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REPORT

Preliminary Design Report for New Primary Sedimentation Tanks at Bushkoppie Wastewater Treatment Works

Report No : 18057-45-Rep-001

Submitted to :

Johannesburg Water SOC Limited
17 Harrison Street
Johannesburg
2001

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DOCUMENT APPROVAL

ACTION	DESIGNATION	NAME	DATE	SIGNATURE
Prepared	Project Engineer	N Govender		
Reviewed	Project Manager	J Swart		
Reviewed	Project Reviewer	L Naude'		
Approved	JW Project Manager	R Dodding		
Approved	JW Operations	R Viljoen		
Approved	JW Environmental	E Nduvheni		
Approved	JW Planning	W Bedser		

RECORD OF REVISIONS

Date	Revision	Author	Comments
12.10.2018	0	N Govender	Issued for comment
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EXECUTIVE SUMMARY

Johannesburg Water SOC Limited (JW) appointed Zitholele Consulting (ZC) to render professional services for the addition of two new Primary Sedimentation Tanks (PSTs) at Bushkoppie Wastewater Treatment Works (WwTW). The project is required to assist with the high inflow and to give redundancy when maintenance of the PSTs is undertaken. During the project inception phase the scope of the project was expanded to include construction of new PSTs and the refurbishment of the existing PSTs and Fermenters. A project inception report was approved by JW on the 2nd November 2018. Following the inception phase, the preliminary design is required to evaluate various design options and select preferred design options that will be developed during the detailed design phase of the project. This report documents the outcomes from the preliminary design phase.

Scope of work

The scope of work for the project was divided into the refurbishment of existing infrastructure and construction of new infrastructure.

- **Refurbishment of existing infrastructure**

A conditional assessment was undertaken by ZC to determine the condition of existing infrastructure at the PST complex. The conditional assessment indicated that the existing PSTs and Fermenters require civil and electro-mechanical refurbishment due to deterioration that has occurred over time. The civil refurbishment primarily involves concrete and joint repair whilst the mechanical refurbishment includes replacing broken mechanical equipment and refurbishing installed equipment.

For both the Primary Sludge and Fermented Sludge Pump Stations various options were explored to retrofit the existing Pump Stations with wet wells. This report documents a comparison of the various design Options. The preferred Option for both the Primary Sludge and Fermented Sludge Pump Stations entails retrofitting the existing Pump Stations with wet well configurations and pumps that utilise a flooded suction.

- **New PST infrastructure**

Three design Options were evaluated for construction of the new PSTs. The three Options have been outlined below:

1. Converting the existing Fermenters to PSTs
2. Positioning the new PSTs west of the existing PST complex
3. Positioning the new PSTs south of the existing PST complex

A description of each Option followed by the advantages and disadvantages of the various Options are presented in this report. A multi-criteria assessment was utilised as a selection tool to compare various design Options and assist in the selection of a Preferred Option.

The multi-criteria assessment is usually introduced once all the Options identified have been defined at a high level and sufficient information exists for them to undergo a comparative assessment. The multi-criteria assessment was undertaken using a single phased approach that assesses financial and non-financial criteria simultaneously.

Positioning the new PSTs west of the existing PST complex scored the highest for both the financial and non-financial criteria. Therefore, it was selected as the Preferred Design Option.

Risk Management

The two major risks on this project are as follows:

- Project funding – the uncertainty of securing the full project budget for this long-term project may impact on whether this project will proceed as programmed, or not.
- Environmental authorisation – getting an environmental authorisation may delay the implementation of the project.

Project Investment

A detailed estimate of the project construction value has been compiled. This estimate is based on the following:

- A Bill of Quantities was developed for the project that consisted of the major construction items.
- Rates from recently completed, similar projects, were extracted and were escalated to current rates.
- Rates for major construction items such as ready-mix concrete, reinforcing, earthworks and mechanical & electrical equipment were used as budget prices.

A summary of the expected project cost is as follows:

Summary of Costs		
Description		**Amount (R)**
New PSTs Preferred Option	R	48 297 625.00
Refurbishment of Existing Pump Stations	R	5 628 500.00
Refurbishment Existing PSTs	R	15 110 850.00
Refurbishment Existing Fermenters	R	5 531 315.00
Sub-Total 1	R	74 568 290.00
Contingencies at 10%	R	7 456 829.00

Summary of Costs		
Description		**Amount (R)**
Sub-Total 2 (excl. VAT)	**R**	**82 025 119.00**
VAT at 15%	R	12 303 800.00
Total (Incl. VAT)	R	94 328 919.00

Approval of Report and Design Development Stage

This Preliminary Design Report documents the activities that have been undertaken on the project thus far. The next stage of the project is the Design Development stage, which will be followed by the Tender and Procurement stage (i.e. the tender process and appointment of contractors to undertake the construction works). Formal approval of this report is required from JW before the Zitholele can proceed with the next project stage.

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LIST OF ACRONYMS

BA	Basic Assessment
EIA	Environmental Impact Assessment
JW	Johannesburg Water SOC Limited
MCC	Motor Control Centre
NEMA	National Environmental Management Act
PST	Primary Sedimentation Tank
WwTW	Wastewater Treatment Works
ZC	Zitholele Consulting

1 INTRODUCTION

The Bushkoppie Wastewater Treatment Works is situated on the Farm Misgund No 322-IQ in the south west of the Greater Johannesburg Metropolitan area. The works receives wastewater from the southern areas of Johannesburg via the South Eastern Outfall sewer and from the south western areas of Johannesburg, Soweto and parts of Roodepoort through the Bushkoppie Phase 1 and 2 outfall sewers.

The current rated capacity of the works is 200 Mℓ/d and, according to information received from JW's planning department, the average daily flow to the works during the current 2018 calendar year is 228 Mℓ/d. The works effluent is discharged to the Harrington Spruit which then discharges into the Klip River.

Knight Piesold prepared a Capacity Report during 2014 on all JW WwTWs and the following was stated in the report, regarding Bushkoppie:

On the basis of the limiting liquid and hydraulic capacities it is concluded that Bushkoppie Works should be rated at a capacity of 200Mℓ/d. To beneficially utilize the liquid phase treatment capacity available at Bushkoppie Works the limitations associated with the primary sedimentation tanks need to be addressed so that the works could potentially be rerated at 240Mℓ/d.

JW appointed ZC to render professional services for the addition of two new PSTs at Bushkoppie WwTW. The project is required to assist with the high inflow and to give redundancy when maintenance of the PSTs is undertaken. During the project inception phase the scope of the project was expanded to include construction of new PSTs and the refurbishment of the existing PSTs and Fermenters. A project inception report was approved by JW on the 2nd November 2018. Following the inception phase, the preliminary design is required to evaluate various design options and select preferred design options that will be developed during the detailed design phase of the project. This report documents the outcomes from the preliminary design phase.

2 BACKGROUND

2.1 Details of appointment

JW appointed ZC to provide professional services for the addition of two new PSTs at the Bushkoppie WwTW. Works Order BWW1505 and a Project Charter, dated 16 March 2018, was issued to Zitholele.

2.2 Scope of work

The scope of work entails the following:

- Refurbishment of the existing PSTs and equipment;
- Refurbishment of the existing Fermenters and equipment;

- Refurbishment of existing Primary Sludge Pump Stations and equipment;
- Refurbishment of existing Fermented Sludge Pump Station and equipment;
- Retrofitting existing Primary Sludge Pump Stations with wet wells;
- Retrofitting existing Fermented Sludge Pump Stations with wet wells; and
- Construction of two new PSTs, their Pump Station and associated pipework.

2.3 Scope of services

- Project Management
- Hydraulic Engineering
- Structural Engineering
- Civil Engineering
- Electrical Engineering
- Mechanical and Fire Engineering
- Control and Instrumentation (C & I) Engineering
- Quantity Surveying Services

2.4 Details of project team

Name	Designation
Mr. Russel Dodding	Project Manager – JW
Mr. William Bedser	Project Planning – JW
Ms. Ronell Viljoen	Operations – JW
Mr. Sugen Pillay Pr. Eng.	Project Director – ZC
Mr. Jan Swart Pr. Eng.	Lead Design Engineer (Civil and Mechanical) – ZC
Mr. Neil Govender Pr. Eng.	Project Manager/ Design Engineer (Civil and Mechanical) – ZC
Mr. Douglas McDougall	Design Engineer (Electrical and C & I) – ZC
Mr. Leon Naude Pr. Eng.	External Project Reviewer – KWJV
Mr. E Nduvheni	Environmental Manager – JW

3 PROJECT OBJECTIVE

JW's objective is to construct two new PSTs and refurbish the existing PSTs and Fermenters including all associated infrastructure. The project is being undertaken to assist with the high inflow and give redundancy when maintenance is required. The retrofitting of wet wells at the existing Primary Sludge and Fermented Sludge Pump Stations will enable easier maintenance.

4 PROJECT INCEPTION

A project inception report (Report No. 18057-42-Rep-001) was prepared for JW. One of the critical aspects covered in the report was the scope of the project. The scope for this project (BWW 1505) was expanded to include refurbishment of the existing PSTs, Fermenters and Pump Stations. This scope was previously allocated to another project (BWW 1503).

5 BASIS OF DESIGN

5.1 Design wastewater flows

The average wastewater flows and the flows utilised for the hydraulic design of the PSTs are presented in Table 1.

