Report No: PB1 U100-00-1399

DEPARTMENT OF WATER AFFAIRS
AND FORESTRY

in association with

UMGENI WATER
Corporate Services Division

MKOMAZI/MOOI-MGENI TRANSFER SCHEME PRE-FEASIBILITY STUDY

MKOMAZI-MGENI TRANSFER SCHEME

SUPPORTING REPORT No 6

ENGINEERING DESIGN & COSTING

VOLUME 1

Report No 2787I/7856
May 1999

NINHAM SHAND
CONSULTING ENGINEERS

MKOMAZI/MOOI-MGENI TRANSFER SCHEME PRE-FEASIBILITY STUDY REPORT STRUCTURE

MGENI AUGMENTATION OVERVIEW REPORT

MKOMAZI-MGENI TRANSFER SCHEME MAIN REPORT

- SUPPORTING REPORT No 1
  RECONNAISSANCE INVESTIGATIONS
- SUPPORTING REPORT No 2
  MGENI SYSTEM WATER DEMANDS
- SUPPORTING REPORT No 3
  RECONNAISSANCE BASIN STUDY
- SUPPORTING REPORT No 4
  HYDROLOGY & WATER RESOURCES
- SUPPORTING REPORT No 5
  ENVIRONMENTAL
  - VOLUME 1
  - VOLUME 2: SUPPLEMENTARY DOCUMENTS
    - Environmental Prognosis of Impact of Transfer of Water from Mkomazi River to Mgeni & Mlazi catchments
    - Environmental Scoping for Components of the Conveyance Route
    - Mkomazi Estuarine Freshwater Requirements
  - VOLUME 3: SUPPLEMENTARY DOCUMENTS
    - Mkomazi IFR Study
  - VOLUME 4: SUPPLEMENTARY DOCUMENTS
    - Social Impact Assessment Report
    - Impact on Fauna and Flora of the Impendle and Smithfield Dam Sites
- SUPPORTING REPORT No 6
  ENGINEERING DESIGN & COSTING
  - VOLUME 1
  - VOLUME 2: SUPPLEMENTARY DOCUMENTS
    - Risk Assessment
    - Water Quality Assessment
- SUPPORTING REPORT No 7
  ECONOMICS
  - VOLUME 1
  - VOLUME 2: SUPPLEMENTARY DOCUMENTS
    - Socio-Economic Impact of outcomes relating to the Mkomazi-Mgeni Augmentation Scheme

MOOI-MGENI TRANSFER SCHEME MAIN REPORT

- SUPPORTING REPORT No 1
  WATER DEMANDS AND
  RECONNAISSANCE BASIN STUDY
- SUPPORTING REPORT No 2
  HYDROLOGY & WATER RESOURCES
- SUPPORTING REPORT No 3
  ENVIRONMENTAL
  - VOLUME 1
  - VOLUME 2: SUPPLEMENTARY DOCUMENTS
    - Spring Grove - Dartington Pre-feasibility Social Impact Assessment
  - VOLUME 3: SUPPLEMENTARY DOCUMENTS
    - Mooi IFR Refinement Study
  - VOLUME 4: SUPPLEMENTARY DOCUMENTS
    - Impact of Fauna and Flora of the Spring Grove & Dartington Dam Sites
- SUPPORTING REPORT No 4
  ENGINEERING DESIGN & COSTING
  - VOLUME 1
  - VOLUME 2: SUPPLEMENTARY DOCUMENTS
    - Engineering Geological Report

\7856\Mgeni report structure.wb1

MKOMAZI / MOOI-MGENI TRANSFER SCHEME PRE-FEASIBILITY STUDY

PREFACE

In January 1997, the Department of Water Affairs & Forestry: Directorate of Project Planning, in conjunction with Umgeni Water: Corporate Services Division, invited various firms of consulting engineers to submit proposals to undertake a Pre-Feasibility Study for a scheme to transfer water from the upper Mkomazi River to the Mgeni System. In July 1997, a multi-disciplinary team led by Ninham Shand was appointed.

This Study follows on from the Mgeni River System Analysis Study carried out between 1991 and 1994, in which the Mkomazi River was identified as a potentially viable source of water for augmentation of the Mgeni System, and the Mooi-Mgeni Transfer Feasibility Study carried out in 1995, in which the first phase scheme to augment the Mgeni System from the Mooi River was investigated in detail and possible second phase schemes were identified.

This Study comprises two distinct parts; a pre-feasibility investigation of augmentation schemes on the Mkomazi River preceded by scheme identification and reconnaissance investigations, and a pre-feasibility investigation of second phase transfer schemes from the Mooi River. A comparison of the two main augmentation options is made at the culmination of the Study. The report structure is given overleaf.

Sub-consultants employed by Ninham Shand to undertake various aspects of the Study included:

- IWR Environmental: Environmental studies and IEM co-ordination
- Scott Wilson: Social studies
- Keeve Steyn: Engineering aspects of tunnels and pumpstations, and involvement with Basin Studies
- Simmer Biggar and Associates: Infrastructure aspects.

As part of the Study Team, the following Client departments were involved:

- Council for Geoscience: Geological Survey
- Department of Water Affairs & Forestry: Project Planning (East)
- Department of Water Affairs & Forestry: Environment Studies
- Department of Water Affairs & Forestry: Hydrology
- Umgeni Water: Corporate Services Division: Water Resources Planning
- Umgeni Water: Scientific Services Division: Water Quality
- Umgeni Water: Scientific Services Division: Hydro-biology.

EXECUTIVE SUMMARY

During the reconnaissance phase of this study, a number of potential schemes to augment the Mgeni System from the Mkomazi River were identified and evaluated. Of these, two were recommended for further investigation during the pre-feasibility phase, the Impendle Scheme and the Smithfield Scheme. Both schemes will deliver clear water to a proposed reservoir at Umlaas Road. Three possible configurations of each scheme were evaluated and consist of the following main components:

Impendle Scheme

- *A dam on the Mkomazi River, a short distance downstream of the Nzinga River confluence (Impendle Dam), possibly implemented in two phases by raising, incorporating a multi-level outlet tower, feeding twin pipelines to a free water surface or pressure gravity tunnel, discharging into a stream at Midmar Dam.*
- *Twin pipelines from Midmar Dam to an ended Midmar Pumpstation and from there to an extended Midmar Water Treatment Works. The Midmar Dam outlets will also require upgrading.*
- *Twin pipelines from the waterworks to the proposed Stuckenberg Tunnel and from the tunnel outlet to the existing Midmar Tunnel. A branch will be provided to the existing Ferncliffe Tunnel, which will be upgraded.*
- *A control structure near the Midmar and Ferncliffe Tunnel outlet portals feeding twin pipelines to the start of the proposed Northern Feeder pipeline.*
- *Twin pipelines along the Northern Feeder route to a proposed clear water reservoir immediately to the south of the N3 freeway at Umlaas Road.*

Smithfield Scheme

- *An initial dam on the Mkomazi River, approximately midway between the Lundy's Hill bridge and Deepdale (Smithfield Dam).*
- *A second dam on the Mkomazi River, a short distance downstream of the Nzinga River confluence (Impendle Dam), possibly implemented in two phases by raising, releasing water down the Mkomazi River to the lower dam for transfer.*
- *A multi-level outlet tower in the Smithfield Dam basin, incorporating a pumpstation, feeding twin pipelines to a free water surface tunnel, discharging near Baynesfield, either into a balancing dam or a pipeline to a proposed waterworks.*
- *Raising of the existing Baynesfield Dam for raw water balancing storage.*
- *Twin pipelines from Baynesfield Dam and the tunnel outlet to a new waterworks.*
- *Twin pipelines from the waterworks to a proposed clear water reservoir immediately to the south of the N3 freeway at Umlaas Road.*

Both schemes were sized to maximise the available yield of the Mkomazi River and the conveyance and treatment infrastructure was sized to handle the 1:100 year yield of the dams, plus a 25% peak factor, where applicable. The schemes will, as far as possible, be implemented in phases, in order to delay capital expenditure.

The most important characteristic of the Impendle Scheme is the fact that much of the infrastructure is an extension of existing facilities, such as the waterworks and pipelines, and also makes use of existing facilities or facilities that will be implemented prior to the Mkomazi Scheme, such as the Midmar and Stuckenberg Tunnels. The scheme is largely a gravity scheme, with limited boosting required between Midmar Dam and the waterworks.

