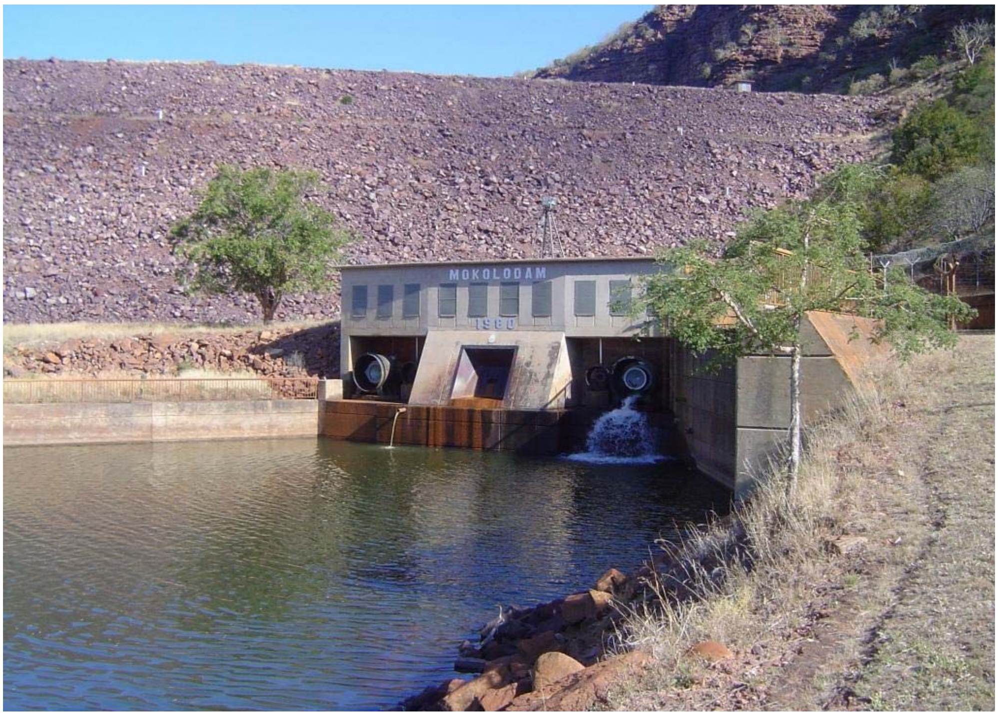
REPORT NUMBER: P RSA A000/00/9309

Department:
Water Affairs and Forestry

Chief Directorate: Integrated Water Resource Planning
Directorate: Options Analysis

MOKOLO AND CROCODILE (WEST) WATER AUGMENTATION PROJECT (MCWAP) FEASIBILITY STUDY: TECHNICAL MODULE

Project No. WP9528



SUPPORTING REPORT NO. 6
WATER TRANSFER SCHEME OPTIONS

Lead Consultant: Africon

In association with: KV3, VELA VKE

LIST OF REPORTS

REPORT NO	DESCRIPTION	REPORT NAME
FEASIBILITY STAGE		
P RSA A000/00/8109	Main Report	MCWAP FEASIBILITY STUDY TECHNICAL MODULE SUMMARY REPORT
P RSA A000/00/8409	Supporting Report 8A	GEOTECHNICAL INVESTIGATIONS PHASE 1
P RSA A000/00/8709	Supporting Report 8B	GEOTECHNICAL INVESTIGATIONS PHASE 2
P RSA A000/008509	Supporting Report 9	TOPOGRAPHICAL SURVEYS
P RSA A000/00/8609	Supporting Report 10	REQUIREMENTS FOR THE SUSTAINABLE DELIVERY OF WATER
P RSA A000/00/8209	Supporting Report 11	PHASE 1 FEASIBILITY STAGE
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PRE-FEASIBILITY STAGE		
P RSA A000/00/8809	Supporting Report 1	WATER REQUIREMENTS
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P RSA A000/00/9209	Supporting Report 5	MOKOLO RIVER DEVELOPMENT OPTIONS
P RSA A000/00/9309	**Supporting Report 6**	**WATER TRANSFER SCHEME OPTIONS**
P RSA A000/00/9409	Supporting Report 7	SOCIAL AND ENVIRONMENTAL SCREENING
INCEPTION STAGE		
P RSA A000/00/9609	Inception	INCEPTION REPORT

REFERENCE

This report is to be referred to in bibliographies as:

Department: Water Affairs, South Africa, 2008. Mokolo Crocodile (West) Water Augmentation Project (MCWAP) Feasibility Study. Report 7: Environmental and Social Screening. Prepared by Africon in association with Kwezi V3 Engineers, Vela VKE, WRP Consulting Engineers and specialists.

DWA Report No. P RSA A000/00/9309

REPORT DETAILS PAGE

Project name:	***Mokolo and Crocodile (West) Water Augmentation Project (MCWAP)***
Report Title:	**Pre-Feasibility Study Report 6 - Water Transfer Scheme Options**
Author:	***J Pienaar***
DWA report reference no.:	***P RSA A000/00/9309***
PSP project reference no.:	***WP 9528***
Status of report:	***Final***
First issue:	***November 2008***
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PSP

Approved for PSP by:

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Study Leader

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Project Coordinator & Manager

DEPARTMENT OF WATER AFFAIRS (DWA)
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Acting Chief Director: Integrated Water Resources Planning

Preface

The Mokolo (Mogol) River catchment is part of the Limpopo Water Management Area (WMA). The Mokolo River originates close to Modimolle (Nylstroom) and then drains to the north into the Limpopo River. The Mokolo Dam (formerly known as the Hans Strijdom Dam) is the largest dam in the catchment. The dam was constructed in the late 1970s and completed in July 1980, to supply water to Matimba Power Station, Grootegeluk Mine, Lephalale (Ellisras) Municipality and for irrigation downstream of the dam. Based on the water infrastructure, the current water availability and water use allows only limited spare yield existing for future allocations for the anticipated surge in economic development in the area.

There are a number of planned and anticipated consequential developments in the Lephalale area associated with the rich coal reserves in the Waterberg coal field for which additional water will be required. These developments include inter alia the development of four further power stations by Eskom, the potential development of two coal to liquid facilities by Sasol and the associated growth in mining activities and residential development.

The development of new power stations is of high strategic importance with tight timeframes. Commissioning of the first generation unit will start in September 2010 and additional water needs to be available by mid-2011 according to the expected water requirements. A solution addressing the water needs of the Lephalale area must be pursued. The options to augment existing water supplies include transferring surplus effluent return flows from the Crocodile River (West) / Marico WMA to Lephalale and the area around Steenbokpan. Refer to the map indicating the study area on the following page.

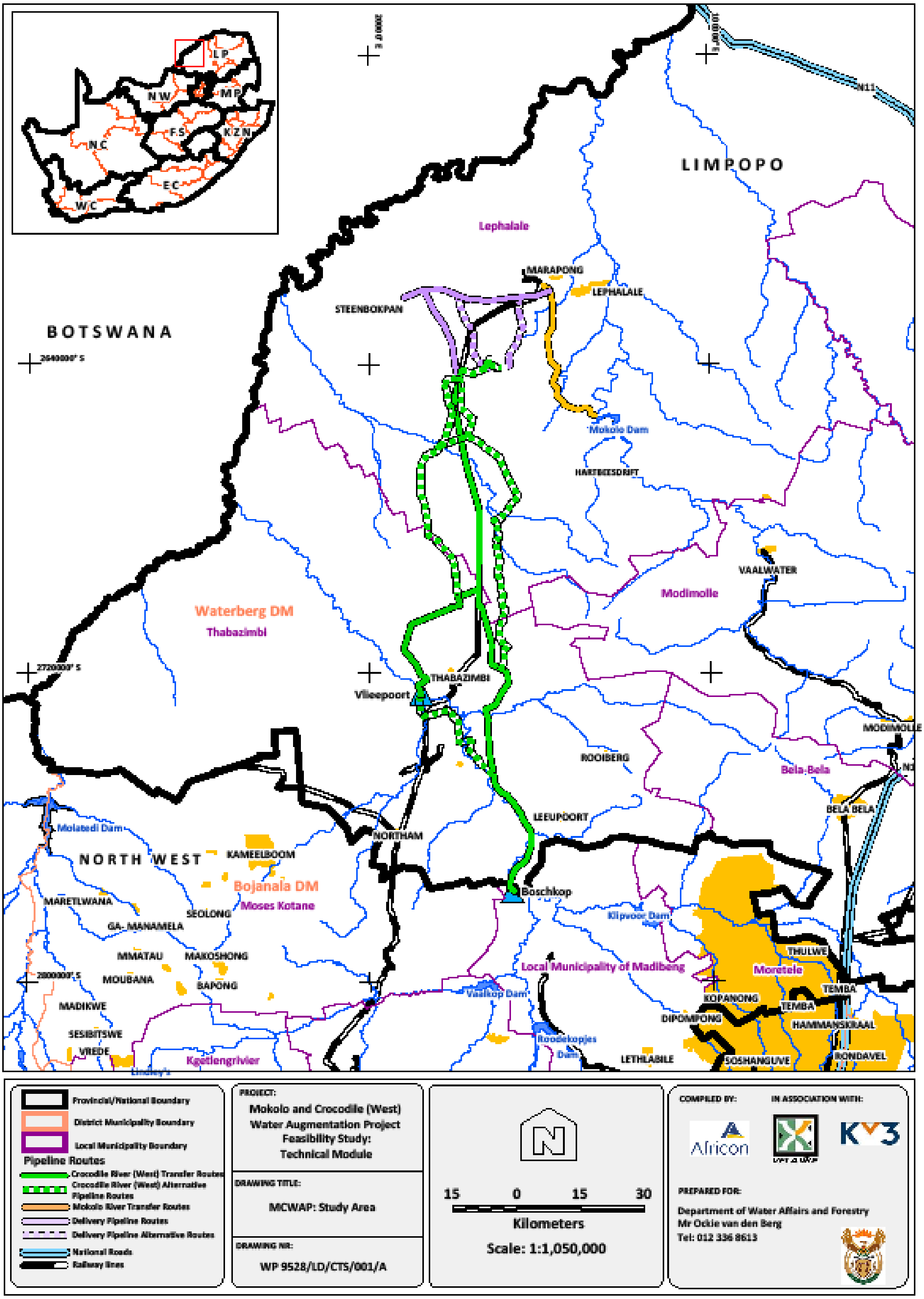
The Department of Water Affairs (DWA) commissioned the Mokolo and Crocodile River (West) Water Augmentation Project (MCWAP) to analyse the options for transferring water from the Crocodile River (West). In April 2008, the Technical Module of this study was awarded to Africon in association with Kwezi V3, Vela VKE and specialists. The focus of the Technical Module is to investigate the feasibility of options to:

- **Phase 1A:** Augment the supply from Mokolo Dam to supply in the growing water use requirement for the interim period until a transfer pipeline from the Crocodile River (West) can be implemented. The solution must over the long term optimally utilise the full yield from Mokolo Dam.
- **Phase 2:** Transfer water from the Crocodile River (West) to the Lephalale area. Options to phase the capacity of the transfer pipeline (Phases 2A and 2B) must be investigated.

A further phase of the project (Phase 1B) may look at options to raise the full supply level of Mokolo Dam, but this is not currently the focus of this study.

The Technical Module has been programmed to be executed in a Pre-feasibility level investigation into different options, which will be followed by a Feasibility level investigation into the preferred transfer scheme. This report (Report 6 – Water Transfer Scheme Options, P RSA A000/00/9309) is the sixth in a series of eight supporting reports to the Pre-Feasibility Stage Main Report.

Pre-Feasibility Stage Main Report details how options for Phases 1A and 2 were developed and evaluated to arrive at a recommendation for the final transfer scheme option to be investigated at Feasibility level. The study team submitted this reports during December 2008 to the MCWAP Project Coordinators, Ninham Shand, and the Department of Water Affairs for approval of the recommended options.


BOTSWANA
LIMPOPO
NORTH WEST
Lephalale
MARAPONG
LEPHALALE
STEENBOKPAN
Mokolo Dam
HARTBEESDRIFT
VAALWATER
Modimolle
Waterberg DM
Thabazimbi
THABAZIMBI
Vlieepoort
MODIMOLLE
ROOIBERG
Bela-Bela
BELA BELA
LEEUPOORT
NORTHAM
Molatedi Dam
KAMEELBOOM
Bojanala DM
Moses Kotane
MARETLWANA
SEOLONG
GA- MANAMELA
MMATAU
MAKOSHONG
MOUBANA
BAPONG
MADIKWE
SESIBITSWE
VREDE
Kgetlengrivier
Boschkop
Klipvoor Dam
Local Municipality of Madibeng
Vaalkop Dam
Roodekopjes Dam
LETHLABILE
DIPOMPONG
KOPANONG
SOSHANGUVE
Moretele
THULWE
TEMBA
HAMMANSKRAAL
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N11
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Provincial/National Boundary
District Municipality Boundary
Local Municipality Boundary
Pipeline Routes
Crocodile River (West) Transfer Routes
Crocodile River (West) Alternative Pipeline Routes
Mokolo River Transfer Routes
Delivery Pipeline Routes
Delivery Pipeline Alternative Routes
National Roads
Railway lines
PROJECT:
Mokolo and Crocodile (West) Water Augmentation Project Feasibility Study: Technical Module
DRAWING TITLE:
MCWAP: Study Area
DRAWING NR:
WP 9528/LD/CTS/001/A
15 0 15 30
Kilometers
Scale: 1:1,050,000
COMPILED BY:
IN ASSOCIATION WITH:
PREPARED FOR:
Department of Water Affairs and Forestry
Mr Ockie van den Berg
Tel: 012 336 8613

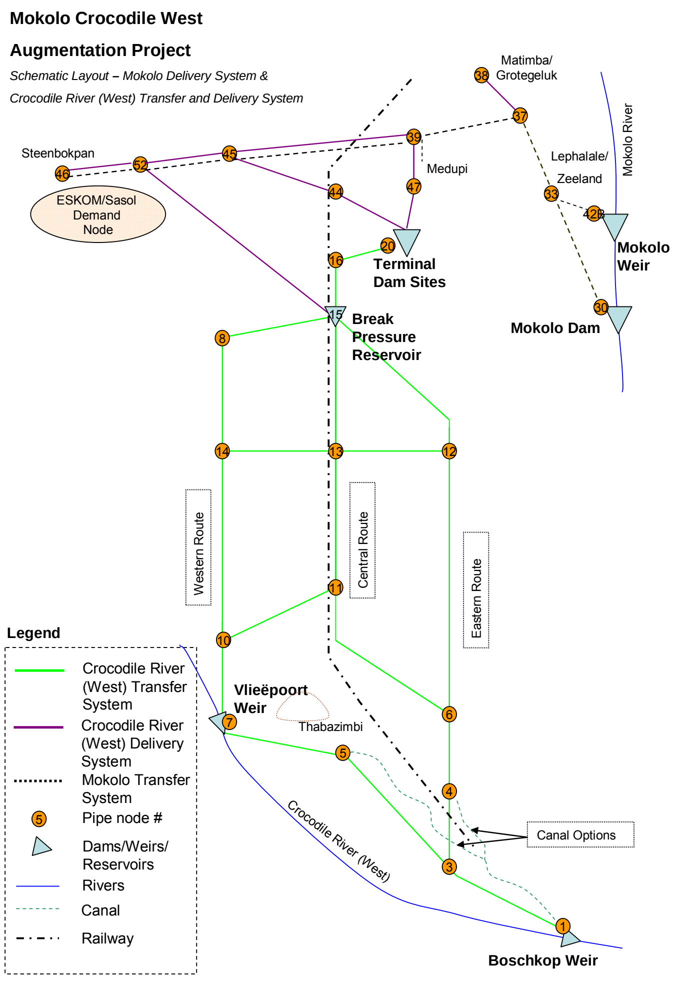
MOKOLO CROCODILE (WEST) WATER AUGMENTATION PROJECT FEASIBILITY STUDY: WATER TRANSFER SCHEME OPTIONS PRE-FEASIBILITY STAGE

EXECUTIVE SUMMARY

Introduction

The primary purpose of the Mokolo and Crocodile River (West) Augmentation Project is to investigate the options to transfer water from the Mokolo and Crocodile River (West) to the Lephalale and Steenbokpan areas to supply the primary and industrial users in this fast developing area.

Various options have been identified to convey water to the end users. These include the Crocodile River (West) transfer and delivery system, as well as the Mokolo transfer system. The latter is intended to supply the interim water requirements for a period until the Crocodile River (West) transfer and delivery system has been constructed and to support the reliability and redundancy requirements once the Crocodile River (West) transfer and delivery system is operational. The Mokolo and Crocodile (West) scheme is illustrated below showing the different components forming part of the combined scheme.



Water Requirements

Development from Lephalale westwards towards Steenbokpan and the Botswana border is driven by large coal deposits. The expected interim to long term industrial, commercial and domestic water requirements were obtained from large users (Eskom, Exxaro and Sasol) and also quantified for the Lephalale Local Municipality where significant growth is expected.

Two water requirement scenarios were compiled for the period up to 2030:

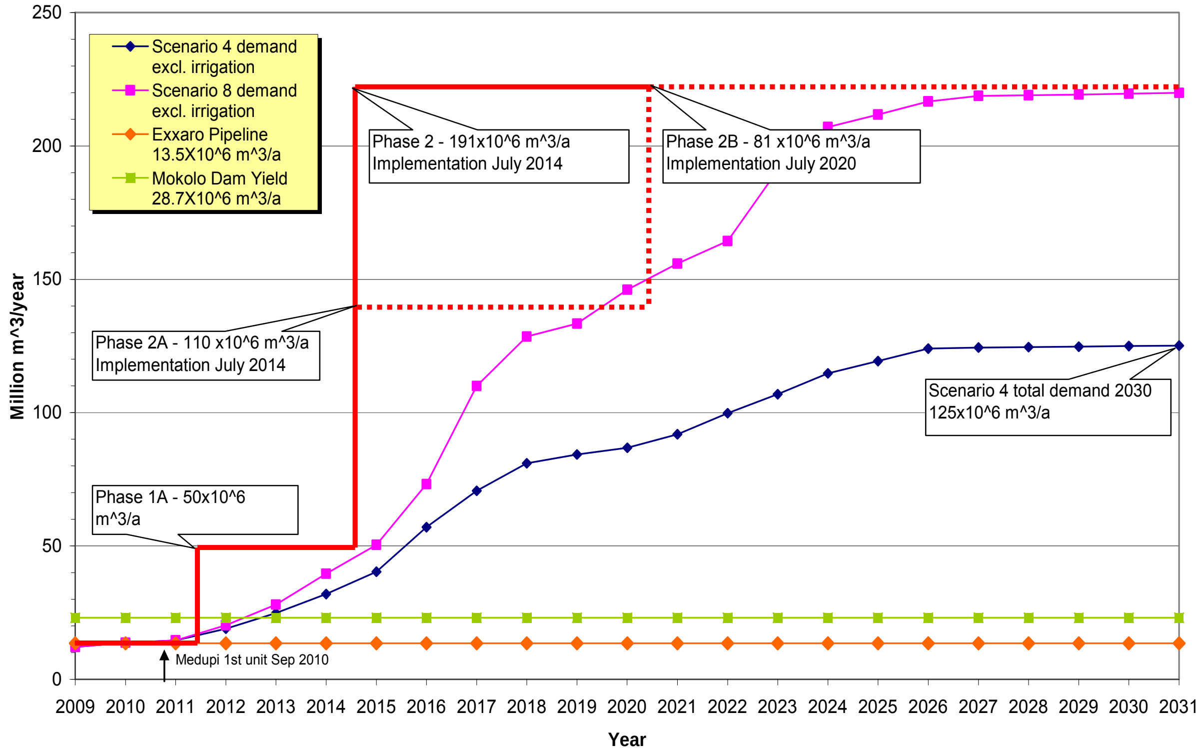
- *Scenario 4 – Matimba Power Station (FBC); Medupi power station (FGD); 3 new power stations (FGD); coal supply to five (5) power stations; Exxaro project,;the associated construction activities and the associated growth in Lephalale and Steenbokpan.*
- *Scenario 8 – Scenario 4 + Sasol development of two CTL plants; the associated construction activities and the associated growth in Steenbokpan.*

The baseline figures (excluding losses, irrigation and reliability and redundancy requirements) to be used for planning and sizing the options for the interim transfer from Mokolo Dam and the ultimate transfer from both the Mokolo Dam and the Crocodile River (West) are as follows:

- ***Phase 1A:*** *Interim Scheme delivering from Mokolo Dam:*
  - Capacity of the existing pipeline from Mokolo Dam to the end users - 13.5 Million m^3/annum
  - Minimum required combined Mokolo system capacity during the interim period (May 2011 to July 2014) - 50.4 Million m^3/annum
  - Minimum required capacity of the new Mokolo pipeline - 36.9 Million m^3/annum (50.4 Million m^3/annum - 13.5 Million m^3/annum)
  - Ultimate Mokolo system capacity after commissioning of the Crocodile River (West) transfer system – 28.7x10 Million m^3/annum (long term yield of the Mokolo Dam of 39.1 Million m^3/annum less the irrigation requirement downstream of the dam of 10.4 Million m^3/annum)

- ***Phase 2A:*** *First phase of a transfer system from the Crocodile River (West) – 110 Million m^3/annum (Starting from July 2014 onwards)*
- ***Phase 2B:*** *Second phase of a transfer system from the Crocodile River (West) – 81 Million m^3/annum (incremental transfer volume)*
- ***Phases 2 or 3:*** *Total Crocodile River (West) transfer volume - 191 Million m^3/annum (Delivered via a phased or un-phased approach)*

The combined system volumes to be transferred are illustrated below.



Reliability and Redundancy

The strategic importance of the users that will account for the bulk of the water consumption requires that the risk of failure in the supply of water be kept to a minimum. Specific allowance for reliability and redundancy was therefore made in the combined Mokolo and Crocodile River (West) water supply scheme.

Infrastructure Components

The following infrastructure components were considered during the pre-feasibility assessment of the scheme:

- *Abstraction Weir: Five sites along the Crocodile River were investigated for appropriateness. Two sites along the Crocodile River (Boschkop and Vlieëpoort) were selected and taken to pre-feasibility design level. Components associated with the abstraction weirs included:*
  - Abstraction pump stations
  - De-siltation structures
  - High-Lift pump station balancing dams

- *High lift pumping stations*

- *Conveyance option: The following conveyance options were considered as part of the pre-feasibility investigation:*
  - River conveyance
  - Canal conveyance
  - Pipeline conveyance

- *A combination of reliability storage and balancing storage options were investigated*

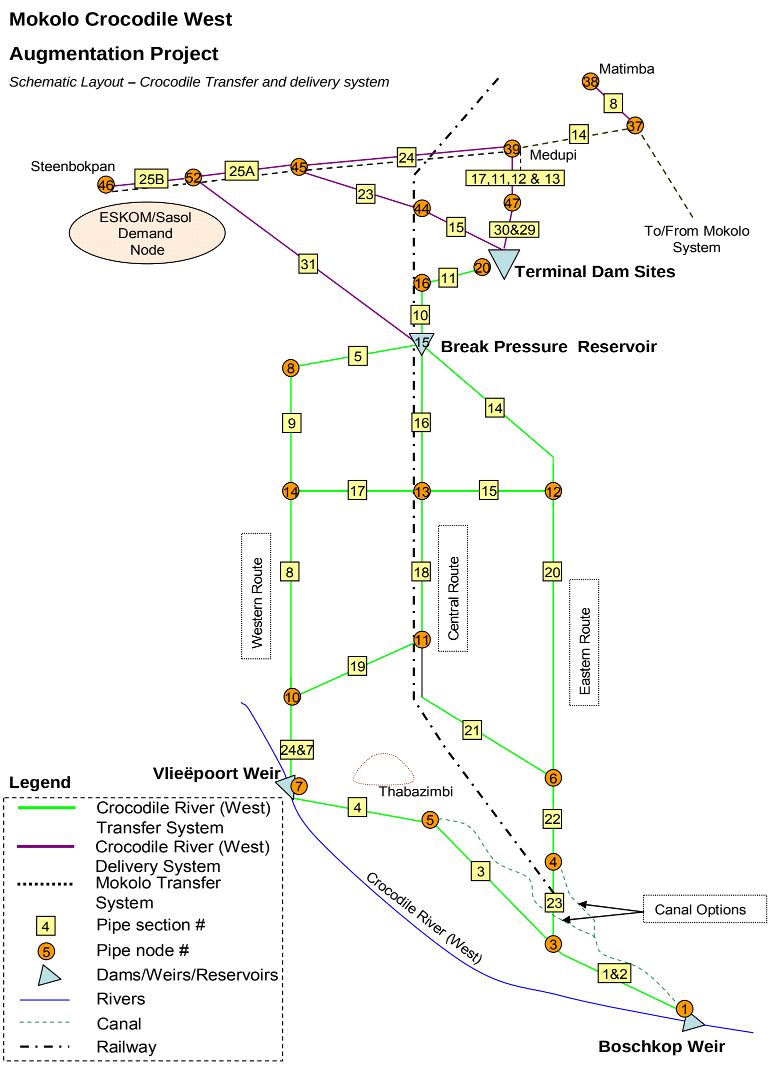
An updated and revised version of the Vaal Augmentation Planning Study (VAPS) guideline was adopted for preliminary sizing, costing and engineering economic evaluation of the development options.

Route Options

The following aspects were considered in defining and evaluating the different pipeline routes:

- *Possible abstraction and delivery locations.*
- *Existing roads, as well as boundaries between land owners along the routes.*
- *Historical and planned future mining activities in the area.*
- *Existing and planned future services and infrastructure.*
- *Site constraints, potential river/stream crossings, and road and railway crossings.*
- *Geotechnical conditions based on a high level geotechnical screening.*
- *Cathodic protection requirements with special consideration of the impact that the potential future 765 kV overhead power line corridors might have on the AC mitigation requirements.*
- *Environmental overview.*
- *Social impact of the proposed pipe route.*

Based on the two abstraction weir sites (Boschkop and Vlieëpoort), water from the Crocodile River (West) can be delivered along alternative route(s) to either one of the two identified Terminal Dam sites (Sites 1 or 3), or via a break pressure balancing reservoir to Terminal Reservoirs at the major consumer sites. A schematic diagram of the alternative pipeline route options and system nodes are shown below. A layout drawing of the scheme is included in ***Appendix A*** *(DWG No WP 9528/LC/CTS/001/A).*



The alternative pipeline routes that were identified are summarised below for the Crocodile River (West) transfer and delivery systems.

Description	Flow Routing – Transfer System (Pipe Section No – Refer Schematic)	Section Length (km)	Route Option Number
Vlieëpoort Weir Abstraction Options			
Abstraction at Vlieëpoort Weir with conveyance to Terminal Dam/Break Pressure Reservoir (Phased or un-phased)	*Western Route to Terminal Dam site entrance: <24-7-8-9-5-10-11>*	*111.3*	*1*
	Central Route to Terminal Dam site entrance: <24-7-19-18-16-10-11>	*106.1*	*2*
	Central Route to Break Pressure Reservoir (Node 15): <24-7-19-18-16>	*97.9*	*3*
Boschkop Weir Abstraction Options			
Abstraction at Boschkop Weir with conveyance to Terminal Dam/Break Pressure Reservoir (Phased or un-phased)	*Eastern Route to Terminal Dam site entrance: <1-2-23-22-20-14-10-11>*	*161.8*	*4*
	Central Route to Terminal Dam site entrance: <1-2-23-22-21-18-16-10-11>	*152.8*	*5*
	Eastern Route to Break Pressure Reservoir (Node 15): <1-2-23-22-20-14>	*153.6*	*6*
	Central Route to Break Pressure Reservoir (Node 15): <1-2-23-22-21-18-16>	*144.6*	*7*
Boschkop/Vlieëpoort Weir Abstraction Options			
Abstraction at Boschkop Weir with conveyance to Vlieëpoort Weir for transfer to Terminal Dam/Break Pressure Reservoir (Phase 3)	*Western-Route to Vlieëpoort Weir: <1-2-3-4>*	*70.0*	*8*

Description	Flow Routing – Delivery (Pipe Section No – Refer Schematic)	Section Length (km)	Route Option Number
Delivery from the Terminal Dams			
Conveyance from Terminal Dam No 1 to end users	*<15-23> Link to Lephalale-Steenbokpan Pipeline (Node 45) <25A-25B> Link to Steenbokpan <24-14> Link to Lephalale (Constructed as part of Phase 1A) <8> Link to Matimba (Constructed as part of Phase 1A) <13> Link to Medupi*	*21.8 13.8 22.2 1.9 1.7*	*2A*
Conveyance from Terminal Dam No 3 to end users	*<30-29-17-11-12-13> Link to Lephalale-Steenbokpan Pipeline (Node 39) <24-25A-25B> Link to Steenbokpan <8> Link to Matimba (Constructed as part of Phase 1A) <14> Link to Lephalale (Constructed as part of Phase 1A)*	*19.3 28.4 1.9 7.6*	*2B*
Delivery from the Balancing Reservoir			
Conveyance from Break Pressure Reservoir to end users	*<31> Link to Lephalale-Steenbokpan Pipeline (Node 52) <25B> Link to Steenbokpan <25A-24-14> Link to Lephalale (Constructed as part of Phase 1A) <8> Link to Matimba (Constructed as part of Phase 1A) <13> Link to Medupi*	*24.8 5.1 30.8 1.9 1.7*	*3*

A feasibility screening of the following aspects were performed on the different route options:

- *Geology and geotechnical screening*
- *Cathodic protection and AC mitigation*
- *Bulk electrical supply*
- *Environmental and social screening.*
- *Technical and practical considerations*

The findings of the feasibility screening is summarised below.

Geology and Geotechnical Screening

No adverse geological conditions are expected that would totally prohibit the construction of the pipelines along any of the alternative route options investigated. There is also not a great variation in the geological conditions along the respective pipeline routes that would create a major advantage of one over the other.

A variation in the geology generally occurs from the south to the north. The geology in the southern regions consists predominantly of dolomites and granites, changing to predominantly Waterberg quartzite, dolomite and granite in the central regions with Khalahari sands and Waterberg quartzite becoming more prominent towards the north and west.

A slightly shallower hard material interface level can be expected along southern and eastern route options. This would increase the volume of hard rock encountered and would impact on the cost and the construction period of the transfer route options from Boschkop to Vlieëpoort or from Boschkop directly to the terminal dams/balancing reservoir via the eastern route.

Relatively high re-use of excavated material for bedding and backfill purposes is expected along all route options.

Overall, the most favourable geological conditions are expected along the Central transfer route.

The geology and geotechnical conditions along the delivery system route options are generally similar with no clear distinction between the various alternatives at this level of detail.

Cathodic Protection and AC Mitigation

The proposed pipeline routes run parallel to and cross a number of existing and proposed future high voltage power lines. There are also a number of rail crossings which is currently not electrified, but if electrified in future, is expected to be with AC power.

A high level assessment was done to determine the required cathodic protection (CP) and AC mitigation measures that will be required to protect the proposed pipelines. The soil resistivity along the main transfer pipeline route options (west, central and east) was also investigated. Resistivity values are generally higher (less corrosive) along the eastern transfer route compared to the central and western routes.

The investigation concluded that CP and AC mitigation will be required on all transfer and delivery pipelines. Some saving could be achieved if the pipeline was not located parallel to one of the proposed Eskom power line corridors (6 x 765 kV parallel high voltage power lines). It was, however, found that the cost saving that could be affected was not significant compared to the overall cost of the CP and AC mitigation. Locating the pipeline adjacent to the railway line is also not considered to be a fatal flaw from a CP point of view.

The presence of high voltage transmission lines parallel to a pipeline would result in a bigger maintenance burden on the operator of the scheme to ensure that the CP and AC mitigation system is diligently operated and maintained. It would also imply a higher health and safety risk associated with the maintenance of the system. Due to the uncertainty regarding the power line *corridor that will be opted for by Eskom, no significant differentiation is currently possible between different route alternatives from a CP and AC mitigation point of view.*

Bulk Electrical Supply

The capacity of the existing high and medium voltage networks in area was investigated and the need for upgrading of the existing systems or the construction of new infrastructure to supply the sites was determined.

Additional infrastructure will be required to provide 132 kV loop in – loop out firm supplies to both Vlieëpoort and Boschkop sites.

Environmental and Social Screening

The environmental screening was carried out to confirm the environmental feasibility of the various transfer and delivery pipeline route options while a social impact screening was carried out to provide an indication of the potential social impacts of the proposed transfer and delivery systems from the Crocodile River (West) to the balancing dams/reservoir and further to the end users. The conclusions are summarised below:

- *There is no environmental or social impact totally prohibiting the construction of any of the route options.*
- *Transfer route options:*
  - *The eastern transfer route passes through the Marakele Nature Reserve. This will increase the environmental and social impact, and it is expected that obtaining the necessary environmental approvals will be difficult.*
  - *The central transfer route will have the least environmental and social impact due to the disturbance already caused by the railway line. This route is preferred from an environmental and social point of view.*
  - *The western transfer route passes through an area characterised by extensive game farming. This will increase the environmental and social impact associated with the project.*
- *Terminal Dams/Terminal Reservoir:*
  - *The environmental and social impact of the Terminal Reservoirs (including the connecting pipelines and tunnel sections) on the Farm Witvogelfontein is expected to be considerably more than the Balancing Reservoir option with terminal storage at the individual end users.*
- *Delivery route options*
  - *No adverse environmental or social impacts can be attributed to any of the three delivery route options.*

Technical and Practical Considerations

The following practical considerations will also influence the choice of transfer and delivery route:

- *Length of Pipeline – a shorter pipe length will reduce costs and shorten construction periods. The Central route option from both Vlieëpoort and Boschkop is the shortest possible route to either the terminal dam or the balancing reservoir.*
- *Constructability – Constructability of a pipeline is influenced by the horizontal alignment (straight or with many bends/curves), site conditions (disturbed or un-disturbed), access, geotechnical conditions, environmental sensitivity etc. Considering these aspects, the Central route options are preferred from a constructability point of view.*
- *Hydraulic performance - A pump-gravity system can be considered for options supplying the balancing reservoir in order to simplify the operation of the system.*

Options Evaluation

The Mokolo and Crocodile River (West) Augmentation Project will be implemented in phases with a number of sub-options as follows:

- ***Phase 1:** Augment the supply from Mokolo Dam:*
  - *Phase1A – Provide a peak delivery capacity of 50.4 Million m^3/annum by implementing either one of the following options:*

1) Option 1 – Pipeline from Mokolo Dam to the Lephalale and Steenbokpan demand areas.
2) Option 2 – Weir in the Mokolo River downstream of the dam and pipeline to Lephalale and Steenbokpan.