Table 1: Bushkoppie WwTW design flow rates

Average wastewater flows:	
Mℓ/d	200
m^3/sec	2.31
Average Dry Weather Flows (per PST):	
Mℓ/d	40
m^3/sec	0.46
Peak Wet Weather Flows (per PST):	
Peak Factor	2.4
Mℓ/d	96
m^3/sec	1.11

6 SITE DESCRIPTION

6.1 Location

The Bushkoppie WwTW is located in Johannesburg, Southeast of Eldorado Park on the site bound by the Golden Highway (R553) to the West, the N12 to the North and the N1 to the East. An aerial view of the site is shown in Figure 1.

Figure 1: Aerial view of Bushkoppie WwTW

6.2 Topography, vegetation and site drainage

The site has a uniform gradient of about 7%, it falls from an elevation of 1562m in the northern corner down to about 1540m in the southern corner. Most of the site is built up which makes it difficult for vegetation to establish. However, vegetation is present on the proposed areas where the new PSTs will be constructed. A stormwater management system has been installed around existing structures to ensure adequate drainage of the roads and terracing.

7 SITE INVESTIGATION – EXISTING INFRASTRUCTURE

7.1 Overview

Several site visits were conducted by Zitholele between September and December 2018. The purpose of the site visits was to conduct civil and electro-mechanical conditional assessments on the following existing infrastructure:-

- PST 1 – 5;
- Pump stations servicing PST 1 – 5;
- Fermenters; and
- Fermented Sludge Pump Station.

Note: PST 1 – 4 were not emptied due to the large amounts of sand that accumulated in those PSTs. A conditional assessment was only conducted on PST 5. Since PST 1 – 4 are older and more susceptible to deterioration, recommendations made for PST 1 – 4 will be based on the assessment of PST 5.

7.2 Civil Conditional Assessment

7.2.1 PST 1 – 5

During the conditional assessment, there was evidence of cracking in some areas around the floor joints. In other areas residual sludge in the joints that was not removed by the scraper indicates that the joint is sunken and may soon fail. Figure 2 shows the residual sludge in the floor joints and cracking around some of the floor joints.

Figure 2: Floor joints in PST 5

The quality of concrete on the walls seem to be in good condition with no evidence of cracking. Figure 3 shows the quality of concrete on the walls of PST 5.

Figure 3: Concrete Walls of PST 5 and box

7.2.2 PST division box

Most of the concrete In the PST division box is in a fair condition however, there are some areas in the division box where the concrete has deteriorated as shown in Figure 4.

Figure 4: Deterioration of concrete inside PST division box

7.2.3 Pump Stations

The interior and exterior of the Pump Stations servicing PSTs 1 – 4 are in good condition. The Pump Stations currently have a dry well configuration. Figure 5 and Figure 6 shows the interior of Pump Stations servicing PST 1 – 4 and the Pump Station servicing PST 5 respectively.


Figure 5: Interior of Pump Stations servicing PST 1 -4

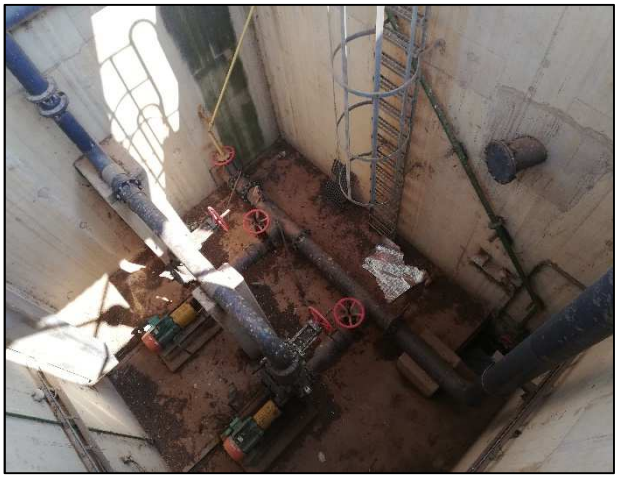


Figure 6: Pump station servicing PST 5

7.2.4 Fermenters

The concrete in the Fermenters is severely deteriorated and has resulted in the aggregate being exposed in the launder and outlet boxes. Figure 7 shows the deteriorated concrete in the launder and outlet box of the Fermenter.

Figure 7: Deteriorated concrete in the Fermenter launder and Fermenter Outlet Box

7.3 Mechanical Conditional Assessment

7.3.1 PST 1 – 5

The scraper mechanism for PST 4 appears to be bent as illustrated in Figure 8. Apart from a few areas of rust no other significant defects were identified in PST 4. The structural components of the scraper mechanism, stilling well and bridge in PST 5 are in good condition although some rust has developed. Figure 9 shows the stilling well for PST 5 and the scraper mechanism.

Figure 8: Bridge and scraper mechanism for PST 4

Figure 9: PST 5 – Bridge, stilling well & bridge

7.3.2 PST division box

Figure 10 shows the sluice gate with a bent spindle at the PST division box. All five sluice gates lack adequate access and are not actuated.

Figure 10: Sluice gates at the existing PST division box

7.3.3 Fermenters

The structural components of the pickets, stilling well and bridge in the Fermenters are in good condition. The material seems to be mild steel with a recent coat of normal enamel paint. Apart from a few areas of rust no other significant defects were identified. Figure 11 shows areas of rust on the stilling well and the condition of the bridge and scraper mechanism.

Figure 11: Fermenter bridge and scraper mechanism

7.3.4 Fermented Sludge Pump Station

The capacity of the pumps in the Fermented Sludge Pump Station needs to be assessed to determine if they can accommodate the additional fermented sludge from the new PSTs.

8 REFURBISHMENT OF EXISTING INFRASTRUCTURE

8.1 PST Pump Stations

The existing Pump Stations for PSTs 1 – 5 need to be refurbished. The Pump Stations will be retrofitted to have a wet well which is a JW operational preference.

8.1.1 Option 1 – Pump Station with a wet well (pumps without a flooded suction)

8.1.1.1 Overview

The existing four pumps in the two Pump Stations servicing PST 1 – 4 will be removed and replaced with two pumps (duty standby arrangement) – refer to Drawings 18057-73-04-101, 102, 108, 109, 115 & 116.

By creating a wet well, the staircase in the two Pump Stations servicing PST 1 – 4 will be demolished and a slab installed over the wet well. Pumps with a suction lift capability will be installed since the pumps will not have a flooded suction. Sludge will be pumped from the Pump Station to the Fermenters.

The existing pipework in the Pump Station that services PST 5 will be removed to allow for a wet well configuration. The pipe entering the sump will have a valve installed with an extended spindle and handwheel. A purge connection will also be installed on the pipe upstream of the valve (refer to Drawing 18057-73-04-115 & 116).

8.1.1.2 Viability of Option 1

Option 1 is not the Preferred Option as the gas build up in the piping may cause air locks and cavitation in the pump. JW operations have indicated that they are not in favour of this Option.

8.1.1.3 Cost Estimate – Option 1

The cost estimate for Option 1 is provided in Table 2.

Table 2: Cost Estimate – Pump Station Refurbishment Option 1

Pump Station Refurbishment - Option 1	
Description	**Amount (R)**
Civil refurbishment	R 2 366 500.00
Mechanical refurbishment	R 3 065 000.00
Electrical and C & I refurbishment	R 1 457 400.00
P & G at 25%	R 1 722 225.00
Sub-Total 1	R 8 611 125.00
Contingencies at 10%	R 861 200.00
Sub-Total 2 (excl. VAT)	**R 9 472 325.00**
VAT at 15%	R 1 420 900.00
Total (Incl. VAT)	R 10 893 225.00

8.1.2 Option 2 – Pump Station with a wet well (pumps with a flooded suction)

8.1.2.1 Overview

Option 2 entails retrofitting the existing Pump Stations with a wet well. Due to spatial constraints, the wet well will be constructed behind the Pump Station. The position of the wet well servicing PST 1 & 2 will encroach into the road. This will require the wet well to be covered and constructed under the road – the design will allow vehicles to drive over the wet well. An access hatch will be provided on the covered sump of all the pump stations to allow for cleaning by means of a mobile pump or honeysucker. Pumps installed in the Pump Station will have a flooded suction. Details of this Option for Pump Stations servicing PST 1 – 5 are provided on Drawings 18057-73-04-103, 104, 105, 106, 110, 111, 112,113, 117, 118 & 119.

8.1.2.2 Viability of Option 2

The flooded suction configuration allows for any type of centrifugal pump (that can handle solids) to be installed, with low NPSH requirements and ensures that the pump is continuously primed.

8.1.2.3 Cost Estimate – Option 2

The cost estimate for Option 2 is provided in Table 3.

Table 3: Cost Estimate – Pump Station Refurbishment Option 2

Pump Station Refurbishment - Option 2	
Description	**Amount (R)**
Civil refurbishment	R 2 283 600.00
Mechanical refurbishment	R 625 000.00
Electrical and C & I refurbishment	R 1 594 200.00
P & G at 25%	R 1 125 700.00
Sub-Total 1	R 5 628 500.00
Contingencies at 10%	R 562 850.00
Sub-Total 2 (excl. VAT)	**R 6 191 350.00**
VAT at 15%	R 928 800.00
Total (Incl. VAT)	R 7 120 150.00

8.1.3 Option 3 – Common Pump Station with a wet well

8.1.3.1 Overview

Option 3 entails utilising a common Pump Station and sump that services all the PSTs. This Option will require new sludge draw off pipelines to be installed from the existing PSTs to the common sump and a delivery line from the new Pump Station to the Fermenters. The general arrangement of this Option is provided on Drawing 18057-73-04-125.

