
WTP	Water Treatment Plant

Measurement Units

Symbol	Description
Ha	Hectares
km	Kilometres
m	Meters
m^3/a	Cubic meters per annum
m^3/d	Cubic meters per day
m^3/s	Cubic meters per second
mg/L	Milligrams per litre
ML/d	Megalitres per day

Symbol	Description
million m^3	Million cubic meters
mm/a	Millimetres per annum
million m^3/a	Million cubic meters per annum
ntu	Nephelometric Turbidity Units (measure of the cloudiness of a fluid)

1 Introduction

This report is a record of the Zutari and DWS team's visit to the infrastructure and sites pertinent to the Xhariep Pipeline Feasibility Study. The site visit took place on 20 to 22 February 2023, see Figure 2-1 for the route of the site visit.

Table 1-1 provides a list of the site visit participants.

Table 1-1 List of site visit participants

Name	Institution
Menard Mugumo	DWS: NWRP (South)
Sanet van Jaarsveld	DWS: WRDP (Central)
Louis van Oudtshoorn	BloemWater
Stephan Kleynhans	Zutari (Cape Town)
Verno Jonker	Zutari (Cape Town)
Brendon Theunissen	Zutari (Cape Town)
Schalk van der Merwe	Zutari (Cape Town)
Werner Barnard	Zutari (Bloemfontein)
Frankie A'Bear	Zutari (Cape Town)

2 Site Visit Itinerary

Table 2-1 shows the itinerary for the site visit, Figure 2-1 below shows the routes and list of infrastructure visited.

Table 2-1: Itinerary for Site Visit

Time	Itinerary for Site Visits
20 Feb 2023 – Day 1	
8:00am	Leave from Bram Fisher Airport
Travel on the M10 / R702	Novo Pump Station
	Tienfontein Pump Station
	Welbedacht Water Treatment Plant
Travel Via R701	Travel to Lodge at Xhariep Dam
21 Feb 2023 – Day 2	
8:00am	Leave Lodge
	Xhariep Dam and Outlet Works
Travel Via N1	Travel to Bloemfontein
	Visit proposed pipeline infrastructure sites enroute
	Return to Bloemfontein
22 Feb 2023 – Day 3	
10:00am	Rustfontein Water Treatment Plant (Attended by Brendon Theunissen while remaining team members attended the Project Steering Committee (PSC) Meeting No 1)

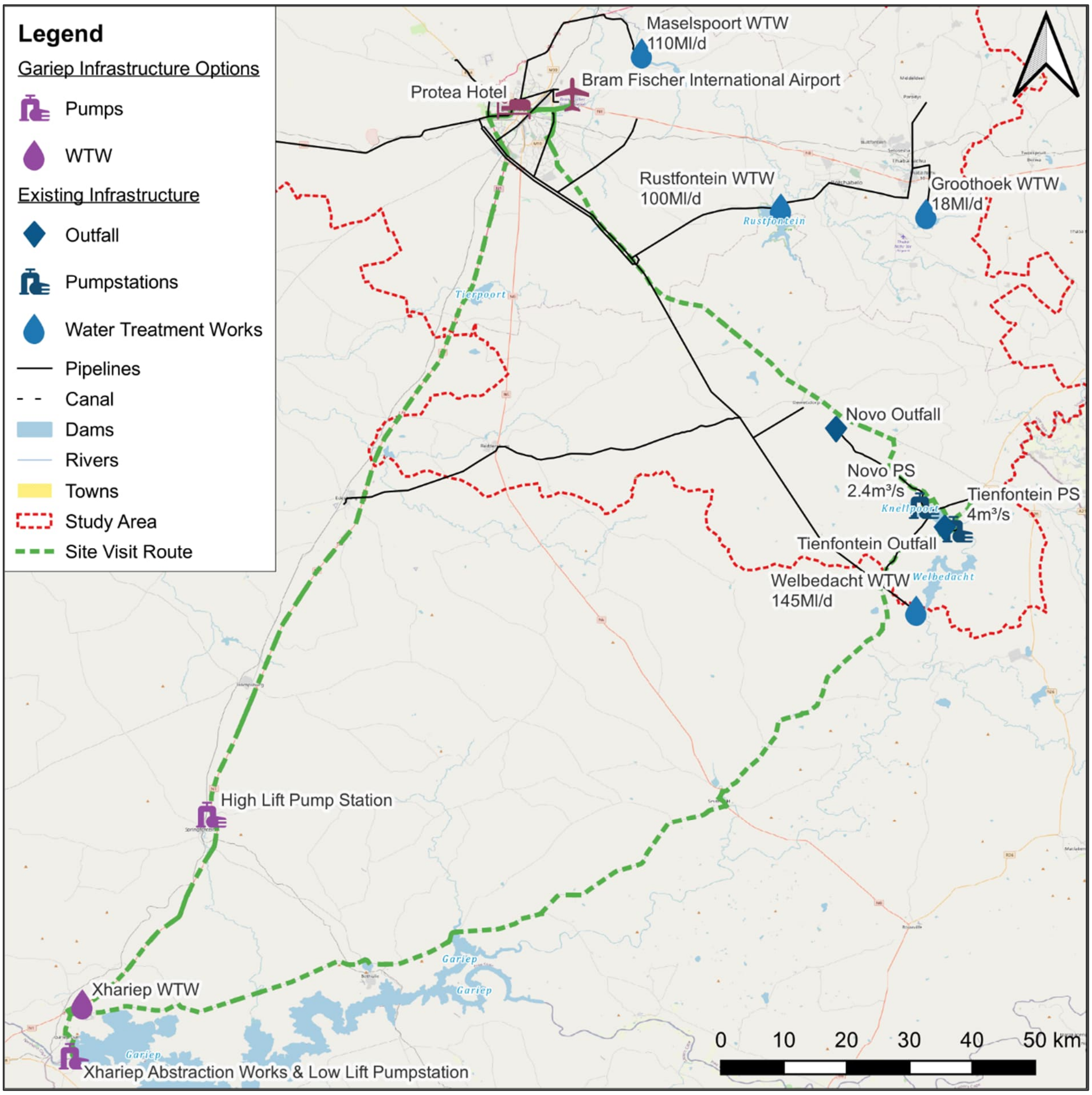

Figure 2-1: Figure of route and infrastructure visited on the site visit.

3 Observations of Existing Infrastructure

3.1 Novo Pump Station

The Novo Pump Station was not in operation at the time of the site visit and, according to the BloemWater (BW) representative, had not been operated for two or more years due to the water levels in the Rustfontein dam being sufficient without supplementary supply from the Knellpoort dam. Table 3-1 contains the summary of the key information received from BloemWater.

Table 3-1: Summary of Novo Pump Station Key Parameters

Pump Station	Installed capacity	Max operational capacity	Comments
Novo	2950L/s	2200L/s	2 X 750L/s pumps 1 X 1450L/s pump

The observations made by the Zutari team are:

- The grounds and pump station were in reasonable condition, however, there are many general housekeeping aspects to attend to (painting, clearing and cutting grass from access road etc.)
- The building was in good condition, again housekeeping needs to be attended to.
- Three pump sets were installed, two were the original 750l/s pumpsets and the additonal 1450l/s pump set installed to increase the capacity of the pump station.
- The operator indicated that they only operate the two old pumps or the new pump, but never the new pump in combination with one of the old pumps or all three pumps.
- The pumpsets (pump and motor), pipework and valves appear to be in a reasonable condition. The operator did not report any problems with the pumpsets.
- The condition of the instruments (e.g. pressure gauges, flow meter, etc.) could not be assessed as the pump station was not functional. The suction pressure gauges appear to be malfunctioning.
- The electrical switchgear appears to be in reasonable condition.
- The pump station has space to fit a fourth pump in future.
- The Novo pipeline operates without problems. It is uncertain whether the cathodic protection of the pipeline is functional.
- The electrical supply to the area was insufficient to operate the Tienfontein pump station and Novo pump station similtaneously, however, the Eskom representative at the PSC meeting stated that the supply line had been upgraded. It should be noted that BW has not faced the need to test the supply line in over two years and may be operating on outdated information.