- ***Phase 2:*** *Transfer scheme from the Crocodile River (West) to the demand area via a system consisting of:*
- *Various potential pipeline routes. Three general routes have been identified – East, Central and West.*
- *A number of different weir and abstraction work sites.*
- *Terminal and/or on-site storage:*
  1) *Terminal Dam options providing 18 days storage together with Balancing Reservoirs at the end user sites with minimum 9 days storage plus additional user requirements to achieve the required balancing capacity and emergency storage; this is to provide for the reliability required for the gravity pipelines from the Terminal Dams.*
  2) *Alternatively a break pressure reservoir with short term balancing storage between the end of the rising main section and the gravity main section used in conjunction with end user terminal reservoirs consisting of seven (7) on-site reservoirs with 18 days storage capacity plus additional user requirements to achieve the required balancing capacity and emergency storage.*
- Two approaches:
  3) *Un-phased (full capacity) scheme implemented in a single construction phase with an ultimate net transfer capacity of 191 Million m^3/annum (excluding system losses).*
  4) *Phased approach where the capacity is provided through two parallel pipes constructed during two consecutive construction phases.*

- ***Phase 2A****: First phase pipeline from Vlieëpoort Weir with a net transfer capacity of 110 Million m^3/annum.*
- ***Phase 2B:*** *Second phase pipeline from Vlieëpoort Weir to achieve ultimate required net transfer capacity of 191 Million m^3/annum.*
- ***Phase 3:***
  - *Third construction phase during which a pipeline is built from Boschkop Weir to Vlieëpoort Weir to link with the infrastructure built during Phase 2 in order to reduce river losses between the Boschkop and Vlieëpoort Weir sites.*

The following options were evaluated as part of the investigations:

Option Nr	***Option Code***	***Description***	***Flow Routing (Refer to schematic diagram)***
1	*8-P1A-MD-ID1*	*Scenario 8 – Phase 1A, transfer from Mokolo Dam via pump/gravity main to the users.*	*Refer Mokolo River Development Options Report (P RSA A000/00/9209)*
2	*8-P1A-RBW-IW1*	*Scenario 8 – Phase 1A, transfer from weir in Mokolo River (Rivers Bend) via rising main to users.*	*Refer Mokolo River Development Options Report (P RSA A000/00/9209)*
3	*8-P2-TVCD1-DD1*	*Scenario 8 - Phase 2, transfer from Vlieëpoort via Central Route to Terminal Dam 1 and deliver via Delivery Route 2A*	*Transfer Route Option 2: <24-7-19-18-16-10-11> Delivery Route Option 2A: <15-23> <25A-25B > <24-14-8> <13>*
4	*8-P2-TVCD3-DD3*	*Scenario 8 - Phase 2, transfer from Vlieëpoort via Central Route to Terminal Dam 3 and deliver via Delivery Route 2B*	*Transfer Route Option 2: <24-7-19-18-16-10-11> Delivery Route Option 2B: <30-29-17-11-12-13> <24-25A-25B > <14-8>*

Option Nr	Option Code	Description	Flow Routing (Refer to schematic diagram)
5	*8-P2-TVCB1-DB1*	*Scenario 8 - Phase 2, transfer from Vlieëpoort via Central Route to Break Pressure Reservoir and delivery to the Terminal Reservoirs via Delivery Route 3.*	*Transfer Route Option 3:* *<24-7-19-18-16>* *Delivery Route Option 3:* *<31> <25B> <25A-24-14-8> <13>*
6	*8-P2-TVWB1-DB1*	*Scenario 8 - Phase 2, transfer from Vlieëpoort via Western Route to Break Pressure Reservoir and delivery to the Terminal Reservoirs via Delivery Route 3.*	*Transfer Route Option 1(part)* *<24-7-8-9-5>* *Delivery Route Option 3:* *<31> <25B> <25A-24-14-8> <13>*
7	*8-P2-TBCB1-DB1*	*Scenario 8 – Phase 2, transfer from Boschkop via Central Route to Break Pressure Reservoir and delivery to the Terminal Reservoirs via Delivery Route 3.*	*Transfer Route Option 7:* *<1-2-23-22-21-18-16>* *Delivery Route Option 3:* *<31> <25B> <25A-24-14-8> <13>*
8	*8-P2-TBEB1-DB1*	*Scenario 8 – Phase 2, transfer from Boschkop via Eastern Route to Break Pressure Reservoir and delivery to the Terminal Reservoirs via Delivery Route 3.*	*Transfer Route Option 6:* *<1-2-23-22-20-14>* *Delivery Route Option 3:* *<31> <25B> <25A-24-14-8> <13>*
9	*8-P2A-TVCB1-DB1*	*Scenario 8 - Phase 2A (first pipeline), transfer from Vlieëpoort via Central Route to Break Pressure Reservoir and delivery to the Terminal Reservoirs via Delivery Route 3.*	*Transfer Route Option 3:* *<24-7-19-18-16>* *Delivery Route Option 3:* *<31> <25B> <25A-24-14-8> <13>*
10	*8-P2B-TVCB1-DB1*	*Scenario 8 - Phase 2B (second pipeline), transfer from Vlieëpoort via Central Route to Break Pressure Reservoir and delivery to the Terminal Reservoirs via Delivery Route 3.*	*Transfer Route Option 3:* *<24-7-19-18-16>* *Delivery Route Option 3:* *<31> <25B> <25A-24-14-8> <13>*
11	*8-P2A&B-TVCB1-DB1*	*Scenario 8 - Phase 2A&B, transfer from Vlieëpoort via Central Route to Break Pressure Reservoir and delivery to the Terminal Reservoirs via Delivery Route 3.*	*Transfer Route Option 3:* *<24-7-19-18-16>* *Delivery Route Option 3:* *<31> <25B> <25A-24-14-8> <13>*
12	*8-P3-TBVCB1-DB1*	*Scenario 8 - Phase 3, transfer from Boschkop through Vlieëpoort via Central Route to Break Pressure Reservoir and delivery to the Terminal Reservoirs via Delivery Route 3 (Option 5).*	*Transfer Route Option 8&3:* *<1-2-3-4> <24-7-19-18-16>* *Delivery Route Option 3:* *<31> <25B> <25A-24-14-8> <13>*
13	*4-P2-TBCB1-DB1*	*Scenario 4 – Phase 2, transfer from Boschkop via Central Route to Break Pressure Reservoir and delivery to the Terminal Reservoirs via Delivery Route 3.*	*Transfer Route option 7:* *<1-2-23-22-21-18-16>* *Delivery Route Option 3:* *<31> <25B> <25A-24-14-8> <13>*
14	*4-P2-TVCB1-DB1*	*Scenario 4 – Phase 2, transfer from Vlieëpoort via Central Route to Break Pressure Reservoir and delivery to the Terminal Reservoirs via Delivery Route 3.*	*Transfer Route Option 3:* *<24-7-19-18-16>* *Delivery Route Option 3:* *<31> <25B> <25A-24-14-8> <13>*

The following logical decision-making process was followed to eliminate options based on the unit reference value (URV). The unit reference value method is used to select the most "beneficial" system from a set of options. The scheme with the lowest unit reference value (has the lowest average total life cycle cost per unit of water delivered) provides the most benefit for the funds employed in constructing, operating and maintaining the scheme.

(1) Determine preferred option for Phase 1A – Mokolo Transfer System

Calculate URVs for Phase 1A (Mokolo Transfer System)

Option 1 – Pipeline < 8-P1A-MD-ID1>
And Option 2 – Weir < 8-P1A-RBW-IW1>

Select preferred option and use further in combination with Crocodile River (West) transfer and delivery options. Refer to Supporting Report 5: Mokolo River Development Options (P RSA A000/00/9209) for pre-feasibility findings and recommendations.

(2) Determine the preferred Terminal Dam / Break Pressure Reservoir Option

Calculate URVs for Scenario 8, Phase 2, Vlieëpoort Abstraction via Central Route

to Terminal Dam 1 < 8-P2-TV CD1-DD1>
or Terminal Dam 3 < 8-P2-TV CD3-DD3>
or Break Pressure Reservoir < 8-P2-TV CB1-DB1>

Select preferred dam option and use further in combination with route options.

(3) Select between the Western and Central Routes

Calculate URVs for Scenario 8, Phase 2, Vlieëpoort Abstraction via Western Route
to selected Terminal Dam/Break Pressure Reservoir option < 8-P2-TV WB1-DB1>

Compare with (2) and select preferred route option for Vlieëpoort abstraction.

(4) Select between the Eastern and Central Routes and between Abstraction at Vlieëpoort or Boschkop

Calculate URVs for Scenario 8, Phase 2, Boschkop Abstraction to Break Pressure Reservoir

via Eastern route < 8-P2-TBEB1-DB1>
and via Central Route < 8-P2-TBCB1-DB1>

Select preferred route option for Boschkop abstraction; and
Select between Vlieëpoort and Boschkop as the abstraction point.

(5) Determine whether the Phased Approach is Preferred

Calculate URVs for Scenario 8, Phase 2A, Vlieëpoort Abstraction
via Central Route to Break Pressure Reservoir < 8-P2A-TV CB1-DB1>

and Scenario 8, Phase 2B, Vlieëpoort Abstraction
via Central Route to Break Pressure Reservoir < 8-P2B-TV CB1-DB1>

Compare the un-phased approach and select.

(6) Compare the cost of Phase 3 pipeline with River Management

Calculate URVs for Scenario 8, Phases 2 & 3, Boschkop Abstraction
via Vlieëpoort and Central Route to Break < 8-P3-TBVCB1-DB1>
plus
Pressure Reservoir < 8-P2-TVCB1-DB1>

Compare with (4).

(7) Determine URV's for Scenario 4 Demands and Compare

Calculate URV for Scenario 4, Phase 2, Vlieëpoort Abstraction
Central Route to Balancing Reservoir < 4-P2-TV CB1-DB1>

Calculate URV for Scenario 4, Phase 2, Boschkop Abstraction
Central Route to Balancing Reservoir < 4-P2-TB CB1-DB1>

The table below summarises the calculated URVs for each of the options evaluated according to the above logic. The preferred option determined in each calculation step is indicated in bold.

Calculation Step	Option		Preferred	URV (excluding VAT)		
				@6%	@8%	@10%
1	**Determine Preferred Option for Phase 1A**					
1.1	**1**	**<8-P1A-MD-ID1>**	Option 1 (Pipeline)	**5.920**	**6.730**	**7.570**
1.2	2	<8-P1A-RBW-IW1>		7.380	8.180	9.010
2	**Determine Preferred Terminal Dam/Reservoir Option**					
2.1	3	<8-P2-TVCD1-DD1>		10.102	11.679	13.481
2.2	4	<8-P2-TVCD3-DD3>		10.319	11.975	13.868
2.3	**5**	**<8-P2-TVCB1-DB1>**	Break Pressure Reservoir + end user storage	**9.390**	**10.741**	**12.283**
3	**Select between Western and Central Routes**					
3.1	6	<8-P2-TVWB1-DB1>		9.509	10.898	12.483
3.2	**5**	**<8-P2-TVCB1-DB1>**	Central Route	**9.390**	**10.741**	**12.283**
4	**Select between Eastern and Central Routes and between Abstraction at Vlieëpoort or Boschkop**					
4.1	8	<8-P2-TBEB1-DB1>		10.264	12.173	14.347
4.2	7	<8-P2-TBCB1-DB1>	Central Route	10.065	11.910	14.012
4.3	**5**	**<8-P2-TVCB1-DB1>**	Vlieëpoort Abstraction	**9.390**	**10.741**	**12.283**
5	**Determine whether a Phased Approach is preferred**					
5.1	9	<8-P2A-TVCB1-DB1>		9.534	10.934	12.458
5.2	10	<8-P2B-TVCB1-DB1>		5.074	5.284	5.446
5.3	11	<8-P2A&B-TVCB1-DB1>		9.562	10.834	12.254
5.4	**5**	**<8-P2-TVCB1-DB1>**	Un-phased	**9.390**	**10.741**	**12.283**
6	**Compare the Cost of Phase 3 with River Management**					
6.1	12	<8-P3-TBVCB1-DB1>		10.177	12.026	14.130
6.2	**5**	**<8-P2-TVCB1-DB1>**	Vlieëpoort Abstraction	**9.390**	**10.741**	**12.283**
7	**Determine URV's for Scenario 4 Demands**					
7.1	13	<4-P2-TBCB1-DB1>		10.252	12.154	14.235
7.2	14	<4-P2-TVCB1-DB1>		10.006	11.531	13.205

Conclusions and Recommendations

The following is concluded based on the options evaluation:

1. *The pipeline from Mokolo Dam to the users is the preferred option for Phase 1A Mokolo Transfer System. The feasibility level investigation of this option is currently taking place. Further detail regarding the option is provided in Supporting Report 5: Mokolo River Development Options (P RSA A000/00/9209).*
2. *The Break Pressure Reservoir option is preferred above the Terminal Dam options for the following reasons:*
    a. *Lowest unit reference value for the total system.*
    b. *The potential negative environmental impact of some of the proposed terminal dam sites.*
    c. *The Crocodile River (West) water will be prone to the development and growth of algae. It will be more difficult to manage algae growth on the surface of the terminal dams compared to the smaller break pressure and terminal storage reservoirs at user sites.*
    d. *Reliability storage capacity can be limited to 18 days in total as the storage is provided on-site (as opposed to 18 days at the end of the rising main and 9 days at the end of the gravity main). The break pressure reservoir will provide short term balancing storage between the end of the rising main section and the gravity main section to facilitate pump control. The rising main and gravity sections will however operate as a combined system.*

3. *The Central route is the preferred route for the transfer pipeline from Vlieëpoort Weir for the following reasons:*
   a. *It is the shortest route with the lowest total scheme cost (and unit reference value).*
   b. *It is a straight route along the railway line that could improve constructability and the rate of construction*
   c. *It is the preferred route from an environmental and social point of view due to it being located along a disturbed corridor.*
   d. *It is the route option where the least hard rock excavation is expected based on the geotechnical screening.*
   e. *Access to the route along the railway is generally good.*
   f. *Neither the electrification of the Lephalale railway line nor the positioning of the future Eskom 765 kVA power line corridors would result in unmanageable CP and AC mitigation conditions. Locating the pipeline along an Eskom power line corridor would however increase the operational and maintenance burden associated with the pipeline and will also have to be properly considered from a Health and Safety point of view during the operation of the system.*
4. *The Central route is the preferred route for the transfer pipeline from Boschkop Weir due to this being the shortest route with the lowest total scheme cost (and URV). The eastern route will be negatively impacted by higher quantities of hard material excavation and the expected higher environmental and social sensitivity.*
5. *The topography along all three the main transfer system routes (East, Central and West) could allow the break pressure reservoir to be placed closer to the abstraction works, with a gravity supply from there to the end users. A sensitivity analyses revealed that scheme cost and unit reference values for the different options would not influence the decision at pre-feasibility level. The final location of the break pressure reservoir and the merits of an increased length of gravity supply to the end users will be investigated in more detail during the feasibility stage.*
6. *Abstraction at Vlieëpoort Weir is preferred based on the lower total scheme unit reference value (river losses and management included) compared to abstraction at Boschkop Weir. The unit reference values for the different schemes are however within 8% and should not be the only factor considered for eliminating Boschkop Weir. An important factor to consider is the additional length of pipeline to be constructed for abstraction at Boschkop Weir (145-98 = 47 km) and the additional time required to construct this pipeline (47km / 0.2 km/day = 230 workdays or 11 months). Considering the risk of Mokolo Dam being emptied, the shortest possible construction duration should be implemented, i.e. shortest possible pipeline.*
7. *A phased approach to constructing the transfer system from Vlieëpoort can be considered due to the benefit it provides in delaying the decision on the final capacity of the pipeline. It also distributes the capital expenditure programme over a longer period. The unit reference value calculations, however, indicate this will not be the least cost solution, but the difference is small and could easily be outweighed by the benefits of the other considerations or a slight delay in the growth of the water requirements beyond the capacity of Phase 2A.*
8. *The option to construct a pipeline from Boschkop to Vlieëpoort as Phase 3 of the project will not be cost effective unless the implementation of Phase 3 is postponed until 2026. This is, however, sensitive to the cost of raw water and the extent of river losses and should be reconsidered once the water tariff has been determined and a more accurate estimate of the river losses has been made.*
9. *The unit reference values calculated for the Scenario 4 options indicate that Vlieëpoort will again be the preferred option based on total life cycle cost.*
10. *The river losses are being revised with the expectation that the actual river losses between Boschkop and Vlieëpoort will be less than that stated in the report. A reduction in the river losses will further benefit the Vlieëpoort Weir abstraction options.*

A sensitivity analysis on selected options revealed the following:

- ***Pumped vs. Pump-gravity:*** *The gravity supply option is less favourable from a financial point of view. There are, however, practical and operational benefits that can be derived from having gravity supply from Node 10. The cost of the gravity supply section can also be reduced by optimising the wall thickness of the steel pipe as less operational variations that could cause pressure surged are expected in the gravity section. This would make the gravity supply options financially comparable to the pumped scenario. The final decision on the pump-gravity approach should be based on practical considerations rather than price.*
- ***Raw water cost:*** *To make the Boschkop abstraction options viable compared to Option 5 will require the cost of raw water to be R2.18/m^3 and R1.95/m^3 for Options 7 and 12, respectively. This is similar to the current raw water cost of the existing Crocodile River (West) allocation and less than the current VRESS raw water cost of approximately R4.50/$m^{3.}$ It is generally accepted that it would not be possible to supply additional raw water at less than the VRESS tariff. The river losses between Boschkop and Vlieepoort given in this report are most probably over-stated. A reduction in the river losses will further advantage the Vlieëpoort abstraction options.*
- ***Project phasing:*** *Due to the steep water requirement curve, it would not be practical to delay the implementation of Phase 2B beyond 2020. The unit reference values of the phased and un-phased approaches is almost equal (compare Options 5 and 11) with a one or two year delay in the implementation of Phase 2B making the phased approach more feasible. It should, however, be noted that this will require either increased transfer capacity to be provided as part of Phase 2A or it will result in the over utilisation of the Mokolo Dam until Phase 2B is commissioned. Neither of these options was analysed in detail as part of the sensitivity analysis. Phase 3 of the project will become viable if the commissioning of the abstraction works, pump station and pipeline from Boschkop to Vlieëpoort is delayed until* ***2026****.*
- ***Reduction in steel prices:*** *The ranking of options is not affected by the reduction in steel pipe prices.*

Based on these findings, the following is recommended for further consideration during the feasibility stage of the project:

- *Phase 1A – Mokolo Transfer System: Option 1 which consists of a pipeline from Mokolo Dam to Lephalale and further to Steenbokpan. <8-P1A-MD-ID1>*

- *Phase 2 – Abstraction at Vlieëpoort Weir with a rising main along the Central Route to the position of the Break Pressure Reservoir providing short term balancing storage. From here the water will be gravity fed into on-site terminal reservoirs (capacity 18 days + user balancing and emergency storage requirements) at each of the users. Option 5 <8-P2-TVCB1-DB1> or Option 11 <8-P2A&B-TVCB1-DB1>. The option to locate the break pressure reservoir at Node 10 should be investigated in more detail during feasibility assessment.*

- *Phase 3 – Delayed implementation of the link from Boschkop to Vlieëpoort to be considered in order to limit river losses. <8-P3-TBVCB1-DB1>*

The scheme components and capital costs associated with the preferred option (Option 5) is summarised below. Costs include P&G's, contingencies and fees (excluding VAT). The base date for costs is March 2008.

Summary of Scheme Components: Option 5: 8-P2-TVCB1-DB1

Component	Description
Phase 1A	
Phase 1A Supporting Report 5: Mokolo River Development Options Report (P RSA A000/00/9209)	Pipeline from Mokolo Dam: Option 1: 8-P1A-MD-ID1
Phase 2	
Vlieëpoort Weir	Concrete weir and primary desilting
Abstraction pump station Abstraction pump station, secondary desilting works and balancing dam	6 x 1.1 m^3/s submersible pumps 2 x standby units (stored on site) 4 hours balancing storage
High lift pump station	Static head : 95 m Design peak flow (DPF) : 6.5 m^3/s Dynamic head at DPF : 235 m Emergency peak flow (EPF) : 7.4 m^3/s Dynamic head at EPF : 247 m Power consumption DPF/EPF : 17/21 MW
Transfer System Rising main - High lift pump station to break pressure reservoir (Node 15)	 Diameter : 2100 mm ND Length : 97.9 km Flow velocity : 1.88 m/s
Balancing Reservoir	24 hours storage
Delivery System Link to Lephalale-Steenbokpan pipeline <31> Link to Steenbokpan <25B> Link to Lephalale (Built under Phase 1A) <25A-24-14> Link to Matimba (Built under Phase 1A) <8> Link to Medupi <13>	 Diameter : 2300 mm ND Length : 24.8 km Diameter : 2200 mm ND Length : 5.1 km Diameter : 800 mm ND Length : 30.9 km Diameter : 800 mm ND Length : 1.9 km Diameter : 500 mm ND Length : 1.7 km
End user storage reservoirs (7 of)	18 days storage + user required balancing storage Location: Supply source: 1. Eskom Terminal Reservoir : Crocodile 2. Sasol Terminal Reservoir : Crocodile 3. Exxaro Terminal Reservoir : Crocodile 4. Medupi Terminal Reservoir : Crocodile 5. Medupi RWR : Mokolo 6. Matimba RWR (Existing) : Mokolo 7. Zeeland RWR : Mokolo

Breakdown of Capital Cost for Option 5: <8-P2-TVCB1-DB1>

Component	**Total (R)**
Pump Station (Peak Pumping Head 247.05 m)	381,938,000
Terminal Dam or Balancing Reservoir	76,482,000
Rising Main	
2100 mm Ø Rising Main	5,134,677,000
Weir	275,013,000
Total Crocodile Transfer System	**5,868,110,000**
Total Crocodile Delivery System (Gravity Delivery Pipes and 18 Day End User On Site Storage)	2,916,657,000
Total Mokolo System (Phase 1A)	1,445,195,000
Total Combined Scheme Cost	**10,229,962,000**

Including P&G's, Contingencies & Fees. Excluding VAT. Base date: March 2008.

Breakdown of Annual O&M Costs for 0ption 5: <8-P2-TVCB1-DB1>

Component	**Total (R)**
Pump Station	
Civil	112,000
Mechanical and Electrical Maintenance	4,187,000
Electricity	79,692,000
Rising Main	
2100 mm Ø Rising Main	12,312,000
Weir	2,560,000
Terminal Dam or Rising Main	213,000
Raw Water Costs	1,058,134,000
River Management Costs	4,500,000
Total Annual O&M - Crocodile Transfer System	**1,161,710,000**
Total Annual O&M - Crocodile Delivery System	10,515,000
Total Annual O&M - Mokolo System	81,173,000
Total Annual Combined O&M Cost	**1,253,398,000**

Summary of Discounted Present Values (PVs) for Option 5: <8-P2-TVCB1-DB1> (Total Scheme)

Discount Rate	**Capital (R)**	**O & M (R)**	**Total (R)**
6%	8,412,536,000	11,764,276,000	20,176,812,000
8%	7,905,901,000	8,035,558,000	15,941,459,000
10%	7,441,844,000	5,742,629,000	13,184,473,000

Unit Reference Values for Option 5: <8-P2-TVCB1-DB1> (Total Scheme)

Discount Rate	**Discounted Present Value of Water @ R1/m^3**	**Discounted Present Value (R)**	**URV (R/m^3)**
6%	2,149	20,176,811,000	9.390
8%	1,484	15,941,460,000	10.741
10%	1,073	13,184,473,000	12.283

MOKOLO CROCODILE (WEST) WATER AUGMENTATION PROJECT FEASIBILITY STUDY:
WATER TRANSFER SCHEME OPTIONS
PRE-FEASIBILITY STAGE

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a	Annum
CP	Cathodic Protection
deg	degree
DPF	Design Peak Flow
DRA	Definition Release Approval
DWAF	Department of Water Affairs and Forestry
Em	Efficiency of Motor
Ep	Efficiency of Pump
EPF	Emergency Peak Flow
FSL	Full Supply Level
km	Kilometre
m	Metre
MCWAP	Mokolo and Crocodile River (West) Water Augmentation Project
NDU	Natural Drain Unit
NKP	National Key Point
NPV	Net Present Value
O&M	Operation and Maintenance
PBS	Product Breakdown Structure
Pf	Power Factor
PMF	Probable Maximum Flood
PV	Present Value
RSA	Republic of South Africa
ToR	Terms of Reference
TRU	Transformer Rectifier Unit
URV	Unit Reference Value
VAPS	Vaal Augmentation Planning Study
VAT	Value Added Tax
WMA	Water Management Area
WTW	Water Treatment Works

1. INTRODUCTION AND BACKGROUND

The primary purpose of the Mokolo and Crocodile River (West) Augmentation Project (MCWAP) is to investigate the options to transfer water from the Mokolo and Crocodile (West) Rivers to the Lephalale area to supply the primary and industrial users in this fast developing area.

Various options have been identified to convey water to the end users. These include the Crocodile River (West) transfer and delivery systems, as well as the Mokolo transfer system. The latter is intended to supply the interim water requirements for a period until the Crocodile River (West) transfer and delivery system has been constructed and to support the reliability and redundancy requirements once the Crocodile River (West) transfer and delivery system is operational. The combined Mokolo and Crocodile River (West) scheme is illustrated by Figure 1-1, showing the different components forming part of the combined scheme. The infrastructure components associated with the different systems are described later in this report, as well as in other supporting reports listed in the front of this document. A locality plan is included in **Appendix A** of the report (DWG No WP 9528/LD/CTS/001/A).

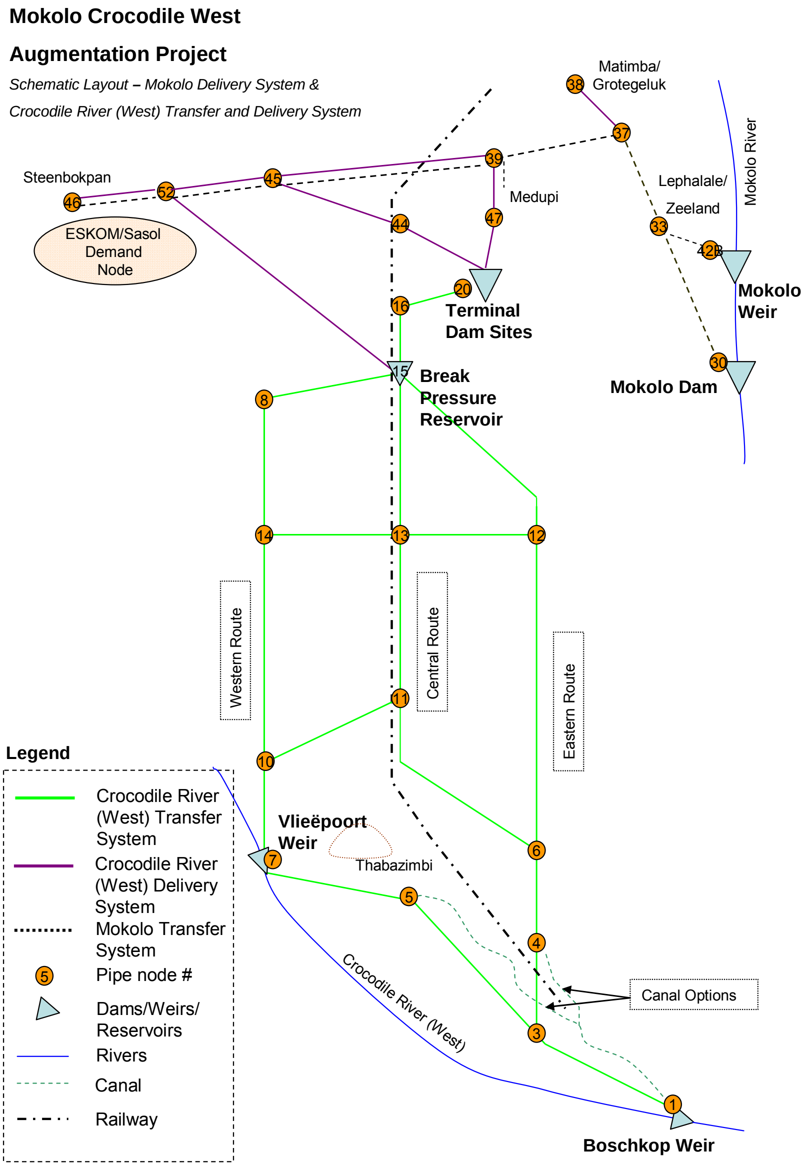

Figure 1-1: MCWAP Project - Scheme Components

The MCWAP will be implemented in phases with a number of sub-options as follows:

- **Phase 1:** Augment the supply from Mokolo Dam:
  - Phase1A: Provide a peak delivery capacity of 50.4 Million m^3/a by implementing either one of the following options:
    1) Option 1 – Pipeline from Mokolo Dam to the Lephalale and Steenbokpan demand areas.
    2) Option 2 – Weir in the Mokolo River downstream of the dam and pipeline to Lephalale and Steenbokpan.

- **Phase 2:** Transfer scheme from the Crocodile River (West) to the demand area via a system consisting of:
  - Various potential pipeline routes. Three general routes have been identified – East, Central and West.
  - A number of different weir and abstraction work sites.
  - Terminal and/or on-site storage:
    1) Terminal Dam options providing 18 days storage together with Balancing Reservoirs at the end user sites with minimum nine (9) days storage plus additional user requirements to achieve the required balancing capacity and emergency storage; this is to provide for the reliability required for the gravity pipelines from the Terminal Dams.
    2) Alternatively, a break pressure reservoir with short-term balancing storage between the end of the rising main section and the gravity main section used in conjunction with end user terminal reservoirs consisting of seven (7) on-site reservoirs with 18 days storage capacity, plus additional user requirements to achieve the required balancing capacity and emergency storage.
  - Two approaches:
    1) Un-phased (full capacity) scheme implemented in a single construction phase with an ultimate net transfer capacity of 191 Million m^3/a (excluding system losses).
    2) Phased approach where the capacity is provided through two parallel pipelines constructed during two consecutive construction phases.
       a. Phase 2A – First phase pipeline from the abstraction site with a net transfer capacity of 110 Million m^3/a.
       b. Phase 2B – Second phase pipeline from the abstraction site to achieve ultimate required total net transfer capacity of 191 Million m^3/a.
- **Phase 3:**
  - Third construction phase during which a pipeline is built from Boschkop weir to Vlieëpoort weir to link with the infrastructure built during Phase 2 in order to reduce river losses between the Boschkop and Vlieëpoort Weir sites, if Vlieëpoort Weir were selected for Phase 2.

Transfer of water from the Klip River to the Crocodile River (West) is being investigated under other DWAF assignments. For the purposes of this investigation, it was confirmed by the Department of Water Affairs (DWA) that sufficient flow would be made available at the planned abstraction sites at an acceptable assurance of supply.

2. WATER REQUIREMENTS

A detailed discussion of the expected interim and long-term water requirements is included in Supporting Report 1: Water Requirements (P RSA A000/00/8809).

2.1. Projected Water Requirements

Development from Lephalale westwards towards Steenbokpan and the Botswana border is driven by large coal deposits. Potential large users (Eskom, Exxaro and Sasol) have provided estimates of their expected water consumption for the immediate too long term industrial, commercial and domestic use. DWA's Regional Office in Polokwane also commissioned a study that quantified the expected water use of the Lephalale Local Municipality as a result of the expected growth in the area.

Two water requirement scenarios have been compiled for the period up to 2030, i.e.:

- Scenario 4 – Matimba Power Station (FBC); Medupi Power Station (FGD); three (3) new power stations (FGD); coal supply to five (5) power stations; Exxaro project; the associated construction activities and the associated growth in Lephalale and Steenbokpan.
- Scenario 8 – Scenario 4 + Sasol development of two CTL plants, the associated construction activities and the associated growth in Steenbokpan.

Figure 2-1 illustrates the water requirement scenarios for the April 2008 estimates and the revised July 2008 estimates. The graphs indicate year end totals and include the requirement of 10.4 Million m^3/a for irrigation below the Mokolo Dam.

Detailed water requirement tables are included in an annexure to the Water Requirements Report (P RSA A000/00/8809). These tables indicate the contribution of each user to the annual totals. The tables further indicate the split in water requirement between Lephalale and the Steenbokpan area.

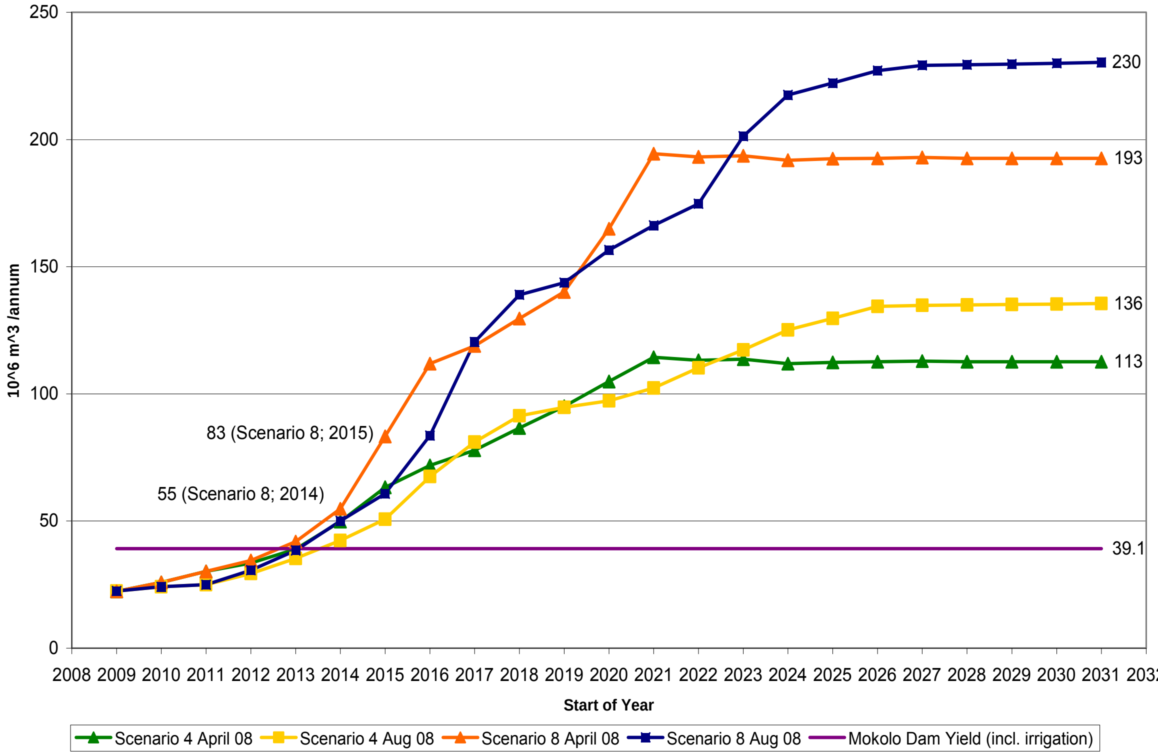

Figure 2-1: Comparison of Water Requirement Scenarios, incl. Irrigation (25 August 2008 Release)

2.2. Transfer Volumes for Sizing Scheme Components

The baseline figures (excluding losses, irrigation and reliability and redundancy requirements) to be used for planning and sizing the options for the interim transfer from Mokolo Dam and the ultimate transfer from both the Mokolo Dam and the Crocodile River (West) have been established using the water requirement figures presented above:

- Phase 1A: Interim Scheme delivering from Mokolo Dam:
  - Capacity of the existing pipeline from Mokolo Dam to the end users - 13.5 Million m^3/a
  - Minimum required combined Mokolo system capacity during the interim period (May 2011 to July 2014) - 50.4 Million m^3/a
  - Minimum required capacity of the new Mokolo pipeline - 36.9 Million m^3/a (50.4 Million m^3/a - 13.5 Million m^3/a)
  - Ultimate Mokolo system capacity after commissioning of the Crocodile River (West) transfer system – 28.7 Million m^3/a (long term yield of the Mokolo Dam of 39.1 Million m^3/a less the irrigation requirement downstream of the dam of 10.4 Million m^3/a)

- Phase 2A: First phase of a transfer system from the Crocodile River (West) – 110 Million m^3/a (Starting from July 2014 onwards).
- Phase 2B: Second phase of a transfer system from the Crocodile River (West) – 81 Million m^3/a (incremental transfer volume).
- Phases 2 or 3: Total Crocodile River (West) transfer volume - 191 Million m^3/a (Delivered via a phased or un-phased approach).

The combined system volumes to be transferred are indicated below in Figure 2-2.

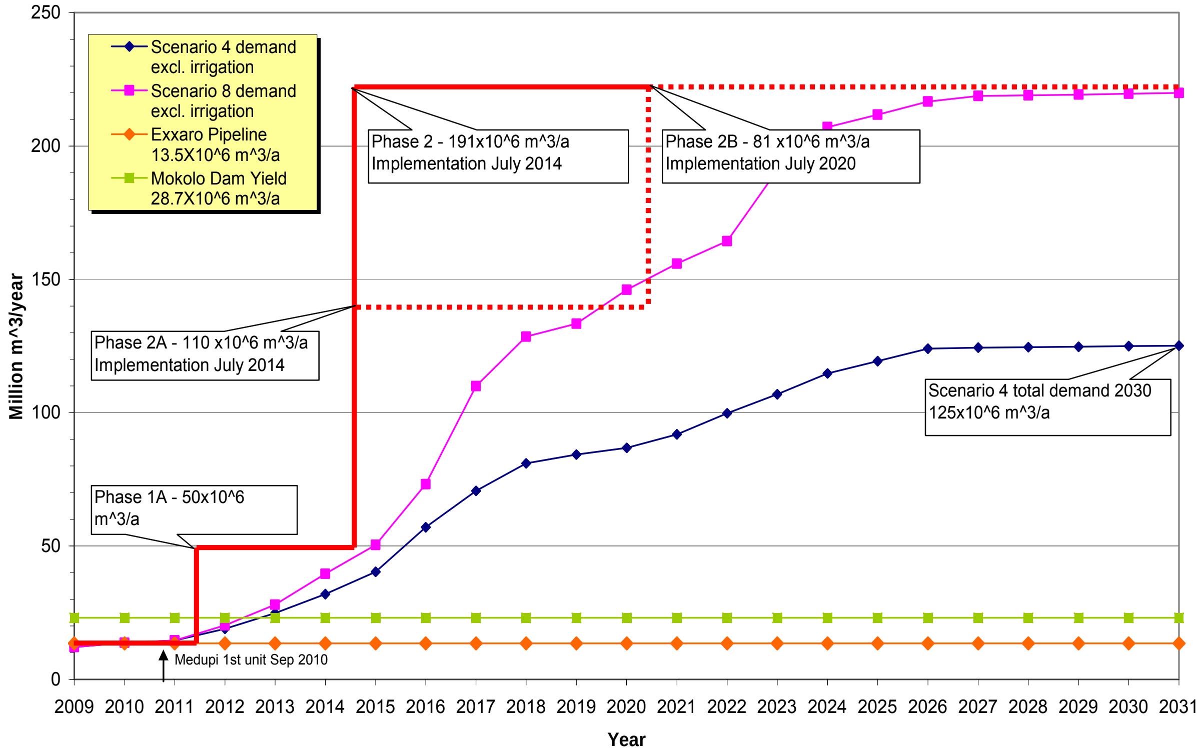

Figure 2-2: Indication of Transfer Volumes (excl. Reliability, Redundancy Losses & Irrigation Requirements)

The expected annual peak requirements on the system are illustrated by Figure 2-3. Peak flow requirements have been applied on the monthly water requirement for Eskom and Lephalale Municipality. The peak factor included for Eskom is based on historic measurements at Matimba Power Station, which indicates that a 25% peak is experienced annually from August to October. Monthly peaks included for Lephalale Municipality are based on historic flow measurements taken at Zeeland Water Treatment Works (WTW).

