DWA REPORT NUMBER: P RSA D000/00/18312/9

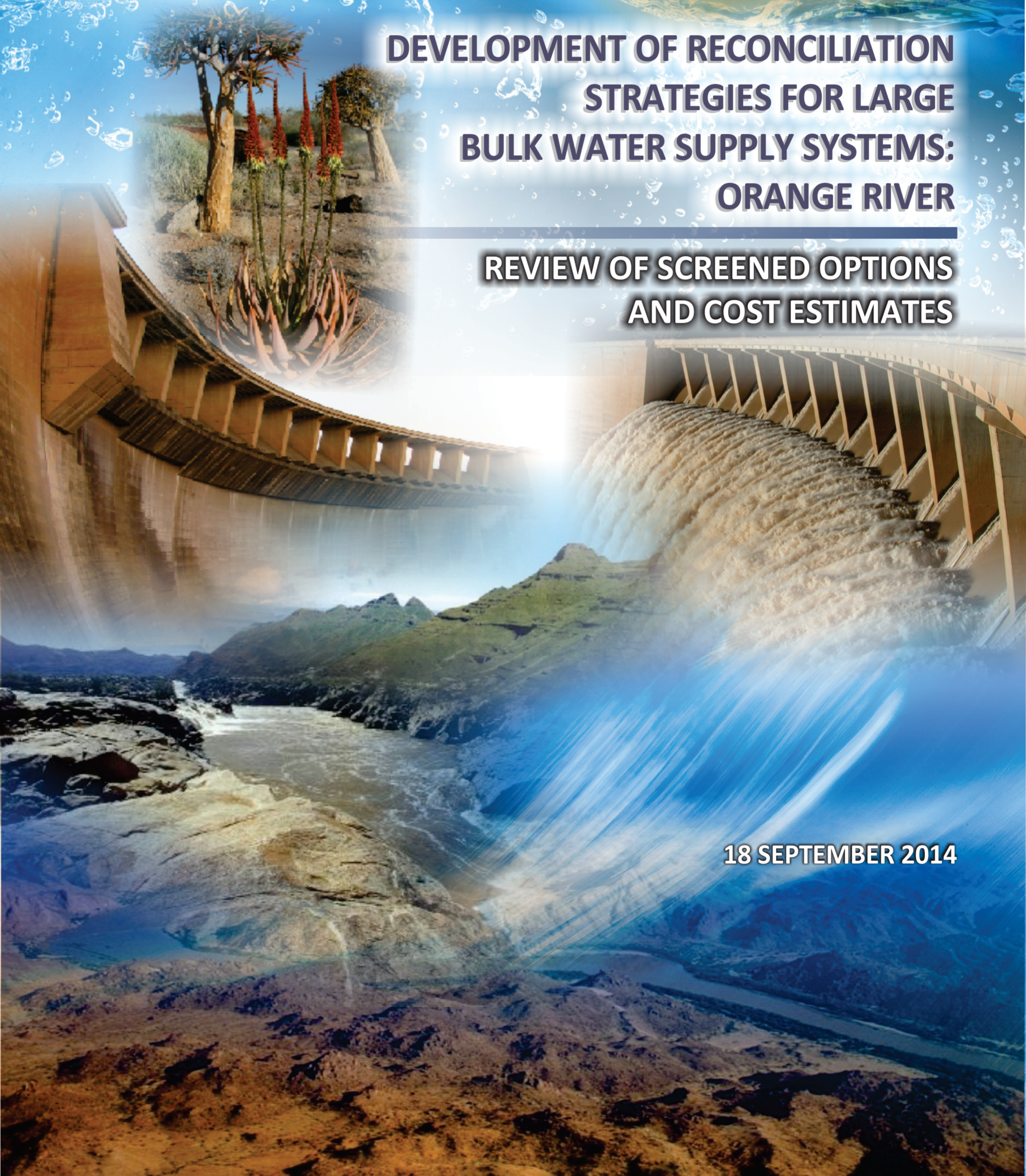
water affairs

Department:
Water Affairs
REPUBLIC OF SOUTH AFRICA

Directorate: National Water Resource Planning

DEVELOPMENT OF RECONCILIATION STRATEGIES FOR LARGE BULK WATER SUPPLY SYSTEMS: ORANGE RIVER

REVIEW OF SCREENED OPTIONS AND COST ESTIMATES



18 SEPTEMBER 2014

DEVELOPMENT OF RECONCILIATION STRATEGIES FOR BULK WATER SUPPLY SYSTEMS

ORANGE RIVER

REFERENCE

This report is to be referred to in bibliographies as:

Department of Water Affairs, South Africa, 2013. ***DEVELOPMENT OF RECONCILLIATION STRATEGIES FOR LARGE BULK WATER SUPPLY SYSTEMS ORANGE RIVER: REVIEW OF SCREENED OPTIONS AND COST ESTIMATES***

Prepared by:

WRP Consulting Engineers, Aurecon, Golder Associates Africa, and Zitholele Consulting.

Report No. P RSA D000/00/18312/9

Title:	***Review of Screened Options and Cost Estimates***
Authors:	*Study Team*
Project Name:	***Development of Water of Reconciliation Strategies for Large Bulk Water Supply Systems: Orange River***
DWA Report No:	*P RSA D000/00/18312/9*
Status of Report:	*Final*
First Issue:	*3 October 2013*
Final:	*18 September 2014*

Consultants: WRP Consulting Engineers (Pty) Ltd in association with Aurecon, Golder Associates Africa and Zitholele Consulting

Approved for the Consultants by:

....

PG van Rooyen

Study Leader

DEPARTMENT OF WATER AFFAIRS

Directorate: National Water Resource Planning

Approved for DWA by:

....

ST Makombe

Production Engineer: National Water Resource Planning

....

JI Rademeyer

Chief Engineer: National Water Resource Planning

....

T Nditwani

Acting Director: National Water Resource Planning

LIST OF REPORTS

The following reports form part of this study:

Report Title	Report number
Inception Report	P RSA D000/00/18312/1
Literature Review Report	P RSA D000/00/18312/2
International obligations	P RSA D000/00/18312/3
Current and future Water Requirements	P RSA D000/00/18312/4
Urban Water Conservation and Water Demand Management	P RSA D000/00/18312/5
Irrigation Demands and Water Conservation/Water Demand Management	P RSA D000/00/18312/6
Surface Water Hydrology and System Analysis	P RSA D000/00/18312/7
Water Quality and Effluent Re-use	P RSA D000/00/18312/8
Review Schemes and Update Cost Estimates	**P RSA D000/00/18312/9**
Preliminary Reconciliation Strategy Report	P RSA D000/00/18312/10
Final Reconciliation Strategy Report	P RSA D000/00/18312/11
Executive Summary	P RSA D000/00/18312/12
Reserve Requirement Scenarios and Scheme Yield	P RSA D000/00/18312/13
Preliminary Screening Options Agreed: Workshop of February 2013	P RSA D000/00/18312/14

DEVELOPMENT OF RECONCILIATION STRATEGIES FOR LARGE BULK WATER SUPPLY SYSTEMS: ORANGE RIVER

Review of Screened Options and Cost Estimates

EXECUTIVE SUMMARY

Introduction

The Department of Water Affairs (DWA) has identified the need for detailed water resource management strategies as part of their Internal Strategic Perspective (ISP) planning initiative, which recommended studies to identify and formulate intervention measures that will ensure enough water can be made available to supply the water requirements for the next three to four decades.

As part of this process the need for the Reconciliation Strategy Study for the Large Bulk Water Supply Systems in the Orange River was also defined. Given the location of the Orange River System and its interdependencies with other WMAs as well as other countries, various water resource planning and management initiatives compiled during the past few years as well as those currently in progress will form an integral part of the strategy development process.

Since 1994, a significant driver of change in the water balance of the Orange River System was brought about by the storing of water in Katse Dam as the first component of the multi-phase Lesotho Highlands Water Project (LHWP). Currently Phase 1 of the LHWP (consisting of Katse, and Mohale dams, Matsoku Weir and associated conveyance tunnels) transfers 780 million cubic metres per annum via the Liebenbergsvlei River into the Vaal Dam to augment the continuously growing water needs of the Gauteng Province. Phase 2 of the LWHP comprising of Polihali Dam and connecting tunnel to Katse Dam is already in its planning stages. Polihali Dam is expected to be in place by around 2022. Flows that are currently still entering into Gariep and Vanderkloof dams wil then be captured by Polohali Dam, thus reducing the inflow to Gariep and Vanderkloof dams. This will result in a reduction in yield of the Orange River Project (Gariep and Vanderkloof dams) to such an extent that shortages will be experienced in the ORP system. Some sort of yield replacement is then required in the Orange River to correct the yield versus demand imbalance in the ORP system.The objective of the study is to develop a reconciliation strategy for the bulk water resources of the Orange River System, to ensure that sufficient water can be made available to supply the current and future water needs for a 25 year planning horison. This Strategy must be flexible to accommodate future changes in the actual water requirements and transfers, with the result that the Strategy will evolve over time as part of an on-going planning process.

Appropriate integration with other planning and management processes as well as cooperation among stakeholders will be key success factors in formulating coherent recommendations and action plans.

The purpose of this report

Possible schemes for increasing the yield of the Orange River System, which were identified in previous studies, have been reviewed and re-assessed as part of this study. These possible schemes have then been evaluated and screened during a preliminary screening workshop held in February 2013. The outcome of this workshop was a short-list of the most promising possible schemes.

The purpose of this report is to describe the short-listed schemes in terms of their layouts, estimated costs, Unit Reference Values (URVs) and potential yield contributions.

Outcome of the screening process

Options to reduce the water requirements:

- *WC/WDM for Domestic, Irrigation and Industrial Water Use Sectors.*
- *Reducing assurances of supply.*
    - Options to increase the water availability:
- *Groundwater development.*
- *System operating rules.*
    - *Real time monitoring of flows downstream of Vanderkloof Dam and in the Vaal River upstream of its confluence with the Orange River.*
    - *Lower minimum operating level in Vanderkloof Dam.*
- *Removal of invasive alien plants in the Kraai catchment.*
- *Promote prevention of soil erosion.*
- *Dams:*
    - *Ntoahae Dam*
    - *Malatsi Dam*

      } *Senqu-Catchment*
    - *Bosberg Dam*
    - *Boskraai Dam*
    - *Kraai Dam*
    - *Gariep Dam Raising*
    - *Knoffelfontein Dam*

      } *Upper Orange*
    - *New Boegoeberg Dam*
    - *Vioolsdrift Dam*

      } *Lower Orange*

It needs to be noted that this report only covers the costing of development schemes and not the management options to reduce water requirements. Similarly, for the options to increase the system yield, only the identified infrastructure schemes are covered and not options such as removal of alien plants and promotion of soil erosion.

Groundwater

Groundwater should be prioritised as the first choice to augment the water resources of towns and communities located far from the Orange River. A typical groundwater scheme consists of a borehole or wellfield of boreholes, borehole casings, pumping equipment, treatment facility and pumping main to a reservoir and distribution system.

The yield gain will vary from one groundwater scheme to the other and depends on the formations of the aquifers, the groundwater recharge - and the groundwater harvesting potential.

Since the costs of equipped boreholes vary significantly between groundwater schemes and the specific groundwater schemes have not as yet been identified, the costs and URVs have not been determined.

A number of strategies, known as the "All Towns Strategies" have been prepared for the DWA in which the demographics, water requirements and water availability have been studied and interventions have been recommended. The reader is specifically referred to the report "Development of Reconciliation Strategies for All Towns in the Central Region (DWA, 2011). Many of the towns studied in that report, which are located in the study area, are dependent on ground water.

Surface water infrastructure

All infrastructure options agreed upon during the Preliminary Screening Workshop have been re-assessed and the potential yield, estimated cost and URVs for discount rates of respectively 6%. 8% and 10% have been calculated.

An additional dam, which was not on the list of identified dams, namely the Verbeeldingskraal Dam was also investigated as an alternative to the proposed Bosberg Dam. The estimated cost of the proposed Verbeeldingskraal Dam is much less than Bosberg Dam and the evaporation losses will be significantly less than from the raised Gariep Dam.

Summary of costs, potential yield gain and URVs

***Table E1** provides a summary of the estimated costs, yields and URVs for each of the selected schemes.*

***Table E1:** Summary of estimated costs, yields and URVs of selected schemes*

Option	***Cost (R million)***	***Yield (mil m^3/a)***	***URV***		
			6%	***8%***	***10%***
Vd Kloof Low Level Storage	*150*	*137*	*R 0.17*	*R 0.20*	*R 0.23*
Vioolsdrift FSL 210	*986*	*192*	*R 0.37*	*R 0.47*	*R 0.58*
Gariep 10m raising	*1368*	*350*	*R 0.31*	*R 0.40*	*R 0.50*
Bosberg FSL 1385	*4133*	*377*	*R 0.86*	*R 1.11*	*R 1.40*
Verbeeldingskraal FSL 1385	1048	200	R 0.39	R 0.51	R 0.63
Kraai FSL 1372	*1999*	*330*	*R 0.46*	*R 0.58*	*R 0.73*
Boskraai FSL 1385	*4962*	*937*	*R 0.43*	*R 0.56*	*R 0.72*
Malatsi FSL 1652	*1373*	*119*	*R 0.87*	*R 1.11*	*R 1.39*
Ntoahae FSL 1545	*1370*	*232*	*R 0.44*	*R 0.57*	*R 0.71*
Knoffelfontein	*240*	*3.2*	*R 5.42*	*R 6.89*	*R 8.49*

Conclusions and Recommendations

Based on the costs and URVs presented above, it is recommended that the following options be considered in the implementation scenarios:

- *Real time monitoring downstream of Vanderkloof Dam*
- *Vanderkloof Dam low level storage*
- *Vioolsdrift Dam*
- *Gariep Dam raising or Verbeeldingskraal Dam*

For the purpose of this study, which planning horizon will take us up to the year 2040, it would be either the raising of Gariep Dam or the construction of Verbeeldingskraal Dam. Both these options won't be required before 2040. If one however looks further in the future, beyond 2040, then both these options can be considered.

Eskom prepared a brief report which was received almost at the study closure. This report provides details on hydro-power related impacts on two of the proposed intervention options.

- *Vanderkloof Dam low level storage*
- *Gariep Dam raising*

The Eskom report is included in ***Appendix D.***

It is recommended that the Eskom report be taken into concideration during the feasibility study for the Raising of Gariep Dam/Verbeeldingskraal Dam as well as when the Bridging Study is commissioned to proceed with the implementation of the option to utilise the Vanderkloof Lower Level Storage.

Development of Reconciliation Strategies for for Large Bulk Water Supply Systems: Orange River

Review of Screened Options and Cost Estimates

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

Appendix A – Summary of Dam Yields

Appendix B – Dam Layout, Schedule of Quantities, Cost Calculations and URV Calculations

Appendix C – Environmental and Social Screening of Options

Appendix D – Eskom Report: Impact of development of reconciliation strategies for large bulk water supply systems: Orange River on Eskom Peaking Generation

LIST OF ABBREVIATIONS

CPA	Contract Price Adjustment
DWA	Department of Water Affairs
EWR	Environmental Water Requirement
FSL	Full Supply Level
ISP	Internal Strategic Perspective
IWMP	Integrated Water Management Plan
km	Kilometre
LHWP	Lesotho Highlands Water Project

LORMS	Lower Orange River Management Study
m	Metre
masl	metres above sea level
m^3	Cubic metre
m^3/s	Cubic metres per second
m^3/a	Cubic metres per annum
MAR	Mean Annual Runoff
MFL	Maximum Flood Level
MOL	Minimum Operating Level
MW	MegaWats
NPSH	Net Positive Suction Head
NWRP	National Water Resource Planning
ORASECOM	Orange Senqu River Commission
ORRS	Orange River Replanning Study
RBL	River Bed Level
RSA	Republic of South Africa
SANCOLD	South African National Committee on Large Dams
URV	Unit Reference Value
VAPS	Vaal Augmentation Planning Study
WC/WDM	Water Conservation and Water Demand Management
WMA	Water Management Area

Development of Reconciliation Strategies for Large Bulk Water Supply Systems: Orange River

Review of Sceened Options and Cost Estimates

1 INTRODUCTION

1.1 Background

The Department of Water Affairs (DWA) has identified the need for detailed water resource management strategies as part of their Internal Strategic Perspective (ISP) planning initiative, which recommended studies to identify and formulate intervention measures that will ensure enough water can be made available to supply the water requirements for the next three to four decades.

The DWA Directorate: National Water Resource Planning (NWRP) therefore commenced the strategy development process in 2004 by initially focusing on the water resources supporting the large metropolitan clusters, followed by the systems supplying the smaller urban areas to systematically cover all the municipalities in the country.

As part of this process the need for the Reconciliation Strategy Study for the Large Bulk Water Supply Systems in the Orange River was also defined. Given the location of the Orange River System and its interdependencies with other WMAs as well as other countries (see study area description in Section 1.3), various water resource planning and management initiatives compiled during the past few years as well as those currently in progress will form an integral part of the strategy development process.

Major water resource infrastructure in the study area are the Gariep and Vanderkloof dams with associated conveyance conduits supporting large irrigation farming in the provinces of the Free State, Northern Cape and the Eastern Cape - through the Orange-Fish Tunnel. This system is currently almost in balance.

The Caledon-Modder System supplies water to the Mangaung-Bloemfontein urban cluster (largest urban centre in the study area). The 2 200 km long Orange-Senqu River is the lifeline for various industries, mines, towns and communities located along the way until the river discharges into the Atlantic Ocean in the far west at Alexander Bay.

Since 1994, a significant driver of change in the water balance of the Orange River System was brought about by the storing of water in Katse Dam as the first component of the multi-phase Lesotho Highlands Water Project (LHWP). Currently Phase 1 of the LHWP (consisting of Katse, and Mohale dams, Matsoku Weir and associated conveyance tunnels) transfers 780 million cubic metres per annum via the Liebenbergsvlei River into the Vaal Dam to augment the continuously growing water needs of the Gauteng Province. Phase 2 of the LWHP comprising of Polihali Dam and connecting tunnel to Katse Dam is already in its planning stages and is expected to be in place by 2022. Flows that are currently still entering into Gariep and Vanderkloof dams wil then be captured by Polohali Dam, thus reducing the inflow to Gariep and Vanderkloof dams. This will result in a reduction in yield of the Orange River Project (Gariep and Vanderkloof dams) to such an extent that shortages will be experienced in the ORP system. Some sort of yield replacement is then required in the Orange River to correct the yield versus demand imbalance in the ORP system.

The above description illustrates the complex assortment of interdependent water resources and water uses which spans across various international and institutional boundaries that will be considered in the development of the Orange River Reconciliation Strategy.

1.2 Main Objectives of this Study

The objective of the study is to develop a reconciliation strategy for the bulk water resources of the Orange River System, to ensure that sufficient water can be made available to supply the current and future water needs of all the users up to the year 2040. This Strategy must be flexible to accommodate future changes in the actual water requirements and transfers, with the result that the Strategy will evolve over time as part of an on-going planning process.

Appropriate integration with other planning and management processes, as well as cooperation among stakeholders, will be key success factors in formulating coherent recommendations and action plans.

The outcomes of the Strategy will be specific interventions with particular actions needed to balance the water needs with the availability through the implementation of regulations, demand management measures, as well as infrastructure development options.

1.3 Study Area

As depicted in **Figure A-1** of **Appendix A** (Map of study area), the study will focus on the water resources of the Upper and Lower Orange River Water Management Areas (WMAs), while also considering all the tributary rivers and transfers affecting the water balance of the system. This core area forms part of the Orange-Senqu River Basin, which straddles four International Basin States with the Senqu River originating in the highlands of Lesotho, Botswana in the north eastern part of the Basin, the Fish River in Namibia and the largest area situated in South Africa.

The focus area of the study comprises only the South African portion of the Orange River Basin, excluding the Vaal River Catchment. The Vaal River is an important tributary of the Orange River, but since the Vaal River Reconciliation Strategy has already been developed, the Vaal River Catchment will not form part of the study area. However, strategies developed for the Vaal River System that will have an impact on the Orange River, will be taken into account as well as the impacts of flows from the Vaal into the Orange for selected Integrated Vaal system scenarios.

The Orange River is an international resource, shared by four countries i.e. Lesotho, South Africa, Botswana and Namibia. Any developments, strategies or decisions taken by any one of the countries that will impact on the water availability or quality in South Africa must be taken into account and will form part of this study. The opposite is also applicable. If this strategy plans anything in South Africa that will impact on any of the other countries, this impact must be considered as part of this study in terms of South Africa’s international obligations.

The Orange River, the largest river in South Africa, has its origin in the high lying areas of Lesotho. The river drains a total catchment area of about 1 million km², runs generally in a westerly direction and finally discharges into the Atlantic Ocean at Alexander Bay.

The Caledon River, forming the north-western boundary of Lesotho with the Republic of South Africa (RSA), is the first major tributary of the Orange River. The Caledon and the Orange (called the Senqu River in Lesotho) rivers have their confluence in the upper reaches of the Gariep Dam.

Other major tributaries into the Orange River are:

- The Kraai River draining from the North Eastern Cape.
- The Vaal River joining the Orange River at Douglas.
- The Ongers and Sak Rivers draining from the northern parts of the Karoo.
- The Molopo and Nossob Rivers in Namibia, Botswana and the Northern Cape Province have not contributed to the Orange River in recorded history as the stream bed is impeded by sand dunes.
- The Fish River draining the southern part of Namibia.

A separate study was also done for the Greater Bloemfontein Area i.e. Water Reconciliation Strategy Study for Large Bulk Water Supply Systems: Greater Bloemfontein Area with it's follow up continuation study currently in process. The recommendations of this strategy and its continuation study will also be taken into account in this study.

Although the Senqu River Catchment in Lesotho does not form part of the focus study area, the development in this catchment impacts directly on the water availability in the study area.

The South African portion of the Orange River Basin is currently divided in two Water Management Areas, i.e. the Upper and Lower Orange WMAs. The Upper WMA stretches from the headwaters of the Caledon River and Lesotho boundary down to the confluence of the Vaal River and the Lower Orange WMA from this point to the sea. (See **Figure A-1** in **Appendix A**). It should be noted that the DWA recently proposed that the two WMAs are managed as a unit.

1.4 Purpose and Structure of this Report

Possible schemes for increasing the yield of the Orange River System, which were identified in previous studies, have been reviewed and re-assessed as part of this study. These possible schemes have then been evaluated and screened during a preliminary screening workshop held in February 2013. The outcome of this workshop was a short-list of the most promising possible schemes.

The purpose of this report is to describe the short-listed schemes in terms of their layouts, estimated costs, Unit Reference Values (URVs) and potential yield contributions.

The report firstly describes the **screening process** and its outcome.

It then continues to **describe each of the screened options** in terms of layout, estimated cost and URVs and yields.

The Costs, URVs and yields **are then summarised**.

Finally the report concludes with **recommendations**.

2 PRELIMINARY SCREENING OF OPTIONS

2.1 The purpose of screening process

Approximately 30 possible development options were identified in previous studies (ORRS, 1997 and LORMS, 2005). These options had to be narrowed down to a manageable number for further investigation. This was done during the Preliminary Screening Workshop held in February 2013.

The primary objectives of the Preliminary Screening Workshop were to understand the water resource status in the basin, agree on the possible reconciliation options and to decide which options had to be further investigated.

The proceedings of the Preliminary Screening Workshop are documented in a separate report of this study titled "Preliminary Screening Options Identified and Agreed on during the Workshop of February 2013" (P RSA D000/00/18312/13).

2.2 Screening Process

Key stakeholders were invited to the Preliminary Screening Workshop which was held in Kimberley on 7 February 2013. A Starter Document was attached to the invitation to provide each stakeholder with the necessary background and the identified reconciliation options.

The 39 page Starter Document contained the following information:

- Objectives of the study.
- Description of the study area.
- Overview of the current water resource status in the Orange River Basin.
- The need for water reconciliation in the basin.
- Summary of the identified reconciliation options.
- Description of the proposed screening process.
- Description of the envisaged way forward.

A multi-criteria decision support tool was proposed and accepted by the workshop to evaluate the identified reconciliation options. The possible reconciliation options were then presented and these were jointly assessed using the multi-criteria decision support matrix. Consensus was reached on the options which could be discarded and those options which will be taken forward for further investigation.

Finally, the findings were summarised and agreed upon and the way forward was decided.

2.3 Outcome of Screening Process

The outcomes of the Preliminary Screening Workshop are summarised below.

Options to reduce the water requirements:

- WC/WDM for Domestic, Irrigation and Industrial Water Use Sectors.
- Reducing assurances of supply.
    - Options to increase the water availability:
- Groundwater development.

- System operating rules.
  - Real time monitoring of flows downstream of Vanderkloof Dam and in the Vaal River upstream of its confluence with the Orange River.
  - Lower minimum operating level in Vanderkloof Dam.
- Removal of invasive alien plants in the Kraai catchment.
- Promote prevention of soil erosion.
- Dams:

Dam	Area
Ntoahae Dam Malatsi Dam	Senqu-Catchment Lesotho
Bosberg Dam Boskraai Dam Kraai Dam Gariep Dam Raising Knoffelfontein Dam	Upper Orange
New Boegoeberg Dam Vioolsdrift Dam	Lower Orange

It needs to be noted that this report only covers the costing of development schemes and not the management options to reduce water requirements. Similarly, for the options to increase the system yield, only the identified infrastructure schemes are covered and not options such as removal of alien plants and promotion of soil erosion.

3 THE SCREENED OPTIONS

3.1 GROUNDWATER

Groundwater should be prioritised as the first choice to augment the water resources of towns and communities located far from the Orange River. A typical groundwater scheme consists of a borehole or wellfield of boreholes, borehole casings, pumping equipment, treatment facility and pumping main to a reservoir and distribution system.

The yield gain will vary from one groundwater scheme to the other and depends on the formations of the aquifers, the groundwater recharge - and the groundwater harvesting potential.

Since the costs of equipped boreholes vary significantly between groundwater schemes and the specific groundwater schemes have not as yet been identified, the costs and URVs have not been determined.

A number of strategies, known as the “All Towns Strategies” have been prepared for the DWA in which the demographics, water requirements and water availability have been studied and interventions have been recommended. The reader is specifically referred to the report “Development of Reconciliation Strategies for All Towns in the Central Region (DWA, 2011). Many of the towns studied in that report, which are located in the study area, are dependent on ground water.

3.2 Surface water infrastructure

A number of options have been investigated for creating additional storage. The yield of any dam is dependent on any new developments upstream. The yields quoted for different dams are therefore dependent on the scenario of dam combinations considered. All scenarios that were analysed consisted of the Vioolsdrift Dam (regulation and optimum yield), the real time monitoring benefit and the Vanderkloof Low Level Storage as base scenario. Further dam options were then added to this base scenario. The yields analyses are fully described in the Surface Water Hydrology and System Analysis report of the study. A summary of the dam yields are provided in **Appendix A**.

3.2.1 Malatsi Dam

The dam layout, schedule of quantities, cost calculations and URV calculations are shown in **Appendix B1**.