Figure 3-1: Novo Pump Station building

Figure 3-2: Novo pump sets with one open pump bay

Figure 3-3: Original pump set

Figure 3-4: New pump set

Figure 3-5: MCC in Control Room

Figure 3-6: MCC in Control Room

Figure 3-7: New pump set

Figure 3-8: Old pump set

3.2 Knellpoort Dam Wall

The Knellpoort dam was spilling at the time of the site visit. The observations made by the Zutari team are:

- Evidence of seepage on the dam wall and roof of the structure on the downstream side of the dam.
- The outlet works chamber was left open which was a safety risk.
- Pipework seems to be in good condition.
- Drawings of the Knellpoort Dam were available in Tienfontein Pump Station.

Figure 3-9: Knellpoort Dam Wall spilling

Figure 3-10: Downstream side of Knellpoort Dam, water on top of structure in bottom left corner

Figure 3-11: Water seeping through dam wall on right side of image

Figure 3-12: Outlet works left open

Figure 3-13: Looking down the outlet works chamber/shaft

Figure 3-14: Water level of Knellpoort at time of visit

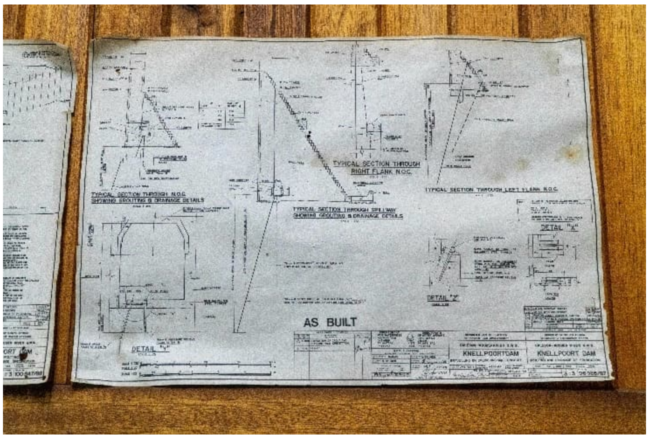

Figure 3-15: Typical section through Knellpoort

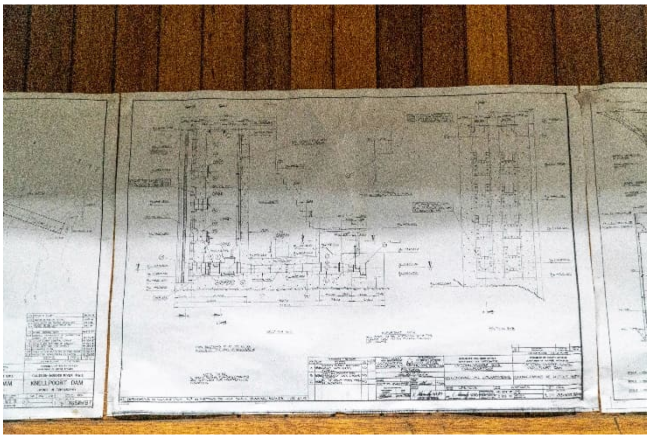

Figure 3-16: Section through outlet works

3.3 Silt Traps at Tienfontein Pump Station

The silt traps at Tienfontein Pump Station were overgrown and not functioning at the time of the site visit. Observations from the Zutari team are:

- Silt traps were overgrown and not used for at least two years.
- The sluices for scouring of the silt traps are manually operated.
- The mechanical equipment of the silt traps are in a very bad condition and unlikely to function if the pump station is to be used.
- The headstock for some of the sluices is inoperable due to the shafts being buckled or other damages.
- Design changes to the silt traps can improve the effectiviness and ease of operation of the facility.
- Substantial work is required to clear the traps and to reinstate or replace equipment, before they can be used again.

Figure 3-17: Silt trap above Tienfontein Pump Station

Figure 3-18: Overgrown and silted up channels

Figure 3-19: Downstream channel also overgrown

Figure 3-20: Rusted equipment

3.4 Tienfontein Pump Station

As with the Novo Pump Station the Tienfontein Pump Station was not operational at the time of the site visit. Table 3-2 summarises the key parameters of the pump station.

Table 3-2: Summary of Tienfontein Pump Station Key Parameters

Pump Station	Installed capacity	Max operational capacity	Comments
Tienfontein	5700L/s	3800L/s	6 X 950L/s pumps _ sixth pump has never been operational due to siltation challenges at position 6.

Observations from the Zutari team are:

- Six vertical turbine pumps are installed.
- The pump station were upgraded to 4 m³/s not long ago.
- Siltation problems at the inlet of the pump station prevent the pump station to operate at maximum capacity.
- Siltation is a major problem for the operators and causes frequent breakages.
- Pump station building seems to be structurally in reasonable condition, although general housekeeping needs to be attended to.
- The mechanical and electrical equipment seems to be in good condition although general maintenance and cleaning is required.
- There are no additional bays for new pump sets to be installed and larger pumps will need to be installed if the capacity of the pump station is to be increased.

Figure 3-21: Tienfontein pump station entrance

Figure 3-22: Six pump sets installed

Figure 3-23: New pump set

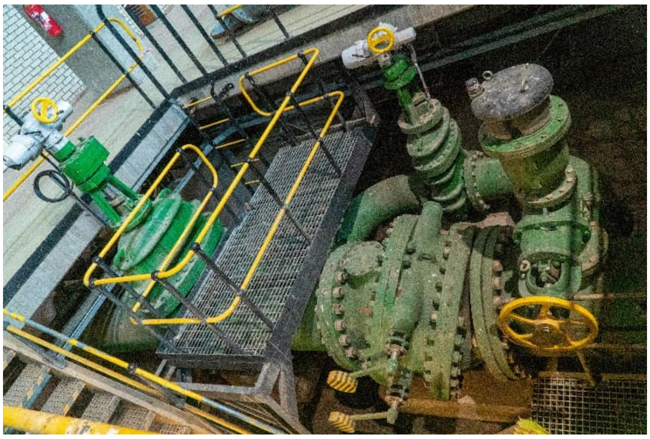

Figure 3-24: Old pump set

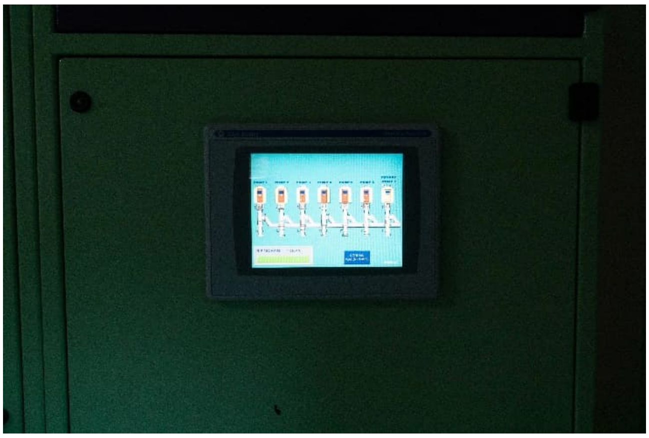

Figure 3-25: MCC panel

Figure 3-26: Abstraction inlet screening wall

Figure 3-27: Inlet screening into pump sumps

Figure 3-28: General housekeeping not done

3.5 Welbedacht Dam Wall

Welbedacht Dam had sluice gate 5 open at the time of the site visit. The dam has reportedly accumulated silt to the extent that less than 5% of the dam's original storage capacity of 114 million m^3 remains.

Observations from the Zutari team are:

- Evidence of the siltation of the dam basin is clearly visible and most of the dam basin is covered with reeds.
- Releases from Knellpoort takes roughly 1.5-2 days to reach Welbedacht with high (50% according to the operators) losses along the route.
- Upstream scouring of the dam basin is not effective as only two sluice gates are functioning.

- Scouring efforts resulted in scouring at toe of dam wall due to the sluices not functioning and unbalanced release of the water.
- Scouring at the downstream side of the dam wall is evident.