The resultant monthly peak flow requirement based on the annual average daily demand for the total scheme is 9%. No additional allowance was made in the sizing of the components for the annual peaks as sufficient capacity will be provided as part of the reliability and redundancy sizing criteria (refer to Section 3).

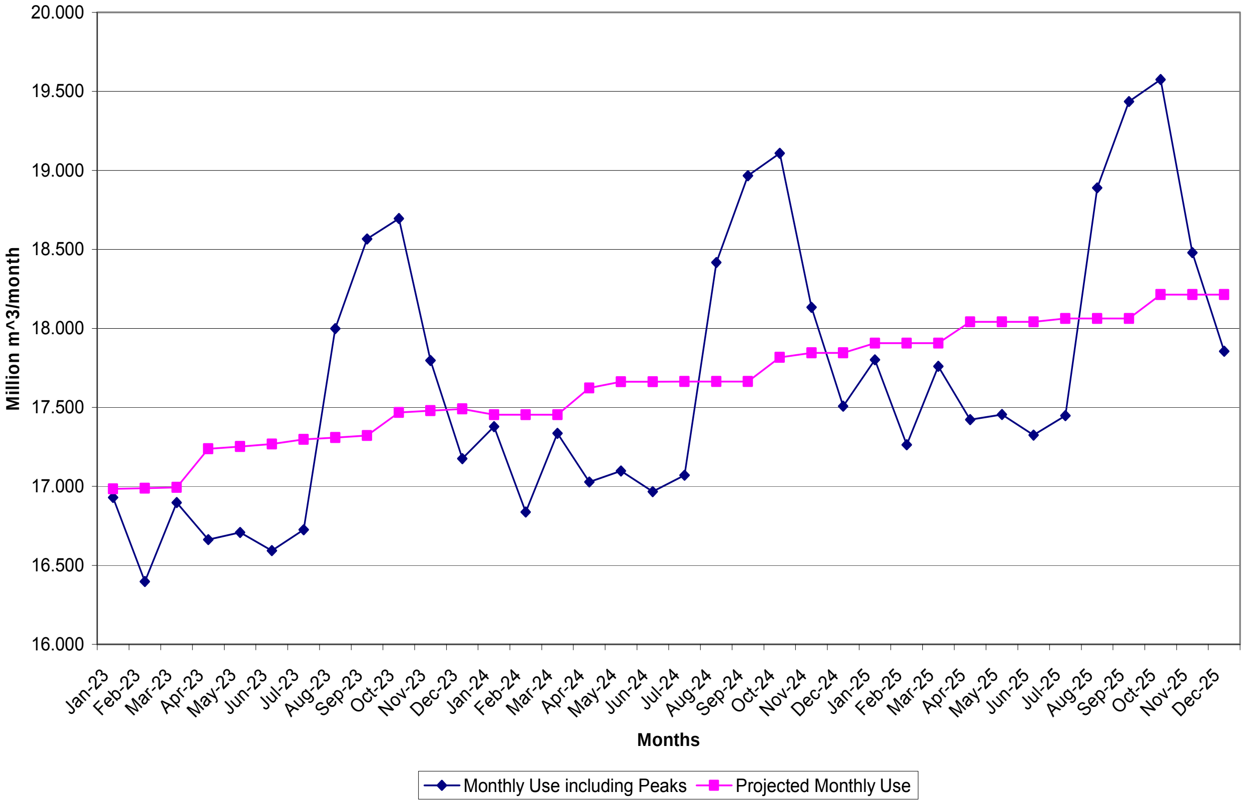

Figure 2-3: Annual Peak Water Requirements

3. ASPECTS OF RELIABILITY AND REDUNDANCY

The strategic importance of the users that will account for the bulk of the water consumption requires that the risk of failure in the supply of water be kept to a minimum. Sufficient reliability and redundancy must therefore be provided in the combined Mokolo and Crocodile River (West) water supply scheme. A comprehensive review of all aspects related to reliability and redundancy is included in the Main Report (P RSA A000/00/8109). Relevant aspects are repeated here.

3.1. General Criteria

It is not feasible or possible to provide absolute reliability, i.e. no risk of an interruption in the delivery of water. It is however, possible to reduce the risks to acceptably low levels, to cater for the strategic importance of most of the water that will be supplied by the project. The risk can further be reduced by providing redundancy. The following general criteria will apply (adopted from the ToR) when designing for reliability and redundancy:

- The transfer systems shall be designed for 95% reliability, implying that water shall continue to be supplied without interruption even if the scheme is inoperative for up to 18 days of any one year, and the scheme capacity adjusted to allow the full annual requirements to be supplied in 347 days.
- Two options of providing strategic storage were considered:
  - Terminal Dam options providing 18 days storage together with Balancing Reservoirs at end user sites with minimum nine (9) days storage plus any additional user requirements to achieve the required balancing capacity and emergency storage; this is to provide for the reliability required for the gravity pipelines from the Terminal Dams.
  - Alternatively, a break pressure reservoir with short-term balancing storage, between the end of the rising main section and the gravity main section, may be used in conjunction with end user terminal reservoirs consisting of seven (7) on-site reservoirs with minimum 18 days storage capacity plus any additional user requirements to achieve the required balancing capacity and emergency storage.
- The Terminal Dam or Terminal Reservoir(s) referred to above will be provided to reduce the risk of failure of water supply to strategic industries due to interruptions in the delivery/supply by the transfer systems.
- Optimisation of the system components considered three options namely, (i) supplying only the allocated portion of the demand from each source; (ii) sizing the delivery systems to supply the full demand from each source for short periods to improve the assurance of supply by providing Redundancy; and (iii) inter-connecting the two systems. A combination of the approaches was ultimately recommended for implementation (refer to Section 3.3).

Allowing for a scheme to be inoperative for 5% of the time during any one year (18 days) will be sufficient to cater for the following situations:

- Pump station failures if there had been severe damage such as flooding; etc.
- Constructing temporary by-passes to repair pipeline linings and joints; and
- The time required to restore power supplies after major interruptions such as bushfires, flooding, etc.

Limited redundancy will be provided by interconnecting the Mokolo and Crocodile River (West) systems. No redundancy will, however, be available during the interim period (Phase 1A) before the Crocodile River (West) Transfer scheme has been commissioned.

3.2. Specific Capacity Criteria to ensure Reliability of Supply

The following criteria were incorporated into the planning, sizing and costing of components to ensure reliability of supply:

- A Terminal Dam or on-site storage with a minimum storage capacity of 18 days will be provided.
- The diameter optimisation of the rising mains was based on 105% of the gross annual average water requirement (including system losses).
- Pumping stations were sized and pipe strengths (wall thickness) determined to enable a transfer rate of 120% of the gross annual water requirement (at more than the economically optimum pumping rate) in order to refill the Terminal Dam/Reservoirs over a 90 day period following 18 days of continuous downtime.
- The annual peak (refer to Section 2.2) was not allowed for separately in the sizing of components. The reliability peak flow allowance (120% of gross average annual demand), as well as adequate on site storage will cater for the expected annual peak requirements once the system reaches full operating capacity (2030). In the interim period, the system will have sufficient capacity under normal operating conditions to accommodate the expected annual peak requirements.
- Abstraction pump station sites will have the switchgear and instrumentation sited in the superstructure of the abstraction weir, or on the river bank next to the weir, but in both cases the equipment will be located above the PMF level (probable maximum flood level). Other components forming part of the abstraction and desalting process (i.e. secondary desalting bays, balancing dam, etc.) will also be located above the probable maximum flood level (PMF).
- High lift and booster pump stations will be positioned above the PMF and designed such that they will always be free-draining in the event of flooding due to failure of internal pipework.
- High lift and booster pump stations will be designed with a minimum of one (1) standby pump unit per station ensuring a minimum standby capacity of 25%. The maximum motor size will be limited to 10 MW per unit. A three (3) duty-1 standby configuration is preferred.
- Abstraction pump stations will consist of multiple abstraction bays housing submersible pumps capable of pumping a maximum of 1 m^3/s per unit. Complete replacement pump units will be kept on site. In the case of Vlieëpoort and Boschkop, the abstraction pump station will consist of eight (8) abstraction pumps with two (2) complete replacement pump units on site.
- All electrical equipment will be located above the PMF level.
- Strategic spares and equipment will be kept for all components.
- 100% spares will be maintained for all MV and LV switchboards.
- 100% duplication of the power supply from the switch yards to the pump stations will be provided and a duplicate power supply will be provided.
- Gravity pipelines downstream of a Terminal Dam (with 18 days storage) will have a capacity of 110% of the gross average annual demand. Downstream of a break pressure reservoir, the gravity system will, however, be sized to have a capacity of 120% of the gross average annual requirement.

3.3. Specific Redundancy Capacity Criteria

The following criteria were incorporated into the planning, sizing and costing of components to ensure redundancy of supply:

- The existing pipeline from the Mokolo Dam will be refurbished and operated in parallel with the new pipeline to provide redundancy for this system. The combined peak transfer capacity of the Mokolo Transfer system is 61.7 Million m^3/a [(Q_{AADD} (50.4 Million m^3/a) + losses (2%)) x 1.20].

- Redundancy will further be provided by an interconnection between the Crocodile River (West) and the Mokolo Dam systems so that either system can be augmented from the other (up to the maximum delivery capacity of either system as stated in Section 2.2 and incorporating the reliability design criteria stated in Section 3.2).
  - When the system reaches ultimate design capacity (Scenario 8, 2030), the maximum redundancy capacity available from the Mokolo system in the event of a failure on the Crocodile system will be approximately 36.49 Million m^3/a [combined peak transfer capacity of the Mokolo system (61.69 Million m^3/a) less consumer demands in the Lephalale region dependant on Mokolo water - Lephalale Municipality (12.5 Million m^3/a), Eskom (7.1 Million m^3/a) and Exxaro (5.6 Million m^3/a)]. This will, however, imply that the Mokolo Dam is over utilised during this period. The overall storage capacity available in the combined system (Mokolo and Crocodile River West) increases to 21.6 days under these circumstances, assuming the connection between the Mokolo and Crocodile River systems is opened as soon as the Crocodile River system experiences a supply failure.
  - When the system reaches ultimate design capacity (Scenario 8, 2030), the maximum redundancy capacity available from the Crocodile River system in the event of a failure on the Mokolo System will be approximately 39.0 Million m^3/a [Crocodile River system emergency transfer capacity of 234.1 Million m^3/a (120% of gross average annual demand) less gross average annual demand of 195.1 (AADD + 2% losses)]. The overall storage capacity available in the combined system (Mokolo and Crocodile River West) increases to 21.9 days under these circumstances, assuming the connection between the Mokolo and Crocodile Rivers systems is opened as soon as the Mokolo system experiences a supply failure. Not all end users (i.e. Zeeland WTW) will, however, have the capability to receive Crocodile River water due to quality concerns and therefore adequate on site storage is recommended to ensure reliability of supply (18 days).
  - Practically, a larger volume of water would be available for redundancy supply in both cases, as most large consumers would be able to implement short-term water conservation measures in a time of crisis.
  - Before the system reaches full design capacity, a higher level of redundancy supply capacity will be available.
- Sufficient additional flow will be made available by DWA in the Crocodile River (West) to continuously supply the emergency peak demand (120% of the gross average annual demand) at the point of abstraction for a limited period. This will not affect the annual average water supply requirements.

4. INFRASTRUCTURE COMPONENTS

The MCWAP Project consists of the Mokolo and Crocodile River schemes operating as a combined project. The planning and engineering economic analysis therefore needs to consider the infrastructure provided as part of both schemes.

The infrastructure components required as part of Phase 2 to transfer water from the Crocodile River (West) via Terminal Dams and on-site reservoirs or only on-site terminal reservoirs to the end users are described in this report while the Mokolo transfer system is described in Supporting Report 5: Mokolo River Development Options (P RSA A000/00/9209).

Refer to Figure 1-1 for a schematic summary of the combined scheme components. The methodology applied in sizing and costing the different infrastructure components is described in Supporting Report 3: Guidelines for Preliminary Costing and Economic Evaluation of Development Options (P RSA A000/00/9009).

4.1. Abstraction Sites - Crocodile River (West)

Several possible abstraction weir sites along the Crocodile River (West) were identified from aerial photography and during a site visit on 11 to 13 June 2008. A second site inspection took place on 22 July 2008. Each site was evaluated for suitability with respect to topography, access, founding conditions and river morphology. Detailed descriptions of the respective sites and the evaluation process are included in Supporting Report 4: Dams, Abstraction Weirs and River Works (P RSA A000/00/9109).

The following sites were considered:

- Boschkop Site (Original Dam Site)
- Nooitgedacht DWA Gauging Weir
- Hugo’s Weir (Existing Farmer Abstraction Weir)
- Vlieëpoort Upper Site (Original Site)
- Vlieëpoort Lower Site

Based on the initial scoping and visits to the respective sites, the following two abstraction locations were identified as viable for further consideration during the pre-feasibility stage of the project:

- Boschkop Site on the farm Boschkop 138 JQ (S25^0 05’ 37.3’’ E27^0 31’ 54.0’’)
- Vlieëpoort Upper Site on the farm Mooivallei 342 KQ (S24^0 38’ 10.4’’ E27^0 18’ 59.7’’)

The locations of these two sites are illustrated on the layout map included in Appendix A (DWG WP 9528/LD/CTS/002/A).

A number of river abstraction works’ options were considered before agreeing on the proposed arrangement. These options included a diversion weir and:

- Floating platform intake;
- Fixed platform intake above the riverbank;
- Off-channel reservoir with a channel connection to the river; and
- Fixed intake facility in the river.

Sediment bed load, design flood levels and the nature of the riverbanks dictated against any of the above options and an arrangement that has worked well in similar conditions encountered along the Berg and Olifants Rivers was adopted. The arrangement adopted consists of:

- Mass concrete gravity type diversion weir with ogee and roller bucket spillway;
- Gravel traps in a weir basin with flushing facility and trash rack with concrete channels leading from the gravel trap to each pump-well in the abstraction pump station (primary desilting);
- Low pressure pipeline to the secondary desilting works;
- Secondary desilting works with flushing facility located near the high-lift pump station, above the PMF;
- Gravity flow between the secondary desilting works and a balancing dam; and
- Balancing dam to supply the adjacent high-lift pump station.

4.2. Pump Stations

The MCWAP is to supply raw water to at least two (2) power stations plus possible liquid fuel from coal installations together with various industries and mines that are likely to arise from the development of the area. It must be appreciated that the water supply is of highly strategic importance for the development of the RSA. Accordingly, very high reliability and redundancy standards have to be allowed for in the planning and design of the scheme.

Wherever possible, pump stations will be sited such that the pump station building and all associated ancillary structures will experience no risk from natural flood waters. In the case of river abstraction pumping stations, similarly all electrical switchgear will be located above the PMF flood level.

The external power supply to a pump station site must be firm and the risk to the power lines from natural flooding, bush fires and lightning must be minimised.

Pump station installations will be secured and hardened to National Key Point (NKP) requirements.

4.2.1. River Abstraction Pump Station

Abstraction pump station options have been identified for the pre-feasibility stage in conjunction with the most suitable weir and de-silting structure configuration and conditions. The abstraction pump stations will be integrated with the weir and primary desilting works and is discussed in detail in Supporting Report 4: Dam, Abstraction Weirs and River Works (P RSA A000/00/9109). Relevant aspects are repeated below.

River abstraction sites were considered based on the following parameters:

- First Stage de-gritting will be done in the river.
- Second Stage de-silting to a maximum particle size of 0,07 mm will be done close to the weir and the river, i.e. sited against a hillside or on higher ground alongside it since the sites along both the Crocodile and the Mokolo Rivers did not lend themselves to any second stage de-silting in the river.
- The electrical switchgear will be above the PMF flood level.

The Boschkop and Vlieëpoort site configurations are very similar. The norms and criteria will thus apply to both sites.

Further factors and site considerations that affect the selection of options are:

- Delivery heads and absorbed energy of the abstraction pump station(s).
- Only submersible pumps were considered for this application based on the following:
  - They are more suitable, particularly for the considerations of reliability.
  - With the PMF being approximately 25 m above the weir crest level, vertical spindle pumps will have unacceptably long pump shaft lengths. This has very specific disadvantages.
  - If the same criteria of a minimum of 25% standby capacity are adopted, two additional channels with installed pumps will be required for vertical spindle pumps. In the case of submersible pumps, the standby units can be stored on site because of its quick replacement time.
  - The approximate maximum delivery head for the river abstraction pumps to the second stage de-silting facility will be less than 40 m (refer to Figure 4-1 for the approximate site configuration at both Boschkop and Vlieëpoort sites). This is well within the pumping range of submersible pumps.

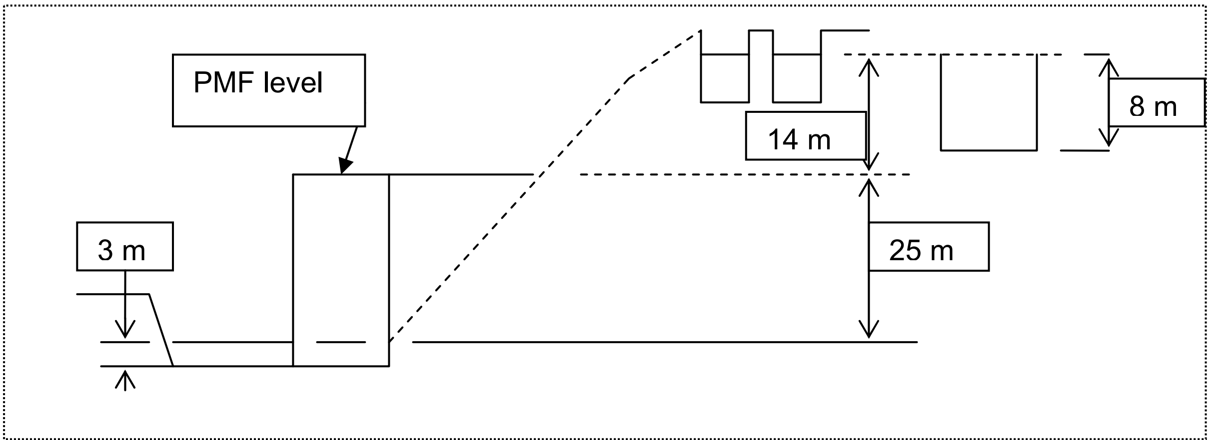

Figure 4-1: Approximate Site Configuration Abstraction Weir and Pump Station

4.2.2. High Lift Pumping Stations

Based on the two abstraction weir sites (Boschkop and Vlieëpoort), the high lift pump station(s) will deliver water from the Crocodile River along a selected route(s) to either one of four Terminal Dam options, or via a balancing reservoir at the end of the rising main section to Terminal Reservoirs at the major consumer sites.

With an assumed optimum flow velocity of 1.8 m/s for the pre-feasibility assessment, a total pumping head of less than 400 m can be achieved which is presently regarded as the upper limit for a single high lift pump station.

One high lift pumping station on the Crocodile River transfer system is preferred in order to simplify the operation of the system. The following criteria will generally apply:

- Pumping stations were sized to enable a transfer rate of 120% of the gross annual water requirement (at more than the economically optimum pumping rate) in order to refill the Terminal Dam/Reservoirs over a 90 day period following 18 days of continuous downtime.
- High lift pump stations will be positioned above the PMF and designed such that they will always be free-draining in the event of flooding due to failure of internal pipework.
- High lift pump stations will be designed with a minimum of 1 standby pump unit per station and/or a minimum standby capacity of 25%. The estimated capacity of the pumping stations varies from 11 to 26 MW for the different route options and demand scenarios

investigated. A 3 duty-1 standby configuration will therefore be possible while still limiting the size of the motors to less than 10 MW per unit.

- All electrical equipment will be located above the PMF level.
- Strategic spares and equipment will be kept for all components.
- 100% spares will be maintained for all MV and LV switchboards.
- 100% duplication of the power supply from the switch yards to the pump stations will be provided and a duplicate power supply will be provided.

The typical river abstraction, desilting works, balancing storage and high lift pumping station layout for Boschkop and Vlieëpoort is illustrated by the drawings included in Appendix A (DWG LD/VPW/001 and LD/BKW/001).

4.3. Conveyance Options

The following conveyance options to transfer water from the Crocodile River (West) to the end users were investigated:

- River conveyance;
- Canal conveyance; and
- Pipeline conveyance

4.3.1. River Conveyance

This study component analysed the river losses along the Crocodile River (West) and the Mokolo River downstream of the Mokolo Dam. A detailed description of the methodology, assumptions and findings is included in Supporting Report 4: Dam, Abstraction Weirs and River Works (P RSA A000/00/9109).

The findings of the assessment are summarised in Table 4-1 for Scenarios 4 and 8 for no irrigation abstraction control.

Table 4-1: Provisional Maximum: Incremental Losses Associated with River Conveyance Options with no Irrigation Abstraction Control

Total Water Scheme Requirements	Units	Scenario 8	Scenario 4
Crocodile (Transfer Scheme): River Losses - Dams to Boschkop	Million m^3/a	30.0	22.1
Crocodile (Transfer Scheme): River Losses - Dams to Vlieëpoort	Million m^3/a	70.6	51.0
Mokolo Weir Option: River Losses – Mokolo Dam to Abstraction Weir	Million m^3/a	9.4	6.9

These losses were considered in determining the gross water requirement that was used to calculate the raw water cost associated with each scheme option in the economic comparison of options. The cost of river management along the Crocodile River up to the respective abstraction sites was also incorporated into the costing.

A more detailed investigation of the river losses was underway at the time this report was being prepared. The findings will be incorporated during feasibility stage. The results, however, show that the loss figures given above are over-stated. Any reduction in the loss figures would favour the Vlieëpoort option due to the greater provision that was made for losses.

4.3.2. Canal Conveyance

An alternative conveyance option for the Crocodile River (West) Transfer scheme that was investigated, is to have a diversion weir, low lift pump station and canal section situated upstream of the start of the rising main section. The purpose of the canal section would be to avoid the incremental river conveyance losses due to evaporation and potential unauthorised irrigation water abstraction along the river and reduce the river management that would be required if water is conveyed down via the river.

Canal conveyance is, however, significantly more vulnerable and requires more frequent shut-downs for maintenance than a pipeline. It is therefore proposed that any scheme that includes a canal conveyance of any significant length must allow for an availability of only approximately 92% of the time in any one year in the canal component alone (assumed to be inoperable for up to 28 days continuously per year). This implies that more downtime will be allowed for in the canal reach than the general requirement of 5% (18 days per year) prescribed in the ToR. It is accepted that a provision for a 28-day interruption per year will allow for both scheduled and unscheduled repairs, as well as routine maintenance.

Because of the reduction in the reliability of the Crocodile River (West) transfer scheme if it comprises both a canal reach and a rising main reach, the risk of an interruption in the supply of water is much higher and the corresponding duration of the interruption that must be allowed for in the transfer portion of the scheme amounts to 365 x [1 – (1 – 28/365) x (1 – 18/365)] or 44.6 days if the Terminal Dam/End User Terminal Reservoir(s) provides the only reserve storage between the point of abstraction and the delivery to end users. If an intermediate balancing dam is provided at the end of the canal the interruption that must be allowed for in the canal amounts to 28 days. The required reserve storage in the Terminal Dam/End User Terminal Reservoir(s) can then revert back to the normal 18 days storage period.

The design capacity of the canal must be such that, after interruptions of the supply, the storage reservoirs can be refilled within 90 days. This means that the peak design flow capacity of the canal at the head works must be at least 130% of the gross average annual flow (including losses) to be delivered into the intermediate balancing dam at the end of the canal or to 150% of the gross average annual flow (including losses) to be delivered into the Terminal Dam/End User Terminal Reservoir(s) if there is no intermediate balancing dam. The latter option was discarded as it will not be cost effective to size the total system to 150% of the design flow.

When considering a design peak factor of 1.3, as well as evaporation, seepage and probable system losses, a canal with a base width of 2 m, top width of 8 m and a depth of 2 m would typically be required to provide adequate flow capacity.

Based on the average annual water requirement of the users, the capacity of a 28-day balancing reservoir at the end of the canal section would be 14.7 Million m^3. Should this dam be an artificially constructed reservoir, an approximate size would be 2 000 m long x 1 000 m wide x 7.5 m deep. Apart from the footprint size, water quality management will become a much larger task because of the large surface area. A non-ideal dam shape (from a cut-fill point of view) in the form of a pointed ellipse will also be required.

Contrary to a pipeline, a canal is a permanent open structure that will not allow for the re-growth of the natural vegetation. The initial removal of vegetation is also required over a bigger area compared to a pipeline. A canal permanently and severely impacts on farming activities where it crosses farming areas. The biggest environmental impact, especially in this intensive game farming area, is the fragmentation of habitat and limiting migration of faunal species. The natural migration of faunal species for foraging and breeding purposes will be restricted due to the inability to cross the canal. Although the construction of game crossing bridges may enable the migration for the larger mammal species, smaller mammal, reptile and amphibian species will generally be isolated. This may potentially lead to a decline of the population numbers. Additional impacts therefore include:

- Habitat fragmentation;
- Restriction of migration and foraging routes; and
- Injuring or Drowning of animals accidentally falling into the canal.

Table 4-2 provides a comparison between canals and pipelines.

Table 4-2: Comparison: Pipeline vs. Canal

Pipelines	Canals
1. Requires narrower servitude – approximately 10 to 20 m	1. Wide servitude – approximately 40 m
2. Does not require intermediate balancing storage	2. Requires large intermediate balancing storage – 14,7 Million m³
3. Can be re-lined after 20 to 30 years without huge implications	3. Canal must be re-built or replaced with pipeline system when it reaches the end of its useful life
4. Pipeline problems can be repaired in relatively short periods	4. Failure of a canal section in fill can have catastrophic consequences
5. Minimal environmental impact during operation.	5. Major environmental impact – limiting migration of faunal species

Taking the above aspects into consideration it was decided not to consider options involving a canal conveyance further in the pre-feasibility assessment and that only the pipeline options would be investigated from the Boschkop weir site.

4.3.3. Pipeline Conveyance

Alternative pipeline routes were identified based on the defined interim and ultimate abstraction and supply options. The following aspects were considered in defining the pipeline routes:

- Possible abstraction and delivery locations.
- Existing roads, as well as boundaries between land owners along the routes.
- Historical and planned future mining activities in the area.
- Existing and planned future services and infrastructure.
- Site constraints, potential river/stream crossings, and road and railway crossings.
- Geotechnical conditions based on high level geotechnical screening.
- CP requirements with special consideration of the impact that the potential future 765 kV overhead power line corridors might have on the AC mitigation requirements.
- Environmental overview.
- Social impact of pipeline location.

For the pre-feasibility investigation, the following criteria were applied in line with the approach developed for the VAPS study in the sizing and costing of the pipeline alternatives:

- All pipes to be fabricated from Grade X 42 – 300 WA welded mild steel (290 MPa allowable yield stress). The required wall thickness was calculated based on 50% of the material yield. A surge analysis was not performed for this investigation and will be carried out during the feasibility stage on the preferred option.
- Corrosion protection was assumed to be Medium Density Poly-Ethylene (Sintakote) external coating and a 400 micron thick epoxy internal lining.
- All joints to be butt welded.

- Pipeline sizing incorporated transfer losses and reliability and redundancy peak factors (as described previously).
- For the pre-feasibility comparison of options, the pipe sizes were calculated based on a flow velocity of 1.8 m/s. This is in line with the VAPS guideline which states that acceptable flow velocities are between 1 and 3 m/s with 1.5 to 2 m/s accepted as the norm.
- Friction losses based on the Colebrook-White and Darcey-Weisbach formulae with an effective roughness of 0.1 mm for epoxy lined pipe over the economic life-span of the pipeline (45 years). The long-term roughness parameters will be re-evaluated in more detail during the feasibility stage of the project to ensure that a realistic figure is used for the final pipe sizing and hydraulic analysis.
- Secondary losses of 0.25 m/km of pipe have been assumed to cater for bends, valves, etc.
- The economic evaluation is based on 24 hour pumping per day.
- A minimum residual pressure at the end of the rising mains of 15 m to ensure adequate discharge pressure and allow for inaccuracies in static heads determined from the 1:50 000 mapping.
- All pipes to be installed underground.
- The trench geometry adopted for costing is illustrated by Figure 4-2:
  - Side Allowance for D up to 2 000 — 500 mm
  - Side Allowance for D > 2 000 — 600 mm
  - Bedding thickness — 300 mm
  - Selected Fill Over Pipe — 300 mm
  - Batter angle (from vertical) — 15 deg
  - Min Cover for D up to 2 000 — 1 300 mm
  - Min Cover for D > 2 000 — 1 800 mm
  - The % hard material and re-use potential of in-situ material was based on the findings of the geotechnical overview (refer to Section 5.3.1).

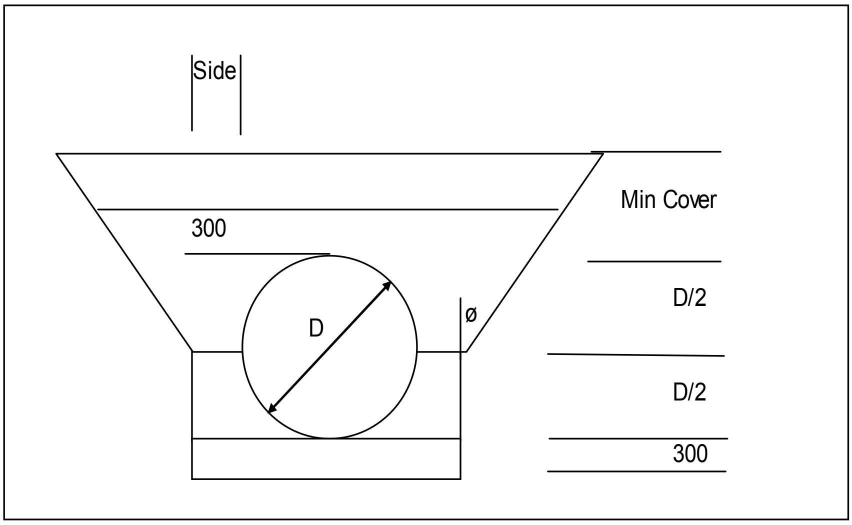

Figure 4-2: Trench Geometry Adopted for Pricing

4.4. Reliability Storage and Balancing Storage Options

The following terminal dam and end reservoir storage alternatives were investigated:

1. The original four terminal dam sites on the farm Witvogelfontein as were specified in the Terms of Reference and the Inception Report plus storage facilities on site to provide the necessary reliability to the gravity pipeline from the Terminal Dam. Refer to the layout plan included in **Appendix A** (DWG WP9528/LD/CTS/002/A).
2. A reservoir with the same storage capacity as the Terminal Dam, but located at the centroid of the end users near Steenbokpan.
3. Multiple terminal reservoirs (at each of the large users) with 18 days storage capacity. [The break pressure reservoir will provide short term balancing storage (typically 24 hours of AADD) between the end of the rising main section and the gravity main section in order to facilitate easier pump control from the high lift pumping station.]
4. No Terminal Dam. Users to supply own facilities and the Transfer System would then pump water directly into these storage facilities (with the concomitant operational provisions that will be required).

A detailed description of the respective dam sites and the evaluation process that was followed is described in Supporting Report 4: Dams, Abstraction Weirs and River Works (P RSA A000/00/9109). The investigation concluded that only alternative 1 (and specifically dam sites 1 and 3) and alternative 3 was viable for further consideration during the pre-feasibility investigation.

4.5. Sizing and Costing

The purpose of the pre-feasibility investigation is to identify the most viable transfer option for the project considering the total life cycle cost as well as practical, programming, environmental and social implications associated with alternative scheme options.

The various options had to be sized, costed and measured on a similar basis to be able to compare them and decide on the most favourable option. An updated and revised version of the VAPS guideline was adopted for preliminary sizing, costing and engineering economic evaluation of the development options.

At the pre-feasibility level, the objective was to carry out sufficient work to enable a proper comparison of alternatives in order to ensure that correct recommendations are made for further investigation and refinement during the feasibility stage of the project. As such, the pre-feasibility approach to sizing the transfer system components did not involve a comprehensive optimisation exercise considering realistic long term roughness parameters, alternative lining and coating solutions, the use of higher grades of steel to reduce the pipe wall thickness, etc. These matters will be developed and investigated in more detail during the feasibility investigation once the preferred option has been identified.

Sizing and costing parameters are listed in the previous sections and are described in more detail in Supporting Report 3: Guidelines for Preliminary Costing and Economic Evaluation of Development Options (P RSA A000/00/9009). The base date for prices is March 2008.

5. ALTERNATIVE PIPELINE ROUTE DESCRIPTION

5.1. Mokolo Dam Transfer Scheme

The Mokolo Dam is considered to be the only viable source of water that can supply the water requirements in the interim period until the Crocodile River (West) Transfer Scheme has been constructed. The exact quantity of water to be provided from the Mokolo Dam depends on which water requirement scenario will be selected and the year in which the Crocodile River (West) Transfer Scheme will be completed. To allow for a worst case scenario, the water requirement for Scenario 8 has been taken at the time of probable first delivery from the Crocodile River (West) (July 2014), i.e. 50.4 Million m^3/a as a volume to be transferred.

The ultimate water requirement figures supplied by the users indicated that the larger portion of the water will be required in the Steenbokpan area (30 km west of Grootegeluk Mine). During the interim period, the peak demand to this area will be provided from the Mokolo Dam.

Delivery of Mokolo Dam water to Steenbokpan will, however, only be an interim measure and will be discontinued as soon as the Crocodile River (West) Transfer Scheme starts delivering water. This is necessary as the long term requirement for Mokolo Dam water in the Lephalale area exceeds the sustainable yield of the Mokolo Dam.

The interim pipeline supplying the Steenbokpan area may in the long term serve as a redundancy interconnection between the Mokolo and Crocodile River (West) Schemes (refer to Section 3.3) or to supply water to users that develop along the Lephalale/Steenbokpan road. The sizing of the Steenbokpan pipeline therefore considered both the interim (from Mokolo Dam) and ultimate (from the Crocodile River Transfer Scheme) design flows that had to be transferred along this route. The technical and financial evaluation and recommendation of the proposed Mokolo Dam Scheme components are described in Supporting Report 5: Mokolo River Development Options (P RSA A000/00/9209).

5.2. Crocodile River (West) Transfer and Delivery Scheme

The components forming part of the Crocodile River (West) transfer and delivery systems include two potential river abstraction points downstream of the confluence of the Moretele and Crocodile Rivers, conveyance by means of different options and routes to one of two potential Terminal Dam sites, from where the water will further be distributed to the end users via the delivery system supplying the Steenbokpan region in the west and as far as Medupi Power Station in the east. This system will also be linked to the Mokolo Dam Scheme to provide redundancy of supply (refer to Section 3.3).

The choice of abstraction point will amongst others be determined by the extent of river losses and the cost of the water and the additional costs associated with river management action upstream of the abstraction site considered to be the most viable, via Boschkop or Vlieëpoort, as well as the need for and benefit of implementing a phased approach to deliver water to the end users in a shorter timeframe.

The basic options to convey water from the Crocodile River to the Terminal Dam/Balancing Reservoirs are summarised in Table 5-1. The options are cross referenced to the definition of options given in the ToR (where applicable). The basic options are developed further to compare alternative abstraction sites, transfer routes and balancing and reliability storage options in the options evaluation section of the report (Section 6).

