DWS report number: P WMA 03/X22/00/6718/6

water & sanitation

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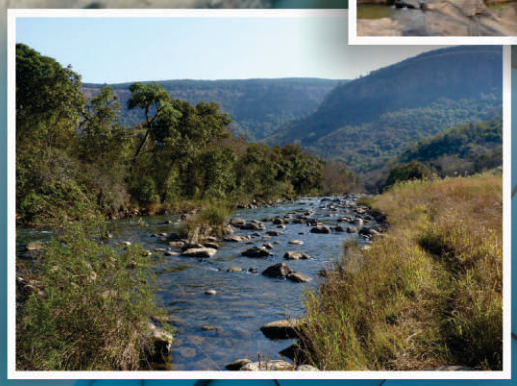
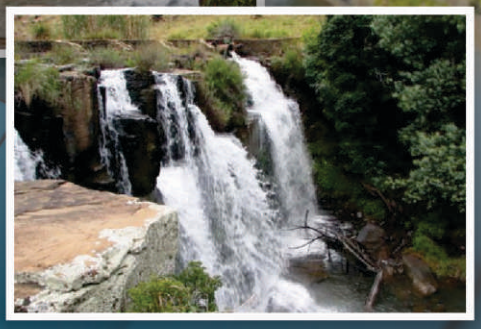
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

CONTINUATION OF WATER REQUIREMENTS AND AVAILABILITY RECONCILIATION STRATEGY STUDY FOR THE MBOMBELA MUNICIPAL AREA

Infrastructure and Cost Assessment Report





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CONTINUATION OF WATER REQUIREMENTS AND AVAILABILITY RECONCILIATION STRATEGY FOR THE MBOMBELA MUNICIPAL AREA

INFRASTRUCTURE AND COST ASSESSMENT REPORT

FEBRUARY 2021

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CONTINUATION OF WATER REQUIREMENTS AND AVAILABILITY RECONCILIATION STRATEGY FOR THE MBOMBELA MUNICIPAL AREA

INFRASTRUCTURE AND COST ASSESSMENT REPORT

FEBRUARY 2021

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LIST OF STUDY REPORTS

Report Name	Report Number	DWS Report Number
Inception	1	P WMA 03/X22/00/6718
Economic Growth and Demographic Analysis	2	P WMA 03/X22/00/6818
Water Requirements and Return Flows	3	P WMA 03/X22/00/6918
Water Conservation and Water Demand Management	4	P WMA 03/X22/00/6718/4
Water Resources Analysis	5	P WMA 03/X22/00/6718/5
Infrastructure and Cost Assessment	**6**	P WMA 03/X22/00/6718/6
Updated Reconciliation Strategy	7	
Executive Summary: Updated Reconciliation Strategy	8	

Title:	**Infrastructure and Cost Assessment Report**
Authors:	**Study Team**
Project Name:	**Continuation of Water Requirements and Availability Reconciliation Strategy for the Mbombela Municipal Area**
DWS Report No:	**P WMA 03/X22/00/6718/6**
Status of Report:	**Final Report**
First Issue:	**February 2021**

Consultants: **BJE/iX/WRP Joint Venture**

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LIST OF ABBREVIATIONS AND ACRONYMS

BBR	Bushbuckridge
BJE	Black Jills Engineers Pty Ltd.
CAPEX	Capital Expenditure
CoM	City of Mbombela
CPI	Consumer Price Indices
DM	District Municipality
DEA	Department of Environmental Affairs
DWA	Department of Water Affairs (now DWS)
DWAF	Department of Water Affairs and Forestry (now DWS)
DWS	Department of Water and Sanitation
EWR	Environmental/Ecological Water Requirements
FSC	Full Supply Capacity
GCTWFSC	Greater Cape Town Water Fund Steering Committee
GRA	Groundwater Resource Assessment
GRIP	Groundwater Resource Information Project
HFY	Historic Firm Yield
IAPs	Invasive Alien Plants
IDP	Integrated Development Plan
IUCMA)	Inkomati Usuthu Catchment Management Agency
iX	iX Engineers Pty Ltd.
iWAAS	Inkomati Water Availability Assessment Study
JV	Joint Venture
LM	Local Municipality
NWRP	National Water Resource Planning
PSP	Professional Service Provider
PV	Present Value
SANParks	South African National Parks
URV	Unit Reference Value
WCWDM	Water Conservation and Water Demand Management
WDC	Water Demand Centre
WfW	Working for Water
WRP	WRP Consulting Engineers Pty Ltd.
WSA	Water Service Authority
WSS	Water Supply System

WTW	Water Treatment Works
WWTW	Waste Water Treatment Works
WUA	Water User Associations

LIST OF UNITS AND SYMBOLS

ha	Hectare
km²	Square Kilometres
Mℓ	Mega Litres
Mℓ/d	Mega Litres per Day
m²	Square Metres
m³	Cubic Metres
m³/a	Cubic Metres per Annum
Mm³	Million Cubic Metre
million m³/a	Million Cubic Metres per Annum
m³/s	Cubic Metres per Second
%	Percentage
R	Rand
R/m³	Rand per Cubic Metres
t	ton

EXECUTIVE SUMMARY

Introduction

The Continuation of Water Requirements and Availability Reconciliation Strategy for the Mbombela Municipal Area (this Study) followed on the *Water Requirements and Availability Reconciliation Strategy for the Mbombela Municipal Area (DWA, 2014)*. The overall objective of this Study was to systematically update, improve and extend the Water Resource Reconciliation Strategy to cover the entire Crocodile (East) and Sabie Sub-Catchments, in order for the Strategy to remain relevant, technically sound, economically viable, socially acceptable and sustainable.

This would ensure that the identified planned intervention options for implementation will also be revised where necessary to consider any changes that may have potential impacts on the projected water balance.

Overview of Study Area

The Study Area includes both the Crocodile (East) and the Sabie Sub-Catchments, which form part of the Ehlanzeni District Municipality (DM). The focus of this Study was on the City of Mbombela Local Municipality (CoM LM) (centre of the Study Area), the former Umjindi LM (South), which was recently amalgamated with the CoM LM, and Bushbuckridge (BBR) LM (North). The remainder of the Study Area incorporates parts of the Emakhazeni LM (West), Thaba Chweu LM (North-West) and Nkomazi LM (South-East), which are situated in and form part of the Crocodile (East) and Sabie Sub-Catchments.

The confluence of the Crocodile (East) River and Sabie River, which are the main rivers in the Study Area, is in neighbouring Mozambique. These two rivers are both trans-boundary waterways and are therefore governed by an international treaty stating the minimum flows that are required to flow into the neighbouring country Mozambique.

The two largest dams in the Study Area are the Inyaka Dam in BBR LM and Kwena Dam in the Thaba Chweu LM, as well as smaller dams in the CoM LM such as Witklip Dam, Longmere Dam, Klipkopjes Dam, Primkop Dam and Da Gama Dam.

Background and Approach

This Report provides an overview and summary of the potential interventions (long list from previous studies and new options) to augment the water supply of the Study Area, the selection of potential interventions (short list) for further evaluation, costing of the selected

intervention options, as well as an engineering economic analyses (expressed as Unit Reference Values) taking cognizance of the results of the water resources analyses task.

Baseline Interventions

The following baseline intervention options were identified that can provide smaller yields to increase the water availability of the Study Area.

- Water Conservation and Water Demand Management (WC/WDM)
- Groundwater Development
- Removal of Invasive Alien Plants (IAPs)

WC/WDM and Groundwater Development are addressed in the following reports compiled as part of this Study.

Report Name	DWS Report Number
Water Conservation and Water Demand Management	P WMA 03/X22/00/6718/4
Water Resources Analysis	P WMA 03/X22/00/6718/5

- **Water Conservation and Water Demand Management (WC/WDM)**

  There is significant scope for WC/WDM in the Study Area. WC/WDM will result in both a reduction of Non-Revenue Water and the total system input volume. A serious concern however, is the pervasive limitation in institutional capacity and technical skills to embark on WC/WDM programmes in the municipalities.

  The estimated budget requirements for the proposed WC/WDM Intervention Options over a five year period for the City of Mbombela and the Bushbuckridge Local Municipalities are respectively R 120 million and R 60 million and per annum.

  Unit Reference Values (URVs) for the implementation of WC/WDM measures were determined for a discount rate of 6% over a 45 year period. The costs included capital and operational expenditures, as well as savings due to reduced production costs and increased revenue water. Unit reference values for the City of Mbombela and the Bushbuckridge Local Municipalities are summarized in **Tables i** (overleaf).

Table i: Summary of Unit Reference Values for WC/WDM

Discount Rate	Total Discounted Cost	Total Realistic Discounted Saving (m^3)	URV (R/m^3)	Total Optimistic Discounted Saving (m^3)	URV (R/m^3)
City of Mbombela					
6%	R 1 333 761 763	137 776 487	9.68	230 514 555	5.79
Bushbuckridge Local Municipality					
6%	R 980 000 576	168 612 040	5.81	214 677 346	4.56

- **Groundwater Development**

  The Mbombela Reconciliation Strategy (DWA, 2014) stated that there is only limited scope for groundwater development for primary water supply. The main reason for this is the potential reduction in surface water baseflows in the Mbombela area, should the groundwater be abstracted.

  The availability of groundwater in the Sabie River Catchment provides for the potential conjunctive use of groundwater and surface water resources in the future as the water requirements increase.

  The further development of groundwater resources will depend on the outcome of a detailed groundwater assessment study currently being conducted by the Inkomati Usuthu Catchment Management Agency (IUCMA).

  Costs for implementing groundwater development in the Study Area were not readily available and information was obtained from a study (GCTWFSC 2019), commissioned by the Greater Cape Town Water Fund Steering Committee. The Average Unit Reference Value for the development of groundwater at a discount rate of 6% over a 30 year period was R7.10/m³.

- **Removal of Invasive Alien Plants (IAPs)**

  As with WCWDM, removing alien vegetation is a standard intervention measure for saving water in all Reconciliation Strategies, and is very important in severely water stressed catchments.

  The Mbombela Reconciliation Strategy (DWA, 2014) assumed that removal of invasive alien pants (IAPs) upstream of the Nelspruit diversion works on the Crocodile River would make water available that could be allocated to the City of Mbombela. It was estimated that up to 4 million m³/annum could be made available if the IAPs upstream of Kwena Dam in the Crocodile Catchment, were removed. The Sabie River Reconciliation Strategy (DWS, 2016) did not consider this intervention option.

The World Wildlife Fund – South Africa, through the co-ordination of SANParks and the Kruger2Canyons Biosphere (DWS, 2020b), have now started with initiatives to undertake IAP removal in the Sabie Catchment. In water stressed catchments such as the Crocodile and the Sabie this intervention is necessary. This intervention would be beneficial in the Sabie Catchment due to the locations of IAPs upstream of Inyaka dam, and it estimated that approximately 3 million m³/annum could be added to the yield of the dam by removing IAPs.

Costs for implementing the intervention option of alien invasive plant removal in the Study Area were not readily available and information was obtained from a study commissioned by the Greater Cape Town Water Fund Steering Committee to evaluate the impact of nature-based solutions on water supply, beginning with targeted removals of alien plant invasions, and determining whether investing at scale in catchment restoration is cost competitive with other supply-side solutions. The results of this study (GCTWFSC 2019) indicated that an investment of R394 million (present value 2020) will generate expected annual water gains of 100 billion liters (100 Mm³) over thirty years and an additional 55 billion liters (55 Mm³) within the first six years.

The Average Unit Reference Value for the removal of invasive alien plants at a discount rate of 6% over a 30 year period was R1.27/m³ (including water treatment costs of R0.85/m³).

Key Interventions (Dams)

Due to the severity of the deficits in the Study Area, new dams will be required in order to provide the existing users with a more reliable assurance of supply as well as to augment future growth in water requirements.

The following dam intervention options were evaluated:

- **Boschjeskop Dam on the Nels River**

  The objectives of the proposed Boschjeskop Dam are to:

  - Augment the water supply to Mbombela.
  - Increase the yield of the Crocodile (East) System.

  No infrastructure will be required to convey water from the Boschjeskop Dam to Mbombela. Water can be released from the Boschjeskop Dam and abstracted downstream at the Mbombela Water Treatment Works (WTW).

- **Mountain View Dam on the Kaap River**

  The objectives of the proposed Mountain View Dam are to:

  - Act in combination with the existing Kwena Dam and provide releases downstream for irrigators, environmental requirements and international obligations.
  - Reduce pressure on the Kwena Dam which can then be used to supply Mbombela.

  Water can be released from the Kwena Dam and abstracted downstream at Mbombela to augment the supply to Mbombela. Therefore no additional downstream infrastructure will be required for the proposed Mountain View Dam.

- **New Forest Dam on the Mutlumuvi River**

  The objectives of the proposed New Forest Dams are to:

  - Augment the supply to the Bushbuckridge Area.
  - Supply the Acornhoek/Thulamahashe users, which is currently supplied from the Inyaka Dam via the BBR Pipeline.
  - Supplement the runoff in Sand River at the confluence of the Mutlumuvi and Nwandlamuhari Rivers.

  The construction of a WTW at the New Forest Dam is proposed to supply the Acornhoek/Thulamahashe users. Currently these users are supplied with water from the Inyaka Dam (on the Sabie River) via the BBR Pipeline. It would not be practical for this transfer to continue whilst a second transfer moves water back from the Sand to the Sabie.

  The proposed infrastructure includes the following:

  - A WTW at the proposed New Forest Dam.
  - A Pump Station at the WTW to pump water to Acornhoek.
  - A Rising Main from the Pump Station to Acornhoek.
  - A Reservoir at Acornhoek.
  - A Gravity Main from the WTW to Thulamahashe.
  - A Reservoir at Thulamahashe.

- **Dingleydale Dam on the Nwandlamuhari River**

  The objectives of the proposed Dingleydale are similar to those of the proposed New Forest Dam.

  The construction of a WTW at the Dingleydale Dam is proposed to supply the Acornhoek/Thulamahashe users. Currently, these users are supplied with water from the Inyaka Dam (in the Sabie River) via the BBR Pipeline. It would not be practical for this transfer to continue whilst a second transfer moves water back from the Sand to the Sabie.

  The proposed infrastructure includes the following:

  - A WTW at the proposed Dingleydale Dam.
  - A Pump Station at the WTW to pump water to Acornhoek.
  - A Rising Main from the Pump Station to Acornhoek.
  - A Reservoir at Acornhoek.
  - A Gravity Main from the WTW to Thulamahashe.
  - A Reservoir at Thulamahashe.

- **Raising of Primkop Dam on the White River**

  There is a potentially catastrophic shortage of water resources in the City of Mbombela Area and the objective of raising the Primkop Dam is to alleviate the situation in the short term by increasing the yield of the White River and by implication also the Crocodile (East) River.

  The possibility of raising Primkop Dam appears to be the City of Mbombela's preferred option for short term relief to the system with a Terms of Reference for the Feasibility Study being released in late 2019. Results from the Feasibility Study should be incorporated into a future Strategy update.

Cost Estimates for Key Interventions (Dams)

A summary of the Total Estimated Capital Costs for the Proposed Dams (excluding Downstream Infrastructure) is given in **Table ii** (overleaf), at August 2020 rates, including Miscellaneous, Preliminary and General (P&G), Contingencies and Design fees, but excluding VAT.

Table ii: Total Estimated Capital Costs for the Proposed Dams (excluding Downstream Infrastructure)

Proposed Option	Total Estimated Capital Costs
Boschjeskop Dam	**R1,119,934,266**
Mountain View Dam	**R873,422,420**
Dingleydale Dam	**R1,331,310,032**
New Forest Dam	**R1,648,171,593**
Raising of Primkop Dam	**See Note 1 below**

(1) An investigation funded by the City of Mbombela (CoM) confirmed the technical feasibility to raise the Primkop Dam wall. A Terms of Reference for the Feasibility Study was issued in late 2019. This Study needs to be updated with the results of the Feasibility Study.

A summary of the Total Estimated Capital Costs for the Proposed Dams (including Downstream Infrastructure, which entails WTWs, Pump Stations, Rising and Gravity Mains, as well as Reservoirs) is given in **Table iii** below, at August 2020 rates, including Miscellaneous, Preliminary and General (P&G), Contingencies and Design fees, but excluding VAT.

Table iii: Total Estimated Capital Costs for the Proposed Dams (including Downstream Infrastructure)

Proposed Option	Total Estimated Capital Costs	Requirements of Downstream Infrastructure
Boschjeskop Dam	**R1,119,934,266**	None
Mountain View Dam	**R873,422,420**	None
Dingleydale Dam	**R3,048,203,173**	WTW, Pump Station, Rising and Gravity Mains and Reservoirs.
New Forest Dam	**R3,501,501,819**	WTW, Pump Station, Rising and Gravity Mains and Reservoirs.
Raising of Primkop Dam	**See Note 1 below**	None

(1) An investigation funded by the City of Mbombela (CoM) confirmed the technical feasibility to raise the Primkop Dam wall. A Terms of Reference for the Feasibility Study was issued in late 2019. This Study needs to be updated with the results of the Feasibility Study.

Yields

A Summary of the Historic Firm Yields for the Proposed Dam Options (sourced from the Water Resources Analysis Report No. P WMA 03/X22/00/6718/5) used in the Engineering Economic Analysis is given in **Table iv** below.

Table iv: Summary of Yields for the Proposed Dam Options

Dam Option	Historic Firm Yield (million m³/annum)
Boschejskop Dam	**31.2**
Mountain View Dam	**78.1**
Dingleydale Dam	**20.6**
New Forest Dam	**19.6**

Unit Reference Values

In the engineering economic analyses, the capital costs were spread out over various construction periods and operational and maintenance costs over a 45 year period (from completion of construction). All the costs were discounted to the base year which is 2020. Unit Reference Values (URVs) were determined for discount rates of 6%, 8% and 10% per annum, and for a 45 year period (from completion of construction). A Summary of the URVs for the Crocodile (East) River Catchment is given in **Table v** below. A Summary of the Unit Reference Values for the Sand River Catchment is given in **Table vi** (overleaf).

Table v: Summary of the Unit Reference Values for the Crocodile River (East) Catchment

Dam Option	Discount Rate	Total Discounted Costs	Total Discounted Yield (million m³)	URV (R/m³)
Boschjeskop Dam	6%	R839,757,728	320.71	2.62
Mountain View Dam	6%	R655,827,506	802.79	0.82
Boschjeskop Dam	8%	R753,788,822	220.43	3.42
Mountain View Dam	8%	R589,473,151	551.79	1.07
Boschjeskop Dam	10%	R679,751,438	157.91	4.31
Mountain View Dam	10%	R532,223,251	395.28	1.35

Table vi: Summary of the Unit Reference Values for the Sand River Catchment

Dam Option	Discount Rate	Total Discounted Costs	Total Discounted Yield (million m³)	URV (R/m³)
Dingleydale Dam(1)	6%	R998,070,958	211.75	4.71
New Forest Dam(1)	6%	R1,235,618,583	201.47	6.13
Dingleydale Dam(2)	6%	R2,427,614,407	211.75	11.47
New Forest Dam(2)	6%	R2,768,874,924	201.47	13.74
Dingleydale Dam(1)	8%	R895,948,917	145.54	6.16
New Forest Dam(1)	8%	R1,109,127,109	138.48	8.01
Dingleydale Dam(2)	8%	R2,135,112,112	145.54	14.67
New Forest Dam(2)	8%	R2,439,298,361	138.48	17.62
Dingleydale Dam(1)	10%	R807,986,394	104.26	7.75
New Forest Dam(1)	10%	R1,000,184,557	99.20	10.08
Dingleydale Dam(2)	10%	R1,896,427,156	104.26	18,19
New Forest Dam(2)	10%	R2,169,142,033	99.20	21.87

(1) Excluding Downstream Infrastructure Costs.

(2) Including Downstream Infrastructure Costs.

Conclusions and Recommendations

- **Baseline Interventions**

A Summary of the URVs for the baseline interventions is given in **Table vii** below.

Table vii: Summary of the Unit Reference Values for the Baseline Intervention Options

Intervention Option	Discount Rate	URV (R/m³)	Analyses Period
Water Conservation and Water Demand Management: City of Mbombela LM	6%	9.68	45 Years
Water Conservation and Water Demand Management: Bushbuckridge LM	6%	5.81	45 Years
Groundwater Development	6%	7.10	30 Years
Removal of Invasive Alien Plants	6%	1.27	30 Years

The URVs in **Table vii** above for the three (3) baseline interventions are relatively low, with the exception of the URV for WC/WDM for the City of Mbombela, and confirms the execution thereof regardless of the implementation of any 'major' interventions. The implementation of the baseline interventions is considered **essential** and **not optional**.

Results from the IUCMA's detailed groundwater assessment should be incorporated into a future Strategy update.

- **Key Interventions (Dams)**

A Summary of the URVs for the key interventions is given in **Table viii** below.

Table viii: Summary of the Unit Reference Values for the Selected Key Intervention Options

Dam Option	Discount Rate	Total Discounted Costs [(1)]	Total Discounted Yield (million m³)	URV (R/m³)
Crocodile River (East Catchment)				
Boschjeskop Dam	8%	R753,788,822	220.43	3.42
Mountain View Dam	8%	R589,473,151	551.79	1.07
Sand River Catchment				
Dingleydale Dam[(2)]	8%	R2,135,112,112	145.54	14.67
New Forest Dam[(2)]	8%	R2,439,298,361	138.48	17.62

(1) Including Capital Costs, Operations and Maintenance Costs, as well as Energy Costs.

(2) Including Downstream Infrastructure Costs.

- **Crocodile River (East) Catchment**

From **Table viii** above it is evident that the Mountain View Dam offers significantly lower URVs than Boschjeskop Dam. In addition the yield of Mountain View Dam (78.1 million m³/a) is more than double that of the Boschjeskop Dam (31.2 million m³/a).

From an engineering economic point of view the proposed Mountain View Dam is the preferred option.

It is recommended that the proposed Mountain View Dam be considered for higher levels of investigation (feasibility).

Social and environmental impacts have not been addressed as part of this Study and may have an impact on the selection of the most feasible option.

- **Sand River Catchment**

From **Table viii** above it is evident that the Dingleydale Dam has the lowest URVs for the Sand River Catchment. The yields of both dams are relatively low (Dingleydale Dam 20.6 million m^3/a and New Forest Dam 19.6 million m^3/a). Furthermore, the URVs for both the Dingleydale and New Forest Dams are high.

Although from an engineering economic point of view the proposed Dingleydale Dam is the preferred option, it is, however, recommended that both the Dingleydale and New Forest Dams be considered for higher levels of investigation (feasibility). Social and environmental impacts have not been addressed as part of this Study and may have an impact on the selection of the most feasible option.

1 INTRODUCTION

1.1 Background to this Study

The Department of Water and Sanitation (DWS) commissioned a study on the development of a Water Reconciliation Strategy for the Mbombela Municipal Area (2013-2015), to inform the planning and implementation of water resource management interventions necessary to reconcile future water requirements and water use patterns for a period of up to thirty (30) years.

For the Reconciliation Strategy for the Mbombela Municipal Area, referred to as the Strategy hereafter, to be implemented, and for the Strategy to remain relevant to properly fulfil its purpose into the future, it has to be dynamic. Hence, the water balance has to be continuously monitored and the developed Strategy has to be regularly updated and maintained. This would ensure that the identified planned intervention options for implementation will also be revised where necessary to consider any changes that may have potential impacts on the projected water balance.

The DWS commissioned the Implementation and Continuation of the Water Reconciliation Strategy for the Mbombela Municipal Area, referred to as this Study hereafter, to facilitate a process to maintain the relevance of the Strategy.

1.2 Objectives of this Study

The overall objective of this Study was to systematically update, improve and extend the Strategy in order for the Strategy to remain technically sound, economically feasible, as well as socially and environmentally acceptable and sustainable. In addition to the Mbombela Municipal Area, smaller towns in the neighbouring catchments were also considered at a desktop level of detail, namely Machadodorp, Waterval Boven, Dullstroom, Sabie, Graskop, Malelane, Hectorspruit and Komatipoort, which is an extension of the footprint of the 2015 Strategy.

This Report provides an overview and summary of the potential interventions (long list from previous studies and new options) to augment the water supply of the Study Area, the selection of potential interventions (short list) for further evaluation, costing of the selected intervention options, as well as an engineering economic analyses (expressed as Unit Reference Values) taking cognizance of the results of the water resources analyses task.

The results of this infrastructure and cost assessment were used as inputs in the formulation of the Final Strategy prepared for the Study Area.

1.3 Study Area

The Study Area included both the Crocodile (East) and the Sabie Sub-Catchments, which form part of the Ehlanzeni District Municipality (DM) as illustrated in the Study Area Map in **Figure 1.1** (overleaf). The focus of this Study was on the City of Mbombela (CoM) Local Municipality (LM) (centre of the Study Area), the former Umjindi LM (South), which was recently amalgamated with the CoM LM, and Bushbuckridge (BBR) LM (North). The remainder of the Study Area incorporated parts of the Emakhazeni LM (West), Thaba Chweu LM (North-West) and Nkomazi LM (South-East), which are situated and form part of the Crocodile (East) and Sabie Sub- Catchments.

The two (2) major water courses that traverse the two Sub-Catchments in the Study Area, are the Crocodile (East) River and the Sabie River. The Crocodile (East) River, originates at Dullstroom and joins the Lunsklip River before entering the Kwena Dam from which it flows through the Schoemanskloof Mountains. The Crocodile (East) River joins with a major tributary, the Elands River, which originates at Machadodorp and flows through Waterval Boven before its confluence with Ngodwana River. The confluence of the Crocodile (East) and Elands Rivers is at Montrose. The river meanders through the catchment from West to East, where it joins with smaller tributaries such as the Nels River, Wit River, Kaap River and Nsikazi River. The Crocodile (East) River finally merges with the Komati River close to Komatipoort, where it becomes the Inkomati River. A major tributary of the Sabie River is the Sand River, which has its origin on the border of Thaba Chweu LM and BBR LM and the Marite River, which is regulated by releases from the Inyaka Dam. The Corumana Dam in Mozambique impounds the Sabie River, which is upstream of the confluence with the Sabie and the Inkomati Rivers within Mozambique, where it discharges into the Indian Ocean as the Inkomati River to the north of the City of Maputo, Mozambique.

There are two major dams in the Study Area, namely the Inyaka Dam in BBR LM and the Kwena Dam in the Thaba Chweu LM, as well as smaller dams in the CoM LM such as Witklip Dam, Longmere Dam, Klipkopje Dam, Primkop Dam and Da Gama Dam.

Water transfers from the neighbouring Lomati Catchment support the towns of Barberton and Shiyalongubo. There is also a transfer from the Sabie Sub-Catchment to the Crocodile (East) Sub-Catchment to support the Nsikazi North demand centre.

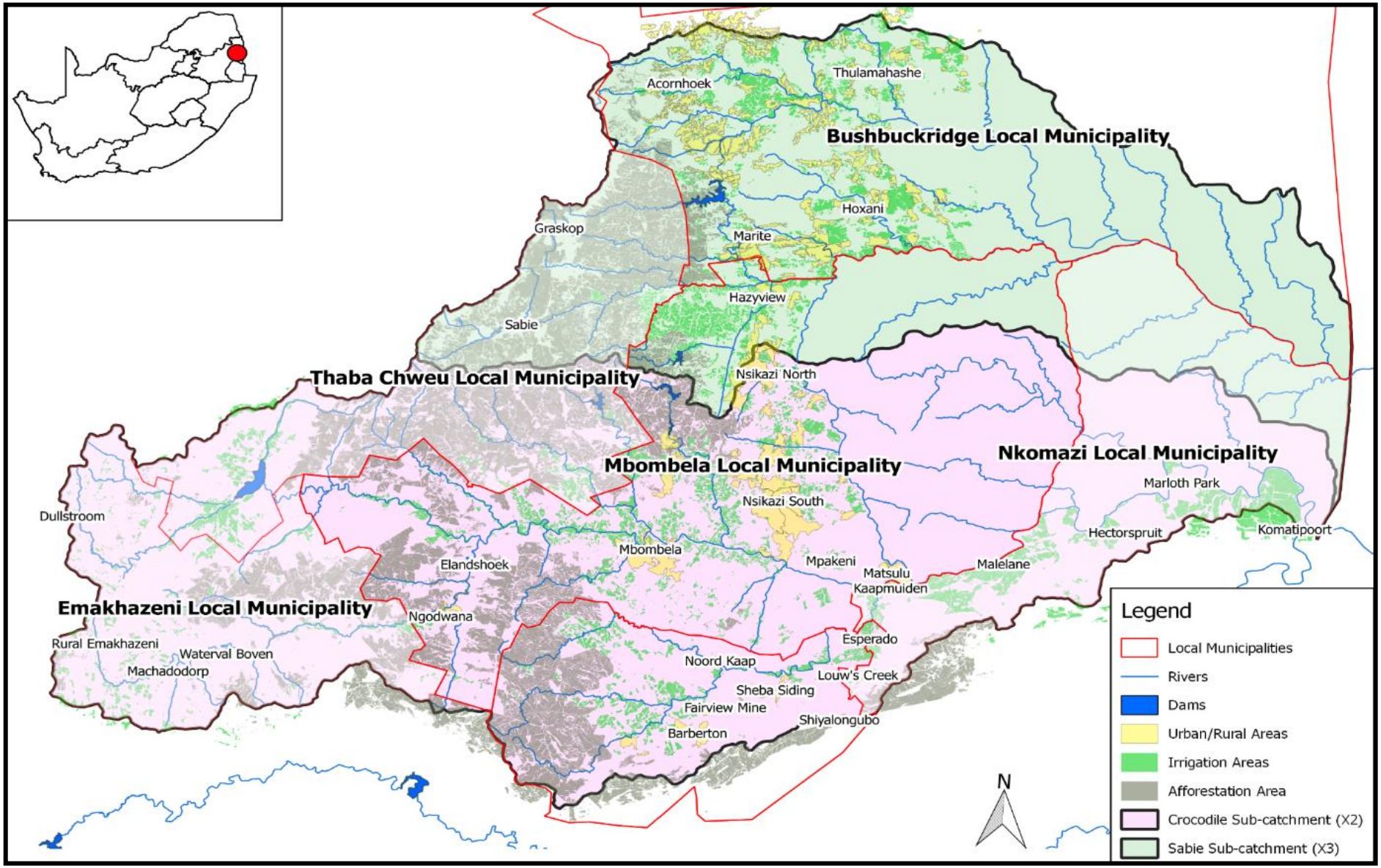

Figure 1-1 Study Area Map

1.4 Purpose of this Report

A significant number of potential interventions, which could contribute to meeting the future water requirements of the Study Area, were identified from previous and on-going studies, liaison with officials and stakeholders, as well as from formulating some new potential interventions.

The purpose of this Report is to:

- Identify potential interventions (long list from previous studies and new options) to augment the water supply.
- Screen the list of interventions.
- Select potential interventions (short list) for further evaluation.
- Evaluate the short-listed interventions.
- Describe the features of the selected potential interventions.
- Review previous designs/concepts of the selected potential interventions.
- Review and update cost estimates of the selected potential interventions.
- Engineering economic analyses of the selected potential interventions and assessing life cycle costs (expressed as Unit Reference Values).

1.5 Structure of this Report

The Report is structured as follows:

- **Section 1** provides a formal overview of the Study Area, the Strategy, Purpose and Structure of this Report.
- **Section 2** presents an overview of potential interventions (long list from previous studies and new options) to augment the water supply of the Study Area and the selection of potential interventions (short list) for further evaluation.
- **Section 3** provides information on the baseline intervention options, including unit reference values.
- **Section 4** provides information on the key intervention options (dams), objectives of the schemes and details of the proposed infrastructure.
- **Section 5** covers the financial implications (capital, including operation and maintenance costs, etc.) of the key intervention options (dams), as well as an engineering economic analysis (present values, including unit reference values, etc.).

- **Section 6** provides information on the upgrading of selected existing infrastructure.
- **Section 7** contains the Conclusions and Recommendations of this Report.
- **Section 8** indicates the Study References.

2 INTERVENTION OPTIONS

2.1 Identified Interventions

A significant number of potential interventions, which could contribute to meeting the future water requirements of the Study Area, were identified from previous and on-going studies, liaison with officials and stakeholders, as well as formulating some new potential interventions.

An intervention can be any measure that could potentially make additional water available i.e. that improves the water balance of the Study Area. It can therefore be demand-side (lowering water requirements) or supply side (increasing the water supply) focussed.

Several options for reconciling increasing water demands with the current supply were considered in previous studies. These options can be broadly categorized into options which:

(i) Reduce the water demand, such as Water Conservation and Water Demand Management (WC/WDM);

(ii) Groundwater Development;

(iii) Removal of Invasive Alien Plants (IAPs);

(iv) Augment the water resource, such as water transfers and the construction of dams, as well as

(v) Upgrading of existing infrastructure.

A Summary of the Identified Intervention Options for the Study Area is given in **Table 2.1** below:

Table 2.1: Summary of the Identified Intervention Options for the Study Area

Description	Reference
Crocodile (East) River Catchment	
Nelspruit WDC	Water Requirements and Availability Reconciliation Strategy for the Mbombela Municipal Area Report No. PWMA 05/X22/00/2012/6 **February 2014**
WC/WDM	
Removal of IAPs	
Confirming DWS's approval of conversion of irrigation entitlements into licences for domestic water use	
Groundwater development	
Construction of a new dam	

Description	Reference
Crocodile (East) River Catchment	
White River / Rockey Drift WDC	Water Requirements and Availability Reconciliation Strategy for the Mbombela Municipal Area Report No. PWMA 05/X22/00/2012/6 **February 2014**
WC/WDM	
Karion / Plaston Corridor WDC	
WC/WDM	
Groundwater development	
Confirming DWS's approval for conversion of irrigation entitlements into licences for domestic water use	
System operating rules for Primkop Dam and other upstream dams	
Reallocation of water	
Nsikazi South WDC	
WC/WDM	
Groundwater development	
Matsulu WDC	
WC/WDM	
Removal of IAPs in the Primkop Dam Catchment Area	
Groundwater development	
Water reallocation	
Confirming DWS's approval for conversion of irrigation entitlements into licences for domestic water use	
System operating rules for Primkop Dam and other upstream dams	
Crocodile River Catchment (and Lomati River): Barberton WDC	Development of Water Reconciliation Strategy for All Towns in the Eastern Region, First Order Reconciliation Strategy for Barberton, Verulam and Emjindini **June 2011**
WC/WDM	
Develop additional water resources	
Elandshoek / Kaapsehoop / Ngodwana WDC	Water Requirements and Availability Reconciliation Strategy for the Mbombela Municipal Area Report No. PWMA 05/X22/00/2012/6 **February 2014**
Groundwater development	
Rain and fog harvesting	
Regional schemes	
Montrose Dam	
Boschjeskop Dam	
Mountain View Dam	
Strathmore Off-Channel Storage Dam	

Description	Reference
Crocodile (East) River Catchment	
Hazyview WDC	Water Requirements and Availability Reconciliation Strategy for the Mbombela Municipal Area Report No. PWMA 05/X22/00/2012/6 **February 2014**
WC/WDM	
Water demand reduction measures in the irrigation sector	
Groundwater development	
Nsikazi North WDC	
Groundwater development	
Reallocate unused irrigation water entitlements to allocations for domestic use	
Sabie and Sand River Catchments	
WC/WDM	Water Reconciliation Strategy Update for the Schemes in the Sabie and Sand River System for 2015 to 2045 Bushbuckridge LM **August 2016**
Groundwater development	
Augmentation of bulk water infrastructure	
Develop additional storage in the Sabie and Sand River System	Crocodile East River Development: Reconnaissance Study Report No. PWMA 05/X22/00/0608 **September 2008** Feasibility Study for the First Phase Development of the Water Resources of the Sabie River Catchment Report No. P.X 300/00/0194 **March 1991**
White River Catchment	
Raising of Primkop Dam	Reconnaissance Study into Increased Storage on the White and Ngonini Rivers, Mpumalanga Report No. P0102/02 **January 2016**

2.2 Baseline Interventions

The following identified options are considered to be attractive '**baseline**' interventions that can provide smaller yields to increase the water availability of the region:

- Water Conservation and Water Demand Management (WC/WDM);
- Groundwater Development, and
- Removal of Invasive Alien Plants (IAPs).

The above-mentioned baseline interventions should be executed regardless of the implementation of any other key interventions.

2.3 Key Interventions

Due to the severity of the deficits in the Study Area, new dams will be required in order to provide the existing users with a more reliable assurance of supply as well as to augment future growth in water requirements. In addition to the new dams, upgrading of existing infrastructure will also be required. A Summary of the Selected Key Intervention Options adopted for further assessment are given in **Table 2.2** below.