Figure 3-29: Dam wall

Figure 3-30: Overhead crane

Figure 3-31: Sluice Gate 5 open

Figure 3-32: Sluice gate 5 hydraulic piston

Figure 3-33: Evidence of downstream scouring and debris

Figure 3-34: Newly painted hydraulic power pack

3.6 Welbedacht Water Treatment Plant

The visit to Welbedacht Water Treatment Plant (Welbedacht WTP) began with a meeting in the boardroom where the plant manager gave an overview of the plant, key performance criteria, challenges encountered, and answered questions from the Zutari team. The Zutari team then inspected the plant in the order of the general process flow, accompanied by a knowledgeable plant operator who answered further questions.

The key observations from the Zutari team are:

- Raw water source and quality
  - General
    - The raw water is sourced from Welbedacht Dam on the Caledon River.
    - The Caledon River has a wide variation in settleable and suspended solids, which is proportional to the river flow. Much of the solid's load is transferred to Welbedacht WTP.
    - During periods of high rainfall, substantial amounts of silt and sand pass through the Welbedacht Dam and into the plant.
    - The flow to the plant is supplemented with water from Knellpoort Dam (mainly) in winter. The water quality of this source is less variable.
  - Turbidity
    - Typical base winter flow of the Caledon River ~ 10 to 50 ntu.
    - Typical base summer flow of the Caledon River ~ 500 to 1 000 ntu.
    - Typical high flow of the Caledon River ~ 35 000 to 40 000 ntu.
    - Typical Knellpoort Dam ~ 10 to 50 ntu.
  - Other water quality considerations
    - Problems with algae and cyanobacteria (blue-green algae) – such as short filter runs, excessive filter backwashing requirements, algal toxins and other metabolites, algae-based taste, and odour problems – in the raw water have not been observed by the operations team.
    - Iron and manganese are occasionally elevated in winter, but these metals and "straw coloured" water is reported in Bloemfontein as a result.
    - The operations staff did not report any other significant raw water quality challenges or contents that require tailored treatment.
- Design and production capacity
  - The rated design capacity is 145 ML/d.
  - As turbidity increases, the plant production is proportionately not able to meet the design capacity.
  - The plant can maintain the design production when turbidity is low, such as for base winter flow.
  - The operators report that the design capacity, or close to it, can be maintained at turbidities of up to 500 ntu.
  - The plant production drops to:
    - ~ 90 to 125 ML/d during typical base summer flow of the Caledon River.
    - As low as 50 ML/d during typical high flow of the Caledon River.
  - Compliance with the SANS 241 national drinking water standards has not been verified as part of this exercise as extensive data will need to be obtained from the operations staff and analysed.
- Process train

- The treatment process train comprises:
  - Inlet chemical dosing, mixing and flow splitting.
  - Primary sedimentation via parallel:
    - → Clariflocculator
    - → Horizontal flow baffled flocculation and sedimentation tanks.
  - Secondary settling via a bank of Pulsators.
  - Rapid gravity sand filtration.
  - Final disinfection.
  - Ancillary facilities including:
    - → Backwash recovery tank and associated equipment.
    - → Sludge lagoons.

► Chemical dosing regime

- The chemical dosing regimen comprises:
- Pre-chlorination for algae control (and iron and manganese oxidation).
- Coagulation with a polyaluminium chloride and organic polymer blend, selected based on prevailing water quality (such as U3800, or S3835, or U6800).
- pH control with lime (targeting 8.4 to 8.6 at the time of the site visit).
- Coagulant can be (and was at the time of the site visit) dosed again after the primary sedimentation step (ahead of the Pulsators).
- Intermediate chlorination before the Pulsators for algae control (and iron and manganese oxidation).
- Intermediate chlorination before the filters for algae control (and iron and manganese oxidation).
- Final chlorination for disinfection.

► General comment on the plant and process units

- Inlet chemical dosing, mixing and flow splitting, and chemical dosing regimen:
  - Rapid mixing at the inlet mixing and flow splitting unit is provided but is not optimal. Improvements in plant performance could be gained by modification or enhancement of the rapid mixing.
  - Flow measurement or other means of quantifiably controlling the split between the two parallel primary sedimentation units is not provided, which would be helpful for better plant control.
  - No proper rapid mixing facilities are provided for the coagulant dosing step after primary settling.
  - The chemical dose points do not have proper distribution units (spreader bars) which may improve mixing and performance.
  - Pre-chlorination and intermediate chlorination can cause the production of potentially harmful elevated halogenated disinfection by-products (DBPs), depending on the presence and nature of dissolved organic carbon in the raw water. This can be mitigated by removing the DBP-precursors by coagulation and filtration before any chlorine is dosed. If pre and intermediate chlorination is essential for algae or dissolved metal control, the DBP production should be regularly monitored to make sure recommended standards are not exceeded.
- Primary sedimentation - clariflocculator
  - The rotating bridge and the attached flocculation mixers have reportedly not been functional for over a year. The combined flocculation and sedimentation processes of the clariflocculator cannot function without the mixing and settled sludge collection provided by the bridge. The process is thus compromised and should be repaired urgently. Failing this, both flocculation and sedimentation are inefficient, resulting in

carry-over of solids to the Pulsators and over-loading of that process step with similar knock-on effects for filtration.

- When very high turbidity is received by the plant, sand and silt are dumped in the clariflocculator and the bridge (even when it has been operable in the past) is overloaded and cannot rotate. The attached flocculation mixers also become jammed by the accumulated sediment. The clariflocculator then must be emptied and cleaned out by manual labour. Larger gearboxes were apparently installed on the rotating drives for the clariflocculator, and whilst this provides some help, the problem remains that the sludge cannot be removed fast enough, and the bridge and flocculation stirrers become jammed.
- A typical effect of the unit, when it is functioning reasonably, can be a turbidity reduction from ~ 2 000 ntu at the inlet to 100 ntu. At an inlet turbidity of 700 ntu, a reduction to about 40 ntu would be expected.
- The de-sludge flow is not quantified and hence the plant recovery efficiency is unknown.

- Primary sedimentation – Horizontal flow system
  - The horizontal flow system comprises a baffled flocculation basin followed by a horizontal flow sedimentation tank.
  - These facilities reportedly do not perform as well in reducing the turbidity as the clariflocculator. Further investigation would be required to confirm this and understand the reasons. The investigations should quantify the flow and the split between the two primary sedimentation facilities so that the hydraulic loading on each can be checked.
  - The settled water collection launders are unusually deep and hence do not utilise the full available settling depth. The launders also do not provide for optimally even collection of the settled water. Addressing these issues would likely yield an improvement in performance.
  - After heavy silt and sand loads have been received by the plant, the de-sludging of the sedimentation tanks must be manually assisted as the hydraulic drainage of the sludge hoppers cannot remove the solids fully. This is apparently exacerbated by problems with the de-sludge valves, which should be repaired as a priority.
  - It was reported that the sedimentation tank is unable to cope with or adequately reduce the solids load when the raw water turbidity is above 700 ntu.
  - The de-sludge flow is not quantified and hence the plant recovery efficiency is unknown.

- Pulsators
  - A secondary sedimentation step is provided by two Degremont Pulsators.
  - Under baseline (not high turbidity) conditions, the Pulsators are reportedly de-sludged once per shift, for about 5 minutes. The de-sludge flow is not quantified and hence the plant recovery efficiency is unknown.
  - The pulsation system has not been functional for an extended period, as there is a problem with the vacuum generation control equipment in the central vacuum chamber for each Pulsator. Water is apparently drawn into the vacuum pump, which could be the result of the vacuum control valve not operating properly. The problem is also likely exacerbated by the accumulation of solids carried over from the over-loaded primary sedimentation, which has blocked the inlet holes from the inlet flumes into the main compartment of the Pulsators, resulting in a flow back-up. These inner components of the Pulsators were apparently last cleaned out in 2014 and should be cleaned more regularly (say quarterly).
  - As a result of the pulsation system not working, the Pulsators function sub-optimally as upflow clarifiers. A proper suspended sludge blanket is not formed, and

flocculation is hence compromised, resulting in poor performance of the Pulsators and the transfer of an excessive solids load to the downstream filters.