- **Description of the Dam**

The proposed dam site is situated on the Senqunyane River, approximately 80 km downstream of Mohale Dam and 10 km upstream of the confluence with the Senqu River. The relatively steep-sided narrow gorge, in which the proposed dam site is situated, is cut into gently dipping massive sandstones inter-bedded with siltstones of the Clarens Formation.

The site is suitable for a concrete faced rockfill dam. A saddle exists on the right flank for a chute spillway. The optimum spillway crest length appears to be 100 m. The routed probable maximum flood peak of 5 885 m^3/s will require a freeboard of 9.0 m.

Based on the diversion flood of 1 270 m^3/s, it is estimated that the handling of the river during construction will consist of a cofferdam upstream of the plinth, a downstream cofferdam, which will be incorporated into the toe of the main embankment, and two diversion tunnels. The smaller

Tunnel 1 will be lined and will become the low level and compensation flow outlet. The larger Tunnel 2 will be unlined. From the optimisation exercise, it appears that two 8.3 m horseshoe diversion tunnels and 38-40 m high cofferdam are most economical. As above noted, Tunnel 2 should be made larger and Tunnel 1 smaller.

The low level outlet will consist of a gate arrangement at the upstream end of Tunnel 1. Depending on the required outlet capacity (assumed at 60 m^3/s at full supply level), the gate will either be a radial gate or a Howell Bunger valve.

As part of the LHWP, this dam was conceived with a high minimum operating level (mol) so that the live storage could gravitate through a tunnel to Ntoahae Dam. In this study, it has been assumed that the water will be released down the river, making the large dead storage unnecessary resulting in a lower dam with the same live storage.

- **Yields and Costs**

The historic firm yield increase for the system including the effects of the upstream dam in Lesotho is 119 million m^3/a.

Capital costs of the dam are based on quantities taken from the *LHWP Consulting Services for the Feasibility Study for Phase 2: Dam Design, September 2007,* and have been escalated from 2006 to 2012 by a factor of 1.29, based on historic indices as used in CPA formulae. Operation costs have been based on DWA standard percentages as in the VAPS model.

It should be noted that there are royalties payable to the Lesotho Government for water supplied from the LHWP. It can be expected that the same principle would apply to the Malatsi Dam, but no attempt has been made to estimate what the value might be.

The estimated capital and operational costs as well as the URVs are provided in **Table 3.1.**

Table 3.1: Height, Costs and URVs of proposed Malatsi Dam

Malatsi Dam FSL (masl)		1 652
River Bed Level (RBL) (masl)		1 521
Height RBL to FSL (m)		131
Capital cost (R million)		1 373
Operating Cost (R million/a)		3.4
Historic Firm Yield (million m^3/a)		119
URV (R/m^3)	6%	0.87
(Excluding royalties)	8%	1.11
	10%	1.39

3.2.2 Ntoahae Dam

The dam layout, schedule of quantities, cost calculations and URV calculations are shown in **Appendix B2**.

- **Description of the Dam**

The proposed dam site is situated on the Senqu River, approximately 62 km downstream of the confluence with the Tsoelike River and 15.5 km upstream of the confluence with the Senqunyane River. The site is located in a sheer-sided gorge cut into sandstones (with minor siltstones and thinner-bedded sandstones) of the Clarens Formation.

A roller compacted concrete gravity dam was selected for this site due to the steep abutments which preclude a chute type spillway associated with a concrete faced rockfill dam. The spillway crest length was selected at 90 m to fit the valley topography. The routed probable maximum flood peak of 11 750 m^3/s will require a freeboard of 15.3 m. Energy dissipation will be by means of a deflector bucket and tailpond arrangement.

The handling of the river during construction will be done by means of a culvert river diversion arrangement. The first phase will consist of four 4 x 4 m culverts installed on the left hand side of the river behind a cofferdam parallel to the river, which will retain a channel of almost 50 m width on the right hand side. The second phase will consist of a cofferdam protecting the right hand side of the river whilst the river is diverted through the culverts.

The wet well for the outlet works, will be constructed upstream of the roller compacted concrete wall and will discharge through the wall via a steel pipe. The flow rate will be controlled by a Howell Bunger valve on the downstream side.

For the LHWP, this dam was planned with a high mol to reduce the cost of transferring the water upstream to Tsoelike Dam. In this study, it has been assumed that the water will be released down the river, making the large dead storage unnecessary resulting in a lower dam with the same live storage.

- **Yields and Costs**

The historic firm yield including the effects of the planned Polihali Dam in Lesotho is 232 million m^3/a.

Capital costs of the dam are based on quantities taken from the *LHWP Consulting Services for the Feasibility Study for Phase 2: Dam Design, September 2007,* and have been escalated from 2006 to 2013 by a factor of 1.29, based on historic indices as used in CPA formulae. Operation costs have been based on DWA standard percentages as in the VAPS model.It should be noted that there are royalties payable to the Lesotho Government for water supplied from the LHWP. It can be expected that the same principle would apply to the Ntoahae Dam, but no attempt has been made to estimate what the value might be.

The height difference between FSL and RBL, the estimated capital and operational costs as well as the URVs are provided in **Table 3.2.**

Table 3.2: Height, Costs and URVs of proposed Ntoahae Dam

Ntoahae Dam FSL (masl)		1645
River Bed Level (RBL) (masl)		1522
Height RBL to FSL (m)		123
Capital cost (R million)		1370
Operating Cost (R million / a)		3.4
Historic Firm Yield (million m^3/a)		232
URV (R/m^3)	6%	0.44
(Excluding royalties)	8%	0.57
	10%	0.71

3.2.3 Bosberg Dam

The dam layout, schedule of quantities, cost calculations and URV calculations are shown in **Appendix B3**.

- **Description of Dam**

The Bosberg site is on the Orange River about 10 km upstream of the Kraai River confluence, which in turn, is about 5 km upstream of Aliwal North. The site was first identified in the 1985 Lesotho Highlands Feasibility Study: Orange Vaal Transfer Scheme, and has been considered further in both the 1995 Pre-feasibility Stage of the Vaal Augmentation Planning Study, and the 1998 Pre-feasibility Phase of the Orange River Development Replanning Study (ORRS).

The site is in a narrow gorge formed by a prominent ridge crossing the river at that point, with the top of the ridge formed by a dolerite cill, and with a river bed level (RBL) of 1304 masl. For the larger dams considered, a low point on the left (south) flank will require a saddle dam with a minimum ground level of about 1365 masl.

There appears to be scattered areas of outcropping bedrock within the Orange River, albeit slightly downstream of the optimal centre-line position. The extent of these outcrops seems to be rather limited. It is possible that the shortest possible centre-line topographically might not be most favourable from a geological perspective. The thickness of the covering alluvial deposits would have to be verified. It is expected that these outcrops comprise dolerite. Upstream of the centre-line the alluvial deposits appear substantial.

The flanks might be underlain by dolerite, although the possibility of mudrock and or sandstone cannot be excluded, depending on the final centre-line alignment.

A further possible constraint is that larger dams will push back into Lesotho, with the RBL at the border being 1390 masl.

Both studies assumed a rollcrete gravity dam with a 200 m central overflow spillway and a total freeboard to NOC of 12 m. The studies considered different dam sizes with FSLs ranging from 1352 masl to 1400 masl. Earthfill embankments were assumed on the saddle for the larger dams.

For the purposes of this study, a maximum FSL of 1385 masl was assumed. This would push up to about 13 km horizontally and 5 m vertically of the Lesotho border, although the tailwater effects of large floods would impact on water levels in Lesotho.

The dam basin is located almost entirely within a narrow gorge resulting in relatively small storage capacities for dams of any particular height, but with the advantage that the small water surface areas result in low evaporation losses. These factors are automatically taken into account in the yield and URV calculations.

This dam would inundate relatively little infrastructure. The R58 in the vicinity of the Boskraai saddle would be inundated and would be replaced by a length of new road about 2.4 km. The R726 tarred road between Zastron and Barkley East/Elliot/Maclear, crosses the Orange River where the basin would be about 350 m wide. The existing 125 m long bridge would need to be replaced by a new bridge about 20 m high, and 225 m long approach fills would be required.

- **Yields and Costs**

The historic firm yield including the effects of the planned Polihali Dam in Lesotho is 377 million m^3/a.

Capital costs of the dam are based on quantities taken from the *ORRS Potential Dam Development and Hydro Power Options 1994* and have been escalated from 1994 to 2012 by a factor of 3.55, based on historic indices as used in CPA formulae. Operation costs have been based on DWA standard percentages as in the VAPS model.

The height difference between FSL and RBL, the estimated capital and operational costs as well as the URVs are provided in **Table 3.3.**

Table 3.3: Height, Costs and URVs of proposed Bosberg Dam

Bosberg Dam FSL (masl)		1385
River Bed Level (RBL) (masl)		1304
Height RBL to FSL (m)		81
Capital cost (R million)		4133
Operating Cost (R million / a)		10.3
Historic Firm Yield (million m^3/a)		377
URV (R/m^3)	6%	0.86
	8%	1.11
	10%	1.40

3.2.4 Upper Orange Dams

The dam layout, schedule of quantities, cost calculations and URV calculations are shown in **Appendix B4**.

- **Description of Dams**

The earthfill embankment for the 32m high saddle dam wall, with a length of 2.5km, resulted in a relatively high capital cost for Bosberg Dam and this motivated the consideration of other possible sites further upstream where the Orange River is confined in narrow gorges over significan lengths and where a saddle wall wouldn't be necessary. Three possible sites were identified on the farms Vebeeldingskraal, Drie Fontein and Lichtenstein, being 13, 18.5 and 24 km upstream of the Bosberg site respectively. An alternative to Lichtenstein was identified on the adjacent farm Diep Kloof but was not considered further as it had no obvious advantages.

While the river valley is progressively narrower moving upstream, each site excludes a relatively wide basin, reducing the storage capacity significantly moving upstream.

Costs have been calculated for each site assuming a rollcrete gravity dam with a FSL of 1385 as at Bosberg, because of the constraint of impoundment into Lesotho. Founding conditions are expected to be better than at Bosberg and a standard excavation depth of 5m has been assumed. Costs have been based on a simple all-in rate developed from the more detailed estimate undertaken for the Kraai site, as that dam is more similar than Bosberg. These are compared in the **Table 3.4.**

Table 3.4: Comparison of dam capacities and costs between three dam sites upstream of the Bosberg site

	Verbeeldingskraal	Drie Fontein	Lichtenstein
FSL (masl)	1385	1385	1385
Cost (R million)	866	1 015	658
Capacity (Million m^3)	1363	1171	865
Cost of Storage (R/m^3)	0.64	0.87	0.76

The cost of storage should not be confused with the URV, as it does not take the yield into account, but where river flows are essentially the same, as in this case, then the cost of storage provides a similar but simpler comparison between sites.

Based on the cost of storage, it is clear that the Verbeeldingskraal site is the most favourable, and only this site has been considered further.

The dam layout, schedule of quantities, cost calculations and URV calculations of Verbeeldingskraal Dam are shown in **Appendix B4**.

There are other sites further upstream which might be more favourable if smaller yields are required, and a more detailed prefeasibility study is required once the required yield is known, before the optimal location for a dam on the upper Orange can be finalised.

- **Yields and Costs**

The historic firm yield including the effects of the planned Polihali Dam in Lesotho is 200 million m^3/a.

The costs for Vebeeldingskraal have been recalculated using similar assumptions and rates as for the other dams, and the results are summarised in **Table 3.5**.

Table 3.5: Height, Costs and URVs of proposed Verbeeldingskraal Dam

Verbeeldingskraal Dam FSL (masl)		1385
River Bed Level (RBL) (masl)		1318
Height RBL to FSL (m)		67
Capital cost (R million)		1048
Operating Cost (R million / a)		2.6
Historic Firm Yield (million m^3/a)		200
URV (R/m^3)	6%	0.39
	8%	0.51
	10%	0.63

3.2.5 Kraai Dam

The dam layout, schedule of quantities, cost calculations and URV calculations are shown in **Appendix B5.**

- **Description of Dam**

The same ridge crossing the Orange River at the Bosberg site crosses the Kraai River about 11 km along the river from the Orange River confluence. The RBL at this site is at 1314 masl, and the site is effected by the same saddle at 1365 masl as the Bosberg site, now being on the right (north) flank of the Kraai River. This saddle has been designated the partition Saddle.

Another saddle exists on the left (south) flank of the Kraai, with a minimum ground level of 1393 masl. This has been designated the Kraai River saddle.

The previous studies considered dams with FSLs ranging from 1372 masl to 1400 masl. For the purposes of this study, a mass gravity rollcrete dam has been assumed with a FSL of 1372 masl and a NOC of 1384 masl and a 135 m central spillway.

The dam basin is very flat, providing high storage capacities for relatively low dams, but with the disadvantage that the large water surface areas result in high evaporation losses. These factors are automatically taken into account in the yield and URV calculations.

A dam at this site will inundate significate lengths of major roads and a railway line. The costs of these appear to have been under estimated in previous studies, and are described below.

The N6 between Aliwal North and Jamestown, passes through the Kraai saddle then descends to cross a tributary of the Kraai, with a length of about 6 km being inundated. A replacement road would need to go around the tributary above MFL, requiring approximately 23 km of new road through moderately rugged terrain.

The R58 tarred road between Aliwal North and Lady Grey passes through the Kraai Dam site adjacent to the river, before crossing the river and ascending out of the valley, with approximately 8.4 km being inundated. A replacement road would probably cross the river downstream of the dam, ascend steeply up the right (north) flank of the river to above the dam wall, then stay just above the MFL to the Boskraai saddle, traversing very rugged terrain with steep cross falls. It would then cross the saddle over the saddle dam to rejoin the existing road just above the MFL. The total length of new road would be about 9.5 km of which 7.5 km would be through extremely rugged terrain with steep cross falls, requiring high cuts and fills with associated environmental impacts.

The gravel R344, between the N6 near Jamestown and the R58 near Lady Grey, crosses the Kraai River and is inundated for about 8.5 km. A replacement road about 10 km long could cross the dam basin further upstream where the length below the MFL is about 2km long, requiring a bridge about 50 m high. An alternative solution would be to cross the basin some 4 km further upstream where the river passes through a steep gorge, reducing the basin width to 400 m, but the road would need to traverse some very rugged terrain and would almost certainly require a tunnel about 700m long to avoid about 5 km of extremely steep terrain.

A gravel road linking the R58 with the R344 on the northern side of the river will be inundated for about 9km which would have to be replaced by a new road at higher elevation, passing through moderately rugged terrain.

The R392 gravel road between Lady Grey and Dordrecht crosses the Kraai River above the FSL of the largest dam considered, but about 400m of the road, including a 60 m wide bridge, is below the MFL ignoring tail water effects and would need to be raised.

A railway line between Aliwal North and Lady Grey passes through the Kraai saddle, then descends to cross the Kraai River, before ascending the other side, and would be inundated for about 37 km. The only route for a replacement line would be to follow the realigned R58 as described above, and then to follow the MFL till it rejoins the existing line, a total length of about 22 km. In the rugged terrain, the limited grades and bend radii allowed for railway lines would make this an extremely expensive line. The degree of any current use of the line is unknown, but this realignment is unlikely to be economically justifiable, and it has been assumed that the line will be abandoned, despite recent public announcements by Transnet on their intention to reinstate and upgrade the national railway system.

Numerous smaller gravel roads branch off the above roads into the basin, but as they provide access only to farmsteads which are to be inundated, they have been ignored.

- **Yields and Costs**

The historic firm yield is 330 million m^3/a.

Capital costs of the main dam are based on quantities taken from the *ORRS Potential Dam Development and Hydro Power Options 1994* and have been escalated from 1994 to 2012 by a factor of 3.55, based on historic indices as used in CPA formulae. Quantities for the Kraai River saddle dam have been estimated as part of this study. Operation costs have been based on DWA standard percentages as in the VAPS model.

The costs of Kraai Dam have been recalculated using similar assumptions and rates as for the other dams, and the results are summarised in **Table 3.6.**

A social and environmental analysis (See **Appendix C**) concluded that this dam should not go ahead and should be regarded as a fatal flaw.

Table 3.6: Height, Costs and URVs of proposed Kraai Dam

Kraai Dam FSL (masl)		1372
River Bed Level (RBL) (masl)		1313
Height RBL to FSL (m)		59
Capital cost (R million)		199
Operating Cost (R million / a)		5.0
Historic Firm Yield (million m^3/a)		330
URV (R/m^3)	6%	0.46
	8%	0.58
	10%	0.73

3.2.6 Boskraai Dam

The dam layout, schedule of quantities, cost calculations and URV calculations are shown in **Appendix B5.**

- **Description of Dam**

This option comprises a combination of the Bosberg and Kraai Dams, with the two dams being at the same level above the height of the central saddle. This option has the advantage that the large flows in the Orange River can be stored in the large storage capacity in the Kraai River portion of the basin, providing a larger yield than can be provided by the two dams separately.

It would appear that the upstream portion of the narrow gorge identified for the Boskraai centre-line might be underlain by the sedimentary strata, whereas the downstream portion is underlain by the intrusive dolerite. A site walk-over would be necessary to verify the geological conditions.

There is no evidence of any bedrock outcrop within the river section, and the thickness of the alluvial deposits is uncertain. The fact that there are cultivated lands on the left bank of the Kraai River suggests, however, that the alluvial deposits are perhaps well-developed.

The respective flanks appear relatively gently sloping, indicating a fairly wide dam site. The thickness of the soil cover is uncertain, but there is a chance that the underlying bedrock occurs at relatively shallow depths.

For the purpose of this study, a FSL of 1385 masl has been adopte. The dams would be as described above for the two dams separately, except that the central saddle dam would not be required.

- **Yields and Costs**

The historic firm yield including the effects of the planned Polihali Dam in Lesotho is 937 million m^3/a.

Capital costs of the main dam wall are based on quantities taken from ORRS Potential Dam Development and Hydro Power Options 1994 and have been escalated from 1994 to 20123 by a factor of 3.55, based on historic indices as used in CPA formulae. Operation costs have been based on DWA standard percentages as in the VAPS model.

The costs of the Boskraai Dam have been recalculated using similar assumptions and rates as for the other dams, and the results are summarised in **Table 3.7.**

Table 3.7: Height, Costs and URVs of proposed Boskraai Dam

Boskraai Dam FSL (masl)		1385
River Bed Level (RBL) (masl)		1304
Height RBL to FSL (m)		
- Orange River		81
- Kraai River		72
Capital cost (R million)		4962
Operating Cost (R million / a)		12.4
Historic Firm Yield (million m^3/a)		937
URV (R/m^3)	6%	0.43
	8%	0.56
	10%	0.72

The social and environmental analysis (See **Appendix C**) which ruled out the Kraai Dam is also applicable to the possible Boskraai Dam. This option should therefore be be regarded as a fatal flaw.

3.2.7 Raising of Gariep Dam

The dam layout, schedule of quantities, cost calculations and URV calculations are shown in **Appendix B6.**

- **Description of Dam**

The Gariep Dam is located on the Orange River between the Eastern Cape and Free State and about 30 km north east of Colesberg. It is situated in a gorge at the entrance to the Ruigte Valley some 5 km east of Norvalspont.

The existing dam consists of a central double curvature arch with a gravity section on each flank, a main spillway on the crest of the central section and chute spillways on both flanks with gated inlet structures in the gravity sections. A power generation station was provided on the left flank with inlet structures also through the left gravity section. The existing FSL is 1258.69 masl and the raising of the Gariep Dam with 5 or 10 m above the existing FSL was investigated in the 1998 Pre-feasibility Phase of the Orange River Development Replanning Study (ORRS). The dam capacity will increase to 1.4 and 2.2 MAR respectively (MAR = 5104 million m^3 determined with the existing system after implementation of Lesotho Highlands Phase 1).

Previous studies indicated that the raising of the Gariep Dam will provide additional yields at very low URV but will result in a significant increase in evaporation losses from the system. This led to the investigation of a large upstream storage reservoir; the Bosberg, or Boskraai Dam. The

Bosberg and Boskraai will be alternative options to the raising of the Gariep Dam option to store the bulk of the water further upstream in the catchment.

The study considered two methods to raise the dam; raising the central spillway by 15 radial gates or by adding a solid concrete section. The raising with gates was not favoured due to the risk that the gates cannot be opened during floods. Damage to the infrastructure can occur and the cost of anchoring the gates to the thin crest of the existing spillway and piers is too high. The solid concrete option was more favourable as the uncontrolled spillway needs no human, mechanical or electrical reliance during a flood event. The piers and road over the crest of the dam will have to be raised for all options except the 5 m gated rising which can be accommodated using flood protection beams.

For the purpose of this study a 10 m rise up to a new FSL of 1268.98 masl has been adopted. The spillway, bridge and flanks needs to be raised by 10 m by the addition of concrete. The purchase line around the dam basin including developments at Bethulie and Aventura and the saddle bank should be raised by 10 m. The intake structure at Oviston that provides water into the Oviston tunnel will encounter no problems if the water level rises above the existing FSL and a 21m rise in water level can be tolerated. No alterations to the Oviston intake structure will therefore be required.

- **Yields and Costs**

The increase in historic firm yield as a result of the raising, including the effects of the planned Polihali Dam in Lesotho, but excluding a new upstream dam, is 350 million m^3/a.

Capital costs of the main dam wall are based on quantities taken from the *ORRS Potential Dam Development and Hydro Power Options 1994* and have been escalated from 1994 to 2012 by a factor of 3.55, based on historic indices as used in CPA formulae. Operation costs have been based on DWA standard percentages as in the VAPS model.

The costs of the Gariep Dam Raising have been recalculated using similar assumptions and rates as for the other dams, and the results are summarised in **Table 3.8.**

Table 3.8: Costs and URVs of proposed Gariep Dam Raising

Gariep Dam FSL (masl) (10m raising)		1268.7
Capital cost (R million)		1368
Operating Cost (R million / a)		3.4
Historic Firm Yield (million m^3/a)		350
URV (R/m^3)	6%	0.31
	8%	0.40
	10%	0.50

3.2.8 New Boegoeberg Dam

A dam downstream of the existing Boegoeberg Dam was considered in the LORMS study but was eliminated because it was considerably more expensive than the alternative Vioolsdrift option and had higher environmental and social risks. However, in this study's screening process, it was reported that the existing Boegoeberg Dam was in a poor condition and would need to be replaced, and that the replacement cost should be taken into account when comparing Vioolsdrift and new Boegoberg.

This study therefore reviewed reports prepared by the DWA Dam Safety Office in 1993, 2002 and 2009. These reports all concluded that the main structure was in good condition and shortcomings with the mechanical equipment, identified in the first study, were described as rectified in the subsequent studies, with detailed programmes for ongoing maintenance put in place.

It is therefore concluded that the existing dam will not in fact, need to be replaced, and will therefore not impact on the comparison of Vioolsdrift and a New Boegoeberg.

The New Boegoeberg Dam has therefore not been considered further in this study

3.2.9 Vioolsdrift Dam

The dam layout, schedule of quantities, cost calculations and URV calculations are shown in **Appendix B7.**

- **Description of Dam**

The existing Vioolsdrift Weir, constructed in 1930, provides water to the Vioolsdrift left bank irrigation canal and inundates the river for some 7 km. Just upstream of the basin the river valley forms its narrowest part in the area where various sites for dam walls were identified. The ORRS report stipulates that the main purpose of the new dam is to regulate river flow to improve supply to far lower Orange River and for storage capacity for irrigation supply.

Three dam options were considered; operational dam at a full supply level of 195 masl, and water yield dams at full supply level of 233 masl; and 235 masl.

The best dam wall site was chosen some 8.5 km upstream of the existing weir. The raising of the existing dam wall was considered but was abandoned due to unsuitable foundation conditions on the right bank which includes deeply weathered material. A straight rollcrete gravity dam was selected at a FSL of 235 m while the complete river of 400 m can be used as a spillway.

The subsequent Lower Orange River Planning Study considered a dam with a full supply level of 201.5 masl.

The geology in the river is sound and some excavation through boulder material on the flanks will be necessary.

The Regional Maximum Flood was estimated to be 18 930 m³/s which is based on an effective catchment area of 404 000 km² and a Francou Rodier k-value of 2.8. In accordance with guidelines on safety of dams in relation to floods (SANCOLD, 1991) the Safety Evaluation Discharge was calculated to be 26 325 m³/s and a freebord of 9.5 m. The effective catchment area is small compared to the "nominal" or "theoretical" catchment area because of extensive areas which are very flat and have high infiltration and do not actually contribute to flow in the Orage River.

Access to the site can be obtained by extending the existing road to Vioolsdrift Weir along the alluvium on the left bank. At one section, some rock blasting will be required for approximately 1 km to provide suitable access. Maintenance will be required on this section. No access will be possible during extreme flood cases i.e. floods > 1 000 m^3/s and therefore a helicopter platform must also be provided.

If the water level is at FSL of 210 m it will inundate a farmstead of Goodhouse in the Northern Cape, and at Haklesdoorn in Namibia. Witbank in the Northern Cape is located above the FSL and will likely not be flooded.

- **Yields and Costs**

For the purpose of this study a FSL of 210 masl was adopted

The historic firm yield including the effects of the planned Polihali Dam in Lesotho, but excluding any other upstream development, is 192 million m^3/a. Additional to that, 120 million m^3/a water losses can be saved if the Vioolsdrift Dam is used as a regulating dam. The total yield and water loss savings benefit will therefore be 312 million m^3/a.

Capital costs of the main dam wall are based on quantities taken from the *ORRS Potential Dam Development and Hydro Power Options 1994* and have been escalated from 1994 to 2012 by a factor of 3.55, based on historic indices as used in CPA formulae. Operation costs have been based on DWA standard percentages as in the VAPS model.

The costs of the Vioolsdrift Dam have been recalculated using similar assumptions and rates as for the other dams, and the results are summarised in **Table 3.9.**

Table 3.9: Costs and URVs of proposed Vioolsdrift Dam

Vioolsdrift Dam FSL (masl)		210
River Bed level (masl)		175
Height RBL to FSL		35
Capital cost (R million)		986
Operating Cost (R million / a)		2.5
Historic Firm Yield (million m^3/a) Benefit of saving operational losses Total yield (million m^3/a)		192 120 312
Benefit of saving operational losses		120
URV (R/m^3)	6% 8% 10%	0.23 0.29 0.36

3.2.10 Knoffelfontein Dam

- **Description**

The proposed Knoffelfontein Dam is situated on the Riet River just downstream of the confluence of the Modder River and about 11 km downstream of a small town in the Northern Cape called Ritchie. The ORRS report states that the main purpose of this dam is to provide off-channel storage for balancing of water from Orange Riet canal and for storage capacity for irrigation supply. The proposed dam wall is situated in a relatively steep-sided narrow valley.

A rollcrete gravity dam is proposed with a stepped spillway having a length of 100 m and a slope of 1V:0.75H. Based on an effective catchment area of 30 000 km^2, the regional maximum flood was calculated to be 2 330 m^3/s and used to determine the freebord of 5 m. The surface area at a FSL of 1090 m is 9.71 km^2 and the dam capacity is 12 500 000 m^3.

A cofferdam was included in the cost estimate for river diversion during construction.

The yield of this dam is negligible in terms of the water balance of the Orange River basin, but was included only because it has been proposed as a source of water for a possible downstream irrigation scheme for emerging farmers.

- **Yields and Costs**

The historic firm yield is 3.2 million m^3/a.