Table 2.2: Summary of Selected Key Interventions

Description	Reference
Crocodile River Catchment	
	Water Requirements and Availability Reconciliation Strategy for the Mbombela Municipal Area Report No. PWMA 05/X22/00/2012/6 **February 2014**
Boschjeskop Dam on the Nels River Mountain View Dam on the Kaap River	Crocodile East River Development: Reconnaissance Study Report No. PWMA 05/X22/00/0608 **September 2008** Crocodile East Reconciliation – Dam Costing **June 2013**

Description	Reference
Sand River Catchment	
Dingleydale Dam on the Nwandlamuhari River New Forest Dam on the Mutlumuvi River	Feasibility Study for the First Phase Development of the Water Resources of the Sabie River Catchment Report No. P.X 300/00/0194 **March 1991**
White River Catchment	
Raising of Primkop Dam on the White River	Reconnaissance Study into Increased Storage on the White and Ngonini Rivers, Mpumalanga Report No. P0102/02 **January 2016**
Upgrading of Existing Infrastructure	
Upgrade the Acornhoek WTW, Inyaka WTW, Hoxane WTW. Upgrade Bulk Water Supply Infrastructure (bulk pipelines, service reservoirs).	Water Reconciliation Strategy Update for the Schemes in the Sabie and Sand River System for 2015 to 2045 Bushbuckridge LM **August 2016**

3 BASELINE INTERVENTIONS

3.1 Introduction

The following baseline intervention options were identified that can provide smaller yields to increase the water availability of the region:

- Water Conservation and Water Demand Management (WC/WDM);
- Groundwater Development, and
- Removal of Invasive Alien Plants (IAPs).

The two (2) reports that address WC/WDM and Groundwater Development as part of this Study are the following:

- Water Conservation and Water Demand Management, DWS Report Number P WMA 03/X22/00/6718/4, and
- Water Resources Analysis, DWS Report Number P WMA 03/X22/00/6718/5.

The implementation of the baseline options is considered **essential** and **not optional**.

3.2 Water Conservation and Water Demand Management (WC/WDM)

Reducing water demand by introducing WC/WDM measures is a necessary intervention for all Reconciliation Strategies. A detailed WC/WDM assessment (DWS Report Number P WMA 03/X22/00/6718/4) was undertaken for the Study Area resulting in realistic and optimistic targets for reducing water wastage. The outcome of the assessment is that the City of Mbombela could potentially save 10% (6.1 million m^3) of its water requirements by implementing WC/WDM and the Bushbuckridge Local Municipality could save 15% (7 million m^3).

3.2.1 Water Conservation and Water Demand Management Intervention Options

There is significant scope for WC/WDM in the Study Area. WC/WDM will result in both a reduction of Non-Revenue Water and the total system input volume. A serious concern however, is the pervasive limitation in institutional capacity and technical skills to embark on WC/WDM programmes in the municipalities.

WC/WDM interventions should focus on the following interventions:

- Reduce the high water losses and inefficiencies with set targets and timelines;

- Municipalities should improve service delivery, as this will minimize informal and unauthorized connections in some areas;
- Develop and implement an operation and maintenance plan, if an existing plan is not in place;
- Install bulk meters to measure supply from the zones and districts;
- Maintain satisfactory operating pressures and install control valves in areas experiencing high pressures to ensure that operating pressures do not exceed the DWS regulation of 9 bar;
- Properly investigate the status of the service level for drinking water and sanitation in order to assess the situation and formulate recommendations for future improvements of servicing the entire area;
- Investigate the situation of water supply infrastructure on the base of new data in order to assess properly which investments in the refurbishment of the system are required;
- Provide training for technical staff and for meter readers and perform monthly audits to eliminate estimates and other inaccuracies; and
- Embark on community awareness programmes that promote the value of water wise gardening.

3.2.2 Cost Estimates

A summary of the budget requirements for the proposed WC/WDM Intervention Options for a five year period for the City of Mbombela and the Bushbuckridge Local Municipality are respectively summarized in **Tables 3.1 and 3.2** below.

Table 3.1: Summary of WC/WDM Budget Requirements for the City of Mbombela

Interventions	Type	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Institutional	Capex	100 000	300 000	0	0	0	400 000
	Opex	150 000	150 000	150 000	150 000	150 000	750 000
	Sub Total	**250 000**	**450 000**	**150 000**	**150 000**	**150 000**	**1 150 000**
Financial	Capex	200 000	200 000	0	0	0	400 000
	Opex	45 590 380	45 590 380	45 590 380	45 590 380	45 590 380	227 951 900
	Sub Total	**45 790 380**	**45 790 380**	**45 590 380**	**45 590 380**	**45 590 380**	**228 351 900**
Social	Capex	6 453 496	6 453 496	4 973 496	4 973 496	4 973 496	27 827 480
	Opex	12 809 740	12 809 740	12 809 740	12 809 740	12 809 740	64 048 700
	Sub Total	**19 263 236**	**19 263 236**	**17 783 236**	**17 783 236**	**17 783 236**	**91 876 180**

Interventions	Type	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Technical	Capex	35 760 810	43 225 150	33 375 150	32 937 650	32 937 650	178 236 410
	Opex	21 534 430	21 534 430	21 534 430	21 534 430	21 534 430	107 672 150
	Sub Total	**57 295 240**	**64 759 580**	**54 909 580**	**54 472 080**	**54 472 080**	**285 908 560**
Total		**122 598 856**	**130 263 196**	**118 433 196**	**117 995 696**	**117 995 696**	**607 286 640**

The above budget shows that approximately R 120 million per annum is required over the next five years to address WC/WDM.

Table 3.2: Summary of WC/WDM Budget Requirements for the Bushbuckridge Local Municipality

Interventions	Type	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Institutional	Capex	100 000	300 000	0	0	0	400 000
	Opex	375 000	375 000	375 000	375 000	375 000	1 875 000
	Sub Total	**475 000**	**675 000**	**375 000**	**375 000**	**375 000**	**2 275 000**
Financial	Capex	200 000	200 000	0	0	0	400 000
	Opex	22 605 660	22 605 660	22 605 660	22 605 660	22 605 660	113 028 300
	Sub Total	**22 805 660**	**22 805 660**	**22 605 660**	**22 605 660**	**22 605 660**	**113 428 300**
Social	Capex	3 334 088	3 334 088	2 534 088	2 534 088	2 534 088	14 270 440
	Opex	6 575 220	6 575 220	6 575 220	6 575 220	6 575 220	32 876 100
	Sub Total	**9 909 308**	**9 909 308**	**9 109 308**	**9 909 308**	**9 909 308**	**47 146 540**
Technical	Capex	18 800 440	23 355 530	17735 530	17 073 030	17 073 030	94 037 560
	Opex	11 876 205	11 876 205	11 876 205	11 876 205	11 876 205	59 381 025
	Sub Total	**30 676 645**	**35 231 735**	**29 611 735**	**28 949 235**	**28 949 235**	**153 418 585**
Total		**63 866 613**	**68 621 703**	**61 701 703**	**61 039 203**	**61 039 203**	**316 268 425**

The results above indicate that approximately R 60 million per annum is required for the next 5 years to address WC/WDM.

3.2.3 Unit Reference Values

In the engineering economic analyses the Unit Reference Values (URVs) were determined for discount rates of 6%, 8% and 10% over a 45 year period. The costs included capital and operational expenses, and savings due to reduced production costs and increased revenue water. Unit reference values for the City of Mbombela and the Bushbuckridge Local Municipality are respectively summarized in **Tables 3.3** and **3.4** (overleaf).

Table 3.3: Summary of Unit Reference Values: City of Mbombela

Discount rate	Total Discounted Cost	Total Realistic Discounted Saving (m^3)	URV (R/m^3)	Total Optimistic Discounted Saving (m^3)	URV (R/m^3)
6%	R1,333,761,763	137 776 487	9.68	230 514 555	5.79
8%	R1,044,889,603	103 646 313	10.08	173 411 184	6.03
10%	R851,094,264	81 180 876	10.48	135 824 144	6.27

Table 3.4: Summary of Unit Reference Values: Bushbuckridge Local Municipality

Discount rate	Total Discounted Cost	Total Realistic Discounted Saving (m^3)	URV (R/m^3)	Total Optimistic Discounted Saving (m^3)	URV (R/m^3)
6%	R980,000,576	168 612 040	5.81	214 677 346	4.56
8%	R768,335,830	126 843 241	6.06	161 497 189	4.76
10%	R626,304,668	99 349 848	6.30	126 492 520	4.95

3.3 Groundwater Development

The Mbombela Reconciliation Strategy (DWA, 2014) stated that there is only limited scope for groundwater development for primary water supply. The main reason for this is the potential reduction in surface water baseflows in the Mbombela area, should the groundwater be abstracted. The localized areas for which it was mentioned that further groundwater could potentially be used are as follows:

- Karino, Nsikazi South: 200 000 m³/annum.
- Matsulu: 100 000 m³/annum.
- Elandshoek: can consider as an option however mentioned that there is a low successful borehole drilling rate.
- Hazyview, Nsikazi north: 200 000 m³/annum.

The availability of groundwater in the Sabie River catchment provides for the potential conjunctive use of groundwater and surface water resources in the future as the water requirements increase. Groundwater is currently not being used conjunctively with the surface water supplies in the municipality and the boreholes that were drilled before the construction of Inyaka Dam have been decommissioned. An assessment of the groundwater

potential in Bushbuckridge Municipality indicated that there is approximately 10.5 million m³/annum of exploitable groundwater in the area (DWS, 2016).

The further development of groundwater resources will depend on the outcome of a detailed groundwater assessment study currently being conducted by the Inkomati Usuthu Catchment Management Agency (IUCMA).

3.3.1 Cost Estimates and Unit Reference Values

Costs for implementing groundwater development in the Study Area were not readily available and information was obtained from a study (GCTWFSC 2019), commissioned by the Greater Cape Town Water Fund Steering Committee.

The Average Unit Reference Value in this study for the development of groundwater was R7.10/m³.

3.4 Removal of Invasive Alien Plants (IAPs)

As with WCWDM, removing alien vegetation is a standard intervention measure for saving water in all Reconciliation Strategies, and is very important in severely water stressed catchments.

The Mbombela Reconciliation Strategy (DWA, 2014) assumed that removal of invasive alien pants (IAPs) upstream of the Nelspruit diversion works on the Crocodile River would make water available that could be allocated to the City of Mbombela. It was estimated that up to 8 million m³/annum could be made available if the IAPs upstream of Kwena Dam in the Crocodile Catchment, were removed. However, the strategy further stated that, since it is not realistic or cost effective to remove all IAPs, it is suggested that a more realistic estimate of increased yield would be half this amount, and was estimated as 4 million m³/annum. The Sabie River Reconciliation Strategy (DWS, 2016) did not consider this intervention option.

This intervention implementation appears to have been slow over the years. However, the World Wildlife Fund – South Africa, through the co-ordination of SANParks and the Kruger2Canyons Biosphere (DWS, 2020b), have now started with initiatives to undertake IAP removal in the Sabie Catchment. In water stressed catchments such as the Crocodile and the Sabie this intervention is necessary. It is an intervention that requires continuous attention.

This intervention would be beneficial in the Sabie Catchment due to the locations of IAPs upstream of Inyaka dam, and it estimated that approximately 3 million m³/annum could be added to the yield of the dam by removing IAPs. The denser distribution of IAPs in the Crocodile Catchment are located around tributary and run of river resources.

3.4.1 Cost Estimates

Costs for implementing the intervention option of alien invasive plant removal in the Study Area were not readily available and information was obtained from a study commissioned by the Greater Cape Town Water Fund Steering Committee to evaluate the impact of nature-based solutions on water supply, beginning with targeted removals of alien plant invasions, and determining whether investing at scale in catchment restoration is cost competitive with other supply-side solutions.

In April 2019 the Greater Cape Town Water Fund Steering Committee issued a report (GCTWFSC 2019), which addressed the return on investment for ecological infrastructure restoration. This report focused on invasive plant removal to restore seven priority sub-catchments supplying the Western Cape Water Supply System.

The results of this report (GCTWFSC 2019) indicated that an investment of R394 million (present value 2020) will generate expected annual water gains of 100 billion liters (100 Mm^3) over thirty years and an additional 55 billion liters (55 Mm^3) within the first six years.

The cost of initial clearing was estimated at R239 million (present value 2020) and a further R156 million (Present Value 2020) will be required over the remaining period to ensure lands are kept free of new invasions.

3.4.2 Unit Reference Values

Unit Reference Values (GCTWFSC 2019) were determined for a discount rate of 6% over a 30 year period for the seven sub-catchments. The costs included capital and operational expenses, and savings due to reduced production costs and increased revenue water. Allowance was also made for long-term maintenance and management costs to ensure areas or catchments are kept free of invasions and water gains are maintained in perpetuity.

The Average Unit Reference Value for the removal of invasive alien plants amounts to R1.20/m^3 (including water treatment costs of R0.80/m^3).

4 SELECTED KEY INTERVENTIONS (DAMS)

4.1 Locality of the Schemes

The locations of Potential Dams sites are indicated in **Figure 4-1**. The proposed dam sites that were identified for further investigation are the following:

- Boschjeskop Dam on the Nels River;
- Mountain View Dam on the Kaap River;
- New Forest Dam on the Mutlumuvi River;
- Dingleydale Dam on the Nwandlamuhari River, and
- Raising of Primkop Dam on the White River

4.2 Objectives of the Schemes

Due to the severity of the deficits in the Study Area, new dams will be required in order to provide the existing users with a more reliable assurance of supply as well as to augment future growth in water requirements.

4.2.1 Crocodile Catchment: Boschjeskop and Mountain View Dams

The objectives of the proposed Boschjeskop Dam are to:

- Augment the water supply to Mbombela, and
- Increase the yield of the Crocodile (East) System.

The objectives of the proposed Mountain View Dam are to:

- Act in combination with the existing Kwena Dam and provide releases downstream for irrigators, environmental requirements and international obligations, as well as
- Reduce pressure on the Kwena Dam which can then be used to supply Mbombela.

4.2.2 Sabie/Sand River Catchments: Dingleydale and New Forest Dams

The objectives of the proposed Dingleydale and New Forest Dams are to:

- Augment the supply to the Bushbuckridge Area;
- Supply the Acornhoek/Thulamahashe users, which is currently supplied from the Inyaka Dam via the BBR Pipeline, and
- Supplement the runoff in Sand River at the confluence of the Mutlumuvi and Nwandlamuhari Rivers.

4.2.3 Raising of Primkop Dam

There is a potentially catastrophic shortage of water resources in the City of Mbombela Area and currently the construction of a regional dam to address this seems in the distant future.

To alleviate the situation in the short term the raising of the Primkop Dam Wall is an option to consider to increase the yield of the White River and by implication also the Crocodile (East) River.

In December 2019 the City of Mbombela issued a Terms of Reference for the Appointment of Consultant for a Feasibility Study on the Raising of the Primkop Dam Wall.

The scope of work envisaged for the Feasibility Study can briefly be described as follows:

- Conduct review of hydrological studies to confirm magnitude of run-off in the White River System;
- Determine the optimum raising of the Primkop Dam Wall with its concomitant increased volume and assured yield;
- Recommend optimal utiliaation/allocation of yield and increased yield, with cognisance of all municipal demands (residential, business/commercial, industrial, other), irrigation demands, mining demands and environmental demands;
- Propose integration of additional municipal allocation into the Water Distribution System in accordance with the Water Master Plan;
- Obtain principle approval and co-operation from all stakeholders, current dam owners and land owners in the increased impoundment area;
- Prepare basic operating rules for dam owners in the White River System;
- Propose typical legal agreements between dam owners, municipality and potential funders;
- List critical achievements and possible fatal flaw processes that should be addressed with further detailed planning with cost estimates e.g. environmental assessments and approvals;
- Undertake basic structural assessment of the existing dam;
- Undertake dam site and impoundment area surveys (Lidar);
- Undertake geotechnical studies to underpin design of raised dam wall;
- Prepare conceptual designs of the dam wall raising sufficient for cost estimates;

- Suggest proposals for funding options e.g. Development Bank of Southern Africa (DBSA), grants, as well as
- Prepare a Business Plan to present to potential funders e.g. DBSA, DWS and CoGTA.

Recently the CoM requested extension of time for the validity of tenders submitted by Consultants.

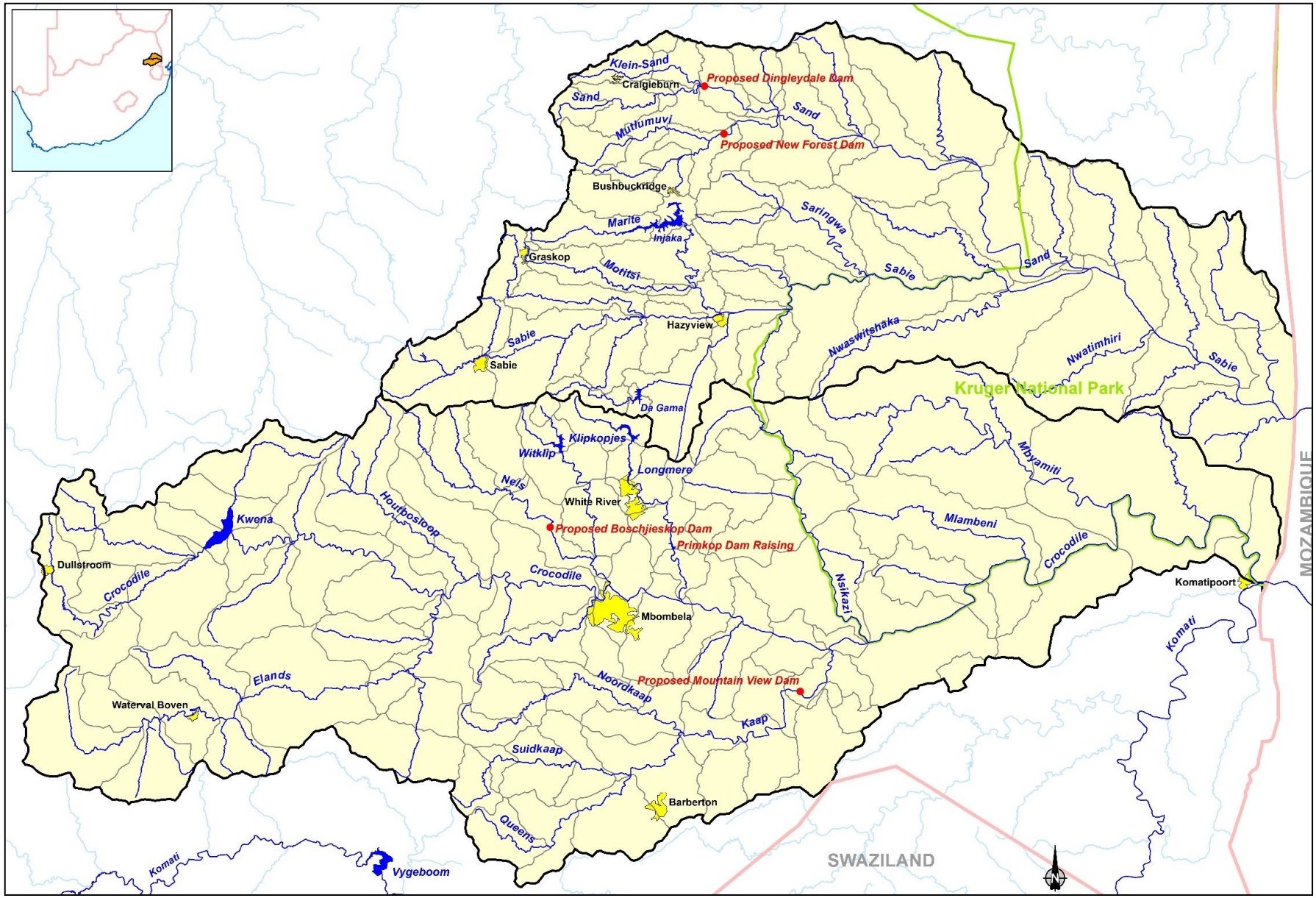

Figure 4-1 Locations of Potential Dams

4.3 Details of Existing and Proposed Schemes

Details about design capacities and component sizes of bulk water resources infrastructure, bulk water services, and irrigation were obtained from existing reports. Limited, or no, information was available from previous studies regarding the transfer infrastructure (pump stations, pipelines, etc.) to transfer water from the proposed dam sites (refer **Sub-section 4.2** above) to the demand centres.

4.4 Proposed Boschjeskop Dam

4.4.1 Location and Site Description

The proposed Boschjeskop Dam site is located about 16 km to the north west of Mbombela, and a small weir has been constructed at the proposed site. Access to the proposed dam site is from the surfaced road between Rosehaugh and White River, from which a farm road branches to the south to provide access to the left flank of the proposed dam site. A Locality Map of the Proposed Boschjeskop Dam Site is presented in **Figure 4-2** below.

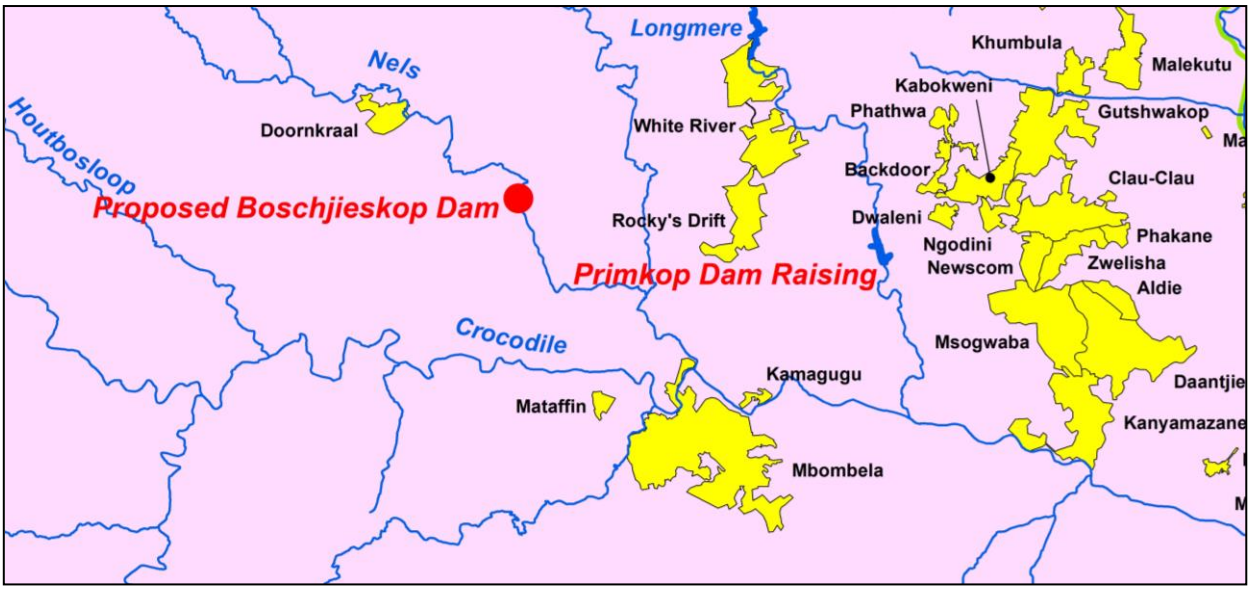

Figure 4-2 Locality Map of the Proposed Boschjeskop Dam Site

4.4.2 General Dam Information

- Catchment: Crocodile River
- River: Nels River
- Proposed Dam:

The proposed Dam Layout and Details are included in **Appendix A1**.

Spillway:	Un-controlled concrete spillway section in the river section (right flank) with Robert's Splitters	
	Spillway length – 75 m	
Dam Wall:	Composite dam with an earthfill embankment on the left flank	
	Maximum Dam Height:	50 m
	Full Supply Capacity:	130.5 million m^3
	Historic Firm Yield:	31.2 million m^3/a

- Foundation Description:

  In terms of likely founding considerations, good founding conditions prevail within the river section and a concrete structure incorporating a spillway might be considered. The deep weathering of the flanks suggests that embankments are likely best suited.

- Transfer Infrastructure required downstream from the proposed Boschjeskop Dam:

  No infrastructure will be required to convey water from the Boschjeskop Dam to Mbombela. Water can be released from the Boschjeskop Dam and abstracted downstream at the Mbombela Water Treatment Works (WTW).

4.5 Proposed Mountain View Dam

4.5.1 Location and Site Description

The proposed Mountain View Dam site is located near the end of a steeply sided valley on the Kaap River, about 10 km upstream of the confluence with the Crocodile (East) River. Site access is via farm tracks at a high elevation on the steep left flank. A Locality Map of the Proposed Mountain View Dam Site is presented in **Figure 4-3** (overleaf).

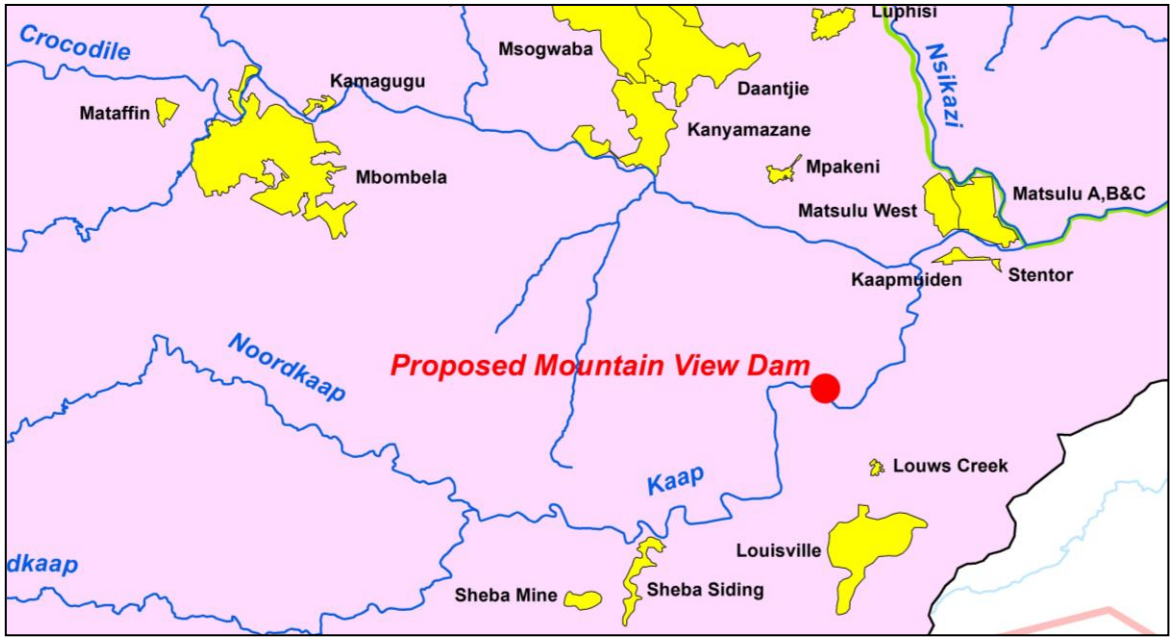

Figure 4-3 Locality Map of the Proposed Mountain View Dam Site

4.5.2 General Dam Information

- Catchment: Crocodile River
- River: Kaap River
- Proposed Dam:

  The proposed Dam Layout and Details are included in **Appendix A2**.

  Spillway: Central un-controlled concrete spillway with Robert's Splitters

  Spillway length – 120m

  Dam Wall: A relatively thick RCC arch

  Maximum Dam Height: 74 m

  Full Supply Capacity: 184.8 million m^3

  Historic Firm Yield: 78.1 million m^3/a

- Foundation Description:

  Geologically, the site is underlain by gneiss of the Stentor Pluton. Diabase dykes are recognized in the vicinity of the center-line. The site is suitable for the construction of a mass concrete gravity structure. The massive granite gneiss bedrock within the river section would further be resistant to scour and a concrete apron is likely unnecessary.

- Transfer Infrastructure required downstream from the proposed Mountain View Dam:

  The proposed Mountain View Dam will act in combination with the existing Kwena Dam and provide releases downstream for irrigators, environmental requirements and international obligations, which will reduce pressure on the Kwena Dam. Water can be released from the Kwena Dam and abstracted downstream at Mbombela to augment the supply to Mbombela. Therefore no additional infrastructure with be required for the proposed Mountain View Dam.

4.6 Proposed Dingleydale Dam

4.6.1 Location and Site Description

The proposed Dingleydale Dam site is within the Sand River Catchment, and is located on the Nwandlamuhari River approximately 11 km downstream of the Hazyview/Hoedspruit (R40) Road Crossing of the Mutlumuvi River, which is in the vicinity of the Klein Sand River and Sand River confluence. A Locality Map of the Proposed Dingleydale Dam Site is presented in **Figure 4-4** below.

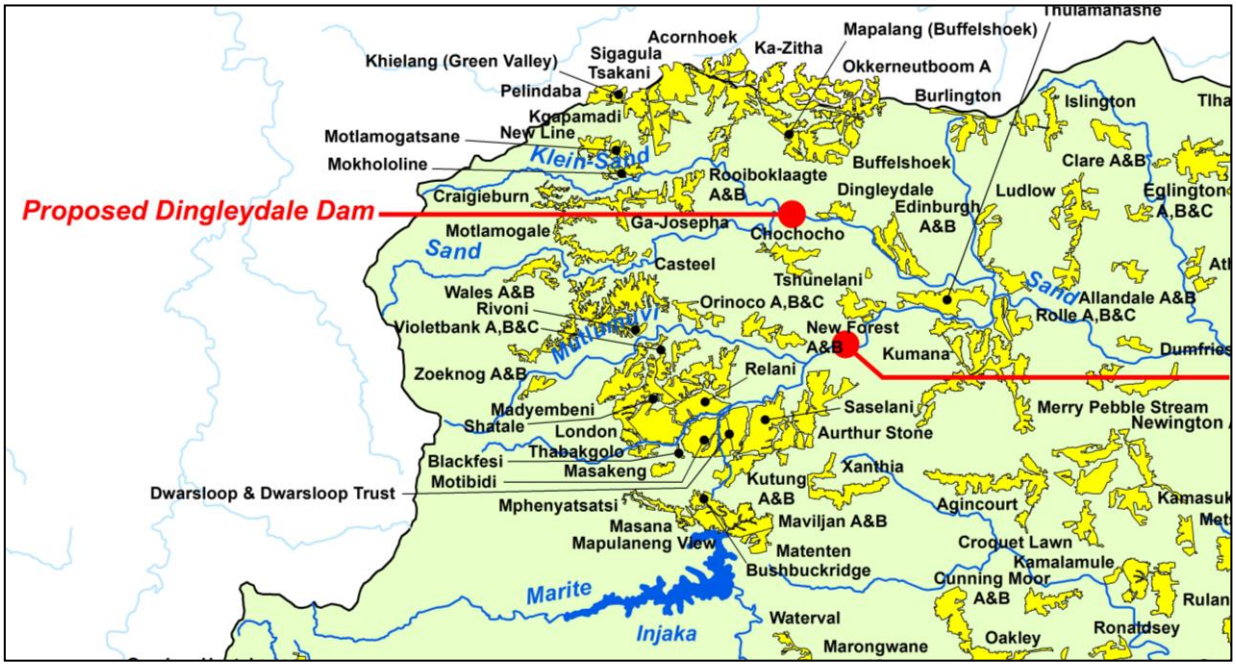

Figure 4-4 Locality Map of the Proposed Dingleydale Dam Site

4.6.2 General Dam Information

- Sub-Catchment: Sand River
- River: Nwandlamuhari River
- Proposed Dam:

The proposed Dam Layout and Details are included in **Appendix A3**.

Spillway:	Central un-controlled concrete gravity spillway with splitters for energy dissipation	
	Spillway length – 120m	
Dam Wall:	Earth embankments with wrap-around junctions to spillway	
	No provision was made for a fishway.	
	Maximum Dam Height:	35 m
	Full Supply Capacity:	62.5 million m^3
	Historic Firm Yield:	20.6 million m^3/a

- Foundation Description:

  Granite outcrop in river. Granite weathered to moderate depth overlain by shallow colluvium on flanks. Post African erosion surface.

- Transfer Infrastructure required downstream from the proposed Dingleydale Dam:

  The construction of a WTW at the Dingleydale Dam is proposed to supply the Acornhoek/Thulamahashe users. Currently these users are supplied with water from the Inyaka Dam (in the Sabie River) via the BBR Pipeline. It would not be practical for this transfer to continue whilst a second transfer moves water back from the Sand to the Sabie.

  The proposed infrastructure includes the following:

  - A WTW at the proposed Dingleydale Dam.
  - A Pump Station at the WTW to pump water to Acornhoek.
  - A Rising Main from the Pump Station to Acornhoek.
  - A Reservoir at Acornhoek.
  - A Gravity Main from the WTW to Thulamahashe.
  - A Reservoir at Thulamahashe.

4.7 Proposed New Forest Dam

4.7.1 Location and Site Description

The proposed New Forest Dam site is within the Sand River Catchment, and is located on the Mutlumuvi River approximately 12 km downstream of the Hazyview/Hoedspruit (R40) Road Crossing of the Mutlumuvi River, which is located in the vicinity of the Nwarhele River and Mtlumuvi River confluence. A Locality Map of the Proposed New Forest Dam Site is presented in **Figure 4-5** below.

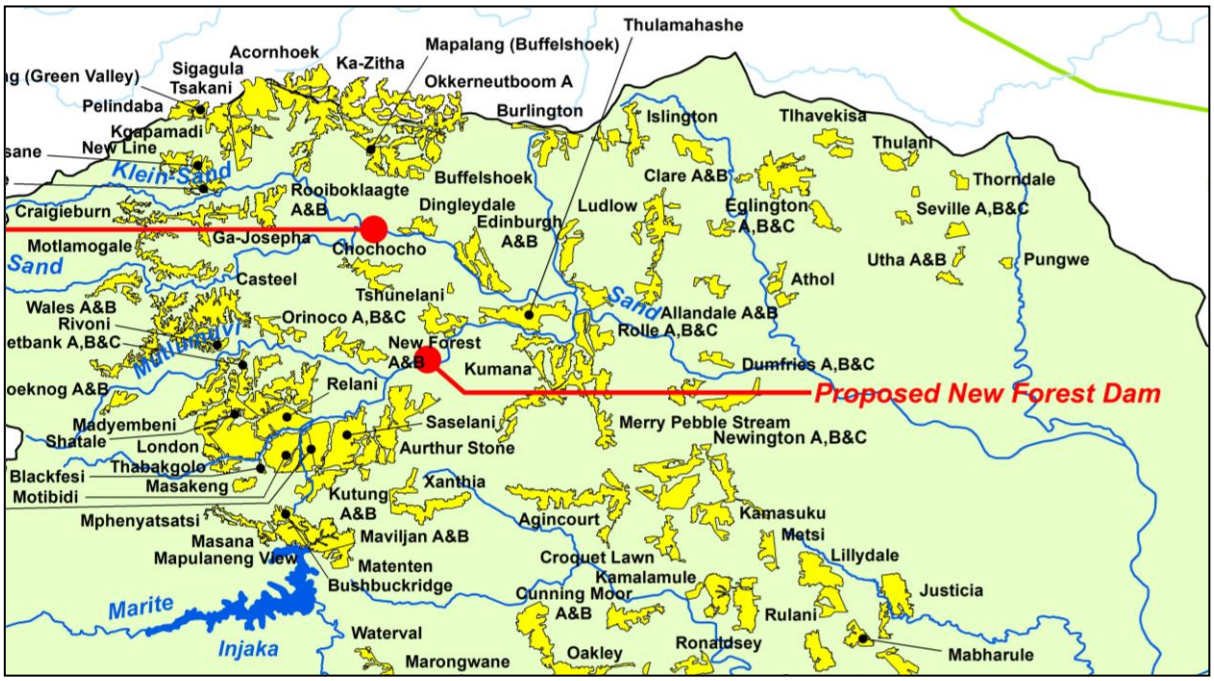

Figure 4-5 Proposed Site: New Forest Dam

4.7.2 General Dam Information

- Sub-Catchment: Sand River
- River: Mutlumuvi River
- Proposed Dam:

  The proposed Dam Layout and Details are included in **Appendix A4**.

  Spillway: Central free concrete gravity spillway with splitter blocks

  Spillway length – 120 m

  Dam Wall: Earth embankments with wrap-around junctions to spillway

  No provision was made for a fishway.

Maximum Dam Height:	42.2 m
Full Supply Capacity:	82 million m^3
Historic Firm Yield:	19.6 million m^3/a

- Foundation Description:

  Granite outcrop in river. Granite weathered to moderate depth overlain by shallow colluvium on flanks. Post African erosion surface.