8.1.3.2 Viability of Option 3

Option 3 is not viable due to the long lengths of pipework with multiple bends that need to be installed. Installation of these pipelines will be extremely difficult due to the existing services that are currently on the PST terrace.

8.1.3.3 Cost Estimate – Option 3

The cost estimate for Option 3 is provided in Table 4.

Table 4: Cost Estimate – Pump Station Refurbishment Option 3

Pump Station Refurbishment - Option 3	
Description	**Amount (R)**
Civil refurbishment	R 5 408 500.00
Mechanical refurbishment	R 1 010 000.00
Electrical and C & I refurbishment	R 1 726 100.00
P & G at 25%	R 2 036 150.00
Sub-Total 1	R 10 180 750.00
Contingencies at 10%	R 1 018 075.00
Sub-Total 2 (excl. VAT)	**R 11 198 825.00**
VAT at 15%	R 1 679 900.00
Total (Incl. VAT)	R 12 878 725.00

8.1.4 Preferred Option

During a Technical Workshop held on the 29th November 2018, JW operations supported Option 2 as the Preferred Option. The Option is both technically and financially feasible when compared to the other two Options.

Option 2 will therefore be developed further during Detailed Design.

8.2 PST 1 – 5

8.2.1 Overview

The refurbishment work required for PST 1 – 5 is provided below:

Civil Works

- Repair of concrete that has deteriorated and where aggregate is exposed
- Clean out vegetation from launders
- Remove and replace the expansion joints sealer

Refer to Drawing 18057-73-03-102, 103, 106 & 107.

Mechanical Works

- Remove and replace scraper system
- Remove and replace scum removal system
- Sand blast and paint bridges

Refer to Drawing 18057-73-03-102, 103, 106 & 107.

Electrical, Control and Instrumentation Works

- Replace motor, gearbox and slip ring
- Flow meters will be installed on all pump delivery pipelines

8.2.2 Cost Estimate – PST refurbishment

The cost estimate for refurbishing the existing PSTs is provided in Table 5.

Table 5: Cost estimate – PST refurbishment

Refurbishment of PSTs	
Description	**Amount (R)**
Civil refurbishment	R 2 550 000.00
Mechanical refurbishment	R 6 948 650.00
Electrical and C & I refurbishment	R 2 590 000.00
P & G at 25%	R 3 022 200.00
Sub-Total 1	R 15 110 850.00
Contingencies at 10%	R 1 511 085.00
Sub-Total 2 (excl. VAT)	**R 16 621 935.00**
VAT at 15%	R 2 493 300.00
Total (Incl. VAT)	R 19 115 235.00

8.3 Fermenters

8.3.1 Overview

The refurbishment work required for the Fermenters is provided below:

Civil Works

- Repair of concrete that has deteriorated and where aggregate is exposed
- Clean out vegetation from launders
- Remove and replace expansion joints sealer

Refer to Drawing 18057-73-05-101.

Mechanical Works

- Remove and replace scraper system
- Remove and replace scum removal system
- Sand blast and paint bridges

Refer to Drawing 18057-73-05-101.

Electrical, Control and Instrumentation Works

- Replace motor, gearbox and slip ring

8.3.2 Cost Estimate – Fermenter refurbishment

The cost estimate for refurbishing the existing Fermenters is provided in Table 6.

Table 6: Cost estimate – Fermenter refurbishment

Refurbishment of Fermenters		
Description		**Amount (R)**
Civil refurbishment	R	1 058 300.00
Mechanical refurbishment	R	2 330 715.00
Electrical and C & I refurbishment	R	1 036 000.00
P & G at 25%	R	1 106 300.00
Sub-Total 1	R	5 531 315.00
Contingencies at 10%	R	553 200.00
Sub-Total 2 (excl. VAT)	**R**	**6 084 515.00**
VAT at 15%	R	912 700.00
Total (Incl. VAT)	R	6 997 215.00

8.4 Fermented Sludge Pump Station

8.4.1 Overview

Only one refurbishment Option of the Fermented Sludge Pump Station was considered. The Option entails adding a wet well and pumps that have a flooded suction similar to the Primary Sludge Pump Stations.

8.4.2 Viability

Due to the existing pipework around the Pump Station and Fermenters, refurbishing the Pump Station will require significant changes to the pipework and inside the Pump Station. Therefore, this Option has been eliminated and no alterations to the Fermented Sludge Pump Station will be undertaken. However, the pumps in the Pump Station will be upgraded to cater for the sand and increased solids removal from the Fermenters.

9 PRELIMINARY DESIGN OPTIONS – NEW PST 6 & 7

9.1 Option 1 – Converting the existing Fermenters to PSTs

9.1.1 Overview

Option 1 entails the conversion of the existing two Fermenters (25m diameter) into PSTs and the construction of an additional 35m PST north of the existing Fermenters. Since the existing Fermenters will be converted to PSTs, two new Fermenters (25m diameter) will be constructed north of the lime dosing plant. A detailed layout of Option 1 is provided on Drawing 18057-73-01-201.

9.1.2 Site constraints

The position of the new 35m diameter PST is constrained by the inlet channel on the west, the access road on the east and the existing Fermenters on the south.

9.1.3 Scope of work

The scope of work for Option 1 is provided below:

- Refurbishment and conversion of the existing two Fermenters to PSTs
- Construction of a new 35m diameter PST (including feed and draw off pipework)
- Installation of a half bridge, centre supported with peripheral drive and half diameter sludge scraper mechanism
- Conversion of the existing Fermented Sludge Pump Station into a Primary Sludge Pump Station (including pipework)
- Construction of minor boxes
- Modifying the old PST division box to accommodate the feed pipeline to the 35m diameter PST
- Construction of pipework:
    - PSTs to the Biological Reactors
    - PSTs to the Fermenters
    - Fermenters to the Biological Reactors
    - Fermenters to Thickened Sludge Pump Station Sump
- Construction of two new 25m diameter Fermenters (including feed and draw off pipework)
- Construction of a new Fermented Sludge Pump Station
- Construction of a new Fermenter Division Box

Table 7 provides details of the PSTs and Fermenters that will form part of Option 1.

Table 7: Details of PSTs and Fermenters

	Unit	Qty
Number of tanks	No.	2 (Fermenters converted to PSTs)
Diameter	m	25
Side Water Depth	m	4
Depth at centre	m	7.775
Number of tanks	No.	1 (New PST)
Diameter	m	35
Side Water Depth	m	4.2
Depth at centre	m	8.65
Number of tanks	No.	2 (New Fermenters)
Diameter	m	25
Side Wall Liquid Depth	m	4
Depth at centre	m	7.775

9.1.4 Viability of Option 1

Table 8 provides the advantages and disadvantages for Option 1.

Table 8: Advantages and disadvantages for Option 1

Advantages	Disadvantages
Flow division structure and pipework already in place to new PSTs (existing Fermenters).	Extensive additional civil works for two new Fermenters (including pipework and construction of the two new Fermenters).
Few access constraints.	Long pumping distance from PSTs to Fermenters.
Incoming access road to the works does not need to re-routed.	New PSTs (existing Fermenters) will need new mechanical equipment to operate as PSTs.
	An additional 35m diameter PST and primary sludge Pump Station will still have to be constructed.
	Screening of Primary Sludge to be relocated to new Fermenters
	Possibility of existing services on new PST footprint.
	High upflow rates for 25m diameter PSTs.
	High cost.

9.1.5 Cost Estimate – Option 1

The cost estimate for Option 1 is provided in Table 9.

Table 9: Cost estimate – New PSTs Option 1

New Primary Sedimentation Tanks - Option 1		
Description		**Amount (R)**
Civil work	R	34 071 700.00
Mechanical work	R	3 240 000.00
Electrical and C & I work	R	7 107 900.00
P & G at 25%	R	11 104 900.00
Sub-Total 1	R	55 524 500.00
Contingencies at 10%	R	5 552 450.00
Sub-Total 2 (excl. VAT)	**R**	**61 076 950.00**
VAT at 15%	R	9 161 600.00
Total (Incl. VAT)	R	70 238 550.00

9.2 Option 2 – Positioning new PSTs west of the existing PST complex

9.2.1 Overview

Option 2 involves constructing two new 35m diameter PSTs to the west of the existing PST complex. The feed to the PSTs will be taken upstream of the existing PST division box with an overflow weir and a pipeline to a new division box that splits the flow to the two new PSTs. The feed line to the PST division box is approximately 44m. To create adequate space for the construction of the two new PSTs, the incoming access road needs to be re-routed. A significant excavation will be required to create the terrace for the two new PSTs. A detailed layout of Option 2 is provided on Drawing 18057-73-01-301.

9.2.2 Site constraints

The position of the two new 35m diameter PSTs is constrained by the incoming access road on the west and the existing PST complex on the east.