The proposed Impendle Dam is a rockfill embankment with a central clay core and side channel spillway. Deep weathering on the flanks preclude a concrete gravity dam and geotechnical investigations indicate that there should be sufficient suitable material available locally. Capacities of up to 1,5 MAR were investigated.

The transfer tunnel will either be a pressure tunnel or a free water surface tunnel, with the pressure tunnel allowing the possibility of surcharging with booster pumps , should more water become available for transfer. The tunnel will be excavated by TBM and fully concrete lined.

The clearwater pipelines will be laid along existing or extended servitudes and care will need to be taken in certain developed areas where space is limited. The system will require very careful operation once the Midmar and Ferncliffe Tunnels are operating together. Very high pressures will be encountered along portions of the pipeline route.

The Smithfield Scheme involves entirely new infrastructure, except for the balancing dam at Baynesfield. The scheme requires raw water to be pumped, unlike the Impendle Scheme, although the possibility exists of providing a larger diameter pressure tunnel which would significantly reduce the amount of pumping required. This alternative warrants further consideration at feasibility stage.

The proposed Smithfield Dam will be a composite structure, with a central RCC gravity spillway section and rockfill embankments on the flanks. A rockfill saddle dam is also provided across a neck on the left flank. The foundations in the river section and lower flanks are suitable for a concrete section, but deep weathering on the upper flanks precludes a concrete section there. Founding conditions on the upper flanks are also unsuitable for a spillway and an embankment option, similar to the Impendle Dam, was therefore excluded. The second phase dam at Impendle would be as described above.

Water for transfer will be abstracted via a multi-level intake tower, incorporating a pumpstation. A short length of rising main links the pumpstation to the transfer tunnel portal. The tunnel will be TBM excavated and will be fully concrete lined.

Balancing storage will be provided by raising the existing Baynesfield Dam, with a direct link between the tunnel portal and waterworks being provided in addition to the link from the dam. The clearwater pipelines will be laid through relatively gently sloping and largely undeveloped terrain and no significant problems are anticipated.

Neither scheme is expected to have water quality problems related to the transfers, as the quality of the Mkomazi River water is generally better than that of the Mgeni. However, the Midmar Dam outlet capacity is limited and water abstracted from the scour outlets will have to be utilised, with associated potential treatment problems.

It is anticipated that approximately nine years would be required to implement the first phase of either of the schemes, including preliminary work (Further geotechnical investigations, feasibility study, procurement of funding and design and tender). The transfer tunnel will be on the critical path in both cases.

The total capital costs of the schemes are very similar, at between R2 400 and R2 700 million. The first phase Smithfield Schemes are 12% to 20% cheaper than the first phase Impendle Schemes, at approximately R1 500 million, and cash flows will be similar.

A number of issues require particular attention during the feasibility study, depending on the scheme selected, the most significant of these being the following:

- *Refine phasing of schemes and review desirability of raising Impendle Dam.*
- *Geohydrological assessments of tunnel routes and quarry investigations for dams.*
- *Optimise spillway lengths and model test.*
- *Evaluate Smithfield pressure tunnel alternative.*
- *Carry out detailed analysis of aqueducts between Midmar Waterworks and Northern Feeder pipeline.*
- *Evaluate long term serviceability of Midmar Dam outlets under ultimate flow conditions.*
- *Assess cost implications of treatment of Midmar Dam scour water.*

An assessment of the risk of operational failure of the two schemes, undertaken by SRK Consulting, using probabilistic fault-event tree techniques, indicated that the risk of a curtailment of supply to Umlaas Road for at least five days would be approximately 60% greater for the Impendle Scheme than for the Smithfield Scheme. However, the risk of curtailment for the Impendle Scheme remains relatively low, at approximately 1:100 years.

On the basis of the technical evaluation of the schemes, it can be concluded that both schemes are technically feasible, but that the Impendle Scheme has various problems, mainly of an operational nature. The risks of operational curtailment are insufficient to warrant the elimination of either scheme from further investigation and the costs of the schemes are similar, with the first phase Smithfield Schemes slightly cheaper.

It can therefore be concluded that the Smithfield Scheme is the preferred scheme from a technical and cost perspective, but that it would be inappropriate to eliminate either scheme on the above grounds alone. Consideration should first be given to the relative environmental impacts and economics of the schemes (see Main Report). The selection of the preferred configuration of the selected scheme should be made after more detailed investigations in the feasibility phase.

MKOMAZI-MGENI TRANSFER SCHEME

SUPPORTING REPORT NO 6: ENGINEERING DESIGN & COSTING

CONTENTS **Page**

CONTENTS (cont'd) **Page**

CONTENTS (cont'd) **Page**

APPENDICES

Bound into this report

CONTENTS (cont'd)

MKOMAZI-MGENI TRANSFER SCHEME

SUPPORTING REPORT NO 6: ENGINEERING DESIGN & COSTING

1. INTRODUCTION

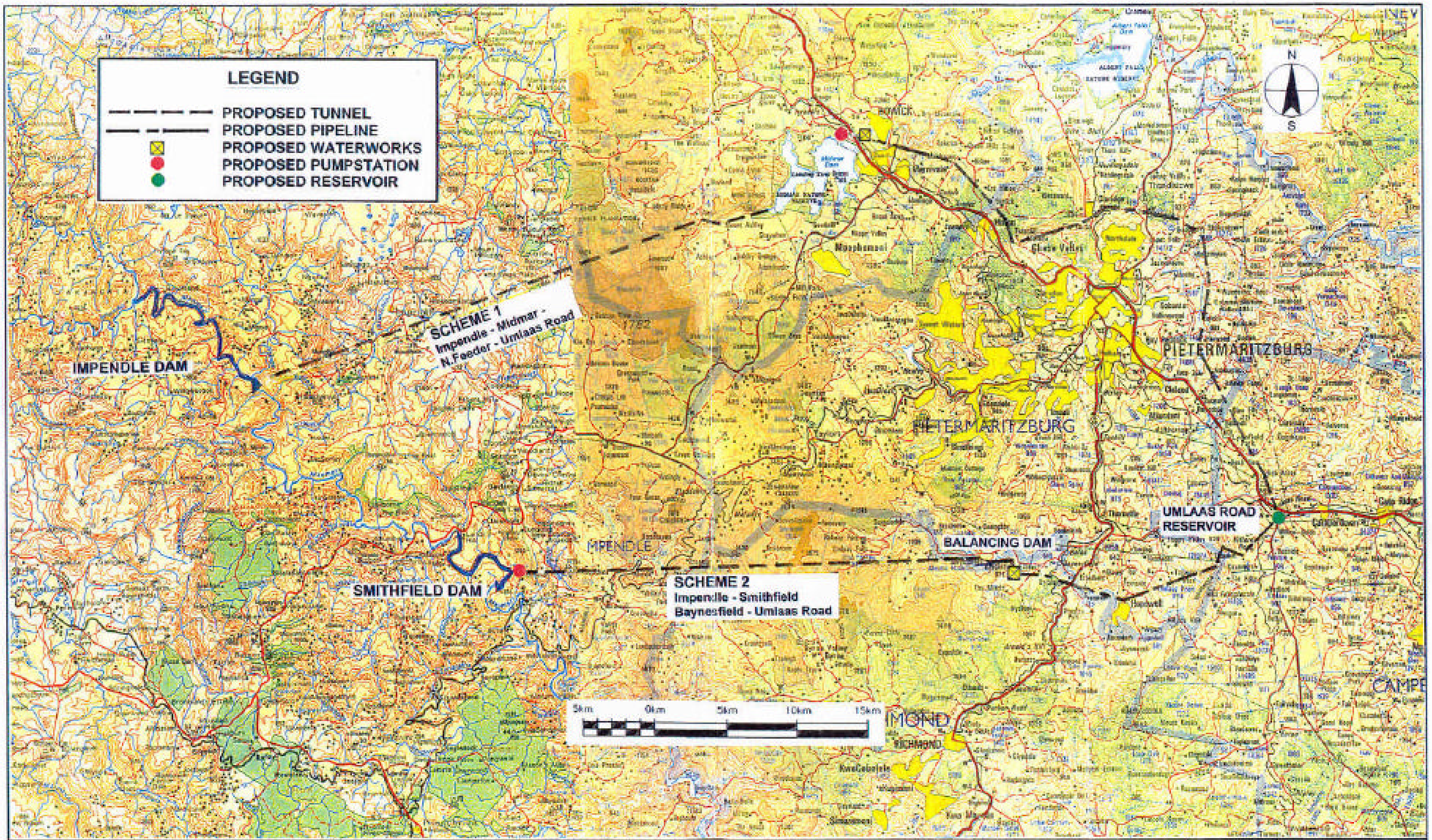
During the reconnaissance phase of the Mkomazi-Mgeni Transfer Scheme Pre-feasibility Study (see Supporting Report No 1: Reconnaissance Investigations), a total of eight possible schemes to augment the Mgeni System from the Mkomazi River were identified. During the course of this investigation, six of these schemes were eliminated and two were selected for further investigation in the pre-feasibility phase of the study, these being the Impendle and Smithfield Schemes. The scheme layouts are shown in **Figure 1.1**.