- It is suspected that the influent distribution baffle plates on the bottom of the Pulsators have been broken or otherwise disturbed by the excessive solids loading that takes place when high raw water turbidity conditions prevail. This situation should be remedied, failing which the Pulsators will not perform properly.

- Rapid gravity sand filters
  - Filtration is via sixteen Degremont Type-T rapid gravity sand filters.
  - Hydraulic control through each of the filters is via a Degremont partialisation / syphon system. These were not functioning properly and hence the hydraulic control and filter performance is compromised. The system components should be checked, cleaned, and repaired as necessary. The float chambers for these systems (generally, not just at Welbedacht) are prone to being choked by sediment accumulation that prevents the float from moving freely. The float chambers should therefore be cleaned out regularly as part of routine maintenance (as least monthly). A drainage system can be used but this has limited effectiveness unless the shape of the float chamber is changed to one with a 60-degree sloped settling cone.
  - One of the filters was out of operation for refurbishment of the filter underdrainage system. It was evident that several other filters, if not all of them, would also require refurbishment. The filter nozzles had become brittle and were failing, resulting in uneven filtration and collection of filtered water, uneven air scour and backwash water collection, uneven and compromised backwashing, and loss of filter media. The filter media loss was significant in some filters and filtration efficiency is thus compromised.
  - The filter under-drainage system was constructed using Degremont type precast filter panels, with are bolted and grouted in place. The grout joints for this under-drainage system are notorious for failing after several years in service. The joints in the filter that was being refurbished and hence had its filter media removed appeared to be intact. However, the joints for the other filters should be inspected as it is possible that there have been failures. The uneven filter media distribution in the filters gives evidence of some disturbance, whether by broken nozzles or failed panel joints, or both.
  - Apparently, the number of duty backwash pumps operating during the backwash rinse cycle has been reduced from three to two, as nozzles were breaking and failures in the filter under-drainage floors were occurring.
  - One filter was permanently out of service due to various problems and needs repair.
  - A filter backwash cycle was observed for one of the eastern banks of filters. During air scour, air bubbling was noticed in other filters indicating that valves are leaking.
  - Functional local controls at the filters are not provided for the backwash pumps and air scour blowers. Similarly, the valves cannot be accessed from the upper filter gallery. This means that the operators must continually move back and forth between the upper gallery (to monitor the filter backwash progress), the motor control centre for the pumps and blowers, and the lower filter gallery where the valve handwheels are accessed. This is far from ideal or even reasonable and should be remedied.
  - The inlet sluice gates require significant manhandling to open and close.
  - The plenum vent valves were not properly set or controlled, resulting in excessive water being discharged during the backwash cycle. These are supposed to assist in rapidly venting the air blanket from the filter plenum once air scour is complete in the backwash cycle, but excessive water discharge thereafter should be avoided.
  - A substantial leak along a reinforced concrete construction joint water bar was observed. It is suspected that water enters the joint from low down in the filter (beneath the under-drainage system) and travels up the water bar, eventually

discharging into the filter. It is fortunate that the water currently discharges into the filter, but this problem should be remedied.

- Final disinfection
  - The product of free chlorine concentration and contact time is a critical parameter to ensure adequate final disinfection. A proper baffled contact tank to ensure proper control of the final disinfection contact time has not been provided at the plant. This may be mitigated by the long retention time in the pipeline to consumers but is noted as a possible matter for further investigation and quantification.
- Backwash recovery tank and associated equipment
  - Backwash water is directed to a recovery tank but the recycle pumping system is not functional and backwash water is thus not recycled.
  - The problems with this system should be investigated and a satisfactory upgrade provided to improve the plant efficiency (less loss of water).

► Other:

- General housekeeping at the plant was reasonably good.
- The plant management and operations team with whom the Zutari team interacted were knowledgeable, enthusiastic, took pride in their work, and appeared competent and diligent and to all appearances, are a credit to their profession and the community they ultimately serve.
- A pre-treatment silt and sand removal step (such as hydrocyclones), upstream of the inlet mixing and flow splitting unit should be considered. The intention of such a step would be to reduce the solids load on the primary sedimentation tanks, the Pulsators, and the filters, with a view to increasing the (currently compromised) production capacity of the plant when high raw water turbidity conditions prevail.
- Welbedacht WTP is currently exempted from load-shedding.
- Plant valves and sluice gates are not provided with actuators and are manually operated. The provision of actuators on certain valves and sluice gates may allow for easier and better operation of the plant, and the optimum solution for this should be investigated.
- Improvements to the system for controlling the filter backwash cycles (valves, control of pumps and blowers) should be considered.
- Despite the challenges encountered, the plant is reasonably well operated. This is in part due to its simplicity, which fosters an intuitive "feel" for the plant by the operators. It is thus not recommended that any extensive automation is provided as this will place a barrier between them and the plant. When it fails (which will happen), the operators will then not be able to respond as intuitively to the requirement for manual operation. Automation will also introduce significantly more advanced equipment that must be maintained and serviced, and which will fail from time to time.
- There appears to be a strong division between the role of the operations staff and that of the maintenance team. Maintenance is not attended to as timeously and proactively as it should be, and the operations team therefore struggle unnecessarily and are doing well under the circumstances. It may be worth investigating if very basic maintenance tasks could be assigned to the operations team or else how maintenance can be enhanced.