Table 5-1: Crocodile River (West) Basic Transfer and Delivery Options

Approach	ToR Option Reference (Phase)	Ave Transfer Volume* (10^6 m^3/a)	Description
Vlieëpoort Weir Abstraction Options			
Un-Phased	2	191.9	• Abstraction at Vlieëpoort Weir • Conveyance to Terminal Dam via a Break Pressure Reservoir • Supply end users via the delivery system
Phased	2A	110	• Abstraction at Vlieëpoort Weir • Conveyance to Terminal Dam via a Break Pressure Reservoir • Supply end users via the delivery system
	2B	+ 81.9	• Augment transfer capacity from Vlieëpoort Weir with parallel pipeline • Conveyance to Terminal Dam/Break Pressure Reservoir • Supply end users via delivery system
Boschkop Weir Abstraction Options			
Un-Phased	2	191.9	• Abstraction at Boschkop Weir • Conveyance to Terminal Dam via a Break Pressure Reservoir • Supply end users via delivery system
Phased	-	110	• Abstraction at Boschkop Weir • Conveyance to Terminal Dam via a Break Pressure Reservoir • Supply end users via delivery system
	-	+ 81.9	• Augment transfer capacity from Boschkop Weir with parallel pipeline • Conveyance to Terminal Dam via a Break Pressure Reservoir • Supply end users via delivery system
Boschkop/Vlieëpoort Weir Abstraction Options			
Phased	2A	110	• Abstraction at Vlieëpoort Weir • Conveyance to Terminal Dam via a Break Pressure Reservoir • Supply end users via delivery system
	2B	+ 81.9	• Augment transfer capacity from Vlieëpoort Weir with parallel pipeline • Conveyance to Terminal Dam via a Break Pressure Reservoir • Supply end users via delivery system
	3	191.9	• Abstraction from Boschkop Weir • Conveyance to Vlieëpoort Weir to reduce river losses and transfer further to Terminal Dam via a Break Pressure Reservoir

* Delivered to the users

Alternative pipeline routes were identified in accordance with the above basic options. The following aspects were considered in defining and evaluating the different pipeline routes:

- Possible abstraction and delivery locations.
- Existing roads, as well as boundaries between land owners along the routes.
- Historical and planned future mining activities in the area.
- Existing and planned future services and infrastructure.
- Site constraints, potential river/stream crossings, and road and railway crossings.
- Geotechnical conditions based on a high level geotechnical screening.
- CP requirements with special consideration of the impact that the potential future 765 kV overhead powerline corridors might have on the AC mitigation requirements
- Environmental overview
- Social impact of the proposed pipe route

Based on the two abstraction weir sites (Boschkop and Vlieëpoort), water from the Crocodile River (West) can be delivered along alternative route(s) to either one of the two identified Terminal Dam sites (Sites 1 or 3) via a break pressure balancing reservoir or to Terminal Reservoirs at the major consumer sites. Figure 5-1 is a schematic diagram of the alternative pipeline route options and system nodes also via a break pressure balancing reservoir. The routes are also shown on a 1:50 000 backdrop on the layout plan (Drawing No WP 9528/LD/CTS/002/A – **Appendix A**)

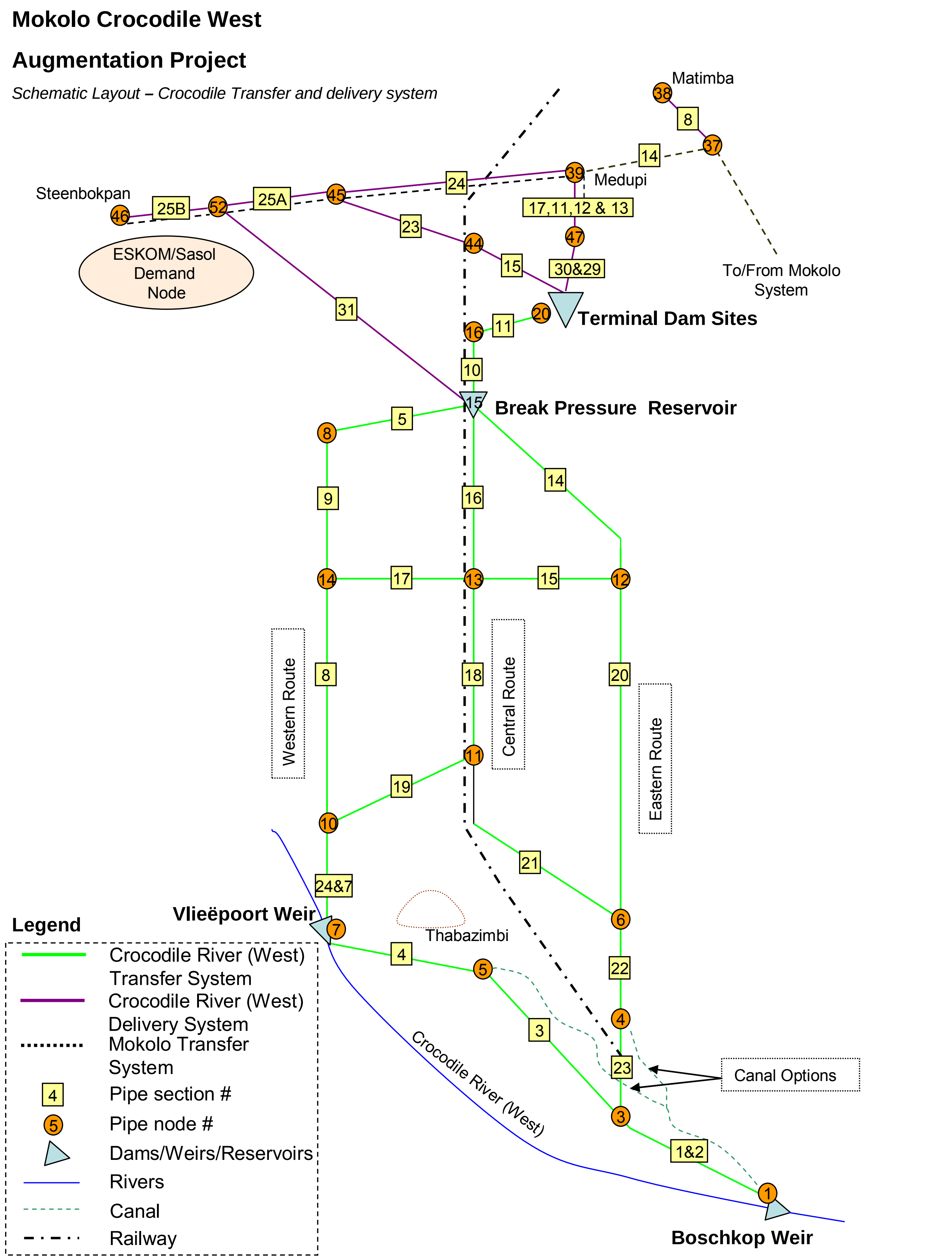

Figure 5-1: Schematic Diagram of the Crocodile River (West) Transfer and Delivery Scheme

The different route options are described in accordance with the pipe section numbering shown on the diagram. A total of eight (8) route options were investigated. The geotechnical, cathodic protection, environmental and social reviews of the respective routes were also done in accordance with the pipe section numbering for ease of reference. The alternative pipeline routes that were identified are shown in Table 5-2 for the Crocodile River (West) Transfer System and in Table 5-4 for the Crocodile River (West) Delivery System.

Table 5-2: Crocodile River (West) Transfer System Route Options

Description	**Flow Routing – Transfer System** (Pipe Section No – Refer Schematic)	**Section Length (km)**	**Route Option Number**
Vlieëpoort Weir Abstraction Options			
Abstraction at Vlieëpoort Weir with conveyance to Terminal Dam (Phased or un-phased)	Western Route to Terminal Dam site entrance: <24-7-8-9-5-10-11>	111.3	T1
	Central Route to Terminal Dam site entrance: <24-7-19-18-16-10-11>	106.1	T2
	Central Route to Node 15: <24-7-19-18-16>	97.9	T3
Boschkop Weir Abstraction Options			
Abstraction at Boschkop Weir with conveyance to Terminal Dam (Phased or un-phased)	Eastern Route to Terminal Dam site entrance: <1-2-23-22-20-14-10-11>	161.8	T4
	Central Route to Terminal Dam site entrance: <1-2-23-22-21-18-16-10-11>	152.8	T5
	Eastern Route to Node 15: <1-2-23-22-20-14>	153.6	T6
	Central Route to Node 15: <1-2-23-22-21-18-16>	144.6	T7
Boschkop/Vlieëpoort Weir Abstraction Options			
Abstraction at Boschkop Weir with conveyance to Vlieëpoort Weir for transfer to Terminal Dam (Phase 3)	Western-Route to Vlieëpoort Weir: <1-2-3-4>	70.0	T8

Connecting pipelines need to be constructed to the Terminal Dam sites 1 and 3 from Node 20. A section of the connecting pipelines will be tunnelled to reduce the pumping head into the dams. The lengths of pipeline and tunnel between Node 20 and the respective Terminal Dams are summarised below. The Terminal Dam site layout is shown on Drawing WP 9528/LD/CTS/002/A (**Appendix A**).

Table 5-3: Crocodile River (West) - Connecting Pipeline and Tunnel Lengths to Terminal Dams

Description	**Pipeline Length (km)**	**Tunnel Length (km)**
Connection between Node 20 and Terminal Dam No 1	0.4	2.8
Connection between Node 20 and Terminal Dam No 3	4.0	0.7

Table 5-4: Crocodile River (West) Delivery System Route Options

Description	Flow Routing – Delivery (Pipe Section No – Refer Schematic)	Section Length (km)	Route Option Number
Delivery from the Terminal Dams			
Conveyance from Terminal Dam No 1 to end users	<15-23> Link to Lephalale-Steenbokpan Pipeline (Node 45) <25A-25B> Link to Steenbokpan <24-14> Link to Lephalale (Constructed as part of Phase 1A) <8> Link to Matimba (Constructed as part of Phase 1A) <13> Link to Medupi	21.8 13.8 22.2 1.9 1.7	D2A
Conveyance from Terminal Dam No 3 to end users	<30-29-17-11-12-13> Link to Lephalale-Steenbokpan Pipeline (Node 39) <24-25A-25B> Link to Steenbokpan <8> Link to Matimba (Constructed as part of Phase 1A) <14> Link to Lephalale (Constructed as part of Phase 1A)	19.3 28.4 1.9 7.6	D2B
Transfer direct to Terminal Reservoirs via Node 15			
Conveyance from Node 15 to end users	<31> Link to Lephalale-Steenbokpan Pipeline (Node 52) <25B> Link to Steenbokpan <25A-24-14> Link to Lephalale (Constructed as part of Phase 1A) <8> Link to Matimba (Constructed as part of Phase 1A) <13> Link to Medupi	24.8 5.1 30.8 1.9 1.7	D3

Delivery of Mokolo Dam water to Steenbokpan will only be an interim measure and will be discontinued as soon as the Crocodile River (West) Transfer Scheme starts delivering water. This is necessary as the long-term requirements for Mokolo Dam water in the Lephalale area exceeds the sustainable yield of the Mokolo Dam.

The sizing of the Steenbokpan pipeline considered both the interim (from Mokolo Dam) and ultimate (from the Crocodile River Transfer Scheme) design flows that had to be transferred along this route. As shown in Table 5-4, certain pipeline sections installed during Phase 1A will have sufficient capacity for the ultimate system requirement (Phase 2) and will thus not be provided as part of the Phase 2 infrastructure.

5.3. Feasibility Screening

A first order screening of the following aspects was carried out in order to inform the planning, costing and decision-making process and to determine the general feasibility of the respective route options with regards to:

- Geotechnical conditions
- CP and AC mitigation
- Environmental and social impact
- Bulk electrical supply to the respective pumping station sites

The findings associated with each aspect are described briefly in the following sections.

5.3.1. Geotechnical Screening

A first order assessment of the anticipated geotechnical conditions along the conveyance routes was done in order to inform the pre-feasibility decision-making process by enabling more accurate estimates of the various quantities involved in constructing the pipelines (excavation, potential re-use of in-situ material, etc.). The investigation was based solely on a visual inspection of the route and on a prediction of the anticipated conditions based on experience of conditions in the area or on similar geotechnical circumstances.

A variation in the geology occurs from the south to the north, as illustrated on the geological map (DWG WP 9528/LD/CTS/005/A – **Appendix A**). The geology in the southern regions consists predominantly of dolomites and granites, changing to predominantly Waterberg quartzite, dolomite and granite in the central regions with Khalahari sands and Waterberg quartzite becoming more prominent towards the north and west.

The geotechnical review indicated slightly shallower hard/soft material interface levels in the southern and eastern regions of the study area. The weighted average percentages of hard and soft material for the western, central and eastern routes are summarised in Table 5-5. Although being a first order estimate, the findings confirm site observations that more hard material would be encountered along the eastern route options. This would influence the cost and the construction period.

Table 5-5: Weighted Average Material Classification

Route	Weighted Average Soft Excavation (%)	Weighted Average Hard Excavation (%)
West (Section 24-7-8-9-5)	51	49
Central (Section 24-7-19-18-16)	54	46
East (Section 20-14)	45	55
South-East (Section 1-2-23-22)	48	52
South-West (Section 1-2-3-4)	49	51

Preliminary indications are that the majority (>90%) of excavated material could be re-used as backfill along all the pipeline routes north of Thabazimbi. The re-use potential along routes south of Thabazimbi (i.e. from Boschkop to Vlieëpoort (pipe sections 1-2-3-4) or to the east (pipe sections 1-2-23-22)) is in the order of 75%.

Side slope stability is expected to vary considerably along the different route options. As result, characteristic side slope stabilities could not be attributed to specific route options and a constraint trench batter angle of 15 degrees was adopted for pricing purposes at pre-feasibility level. The typical trench geometry that was adopted for pricing is illustrated by Figure 4-2.

A more detailed geotechnical review will be performed as part of the feasibility investigation to improve the level of costing accuracy.

5.3.2. First Order Cathodic Protection (CP) and AC Mitigation Evaluation

As illustrated on the layout drawing (WP 9528/LD/CTS/002/A – **Appendix A**), the proposed pipeline routes run parallel to and cross a number of existing and proposed future high voltage power line routes, most notably, the planned new Eskom corridors that will be constructed as part of the Mmamabula-Medupi Transmission Integration Project. These corridors will contain six 765 kV overhead high voltage AC power lines.

There are also a number of crossings of the railway line, which is currently not electrified. If electrified in future, it is expected to be with AC power.

Stray current interference is expected on all pipelines in the area and an assessment was therefore done to determine the required CP and AC mitigation measures that will be required to protect the proposed pipelines and include for these in the financial analysis of each scheme option. The assessment was based on the following conditions and assumptions:

- Preliminary site investigations of the routes of the proposed pipelines have confirmed the presence of significant corrosive soil conditions in places.
- The quantities are based on the route lengths and pipeline diameters as analysed for the pre-feasibility study. Wall thicknesses were based on a D/t ratio of 100.
- Isolation joints at pump stations and reservoirs have not been allowed for at this stage.
- The provision of AC power for the Transformer Rectifier Units (TRU) is based on running overhead cables at a cost of R200 000 per kilometre. It is assumed that TRUs can be positioned within 2 km of distribution lines (11 kV network).
- Allowance is made for temporary CP during construction. This is essential for construction of pipelines with high integrity coatings in AC interference situations.
- The temporary CP costs allow for full time monitoring of the temporary CP during construction.
- The CP system is based on using Sintakote™ pipeline coating and tape wrap at the field joints.
- CP test posts have been allowed at 500 m centres.
- Cross-bonding facilities between pipelines have been allowed for.
- The investigation has assumed that all power line corridors shown on the layout drawings will be populated. Sections with pipe/power line parallelism will require AC mitigation. This comprises the use of two zinc wires in the trench, next to the pipeline and earth mats installed at each test post.
- The railway lines in the area are not electrified at this time and it is envisaged that, when electrified, it will be with AC power as stated earlier. This means that Natural Drain Units (NDU) will not be required.

Soil Resistivity:
The significance of soil resistivity in relation to CP requirements is that it provides an indication of the ability of the soil to conduct current. In high resistivity soils, corrosion currents are small or negligible; hence corrosion is not a major problem. Low resistivity soils not only allow higher corrosion currents, but they are also associated with high moisture contents and dissolved salts, which may be corrosive in themselves.

The most commonly used classification for soil resistivity and the requirement for CP is given in the following table.

Table 5-6: Classification of Soil Resistivity

Resistivity (Ohm.m)	Classification	CP Requirements
< 20Ωm	Extremely corrosive	Definitely required
> 20Ωm but < 50Ωm	Corrosive	Definitely required
> 50Ωm but < 100Ωm	Mildly corrosive	Usually required
> 100Ωm	Not generally corrosive	Not generally required

A first order soil resistivity assessment along the main alternative routes (west, central and east) revealed that there is not a significant difference between the different routes that could influence a decision at this stage. It was, however, found that the Central and Western routes are characterised by lower resistivity, with values of less than 50 Ωm and isolated areas dropping to less than 10 Ωm, compared to the eastern route where resistivity readings generally remained above 50 Ωm. The resistivity readings along the alternative transfer routes are illustrated by Figure 5-2.

Figure 5-2: Resistivity along Alternative Transfer Routes

Due to time constraints, a similar assessment was not carried out along the delivery pipeline routes downstream of the Terminal Dams or Node 15, or along the pipeline routes from the Mokolo Scheme to Steenbokpan (Phase 1A). Similar conditions are however expected and a first order cost estimate for CP and AC mitigation was incorporated into the financial analysis of both the schemes.

Should a corridor not be used for transmission lines, it would result in a cost saving on the AC mitigation requirements for a parallel pipeline. It was, however, found that the cost saving that could be achieved was not significant compared to the overall cost of the CP and AC mitigation. The total cost of CP and AC mitigation, assuming all transmission line corridors to be populated, was thus used in the financial analysis of the different scheme options. The presence of high voltage transmission lines parallel to a pipeline would result in a bigger maintenance burden on the operator of the scheme to ensure that the CP and AC mitigation system is diligently operated and maintained. It would also imply a higher health and safety risk associated with the maintenance of the system.

5.3.3. Bulk Electrical Supply

A complete description of the investigation into the bulk electrical supply to the respective abstraction sites (Vlieëpoort and Boschkop) is included in the Main Report (P RSA A000/00/8109).

The capacity of the existing high and medium voltage networks in the area was investigated. Based on the calculated peak energy requirement at the respective pump station sites (refer to Section 6), the need for upgrading of the existing systems or the construction of new infrastructure to supply the sites was determined. An application for bulk electrical connections was submitted to Eskom in order to be incorporated into their master planning for the area.

The investigations entailed the identification and evaluation of optimum power supply options to ensure redundant power supply to the sites. Each option was analysed from a technical viability and optimum total cost point of view. Both capital and life-cycle costs were considered in deciding on the most viable option.

5.3.3.1. Cost Estimate

Capital costs were calculated following consultation with Eskom based on the following:

- 132 kV line construction costs calculated at R 950,000/km.
- Costs of similar completed substations and MV switching stations.
- Where exact line routes were not available, line lengths were increased by 30% for budget purposes.
- A 10% uncertainty allowance was added.
- Prices exclude Eskom connection charges. (connection charges are insignificant in relationship to the project costs)
- Provision was made at Mokolo Dam for both 132/11 kV and 132/33 kV sub-stations to service the new and existing pump stations

A comparison between Eskom’s Megaflex and Nightsave tariff structures at a 100% load factor and for continuous (24 hour) operation revealed that the Megaflex tariff is more economical. The Megaflex tariff structure was therefore used in calculating the energy costs associated with the different scheme options.

5.3.3.2. Supply Options

Vlieëpoort:
Vlieëpoort pump station will be fed from two 132 kV sub-stations namely, Thabazimbi Munic sub-station and Thabazimbi Rural sub-station. Overland lines will be built from each sub-station to the pump station, in order to ensure redundancy. (Loop in – Loop out system)

Eskom is in the process of strengthening the 132 kV system in the Thabazimbi area. Line routes must, however, still be finalised. The available loading capacity of these lines will exceed the required demand. These lines may be used by Eskom as load transfer lines between the Thabazimbi Munic sub-station and the Thabazimbi Rural sub-station in the future. The planning for these lines is in Eskom’s DRA (Definition Release Approval) stage.

Eskom’s planned network strengthening of the greater Thabazimbi area will ensure a reliable redundant supply to Vlieëpoort with adequate capacity.

Boschkop:
Due to the fact that a firm redundant supply is required, the one option is to loop in and out on the existing 88 kV line between Northam and Beestekraal. The nearby 22 kV and 11 kV networks were not considered because of the load requirement.

Eskom recommended providing a 132 kV loop in – loop out line from other available sub-stations, i.e. Spitskop. Eskom will further investigate the most reliable option, and provide quotations, line layouts and execution dates. These will be incorporated at feasibility stage.

5.3.4. Environmental and Social Screening

The purpose of the environmental screening was to confirm the environmental feasibility for various transfer and delivery pipeline route options from the Crocodile River (West) to the Terminal Dams/Reservoirs and further to the end users. The study was undertaken at a reconnaissance level of detail and no detailed environmental investigations were undertaken. Information was obtained from desktop analysis of the area and online resources.

A social impact screening was carried out to provide an indication of the potential social impacts of the proposed transfer and delivery systems from the Crocodile River (West) to the end users. Prominence was placed on identifying possible social impacts of the proposed route options, as well as providing an indication of the severity of the impact so that a comparison of the different options could be drawn to identify any fatal flaws in order to inform the holistic decision making process.

A brief summary of the findings of the environmental and social screening is provided under the general description of the different route options given in Section 5.4. Further detail is provided in Supporting Report 7: Social and Environmental Screening (P RSA A000/00/9409).

5.4. General description: Transfer Route Options

The different route options for the transfer system from Vlieëpoort or Boschkop to the Terminal Dams or Node 15 are described in the following sections. Figure 5-1 is a schematic diagram of the alternative pipeline route options and system nodes. The routes are also shown on a 1:50 000 backdrop on the layout plan (Drawing No WP 9528/LD/CTS/002/A – **Appendix A**)

5.4.1. Transfer System: Vlieëpoort to Terminal Dam Site via Western Route <24-7-8-9-5-10-11> (Route Option 1)

5.4.1.1. Route Description

Conveyance starts at the abstraction point in the Crocodile River (West) on the farm Mooivallei 342 KQ. The abstraction works consists of a weir incorporating an abstraction pumping station, primary and secondary desilting works and a balancing storage dam feeding a high lift pumping station located on the north-eastern bank of the river (refer to DWG LD/VPW/001 – **Appendix A**).

The route consists of the following pipe sections numbered in sequence from south to north as illustrated schematically by Figure 5-1: <24-7-8-9-5-10-11>.

The transfer pipeline starts at the Vlieëpoort High Lift pumping station and continues in a northerly direction along an existing gravel road (Section 24). A portion of Section 7, on the Farm Paarl 124KQ, runs parallel to existing high voltage overhead power lines along a route that is also being considered for a potential future high voltage power line corridor, before turning east along an existing gravel road connecting to the R510. The route turns north at the T-junction with the R510 and continues along the R510 up to where the R510 turns towards the east on the Farm Honingvley 99KQ. From here, the route continues in a northerly direction along an existing gravel road before turning east, crossing the railway line and continuing towards the entrance to the Terminal Dam site (Node 20).

The length of the pipeline route option is approximately 111.3 km.

5.4.1.2. Environmental Considerations

This section of the route does not maintain its alignment with either the road or the farm boundaries in certain sections. It therefore will have a more significant impact on both the fauna and flora in the area. The area is also dominated by game farming that is more vulnerable to fragmentation of their natural habitat. Although the construction activities will be short term, the faunal species will have their migration, feeding and breeding habits disrupted.

Floral Feasibility:
The proposed pipeline route runs through three different vegetation types namely, Western Sandy Bushveld, Dwaalboom Thronveld and Limpopo Sweet Bushveld. All three the veld types have been listed as Least Threatened. This can be attributed to the fact that the veld is relatively conserved due to the number of game farms in the area.

There are sections where the pipeline alignment strays from the farm boundaries and roads. In these areas, alignments must take into account the size and location of the fragmented land when construction starts.

Faunal Feasibility:
This area mainly traverses game farms and therefore has relatively high species richness. As indicated previously, the short duration of the disturbance during the construction activities will result in the faunal species returning after construction.

Hydrological Feasibility:
There is one major river crossing in this section of the pipeline on the Farm Inkerman 10 KQ. Although the crossing of a river does not present a fatal flaw in the route, it should be noted that river ecology is more sensitive than a terrestrial ecology. More care should therefore be given to the design of the crossing to minimise disturbance to these areas.

5.4.1.3. Social Considerations

From the desktop analysis no impacts were identified that could disqualify this route option as a possible future option. In some cases the pipeline follows the same route as the main road and therefore, this could minimise the impacts, as some of these farms will lose a portion of their farms that is probably not used efficiently.

It can be anticipated that about ten (10) buildings would need to be demolished in order to give way for the pipeline route. The number of household to be relocated is not too large but the impact thereof is significant. It can also be seen that a considerable portion of the land is used for productive agricultural purposes.

It is estimated that the approximate compensation cost of land and improvements could amount to R10.5 Million.

5.4.2. Transfer System: Vlieëpoort to Terminal Dam Site via Central Route <24-7-19-18-16-10-11> (Route Option 2)

5.4.2.1. Route Description

Conveyance starts at the abstraction point in the Crocodile River (West) on the farm Mooivalei 342 KQ. The abstraction works consist of a weir incorporating an abstraction pumping station, primary and secondary desilting works and a balancing storage dam feeding a high lift pumping station located on the north-eastern banks of the river (refer to DWG LD/VPW/001 – **Appendix A**).

The route option consists of the following pipe sections numbered in sequence from south to north as illustrated schematically by Figure 5-1: <24-7-19-18-16-10-11>.

The pipeline starts at the Vlieepoort High Lift pumping station and continues in a northerly direction along an existing gravel road (Section 24). A portion of Section 7, on the farm Paarl 124KQ, runs parallel to existing high voltage overhead power lines along a route that is also being considered for a potential future high voltage power line corridor before turning east along an existing gravel road connecting to the R510. The route continues east (Section 19) and crosses the railway line before turning north and following the railway line up to where the pipeline turns east towards the entrance to the Terminal Dam site at Node 20.

The length of the pipeline route is approximately 106.1 km.

5.4.2.2. Environmental Considerations

The central route runs along the railway line from Thabazimbi to Lepalale. The railway line has a maintenance road running adjacent to the railway line.

Floral Feasibility:
The maintenance road running next to the railway line has resulted in most of the vegetation being cleared in this area. The vegetation types along the route consist of Western Sandy Bushveld and Limpopo Sweet Bushveld. Both these vegetation types are listed as least threatened. Due to the pipeline alignment with the railway line, it does not bisect any significant farm areas and it should not lead to further fragmentation. Some of the connecting pipes do traverse current agricultural land that may lead to temporary disturbance of existing vegetation.

Faunal Feasibility:
The railway corridor has been cleared of much of the natural habitat reducing the occurrence of faunal species in the area. Although much of the natural vegetation has re-established itself, the proposed pipeline will be on the boundary of the surrounding game farms and therefore will have a minimal impact. The regular passing of a train will further prevent the occurrence of many faunal species.

Hydrological Feasibility:
The central route crosses only one major hydrological feature in its alignment. The crossing of the river by the pipeline should preferably coincide with the crossing of the river by the railway. The area has already been disturbed and the river crossing for the pipeline should not be significant.

5.4.2.3. Social Considerations

A large distance of the pipeline runs parallel to a railway line. This has the potential to reduce costs and social impacts since the pipeline would be located adjacent to an existing servitude. No adverse impacts exist that would disqualify this route option from being the preferred option.

The pipeline could possibly impact a minority of households. A small fragment of irrigated land could also be affected.

It is estimated that the approximate compensation cost for land and improvements will be R7.1 Million.

5.4.3. Transfer System: Vlieëpoort to Break Pressure Reservoir (Node 15) via Central Route <24-7-19-18-16> (Route Option 3)

5.4.3.1. Route Description

The route description would be similar to that of Route Option 2, described under Section 5.4.2 with the exception that the pipeline terminates at the site of the proposed balancing reservoir located at Node 15 on the farm Klipkloof 365 LQ.

The route option consists of the following pipe sections numbered in sequence from south to north as illustrated schematically by Figure 5-1: <24-7-19-18-16>.

The length of the pipeline route is approximately 97.9 km.

5.4.3.2. Environmental Considerations

The environmental impact is similar to that described under Section 5.4.2.

5.4.3.3. Social Considerations

The social impact is similar to that described under Section 5.4.2.

It is estimated that the approximate compensation cost for land and improvements will be R5.4 Million.

5.4.4. Transfer System: Boschkop to Terminal Dam Site via Eastern Route <1-2-23-22-20-14-10-11> (Route Option 4)

5.4.4.1. Route Description

Conveyance starts at the abstraction point in the Crocodile River (West) on the farm Boschkop 138 JQ. The abstraction works consist of a weir incorporating an abstraction pumping station, primary and secondary desilting works and a balancing storage dam feeding a high lift pumping station located on the northern banks of the river (refer to DWG LD/BKW/001 – **Appendix A**).

The route option consists of the following pipe sections numbered in sequence from south to north as illustrated schematically by Figure 5-1: <1-2-23-22-20-14-10-11>.

The pipeline starts at the Boschkop high lift pumping station and continues in a northerly direction along the R511. The pipe is located east of the road in order to avoid arable land plots on the western side between the road and the river. At Node 3, the road deviates to the west and the pipeline continues in a northerly direction along an existing gravel road before turning towards the east and passing through a neck in the Vlieëpoort Mountain Range on the Farm McKipzyn Rand 438 KQ. The pipe route continues north along the Hoopdaal dirt road that bisects the Marakele Nature Reserve before linking up with the R510 for a short distance and deviating north again, continuing along farm boundaries and gravel paths to Node 15 before turning east towards the entrance to the Terminal Dam site at Node 20.

The length of the pipeline route is approximately 161.8 km.

5.4.4.2. Environmental Considerations

The alignment of the pipeline is mainly on the eastern side of the R511 to avoid the large number of centre pivots located in the floodplain area on the western side of the R511.

The Eastern Route runs to the east of Thabazimbi and strives to run along road and farm boundaries as much as possible. This is evident from the relatively twisty alignment of the route. The route runs along the Hoopdaal dirt road that bisects the Marakele Nature Reserve.

Marakele Nature Reserve:
Approximately 55% of the park is characterized by the Waterberg Moist Bushveld vegetation type (veld type 12). This vegetation type occurs in the intermediate to high lying areas in the southern and south-eastern portions of the park. This area is characterized by relatively high rainfall (719 mm) and the resultant leaching of the soils results in a fairy low soil nutrient status. This limiting factor in turn results in a fairly low carrying capacity and only ubiquitous species such as kudu and common reedbuck are common in these areas. This vegetation type is characterized by Transvaal beechwoods (Faurea salinga), proteas (Protea caffra) and stem fruit trees (Englerophytum magaliesmontanum). The vegetation along the tarred road leading to the towers is typical of the vegetation type.

Another major vegetation type is the Mixed Bushveld (veld type 18), which covers approximately 42% of the park. This vegetation type is mainly found in the north-western and isolated south-western pockets of the park. It occurs predominantly on the undulating to flat plains and the soils are generally clayey, deeper and more nutrient-rich. Most of the charismatic game species such as black rhino, elephant and wild dog will be associated with this vegetation type. This vegetation type is characterized by species such as silver cluster leaf (Terminalia sericea), sickle bush (Dichrostachys cinerea) and round-leaved teak (Pterocarpus rotundifolias).

Less than 3% of the park is comprised of Sweet Bushveld (veld type 17). This veld type is mostly found along the banks of the Matlabas River and forms an important winter refuge area for game, particularly during limiting periods at the end of the dry season. The planned western expansion of the park will include more of this vegetation type, which is crucial to sustain adequate numbers of prey species for large predators such as lion and spotted hyena.

One of the rare and threatened plant species of Marakele is the Waterberg cycad (Waterbergbroodboom) Encephalartos eugene-maraisii. The naturalist, author and poet Eugene Marais lived in the Waterberg for 16 years and this cycad was named in his honour. This cycad is endemic to the Waterberg region and grows to 5 m tall among low shrubs at an altitude of 1 450 m. From its Waterberg Cycads to Yellow-woods and Camel Thorns, Marakele National Parks supports about 765 plant species (SANParks).

Marakele is home to most of the large mammals synonymous with the African bush, including elephant, black and white rhino, buffalo, leopard and cheetah. Large Predators such as cheetah, wild dog, brown hyena, leopard and now also lion, occur in the park. The wild dogs have been the first of these re-introductions.

Floral Feasibility:
The natural vegetation on the southern section of the pipeline (Sections 1 and 2) has been mainly transformed to agriculture with a large number of central pivots evident along the route. Most of these are, however, located on the western side of the R511. The land-use on the eastern site is a mixture of game farms, livestock farming and agricultural activities.

Due to the large percentage of transformed vegetation along the pipeline route it is not expected to contain any sensitive habitats or threatened or endangered species.

The proposed Eastern Route (north of Node 3) runs through several vegetation types namely, Central Sandy Bushveld, Limpopo Sweet Bushveld, Waterberg Mountain Bushveld and Western Sandy Bushveld. The Central Sandy Bushveld is listed as vulnerable due to the low conservation percentage.

The Marakele Nature reserve is home to several cycad species that are protected by legislation. They occur generally in the more rocky areas of the reserve. Although these cycads have been documented within the park it in all likelihood also occurs in similar areas outside the park. The proposed pipeline route will pass in close proximity to some of these rocky areas. It is extremely difficult to transplant cycads due to their specific habitat requirements.

Due to the status of the national park, it will also be extremely difficult to get the approval from SANParks or the National Department of Environmental Affairs and Tourism to construct the pipeline.

The remainder of the pipeline to the north runs through relatively flat areas where there is not such a distinct habitat definition. Sensitive vegetation along the pipeline route will be able to be removed and transplanted.

Faunal Feasibility:
The transformation of the floral habitat along the southern section of the route (Sections 1 and 2) has diminished the possibility of the occurrence of a large number of faunal species. This is especially the case where domesticated animals have been introduced into the area. Most of the faunal species will occur on the game farms along the route. The alignment of the pipeline is such that it will have minimal impact on the faunal species. The disturbance caused by the pipeline is also short-term.

There is high faunal species diversity along the pipeline route north of Node 3, especially in the Marakele Nature Reserve. Due to the fact that the Nature Reserve is not divided into camps as many game farms, there will be the problem of preventing the game from leaving the reserve should some of the fences be removed for construction purposes. Most of the endangered or threatened species are also present within the Nature Reserve.

Hydrological Feasibility:
The southern section of the pipeline does not cross any significant water features along the proposed alignment. The construction of a weir will, however, have an impact on the flow characteristics of the river that may in turn alter the riverine ecology. The construction of fish ladders at the weir will promote fish migration in the river.

The pipeline route north of Node 3 crosses tributaries of the Motlhabatsi River twice. Due to the relatively flat floodplain the river is prone to the development of wetland areas. These areas are highly sensitive to disturbance and should be avoided.

5.4.4.3. Social Considerations

Route Option 4 is the longest route and runs across many farms and therefore has the potential to have a larger social impact. Most of the farms next to the Crocodile River are small farmlands and therefore, it is assumed that more farms will be affected.

Based on the desktop analysis, this route is expected to impact eleven (11) buildings and four (4) reservoirs. The associated social impact thereof is the relocation of families and loss of water supply. It appears that in all probability, this route will affect the most number of households in terms of social impacts and relocation.

Apart from the large number of households that will be affected, no other major social impacts were identified. The estimated compensation costs of land and improvements for this route will be R16.3 Million.

5.4.5. Transfer System: Boschkop to Terminal Dam Site via Central Route <1-2-23-22-21-18-16-10-11> (Route Option 5)

5.4.5.1. Route Description

Conveyance starts at the abstraction point in the Crocodile River (West) on the farm Boschkop 138 JQ. The abstraction works consist of a weir incorporating an abstraction pumping station, primary and secondary desilting works and a balancing storage dam feeding a high lift pumping station located on the northern banks of the river (refer to DWG LD/BKW/001 – **Appendix A**).

The route option consists of the following pipe sections numbered in sequence from south to north as illustrated schematically by Figure 5-1: <1-2-23-22-21-18-16-10-11>.

The pipeline starts at the Boschkop high lift pumping station and continues in a northerly direction along the R511. The pipe is located east of the road in order to avoid arable land plots on the western side between the road and the river. At Node 3, the road deviates to the west and the pipeline continues in the northerly direction along an existing gravel road before turning towards the east before passing through a neck in the Vlieëpoort Mountain Range on the Farm McKipzyn Rand 438 KQ. North of the maintain range, the pipeline continues along farm boundaries in a north-westerly direction until it reaches the railway line from where it continues north up to Node 15 before turning east towards the entrance to the Terminal Dam site at Node 20

The length of the pipeline route is approximately 152.8 km.

5.4.5.2. Environmental Considerations

The alignment of the pipeline is mainly on the eastern side of the R511 to avoid the large number of centre pivots located in the floodplain area on the western side of the R511.

The Route runs to the east of Thabazimbi through the mountain range before linking up with the Thabazimbi-Lepalale railway line. The railway line has a maintenance road running adjacent to it.

The maintenance road running next to the railway line has resulted in most of the vegetation being cleared in this area. The vegetation types along the route consist of Western Sandy Bushveld and Limpopo Sweet Bushveld. Both these vegetation types are listed as Least Threatened. Due to the pipeline alignment with the railway line, it does not bisect any significant farm areas and it should not lead to further fragmentation. Some of the connecting pipes do traverse current agricultural land that may lead to temporary disturbance of existing vegetation.

Faunal Feasibility:
The railway corridor has been cleared of much of the natural habitat reducing the occurrence of faunal species in the area. Although much of the natural vegetation has re-established itself, the proposed pipeline will be on the boundary of the surrounding game farms and therefore will have a minimal impact. The regular passing of a train will further prevent the occurrence of many faunal species.

Hydrological Feasibility:
The central route crosses only one major hydrological feature in its alignment. The crossing of the river by the pipeline should preferably coincide with the crossing of the river by the railway. The area has already been disturbed and the river crossing for the pipeline should not be significant.

5.4.5.3. Social Considerations

This route option is expected to have an average social impact since part of the pipeline runs parallel to the railway line and the rest of the pipeline runs through farms. From the investigation, no adverse impacts were identified which could disqualify this route as a possible future option.

It is estimated that the approximate compensation costs of the land and improvements will be R11 Million.