This Report describes the engineering design and costing of the two schemes at pre-feasibility level, which was carried out with the objective of confirming the technical feasibility of the schemes, providing input data for the economic comparison of the schemes (see Supporting Report No 7: Economics) and identifying technical preferences which could assist in the selection of the preferred scheme to be investigated further in a feasibility study (see Main Report). Three configurations of each scheme were investigated.

A separate study, in which the risk of interruptions in supply from each of the two schemes due to a component failure, was commissioned by Umgeni Water and carried out by SRK (Umgeni Water, 1998a). The findings of the SRK report are summarised in this report and the full report is included as a separately bound appendix (**Appendix H**).

In the initial phase of the Study, the Project Management Committee proposed that the schemes should be sized to meet the projected 2025 demands. However during the reconnaissance phase, it became apparent that the transfer tunnel costs dominated and the most economical schemes configurations were found to be those which maximised the yield of the Mkomazi System and thus the capacity of the transfer tunnels, which are sized according to practical considerations. This approach was therefore also followed in this phase of the Study.

Conveyance and treatment infrastructure was sized to handle the 1 in 100 year yield of the dams, assuming present day catchment development conditions (see Supporting Report No 3: Reconnaissance Basin Study). This was done to ensure that the yield of the Mkomazi can be maximised in the event of projected future in-basin demands not materialising. However, the economic evaluation of the schemes was carried out assuming future (2040) catchment development.



NINHAM SHAND CONSULTING ENGINEERS

MKOMAZI-MGENI TRANSFER SCHEME PRE-FEASIBILITY STUDY

LAYOUT OF SCHEMES

UMGENI WATER - AMANZI

FIGURE No. 1.1

2. DESIGN ASPECTS OF THE IMPENDLE SCHEME

2.1 Scheme Description

Details of the Impendle Scheme are given in **Table 2.1a, b** and **c**. Note that these are for the selected scheme configurations, the derivation of which is described below. All detailed drawings of the scheme are included in **Appendix A1**. The scheme consists of a dam on the Mkomazi River near Impendle, with a transfer tunnel to Midmar Dam and conveyance and treatment infrastructure supplying potable water to a proposed reservoir at Umlaas Road. Much of the infrastructure is located adjacent to existing infrastructure and some existing infrastructure, such as the Midmar Tunnel, is utilised. The three scheme configurations evaluated are as follows:

Scheme 1A: A dam with a capacity equivalent to 1,5 times the Mean Annual Runoff (MAR), with related conveyance and treatment infrastructure.

Scheme 1B: A dam with capacity of 1,0 MAR with related conveyance and treatment infrastructure.

Scheme 1C: A dam with an initial capacity of 1,0 MAR, later raised to a 1,5 MAR capacity, with related conveyance and treatment infrastructure.

The scheme will be implemented in phases and the main scheme components for the ultimate scheme are as follows:

- A dam on the Mkomazi River, a short distance downstream of the Nzinga River confluence, possibly implemented in two phases by raising, incorporating

- a multi-level outlet tower, feeding twin pipelines to a free water surface or pressure gravity tunnel, discharging into a stream at Midmar Dam.

- Twin pipelines from Midmar Dam to an ended Midmar Pumpstation and from there to an extended Midmar Water Treatment Works. The outlets of Midmar Dam will also require upgrading.

- Twin pipelines from the waterworks to the proposed Stuckenberg Tunnel and from the tunnel outlet to the existing Midmar Tunnel. A branch will be provided to the existing Ferncliffe Tunnel, which will be upgraded.

- A control structure near the Midmar and Ferncliffe Tunnel outlet portals feeding twin pipelines to the start of the proposed Northern Feeder pipeline.

- Twin pipelines along the Northern Feeder route to a proposed clear water reservoir immediately to the south of the N3 freeway at Umlaas Road.

Conveyance infrastructure downstream of Umlaas Road was excluded from consideration in this study.

As indicated above, the conveyance and treatment infrastructure is sized for the 1 in 100 year scheme yield. In addition, allowance was made for a 25% peak factor in all infrastructure downstream of Midmar Dam. Midmar Dam itself has sufficient capacity to handle fluctuations in demand and it was therefore not necessary to consider peaks in the raw water transfer infrastructure.

TABLE 2.1a

<table>
<tr><th colspan="5">IMPENDLE SCHEME 1A - RAISED TO 1,5 MAR</th></tr>
<tr><th></th><th colspan="2">Phase 1</th><th>Phase 2</th><th>Phase 3</th></tr>
<tr><td>Transfer Capacity (Peak)</td><td colspan="2">5,4 m^3/s (6,7 m^3/s)</td><td>Total 9,4 m^3/s (11,8 m^3/s)</td><td>Total 10,7 m^3/s (13,3 m^3/s)</td></tr>
<tr><td>Transfer Route and Description</td><td colspan="4">Impendle Dam-gravity tunnel-Midmar Dam-pumpstation-Midmar Waterworks-gravity pipeline/Stuckenberg Tunnel-Midmar/Ferncliffe Tunnel-gravity pipeline-Umlaas Road reservoir</td></tr>
<tr><td>Dam: Name
Type
Spillway
Crest Level; FSL; River Bed Level
Minimum operating level
Height of wall
Surface area at FSL
Storage capacity at FSL
1:100 year stochastic yield</td><td colspan="2">Impendle for raising
Rockfill embankment with clay core
Side channel
1 192 masl; 1 184 masl; 1 100 masl
1 123 masl
92 m
1 934 ha
535 million m^3 (100% MAR)
296 million m^3/a</td><td></td><td>Impendle raised
Rockfill embankment with clay core
Side channel
1 205 masl; 1 197 masl; 1100 masl
1 123 masl
105 m
2 580 ha
830 million m^3 (150% MAR)
336 million m^3/a</td></tr>
<tr><td>Tunnel: Route
Length
Diameter
Description
Typical rock formation
Average gradient
Inlet invert level
Outlet invert level
Intake works</td><td>Impendle Dam to Midmar Dam
34,9 km
3,5 m bored (3,0 m lined)
TBM bored & fully lined. Gravity pressure flow.
Sandstones, siltstones & dolerite intrusions
1 in 1 000
1 113 masl
1 080 masl
Multi-level intake tower</td><td>Stuckenberg
2,025 km
3,6 m x 3,6 m
D & B, fully lined, gravity pressure flow</td><td colspan="2">Upgrading of existing Ferncliffe Tunnel.
6,4 km
1,8 m dia (lined)
Steel liners & shotcreting, gravity pressure flow</td></tr>
<tr><td>Pumpstation: Location
Capacity
Maximum/Average head</td><td colspan="2">Midmar
6,7 m^3/s
32 m/20 m</td><td>Midmar (upgrade)
13,3 m^3/s total
32 m/20 m</td><td></td></tr>
<tr><td>Pipelines: Routes
General</td><td colspan="4">Raw water: Rising main from Midmar Dam to Midmar Water Treatment Works; Clear water: Gravity main to proposed Stuckenberg Tunnel, gravity link to existing Midmar Tunnel and upgraded existing Ferncliffe Tunnel, gravity main from outlet portals to reservoir at Umlaas Road, along route of proposed Northern Feeder.
All pipelines are buried. Existing pipelines will not be utilised.</td></tr>
<tr><td>Diameter
Length (total)</td><td colspan="2">From 1 600 mm to 1 800 mm
45 km</td><td>From 1 600 mm to 1 800 mm
45 km</td><td>—</td></tr>
<tr><td>Waterworks: Description
Capacity prior to upgrade
Upgraded capacity</td><td colspan="2">Upgrade of existing Midmar Waterworks
370 Ml/d
950 Ml/d</td><td>Upgrade of Midmar Waterworks
950 Ml/d
1 530 Ml/d</td><td>—</td></tr>
<tr><td>Features:</td><td colspan="4">Largely gravity scheme, utilises existing servitudes and infrastructure as far as possible.</td></tr>
</table>