Figure 3-35: Welbedacht WTP office building

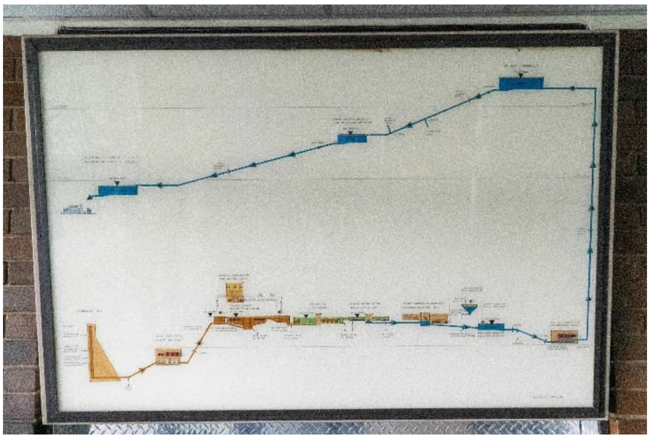

Figure 3-36: Process flow diagram, not 100% accurate

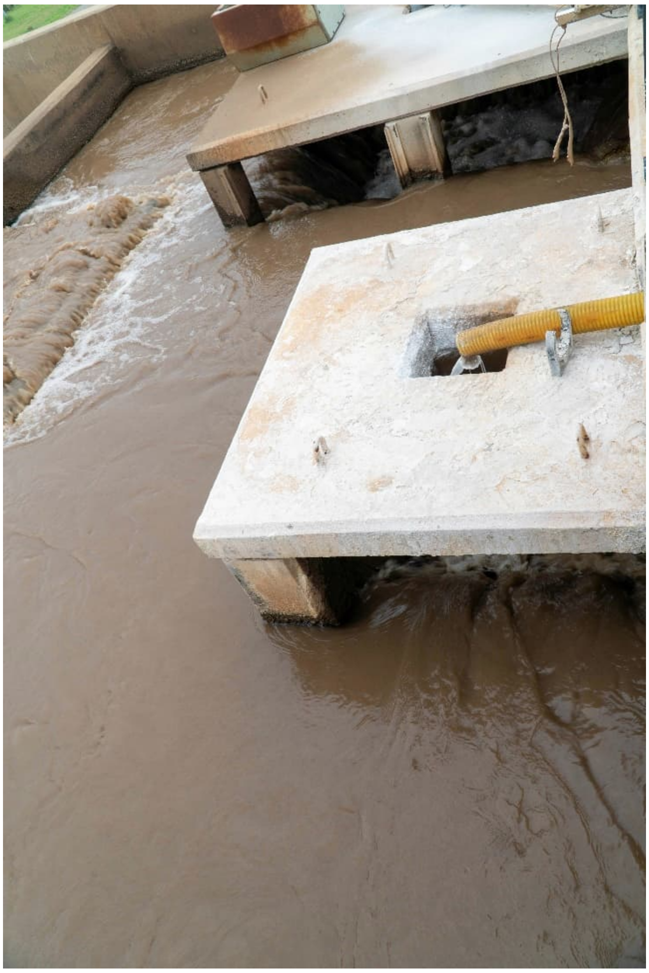

Figure 3-37: Lime dosing

Figure 3-38: Lime slurry dosing pumps

Figure 3-39: Coagulant dosing pumps

Figure 3-40: Inlet mixing and flow splitting

Figure 3-41: Primary sedimentation - clariflocculator

Figure 3-42: Agitators and secondary dosing point

Figure 3-43: Primary sedimentation – horizontal flow system

Figure 3-44: Filters backwashing

Figure 3-45: Filter lower gallery and partialisation / siphon system

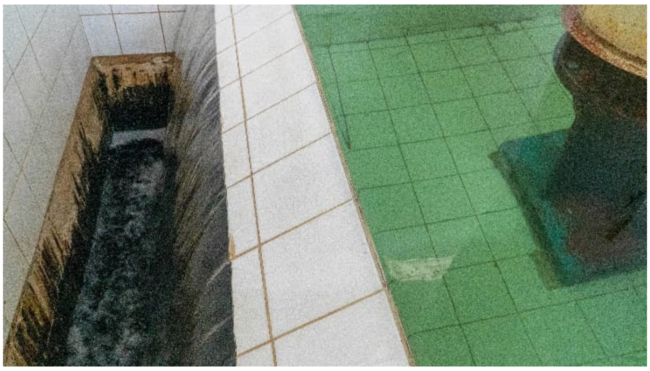

Figure 3-46: Filtered water inspection chamber

Figure 3-47: Refurbishment of filter under-drainage system in process

Figure 3-48: Filtration nozzles being replaced

3.7 Rustfontein Water Treatment Plant

Mr Brendon Theunissen visited the Rustfontein Dam and WTP on his own, whilst the rest of the team attended a Project Steering Committee Meeting. The visit began with a meeting with the area manager, the plant manager, and other experienced operations staff. These staff gave an overview of the plant, key performance criteria, challenges encountered, and answered questions from Mr Theunissen. The plant manager then accompanied Mr Theunissen on an inspection of the plant in order of the general process flow and answered further questions.

The key observations from the site visit are discussed in the following sections.

- Raw water source and quality
  - General
    - The raw water is sourced from Rustfontein Dam.
  - Turbidity:
    - Typical average ~ 70 to 80 ntu.
    - Typical low ~ 30 ntu.
    - Typical high (maximum) ~ 460 ntu.
- Other water quality considerations:
  - The water is slightly soft and has a typical pH of ~ 7.8.
  - Problems with algae and cyanobacteria (blue-green algae) are encountered, especially in summer. These are noticed primarily by taste and odour in the water, derived from algal metabolites. Customer complaints about taste and odour have been received. It is likely that algal toxins may also be present at times, and that halogenated disinfection by-

products may be produced by the reaction of chlorine with the algal metabolites. This should be investigated. The cyanobacteria cause shortened filter runs and loss of plant efficiency due to the need for more water to be used for filter backwashing. The operations team reported that filter runs are reduced from the normal time of around 45 hours, to between 20 and 30 hours when cyanobacteria is present.

- The operations team also reported that Daphnia - a genus of small planktonic crustaceans – occurs in the raw water. It may be that the shortened filter runs are due to the Daphnia rather than cyanobacteria, or that the Daphnia exacerbates the problem. These issues should be investigated further to fully understand the problem and possible solutions if required.
- Normal green algae do grow and cause a nuisance in the plant, though it is not anticipated that this produces problematic metabolites.
- The operations staff did not report any other significant raw water quality challenges or contents that require tailored treatment.

► Design and production capacity

- The plant was commissioned in 1998 with a rated design capacity is 100 ML/d.
- The operators report that they do not have problems or difficulty with achieving the design flow, no matter what the prevailing raw water conditions are. At the time of the site visit, the plant was receiving 110 ML/d. The final production may be lower than this due to loss of backwash water and de-sludging.
- Compliance with the SANS 241 national drinking water standards has not been verified as part of this exercise as extensive data will need to be obtained from the operations staff and analysed.

► Process train

- The treatment process train comprises:
  - Inlet chemical dosing, mixing and flow splitting catering for both the raw inlet (upstream of primary sedimentation) and secondary sedimentation.
  - Primary sedimentation via turbo-circulator clarifiers
  - Secondary settling via a bank of Pulsators.
  - Rapid gravity sand filtration.
  - Final disinfection.
  - Ancillary facilities including:
    - → Backwash recovery tank and associated equipment.
    - → Sludge lagoons.

► Chemical dosing regime

- The chemical dosing regime comprises:
  - Coagulation with a polyaluminium chloride and organic polymer blend, selected based on prevailing water quality (such as Sudfloc 3835, or Ultrafloc 6050).
  - pH control with lime (targeting 8.5 at the time of the site visit).
  - At the time of the site visit, the coagulant was being dosed at ~ 10 mg/L prior to the clariflocculators and again at ~ 7 mg/L ahead of the Pulsators.
  - Final chlorination for disinfection. At the time of the site visit, ~ 4.0 mg/L was being dosed to achieve a free residual of ~ 2.0 mg/L.

► General comment on the plant and process units

- Inlet chemical dosing, mixing and flow splitting, and chemical dosing regime:
  - Reasonable rapid mixing at the inlet mixing and flow splitting unit is provided.
  - Weirs are provided to split the flow between the two parallel streams of sedimentation facilities.

- Chlorination of algal (cyanobacteria) metabolites can cause the production of potentially harmful elevated halogenated disinfection by-products (DBPs). The DBP production should be regularly monitored to make sure recommended standards are not exceeded and to establish if special treatment is required for removal of the DBP-precursors (metabolites).
- Further to the above point, it is understood that BloemWater is undertaking laboratory testing to determine if the taste and odour problems (likely from cyanobacteria) can be controlled via pre-chlorination. Caution should be exercised with this, because potentially harmful DBPs may be created by reaction of the chlorine with the organic substances that give rise to the taste and odour.
- A chlorine dioxide plant was installed to assist with taste and odour control. However, reliability, complexity and high operational cost problems with this equipment were encountered and eventually some of the pipework exploded. BloemWater is apparently intending to reinstate this equipment, which they would prefer to do via a supply-install-operate-maintain contract.

- Primary sedimentation – turbo-circulator clarifiers
  - Primary sedimentation is provided by two Degremont turbo-circulator clarifiers.
  - These units appear to be functioning acceptably and no problems were reported.
  - At the time of the site visit, the turbidity was reduced from ~ 75 ntu (raw water) to ~ 25 ntu across the primary sedimentation step.
  - The de-sludge flow is not quantified and hence the plant recovery efficiency is unknown.
- Pulsators
  - A secondary sedimentation step is provided by two Degremont Pulsators.
  - The Pulsators were received a combined flow of 1 300 L/s (112.3 ML/d), and turbidity across the units was reduced from ~ 25 ntu to ~ 2.5 ntu, which is an acceptable turbidity to be passed onto the filters. The units were not receiving a high turbidity, so were not being tested under challenging conditions at the time of the site visit. Problems observed and possible improvements noted should be seen in this context.
  - The de-sludge flow is not quantified and hence the plant recovery efficiency is unknown.
  - The pulsation system has not been functional for an extended period, as there is a problem with the vacuum generation control equipment in the central vacuum chamber for each Pulsator. The vacuum fans are not functioning but there may be additional problems.
  - As a result of the pulsation system not working, the Pulsators function sub-optimally as upflow clarifiers. A proper suspended sludge blanket is not formed, and flocculation is compromised, resulting in poorer performance of the Pulsators. Finer floc particles are potentially not captured by the floc blanket and hence break through to the filters, causing downstream performance and plant efficiency challenges.
  - The plant manager reported that the vacuum system was previously only able to lift the water level by about 20 to 30 mm, versus a required 40 mm. The design target value should be investigated, and the vacuum generation and control system repaired to restore the pulsation system.
  - Each Pulsator is provided with eight actuated de-sludge valves; four to de-sludge the floc blanket control hopper and four to de-sludge solids that have settled to the bottom of the Pulsator. The valve actuators are not working. The manual opening and closing of the valves takes longer than with an actuator (to reach fully open and full design flushing flow) and hence more water is lost and the efficiency of the units is reduced. The actuators should be repaired and maintained in good working order.
  - It is suspected that some of the influent distribution baffle plates on the bottom of the Pulsators have been broken or otherwise disturbed. This situation should be

remedied to ensure even flow distribution in the units, so performance is not compromised.