- Transfer Infrastructure required downstream from the proposed New Forest Dam:

  The construction of WTW at the New Forest Dam is proposed to supply the Acornhoek/Thulamahashe users. Currently these users are supplied with water from the Inyaka Dam (in the Sabie River) via the BBR Pipeline. It would not be practical for this transfer to continue whilst a second transfer moves water back from the Sand to the Sabie.

  The proposed infrastructure includes the following:

  - A WTW at the proposed New Forest Dam.
  - A Pump Station at the WTW to pump water to Acornhoek.
  - A Rising Main from the Pump Station to Acornhoek.
  - A Reservoir at Acornhoek.
  - A Gravity Main from the WTW to Thulamahashe.
  - A Reservoir at Thulamahashe.

4.8 Primkop Dam

4.8.1 Location and Site Description

The Primkop Dam is an existing water impoundment in the White River, which is a tributary to the Crocodile River. Primkop Dam is located approximately 8 km south east of White River and 12 km north east of Mbombela. Access to the site is from the R358 road.

A Locality Map of the Existing Primkop Dam is presented in **Figure 4-6** (overleaf).

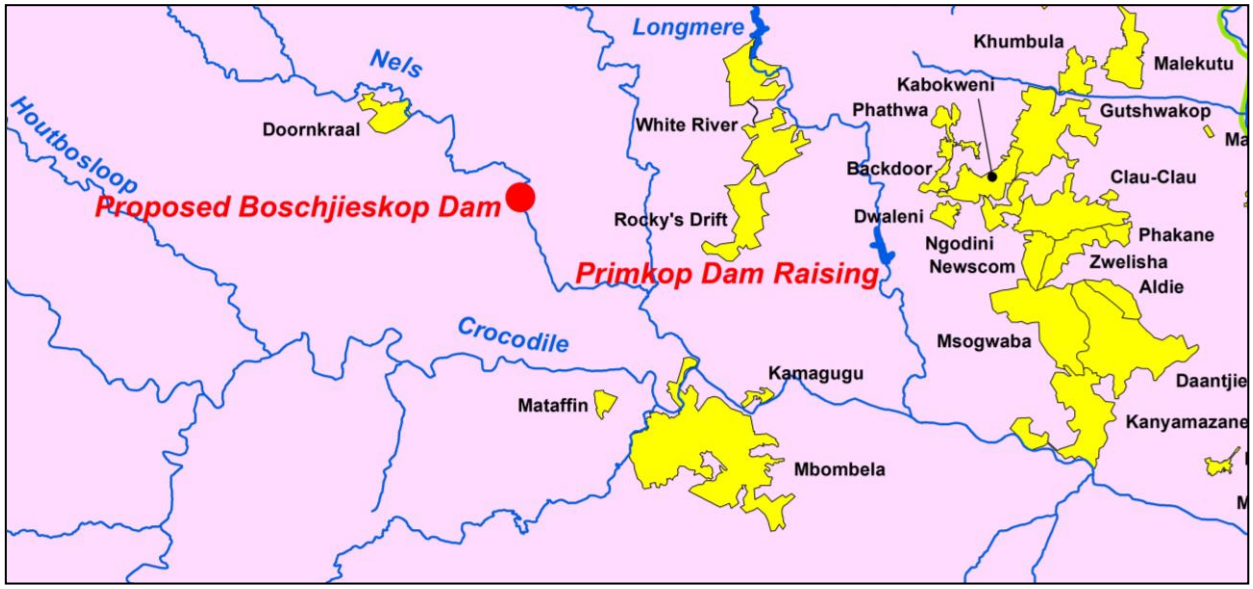

Figure 4-6 Locality Map of the Existing Primkop Dam

4.8.2 General Dam Information

- Catchment: White River
- River: White River
- Existing Dam:

  Spillway: Concrete gravity spillway in the river section

  Dam Wall: A non-overspill concrete gravity section on the left flank and a short earthfill embankment on the right flank

  Maximum Dam Height: 17.5m (from downstream riverbed level to the non-overspill crest level)

  Full Supply Capacity: 2 million m³

  Historic Firm Yield: 3.4 million m³/a

4.8.3 Proposed Raising of Primkop Dam

Following an investigation funded by the City of Mbombela (CoM) it was determined that it is technically feasible to raise the Primkop Dam.

The Reconnaissance Study into Increased Storage on the White and Ngonini Rivers, Mpumalanga Report No. P0102/02 (January 2016), proposed the following to increase the capacity of the Primkop Dam:

The proposed raising of the Dam will entail a composite dam wall with a Piano Key Weir type spillway section in the river section and a concrete gravity section on the left of the spillway

flanked on both sides with a zoned embankment with tongue walls. The main reason for this particular layout is to accommodate construction during high water levels in the existing reservoir. The pipeline to the proposed WTW in Kabokweni is 4.3 km long with a pumping height of 111 m.

The possibility of raising Primkop Dam appears to be the City of Mbombela's preferred option for short term relief to the System with a Terms of Reference for the Feasibility Study being released in late 2019. It has not yet been ascertained as to what height the Dam could be raised to, and therefore the resulting increased capacity of the Dam was still unknown at time of writing this Report. The Water Allocation Plan (IUCMA, 2019b) contained a curve of yields for various capacities of the Primkop Dam. This curve was confirmed as part of this Study and the following yield results were obtained:

- Additional HFY is 1.2 million m³/annum (3,29 Mℓ/day) for a dam capacity of 8 million m^3.
- Additional HFY is 5.9 million m³/annum (16,10 Mℓ/day) for a dam capacity of 30 million m^3.

The results are dependent on the operating rule selected between the three (3) dams, namely Klipkopje, Longmere and Primkop, as well as where the additional abstraction that will take place. This will need to be further investigated as part of the Feasibility Study to be undertaken by the CoM.

5 COST ESTIMATES FOR THE KEY INTERVENTIONS (DAMS)

5.1 Costing

5.1.1 Costing Parameters

For the purposes of this Study the following parameters in **Table 5.1** were utilized in the engineering economic analyses:

Table 5.1: Costing Parameters

Description	Note / Assumption
Energy Tariff	Eskom Megaflex (Local Authority Rates): Average of Standard and Off Peak Rates
Discount Rate (real)	6, 8 and 10%
Analysis Period	45 years

5.2 Construction Values

5.2.1 Bills of Quantities

The Bills of Quantities of previously investigated studies were reviewed and updated. The costs of the options were escalated to a common base date, i.e. August 2020.

5.2.2 Escalation of Unit Rates

The base date for costing of the Continuation of Water Requirements and Availability Reconciliation Strategy for the Mbombela Municipal Area is August 2020.

For the purpose of this study the scheme/option costs utilised in the various planning reports were escalated to the base year, August 2020. The base date for these previous studies varies from 1989 to 2013.

The following Consumer Price Indices (CPIs) obtained from Statistics South Africa were used to adjust/escalate rates to the base date. Refer to **Appendix B**.

Multiplication Factor 1

1989 to August 2020: 7.433

Multiplication Factor 2

2013 to August 2020: 1.376

5.2.3 Contingencies

Allowance was made for a 10% contingency based on the construction value (capital cost), i.e. 10% of Sub-Total B in the Bills of Quantities. Refer to **Appendix C**.

5.3 Planning, Design and Supervision Fees

The following percentages were assumed in the cost models to compare the options on the same basis:

- Planning, Design and Supervision Fees: 15% of the Capital Cost + 10% Contingencies, i.e.

15% of Sub-Total C in the Bills of Quantities. **Refer to Appendix C**.

- Social and Environmental: 1% of the Capital Cost + 10% Contingencies, i.e. 1% of Sub-Total C in the Bills of Quantities. **Refer to Appendix C**.

5.4 Operation and Maintenance Costs

Annual Operation and Maintenance (O&M) costs were based on percentages of the capital cost, as shown below. Refer to **Appendix D**.

Civil:

- 0.5% of the Pipeline Cost
- 0.25% of the Pump Station Civil Cost
- 2.00% of the Water Treatment Works Cost
- 0.5% of the Reservoir Cost
- 0.25% of the Dam Cost

Mechanical:

- 4% of Mechanical Pump Station Cost

Electrical:

- 4% of Electrical Pump Station Cost

Mechanical and Electrical: Pumps and Motors

- Pumps and motors (major overhaul every 15 years)
- 15% of initial capital cost of pump and motor

5.5 Total Estimated Capital Costs

A summary of the Total Estimated Capital Costs for the Proposed Dams (excluding the Downstream Infrastructure) is given in **Table 5.2** below, at August 2020 rates. These estimated capital costs include an allowance for Miscellaneous Costs, Preliminaries and General (P&G) Costs, Contingencies and Design Fees, but excludes VAT.

The mini Bills of Quantities are included as **Appendix C**.

Table 5.2: Summary of the Total Estimated Capital Costs (excluding Downstream Infrastructure)

Proposed Option	Total Estimated Capital Costs
Boschjeskop Dam	**R1,119,934,266**
Mountain View Dam	**R873,422,420**
Dingleydale Dam	**R1,331,310,032**
New Forest Dam	**R1,648,171,593**
Raising of Primkop Dam	**See Note 1 below**

(1) An investigation funded by the City of Mbombela (CoM) confirmed the technical feasibility to raise the Primkop Dam wall. A Terms of Reference for the Feasibility Study was issued in late 2019. This Study needs to be updated with the results of the Feasibility Study.

A summary of the Total Estimated Capital Costs for the Proposed Dams (including Downstream Infrastructure, which entails WTWs, Pump Stations, Rising and Gravity Mains, as well as Reservoirs) is given in **Table 5.3** below, at August 2020 rates. These estimated capital costs include an allowance for Miscellaneous Costs, Preliminaries and General (P&G) Costs, Contingencies and Design Fees, but excludes VAT.

Table 5.3: Summary of the Total Estimated Capital Costs (including Downstream Infrastructure)

Proposed Option	Total Estimated Capital Costs	Requirements of Downstream Infrastructure
Boschjeskop Dam	**R1,119,934,266**	None
Mountain View Dam	**R873,422,420**	None
Dingleydale Dam	**R3,048,203,173**	WTW, Pump Station, Rising and Gravity Mains and Reservoirs.
New Forest Dam	**R3,501,501,819**	WTW, Pump Station, Rising and Gravity Mains and Reservoirs.

Proposed Option	Total Estimated Capital Costs	Requirements of Downstream Infrastructure
Raising of Primkop Dam	**See Note 1 below**	None

(1) An investigation funded by the City of Mbombela (CoM) confirmed the technical feasibility to raise the Primkop Dam wall. A Terms of Reference for the Feasibility Study was issued in late 2019. This Study needs to be updated with the results of the Feasibility Study.

5.6 Yields

A Summary of the Historic Firm Yields for the Proposed Dam Options (sourced from the Water Resources Analysis Report No. P WMA 03/X22/00/6718/5) used in the Engineering Economic Analysis is given in **Table 5.4** below.

Table 5.4: Summary of the Historic Firm Yields

Proposed Option	Historic Firm Yield (million m³/annum)
Boschejskop Dam	**31.2**
Mountain View Dam	**78.1**
Dingleydale Dam	**20.6**
New Forest Dam	**19.6**

5.7 Discounted Present Values

The Present Value (PV) calculations are detailed in **Appendix D**.

A Summary of the Present Values excluding the Downstream Infrastructure is given in **Table 5.5** below, and a Summary of the Present Values including the Downstream Infrastructure is given in **Table 5.6** below.

The capital costs were spread out over various construction periods and the economic life of all components was taken as 45 years. All the costs were discounted to the base year which is 2020.

Table 5.5: Summary of the Present Values (excluding the Downstream Infrastructure)

Proposed Option	Present Value of Cost (2020) at 6% Discount Rate		Present Value of Cost (2020) at 8% Discount Rate		Present Value of Cost (2020) at 10% Discount Rate	
	Capital	O & M	Capital	O & M	Capital	O & M
Crocodile (East) Catchment						
Boschejskop Dam	R815,200,914	24,556,814	736,910,036	16,878,786	667,660,153	12,091,285
Mountain View Dam	637,651,024	18,176,482	576,979,798	12,493,353	523,273,514	8,949,737
Sand River Catchment						
Dingleydale Dam	969,083,267	28,987,691	876,024,629	19,924,288	793,713,433	14,272,961
New Forest Dam	1,199,611,445	36,007,138	1,084,378,101	24,749,008	982,455,361	17,729,196

Table 5.6: Summary of Present Values (including the Downstream Infrastructure)

Dam Option	Present Value of Cost (2020) at 6% Discount Rate		Present Value of Cost (2020) at 8% Discount Rate		Present Value of Cost (2020) at 10% Discount Rate	
	Capital	O & M	Capital	O & M	Capital	O & M
Crocodile (East) Catchment						
Boschejskop Dam	815,200,914	24,556,814	736,910,036	16,878,786	667,660,153	12,091,285
Mountain View Dam	637,651,024	18,176,482	576,979,798	12,493,353	523,273,514	8,949,737
Sand River Catchment						
Dingleydale Dam	2,191,187,225	236,427,182	1,972,688,982	162,423,130	1,780,124,926	116,302,230
New Forest Dam	2,517,494,575	251,380,349	2,266,605,943	172,692,418	2,045,498,272	123,652,761

5.8 Unit Reference Values

The Unit Reference Values (URVs) were determined for discount rates of 6%, 8% and 10% over a 45 year period (from completion of construction). The URV calculations are detailed

in **Appendix E.** A Summary of the URVs for the Crocodile (East) River Catchment is given in **Table 5.7** below.

Table 5.7: Summary of Unit Reference Values for the Crocodile (East) River Catchment

Dam Option	Discount Rate	Total Discounted Costs[(1)]	Total Discounted Yield (million m³)	URV (R/m³)
Boschjeskop Dam	6%	R839,757,728	320.71	2.62
Mountain View Dam	6%	R655,827,506	802.79	0.82
Boschjeskop Dam	8%	R753,788,822	220.43	3.42
Mountain View Dam	8%	R589,473,151	551.79	1.07
Boschjeskop Dam	10%	R679,751,438	157.91	4.31
Mountain View Dam	10%	R532,223,251	395.28	1.35

(1) Including Capital Costs, as well as Operations and Maintenance Costs.

From **Table 5.7** above it is evident that the Mountain View Dam offers significantly lower URVs than Boschjeskop Dam. In addition the yield of Mountain View Dam (78.1 million m³/a) is more than double that of the Boschjeskop Dam (32.1 million m³/a).

From an engineering economic point of view the proposed Mountain View Dam is the preferred option, and therefore it is recommended that the proposed Mountain View Dam be considered for higher levels of investigation (feasibility).

Social and environmental impacts have not been addressed as part of this Study and may have an impact on the selection of the most feasible option.

A Summary of the URVs for the Sand River Catchment is given in **Table 5.8** below.

Table 5.8: Summary of the Unit Reference Values for the Sand River Catchment

Dam Option	Discount Rate	Total Discounted Costs[(1)]	Total Discounted Yield (million m³)	URV Rand/m³
Dingleydale Dam[(2)]	6%	998,070,958	211.75	4.71
New Forest Dam[(2)]	6%	1,235,618,583	201.47	6.13
Dingleydale Dam[(3)]	6%	2,427,614,407	211.75	11.47
New Forest Dam[(3)]	6%	2,768,874,924	201.47	13.74

Dam Option	Discount Rate	Total Discounted Costs[1]	Total Discounted Yield (million m³)	URV Rand/m³
Dingleydale Dam[2]	8%	895,948,917	145.54	6.16
New Forest Dam[2]	8%	1,109,127,109	138.48	8.01
Dingleydale Dam[3]	8%	2,135,112,112	145.54	14.67
New Forest Dam[3]	8%	2,439,298,361	138.48	17.62
Dingleydale Dam[2]	10%	807,986,394	104.26	7.75
New Forest Dam[2]	10%	1,000,184,557	99.20	10.08
Dingleydale Dam[3]	10%	1,896,427,156	104.26	18,19
New Forest Dam[3]	10%	2,169,142,033	99.20	21.87

[1] Including Capital Costs, Operations and Maintenance Costs, as well as Energy Costs.

[2] Excluding Downstream Infrastructure Costs.

[3] Including Downstream Infrastructure Costs.

From **Table 5.8** above it is evident that the Dingleydale Dam has the lowest URVs. The yields of both dams are relatively low (Dingleydale Dam 20.6 million m³/a and New Forest Dam 19.6 million m³/a).

Furthermore, the URVs for both the Dingleydale and New Forest Dams are relatively high, especially when the costs of the downstream infrastructure are included.

Although from an engineering economic point of view the proposed Dingleydale Dam is the preferred option, it is, however, recommended that both the Dingleydale and New Forest Dams be considered for higher levels of investigation (feasibility). Social and environmental impacts have not been addressed as part of this Study and may have an impact on the selection of the most feasible option.

6 SELECTED INTERVENTIONS: UPGRADING OF EXISTING INFRASTRUCTURE

6.1 Upgrading of Existing Infrastructure

There are five (5) main bulk water supply schemes in the Sabie and Sand River Catchments. The Bulk Water Infrastructure in the Water Supply Schemes of the Sabie and Sand River Catchments are illustrated in **Figure 6-1** (overleaf).

6.2 Interventions

The following interventions, which comprise the upgrading of existing infrastructure, have been identified:

- Inyaka WTW;
- Acornhoek WTW;
- Hoxane WTW and
- Bulk water supply infrastructure (bulk pipelines, service reservoirs).

There was insufficient information on the capacity and performance of the bulk pipelines and service storage reservoirs. However, the current operating capacity and the design capacity of the water treatment works of each scheme were determined from an assessment of the treatment plants conducted in 2016.

The capacities of the WTWs are given in **Table 6.1** below:

Table 6.1: Capacities of the Water Treatment Works

Water Supply Scheme	Water Purification Plants	Design Capacity (Ml/d)	Operating Capacity (Ml/d)	Source	Villages Supplied
Thulamahashe WSS	Inyaka WTW	100.00	100.00	Inyaka Dam	Thulamahashe, Dingleydale, Dwarsloop, Dumphries, Hlakakahle, Thorndale, Hluvukani, etc.
	Thulamahashe WTW	9.00	5.00	Mutlumuvi River	
	Edinburg B Package Plant	3.00	2.90	Edinburg Dam	
	Edinburg A Package Plant	1.00	0.80	Edinburg Dam	
	Dingleydale WTW	2.00		Nwandlamuhari River	
	Thorndale WTW	1.50			
	Total Plant Capacity	**115.00**	**108.70**		

Water Supply Scheme	Water Purification Plants	Design Capacity (Ml/d)	Operating Capacity (Ml/d)	Source	Villages Supplied
Acornhoek WSS	Zoeknog WTW	3.00	3.00		Acornhoek, Zoeknog
	Rooiboklaagte (Acornhoek) WTW	2.00		Mutlumuvi River	Shatale, Rooiboklaagte B
	Shatale WTW				
	Mutlumuvi WTW			Mutlumuvi River	
	Sand River (Tintswalo) Package Plant	1.00	0.80	Sand River	
	Total Plant Capacity	**6.00**	**3.80**		
Bushbuckridge WSS	Inyaka WTW			Inyaka Dam	Bushbuckridge Town
Marite WSS	Marite Package Plant	3.00	2.50	Marite River / Inyaka Dam	Marite, Alexandria, Oakley
Hoxane WSS	Hoxane WTW	35.00	29.00	Sand River	Mkhuhlu, Madras, Hoxane
	Cork WTW	3.00	2.50	Sand River	Huntington, Cunning Moor
	Total Plant Capacity	**38.00**	**31.50**		
Sum of Plant Capacities		**163.50**	**146.5**		

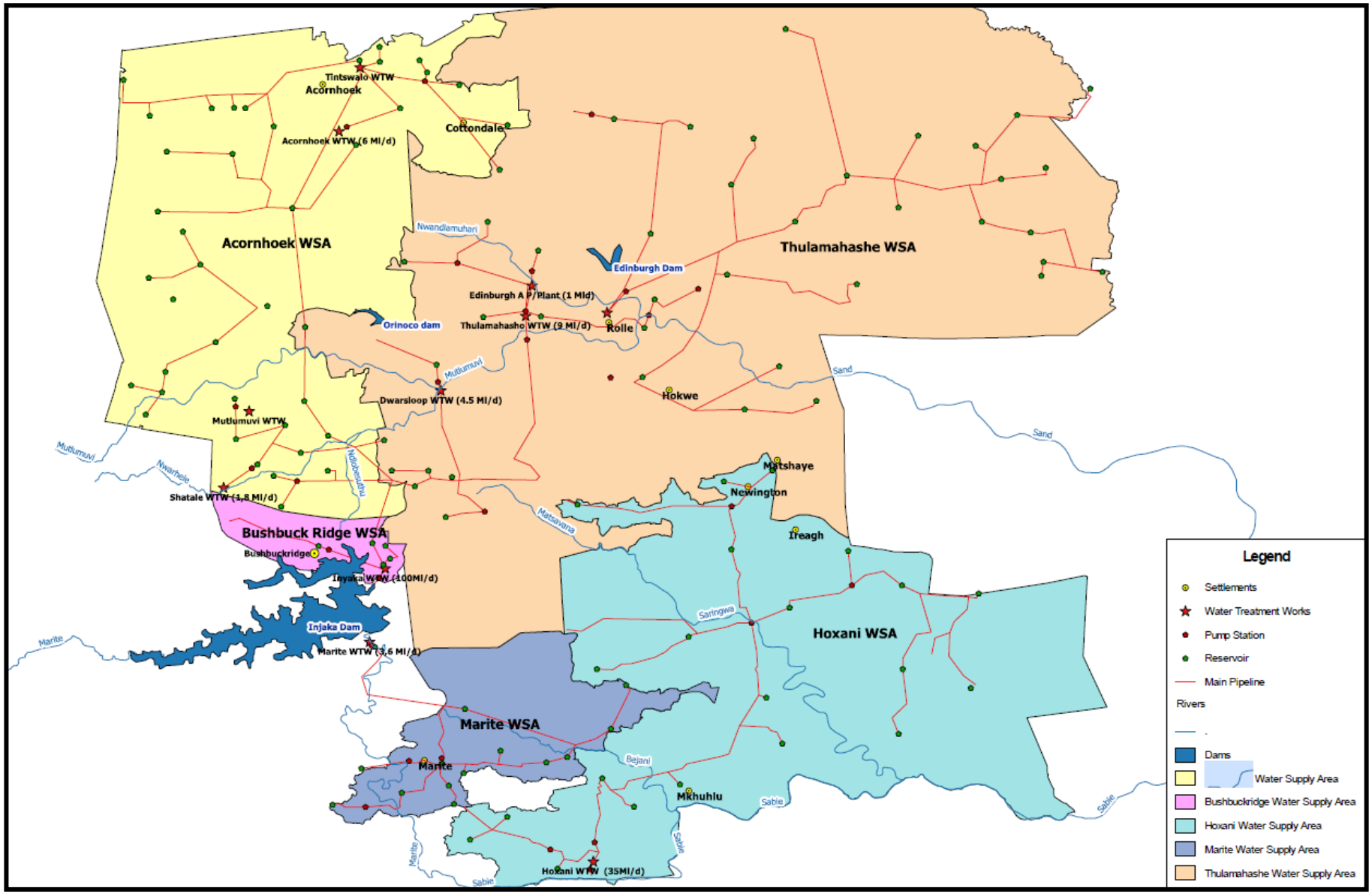

Figure 6-1 Bulk Water Infrastructure in the Water Supply Schemes in the Sabie and Sand River Catchment

6.3 Inyaka Water Treatment Works

The capacity of the raw water abstraction system is 700 ℓ/s (or 60.5 Mℓ/d for a 24-hour pumping period). The capacity of the existing raw pumping plant is not sufficient to meet the Inyaka WTW's current water treatment capacity of 100 Mℓ /d.

The design capacity of the Inyaka Water Treatment Works (WTW) is for an average annual daily flow rate of 90 Mℓ/d. The maximum flow rate of the WTW is 100 Mℓ/d. The current treated water production from the Inyaka Regional WTW alone in 2013 was 56 Mℓ/d (20.44 million m^3/a) which represents over 50% of the WTW's design capacity. (Bushbuckridge Water, 2014). The under utilisation of the Inyaka WTW is because the bulk water supply infrastructure to the northern and to the north western water supply areas has not yet been completed.

The treated water is gravity fed through the following three (3) bulk supply mains:

- A Bulk Main to the 9 Mℓ Dwarsloop Command Reservoir;
- A Bulk Main to the Shatale Service Reservoir from which the bulk supply main will be extended to as far as Acornhoek and Timbavati, as well as
- A Bulk Gravity Main, which delivers water to the Mapulaneng Command Reservoirs, which supply Bushbuckridge Town and townships.

It is the intention of the municipality to develop the Inyaka Regional Water Supply Scheme to supply the whole of Bushbuckridge LM, with the exception of the Hoxane WTW's supply area. The current capacity of the Inyaka WTW alone is not sufficient to meet the future water requirements of the villages and rural towns north of the Sabie River up to Acornhoek – Timbavati in the north and Ludlow and Welverdiend in the Northeast and Marite in the South. The Inyaka WTW, together with the bulk water supply infrastructure, needs to be upgraded as a matter of urgency. It is important to note that the Inyaka WTW was upgraded to 100 Mℓ/d, while some of the regional bulk supply mains and reservoirs are being planned for implementation in the near future.

The total storage capacity for the Inyaka Water Supply Area was determined to be 107.3 Mℓ. Given the current water consumption of 84 Mℓ/d, the current storage capacity is not sufficient to meet the standard of 2 days' summer peak requirement, which is the recommended standard to balance the fluctuating requirements from the distribution system, permitting the source to provide a steady weekly output as well as providing emergency storage to supply water during a failure or shutdowns of the WTW or clear water pump stations.

When the Inyaka Water Supply Area is divided into the three (3) bulk supply scheme areas, the service storage capacity for the Bushbuckridge - Acornhoek Bulk Water Supply Area is 27.65 hours' storage on the annual average daily demand which reduces to 18.44-hour storage on the summer peak demand. Additional storage capacity is required as a matter of urgency to improve the balancing of the fluctuating requirements of the supply area.

For the Dwarsloop – Thulamahashe Water Supply Zone, the total service storage capacity is 44.52 hours of storage which is also below the standard 48-hour storage capacity required to balance fluctuating demands and downtime on the WTW, and therefore additional storage is required.

For the Marite Water Supply Zone, there is approximately 26.87 hours of service storage capacity. The existing service storage capacity cannot meet the current average annual daily demand let alone the summer peak demand for this supply zone.

It is clear that the bulk water supply infrastructure to all the three (3) of the water supply zones supplied from the Inyaka WTW is not adequate to meet the current and future water requirements of the supply area on the summer peak demands.

6.4 Acornhoek Water Treatment Works

The condition and performance of the other WTWs, with the exception of the Acornhoek WTW, are generally in a bad state, with most of these WTWs requiring some refurbishment.

Planning for and upgrading of the Acornhoek WTW are required as the capacity of this WTW is fully utilized, and additional allocations are made from Sabie and Sand River. The timing of upgrading the Acornhoek WTW will depend on the successful implementation of the identified WC/WDM intervention measures, as well as the level of development that will take place in the supply area. Planning and upgrading of the bulk water supply infrastructure, namely the service storage reservoirs and bulk pipelines in the scheme areas where these are required in the short to medium term.

6.5 Hoxane Water Treatment Works

The total pumping capacity of the Raw Water Pump Station with a configuration of two (2) operational pumps and one (1) standby pump is 16.3 Mℓ/d. The Raw Water Pump Station, given the current average demand of 19.3 Mℓ/d, is considered a limiting factor if only two (2) pumps are operational. Because of the limitations in the pumping capacity there are periods when all three (3) raw water pumps are running to meet the water requirements of the supply area. There will be no standby facility, which is a major risk if the pumps break down.

The design capacity of the Hoxane WTW is for an average annual daily flow rate of 29 Mℓ/d, with a maximum flow rate of 35 Mℓ/d. From 2018 (for the high growth scenario) the capacity of the Hoxane WTW is exceeded and upgrading thereof will be required. An additional Water Use License will be required over and above the current water use entitlement that needs to be addressed. Because the Raw Water Pump Station is the limiting factor, there are periods of intermittent water supply to the Hoxane WTW Supply Area.

It is important to note that the Hoxane WTW was scheduled to be upgraded to 53 Mℓ/d to also supply Nsikazi North with treated water in the near future.

The Hoxane Water Supply Scheme Area has a total storage capacity of 48 Mℓ. With the current demand of 25.73 Mℓ/d for the area, there is 47-hours service storage capacity. The current storage capacity is, however, sufficient to meet the standard of two (2) days' summer peak requirement, which is the recommended standard to balance the fluctuating requirements from the distribution system, permitting the source to provide a steady weekly output as well as providing emergency storage to supply water during a failure or shutdowns of the WTW or Potable Water Pump Stations. However, it is important to note that in some of the villages there is insufficient service storage capacity. Therefore, additional storage capacity should be constructed where it is required including the bulk supply mains.

It is therefore recommended to upgrade the Hoxane WTW to augment the water supplies of the Hoxane WSS, which is currently water stressed.

7 CONCLUSIONS AND RECOMMENDATIONS

The overall objective of this Study was to systematically update, improve and extend the Water Resource Reconciliation Strategy to cover the entire Crocodile (East) and Sabie Sub-Catchments, in order for the Strategy to remain relevant, technically sound, economically viable, socially acceptable and sustainable.

This Report provides an overview and summary of the potential interventions (long list from previous studies and new options) to augment the water supply of the Study Area, the selection of potential interventions (short list) for further evaluation, costing of the selected intervention options, as well as an engineering economic analyses (expressed as Unit Reference Values) taking cognizance of the results of the water resources analyses task.

7.1 Baseline Interventions

The following baseline intervention options were identified that can provide smaller yields to increase the water availability of the Study Area.

- Water Conservation and Water Demand Management (WC/WDM)
- Groundwater Development
- Removal of Invasive Alien Plants (IAPs)

WC/WDM and Groundwater Development are addressed in the following reports compiled as part of this Study.

Report Name	DWS Report Number
Water Conservation and Water Demand Management	P WMA 03/X22/00/6718/4
Water Resources Analysis	P WMA 03/X22/00/6718/5

7.1.1 Water Conservation and Water Demand Management (WC/WDM)

There is significant scope for WC/WDM in the Study Area. WC/WDM will result in both a reduction of Non-Revenue Water and the total system input volume. A serious concern however, is the pervasive limitation in institutional capacity and technical skills to embark on WC/WDM programmes in the municipalities.

The estimated budget requirements for the proposed WC/WDM Intervention Options over a five year period for the City of Mbombela and the Bushbuckridge Local Municipalities are respectively R 120 million and R 60 million and per annum

7.1.2 Groundwater Development

The Mbombela Reconciliation Strategy (DWA, 2014) stated that there is only limited scope for groundwater development for primary water supply. The main reason for this is the potential reduction in surface water baseflows in the Mbombela area should the groundwater be abstracted.

The availability of groundwater in the Sabie River Catchment provides for the potential conjunctive use of groundwater and surface water resources in the future as the water requirements increase.

The further development of groundwater resources will depend on the outcome of a detailed groundwater assessment study currently being conducted by the Inkomati Usuthu Catchment Management Agency (IUCMA).

7.1.3 Removal of Invasive Alien Plants (IAPs)

As with WC/WDM, removing alien vegetation is a standard intervention measure for saving water in all Reconciliation Strategies, and is very important in severely water stressed catchments.

The Mbombela Reconciliation Strategy (DWA, 2014) assumed that removal of invasive alien pants (IAPs) upstream of the Nelspruit diversion works on the Crocodile River would make water available that could be allocated to the City of Mbombela. The Sabie River Reconciliation Strategy (DWS, 2016) did not consider this intervention option.

The World Wildlife Fund – South Africa, through the co-ordination of SANParks and the Kruger2Canyons Biosphere (DWS, 2020b), have now started with initiatives to undertake IAP removal in the Sabie Catchment. In water stressed catchments such as the Crocodile and the Sabie this intervention is necessary. This intervention would be beneficial in the Sabie Catchment due to the locations IAPs upstream of Inyaka dam, and it estimated that approximately 3 million m³/annum could be added to the yield of the dam by removing IAPs.

7.2 Key Interventions (Dams)

Due to the severity of the deficits in the Study Area, new dams will be required in order to provide the existing users with a more reliable assurance of supply as well as to augment future growth in water requirements.

The following dam intervention options were evaluated:

- **Boschjeskop Dam on the Nels River**

  The objectives of the proposed Boschjeskop Dam are to:

- Augment the water supply to Mbombela.
- Increase the yield of the Crocodile (East) System.

No infrastructure will be required to convey water from the Boschjeskop Dam to Mbombela. Water can be released from the Boschjeskop Dam and abstracted downstream at the Mbombela Water Treatment Works (WTW).

- **Mountain View Dam on the Kaap River**

The objectives of the proposed Mountain View Dam are to:

- Act in combination with the existing Kwena Dam and provide releases downstream for irrigators, environmental requirements and international obligations.
- Reduce pressure on the Kwena Dam which can then be used to supply Mbombela.

Water can be released from the Kwena Dam and abstracted downstream at Mbombela to augment the supply to Mbombela. Therefore no additional infrastructure with be required for the proposed Mountain View Dam.

- **New Forest Dam on the Mutlumuvi River**

The objectives of the proposed New Forest Dam are to:

- Augment the supply to the Bushbuckridge Area.
- Supply the Acornhoek/Thulamahashe users, which is currently supplied from the Inyaka Dam via the BBR Pipeline.
- Supplement the runoff in Sand River at the confluence of the Mutlumuvi and Nwandlamuhari Rivers.

The construction of a WTW at the New Forest Dam is proposed to supply the Acornhoek/Thulamahashe users. Currently these users are supplied with water from the Inyaka Dam (on the Sabie River) via the BBR Pipeline. It would not be practical for this transfer to continue whilst a second transfer moves water back from the Sand to the Sabie.

The proposed infrastructure includes the following:

- A WTW at the proposed New Forest Dam.
- A Pump Station at the WTW to pump water to Acornhoek.
- A Rising Main from the Pump Station to Acornhoek.
- A Reservoir at Acornhoek.
- A Gravity Main from the WTW to Thulamahashe.
- A Reservoir at Thulamahashe.

- **Dingleydale Dam on the Nwandlamuhari River**

  The objectives of the proposed Dingleydale and New Forest Dams are similar to those of the proposed New Forest Dam.

  The construction of a WTW at the Dingleydale Dam is proposed to supply the Acornhoek/Thulamahashe users. Currently, these users are supplied with water from the Inyaka Dam (in the Sabie River) via the BBR Pipeline. It would not be practical for this transfer to continue whilst a second transfer moves water back from the Sand to the Sabie.

  The proposed infrastructure includes the following:

  - WTW at the proposed Dingleydale Dam.
  - A Pump Station at the WTW to pump water to Acornhoek.
  - A Rising Main from the Pump Station to Acornhoek.
  - A Reservoir at Acornhoek.
  - A Gravity Main from the WTW to Thulamahashe.
  - A Reservoir at Thulamahashe.

- **Raising of Primkop Dam on the White River**

  There is a potentially catastrophic shortage of water resources in the City of Mbombela Area and the objective of raising the Primkop Dam is to alleviate the situation in the short term by increasing the yield of the White River and by implication also the Crocodile (East) River.

  The possibility of raising Primkop Dam appears to be the City of Mbombela's preferred option for short term relief to the system with a Terms of Reference for the Feasibility Study being released in late 2019. Results from the Feasibility Study should be incorporated into a future Strategy update.

7.2.1 Cost Estimates for Key Interventions (Dams)

A summary of the Total Estimated Capital Costs for the Proposed Dams (including Downstream Infrastructure, which entails WTWs, Pump Stations, Rising and Gravity Mains, as well as Reservoirs) is given in **Table 7.4** below, at August 2020 rates, including Miscellaneous Costs, Preliminary and General (P&G) Costs, Contingencies and Design fees, but excluding VAT.

Table 7.1: Total Estimated Capital Costs for the Proposed Dams (including Downstream Infrastructure)

Proposed Option	Total Estimated Capital Costs	Requirements of Downstream Infrastructure
Boschjeskop Dam	**R1,119,934,266**	None
Mountain View Dam	**R873,422,420**	None
Dingleydale Dam	**R3,048,203,173**	WTW, Pump Station, Rising and Gravity Mains and Reservoirs.
New Forest Dam	**R3,501,501,819**	WTW, Pump Station, Rising and Gravity Mains and Reservoirs.
Raising of Primkop Dam	**See Note 1 below**	None

(1) An investigation funded by the City of Mbombela (CoM) confirmed the technical feasibility to raise the Primkop Dam wall. A Terms of Reference for the Feasibility Study was issued in late 2019. This Study needs to be updated with the results of the Feasibility Study.