During the Technical Workshop held on the 29th November 2018, JW personnel advised that 5 x 185mm^2 11kV underground cables would have to be relocated for this Option, as they are located on the designated area for the new PSTs. The relocation of these cables will be part of the detailed design, however, the proposal will be to isolate, cut, extend, reroute and terminate to the 11kV circuit breakers in the 11kV substation.

9.2.3 Scope of work

The scope of work for Option 2 is provided below:

- Construction of two new 35m diameter PSTs (including feed and draw off pipework)
- Installation of half bridges on all PSTs, centre supported with peripheral drive and half diameter sludge scraper mechanism
- Construction of a new flow division box
- Construction of a new Primary Sludge Pump Station
- Construction of a new terrace (including retaining walls)
- Modifying the existing stormwater system
- Demolishing and re-routing the existing access road
- Re-route 11kV cables
- Construction of pipework:
    - PSTs to the existing effluent channel (which feeds the Biological Reactors)
    - Primary Sludge Pump Station to the existing Fermenter division box
    - Fermented Sludge Pump Station to the Biological Reactors (new larger pipe)
    - Fermented Sludge Pump Station to the Thickened Sludge Pump Station Sump (new larger pipe)

Table 10 provides details of the new PSTs that will form part of Option 2.

Table 10: Details of PSTs

	Unit	Qty
Number of tanks	No.	2
Diameter	m	35
Side Water Depth	m	4
Depth at centre	m	8.65

9.2.4 Viability of Option 2

Table 11 provides the advantages and disadvantages for Option 2.

Table 11: Advantages and disadvantages for Option 2

Advantages	Disadvantages
Footprint reasonably clear of existing services and pipework (only the 11kV cable needs to be re-routed).	High retaining wall required at edge of new terrace.
Relatively short lengths of pipework required to tie into existing infrastructure.	Existing access roads and 11kV cables to be re-routed.
Easy access between PSTs.	Existing stormwater channel to be revised to a pipe

Advantages	Disadvantages
Earthworks should be straight forward as the terrace is already cleared.	Odour concerns due to proximity to Admin Building.
Construction can take place with minimal disruption to the existing plant.	
Low cost	

9.2.5 Cost Estimate – Option 2

The cost estimate for Option 2 is provided in Table 12.

Table 12: Cost estimate – New PSTs Option 2

New Primary Sedimentation Tanks - Option 2		
Description		**Amount (R)**
Civil work	R	31 481 900.00
Mechanical work	R	1 010 000.00
Electrical and C & I work	R	6 146 200.00
P & G at 25%	R	9 659 525.00
Sub-Total 1	R	48 297 625.00
Contingencies at 10%	R	4 829 800.00
Sub-Total 2 (excl. VAT)	**R**	**53 127 425.00**
VAT at 15%	R	7 969 200.00
Total (Incl. VAT)	R	61 096 625.00

9.3 Option 3 – Positioning new PSTs south of the existing PST complex

9.3.1 Overview

Option 3 entails the construction of two new PSTs (35m diameter) south of the existing PST complex. The existing access road will need to be re-routed around the new PSTs for access. Similarly, the existing fence line will need to be demolished and installed around the new PST terrace. The bulk earthworks for this Option may be challenging as a large rock outcrop is visible on the proposed site.

Due to the location of the new PSTs, the feed pipeline that begins upstream of the existing PST division box is approximately 167m. The Pump Station servicing PST 3 & 4 needs to be demolished to enable the existing effluent channel to be extended toward the two new PSTs. The demolished pump station will be constructed adjacent to the effluent channel and the associated pipework from PST 3 & 4 will be modified accordingly. A detailed layout of Option 3 is provided on Drawing 18057-73-01-401.

9.3.2 Site constraints

The position of the two new PSTs is constrained by the incoming access road in the north.

9.3.3 Scope of work

The scope of work for Option 3 is provided below:

- Construction of two new 35m diameter PSTs (including feed and draw off pipework)
- Installation of half bridges on all PSTs, centre supported with peripheral drive and half diameter sludge scraper mechanism
- Construction of a new flow division box
- Construction of a new Primary Sludge Pump Station
- Construction of a new terrace
- Modifying the existing stormwater system
- Demolishing and re-routing the existing access road
- Construction of pipework:
    - PSTs to the extended effluent channel (which feeds the Biological Reactors)
    - PSTs to the above ground pipeline (which feeds the Fermenters)
    - Fermenters to the Biological Reactors (new larger pipe)
    - Fermenters to Thickened Sludge Pump Station Sump (new larger pipe)
- Demolish and construct Primary Sludge Pump Station servicing PST 3 & 4
- Modify sludge draw off pipework from PST 3 & 4
- Extend existing effluent channel

Table 13 provides details of the new PSTs that will form part of Option 3.

Table 13: Details of PSTs

	Unit	Qty
Number of tanks	No.	2
Diameter	m	35
Side Water Depth	m	4
Depth at centre	m	8.65

9.3.4 Viability of Option 3

Table 14 provides the advantages and disadvantages for Option 3.

Table 14: Advantages and disadvantages for Option 3

Advantages	Disadvantages
Footprint is expected to be clear of existing services and pipework.	Location in an environmentally sensitive area.

Advantages	Disadvantages
	Construction of access road required for new PSTs.
	Existing access road will have to be demolished to allow for the concrete effluent channel to be extended towards the new PSTs.
	Pump station servicing PST 3 & 4 will have to be demolished. A new Pump Station will need to be constructed. Pipework from PST 3 & 4 to Pump Station needs to be modified accordingly.
	Long feed pipeline to new PSTs resulting in less flow to the two new PSTs.
	Access constraints between PSTs
	High probability of encountering rock during excavations.
	Significant impact on existing works.

9.3.5 Cost Estimate – Option 3

The cost estimate for Option 3 is provided in Table 15.

Table 15: Cost estimate – New PSTs Option 3

New Primary Sedimentation Tanks - Option 3		
Description		**Amount (R)**
Civil work	R	36 548 600.00
Mechanical work	R	2 320 000.00
Electrical and C & I work	R	8 081 700.00
P & G at 25%	R	11 737 575.00
Sub-Total 1	R	58 687 875.00
Contingencies at 10%	R	5 868 800.00
Sub-Total 2 (excl. VAT)	**R**	**64 556 675.00**
VAT at 15%	R	9 683 600.00
Total (Incl. VAT)	R	74 240 275.00

9.4 Multi-criteria Assessment: New PSTs Option 1 – 3

9.4.1 Background

A multi-criteria assessment was utilised to assess Option 1 – 3 and identify a Preferred Design Option that will be developed further during the detailed design stage. Figure 12 provides a schematic diagram of the various criteria that were evaluated to select a Preferred Design Option.

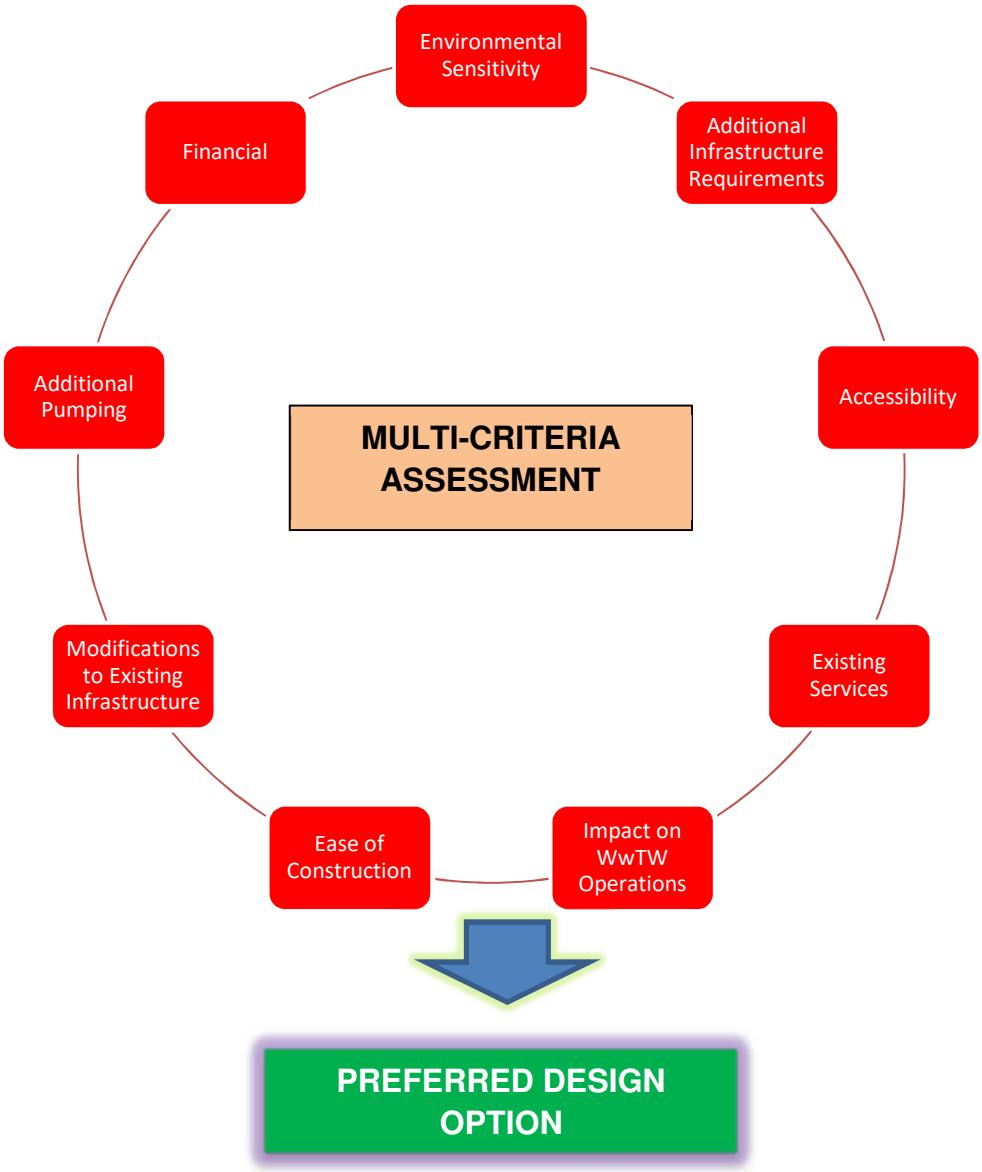

Figure 12: Criteria utilised to select the preferred design option

The various criteria shown in Figure 12 have been defined in Table 16.