TABLE 2.1b

IMPENDLE SCHEME B (SCHEME 1B) - 1,0 MAR DAM			
	Phase 1		**Phase 2**
Transfer Capacity (Peak)	4,7 m³/s (5,9 m³/s)		Total 9,4 m³/s (11,8 m³/s)
Transfer Route and Description	Impendle Dam-gravity tunnel-Midmar Dam-pumpstation-Midmar Waterworks-gravity pipeline/Stuckenberg Tunnel-Midmar/Ferncliffe Tunnel-gravity pipeline-Umlaas Road reservoir		
Dam: Name Type Spillway Crest Level; **FSL**; River Bed Level Minimum operating level Height of wall Surface area at FSL Storage capacity at FSL 1:100 year stochastic yield	Impendle for raising Rockfill embankment with clay core Side channel 1 192 masl; **1 184 masl**; 1 100 masl 1 123 masl 92 m 1 934 ha 535 million m³(100% MAR) 296 million m³/a		
Tunnel: Route Length Diameter Description Typical rock formation Average gradient Inlet invert level Outlet invert level Intake works	Impendle Dam to Midmar Dam 34,9 km 3,5 m bored (3,0 m lined) TBM bored & fully lined. Gravity pressure flow. Sandstones, siltstones & dolerite intrusions 1 in 1 000 1 113 masl 1 080 masl Multi-level intake tower	Stuckenberg 2,025 km 3,6 m x 3,6 m D & B, fully lined, gravity pressure flow	Upgrading of existing Ferncliffe Tunnel. 6,4 km 1,8 m dia (lined) Steel liners & shotcreteing, gravity pressure flow
Pumpstation: Location Capacity Maximum/Average head	Midmar 5,9 m³/s 32 m/20 m		Midmar (upgrade) 11,8 m³/s total 32 m/20 m
Pipelines: Routes General	Raw water: Rising main from Midmar Dam to Midmar Water Treatment Works; Clear water: Gravity main to proposed Stuckenberg Tunnel, gravity link to existing Midmar Tunnel and upgraded existing Ferncliffe Tunnel, gravity main from outlet portals to reservoir at Umlaas Road, along route of proposed Northern Feeder. All pipelines are buried. Existing pipelines will not be utilised.		
Diameter Length (total)	From 1 600 mm to 1 800 mm 45 km		From 1 600 mm to 1 800 mm 45 km
Waterworks: Description Capacity prior to upgrade Upgraded capacity	Upgrade of existing Midmar Waterworks 370 Ml/d 879 Ml/d		Upgrade of existing Midmar Waterworks 879 Ml/d 1 388 Ml/d
Features:	Largely gravity scheme, utilises existing servitudes and infrastructure as far as possible.		

TABLE 2.1c

IMPENDLE SCHEME 1C - 1,5 MAR DAM (NOT RAISED)			
	Phase 1		**Phase 2**
Transfer Capacity (Peak)	5,4 m³/s (6,7 m³/s)		Total 10,7 m³/s (13,3 m³/s)
Transfer Route and Description	Impendle Dam-gravity tunnel-Midmar Dam-pumpstation-Midmar Waterworks-gravity pipeline/Stuckenberg Tunnel-Midmar/Ferncliffe Tunnel-gravity pipeline-Umlaas Road reservoir		
Dam: Name Type Spillway Crest Level; **FSL**; River Bed Level Minimum operating level Height of wall Surface area at FSL Storage capacity at FSL 1:100 year stochastic yield	Impendle for raising Rockfill embankment with clay core Side channel 1 205 masl; **1 197 masl**; 1100 masl 1 123 masl 105 m 2 580 ha 830 million m³ (150% MAR) 336 million m³/a		
Tunnel: Route Length Diameter Description Typical rock formation Average gradient Inlet invert level Outlet invert level Intake works	Impendle Dam to Midmar Dam 34,9 km 3,5 m bored (3,0 m lined) TBM bored & fully lined. Gravity pressure flow. Sandstones, siltstones & dolerite intrusions 1 in 1 000 1 113 masl 1 080 masl Multi-level intake tower	Stukenberg 2,025 km 3,6 m x 3,6 m D & B, fully lined, gravity pressure flow	Upgrading of existing Ferncliffe Tunnel. 6,2 km 1,8 m dia (lined) Steel liners & shotcreteing, gravity pressure flow
Pumpstation: Location Capacity Maximum/Average head	Midmar 6,7 m³/s 32 m/20 m		Midmar (upgrade) 13,3 m³/s total 32 m/20 m
Pipelines: Routes General	Raw water: Rising main from Midmar Dam to Midmar Water Treatment Works; Clear water: Gravity main to proposed Stuckenberg Tunnel, gravity link to existing Midmar Tunnel and upgraded existing Ferncliffe Tunnel, gravity main from outlet portals to reservoir at Umlaas Road, along route of proposed Northern Feeder. All pipelines are buried. Existing pipelines will not be utilised.		
Diameter Length (total)	From 1 600 mm to 1 800 mm 45 km		From 1 600 mm to 1 800 mm 45 km
Waterworks: Description Capacity prior to upgrade Upgraded capacity	Upgrade of existing Midmar Waterworks 370 Ml/d 950 Ml/d		Upgrade of existing Midmar Waterworks 950 Ml/d 1 530 Ml/d
Features:	Largely gravity scheme, utilises existing servitudes and infrastructure as far as possible.		

2.2 Dam Design

2.2.1 Introduction

The proposed Impendle Dam is located on the Mkomazi River near Impendle at co-ordinates 29E39’00” S 29E46’00” E in the Impendle District. It has a catchment area of 1 422 km^2 and a natural MAR of 568 million m^3/a. The proposed dam site is one of various sites that had been identified in previous studies by the Department of Water Affairs and Forestry (DWAF) on this reach of the river. This site, described as centreline D3 is located about 1 200 m downstream of the confluence between the Mkomazi and Nzinga Rivers. The other sites that were considered were centreline D2, situated about 600 m downstream of the Nzinga confluence and another centreline about 1 000 m downstream of the selected D3 centreline.

As indicated in Section 1, it was clear from the reconnaissance phase investigations that schemes which maximise the yield of the Mkomazi are the most economical. It was thus necessary to select a dam site which would allow the construction of the largest practical size of dam. The D3 centreline was selected on the basis of the following:

- Its topography requires the least volume of fill for the size of dam being considered.
- It allows the construction of a common intake tower for transfers and river releases.
- Its location suits the optimum transfer tunnel configuration.
- Its geometry allows river diversion through a tunnel, which can later be used to accommodate the outlet pipes.
- Geological conditions at the site are better than the other sites.

The depth/area/capacity relationships of the basin are given in **Figures A1.21** and **A1.22.**

A composite gravity dam with central spillway and embankment fill on the right flank was considered for the upstream centreline at site D2. This option was found to be about 20% more expensive than the option of an embankment dam with a side channel spillway at site D3 for dams of similar capacity.

The ultimate size of the Impendle Dam was determined on the basis of the limiting topography of the site and the maximum practically attainable yield. A dam 105 m high was therefore selected, with a gross storage capacity of 830 million m^3, equivalent to 1,5 times the Mean Annual Runoff (MAR) at the site. The feasibility of raising was also considered and it was found that the maximum practical raising which could be achieved was approximately 13 m. The first phase dam is therefore 92 m high with a capacity of 535 million m^3, equivalent to 1,0 MAR. Further details are provided in Section 2.2.5 below.

In addition, a 1,0 MAR dam and a 1,5 MAR dam without provision for raising were considered, in order to assess the relative economics of a smaller dam and raising.

2.2.2 Geotechnical aspects

The two dam sites, D2 and D3 that had been previously identified by DWAF at Impendle have been extensively investigated for an earlier study by means of drilling of the dam centrelines, side channel spillway sites and a potential quarry site. These site investigations, which were taken to a greater level of detail than is normally required for pre-feasibility level of investigations, are summarized in the Council for Geoscience review report (Council for Geoscience, 1997a), which is included in a separately bound appendix to this report (**Appendix G**).