Capital costs of the main dam wall are based on quantities calculated from GoogleEarth ground levels. Operation costs have been based on DWA standard percentages as in the VAPS model.

The costs of the Knoffelfontein Dam have been calculated and the results are summarised in **Table 3.10**.

Table 3.10: Costs and URVs of proposed Knoffelfontein Dam

Knoffelfontein Dam FSL (masl)		1090
River bed Level (masl)		1079
Water Height RBL to FSL		11
Capital cost (R million)		240
Operating Cost (R million / a)		0.6
Historic Firm Yield (million m^3/a)		3.2
URV (R/m^3)	6%	5.42
	8%	6.89
	10%	8.49

3.2.11 Utilise water below the minimum operating level of Vanderkloof Dam

The layout of the infrastructure changes, schedule of quantities, cost calculations and URV calculations are shown in **Appendix B9**.

- **Description of the Option**

The current minimum operating level of Vanderkloof Dam is some 40 m above river bed level, being set by the outlets to the Orange-Riet irrigation canal and the Eskom hydropower station. Utilising this currently dead storage can significantly increase the yield of the dam, although this would require water to be pumped from the lower levels to the irrigation canal and would impact on the generation of hydropower.

The ORRS variously quoted the lowest practical operating level as 1128.45 and 1124.78 masl and provided cost estimates for a pump system to the irrigation canal. The finally adopted minimum operating level will depend not only on the level of the available bottom silt outlet, but also on the exact location of the pump station and the NPSH requirements of the pumps selected.

The pumping system comprises a connection to the right bank silt outlet, a 300 m long 2 m diameter suction main, a pump station with a capacity of 15 m3/s, and a connection to the existing river outlet through which flow would be reversed to the irrigation canal.

The loss of power generated is complex as it is determined by the volume of water to be released for downstream purposes, and by the water level in the reservoir. The installed capacity is 2x120MW. The reservoir simulation showed that on average over the 85 year simulation, the water level would be 1.76 m lower than with the current MOL. The effect of the revised operating rule on water level is shown in **Figure 3.1.**

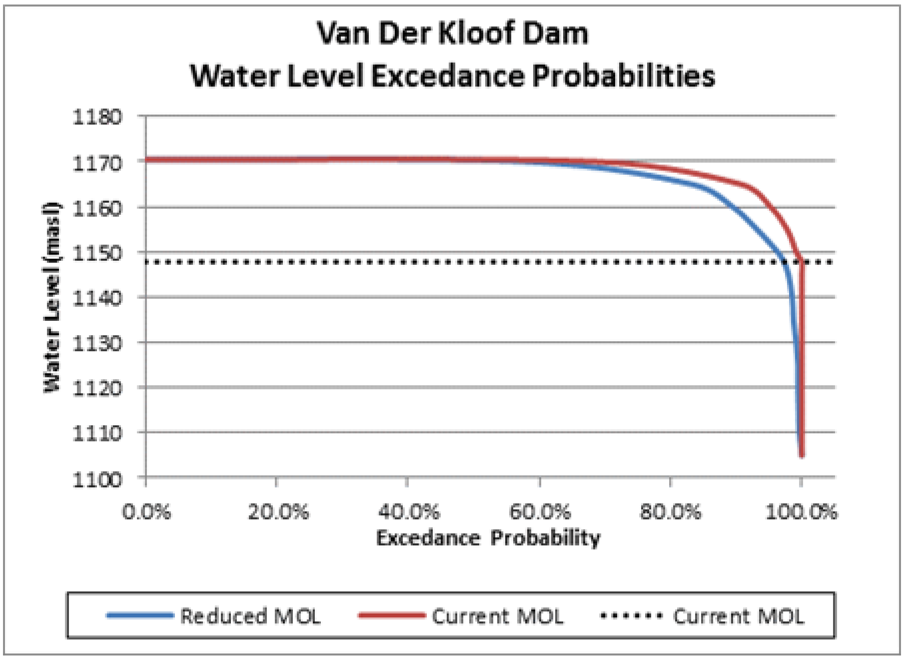


Figure 3.1: Vanderkloof Dam Water Levels

- In addition:
  - No power could be generated at all when the water level is below the current MOL. This would occur only 2.75% of the time.
  - The dam would spill less, reducing the period when river releases do not restrict the flow available for the turbines.
  - These disadvantages would probably be more than compensated by the higher EWRs which could be released through the turbines, although the limited capacity of the

turbines probably mean that the additional energy would not be available during peak periods.

- The economic benefits or disbenefits of the effect on hydropower are considered too uncertain to be estimated in this study, but are not expected to be significant.

- **Yields and Costs**

The increase in historic firm yield as a result of utilising what is currently dead storage, including the effects of the planned Polihali Dam in Lesotho, but excluding any other upstream developments, is 137 million m^3/a.

Capital costs of the pumping system are based on quantities taken from the *ORRS Potential Dam Development and Hydro Power Options 1994* and have been escalated from 1994 to 2012 by a factor of 3.55, based on historic indices as used in CPA formulae. Operation costs have been based on DWA standard percentages of capital costs as in the VAPS model and on current Eskom tariffs for pumping costs and hydropower losses.

- The system model with historic flows showed that in the 85 year record, the pumps would be required to operate only twice, for periods of 13 and 15 months respectively. Averaged over the 85 years for which this yield would be available, the consumptive costs are R110 000 per annum, but the fixed monthly service and admin, access and demand charges amount to R 3.9 million per year. The need to operate the pumps regularly for short periods to ensure their serviceability will prevent the Eskom supply being disconnected when not needed, to avoid these costs. However, it might be possible to negotiate with Eskom to reduce these charges under these circumstances.

The costs of the lowering of the minimum operating level at Vanderkloof Dam have been recalculated using similar assumptions and rates as for the other dams, and the results are summarised in **Table 3.11.**

Table 3.11: Costs and URVs for changing the minimum operating level at Vanderkloof Dam

Vanderkloof Dam Low Level Storage (FSL) (masl)	1170.5
Current MOL (masl)	1147.8
Proposed MOL (masl)	1124.8
Capital cost (R million)	150
Operating Cost (R million / a)	8.5
Addititional Yield (million m^3/a)	137
URV ignoring hydropower losses (R/m^3) 6% 8% 10%	 0.170.20 0.23

3.2.12 Changing of the operating rule of Gariep Dam

A new operating rule to utilise water below the current minimum operating level could be achieved through lowering the minimum operation level of the dam which is set up to make provision for ESKOM power generation. The challenge is that the current operating level also dictates the intake level at Oviston to the Orange Fish Tunnel. The Orange-Fish Tunnel supplies water to the Eastern Cape through a 80km tunnel from Gariep Dam to provide water for irrigation and domestic use. With a lower minimum operating level, water will have to be pumped from a downstream point in the dam to the intake tower to ensure a continuity of water supply to the Eastern Cape. Various abstraction points have previously been considered and the most feasible abstraction point was found to be at Goodlands.

Infrastructure will be required to pump water from the Goodlands abstraction point, a bridge structure 400m into the basin with pumps attached to the 22km long pipeline. It was established that the cost of pumping and infrastructure development will be too expensive compared to the yield gain.

The URV calculation for this option was R54.42 /$m^{3,}$ which is considerably more than other options, and therefore this option was discarded for further investigation.

3.2.13 Real time monitoring of flows at the Vaal/Orange Confluence

Real time motoring through a telemetry system would be installed before the confluence of the Vaal and Orange River systems. It will be used to monitor flows from the Vaal river system as well as the releases from Vanderkloof Dam. This will allow the optimisation of releases from Vanderkloof Dam when excess flows are expected from the Vaal system.

Estimations that were determined by the use of a hydraulic river model as part of the ORASECOM IWMP Phase 2 study showed a possible increase in the available water of 80 million m^3/a when real time modelling is implemented.

A study has already been done by the DWA in this regard which provided a calibrated river model to be used for this purpose. The implementation of the model in practice in combination with real time monitoring has however not yet been implemented. A decision support system will need to be developed to synchronise the Orange and the Vaal system operation. Quality data on river discharges, dam levels and releases, restrictions/curtailments, weather and dam storage projections will be used to set up the system for both catchments. A successful operation system that includes all relevant stakeholders would result in efficient water resource management.

The cost of implementing this scheme is considered to be negligible compared to other schemes, and there is no doubt that this scheme should be implemented as a priority.

4 SUMMARY OF COSTS, POTENTIAL YIELD GAIN AND URVs

Table 4.1 provides a summary of the estimated costs, yields and URVs for each of the selected schemes described in Chapter 3.

Table 4.1: Summary of estimated costs, yields and URVs of selected schemes

Option	Cost (R million)	Yield (mil m^3/a)	URV		
			6%	8%	10%
Vd Kloof Low Level Storage	150	137	R 0.17	R 0.20	R 0.23
Vioolsdrift FSL 210	986	192	R 0.23	R 0.29	R 0.36
Gariep 10m raising	1368	350	R 0.31	R 0.40	R 0.50
Bosberg FSL 1385	4133	377	R 0.86	R 1.11	R 1.40
Verbeeldingskraal FSL 1385	1048	200	R 0.39	R 0.51	R 0.63
Kraai FSL 1372	1999	330	R 0.46	R 0.58	R 0.73
Boskraai FSL 1385	4962	937	R 0.43	R 0.56	R 0.72
Malatsi FSL 1652	1373	119	R 0.87	R 1.11	R 1.39
Ntoahae FSL 1545	1370	232	R 0.44	R 0.57	R 0.71
Knoffelfontein	240	3.2	R 5.42	R 6.89	R 8.49

In **Figure 4.1** and **Figure 4.2** the Costs and URVs are plotted against the yield gain of each specific scheme. It shows clearly that Vanderkloof Low Level Storage has the lowest cost and URV and that Ntoahae Dam, Kraai Dam, Vioolsdrift Dam, Verbeeldingskraal Dam and Gariep Dam Raising are all in the same range as far as URV and yield is concerned. Boskraai also is in that URV range, but has a much higher yield and also costs much more in terms of capital costs.

The URVs of Bosberg and Malatsi Dams are considerably higher.

It needs to be noted that the royalties payable to Lesotho have not been taken into account for Malatsi and Ntoahae Dams as no negotiations on these dams between the two countries have taken place as yet. It is likely that the royalties will further push up the URVs of these two schemes.

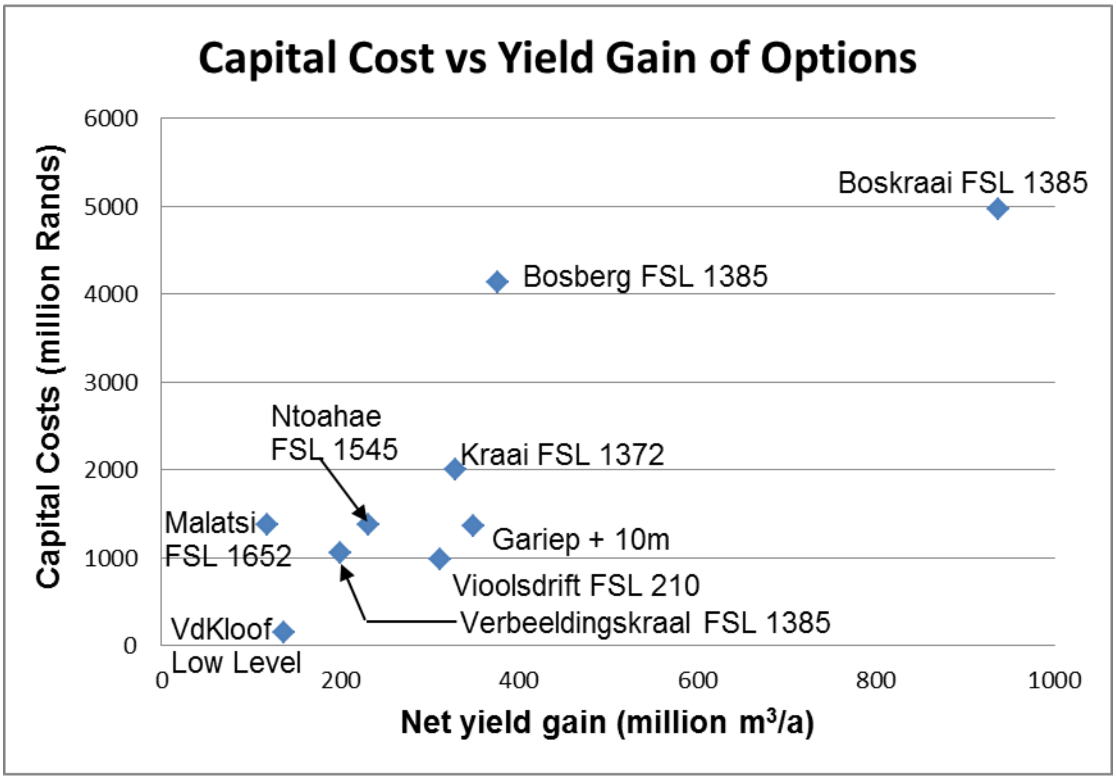


Figure 4.1: Capital Costs of Development Options

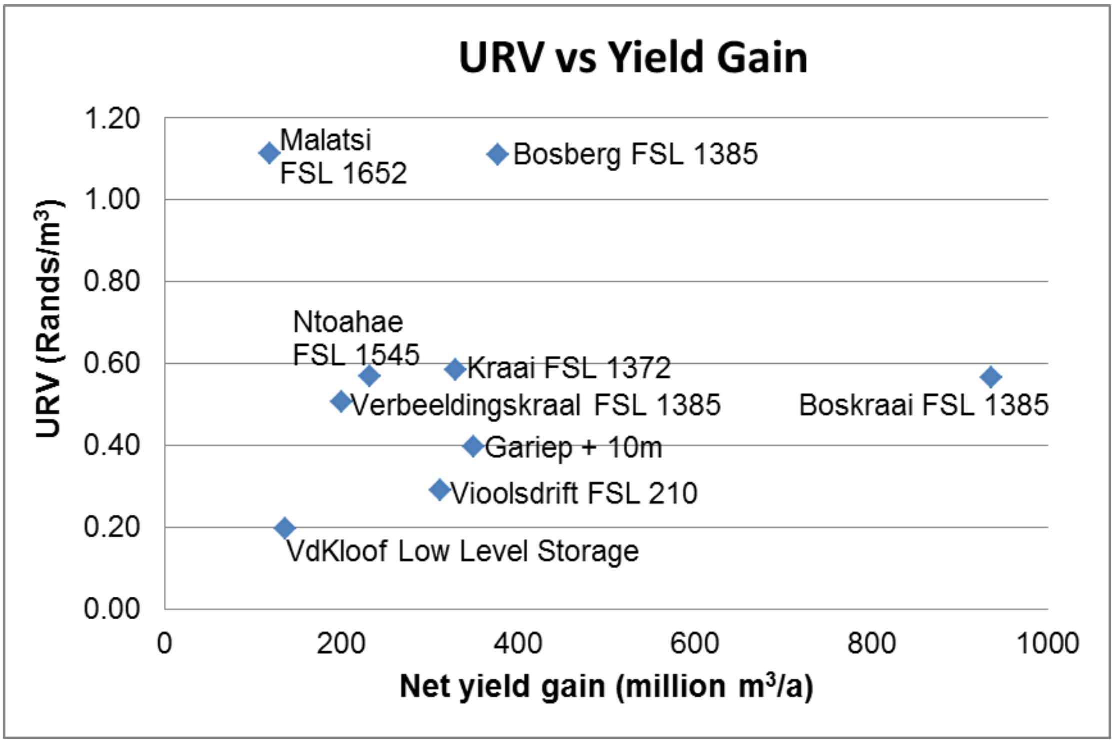


Figure 4.2: URVs (at 8% Discount Rate) of Development Options

5 CONCLUSIONS AND RECOMMENDATIONS

Based on the costs and URVs presented above, it is recommended that the following options be considered in the implementation scenarios:

- Real time monitoring downstream of Vanderkloof Dam
- Vanderkloof Dam low level storage
- Vioolsdrift Dam
- Gariep Dam raising or Verbeeldingskraal Dam

For the purpose of this study, which planning horizon will take us up to the year 2040, it would be either the raising of Gariep Dam or the construction of Verbeeldingskraal Dam. Both these options won't be required before 2040. If one however looks further in the future, beyond 2040, then both these options can be considered.

It should be noted that, depending on the long term demands, the size of Gariep and Verbeeldingskraal Dams can be adjusted from what has been considered here.

The other options have been discarded for the following reasons:

- The Malatsi Dam is very expensive with a high URV.
- The Ntoahae Dam's URV is only marginally higher than the recommended options, but this excludes royalties which are likely to be payable to Lesotho. Together with the complex and time consuming international negotiations which would be required, this make this dam unfavourable
- The Bosberg Dam is very expensive, with a high URV, because of the need for a major saddle dam which was under estimated in previous studies.
- The Kraai and Boskraai Dams have URVs only marginally higher than the recommended options, but flood the pristine Kraai River with significant environmental risks.
- The Boskraai Dam is very large and its yield is significantly higher than the requirements. This dam is only worth further consideration if major new demands should be identified.

Eskom prepared a brief report which was received almost at the study closure. This report provides details on hydro-power related impacts on two of the proposed intervention options.

- Vanderkloof Dam low level storage
- Gariep Dam raising

The Eskom report is included in **Appendix D** of this report and need to be taken into concideration during the feasibility study for the Raising of Gariep Dam/Verbeeldingskraal Dam as well as when the Bridging Study is commissioned to proceed with the implementation of the option to utilise the Vanderkloof Lower Level Storage.

6 REFERENCES

DWA Dam Safety Office in 1993, 2002 and 2009.

Layouts, costs and yields of screened options to increase the water resource availability Report.

LHWP Consulting Services for the Feasibility Study for Phase 2: Dam Design, September 2007,

ORASECOM IWMP Phase 2 study

ORRS, 1997 and LORMS, 2005

ORRS Potential Dam Development and Hydro Power Options 1994

1998 Pre-feasibility Phase of the Orange River Development Replanning Study (ORRS)

Water Reconciliation Strategy Study for Large Bulk Water Supply Systems: Greater Bloemfontein Area, DWa, 2012.

1985 Lesotho Highlands Feasibility Study: Orange Vaal Transfer Scheme,

1995 Pre-feasibility Stage of the Vaal Augmentation Planning Study, and the 1998 Pre-feasibility Phase of the Orange River Development replanning Study (ORRS).

DWA 2013 Preliminary Screening Options Identified and Agreed on during the Workshop of February 2013 report no.P RSA D000/00/18312/13.

Appendix A

Summary of Dam Yields

Table A.1 Summary of Dam Yields

SCENARIO	Brief Description	Development level	Yield Surplus/ Deficit	Yield With EWR	Yield Excluding EWR	Yield EWR impact	Yield increase	Live Storage increase	Total Evaporation	Increase evaporation	Spills	Spill difference	FSL m.a.s.l	Details
1	Current day	2012	212	3,038	3,325	287			815		4,062	0	current	
2b	Current day + new EWR no High flows	2012	-213	2,613	3,325	712	-425	0	825	10	4,421	358	current	
4d	Polihali full transfer to Vaal new EWR & Vioolsdrift reregulating dam & new EWR	2040	-753	2,299	3,021	722	120	110	834	19	4,093	31	205.64	Viools reregulating size: 370 (110 live, 260 dead)
5di	Polihali full Vaal transfer, Vioolsdrift yield (510) & reregulating dam current EWR	2040	-561	2,491	3,213	722	192	250	836	0	4,055	0	210.18	Viools size total storage 510 million m^3, dead storage260, live storage 250 million m^3
6b	Polihali,full Vaal transfer, Raised Gariep by 10m & Viools yield (510) & reregulating	2040	-211	2,841	3,563	722	350	4,740	1,119	283	3,503	-552	1,268.69	Raised Gariep by 10m: 9 683 million m^3 total, increase of 4 485 million m^3
7d	Polihali,full Vaal transfer, Bosberg (3065) & Viools Yield (510) & reregulating	2040	-184	2,868	3,590	722	377	3,315	890	54	3,683	-372	1,385.00	Bosberg aurecon size: 3065, m^3 live storage, 85m high at spill level
8d	Polihali,full Vaal transfer, Boskraai (8288) & Viools Yield(510) & reregulating	2040	376	3,428	4,150	722	937	8,538	978	142	3,134	-921	1,385.00	Boskraai size 8 288 million m^3 live storage, 85m high at spill level
9c	Polihali,full Vaal transfer, Ntoahae (1 720, 20 dead) & Viools Yield(510) & reregulating	2040	-329	2,723	3,445	722	232	1,950	839	3	3,841	-214	1,645.00	Ntoahae size 1 720 million m^3 total storage, 20 dead storage = 1 700 million m^3 live storage
10c	Polihali,full Vaal transfer, Malatsi (878, 7.5 dead) & Viools Yield(510) & reregulating	2040	-442	2,610	3,332	722	119	1,121	842	6	3,943	-112	1,652.00	Malatsi size: 878 million m^3 total storage, 7.5 dead storage = 870.5 million m^3 live storage
11	Polihali,full Vaal transfer, VDK low level use & Viools yield (510) & reregulating	2040	-424	2,628	3,350	722	137	1,100	815	-21	3,939	-116	current	M.O.L in VDK set to dead storage level of 1124.78
12a	Polihali,full Vaal transfer, Kraai (929) & Viools Yield(510) & reregulating	2040	-477	2,575	3,297	722	84	1,179	909	73	3,938	-117	1,352.00	Kraai size 52 m, 929 live, total 947, 18 dead
12b	Polihali,full Vaal transfer, Kraai (2971) & Viools Yield(510) & reregulating	2040	-231	2,821	3,543	722	330	3,221	955	119	3,688	-366	1,372.00	Kraai size 72 m, 2989 live, total 2971, 18 dead
13a	Polihali,full Vaal transfer, Raised Gariep by 10m, VDK low level use & Viools reregulating corrected *	2040	-234	2,818	3,540	722	327							
13a old	Polihali,full Vaal transfer, Raised Gariep by 10m, VDK low level use & Viools reregulating	2040	-131	2,921	3,643	722	430	5,450	1,073	238	3,466	-589	1,268.69	M.O.L in VDK set to dead storage level of 1124.78, Raised Gariep by 10m: 9 683 million m^3 total, in
13b	Polihali,full Vaal transfer, Raised Gariep by 10m, VDK low level use & Viools yield (510) & reregulating *	2040	-72	2,980	3,702	722	489	5,590	1,067	232	3,380	-675	1,268.69	M.O.L in VDK set to dead storage level of 1124.78, Raised Gariep by 10m: 9 683 million m^3 total, in
13c	Polihali,full Vaal transfer, Raised Gariep by 10m, VDK low level use & Viools yield (544.8) & reregulating	2040	-67	2,985	3,707	722	494	5,625					1,385.00	M.O.L in VDK set to dead storage level of 1124.78, Raised Gariep by 10m: 9 683 million m^3 total, in
	Note * - Gain in yield due to Vioolsdrift yield dam is 162 million m^3/a thus 30 million m^3/a less than 5di	59	Vioolsdrift incremental yield based on wrong analysis							51	Saving in evaporation versus Gariep raised option			

Appendix B

Dam layout, Schedule of Quantities, Cost Calculations and URV Calculations

APPENDIX B1 – MALATSI DAM

Figure B1.1 Locality

Table B1.1 Schedule of Quantities

Item No	Description	Unit	Quantity	Rate	Amount
1	**Clearing**	ha	33	6 450	220 000
2	**River Diversion**				
	(a) Cofferdam	m^3	374 464	39	14 610 000
	(b) Tunnel including portals, rock support, concrete and stop logs	m^3	78 454	1 097	86 070 000
3	Excavation				
	(a) Bulk				
	(i) All Materials	m^3	289 123	33	9 550 000
	(ii) Extra over for rock	m^3	72 281	60	4 340 000
	(b) Confined				
	(i) All materials	m^3	3 000	48	150 000
	(ii) Extra over the rock	m^3	3 000	82	250 000
	(c) Preparation of Solum				
	(i) All materials	m^2	109 860	7	770 000
	(ii) Extra over the rock	m^2	3 296	7	30 000
	(iii) Final foundation preparation for plinth	m^2	9 192	52	480 000
4	**Drilling and Grouting**				
	(a) Curtain grouting	m drill	9 538	903	8 620 000
	(b) Consolidation grouting	m drill	3 265	903	2 950 000
5	**Embarkment**				
	(a) Rockfill from Quarry	m^3	5 245 460	69	361 940 000
	(b) Rockfill from Spillway	m^3	186 880	92	17 200 000
	(c) Filters	m^3	264 963	136	36 040 000
	(d) Overhaul beyond 5km	m^3 km			
6	**Formwork**				
	(a) Gang Formed	m^2	19 393	213	4 140 000
	(b) Intricate	m^2	969	297	290 000

Item No	Description	Unit	Quantity	Rate	Amount
7	**Concrete**				
	(a) Mass below plinth	m^3	4 500	516	2 330 000
	(b) Mass in Spillway	m^3	1 400	645	910 000
	(c) Structural in spillway, outletworks, etc	m^3	27 342	813	22 230 000
	(d) Structural in plinth	m^3	1 380	1 058	1 470 000
	(e) Face slab including formwork	m^3	25 642	1 290	33 080 000
8	**Reinforcing**	t	3 324	9 288	30 880 000
	SUB-TOTAL				**638 430 000**
9	**Landscaping (include in 10)**	%			
10	**Miscellaneous (% of 1-8)**	%	638 430 000	10%	63 850 000
	SUB-TOTAL A				**702 270 000**
11	**Preliminary and General**				
	(% of Sub total B)		702 270 000	40%	280 910 000
	SUB-TOTAL B				**983 180 000**
12	**Contigencies**	%	983 180 000	15%	147 480 000
	(% of sub-total E)				
	SUB TOTAL C (Civils Total)				**1 130 660 000**
13	**Mechanical Items**				
	(a) Valves and Gates	Sum	1		32 250 000
	(b) Cranes and hoists	Sum	1		12 900 000
	(c) Structural Steelwork	t	20		460 000
	SUB-TOTAL D				**45 610 000**
14	**Preliminary and General**	%	45 610 000	40%	18 250 000
	(% of sub-total D)				
	SUB-TOTAL E				**63 850 000**

Item No	Description	Unit	Quantity	Rate	Amount
15	**Contingencies**	%	63 850 000	15%	9 580 000
	(% of sub total E)				
	Sub Total F (M/E Total)				73 430 000
	SUB TOTAL G (C+F)				1 204 080 000
16	VAT(% of sub total D)	%	1 204 080 000	14%	168 580 000
	TOTAL CAPITAL COSTS				**1 372 650 000**