Table 16: Description of criteria used for selecting a Preferred Design Option

Criteria	Description
Environmental sensitivity	The environmental sensitivity of the site under consideration.
Additional infrastructure requirements	The amount of additional infrastructure required to implement the design Option.
Accessibility	The ease of accessibility between PSTs and infrastructure built as part of the design Option.
Existing services	The amount of existing services on the site footprint that may render implementation of the design Option difficult due to re-routing of the existing services.
Impact on WwTW operations	The impact that the design Option will have on operations of the existing WwTW during construction.
Ease of construction	The relative ease of constructing a design Option.
Modifications to existing infrastructure	The amount of modifications required on existing infrastructure when constructing the design Option.
Additional pumping	The additional pumping requirements when the design Option is operational.
Financial	The capital investment required to implement the design Option.

9.4.2 Defining the multi-criteria assessment

The multi-criteria assessment is a selection tool used to compare various design Options and assist in the selection of a Preferred Design Option. It is usually introduced once all the options identified have been defined at a high level and sufficient information exists for them to undergo a comparative assessment.

The multi-criteria assessment is undertaken using a single phased approach that assesses financial and non-financial criteria simultaneously. Figure 13 below illustrates the process that was followed when developing the multi-criteria assessment.

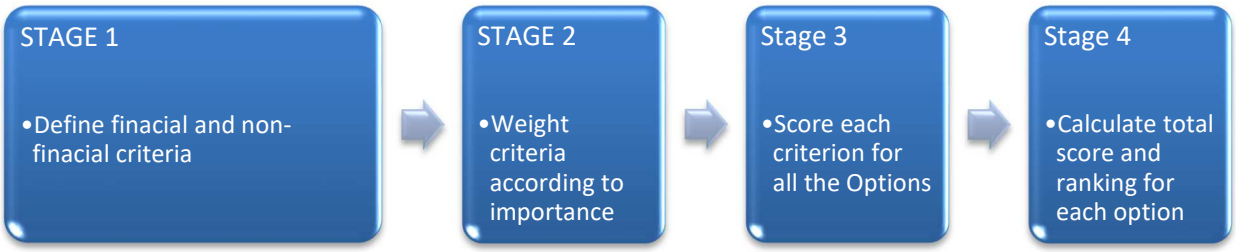

Figure 13: Process diagram for the multi-criteria assessment

The process illustrated in Figure 13 has been detailed below: -

Stage 1

- The financial and non-financial criteria was defined for all the design Options.
- The financial criteria consist solely of the capital investment required to implement the project.
- The non-financial criteria ensured that technical, environmental and operational aspects were considered.

Stage 2

- The weighting was based on the importance of each criterion. The more important criteria were given a higher weighting whilst the less important criteria were given a lower weighting. Section 9.4.3 describes the weighting process.

Stage 3

- The design Options were scored based on the criteria outlined Table 16.

Stage 4

- The total score for each Option was then calculated and are provided in Section 9.4.4.

9.4.3 Multi-criteria assessment weighting

The financial and non-financial criteria were weighted as follows:

Criteria	Weighting
Financial	60%
Non-financial	40%

The financial component was weighted slightly higher since the cost of implementation is an important consideration for JW due to lower expenditure on Bulk Wastewater projects in recent years.

The weighting of the non-financial criteria were based on relative importance of each criterion. The impact on the WwTW operations during construction, additional pumping requirements and accessibility between the PST infrastructure were identified as the most important criteria. Accordingly, they were weighted the highest amongst the non-financial criteria. A breakdown of the weighting is provided in Table 17.

Table 17: Weighting of non-financial criteria

Criteria	Weighting
Impact on WwTW operations	20%
Additional pumping	15%
Accessibility	15%
Existing services	10%
Environmental sensitivity	10%
Ease of construction	10%
Modifications to existing infrastructure	10%
Additional infrastructure requirements	10%
Total	100%

9.4.4 Multi-criteria assessment scoring

9.4.4.1 Financial component

The financial scoring was based on the formula below:

$$\textbf{Financial score} = \frac{Lowest\ capital\ investment}{Capital\ investment\ under\ consideration}\ x\ 5$$

Note: A maximum score of 5 is obtained for the Option with the lowest capital investment

Table 18 shows the capital investment of each Option and their respective score.

Table 18: Capital investment and financial scoring for Option 1 – 3

	Capital Investment (ZAR)	Score
Option 1 – Converting Fermenters to PSTs	R61,076,950.00	4.3
Option 2 – New PSTs west of existing PST complex	R53,127,425.00	5.0
Option 3 – New PSTs south of existing PST complex	R64,556,675.00	3.9

9.4.4.2 Non-financial component

The design Options were evaluated based on the scoring system in Table 19.

Table 19: Scoring system used to evaluate design Options

Score	Description
0	Fatally flawed
1	Undesirable
2	Tolerable
4	Acceptable
5	Good

9.4.4.3 Non-financial component

Criteria	Motivation for scoring		
	Option 1 – Converting Fermenters to PSTs	**Option 2 – New PSTs west of existing PST complex**	**Option 3 – New PSTs south of existing PST complex**
Impact on WwTW operations	Score = 2 Option 1 received a "tolerable" rating since the conversion of Fermenters to PSTs will result on the WwTW not having operational Fermenters during the construction period. This will negatively impact the process and hence has an impact on the WwTW operations.	Score = 4 Option 2 received an "acceptable" rating as there will be a minor impact on the WwTW operations. The main impact will be when tying into the existing structures. This will only take place once all the infrastructure has been constructed and hence should have minimal impact on the operations. The construction of the new access road may also cause minor disruptions on site.	Score = 1 Option 3 received the lowest score as there will be a significant impact on the existing PSTs if this Option is implemented. The Pump Station servicing PST 3 & 4 will have to be demolished for the extension of the effluent channel. Thereafter, PST 3 & 4 will be out of operation while the sludge draw off pipes are modified to the location of the new Pump Station. The construction of the new access road may also cause minor disruptions on site.
Additional pumping	Score = 1 Option 1 scored the lowest as a significant amount of pumping is required for this Option. Pumping will be required from the Fermenters up to the Biological Reactors and to the Thickened Sludge Pump Station Sump. Sludge draw off from the PSTs will also have to be pumped to the Fermenters which will be located opposite the Lime Dosing Facility.	Score = 4 Option 2 received the highest score as it has the least amount of pumping when compared to the other two Options.	Score = 2 Option 3 received a "tolerable" rating as it has slightly more pumping required than Option 2 due to the position of the PSTs and longer length of pipeline.
Accessibility	Score = 4 Option 1 was given a "tolerable" rating. The only concern with this Option is the	Score = 5 Option 2 received the highest score as there are no access constraints associated	Score = 1 Option 3 received the lowest score as accessibility between the structures will be difficult during

Criteria	Motivation for scoring		
	Option 1 – Converting Fermenters to PSTs	**Option 2 – New PSTs west of existing PST complex**	**Option 3 – New PSTs south of existing PST complex**
	access road that is being constructed as part of the Balancing Tank project. The road may constrain access of the 35m diameter PST.	with this Option. There is adequate space for vehicles to gain access to the various structures that form part of this Option.	operations. This is primarily due to the location of the flow division box between the PSTs and the effluent channel which will result in access constraints.
Existing services	Score = 4 Option 1 received an "acceptable" rating as there are existing pipelines on the footprint where the 35m diameter PST will be located. The pipeline will need to be modified during construction.	Score = 4 Option 2 received an "acceptable" rating as there is an 11kV cable that runs through the proposed location of the PSTs. This cable will be re-routed during construction.	Score = 5 Option 3 received the highest score as there are no existing services at the location where the PSTs will be constructed.
Environmental sensitivity	Score = 4 Option 1 received an "acceptable" rating as there are no significant environmental challenges associated with constructing on the proposed footprint.	Score = 4 Option 2 received an "acceptable" rating as there are no significant environmental challenges associated with constructing on the proposed footprint.	Score = 1 Option 3 received the lowest score as the proposed location of the PST is on an environmentally sensitive area.
Ease of construction	Score = 2 Option 1 received a "tolerable" rating. The long lengths of pipeline that must be installed as part of this option will prove difficult due to the existing services that are already present on site.	Score = 5 Option 2 received the highest score as the construction will be relatively simple. The most difficult aspect of the construction will be to tie into the existing structures.	Score = 1 Option 3 received the lowest score. The main concern with this Option is the large rock outcrop evident on the proposed site for the PSTs. This will result in a significant blasting operation during construction. The demolition of the Pump Station servicing PST 3 & 4 and the modifications to the pipework for PST 3 & 4 will also present a challenge to the Contractor.