The geology at the preferred centreline D3, the site of the proposed dam, consists of an unweathered dolerite sill in the river section which is overlain by siltstone and minor sandstone sedimentary rock of the Estcourt formation on both the left and right flanks. The sedimentary rocks are relatively deeply weathered and overlain by hillwash soils and talus to depths of up to 11 m in some places on the mid slopes. Very deep excavations would be required for the foundations of a gravity dam on the abutment slopes and the valley sides are too steep to be suitable for a composite dam. Embankment dams were thus considered for this site. The right flank of this site is underlain by another dolerite sill above elevation 1 190 masl.

The side channel spillway on the right flank will be cut into the sedimentary rocks on the crest of the ridge extending down to the river. Part of the cut for the spillway for phase 2 will be in dolerite. The geological studies indicate that at least 60% of the material excavated from the spillway excavation will be suitable for use in the embankment.

A potential quarry site has been located in a 50 m thick dolerite sill situated about 1,0 km to the north east of the dam site. The quarry is outside the reservoir basin which would allow for its use for the raising of the dam in the second phase. Careful attention will have to be paid to the detailed quarry plan so as to minimize the environmental impact of the excavation.

Clay core material can be obtained from the deeply weathered siltstones and mudstones in the right flank of the valley in the spillway area and upstream of the dam in the dam basin, but the availability of this material should be confirmed at feasibility stage.

2.2.3 Water quality and sedimentation

A study was undertaken by Umgeni Water to assess the probable water quality in the proposed dam. The findings of the study relevant to this scheme are summarised below and the full report is included in **Appendix H** to this report.

The water quality of the Mkomazi is generally good, showing a gradual deterioration towards the estuary. Nutrient levels are low and turbidities vary significantly. Overall, water quality is better than that of the receiving river system, namely the Mgeni at Midmar Dam.

The periodic high turbidities can be attributed to degradation of parts of the catchment through poor land use practices. With the relatively large reservoir volumes being proposed, a large degree of settlement of suspended solids will occur upstream of the intake tower and the turbidity of transferred water will therefore be low. Overall, the water quality in Midmar Dam should be improved by the transfers.

The reservoir will almost certainly stratify during the summer, when low dissolved oxygen concentrations and temperatures will be encountered in the water column below the thermocline. Whilst this will not pose treatment problems, as the transferred water will have sufficient time to become oxygenated in Midmar Dam before it is abstracted, release of this cold, anaerobic water into the river would cause significant ecological damage. It is therefore necessary to provide a multi-level draw-off facility to allow the abstraction of warmer, aerobic water from near the surface.

Estimates of sedimentation rates for the dam were prepared by Professor Albert Rooseboom. A copy of his report is included in **Appendix C** and his findings are summarised below.

The basic yield potential of the soils within the catchments has been classified predominantly as 12 and 15 on a scale of 1 to 20, with 20 having the lowest yield potential. Although there are localised patches of severe erosion, generally the soils are stable and reasonable vegetation cover is present. Given this situation, the probable annual sediment yield would be 150 t/km^2, with a maximum foreseeable yield of 300 t/km^2. However, given current catchment management initiatives, it is to hoped that this higher figure will not materialise. The corresponding sedimentation rates for the dam will thus be as given in **Table 2.2** below.

Table 2.2: Estimated Sedimentation Rates for Impendle Dam

	Sediment Volumes	
	Yield 150 t/km^2.a	**Yield 300 t/km^2.a**
After 20 years	5,2 million m^3	10,4 million m^3
After 50 years	7,9 million m^3	15,8 million m^3

It can be concluded that sedimentation is insignificant in comparison to the proposed dam volumes and can easily be accommodated within the dead storage below the minimum operating level.

2.2.4 Selection of dam type

A rockfill embankment dam with a central clay core was selected as the preferred dam type for this site, rather than a composite dam with a central RCC gravity spillway section and embankments on the flanks. As the river section is relatively narrow and the flanks of the valley are steep and consist of deeply weathered sedimentary rocks it was considered that a gravity dam would not be suitable for the site despite the fact that an unweathered dolerite sill occurs in the valley section. The reason for this decision is that the gravity spillway section and tongue walls would extend into the deeply weathered slopes on the flanks where the steep slopes and poor founding conditions are not suitable for this type of dam. The layout of the proposed dam is shown in plan in **Figure A1.2**, in elevation in **Figure A1.3** and in section in **Figure A1.4**.

A concrete faced rockfill dam was not considered appropriate, due to poor founding conditions on the flanks for the plinth. A rockfill embankment was considered preferable to an earthfill embankment in view of the height of dam and the availability of rock from the spillway excavations and a nearby dolerite sill.

Founding conditions and the topography of the right flank suit a side channel spillway. As indicated in Section 2.2.2 above, at least 60% of the material excavated from the spillway would be suitable for use in the embankment.

2.2.5 Embankment design

The typical rockfill embankment cross section as given in the DWAF VAPS Guidelines (DWAF, 1994) was adopted so as to be consistent with other pre-feasibility studies and as agreed at the commencement of the Study. The design given in the VAPS guidelines was modified to a sloping clay core so as to allow for the raising of the dam, which in turn reduces initial capital expenditure. The two stages are a 1,0 MAR dam with a full supply level (FSL) of 1 184 masl and a non-overspill crest (NOC) level of 1 192 masl in the first stage which can be raised to a FSL of 1 197 masl and a NOC level of 1 205 masl for the raised dam which would have a capacity of 1,5 MAR.

The height of the embankment dam would be 97 m for the first stage and 110 m for the raised second stage of construction. The total volume of embankment fill would be about 4 million m^3 for the first stage and 5,6 million m^3 for the raised dam. An additional 1,6 million m^3 would thus need to be added to raise the dam from a FSL of 1 184 masl to 1 197 masl.

Large quantities of sound dolerite for rockfill are available from deposits located within about 1 km of the dam site. Unweathered siltstones, mudstones and sandstones from spillway and other excavations can be used in the inner part of the rockfill section. It may also be possible to utilise spoil from the transfer tunnel excavations in transition zones within the embankment. It is envisaged that all filter material will have to be crushed.

Provision was made both for curtain and blanket grouting in the cut-off trench, the depth of which is in accordance with recommendations in the geological report.

A 30 m high coffer dam will be incorporated into the upstream portion of the rockfill dam as shown in **Figures A1.2** and **A1.4**.

2.2.6 Spillways

Flood magnitudes at Impendle were determined by the DWAF Directorate of Hydrology based on a statistical analysis of flow records of streamflow gauge U1H005 and extrapolated to the Impendle and Smithfield sites on the basis of their relative catchment areas. In addition, Regional Maximum Floods (RMF's) were determined. This report is presented in **Appendix B**.

In accordance with the VAPS Guidelines and in line with the current SANCOLD Guidelines (SANCOLD, 1991), the spillway should be sized to pass the Safety Evaluation Discharge (SED), where the SED is based on the RMF for the adjacent region with a K-value numerically one step greater than that of the region in which the dam lies, that is $RMF_{+Ä}$. In the case of the Impendle Dam, the K-value for the SED is 5,2. The Recommended Design Flood (RDF) would be the 1 in 200 year flood. The flood magnitudes and spillway surcharges, assuming a spillway length of 100 m, for various return periods are given in **Table 2.3**. Note that flood routing was not assessed.

Table 2.3: Results of Flood Analysis for Impendle Dam

Recurrence Interval (Years)	1:2	1:10	1:20	1:50	RDF 1:200	RMF	SED
Flood Peak (m^3/s)	320	830	1 080	1 460	2 110	3 760	4 400
Flood surcharge with 100 m long spillway (m)					4,5	6,6	7,4

As can be seen from the above, a 100 m long spillway with a discharge coefficient of 2,2 will pass the SED with a surcharge of 7,4 m. Allowance was therefore made for a total freeboard of 8 m, leaving a dry freeboard of 0,6 m to the crest of the dam. Whilst the specific discharge and total spillway capacity are large for a side channel spillway, there are precedents (Charlie Malan Dam) and it can be assumed that the design is feasible.

For the first stage, the side channel control sill would be located about 100 m downstream of the crest of the dam at the upper end of the discharge channel. For the raised dam the discharge channel would be extended upwards in line with the lower section and a new control sill constructed at a higher level. Bulk blasting for the second phase spillway would be carried out at the same time as the first phase excavations, to avoid potential damage to the structure or grout curtain. A diagrammatic longitudinal section on the spillway channel for both stages of construction is shown in **Figure A1.5**.

The side channel spillway solution was chosen on the right bank so as not to conflict with the diversion tunnel, outlet works and transfer tunnel which are located on the left bank to take advantage of the bend in the river at the site and to allow easy connection to the inlet portal of the transfer tunnel which is located downstream of the dam.