Table B1.2 URV Calculations

	ORANGE RIVER RECONCILIATION STRATEGY			
	UNIT REFERENCE VALUES			
	MALATSI DAM		**FSL**	1652
		Yield (million m^3/annum)		119
		Capital Cost (R million)		1373
		Costruction Period		3
	Year	**Yield**	**Capital**	**O&M**
	2012	0.0	0	0
	2013	0.0	0	0
	2014	0.0	103	0
	2015	0.0	103	0.0
	2016	0.0	389.0	0.0
	2017	0.0	389.0	0.0
	2018	0.0	389.0	0.0
	2019	119.0		3.4
	2020	119.0		3.4
	2021	119.0		3.4
	2022	119.0		3.4
	2023	119.0		3.4
	2024	119.0		3.4
	2025	119.0		3.4
	2026	119.0		3.4
	2027	119.0		3.4
	2028	119.0		3.4
	2029	119.0		3.4
	2030	119.0		3.4
	2031	119.0		3.4
	2032	119.0		3.4
	2033	119.0		3.4
	2034	119.0		3.4
	2035	119.0		3.4
	2036	119.0		3.4
	2037	119.0		3.4
	2038	119.0		3.4
	2039	119.0		3.4
	2040	119.0		3.4
	2041	119.0		3.4
	2042	119.0		3.4
	2043	119.0		3.4
	2044	119.0		3.4
	2045	119.0		3.4
	2046	119.0		3.4
	2047	119.0		3.4
	2048	119.0		3.4
	2049	119.0		3.4
	2050	119.0		3.4
	2051	119.0		3.4
	2052	119.0		3.4
	2053	119.0		3.4
	2054	119.0		3.4
	2055	119.0		3.4
	2056	119.0		3.4
	2057	119.0		3.4
NPV @	6%	1,183	992	34.1
	8%	825	894	23.8
	10%	596	808	17.2
URV	6%		R 0.87	
	8%		R 1.11	
	10%		R 1.39	

APPENDIX B2 – NTOAHAE DAM

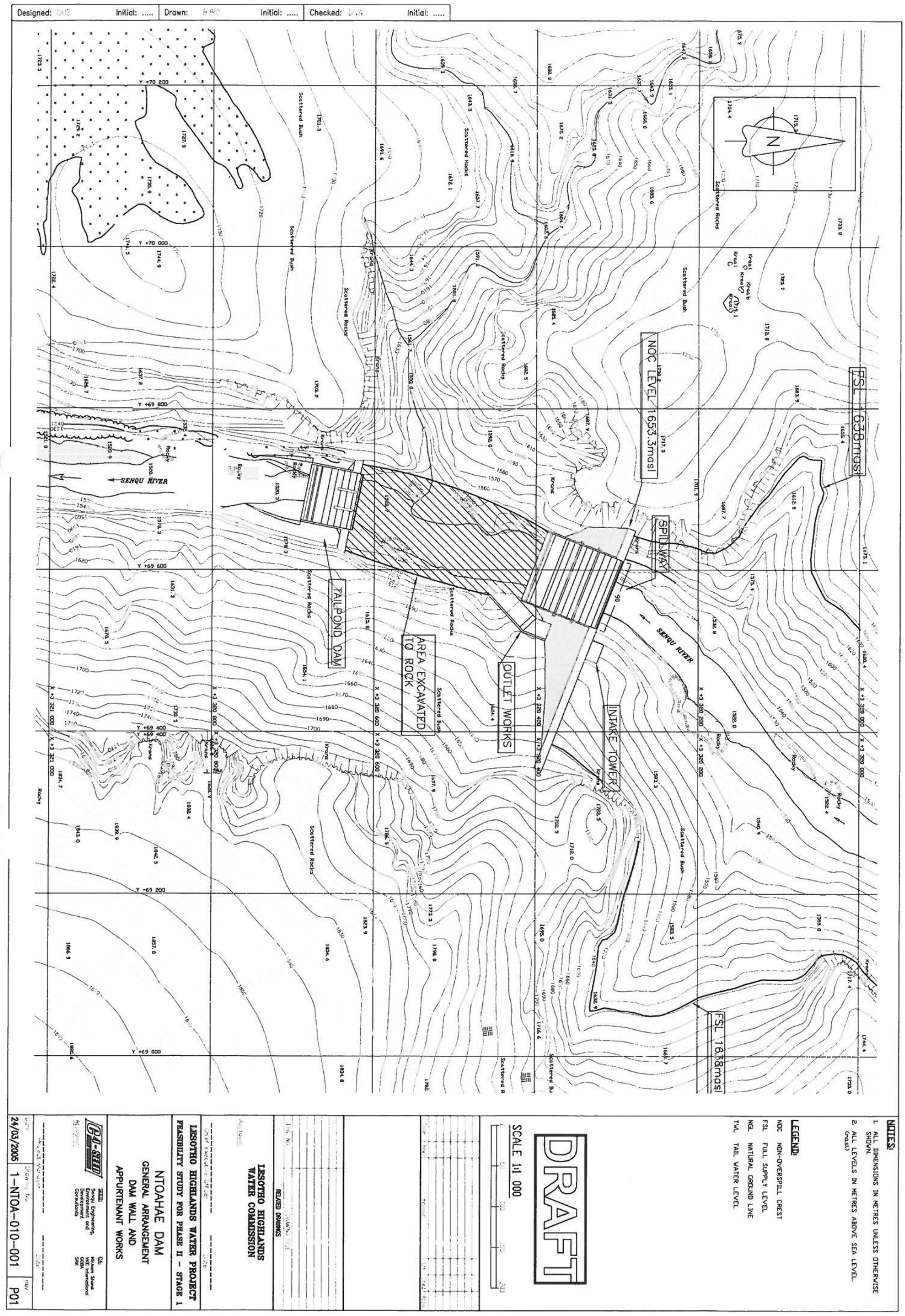


Figure B2.1 Locality

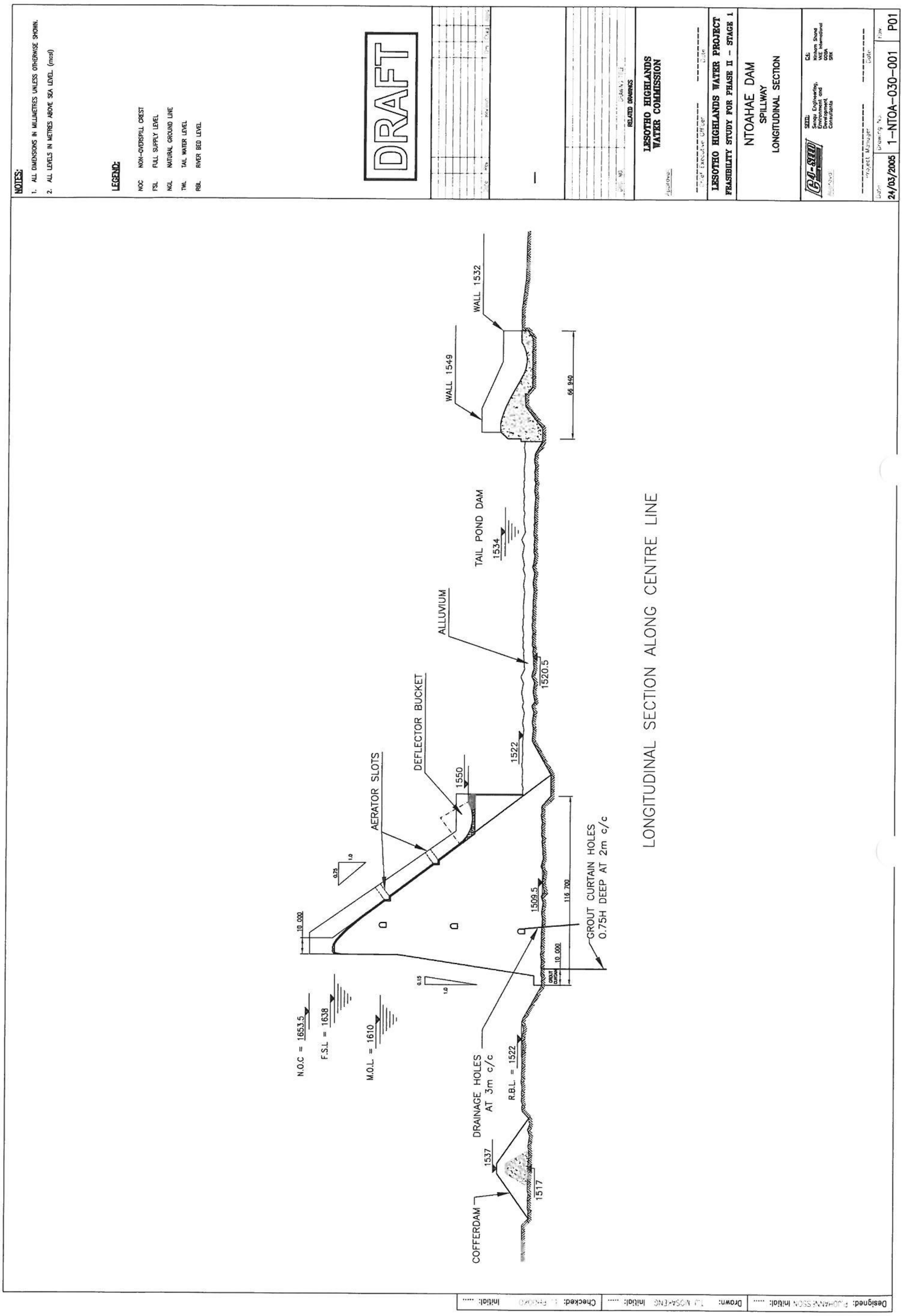


Figure B2.2 Section

Table B2.1 Schedule of Quantities

Item No	Description	Unit	Quantity	Rate	Amount
1	**Clearing**	ha	7	6 450	50 000
2	**River Diversion**				
	(a) Cofferdam	Sum	1	12 900 000	12 900 000
3	**Excavation**				
	(a) Bulk				
	(i) All Materials	m^3	503 012	33	16 600 000
	(ii) Extra over for rock	m^3	111 506	60	6 700 000
	(b) Confined				
	(i) All materials	m^3	3 000	48	150 000
	(ii) Extra over the rock	m^3	3 000	82	250 000
	(c) Final Foundation preparation	m^2	36 063	52	1 880 000
4	**Drilling and Grouting**				
	(a) Curtain grouting	m drill	7 432	903	6 720 000
	(b) Consolidation grouting	m drill	5 420	903	4 900 000
5	**Formwork**				
	(a) Gang Formed	m^2	127 965	142	18 180 000
	(b) Intricate	m^2	6 399	297	1 910 000
6	**Concrete**				
	(a) RCC	m^3	953 274	358	341 280 000
	(b) GE-RCC including joints , etc	m^3	43 532	594	25 860 000
	(c) Mass	m^3	121 678	645	78 490 000
	(d) Structural	m^3	54 545	813	44 350 000
7	**Reinforcing**	t	5 455	9 288	50 670 000
	SUB-TOTAL				**610 810 000**
8	**Landscaping (include in 9)**	%			
9	**Miscellaneous (% of 1-7)**	%	610 810 000	10%	61 090 000.00

Item No	Description	Unit	Quantity	Rate	Amount
	SUB-TOTAL A				**671 890 000**
11	**Preliminary and General**				
	(% of Sub total A)		671 890 000	40%	268 760 000.00
	SUB-TOTAL B				**940 640 000**
12	**Contigencies**	%	940 640 000	20%	188 130 000.00
	(% of sub-total E)				
	SUB TOTAL C (Civils Total)				**1 128 760 000**
13	**Mechanical Items**				
	(a) Valves and Gates	Sum	1	32 250 000	32 250 000.00
	(b) Cranes and hoists	Sum	1	12 900 000	12 900 000.00
	(c) Structural Steelwork	t	20	22 704	460 000.00
	SUB-TOTAL D				**45 610 000.00**
14	**Preliminary and General**	%	45 610 000	40%	18 250 000
	(% of sub-total D)				
	SUB-TOTAL E				**63 850 000**
15	**Contingencies**	%	63 850 000	15%	9 580 000
	(% of sub total E)				
	Sub Total F (M/E Total)				73 430 000
	SUB TOTAL G (C+F)				1 202 190 000
16	VAT(% of sub total D)	%	1 202 190 000	14%	168 310 000
	TOTAL CAPITAL COSTS				**1 370 490 000**

Table B2.2 URV Calculations

	ORANGE RIVER RECONCILIATION STRATEGY			
	UNIT REFERENCE VALUES			
	NTOAHAE DAM		**FSL**	1645
		Yield (million m³/annum		232
		Capital Cost (R million)		1370
		Costruction Period		3
	Year	**Yield**	**Capital**	**O&M**
	2012	0.0	0	0
	2013	0.0	0	0
	2014	0.0	103	0
	2015	0.0	103	0.0
	2016	0.0	388.2	0.0
	2017	0.0	388.2	0.0
	2018	0.0	388.2	0.0
	2019	232.0		3.4
	2020	232.0		3.4
	2021	232.0		3.4
	2022	232.0		3.4
	2023	232.0		3.4
	2024	232.0		3.4
	2025	232.0		3.4
	2026	232.0		3.4
	2027	232.0		3.4
	2028	232.0		3.4
	2029	232.0		3.4
	2030	232.0		3.4
	2031	232.0		3.4
	2032	232.0		3.4
	2033	232.0		3.4
	2034	232.0		3.4
	2035	232.0		3.4
	2036	232.0		3.4
	2037	232.0		3.4
	2038	232.0		3.4
	2039	232.0		3.4
	2040	232.0		3.4
	2041	232.0		3.4
	2042	232.0		3.4
	2043	232.0		3.4
	2044	232.0		3.4
	2045	232.0		3.4
	2046	232.0		3.4
	2047	232.0		3.4
	2048	232.0		3.4
	2049	232.0		3.4
	2050	232.0		3.4
	2051	232.0		3.4
	2052	232.0		3.4
	2053	232.0		3.4
	2054	232.0		3.4
	2055	232.0		3.4
	2056	232.0		3.4
	2057	232.0		3.4
NPV	6%	2,307	990	34.1
	8%	1,608	892	23.7
	10%	1,162	807	17.1
URV	6%		R 0.44	
	8%		R 0.57	
	10%		R 0.71	

APPENDIX B3 – BOSBERG DAM

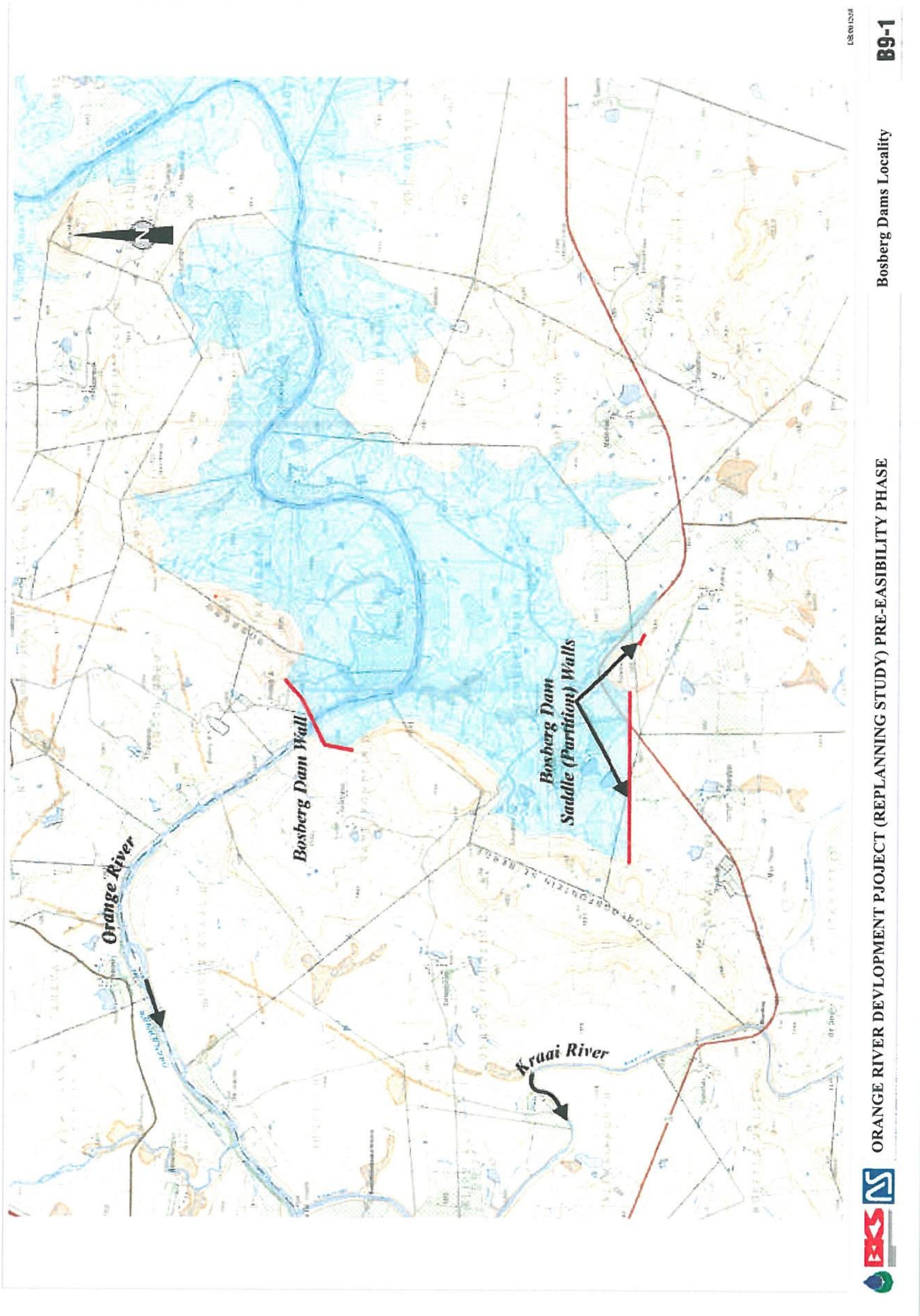


Figure B3.1 Locality

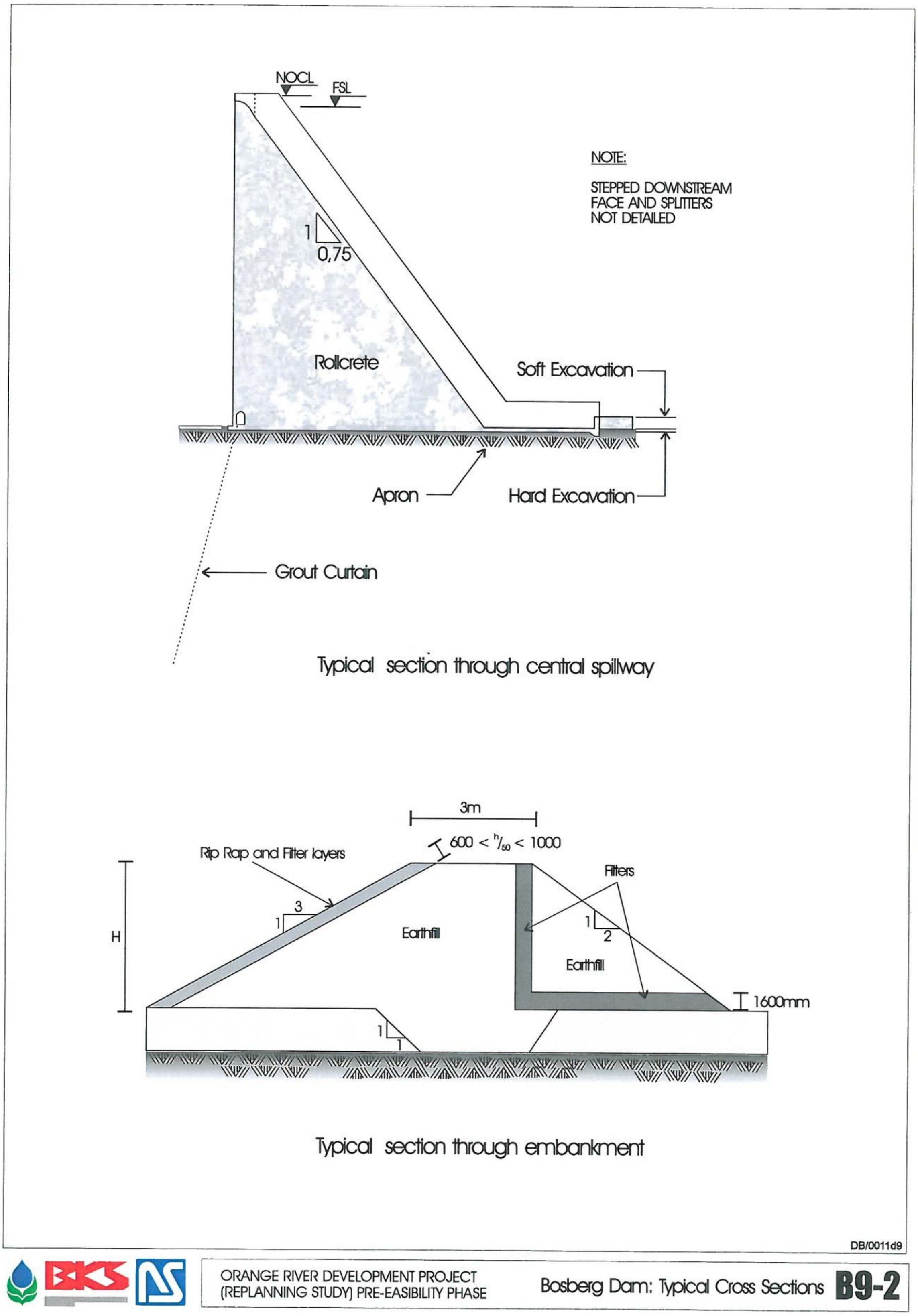


Figure B3.2 Typical Cross Sections

Table B3.1 Schedule of Quantities – Bosberg Partition Dam

Item No	Description	Unit	Quantity	Rate	Amount
1	**Site and Basin Clearing**				
	(a) Sparse	ha	38	4 970	190 000
2	**River Diversion**	Sum			-
3	**Excavation**				
	(a) All Materials	m^3	1 889 710	54	100 630 000
	(b) Extra over the rock	m^3	566 913	68	38 240 000
	(c) Final foundation preparation	m^2	378 731	71	26 890 000
4	**Embankment**				
	(a) Earthfill	m^3	5 148 701	43	219 340 000
	(b) Filters	m^3	889 165	157	138 890 000
	(c) Rip-rap	m^3	212 777	86	18 130 000
	(d) Overhaul beyond 5km	m^3.km	25 743 505	4	91 390 000
4	**Drilling and Grouting**				
	(a) Curtain grouting	m drill		398	-
	(b) Consolidation grouting	m drill		398	-
5	**Formwork**				
	(a) Gang Formed	m^2		178	-
	(b) Intricate	m^2		284	-
6	**Concrete**				
	(a) Rollcrete	m3		568	-
	(b) Facecrete including waterstop	m3		142	-
	(c) Structural	m3		831	-
7	**Reinforcing**	t		8 875	-
8	**Mechanical Items**				
	(a) Valves and Gates	Sum		8 875 000	-
	(b) Cranes and hoists	Sum		1 775 000	-

Item No	Description	Unit	Quantity	Rate	Amount
	(c) Hydraulic Steelwork	t		1 775 000	-
	SUB-TOTAL				**633 690 000**
9	**Fencing**	km	11	24 850	280 000
10	**Landscaping (% 1-10)**	%	633 690 000	5%	31 690 000
11	**Miscellaneous (% of 1-10)**	%	633 690 000	10%	63 370 000
	SUB-TOTAL A				**729 010 000**
12	**Preliminary and General**	%	729 010 000	30%	218 710 000
	(% of sub-total A)				
13	**Preliminary Works**				
	(a) Access Road				
	flat terrain	km		213 000	-
	hilly terrein	km		12 780 000	-
	(b) Electricity to site	Sum	1	1 775 000	1 780 000
	(c) Construction water to site	Sum	1	1 775 000	1 780 000
	(d) Railhead and materials handling	Sum	1	3 550 000	3 550 000
14	**Accomodation**	Sum	1	3 550 000	3 550 000
	SUB TOTAL B				**958 370 000**
15	**Contigencies**	%	958 370 000	10%	95 840 000
	(% of sub-total B)				
	SUB TOTAL C				**1 054 200 000**
16	**Planning design and supervision, fees, time costs and transport (% of sub-total C**	%	1 054 200 000	15%	158 130 000
	SUB-TOTAL D				**1 212 330 000**

Item No	Description	Unit	Quantity	Rate	Amount
17	VAT(% of sub total D)	%	1 212 330 000	14%	169 730 000
	NET PROJECT COST				**1 382 060 000**

Table B3.2 Schedule of Quantities (Total Dam)

Item No	Description	Unit	Quantity	Rate	Amount
1	**Site and Basin Clearing**				
	(a) Sparse	ha	25	4 970	130 000
2	**River Diversion**	Sum	1	31 950 000	31 950 000
3	**Excavation**				
	(a) All Materials	m³	1 096 569	54	58 400 000
	(b) Extra over the rock	m³	328 971	68	22 190 000
	(c) Final foundation preparation	m²	245 574	71	17 440 000
4	**Embankment**				
	(a) Earthfill	m³	3 390 725	43	144 450 000
	(b) Filters	m³	301 902	157	47 160 000
	(c) Rip-rap	m³	111 062	86	9 470 000
	(d) Overhaul beyond 5km	m³.km			
5	**Drilling and Grouting**				
	(a) Curtain grouting	m drill	17 775	398	7 070 000
	(b) Consolidation grouting	m drill	20 085	398	7 990 000
6	**Formwork**				
	(a) Gang Formed	m²	99 900	178	17 740 000
	(b) Intricate	m²	16 959	284	4 820 000
7	**Concrete**				
	(a) Rollcrete	m3	1 276 504	568	725 060 000
	(b) Facecrete including waterstop	m3	99 900	142	14 190 000
	(c) Structural	m3	20 024	831	16 640 000
8	**Reinforcing**	t	2 885	8 875	25 610 000
9	**Mechanical Items**				
	(a) Valves and Gates	Sum	1	8 875 000	8 880 000
	(b) Cranes and hoists	Sum	1	1 775 000	1 780 000
	(c) Hydraulic Steelwork	t	1	1 775 000	1 780 000

Item No	Description	Unit	Quantity	Rate	Amount
	SUB-TOTAL			**-**	**1 162 660 000**
				-	-
10	**Fencing**	km	8	24 850	200 000
11	**Landscaping (% 1-10)**	%	1 162 660 000	5%	58 140 000
12	**Miscellaneous (% of 1-10)**	%	1 162 660 000	10%	116 270 000
	SUB-TOTAL A				**1 337 260 000**
13	**Preliminary and General**	%	1 337 260 000	30%	401 180 000
	(% of sub-total A)				
14	**Preliminary and General**				
	(a) Access Road				
	flat terrain	km	8	213 000	1 710 000
	hilly terrein	km	1	12 780 000	12 780 000
	(b) Electricity to site	Sum	1	3 550 000	3 550 000
	(c) Construction water to site	Sum	1	1 775 000	1 780 000
	(d) Railhead and materials handling	Sum	1	7 100 000	7 100 000
15	**Accomodation**	Sum	1	19 525 000	19 530 000
	SUB TOTAL B				**1 784 870 000**
16	**Contigencies**	%	1 784 870 000	10%	178 490 000
	(% of sub-total B)				
	SUB TOTAL C				**1 963 360 000**
17	**Planning design and supervision, fees, time costs and transport (% of sub-total C**	%	1 963 360 000	15%	294 510 000
	SUB-TOTAL D				**2 257 860 000**
18	VAT(% of sub total D)	%	2 257 860 000	14%	316 110 000
	NET PROJECT COST				**2 573 960 000**