Criteria	Motivation for scoring		
	Option 1 – Converting Fermenters to PSTs	**Option 2 – New PSTs west of existing PST complex**	**Option 3 – New PSTs south of existing PST complex**
Modifications to existing infrastructure	Score = 4 Option 1 received an "acceptable" rating. Modifications will be required at the Fermenter Division Box. The existing Fermenters will also have to be modified to operate as PSTs.	Score = 4 Option 2 received an "acceptable" rating. The only major modification is required at the inlet channel where an overflow weir will be required at the side of the channel to feed the new PSTs.	Score = 1 Option 3 received the lowest score as several modifications will be required for this Option. The inlet channel will have to be modified with an overflow weir at the side of the channel to feed the new PSTs. The Pump Station servicing PST 3 & 4 will need to be demolished and moved to enable the extension of the effluent channel. The sludge draw off pipework from PST 3 & 4 to the new Pump Station will then have to be modified accordingly.
Additional infrastructure requirements	Score = 1 Option 1 received the joint lowest score as there is a lot of additional infrastructure required for this Option. A new 35m diameter PST and Primary Sludge Pump Station with long lengths of pipelines are required adjacent to the existing Fermenters. Two new Fermenters, a Division Box and Pump Station is also be required since the existing Fermenters will be converted into PSTs.	Score = 5 Option 2 received the highest scoring as the only additional infrastructure are the two new PSTs (including associated pipework), the Primary Sludge Pump Station, minor boxes and re-routing of the access road.	Score = 1 Option 3 received the joint lowest score mainly due to the demolition of existing infrastructure that will have to be constructed in different positions as part of this Option. The other additional infrastructure includes two new PSTs (including associated pipework), the Primary Sludge Pump Station, minor boxes, fencing and re-routing of the access road.

A graphical representation of the non-financial comparative assessment is presented below:

OPTION DESCRIPTION		NON-FINANCIAL CRITERIA									
		Environmental Sensitivity	Additional Infrastructure Requirements	Accessibility	Existing Services	Impact on WwTW operations during construction	Ease of construction	Modifications to existing infrastructure	Additional pumping requirements		
		Weighting									
		10.0%	10.0%	15.0%	10.0%	20.0%	10.0%	10.0%	15.0%	Score	Rank
New PSTs	Option 1: Converting Fermenters	4	1	4	4	2	2	4	1	2.65	2
	Option 2: New PSTs west of existing PST complex	4	5	5	4	4	5	4	4	4.35	1
	Option 3: New PSTs south of existing PST complex	1	1	1	5	1	1	1	2	1.55	3

9.4.4.4 Combined scoring

The combined scoring allocates a score to each Option based on the financial and non-financial scoring. Thereafter, the financial and non-financial scores are factored according to their respective weighting. The combined score for each design Option is provided in Table 20.

Table 20: Combined scores for design Options

OPTION DESCRIPTION		NON-FINANCIAL	FINANCIAL (CAPEX)	Score	Rank
		Weighting			
		40.0%	60%		
New PSTs	Option 1: Converting Fermenters	2.65	4.25	3.61	2
	Option 2: New PSTs west of existing PST complex	4.35	5.00	4.74	1
	Option 3: New PSTs south of existing PST complex	1.55	3.92	2.97	3

Based on the comparative assessment Option 2 is the Preferred Design Option.

9.4.4.5 Sensitivity Analysis

A sensitivity analysis was conducted to determine the variances in the outcome of the multi-criteria assessment by adjusting the weighting of the financial and non-financial component. Table 21 shows the outcome of the sensitivity analysis.

Table 21: Sensitivity analysis for the multi-criteria assessment

	Weight		Score	Ranking
	Financial	Non-financial		
Option 1 – Converting Fermenters to PSTs	70%	30%	3.77	2
Option 2 – New PSTs west of existing PST complex			4.81	1
Option 3 – New PSTs south of existing PST complex			3.21	3
Option 1 – Converting Fermenters to PSTs	60%	40%	3.61	2
Option 2 – New PSTs west of existing PST complex			4.74	1
Option 3 – New PSTs south of existing PST complex			2.97	3

	Weight		Score	Ranking
	Financial	Non-financial		
Option 1 – Converting Fermenters to PSTs	50%	50%	3.45	2
Option 2 – New PSTs west of existing PST complex			4.68	1
Option 3 – New PSTs south of existing PST complex			2.74	3
Option 1 – Converting Fermenters to PSTs	40%	60%	3.29	2
Option 2 – New PSTs west of existing PST complex			4.61	1
Option 3 – New PSTs south of existing PST complex			2.50	3
Option 1 – Converting Fermenters to PSTs	30%	70%	3.13	2
Option 2 – New PSTs west of existing PST complex			4.55	1
Option 3 – New PSTs south of existing PST complex			2.26	3

It is evident from the sensitivity analysis that regardless of whether the financial or non-financial criteria has a higher weighting, the Preferred Design Option is still Option 2.

Option 2 will therefore be developed further during Detailed Design.

10 ELECTRICAL DESIGN

10.1 Preferred Option – New PSTs west of the existing PST complex

Available power
Power for the proposed new Pump Station and two new PSTs can either be supplied from Substation No 1 or the 630kVA Balancing Tank Mini Substation. Pump Stations 1, 2 & 3 are connected to Substation No 1, however, due to the shorter distance the recommended power source for the new Pump Station and PSTs is the 630kVA Balancing Tank Mini Substation.

New MCC
A new Motor Control Centre (MCC) will be installed inside the new Pump Station, and will provide power to the pumps, PSTs, actuated valves, aux items, external area lighting and lighting / small power inside the new pump station.

The MCC shall be designed in accordance with SANS 60439 & 1973-1, and will be of a fixed pattern, consisting of modular free standing sections, bolted together to form an extensible MCC. Each section shall comprise of cubicles / starter drives.

11 CONTROL AND INSTRUMENTATION

11.1 Scope of Work.

There are 5 existing PSTS (PST 1 to PST 5). Two new PSTs will be added (PST 6 and PST 7). The 5 existing manual penstocks that control the inflow to PSTs 1 to 5 will be fitted with electrical actuators and the inflow will be automated via the PLC and SCADA. A sixth new electrically actuated penstock will be installed to control the feed to the new PSTs 6 and 7. Closer to PSTs 6 and 7 two more electrically actuated valves will be installed to control the inflow to the individual PSTs. The discharge from each of the seven PSTs will be equipped with new electrically actuated valves with which to control the underflow discharge.

Each PST will discharge into a sump, from where a set of duty/standby pumps will pump the sludge away. It is only the sump at PSTs 6 and 7 that will be equipped with three pumps (two duty and one standby). An electrically actuated valve will be installed on the suction side of each of the 9 pumps. Each of the 4 sumps will be equipped with an ultrasonic level sensor. This can be used for PST discharge control as well as the prevention of pumps running dry. The common discharge pipe from each set of pumps will be equipped with a clamp-on flow meter for pump protection as prescribed in the JW design guidance document. Figure 14 provides an illustration of the proposed new installation.