- Rapid gravity sand filters
  - Filtration is via two mirrored banks of four Degremont Type-V rapid gravity sand filters, with a common central filter gallery.
  - The filtered water on the morning of the site visit ranged from ~ 0.40 ntu to 0.70 ntu, with most around 0.60 ntu. This is a reasonably good, filtered water turbidity, though a target of less than 0.1 ntu should be aimed at to achieve best practise for removal of pathogens.
  - Hydraulic control through each of the filters is via a Degremont partialisation / syphon system. As at Welbedacht WTP, these were not functioning properly and hence the hydraulic control and filter performance is compromised. The system components should be checked, cleaned, and repaired as necessary. The float chambers for these systems are prone to being choked by sediment accumulation that prevents the float from moving freely. The float chambers should therefore be cleaned out regularly as part of routine maintenance (as least monthly). A drainage system can be used but this has limited effectiveness unless the shape of the float chamber is changed to one with a 60-degree sloped settling cone.
  - As the time of the site visit some of the operational filters were operating in a drowned state, with water backing up to the inlet control weir, and with other filters having a reasonably high drop over the corresponding weir. This results in uncontrolled and improper flow proportioning between the various filters and compromised filtration performance. It is likely that the problem is caused by the malfunctioning partialisation / syphon systems. The problem should be further investigated and remedied.
  - One of the float chambers was over-flowing at the time of the site visit.
  - Local control desks are provided in the upper filter gallery. The backwash pumps and air scour blowers cannot be activated and shut down from the local controls and hence, the operators must continually move back and forth between the upper gallery (to monitor the filter backwash progress), and the machine room for the pumps and blowers (or must use two operators communicating with a radio, with one remaining at the machine room). This compromises the efficiency of the backwash process, and the controls should be repaired and restored as a priority.
  - The filter backwash cycle incorporates combined air scour and backwash (with one duty pump operating), followed by backwash rinse (with two duty pumps operating). This is consistent with how Degremont filters of this type normally operate and provides a superior backwash effectiveness to sequential air scour and backwash.
  - The plant manager reported that BloemWater is planning to replace the filter under-drainage nozzles, the filter media (silica sand) and the filter valves. It is recommended that durable nozzles be used, that these be installed accurately level (with a level tolerance of ± 1 mm), and that the integrity of the filter under-drainage floor for each filter be carefully inspected when the filters have been emptied.
  - A substantial amount of stringy algae was visible in the filters and a green algal scum had accumulated at the end of the inlet channels to each of the two banks of filters.
- Final disinfection:
  - The product of free chlorine concentration and contact time is a critical parameter to ensure adequate final disinfection. Chlorine for final disinfection is dosed into a compartment within the treated water service reservoir and a proper baffled contact tank to ensure proper control of the final disinfection contact time has not been provided. This may be mitigated by the long retention time in the pipeline to consumers but is noted as a possible matter for further investigation and quantification.

- Residuals handling and associated equipment:
  - De-sludging flows from the turbo-circulator clarifiers and the Pulsators, and spent backwash water from the filters, is directed to a bank of two residuals holding tanks, from where it is pumped to a set of three drying lagoons.
  - The supernatant from the lagoons overflows to the river downstream of Rustfontein Dam.
  - The three lagoons were last cleaned out in 2013 and the sludge disposed of at a landfill site. The lagoons have reportedly been full since 2019 and should be cleaned out as a priority.

► Other:

- General housekeeping at the plant was reasonably good.
- The plant is provided with some level of semi-automation but is mostly run in manual mode. The filter backwash sequences are controlled automatically after manual initiation of the cycle. However, the problems with starting and stopping the backwash pumps and air scour blowers prevent this from working properly. Manual operation encourages operator involvement, initiative, understanding and an intuition for control. However, the issues with local starting and stopping of the backwash pumps and air scour blowers should be remedied.
- Valves and sluice gates are not provided with actuators and are manually operated. The provision of actuators on certain valves and sluice gates may allow for easier and better operation of the plant, and the optimum solution for this should be investigated.
- The plant is reasonably well operated. As for Welbedacht WTP, this is in part due to its simplicity, which fosters an intuitive “feel” for the plant by the operators. It is not recommended that any more extensive automation is provided.
- Again, there appears to be a strong division between the role of the operations staff and that of the maintenance team. Maintenance is not attended to as timeously and proactively as it should be and the operations team struggle unnecessarily and are doing well under the circumstances.

Figure 3-49: Inlet chemical dosing and flow splitting

Figure 3-50: Lime dosing equipment

Figure 3-51: Coagulant dosing equipment

Figure 3-52: Turbo-circulator clarifier

Figure 3-53: Pulsators

Figure 3-54: Pulsator vacuum control building

Figure 3-55: Pulsator vacuum pump (not operable)

Figure 3-56: Pulsator vacuum control equipment (not operable)

Figure 3-57: Pulsator de-sludge valves (actuators not operable)

Figure 3-58: Filter

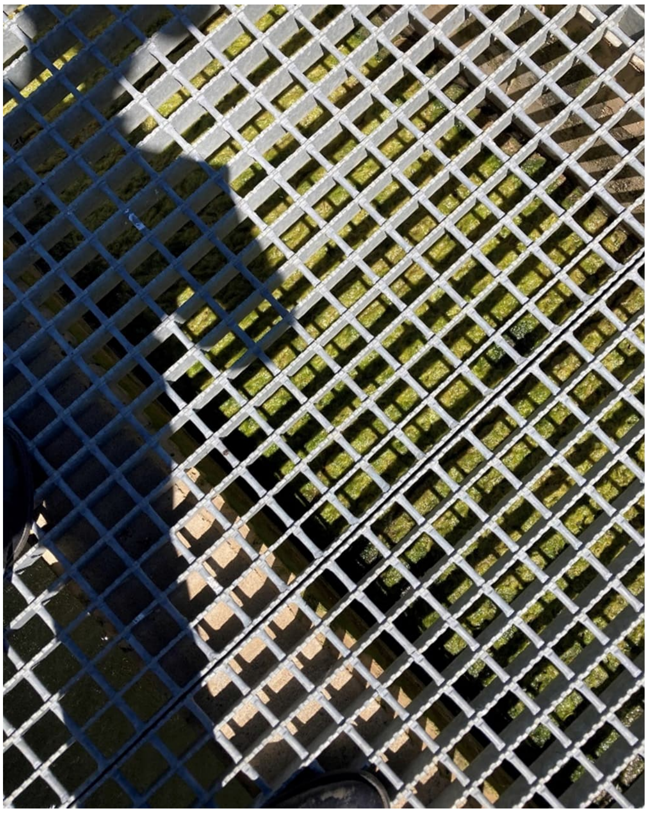 **Figure 3-59: Algae scum in filter inlet channel**	 **Figure 3-60: Lower filter gallery (unsafe access)**
 **Figure 3-61: Filter float chamber overflowing**	 **Figure 3-62: Filtered water inspection chamber (partialisation-siphon system over-aerating)**

Figure 3-63: Filter backwash pumps and air scour blowers

Figure 3-64: Chlorine dosing equipment

Figure 3-65: Chlorine drums

Figure 3-66: Residuals holding tanks

Figure 3-67: Residuals pump station

Figure 3-68: Final water pump station

3.8 Gariep Dam Wall

The Gariep Dam was overtopping during the site visit. The team was able to gain access to the dam wall where the existing two 2.1m diameter pipes are located. The team was unable to see the termination/connection point, however, as the two representatives from operations only knew where the Gariep town outlet was located. As-built drawings of the pipeline were subsequently sourced from DWS.