7.2.2 Yields

A Summary of the Historic Firm Yields for the Proposed Dam Options (sourced from the Water Resources Analysis Report No. P WMA 03/X22/00/6718/5) used in the Engineering Economic Analysis is given in **Table 7.2** below.

Table 7.2: Summary of Yields for the Proposed Dam Options

Dam Option	Historic Firm Yield (million m^3/annum)
Boschejskop Dam	**31.2**
Mountain View Dam	**78.1**
Dingleydale Dam	**20.6**
New Forest Dam	**19.6**

7.3 Unit Reference Values

7.3.1 Baseline Interventions

Summary of the URVs for the baseline interventions is given in **Table 7.3** below.

Table 7.3: Summary of the Unit Reference Values for the Baseline Intervention Options

Intervention Option	Discount Rate	URV (R/m^3)	Analyses Period
Water Conservation and Water Demand Management: City of Mbombela LM	6%	9.68	45 Years
Water Conservation and Water Demand Management: Bushbuckridge LM	6%	5.81	45 Years
Groundwater Development	6%	7.10(1)	30 Years
Removal of Invasive Alien Plants	6%	1.27(1)	30 Years

1) Costs for implementing groundwater development and the removal of IAPs in the Study Area were not readily available and information was obtained from a study (GCTWFSC 2019), commissioned by the Greater Cape Town Water Fund Steering Committee.

The URVs in **Table 7.3** above for the three (3) baseline interventions are relatively low with the exception of the URV for WC/WDM for the City of Mbombela and confirms the execution thereof regardless of the implementation of any 'major' interventions. The implementation of the baseline interventions is considered **essential** and **not optional**.

Results from the IUCMA's detailed groundwater assessment should be incorporated into a future Strategy update.

7.3.2 Key Interventions (Dams)

The capital costs were spread out over various construction periods and operational and maintenance costs over a 45 year period (from completion of construction). All the costs were discounted to the base year which is 2020.

A Summary of the URVs for the key interventions is given in **Table 7.4** (overleaf).

Table 7.4: Summary of the Unit Reference Values for the Key Intervention Options (Dams)

Dam Option	Discount Rate	Total Discounted Costs (including Capital and O & M)	Total Discounted Yield (million m³)	URV (R/m³)
Crocodile River (East Catchment)				
Boschjeskop Dam	8%	R753,788,822	220.43	3.42
Mountain View Dam	8%	R589,473,151	551.79	1.07
Sand River Catchment				
Dingleydale Dam[(2)]	8%	R2,135,112,112	145.54	14.67
New Forest Dam[(2)]	8%	R2,439,298,361	138.48	17.62

[(1)] Including Capital Costs, Operations and Maintenance Costs, as well as Energy Costs.

[(1)] Including Downstream Infrastructure Costs.

- **Crocodile River (East) Catchment**

From **Table 7.4** above it is evident that the Mountain View Dam offers significantly lower URVs than Boschjeskop Dam. In addition the yield of Mountain View Dam (78.1 million m³/a) is more than double that of the Boschjeskop Dam (32.1 million m³/a).

From an engineering economic point of view the proposed Mountain View Dam is the preferred option.

It is recommended that the proposed Mountain View Dam be considered for higher levels of investigation (feasibility).

Social and environmental impacts have not been addressed as part of this Study and may have an impact on the selection of the most feasible option.

- **Sand River Catchment**

From **Table 7.4** above it is evident that the Dingleydale Dam has the lowest URVs for the Sand River Catchment. The yields of both dams are relatively low (Dingleydale Dam 20.6 million m³/a and New Forest Dam 19.6 million m³/a). Furthermore, the URVs for both the Dingleydale and New Forest Dams are high.

Although from an engineering economic point of view the proposed Dingleydale Dam is the preferred option, it is, however, recommended that both the Dingleydale and New Forest

Dams be considered for higher levels of investigation (feasibility). Social and environmental impacts have not been addressed as part of this Study and may have an impact on the selection of the most feasible option.

7.4 Selected Interventions: Upgrading of Existing Infrastructure

The following interventions comprising the upgrading of existing infrastructure were selected for further evaluation:

- Inyaka WTW

  The treatment works, together with the bulk water supply infrastructure needs to be upgraded as a matter of urgency. It is important to note that the Inyaka Regional WTW was upgraded to 100 Mℓ/d, while some of the regional bulk supply mains and reservoirs are being planned for implementation in the near future.

- Acornhoek WTW

  Planning for and upgrading of the Acornhoek water treatment works are required as the capacity of the waterworks is fully utilised and additional allocations are made from Sabie and Sand River. The timing of upgrading the waterworks will depend on the successful implementation of the identified WC/WDM intervention measures as well as the level of development that will take place in the supply area.

- Hoxane WTW

  Upgrading of the Hoxane waterworks is required to augment the water supplies of the Hoxane WSS, which is under water stress. An additional water use license will be required over and above the current water use entitlement that needs to be addressed.

8 REFERENCES

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DWA (2011b) Ehlanzeni District Municipality: Reconciliation Strategy for Barberton Water Supply Scheme area - Umjindi Local Municipality, compiled by Water for Africa (Pty) Ltd in association with Aurecon and Water Geoscience Consulting in 2011, for the Department of Water Affairs Directorate: Water Resource Planning Systems, Pretoria, South Africa.

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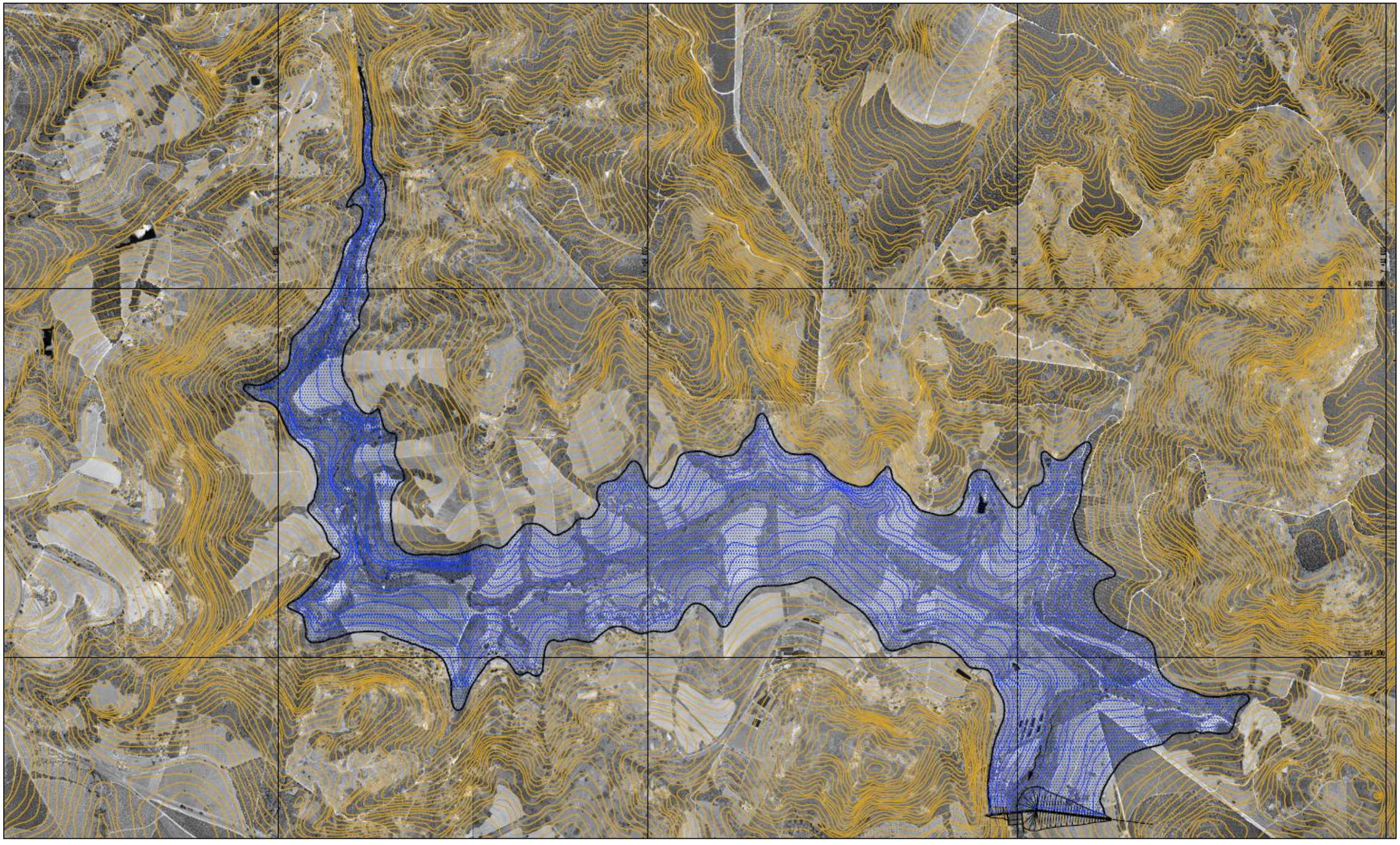
GCTWFSC (2019) Business Case, Assessing the Return on Investment for Ecological Infrastructure Restoration, April 2019.