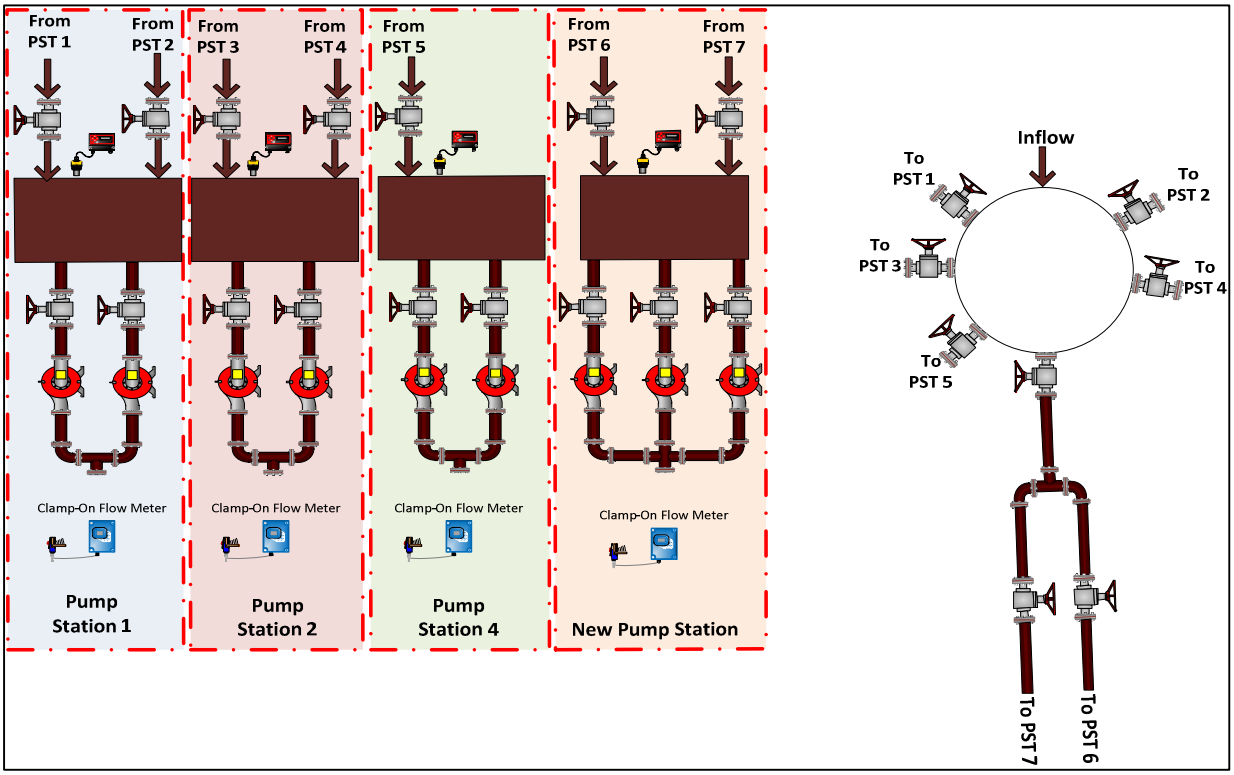

Figure 14: Proposed Control and Instrumentation installation

Currently the discharge from PSTs 1 and 2 goes to Pump Station 1, the discharge from PSTs 3 and 4 goes to Pump Station 2 and the discharge from PST 5 goes to Pump Station 4. The equipment from these pump stations are wired to the PLC in the “Tower” at the old main admin building. Because this PLC equipment has reached the end of its life (i.e. it is not being manufactured anymore), a new PLC (Schneider M580) will be installed in Pump Station 5 (i.e. the pump station for PSTs 6 and 7). Remote I/O racks, also with Schneider M580 PLC equipment, will be installed in Pump Stations 1, 2 and 4. These will then all be remote I/O for the main PLC panel in Pump Station 5. The hard-wired cabling from pump stations 1, 2 and 4 will therefore become obsolete and the unused PLC hardware will provide much-needed spares for Bushkoppie works. One data communication fibre-optic cable will be installed from this new PLC to the core switch in the “Tower” to link this new PLC and all its remote I/O to the Bushkoppie data network. Due to the road alterations which will be done to accommodate the new PSTs, the fibre-optic data cables to the Main Intake Sub and to the new main admin building will be re-routed. These data cables, together with the data cable for the new PSTs PLC will run beside the road from the “Tower”, around PSTs 3 and 4 to the new PLC, the main admin and the main intake sub. Figure 15 shows the C & I scope of work for the new PSTs.

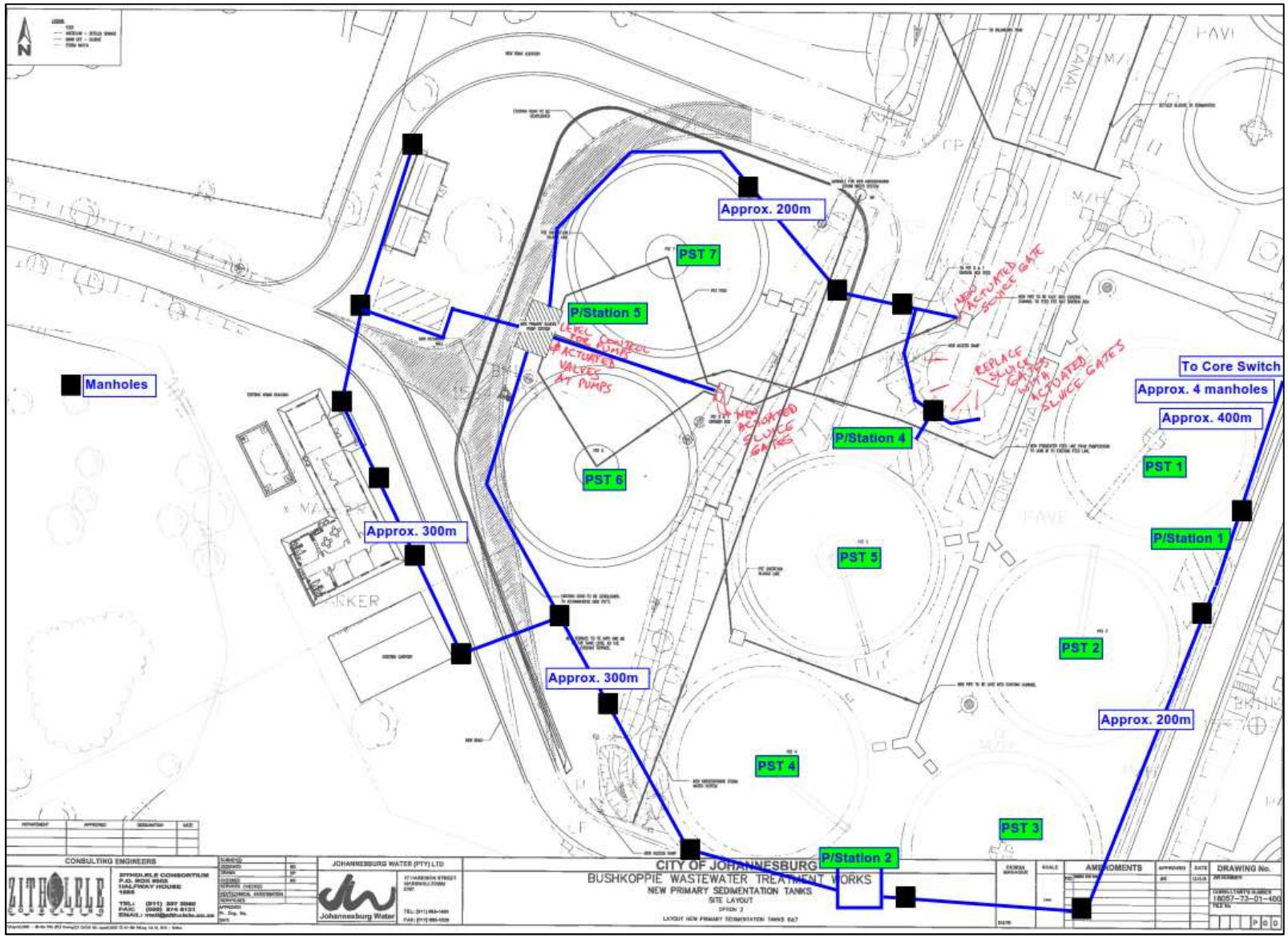

Figure 15: C & I scope of work for new PSTs

12 STRUCTURAL DESIGN

12.1 General Design Philosophy

The purpose of the design is the achievement of acceptable probabilities, as defined in the relevant SANS Codes of Practice that the structures being designed will not become unfit for the use for which it is intended. Two limit states of design are considered; the Ultimate Limit State, and the Serviceability Limit State. The Ultimate Limit State (ULS) concerns safety, and considers the maximum load-carrying capacity of the structure. The Serviceability Limit State (SLS) design restricts excessive deformation or displacement, excessive local damage, excessive crack width, excessive vibration and corrosion of reinforcement in concrete.

The recommended design approach, which has been followed, is to design on the basis of the expected critical limit state and then to check that the remaining limit states will not be reached.

The analysis and design of the reinforced concrete, load bearing masonry and structural steel components of the works were carried out using the PROKON suite of programs, version W3.0.08, February 2016.

12.1.1 Blasting During Construction

Blasting will not be permitted during construction due to the risk of damage to existing structures. Alternative methods of breaking up rock and hard material during excavations will be explored by the Contractor.

12.1.2 Concrete Cover to Reinforcement

The minimum concrete cover to the reinforcement for each type of structure is specified in the sections below. In accordance with BS 8007, a minimum cover of 50mm, suitable for severe and very severe exposure conditions, was specified. In those instances where the concrete is susceptible to chemical attack and the 50mm cover was deemed to be inadequate, coatings providing the required degree of chemical resistance were specified in the Project Specifications and on the drawings.

12.2 Liquid Retaining Structures

The term ‘liquid retaining structures’ includes structures designed to contain, or to exclude liquid, and include the tanks and reactors and similar vessels on the one hand and valve chambers, pump stations and the like on the other hand.

The critical limit state for the design of liquid retaining structures is the Serviceability Limit State, which considers the development of cracks in immature (early drying shrinkage) and mature concrete under service loads and temperature effects. The design entails element sizing and determining the amount of reinforcement required to limit crack widths to within the specified

design limits. Once the reinforcement requirements have been established, compliance of the structure with the ultimate limit state requirements is checked.

A geotechnical investigation will be conducted to confirm the founding conditions on site during the detailed design stage.

12.2.1 Joints in Liquid Retaining Structures

The design of liquid retaining structures against early thermal movement and shrinkage is closely related to the frequency and spacing of construction and expansion joints. All joint types and positions are therefore indicated and specified on the relevant concrete layout drawings.

12.2.2 Codes of Practice

Serviceability Limit State:

- BS 8007: Code of practice for design of concrete structures for retaining aqueous liquids.