The key observation from the Zutari team is:

- These two 2.1m pipelines seemed to have been earmarked for connection to Bloemfontein.

Figure 3-69: Gariep Dam Wall from the DWS Offices

Figure 3-70: Gariep Dam Wall and Spillway

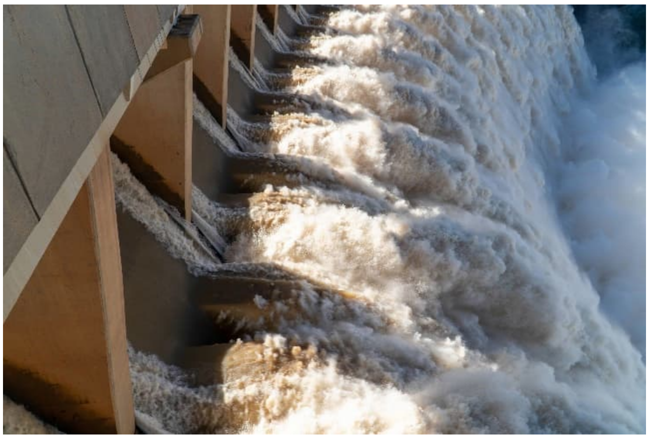

Figure 3-71: 1 500 m³/s overtopping

Figure 3-72: View of Hydropower station downstream

Figure 3-73: One of the existing 2.1m Ø pipes within the dam wall

Figure 3-74: External shaft down to the connection pipes

Figure 3-75: Pipe No. 2 to Free State

Figure 3-76: Smaller pipe feeding Xhariep WTP

4 Observation of Potential Infrastructure Sites

The direct potable pipeline to Bloemfontein, identified as the most favourable in the Mangaung Metropolitan Municipality (MMM) studies, had the most information available regarding the siting of the new infrastructure. The team visited these sites on the way back from Gariep Dam.

4.1 Low Lift Pump Station

The low lift pump station would be located close to the existing Gariep WTP and connect into one of the existing 2.1m Ø pipelines. The water would then be pumped to a new WTP.

The site information available from the Surveyor General's GIS Website is summarised in Table 4-1.

Table 4-1: Summary of land information for low lift pump station site

Parameter	Information
Geometry Identifier	1612110
Parcel Type	Farm Portion
Farm Name	Waschbank No. 274
Parcel Number	1/274
Province Name	Free State
Major Region	Phillippolis
Major Code	F0260000

The key observations from the Zutari team are:

- Site located east of the surfaced road is sloped quite steeply.
- Overhead powerlines are in close proximity to the site.
- Site is accessible from existing roads
- Alternative site located north-west of proposed site has better topography
- Floodline information must be obtained to verify that the site is located above the 1:50 year floodlines.

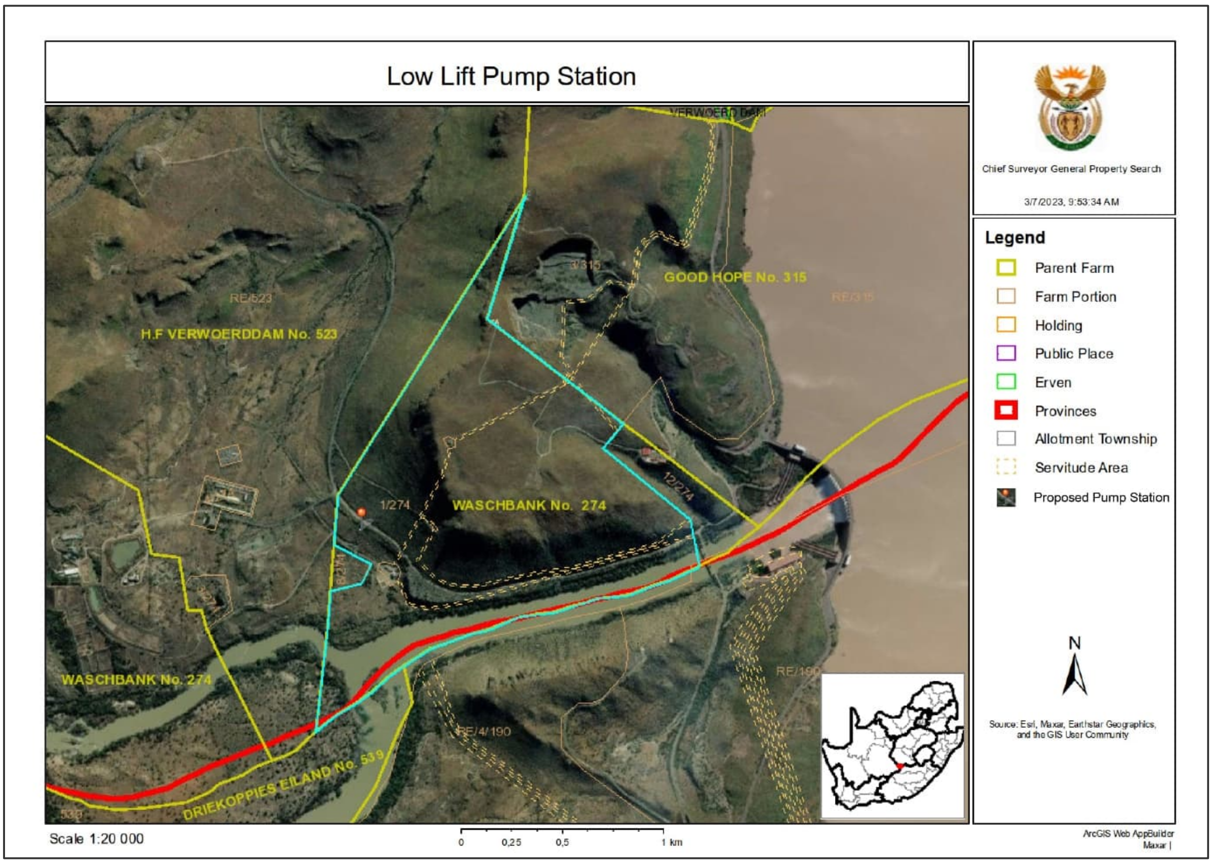

Figure 4-1: Proposed location of low lift pump station (scale 1:20 000 @ A4) shown as red pin

	
Figure 4-2: Gariep WTP	**Figure 4-3: Southern end of potential site**

Figure 4-4: Middle of potential site

Figure 4-5: Northern end of potential site (alternative site to the right of existing structure)

4.2 Water Treatment Plant

The WTP would receive water from the low lift pump station and is located approximately 10 km from the low lift pump station (refer to Figure 4-6 for proposed location of WTP).

The site information available from the Surveyor General's GIS Website is summarised in Table 4-2.

Table 4-2: Summary of land information for WTP site

Parameter	Information
Geometry Identifier	871549
Parcel Type	Farm Portion
Farm Name	Inhoek No. 495
Parcel Number	1/495
Province Name	Free State
Major Region	Phillippolis
Major Code	F0260000

The key observations from the Zutari team are:

- Site is located next to the N1 highway and will be very visible from the road.
- Access to site will need to be created from the R701 road.
- There is plenty of space on this site.
- Site has a gentle slope to aid the treatment process to function under gravity.
- The site is located a long way from any watercourse, meaning that sludge lagoons would most probably be required.
- Overhead powerlines are in close proximity to the site.