The topography of the right bank favours a side channel spillway layout as a conventional by-wash spillway would involve much larger excavation and concrete volumes and would not be amenable to the raising of the dam.

The spillway discharge channel will have a heavy concrete lining which will be dowelled into the underlying rock. The discharge channel is steep and relatively long. It will therefore require the provision of aeration slots to control cavitation with the very high velocity flows that would develop in the chute. These systems must be evaluated in more detail at feasibility and detailed design stages.

2.2.7 River diversion and outlet works

A 7,5 m diameter drill and blast tunnel will be constructed under the left flank of the dam across the bend in the river. The tunnel will be excavated partly in unweathered dolerite and partly in siltstone and interbedded sandstone. The tunnel will be fully concrete lined throughout. The tunnel will be used for river diversion during construction in conjunction with a 30 m high coffer dam and will be capable of passing the 1 in 10 year flood.

A free-standing outlet tower will be provided over the upstream intake to the tunnel. The tower is equipped with trash racks and GRP fine screens and will house twin 1 600 mm diameter pipes with 10 staggered intakes at 7 m centres, each equipped with a butterfly valve. Two 2 000 mm diameter scour offtakes will be provided at elevation 1120 masl, also equipped with butterfly valves. The vertical intake pipes will be connected by twin 2 000 mm diameter pipes laid in the tunnel once the diversion tunnel is closed at its upstream end by a closure block, which would include temporary diversion outlets connected to the outlet pipes. Slab gates will be provided on the upstream side of the intakes for maintenance of valves and pipework. Details of the outlet tower and diversion/access tunnel are shown in **Figures A1.6, A1.7** and **A1.9.**

At the downstream end of the tunnel, a 1 600 mm diameter offtake to the transfer tunnel is provided from each of the outlet pipes. In the outlet house shown in **Figure A1.8**, the outlet pipes have a 1 000 mm diameter branch, fitted with isolating butterfly valves and 1 200 mm and 600 diameter sleeve valves respectively.

The pipework in the tower and the tunnel is sized to accommodate the 11 m^3/s maximum transfer into the transfer tunnel when the dam is at minimum operating level, as well as to simultaneously release the normal I F R flows of up to 40 m^3/s into the Mkomazi River. However, with a reservoir capacity as large as this, achieving emergency drawdown within typical norms is not practically possible. Assuming zero inflow, the dam could be drawn down from FSL to 10% of its volume within 135 days. A reservoir drawdown curve is given in **Figure A1.20.**

Access to the outlet tower will be via the diversion tunnel and hoists and a lift within the tower. It is not intended to provide an access bridge to the top of the tower as the tunnel and tower will be large enough to accommodate the outlet pipes and to provide access for installation and maintenance of valves and pipework. Provision was not made for vehicular access within the tunnel, but this could be provided relatively easily, if required. Crawl beams are provided in the roof of the tunnel for transferring pipework and valves.

All built-in pipework will be of stainless steel, whilst other pipework will be of coated 3Cr-12. The main outlet pipes in the tunnel are concreted in, allowing the use of 3Cr-12 instead of stainless steel, with significant cost savings.

2.3 Transfer Tunnel Design

2.3.1 Introduction

The transfer tunnel is designed to deliver raw water under gravity from the Impendle Dam to Midmar Dam. The design capacity of the tunnel is equal to the 1 in 100 year yield of the Impendle Dam, although practical considerations dictate the diameter of the tunnel, as described below. The process of design of the Impendle transfer tunnel began with an initial screening of the various options available. From this selection, the recommended options were considered further in the light of:

- Alignment
- Portal positions
- Intermediate adits and portals
- Hydraulics (in this case pressure and free surface flow options)
- Geotechnical aspects
- Lining and support

Certain important basic assumptions were made with regard to aspects of the tunnel design:

Tunnel diameter

A diameter of 3,5 m was selected, being the minimum practical diameter of tunnel over this length of drive. Hydraulically a smaller diameter tunnel may well be acceptable, but will not be a practical solution. Reference is made to a larger diameter (4,5 m) that could be considered further at a later stage. The possibility also exists that, during the tender stage, the Contractor could propose an alternative diameter based on machine availability at that stage.

Length of drive

Lengths of tunnel drives have by and large been restricted to approximately 13 km. A study conducted on the Mohale Tunnel of the Lesotho Highlands Project has shown that 15 km is the maximum economical length of drive achievable by a 3,5 m diameter Tunnel Boring Machine (TBM). Aspects such as access and ventilation can become problematic with longer drives.

Lining

All tunnels have been assumed to be fully concrete lined along their entire length. This assumption should be refined at a later stage once more data becomes available. Waterproof membrane and steel lining lengths have been quantified according to tunnel type and known geological conditions, although the lack of available data has limited the level of lining design.

2.3.2 Engineering geology

General

A preliminary report (Council for Geoscience, 1997a) details the most recent information available on the Impendle Dam site and transfer tunnel. The rock mass characterisation and hydrogeology are also discussed.

The bulk of the proposed tunnel alignment, from the inlet to approximately 2 km from the outlet, will be excavated in Ecca Group rocks of the Estcourt formation (94%). The remaining portion at the outlet is expected to be driven in Beaufort Group rocks of the Volksrust formation (6%).

These rocks comprise siltstones and sandstone. The tunnel route is also intersected by intruded dolerite dykes and sills. The dolerites are expected to form approximately 11% of the proposed alignment.

Portals

The proposed new position of the tunnel inlet portal is not discussed in the report by the Council for Geoscience, but no major change is expected from the portal geology described in this report. It is expected that the portal will be in rocks of the Estcourt formation overlain by dolerite. Further investigation of this portal position will need to undertaken.

The outlet portal is expected to be driven in the Volksrust formation.

Geohydrology

The potential for high water inflows exists, particularly at the dolerite contact zones. This is problematic for downgrade drives as proposed for part of the transfer tunnel excavation. The additional risk and associated works to allow for pumping have been allowed for in the costing of downgrade drives.

Expected tunnelling conditions

With the exception of the areas close to the portals, the tunnel is expected to be excavated within an unweathered rock mass. Siltstone, mudstone, sandstone and dolerite, and combinations of these rock types will be encountered across the tunnel section. The dolerite intrusions may have a blocky structure which could lead to instability problems. Certain of the sedimentary rocks are known to be susceptible to slaking. These problems can be overcome by the installation of the correct primary support.

A preliminary assessment of the rock classes to be encountered was completed for preliminary costing purposes.

2.3.3 Initial screening process

To eliminate a number of the various options available, an initial screening process was carried out on the transfer tunnel.

The three variables considered were dam wall alignment, intake position and tunnel control. The first, dam alignment, was not part of the tunnel design process, and as such was excluded from the process early on. A change of the alignment would not significantly affect the process.

Intake positions both upstream and downstream of the dam wall were considered. An upstream position, within the dam basin, would require a dedicated intake tower, with cost and programme implications, and adding unnecessarily to the complexity of the scheme. A position downstream of the wall allows the tunnel to be linked to the dam outlet works via twin steel pipelines. Joint use is thus made of the intake tower and outlet pipework for transfers and river releases.

Various tunnel control options were considered, including pressure and free surface flow, and a “partial pressure flow” option, in which some head is broken at the intake, with flow control at this point.

Consideration of these alternatives and an elimination process resulted in two options being recommended, namely free surface flow and pressure flow tunnels, both with inlet portals downstream of the proposed dam wall. The pressure flow option has a marginally higher cost, but could have its capacity increased in future by surcharging through pumping, an option not available with the free water surface option. Other extraneous factors at a later stage of investigation, such as possible transfers from the Mzimkhulu River to the Mkomazi, could influence a final decision.

2.3.4 Tunnel alignment

General

The use of 3,5 m diameter TBM’s leads to the need of intermediate access, as the length of tunnel drives have to be restricted, as indicated in Section 2.3.1. The Impendle option would thus require three TBM drives if a 3,5 m diameter tunnel were to be constructed. If TBM’s of larger diameter were to be used, only two drives would could be required, one from the inlet and one from the outlet. Further investigation is required at feasibility phase into the option of larger diameter tunnels.

A longitudinal section of the tunnel and details of portal structures are shown in **Figures A1.17** and **A1.18**.