Item No	Description	Unit	Quantity	Rate	Amount
19	**Cost of Relocations**				
	(a) Roads and Bridges	Sum	1	28 800 000	28 800 000
20	**Cost of Land Acquisition**	ha	16 700	8 875	148 220 000
		ha			
21	**Helicopter landing site**	Sum			
	TOTAL PROJECT COSTS (incl. VAT)				**2 750 980 000**
	Partitioning Dam (from Table B4.2)				1 382 060 000
	TOTAL PROJECT COSTS (incl. VAT) including partitioning				**4 133 030 000**

Table B3.3 URV Calculations

	ORANGE RIVER RECONCILIATION STRATEGY			
	UNIT REFERENCE VALUES			
	BOSBERG DAM		**FSL**	1385
		Yield (million m^3/annum		377
		Capital Cost (R million)		4133
		Costruction Period		4
	Year	**Yield**	**Capital**	**O&M**
	2012	0.0	0	0
	2013	0.0	0	0
	2014	0.0	310	0
	2015	0.0	310	0.0
	2016	0.0	878.3	0.0
	2017	0.0	878.3	0.0
	2018	0.0	878.3	0.0
	2019	0.0	878.3	0.0
	2020	377.0		10.3
	2021	377.0		10.3
	2022	377.0		10.3
	2023	377.0		10.3
	2024	377.0		10.3
	2025	377.0		10.3
	2026	377.0		10.3
	2027	377.0		10.3
	2028	377.0		10.3
	2029	377.0		10.3
	2030	377.0		10.3
	2031	377.0		10.3
	2032	377.0		10.3
	2033	377.0		10.3
	2034	377.0		10.3
	2035	377.0		10.3
	2036	377.0		10.3
	2037	377.0		10.3
	2038	377.0		10.3
	2039	377.0		10.3
	2040	377.0		10.3
	2041	377.0		10.3
	2042	377.0		10.3
	2043	377.0		10.3
	2044	377.0		10.3
	2045	377.0		10.3
	2046	377.0		10.3
	2047	377.0		10.3
	2048	377.0		10.3
	2049	377.0		10.3
	2050	377.0		10.3
	2051	377.0		10.3
	2052	377.0		10.3
	2053	377.0		10.3
	2054	377.0		10.3
	2055	377.0		10.3
	2056	377.0		10.3
	2057	377.0		10.3
NPV @	6%	3,512	2,916	96.2
	8%	2,409	2,612	66.0
	10%	1,712	2,346	46.9
URV	6%		R 0.86	
	8%		R 1.11	
	10%		R 1.40	

APPENDIX B4 – UPPER ORANGE DAMS

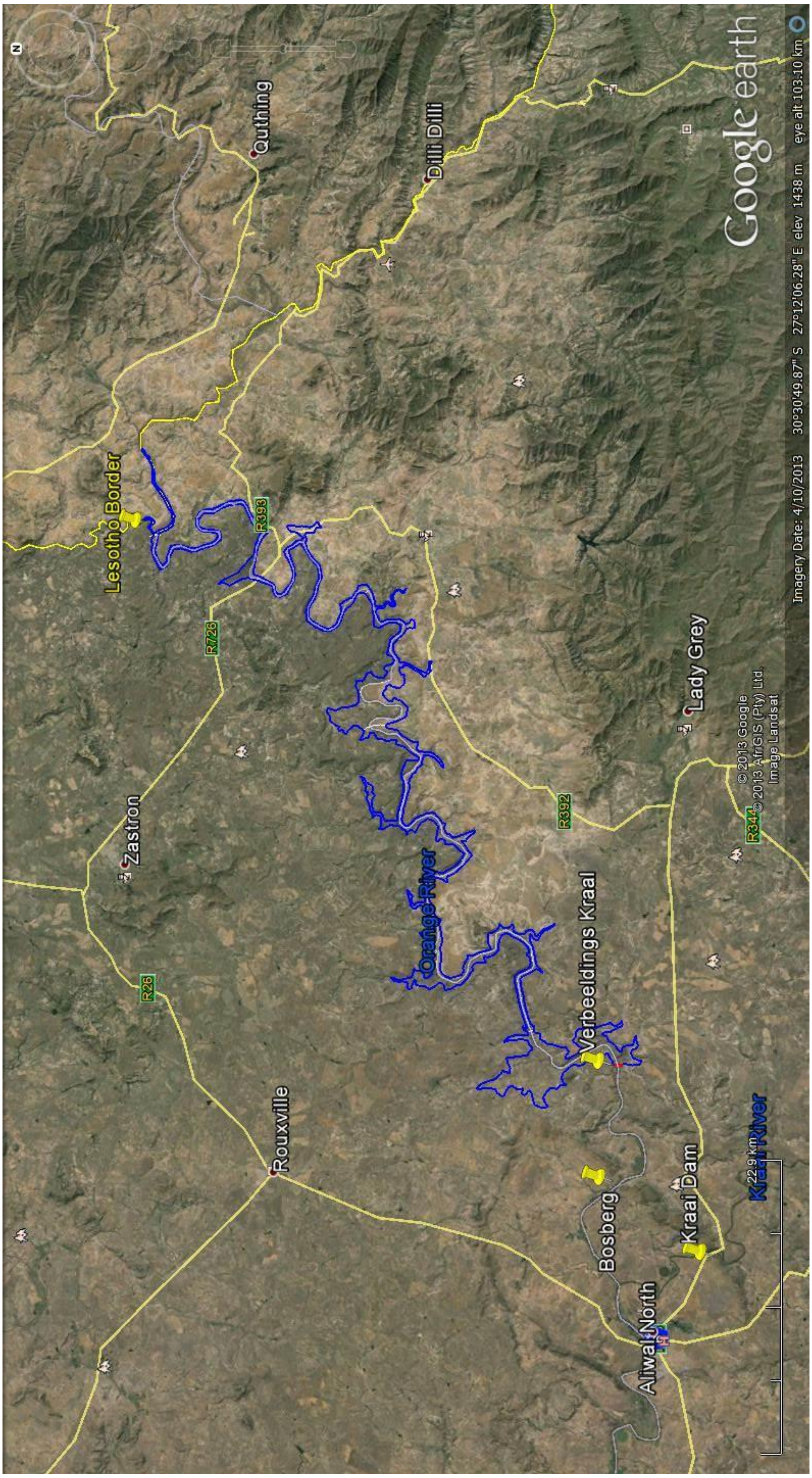


Figure B4.1 Locality Plan

Table B4.1 Schedule of Quantities

Item No	Description	Unit	RATE	Quantity	Amount
1	**Site and Basin Clearing**				
	(a) Sparse	ha	4 970	4.1	30 000
	(b) Bush	ha	14 910		-
	(c) trees	ha	24 850		-
					-
2	**River Diversion**	Sum	31 950 000	1	31 950 000
					-
3	**Excavation**				-
	(a) All Materials	m^3			-
	(b) Extra over the rock	m^3	68	35 482	2 420 000
	(c) Final foundation preparation	m^2	71	23 932	1 700 000
					-
4	**Embarkment**				-
	(a) Earth Fill	m^3	43		-
	(b) Filters	m^3	157		-
	(c) Rip-rap	m^3	86		-
	(d) Overhaul beyond 5 km	m^3 . km	4		-
					-
5	**Drilling and Grouting**				-
	(a) Curtain grouting	m drill	398	11 445	4 560 000
	(b) Consolidation grouting	m drill	398	10 989	4 380 000
					-
6	**Formwork**				-
	(a) Gang Formed	m^2	178	62 122	11 060 000
	(b) Intricate	m^2	284	16 373	4 650 000
					-
7	**Concrete**				-
	(a) Rollcrete	m^3	568	409 900	232 830 000
	(b) Facecrete including waterstop	m^3	142	36 300	5 160 000
	(c) Structural	m^3	831	9 400	7 820 000
				455 683	-
8	**Reinforcing**	t	8 875	1 377	12 220 000
					-
9	**Mechanical Items**				-

Item No	Description	Unit	RATE	Quantity	Amount
	(a) Valves and Gates (outlet)	Sum	8 875 000	1	8 880 000
	(b) Cranes and hoists	Sum	1 775 000	1	1 780 000
	(c) Structural Steelwork	Sum	1 775 000	1	1 780 000
	SUB-TOTAL				331 160 000
					-
10	**Fencing**	km	24 850	5	130 000
					-
11	**Landscaping**	%	5%	331 160 000	16 560 000
					-
12	**Miscellaneous (% of 1-9)**	%	10%	331 160 000	33 120 000
	SUB-TOTAL A				380 950 000
					-
13	**Preliminary and General**	%	30%	380 950 000	114 290 000
	(% of sub-total A)				-
					-
14	**Preliminary works**				-
	(a) Access Road				-
	flat terrrain	km	213 000	2	430 000
	hilly terrain	km	12 780 000	3	38 340 000
	(b) Electricity to site	Sum	3 550 000	1	3 550 000
	(c) Water to site - Construction (not potable)	Sum	1 775 000	1	1 780 000
	(d) Railhead and materials handling	Sum	7 100 000	1	7 100 000
					-
15	**Accomodation**	Sum	19 525 000	1	19 530 000
	SUB TOTAL B				565 950 000
					-
16	**Contigencies**	%	10%	565 950 000	56 600 000
	(% of sub-total B)				-
	SUB TOTAL C				622 550 000
					-
17	**Planning design and supervision, fees, time costs and transport (% o sub-total C**	%	0	622 550 000	93 390 000
	SUB-TOTAL D				715 930 000
					-

Item No	Description	Unit	RATE	Quantity	Amount
18	**VAT**(% of sub total D)	%	0	715 930 000	100 230 000
					-
	NET PROJECT COST				816 160 000
					-
					-
19	**Cost of Relocations**				-
	(a) Roads and Bridges	Sum	20 000 000	1	20 000 000
					-
20	Cost of Land Acquisition	ha	8 875	23 901	212 130 000
					-
21	**Helicopter landing site**	Sum	177 500		-
	TOTAL PROJECT COSTS (incl. VAT)				1 048 280 000

Table B4.2 URV Calculations

	ORANGE RIVER RECONCILIATION STRATEGY			
	UNIT REFERENCE VALUES			
	VERBEELDINGS KRAAL		**FSL**	1385
		Yield (million m^3/annum		200
		Capital Cost (R million)		1048
		Costruction Period		3
	Year	**Yield**	**Capital**	**O&M**
	2012	0.0	0	0
	2013	0.0	0	0
	2014	0.0	79	0
	2015	0.0	79	0.0
	2016	0.0	296.9	0.0
	2017	0.0	296.9	0.0
	2018	0.0	296.9	0.0
	2019	200.0		2.6
	2020	200.0		2.6
	2021	200.0		2.6
	2022	200.0		2.6
	2023	200.0		2.6
	2024	200.0		2.6
	2025	200.0		2.6
	2026	200.0		2.6
	2027	200.0		2.6
	2028	200.0		2.6
	2029	200.0		2.6
	2030	200.0		2.6
	2031	200.0		2.6
	2032	200.0		2.6
	2033	200.0		2.6
	2034	200.0		2.6
	2035	200.0		2.6
	2036	200.0		2.6
	2037	200.0		2.6
	2038	200.0		2.6
	2039	200.0		2.6
	2040	200.0		2.6
	2041	200.0		2.6
	2042	200.0		2.6
	2043	200.0		2.6
	2044	200.0		2.6
	2045	200.0		2.6
	2046	200.0		2.6
	2047	200.0		2.6
	2048	200.0		2.6
	2049	200.0		2.6
	2050	200.0		2.6
	2051	200.0		2.6
	2052	200.0		2.6
	2053	200.0		2.6
	2054	200.0		2.6
	2055	200.0		2.6
	2056	200.0		2.6
	2057	200.0		2.6
NPV	6%	1,988	757	26.0
	8%	1,386	683	18.2
	10%	1,001	617	13.1
URV	6%		R 0.39	
	8%		R 0.51	
	10%		R 0.63	

APPENDIX B5: Kraai Dam

Table B5.1 Schedule of Quantities

Item No	Description	Unit	Quantity	Rate	Amount
1	**Site and Basin Clearing**				
	(a) Sparse	ha	8.25	4 970	50 000
	(b) Bush	ha		14 910	-
	(c) trees	ha		24 850	-
2	**River Diversion**	Sum	1	31 950 000	31 950 000
3	**Excavation**				
	(a) All Materials	m3	409 518	54	21 810 000
	(b) Extra over the rock	m3	122 855	68	8 290 000
	(c) Final foundation preparation	m2	82 512	71	5 860 000
4	**Embarkment**				
	(a) Earth Fill	m3	446 414	43	19 020 000
	(b) Filters	m3	39 206	157	6 130 000
	(c) Rip-rap	m3	22 971	86	1 960 000
	(d) Overhaul beyond 5 km	m3 . km		4	-
5	**Drilling and Grouting**				
	(a) Curtain grouting	m drill	14 842	398	5 910 000
	(b) Consolidation grouting	m drill	19 152	398	7 620 000
6	**Formwork**				
	(a) Gang Formed	m2	82 206	178	14 600 000
	(b) Intricate	m2	18 278	284	5 200 000
7	**Concrete**				
	(a) Rollcrete	m3	1 006 750	568	571 840 000
	(b) Facecrete including waterstop	m3	82 206	142	11 680 000
	(c) Structural	m3	19 166	831	15 930 000
8	**Reinforcing**	t	2 782	8 875	24 700 000

Item No	Description	Unit	Quantity	Rate	Amount
9	**Mechanical Items**				
	(a) Valves and Gates (outlet)	Sum	1	8 875 000	8 880 000
	(b) Cranes and hoists	Sum	1	1 775 000	1 780 000
	(c) Structural Steelwork	Sum	1	1 775 000	1 780 000
	SUB-TOTAL				**764 890 000**
10	**Fencing**	km	5	24 850	130 000
11	**Landscaping**	%	764 890 000	5%	38 250 000
12	**Miscellaneous (% of 1-9)**	%	764 890 000	10%	76 490 000
	SUB-TOTAL A				**879 750 000**
13	**Preliminary and General**	%	879 750 000	30%	263 930 000
	(% of sub-total A)				
14	**Preliminary works**				
	(a) Access Road	km	0	213 000	-
	flat terrrain		1	12 780 000	12 780 000
	hilly terrain				
	(b) Electricity to site	Sum	1	3 550 000	3 550 000
	(c) Water to site - Construction (not potable)	Sum	1	1 775 000	1 780 000
	(d) Railhead and materials handling	Sum	1	7 100 000	7 100 000
15	**Accomodation**	Sum	1	19 525 000	19 530 000
	SUB TOTAL B				1 188 400 000
16	**Contigencies**	%	1 188 400 000	10%	118 840 000
	(% of sub-total B)				
	SUB TOTAL C				**1 307 240 000**
17	**Planning design and supervision, fees, time costs and transport (% o sub-total C**	%	1 307 240 000	15%	196 090 000
	SUB-TOTAL D				**1 503 330 000**

Item No	Description	Unit	Quantity	Rate	Amount
18	VAT(% of sub total D)	%	1 503 330 000	14%	210 470 000
	NET PROJECT COST				**1 713 790 000**
19	**Cost of Relocations**				
	(a) Roads and Bridges	Sum	1	100 800 000	100 800 000
20	**Cost of Land Acquisition**	ha	34 420	8 875	305 480 000
		ha		-	-
21	**Helicopter landing site**	Sum		-	-
	TOTAL PROJECT COSTS (incl. VAT)				**2 120 070 000**
	Kraai Saddle Total				90 580 000
	TOTAL PROJECT COSTS (incl. VAT) including partitioning				**2 210 640 000**

Table B5.2 URV Calculations

	ORANGE RIVER RECONCILIATION STRATEGY			
	UNIT REFERENCE VALUES			
	KRAAI		FSL	1372
		Yield (million m^3/annum		330
		Capital Cost (R million)		1999
		Costruction Period		3
	Year	**Yield**	**Capital**	**O&M**
	2012	0.0	0	0
	2013	0.0	0	0
	2014	0.0	150	0
	2015	0.0	150	0.0
	2016	0.0	566.4	0.0
	2017	0.0	566.4	0.0
	2018	0.0	566.4	0.0
	2019	330.0		5.0
	2020	330.0		5.0
	2021	330.0		5.0
	2022	330.0		5.0
	2023	330.0		5.0
	2024	330.0		5.0
	2025	330.0		5.0
	2026	330.0		5.0
	2027	330.0		5.0
	2028	330.0		5.0
	2029	330.0		5.0
	2030	330.0		5.0
	2031	330.0		5.0
	2032	330.0		5.0
	2033	330.0		5.0
	2034	330.0		5.0
	2035	330.0		5.0
	2036	330.0		5.0
	2037	330.0		5.0
	2038	330.0		5.0
	2039	330.0		5.0
	2040	330.0		5.0
	2041	330.0		5.0
	2042	330.0		5.0
	2043	330.0		5.0
	2044	330.0		5.0
	2045	330.0		5.0
	2046	330.0		5.0
	2047	330.0		5.0
	2048	330.0		5.0
	2049	330.0		5.0
	2050	330.0		5.0
	2051	330.0		5.0
	2052	330.0		5.0
	2053	330.0		5.0
	2054	330.0		5.0
	2055	330.0		5.0
	2056	330.0		5.0
	2057	330.0		5.0
NPV	6%	3,281	1,444	49.7
	8%	2,287	1,302	34.6
	10%	1,652	1,177	25.0
URV	6%		R 0.46	
	8%		R 0.58	
	10%		R 0.73	

APPENDIX B6: Boskraai Dam

Figure B6.1	Locality
Table B6.1	Schedule of Quantities
Table B6.2	URV Calculations

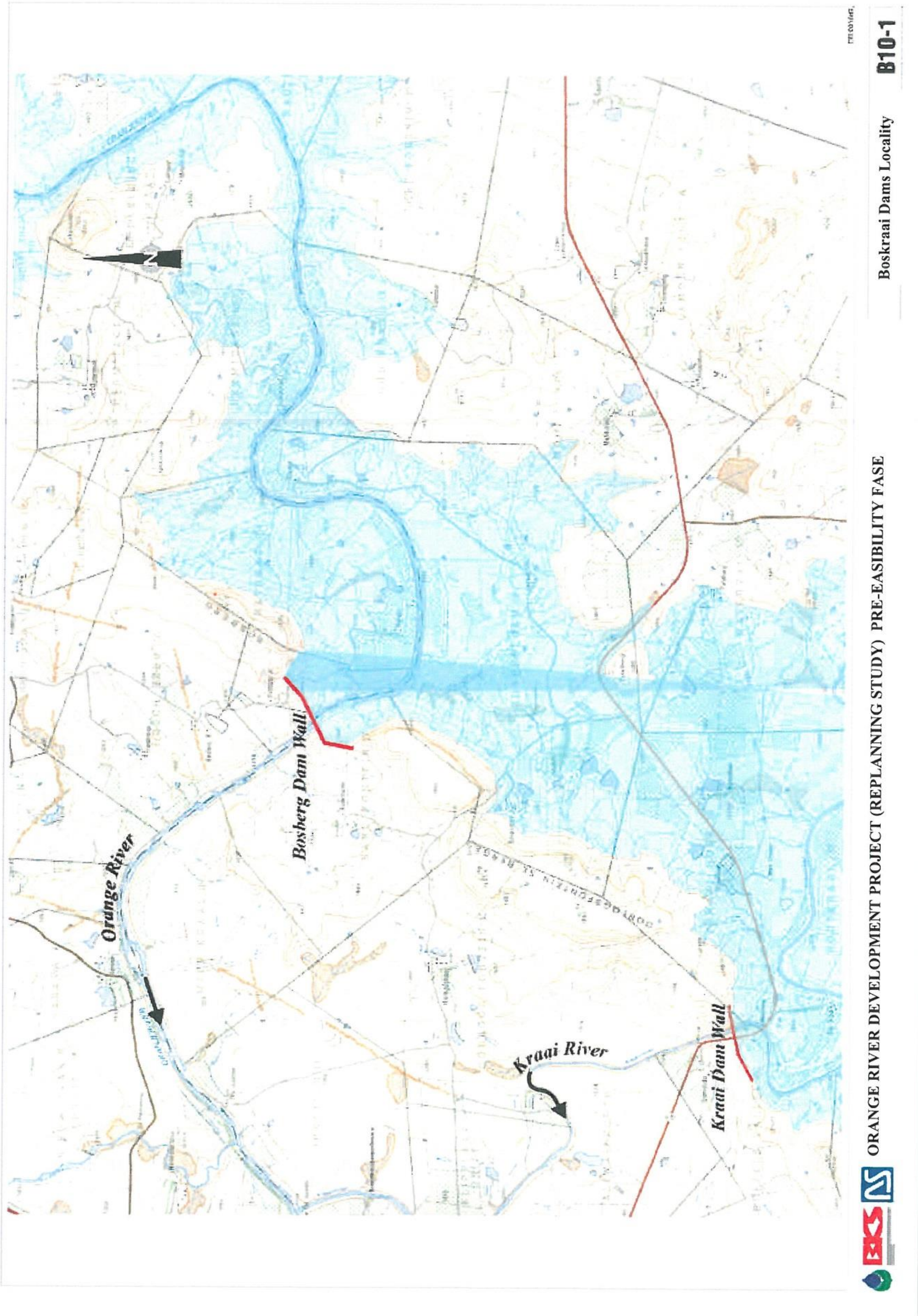


Figure B6.1 Locality

Table B6.1 Schedule of Quantities

Item No	Description	Unit	Quantity	Rate	Amount
1	**Site and Basin Clearing**				
	(a) Sparse	ha	4.1	4 970	30 000
	(b) Bush	ha		14 910	-
	(c) trees	ha		24 850	-
2	**River Diversion**	Sum	1	31 950 000	31 950 000
3	**Excavation**				
	(a) All Materials	m^3			
	(b) Extra over the rock	m^3	60 719	68	4 100 000
	(c) Final foundation preparation	m^2	40 953	71	2 910 000
4	**Embankment**				
	(a) Earth Fill	m^3	48 215	43	2 060 000
	(b) Filters	m^3	7 296	157	1 140 000
	(c) Rip-rap	m^3	4 617	86	400 000
	(d) Overhaul beyond 5 km	m^3 . km		4	-
5	**Drilling and Grouting**				
	(a) Curtain grouting	m drill	11 445	398	4 560 000
	(b) Consolidation grouting	m drill	10 989	398	4 370 000
6	**Formwork**				
	(a) Gang Formed	m^2	62 122	178	11 030 000
	(b) Intricate	m^2	16 373	284	4 650 000
7	**Concrete**				
	(a) Rollcrete	m^3	701 524	568	398 470 000
	(b) Facecrete including waterstop	m^3	62 122	142	8 830 000
	(c) Structural	m^3	16 146	831	13 420 000
8	**Reinforcing**	t	2 356	8 875	20 910 000

Item No	Description	Unit	Quantity	Rate	Amount
9	**Mechanical Items**				
	(a) Valves and Gates (outlet)	Sum	1	8 875 000	8 880 000
	(b) Cranes and hoists	Sum	1	1 775 000	1 780 000
	(c) Structural Steelwork	Sum	1	1 775 000	1 780 000
	SUB-TOTAL			**-**	**521 200 000**
10	**Fencing**	km	5	24 850	130 000
11	**Landscaping**	%	521200 000	5%	26 060 000
12	**Miscellaneous (% of 1-9)**	%	521 200 000	10%	52 120 000
	SUB-TOTAL A				**599 500 000**
13	**Preliminary and General**	%	599 500 000	30%	179 850 000
	(% of sub-total A)				
14	**Preliminary works**				
	(a) Access Road				
	flat terrrain	km	0	213 000	-
	hilly terrain	km	1	12 780 000	12 780 000
	(b) Electricity to site	Sum	1	3 550 000	3 550 000
	(c) Water to site - Construction (not potable)	Sum	1	1 775 000	1 780 000
	(d) Railhead and materials handling	Sum	1	7 100 000	7 100 000
15	**Accomodation**	Sum	1	19 525 000	19 530 000
	SUB TOTAL B				**824 080 000**
16	**Contigencies**	%	824 080 000	10%	82 410 000
	(% of sub-total B)				
	SUB TOTAL C				**906 490 000**
17	**Planning design and supervision, fees, time costs and transport (% o sub-total C**	%	906 490 000	15%	135 980 000

Item No	Description	Unit	Quantity	Rate	Amount
	SUB-TOTAL D				**1 042 460 000**
18	VAT(% of sub total D)	%	1 042 460 000	14%	145 950 000
	NET PROJECT COST				**1 188 410 000**
19	**Cost of Relocations**				
	(a) Roads and Bridges	Sum	1	49 000 000	49 000 000
20	Cost of Land Acquisition	ha	23 901	8 875	212 130 000
		ha		3 550	-
21	**Helicopter landing site**	Sum		177 500	-
	TOTAL PROJECT COSTS (incl. VAT)				**1 449 530 000**
	Kraai saddle Total				549 130 000
	TOTAL PROJECT COSTS (incl. VAT)				**1 998 650 000**

Table B6.2 URV Calculations

	ORANGE RIVER RECONCILIATION STRATEGY			
	UNIT REFERENCE VALUES			
	BOSKRAAI DAM		**FSL**	1385
		Yield (million m^3/annum		937
		Capital Cost (R million)		4962
		Costruction Period		5
	Year	**Yield**	**Capital**	**O&M**
	2012	0.0	0	0
	2013	0.0	0	0
	2014	0.0	372	0
	2015	0.0	372	0.0
	2016	0.0	843.5	0.0
	2017	0.0	843.5	0.0
	2018	0.0	843.5	0.0
	2019	0.0	843.5	0.0
	2020	0.0	843.5	0.0
	2021	937.0		12.4
	2022	937.0		12.4
	2023	937.0		12.4
	2024	937.0		12.4
	2025	937.0		12.4
	2026	937.0		12.4
	2027	937.0		12.4
	2028	937.0		12.4
	2029	937.0		12.4
	2030	937.0		12.4
	2031	937.0		12.4
	2032	937.0		12.4
	2033	937.0		12.4
	2034	937.0		12.4
	2035	937.0		12.4
	2036	937.0		12.4
	2037	937.0		12.4
	2038	937.0		12.4
	2039	937.0		12.4
	2040	937.0		12.4
	2041	937.0		12.4
	2042	937.0		12.4
	2043	937.0		12.4
	2044	937.0		12.4
	2045	937.0		12.4
	2046	937.0		12.4
	2047	937.0		12.4
	2048	937.0		12.4
	2049	937.0		12.4
	2050	937.0		12.4
	2051	937.0		12.4
	2052	937.0		12.4
	2053	937.0		12.4
	2054	937.0		12.4
	2055	937.0		12.4
	2056	937.0		12.4
	2057	937.0		12.4
NPV	6%	8,173	3,422	108.2
	8%	5,519	3,045	73.1
	10%	3,857	2,718	51.1
URV	6%		R 0.43	
	8%		R 0.56	
	10%		R 0.72	