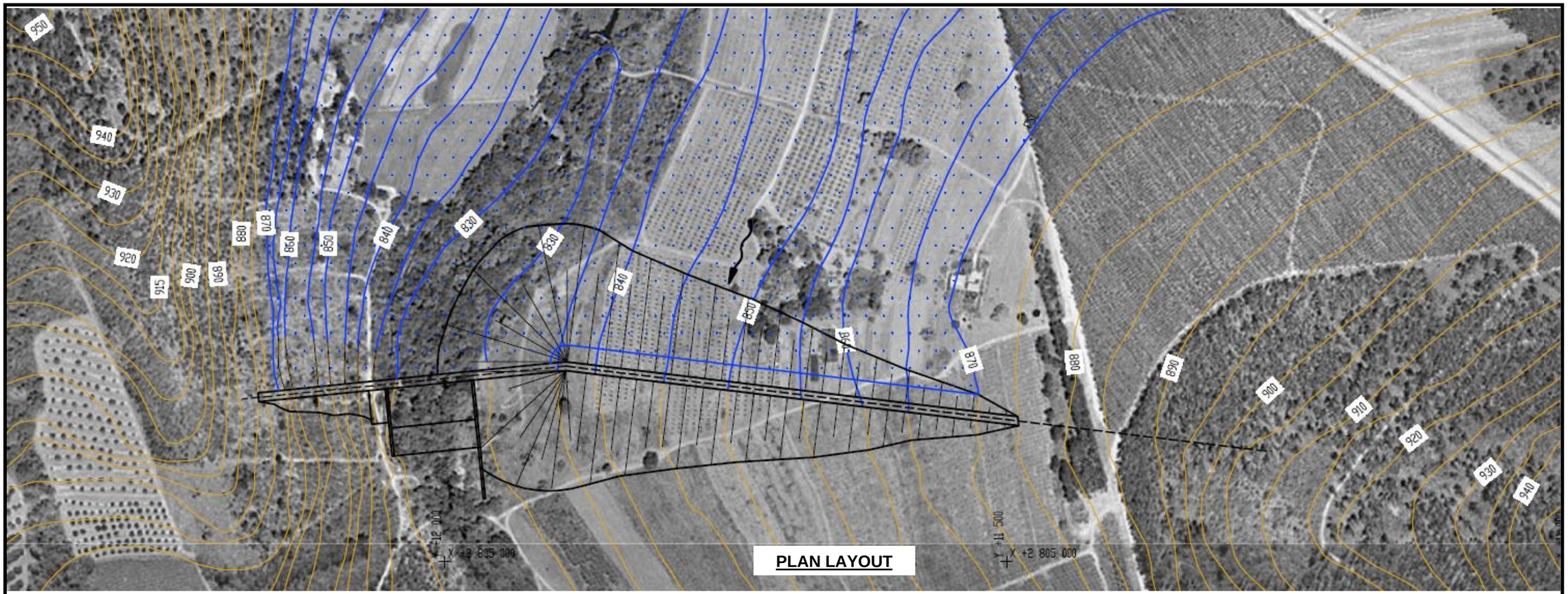
APPENDICES

APPENDIX A

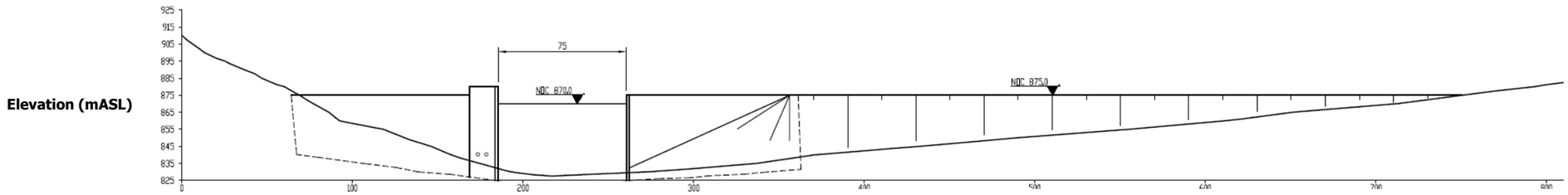
APPENDIX A1: BOSCHJESKOP DAM



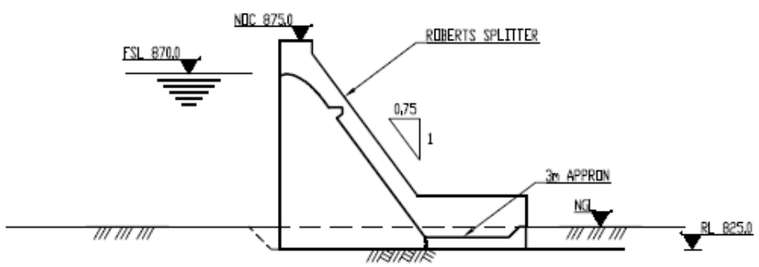
Boschjeskop Dam: Plan of Basin



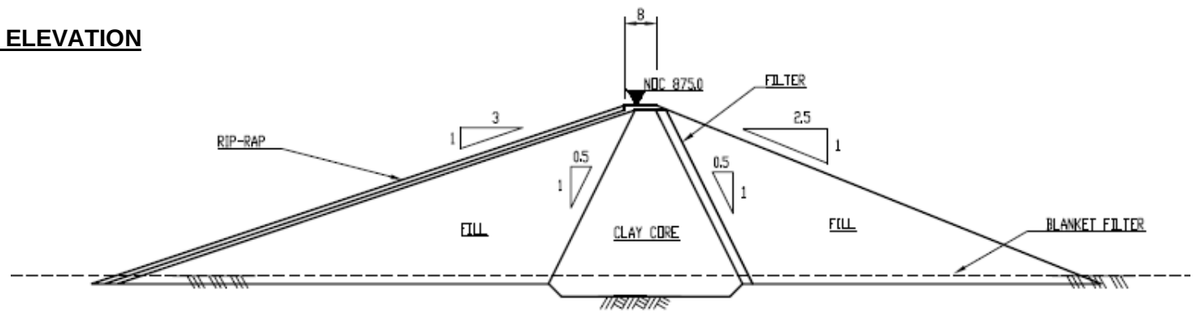
PLAN LAYOUT



DOWNSTREAM ELEVATION



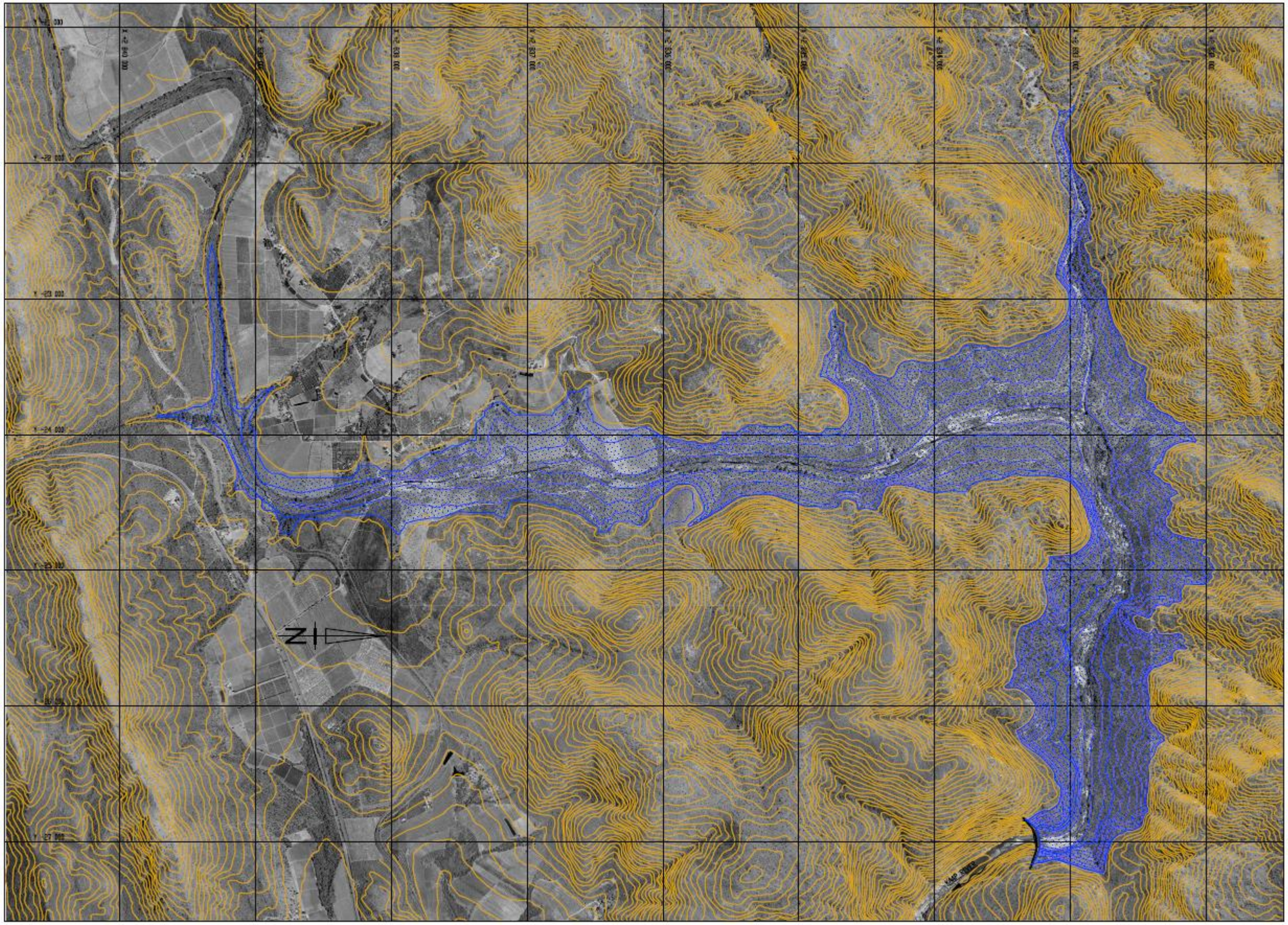
TYPICAL SECTION THROUGH OVERSPILL CREST



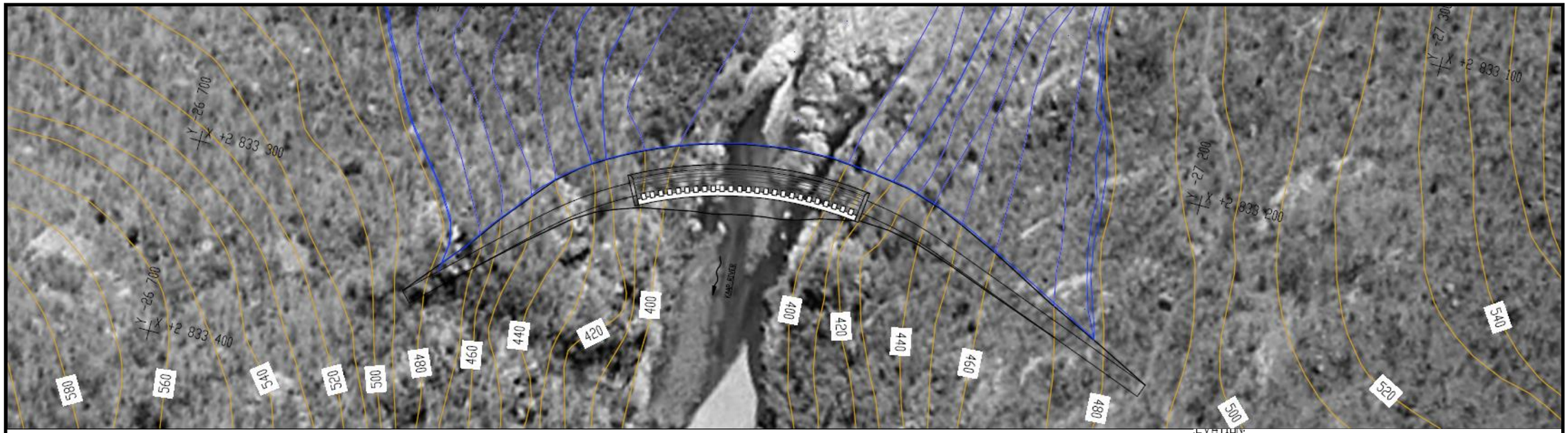
TYPICAL SECTION THROUGH NON-OVERSPILL CREST

Boschjeskop Dam: Plan and Details

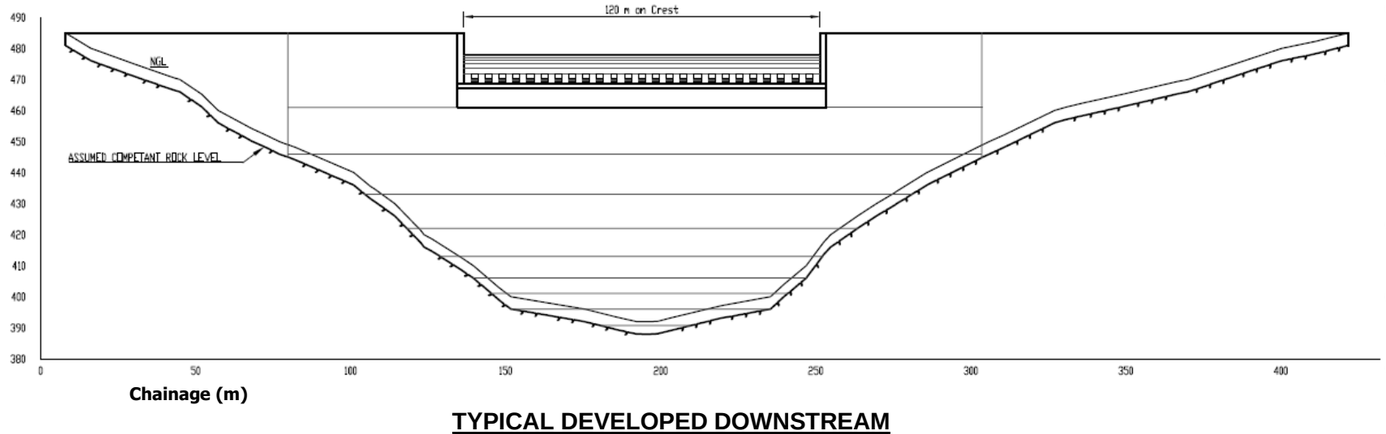
APPENDIX A2: MOUNTAIN VIEW DAM



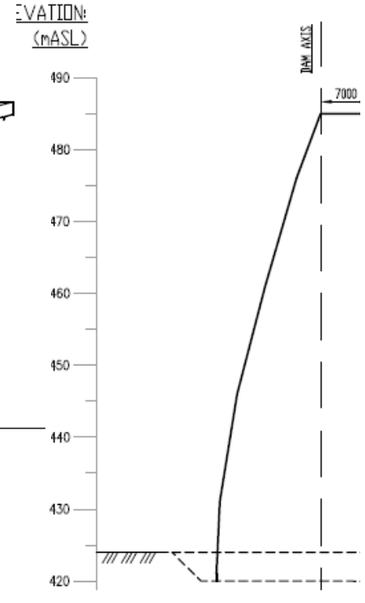
Mountain View Dam: Plan of Basin



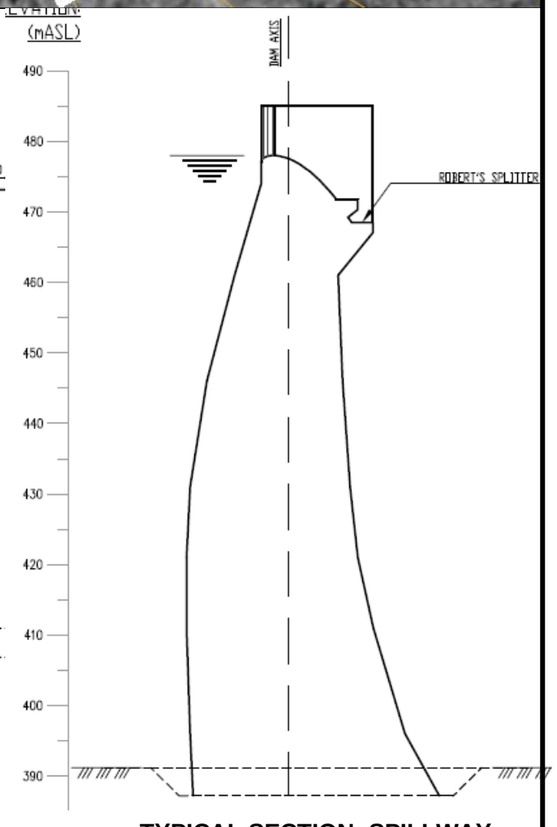
PLAN LAYOUT



TYPICAL DEVELOPED DOWNSTREAM ELEVATION ALONG DOWNSTREAM CREST



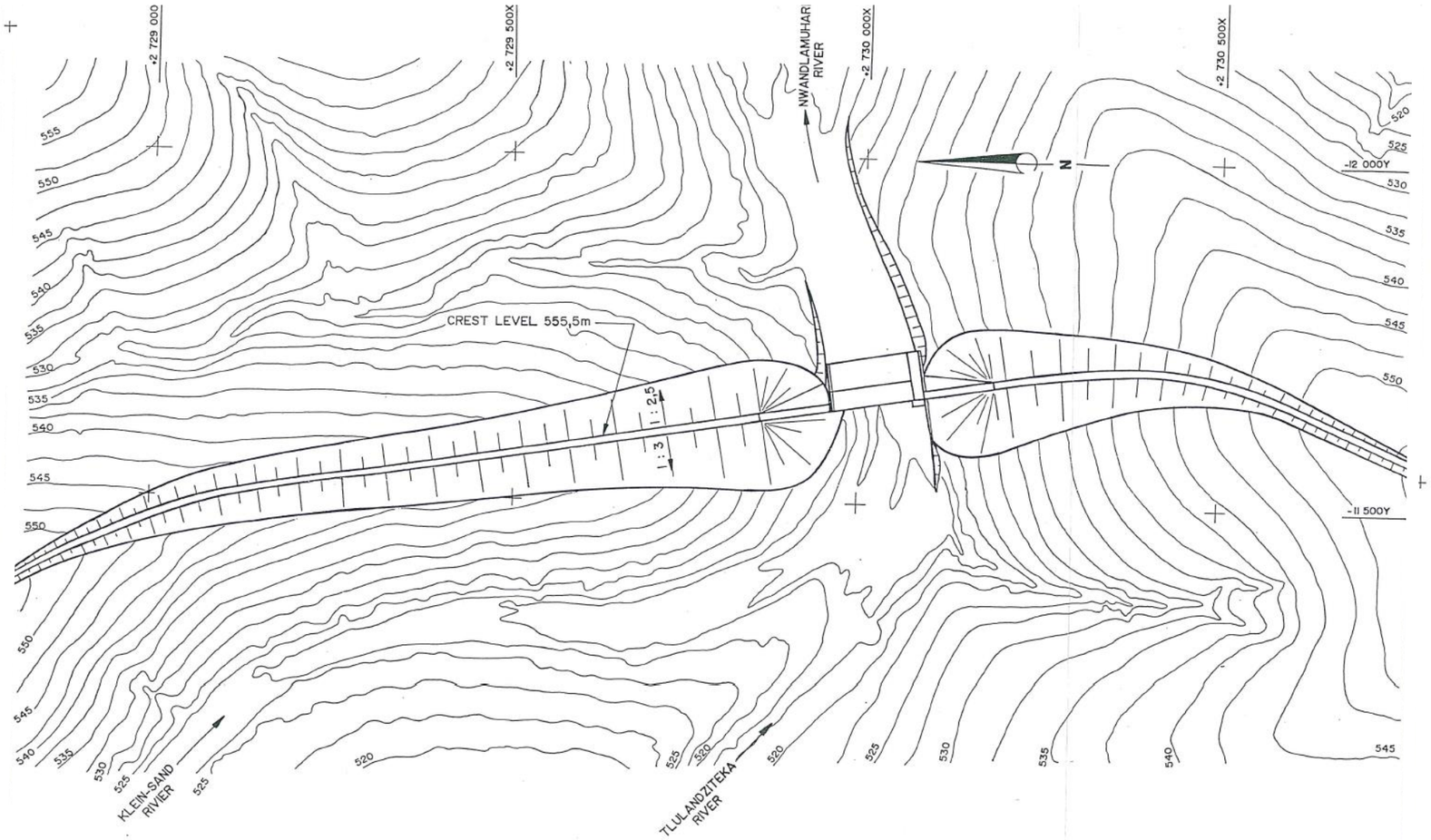
TYPICAL SECTION: NON-OVERSPILL CREST



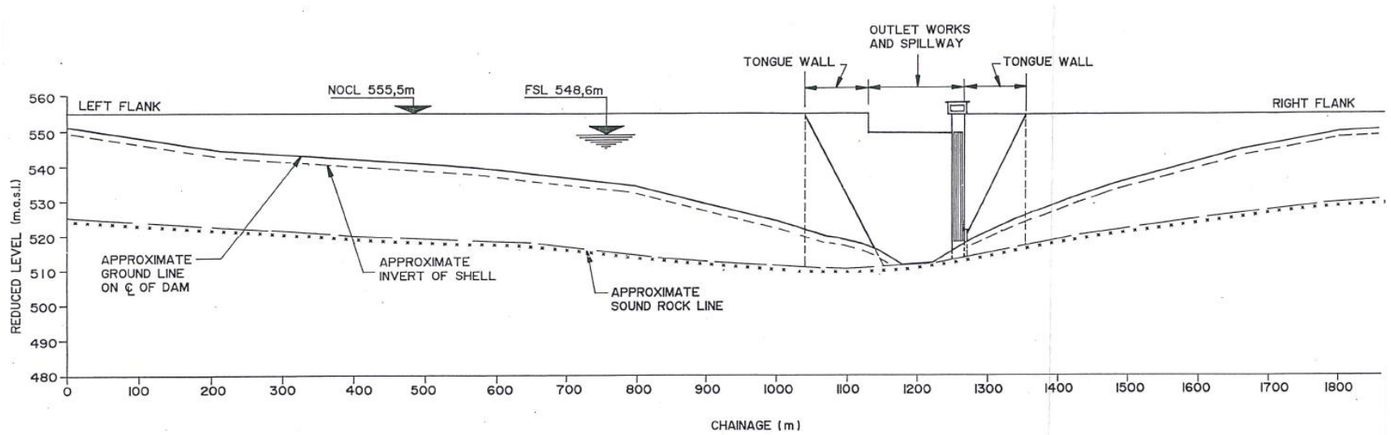
TYPICAL SECTION: SPILLWAY

Mountain View Dam: Plan and Details

APPENDIX A3: DINGLEYDALE DAM

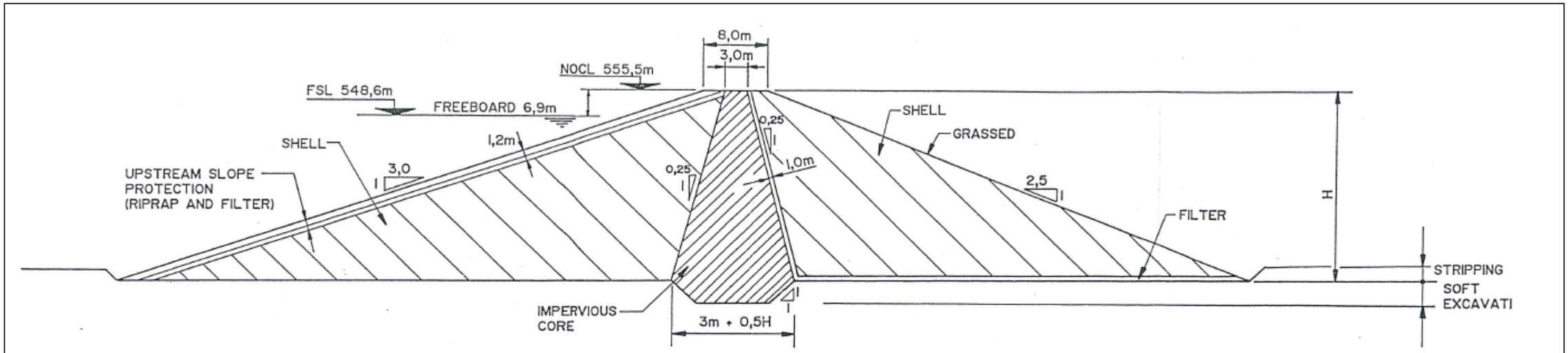


PLAN LAYOUT

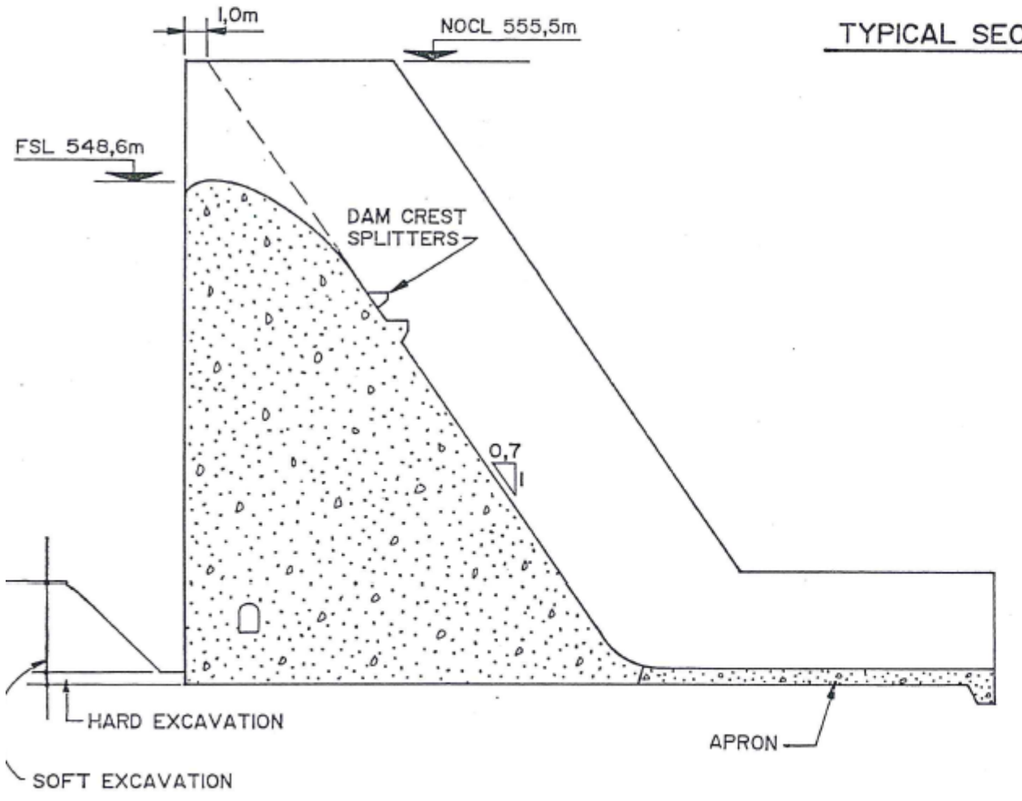


UPSTREAM ELEVATION

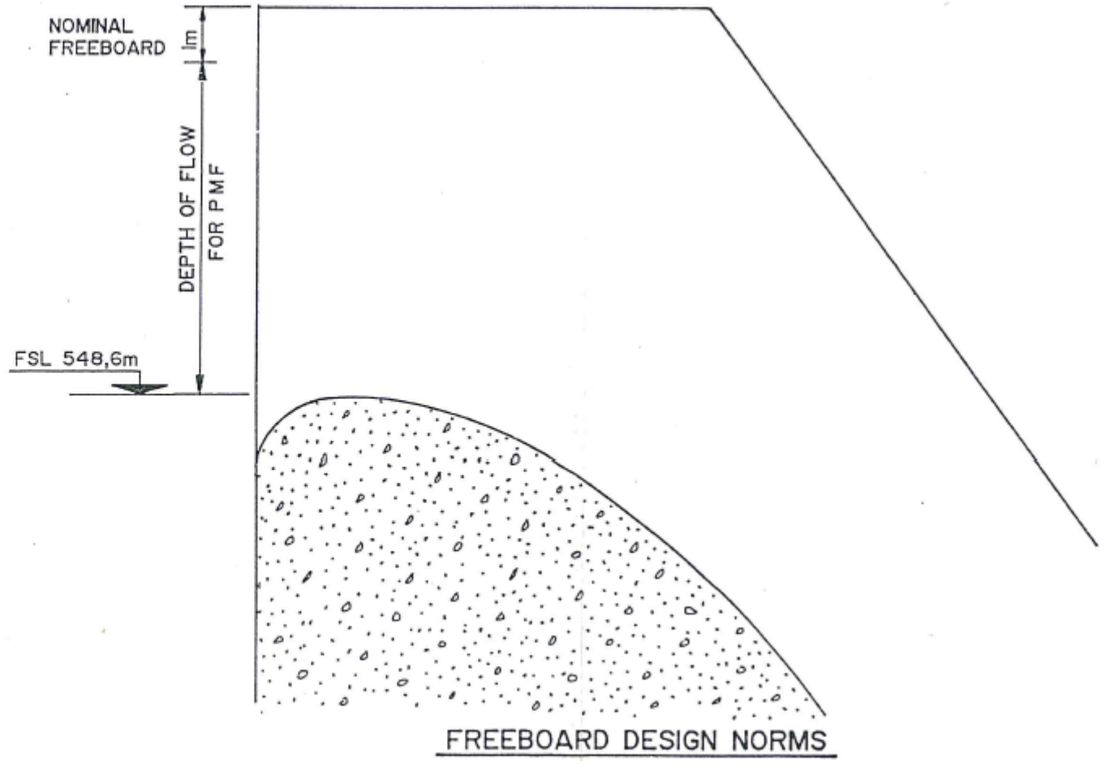
Dingleydale Dam: Plan and Details



TYPICAL SECTION THROUGH EMBANKMENT



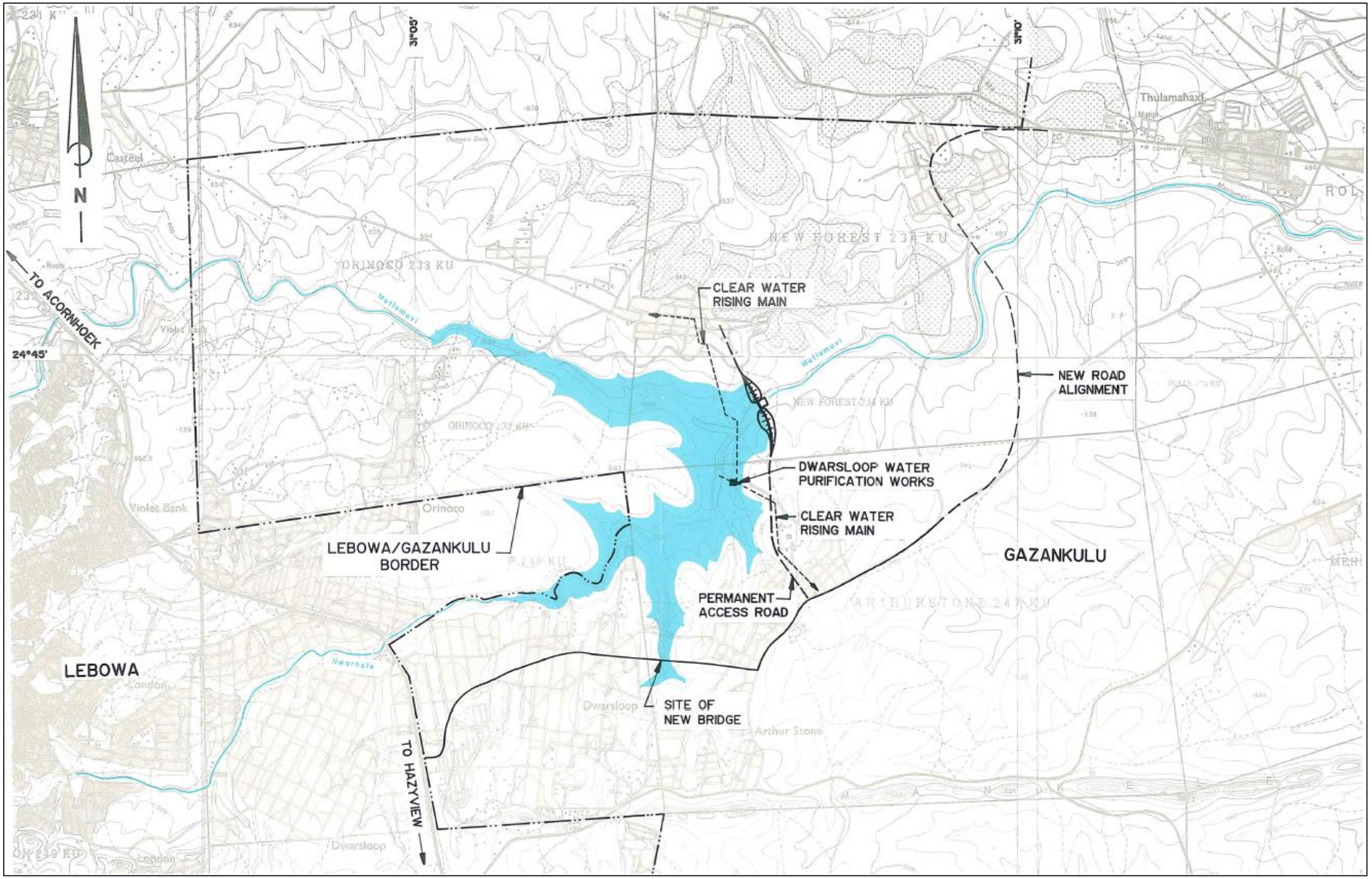
TYPICAL SECTION THROUGH CENTRAL SPILLWAY



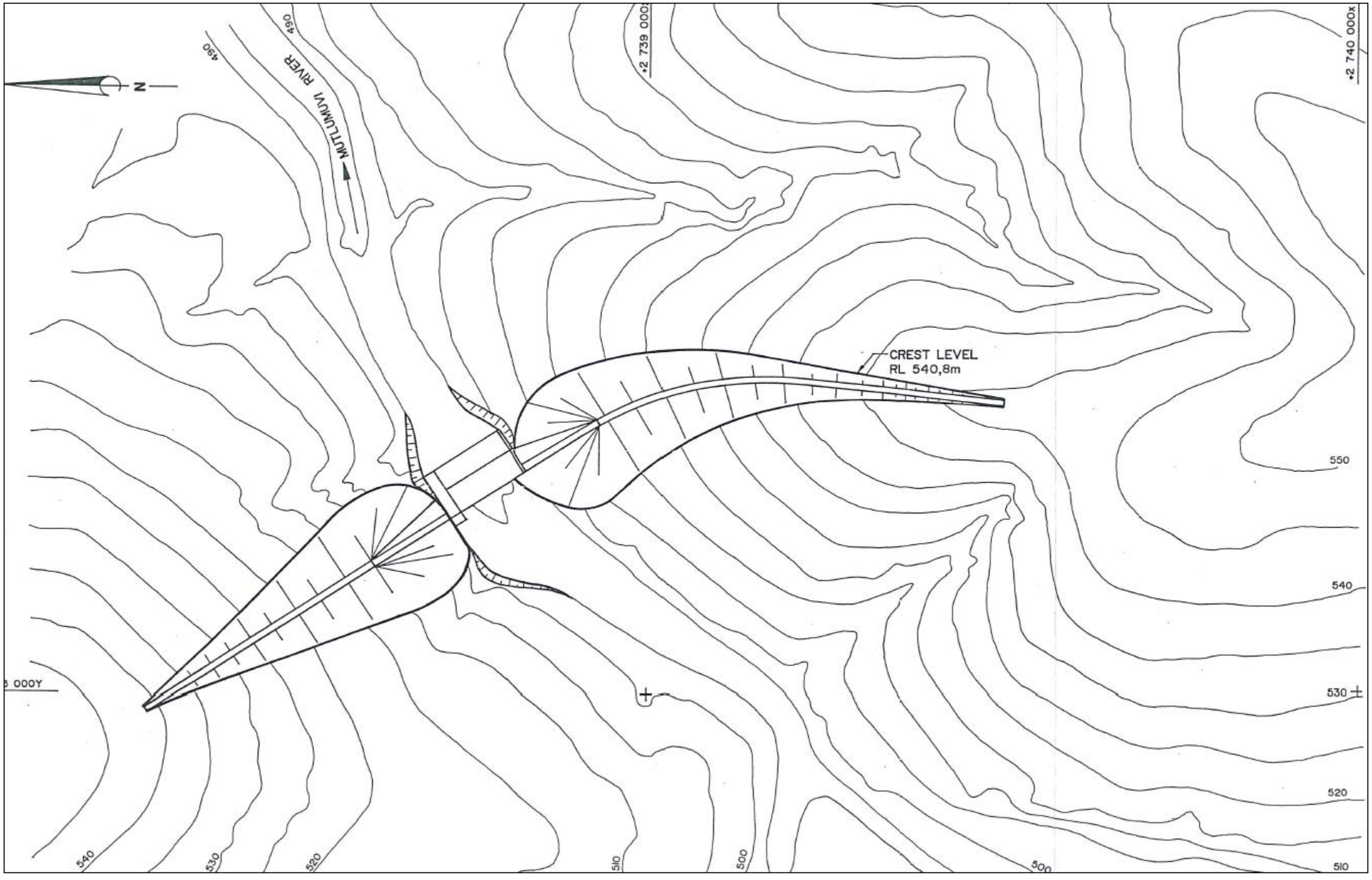
FREEBOARD DESIGN NORMS

Dingleydale Dam: Plan and Details

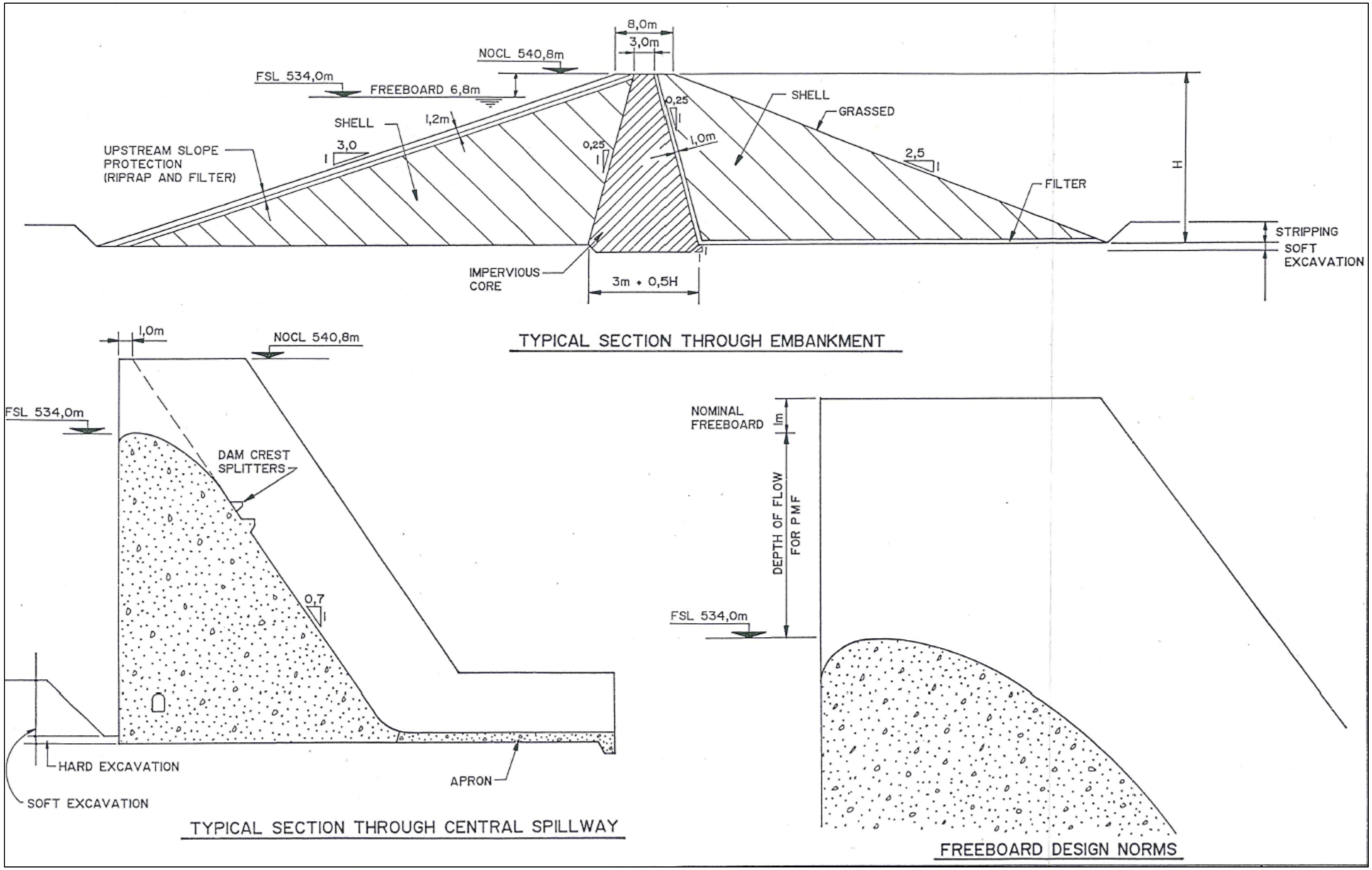
APPENDIX A4: NEW FOREST DAM



New Forest Dam: Plan Layout



New Forest Dam: Plan View



New Forest Dam: Details

APPENDIX B

SOUTH AFRICAN CPI HISTORY (Statistics South Africa (STATSSA) Data - Table B2 available at www.statssa.gov.za)

YEAR	CPI FOR THE YEAR	ACCUMULATIVE ESCALATION FROM YEAR TO YEAR																																						
		1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
1982	14.70																																							
1983	12.40	14.7																																						
1984	11.60	28.9	12.4																																					
1985	16.10	43.9	25.4	11.6																																				
1986	18.70	67.0	45.6	29.6	16.1																																			
1987	16.10	98.3	72.9	53.8	37.8	18.7																																		
1988	12.90	130.2	100.7	78.6	60.0	37.8	16.1																																	
1989	14.70	159.9	126.6	101.6	80.6	55.6	31.1	12.9																																
1990	14.40	198.1	159.9	131.2	107.2	78.5	50.3	29.5	14.7																															
1991	15.30	241.0	197.3	164.5	137.0	104.2	72.0	48.1	31.2	14.4																														
1992	13.90	293.2	242.8	205.0	173.3	135.4	98.3	70.8	51.3	31.9	15.3																													
1993	9.70	347.9	290.5	247.4	211.3	168.1	125.9	94.6	72.3	50.2	31.3	13.9																												
1994	9.00	391.3	328.3	281.1	241.5	194.1	147.8	113.4	89.0	64.8	44.1	24.9	9.7																											
1995	8.70	435.5	366.9	315.4	272.2	220.6	170.1	132.6	106.1	79.6	57.0	36.2	19.6	9.0																										
1996	7.40	482.1	407.5	351.5	304.6	248.5	193.6	152.9	124.0	95.3	70.7	48.0	30.0	18.5	8.7																									
1997	8.60	525.2	445.1	384.9	334.5	274.3	215.3	171.6	140.6	109.7	83.3	59.0	39.6	27.3	16.7	7.4																								
1998	6.90	579.0	491.9	426.6	371.9	306.5	242.4	194.9	161.2	127.8	99.1	72.7	51.6	38.2	26.8	16.6	8.6																							
1999	5.10	625.8	532.8	463.0	404.5	334.5	266.1	215.3	179.3	143.5	112.8	84.6	62.1	47.7	35.5	24.7	16.1	6.9																						
2000	5.30	662.8	565.1	491.7	430.2	356.7	284.7	231.4	193.5	155.9	123.7	94.0	70.3	55.3	42.4	31.0	22.0	12.4	5.1																					
2001	5.70	703.3	600.3	523.0	458.3	380.9	305.1	248.9	209.1	169.5	135.5	104.3	79.4	63.5	50.0	38.0	28.5	18.3	10.7	5.3																				
2002	9.20	749.0	640.2	558.6	490.1	408.3	328.2	268.8	226.7	184.8	149.0	115.9	89.6	72.8	58.5	45.9	35.8	25.1	17.0	11.3	5.7																			
2003	5.80	827.1	708.3	619.1	544.4	455.0	367.6	302.8	256.7	211.0	171.9	135.8	107.0	88.7	73.1	59.3	48.3	36.6	27.7	21.5	15.4	9.2																		
2004	1.40	880.9	755.2	660.9	581.8	487.2	394.7	326.1	277.4	229.1	187.6	149.5	119.0	99.7	83.2	68.5	56.9	44.5	35.1	28.6	22.1	15.5	5.8																	
2005	3.40	894.7	767.2	671.5	591.3	495.5	401.6	332.1	282.7	233.7	191.7	153.0	122.1	102.5	85.7	70.9	59.1	46.5	37.0	30.4	23.8	17.2	7.3	1.4																
2006	4.70	928.5	796.7	697.7	614.8	515.7	418.7	346.8	295.7	245.0	201.6	161.6	129.6	109.3	92.0	76.7	64.5	51.5	41.7	34.8	28.0	21.1	10.9	4.8	3.4															
2007	7.10	976.8	838.8	735.2	648.4	544.6	443.1	367.8	314.3	261.2	215.8	173.9	140.4	119.2	101.1	85.0	72.2	58.6	48.4	41.2	34.1	26.8	16.1	9.8	8.3	4.7														
2008	11.50	1053.3	905.5	794.5	701.6	590.4	481.6	401.0	343.7	286.9	238.2	193.3	157.5	134.7	115.4	98.1	84.5	69.9	58.9	51.2	43.6	35.8	24.4	17.6	15.9	12.1	7.1													
2009	7.10	1185.9	1021.1	897.4	793.7	669.8	548.5	458.6	394.8	331.4	277.1	227.0	187.1	161.7	140.1	120.9	105.7	89.4	77.2	68.6	60.1	51.5	38.7	31.1	29.3	25.0	19.4	11.5												
2010	4.30	1277.2	1100.7	968.2	857.2	724.5	594.6	498.3	429.9	362.0	303.8	250.2	207.5	180.3	157.2	136.6	120.3	102.8	89.7	80.5	71.5	62.2	48.5	40.4	38.5	33.9	27.9	19.4	7.1										
2011	5.00	1336.4	1152.3	1014.2	898.4	759.9	624.4	524.0	452.7	381.8	321.2	265.3	220.7	192.4	168.2	146.8	129.8	111.6	97.9	88.3	78.8	69.2	54.9	46.4	44.4	39.7	33.4	24.6	11.7	4.3									
2012	5.60	1408.2	1214.9	1069.9	948.3	802.9	660.7	555.2	480.3	405.9	342.3	283.6	236.8	207.0	181.6	159.1	141.2	122.1	107.8	97.7	87.8	77.6	62.7	53.8	51.6	46.6	40.1	30.8	17.3	9.5	5.0								
2013	5.70	1492.7	1288.6	1135.4	1007.0	853.5	703.3	591.9	512.8	434.3	367.0	305.1	255.6	224.2	197.4	173.6	154.8	134.6	119.4	108.8	98.3	87.6	71.8	62.4	60.1	54.9	47.9	38.1	23.9	15.6	10.9	5.6							
2014	6.10	1583.5	1367.7	1205.8	1070.1	907.8	749.0	631.3	547.7	464.7	393.6	328.1	275.9	242.7	214.4	189.2	169.3	147.9	131.9	120.7	109.6	98.3	81.6	71.6	69.3	63.7	56.3	46.0	30.9	22.2	17.2	11.6	5.7						
2015	4.60	1686.2	1457.2	1285.5	1141.4	969.3	800.8	675.9	587.3	499.2	423.8	354.3	298.8	263.6	233.5	206.8	185.7	163.1	146.1	134.2	122.4	110.4	92.7	82.1	79.6	73.7	65.9	54.9	38.9	29.7	24.3	18.4	12.1	6.1					
2016	6.40	1768.3	1528.9	1349.2	1198.6	1018.5	842.3	711.6	618.9	526.7	447.8	375.2	317.2	280.3	248.9	221.0	198.8	175.2	157.4	144.9	132.6	120.1	101.5	90.5	87.8	81.7	73.5	62.0	45.3	35.7	30.1	23.9	17.3	11.0	4.6				
2017	5.3	1887.9	1633.1	1441.9	1281.7	1090.1	902.6	763.5	664.9	566.8	482.9	405.6	343.9	304.6	271.2	241.5	218.0	192.8	173.9	160.6	147.5	134.1	114.4	102.7	99.9	93.3	84.6	72.4	54.6	44.3	38.4	31.8	24.8	18.1	11.3	6.4		
2018	4.70	1993.3	1725.0	1523.7	1354.9	1153.1	955.7	809.3	705.4	602.2	513.8	432.4	367.4	326.1	290.9	259.6	234.8	208.3	188.4	174.4	160.6	146.5	125.8	113.4	110.5	103.5	94.4	81.5	62.8	52.0	45.7	38.8	31.4	24.3	17.2	12.0	5.3	
2019	4.1	2091.6	1810.8	1600.0	1423.3	1212.0	1005.3	852.1	743.3	635.2	542.7	457.4	389.4	346.1	309.3	276.5	250.6	222.8	202.0	187.3	172.8	158.1	136.4	123.4	120.3	113.1	103.5	90.0	70.4	59.1	52.6	45.3	37.6	30.2	22.7	17.3	10.2	4.7	