5.4.6. Transfer System: Boschkop to Break Pressure Reservoir (Node 15) via Eastern Route <1-2-23-22-20-14> (Route Option 6)

5.4.6.1. Route Description

The route description is similar to that of Route Option 4, described under Section 5.4.4 with the exception that the pipeline terminates at the site of the proposed balancing reservoir located at Node 15 on the Farm Klipkloof 365 LQ.

The route option consists of the following pipe sections numbered in sequence from south to north as illustrated schematically by Figure 5-1: <1-2-23-22-20-14>.

The length of the pipeline route is approximately 153.6 km.

5.4.6.2. Environmental Considerations

The environmental impact is similar to that described under Section 5.4.4.

5.4.6.3. Social Considerations

The social impact is similar to that described under Section 5.4.4. The impact of this route can be expected to be high.

It is estimated that the approximate compensation costs of land and improvements will be R15.3 Million.

5.4.7. Transfer System: Boschkop to Break Pressure Reservoir (Node 15) via Central Route <1-2-23-22-21-18-16> (Route Option 7)

5.4.7.1. Route Description

The route description is similar to that of Route Option 5, described under Section 5.4.5 with the exception that the pipeline terminates at the site of the proposed balancing reservoir located at Node 15 on the Farm Klipkloof 365 LQ.

The route option consists of the following pipe sections numbered in sequence from south to north as illustrated schematically by Figure 5-1: <1-2-23-22-21-18-16>.

The length of the pipeline route is approximately 154.6 km.

5.4.7.2. Environmental Considerations

The environmental impact is similar to that described under Section 5.4.5.

5.4.7.3. Social Considerations

The social impact is similar to that described under Section 5.4.5.

No adverse impacts were identified which could disqualify this route as a possible future option.

It is estimated that the approximate compensation cost of land will be R10.4 Million.

5.4.8. Transfer System: Boschkop to Vlieepoort Weir via Western Route <1-2-3-4> (Route Option 8)

5.4.8.1. Route Description

Conveyance starts at the abstraction point in the Crocodile River (West) on the farm Boschkop 138 JQ. The abstraction works consist of a weir incorporating an abstraction pumping station, primary and secondary desilting works and a balancing storage dam feeding a high lift pumping station located on the northern banks of the river (refer to DWG LD/BKW/001 – **Appendix A**).

Water is conveyed from Boschkop to the Vlieëpoort high lift pumping station, constructed as part of Phase 2A and upgraded as part of Phase 2B, which will act as a booster pumping station and from where the water can then be conveyed to the terminal dams or break pressure reservoir via either Route Options 1, 2 or 3 described previously.

The route between Boschkop and Vlieëpoort consists of the following pipe sections numbered in sequence from south to north as illustrated schematically by Figure 5-1: <1-2-3-4>.

The pipeline starts at the Boschkop high lift pumping station and continues in a northerly direction along the R511. The pipe is located east of the road in order to avoid arable land plots on the western side between the road and the river. The pipe route continues along the R 511 up to Node 5 where it turns west and follows an existing gravel road and crosses the Crocodile River before turning north up to the R510. The pipeline continues west along the R510 before turning north towards the Vlieëpoort Weir site located at Node 7, again crossing the Crocodile River.

The length of the pipeline route is approximately 70 km.

5.4.8.2. Environmental Considerations

From the abstraction point, the pipeline continues north for approximately 20 km to where the western and eastern alternatives split on the Farm Rietfontein. The land-use in this area is dominated by agricultural activities, in the form of crop production, especially along Sections 1 - 2 with large numbers of Central pivots along the alignment. Most of these central pivots are distributed in close proximity to the R511 and the Crocodile River. This can be attributed to the availability of groundwater close to the river. The remainder of this section is dominated by game and livestock farming.

Floral Feasibility:
The southern part of this section is dominated by transformed agricultural lands under irrigation. This makes the occurrence of sensitive floral habitats unlikely. The remainder of the route is predominantly livestock and game grazing areas. Certain areas show distinct signs of overgrazing. Both vegetation types along this section namely, Dwaalboom Thornveld and Waterberg Mountain Bushveld are classified as Least Threatened.

Faunal Feasibility:
The transformation of the floral habitat along this section of the route has diminished the possibility of the occurrence of a large number of faunal species. This is especially the case where domesticated animals have been introduced into the area. Most of the faunal species will occur on the game farms along the route.

The presence of game farms in the study area has introduced several mammal species into the area. There is a relatively high species richness that may be affected during the pipeline construction. The pipeline alignment will, however, mostly follow existing farm boundaries limiting the potential impact on the faunal habitat.

Hydrological Feasibility:
The proposed pipeline route cross rivers on the farms Haakdoringdrift 374 KQ, Grootfontein 352 KQ and Mooivallei 342 KQ. Although the crossing of a river does not present a fatal flaw in the route, it should be noted that river ecology is more sensitive than a terrestrial ecology. More care should therefore be given to the design of the crossing to minimise disturbance to these areas.

The construction of a weir will, however, have an impact on the flow characteristics of the river that may in turn alter the riverine ecology. The construction of fish ladders at the weir will promote fish migration in the river.

5.4.8.3. Social Considerations

A large section of the pipeline runs parallel to the main road, therefore the impact is low.

It is estimated that the approximate compensation costs of land and improvements will be R8.8 Million.

5.5. General Description: Delivery Route Options

The different route options for the delivery system to the end users from the Terminal Dams located on the Farm Witvogelfontein or the break pressure reservoir (Node 15) located on the Farm Klipkloof 365 LQ are described in the following sections. The environmental and social conditions associated with each route are highlighted briefly for each route option. Figure 5-1 is a schematic diagram of the alternative pipeline route options and system nodes. The routes are also shown on a 1:50 000 backdrop on the layout plan (Drawing No WP 9528/LD/CTS/002/A – **Appendix A**).

5.5.1. Delivery System: Terminal Dam No 1 to Steenbokpan Pipeline and End Users (Route Option 2A)

5.5.1.1. Route Description

This option entails the conveyance of water from Terminal Dam No. 1 to end users via the following system of delivery pipelines as illustrated schematically by Figure 5-1:

- <15-23> Link to Lephalale-Steenbokpan Pipeline – 21.8 km
- <25A-25B> Link to Steenbokpan – 13.8 km
- <24-14> Link to Lephalale – 22.2 km.
- <8> Link to Matimba – 1.9 km
- <13> Link to Medupi - 1.7 km

Pipe sections 8, 14 and 24 will be constructed as part of Phase 1A to the final diameter required under Phase 2. The outlet from Terminal Dam No. 1 is more suited to delivering towards the west. The proposed pipeline from Terminal Dam No. 1 runs in a northerly direction along farm boundaries up to the T-junction with the road linking Steenbokpan and Lephalale. From there, the pipeline runs along the road to Lephalale (East) and Steenbokpan (West).

5.5.1.2. Environmental Considerations

This system will provide water to the prospective water users from Steenbokpan in the west to Lephalale in the east. A number of farms in the area are the property of Eskom, Sasol or mining companies or is in the process of being bought by them.

Floral Feasibility:
The pipeline route is located within the Limpopo Sweet Bushveld vegetation type that is listed as Least Threatened. The construction of mines and industries in the delivery area will in all likelihood be accompanied by the development of extensive infrastructure such as road and other services. The alignment of the pipeline should where possible coincide with the alignment of the other services to minimise impact on the natural vegetation.

Faunal Feasibility:
Due to the proposed mine and industrial development in the area it is foreseen that there will be a severe change in the habitat of faunal species. The area is currently used for game and livestock farming. The mining activities will in all likelihood reduce the faunal diversity significantly.

Hydrological Feasibility:
This pipeline routes does not cross any significant hydrological features.

5.5.1.3. Social Considerations

From the investigation it appears that the there are no adverse social impacts that could be expected with this option. In most cases, the pipeline runs adjacent to farm boundaries or roads therefore minimising the social impact thereof.

The estimated compensations cost of land and improvements for this option are R3.9 Million.

5.5.2. Delivery System: Terminal Dam No. 3 to Steenbokpan Pipeline and End Users (Route Option 2B)

5.5.2.1. Route Description

This option entails the conveyance of water from Terminal Dam No. 3 to end users via the following system of delivery pipelines as illustrated schematically by Figure 5-1:

- <30-29-17-11-12-13> Link to Lephalale-Steenbokpan Pipeline – 19.3 km
- <24-25A-25B> Link to Steenbokpan – 28.4 km
- <14> Link to Lephalale – 7.6 km.
- <8> Link to Matimba – 1.9 km

Pipe sections 8 and 14 will be constructed as part of Phase 1A to the final diameter required under Phase 2. The outlet from Terminal Dam No. 3 is more suited to delivering towards the east (Lephalale region). The proposed pipeline from Terminal Dam No. 3 runs in a north-easterly direction along farm boundaries and gravel roads up to the T-junction with the road linking Steenbokpan and Lephalale. From there, the pipeline runs along the road to Lephalale (East) and Steenbokpan (West).

5.5.2.2. Environmental Considerations

The environmental impact is similar to that described under Section 5.5.1.

5.5.2.3. Social Considerations

From the desktop analysis, it appears that there are no major social impacts along the route which could disqualify this route as a possible future option.

The estimated compensations cost of land and improvements for this option are R2.9 Million.

5.5.3. Delivery System: Break Pressure Reservoir (Node 15) to Steenbokpan Pipeline and End Users (Route Option 3)

5.5.3.1. Route Description

The system entails the conveyance of water from the break pressure reservoir located at Node 15 to end users via the following system of delivery pipelines as illustrated schematically by Figure 5-1:

- <31> Link to Lephalale-Steenbokpan Pipeline – 24.8 km
- <25B> Link to Steenbokpan – 5.1 km
- <25A-24-14> Link to Lephalale – 30.8 km.
- <8> Link to Matimba – 1.9 km
- <13> Link to Medupi – 1.7 km

Pipe sections 8, 14, 24 and 25A will be constructed as part of Phase 1A to the final diameter required under Phase 2. The balancing reservoir is located further to the west, and therefore closer to the centroid of the expected future water demand centre around Steenbokpan. The proposed pipeline from the Balancing Reservoir runs in a north-westerly direction to the T-junction with the road linking Steenbokpan and Lephalale. From there, the pipeline runs along the road to Lephalale (East) and Steenbokpan (West).

5.5.3.2. Environmental Considerations

The environmental impact is similar to that described under Section 5.5.1.

5.5.3.3. Social Considerations

The pipeline runs across farms, therefore the impact is expected to be high. However, it can be mentioned that from the investigation, it appears that there are no major social impacts along the route that could disqualify this route as a possible future option.

It is estimated that the approximate compensation cost of land and improvements will be R2.9 Million.

5.6. Hydraulic Considerations

The longitudinal section profile of the following route options is illustrated below:

- Vlieëpoort to the break pressure reservoir via the central route <24-7-19-18-16> (Route Option 3) – Figure 5.3.
- Boschkop to the break pressure reservoir via the central route <1-2-23-22-21-18-16> (Route Option 7) – Figure 5.4.

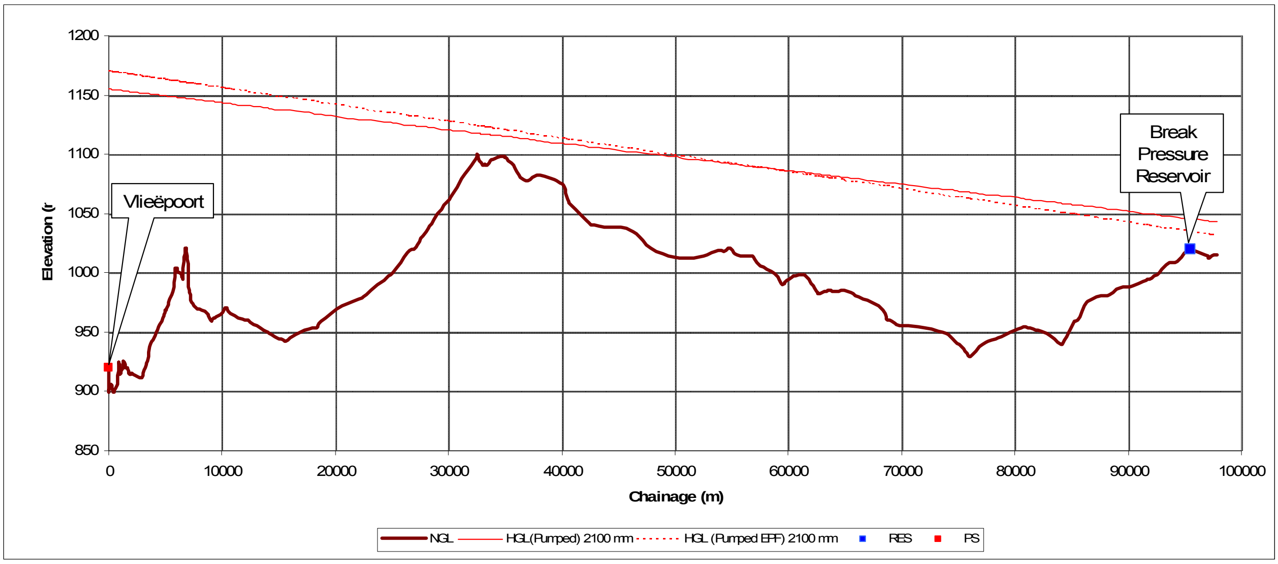

Figure 5-3: Vlieëpoort – Break Pressure Reservoir via Central Route <24-7-19-18-16>: Profile and HGL

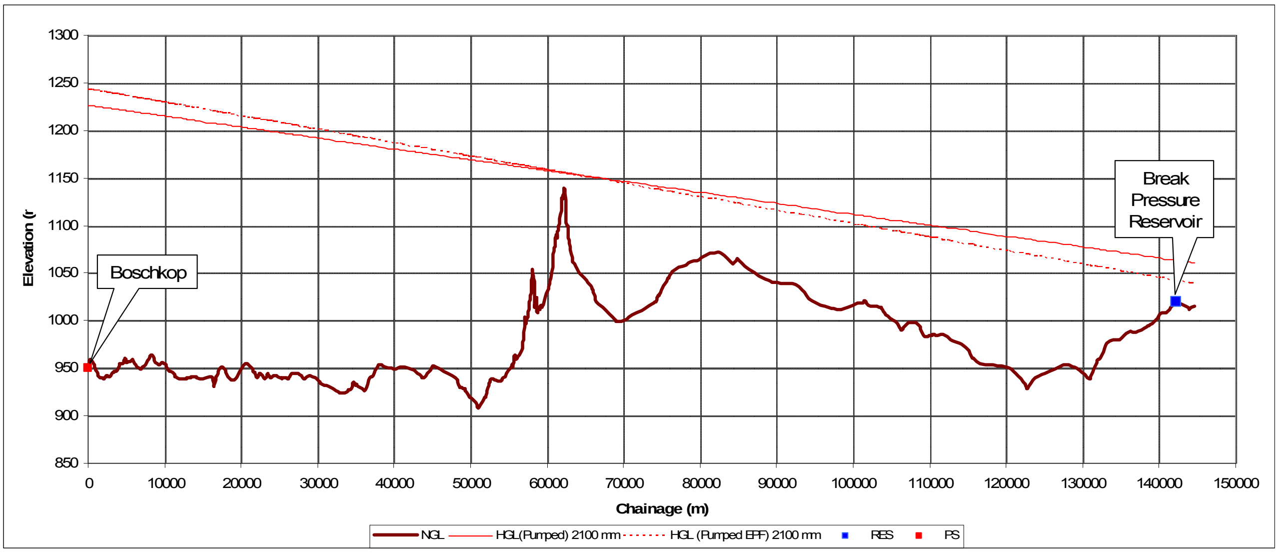

Figure 5-4: Boschkop - Break Pressure Reservoir Central Route <1-2-23-22-21-18-16>: Profile and HGL

Also shown, is the energy grade line for the system when pumping directly to the break pressure reservoir for both the normal and emergency peak flow rates calculated as follows (refer to Section 6 for a more detailed summary of the design criteria):

Crocodile River (West) ultimate average annual water requirement	:	191.25 Million m^3/a
Losses	:	2%
Reliability design peak factor	:	1.05
Design peak flow	:	6.51 m^3/s
Emergency peak factor to enable refill of storage dams in 90 days	:	1.2
Emergency peak flow	:	7.43 m^3/s
Rising main flow velocity under design peak flow conditions	:	1.8 m/s
Rising main flow velocity under emergency peak flow conditions	:	2.1 m/s

The following was noted with regards to the profile and hydraulic performance of the system:

- The longitudinal profiles are typical of all the transfer route options (West, Central and East). All the routes pass over a high lying area in the vicinity of Thabazimbi. This could cause excessive negative pressures and result in pressure surges following pump station shut downs or pump trips or power failures.
- The option to locate a break pressure reservoir at the first high point on the profile and gravitate further was therefore investigated:
  - It was found that it would not be viable to convey the water from the first high point to the Terminal Dam sites under gravity due to insufficient head difference between the two points. It would require the diameter of the gravity pipe section to be increased by three to four pipe sizes, making it financially unviable (Refer to Figure 5-5 for an illustration of the energy grade line of a 2 500 mm diameter gravity pipe section)
  - It will be possible to convey the water under gravity to the planned break pressure reservoir position (Node 15) located at an elevation approximately 25 m lower than Terminal Dam site 1 by increasing the gravity pipe diameter by one size increment in order to have sufficient capacity to convey the emergency peak flow rate. The energy grade line for a pump-gravity system is illustrated by Figure 5-6 and Figure 5-7 for above two scenarios. The diameter of the rising main and gravity sections is given in the graph legend.

- The increase in the required pipe diameter for the gravity section is the same for all the options that involve supplying the break pressure reservoir. It is therefore a common component that would not differentiate between the options and influence the decision. As stated, the cost of a gravity supply to the terminal dam sites will be excessive and is not considered viable.
- The optimal positioning of the hydraulic components, as well as the optimisation of the pipe material and wall thickness will be done during the feasibility stage of the project when the preferred option(s) has been selected.

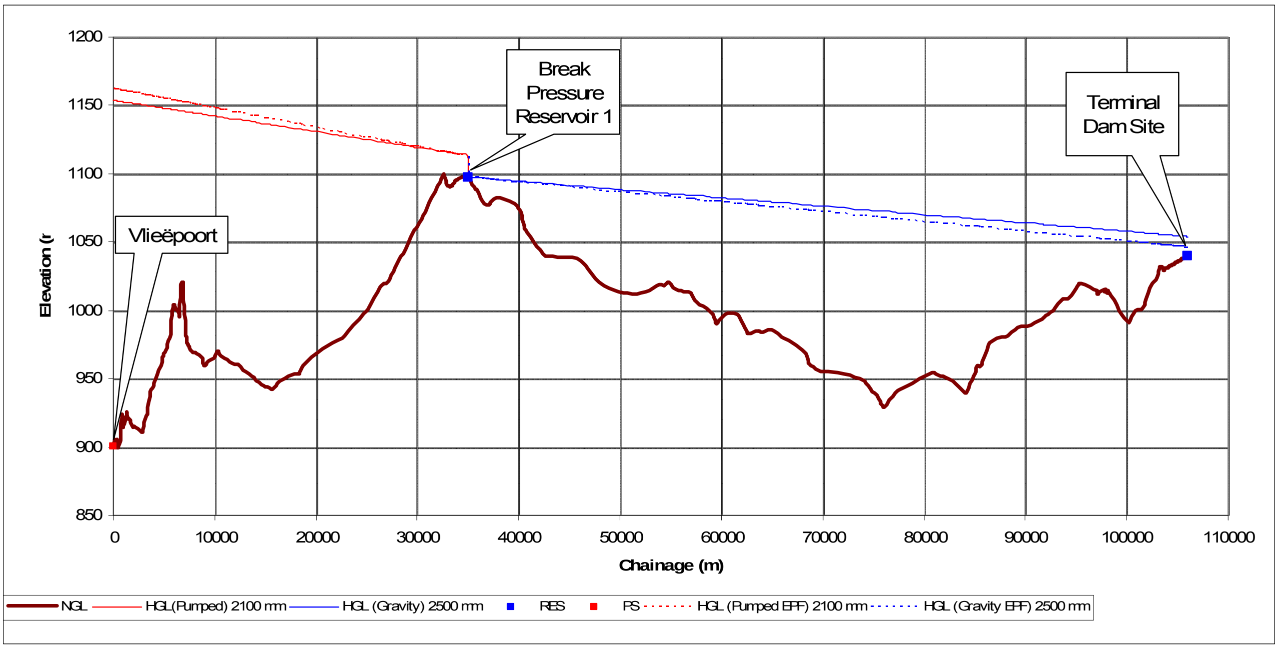

Figure 5-5: Vlieëpoort – Terminal Dam Site via Central Route <24-7-19-18-16-10-11>: Profile and HGL for Pump Gravity System

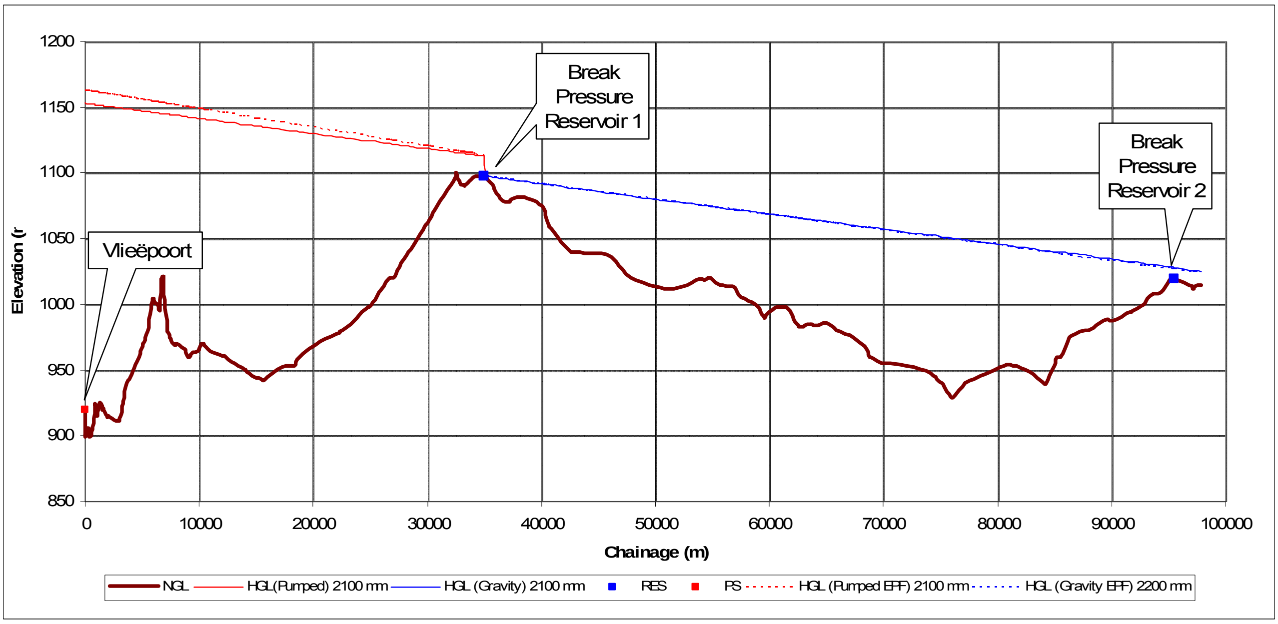

Figure 5-6: Vlieëpoort – Break Pressure Reservoir via Central Route <24-7-19-18-16>: Profile and HGL for Pump Gravity System

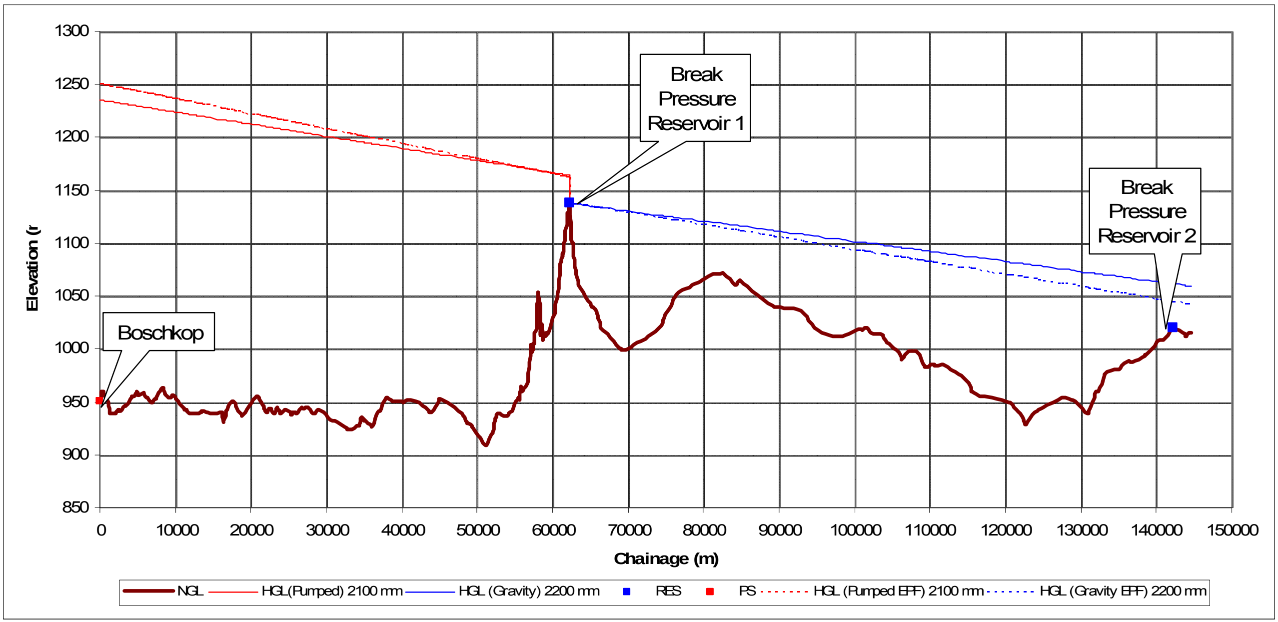

Figure 5-7: Boschkop - Break Pressure Reservoir Central Route <1-2-23-22-21-18-16>: Profile and HGL for Pump Gravity System

5.7. Conclusion: Route Options Feasibility Screening

The following can be concluded based on the above screening of alternative pipeline routes.

Geology and Geotechnical Screening:
No adverse geological conditions are expected that would totally prohibit the construction of the pipelines along any of the alternative route options investigated. There is also not a great variation in the geological conditions along the respective pipeline routes that would create a major advantage of one over the other.

A variation in the geology generally occurs from the south to the north. The geology in the southern regions consists predominantly of dolomites and granites, changing to predominantly Waterberg quartzite, dolomite and granite in the central regions with Khalahari sands and Waterberg quartzite becoming more prominent towards the north and west.

A slightly shallower hard material interface level can be expected along southern and eastern route options. This would increase the volume of hard rock encountered and would impact on the cost and the construction period of the transfer route options from Boschkop to Vlieëpoort or from Boschkop directly to the terminal dams/balancing reservoir via the eastern route.

Relatively high re-use of excavated material for bedding and backfill purposes is expected along all route options.

Overall, the most favourable geological conditions are expected along the Central transfer route.

The geology and geotechnical conditions along the delivery system route options are generally similar with no clear distinction between the various alternatives at this level of detail.

Cathodic Protection (CP) and AC Mitigation:
The proposed pipeline routes run parallel to and cross a number of existing and proposed future high voltage power lines. There are also a number of rail crossings which is currently not electrified, but if electrified in future, is expected to be with AC power.

A high level assessment was done to determine the required CP and AC mitigation measures that will be required to protect the proposed pipelines. The soil resistivity along the main transfer pipeline route options (West, Central and East) was also investigated. Resistivity values are generally higher (less corrosive) along the eastern transfer route compared to the central and western routes.

The investigation concluded that CP and AC mitigation will be required on all transfer and delivery pipelines. Some saving could be achieved if the pipeline was not located parallel to one of the proposed Eskom power line corridors (6 x 765 kV parallel high voltage power lines). It was, however, found that the cost saving that could be affected was not significant compared to the overall cost of the CP and AC mitigation. Locating the pipeline adjacent to the railway line is also not considered to be a fatal flaw from a CP point of view.

The presence of high voltage transmission lines parallel to a pipeline would result in a bigger maintenance burden on the operator of the scheme to ensure that the CP and AC mitigation system is diligently operated and maintained. It would also imply a higher health and safety risk associated with the maintenance of the system. Due to the uncertainty regarding the power line corridor that will be opted for by Eskom, no significant differentiation is currently possible between different route alternatives from a CP and AC mitigation point of view.

Bulk Electrical Supply:
The capacity of the existing high and medium voltage networks in area was investigated and the need for upgrading of the existing systems or the construction of new infrastructure to supply the sites was determined.

Additional infrastructure will be required to provide 132 kV loop in – loop out firm supplies to both Vlieëpoort and Boschkop sites.

Environmental and Social Screening:
The environmental screening was carried out to confirm the environmental feasibility of the various transfer and delivery pipeline route options while a social impact screening was carried out to provide an indication of the potential social impacts of the proposed transfer and delivery systems from the Crocodile River (West) to the balancing dams/reservoir and further to the end users. The conclusions are summarised below:

- There is no environmental or social impact totally prohibiting the construction of any of the route options.
- Transfer route options:
  - The eastern transfer route passes through the Marakele Nature Reserve. This will increase the environmental and social impact and it is expected that obtaining the necessary environmental approvals will be difficult.
  - The central transfer route will have the least environmental and social impact due to the disturbance already caused by the railway line. This route is preferred from an environmental and social point of view.
  - The western transfer route passes through an area characterised by extensive game farming. This will increase the environmental and social impact associated with the project.
- Terminal Dams/Terminal Reservoir:
  - The environmental and social impact of the Terminal Reservoirs (including the connecting pipelines and tunnel sections) on the Farm Witvogelfontein is expected to

be considerably more than the Balancing Reservoir option with terminal storage at the individual end users.

- Delivery route options:
  - No adverse environmental or social impacts can be attributed to any of the three delivery route options.

Technical and Practical Considerations:
The following practical considerations will also influence the choice of transfer and delivery route:

- Length of Pipeline – a shorter pipe length will reduce costs and shorten construction periods. The Central route option from both Vlieëpoort and Boschkop is the shortest possible route to either the terminal dam or the balancing reservoir.
- Constructability – Constructability of a pipeline is influenced by the horizontal alignment (straight or with many bends/curves), site conditions (disturbed or un-disturbed), access, geotechnical conditions, environmental sensitivity, etc. Considering these aspects, the Central route options are preferred from a constructability point of view.
- Hydraulic performance - A pump-gravity system can be considered for options supplying the balancing reservoir in order to simplify the operation of the system.

6. OPTIONS EVALUATION

6.1. Methodology

The Unit Reference Value method is used to select the most "beneficial" system from a set of options. The scheme with the lowest URV (has the lowest average total life cycle cost per unit of water delivered) provides the most benefit for the funds employed in constructing, operating and maintaining the scheme.

The URV is calculated by solving for the unknown "unit water cost" in the equation where the present values of costs are set equal to the present value of income from the water if priced at a unit cost equal to the URV (at a chosen discount rate and discounting period), i.e. the condition where the benefit to cost ratio is equal to 1. It must be noted that the URV is not a water tariff but a reference value by which different options are compared on the same economic basis.

This method was used to compare the scheme options identified during the course of this study. The sections below provide a summary of the options considered, input values and assumptions.

6.2. Definition of Project Phases

The implementation phases of the MCWAP Project are repeated here for ease of reference:

- Phase 1: Augment the supply from Mokolo Dam:
  - Phase1A – Provide a peak delivery capacity of 50.4 million m^3/a (excluding losses and reliability and redundancy requirements) by implementing either one of the following options:
    1) Option 1 – Pipeline from Mokolo Dam to the Lephalale and Steenbokpan demand areas.
    2) Option 2 – Weir in the Mokolo River downstream of the dam and pipeline to Lephalale and Steenbokpan.
- Phase 2: Transfer scheme from the Crocodile River (West) to the demand area via a system consisting of:
  - Various potential pipeline routes. Three general routes have been identified – East, Central and West.
  - A number of different weir and abstraction works sites.
  - Terminal and/or on-site storage:
    1) Terminal Dam options providing 18 days storage together with Balancing Reservoirs at the end user sites with minimum of 9 days storage plus additional user requirements to achieve the required balancing capacity and emergency storage; this is to provide for the reliability required for the gravity pipelines from the Terminal Dams.
    2) Alternatively a break pressure reservoir providing short term balancing storage between the end of the rising main section and the gravity main section in conjunction with end user terminal reservoirs consisting of seven (7) on-site reservoirs with 18 days storage capacity plus additional user requirements to achieve the required balancing capacity and emergency storage.
  - Two approaches:
    1) Un-phased (full capacity) scheme implemented in a single construction phase with an ultimate net transfer capacity of 191.25 Million m^3/a (excluding system losses and reliability and redundancy requirements).
    2) Phased approach where the capacity is provided through two parallel pipes constructed during two consecutive construction phases.
       a. Phase 2A – First phase pipeline from Vlieëpoort weir with a net transfer capacity of 110 Million m^3/a.

b. Phase 2B – Second phase pipeline from Vlieëpoort weir to achieve ultimate required net transfer capacity of 191.25 Million m^3/a (excluding system losses and reliability and redundancy requirements).

- Phase 3:
  - Third construction phase during which a pipeline is built from Boschkop weir to Vlieëpoort weir to link with the infrastructure built during Phase 2 in order to reduce river losses between the Boschkop and Vlieëpoort Weir sites.

6.3. Definition of Options

The combined Mokolo and Crocodile (West) Augmentation Scheme will comprise of infrastructure implemented as part of Phase 1A and Phase 2 operating as a combined scheme. The URV calculations therefore considered the capital, operations and maintenance costs of the total scheme.

The pre-feasibility investigation of the Mokolo River Development Options (Phase 1A) concluded that the Mokolo Dam pipeline option is preferred from an engineering, environmental and practical point of view (Supporting Report 5 – P RSA A000/00/9209). The cost stream associated with this option was therefore incorporated in the URV calculations of the combined scheme.

As described in previous sections, a number of options exist for the abstraction and conveyance of water from the Crocodile River (West) to the end users located between Steenbokpan and Lephalale. Considering both demand scenarios (Scenarios 4 and 8), a possible phased or un-phased implementation approach, alternative abstraction sites, conveyance routes and terminal reservoir sites, as well as various balancing or end storage options, a large combination of options exist that could be considered. Numerous options are however similar in nature, and a number of options could be eliminated based on practical considerations and engineering judgement.

A coding system was developed to give the different options indicative names. A description of the codes used in the naming is summarised in Table 6-1. An option name is made up of a combination of codes as shown by the example below for Option 8-P2-TV CB1-DB1:

	Demand Scenario	-	Project Phase	-	Transfer “From” Location	Route	Transfer “To” Location	-	Delivery Route Option
Code	8	-	P2	-	TV	C	B1	-	DB1
Description	Scenario 8	-	Phase 2	-	Transfer from Vlieëpoort	Via Central Route	To Balancing Reservoir	-	Delivery from balancing reservoir

Table 6-1: Naming Code Descriptions

Code	Description
4	Scenario 4 -
8	Scenario 8 -
B	Boschkop
B1	Balancing Reservoir
BV	Boschkop through Vlieëpoort
C	via Central Route to
D1	Terminal Dam 1
D3	Terminal Dam 3
DB1	and delivery from the Balancing Reservoir
DD1	and deliver via Delivery Route 1
DD3	and deliver via Delivery Route 3
E	via Eastern Route to
ID1	via pump/gravity main to the users
IW1	via rising main to users
MD	Mokolo Dam
P1A	Phase 1A, transfer from
P2	Phase 2, transfer from
P2A	Phase 2A (first pipeline), transfer from
P2B	Phase 2B (second pipeline), transfer from
P3	Phase 3, transfer from
RBW	Weir in Mokolo River (River Bend)
RM	Mokolo River and Mokolo River Management
RMB	River Management up to Boschkop
RMV	River Management up to Vlieëpoort
V	Vlieëpoort
W	via Western Route to

A list of options that was identified is included in **Appendix B**. The number of options for detailed analysis was reduced through a logical decision making process described in Section 6.4 to ensure that the relevant opposing alternatives were compared.

6.4. Decision Process

The following summarises the process followed to eliminate options based on URVs.

(1) Determine preferred option for Phase 1A – Mokolo Transfer System

Calculate URVs for Phase 1A (Mokolo Transfer System)

Option 1 – Pipeline < 8-P1A-MD-ID1>
And Option 2 – Weir < 8-P1A-RBW-IW1>

Select preferred option and use further in combination with Crocodile River (West) Transfer and Delivery options. Refer to Supporting Report 5: Mokolo River Development Options (P RSA A000/00/9209) for pre-feasibility findings and recommendations.

(2) Determine the preferred Terminal Dam / Break Pressure Reservoir Option

Calculate URVs for Scenario 8, Phase 2, Vlieëpoort Abstraction via Central Route

to Terminal Dam 1 < 8-P2-TV CD1-DD1>
or Terminal Dam 3 < 8-P2-TV CD3-DD3>
or Break Pressure Reservoir < 8-P2-TV CB1-DB1>

Select preferred dam option and use further in combination with route options.