APPENDIX B7: RAISING OF GARIEP DAM

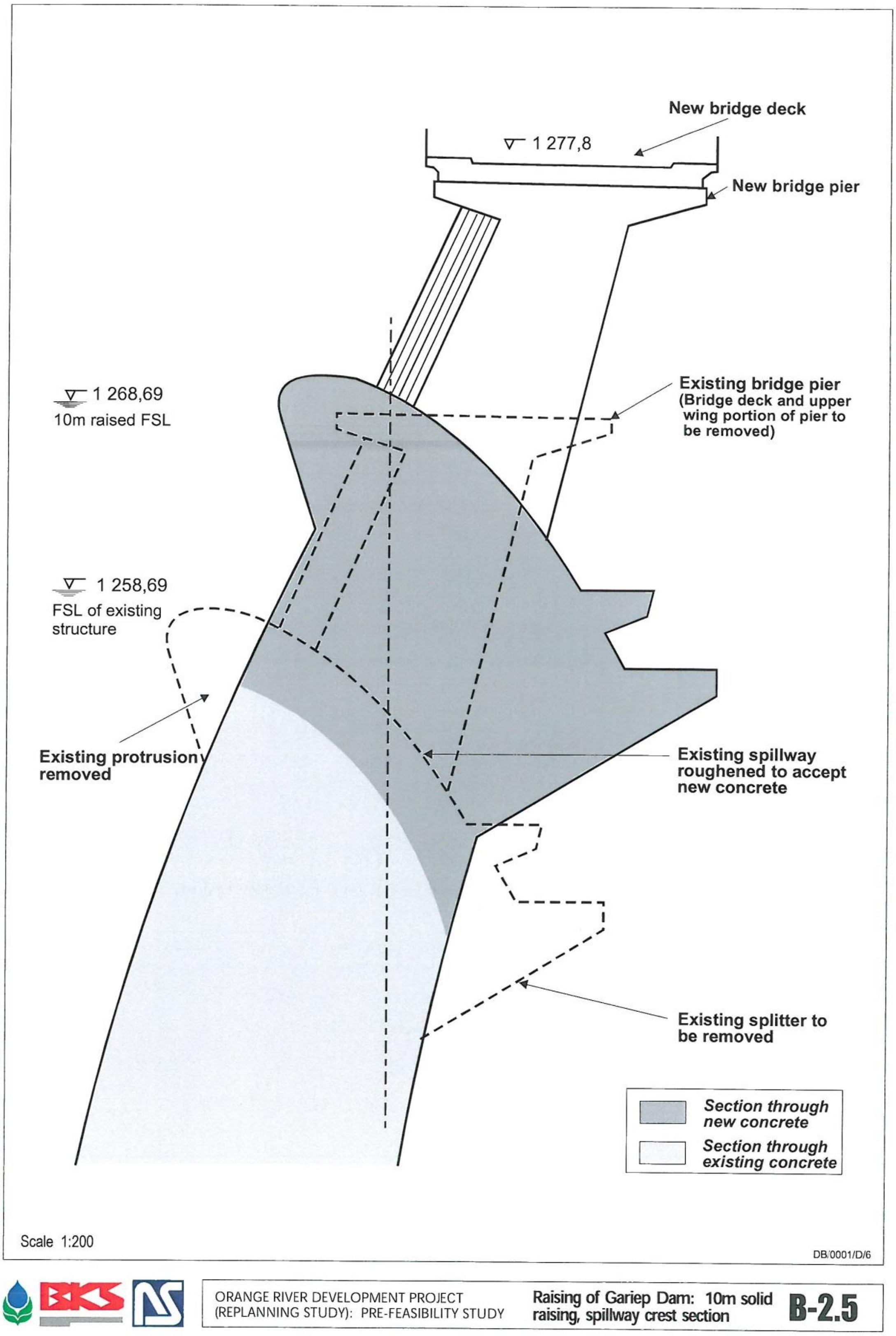


Figure B7.1 Cross section through Raised Gariep Dam

Table B7.2: Schedule of Quantities - 10m Raising of Gariep Dam

Item No	Description	Unit	Rate	Quantity	Amount (Rand)
1	**Site and *Basin* Clearing**	ha		0	
2	**River Diversion**	Sum		0	
3	**Preparation of existing structure**				
	(a) Erect blondin	Sum	7 100 000	1	7 100 000
	(b) Demolish & remove concrete	m^3	355	13 300	4 730 000
	(c) Roughen and prepare surfaces	m^2	178	4 500	800 000
4	**Drilling & Grouting Joints**				
	(a) vertical joint grouting	m drill	398	45 000	17 900 000
5	**Embankment (Saddle Dam)**				
	(a) Earthfill	m^3	43	60 000	2 560 000
	(b) Rockfill	m^3	125	500 000	62 130 000
	(c) Filters	m^3	157	50 000	7 810 000
6	**Formwork**				
	(a) Gang Formed	m^2	213	14 000	2 990 000
	(b) Intricate	m^2	426	12 800	5 460 000
7	**Concrete**				
	(a) Mass	m^3	835	84 000	70 080 000
	(b) Structural	m^3	923	41 000	37 850 000
8	**Reinforcing**	t	8 875	1 640	14 560 000
	Additional cable support	Sum	2 130 000	1	2 130 000
9	**Mechanical Items**				
	(a) Valves and Gates (outlet)	Sum	-	1	-
	(b) Cranes and hoists	Sum	1 775 000	1	1 780 000
	(c) Structural Steelwork	t	17 750	0	-
	(d) Upgrade replaceable parts	Sum	10 650 000	1	10 650 000
	SUB-TOTAL				**248 470 000**

10	**Fencing**	km	24 850	0	-
11	**Landscaping**	%	5%	248 470 000	12 430 000
12	**Miscellaneous (% of 1-9)**	%	10%	248 470 000	24 850 000
	SUB-TOTAL A				**285 740 000**
13	**Preliminary and General**	%	30%	285 740 000	85 730 000
	(% of sub-total A)				
14	**Preliminary works**				
	(a) Access Road				
	flat terrrain	km	213 000	0	-
	hilly terrain	km	1 775 000	1	1 780 000
	(b) Electricity to site	Sum	355 000	1	360 000
	(c) Water to site - Construction (not potable)	Sum	-	0	-
	(d) Railhead and materials handling	Sum	1 775 000	1	1 780 000
15	**Accommodation**	Sum	1 775 000	1	1 780 000
	SUB TOTAL B				**377 150 000**
16	**Contingencies**	%	10%	377 150 000	37 720 000
	(% of sub-total B)				
	SUB TOTAL C				**414 860 000**
17	**Planning design and supervision, fees, time costs and transport (% o sub-total C**	%	15%	414 860 000	62 230 000
	SUB-TOTAL D				**477 090 000**
18	**VAT**(% of sub total D)	%	14%	477 090 000	66 800 000
	NET PROJECT COST				**543 880 000**

19	**Cost of Relocations**	Sum	390 000 000	1	390 000 000
20	**Cost of Land Acquisition**	ha	434 520 000	1	434 520 000
	TOTAL PROJECT COSTS (incl. VAT)				**1 368 400 000**

Table B7.2 URV Calculations

	ORANGE RIVER RECONCILIATION STRATEGY			
	UNIT REFERENCE VALUES			
	GARIEP RAISING 10m		**FSL**	1268.7
		Yield (million m^3/annum)		350
		Capital Cost (R million)		1368
		Costruction Period		4
	Year	**Yield**	**Capital**	**O&M**
	2012	0.0	0	0
	2013	0.0	0	0
	2014	0.0	103	0
	2015	0.0	103	0.0
	2016	0.0	290.7	0.0
	2017	0.0	290.7	0.0
	2018	0.0	290.7	0.0
	2019	0.0	290.7	0.0
	2020	350.0		3.4
	2021	350.0		3.4
	2022	350.0		3.4
	2023	350.0		3.4
	2024	350.0		3.4
	2025	350.0		3.4
	2026	350.0		3.4
	2027	350.0		3.4
	2028	350.0		3.4
	2029	350.0		3.4
	2030	350.0		3.4
	2031	350.0		3.4
	2032	350.0		3.4
	2033	350.0		3.4
	2034	350.0		3.4
	2035	350.0		3.4
	2036	350.0		3.4
	2037	350.0		3.4
	2038	350.0		3.4
	2039	350.0		3.4
	2040	350.0		3.4
	2041	350.0		3.4
	2042	350.0		3.4
	2043	350.0		3.4
	2044	350.0		3.4
	2045	350.0		3.4
	2046	350.0		3.4
	2047	350.0		3.4
	2048	350.0		3.4
	2049	350.0		3.4
	2050	350.0		3.4
	2051	350.0		3.4
	2052	350.0		3.4
	2053	350.0		3.4
	2054	350.0		3.4
	2055	350.0		3.4
	2056	350.0		3.4
	2057	350.0		3.4
NPV @	6%	3,260	965	31.9
	8%	2,237	865	21.9
	10%	1,589	777	15.5
URV	6%		R 0.31	
	8%		R 0.40	
	10%		R 0.50	

APPENDIX B8: VIOOLDRIFT DAM

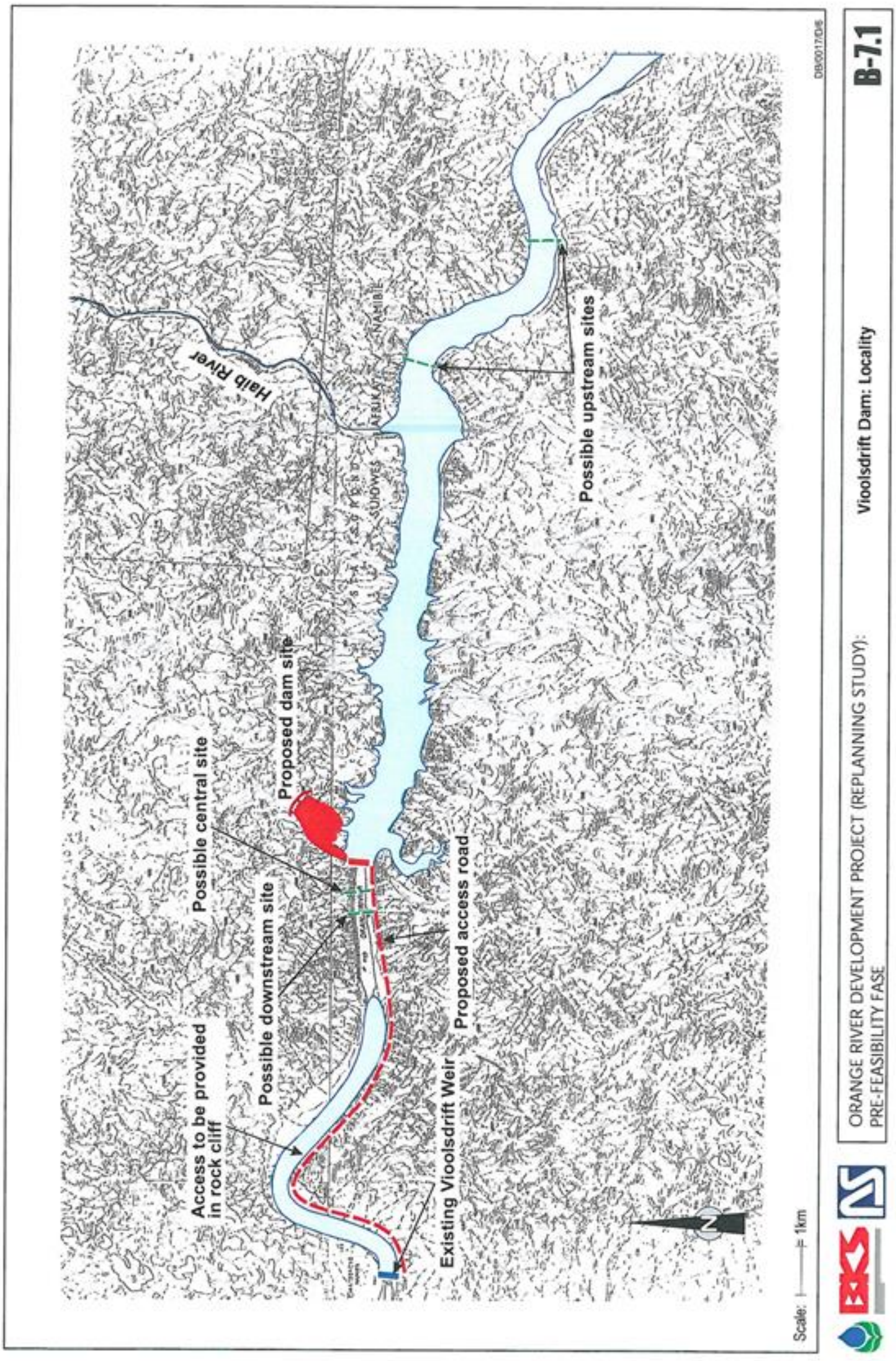


Figure B8.1 Locality

Table B8.1 Schedule of Quantities

Item No	Description	Unit	Quantity	Rate (2012)	Amount
1	**Clearing**				
	(a) Sparse	ha	6	4 970	30 000
	(b) Bush	ha	6	14 910	90 000
	(c)Trees	ha	-	24 850	
			-		
2	**River Diversion**	Sum	1	17 750 000	17 750 000
			-		
3	**Excavation**		-		
	(a) Bulk		-		
	(i) All Materials	m^3	91 766	54	4 890 000
	(ii) Extra over for rock	m^3	44 255	68	2 990 000
			-		
	(b) Confined		-		
	(i) All materials	m^3	-		
	(ii) Extra over the rock	m^3	-		
			-		
	(c) Final foundation preparation for plinth	m^2	28 963	71	2 060 000
			-		
4	**Drilling and Grouting**		-		
	(a) Curtain grouting	m drill	9 858	398	3 920 000
	(b) Consolidation grouting	m drill	8 168	398	3 250 000
			-		
5	**Formwork**		-		
	(a) Gang Formed	m^2	50 622	178	8 990 000
	(b) Intricate	m^2	11 831	284	3 370 000
			-		
6	**Concrete**		-		
	(a) Rollcrete	m^3	533 129	568	302 820 000
	(b) Facecrete including waterstop	m^3	50 622	710	35 950 000
	(c) Structural	m^3	13 494	831	11 210 000
			-		
7	**Reinforcing**	t	538	8 875	4 780 000
			-		
8	**Mechanical Items**		-		

Item No	Description	Unit	Quantity	Rate (2012)	Amount
	(a) Pipes, valves and Gates	Sum	1	8 875 000	8 880 000
	(b) Cranes and hoists	Sum	1	1 775 000	1 780 000
	(c) Structural steelwork	Sum	1	1 775 000	1 780 000
			-		
9	**Fencing**	km	2	24 850	50 000
	SUB-TOTAL				**414 530 000**
10	**Landscaping (include in 1-9)**	%	414 530 000	5%	20 730 000
11	**Miscellaneous (% of 1-9)**	%	414 530 000	10%	41 460 000
	SUB-TOTAL A				**476 710 000**
12	**Preliminary and General (% of sub-total A)**	%	476 710 000	30%	143 020 000
13	**Preliminary Works**				
	(a) Access Road				
	flat terrein	km	8	213 000	1 710 000
	hilly terrain	km	1	12 780 000	12 780 000
	(b) Electricity supply to site	Sum	1	3 550 000	3 550 000
	(c) Construction water to site	Sum	1	1 775 000	1 780 000
	(d) Railhead and materials handling	Sum	1	7 100 000	7 100 000
14	**Accomodation**	Sum	1	5 325 000	5 330 000
	SUB-TOTAL B				**651 950 000**
15	**Contigencies**	%	651 950 000	10%	65 200 000
	(% of sub-total B)				
	SUB TOTAL C				**717 150 000**
16	**Planning design and Supervision**				
	(% of sub total C)	%	717 150 000	15%	107 580 000
	SUB-TOTAL D				**824 720 000**
17	VAT(% of sub total D)	%	824 720 000	14%	115 470 000
	NETT PROJECT COST				**940 180 000**

Item No	Description	Unit	Quantity	Rate (2012)	Amount
18	**Cost of relocations**				
	(a) Roads and Bridges	Sum	1	355 000	360 000
19	**Cost of land acquisition**				
	(a) Undeveloped	ha	5 840	5 325	31 100 000
	(b) Developed	ha	2 600	5 325	13 850 000
	Helicopter landing site	Sum	1	177 500	
	TOTAL PROJECT COSTS				**985 660 000**

Table B8.2 URV Calculations

	ORANGE RIVER RECONCILIATION STRATEGY			
	UNIT REFERENCE VALUES			
	VIOOLSDRIFT		FSL	210
		Yield (million m^3/annum)		312
		Capital Cost (R million)		986
		Costruction Period		2
	Year	Yield	Capital	O&M
	2012	0.0	0	0
	2013	0.0	0	0
	2014	0.0	74	0
	2015	0.0	74	0.0
	2016	0.0	419.1	0.0
	2017	0.0	419.1	0.0
	2018	312.0		2.5
	2019	312.0		2.5
	2020	312.0		2.5
	2021	312.0		2.5
	2022	312.0		2.5
	2023	312.0		2.5
	2024	312.0		2.5
	2025	312.0		2.5
	2026	312.0		2.5
	2027	312.0		2.5
	2028	312.0		2.5
	2029	312.0		2.5
	2030	312.0		2.5
	2031	312.0		2.5
	2032	312.0		2.5
	2033	312.0		2.5
	2034	312.0		2.5
	2035	312.0		2.5
	2036	312.0		2.5
	2037	312.0		2.5
	2038	312.0		2.5
	2039	312.0		2.5
	2040	312.0		2.5
	2041	312.0		2.5
	2042	312.0		2.5
	2043	312.0		2.5
	2044	312.0		2.5
	2045	312.0		2.5
	2046	312.0		2.5
	2047	312.0		2.5
	2048	312.0		2.5
	2049	312.0		2.5
	2050	312.0		2.5
	2051	312.0		2.5
	2052	312.0		2.5
	2053	312.0		2.5
	2054	312.0		2.5
	2055	312.0		2.5
	2056	312.0		2.5
	2057	312.0		2.5
NPV @	6%	3,309	729	26.1
	8%	2,345	662	18.5
	10%	1,722	603	13.6
URV	6%		R 0.23	
	8%		R 0.29	
	10%		R 0.36	

APPENDIX B9: Knoffelfontein Dam

Table B9.1 Schedule of Quantities

Item No	Description	Unit	Quantity	Rate	Amount
1	**Clearing**	ha			
	(a) Sparse	ha	2	4 970	10 000
	(b) Bush	ha	2	14 910	30 000
2	**River Diversion**				
	(a) Cofferdam	Sum	1	28 400 000	28 400 000
3	**Excavation**				
	(a) Bulk				
	(i) All Materials	m^3	118 779	54	6 330 000
	(ii) Extra over for rock	m^3	39 852	68	2 690 000
	(b) Confined				
	(i) All materials	m^3			
	(ii) Extra over the rock	m^3			
	(c) Final Foundation preparation	m^2	8 676	71	620 000
4	**Drilling and Grouting**				
	(a) Curtain grouting	m drill	1 699	398	680 000
	(b) Consolidation grouting	m drill	9 030	398	3 600 000
5	**Formwork**				
	(a) Gang Formed	m^2	8 317	178	1 480 000
	(b) Intricate	m^2	416	284	120 000
6	**Concrete**				
	(a) Rollcrete	m^3	39 636	568	22 520 000
	(b) face crete including water stop	m^3	1 904	710	1 360 000
	(d) Structural	m^3	5 628	831	4 680 000
7	**Reinforcing**	t	563	8 875	5 000 000
8	**Mechanical Items**				

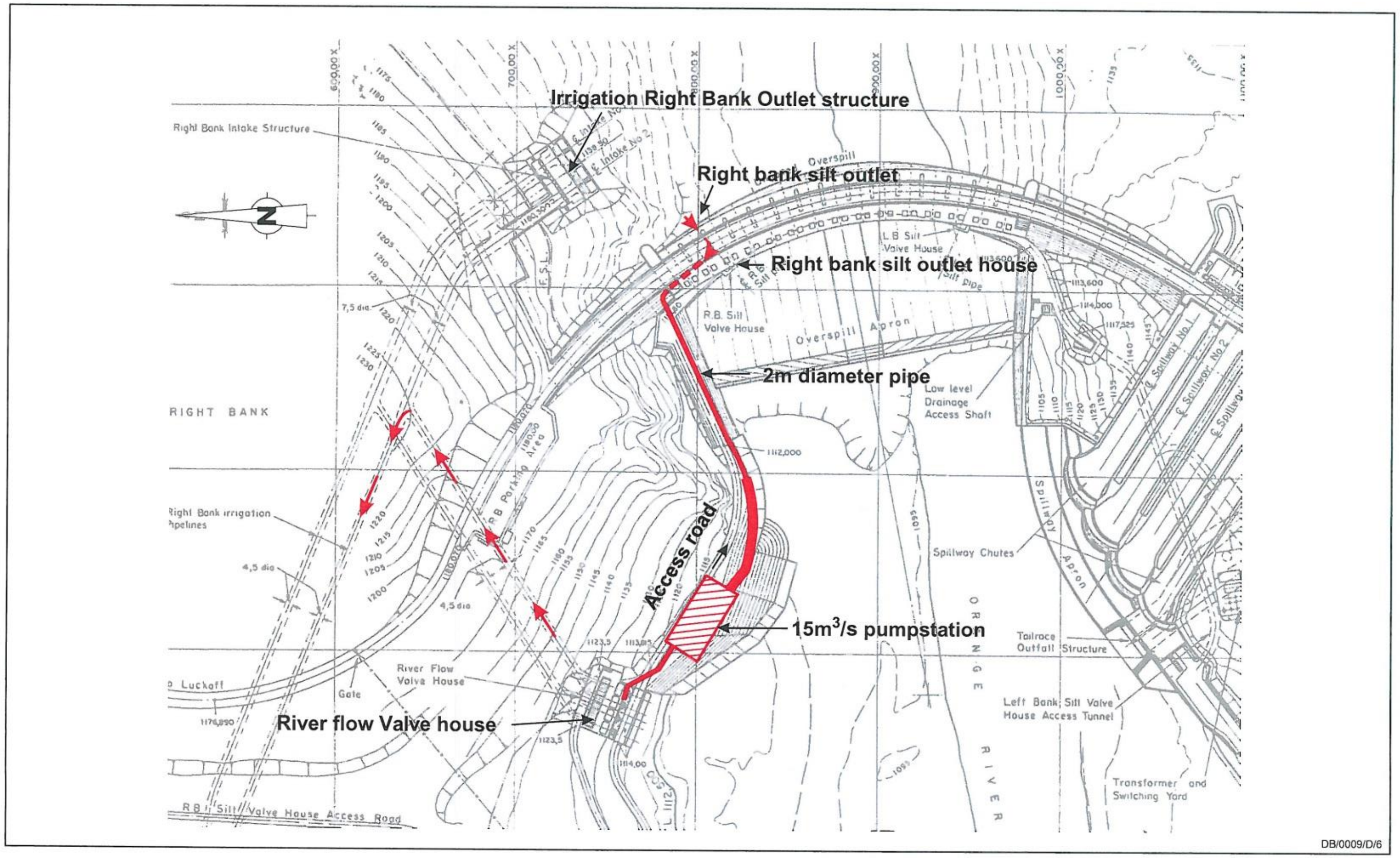
Item No	Description	Unit	Quantity	Rate	Amount
	(a) Valves and Gates	Sum	1	8 875 000	8 880 000
	(b) Cranes and hoists	Sum	1	1 775 000	1 780 000
	(c) Structural Steelwork	t	1	1 775 000	780 000
9	**Fencing**	km	10	24 850	250 000
	SUB-TOTAL				**90 140 000**
10	**Landscaping (include in 9)**	%	90 140 000	5%	4 510 000
11	**Miscellaneous (% of 1-7)**	%	90 140 000	10%	9 020 000
	SUB-TOTAL A				**103 660 000**
12	**Preliminary and General**				
	(% of Sub total A)		103 660 000	30%	31 100 000
13	**Preliminary Works**				
	(a) Access Road				
	flat terrein	km	5	213 000	1 070 000
	hilly terrain	km	1	12 780 000	12 780 000
	(b) Electricity supply to site	Sum	1	3 550 000	3 550 000
	(c) Construction water to site	Sum	1	1 775 000	1 780 000
	(d) Railhead and materials handling	Sum	1	7 100 000	7 100 000
14	**Accomodation**	Sum	1	5 325 000	5 330 000
	SUB-TOTAL B				**166 350 000**
15	**Contigencies**	%	166 350 000	10%	**16 640 000**
	(% of sub-total B)				
	SUB TOTAL C (Civils Total)				**182 980 000**
16	**Planning design and Supervision**	%	182 980 000	15%	27 450 000
	(% of sub-total C)				
	SUB-TOTAL D				**210 430 000**
16	VAT(% of sub total D)	%	210 430 000	14%	29 470 000

Item No	Description	Unit	Quantity	Rate	Amount
	NETT PROJECT COST				**239 890 000**
18	**Cost of relocations**	Sum	1	6 500	10 000
19	**Cost of land acquisition**				
	(a) Undeveloped	ha		8 875	
	(b) Developed	ha		3 550	
	TOTAL CAPITAL COSTS				**239 890 000**

Table B9.2 URV Calculations

	ORANGE RIVER RECONCILIATION STRATEGY			
	UNIT REFERENCE VALUES			
	KNOFFELFONTEIN		FSL	1090
		Yield (million m^3/annum		3.2
		Capital Cost (R million)		240
		Costruction Period		2
	Year	**Yield**	**Capital**	**O&M**
	2012	0.0	0	0
	2013	0.0	0	0
	2014	0.0	18	0
	2015	0.0	18	0.0
	2016	0.0	102.0	0.0
	2017	0.0	102.0	0.0
	2018	3.2		0.6
	2019	3.2		0.6
	2020	3.2		0.6
	2021	3.2		0.6
	2022	3.2		0.6
	2023	3.2		0.6
	2024	3.2		0.6
	2025	3.2		0.6
	2026	3.2		0.6
	2027	3.2		0.6
	2028	3.2		0.6
	2029	3.2		0.6
	2030	3.2		0.6
	2031	3.2		0.6
	2032	3.2		0.6
	2033	3.2		0.6
	2034	3.2		0.6
	2035	3.2		0.6
	2036	3.2		0.6
	2037	3.2		0.6
	2038	3.2		0.6
	2039	3.2		0.6
	2040	3.2		0.6
	2041	3.2		0.6
	2042	3.2		0.6
	2043	3.2		0.6
	2044	3.2		0.6
	2045	3.2		0.6
	2046	3.2		0.6
	2047	3.2		0.6
	2048	3.2		0.6
	2049	3.2		0.6
	2050	3.2		0.6
	2051	3.2		0.6
	2052	3.2		0.6
	2053	3.2		0.6
	2054	3.2		0.6
	2055	3.2		0.6
	2056	3.2		0.6
	2057	3.2		0.6
NPV	6%	34	177	6.4
	8%	24	161	4.5
	10%	18	147	3.3
URV	6%		R 5.42	
	8%		R 6.89	
	10%		R 8.49	

APPENDIX B10 – VAN DER KLOOF DAM DEAD STORAGE



ORANGE RIVER DEVELOPMENT PROJECT (REPLANNING STUDY):
PRE-FEASIBILITY FASE

Utilise water below minimum operating level at Vanderkloof Dam: Locality of abstraction works

B-3.1

Figure B10.1 Locality of Abstractiion Works

Table B10.1 URV Calculations

	ORANGE RIVER RECONCILIATION STRATEGY				
	UNIT REFERENCE VALUES				
	VD KLOOF LLS				
		Yield (million m³/annum)		137	
		Capital Cost (R million)		150	
		Costruction Period		2	
	Year	Yield	Capital	O&M	Pumping Energy
	2012	0.0	0	0	
	2013	0.0	0	0	
	2014	0.0	11	0	
	2015	0.0	11	0.0	
	2016	0.0	63.8	0.0	
	2017	0.0	63.8	0.0	
	2018	137.0		4.5	4.0126
	2019	137.0		4.5	4.0126
	2020	137.0		4.5	4.0126
	2021	137.0		4.5	4.0126
	2022	137.0		4.5	4.0126
	2023	137.0		4.5	4.0126
	2024	137.0		4.5	4.0126
	2025	137.0		4.5	4.0126
	2026	137.0		4.5	4.0126
	2027	137.0		4.5	4.0126
	2028	137.0		4.5	4.0126
	2029	137.0		4.5	4.0126
	2030	137.0		4.5	4.0126
	2031	137.0		4.5	4.0126
	2032	137.0		4.5	4.0126
	2033	137.0		4.5	4.0126
	2034	137.0		4.5	4.0126
	2035	137.0		4.5	4.0126
	2036	137.0		4.5	4.0126
	2037	137.0		4.5	4.0126
	2038	137.0		4.5	4.0126
	2039	137.0		4.5	4.0126
	2040	137.0		4.5	4.0126
	2041	137.0		4.5	4.0126
	2042	137.0		4.5	4.0126
	2043	137.0		4.5	4.0126
	2044	137.0		4.5	4.0126
	2045	137.0		4.5	4.0126
	2046	137.0		4.5	4.0126
	2047	137.0		4.5	4.0126
	2048	137.0		4.5	4.0126
	2049	137.0		4.5	4.0126
	2050	137.0		4.5	4.0126
	2051	137.0		4.5	4.0126
	2052	137.0		4.5	4.0126
	2053	137.0		4.5	4.0126
	2054	137.0		4.5	4.0126
	2055	137.0		4.5	4.0126
	2056	137.0		4.5	4.0126
	2057	137.0		4.5	4.0126
NPV	6%	1,453	111	47.7	60.4
	8%	1,029	101	33.8	47.8
	10%	756	92	24.8	39.2
URV	6%	0.15			
	8%	0.18			
	10%	0.21			
	Hydropower losses excluded.				