APPENDIX C

APPENDIX C1: BOSCHJESKOP DAM

APPENDIX C2: MOUNTAIN VIEW DAM

APPENDIX C3: DINGLEYDALE DAM

APPENDIX C4: NEW FOREST DAM

APPENDIX D

APPENDIX D1: BOSCHJESKOP DAM

APPENDIX D2: MOUNTAIN VIEW DAM

APPENDIX D3: DINGLEYDALE DAM

APPENDIX D4: NEW FOREST DAM

APPENDIX E

APPENDIX E1: BOSCHEJSKOP DAM

APPENDIX E2: MOUNTAIN VIEW DAM

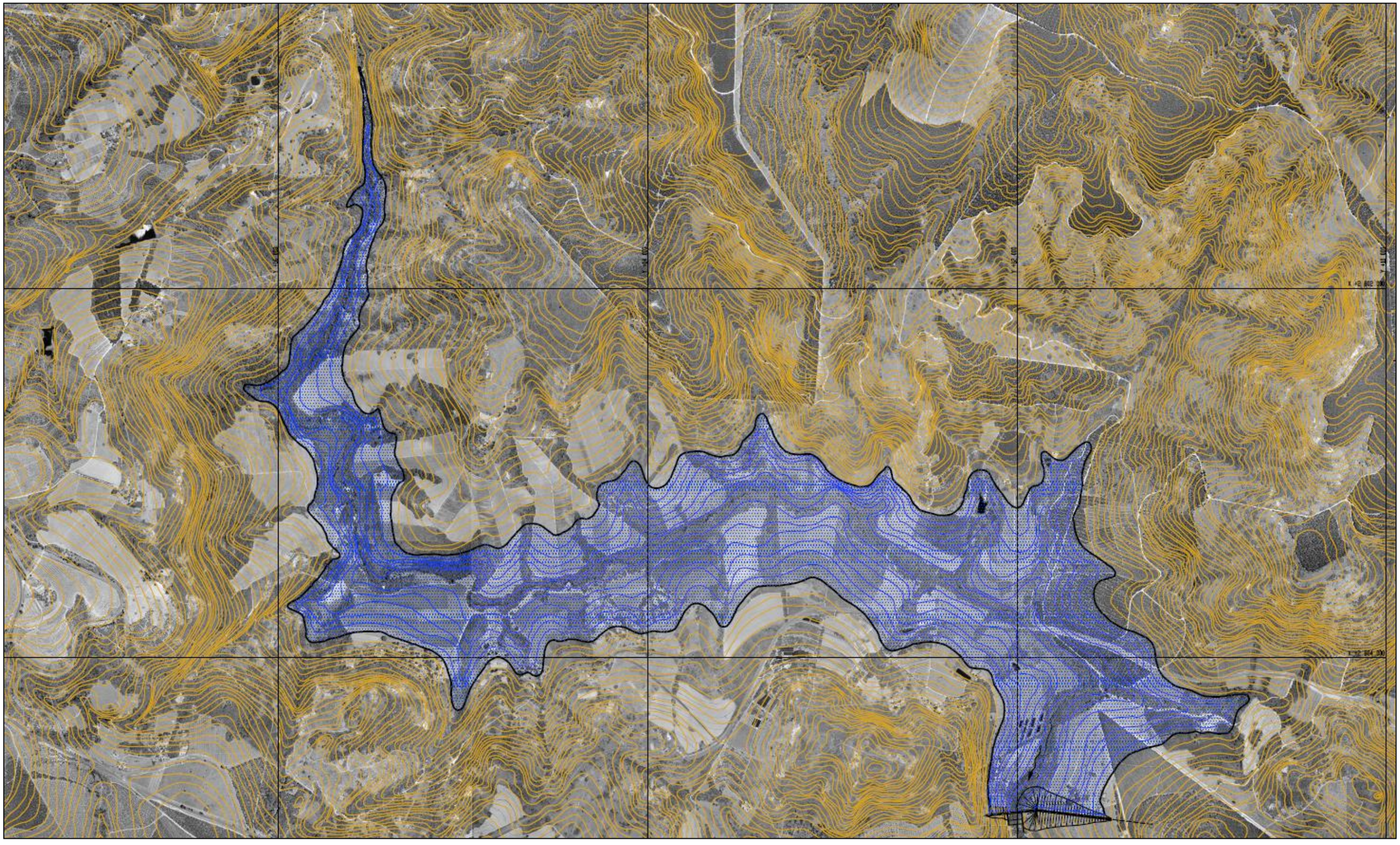
APPENDIX E3: DINGLEYDALE DAM

APPENDIX E4: NEW FOREST DAM

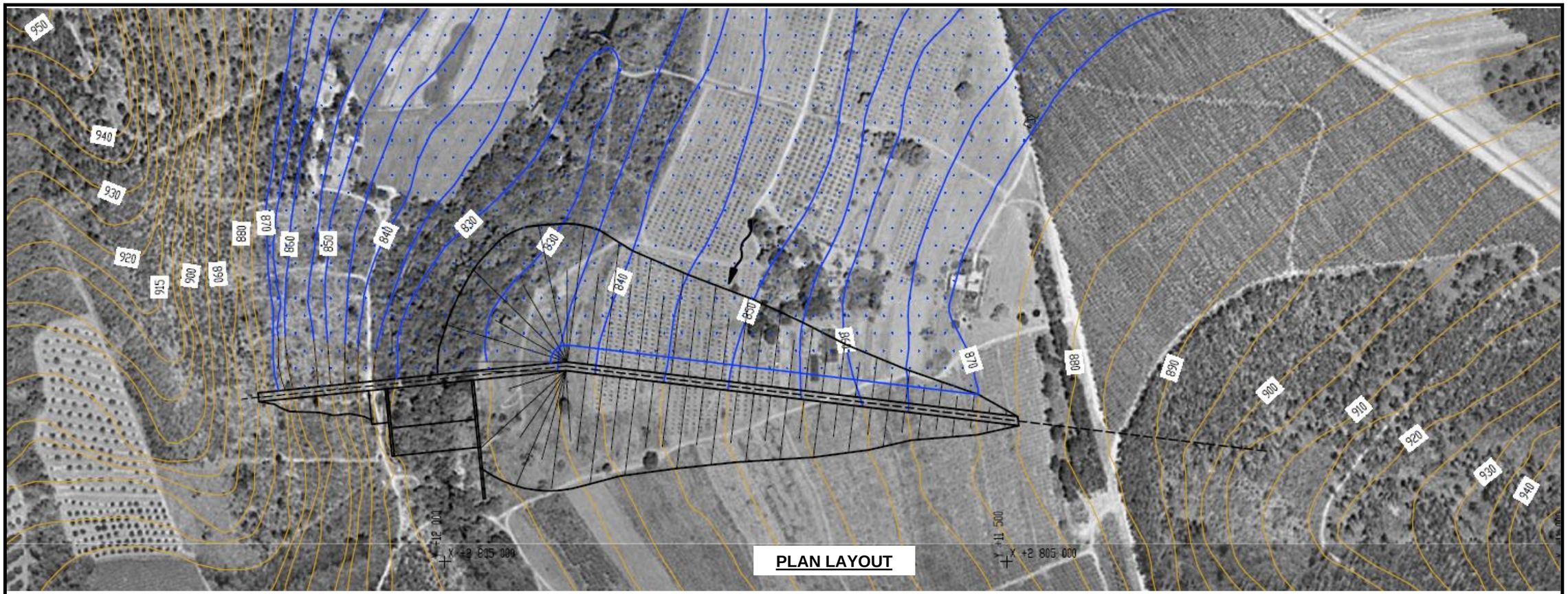
APPENDICES

APPENDIX A

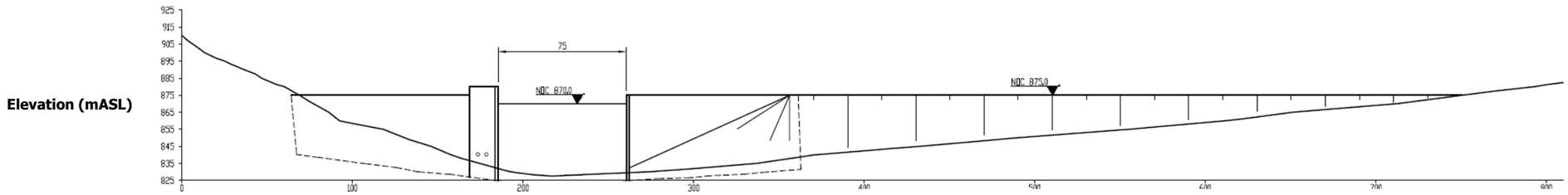
APPENDIX A1: BOSCHJESKOP DAM



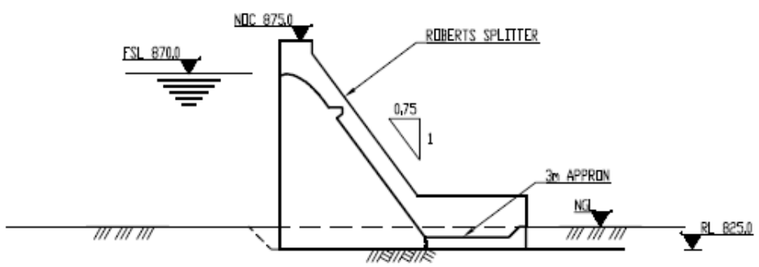
Boschjeskop Dam: Plan of Basin



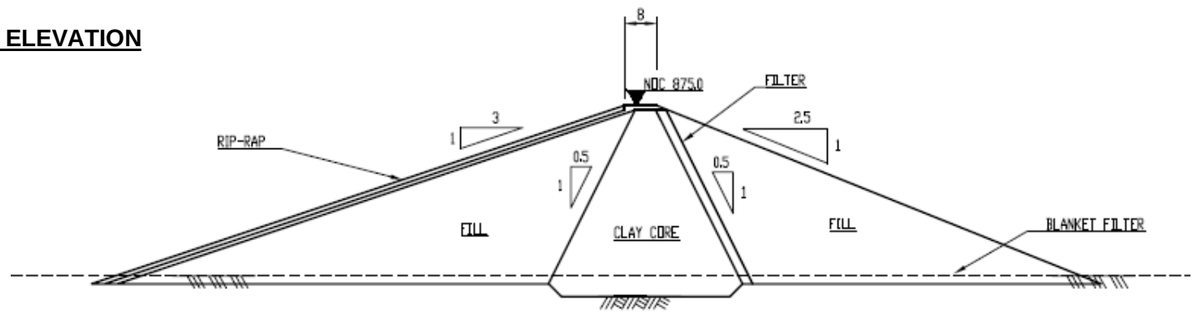
PLAN LAYOUT



DOWNSTREAM ELEVATION



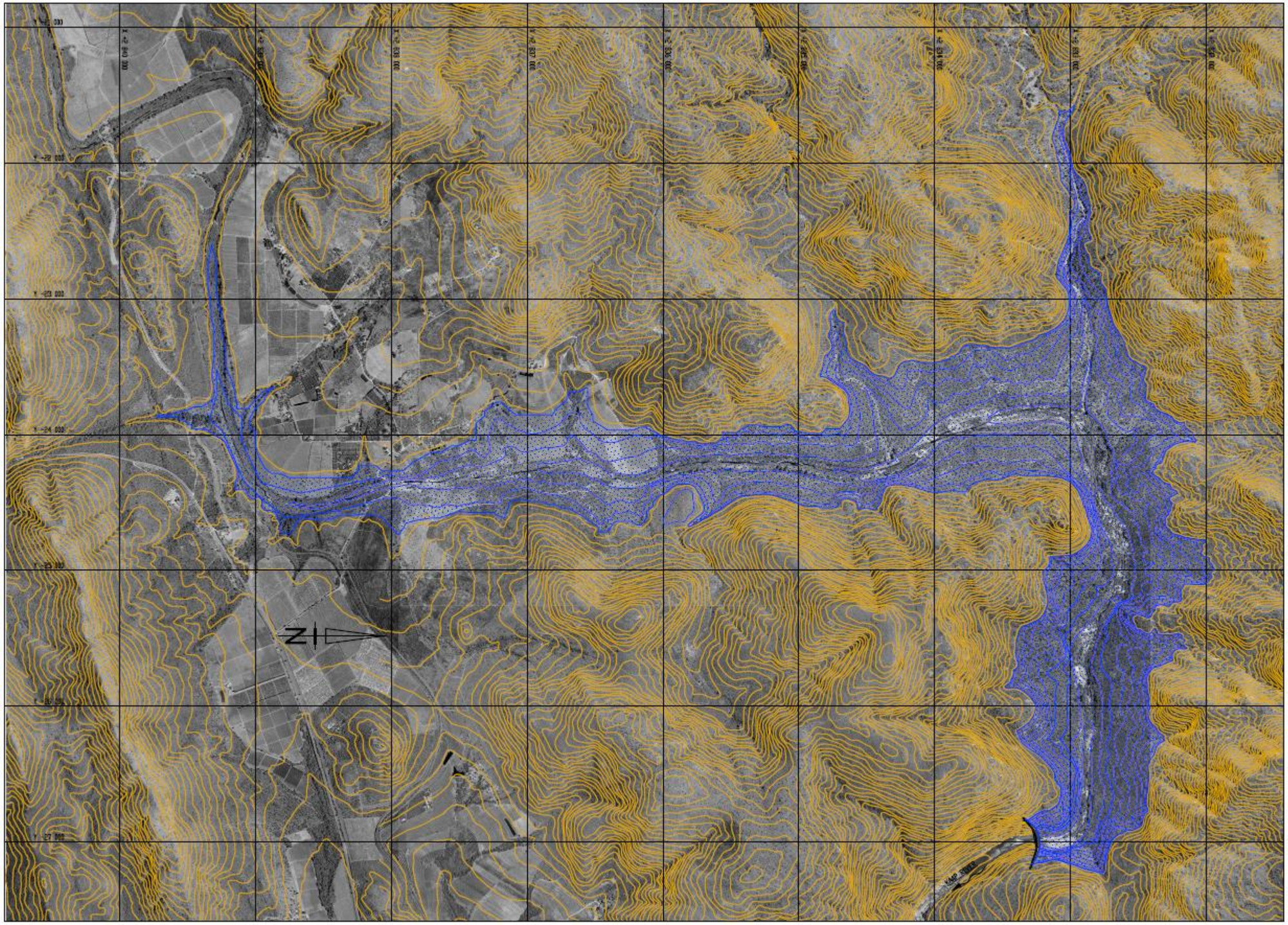
TYPICAL SECTION THROUGH OVERSPILL CREST



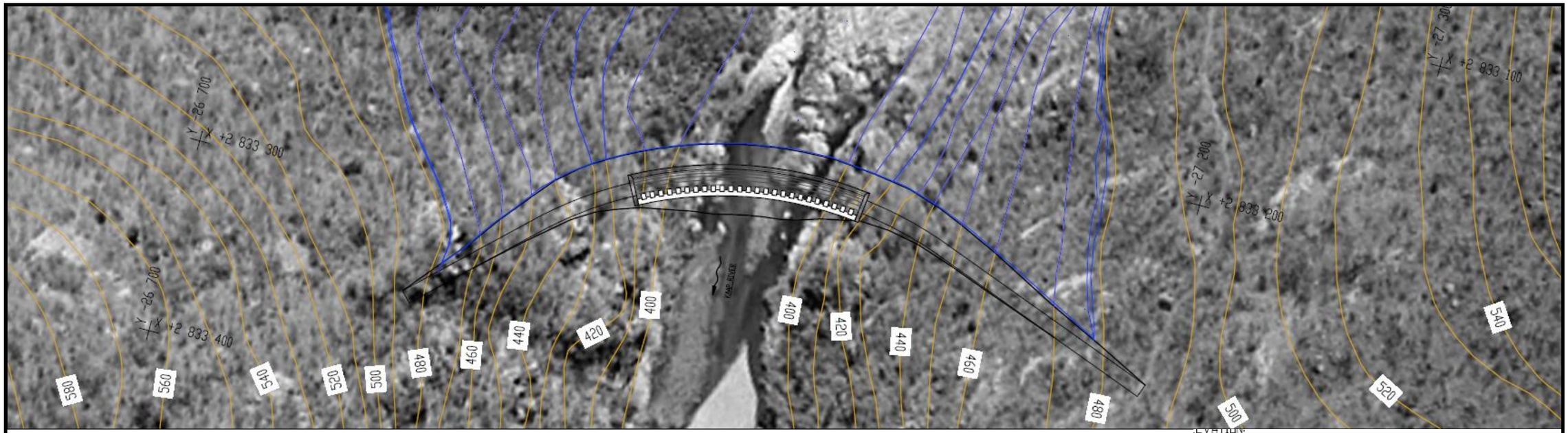
TYPICAL SECTION THROUGH NON-OVERSPILL CREST

Boschjeskop Dam: Plan and Details

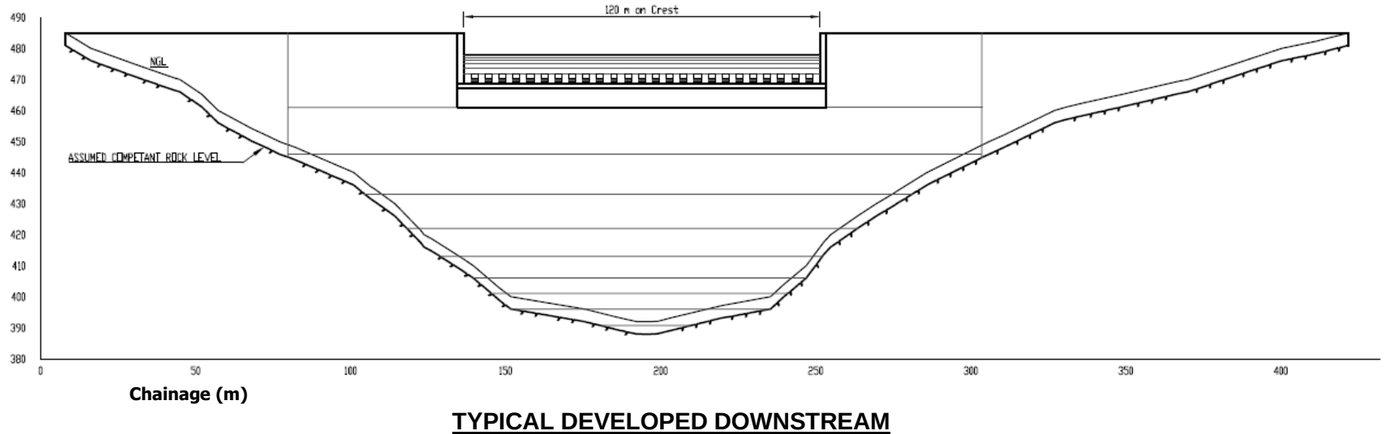
APPENDIX A2: MOUNTAIN VIEW DAM



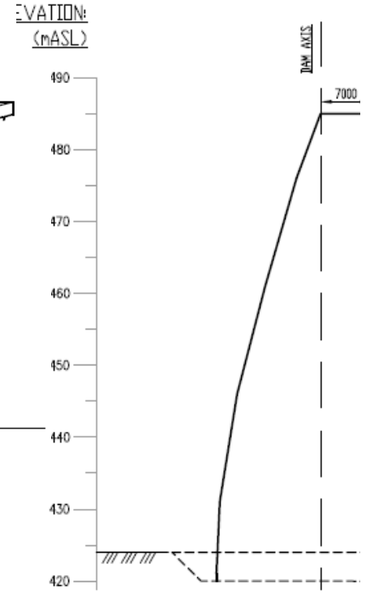
Mountain View Dam: Plan of Basin



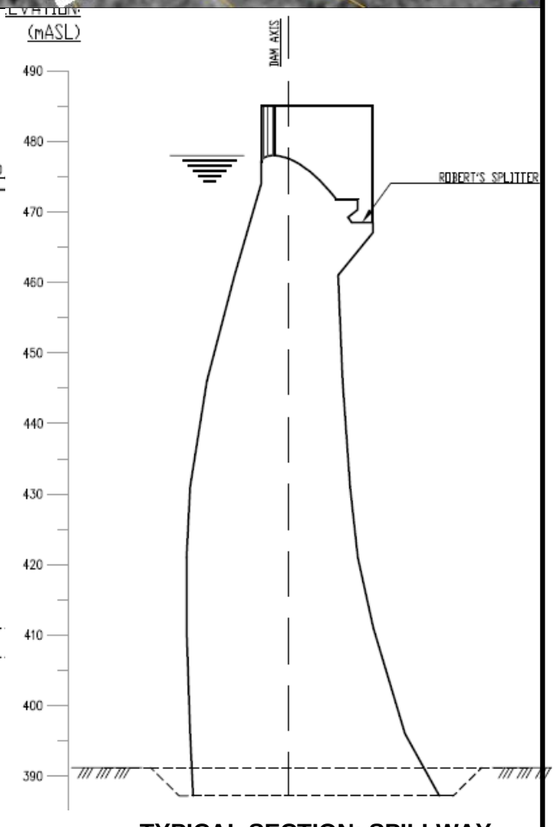
PLAN LAYOUT



TYPICAL DEVELOPED DOWNSTREAM ELEVATION ALONG DOWNSTREAM CREST



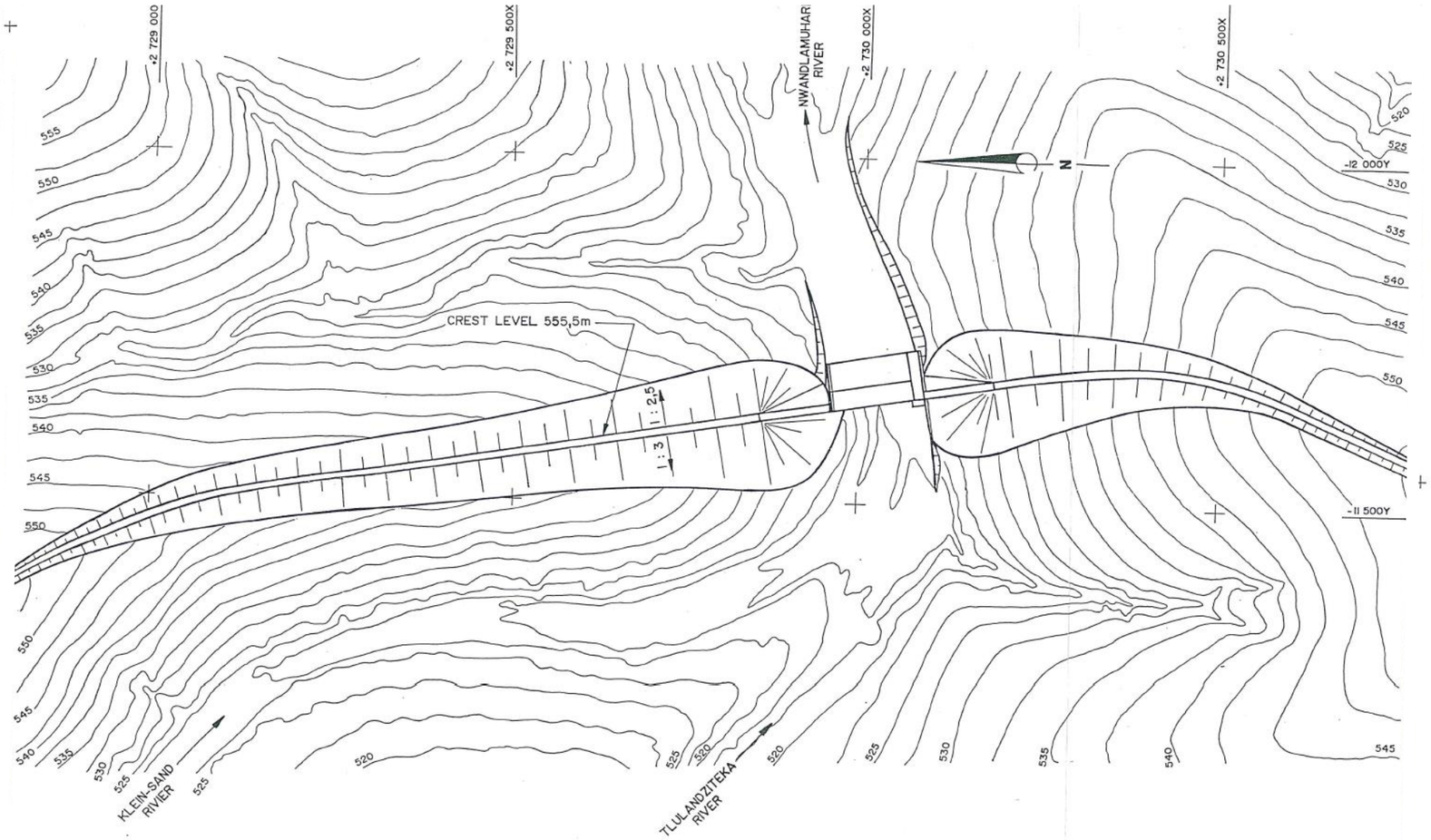
TYPICAL SECTION: NON-OVERSPILL CREST



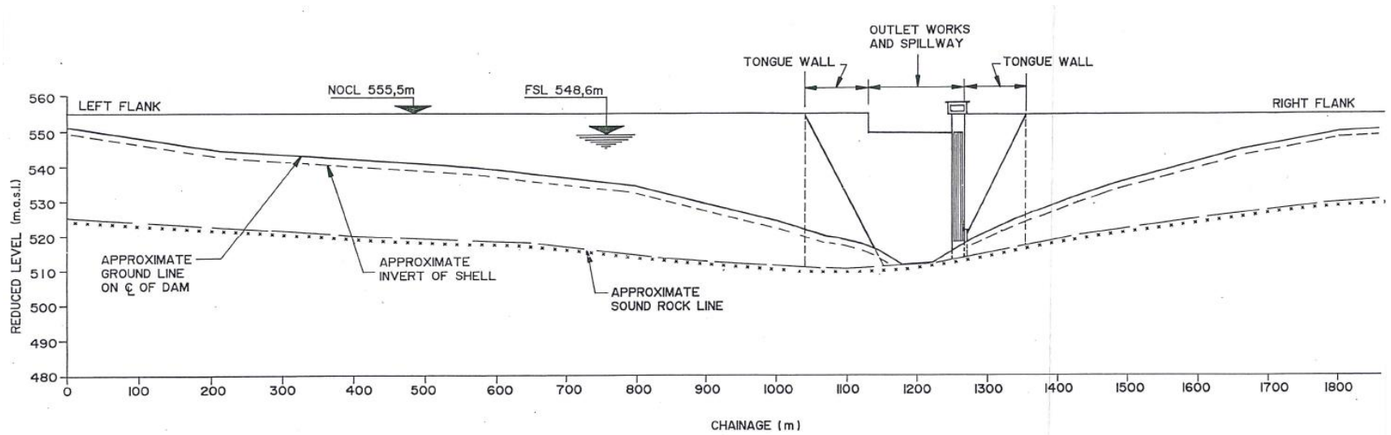
TYPICAL SECTION: SPILLWAY

Mountain View Dam: Plan and Details

APPENDIX A3: DINGLEYDALE DAM

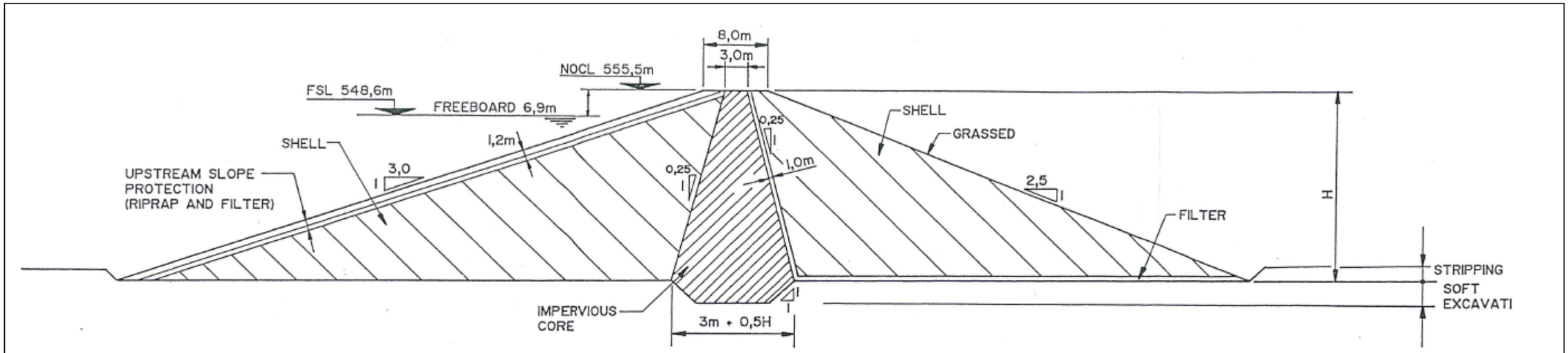


PLAN LAYOUT

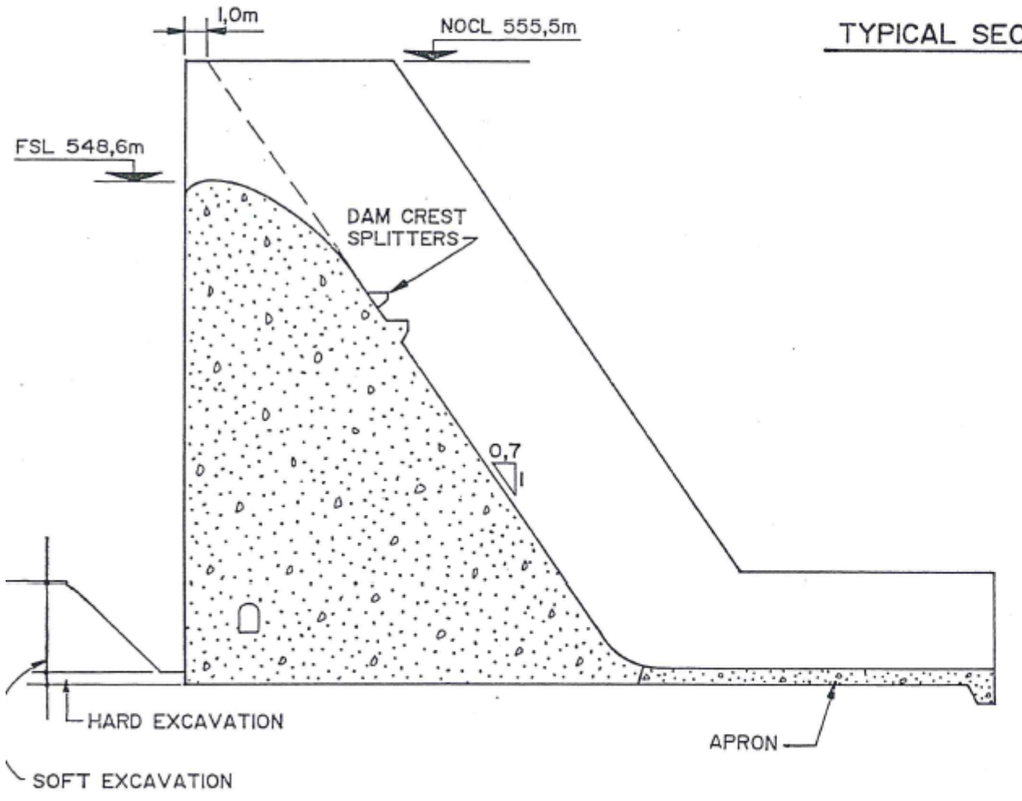


UPSTREAM ELEVATION

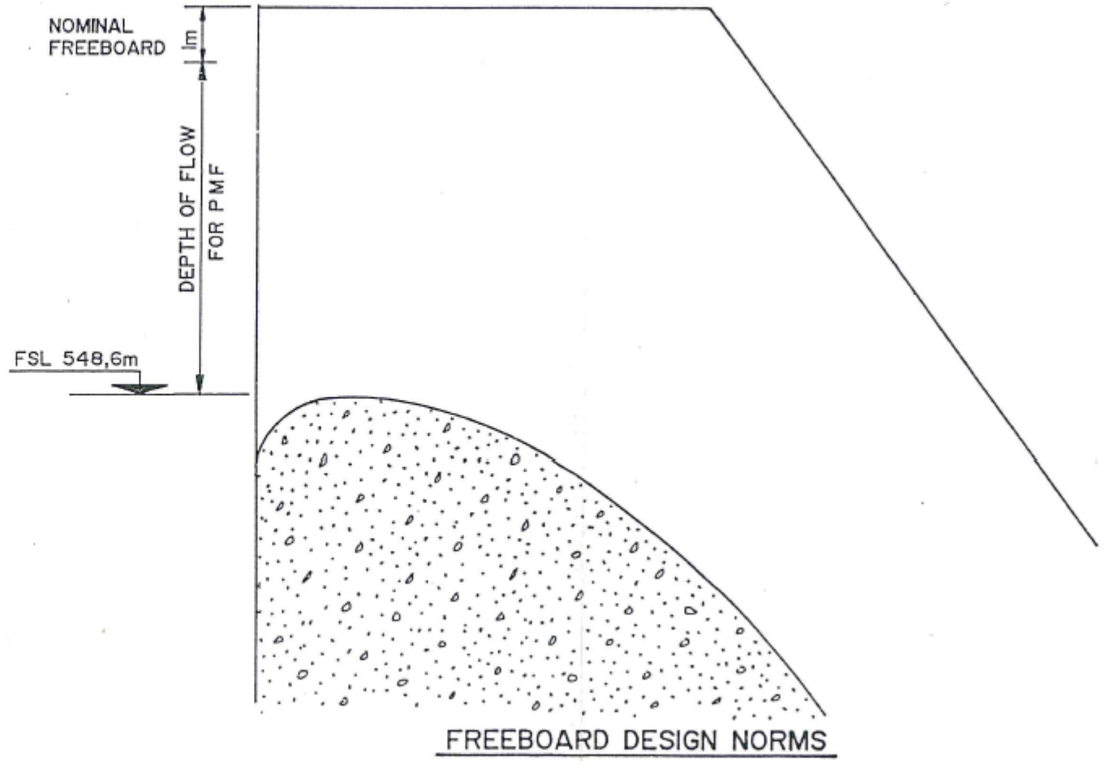
Dingleydale Dam: Plan and Details



TYPICAL SECTION THROUGH EMBANKMENT



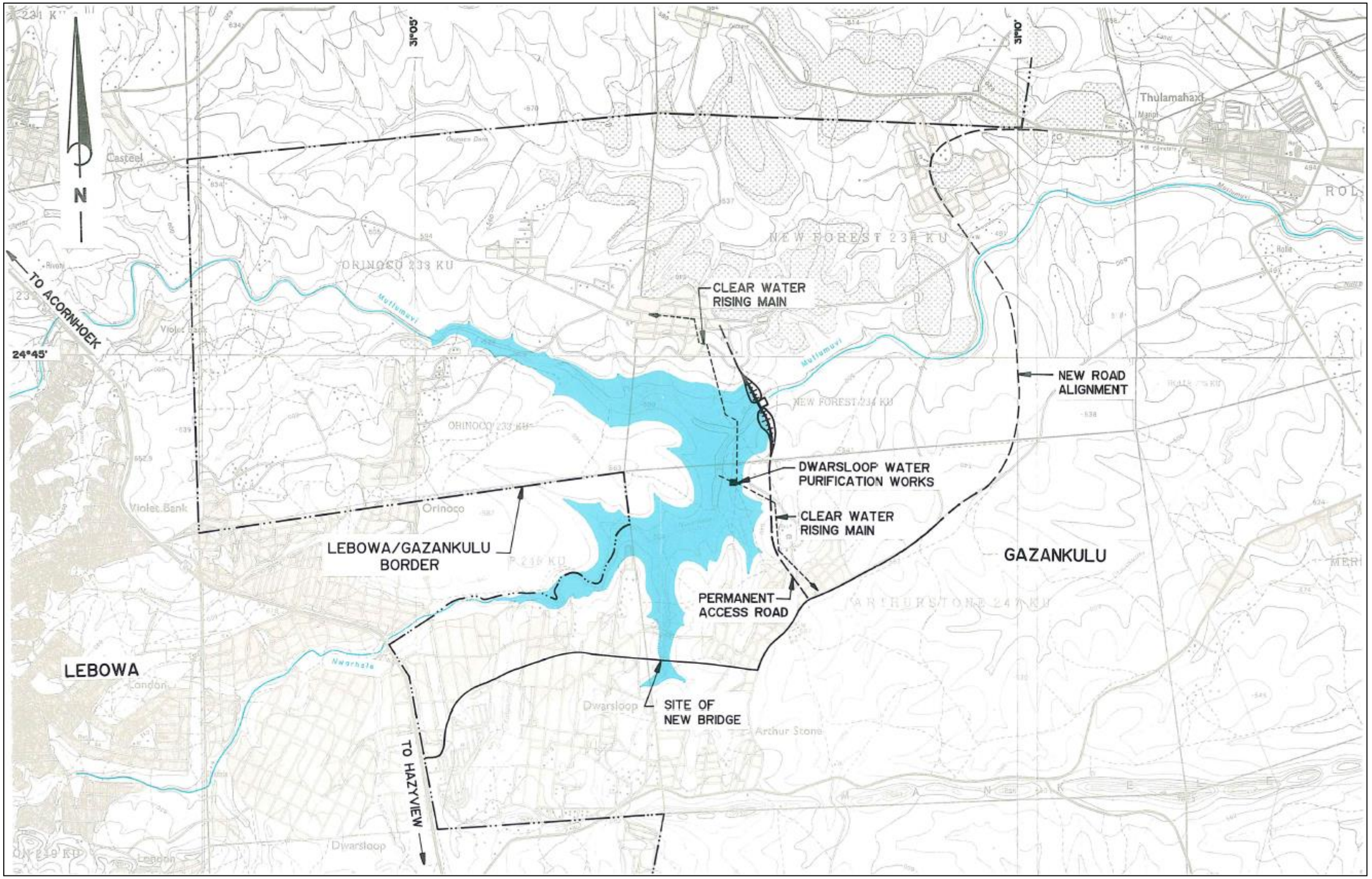
TYPICAL SECTION THROUGH CENTRAL SPILLWAY



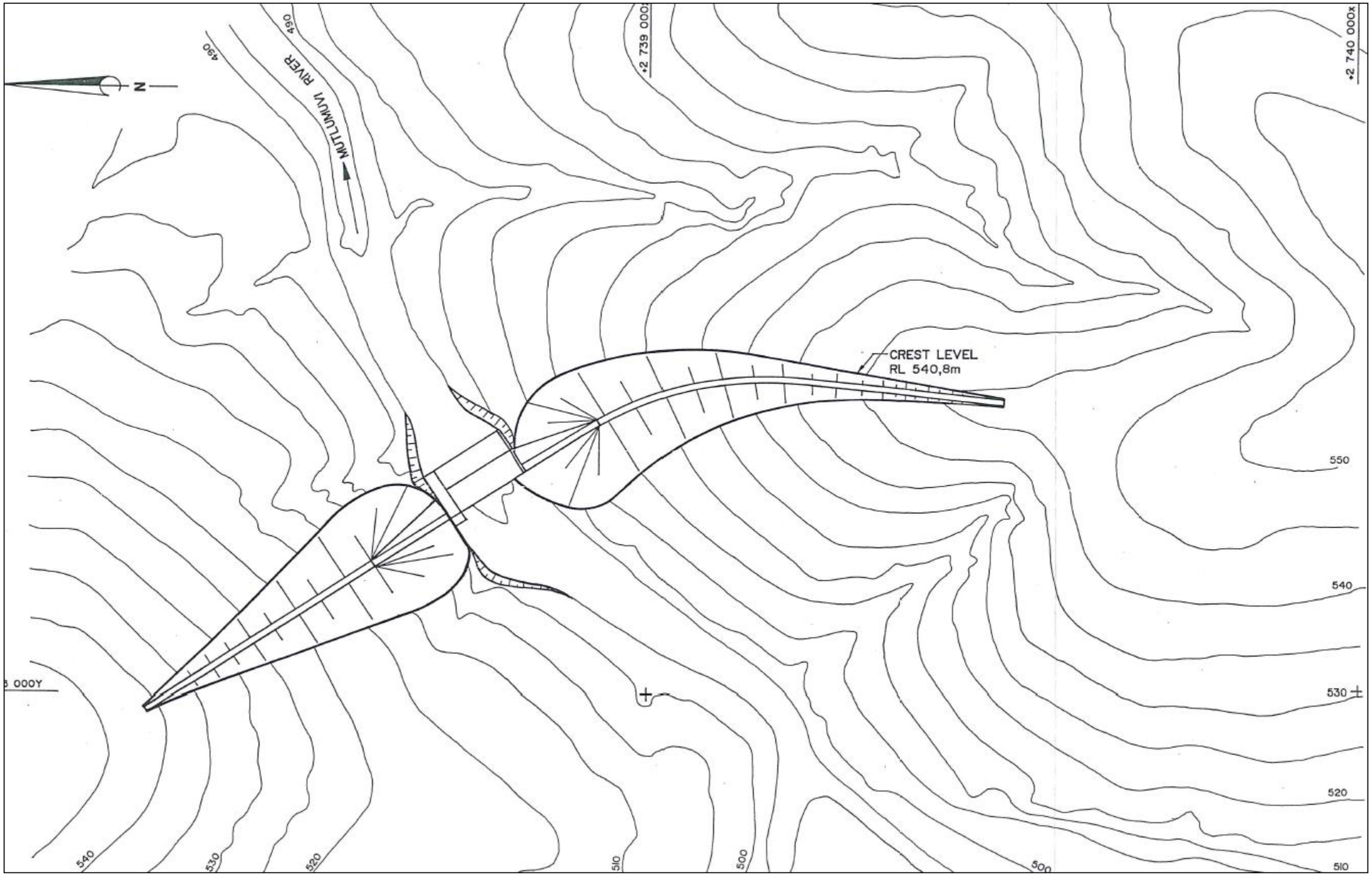
FREEBOARD DESIGN NORMS

Dingleydale Dam: Plan and Details

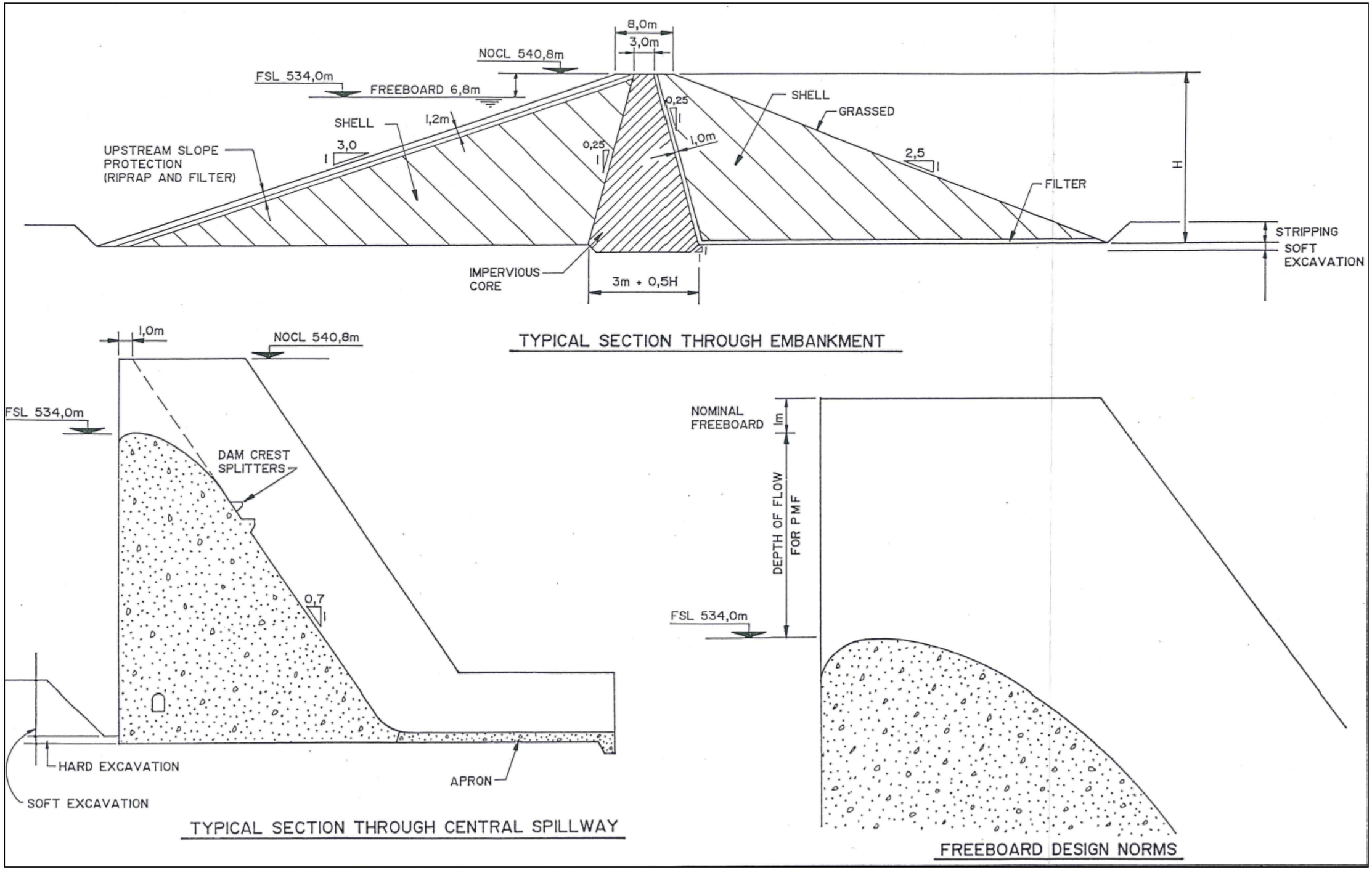
APPENDIX A4: NEW FOREST DAM



New Forest Dam: Plan Layout



New Forest Dam: Plan View



New Forest Dam: Details

APPENDIX B

SOUTH AFRICAN CPI HISTORY (Statistics South Africa (STATSSA) Data - Table B2 available at www.statssa.gov.za)

YEAR	CPI FOR THE YEAR	ACCUMULATIVE ESCALATION FROM YEAR TO YEAR																																						
		1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
1982	14.70																																							
1983	12.40	14.7																																						
1984	11.60	28.9	12.4																																					
1985	16.10	43.9	25.4	11.6																																				
1986	18.70	67.0	45.6	29.6	16.1																																			
1987	16.10	98.3	72.9	53.8	37.8	18.7																																		
1988	12.90	130.2	100.7	78.6	60.0	37.8	16.1																																	
1989	14.70	159.9	126.6	101.6	80.6	55.6	31.1	12.9																																
1990	14.40	198.1	159.9	131.2	107.2	78.5	50.3	29.5	14.7																															
1991	15.30	241.0	197.3	164.5	137.0	104.2	72.0	48.1	31.2	14.4																														
1992	13.90	293.2	242.8	205.0	173.3	135.4	98.3	70.8	51.3	31.9	15.3																													
1993	9.70	347.9	290.5	247.4	211.3	168.1	125.9	94.6	72.3	50.2	31.3	13.9																												
1994	9.00	391.3	328.3	281.1	241.5	194.1	147.8	113.4	89.0	64.8	44.1	24.9	9.7																											
1995	8.70	435.5	366.9	315.4	272.2	220.6	170.1	132.6	106.1	79.6	57.0	36.2	19.6	9.0																										
1996	7.40	482.1	407.5	351.5	304.6	248.5	193.6	152.9	124.0	95.3	70.7	48.0	30.0	18.5	8.7																									
1997	8.60	525.2	445.1	384.9	334.5	274.3	215.3	171.6	140.6	109.7	83.3	59.0	39.6	27.3	16.7	7.4																								
1998	6.90	579.0	491.9	426.6	371.9	306.5	242.4	194.9	161.2	127.8	99.1	72.7	51.6	38.2	26.8	16.6	8.6																							
1999	5.10	625.8	532.8	463.0	404.5	334.5	266.1	215.3	179.3	143.5	112.8	84.6	62.1	47.7	35.5	24.7	16.1	6.9																						
2000	5.30	662.8	565.1	491.7	430.2	356.7	284.7	231.4	193.5	155.9	123.7	94.0	70.3	55.3	42.4	31.0	22.0	12.4	5.1																					
2001	5.70	703.3	600.3	523.0	458.3	380.9	305.1	248.9	209.1	169.5	135.5	104.3	79.4	63.5	50.0	38.0	28.5	18.3	10.7	5.3																				
2002	9.20	749.0	640.2	558.6	490.1	408.3	328.2	268.8	226.7	184.8	149.0	115.9	89.6	72.8	58.5	45.9	35.8	25.1	17.0	11.3	5.7																			
2003	5.80	827.1	708.3	619.1	544.4	455.0	367.6	302.8	256.7	211.0	171.9	135.8	107.0	88.7	73.1	59.3	48.3	36.6	27.7	21.5	15.4	9.2																		
2004	1.40	880.9	755.2	660.9	581.8	487.2	394.7	326.1	277.4	229.1	187.6	149.5	119.0	99.7	83.2	68.5	56.9	44.5	35.1	28.6	22.1	15.5	5.8																	
2005	3.40	894.7	767.2	671.5	591.3	495.5	401.6	332.1	282.7	233.7	191.7	153.0	122.1	102.5	85.7	70.9	59.1	46.5	37.0	30.4	23.8	17.2	7.3	1.4																
2006	4.70	928.5	796.7	697.7	614.8	515.7	418.7	346.8	295.7	245.0	201.6	161.6	129.6	109.3	92.0	76.7	64.5	51.5	41.7	34.8	28.0	21.1	10.9	4.8	3.4															
2007	7.10	976.8	838.8	735.2	648.4	544.6	443.1	367.8	314.3	261.2	215.8	173.9	140.4	119.2	101.1	85.0	72.2	58.6	48.4	41.2	34.1	26.8	16.1	9.8	8.3	4.7														
2008	11.50	1053.3	905.5	794.5	701.6	590.4	481.6	401.0	343.7	286.9	238.2	193.3	157.5	134.7	115.4	98.1	84.5	69.9	58.9	51.2	43.6	35.8	24.4	17.6	15.9	12.1	7.1													
2009	7.10	1185.9	1021.1	897.4	793.7	669.8	548.5	458.6	394.8	331.4	277.1	227.0	187.1	161.7	140.1	120.9	105.7	89.4	77.2	68.6	60.1	51.5	38.7	31.1	29.3	25.0	19.4	11.5												
2010	4.30	1277.2	1100.7	968.2	857.2	724.5	594.6	498.3	429.9	362.0	303.8	250.2	207.5	180.3	157.2	136.6	120.3	102.8	89.7	80.5	71.5	62.2	48.5	40.4	38.5	33.9	27.9	19.4	7.1										
2011	5.00	1336.4	1152.3	1014.2	898.4	759.9	624.4	524.0	452.7	381.8	321.2	265.3	220.7	192.4	168.2	146.8	129.8	111.6	97.9	88.3	78.8	69.2	54.9	46.4	44.4	39.7	33.4	24.6	11.7	4.3									
2012	5.60	1408.2	1214.9	1069.9	948.3	802.9	660.7	555.2	480.3	405.9	342.3	283.6	236.8	207.0	181.6	159.1	141.2	122.1	107.8	97.7	87.8	77.6	62.7	53.8	51.6	46.6	40.1	30.8	17.3	9.5	5.0								
2013	5.70	1492.7	1288.6	1135.4	1007.0	853.5	703.3	591.9	512.8	434.3	367.0	305.1	255.6	224.2	197.4	173.6	154.8	134.6	119.4	108.8	98.3	87.6	71.8	62.4	60.1	54.9	47.9	38.1	23.9	15.6	10.9	5.6							
2014	6.10	1583.5	1367.7	1205.8	1070.1	907.8	749.0	631.3	547.7	464.7	393.6	328.1	275.9	242.7	214.4	189.2	169.3	147.9	131.9	120.7	109.6	98.3	81.6	71.6	69.3	63.7	56.3	46.0	30.9	22.2	17.2	11.6	5.7						
2015	4.60	1686.2	1457.2	1285.5	1141.4	969.3	800.8	675.9	587.3	499.2	423.8	354.3	298.8	263.6	233.5	206.8	185.7	163.1	146.1	134.2	122.4	110.4	92.7	82.1	79.6	73.7	65.9	54.9	38.9	29.7	24.3	18.4	12.1	6.1					
2016	6.40	1768.3	1528.9	1349.2	1198.6	1018.5	842.3	711.6	618.9	526.7	447.8	375.2	317.2	280.3	248.9	221.0	198.8	175.2	157.4	144.9	132.6	120.1	101.5	90.5	87.8	81.7	73.5	62.0	45.3	35.7	30.1	23.9	17.3	11.0	4.6				
2017	5.3	1887.9	1633.1	1441.9	1281.7	1090.1	902.6	763.5	664.9	566.8	482.9	405.6	343.9	304.6	271.2	241.5	218.0	192.8	173.9	160.6	147.5	134.1	114.4	102.7	99.9	93.3	84.6	72.4	54.6	44.3	38.4	31.8	24.8	18.1	11.3	6.4		
2018	4.70	1993.3	1725.0	1523.7	1354.9	1153.1	955.7	809.3	705.4	602.2	513.8	432.4	367.4	326.1	290.9	259.6	234.8	208.3	188.4	174.4	160.6	146.5	125.8	113.4	110.5	103.5	94.4	81.5	62.8	52.0	45.7	38.8	31.4	24.3	17.2	12.0	5.3	
2019	4.1	2091.6	1810.8	1600.0	1423.3	1212.0	1005.3	852.1	743.3	635.2	542.7	457.4	389.4	346.1	309.3	276.5	250.6	222.8	202.0	187.3	172.8	158.1	136.4	123.4	120.3	113.1	103.5	90.0	70.4	59.1	52.6	45.3	37.6	30.2	22.7	17.3	10.2	4.7	