Ultimate Limit State:

- SANS 10100-Part 1: The structural use of concrete - Design
- SANS 10100-Part 2: The structural use of concrete - Materials and workmanship
- SANS 2001-CC1:2007: Concrete works (Structural)
- SANS 10144: Detailing of steel reinforcement for concrete
- SABS 920: Steel bars for concrete reinforcement
- SANS 10160-Parts 1 to 8 (as applicable): Basis of structural design and actions for buildings and industrial structures

12.2.3 Material Properties and Design Data

(i) Density of contained liquid: 11 kN/m^3
(ii) Density of concrete: 24 kN/m^3
(iii) Density of soil: 20 kN/m^3
(iv) Internal friction angle of soil: 30 degrees
(v) Concrete classes:
Structural concrete: Class 35/19 (35 MPa)
Benching: Class 20/19 (20 MPa)
Blinding: Class 15/19 (15 MPa)
(vi) Design crack width: 0,20mm (severe or very severe exposure)
(vii) Concrete cover to reinforcement: 50mm (minimum)

12.2.4 General Loading, Analysis and Design of Liquid Retaining Structures

In accordance with the relevant design codes, the liquid level inside the structures is taken as the top of the working top liquid level for the serviceability limit state design. For the ultimate limit state design, liquid levels were taken to the tops of walls, assuming that all liquid outlets are blocked.

Allowance has been made for the effects of adverse soil pressure on walls due to compaction and surcharge. The beneficial effect of external soil pressures on the liquid retaining structures in the filled condition was ignored.

In non-cylindrical structures, an assessment was made of the pressures to be resisted by horizontal and vertical bending moments in the walls. Allowance was also made for the effects of direct tension in walls induced by flexural action in adjacent walls.

The maximum hoop tension in the walls of cylindrical structures was determined assuming a pinned connection between the wall and the base. The maximum negative vertical bending moments in the walls of cylindrical structures were determined by considering a fixed connection at the wall/base interface. For the determination of positive midspan bending moments in the walls, a pinned connection was assumed.

As a rule, the floor slabs in both cylindrical and non-cylindrical structures were not monolithic with the wall foundations. The floors were divided into panels separated by sealed expansion joints, and either fibre-reinforced, or reinforced with high tensile steel reinforcement, as specified on the drawings.

The partial load factor for retained liquids and external soil pressure for the ultimate limit state was taken as 1.35.

12.3 Earth Retaining Structures

The preferred design Option for the two new PSTs will entail construction of earth retaining structures/retaining walls are required to accommodate the change in grade of the natural ground level over the site of the proposed works, and to create the required elevations for the various components of the works. Primarily, use is made of reinforced concrete retaining walls and, where required or allowed by the topography of the site, concrete block retaining structures.

12.3.1 Design Philosophy

The lateral earth pressures behind the walls were determined by considering the internal angle of friction of the retained soil (which will generally be specified to be a granular material), the surcharge at the top of the fill behind the wall, as well as the direction and magnitude of movement the retaining structure is expected to undergo. The latter is required to ensure that the correct soil pressure coefficient is used. The at-rest pressure coefficient assumes no lateral movement of the wall while the active pressure develops when lateral movement of the wall takes place. Friction between the back of the concrete wall and the soil backfill was ignored, this is a conservative approach. The friction coefficient between the underside of the base and the foundation material was taken as 0,50.

The allowance for the build-up of water behind the retaining wall was eliminated by designing and specifying suitable sub-soil drainage systems for the walls. This eliminates the hydrostatic pressure and improves the stability of the material behind the wall.

The factor of safety of the wall against sliding and overturning was taken as 1,5 under service loads. The partial load factors for dead loads (1,2), soil loads (1,4) and imposed loads (1,6) used are in accordance with the requirements of SANS 10160. The factorised loads were used for the Ultimate Limit State design of the wall, including wall thickness and reinforcement requirements.

12.3.2 Codes of Practice

- SANS 10100-Part 1: The structural use of concrete - Design
- SANS 10100-Part 2: The structural use of concrete - Materials and workmanship
- SANS 2001-CC1:2007: Concrete works (Structural)
- SANS 10144: Detailing of steel reinforcement for concrete
- SABS 920: Steel bars for concrete reinforcement
- SANS 10160-Parts 1 to 8 (as applicable): Basis of structural design and actions for buildings and industrial structures

12.3.3 Material Properties and Design Data

(i) Density of contained liquid: 11 kN/m^3
(ii) Density of concrete: 24 kN/m^3
(iii) Density of soil: 20 kN/m^3
(iv) Internal friction angle of soil: 30 degrees
(v) Concrete classes:
(vi) Structural concrete: Class 35/19 (35 MPa)
(vii) Benching: Class 20/19 (20 MPa)
(viii) Blinding: Class 15/19 (15 MPa)
(ix) Concrete cover to reinforcement: 50mm (minimum)

12.4 Buildings

12.4.1 Design Philosophy

Buildings that will be constructed as part of this project include new Pump Stations.

12.4.2 Codes of Practice

- SANS 10160-Parts 1 to 8 (as applicable): Basis of structural design and actions for buildings and industrial structures
- SANS 10100-Part 1: The structural use of concrete - Design
- SANS 10100-Part 2: The structural use of concrete - Materials and workmanship
- SANS 2001-CC1:2007: Concrete works (Structural)
- SANS 10144: Detailing of steel reinforcement for concrete
- SABS 920: Steel bars for concrete reinforcement

- SANS 10162-Part 1: The structural use of steel –Design (Hot rolled steelwork)
- SANS 10164-Part 1: The structural use of masonry (Unreinforced)

12.4.3 Material Properties and Design Data

The following material properties are applicable to the buildings:

(i) Density of concrete: 24 kN/m^3
(ii) Concrete classes:
(iii) Structural concrete: Class 35/19 (35 MPa)
(iv) Benching: Class 20/19 (20 MPa)
(v) Blinding: Class 15/19 (15 MPa)
(vi) Concrete cover to reinforcement: 30mm (minimum)
(vii) Reinforcement: High yield bars (f_y=450 N/mm^2) and Mild steel bars (f_y=250 N/mm^2)
(viii) All Steelwork to be Grade 355JR and hot-rolled steelwork will be used for the steelwork on the project
(ix) Density of steel: 7850 kg/m^3
(x) Load-bearing masonry to be from masonry clay brick units – NFX/NFP with mortar class II

The following design data was considered in the designs for the buildings:

(i) All floor slabs (except for roofs) was taken as for offices (2.5kN/m^2) and as industrial (5kN/m^2) for the pump station buildings.
(ii) The wind loading has been taken into account for the structures and a factor of 1.2 has been used for ULS designs and 1.3 (uplift) and 0.9 for SLS.
(iii) No seismic or accidental loads have been taken into account for the designs and these will be done in the detailed designs.

13 ENVIRONMENTAL AUTHORISATION

The applicability of the activities listed in Government Notice No. R.327, promulgated in terms of the National Environmental Management Act (107 of 1998) were determined based on the scope of work and planned project activities.

Accordingly, a Basic Assessment (BA) Process in accordance with Regulations 16-20 of the NEMA EIA Regulations 2014, as amended (Government Notice No. R.326) and a Water Use License in terms Section 21 of the National Water Act (Act 36 of 1998) as amended, will be required.

14 HEALTH AND SAFETY

A Health and Safety Practitioner must be consulted during the detailed design stage of the project to advise on any health and safety requirements that need to be addressed prior to construction.

15 RISK MANAGEMENT

The two current major risks on this project are as follows:

- Project funding – the uncertainty of securing the full project budget for this long term project may impact on whether this project will proceed as programmed, or not.
- Environmental authorisation – getting an environmental authorisation may delay the implementation of the project.

16 PROJECT PROGRAMME

The project programme is updated monthly as part of the reporting to JW. The Project Programme as updated in December 2018 can be found in Appendix A.

17 PROJECT INVESTMENT

A summary of the consolidated project investment is provided in Table 22.

Table 22: Consolidated summary of costs

Summary of Costs		
Description		**Amount (R)**
New PSTs Preferred Option	R	48 297 625.00
Refurbishment of Existing Pump Stations	R	5 628 500.00
Refurbishment Existing PSTs	R	15 110 850.00
Refurbishment Existing Fermenters	R	5 531 315.00
Sub-Total 1	R	74 568 290.00
Contingencies at 10%	R	7 456 829.00
Sub-Total 2 (excl. VAT)	**R**	**82 025 119.00**
VAT at 15%	R	12 303 800.00
Total (Incl. VAT)	R	94 328 919.00

Detailed cost estimates can be found in Appendix B.

18 WAY FORWARD

The Preliminary Design Report documents the options considered as part of the Preliminary Design as well as the preferred design options that will be developed further during the Detailed Design. The following design options will be developed further during the Detailed design:

1. **New PSTs Option 2 – Positioning new PSTs west of the existing PST complex**
2. **Refurbishing Existing Pump Stations Option 2 – Pump Station with a wet well (pumps with a flooded suction)**

3. **Refurbishing existing PSTs**
4. **Refurbishing existing Fermenters**

Approval of this report is required for Zitholele to commence with the next stage of the project, viz. Detailed Design.

ZITHOLELE CONSULTING (PTY) LTD

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APPENDIX A : PROJECT PROGRAMME

APPENDIX B : DETAILED COST ESTIMATES