APPENDIX B11 – CHANGING OF THE OPERATING RULE OF GARIEP DAM

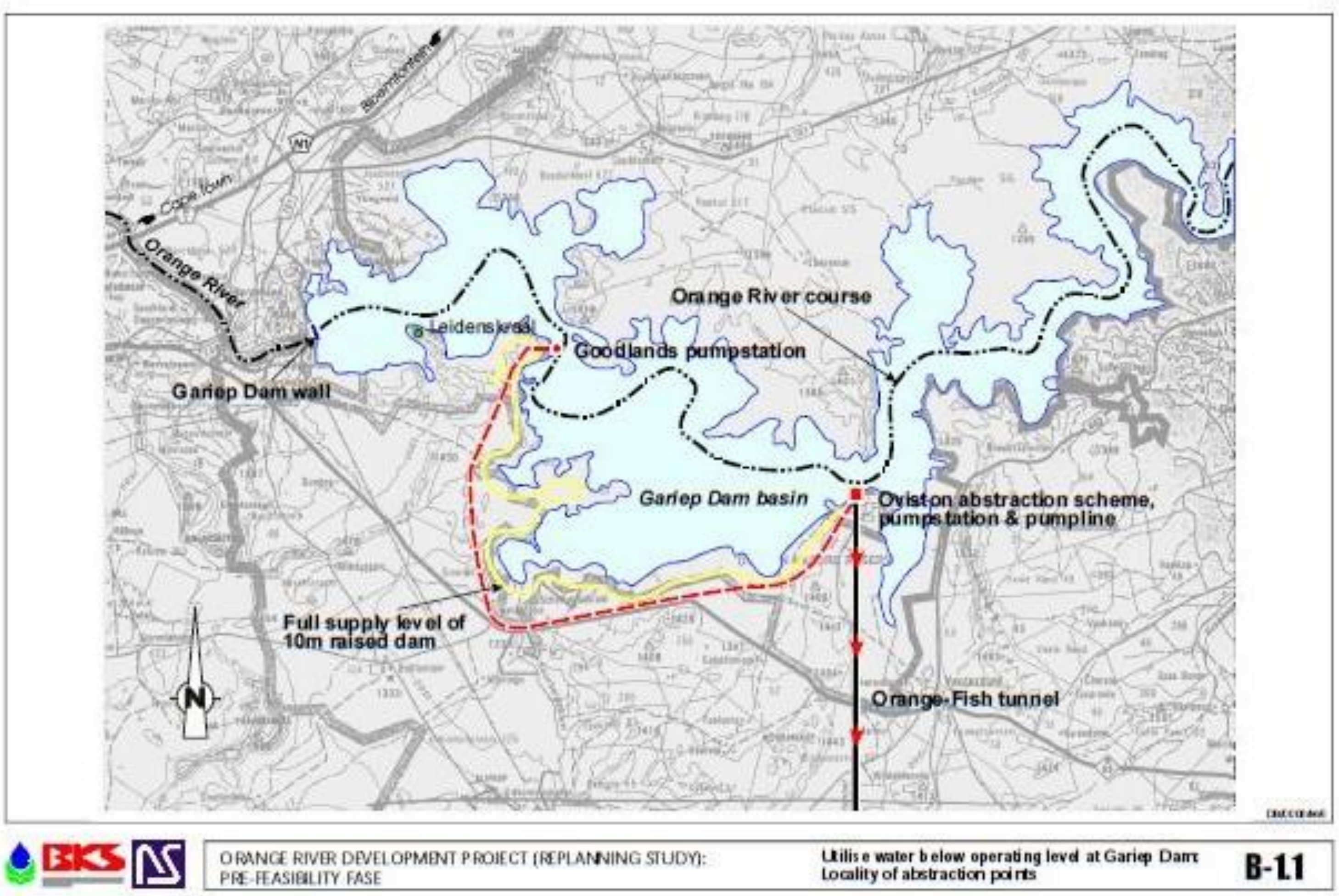


Figure B11.1 Layout

Appendix C

Environmental and Social Screening of Options

Contents

Index of Tables

List of Acronyms

Acronym	Meaning
LORMS	Lower Orange River Management Study
NFEPA	National Freshwater Ecosystem Priority Atlas
FEPA	Freshwater Ecosystem Priority Area
FSA	Fish Support Area
GIS	Geographic Information System
MCA	Multi-Criteria Analysis
CBA	Critical Biodiversity Area
NBA	National Biodiversity Assessment
SANBI	South African National Biodiversity Assessment
PES	Present Ecological State

1 SOCIAL AND ENVIRONMENTAL IMPACTS

1.1 INTRODUCTION

This chapter aims to achieve the following, in line with the inception report:

- Determine the key social impacts of identified schemes;
- Determine key environmental impacts of identified schemes; and
- Summarise the findings on social and environmental impacts
- Aid in optimizing preliminary site selection with regards to environmental and social suitability.

1.2 LITERATURE REVIEW

The following documents and policies were studied as background for the desktop assessment:

- Lesotho Highlands Phase 2 Feasibility Study, 1998;
- Lower Orange River Management Study, 2005 (LORMS);
- National Freshwater Ecosystem Priority Atlas (NFEPA) (Nel, et al., 2011)
- National Biodiversity Assessment (NBA) (Nel & Driver, 2012)
- Vegetation of South Africa, Lesotho and Swaziland (Mucina & Rutherford, 2006));

For **environmental aspects**, the NFEPA, NBA and South African National Biodiversity Institute (SANBI) Mosaic Land cover national databases were used to identify

- protected areas such as national parks, provincial nature reserves
- national conservation plans
- national important freshwater ecosystems
- national important terrestrial ecosystems
- significant heritage resources
- Agricultural land uses
- For **social aspects**, the Stats SA Census 2001 and Demarcation Board geographical information systems (GIS) national databases were used to identify:
- Settlement positions in relation to the proposed schemes; and
- Population density in close proximity to the schemes

1.3 APPROACH AND METHODOLOGY

1.3.1 Environmental Screening

In order to determine potential fatal flaws with regards to environmental receptors that can be related across the entire study area, a consistent and representative dataset was necessary. As a result the latest national datasets available for biodiversity importance were used in the environmental screening process. These datasets included the NFEPA and NBA datasets released in 2011 and was considered as the only consistent datasets that could be applied at a

- sub-quaternary catchment level for aquatic ecosystems and
- vegetation type level for terrestrial ecosystems

from the Lesotho to the Namibian border. Although Critical Biodiversity plans (CBA) at provincial level for terrestrial and aquatic ecosystems are available, they do not cover the entire study area as some provinces are still in the process of setting up CBA plans.

1.3.2 Social Screening

In order to determine potential fatal flaws with regards to social aspects that can be related across the entire study area, a consistent and representative dataset was necessary. As a result the latest national datasets available for social information were used in the social screening process.

1.3.3 Impacts and Ratings

Some of the potential impacts are generic for new dam projects, and is therefore expected as a result of all the schemes. These impacts may include:

Positive social impacts:

- Employment opportunities
- Opportunity to generate hydropower
- New tourism opportunities

Negative environmental impacts:

- Loss of important terrestrial ecosystems
- Loss of important aquatic ecosystems
- Loss of important terrestrial/aquatic species
- Changes in water quality and quantity

This assessment focused on potential negative impacts that are differentiators, thereby adding value for decision-making purposes.

1.3.4 Risk rating of each project

Based on previous experience, each of the projects has been assigned a qualitative risk rating as follows:

- The risk rating relates to the Multi-Criteria Analysis (MCA) scoring spread sheet attached;
- The highest risk factor of each project was used as its risk rating. (For example, if a project has a high risk based on social factors that become the risk rating. Using an average of environmental and social risk for each project would buffer the high risk issues.)

High Risk	Moderate Risk	Low Risk
Project contains at least one potential fatal flaw.	Project does not contain any potential fatal flaws	Project does not contain any potential fatal flaws
Significant stakeholder resistance to project expected	Some stakeholder resistance to project expected	Little stakeholder resistance to project expected
Risk expected to cause significant time/cost overruns	Risk expected to potentially cause time/cost overruns	Risk not expected to cause time/cost overruns
Due to high risk, not advisable to continue with this option.	If not managed appropriately, can become a high risk project.	

1.4 LIMITATIONS

The assessment was restricted to rating only the negative impacts, in order to identify high risks or fatal flaws. Positive impacts are typically hard to prove, and typically does not affect critical decisions about whether a scheme should proceed or not.

It is assumed that the ecological reserve determination for all the dams have already been taken into account; therefore this aspect will not be considered in this assessment. However, due to the potential changes that have occurred since the initial studies, the latest information available on a national scale was used as good practice. These included the NFEPA and NBA reports completed in 2011.

Due to the desktop nature and limited timeframe of the work, the assessment is qualitative, in that actual costs of replacing infrastructure or urban settlements were not considered, and the combination of aspects were considered in order to derive a rating.

As the schemes vary greatly in terms of cost and potential additional yield, a weighting should be attached to each scheme before it is inserted in a Multi-Criteria Analysis. This assessment has not attached any weighting to the various schemes.

The level of confidence for the social data is low as very little information was available with regards to the number of people or households per settlement. A settlement as indicated on the national database could range from a small farm community to large settlements containing thousands of residents.

1.4.1 Environmental considerations

The NFEPA and NBA datasets are limited to a sub-quaternary catchment level for aquatic ecosystems and vegetation type level for terrestrial ecosystems.

1.4.2 Social considerations

Although the 2011 Census information is available, it has not yet been released in GIS database format, and for this reason was not used. Population growth since 2001 was not considered, due to the fact that 2011 Census population density is currently only available to municipal level.

The criteria for assessing social impacts is based on international best practice and may provide varying results between the social environments of the different schemes.

For the purpose of uniformity, this assessment is based on an average of 5 people per household for all schemes.

1.4.3 Impacts matrix

Due to the limited amount of detailed information, the scores given according to each of the criteria is qualitative.

1.5 ENVIRONMENTAL DATABASE DESCRIPTIONS

1.5.1 NFEPA categories

1.5.1.1 River freshwater ecosystem priority area (FEPA) and its associated sub-quaternary catchment

River FEPA's were identified as rivers that are currently in a good condition (Present Ecological Class (PES) Class A or B) and as such they achieve biodiversity targets for river ecosystems and threatened fish species. A river and its associated sub-quaternary catchment with FEPA status should remain in a good condition in order to contribute to national biodiversity targets

1.5.1.2 Fish sanctuary and associated sub-quaternary catchment

Rivers that are considered essential for the protection of indigenous freshwater fish species that are threatened and near threatened were identified as fish sanctuaries. All fish sanctuaries that were identified as being in a good condition were included as FEPA's and the remaining fish sanctuaries were identified as Fish Support Areas (FSA) (refer below)

1.5.1.3 Fish Support Area

These were identified as fish sanctuaries that are currently considered to be lower than a class A or B ecological condition. These areas include rivers that are important for the migration of threatened and near-threatened fish species.

1.5.1.4 Upstream Management Area

All sub-quaternary catchments that are upstream from FEPA's and Fish Support Areas wherein human activities need to be managed in such a way to prevent the downstream degradation of these FEPA's and Fish Support Areas were identified as Upstream Management Areas.

1.5.1.5 Phase 2 FEPA

Areas wherein moderately modified rivers (PES Class C) are located that could not meet biodiversity targets for river ecosystems were identified as Phase 2 FEPA's. These areas should not be allowed to degrade further as they may in future be considered for rehabilitation once FEPA's in good condition (A or B) have been successfully rehabilitated.

1.5.1.6 Flagship free-flowing rivers

Of all the rivers flowing through South Africa, only 63 rivers are classified as free-flowing rivers. These are rivers that have not been dammed along its length and flow undisturbed from its source to wherever it confluences with another river or the sea. Only 25 of the remaining 63 free-flowing rivers are longer than 100km.

Flagship free-flowing rivers were chosen by the NFEPA project based on:

- The way in which they represent free-flowing rivers across the country
- Importance towards ecological processes
- Biodiversity value

As part of the actions taken to maintain free-flowing rivers, the following top priorities were given:

- Dams should not be constructed in free-flowing rivers
- They should be maintained in a natural or near-natural ecological condition
- They should preferably be incorporated into protected areas and as part of the biodiversity stewardship approach

1.5.2 NBA categories

For the NBA ecosystems were classified according to their threatened status. These categories are critically endangered, endangered, vulnerable and least threatened. The first three categories are collectively seen as ecosystems that are currently threatened and is the equivalent of the category for threatened species. The ecosystem threat status categories are defined in layman terms as follow according to the NBA 2011 Synthesis Report:

"**Critically endangered ecosystems** are ecosystem types that have very little of their original extent (measured as area, length or volume) left in natural or near-natural condition. Most of the ecosystem type has been severely or moderately modified from its natural state. These ecosystem types are likely to have lost much of their natural structure and functioning, and species associated with the ecosystem may have been lost. Few natural or near-natural examples of these ecosystems remain. Any further loss of natural habitat or deterioration in condition of the remaining healthy examples of these ecosystem types must be avoided, and the remaining healthy examples should be the focus of urgent conservation action.

Endangered ecosystems are ecosystem types that are close to becoming critically endangered. Any further loss of natural habitat or deterioration of condition in these ecosystem types should be avoided, and the remaining healthy examples should be the focus of conservation action.

Vulnerable ecosystems are ecosystem types that still have the majority of their original extent (measured as area, length or volume) left in natural or near-natural condition, but have experienced some loss of habitat or deterioration in condition. These ecosystem types are likely to have lost some of their structure and functioning, and will be further compromised if they continue to lose natural habitat or deteriorate in condition. Maps of biodiversity priority areas should guide planning, resource management and decision making in these ecosystem types.

Least threatened ecosystems are ecosystem types that have experienced little or no loss of natural habitat or deterioration in condition. Maps of biodiversity priority areas should guide planning, resource management and decision-making in these ecosystem types."

1.5.3 Impacts Matrix Categories

Environmental and social impact categories were created in order to compare the different schemes to one another, based on a consistent level of information available throughout the study area. These are presented in **Table** 3 and

Table 4 below.

Table 3 **|** Environmental Impact Categories

Category Descriptions				
Environmental				
Terrestrial Biodiversity	National Biodiversity Assessment (2011) database used as the basis for identifying potential fatal flaws with regards to terrestrial ecosystem loss or damage	1	Fatal Flaw	Critically Endangered/ Endangered
		2	High Impact	Vulnerable
		3	Moderate Impact	Near-threatened
		4	Low impact	Least Concern (national targets not met)
		5	Insignificant	Least Concern (national targets met)
Aquatic Biodiversity	National Freshwater Ecosystem Priority Areas Project (2011) database used as basis for the identification of potential fatal flaws with regards to aquatic ecosystem loss or damage	1	Fatal Flaw	Flagship Free flowing river
		2	High Impact	FEPA area
		3	Moderate Impact	Fish Support Area
		4	Low impact	Phase 2 Priority Area
		5	Insignificant	Upstream management Area
Protected Areas	National Protected Areas database used as the basis for identifying potential fatal flaws with regards to terrestrial ecosystem loss or damage	1	Fatal Flaw	National Park
		2	High Impact	Within 10 km buffer zone
		3	Moderate Impact	Provincial Nature Reserve
		4	Low impact	Within 5 km buffer zone
		5	Insignificant	Other

Table **4 | Social Impact Categories**

Category Descriptions

Social				
Resettlement/ Relocation impact	1. Is there involuntary resettlement? How many households or settlements are affected (Public infrastructure costs to be determined by others) 2. Is the scheme affecting people's income or survival such as subsistence agriculture, especially those people close to the world bank poverty level of $1.25 per day (R416/month) (i.e 38% of South Africans (Stats SA 2009)	1	Fatal Flaw	Resettlement and loss of livelihoods/ subsistence of 200 poverty threshold households (for example 1000 people) or more
		2	High Impact	Resettlement and loss of livelihoods/ subsistence of 50-200 poverty threshold households (for example 250-999 people) or more OR 2. resettlement of 100 households or more that are not poor (due to project delay and capacity for resistance)
		3	Moderate Impact	1. Resettlement and loss of livelihoods/ subsistence of 20-50 poverty threshold households (i.e. 0-100 people) OR 2. resettlement of 20-100 households that are not poor (due to project delay and capacity for resistance)
		4	Low impact	1. Resettlement and loss of livelihoods/ subsistence of 0-20 poverty threshold households (i.e. 0-100 people) OR 2. resettlement of 0-20 households that are not poor or more
		5	Insignificant	No resettlement or loss of livelihoods & subsistence
Social impacts due to construction	Crime, HIV, prostitution, migrant workers etc. associated with the construction process: 1. What is the proximity of construction site / camp in relation to existing settlements 2. What is the size of the construction team vs. that of the existing settlement (i.e.1:1 or 1:5)	1	Fatal Flaw	n/a
		2	High Impact	1. Project is in close proximity to a settlement of 500 or more inhabitants of (0-10km) AND 2. Construction team in relation to no. of people of 1:5 or greater
		3	Moderate Impact	1. Project is in local proximity to a settlement of 500 or more people (10km to 50km) AND 2. Construction team in relation to no. of people of 1:5 or greater

Category Descriptions				
Social				
		4	Low impact	1. Project is in regional proximity to a settlement of 500 or more inhabitants (50km - 100km) AND 2. Construction team in relation to no. of people of 1:5 or greater
		5	Insignificant	1. Project is not close to a settlement of 500 or more people (more than 100km) AND 2. Construction team in relation to no. of people of 1:5 or greater
Access impacts		1	Fatal Flaw	n/a
		2	High Impact	1. Permanent impact on access for a settlement of 500 people or more, dependent on public transport
		3	Moderate Impact	1. Construction impact on access for a settlement of 500 people or more, dependent on public transport 2. Construction impact on access for a settlement of 500 people or more (not dependent on public transport)
		4	Low impact	1. Construction impact on access for a settlement of 100-500 people (dependent on public transport) OR 2. Construction impact on access for a settlement of 100 people or more (not dependent on public transport)
		5	Insignificant	1. No access impact on people dependent on public transport during construction 2. Construction impact on access for a settlement of 100 people or less (not dependent on public transport)

1.6 MALATSI DAM

1.6.1 Location and Context

The study site is located in Lesotho, within the "Least threatened" Senqu Montane Shrubland ((Mucina & Rutherford, 2006)) which is characteristically limited to steep slopes of valleys and gullies with boulders. It consists mainly of evergreen shrubs.

The height used in calculating the flood line for Malatsi Dam was set at 1680m. No settlements are located within the proposed flood line or a 500m buffer area from the proposed flood line. The area is distinctly rural, with no significant access roads or notable infrastructure present

1.6.2 Site-specific desktop analysis

Table 5 **|** Malatsi Dam Screening

Malatsi Dam Environmental and Social Screening						
Environmental						
Category	**Impact Rating**					**Comments**
	1	2	3	4	5	
Terrestrial Biodiversity				4		The National Biodiversity Assessment status for the study area is classified as Least Concern (LC). However, national conservation targets for vegetation types within the study area are not yet met
Aquatic Biodiversity					5	The National Freshwater Ecosystem Priority Atlas status for the study area is classified as Low Priority or Unknown.
Protected Areas					5	No known National Parks or Provincial Nature Reserves are located within the study area. The presence of privately owned nature reserves or ranches are not included in this assessment
Final Score	4.7					This is a non-weighted average and only serves to indicate overall environmental risk associated with the project.
Social						
Resettlement/ Livelihoods impact				4		No settlements are inside the proposed flood line.
Social impacts due to construction				4		Influx of construction workers and related issues.
Access impacts					5	Expected access impacts are insignificant.
Final Scoring	4.3					This is a non-weighted average and only serves to indicate overall environmental risk associated with the project.

1.6.3 Environmental Impacts

Potential environmental impacts expected with the Malatsi dam is considered to be low to insignificant on a national/sub-quaternary scale. Threats towards biodiversity conservation are considered to be low.

1.6.4 Social Impacts

As no settlements will be affected, the main expected impact is influx of construction workers into the poor, rural community structure.

1.6.5 Conclusion

Project risk for the Malatsi dam as an option from environmental and social perspective is rated as **low.**

1.7 NTOAHAE DAM

1.7.1 Location and Context

The study site is located in Lesotho, within the "Least threatened" Senqu Montane Shrubland which is characteristically limited to steep slopes of valleys and gullies with boulders. It consists mainly of evergreen shrubs.

The height used in calculating the flood line for Ntoahae Dam was set at 1680m. There are approximately 5 settlements inside the proposed flood line, and 11 settlements within a 500m radius of the proposed flood line.

1.7.2 Site-specific desktop analysis

Table 6 | Ntoahae Dam Screening

Ntoahae Dam Environmental and Social Screening						
Environmental						
Category	**Impact Rating**					**Comments**
	1	2	3	4	5	
Terrestrial Biodiversity				4		The National Biodiversity Assessment status for the study area is classified as Least Concern (LC). However, national conservation targets for vegetation types within the study area are not yet met
Aquatic Biodiversity					5	The National Freshwater Ecosystem Priority Atlas status for the study area is classified as Low Priority or Unknown.
Protected Areas					5	No known National Parks or Provincial Nature Reserves are located within the study area. The presence of privately owned nature reserves or ranches are not included in this assessment
Final Score	4.7					This is a non-weighted average and only serves to indicate overall environmental risk associated with the project.
Social						
Resettlement/ Livelihoods impact			3			5 Settlements are inside the proposed flood line. Resettlement and loss of livelihoods/ subsistence of 20-50 poverty threshold households (i.e. 0-100 people) is anticipated.
Social impacts due to construction			3			Influx of construction workers and related issues.
Access impacts				4		Construction impact on access for 500 people or more, dependent on public transport
Final Scoring	3.3					This is a non-weighted average and only serves to indicate overall environmental risk associated with the project.

1.7.3 Environmental Impacts

Potential environmental impacts expected with the Malatsi dam is considered to be low to insignificant on a national/sub-quaternary scale. Threats towards biodiversity conservation are considered to be low.

1.7.4 Social Impacts

Some 5 settlements will be affected, and the influx of construction workers into the poor, rural community structure will cause associated issues.

1.7.5 Conclusion

Project risk for the Ntoahai dam as an option from environmental and social perspective is rated as **low.**

1.8 BOSBERG DAM

1.8.1 Location and Context

The study site is located within the "Least threatened" Aliwal North Dry Grassland and Besemkaree Koppies Shrubland vegetation types. The Aliwal North Dry Grassland is typically interspersed with rocky outcrops which constitute the Besemkaree Koppies Shrubland. It is mainly broken terrain with irregular plains which support grassland and patchy dwarf karroid shrub vegetation. Endemic taxa to the Besemkaree Koppies Shrubland are *Cussonia* sp., *Euphorbia crassipes*, *Neohenricia sibettii* and *Neohenricia spiculata*.

The height used in calculating the flood line for Bosberg Dam was set at 1400m. There are approximately 14 settlements inside the proposed flood line, and 21 settlements within a 500m radius of the proposed flood line.

1.8.2 Site-specific desktop analysis

Table 7 | Bosberg Dam Screening

Bosberg Dam Environmental and Social Screening						
Environmental						
Category	**Impact Rating**					**Comments**
	1	2	3	4	5	
Terrestrial Biodiversity				4		The National Biodiversity Assessment status for the study area is classified as Least Concern (LC). However, national conservation targets for vegetation types within the study area are not yet met
Aquatic Biodiversity		2				The National Freshwater Ecosystem Priority Atlas status for the study area is classified as a High Priority. This indicates that rivers within the study area have a Present Ecological Status (PES) Class of A or B.
Protected Areas					5	No known National Parks or Provincial Nature Reserves are located within the study area. The presence of privately owned nature reserves or ranches are not included in this assessment
Final Score	3.7					This is a non-weighted average and only serves to indicate overall environmental risk associated with the project.
Social						
Resettlement/ Livelihoods impact		2				14 Settlements are inside the proposed flood line / Deep river channel thus low impact on subsistence agric.
Social impacts due to construction			3			Project in close proximity to settlements (incl. Aliwal-north), although lower than 1:10 ratio of project vs local people
Access impacts				4		Construction access impact on some Eastern Cape communities to Zastron is expected.
Final Scoring	3.0					This is a non-weighted average and only serves to indicate overall environmental risk associated with the project.

1.8.3 Environmental Impacts

Potential environmental impacts expected with the Bosberg dam is considered to be high to moderate on a national/sub-quaternary catchment scale. FEPA Rivers located within the study area earns the highest priority level of importance with regards to the protection of South Africa's freshwater ecosystems (rivers with Class A/B PES).

1.8.4 Social Impacts

Some 14 settlements will be affected, and the influx of construction workers into the poor, rural community structure will cause associated issues. Due to the deep valley channel and steep slopes of the Orange in this area, there is likely to be a reduced impact on subsistence agriculture The project is in close proximity to Aliwal-north, but the ratio of project personnel to people in the community is low, therefore the social impacts associated with construction are manageable. Some access impacts will also occur, especially for Eastern Cape communities that travel to the Free State (towns such as Zastron) on the R726 provincial road.