APPENDIX C

APPENDIX C1: BOSCHJESKOP DAM

Boschjeskop Dam: Cost Estimates
Full Supply Level Capacity: 130.5 Mm³
Dam Wall Height: 50 m

Item No.	Description	Unit	Quantity	Unit Cost/Rate 2013	Escalation Factor 2013 to 2020	Escalated Rate Aug 2020	Amount
1	Clearing						
	(a) sparse	ha	51	R20,000.00	1.376	R27,520.00	R1,403,520.00
	(b) brush	ha	51	R30,000.00	1.376	R41,280.00	R2,105,280.00
	(c) trees	ha	465	R40,000.00	1.376	R55,040.00	R25,593,600.00
2	River Diversion	Sum	1	R6,000,000.00	1.376	R8,256,000.00	R8,256,000.00
3	Excavation						
	(a) Bulk						
	(i) all materials	m³	78073	R55.00	1.376	R75.68	R5,908,564.64
	(ii) extra over for rock	m³	3904	R140.00	1.376	R192.64	R752,066.56
4	Preparation of Solum						
	(i) all materials	m²	14165	R20.00	1.376	R27.52	R389,820.80
	(ii) extra over for rock	m²	2125	R20.00	1.376	R27.52	R58,480.00
5	Drilling and Grouting						
	(a) curtain grouting	m drill	2670	R800.00	1.376	R1,100.80	R2,939,136.00
	(b) consolidation grouting	m drill	5902	R800.00	1.376	R1,100.80	R6,496,921.60
6	Embankment						
	(a) Earthfill	m³	869664	R48.00	1.376	R66.05	R57,439,567.87
	(b) Filters	m³	88934	R176.00	1.376	R242.18	R21,537,680.38
	(c) Rip-rap	m³	39089	R96.00	1.376	R132.10	R5,163,500.54
	(d) Overhaul beyond	m³-km	44467	R4.00	1.376	R5.50	R244,746.37
7	Concrete Works						
	(a) Formwork						
	(i) Gang formed	m²	26345	R260.00	1.376	R357.76	R9,425,187.20
	(ii) Intricate	m²					
	(b) Concrete						
	(i) Mass	m³	168029	R1,400.00	1.376	R1,926.40	R323,691,065.60
	(ii) Structural	m³					
	(iii) Rollcrete	m³					
	(c) Reinforcing	t	5036	R11,000.00	1.376	R15,136.00	R76,224,896.00
8	Mechanical Items						
	(a) Valves and Gates	Sum	1	R8,000,000.00	1.376	R11,008,000.00	R11,008,000.00
	(b) Cranes & Hosts	Sum	1	R2,000,000.00	1.376	R2,752,000.00	R2,752,000.00
	(c) Structural Steel	t	100	R20,000.00	1.376	R27,520.00	R2,752,000.00
9	Fencing	km	10	R28,000.00	1.376	R38,528.00	R385,280.00
10	Landscaping (% of Items 1 to 9)	%	5				R28,226,365.68
11	Miscellaneous (% of Items 1 to 9)	%	10				R56,452,731.36
	SUB TOTAL A						**R649,206,410.60**
12	Preliminary and General (% of Sub Total A)	%	30				R194,761,923.18
13	Preliminary Works						
	(a) Access road	km	10	R500,000.00	1.376	R688,000.00	R6,880,000.00
	(b) Electricity	Sum	1	R5,000,000.00	1.376	R6,880,000.00	R6,880,000.00
	(c) Construction water	Sum	1	R1,000,000.00	1.376	R1,376,000.00	R1,376,000.00
	(d) Railhead and Materials Handling	Sum	1	R1,000,000.00	1.376	R1,376,000.00	R1,376,000.00

Boschjeskop Dam: Cost Estimates
Full Supply Level Capacity: 130.5 Mm³
Dam Wall Height: 50 m

Item No.	Description	Unit	Quantity	Unit Cost/Rate 2013	Escalation Factor 2013 to 2020	Escalated Rate Aug 2020	Amount
14	Accommodation	Sum	1	R6,000,000.00	1.376	R8,256,000.00	R8,256,000.00
	SUB TOTAL B						**R868,736,333.78**
15	Contingencies (% of Sub Total B)	%	10				R86,873,633.38
	SUB TOTAL C						**R955,609,967.16**
16	Planning, Design and Supervision (% of Sub Total C)	%	15				R143,341,495.07
17	Social and Environmental (% of Sub Total C)	%	1				R9,556,099.67
	SUB TOTAL D						**R1,108,507,561.91**
18	Cost of Relocations	Sum	1	R2,000,000.00	1.376	R2,752,000.00	R2,752,000.00
19	Cost of Land Acquisition	Sum	1	R1,018,291.00	1.376	R1,401,168.42	R1,401,168.42
19	Infrastructure Costs	Sum	1	R5,286,000.00	1.376	R7,273,536.00	R7,273,536.00
	TOTAL PROJECT COST						**R1,119,934,266.32**

APPENDIX C2: MOUNTAIN VIEW DAM

Mountain View Dam: Cost Estimates
Full Supply Capacity: 184.8 Mm³
Dam Wall Height: 74 m

Item No.	Description	Unit	Quantity	Unit Cost/Rate 2013	Escalation Factor 2013 to 2020	Escalated Rate Aug 2020	Amount
1	Clearing						
	(a) sparse	ha	10	R20,000.00	1.376	R27,520.00	R275,200.00
	(b) brush	ha	10	R30,000.00	1.376	R41,280.00	R412,800.00
	(c) trees	ha	849	R40,000.00	1.376	R55,040.00	R46,728,960.00
2	River Diversion	Sum	1	R6,000,000.00	1.376	R8,256,000.00	R8,256,000.00
3	Excavation						
	(a) Bulk						
	(i) all materials	m³	741	R55.00	1.376	R75.68	R56,078.88
	(ii) extra over for rock	m³	37	R140.00	1.376	R192.64	R7,127.68
4	Preparation of Solum						
	(i) all materials	m²	3172	R20.00	1.376	R27.52	R87,293.44
	(ii) extra over for rock	m²	476	R20.00	1.376	R27.52	R13,099.52
5	Drilling and Grouting						
	(a) curtain grouting	m drill		R800.00	1.376	R1,100.80	
	(b) consolidation grouting	m drill	1322	R800.00	1.376	R1,100.80	R1,455,257.60
6	Embankment						
	(a) Earthfill	m³					
	(b) Filters	m³					
	(c) Rip-rap	m³					
	(d) Overhaul beyond	m³-km					
7	Concrete Works						
	(a) Formwork						
	(i) Gang formed	m²	6706	R260.00	1.376	R357.76	R2,399,138.56
	(ii) Intricate	m²					
	(b) Concrete						
	(i) Mass	m³					
	(ii) Structural	m³					
	(iii) Rollcrete	m³	188530	R1,100.00	1.376	R1,513.60	R285,359,008.00
	(c) Reinforcing	t					
	(d) Facecrete incl. water stop	m³	25417	R1,200.00	1.376	R1,651.20	R41,968,550.40
8	Mechanical Items						
	(a) Valves and Gates	Sum	1	R12,000,000.00	1.376	R16,512,000.00	R16,512,000.00
	(b) cranes & hosts	Sum	1	R5,000,000.00	1.376	R6,880,000.00	R6,880,000.00
	(c) structural steel	t	100	R20,000.00	1.376	R27,520.00	R2,752,000.00
9	Fencing	km	10	R28,000.00	1.376	R38,528.00	R385,280.00
10	Landscaping (% of Items 1 to 9)	%	5				R20,677,389.70
11	Miscellaneous (% of Items 1 to 9)	%	10				R41,354,779.41
	SUB TOTAL A						**R475,579,963.19**
12	Preliminary and General (% of Sub Total A)	%	30				R142,673,988.96
13	Preliminary Works						
	(a) Access road	km	10	R500,000.00	1.376	R688,000.00	R6,880,000.00
	(b) Electricity	Sum	1	R5,000,000.00	1.376	R6,880,000.00	R6,880,000.00
	(c) Construction water	Sum	1	R1,000,000.00	1.376	R1,376,000.00	R1,376,000.00
	(d) Railhead and Materials Handling	Sum	1	R1,000,000.00	1.376	R1,376,000.00	R1,376,000.00
14	Accommodation	Sum	1	R6,000,000.00	1.376	R8,256,000.00	R8,256,000.00
	SUB TOTAL B						**R643,021,952.15**

Mountain View Dam: Cost Estimates
Full Supply Capacity: 184.8 Mm³
Dam Wall Height: 74 m

Item No.	Description	Unit	Quantity	Unit Cost/Rate 2013	Escalation Factor 2013 to 2020	Escalated Rate Aug 2020	Amount
15	Contingencies (% of Sub Total B)	%	10				R64,302,195.21
	SUB TOTAL C						**R707,324,147.36**
16	Planning, Design and Supervision (% of Sub Total C)	%	15				R106,098,622.10
17	Social and Environmental (% of Sub Total C)	%	1				R7,073,241.47
	SUB TOTAL D						**R820,496,010.94**
18	Cost of Relocations	Sum	1	R2,000,000.00	1.376	R2,752,000.00	R2,752,000.00
19	Cost of Land Acquisition	Sum	1	R1,247,960.00	1.376	R1,717,192.96	R1,717,192.96
19	Infrastructure Costs	Sum	1	R35,216,000.00	1.376	R48,457,216.00	R48,457,216.00
	TOTAL PROJECT COST						**R873,422,419.90**

APPENDIX C3: DINGLEYDALE DAM

Dingleydale Dam & Associated Infrastructure: Cost Estimates
Full Supply Capacity: 62.5 Mm³
Dam Wall Height: 35 m

Item No.	Description	Unit	Quantity	Unit Cost/Rate 2013	Unit Cost/Rate 1989	Escalation Factor 2013 to 2020	Escalation Factor 1989 to 2020	Escalated Rate Aug 2020	Amount
	Dam								
1	Clearing								
	(a) sparse	ha	100	R20,000.00		1.376		R27,520.00	R2,752,000.00
	(b) brush	ha	100	R30,000.00		1.376		R41,280.00	R4,128,000.00
	(c) trees	ha	600	R40,000.00		1.376		R55,040.00	R33,024,000.00
2	River Diversion	Sum	1	R6,000,000.00		1.376		R8,256,000.00	R8,256,000.00
3	Excavation								
	(a) Bulk								
	(i) all materials	m³	374190	R55.00		1.376		R75.68	R28,318,699.20
	(ii) extra over for rock	m³	11780	R140.00		1.376		R192.64	R2,269,299.20
	(b) Confined								
	(i) all materials	m³							
	(ii) extra over for rock	m³							
4	Preparation of Solum								
	(i) all materials	m²							
	(ii) extra over for rock	m²							
5	Drilling and Grouting								
	(a) curtain grouting	m drill	10500	R800.00		1.376		R1,100.80	R11,558,400.00
	(b) consolidation grouting	m drill							
6	Embankment								
	(a) Earthfill	m³	1078700	R48.00		1.376		R66.05	R71,245,977.60
	(b) Filters	m³	70540	R176.00		1.376		R242.18	R17,083,095.04
	(c) Rip-rap	m³							
	(d) Overhaul beyond	m³-km							
	(e) Core	m³	178450		R9.90		7.433	R73.59	R13,131,546.62
	(f) Upstream slope protection	m³	96400		R71.10		7.433	R528.49	R50,946,079.32
	(g) Downstream slope protection	m³	70670		R4.00		7.433	R29.73	R2,101,160.44
	(h) Special preparation of core trench	Sum	1		R50,300.00		7.433	R373,879.90	R373,879.90
7	Concrete Works								
	(a) Formwork								
	(i) Gang formed	m²							
	(ii) Intricate	m²							
	(b) Concrete								
	(i) Mass	m³	204680	R1,400.00		1.376		R1,926.40	R394,295,552.00
	(ii) Structural	m³	9100		R273.00		7.433	R2,029.21	R18,465,801.90
	(iii) Rollcrete	m³							
	(c) Reinforcing	t							
8	Mechanical Items								
	(a) Valves and Gates	Sum	1	R8,000,000.00		1.376		R11,008,000.00	R11,008,000.00
	(b) Cranes & Hosts	Sum							
	(c) Structural Steel	t	100	R20,000.00		1.376		R27,520.00	R2,752,000.00
9	Fencing	km	35	R28,000.00		1.376		R38,528.00	R1,348,480.00
10	**Water Treatment Works (84.65 Mℓ/day)**	Sum	1					R508,746,500.00	R508,746,500.00
11	**Pump Station (1156 kW Total Head 240.55 m Flow Rate 489.92 l/s)**								
	Civil & Pipes	Sum	1					R13,776,576.27	R13,776,576.27
	Mechanical & Electrical	Sum	1					R12,588,120.76	R12,588,120.76
12	**Pipelines**								
	Gravity Main to Thulamahashe - 700 ND	m	12600					R7,283.23	R91,768,692.74
	Rising Main to Acorn Hoek - 700 ND	m	17700					R7,283.23	R128,913,163.61
13	**Reservoir (56 Mℓ)**	Sum	2					R72,112,683.96	R144,225,367.91
14	Landscaping (% of Items 1 to 13)	%	5						R78,653,819.62
15	Miscellaneous (% of Items 1 to 13)	%	10						R157,307,639.25
	SUB TOTAL A								**R1,809,037,851.37**
16	Preliminary and General (% of Sub Total A)	%	30						R542,711,355.41
17	Preliminary Works								
	(a) Access road	km	2	R500,000.00		1.376		R688,000.00	R1,376,000.00
	(b) Electricity	Sum	1	R5,000,000.00		1.376		R6,880,000.00	R6,880,000.00
	(c) Construction water	Sum	1	R1,000,000.00		1.376		R1,376,000.00	R1,376,000.00
	(d) Railhead and Materials Handling	Sum	1	R1,000,000.00		1.376		R1,376,000.00	R1,376,000.00
18	Accommodation	Sum	1	R6,000,000.00		1.376		R8,256,000.00	R8,256,000.00
	SUB TOTAL B								**R2,371,013,206.78**
19	Contingencies (% of Sub Total B)	%	10						R237,101,320.68

Dingleydale Dam & Associated Infrastructure: Cost Estimates
Full Supply Capacity: 62.5 Mm³
Dam Wall Height: 35 m

Item No.	Description	Unit	Quantity	Unit Cost/Rate 2013	Unit Cost/Rate 1989	Escalation Factor 2013 to 2020	Escalation Factor 1989 to 2020	Escalated Rate Aug 2020	Amount
	SUB TOTAL C								**R2,608,114,527.45**
20	Planning, Design and Supervision (% of Sub Total C)	%	15						R391,217,179.12
21	Social and Environmental (% of Sub Total C)	%	1						R26,081,145.27
	SUB TOTAL D								**R3,025,412,851.85**
22	Cost of Relocations	Sum	1		R2,160,000.00	1.376	7.433	R16,055,280.00	R16,055,280.00
	Compensation:								
	Homesteads	No	2		R4,100.00		7.433	R30,475.30	R60,950.60
	Cultivated land	ha	70		R2,200.00		7.433	R16,352.60	R1,144,682.00
23	Cost of Land Acquisition	Sum	1		R743,900.00	1.376	7.433	R5,529,408.70	R5,529,408.70
24	Infrastructure Costs / Minor Works	Sum	0		R3,912,172.00	1.376	7.433	R29,079,174.48	R0.00
	TOTAL PROJECT COST								**R3,048,203,173.15**

APPENDIX C4: NEW FOREST DAM

New Forest Dam & Associated Infrastructure: Cost Estimates
Full Supply Capacity: 82 Mm³
Dam Wall Height: 42.2 m

Item No.	Description	Unit	Quantity	Unit Cost/Rate 2013	Unit Cost/Rate 1989	Escalation Factor 2013 to 2020	Escalation Factor 1989 to 2020	Escalated Rate Aug 2020	Amount
	Dam								
1	Clearing								
	(a) sparse	ha	100	R20,000.00		1.376		R27,520.00	R2,752,000.00
	(b) brush	ha	100	R30,000.00		1.376		R41,280.00	R4,128,000.00
	(c) trees	ha	620	R40,000.00		1.376		R55,040.00	R34,124,800.00
2	River Diversion	Sum	1	R6,000,000.00		1.376		R8,256,000.00	R8,256,000.00
3	Excavation								
	(a) Bulk								
	(i) all materials	m³	368550	R55.00		1.376		R75.68	R27,891,864.00
	(ii) extra over for rock	m³	14460	R140.00		1.376		R192.64	R2,785,574.40
	(b) Confined								
	(i) all materials	m³							
	(ii) extra over for rock	m³							
4	Preparation of Solum								
	(i) all materials	m²							
	(ii) extra over for rock	m²							
5	Drilling and Grouting								
	(a) curtain grouting	m drill	10000	R800.00		1.376		R1,100.80	R11,008,000.00
	(b) consolidation grouting	m drill							
6	Embankment								
	(a) Earthfill	m³	1046810	R48.00		1.376		R66.05	R69,139,706.88
	(b) Filters	m³	45110	R176.00		1.376		R242.18	R10,924,559.36
	(c) Rip-rap	m³							
	(d) Overhaul beyond	m³-km							
	(e) Core	m³	128530		R9.90		7.433	R73.59	R9,458,098.55
	(f) Upstream slope protection	m³	74010		R71.10		7.433	R528.49	R39,113,271.06
	(g) Downstream slope protection	m³	55420		R4.00		7.433	R29.73	R1,647,747.44
	(h) Special preparation of core trench	Sum	1		R30,400.00		7.433	R225,963.20	R225,963.20
7	Concrete Works								
	(a) Formwork								
	(i) Gang formed	m²							
	(ii) Intricate	m²							
	(b) Concrete								
	(i) Mass	m³	308050	R1,400.00		1.376		R1,926.40	R593,427,520.00
	(ii) Structural	m³	5780		R273.00		7.433	R2,029.21	R11,728,828.02
	(iii) Rollcrete	m³							
	(c) Reinforcing	t							
8	Mechanical Items								
	(a) Valves and Gates	Sum	1	R8,000,000.00		1.376		R11,008,000.00	R11,008,000.00
	(b) Cranes & Hosts	Sum							
	(c) Structural Steel	t							
9	Fencing	km	40	R28,000.00		1.376		R38,528.00	R1,541,120.00
10	**Water Treatment Works (80.55 Mℓ/day)**	Sum	1					R484,105,500.00	R484,105,500.00
11	**Pump Station (1273 kW Total Head 278.38 m Flow Rate 466.13 l/s)**								
	Civil & Pipes	Sum	1					R15,170,918.33	R15,170,918.33
	Mechanical & Electrical	Sum	1					R13,862,177.96	R13,862,177.96
12	**Pipelines**								
	Gravity Main to Thulamahashe - 800 ND	m	11000					R9,365.05	R103,015,594.98
	Rising Main to Acorn Hoek - 700 ND	m	29700					R7,283.23	R216,311,918.59
13	**Reservoir (54 Mℓ)**	Sum	2					R69,537,230.96	R139,074,461.91
14	Landscaping (% of Items 1 to 13)	%	5						R90,535,081.23
15	Miscellaneous (% of Items 1 to 13)	%	10						R181,070,162.47
	SUB TOTAL A								**R2,082,306,868.40**
16	Preliminary and General (% of Sub Total A)	%	30						R624,692,060.52
17	Preliminary Works								
	(a) Access road	km	2	R500,000.00		1.376		R688,000.00	R1,376,000.00
	(b) Electricity	Sum	1	R5,000,000.00		1.376		R6,880,000.00	R6,880,000.00
	(c) Construction water	Sum	1	R1,000,000.00		1.376		R1,376,000.00	R1,376,000.00
	(d) Railhead and Materials Handling	Sum	1	R1,000,000.00		1.376		R1,376,000.00	R1,376,000.00
18	Accommodation	Sum	1	R6,000,000.00		1.376		R8,256,000.00	R8,256,000.00
	SUB TOTAL B								**R2,726,262,928.92**
19	Contingencies (% of Sub Total B)	%	10						R272,626,292.89

New Forest Dam & Associated Infrastructure: Cost Estimates
Full Supply Capacity: 82 Mm³
Dam Wall Height: 42.2 m

Item No.	Description	Unit	Quantity	Unit Cost/Rate 2013	Unit Cost/Rate 1989	Escalation Factor 2013 to 2020	Escalation Factor 1989 to 2020	Escalated Rate Aug 2020	Amount
	SUB TOTAL C								**R2,998,889,221.81**
20	Planning, Design and Supervision (% of Sub Total C)	%	15						R449,833,383.27
21	Social and Environmental (% of Sub Total C)	%	1						R29,988,892.22
	SUB TOTAL D								**R3,478,711,497.30**
22	Cost of Relocations	Sum	1		R2,160,000.00	1.376	7.433	R16,055,280.00	R16,055,280.00
	Compensation:								
	Homesteads	No	2		R4,100.00		7.433	R30,475.30	R60,950.60
	Cultivated land	ha	70		R2,200.00		7.433	R16,352.60	R1,144,682.00
23	Cost of Land Acquisition	Sum	1		R743,900.00	1.376	7.433	R5,529,408.70	R5,529,408.70
24	Infrastructure Costs / Minor Works	Sum	0		R3,912,172.00	1.376	7.433	R29,079,174.48	R0.00
	TOTAL PROJECT COST								**R3,501,501,818.60**

APPENDIX D

APPENDIX D1: BOSCHJESKOP DAM

Intervention Option: Boschjeskop Dam
Base Date: August 2020
Base Year: 2020

YEAR	PROFESSIONAL FEES	SOCIAL AND ENVIRONMENTAL	REPLACEMENT OF INFRASTRUCTURE	LAND ACQUISITION AND RELOCATION	NEW DAM COSTS		TOTAL ANNUAL COST COMBINED SCHEME		PRESENT VALUE OF COST (2020) AT 6%		PRESENT VALUE OF COST (2020) AT 8%		PRESENT VALUE OF COST (2010) AT 10%	
					CAPITAL	MAINTENANCE & OPERATION	CAPITAL	MAINTENANCE & OPERATION	CAPITAL	MAINTENANCE & OPERATION	CAPITAL	MAINTENANCE & OPERATION	CAPITAL	MAINTENANCE & OPERATION
2020							0	0	0	0	0	0	0	0
2021							0	0	0	0	0	0	0	0
2022							0	0	0	0	0	0	0	0
2023		1,911,220	1,818,384	830,634			4,560,238	0	3,828,863	0	3,620,064	0	3,426,174	0
2024	35,835,374	1,911,220	1,818,384	830,634	238,902,492		279,298,103	0	221,230,258	0	205,292,444	0	190,764,363	0
2025	35,835,374	1,911,220	1,818,384	830,634	238,902,492		279,298,103	0	208,707,790	0	190,085,596	0	173,422,148	0
2026	35,835,374	1,911,220	1,818,384	830,634	238,902,492		279,298,103	0	196,894,142	0	176,005,181	0	157,656,498	0
2027	35,835,374	1,911,220		830,634	238,902,492		277,479,719	0	184,539,861	0	161,906,751	0	142,390,971	0
2028						2,389,025	0	2,389,025	0	1,498,904	0	1,290,716	0	1,114,498
2029						2,389,025	0	2,389,025	0	1,414,060	0	1,195,107	0	1,013,180
2030						2,389,025	0	2,389,025	0	1,334,019	0	1,106,581	0	921,073
2031						2,389,025	0	2,389,025	0	1,258,509	0	1,024,612	0	837,339
2032						2,389,025	0	2,389,025	0	1,187,272	0	948,715	0	761,217
2033						2,389,025	0	2,389,025	0	1,120,068	0	878,440	0	692,015
2034						2,389,025	0	2,389,025	0	1,056,668	0	813,370	0	629,105
2035						2,389,025	0	2,389,025	0	996,857	0	753,120	0	571,914
2036						2,389,025	0	2,389,025	0	940,431	0	697,334	0	519,921
2037						2,389,025	0	2,389,025	0	887,199	0	645,679	0	472,656
2038						2,389,025	0	2,389,025	0	836,980	0	597,851	0	429,687
2039						2,389,025	0	2,389,025	0	789,604	0	553,566	0	390,625
2040						2,389,025	0	2,389,025	0	744,909	0	512,561	0	355,113
2041						2,389,025	0	2,389,025	0	702,745	0	474,594	0	322,830
2042						2,389,025	0	2,389,025	0	662,967	0	439,438	0	293,482
2043						2,389,025	0	2,389,025	0	625,440	0	406,887	0	266,802
2044						2,389,025	0	2,389,025	0	590,038	0	376,748	0	242,547
2045						2,389,025	0	2,389,025	0	556,640	0	348,840	0	220,497
2046						2,389,025	0	2,389,025	0	525,132	0	323,000	0	200,452
2047						2,389,025	0	2,389,025	0	495,407	0	299,074	0	182,229
2048						2,389,025	0	2,389,025	0	467,365	0	276,921	0	165,663
2049						2,389,025	0	2,389,025	0	440,911	0	256,408	0	150,603
2050						2,389,025	0	2,389,025	0	415,953	0	237,415	0	136,912
2051						2,389,025	0	2,389,025	0	392,409	0	219,829	0	124,465
2052						2,389,025	0	2,389,025	0	370,197	0	203,545	0	113,150
2053						2,389,025	0	2,389,025	0	349,243	0	188,468	0	102,864
2054						2,389,025	0	2,389,025	0	329,474	0	174,507	0	93,512
2055						2,389,025	0	2,389,025	0	310,825	0	161,581	0	85,011
2056						2,389,025	0	2,389,025	0	293,231	0	149,612	0	77,283
2057						2,389,025	0	2,389,025	0	276,633	0	138,529	0	70,257
2058						2,389,025	0	2,389,025	0	260,974	0	128,268	0	63,870
2059						2,389,025	0	2,389,025	0	246,202	0	118,767	0	58,064
2060						2,389,025	0	2,389,025	0	232,266	0	109,969	0	52,785
2061						2,389,025	0	2,389,025	0	219,119	0	101,823	0	47,987
2062						2,389,025	0	2,389,025	0	206,716	0	94,281	0	43,624
2063						2,389,025	0	2,389,025	0	195,015	0	87,297	0	39,658
2064						2,389,025	0	2,389,025	0	183,977	0	80,831	0	36,053
2065						2,389,025	0	2,389,025	0	173,563	0	74,843	0	32,776
2066						2,389,025	0	2,389,025	0	163,739	0	69,299	0	29,796
2067						2,389,025	0	2,389,025	0	154,470	0	64,166	0	27,087
2068						2,389,025	0	2,389,025	0	145,727	0	59,413	0	24,625
2069						2,389,025	0	2,389,025	0	137,478	0	55,012	0	22,386
2070						2,389,025	0	2,389,025	0	129,696	0	50,937	0	20,351
2071						2,389,025	0	2,389,025	0	122,355	0	47,164	0	18,501
2072						2,389,025	0	2,389,025	0	115,429	0	43,670	0	16,819
TOTAL	**143,341,495**	**9,556,100**	**7,273,536**	**4,153,168**	**955,609,967**	**107,506,121**	**1,119,934,266**	**107,506,121**	**815,200,914**	**24,556,814**	**736,910,036**	**16,878,786**	**667,660,153**	**12,091,285**

APPENDIX D2: MOUNTAIN VIEW DAM

Intervention Option: Mountain View Dam
Base Date: August 2020
Base Year: 2020

YEAR	PROFESSIONAL FEES	SOCIAL AND ENVIRONMENTAL	REPLACEMENT OF INFRASTRUCTURE	LAND ACQUISITION AND RELOCATION	NEW DAM COSTS		TOTAL ANNUAL COST COMBINED SCHEME		PRESENT VALUE OF COST (2020) AT 6%		PRESENT VALUE OF COST (2020) AT 8%		PRESENT VALUE OF COST (2010) AT 10%	
					CAPITAL	MAINTENANCE & OPERATION	CAPITAL	MAINTENANCE & OPERATION	CAPITAL	MAINTENANCE & OPERATION	CAPITAL	MAINTENANCE & OPERATION	CAPITAL	MAINTENANCE & OPERATION
2020							0	0	0	0	0	0	0	0
2021							0	0	0	0	0	0	0	0
2022							0	0	0	0	0	0	0	0
2023		1,414,648	12,114,304	893,839			14,422,791	0	12,109,653	0	11,449,276	0	10,836,056	0
2024	26,524,656	1,414,648	12,114,304	893,839	176,831,037		217,778,483	0	172,500,957	0	160,073,686	0	148,745,634	0
2025	26,524,656	1,414,648	12,114,304	893,839	176,831,037		217,778,483	0	162,736,751	0	148,216,376	0	135,223,304	0
2026	26,524,656	1,414,648	12,114,304	893,839	176,831,037		217,778,483	0	153,525,237	0	137,237,386	0	122,930,276	0
2027	26,524,656	1,414,648		893,839	176,831,037		205,664,179	0	136,778,425	0	120,003,073	0	105,538,243	0
2028						1,768,310	0	1,768,310	0	1,109,460	0	955,363	0	824,930
2029						1,768,310	0	1,768,310	0	1,046,660	0	884,595	0	749,936
2030						1,768,310	0	1,768,310	0	987,415	0	819,070	0	681,760
2031						1,768,310	0	1,768,310	0	931,524	0	758,398	0	619,782
2032						1,768,310	0	1,768,310	0	878,796	0	702,220	0	563,438
2033						1,768,310	0	1,768,310	0	829,053	0	650,204	0	512,217
2034						1,768,310	0	1,768,310	0	782,125	0	602,041	0	465,651
2035						1,768,310	0	1,768,310	0	737,854	0	557,445	0	423,319
2036						1,768,310	0	1,768,310	0	696,089	0	516,153	0	384,836
2037						1,768,310	0	1,768,310	0	656,688	0	477,919	0	349,851
2038						1,768,310	0	1,768,310	0	619,517	0	442,518	0	318,046
2039						1,768,310	0	1,768,310	0	584,450	0	409,739	0	289,133
2040						1,768,310	0	1,768,310	0	551,368	0	379,388	0	262,848
2041						1,768,310	0	1,768,310	0	520,158	0	351,285	0	238,953
2042						1,768,310	0	1,768,310	0	490,715	0	325,264	0	217,230
2043						1,768,310	0	1,768,310	0	462,939	0	301,170	0	197,482
2044						1,768,310	0	1,768,310	0	436,735	0	278,861	0	179,529
2045						1,768,310	0	1,768,310	0	412,014	0	258,205	0	163,208
2046						1,768,310	0	1,768,310	0	388,692	0	239,079	0	148,371
2047						1,768,310	0	1,768,310	0	366,691	0	221,369	0	134,883
2048						1,768,310	0	1,768,310	0	345,935	0	204,971	0	122,621
2049						1,768,310	0	1,768,310	0	326,354	0	189,788	0	111,473
2050						1,768,310	0	1,768,310	0	307,881	0	175,730	0	101,339
2051						1,768,310	0	1,768,310	0	290,454	0	162,713	0	92,127
2052						1,768,310	0	1,768,310	0	274,013	0	150,660	0	83,751
2053						1,768,310	0	1,768,310	0	258,503	0	139,500	0	76,138
2054						1,768,310	0	1,768,310	0	243,870	0	129,167	0	69,216
2055						1,768,310	0	1,768,310	0	230,066	0	119,599	0	62,924
2056						1,768,310	0	1,768,310	0	217,044	0	110,740	0	57,203
2057						1,768,310	0	1,768,310	0	204,758	0	102,537	0	52,003
2058						1,768,310	0	1,768,310	0	193,168	0	94,941	0	47,276
2059						1,768,310	0	1,768,310	0	182,234	0	87,909	0	42,978
2060						1,768,310	0	1,768,310	0	171,919	0	81,397	0	39,071
2061						1,768,310	0	1,768,310	0	162,188	0	75,368	0	35,519
2062						1,768,310	0	1,768,310	0	153,007	0	69,785	0	32,290
2063						1,768,310	0	1,768,310	0	144,347	0	64,616	0	29,354
2064						1,768,310	0	1,768,310	0	136,176	0	59,829	0	26,686
2065						1,768,310	0	1,768,310	0	128,468	0	55,397	0	24,260
2066						1,768,310	0	1,768,310	0	121,196	0	51,294	0	22,054
2067						1,768,310	0	1,768,310	0	114,336	0	47,494	0	20,049
2068						1,768,310	0	1,768,310	0	107,864	0	43,976	0	18,227
2069						1,768,310	0	1,768,310	0	101,759	0	40,719	0	16,570
2070						1,768,310	0	1,768,310	0	95,999	0	37,703	0	15,063
2071						1,768,310	0	1,768,310	0	90,565	0	34,910	0	13,694
2072						1,768,310	0	1,768,310	0	85,438	0	32,324	0	12,449
TOTAL	**106,098,622**	**7,073,241**	**48,457,216**	**4,469,193**	**707,324,147**	**79,573,967**	**873,422,420**	**79,573,967**	**637,651,024**	**18,176,482**	**576,979,798**	**12,493,353**	**523,273,514**	**8,949,737**

APPENDIX D3: DINGLEYDALE DAM

Intervention Option: Dingleydale Dam & Associated Infrastructure
Base Date: August 2020
Base Year: 2020