Two tunnel alignments have previously been considered by DWAF, (Council for Geoscience, 1997a), namely a more direct northerly route and a southern route. These were variations of drill and blast tunnels with access shafts. For the current study, variations on these two proposals were considered.

The portals and alignment for the free surface and pressure flow tunnel options have been assumed to be the same. Options of reverse grade tunnels were also investigated for the pressure tunnel option.

Inlet portal

For the purposes of this study an inlet below the dam wall has been assumed, the reasons for which have been discussed in Section 2.3.2. The portal is situated on the farm Compensation and has the following approximate coordinates (Lo 31E):

Y : + 118,950
X : + 3,281,130
Invert level : 1113 masl
(See **Figure A1.11** for the proposed position)

This position is on the north bank approximately 50 m downstream of the dam outlet works. In order to portal virtually perpendicular to the contours and gain cover quickly under a relatively steep slope (1:2,5), a horizontal curve has been incorporated at this portal. A relatively small open excavation and short drill and blast adit is anticipated to allow access to competent rock.

Assuming a 3,5 m diameter 13,500 m TBM drive, approximately 130 000 m^3 of spoil material will be generated from the tunnel. If a 4,5 m diameter TBM were to be implemented and the intermediate adit thus eliminated, this spoil volume would increase to approximately 280 000 m^3. This excavated material can be used in the inner portion of the downstream rockfill dam shell.

Outlet portal

Various options were considered for the outlet portal site. The proposed position is dictated by the hydraulic grade line if a free surface tunnel is considered. The same portal position has been assumed for the pressure tunnel option. The position utilises 350 m of the Kwa Gqishi stream which flows into Midmar Dam, reducing the required length and thus cost of the tunnel. It is situated on the farm Mount Ashley and its co-ordinates are as follows (Lo 31E):

Y : +86 480
X : +3 269 630
Invert level 1080 masl
(See **Figure A1.13** for the proposed position)

In order to portal virtually perpendicular to the contours and gain cover quickly under the steep slope, a horizontal curve has also been incorporated at this portal. A relatively small open excavation and short drill and blast adit is anticipated to allow access to competent rock.

Assuming a 3,5 m diameter 7 900 m TBM drive with an intermediate adit or shaft, approximately 80 000 m^3 to 100 000 m^3 of spoil material will be generated from the tunnel. If the option of a 4,5 m diameter TBM were to be implemented and the intermediate adit eliminated, the spoil volume would increase to approximately 280 000 m^3. This excavated material can be spoiled on the north side of the stream against the flanks of Mount Ashley.

Tunnel alignment

Various options of intermediate portal sites, up- and downgrade drives, and number of TBM's were considered.

i) 2 No 3,5 m diameter TBM's, one downgrade from the inlet and one upgrade from the outlet
ii) 2 No 3,5 m diameter TBM's, one upgrade from the outlet and one upgrade from a central point
iii) 3 No 3,5 m diameter TBM's, one downgrade from the inlet, one upgrade from the outlet and one upgrade from a 2/3 point.
iv) 4 No 3,5 m diameter TBM's, one downgrade from the inlet, one upgrade from the outlet, one upgrade from a 3/4 point and one downgrade from a 1/4 point.

These options were advanced to a similar level of detail which allowed comparative costing, including programming and the determination of setup costs and time related P&G costs, to be considered.

Option (iii) proved to be the most economical and practical solution for the 3,5 m diameter tunnel option, and is detailed as follows:

- 13 500 m downgrade drive from the inlet
- 7 900 m upgrade drive from the outlet
- 13 500 m upgrade drive from an intermediate position.

The tunnel alignment assumes the northerly route with a total length of 34 900 m. (See **Figure A1.10**).

The northerly route has been chosen, as a suitable intermediate adit position is available from the north within the Dargle Plantation. This is also the most direct route and allows for two of the drives to be upgrade, thus reducing the risk associated with high water inflows.

Intermediate portal

Provision has been made for an intermediate adit, sloping down to the tunnel invert at a grade of 1:10 for a length of 1 350 m. The excavated profile of the adit has been assumed to be 5,5 m wide by 6 m high. The selection of an adit over a shaft has been made to allow easier access and mucking from the tunnel. The proposed adit site is located within the Dargle Plantation, with the following approximate coordinates (Lo 31E):

Y :	+93 000
X :	+3 270 800
Invert level	1225 masl

(See **Figure No A1.12** for the proposed position)

Due to the nature of the topography, the open excavation will require approximately 200 000 m^3 of excavation. This excavation can be backfilled on completion with a section of "cut and cover" tunnel if maintenance access through this adit is required.

Assuming a 3,5 m diameter 13 500 m TBM drive and 6 x 5,5 m adit for 1350 m, approximately 180 000 m^3 of spoil material will be generated from the adit and tunnel.
This excavated material can be spoiled in the valleys adjacent to the portal site.

2.3.5 Hydraulics and portal structures

Pressure flow option

The option of pressure flow considers a tunnel operating at the full head from Impendle Dam, with no break in pressure at the tunnel inlet. Control under this option will take place at the tunnel outlet, using sleeve valves.

Design of the tunnel and pipework from the dam outlet works allows for the ultimate (Phase 3) configuration. The outlet works is linked to the tunnel via twin 1,6 m diameter cement mortar lined steel pipelines along the left bank of the river, connecting into the dam outlet pipes at the upstream end of the outlet works. All pipelines have been sized for a maximum velocity of 3,0 m/s.

The tunnel inlet portal will include twin 1 600 mm diameter isolating butterfly valves on the incoming link pipeline. Twin 600 mm diameter sleeve valves will be provided in the inlet portal structure, for the purpose of filling the tunnel. The high upstream head precludes the use of the main isolating valves for this purpose. A transition section will link the valve chamber to the tunnel.

The invert level of the tunnel inlet (1 113 masl) has been set according the minimum operating level (MOL) of the dam. Given this level, and expected headloss through the outlet pipes, the tunnel invert has been set to give approximately 5 m head over the crown of the tunnel and on any air valves on the inlet pipes at the peak flow of

11 m^3/s. This is a fairly low residual head, but will occur only under MOL conditions, when it is unlikely that the full transfer rate will take place

The outlet portal structure will comprise a transition section from the steel tunnel liner to the structure, and a transition chamber that will house the isolating butterfly valves and sleeve valve actuators. Energy will be dissipated against a baffle wall in a stilling basin, with the water flowing over a weir to the receiving stream. The 2 No 1 000 mm diameter sleeve valves will be mounted in this stilling basin.

A peak flow of 11 m^3/s has been assumed in the hydraulic design of the tunnel. A minimum grade of 1:1 000 has been retained for drainage purposes in the pressure tunnel option.

Access into the tunnel will be provided through a separate steel lined adit with a pressure dome. This configuration has been adopted to reduce the complexity of the steel liner in the transition section, and is duplicated at the inlet and outlet. Access at intermediate adits can be considered at a later stage if required.

To prevent overpressures on valve closure, that could damage the tunnel lining, a surge shaft has been allowed for at the downstream end of the tunnel. This would comprise a lined shaft of approximately 2 m diameter and height 120 m, with a facility to contain or safely pass any surge flows to the receiving stream.

The possibility of limited power generation at the outlet of the Impendle Tunnel (pressure option) should be considered further at a later stage, but has not been considered here.

Free surface flow option

Under this option, the tunnel will be linked to the dam outlet works in the same way, but control will be at the tunnel inlet portal structure, with sleeve valves mounted in a stilling basin, beneath an energy dissipation baffle sill.

The inlet portal structure will comprise a transition chamber housing 2 No isolating butterfly valves and the sleeve valve actuators, an inlet chamber in which the 2 No 1 000 mm diameter sleeve valves will be mounted, and a transition section between the inlet chamber and tunnel.

With a slope of 1:1 000, a flow of 11 m^3/s will have a flow depth of 2,1 m or 72% of the available depth after lining. Should the slope be reduced to one of say 1:1 250 with the MOL constraint at the tunnel inlet, then the maximum flow rate would have a depth of 2,3 m, or 80% of the available depth. This is still acceptable in terms of flow stability in the tunnel.

2.3.6 *Tunnel construction methods*

The available geological information is insufficient for a comprehensive boreability analysis. This can be completed once the necessary further work outlined in Section 6.1 is carried out. The information is, however, sufficient to suggest that the tunnel will be suitable for excavation by a hard rock tunnel boring machine, based on experience gained in construction on the Midmar Tunnel and information obtained from the investigation of the Wellington Tunnel as part of the Mooi-Mgeni Transfer Scheme.