(3) Select between the Western and Central Routes

Calculate URVs for Scenario 8, Phase 2, Vlieëpoort Abstraction via Western Route to selected Terminal Dam/Break Pressure Reservoir option < 8-P2-TV WB1-DB1>

Compare with (2) and select preferred route option for Vlieëpoort abstraction.

(4) Select between the Eastern and Central Routes and between Abstraction at Vlieëpoort or Boschkop

Calculate URVs for Scenario 8, Phase 2, Boschkop Abstraction to Break Pressure Reservoir
via Eastern route < 8-P2-TBEB1-DB1>
and via Central Route < 8-P2-TBCB1-DB1>

Select preferred route option for Boschkop abstraction; and
Select between Vlieëpoort and Boschkop as the abstraction point.

(5) Determine whether the Phased Approach is preferred

Calculate URVs for Scenario 8, Phase 2A, Vlieëpoort Abstraction via Central Route to Break Pressure Reservoir < 8-P2A-TV CB1-DB1>

and Scenario 8, Phase 2B, Vlieëpoort Abstraction via Central Route to Break Pressure Reservoir < 8-P2B-TV CB1-DB1>

Compare the un-phased approach and select.

(6) Compare the Cost of Phase 3 Pipeline with River Management

Calculate URV for Scenario 8, Phase 2 & 3, Boschkop Abstraction via Vlieëpoort and Central Route to Break Pressure Reservoir < 8-P3-TBVCB1-DB1>
plus
<8-P2-TVCB1-DB1>

Compare with (4).

(7) Determine URV's for Scenario 4 Demands and compare

Calculate URV for Scenario 4, Phase 2, Vlieëpoort Abstraction Central Route to Balancing Reservoir < 4-P2-TV CB1-DB1>

Calculate URV for Scenario 4, Phase 2, Boschkop Abstraction Central Route to Balancing Reservoir < 4-P2-TB CB1-DB1>

Two options were evaluated for the Mokolo Transfer System (Calculation step 1). The selected option was incorporated into the evaluation of a further 12 Mokolo-Crocodile combined scheme options (Calculation steps 2-7). A total of 14 options were therefore evaluated in detail in order to carry out the required scheme comparisons and selection process.

A description of the 14 options is given in Table 6-2. The flow routing is described in accordance with the labelling shown on the schematic diagram of the pipeline routes and system nodes illustrated by Figure 5-1. The layout plan of the scheme is included in **Appendix A** (Drawing No WP 9528/LD/CTS/002/A). The scheme options are also cross referenced to the route option numbers defined in Section 5 according to which the feasibility screening was done.

Table 6-2: Mokolo Crocodile River West Scheme – Description of Options

Option Nr	Option Code	Description	Flow Routing (Refer to Figure 5-1 schematic)
1	8-P1A-MD-ID1	Scenario 8 – Phase 1A, transfer from Mokolo Dam via pump/gravity main to the users.	Refer Mokolo River Development Options Report (P RSA A000/00/9209)
2	8-P1A-RBW-IW1	Scenario 8 – Phase 1A, transfer from weir in Mokolo River (Rivers Bend) via rising main to users.	Refer Mokolo River Development Options Report (P RSA A000/00/9209)
3	8-P2-TVCD1-DD1	Scenario 8 - Phase 2, transfer from Vlieëpoort via Central Route to Terminal Dam 1 and deliver via Delivery Route 2A	Transfer Route Option 2: <24-7-19-18-16-10-11> Delivery Route Option 2A: <15-23> <25A-25B > <24-14-8> <13>
4	8-P2-TVCD3-DD3	Scenario 8 - Phase 2, transfer from Vlieëpoort via Central Route to Terminal Dam 3 and deliver via Delivery Route 2B	Transfer Route Option 2: <24-7-19-18-16-10-11> Delivery Route Option 2B: <30-29-17-11-12-13> <24-25A-25B > <14-8>
5	8-P2-TVCB1-DB1	Scenario 8 - Phase 2, transfer from Vlieëpoort via Central Route to Break Pressure Reservoir and delivery to the Terminal Reservoirs via Delivery Route 3.	Transfer Route Option 3: <24-7-19-18-16> Delivery Route Option 3: <31> <25B> <25A-24-14-8> <13>
6	8-P2-TVWB1-DB1	Scenario 8 - Phase 2, transfer from Vlieëpoort via Western Route to Break Pressure Reservoir and delivery to the Terminal Reservoirs via Delivery Route 3.	Transfer Route Option 1(part) <24-7-8-9-5> Delivery Route Option 3: <31> <25B> <25A-24-14-8> <13>
7	8-P2-TBCB1-DB1	Scenario 8 – Phase 2, transfer from Boschkop via Central Route to Break Pressure Reservoir and delivery to the Terminal Reservoirs via Delivery Route 3.	Transfer Route Option 7: <1-2-23-22-21-18-16> Delivery Route Option 3: <31> <25B> <25A-24-14-8> <13>
8	8-P2-TBEB1-DB1	Scenario 8 – Phase 2, transfer from Boschkop via Eastern Route to Break Pressure Reservoir and delivery to the Terminal Reservoirs via Delivery Route 3.	Transfer Route Option 6: <1-2-23-22-20-14> Delivery Route Option 3: <31> <25B> <25A-24-14-8> <13>
9	8-P2A-TVCB1-DB1	Scenario 8 - Phase 2A (first pipeline), transfer from Vlieëpoort via Central Route to Break Pressure Reservoir and delivery to the Terminal Reservoirs via Delivery Route 3.	Transfer Route Option 3: <24-7-19-18-16> Delivery Route Option 3: <31> <25B> <25A-24-14-8> <13>
10	8-P2B-TVCB1-DB1	Scenario 8 - Phase 2B (second pipeline), transfer from Vlieëpoort via Central Route to Break Pressure Reservoir and delivery to the Terminal Reservoirs via Delivery Route 3.	Transfer Route Option 3: <24-7-19-18-16> Delivery Route Option 3: <31> <25B> <25A-24-14-8> <13>
11	8-P2A&B-TVCB1-DB1	Scenario 8 - Phase 2A&B, transfer from Vlieëpoort via Central Route to Break Pressure Reservoir and delivery to the Terminal Reservoirs via Delivery Route 3.	Transfer Route Option 3: <24-7-19-18-16> Delivery Route Option 3: <31> <25B> <25A-24-14-8> <13>
12	8-P3-TBVCB1-DB1	Scenario 8 - Phase 3, transfer from	Transfer Route Option 8&3:

Option Nr	Option Code	Description	Flow Routing (Refer to Figure 5-1 schematic)
		Boschkop through Vlieëpoort via Central Route to Break Pressure Reservoir and delivery to the Terminal Reservoirs via Delivery Route 3 (Option 5).	<1-2-3-4> <24-7-19-18-16> Delivery Route Option 3: <31> <25B> <25A-24-14-8> <13>
13	4-P2-TBCB1-DB1	Scenario 4 – Phase 2, transfer from Boschkop via Central Route to Break Pressure Reservoir and delivery to the Terminal Reservoirs via Delivery Route 3.	Transfer Route option 7: <1-2-23-22-21-18-16> Delivery Route Option 3: <31> <25B> <25A-24-14-8> <13>
14	4-P2-TVCB1-DB1	Scenario 4 – Phase 2, transfer from Vlieëpoort via Central Route to Break Pressure Reservoir and delivery to the Terminal Reservoirs via Delivery Route 3.	Transfer Route Option 3: <24-7-19-18-16> Delivery Route Option 3: <31> <25B> <25A-24-14-8> <13>

6.5. Input Values and Assumptions used in the Calculations

The approach to sizing and costing of engineering infrastructure components are described in Supporting Report 3: Guidelines for Preliminary Costing and Economic Evaluation of Development Options (P RSA A000/00/9009)

6.5.1. Electricity Costs

- Eskom MegaFlex Tariff structure.
- Allowance for peak and off-peak electricity (active and reactive energy) tariffs and further differentiation between summer and winter tariffs.
- Annual pumping hours calculated based on the annual average water requirements from the water requirement tables.
- Fixed network, admin., etc. charges included.

6.5.2. Economic Parameters

- Discount rates of 6, 8 and 10%.
- Useful life (or discounting period) taken as 45 years.
- Electricity cost escalated by 20% per annum (compounded) over the first five years.

6.5.3. Engineering Parameters

The costing and sizing principles developed for the VAPS studies by DWAF (1996) have been adopted for the pre-feasibility stage of this study. The specific parameters that have been adopted for sizing and costing of the pipelines and pump stations are given below and have been based on the VAPS parameters that have been adapted where considered to be more appropriate to this project.

• Long Term Pipe roughness (epoxy lined)	0.1	mm
• Max design flow velocity for pre-feasibility pipe sizing	1.8	m/s
• Secondary losses	0.25	m/km
• Steel pipe material yield strength	290	Mpa (Grade X42)
• Max allowable design stress	50%	of yield strength

• Maximum pumping head (approx..)	400	m (per pump station)
• High lift pump sets	3/4 duty + 1 standby	
• Low lift pump sets	6 duty + 2 spare	
• Efficiency of pump (Ep)	90%	
• Efficiency of motor (Em)	97%	
• MW/MVA ratio (power factor Pf)	0.96	
• Boschkop Weir Abstraction PS Elevation	924.0	masl
• Boschkop Weir High Lift PS Elevation	950.0	masl
• Vlieëpoort Weir Abstraction PS Elevation	885.0	masl
• Vlieëpoort Weir High Lift PS	920.0	masl
• Terminal Dams (max FSL)	1044.0	masl
• Break Pressure Reservoir (max FSL)	1015.0	masl
• Minimum residual head at delivery point	15.0	m
• Annual Downtime (pumping system)	18.0	days
• Reliability design peak factor (pumping)	1.05	factor
• Terminal Dam/ Terminal Reservoir refill period	90	days
• Peak factor required to refill (pumping max)	1.20	factor
• System losses (including losses in dams)	2.0	%

6.5.4. Maintenance Requirements

• Major overhaul every 15 years	15%	of initial capital cost of pump and motor
• Maintenance cost (mechanical & electrical)	4%	of electrical/mechanical cost
• Maintenance cost (dams and weirs civil)	0.25%	of civil cost
• Maintenance cost (pump station civil)	0.25%	of civil cost
• Maintenance cost (pipelines)	0.50%	of pipeline cost

6.5.5. Net Water Requirements and Transfer Volumes

6.5.5.1. Mokolo Dam

The annual volumes of water to be transferred from the Mokolo Dam are indicated in the table below. The calculation of the water requirements is described in Supporting Report 1: Water Requirements (P RSA A000/00/8809).

The net water requirement is based on the total annual water requirement (taking cognisance of the installed transfer capacity). Transfer and evaporation losses are estimated at 2% and river losses are added to obtain the gross water requirement used to calculate the raw water costs for each scheme option.

Table 6-3: Annual Transfer Volumes for Mokolo Dam Abstraction (Million m^3/a)

Year	Net Water Requirement	Add Transfer Losses (2%)	Gross Water Requirement	
			Mokolo Dam	Rivers Bend Weir
2008	12.131	12.374	12.374	15.251
2009	13.747	14.022	14.022	17.283
2010	14.597	14.889	14.889	18.352
2011	20.252	20.657	20.657	25.461
2012	28.025	28.586	28.586	35.234
2013	39.629	40.421	40.421	49.821
2014	36.412	37.140	37.140	45.777
2015	27.400	27.948	27.948	34.447
2016	28.700	29.274	29.274	36.082
2017	28.700	29.274	29.274	36.082
2018	28.700	29.274	29.274	36.082
2019	28.700	29.274	29.274	36.082
2020	28.700	29.274	29.274	36.082
2021	28.700	29.274	29.274	36.082
2022	28.700	29.274	29.274	36.082
2023	28.700	29.274	29.274	36.082
2024	28.700	29.274	29.274	36.082
2025	28.700	29.274	29.274	36.082
2026	28.700	29.274	29.274	36.082
2027	28.700	29.274	29.274	36.082
2028	28.700	29.274	29.274	36.082
2029	28.700	29.274	29.274	36.082
2030	28.700	29.274	29.274	36.082

The safe yield of Mokolo Dam has been determined to be 28.7 Million m^3/a. The long term gross water requirements for the Mokolo Dam option that includes the transfer and evaporation losses (29.274 Million m^3/a) can therefore not be supplied from Mokolo Dam. The deficit is small and can potentially be supplied from the Crocodile River (West).

The gross water requirement for the Rivers Bend Weir option exceeds the safe yield of Mokolo Dam from 2012 onwards. This deficit cannot be replaced with Crocodile River (West) water as this will require that the Zeeland WTW be upgraded to treat Crocodile River (West) water. This is currently not planned.

6.5.5.2. Crocodile River (West)

The annual volumes of water to be transferred from Crocodile River (West) for the scheme options are indicated in the tables below. The determination of the water requirements is described in Supporting Report 1: Water Requirements (P RSA A000/00/8809).

The net water requirement is based on the total annual water requirement (taking cognisance of installed transfer capacity). Transfer, evaporation and leakage losses from the terminal reservoirs are estimated at 2%. These plus river losses are added to obtain the gross water requirement used to calculate the raw water costs for each scheme option.

Table 6-4: Annual Transfer Volumes Crocodile (West) Abstraction, Phase 2, Scenario 4 (Million m^3/a)

Year	Net Water Requirement	Add Transfer Losses	Gross Water Requirement of Option	
			Boschkop	Vlieëpoort
2008	0.000	0.000	0.000	0.000
2009	0.000	0.000	0.000	0.000
2010	0.000	0.000	0.000	0.000
2011	0.000	0.000	0.000	0.000
2012	0.000	0.000	0.000	0.000
2013	0.000	0.000	0.000	0.000
2014	9.689	9.883	12.104	15.008
2015	28.453	29.022	35.543	44.072
2016	42.009	42.849	52.478	65.070
2017	52.378	53.426	65.431	81.131
2018	55.608	56.720	69.466	86.134
2019	58.127	59.289	72.612	90.035
2020	63.307	64.573	79.084	98.060
2021	71.177	72.600	88.915	110.249
2022	78.212	79.777	97.704	121.147
2023	86.065	87.787	107.514	133.311
2024	90.618	92.430	113.201	140.362
2025	95.337	97.244	119.096	147.672
2026	95.665	97.578	119.506	148.180
2027	95.851	97.768	119.738	148.467
2028	96.038	97.959	119.972	148.758
2029	96.227	98.152	120.208	149.051
2030	96.418	98.346	120.446	149.346

Table 6-5: Annual Transfer Volumes Crocodile (West) Abstraction, Phase 2, Scenario 8 (Million m^3/a)

Year	Net Water Requirement	Add Transfer Losses	Gross Water Requirement of Option	
			Boschkop	Vlieëpoort
2008	0.000	0.000	0.000	0.000
2009	0.000	0.000	0.000	0.000
2010	0.000	0.000	0.000	0.000
2011	0.000	0.000	0.000	0.000
2012	0.000	0.000	0.000	0.000
2013	0.000	0.000	0.000	0.000
2014	13.990	14.270	16.464	19.434
2015	44.668	45.562	52.569	62.051
2016	81.321	82.947	95.704	112.967
2017	99.884	101.881	117.550	138.754
2018	104.662	106.755	123.173	145.392
2019	117.523	119.873	138.309	163.258
2020	127.226	129.770	149.728	176.737
2021	135.683	138.396	159.680	188.485
2022	162.257	165.502	190.955	225.401
2023	178.442	182.011	210.003	247.885
2024	183.139	186.802	215.531	254.410
2025	188.004	191.764	221.256	261.168
2026	190.067	193.868	223.683	264.033
2027	190.296	194.102	223.953	264.352
2028	190.525	194.336	224.223	264.670
2029	190.884	194.701	224.645	265.168
2030	191.245	195.070	225.070	265.670

Table 6-6: Annual Transfer Volumes Crocodile (West) Abstraction, Phase 2A, Scenario 8 (Million m³/a)

Year	Net Water Requirement	Add Transfer Losses	Gross Water Requirement of Option	
			Boschkop	Vlieëpoort
2008	0.000	0.000	0.000	0.000
2009	0.000	0.000	0.000	0.000
2010	0.000	0.000	0.000	0.000
2011	0.000	0.000	0.000	0.000
2012	0.000	0.000	0.000	0.000
2013	0.000	0.000	0.000	0.000
2014	13.990	14.270	16.464	19.434
2015	44.668	45.562	52.569	62.051
2016	81.321	82.947	95.704	112.967
2017	99.884	101.881	117.550	138.754
2018	104.662	106.755	123.173	145.392
2019	110.000	112.200	129.455	152.808
2020	110.000	112.200	129.455	152.808
2021	110.000	112.200	129.455	152.808
2022	110.000	112.200	129.455	152.808
2023	110.000	112.200	129.455	152.808
2024	110.000	112.200	129.455	152.808
2025	110.000	112.200	129.455	152.808
2026	110.000	112.200	129.455	152.808
2027	110.000	112.200	129.455	152.808
2028	110.000	112.200	129.455	152.808
2029	110.000	112.200	129.455	152.808
2030	110.000	112.200	129.455	152.808

Table 6-7: Annual Transfer Volumes Crocodile (West) Abstraction , Phase 2B, Scenario (Million m³/a)

Year	Net Water Requirement	Add Transfer Losses	Gross Water Requirement of Option	
			Boschkop	Vlieëpoort
2008	0.000	0.000	0.000	0.000
2009	0.000	0.000	0.000	0.000
2010	0.000	0.000	0.000	0.000
2011	0.000	0.000	0.000	0.000
2012	0.000	0.000	0.000	0.000
2013	0.000	0.000	0.000	0.000
2014	0.000	0.000	0.000	0.000
2015	0.000	0.000	0.000	0.000
2016	0.000	0.000	0.000	0.000
2017	0.000	0.000	0.000	0.000
2018	0.000	0.000	0.000	0.000
2019	7.523	7.673	8.854	10.451
2020	17.226	17.570	20.272	23.929
2021	25.683	26.196	30.225	35.677
2022	52.257	53.302	61.500	72.594
2023	68.442	69.811	80.548	95.077
2024	73.139	74.602	86.075	101.602
2025	78.004	79.564	91.800	108.360
2026	80.067	81.668	94.228	111.225
2027	80.296	81.902	94.498	111.544
2028	80.525	82.136	94.768	111.863
2029	80.884	82.501	95.189	112.360
2030	81.245	82.870	95.615	112.863

Table 6-8: Annual Transfer Volumes Crocodile (West) Abstraction, Phases 2 & 3, Scenario 8 (Million m^3/a)

Year	Net Water Requirement	Add Transfer Losses	Gross Water Requirement of Option	
			Boschkop	Vlieëpoort
2008	0.000	0.000		0.000
2009	0.000	0.000		0.000
2010	0.000	0.000		0.000
2011	0.000	0.000		0.000
2012	0.000	0.000		0.000
2013	0.000	0.000		0.000
2014	12.596	12.848		17.498
2015	44.668	45.562		62.051
2016	81.321	82.947	95.704	
2017	99.884	101.881	117.550	
2018	104.662	106.755	123.173	
2019	117.523	119.873	138.309	
2020	127.226	129.770	149.728	
2021	135.683	138.396	159.680	
2022	162.257	165.502	190.955	
2023	178.442	182.011	210.003	
2024	183.139	186.802	215.531	
2025	188.004	191.764	221.256	
2026	190.067	193.868	223.683	
2027	190.296	194.102	223.953	
2028	190.525	194.336	224.223	
2029	190.884	194.701	224.645	
2030	191.245	195.070	225.070	

6.5.6. River Losses

River losses were determined using information from studies done on the Crocodile River (West). Information on the losses in the Mokolo River is scarce; thus the assumption was made that losses can be expected to be similar to that experienced in the Crocodile River (West). The calculated (expected) losses for each of the rivers based on the releases for the 2030 demand are given in Table 6-9.

Table 6-9: Expected River Losses

Total Water Scheme Requirements	Units	Scenario 8	Scenario 4
Crocodile (Transfer Scheme): River Losses - Dams to Boschkop	Million m^3/a	30.0	22.1
Crocodile (Transfer Scheme): River Losses - Dams to Vlieëpoort	Million m^3/a	70.6	51.0
Mokolo Weir Option: River Losses – Mokolo Dam to abstraction weir	Million m^3/a	9.4	6.9

Losses are considered in calculating the volumes to be released from upstream dams (Gross water requirement) to establish the associated cost of supplying the water at the point of abstraction (refer to Section 6.5.8 for raw water costs assumed for the analysis).

A more detailed investigation of the river losses is currently underway. The findings will be reported on during feasibility stage. Preliminary results however indicate that the loss figures given above are over-stated. Any reduction in the loss figures would favour the Vlieëpoort options due to the shorter transfer distance between the abstraction point and the end users.

6.5.7. River Management

The following costs for river management of the Crocodile River were estimated for the purpose of calculating the URVs. Refer to Supporting Report 4: Dam, Weir and River Engineering (P RSA A000/00/9109)

Table 6-10: Crocodile River Management Costs

Abstraction Site	Initial Capital Cost	Annual Maintenance Cost
Boschkop Weir	R 15,000,000	R 4,500,000
Vlieëpoort Weir	R 70,000,000	R 4,500,000

6.5.8. Raw Water Cost

The raw water cost was assumed to be R2.00/m^3 for the Mokolo System. The Crocodile System has a current allocation of 80 Million m^3 at a cost of R2.00/m^3. Raw water requirements in excess of the 80 Million m^3 were assumed to cost R4.50/m^3 based on the current VRESAP tariff. This rate compensates for the cost of transferring water from the Klip River to the Crocodile River (West) basin. This is a conservative approach that could be refined once more accurate information is available. A reduction in the raw water cost will be to the advantage of the Vlieëpoort abstraction options.

6.5.9. Design Flow

The transfer capacity of the scheme must allow for a continuous downtime period of 18 days per year (105% of AADD) for planned and unplanned closures in accordance with the reliability criteria adopted for the scheme (refer to Section 3). In addition, the storage dam re-fill peak of 120% (emergency peak flow) must be included to enable the storage dams to be re-filled in 90 days following 18 days of downtime. These peak factors will however not be applied simultaneously. Losses were assumed to be 2% of AADD for the Pre-Feasibility stage. Due to the low probability of occurrence of the emergency peak flow, it is not economically viable or practical to size the pipes based on the higher flow rate. The pipe sizing and engineering economic evaluation was therefore based on the reliability design peak flow, incorporating a 1.05 peak factor. Pumps and pipe wall thickness were however selected and priced to be capable of transferring the emergency peak flow rate at a higher flow velocity and pumping head. The design peak flows were calculated as follows:

$Q_{\text{reliability design}} = ((Q_{\text{AAD}} + \text{losses}) \times 1.05)$	Pipe size and economic evaluation
$Q_{\text{emergency peak}} = ((Q_{\text{AAD}} + \text{losses}) \times 1.20)$	Pump selection and pipe wall thickness determination

6.6. Scheme Option Components

The scheme components associated with the Phase 1A options are described in Supporting Report 5: Mokolo River Development Options Report (P RSA A000/00/9209). The investigation recommended that the pipeline from the Mokolo Dam (Option 1: 8-P1A-MD-ID1) be implemented.

The following tables summarise the scheme components included in the evaluation of Scheme Options 3 to 14.

Table 6-11: Summary of Scheme Components - Option 3: 8-P2-TVCD1-DD1

Component	Description	
Phase 1A		
Phase 1A Supporting Report 5: Mokolo River Development Options Report (P RSA A000/00/9209)	Pipeline from Mokolo Dam: Option 1: 8-P1A-MD-ID1	
Phase 2		
Vlieëpoort Weir	Concrete weir and primary desilting	
Abstraction pump station Abstraction pump station, secondary desilting works and balancing dam	6 x 1.1 m^3/s submersible pumps 2 x standby units (stored on site) 4 hours balancing storage	
High lift pump station	Static head Design peak flow (DPF) Dynamic head at DPF Emergency peak flow (EPF) Dynamic head at EPF Power consumption DPF/EPF	: 124 m : 6.5 m^3/s : 282 m : 7.4 m^3/s : 298 m : 21/25 MW
Transfer System Rising main - High lift pump station to Terminal Dam entrance (Node 20)	Diameter Length Flow velocity	: 2100 mm ND : 111.3 km : 1.88 m/s
Link to Terminal Dam 1 (From node 20) Rising main Tunnel section	Diameter Length Size Length	: 2100 mm ND : 0.4 km : 3m x 2.9m portal : 2.8 km
Terminal Dam	18 days storage	
Delivery System Link to Lephalale-Steenbokpan pipeline <15-23> Link to Steenbokpan <25A-25B> Link to Lephalale (Built under Phase 1A) <24-14> Link to Matimba (Built under Phase 1A) <8> Link to Medupi <13>	Diameter Length Diameter Length Diameter Length Diameter Length Diameter Length	: 2300 mm ND : 21.8 km : 2200 mm ND : 13.8 km : 800 mm ND : 22.2 km : 800 mm ND : 1.9 km : 500 mm ND : 1.7 km
End user storage reservoirs (7 of)	9 days storage + user required balancing storage Location: 1. Eskom Terminal Reservoir 2. Sasol Terminal Reservoir 3. Exxaro Terminal Reservoir 4. Medupi Terminal Reservoir 5. Medupi RWR 6. Matimba RWR (Existing) 7. Zeeland RWR	 Supply source: : Crocodile : Crocodile : Crocodile : Crocodile : Mokolo : Mokolo : Mokolo

Table 6-12: Summary of Scheme Components - Option 4: 8-P2-TVCD3-DD3

Component	Description
Phase 1A	
Phase 1A Supporting Report 5: Mokolo River Development Options Report (P RSA A000/00/9209)	Pipeline from Mokolo Dam: Option 1: 8-P1A-MD-ID1
Phase 2	
Vlieëpoort Weir	Concrete weir and primary desilting
Abstraction pump station Abstraction pump station, secondary desilting works and balancing dam	6 x 1.1 m^3/s submersible pumps 2 x standby units (stored on site) 4 hours balancing storage
High lift pump station	Static head : 124 m Design peak flow (DPF) : 6.5 m^3/s Dynamic head at DPF : 282 m Emergency peak flow (EPF) : 7.4 m^3/s Dynamic head at EPF : 298 m Power consumption DPF/EPF : 21/25 MW
Transfer System Rising main - High lift pump station to Terminal Dam entrance (Node 20)	Diameter : 2100 mm ND Length : 111.3 km Flow velocity : 1.88 m/s
Link to Terminal Dam 1 (From node 20) Rising main Tunnel section	Diameter : 2100 mm ND Length : 4.0 km Size : 3m x 2.9m portal Length : 0.7 km
Terminal Dam	18 days storage
Delivery System Link to Lephalale-Steenbokpan pipeline <30-29-17-11-12-13> Link to Steenbokpan <24-25A-25B> Link to Lephalale (Built under Phase 1A) <14> Link to Matimba (Built under Phase 1A) <8>	Diameter : 2300 mm ND Length : 19.3 km Diameter : 2200 mm ND Length : 28.4 km Diameter : 800 mm ND Length : 7.6 km Diameter : 800 mm ND Length : 1.9 km
End user storage reservoirs (7 of)	9 days storage + user required balancing storage Location: Supply source: 1. Eskom Terminal Reservoir : Crocodile 2. Sasol Terminal Reservoir : Crocodile 3. Exxaro Terminal Reservoir : Crocodile 4. Medupi Terminal Reservoir : Crocodile 5. Medupi RWR : Mokolo 6. Matimba RWR (Existing) : Mokolo 7. Zeeland RWR : Mokolo

Table 6-13: Summary of Scheme Components - Option 5: 8-P2-TVCB1-DB1

Component	**Description**
Phase 1A	
Phase 1A Supporting Report 5: Mokolo River Development Options Report (P RSA A000/00/9209)	Pipeline from Mokolo Dam: Option 1: 8-P1A-MD-ID1
Phase 2	
Vlieëpoort Weir	Concrete weir and primary desilting
Abstraction pump station Abstraction pump station, secondary desilting works and balancing dam	6 x 1.1 m^3/s submersible pumps 2 x standby units (stored on site) 4 hours balancing storage
High lift pump station	Static head : 95 m Design peak flow (DPF) : 6.5 m^3/s Dynamic head at DPF : 235 m Emergency peak flow (EPF) : 7.4 m^3/s Dynamic head at EPF : 247 m Power consumption DPF/EPF : 17/21 MW
Transfer System Rising main - High lift pump station to break pressure reservoir (Node 15)	Diameter : 2100 mm ND Length : 97.9 km Flow velocity : 1.88 m/s
Balancing Reservoir	24 hours storage
Delivery System Link to Lephalale-Steenbokpan pipeline <31> Link to Steenbokpan <25B> Link to Lephalale (Built under Phase 1A) <25A-24-14> Link to Matimba (Built under Phase 1A) <8> Link to Medupi <13>	Diameter : 2300 mm ND Length : 24.8 km Diameter : 2200 mm ND Length : 5.1 km Diameter : 800 mm ND Length : 30.9 km Diameter : 800 mm ND Length : 1.9 km Diameter : 500 mm ND Length : 1.7 km
End user storage reservoirs (7 of)	18 days storage + user required balancing storage Location: Supply source: 1. Eskom Terminal Reservoir : Crocodile 2. Sasol Terminal Reservoir : Crocodile 3. Exxaro Terminal Reservoir : Crocodile 4. Medupi Terminal Reservoir : Crocodile 5. Medupi RWR : Mokolo 6. Matimba RWR (Existing) : Mokolo 7. Zeeland RWR : Mokolo

Table 6-14: Summary of Scheme Components - Option 6: 8-P2-TVWB1-DB1

Component	**Description**
Phase 1A	
Phase 1A Supporting Report 5: Mokolo River Development Options Report (P RSA A000/00/9209)	Pipeline from Mokolo Dam: Option 1: 8-P1A-MD-ID1
Phase 2	
Vlieëpoort Weir	Concrete weir and primary desilting
Abstraction pump station Abstraction pump station, secondary desilting works and balancing dam	6 x 1.1 m^3/s submersible pumps 2 x standby units (stored on site) 4 hours balancing storage
High lift pump station	Static head : 95 m Design peak flow (DPF) : 6.5 m^3/s Dynamic head at DPF : 242 m Emergency peak flow (EPF) : 7.4 m^3/s Dynamic head at EPF : 255 m Power consumption DPF/EPF : 18/22 MW
Transfer System Rising main - High lift pump station to break pressure reservoir (Node 15)	Diameter : 2100 mm ND Length : 103.2 km Flow velocity : 1.88 m/s
Balancing Reservoir	24 hours storage
Delivery System Link to Lephalale-Steenbokpan pipeline <31> Link to Steenbokpan <25B> Link to Lephalale (Built under Phase 1A) <25A-24-14> Link to Matimba (Built under Phase 1A) <8> Link to Medupi <13>	Diameter : 2300 mm ND Length : 24.8 km Diameter : 2200 mm ND Length : 5.1 km Diameter : 800 mm ND Length : 30.9 km Diameter : 800 mm ND Length : 1.9 km Diameter : 500 mm ND Length : 1.7 km
End user storage reservoirs (7 of)	18 days storage + user required balancing storage Location: Supply source: 1. Eskom Terminal Reservoir : Crocodile 2. Sasol Terminal Reservoir : Crocodile 3. Exxaro Terminal Reservoir : Crocodile 4. Medupi Terminal Reservoir : Crocodile 5. Medupi RWR : Mokolo 6. Matimba RWR (Existing) : Mokolo 7. Zeeland RWR : Mokolo

Table 6-15: Summary of Scheme Components - Option 7: 8-P2-TBCB1-DB1

Component	Description
Phase 1A	
Phase 1A Supporting Report 5: Mokolo River Development Options Report (P RSA A000/00/9209)	Pipeline from Mokolo Dam: Option 1: 8-P1A-MD-ID1
Phase 2	
Boschkop Weir	Concrete weir and primary desilting
Abstraction pump station Abstraction pump station, secondary desilting works and balancing dam	6 x 1.1 m^3/s submersible pumps 2 x standby units (stored on site) 4 hours balancing storage
High lift pump station	Static head : 65 m Design peak flow (DPF) : 6.5 m^3/s Dynamic head at DPF : 281 m Emergency peak flow (EPF) : 7.4 m^3/s Dynamic head at EPF : 290 m Power consumption DPF/EPF : 21/25 MW
Transfer System Rising main - High lift pump station to break pressure reservoir (Node 15)	Diameter : 2100 mm ND Length : 144.6 km Flow velocity : 1.88 m/s
Balancing Reservoir	24 hours storage
Delivery System Link to Lephalale-Steenbokpan pipeline <31> Link to Steenbokpan <25B> Link to Lephalale (Built under Phase 1A) <25A-24-14> Link to Matimba (Built under Phase 1A) <8> Link to Medupi <13>	Diameter : 2300 mm ND Length : 24.8 km Diameter : 2200 mm ND Length : 5.1 km Diameter : 800 mm ND Length : 30.9 km Diameter : 800 mm ND Length : 1.9 km Diameter : 500 mm ND Length : 1.7 km
End user storage reservoirs (7 of)	18 days storage + user required balancing storage Location: Supply source: 1. Eskom Terminal Reservoir : Crocodile 2. Sasol Terminal Reservoir : Crocodile 3. Exxaro Terminal Reservoir : Crocodile 4. Medupi Terminal Reservoir : Crocodile 5. Medupi RWR : Mokolo 6. Matimba RWR (Existing) : Mokolo 7. Zeeland RWR : Mokolo

Table 6-16: Summary of Scheme Components - Option 8: 8-P2-TBEB1-DB1

Component	Description
Phase 1A	
Phase 1A Supporting Report 5: Mokolo River Development Options Report (P RSA A000/00/9209)	Pipeline from Mokolo Dam: Option 1: 8-P1A-MD-ID1
Phase 2	
Boschkop Weir	Concrete weir and primary desilting
Abstraction pump station Abstraction pump station, secondary desilting works and balancing dam	6 x 1.1 m^3/s submersible pumps 2 x standby units (stored on site) 4 hours balancing storage
High lift pump station	Static head : 65 m Design peak flow (DPF) : 6.5 m^3/s Dynamic head at DPF : 291 m Emergency peak flow (EPF) : 7.4 m^3/s Dynamic head at EPF : 305 m Power consumption DPF/EPF : 22/26 MW
Transfer System Rising main - High lift pump station to break pressure reservoir (Node 15)	Diameter : 2100 mm ND Length : 153.6 km Flow velocity : 1.88 m/s
Balancing Reservoir	24 hours storage
Delivery System Link to Lephalale-Steenbokpan pipeline <31> Link to Steenbokpan <25B> Link to Lephalale (Built under Phase 1A) <25A-24-14> Link to Matimba (Built under Phase 1A) <8> Link to Medupi <13>	Diameter : 2300 mm ND Length : 24.8 km Diameter : 2200 mm ND Length : 5.1 km Diameter : 800 mm ND Length : 30.9 km Diameter : 800 mm ND Length : 1.9 km Diameter : 500 mm ND Length : 1.7 km
End user storage reservoirs (7 of)	18 days storage + user required balancing storage Location: Supply source: 1. Eskom Terminal Reservoir : Crocodile 2. Sasol Terminal Reservoir : Crocodile 3. Exxaro Terminal Reservoir : Crocodile 4. Medupi Terminal Reservoir : Crocodile 5. Medupi RWR : Mokolo 6. Matimba RWR (Existing) : Mokolo 7. Zeeland RWR : Mokolo

Table 6-17: Summary of Scheme Components - Option 9: 8-P2A-TVCB1-DB1

Component	Description
Phase 1A	
Phase 1A Supporting Report 5: Mokolo River Development Options Report (P RSA A000/00/9209)	Pipeline from Mokolo Dam: Option 1: 8-P1A-MD-ID1
Phase 2	
Weir	Concrete weir and primary desilting
Abstraction pump station Abstraction pump station, secondary desilting works and balancing dam	4 x 1.1 m^3/s submersible pumps 2 x standby units (stored on site) 4 hours of ultimate flow balancing storage
High lift pump station	Static head : 95 m Design peak flow (DPF) : 3.7 m^3/s Dynamic head at DPF : 256 m Emergency peak flow (EPF) : 4.3 m^3/s Dynamic head at EPF : 293 m Power consumption DPF/EPF : 11/14 MW
Transfer System Rising main - High lift pump station to break pressure reservoir (Node 15)	Diameter : 1600 mm ND Length : 97.9 km Flow velocity : 1.86 m/s
Balancing Reservoir	24 hours storage
Delivery System Link to Lephalale-Steenbokpan pipeline <31> Link to Steenbokpan <25B> Link to Lephalale (Built under Phase 1A) <25A-24-14> Link to Matimba (Built under Phase 1A) <8> Link to Medupi <13>	Diameter : 2300 mm ND Length : 24.8 km Diameter : 2200 mm ND Length : 5.1 km Diameter : 800 mm ND Length : 30.9 km Diameter : 800 mm ND Length : 1.9 km Diameter : 500 mm ND Length : 1.7 km
End user storage reservoirs (7 of)	18 days storage + user required balancing storage Location: Supply source: 1. Eskom Terminal Reservoir : Crocodile 2. Sasol Terminal Reservoir : Crocodile 3. Exxaro Terminal Reservoir : Crocodile 4. Medupi Terminal Reservoir : Crocodile 5. Medupi RWR : Mokolo 6. Matimba RWR (Existing) : Mokolo 7. Zeeland RWR : Mokolo