YEAR	PROFESSIONAL FEES	SOCIAL AND ENVIRONMENTAL	LAND ACQUISITION AND RELOCATION	PUMP STATION COSTS					WATER TREATMENT WORKS COSTS		RESERVOIR COSTS		PIPELINES (PUMPING & GRAVITY) COSTS		DAM COSTS		YEAR	TOTAL ANNUAL COST COMBINED SCHEME		PRESENT VALUE OF COST (2020) AT 6%		PRESENT VALUE OF COST (2020) AT 8%		PRESENT VALUE OF COST (2020) AT 10%	
				CAPITAL	MAINTENANCE CIVIL	MAINTENANCE E&M	MAJOR OVERHAUL EVERY 15 YEARS	ELECTRICITY	CAPITAL	MAINTENANCE & OPERATION	CAPITAL	MAINTENANCE & OPERATION	CAPITAL	MAINTENANCE & OPERATION	CAPITAL	MAINTENANCE & OPERATION		CAPITAL	MAINTENANCE & OPERATION	CAPITAL	MAINTENANCE & OPERATION	CAPITAL	MAINTENANCE & OPERATION	CAPITAL	MAINTENANCE & OPERATION
2020																	2020	0	0	0	0	0	0	0	0
2021																	2021	0	0	0	0	0	0	0	0
2022																	2022	0	0	0	0	0	0	0	0
2023		5,216,229	4,558,064														2023	9,774,293	0	8,206,685	0	7,759,149	0	7,343,571	0
2024	97,804,295	5,216,229	4,558,064												427,024,027		2024	534,602,615	0	423,455,343	0	392,948,881	0	365,140,779	0
2025	97,804,295	5,216,229	4,558,064	8,788,232					169,582,167						427,024,027		2025	712,973,014	0	532,774,911	0	485,237,453	0	442,700,147	0
2026	97,804,295	5,216,229	4,558,064	8,788,232					169,582,167		72,112,684		110,340,928		427,024,027		2026	895,426,626	0	631,240,438	0	564,270,663	0	505,444,987	0
2027	97,804,295	5,216,229	4,558,064	8,788,232					169,582,167		72,112,684		110,340,928		427,024,027		2027	895,426,626	0	595,509,847	0	522,472,836	0	459,495,442	0
2028					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2028	0	22,919,843	0	14,380,193	0	12,382,878	0	10,692,276
2029					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2029	0	22,919,843	0	13,566,220	0	11,465,628	0	9,720,251
2030					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2030	0	22,919,843	0	12,798,320	0	10,616,322	0	8,836,592
2031					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2031	0	22,919,843	0	12,073,887	0	9,829,928	0	8,033,265
2032					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2032	0	22,919,843	0	11,390,460	0	9,101,785	0	7,302,968
2033					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2033	0	22,919,843	0	10,745,717	0	8,427,579	0	6,639,062
2034					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2034	0	22,919,843	0	10,137,469	0	7,803,313	0	6,035,511
2035					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2035	0	22,919,843	0	9,563,650	0	7,225,290	0	5,486,828
2036					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2036	0	22,919,843	0	9,022,311	0	6,690,084	0	4,988,026
2037					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2037	0	22,919,843	0	8,511,614	0	6,194,522	0	4,534,569
2038					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2038	0	22,919,843	0	8,029,825	0	5,735,668	0	4,122,335
2039					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2039	0	22,919,843	0	7,575,306	0	5,310,804	0	3,747,577
2040					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2040	0	22,919,843	0	7,146,515	0	4,917,411	0	3,406,889
2041					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2041	0	22,919,843	0	6,741,996	0	4,553,158	0	3,097,171
2042					34,441	503,525	1,888,218	6,112,170		10,174,930		721,127		1,103,409		4,270,240	2042	0	24,808,061	0	6,884,363	0	4,563,207	0	3,047,570
2043					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2043	0	22,919,843	0	6,000,352	0	3,903,600	0	2,559,646
2044					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2044	0	22,919,843	0	5,660,709	0	3,614,444	0	2,326,951
2045					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2045	0	22,919,843	0	5,340,292	0	3,346,707	0	2,115,410
2046					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2046	0	22,919,843	0	5,038,011	0	3,098,803	0	1,923,100
2047					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2047	0	22,919,843	0	4,752,841	0	2,869,262	0	1,748,273
2048					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2048	0	22,919,843	0	4,483,812	0	2,656,724	0	1,589,339
2049					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2049	0	22,919,843	0	4,230,011	0	2,459,930	0	1,444,853
2050					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2050	0	22,919,843	0	3,990,577	0	2,277,713	0	1,313,503
2051					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2051	0	22,919,843	0	3,764,695	0	2,108,993	0	1,194,094
2052					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2052	0	22,919,843	0	3,551,599	0	1,952,772	0	1,085,540
2053					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2053	0	22,919,843	0	3,350,565	0	1,808,122	0	986,854
2054					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2054	0	22,919,843	0	3,160,911	0	1,674,187	0	897,140
2055					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2055	0	22,919,843	0	2,981,991	0	1,550,173	0	815,582
2056					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2056	0	22,919,843	0	2,813,199	0	1,435,345	0	741,438
2057					34,441	503,525	1,888,218	6,112,170		10,174,930		721,127		1,103,409		4,270,240	2057	0	24,808,061	0	2,872,604	0	1,438,513	0	729,564
2058					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2058	0	22,919,843	0	2,503,737	0	1,230,577	0	612,759
2059					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2059	0	22,919,843	0	2,362,016	0	1,139,423	0	557,054
2060					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2060	0	22,919,843	0	2,228,317	0	1,055,022	0	506,412
2061					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2061	0	22,919,843	0	2,102,186	0	976,872	0	460,375
2062					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2062	0	22,919,843	0	1,983,194	0	904,511	0	418,523
2063					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2063	0	22,919,843	0	1,870,938	0	837,510	0	380,475
2064					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2064	0	22,919,843	0	1,765,036	0	775,472	0	345,886
2065					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2065	0	22,919,843	0	1,665,128	0	718,030	0	314,442
2066					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2066	0	22,919,843	0	1,570,876	0	664,843	0	285,857
2067					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2067	0	22,919,843	0	1,481,958	0	615,595	0	259,870
2068					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2068	0	22,919,843	0	1,398,074	0	569,995	0	236,245
2069					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2069	0	22,919,843	0	1,318,938	0	527,774	0	214,768
2070					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2070	0	22,919,843	0	1,244,281	0	488,679	0	195,244
2071					34,441	503,525		6,112,170		10,174,930		721,127		1,103,409		4,270,240	2071	0	22,919,843	0	1,173,850	0	452,481	0	177,494
2072					34,441	503,525	1,888,218	6,112,170		10,174,930		721,127		1,103,409		4,270,240	2072	0	24,808,061	0	1,198,637	0	453,479	0	174,652
TOTAL	**391,217,179**	**26,081,145**	**22,790,321**	**26,364,697**	**1,549,865**	**22,658,617**	**5,664,654**	**275,047,650**	**508,746,500**	**457,871,850**	**144,225,368**	**32,450,708**	**220,681,856**	**49,653,418**	**1,708,096,106**	**192,160,812**	**TOTAL**	**3,048,203,173**	**1,037,057,574**	**2,191,187,225**	**236,427,182**	**1,972,688,982**	**162,423,130**	**1,780,124,926**	**116,302,230**

APPENDIX D4: NEW FOREST DAM

Intervention Option: New Forest Dam & Associated Infrastructure: Cost Estimates
Base Date: August 2020
Base Year: 2020

YEAR	PROFESSIONAL FEES	SOCIAL AND ENVIRONMENTAL	LAND ACQUISITION AND RELOCATION	PUMP STATION COSTS					WATER TREATMENT WORKS COSTS		RESERVOIR COSTS		PIPELINES (PUMPING & GRAVITY) COSTS		DAM COSTS		YEAR	TOTAL ANNUAL COST COMBINED SCHEME		PRESENT VALUE OF COST (2020) AT 6%		PRESENT VALUE OF COST (2020) AT 8%		PRESENT VALUE OF COST (2020) AT 10%	
				CAPITAL	MAINTENANCE CIVIL	MAINTENANCE E&M	MAJOR OVERHAUL EVERY 15 YEARS	ELECTRICITY	CAPITAL	MAINTENANCE & OPERATION	CAPITAL	MAINTENANCE & OPERATION	CAPITAL	MAINTENANCE & OPERATION	CAPITAL	MAINTENANCE & OPERATION		CAPITAL	MAINTENANCE & OPERATION	CAPITAL	MAINTENANCE & OPERATION	CAPITAL	MAINTENANCE & OPERATION	CAPITAL	MAINTENANCE & OPERATION
2020																	2020	0	0	0	0	0	0	0	0
2021																	2021	0	0	0	0	0	0	0	0
2022																	2022	0	0	0	0	0	0	0	0
2023		5,997,778	4,558,064														2023	10,555,843	0	8,862,889	0	8,379,568	0	7,930,761	0
2024	112,458,346	5,997,778	4,558,064												506,837,163		2024	629,851,351	0	498,901,264	0	462,959,546	0	430,196,948	0
2025	112,458,346	5,997,778	4,558,064	9,677,699					161,368,500						506,837,163		2025	800,897,550	0	598,477,240	0	545,077,415	0	497,294,366	0
2026	112,458,346	5,997,778	4,558,064	9,677,699					161,368,500		69,537,231		159,663,757		506,837,163		2026	1,030,098,538	0	726,178,822	0	649,136,811	0	581,463,770	0
2027	112,458,346	5,997,778	4,558,064	9,677,699					161,368,500		69,537,231		159,663,757		506,837,163		2027	1,030,098,538	0	685,074,360	0	601,052,603	0	528,603,427	0
2028					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2028	0	24,364,955	0	15,286,874	0	13,163,627	0	11,366,431
2029					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2029	0	24,364,955	0	14,421,579	0	12,188,544	0	10,333,119
2030					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2030	0	24,364,955	0	13,605,264	0	11,285,688	0	9,393,745
2031					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2031	0	24,364,955	0	12,835,154	0	10,449,712	0	8,539,768
2032					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2032	0	24,364,955	0	12,108,636	0	9,675,659	0	7,763,426
2033					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2033	0	24,364,955	0	11,423,242	0	8,958,943	0	7,057,660
2034					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2034	0	24,364,955	0	10,776,643	0	8,295,318	0	6,416,054
2035					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2035	0	24,364,955	0	10,166,644	0	7,680,850	0	5,832,776
2036					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2036	0	24,364,955	0	9,591,174	0	7,111,898	0	5,302,524
2037					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2037	0	24,364,955	0	9,048,277	0	6,585,091	0	4,820,476
2038					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2038	0	24,364,955	0	8,536,111	0	6,097,306	0	4,382,251
2039					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2039	0	24,364,955	0	8,052,935	0	5,645,654	0	3,983,865
2040					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2040	0	24,364,955	0	7,597,108	0	5,227,457	0	3,621,695
2041					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2041	0	24,364,955	0	7,167,083	0	4,840,238	0	3,292,450
2042					37,927	554,487	2,079,327	6,730,049		9,682,110		695,372		1,596,638		5,068,372	2042	0	26,444,282	0	7,338,423	0	4,864,175	0	3,248,574
2043					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2043	0	24,364,955	0	6,378,678	0	4,149,724	0	2,721,033
2044					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2044	0	24,364,955	0	6,017,621	0	3,842,337	0	2,473,667
2045					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2045	0	24,364,955	0	5,677,001	0	3,557,720	0	2,248,788
2046					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2046	0	24,364,955	0	5,355,661	0	3,294,185	0	2,044,353
2047					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2047	0	24,364,955	0	5,052,511	0	3,050,171	0	1,858,502
2048					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2048	0	24,364,955	0	4,766,520	0	2,824,233	0	1,689,548
2049					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2049	0	24,364,955	0	4,496,717	0	2,615,030	0	1,535,952
2050					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2050	0	24,364,955	0	4,242,185	0	2,421,324	0	1,396,320
2051					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2051	0	24,364,955	0	4,002,062	0	2,241,967	0	1,269,382
2052					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2052	0	24,364,955	0	3,775,530	0	2,075,895	0	1,153,984
2053					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2053	0	24,364,955	0	3,561,821	0	1,922,125	0	1,049,076
2054					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2054	0	24,364,955	0	3,360,208	0	1,779,746	0	953,706
2055					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2055	0	24,364,955	0	3,170,008	0	1,647,913	0	867,005
2056					37,927	554,487	2,079,327	6,730,049		9,682,110		695,372		1,596,638		5,068,372	2056	0	26,444,282	0	3,245,792	0	1,656,062	0	855,451
2057					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2057	0	24,364,955	0	2,821,296	0	1,412,819	0	716,533
2058					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2058	0	24,364,955	0	2,661,600	0	1,308,166	0	651,394
2059					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2059	0	24,364,955	0	2,510,943	0	1,211,265	0	592,176
2060					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2060	0	24,364,955	0	2,368,814	0	1,121,542	0	538,342
2061					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2061	0	24,364,955	0	2,234,730	0	1,038,464	0	489,402
2062					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2062	0	24,364,955	0	2,108,236	0	961,541	0	444,911
2063					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2063	0	24,364,955	0	1,988,902	0	890,316	0	404,464
2064					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2064	0	24,364,955	0	1,876,323	0	824,367	0	367,695
2065					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2065	0	24,364,955	0	1,770,116	0	763,302	0	334,268
2066					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2066	0	24,364,955	0	1,669,921	0	706,761	0	303,880
2067					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2067	0	24,364,955	0	1,575,397	0	654,409	0	276,255
2068					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2068	0	24,364,955	0	1,486,223	0	605,934	0	251,140
2069					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2069	0	24,364,955	0	1,402,097	0	561,050	0	228,310
2070					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2070	0	24,364,955	0	1,322,733	0	519,491	0	207,554
2071					37,927	554,487		6,730,049		9,682,110		695,372		1,596,638		5,068,372	2071	0	24,364,955	0	1,247,862	0	481,010	0	188,686
2072					37,927	554,487	2,079,327	6,730,049		9,682,110		695,372		1,596,638		5,068,372	2072	0	26,444,282	0	1,277,694	0	483,389	0	186,171
TOTAL	**449,833,383**	**29,988,892**	**22,790,321**	**29,033,096**	**1,706,728**	**24,951,920**	**6,237,980**	**302,852,205**	**484,105,500**	**435,694,950**	**139,074,462**	**31,291,754**	**319,327,514**	**71,848,691**	**2,027,348,650**	**228,076,723**	**TOTAL**	**3,501,501,819**	**1,102,660,951**	**2,517,494,575**	**251,380,349**	**2,266,605,943**	**172,692,418**	**2,045,489,272**	**123,652,761**

APPENDIX E

APPENDIX E1: BOSCHEJSKOP DAM

Intervention Option: Boschjeskop Dam
Base Date: August 2020
Base Year: 2020

UNIT REFERENCE VALUE CALCULATIONS AT DIFFERENT DISCOUNT RATES								
Year	Yield Mm³	Total Annual Costs (excl VAT)	Discounted to 2020 at 6%		Discounted to 2020 at 8%		Discounted to 2020 at 10%	
			Yield	Costs	Yield	Costs	Yield	Costs
2020	0.00	0	0.00	0	0.00	0	0.00	0
2021	0.00	0	0.00	0	0.00	0	0.00	0
2022	0.00	0	0.00	0	0.00	0	0.00	0
2023	0.00	4,560,238	0.00	3,828,863	0.00	3,620,064	0.00	3,426,174
2024	0.00	279,298,103	0.00	221,230,258	0.00	205,292,444	0.00	190,764,363
2025	0.00	279,298,103	0.00	208,707,790	0.00	190,085,596	0.00	173,422,148
2026	0.00	279,298,103	0.00	196,894,142	0.00	176,005,181	0.00	157,656,498
2027	0.00	277,479,719	0.00	184,539,861	0.00	161,906,751	0.00	142,390,971
2028	31.20	2,389,025	19.58	1,498,904	16.86	1,290,716	14.56	1,114,498
2029	31.20	2,389,025	18.47	1,414,060	15.61	1,195,107	13.23	1,013,180
2030	31.20	2,389,025	17.42	1,334,019	14.45	1,106,581	12.03	921,073
2031	31.20	2,389,025	16.44	1,258,509	13.38	1,024,612	10.94	837,339
2032	31.20	2,389,025	15.51	1,187,272	12.39	948,715	9.94	761,217
2033	31.20	2,389,025	14.63	1,120,068	11.47	878,440	9.04	692,015
2034	31.20	2,389,025	13.80	1,056,668	10.62	813,370	8.22	629,105
2035	31.20	2,389,025	13.02	996,857	9.84	753,120	7.47	571,914
2036	31.20	2,389,025	12.28	940,431	9.11	697,334	6.79	519,921
2037	31.20	2,389,025	11.59	887,199	8.43	645,679	6.17	472,656
2038	31.20	2,389,025	10.93	836,980	7.81	597,851	5.61	429,687
2039	31.20	2,389,025	10.31	789,604	7.23	553,566	5.10	390,625
2040	31.20	2,389,025	9.73	744,909	6.69	512,561	4.64	355,113
2041	31.20	2,389,025	9.18	702,745	6.20	474,594	4.22	322,830
2042	31.20	2,389,025	8.66	662,967	5.74	439,438	3.83	293,482
2043	31.20	2,389,025	8.17	625,440	5.31	406,887	3.48	266,802
2044	31.20	2,389,025	7.71	590,038	4.92	376,748	3.17	242,547
2045	31.20	2,389,025	7.27	556,640	4.56	348,840	2.88	220,497
2046	31.20	2,389,025	6.86	525,132	4.22	323,000	2.62	200,452
2047	31.20	2,389,025	6.47	495,407	3.91	299,074	2.38	182,229
2048	31.20	2,389,025	6.10	467,365	3.62	276,921	2.16	165,663
2049	31.20	2,389,025	5.76	440,911	3.35	256,408	1.97	150,603
2050	31.20	2,389,025	5.43	415,953	3.10	237,415	1.79	136,912
2051	31.20	2,389,025	5.12	392,409	2.87	219,829	1.63	124,465
2052	31.20	2,389,025	4.83	370,197	2.66	203,545	1.48	113,150
2053	31.20	2,389,025	4.56	349,243	2.46	188,468	1.34	102,864
2054	31.20	2,389,025	4.30	329,474	2.28	174,507	1.22	93,512
2055	31.20	2,389,025	4.06	310,825	2.11	161,581	1.11	85,011
2056	31.20	2,389,025	3.83	293,231	1.95	149,612	1.01	77,283
2057	31.20	2,389,025	3.61	276,633	1.81	138,529	0.92	70,257
2058	31.20	2,389,025	3.41	260,974	1.68	128,268	0.83	63,870
2059	31.20	2,389,025	3.22	246,202	1.55	118,767	0.76	58,064
2060	31.20	2,389,025	3.03	232,266	1.44	109,969	0.69	52,785
2061	31.20	2,389,025	2.86	219,119	1.33	101,823	0.63	47,987
2062	31.20	2,389,025	2.70	206,716	1.23	94,281	0.57	43,624
2063	31.20	2,389,025	2.55	195,015	1.14	87,297	0.52	39,658
2064	31.20	2,389,025	2.40	183,977	1.06	80,831	0.47	36,053
2065	31.20	2,389,025	2.27	173,563	0.98	74,843	0.43	32,776
2066	31.20	2,389,025	2.14	163,739	0.91	69,299	0.39	29,796
2067	31.20	2,389,025	2.02	154,470	0.84	64,166	0.35	27,087
2068	31.20	2,389,025	1.90	145,727	0.78	59,413	0.32	24,625
2069	31.20	2,389,025	1.80	137,478	0.72	55,012	0.29	22,386
2070	31.20	2,389,025	1.69	129,696	0.67	50,937	0.27	20,351
2071	31.20	2,389,025	1.60	122,355	0.62	47,164	0.24	18,501
2072	31.20	2,389,025	1.51	115,429	0.57	43,670	0.22	16,819
TOTAL	**1404.00**	**1,227,440,388**	**320.71**	**839,757,728**	**220.43**	**753,788,822**	**157.91**	**679,751,438**
URV			**2.618**		**3.420**		**4.305**	

Discounted to 2020 at 6%	Discounted to 2020 at 8%	Discounted to 2020 at 10%

APPENDIX E2: MOUNTAIN VIEW DAM

Intervention Option: Mountain View Dam
Base Date: August 2020
Base Year: 2020

UNIT REFERENCE VALUE CALCULATIONS AT DIFFERENT DISCOUNT RATES								
Year	Yield Mm³	Total Annual Costs (excl VAT)	Discounted to 2020 at 6%		Discounted to 2020 at 8%		Discounted to 2020 at 10%	
			Yield	Costs	Yield	Costs	Yield	Costs
2020	0.00	0	0.00	0	0.00	0	0.00	0
2021	0.00	0	0.00	0	0.00	0	0.00	0
2022	0.00	0	0.00	0	0.00	0	0.00	0
2023	0.00	14,422,791	0.00	12,109,653	0.00	11,449,276	0.00	10,836,056
2024	0.00	217,778,483	0.00	172,500,957	0.00	160,073,686	0.00	148,745,634
2025	0.00	217,778,483	0.00	162,736,751	0.00	148,216,376	0.00	135,223,304
2026	0.00	217,778,483	0.00	153,525,237	0.00	137,237,386	0.00	122,930,276
2027	0.00	205,664,179	0.00	136,778,425	0.00	120,003,073	0.00	105,538,243
2028	78.10	1,768,310	49.00	1,109,460	42.19	955,363	36.43	824,930
2029	78.10	1,768,310	46.23	1,046,660	39.07	884,595	33.12	749,936
2030	78.10	1,768,310	43.61	987,415	36.18	819,070	30.11	681,760
2031	78.10	1,768,310	41.14	931,524	33.50	758,398	27.37	619,782
2032	78.10	1,768,310	38.81	878,796	31.01	702,220	24.89	563,438
2033	78.10	1,768,310	36.62	829,053	28.72	650,204	22.62	512,217
2034	78.10	1,768,310	34.54	782,125	26.59	602,041	20.57	465,651
2035	78.10	1,768,310	32.59	737,854	24.62	557,445	18.70	423,319
2036	78.10	1,768,310	30.74	696,089	22.80	516,153	17.00	384,836
2037	78.10	1,768,310	29.00	656,688	21.11	477,919	15.45	349,851
2038	78.10	1,768,310	27.36	619,517	19.54	442,518	14.05	318,046
2039	78.10	1,768,310	25.81	584,450	18.10	409,739	12.77	289,133
2040	78.10	1,768,310	24.35	551,368	16.76	379,388	11.61	262,848
2041	78.10	1,768,310	22.97	520,158	15.52	351,285	10.55	238,953
2042	78.10	1,768,310	21.67	490,715	14.37	325,264	9.59	217,230
2043	78.10	1,768,310	20.45	462,939	13.30	301,170	8.72	197,482
2044	78.10	1,768,310	19.29	436,735	12.32	278,861	7.93	179,529
2045	78.10	1,768,310	18.20	412,014	11.40	258,205	7.21	163,208
2046	78.10	1,768,310	17.17	388,692	10.56	239,079	6.55	148,371
2047	78.10	1,768,310	16.20	366,691	9.78	221,369	5.96	134,883
2048	78.10	1,768,310	15.28	345,935	9.05	204,971	5.42	122,621
2049	78.10	1,768,310	14.41	326,354	8.38	189,788	4.92	111,473
2050	78.10	1,768,310	13.60	307,881	7.76	175,730	4.48	101,339
2051	78.10	1,768,310	12.83	290,454	7.19	162,713	4.07	92,127
2052	78.10	1,768,310	12.10	274,013	6.65	150,660	3.70	83,751
2053	78.10	1,768,310	11.42	258,503	6.16	139,500	3.36	76,138
2054	78.10	1,768,310	10.77	243,870	5.70	129,167	3.06	69,216
2055	78.10	1,768,310	10.16	230,066	5.28	119,599	2.78	62,924
2056	78.10	1,768,310	9.59	217,044	4.89	110,740	2.53	57,203
2057	78.10	1,768,310	9.04	204,758	4.53	102,537	2.30	52,003
2058	78.10	1,768,310	8.53	193,168	4.19	94,941	2.09	47,276
2059	78.10	1,768,310	8.05	182,234	3.88	87,909	1.90	42,978
2060	78.10	1,768,310	7.59	171,919	3.60	81,397	1.73	39,071
2061	78.10	1,768,310	7.16	162,188	3.33	75,368	1.57	35,519
2062	78.10	1,768,310	6.76	153,007	3.08	69,785	1.43	32,290
2063	78.10	1,768,310	6.38	144,347	2.85	64,616	1.30	29,354
2064	78.10	1,768,310	6.01	136,176	2.64	59,829	1.18	26,686
2065	78.10	1,768,310	5.67	128,468	2.45	55,397	1.07	24,260
2066	78.10	1,768,310	5.35	121,196	2.27	51,294	0.97	22,054
2067	78.10	1,768,310	5.05	114,336	2.10	47,494	0.89	20,049
2068	78.10	1,768,310	4.76	107,864	1.94	43,976	0.81	18,227
2069	78.10	1,768,310	4.49	101,759	1.80	40,719	0.73	16,570
2070	78.10	1,768,310	4.24	95,999	1.67	37,703	0.67	15,063
2071	78.10	1,768,310	4.00	90,565	1.54	34,910	0.60	13,694
2072	78.10	1,768,310	3.77	85,438	1.43	32,324	0.55	12,449
TOTAL	**3514.50**	**952,996,386**	**802.79**	**655,827,506**	**551.79**	**589,473,151**	**395.28**	**532,223,251**
URV			**0.817**		**1.068**		**1.346**	

Discounted to 2020 at 6%	Discounted to 2020 at 8%	Discounted to 2020 at 10%

APPENDIX E3: DINGLEYDALE DAM

Intervention Option: Dingleydale Dam & Associated Infrastructure
Base Date: August 2020
Base Year: 2020

UNIT REFERENCE VALUE CALCULATIONS AT DIFFERENT DISCOUNT RATES								
Year	Yield Mm³	Total Annual Costs (excl VAT)	Discounted to 2020 at 6%		Discounted to 2020 at 8%		Discounted to 2020 at 10%	
			Yield	Costs	Yield	Costs	Yield	Costs
2020	0.00	0	0.00	0	0.00	0	0.00	0
2021	0.00	0	0.00	0	0.00	0	0.00	0
2022	0.00	0	0.00	0	0.00	0	0.00	0
2023	0.00	9,774,293	0.00	8,206,685	0.00	7,759,149	0.00	7,343,571
2024	0.00	534,602,615	0.00	423,455,343	0.00	392,948,881	0.00	365,140,779
2025	0.00	712,973,014	0.00	532,774,911	0.00	485,237,453	0.00	442,700,147
2026	0.00	895,426,626	0.00	631,240,438	0.00	564,270,663	0.00	505,444,987
2027	0.00	895,426,626	0.00	595,509,847	0.00	522,472,836	0.00	459,495,442
2028	20.60	22,919,843	12.92	14,380,193	11.13	12,382,878	9.61	10,692,276
2029	20.60	22,919,843	12.19	13,566,220	10.31	11,465,628	8.74	9,720,251
2030	20.60	22,919,843	11.50	12,798,320	9.54	10,616,322	7.94	8,836,592
2031	20.60	22,919,843	10.85	12,073,887	8.83	9,829,928	7.22	8,033,265
2032	20.60	22,919,843	10.24	11,390,460	8.18	9,101,785	6.56	7,302,968
2033	20.60	22,919,843	9.66	10,745,717	7.57	8,427,579	5.97	6,639,062
2034	20.60	22,919,843	9.11	10,137,469	7.01	7,803,313	5.42	6,035,511
2035	20.60	22,919,843	8.60	9,563,650	6.49	7,225,290	4.93	5,486,828
2036	20.60	22,919,843	8.11	9,022,311	6.01	6,690,084	4.48	4,988,026
2037	20.60	22,919,843	7.65	8,511,614	5.57	6,194,522	4.08	4,534,569
2038	20.60	22,919,843	7.22	8,029,825	5.16	5,735,668	3.71	4,122,335
2039	20.60	22,919,843	6.81	7,575,306	4.77	5,310,804	3.37	3,747,577
2040	20.60	22,919,843	6.42	7,146,515	4.42	4,917,411	3.06	3,406,889
2041	20.60	22,919,843	6.06	6,741,996	4.09	4,553,158	2.78	3,097,171
2042	20.60	24,808,061	5.72	6,884,363	3.79	4,563,207	2.53	3,047,570
2043	20.60	22,919,843	5.39	6,000,352	3.51	3,903,600	2.30	2,559,646
2044	20.60	22,919,843	5.09	5,660,709	3.25	3,614,444	2.09	2,326,951
2045	20.60	22,919,843	4.80	5,340,292	3.01	3,346,707	1.90	2,115,410
2046	20.60	22,919,843	4.53	5,038,011	2.79	3,098,803	1.73	1,923,100
2047	20.60	22,919,843	4.27	4,752,841	2.58	2,869,262	1.57	1,748,273
2048	20.60	22,919,843	4.03	4,483,812	2.39	2,656,724	1.43	1,589,339
2049	20.60	22,919,843	3.80	4,230,011	2.21	2,459,930	1.30	1,444,853
2050	20.60	22,919,843	3.59	3,990,577	2.05	2,277,713	1.18	1,313,503
2051	20.60	22,919,843	3.38	3,764,695	1.90	2,108,993	1.07	1,194,094
2052	20.60	22,919,843	3.19	3,551,599	1.76	1,952,772	0.98	1,085,540
2053	20.60	22,919,843	3.01	3,350,565	1.63	1,808,122	0.89	986,854
2054	20.60	22,919,843	2.84	3,160,911	1.50	1,674,187	0.81	897,140
2055	20.60	22,919,843	2.68	2,981,991	1.39	1,550,173	0.73	815,582
2056	20.60	22,919,843	2.53	2,813,199	1.29	1,435,345	0.67	741,438
2057	20.60	24,808,061	2.39	2,872,604	1.19	1,438,513	0.61	729,564
2058	20.60	22,919,843	2.25	2,503,737	1.11	1,230,577	0.55	612,759
2059	20.60	22,919,843	2.12	2,362,016	1.02	1,139,423	0.50	557,054
2060	20.60	22,919,843	2.00	2,228,317	0.95	1,055,022	0.46	506,412
2061	20.60	22,919,843	1.89	2,102,186	0.88	976,872	0.41	460,375
2062	20.60	22,919,843	1.78	1,983,194	0.81	904,511	0.38	418,523
2063	20.60	22,919,843	1.68	1,870,938	0.75	837,510	0.34	380,475
2064	20.60	22,919,843	1.59	1,765,036	0.70	775,472	0.31	345,886
2065	20.60	22,919,843	1.50	1,665,128	0.65	718,030	0.28	314,442
2066	20.60	22,919,843	1.41	1,570,876	0.60	664,843	0.26	285,857
2067	20.60	22,919,843	1.33	1,481,958	0.55	615,595	0.23	259,870
2068	20.60	22,919,843	1.26	1,398,074	0.51	569,995	0.21	236,245
2069	20.60	22,919,843	1.19	1,318,938	0.47	527,774	0.19	214,768
2070	20.60	22,919,843	1.12	1,244,281	0.44	488,679	0.18	195,244
2071	20.60	22,919,843	1.06	1,173,850	0.41	452,481	0.16	177,494
2072	20.60	24,808,061	1.00	1,198,637	0.38	453,479	0.15	174,652
TOTAL	**927.00**	**4,085,260,747**	**211.75**	**2,427,614,407**	**145.54**	**2,135,112,112**	**104.26**	**1,896,427,156**
URV			**11.465**		**14.670**		**18.189**	

Discounted to 2020 at 6%	Discounted to 2020 at 8%	Discounted to 2020 at 10%

APPENDIX E4: NEW FOREST DAM

Intervention Option: New Forest Dam & Associated Infrastructure: Cost Estimates
Base Date: August 2020
Base Year: 2020

UNIT REFERENCE VALUE CALCULATIONS AT DIFFERENT DISCOUNT RATES								
Year	Yield Mm³	Total Annual Costs (excl VAT)	Discounted to 2020 at 6%		Discounted to 2020 at 8%		Discounted to 2020 at 10%	
			Yield	Costs	Yield	Costs	Yield	Costs
2020	0.00	0	0.00	0	0.00	0	0.00	0
2021	0.00	0	0.00	0	0.00	0	0.00	0
2022	0.00	0	0.00	0	0.00	0	0.00	0
2023	0.00	10,555,843	0.00	8,862,889	0.00	8,379,568	0.00	7,930,761
2024	0.00	629,851,351	0.00	498,901,264	0.00	462,959,546	0.00	430,196,948
2025	0.00	800,897,550	0.00	598,477,240	0.00	545,077,415	0.00	497,294,366
2026	0.00	1,030,098,538	0.00	726,178,822	0.00	649,136,811	0.00	581,463,770
2027	0.00	1,030,098,538	0.00	685,074,360	0.00	601,052,603	0.00	528,603,427
2028	19.60	24,364,955	12.30	15,286,874	10.59	13,163,627	9.14	11,366,431
2029	19.60	24,364,955	11.60	14,421,579	9.80	12,188,544	8.31	10,333,119
2030	19.60	24,364,955	10.94	13,605,264	9.08	11,285,688	7.56	9,393,745
2031	19.60	24,364,955	10.33	12,835,154	8.41	10,449,712	6.87	8,539,768
2032	19.60	24,364,955	9.74	12,108,636	7.78	9,675,659	6.25	7,763,426
2033	19.60	24,364,955	9.19	11,423,242	7.21	8,958,943	5.68	7,057,660
2034	19.60	24,364,955	8.67	10,776,643	6.67	8,295,318	5.16	6,416,054
2035	19.60	24,364,955	8.18	10,166,644	6.18	7,680,850	4.69	5,832,776
2036	19.60	24,364,955	7.72	9,591,174	5.72	7,111,898	4.27	5,302,524
2037	19.60	24,364,955	7.28	9,048,277	5.30	6,585,091	3.88	4,820,476
2038	19.60	24,364,955	6.87	8,536,111	4.90	6,097,306	3.53	4,382,251
2039	19.60	24,364,955	6.48	8,052,935	4.54	5,645,654	3.20	3,983,865
2040	19.60	24,364,955	6.11	7,597,108	4.21	5,227,457	2.91	3,621,695
2041	19.60	24,364,955	5.77	7,167,083	3.89	4,840,238	2.65	3,292,450
2042	19.60	26,444,282	5.44	7,338,423	3.61	4,864,175	2.41	3,248,574
2043	19.60	24,364,955	5.13	6,378,678	3.34	4,149,724	2.19	2,721,033
2044	19.60	24,364,955	4.84	6,017,621	3.09	3,842,337	1.99	2,473,667
2045	19.60	24,364,955	4.57	5,677,001	2.86	3,557,720	1.81	2,248,788
2046	19.60	24,364,955	4.31	5,355,661	2.65	3,294,185	1.64	2,044,353
2047	19.60	24,364,955	4.06	5,052,511	2.45	3,050,171	1.50	1,858,502
2048	19.60	24,364,955	3.83	4,766,520	2.27	2,824,233	1.36	1,689,548
2049	19.60	24,364,955	3.62	4,496,717	2.10	2,615,030	1.24	1,535,952
2050	19.60	24,364,955	3.41	4,242,185	1.95	2,421,324	1.12	1,396,320
2051	19.60	24,364,955	3.22	4,002,062	1.80	2,241,967	1.02	1,269,382
2052	19.60	24,364,955	3.04	3,775,530	1.67	2,075,895	0.93	1,153,984
2053	19.60	24,364,955	2.87	3,561,821	1.55	1,922,125	0.84	1,049,076
2054	19.60	24,364,955	2.70	3,360,208	1.43	1,779,746	0.77	953,706
2055	19.60	24,364,955	2.55	3,170,008	1.33	1,647,913	0.70	867,005
2056	19.60	26,444,282	2.41	3,245,792	1.23	1,656,062	0.63	855,451
2057	19.60	24,364,955	2.27	2,821,296	1.14	1,412,819	0.58	716,533
2058	19.60	24,364,955	2.14	2,661,600	1.05	1,308,166	0.52	651,394
2059	19.60	24,364,955	2.02	2,510,943	0.97	1,211,265	0.48	592,176
2060	19.60	24,364,955	1.91	2,368,814	0.90	1,121,542	0.43	538,342
2061	19.60	24,364,955	1.80	2,234,730	0.84	1,038,464	0.39	489,402
2062	19.60	24,364,955	1.70	2,108,236	0.77	961,541	0.36	444,911
2063	19.60	24,364,955	1.60	1,988,902	0.72	890,316	0.33	404,464
2064	19.60	24,364,955	1.51	1,876,323	0.66	824,367	0.30	367,695
2065	19.60	24,364,955	1.42	1,770,116	0.61	763,302	0.27	334,268
2066	19.60	24,364,955	1.34	1,669,921	0.57	706,761	0.24	303,880
2067	19.60	24,364,955	1.27	1,575,397	0.53	654,409	0.22	276,255
2068	19.60	24,364,955	1.20	1,486,223	0.49	605,934	0.20	251,140
2069	19.60	24,364,955	1.13	1,402,097	0.45	561,050	0.18	228,310
2070	19.60	24,364,955	1.06	1,322,733	0.42	519,491	0.17	207,554
2071	19.60	24,364,955	1.00	1,247,862	0.39	481,010	0.15	188,686
2072	19.60	26,444,282	0.95	1,277,694	0.36	483,389	0.14	186,171
TOTAL	**882.00**	**4,604,162,770**	**201.47**	**2,768,874,924**	**138.48**	**2,439,298,361**	**99.20**	**2,169,142,033**
URV			**13.743**		**17.615**		**21.867**	

Discounted to 2020 at 6%	Discounted to 2020 at 8%	Discounted to 2020 at 10%