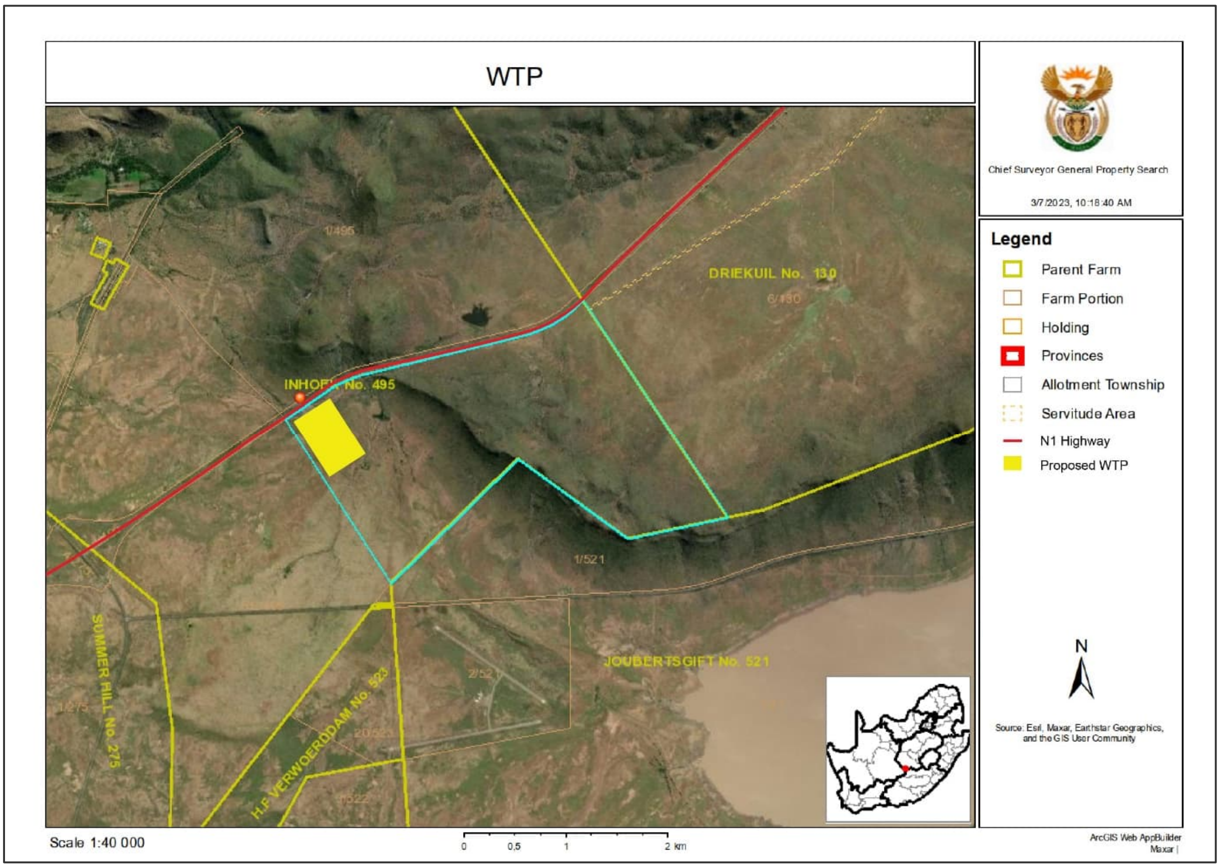

Figure 4-6: Proposed location of WTP (scale 1:40 000 @ A4)

Figure 4-7: Location next to the N1

Figure 4-8: View towards the eastern boundary of the site

Figure 4-9: View of the middle of the site

Figure 4-10: View towards to the western boundary

4.3 High Lift Pump Station

The high lift pump stations would pump treated water from the WTP to Bloemfontein. The first high lift pump station will be located at the WTP. A second high lift pump station, or alternatively a large balancing reservoir, might be required in the vicinity of Springfontein (refer to Figure 4-7 for proposed location).

The site information available from the Surveyor General's GIS Website is summarised in Table 4-2 Table 4-3.

Table 4-3: Summary of land information for high lift pump station site

Parameter	Information
Geometry Identifier	10788040
Parcel Type	Farm Portion
Farm Name	Koppie Alleen No. 497
Parcel Number	RE/497
Province Name	Free State
Major Region	Bethulie
Major Code	F0020000

The key observations from the Zutari team are:

- Site access will be off the road leading to Springfontein.

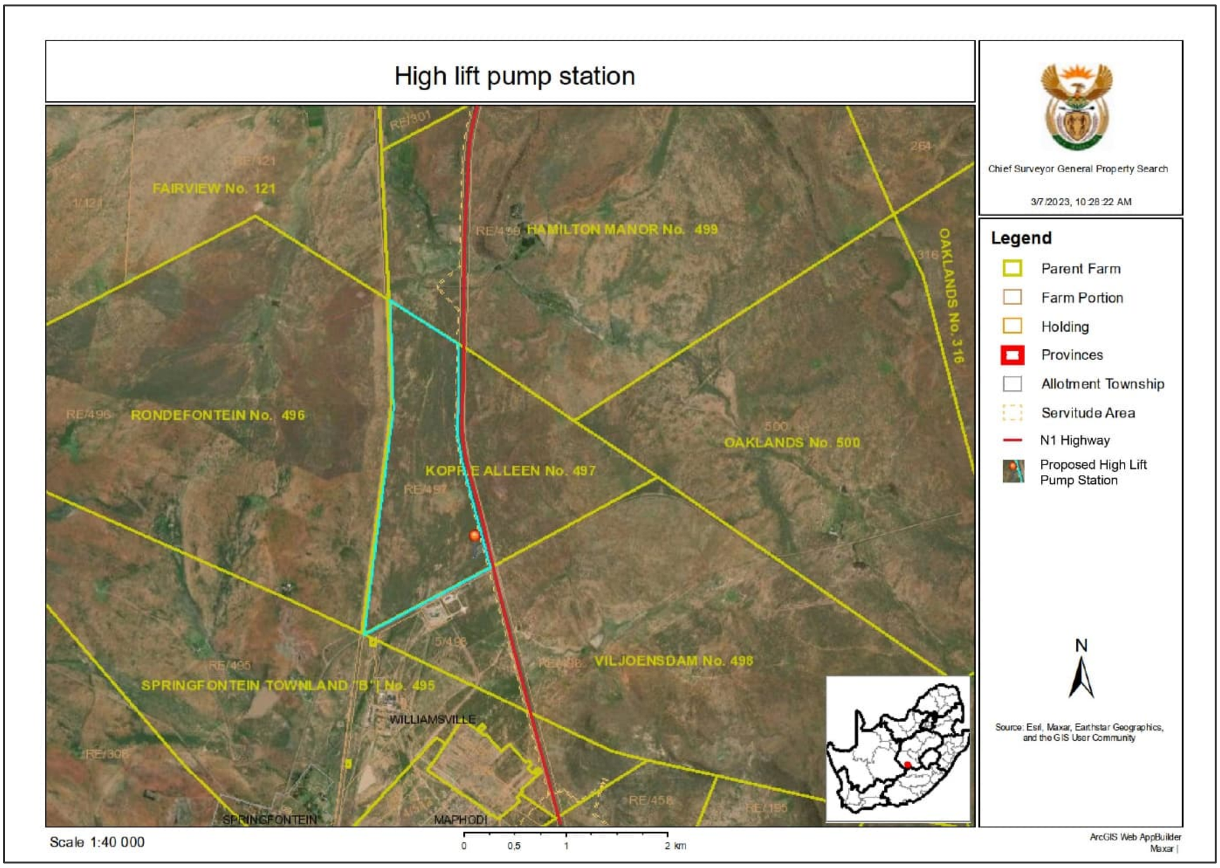

Figure 4-11: Location of proposed high lift pump station (scale 1:40 000 @ A4) shown as red pin

Figure 4-12: Existing intersection off N1 and eastern end of potential site

Figure 4-13: Site located before truck stop and Springfontein

Figure 4-14: Western end of potential site

Figure 4-15: Middle of potential site

5 Conclusions

The existing infrastructure while functioning, is not in great condition. It is not possible to give detailed comments on the functionality of the Novo and Tienfontein Pump Stations as they were not operational during the site visit and have also not been operational for the past two or three years. It is likely that equipment challenges might be experienced when re-starting the pumps after such a long time of not operating it.

The team would also like to visit the Maselspoort WTP, but Mangaung Metropolitan Municipality did not grant access to their infrastructure.