Table 6-18: Summary of Scheme Components - Option 11: 8-P2A&B-TVCB1-DB1

Component	Description
Phase 1A	
Phase 1A Supporting Report 5: Mokolo River Development Options Report (P RSA A000/00/9209)	Pipeline from Mokolo Dam: Option 1: 8-P1A-MD-ID1
Phase 2A	
Vlieëpoort Weir	Concrete weir and primary desilting
Abstraction pump station Abstraction pump station, secondary desilting works and balancing dam	4 x 1.1 m^3/s submersible pumps 2 x standby units (stored on site) 4 hours balancing storage (of ultimate flow rate)
High lift pump station	Static head : 95 m Design peak flow (DPF) : 3.7 m^3/s Dynamic head at DPF : 256 m Emergency peak flow (EPF) : 4.3 m^3/s Dynamic head at EPF : 293 m Power consumption DPF/EPF : 11/14 MW
Transfer System Rising main - High lift pump station to break pressure reservoir (Node 15)	Diameter : 1600 mm ND Length : 97.9 km Flow velocity : 1.86 m/s
Balancing Reservoir	24 hours storage of ultimate
Delivery System (Sized for ultimate) Link to Lephalale-Steenbokpan pipeline <31> Link to Steenbokpan <25B> Link to Lephalale (Built under Phase 1A) <25A-24-14> Link to Matimba (Built under Phase 1A) <8> Link to Medupi <13>	Diameter : 2300 mm ND Length : 24.8 km Diameter : 2200 mm ND Length : 5.1 km Diameter : 800 mm ND Length : 30.9 km Diameter : 800 mm ND Length : 1.9 km Diameter : 500 mm ND Length : 1.7 km
End user storage reservoirs (7 of)	18 days storage + user required balancing storage Location: Supply source: 1. Eskom Terminal Reservoir : Crocodile 2. Sasol Terminal Reservoir : Crocodile 3. Exxaro Terminal Reservoir : Crocodile 4. Medupi Terminal Reservoir : Crocodile 5. Medupi RWR : Mokolo 6. Matimba RWR (Existing) : Mokolo 7. Zeeland RWR : Mokolo

Component	Description
Phase 2B	
Abstraction pump station Additional abstraction	+2 x 1.1 m^3/s submersible pumps 2 x standby units (stored on site) 4 hours balancing storage (of ultimate flow rate)
High lift pump station	Static head : 95 m Design peak flow (DPF) : 2.8 m^3/s Dynamic head at DPF : 270 m Emergency peak flow (EPF) : 3.2 m^3/s Dynamic head at EPF : 309 m Power consumption DPF/EPF : 9/11 MW
Transfer System Rising main - High lift pump station to Terminal Dam entrance (Node 20)	Diameter : 1400 mm ND Length : 97.9km Flow velocity : 1.8 m/s

Table 6-19: Summary of Scheme Components - Option 12: 8-P3-TBVCB1-DB1

Component	Description
Phase 1A	
Phase 1A Supporting Report 5: Mokolo River Development Options Report (P RSA A000/00/9209)	Pipeline from Mokolo Dam: Option 1: 8-P1A-MD-ID1
Phase 2	
Vlieëpoort Weir	Concrete weir and primary desilting
Abstraction pump station Abstraction pump station, secondary desilting works and balancing dam	6 x 1.1 m^3/s submersible pumps 2 x standby units (stored on site) 4 hours balancing storage
High lift pump station	Static head : 95 m Design peak flow (DPF) : 6.5 m^3/s Dynamic head at DPF : 270 m Emergency peak flow (EPF) : 7.4 m^3/s Dynamic head at EPF : 247 m Power consumption DPF/EPF : 18/21MW
Transfer System Rising main - High lift pump station to break pressure reservoir (Node 15)	Diameter : 2100 mm ND Length : 97.6 km Flow velocity : 1.88 m/s
Balancing Reservoir	24 hours storage of ultimate
Delivery System (Sized for ultimate) Link to Lephalale-Steenbokpan pipeline <31> Link to Steenbokpan <25B> Link to Lephalale (Built under Phase 1A) <25A-24-14> Link to Matimba (Built under Phase 1A) <8> Link to Medupi <13>	Diameter : 2300 mm ND Length : 24.8 km Diameter : 2200 mm ND Length : 5.1 km Diameter : 800 mm ND Length : 30.9 km Diameter : 800 mm ND Length : 1.9 km Diameter : 500 mm ND Length : 1.7 km

Component	Description
End user storage reservoirs (7 of)	18 days storage + user required balancing storage Location: Supply source: 1. Eskom Terminal Reservoir : Crocodile 2. Sasol Terminal Reservoir : Crocodile 3. Exxaro Terminal Reservoir : Crocodile 4. Medupi Terminal Reservoir : Crocodile 5. Medupi RWR : Mokolo 6. Matimba RWR (Existing) : Mokolo 7. Zeeland RWR : Mokolo
Phase 3	
Boschkop Weir	Concrete weir and primary desilting
Abstraction pump station Abstraction pump station, secondary desilting works and balancing dam	6 x 1.1 m^3/s submersible pumps 2 x standby units (stored on site) 4 hrs balancing storage
High lift pump station	Static head : -30 m Design peak flow (DPF) : 6.5 m^3/s Dynamic head at DPF : 96 m Emergency peak flow (EPF) : 7.4 m^3/s Dynamic head at EPF : 112 m Power consumption DPF/EPF : 7/9 MW
Transfer System (Boschkop – Vlieëpoort) Rising main – Boschkop High lift pump station to Vlieepoort boosting station	Diameter : 2100 mm ND Length : 70.5 km Flow velocity : 1.88 m/s

Table 6-20: Summary of Scheme Components - Option 13: 4-P2-TBCB1-DB1

Component	**Description**
Phase 1A	
Phase 1A Supporting Report 5: Mokolo River Development Options Report (P RSA A000/00/9209)	Pipeline from Mokolo Dam: Option 1: 8-P1A-MD-ID1
Phase 2	
Boschkop Weir	Concrete weir and primary desilting
Abstraction pump station Abstraction pump station, secondary desilting works and balancing dam	4x 1 m^3/s submersible pumps 2 x standby units (stored on site) 4 hours balancing storage
High lift pump station	Static head : 65 m Design peak flow (DPF) : 3.3 m^3/s Dynamic head at DPF : 314 m Emergency peak flow (EPF) : 3.7 m^3/s Dynamic head at EPF : 375 m Power consumption DPF/EPF : 12/16 MW
Transfer System Rising main - High lift pump station to break pressure reservoir (Node 15)	Diameter : 1500 mm ND Length : 144.6 km Flow velocity : 1.86 m/s
Balancing Reservoir	24 hours storage
Delivery System Link to Lephalale-Steenbokpan pipeline <31> Link to Steenbokpan <25B> Link to Lephalale (Built under Phase 1A) <25A-24-14> Link to Matimba (Built under Phase 1A) <8> Link to Medupi <13>	Diameter : 1700 mm ND Length : 24.8 km Diameter : 1500 mm ND Length : 5.1 km Diameter : 800 mm ND Length : 30.9 km Diameter : 800 mm ND Length : 1.9 km Diameter : 500 mm ND Length : 1.7 km
End user storage reservoirs (7 of)	18 days storage + user required balancing storage Location: Supply source: 1. Eskom Terminal Reservoir : Crocodile 2. Sasol Terminal Reservoir : Crocodile 3. Exxaro Terminal Reservoir : Crocodile 4. Medupi Terminal Reservoir : Crocodile 5. Medupi RWR : Mokolo 6. Matimba RWR (Existing) : Mokolo 7. Zeeland RWR : Mokolo

Table 6-21: Summary of Scheme Components - Option 14: 4-P2-TVCB1-DB1

Component	Description
Phase 1A	
Phase 1A Supporting Report 5: Mokolo River Development Options Report (P RSA A000/00/9209)	Pipeline from Mokolo Dam: Option 1: 8-P1A-MD-ID1
Phase 2	
Vlieëpoort Weir	Concrete weir and primary desilting
Abstraction pump station Abstraction pump station, secondary desilting works and balancing dam	4 x 1.0m^3/s submersible pumps 2 x standby units (stored on site) 4 hours balancing storage
High lift pump station	Static head : 95 m Design peak flow (DPF) : 3.3 m^3/s Dynamic head at DPF : 267 m Emergency peak flow (EPF) : 3.7 m^3/s Dynamic head at EPF : 306 m Power consumption DPF/EPF : 10/13 MW
Transfer System Rising main - High lift pump station to break pressure reservoir (Node 15)	Diameter : 1500 mm ND Length : 97.9 km Flow velocity : 1.86 m/s
Balancing Reservoir	24 hours storage
Delivery System Link to Lephalale-Steenbokpan pipeline <31> Link to Steenbokpan <25B> Link to Lephalale (Built under Phase 1A) <25A-24-14> Link to Matimba (Built under Phase 1A) <8> Link to Medupi <13>	Diameter : 1700 mm ND Length : 24.8 km Diameter : 1500 mm ND Length : 5.1 km Diameter : 800 mm ND Length : 30.9 km Diameter : 800 mm ND Length : 1.9 km Diameter : 500 mm ND Length : 1.7 km
End user storage reservoirs (7 of)	18 days storage + user required balancing storage Location: Supply source: 1. Eskom Terminal Reservoir : Crocodile 2. Sasol Terminal Reservoir : Crocodile 3. Exxaro Terminal Reservoir : Crocodile 4. Medupi Terminal Reservoir : Crocodile 5. Medupi RWR : Mokolo 6. Matimba RWR (Existing) : Mokolo 7. Zeeland RWR : Mokolo

7. CAPITAL COST AND ENGINEERING ECONOMIC ANALYSIS

7.1. Capital Cost

The tables below summarise the capital cost for the options compared. The capital cost includes landscaping, miscellaneous, P & G, contingencies and design fees, but excludes VAT. The base date for all costs is March 2008.

7.2. Operation and Maintenance (O&M) costs

Annual Operation and Maintenance (O&M) costs are based on percentages of capital cost as per the VAPS guidelines accepted for this study, and are calculated as follows:

- 0.5% of pipeline capital cost per annum.
- 4% of the electrical and mechanical installation of a pump station per annum
- 15% of the initial capital cost of pump and motors every 15 years for major overhaul
- 0.25% of the capital cost of civil structures, including the civil portion of pump stations per annum.
- Apart from the capital investment every 15 years on mechanical components, the cost of replacement infrastructure, land acquisition, design and supervision fees were excluded from the calculated O&M costs.
- Electrical costs were based on the Megaflex tariff structure.

The annual O&M costs, when the scheme is operating at maximum capacity (2030), excluding overhaul costs of pump stations and VAT, are listed in the following tables for each scheme option.

7.3. Present Value

The present value calculations are included in **Appendix C** and summarised in the tables below for each scheme option. The detailed calculations of only two (2) options are included in **Appendix C**. The economic life of all components was taken as 45 years.

7.4. Unit Reference Values (URVs)

The URVs of water has been determined for a discount rate of 6%, 8% and 10% and is based on water transferred to the demand centres for a 45 year period. The URV is not the tariff for the water transferred and is only used to compare options with one another. The results are indicated in the tabled below for each scheme option.

A comprehensive summary result is given in Table 7-45.

7.5. System Costing

The costing of the above components for each option is summarised in the following tables. The option number and description of each option is as per Table 6-2.

7.5.1. Results - Option 3: 8-P2-TVCD1-DD1

Table 7-1: Breakdown of Capital Cost for Option 3: <8-P2-TVCD1-DD1>

Component	**Total (R)**
Pump Station (Peak Pumping Head 298.5 m)	428,621,000
Terminal Dam or Balancing Reservoir	224,912,000
Rising Main	
2100 mm Ø Rising Main	6,569,243,000
Weir	275,013,000
Tunnel	130,385,000
Total Crocodile Transfer System	**7,628,174,000**
Total Crocodile Delivery System (Gravity Delivery Pipes and 9 Day End User On Site Storage)	2,745,097,000
Total Mokolo System (Phase 1A)	1,445,195,000
Total Combined Scheme Cost	**11,818,466,000**

Including P&G's, Contingencies & Fees. Excluding VAT. Base date: March 2008.

Table 7-2: Breakdown of Annual O&M Costs for Option 3: <8-P2-TVCD1-DD1>

Component	**Total (R)**
Pump Station	
Civil	129,000
Mechanical and Electrical Maintenance	4,808,000
Electricity	95,645,000
Rising Main	
2100 mm Ø Rising Main	15,773,000
Weir	2,560,000
Tunnel	244,000
Terminal Dam or Rising Main	623,000
Raw Water Costs	1,058,134,000
River Management Costs	4,500,000
Total Annual O&M - Crocodile Transfer System	**1,182,416,000**
Total Annual O&M - Crocodile Delivery System	10,488,000
Total Annual O&M - Mokolo System	81,173,000
Total Annual Combined O&M Cost	**1,274,077,000**

Table 7-3: Summary of Discounted PVs for Option 3: <8-P2-TVCD1-DD1> (Total Scheme)

Discount Rate	**Capital (R)**	**O & M (R)**	**Total (R)**
6%	9,739,567,000	11,967,274,000	21,706,841,000
8%	9,159,252,000	8,175,075,000	17,334,327,000
10%	8,627,314,000	5,842,738,000	14,470,052,000

Table 7-4: URVs for Option 3: <8-P2-TVCD1-DD1> (Total Scheme)

Discount Rate	Discounted Present Value of Water @ R1/m^3	Discounted Present Value (R)	URV (R/m^3)
6%	2,149	21,706,841,000	10.102
8%	1,484	17,334,327,000	11.679
10%	1,073	14,470,053,000	13.481

7.5.2. Results – Option 4: 8-P2-TVCD3-DD3

Table 7-5: Breakdown of Capital Cost for Option 4: <8-P2-TVCD3-DD3>

Component	Total (R)
Pump Station (Peak Pumping Head 298.5 m)	428,621,000
Terminal Dam or Balancing Reservoir	276,496,000
Rising Main	
2100 mm Ø Rising Main	6,569,243,000
Weir	275,013,000
Tunnel	36,900,000
Total Crocodile Transfer System	**7,586,273,000**
Total Crocodile Delivery System (Gravity Delivery Pipes and 9 Day End User On Site Storage)	3,308,867,000
Total Mokolo System (Phase 1A)	1,445,195,000
Total Combined Scheme Cost	**12,340,335,000**

Including P&G's, Contingencies & Fees. Excluding VAT. Base date: March 2008.

Table 7-6: Breakdown of Annual O&M Costs for Option 4: <8-P2-TVCD3-DD3>

Component	Total (R)
Pump Station	
Civil	129,000
Mechanical and Electrical Maintenance	4,808,000
Electricity	95,645,000
Rising Main	
2100 mm Ø Rising Main	15,773,000
Weir	2,560,000
Tunnel	65,000
Terminal Dam or Rising Main	767,000
Raw Water Costs	1,058,134,000
River Management Costs	4,500,000
Total Annual O&M - Crocodile Transfer System	**1,182,381,000**
Total Annual O&M - Crocodile Delivery System	12,939,000
Total Annual O&M - Mokolo System	81,173,000
Total Annual Combined O&M Cost	**1,276,493,000**

Table 7-7: Summary of discounted PVs for Option 4: <8-P2-TVCD3-DD3> (Total Scheme)

Discount Rate	Capital (R)	O & M (R)	Total (R)
6%	10,190,424,000	11,983,098,000	22,173,522,000
8%	9,589,530,000	8,183,809,000	17,773,339,000
10%	9,038,345,000	5,847,214,000	14,885,559,000

Table 7-8: URVs for Option 4: <8-P2-TVCD3-DD3> (Total Scheme)

Discount Rate	Discounted Present Value of Water @ R1/m^3	Discounted Present Value (R)	URV (R/m^3)
6%	2,149	22,173,522,000	10.319
8%	1,484	17,773,339,000	11.975
10%	1,073	14,885,559,000	13.868

7.5.3. Results – Option 5: 8-P2-TVCB1-DB1

Table 7-9: Breakdown of Capital Cost for Option 5: <8-P2-TVCB1-DB1>

Component	Total (R)
Pump Station (Peak Pumping Head 247.05 m)	381,938,000
Terminal Dam or Balancing Reservoir	76,482,000
Rising Main	
2100 mm Ø Rising Main	5,134,677,000
Weir	275,013,000
Total Crocodile Transfer System	**5,868,110,000**
Total Crocodile Delivery System (Gravity Delivery Pipes and 18 Day End User On Site Storage)	2,916,657,000
Total Mokolo System (Phase 1A)	1,445,195,000
Total Combined Scheme Cost	**10,229,962,000**

Including P&G's, Contingencies & Fees. Excluding VAT. Base date: March 2008.

Table 7-10: Breakdown of Annual O&M Costs for Option 5: <8-P2-TVCB1-DB1>

Component	Total (R)
Pump Station	
Civil	112,000
Mechanical and Electrical Maintenance	4,187,000
Electricity	79,692,000
Rising Main	
2100 mm Ø Rising Main	12,312,000
Weir	2,560,000
Terminal Dam or Rising Main	213,000
Raw Water Costs	1,058,134,000
River Management Costs	4,500,000
Total Annual O&M - Crocodile Transfer System	**1,161,710,000**
Total Annual O&M - Crocodile Delivery System	10,515,000
Total Annual O&M - Mokolo System	81,173,000
Total Annual Combined O&M Cost	**1,253,398,000**

Table 7-11: Summary of Discounted PVs for Option 5: <8-P2-TVCB1-DB1> (Total Scheme)

Discount Rate	Capital (R)	O & M (R)	Total (R)
6%	8,412,536,000	11,764,276,000	20,176,812,000
8%	7,905,901,000	8,035,558,000	15,941,459,000
10%	7,441,844,000	5,742,629,000	13,184,473,000

Table 7-12: URVs for Option 5: <8-P2-TVCB1-DB1> (Total Scheme)

Discount Rate	Discounted Present Value of Water @ R1/m^3	Discounted Present Value (R)	URV (R/m^3)
6%	2,149	20,176,811,000	9.390
8%	1,484	15,941,460,000	10.741
10%	1,073	13,184,473,000	12.283

7.5.4. Results – Option 6: 8-P2-TVWB1-DB1

Table 7-13: Breakdown of Capital Cost for Option 6: <8-P2-TVWB1-DB1>

Component	Total (R)
Pump Station (Peak Pumping Head 255.05 m)	402,990,000
Terminal Dam or Balancing Reservoir	76,482,000
Rising Main	
2100 mm Ø Rising Main	5,405,099,000
Weir	275,013,000
Total Crocodile Transfer System	**6,159,584,000**
Total Crocodile Delivery System (Gravity Delivery Pipes and 18 Day End User On Site Storage)	2,916,657,000
Total Mokolo System (Phase 1A)	1,445,195,000
Total Combined Scheme Cost	**10,521,436,000**

Including P&G's, Contingencies & Fees. Excluding VAT. Base date: March 2008.

Table 7-14: Breakdown of Annual O&M Costs for Option 6: <8-P2-TVWB1-DB1>

Component	Total (R)
Pump Station	
Civil	115,000
Mechanical and Electrical Maintenance	4,286,000
Electricity	81,891,000
Rising Main	
2100 mm Ø Rising Main	12,965,000
Weir	2,560,000
Terminal Dam or Rising Main	213,000
Raw Water Costs	1,058,134,000
River Management Costs	4,500,000
Total Annual O&M - Crocodile Transfer System	**1,164,664,000**
Total Annual O&M - Crocodile Delivery System	10,515,000
Total Annual O&M - Mokolo System	81,173,000
Total Annual Combined O&M Cost	**1,256,352,000**

Table 7-15: Summary of Discounted PVs for Option 6: <8-P2-TVWB1-DB1> (Total Scheme)

Discount Rate	Capital (R)	O & M (R)	Total (R)
6%	8,639,548,000	11,793,191,000	20,432,739,000
8%	8,118,853,000	8,055,400,000	16,174,253,000
10%	7,641,931,000	5,756,837,000	13,398,768,000

Table 7-16: URVs for Option 6: <8-P2-TVWB1-DB1> (Total Scheme)

Discount Rate	Discounted Present Value of Water @ R1/m^3	Discounted Present Value (R)	URV (R/m^3)
6%	2,149	20,432,739,000	9.509
8%	1,484	16,174,252,000	10.898
10%	1,073	13,398,767,000	12.483

7.5.5. Results – Option 7: 8-P2-TBCB1-DB1

Table 7-17: Breakdown of Capital Cost for Option 7: <8-P2-TBCB1-DB1>

Component	Total (R)
Pump Station (Peak Pumping Head 290.46 m)	401,645,000
Terminal Dam or Balancing Reservoir	76,482,000
Rising Main	
2100 mm Ø Rising Main	8,570,543,000
Weir	317,889,000
Total Crocodile Transfer System	**9,366,559,000**
Total Crocodile Delivery System (Gravity Delivery Pipes and 18 Day End User On Site Storage)	2,916,657,000
Total Mokolo System (Phase 1A)	1,445,195,000
Total Combined Scheme Cost	**13,728,411,000**

Including P&G's, Contingencies & Fees. Excluding VAT. Base date: March 2008.

Table 7-18: Breakdown of annual O&M costs for option 7: <8-P2-TBCB1-DB1>

Component	Total (R)
Pump Station	
Civil	126,000
Mechanical and Electrical Maintenance	4,713,000
Electricity	95,081,000
Rising Main	
2100 mm Ø Rising Main	20,576,000
Weir	2,680,000
Terminal Dam or Rising Main	213,000
Raw Water Costs	875,434,000
River Management Costs	4,500,000
Total Annual O&M - Crocodile Transfer System	**1,003,323,000**
Total Annual O&M - Crocodile Delivery System	10,515,000
Total Annual O&M - Mokolo System	81,173,000
Total Annual Combined O&M Cost	**1,095,011,000**

Table 7-19: Summary of discounted PVs for Option 7: <8-P2-TBCB1-DB1> (Total Scheme)

Discount Rate	Capital (R)	O & M (R)	Total (R)
6%	11,269,927,000	10,358,054,000	21,627,981,000
8%	10,585,844,000	7,091,614,000	17,677,458,000
10%	9,959,417,000	5,080,815,000	15,040,232,000

Table 7-20: URVs for option 7: <8-P2-TBCB1-DB1> (Total scheme)

Discount Rate	Discounted Present Value of Water @ R1/m^3	Discounted Present Value (R)	URV (R/m^3)
6%	2,149	21,627,981,000	10.065
8%	1,484	17,677,458,000	11.910
10%	1,073	15,040,232,000	14.012

7.5.6. Results – Option 8: 8-P2-TBEB1-DB1

Table 7-21: Breakdown of Capital Cost for Option 8: <8-P2-TBEB1-DB1>

Component	Total (R)
Pump Station (Peak Pumping Head 305.16 m)	414,409,000
Terminal Dam or Balancing Reservoir	76,482,000
Rising Main	
2100 mm Ø Rising Main	9,026,090,000
Weir	317,889,000
Total Crocodile Transfer System	**9,834,870,000**
Total Crocodile Delivery System (Gravity Delivery Pipes and 18 Day End User On Site Storage)	2,916,657,000
Total Mokolo System (Phase 1A)	1,445,195,000
Total Combined Scheme Cost	**14,196,722,000**

Including P&G's, Contingencies & Fees. Excluding VAT. Base date: March 2008.

Table 7-22: Breakdown of Annual O&M Costs for Option 8: <8-P2-TBEB1-DB1>

Component	Total (R)
Pump Station	
Civil	131,000
Mechanical and Electrical Maintenance	4,886,000
Electricity	98,429,000
Rising Main	
2100 mm Ø Rising Main	21,658,000
Weir	2,680,000
Terminal Dam or Rising Main	213,000
Raw Water Costs	875,434,000
River Management Costs	4,500,000
Total Annual O&M - Crocodile Transfer System	**1,007,931,000**
Total Annual O&M - Crocodile Delivery System	10,515,000
Total Annual O&M - Mokolo System	81,173,000
Total Annual Combined O&M Cost	**1,099,619,000**

Table 7-23: Summary of Discounted PVs for Option 8: <8-P2-TBEB1-DB1> (Total Scheme)

Discount Rate	Capital (R)	O & M (R)	Total (R)
6%	11,652,767,000	10,403,357,000	22,056,124,000
8%	10,944,969,000	7,122,733,000	18,067,702,000
10%	10,296,846,000	5,103,124,000	15,399,970,000

Table 7-24: URVs for Option 8: <8-P2-TBEB1-DB1> (Total Scheme)

Discount Rate	Discounted Present Value of Water @ R1/m^3	Discounted Present Value (R)	URV (R/m^3)
6%	2,149	22,056,123,000	10.264
8%	1,484	18,067,702,000	12.173
10%	1,073	15,399,970,000	14.347

7.5.7. Results - Option 9: 8-P2A-TVCB1-DB1

Table 7-25: Breakdown of Capital Cost for Option 9: <8-P2A-TVCB1-DB1>

Component	Total (R)
Pump Station (Peak Pumping Head 293.19 m)	305,919,000
Terminal Dam or Balancing Reservoir	76,482,000
Rising Main	
1600 mm Ø Rising Main	3,659,317,000
Weir	257,073,000
Total Crocodile Transfer System	**4,298,791,000**
Total Crocodile Delivery System (Gravity Delivery Pipes and 18 Day End User On Site Storage)	2,916,657,000
Total Mokolo System (Phase 1A)	1,445,195,000
Total Combined Scheme Cost	**8,660,643,000**

Including P&G's, Contingencies & Fees. Excluding VAT. Base date: March 2008.

Table 7-26: Breakdown of Annual O&M Costs for Option 9: <8-P2A-TVCB1-DB1>

Component	Total (R)
Pump Station	
Civil	85,000
Mechanical and Electrical Maintenance	3,168,000
Electricity	49,925,000
Rising Main	
1600 mm Ø Rising Main	8,737,000
Weir	2,110,000
Terminal Dam or Rising Main	213,000
Raw Water Costs	550,251,000
River Management Costs	4,500,000
Total Annual O&M - Crocodile Transfer System	**618,989,000**
Total Annual O&M - Crocodile Delivery System	10,515,000
Total Annual O&M - Mokolo System	81,173,000
Total Annual Combined O&M Cost	**710,677,000**

Table 7-27: Summary of discounted PVs for Option 9: <8-P2A-TVCB1-DB1> (Total Scheme)

Discount Rate	Capital (R)	O & M (R)	Total (R)
6%	7,130,192,000	7,956,016,000	15,086,208,000
8%	6,703,339,000	5,643,609,000	12,346,948,000
10%	6,312,222,000	4,182,175,000	10,494,397,000

Table 7-28: URVs for Option 9: <8-P2A-TVCB1-DB1> (Total Scheme)

Discount Rate	Discounted Present Value of Water @ R1/m^3	Discounted Present Value (R)	URV (R/m^3)
6%	1,582	15,086,208,000	9.534
8%	1,129	12,346,948,000	10.934
10%	842	10,494,397,000	12.458

7.5.8. Results - Option 11: 8-P2A&B-TVCB1-DB1

Table 7-29: Breakdown of Capital Cost for Option 11: <8-P2A&B-TVCB1-DB1>

Component	Total (R)
Pump Station (Peak Pumping Head 293.19/309.36 m)	525,807,000
Terminal Dam or Balancing Reservoir	76,482,000
Rising Main	
1600/1mm Ø Rising Main	6,478,192,000
Weir	257,073,000
Total Crocodile Transfer System	**7,337,554,000**
Total Crocodile Delivery System (Gravity Delivery Pipes and 18 Day End User On Site Storage)	2,916,657,000
Total Mokolo System (Phase 1A)	1,445,195,000
Total Combined Scheme Cost	**11,699,406,000**

Including P&G's, Contingencies & Fees. Excluding VAT. Base date: March 2008.

Table 7-30: Breakdown of Annual O&M Costs for Option 11: <8-P2A&B-TVCB1-DB1>

Component	Total (R)
Pump Station	
Civil	156,000
Mechanical and Electrical Maintenance	6,807,000
Electricity	88,922,000
Rising Main	
1600/1400 mm Ø Rising Main	15,454,000
Weir	2,110,000
Terminal Dam or Rising Main	213,000
Raw Water Costs	1,058,134,000
River Management Costs	4,500,000
Total Annual O&M - Crocodile Transfer System	**1,176,296,000**
Total Annual O&M - Crocodile Delivery System	10,515,000
Total Annual O&M - Mokolo System	81,173,000
Total Annual Combined O&M Cost	**1,267,984,000**

Table 7-31: Summary of discounted PVs for Option 11: <8-P2A&B-TVCB1-DB1> (Total Scheme)

Discount Rate	Capital (R)	O & M (R)	Total (R)
6%	8,783,283,000	11,764,876,000	20,548,159,000
8%	8,063,639,000	8,016,743,000	16,080,382,000
10%	7,436,161,000	5,716,388,000	13,152,549,000

Table 7-32: URVs for Option 11: <8-P2A&B-TVCB1-DB1> (Total Scheme)

Discount Rate	Discounted Present Value of Water @ R1/m^3	Discounted Present Value (R)	URV (R/m^3)
6%	2,149	20,548,160,000	9.562
8%	1,484	16,080,382,000	10.834
10%	1,073	13,152,548,000	12.254

7.5.9. Results – Option 12: 8-P3-TBVCB1-DB1

Table 7-33: Breakdown of Capital Cost for Option 12: <8-P3-TBVCB1-DB1>

Component	Total (R)
Pump Station (Peak Pumping Head 111.53/247.05 m)	597,285,000
Terminal Dam or Balancing Reservoir	76,482,000
Rising Main	
2100 mm Ø Rising Main	8,138,211,000
Weir	592,902,000
Total Crocodile Transfer System	**9,404,880,000**
Total Crocodile Delivery System (Gravity Delivery Pipes and 18 Day End User On Site Storage)	2,916,657,000
Total Mokolo System (Phase 1A)	1,445,195,000
Total Combined Scheme Cost	**13,766,732,000**

Including P&G's, Contingencies & Fees. Excluding VAT. Base date: March 2008.

Table 7-34: Breakdown of Annual O&M Costs for Option 12: <8-P3-TBVCB1-DB1>

Component	Total (R)
Pump Station	
Civil	175,000
Mechanical and Electrical Maintenance	6,528,000
Electricity	112,269,000
Rising Main	
2100 mm Ø Rising Main	19,488,000
Weir	5,240,000
Terminal Dam or Rising Main	213,000
Raw Water Costs	875,434,000
River Management Costs	4,500,000
Total Annual O&M - Crocodile Transfer System	**1,023,847,000**
Total Annual O&M - Crocodile Delivery System	10,515,000
Total Annual O&M - Mokolo System	81,173,000
Total Annual Combined O&M Cost	**1,115,535,000**

Table 7-35: Summary of Discounted PVs for Option 12: <8-P3-TBVCB1-DB1>

Discount Rate	Capital (R)	O & M (R)	Total (R)
6%	11,289,380,000	10,568,526,000	21,857,906,000
8%	10,599,791,000	7,237,993,000	17,837,784,000
10%	9,968,686,000	5,187,134,000	15,155,820,000

Table 7-36: URVs for Option 12: <8-P3-TBVCB1-DB1>

Discount Rate	Discounted Present Value of Water @ R1/m^3	Discounted Present Value (R)	URV (R/m^3)
6%	2,148	21,857,906,000	10.177
8%	1,483	17,837,785,000	12.026
10%	1,073	15,155,820,000	14.130

7.5.10. Results – Option 13: 4-P2-TBCB1-DB1

Table 7-37: Breakdown of Capital Cost for Option 13: <4-P2-TBCB1-DB1>

Component	Total (R)
Pump Station (Peak Pumping Head 374.81 m)	308,026,000
Terminal Dam or Balancing Reservoir	76,482,000
Rising Main	
1500 mm Ø Rising Main	4,859,438,000
Weir	317,889,000
Total Crocodile Transfer System	**5,561,835,000**
Total Crocodile Delivery System (Gravity Delivery Pipes and 18 Day End User On Site Storage)	2,317,521,000
Total Mokolo System (Phase 1A)	1,445,195,000
Total Combined Scheme Cost	**9,324,551,000**

Including P&G's, Contingencies & Fees. Excluding VAT. Base date: March 2008.

Table 7-38: Breakdown of Annual O&M Costs for Option 13: <4-P2-TBCB1-DB1>

Component	Total (R)
Pump Station	
Civil	92,000
Mechanical and Electrical Maintenance	3,442,000
Electricity	53,683,000
Rising Main	
1500 mm Ø Rising Main	11,582,000
Weir	2,680,000
Terminal Dam or Rising Main	213,000
Raw Water Costs	404,627,000
River Management Costs	4,500,000
Total Annual O&M - Crocodile Transfer System	**480,819,000**
Total Annual O&M - Crocodile Delivery System	7,910,000
Total Annual O&M - Mokolo System	81,173,000
Total Annual Combined O&M Cost	**569,902,000**

Table 7-39: Summary of Discounted PVs for Option 13: <4-P2-TBCB1-DB1> (Total Scheme)

Discount Rate	Capital (R)	O & M (R)	Total (R)
6%	7,641,559,000	5,782,789,000	13,424,348,000
8%	7,173,606,000	4,048,370,000	11,221,976,000
10%	6,745,414,000	2,971,113,000	9,716,527,000

Table 7-40: URVs for Option 13: <4-P2-TBCB1-DB1> (Total Scheme)

Discount Rate	Discounted Present Value of Water @ R1/m^3	Discounted Present Value (R)	URV (R/m^3)
6%	1,309	13,424,348,000	10.252
8%	923	11,221,976,000	12.154
10%	683	9,716,527,000	14.235

7.5.11. Results – Option 14: 4-P2-TVCB1-DB1

Table 7-41: Breakdown of Capital Cost for Option 14: <4-P2-TVCB1-DB1>

Component	Total (R)
Pump Station (Peak Pumping Head 305.93 m)	291,182,000
Terminal Dam or Balancing Reservoir	76,482,000
Rising Main	
1500 mm Ø Rising Main	3,292,233,000
Weir	275,013,000
Total Crocodile Transfer System	**3,934,910,000**
Total Crocodile Delivery System (Gravity Delivery Pipes and 18 Day End User On Site Storage)	2,317,521,000
Total Mokolo System (Phase 1A)	1,445,195,000
Total Combined Scheme Cost	**7,697,626,000**

Including P&G's, Contingencies & Fees. Excluding VAT. Base date: March 2008.

Table 7-42: Breakdown of Annual O&M Costs for Option 14: <4-P2- TVCB1-DB1>

Component	Total (R)
Pump Station	
Civil	79,000
Mechanical and Electrical Maintenance	2,968,000
Electricity	45,629,000
Rising Main	
1500 mm Ø Rising Main	7,847,000
Weir	2,560,000
Terminal Dam or Rising Main	213,000
Raw Water Costs	534,677,000
River Management Costs	4,500,000
Total Annual O&M - Crocodile Transfer System	**598,473,000**
Total Annual O&M - Crocodile Delivery System	7,910,000
Total Annual O&M - Mokolo System	81,173,000
Total Annual Combined O&M Cost	**687,556,000**

Table 7-43: Summary of Discounted PVs for Option 14: <4-P2- TVCB1-DB1> (Total Scheme)

Discount Rate	Capital (R)	O & M (R)	Total (R)
6%	6,313,688,000	6,788,249,000	13,101,937,000
8%	5,928,574,000	4,718,086,000	10,646,660,000
10%	5,576,145,000	3,437,413,000	9,013,558,000

Table 7-44: URVs for Option 14: <4-P2- TVCB1-DB1> (Total Scheme)

Discount Rate	Discounted Present Value of Water @ R1/m^3	Discounted Present Value (R)	URV (R/m^3)
6%	1,309	13,101,937,000	10.006
8%	923	10,646,660,000	11.531
10%	683	9,013,558,000	13.205

Table 7-45: Combined System Summary (Sub Table 1 & 2)

All costs include P&Gs, contingencies and fees, excluding VAT. Base date: March 2008.