1.8.5 Conclusion

Project risk for the Bosberg dam as an option from environmental and social perspective is rated as **moderate.**

1.9 KRAAI DAM

1.9.1 Location and Context

The study site is located within the “Vulnerable” Upper Gariep Alluvial vegetation type. This is characterized by flat alluvial terraces that consist of a variety of riparian thickets, flooded grasslands and reed beds. The building of dams and agriculture constitute the greatest threats towards biodiversity conservation of this vegetation type.

The Kraai River is one of the last 63 remaining free-flowing rivers of South Africa. As part of the actions taken to maintain free-flowing rivers, the following top priorities were given:

- Dams should not be constructed in free-flowing rivers
- They should be maintained in a natural or near-natural ecological condition
- They should preferably be incorporated into protected areas and as part of the biodiversity stewardship approach

The height used in calculating the flood line for Kraai Dam was set at 1400m. There are approximately 30 settlements inside the proposed flood line, and 40 settlements within a 500m radius of the proposed flood line.

1.9.2 Site-specific desktop analysis

Table 8 | Kraai Dam Screening

Kraai Dam Environmental and Social Screening						
Environmental						
Category	**Impact Rating**					**Comments**
	1	2	3	4	5	
Terrestrial Biodiversity		2				The National Biodiversity Assessment status for the study area is classified as Vulnerable.
Aquatic Biodiversity	1					The National Freshwater Ecosystem Priority Atlas status for the study area is classified as Highest Priority. The Kraai River is regarded as one of the last remaining free-flowing rivers in the country and has a PES Class of A or B
Protected Areas					5	No known National Parks or Provincial Nature Reserves are located within the study area. The presence of privately owned nature reserves or ranches are not included in this assessment
Final Score	2.7					This is a non-weighted average and only serves to indicate overall environmental risk associated with the project.
Social						
Resettlement/ Livelihoods impact	1					30 Settlements are inside the proposed flood line. Subsistence agriculture of poor communities affected.
Social impacts due to construction		2				Project in close proximity to settlements (incl. Aliwal-north), although lower than 1:10 ratio of project vs local people
Access impacts		2				Permanent access impact on impoverished communities is expected.
Final Scoring	1.7					This is a non-weighted average and only serves to indicate overall environmental risk associated with the project.

1.9.3 Environmental Impacts

The Kraai dam as a possibility for the scheme is considered a fatal flaw with regards to the presence of certain ecologically important drivers/ ecosystems. The Kraai River is one of the few remaining free-flowing rivers of South Africa and is considered as one of the Flagship Free Flowing Rivers of South Africa. According to the 2011 NFEPA Atlas, Flagship Rivers obtain top priority in order to retain their free-flowing character.

The Upper Gariep Alluvial Vegetation Type within the study area is classified as a vulnerable vegetation type and exacerbates the environmental and biodiversity threats associated with the Kraai Dam.

1.9.4 Social Impacts

Approximately 30 settlements will be affected which is currently below the proposed flood line. Actual population data is not available, although it can be estimated that more than 1000 people may have to be resettled.

These communities are dependent on subsistence agriculture. Livelihoods and subsistence will be affected as well, since the flatter slope of the Kraai catchment allows for agriculture. The project is in close proximity to settlements (incl. Aliwal-north), but smaller than 1:10 ratio. Permanent access impact is further expected on these impoverished communities, as the N6 national and the R58 will be affected by the project. Due to the high impact and extensive resettlement action planning and livelihoods restoration expected to be required, this project is considered a fatal flaw from a social point of view.

1.9.5 Conclusion

Project risk for the Kraai dam as an option from environmental and social perspective is rated as **high.**

1.10 BOSKRAAI DAM

1.10.1 Location and Context

The study site is located within the "Vulnerable" Upper Gariep Alluvial vegetation type. This is characterized by flat alluvial terraces that consist of a variety of riparian thickets, flooded grasslands and reed beds. The building of dams and agriculture constitute the greatest threats towards biodiversity conservation of this vegetation type.

The Kraai River is one of the last 63 remaining free-flowing rivers of South Africa. As part of the actions taken to maintain free-flowing rivers, the following top priorities were given:

- Dams should not be constructed in free-flowing rivers
- They should be maintained in a natural or near-natural ecological condition
- They should preferably be incorporated into protected areas and as part of the biodiversity stewardship approach

The height used in calculating the flood line for Boskraai Dam was set at 1400m. There are approximately 30 settlements inside the proposed flood line, and 40 settlements within a 500m radius of the proposed flood line.

1.10.2 Site-specific desktop analysis

Table 9 | Boskraai Dam Screening

Boskraai Dam Environmental and Social Screening						
Environmental						
Category	**Impact Rating**					**Comments**
	1	2	3	4	5	
Terrestrial Biodiversity		2				The National Biodiversity Assessment status for the study area is classified as Vulnerable.
Aquatic Biodiversity	1					The National Freshwater Ecosystem Priority Atlas status for the study area is classified as Highest Priority. The Kraai River is regarded as one of the last remaining free-flowing rivers in the country and has a PES Class of A or B
Protected Areas					5	No known National Parks or Provincial Nature Reserves are located within the study area. The presence of privately owned nature reserves or ranches are not included in this assessment
Final Score	2.7					This is a non-weighted average and only serves to indicate overall environmental risk associated with the project.
Social						
Resettlement/ Livelihoods impact	1					30 Settlements are inside the proposed flood line. Subsistence agriculture of poor communities affected.
Social impacts due to construction		2				Project in close proximity to settlements (incl. Aliwal-north), although lower than 1:10 ratio of project vs local people
Access impacts		2				Permanent access impact on impoverished communities is expected.
Final Scoring	1.7					This is a non-weighted average and only serves to indicate overall environmental risk associated with the project.

1.10.3 Environmental Impacts

The Boskraai dam as a possibility for the scheme is considered a fatal flaw with regards to the presence of certain ecologically important drivers/ ecosystems. The Kraai River is one of the few remaining free-flowing rivers of South Africa and is considered as one of the Flagship Free Flowing Rivers of South Africa. According to the 2011 NFEPA Atlas, Flagship Rivers obtain top priority in order to retain their free-flowing character.

The Upper Gariep Alluvial Vegetation Type within the study area is classified as a vulnerable vegetation type and exacerbates the environmental and biodiversity threats associated with the Boskraai Dam.

1.10.4 Social Impacts

Approximately 30 settlements will be affected which is currently below the proposed flood line. Actual population data is not available, although it can be estimated that more than 1000 people may have to be resettled.

These communities are dependent on subsistence agriculture. Livelihoods and subsistence will be affected as well, since the flatter slope of the Kraai catchment allows for agriculture. The project is in close proximity to settlements (incl. Aliwal-north), but smaller than 1:10 ratio. Permanent access impact is further expected on these impoverished communities, as the N6 national and the R58 will be affected by the project. Due to the high impact and extensive resettlement action planning and livelihoods restoration expected to be required, this project is considered a fatal flaw from a social point of view.

1.10.5 Conclusion

Project risk for the Boskraai dam as an option from environmental and social perspective is rated as **high.**

1.11 GARIEP DAM

1.11.1 Location and Context

The study site is located within the "Least Threatened" Besemkaree Koppies Shrubland, Xhariep Karroid Grassland and the Eastern Upper Karoo vegetation types.

The Oviston and Hendrik Verwoerd Provincial Nature Reserves are located within the flood line of the proposed enlargement of the Gariep Dam. These nature reserves will expectedly be largely inundated due to the proposed scheme. They have a high value to the surrounding community, and the project will therefore be met with some resistance.

The height used in calculating the flood line for Gariep Dam was set at 1280m. There are approximately 7 settlements inside the proposed flood line, and 29 settlements within a 500m radius of the proposed flood line. This includes the town of Bethulie, which has a population of approximately 1,500 people.

1.11.2 Site-specific desktop analysis

Table 10 | Gariep Dam Screening

Gariep Dam Environmental and Social Screening						
Environmental						
Category	**Impact Rating**					**Comments**
	1	2	3	4	5	
Terrestrial Biodiversity				4		The National Biodiversity Assessment status for the study area is classified as Least Concern (LC). However, national conservation targets for vegetation types within the study area are not yet met
Aquatic Biodiversity					5	The National Freshwater Ecosystem Priority Atlas status for the study area is classified as Low Priority or Unknown.
Protected Areas			3			The Oviston and Hendrik Verwoerd Nature Reserves are located within the flood line of the proposed enlargement of the Gariep Dam
Final Score	4.0					This is a non-weighted average and only serves to indicate overall environmental risk associated with the project.
Social						
Resettlement/ Livelihoods impact		2				7 Settlements are inside the proposed flood line.
Social impacts due to construction			3			
Access impacts				4		Due to the dam being existing - little new access impacts are expected.
Final Scoring	3.0					This is a non-weighted average and only serves to indicate overall environmental risk associated with the project.

1.11.3 Environmental Impacts

Potential environmental impacts expected with the Gariep dam is considered to be low to moderate on a national/sub-quaternary scale. The main environmental concern is the presence of the formally protected Oviston and Hendrik Verwoerd Provincial Nature Reserves that are established around the existing Gariep Dam.

1.11.4 Social Impacts

7 settlements affected (including half of Bethulie of approximately 1,500 people) will be inundated by the project. As the population of Bethulie is predominantly “urban” (i.e. not dependent on subsistence agriculture) the resettlement will carry a significant cost, but is manageable in terms of a project risk.

As the dam is existing - little new permanent access impacts are expected. There will also be a significant loss of grazing land (due to the flat topography), which may presumably be compensated.

1.11.5 Conclusion

Project risk for the Gariep dam 10m wall raise as an option from environmental and social perspective is rated as **moderate.**

1.12 VIOOLSDRIFT DAM

1.12.1 Location and Context

The study area is located within the "Endangered" Lower Gariep Alluvial Vegetation type (South African classification) and the "Inadequately Protected" Karas Dwarf Shrubland (Namibia classification) (NMET, 2010). It is mainly characterized by flat alluvial terraces that support variety of riparian thickets dominated by *Ziziphus mucronata* and *Euclea pseudebenus* with *Phragmites australis* reedbeds dominating the sandbanks.

Main threats associated with the conservation of the vegetation types are agriculture and alluvial diamond mining operations.

The height used in calculating the flood line for Vioolsdrift Dam was set at 220m. There are approximately 2 settlements inside the proposed flood line, and 2 settlements within a 500m radius of the proposed flood line.

1.12.2 Site-specific desktop analysis

Table 11 | Vioolsdrift Dam Screening

Vioolsdrift Dam Environmental and Social Screening						
Environmental						
Category	**Impact Rating**					**Comments**
	1	2	3	4	5	
Terrestrial Biodiversity	1					The National Biodiversity Assessment status for the study area is classified as Critical Biodiversity Area.
Aquatic Biodiversity		2				The National Freshwater Ecosystem Priority Atlas status for the study area is classified as a High Priority. This indicates that rivers within the study area have a Present Ecological Status (PES) Class of A or B.
Protected Areas					5	No known National Parks or Provincial Nature Reserves are located within the study area. The presence of privately owned nature reserves or ranches are not included in this assessment
Final Score	2.7					This is a non-weighted average and only serves to indicate overall environmental risk associated with the project.
Social						
Resettlement/ Livelihoods impact				4		2 Settlements are inside the proposed flood line.
Social impacts due to construction				4		Very low population density and related impacts – river rafting companies may cause public resistance due to their livelihoods
Access impacts					5	Expected access impacts are insignificant.
Final Scoring	4.3					This is a non-weighted average and only serves to indicate overall environmental risk associated with the project.

1.12.3 Environmental Impacts

The Vioolsdrift dam as a possibility for the scheme is considered a fatal flaw with regards to the presence of certain ecologically important drivers/ ecosystems. The area is classified as a terrestrial critical biodiversity area according to the 2011 NBA. It contains the Endangered Lower Gariep Alluvial Vegetation Type.

FEPA Rivers located within the study area earns the highest priority level of importance with regards to the protection of South Africa's freshwater ecosystems (rivers with Class A/B PES) and exacerbates the environmental and biodiversity threats associated with the Vioolsdrift Dam.

1.12.4 Social Impacts

2 settlements affected with very low populations. Insignificant access impacts are expected. Some river rafting companies might cause public resistance to the project, due to their use of the river in this area.

1.12.5 Conclusion

Project risk for the Vioolsdrift dam as an option from environmental and social perspective is rated as **high.**

1.13 NEW BOEGOEBERG DAM

1.13.1 Location and Context

The study area is located within the "Endangered" Lower Gariep Alluvial and the "Least Threatened" Lower Gariep Broken Veld vegetation types. It is mainly characterized by flat alluvial terraces that support variety of riparian thickets dominated by *Ziziphus mucronata* and Euclea pseudebenus with *Phragmites australis* reedbeds dominating the sandbanks. Main threats associated with the conservation of the Lower Gariep Alluvial vegetation type are agriculture and alluvial diamond mining operations.

The shrub *Ruschia pungens* is endemic to the Lower Gariep Broken Veld vegetation type.

The height used in calculating the flood line for New Boegoeberg Dam was set at 900m. There are approximately 2 settlements inside the proposded floodline, and 4 settlements within a 500m radius of the proposed flood line.

1.13.2 Site-specific desktop analysis

Table 12 | New Boegoeberg Dam Screening

New Boegoeberg Dam Environmental and Social Screening						
Environmental						
Category	**Impact Rating**					**Comments**
	1	2	3	4	5	
Terrestrial Biodiversity	1					The National Biodiversity Assessment status for the study area is classified as Critical Biodiversity Area.
Aquatic Biodiversity		2				The National Freshwater Ecosystem Priority Atlas status for the study area is classified as a High Priority. This indicates that rivers within the study area have a Present Ecological Status (PES) Class of A or B.
Protected Areas					5	No known National Parks or Provincial Nature Reserves are located within the study area. The presence of privately owned nature reserves or ranches are not included in this assessment
Final Score	2.7					This is a non-weighted average and only serves to indicate overall environmental risk associated with the project.
Social						
Resettlement/ Livelihoods impact				4		2 Settlements are inside the proposed flood line.
Social impacts due to construction				4		No comment – very low population density and related impacts
Access impacts					5	Expected access impacts are insignificant.
Final Scoring	4.3					This is a non-weighted average and only serves to indicate overall environmental risk associated with the project.

1.13.3 Environmental Impacts

The New Boegoeberg dam as a possibility for the scheme is considered a fatal flaw with regards to the presence of certain ecologically important drivers/ ecosystems. The area is classified as a terrestrial critical biodiversity area according to the 2011 NBA. It contains the Endangered Lower Gariep Alluvial Vegetation Type.

FEPA Rivers located within the study area earns the highest priority level of importance with regards to the protection of South Africa's freshwater ecosystems (rivers with Class A/B PES) and exacerbates the environmental and biodiversity threats associated with the New Boegoeberg Dam.

1.13.4 Social Impacts

Few social impacts are expected due to the low population density – the settlements indicated on GIS is only a few homesteads.

1.13.5 Conclusion

Project risk for the Malatsi dam as an option from environmental and social perspective is rated as **high.**

1.14 KNOFFELFONTEIN DAM

1.14.1 Location and Context

The study site is located within the "Vulnerable" Upper Gariep Alluvial and the "Least Threatened" Northern Upper Karoo vegetation types. The Upper Gariep Alluvial vegetation type is characterized by flat alluvial terraces that consist of a variety of riparian thickets, flooded grasslands and reed beds. The building of dams and agriculture constitute the greatest threats towards biodiversity conservation of this vegetation type.

Taxa endemic to the Northern Upper Karoo vegetation type are *Lithops hookeri*, *Stomatium pluridens*, *Atriplex spongiosa*, *Galenia exigua* and *Manulea deserticola.*

The Mokala National Park located less than 10 km downstream from the study area.

The height used in calculating the flood line for Knoffelfontein Dam was set at 1100m. No settlements are located inside the proposed flood line for Knoffelfontein Dam.

1.14.2 Site-specific desktop analysis

Table 13 | Knoffelfontein Dam Screening

Knoffelfontein Dam Environmental and Social Screening						
Environmental						
Category	**Impact Rating**					**Comments**
	1	2	3	4	5	
Terrestrial Biodiversity		2				The National Biodiversity Assessment status for the study area is classified as Vulnerable.
Aquatic Biodiversity					5	The National Freshwater Ecosystem Priority Atlas status for the study area is classified as Low Priority or Unknown.
Protected Areas		2				The Mokala National Park is located less than 10km downstream from the study area. The presence of privately owned nature reserves or ranches are not included in this assessment
Final Score	4.0					This is a non-weighted average and only serves to indicate overall environmental risk associated with the project.
Social						
Resettlement/ Livelihoods impact					5	No settlements are inside the proposed flood line.
Social impacts due to construction				4		The project is in close proximity to the town of Ritchie, however the ratio of project people vs. community numbers are low.
Access impacts					5	Expected access impacts are insignificant.
Final Scoring	4.7					This is a non-weighted average and only serves to indicate overall environmental risk associated with the project.

1.14.3 Environmental Impacts

Potential environmental impacts expected with the Knoffelfontein Dam are considered to be moderate to high on a national/sub-quaternary scale. Threats towards biodiversity conservation are considered to be moderate due to the presence of the Mokala National Park located less than 10 km downstream from the study area and the presence of the Vulnerable Upper Gariep Alluvial Vegetation Type within the study area.

1.14.4 Social Impacts

Few negative social impacts are expected as a result of the project.

1.14.5 Conclusion

Project risk for the Knoffelfontein dam as an option from environmental and social perspective is rated as **moderate.**

1.14.6 Scaling

As part of the overall conclusion for assessing potential risks associated with the proposed and existing dam locations, the scale of each project was assessed.

When scale is taken into account for Vioolsdrift and New Boegoeberg, the environmental and social risks for both dams are decreased from being potential High risk options to Moderate risk options.

1.15 VIOOLSDRIFT

The main function and aim for the construction of Vioolsdrift dam is to create a regulating dam that will serve to regulate the quantity and timing of the water supply towards the downstream estuaries.

2 OVERALL CONCLUSION

The following presents an overall conclusion, based on the un-weighted score of each of the schemes.

From a risk point of view, the various schemes can be summarised as follows:

High-risk options:

- Boskraai (social and environmental drivers)
- Kraai (Social and environmental drivers)

Moderate risk options:

- Bosberg
- Gariep
- Knoffelfontein
- Vioolsdrift (environmental drivers)
- New Boegoeberg (environmental drivers)

Low risk options:

- Ntoahai
- Malatsi

Appendix D

Eskom Report: Impact of development of reconciliation strategies for large bulk water supply systems: Orange River on Eskom Peaking Generation

Eskom Generation	PEAKING GENERATION	Doc No.: 151A/35642 Template No: 167A/27-J — Rev: 04 Page: 1 of 4 — Date: 2013/11/27 HBS:

Title: **REPORT – IMPACT OF DEVELOPMENT OF RECONCILIATION STRATEGIES FOR LARGE BULK WATER SUPPLY SYSTEMS: ORANGE RIVER ON ESKOM PEAKING GENERATION**	Document type: REPORT

CONSULTANTS:	
CLIENT:	
PROJECT CODE:	
PLANT CODE:	

PREPARED BY:

Tinus Keyser Pr Eng Chief Engineer (Turbines)		2013-11-29
NAME	SIGNATURE	DATE

PREPARED BY:

NAME	SIGNATURE	DATE

ACCEPTED BY:

Avi Singh Power Station Manager		2013-12-09
NAME	SIGNATURE	DATE

CONFIDENTIALITY CLASSIFICATION: CONTROLLED DISCLOSURE

Promotion of the Access to Information Act 2000

(Refer to the list on Procedure GGP1067)

NOTE: THE ELECTRONIC MASTER IS MAINTAINED WITHIN THE EMDS ONCE THIS DOCUMENT HAS BEEN COPIED OR PRINTED IT WILL BECOME A WORKING COPY ONLY!!

Contents

Executive Summary

This report is an assessment of the impact of the proposed reconciliation strategies for the Orange River Bulk Water Supply System on Eskom Peaking Generation. The Minimum Operating Level – Vanderkloof Dam would impact Peaking Generation negatively in an increase of the periods where no water is available for generation. The Gariep Dam Raisin has the potential of increased power and energy output, but there would be financial costs involved.

Introduction

DWAF is investigating strategies of increasing the yield on the Orange Water River System. Two of the proposals would affect Eskom Peaking generation, *viz* Minimum Operating Level – Vanderkloof Dam and Gariep Dam Raising. The Vioolsdrift Dam was not considered as not enough information is available assess its potential for hydro power generation.

1. Normative References

Here the applicable references are made to which this document was compiled.

- Bridging Study into the Utilisation of the Low Level Storage at Vanderkloof Dam, Jonck & Rossouw, DWAF Report No: P WMA 13/000/00/0404, 151A/GRP247M/12
- Development Of Reconciliation Strategies For Large Bulk Water Supply Systems: Orange River. Background Information Document (No.2). Preliminary Strategy – November 2013 – Department of Water Affairs
- Gariep characteristic diagram, 151A/GRP247M/94
- Power House Equipment Layout Section, Gariep Drawing 0.38/174 Rev 2

2. Abbreviations

DWA – Department of Water Affairs
LLS - Low Level Storage
masl –Meter Above Mean Sea Level
MW – Megawatts
MWC - Megawatt Continuous
WRPM - Water Resources Planning Model

3. Minimum Operating Level – Vanderkloof Dam

3.1 Proposal

The Vanderkloof Dam can be operated by lowering its operating level and the yield of the system could increase by approximately 137 million m^3/annum. The current minimum operation level is 1147.8 masl and it is proposed to be lowered to 1111.0 masl. The new proposed minimum operating level is below the irrigation outlet and to continue to supply for irrigation, water would be abstracted from the right bank silt outlet. A pump station will pump the water into the canal which supplies water to Ramah and Orange-Riet canals. This is proposed for 2022.

3.2 Impact on Peaking Generation

The current minimum operational level of 1147.8 is just below the top of the penstock inlet. The turbine centreline is at 1092.0 masl so that is a relative head of 55.8 m. This is the minimum head for power generation. Any lowering of this will prevent the operation of the turbines.

The main impact on Peaking Generation will be when the dam level is below the minimum level for power generation. For these periods Vanderkloof Power Station will not be able to contribute to the grid and the emergency generation capacity will be reduced by 240 MW.

Because of the seasonal nature of the inflows to the dam, the proposed strategy would draw down the dam level in the dry months and it will then be replenished in the rainy season. However, if there is not enough inflow, the risk exist of the dam level not recovering to above the minimum operating level for power generation. With the present operating levels, there is 5% probability that maximum number of consecutive months of no power generation is five months. If the low level strategy is followed, then this number goes to 17 months as can be seen in Table 1 below.

Out of the 201 sequences analysed with the WRPM, 38 sequences (19%) contain at least 1 month in which zero power could be generated at Vanderkloof Dam for the status quo scenario. The corresponding percentage of sequences for Scenarios 4 and 5 is 100% and 50% respectively. The current risk of having one month of no power generation is therefore 19% and this increases to 50% if the LLS is utilised and water is pumped into the canal. If the low level strategy is followed, then provision will have to be made for the possibility of unavailability of Vanderkloof for extended periods. The analyses indicate that the most affected period will be from June to September, coinciding with winter peak.

Table 1 Maximum number of consecutive months of no power generation at Vanderkloof

Percentiles	Scenario 1 Status quo	Scenario 4 Utilise LLS + no	Scenario 5 Utilise LLS + pumping
0.0	16	42	41
0.5	14	39	38
1.0	12	30	32
5.0	5	16	17
10.0	3	15	15
25.0	0	7	8
50.0	0	0	0
75.0	0	0	0
90.0	0	0	0
95.0	0	0	0
99.0	0	0	0
99.5	0	0	0
100.0	0	0	0

Since the water below the minimum level for power operation is not available for power generation anyway, there is little difference on the total energy extracted.

Table 2 - Energy (MW Continuous) from Vanderkloof

Percentiles	Scenario 1 Status quo	Scenario 4 Utilise LLS + no pumping	Scenario 5 Utilise LLS + pumping
0.0	77.4	78.2	78.2
0.5	76.9	77.4	77.4
1.0	74.3	75.4	75.4
5.0	71.5	72.8	72.8
10.0	68.9	69.8	69.8
25.0	65.5	65.9	65.9
50.0	61.2	61.3	61.3
75.0	57.4	56.9	56.8
90.0	54.1	52.7	52.5
95.0	51.9	50.2	50.1
99.0	46.5	45.2	45.2
99.5	46.4	44.4	44.6
100.0	45.7	44.1	44.1

4. Gariep Dam Raising

4.1 Proposal

A 10m raising of Gariep Dam is envisaged by approximately 2032. The proposal will increase yield by 350 million m^3/annum and is DWAF's preferred option.

4.2 Impact on Peaking Generation

The raising of the dam wall by 10 m will have a significant impact on Peaking Generation. The main issue is that the head on the turbines will be outside the design envelope of the current turbines. There are a few scenarios that can be explored.

4.2.1 Use the existing turbines and generators

The existing turbine and generator set can be run to 110 MW. The limiting factor is the shaft which can only handle 112 MW. At the new maximum head the turbine can produce 110 MW with a guide vane opening of 60%, flow of 178 m^3/s and efficiency of 89%. However, this operating point would be well in the cavitation zone and one would expect serious metal loss on the runners.

The advantages of this option would be little or no capital investment and increased energy depending on releases. There is also a 15% decrease in specific water consumption for the same amount of energy. The disadvantage would be increased maintenance periods and costs to repair the runners.

4.2.2 Install uprated turbines, generators and transformers

With the increased head there is potential to uprate the turbine and generators. To calculate the potential, one must recognise that the limiting factor would be the flow in the penstocks. It is assumed that the penstock would be able to handle the increase in pressure, since Gariep dam was initially designed to be heightened to compensate for storage loss due to siltation.

The penstocks are steel lined, so the maximum velocity can be up to 7 m/s. This gives a flow of 294 m^3/s and a potential of 191 MW at an assumed efficiency of 94%. These flows give a projected tailwater increase of almost 6 m, but that is still below full flood level.

The advantage of this scenario is the increase in rated power output for the station from 360 MW to 764 MW. It is also clean energy and may be used for carbon credits. The disadvantages would be the capital expenditure to upgrade the turbines, generators, transformers and transmission network. The economic viability of this scenario would also depend heavily on the amount of water available for release from the dam, although if the raising of the Gariep dam wall is combined with the Vanderkloof Low Level Strategy, then there could be a large increase in Gariep releases. A lot would depend on the new control curves for Gariep and Vanderkloof dams.

Table 3 Summary of Gariep scenarios

	Existing	Existing (raised wall)	Uprated (max)
Power [MW]	90	110	191
Dam level [masl]	1258.7	1268.8	1268.8
Flow [m^3/s]	162	178	294
Net head [m]	61.5	71.4	71.3
Guide vane [%]	63	60	
Efficiency [%]	93	89	94
Capital cost	None	None	High
Maintenance cost	Medium	High	Low