Sub Table 1 of 2:

			Water Requirements							Crocodile Transfer System Parameters												
			Crocodile System		Mokolo System		Total Scheme															
No.	Option	Description	Net Demand Mm^3/a	Gross Demand Mm^3/a (incl losses)	Net Demand Mm^3/a	Gross Demand Mm^3/a (incl losses)	Net Water Requirement Mm^3/a	Gross Water Requirement Mm^3/a	Gross Water Requirement Mm^3/a (Raw water release) Incl River Losses	Conveyance	OD (mm)	ND (mm)	Length (km)	Peak. Pumping Rate (m^3/s)	Installed Pump Capacity (m^3/s)	Emergency Peak Flow (m^3/s)	Design Velocity (m/s)	Static Head	Pumping Head (Duty) (m)	Pumping Head (Peak) (m)	Power Required at Duty Point (MW)	Power Required at Peak Point (MW)
3	8-P2-TVCD1-DD1	Scenario 8 - Phase 2, transfer from Vlieëpoort via Central Route to Terminal Dam 1 and deliver via Delivery Route 1	191.2	195.2	28.7	29.3	219.9	224.4	295.5	Rising Main	2134	2100	111.348	6.509	9.28	7.426	1.881	124	282.3	298.5	21	25.3
4	8-P2-TVCD3-DD3	Scenario 8 - Phase 2, transfer from Vlieëpoort via Central Route to Terminal Dam 3 and deliver via Delivery Route 3	191.2	195.2	28.7	29.3	219.9	224.4	295.5	Rising Main	2134	2100	111.348	6.509	9.28	7.426	1.881	124	282.3	298.5	21	25.3
5	8-P2-TVCB1-DB1	Scenario 8 - Phase 2, transfer from Vlieëpoort via Central Route to BPT and delivery to the Terminal Reservoirs.	191.2	195.2	28.7	29.3	219.9	224.4	295.5	Rising Main	2134	2100	97.864	6.509	9.28	7.426	1.881	95	235.15	247.05	17.5	20.9
6	8-P2-TVWB1-DB1	Scenario 8 - Phase 2, transfer from Vlieëpoort via Western Route to BPT and delivery to the Terminal Reservoirs.	191.2	195.2	28.7	29.3	219.9	224.4	295.5	Rising Main	2134	2100	103.158	6.509	9.28	7.426	1.881	95	241.65	255.05	17.9	21.6
7	8-P2-TBCB1-DB1	Scenario 8 - Phase 2, transfer from Boschkop via Central Route to BPT and delivery to the Terminal Reservoirs.	191.2	195.2	28.7	29.3	219.9	224.4	254.9	Rising Main	2134	2100	144.628	6.509	9.28	7.426	1.881	65	280.63	290.46	20.8	24.6
8	8-P2-TBEB1-DB1	Scenario 8 - Phase 2, transfer from Boschkop via Eastern Route to BPT and delivery to the Terminal Reservoirs.	191.2	195.2	28.7	29.3	219.9	224.4	254.9	Rising Main	2134	2100	153.609	6.509	9.28	7.426	1.881	65	290.52	305.16	21.6	25.9
9	8-P2A-TVCB1-DB1	Scenario 8 - Phase 2A (first pipeline), transfer from Vlieëpoort via Central Route to BPT and delivery to the Terminal Reservoirs.	110.0	112.2	28.7	29.3	138.7	141.5	182.7	Rising Main	1626	1600	97.864	3.744	5.34	4.271	1.864	95	255.89	293.19	10.9	14.3
10	8-P2B-TVCB1-DB1	Scenario 8 - Phase 2B (second pipeline), transfer from Vlieëpoort via Central Route to BPT and delivery to the Terminal Reservoirs.	81.3	82.9	28.7	29.3	109.9	112.2	142.7	Rising Main	1422	1400	97.864	2.765	3.94	3.155	1.8	95	270.44	309.36	8.5	11.1
11	8-P2A&B-TVCB1-DB1	Scenario 8 - Phase 2A and Phase 2B combined, transfer from Vlieëpoort via Central Route to BPT and delivery to the Terminal Reservoirs.	191.2	195.2	28.7	29.3	219.9	224.4	254.9	Rising Main	1626/1422	1600/1400	97.864	3.744/2.765	5.34/3.94	4.271/3.155	1.864/1.8	95	255.89/270.44	293.19/309.36	10.9/8.5	14.3/11.1
12	8-P3-TBVCB1-DB1	Scenario 8 - Phase 3, transfer from Boschkop through Vlieëpoort via Central Route to BPT and delivery to the Terminal Reservoirs.	191.2	195.2	28.7	29.3	219.9	224.4	254.9	Rising Main	2134	2100	70.499/97.864	6.509	9.28	7.426	1.881	-30+95	95.92/235.15	111.53/247.05	7.1/17.5	9.4//20.9
13	4-P2-TBCB1-DB1	Scenario 4 - Phase 2, transfer from Boschkop via Central Route to BPT and delivery to the Terminal Reservoirs.	96.4	98.4	28.7	29.3	125.1	127.7	150.3	Rising Main	1524	1500	144.628	3.282	4.68	3.744	1.859	65	313.97	374.81	11.8	16
14	4-P2-TVCB1-DB1	Scenario 4 - Phase 2, transfer from Vlieëpoort via Central Route to BPT and delivery to the Terminal Reservoirs.	96.4	98.4	28.7	29.3	125.1	127.7	179.2	Rising Main	1524	1500	97.864	3.282	4.68	3.744	1.859	95	266.76	305.93	10	13.1

Sub Table 2 of 2:

			Costing																						Present Value (March 2008)		Unit Reference Values		
			Raw Water	River Management	Balancing Reservoir /Terminal Dam		Rising Main		Weir		Tunnel		Pump Station					Total Crocodile Transfer System		Total Crocodile Delivery System		Total Mokolo Transfer System (Phase 1A)		Combined Scheme Cost		@ 8%		Discounted Figures 8%		
No.	Option	Description	Annual Cost @ 2030	Annual Cost @ 2030	Capital	Maintenance & Operation (2030)	Capital	Maintenance & Operation (2030)	Capital	Maintenance & Operation (2030)	Capital	Maintenance & Operation (2030)	Capital (excluding refurbishment Cost)	Maintenance Civil	Maintenance E & M	Electricity	Maintenance & Operation (2030)	Capital	Maintenance & Operation (2030)	Capital	Maintenance & Operation (2030)	Capital	Maintenance & Operation (2030)	Capital	Maintenance & Operation (2030)	Capital	Maintenance & Operation	Demand	Costs	URV
3	8-P2-TVCD1-DD1	Scenario 8 - Phase 2, transfer from Vlieëpoort via Central Route to Terminal Dam 1 and deliver via Delivery Route 1	1,058,134,000	4,500,000	224,912,000	623,000	6,569,243,000	15,773,000	275,013,000	2,560,000	130,385,000	244,000	428,621,000	129,000	4,808,000	95,645,000	100,582,000	7,628,174,000	1,182,416,000	2,745,097,000	10,488,000	1,445,195,000	81,173,000	11,818,466,000	1,274,077,000	9,159,252,000	8,175,075,000	1,484	17,334,327,000	11.679
4	8-P2-TVCD3-DD3	Scenario 8 - Phase 2, transfer from Vlieëpoort via Central Route to Terminal Dam 3 and deliver via Delivery Route 3	1,058,134,000	4,500,000	276,496,000	767,000	6,569,243,000	15,773,000	275,013,000	2,560,000	36,900,000	65,000	428,621,000	129,000	4,808,000	95,645,000	100,582,000	7,586,273,000	1,182,381,000	3,308,867,000	12,939,000	1,445,195,000	81,173,000	12,340,335,000	1,276,493,000	9,589,530,000	8,183,809,000	1,484	17,773,339,000	11.975
5	8-P2-TVCB1-DB1	Scenario 8 - Phase 2, transfer from Vlieëpoort via Central Route to BPT and delivery to the Terminal Reservoirs.	1,058,134,000	4,500,000	76,482,000	213,000	5,134,677,000	12,312,000	275,013,000	2,560,000			381,938,000	112,000	4,187,000	79,692,000	83,991,000	5,868,110,000	1,161,710,000	2,916,657,000	10,515,000	1,445,195,000	81,173,000	10,229,962,000	1,253,398,000	7,905,901,000	8,035,558,000	1,484	15,941,460,000	10.741
6	8-P2-TVWB1-DB1	Scenario 8 - Phase 2, transfer from Vlieëpoort via Western Route to BPT and delivery to the Terminal Reservoirs.	1,058,134,000	4,500,000	76,482,000	213,000	5,405,099,000	12,965,000	275,013,000	2,560,000			402,990,000	115,000	4,286,000	81,891,000	86,292,000	6,159,584,000	1,164,664,000	2,916,657,000	10,515,000	1,445,195,000	81,173,000	10,521,436,000	1,256,352,000	8,118,853,000	8,055,400,000	1,484	16,174,252,000	10.898
7	8-P2-TBCB1-DB1	Scenario 8 - Phase 2, transfer from Boschkop via Central Route to BPT and delivery to the Terminal Reservoirs.	875,434,000	4,500,000	76,482,000	213,000	8,570,543,000	20,576,000	317,889,000	2,680,000			401,645,000	126,000	4,713,000	95,081,000	99,920,000	9,366,559,000	1,003,323,000	2,916,657,000	10,515,000	1,445,195,000	81,173,000	13,728,411,000	1,095,011,000	10,585,844,000	7,091,614,000	1,484	17,677,458,000	11.910
8	8-P2-TBEB1-DB1	Scenario 8 - Phase 2, transfer from Boschkop via Eastern Route to BPT and delivery to the Terminal Reservoirs.	875,434,000	4,500,000	76,482,000	213,000	9,026,090,000	21,658,000	317,889,000	2,680,000			414,409,000	131,000	4,886,000	98,429,000	103,446,000	9,834,870,000	1,007,931,000	2,916,657,000	10,515,000	1,445,195,000	81,173,000	14,196,722,000	1,099,619,000	10,944,969,000	7,122,733,000	1,484	18,067,702,000	12.173
9	8-P2A-TVCB1-DB1	Scenario 8 - Phase 2A (first pipeline), transfer from Vlieëpoort via Central Route to BPT and delivery to the Terminal Reservoirs.	550,251,000	4,500,000	76,482,000	213,000	3,659,317,000	8,737,000	257,073,000	2,110,000			305,919,000	85,000	3,168,000	49,925,000	53,178,000	4,298,791,000	618,989,000	2,916,657,000	10,515,000	1,445,195,000	81,173,000	8,660,643,000	710,677,000	6,703,339,000	5,643,609,000	1,129	12,346,948,000	10.934
10	8-P2B-TVCB1-DB1	Scenario 8 - Phase 2B (second pipeline), transfer from Vlieëpoort via Central Route to BPT and delivery to the Terminal Reservoirs.	370,500,000	4,500,000			2,818,875,000	6,717,000					219,888,000	71,000	3,640,000	38,997,000	42,708,000	3,038,763,000	424,425,000					3,038,763,000	424,425,000	1,360,301,000	2,323,386,000	697	3,683,686,000	5.284
11	8-P2A&B-TVCB1-DB1	Scenario 8 - Phase 2A and Phase 2B combined, transfer from Vlieëpoort via Central Route to BPT and delivery to the Terminal Reservoirs.	1,058,134,000	4,500,000	76,482,000	213,000	6,478,192,000	15,454,000	257,073,000	2,110,000			525,807,000	156,000	6,807,000	88,922,000	95,885,000	7,337,554,000	1,176,296,000	2,916,657,000	10,515,000	1,445,195,000	81,173,000	11,699,406,000	1,267,984,000	8,063,639,000	8,016,743,000	1,484	16,080,382,000	10.834
12	8-P3-TBVCB1-DB1	Scenario 8 - Phase 3, transfer from Boschkop through Vlieëpoort via Central Route to BPT and delivery to the Terminal Reservoirs.	875,434,000	4,500,000	76,482,000	213,000	8,138,211,000	19,488,000	592,902,000	5,240,000			597,285,000	175,000	6,528,000	112,269,000	118,972,000	9,404,880,000	1,023,847,000	2,916,657,000	10,515,000	1,445,195,000	81,173,000	13,766,732,000	1,115,535,000	10,599,791,000	7,237,993,000	1,483	17,837,785,000	12.026
13	4-P2-TBCB1-DB1	Scenario 4 - Phase 2, transfer from Boschkop via Central Route to BPT and delivery to the Terminal Reservoirs.	404,627,000	4,500,000	76,482,000	213,000	4,859,438,000	11,582,000	317,889,000	2,680,000			308,026,000	92,000	3,442,000	53,683,000	57,217,000	5,561,835,000	480,819,000	2,317,521,000	7,910,000	1,445,195,000	81,173,000	9,324,551,000	569,902,000	7,173,606,000	4,048,370,000	923	11,221,976,000	12.154
14	4-P2-TVCB1-DB1	Scenario 4 - Phase 2, transfer from Vlieëpoort via Central Route to BPT and delivery to the Terminal Reservoirs.	534,677,000	4,500,000	76,482,000	213,000	3,292,233,000	7,847,000	275,013,000	2,560,000			291,182,000	79,000	2,968,000	45,629,000	48,676,000	3,934,910,000	598,473,000	2,317,521,000	7,910,000	1,445,195,000	81,173,000	7,697,626,000	687,556,000	5,928,574,000	4,718,086,000	923	10,646,660,000	11.531

7.6. Comparison of Options

The table below summarises the calculated URVs for each of the options evaluated in the above logic. The preferred option determined in each calculation step is indicated in bold.

Table 7-46: URV Comparison

Calculation Step	Option		Preferred	URV (excluding VAT)		
				@6%	@8%	@10%
1	**Determine preferred Option for Phase 1A**					
1.1	**1**	**<8-P1A-MD-ID1>**	Option 1 (Pipeline)	**5.920**	**6.730**	**7.570**
1.2	2	<8-P1A-RBW-IW1>		7.380	8.180	9.010
2	**Determine preferred Terminal Dam/Reservoir Option**					
2.1	3	<8-P2-TVCD1-DD1>		10.102	11.679	13.481
2.2	4	<8-P2-TVCD3-DD3>		10.319	11.975	13.868
2.3	**5**	**<8-P2-TVCB1-DB1>**	Break Pressure Reservoir + end user storage	**9.390**	**10.741**	**12.283**
3	**Select between Western and Central Routes**					
3.1	6	<8-P2-TVWB1-DB1>		9.509	10.898	12.483
3.2	**5**	**<8-P2-TVCB1-DB1>**	Central Route	**9.390**	**10.741**	**12.283**
4	**Select between Eastern and Central Routes and between Abstraction at Vlieëpoort or Boschkop**					
4.1	8	<8-P2-TBEB1-DB1>		10.264	12.173	14.347
4.2	7	<8-P2-TBCB1-DB1>	Central Route	10.065	11.910	14.012
4.3	**5**	**<8-P2-TVCB1-DB1>**	Vlieëpoort abstraction	**9.390**	**10.741**	**12.283**
5	**Determine whether a Phased Approach is preferred**					
5.1	9	<8-P2A-TVCB1-DB1>		9.534	10.934	12.458
5.2	10	<8-P2B-TVCB1-DB1>		5.074	5.284	5.446
5.3	11	<8-P2A&B-TVCB1-DB1>		9.562	10.834	12.254
5.4	**5**	**<8-P2-TVCB1-DB1>**	Un-phased	**9.390**	**10.741**	**12.283**
6	**Compare the Cost of Phase 3 with River Management**					
6.1	12	<8-P3-TBVCB1-DB1>		10.177	12.026	14.130
6.2	**5**	**<8-P2-TVCB1-DB1>**	Vlieëpoort abstraction	**9.390**	**10.741**	**12.283**
7	**Determine URVs for Scenario 4 Demands**					
7.1	13	<4-P2-TBCB1-DB1>		10.252	12.154	14.235
7.2	14	<4-P2-TVCB1-DB1>		10.006	11.531	13.205

From the above, it is evident that the following options are preferred from an engineering economics perspective:

- Scenario 8
  - Phase 1A: Option 1 (8-P1A-MD-ID1) – Transfer from Mokolo Dam via pump/gravity main the users
  - Phase 2: Option 5 (8-P2-TVCB1-DB1) – Transfer from Vlieëpoort via central route to break pressure reservoir and delivery to the terminal reservoirs (18 days storage) via delivery Route 3 (most western route to Steenbokpan)
- Scenario 4
  - Phase 1A: Due to the relatively small difference in the augmentation required in 2014 between Scenarios 8 and 4 (refer to Supporting Report 5: Mokolo River Development

Options), Phase 1A will only be implemented so supply the Scenario 8 water requirements.

- Phase 2: Option 14 (4-P2-TVCB1-DB1) – Transfer from Vlieëpoort via central route to break pressure reservoir and delivery to the terminal reservoirs (18 days storage) via delivery Route 3 (most western route to Steenbokpan)

An analysis was performed on some of the options to test the sensitivity of the findings (Refer to Section 8).

8. SENSITIVITY ANALYSIS

The following analysis was carried out in order to test the sensitivity of the decisions and certain input parameters:

1. **Pumped vs. Pump-gravity:** Pumped supply to the break pressure reservoir located at Node 15 vs. gravity supply from high ground near Thabazimbi (Node 10). Refer to Section 5.6 for a discussion on the hydraulic performance of the respective systems. The gravity supply option would require an increase in the pipe size for the gravity pipe section in order to deliver the required peak flow rate. The sensitivity was tested by comparing the URV of Option 5 <8-P2-TVCB1-DB1> with an option following a similar route, but with a rising main section up to Node 10 and gravity supply from Node 10 to the end users via a 2 200 mm ND gravity section with a similar D/t ratio as the rising main section.
2. **Raw water cost:** Calculate the raw water cost where Option 7 (abstraction at Boschkop Weir with delivery via central route to break pressure reservoir) <8-P2-TBCB1-DB1> and Option 12 (Phase 3 pipeline from Boschkop to Vlieëpoort and onwards to break pressure reservoir via the central route) <8-P3-TBVCB1-DB1> becomes comparable to the preferred Option 5 to determine the cost of raw water that would make the abstraction and supply from Boschkop Weir viable.
3. **Project Phasing:** Determine whether a longer delay in the implementation of Phase 2B could make the phased approach more feasible. Determine whether the delayed implementation of the Phase 3 infrastructure between Boschkop and Vlieëpoort could make Phase 3 more feasible.
4. **Reduction in steel prices:** Test the sensitivity of selected options with a 40% reduction in the steel price to determine the influence of the recent fall in steel prices on the evaluation parameters.

The findings of the sensitivity analysis is summarised in the following table.

Table 8-1: Sensitivity Analysis Summary of Results

	Option	Description	URV @8%
1.	**Pumped vs. Pump-gravity System**		
	Option 5 <8-P2-TVCB1-DB1>	Scenario 8 - Phase 2, transfer from Vlieëpoort via Central Route to Break Pressure Reservoir at Node 15 and delivery to the Terminal Reservoirs via Delivery Route 3.	10.741
	Option 5a <8-P2-TVCB1-DB1>a	Scenario 8 - Phase 2, transfer from Vlieëpoort via Central Route to Break Pressure Reservoir at Node 10. Gravity supply to the Terminal Reservoirs via 2 200 mm ND gravity pipe section.	10.835
2.	**Raw Water Cost**		
	Option 5: <8-P2-TVCB1-DB1>	Scenario 8 - Phase 2, transfer from Vlieëpoort via Central Route to Break Pressure Reservoir at Node 15 and delivery to the Terminal Reservoirs via Delivery Route 3. Raw water cost was calculated at a cost of R2.00/m^3 for the Mokolo system, as well as the first 80 million m^3/a on the Crocodile system and R4.50/m^3 thereafter.	10.741
	Option 7a: <8-P2-TBCB1-DB1>a	Scenario 8 – Phase 2, transfer from Boschkop via Central Route to Break Pressure Reservoir and delivery to the Terminal	10.742

	Option	Description	URV @8%
		Reservoirs via Delivery Route 3. Raw water cost calculated at a cost of R2.00/m^3 for the Mokolo system as well as the first 80 million m^3/a on the Crocodile system and **R2.18/m^3** thereafter.	
	Option 12a: <8-P3-TBVCB1-DB1>a	Scenario 8 - Phase 3, transfer from Boschkop through Vlieëpoort via Central Route to Break Pressure Reservoir and delivery to the Terminal Reservoirs via Delivery Route 3. Raw water cost calculated at a cost of R2.00/m^3 for the Mokolo system as well as the first 80 million m^3/a on the Crocodile system and **R1.95/m^3** thereafter.	10.741
3	**Project Phasing**		
	Option 5: <8-P2-TVCB1-DB1>	Scenario 8 - Phase 2, transfer from Vlieëpoort via Central Route to Break Pressure Reservoir at Node 15 and delivery to the Terminal Reservoirs via Delivery Route 3. Total scheme commissioned in **2014**.	10.741
	Option 11a: <8-P2A&B-TVCB1-DB1>a	Scenario 8 - Phase 2A&B, transfer from Vlieëpoort via Central Route to Break Pressure Reservoir and delivery to the Terminal Reservoirs via Delivery Route 3. Phase 2A commissioned in 2014 and Phase 2B in **2023** (2 years later than the original Option 11 planning)	10.682
	Option 12b: <8-P3-TBVCB1-DB1>b	Scenario 8 - Phase 3, transfer from Boschkop through Vlieëpoort via Central Route to Break Pressure Reservoir and delivery to the Terminal Reservoirs via Delivery Route 3. Delay implementation of phase 3 pipeline between Boschkop and Vlieëpoort until **2026**	10.743
4	**Steel Price**		
	Option 5: <8-P2-TVCB1-DB1>	Scenario 8 - Phase 2, transfer from Vlieëpoort via Central Route to Break Pressure Reservoir at Node 15 and delivery to the Terminal Reservoirs via Delivery Route 3. URV Calculated at March 2008 steel prices.	10.741
	Option 5b: <8-P2-TVCB1-DB1>b	Scenario 8 - Phase 2, transfer from Vlieëpoort via Central Route to Break Pressure Reservoir at Node 15 and delivery to the Terminal Reservoirs via Delivery Route 3. URV Calculated with at a 40% reduction in the March 2008 steel prices.	9.881
	Option 11b: <8-P2A&B-TVCB1-DB1>b	Scenario 8 - Phase 2A&B, transfer from Vlieëpoort via Central Route to Break Pressure Reservoir and delivery to the Terminal Reservoirs via Delivery Route 3. URV Calculated with at a 40% reduction in the March 2008 steel prices.	9.969
	Option 12c: <8-P3-TBVCB1-DB1>c	Scenario 8 - Phase 3, transfer from Boschkop through Vlieëpoort via Central Route to Break Pressure Reservoir and delivery to the Terminal Reservoirs via Delivery Route 3. URV Calculated with at a 40% reduction in the March 2008 steel prices.	10.685

The following is evident form the above assessment:

1. **Pumped vs. Pump-gravity:** The gravity supply option is less favourable from a financial point of view. There is, however, practical and operational benefits that can be derived from having gravity supply from Node 10. The cost of the gravity supply section can also be reduced by optimising the wall thickness of the steel pipe as less operational variations that could cause pressure surged are expected in the gravity section. This would make the gravity supply options financially comparable to the pumped scenario. The final decision on the pump-gravity approach should be based on practical considerations rather than price.
2. **Raw water cost:** To make the Boschkop abstraction options viable compared to Option 5 will require the cost of raw water to be R2.18/m^3 and R1.95/m^3 for Options 7 and 12, respectively. This is similar to the current raw water cost of the existing Crocodile River (West) allocation and less than the current VRESS raw water cost of approximately R4.50/m^3. It is generally accepted that it would not be possible to supply additional raw water at less than the VRESS tariff. As stated previously, the river losses between Boschkop and Vlieëpoort given in this report is most probably over-stated. A reduction in the river losses will further advantage the Vlieëpoort abstraction options.
3. **Project phasing:** Due to the steep water requirement curve, it would not be practical to delay the implementation of Phase 2B beyond 2020. The URVs of the phased and un-phased approaches is almost equal (compare Options 5 and 11) with a one or two year delay in the implementation of Phase 2B making the phased approach more feasible. It should, however, be noted that this will require either increased transfer capacity to be provided as part of Phase 2A or it will result in the over utilisation of the Mokolo Dam until Phase 2B is commissioned. Neither of these options was analysed in detail as part of the sensitivity analysis. Phase 3 of the project will become viable if the commissioning of the abstraction works, pump station and pipeline from Boschkop to Vlieëpoort is delayed until **2026**.
4. **Reduction in steel prices:** The ranking of options is not affected by the reduction in steel pipe prices.

9. CONCLUSIONS AND RECOMMENDATIONS

The following can be concluded from the analysis done in Sections 7 and 8:

1. The pipeline from Mokolo Dam to the users is the preferred option for Phase 1A Mokolo Transfer System. The feasibility level investigation of this option is currently taking place. Further detail regarding the option is provided in Supporting Report 5: Mokolo River Development Options (P RSA A000/00/9209).
2. The Break Pressure Reservoir option is preferred above the Terminal Dam options for the following reasons:
    a. Lowest URV for the total system.
    b. The potential negative environmental impact of some of the proposed terminal dam sites.
    c. The Crocodile River (West) water will be prone to the development and growth of algae. It will be more difficult to manage algae growth on the surface of the terminal dams compared to the smaller break pressure and terminal storage reservoirs at user sites.
    d. Reliability storage capacity can be limited to 18 days in total as the storage is provided on-site (as opposed to 18 days at the end of the rising main and 9 days at the end of the gravity main). The break pressure reservoir will provide short term balancing storage between the end of the rising main section and the gravity main section to facilitate pump control. The rising main and gravity sections will however operate as a combined system.
3. The Central route is the preferred route for the transfer pipeline from Vlieëpoort Weir for the following reasons:
    a. It is the shortest route with the lowest total scheme cost (and URV).
    b. It is a straight route along the railway line that could improve the rate of construction.
    c. It is the preferred route from an environmental and social point of view due to it being located along a disturbed corridor.
    d. It is the route option where the least hard rock excavation is expected, based on the geotechnical screening.
    e. Access to the route along the railway is generally good.
    f. Neither the electrification of the Lephalale railway line nor the positioning of the future Eskom 765 kVA power line corridors would result in unmanageable CP and AC mitigation conditions. Locating the pipeline along an Eskom power line corridor would, however, increase the operational and maintenance burden associated with the pipeline and will also have to be properly considered from a Health and Safety point of view during the operation of the system.
4. The Central route is the preferred route for the transfer pipeline from Boschkop Weir due to this being the shortest route with the lowest total scheme cost (and URV). The eastern route will be negatively impacted by higher quantities of hard material excavation and the expected higher environmental and social sensitivity.
5. The topography along all three the main transfer system routes (East, Central and West) could allow the Break Pressure Reservoir to be placed closer to the abstraction works, with a gravity supply from there to the end users. A sensitivity analyses revealed that scheme cost and URV for the different options would not influence the decision at pre-feasibility level. The final location of the break pressure reservoir and the merits of an increased length of gravity supply to the end users will be investigated in more detail during the feasibility stage.
6. Abstraction at Vlieëpoort Weir is preferred based on the lower total scheme URV (river losses and management included) compared to abstraction at Boschkop Weir. The URVs for the different schemes are, however, within 8% and should not be the only factor considered for eliminating Boschkop Weir. An important factor to consider is the additional length of pipeline to be constructed for abstraction at Boschkop Weir (145-98 = 47 km) and the additional time required to construct this pipeline (47km / 0.2 km/day = 230 workdays or 11 months).

Considering the risk of Mokolo Dam being emptied the shortest possible construction duration should be implemented i.e. shortest possible pipeline.

7. A phased approach to constructing the transfer system from Vlieëpoort can be considered due to the benefit it provides in delaying the decision on the final capacity of the pipeline. It also distributes the capital expenditure programme over a longer period. The URV calculations, however, indicate this will not be the least cost solution, but the difference is small and could easily be outweighed by the benefits of the other considerations or a slight delay in the growth of the water requirements beyond the capacity of Phase 2A.
8. The option to construct a pipeline from Boschkop to Vlieëpoort as Phase 3 of the project will not be cost effective unless the implementation of Phase 3 is postponed until 2026. This is, however, sensitive to the cost of raw water and the extent of river losses and should be reconsidered once the water tariff has been determined and a more accurate estimate of the river losses has been made.
9. The URVs calculated for the Scenario 4 options indicate that Vlieëpoort will again be the preferred option based on total life cycle cost.
10. The river losses are being revised with the expectation that the actual river losses between Boschkop and Vlieëpoort will be less than that stated in the report. A reduction in the river losses will further benefit the Vlieëpoort Weir abstraction options.

Based on the results the following is recommended for further consideration during the feasibility stage of the project:

- Phase 1A – Mokolo Transfer System: Option 1 which consists of a pipeline from Mokolo Dam to Lephalale and further to Steenbokpan. <8-P1A-MD-ID1>

- Phase 2 – Abstraction at Vlieëpoort Weir with a rising main along the Central Route to the position of the Break Pressure Reservoir providing short term balancing storage. From here the water will be gravity fed into on-site terminal reservoirs (capacity 18 days + user balancing and emergency storage requirements) at each of the users. Option 5 <8-P2-TVCB1-DB1> or Option 11 <8-P2A&B-TVCB1-DB1>. The option to locate the break pressure reservoir at Node 10 should be investigated in more detail during feasibility assessment.

- Phase 3 – Delayed implementation of the link from Boschkop to Vlieëpoort to be considered in order to limit river losses. <8-P3-TBVCB1-DB1>

The scheme components and capital costs associated with Option 5 is summarised below. Costs include P&Gs, contingencies and fees, excluding VAT. The base date for costs is March 2008.

Table 9-1: Summary of Scheme Components - Option 5: 8-P2-TVCB1-DB1

Component	**Description**
Phase 1A	
Phase 1A Supporting Report 5: Mokolo River Development Options Report (P RSA A000/00/9209)	Pipeline from Mokolo Dam: Option 1: 8-P1A-MD-ID1
Phase 2	
Vlieëpoort Weir	Concrete weir and primary desilting
Abstraction pump station Abstraction pump station, secondary desilting works and balancing dam	6 x 1.1 m^3/s submersible pumps 2 x standby units (stored on site) 4 hours balancing storage
High lift pump station	Static head : 95 m Design peak flow (DPF) : 6.5 m^3/s Dynamic head at DPF : 235 m Emergency peak flow (EPF) : 7.4 m^3/s Dynamic head at EPF : 247 m Power consumption DPF/EPF : 17/21 MW
Transfer System Rising main - High lift pump station to Terminal Dam entrance (Node 20)	Diameter : 2100 mm ND Length : 97.9 km Flow velocity : 1.88 m/s
Balancing Reservoir	24 hours storage
Delivery System Link to Lephalale-Steenbokpan pipeline <31> Link to Steenbokpan <25B> Link to Lephalale (Built under Phase 1A) <25A-24-14> Link to Matimba (Built under Phase 1A) <8> Link to Medupi <13>	Diameter : 2300 mm ND Length : 24.8 km Diameter : 2200 mm ND Length : 5.1 km Diameter : 800 mm ND Length : 30.9 km Diameter : 800 mm ND Length : 1.9 km Diameter : 500 mm ND Length : 1.7 km
End user storage reservoirs (7 of)	18 days storage + user required balancing storage Location: Supply source: 8. Eskom Terminal Reservoir : Crocodile 9. Sasol Terminal Reservoir : Crocodile 10. Exxaro Terminal Reservoir : Crocodile 11. Medupi Terminal Reservoir : Crocodile 12. Medupi RWR : Mokolo 13. Matimba RWR (Existing) : Mokolo 14. Zeeland RWR : Mokolo

Table 9-2: Breakdown of Capital Cost for Option 5: <8-P2-TVCB1-DB1>

Component	Total (R)
Pump Station (Peak Pumping Head 247.05 m)	381,938,000
Terminal Dam or Balancing Reservoir	76,482,000
Rising Main	
2100 mm Ø Rising Main	5,134,677,000
Weir	275,013,000
Total Crocodile Transfer System	**5,868,110,000**
Total Crocodile Delivery System (Gravity Delivery Pipes and 18 Day End User On Site Storage)	2,916,657,000
Total Mokolo System (Phase 1A)	1,445,195,000
Total Combined Scheme Cost	**10,229,962,000**

Including P&G's, Contingencies & Fees. Excluding VAT. Base date: March 2008.

Table 9-3: Breakdown of Annual O&M Costs for Option 5: <8-P2-TVCB1-DB1>

Component	Total (R)
Pump Station	
Civil	112,000
Mechanical and Electrical Maintenance	4,187,000
Electricity	79,692,000
Rising Main	
2100 mm Ø Rising Main	12,312,000
Weir	2,560,000
Terminal Dam or Rising Main	213,000
Raw Water Costs	1,058,134,000
River Management Costs	4,500,000
Total Annual O&M - Crocodile Transfer System	**1,161,710,000**
Total Annual O&M - Crocodile Delivery System	10,515,000
Total Annual O&M - Mokolo System	81,173,000
Total Annual Combined O&M Cost	**1,253,398,000**

Table 9-4: Summary of Discounted PVs for Option 5: <8-P2-TVCB1-DB1> (Total Scheme)

Discount Rate	Capital (R)	O & M (R)	Total (R)
6%	8,412,536,000	11,764,276,000	20,176,812,000
8%	7,905,901,000	8,035,558,000	15,941,459,000
10%	7,441,844,000	5,742,629,000	13,184,473,000

Table 9-5: URVs for Option 5: <8-P2-TVCB1-DB1> (Total Scheme)

Discount Rate	Discounted Present Value of Water @ R1/m^3	Discounted Present Value (R)	URV (R/m^3)
6%	2,149	20,176,811,000	9.390
8%	1,484	15,941,460,000	10.741
10%	1,073	13,184,473,000	12.283

A longitudinal section profile and schematic layout of the preferred option is illustrated by Figure 9-1.

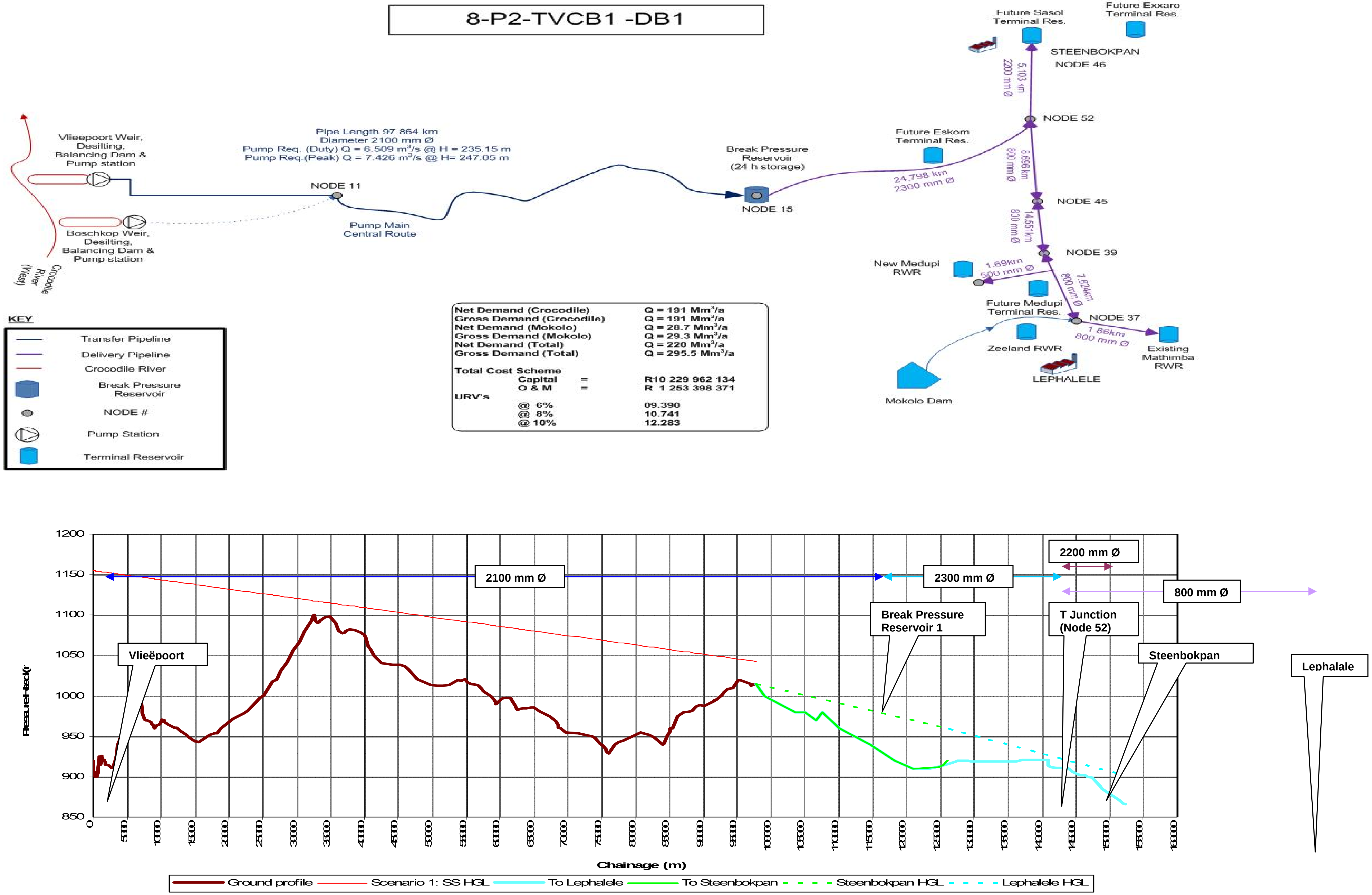

Figure 9-1: Option 5: 8-P2-TVCB1-DB1 Schematic Layout and Longitudinal Section Profile

APPENDIX A

MAPS AND DRAWINGS

APPENDIX B

DEFINITION OF OPTIONS

APPENDIX C

CAPITAL COST AND ENGINEERING ECONOMIC ANALYSIS

REPORT DETAILS PAGE

Project name:	***Mokolo and Crocodile (West) Water Augmentation Project (MCWAP)***
Report Title:	**Pre-Feasibility Study Report 6 - Water Transfer Scheme Options**
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