Due to the length of the transfer tunnel, the use of TBM's will be far more economical than conventional (drill and blast) tunnelling methods. As stated previously, the use of 3,5 m diameter machines excavating on three headings, or larger diameter machines excavating on two headings will need to be investigated further. Special precautions will have to be taken for machines operating on downgrade drives.

For the purpose of this study the transfer tunnel has been assumed to require full lining. Further investigation into the durability of the rock will need to be completed before any decision on unlined lengths of tunnel can be made.

Three options exist for the lining of the tunnel : concrete, sprayed concrete (shotcrete) and precast segments. Precast tunnel invert segments are recommended for the TBM tunnels. Cast in-situ concrete invert lining would be constructed for the drill and blast sections. It has been assumed for costing purposes that the tunnel will be fully lined, constructed by pumping concrete into a rail mounted shutter. Further investigation is required into the costing and construction duration of the various options. If the tunnel were to be constructed at 3,5 m diameter, the use of precast segments would be unlikely as working space is at a premium, but the construction of a 4,5 m diameter tunnel could permit this option to be pursued.

Allowance has been made in the costing for the use of waterproof membrane at the portals and at various intervals along the route. Additional lengths of WPM have been allowed for in the pressure tunnel option in areas of low external hydrostatic head. The pressure tunnel option would require the installation of steel liners at the portals (low cover areas).

The geological assessment suggests that no major support problems should be expected when excavating the tunnel. As the tunnel has been assumed to be fully concrete lined, only temporary support will be needed during excavation of the tunnel. This support would take the form of rockbolts and weldmesh, or in poor ground conditions the use of shotcrete may be required.

Steel arches may be necessary for the portal excavations, until competent rock is reached. These additional support measures have been allowed for in the costing under the portal excavations.

2.4 Raw Water Conveyance: Midmar Dam to Midmar Waterworks

2.4.1 Pipelines

The existing pipelines between the Midmar Dam and the existing Midmar Pumpstation, as well as between the pumpstation and the existing Midmar Waterworks, were assumed to be fully committed with the proposed raising of Midmar Dam and implementation of the Mooi-Mgeni Transfer Scheme. Provision was therefore made for new pipelines 1,9 km long, following the most direct route to the pumpstation and waterworks. Twin 1600 mm diameter cement mortar lined steel pipelines will adequately handle the 1 in 100 year yield of the larger Impendle Scheme with a peak factor of 25%, namely 13,5 m^3/s. Under normal operating conditions, the maximum velocity in the pipelines will be less than 3 m/s. It is envisaged that the pipelines would be implemented in two phases.

The proposed pipelines will have to be laid in jacked sleeves under the R103, the N3 and the railway line.

2.4.2 Midmar Dam outlet works

The existing Midmar Dam outlet works has insufficient capacity for the additional yield of the proposed Mooi-Mgeni Transfer Scheme and the Impendle Scheme. The main 1 500 mm diameter outlet pipes, which have multi-level intakes, join into a single pipe immediately downstream of the outlet works, before branching again into twin pipes some distance downstream, one of which feeds the pumpstation and waterworks. Within the outlet house, the pipes are fitted short sections of smaller diameter pipe equipped with meters, which will also reduce their capacity. The twin 1 800 mm diameter scour pipes are currently used for river releases. It should be noted that a parallel study was commissioned by Umgeni Water to determine the as-built configuration of the outlets and to determine their capacity, but detailed results are not yet available.

In order to create sufficient outlet capacity for the full yield of the Impendle Scheme, it will be necessary to duplicate the single section of 1 500 mm pipe from the main outlets, as well as to tap into the scour pipes. It is envisaged that as much of the required flow as possible would be drawn from the main outlets, as these have multi-level intakes with obvious water quality benefits. The balance would have to be drawn from the scours, which will create treatment problems, as the quality of the scour water will be poorer, with relatively low dissolved oxygen concentrations and higher iron and manganese concentrations than the water drawn from higher levels. A brief report prepared by Umgeni Water is included in **Appendix D** (Umgeni Water, 1998b). However, these problems will probably not be insurmountable, although treatment costs will be higher.

Provisional allowance was therefore made for pipework and related butterfly valves to permit abstraction to the waterworks from both sets of outlets, but this aspect will require significantly more detailed investigation at feasibility stage.

2.4.3 Pumpstation

In order to supply the waterworks at the required rate over the full operating range of water levels in Midmar Dam, it is necessary to boost the pressure. It is envisaged that the existing pumpstation would be extended to an additional capacity of 13,5 m^3/s with an operating range of 8 to 32 m total head. The configuration would be as per the existing pumpstation, with pumps equipped with variable speed motors to allow the necessary flexibility in supply to the waterworks, housed in a typical industrial-type building.

2.5 Water Treatment Works

It was assumed that the treatment process and therefore the basic configuration of the waterworks would be the same as that of the existing Midmar Waterworks. No allowance was made at this stage for pre-treatment which may be required for water drawn from the Midmar scour pipes. The extended works will be located adjacent to the existing works in order to maximise use of existing infrastructure.

A 25% peak factor has been allowed for, yielding a capacity of 1 160 Mℓ/day for the larger schemes and 1 020 Mℓ/day for the smaller scheme. The waterworks will be common cost components for the two schemes and detailed investigations were not considered appropriate at this level of planning.

2.6 Clearwater Conveyance

2.6.1 Pipelines

From the Midmar Waterworks to the Northern Feeder offtake and links into the inland system, there is the following existing clearwater aqueduct infrastructure (See **Figure A1.14**):

- 251 line from Midmar Waterworks to Midmar Reservoir (1 600 mm diameter, steel, Copon lined and coated).
- Midmar Tunnel under Hilton Ridge (3,5 m TBM bored, partially lined).
- Midmar pipeline from Midmar Tunnel outlet to DV Harris Waterworks, Northern Feeder offtake and tie-in to inland system, (1 600 mm diameter, cement mortar lined, Sintakote coated steel)

All of this infrastructure, other than the Midmar Tunnel, was assumed to be fully committed for existing or proposed schemes other than the Mkomazi-Mgeni Transfer Scheme.

Midmar Waterworks to Northern Feeder

From the Midmar Waterworks, the existing pipeline servitude will be utilised to lay an additional 2 No 1 800 mm diameter steel pipelines, for the ultimate flow configuration. It has been assumed at this stage that the current servitude will be widened to accommodate the final configuration of the pipeline, but where there are constraints, such as through Howick, the existing concrete 51 pipeline, which should be decommissioned by that stage, will be removed and replaced by one of the new lines. hydraulic grade line problems, particularly in the vicinity of the Howick Golf Course, necessitate the 1 800 mm diameter pipe selected.

The possibility of utilising the existing 51 pipeline and providing a larger diameter third new line should be considered further at a later stage of investigation, but is unlikely to be a viable option.

River crossings will be constructed for the ultimate phase of 2 No 1800 mm diameter lines, although the actual pipelines will only be constructed as and when required.

It is envisaged that the section of existing pipeline around Stuckenberg Ledge, where stability problems have been encountered, will be replaced by a tunnel, as described in Section 2.6.2.

In the initial phase of the scheme, one of the new 1 800 mm diameter lines will tie into the Midmar Reservoir, discharging through 2 No new 1 000 mm diameter sleeve valves, for which the inlet structure was originally designed. It is proposed that the second phase 1 800 mm diameter line will tie into the existing Ferncliffe Tunnel, also running under the Hilton ridge, but at a higher elevation. The residual head from the Midmar Waterworks will be used to drive water through the Ferncliffe Tunnel, which will be upgraded and refurbished.

The Midmar pipeline between the Midmar Tunnel outlet and the Northern Feeder offtake will be upgraded from the existing 1 No 1 600 mm diameter line to 3 No 1 600 mm diameter pipes. The current tie-in to the 61 line to Worlds View Reservoir will remain, as will the offtake at DV Harris Waterworks, supplying directly to the Old Clarendon, Belfort and Ferncliffe Reservoirs. It has been assumed that the existing 53 pipeline in the same servitude will be replaced by the third 1 800 mm diameter pipeline.

Northern Feeder Pipeline

Umgeni Water are currently designing the Northern Feeder Pipeline, which will deliver potable water from the end of the Midmar pipeline to a reservoir at the Umlaas Road Waterworks (**Figure A1.15**). For the purposes of this study, it was assumed that the same route would be utilised to its limit at the Umlaas Road Waterworks, whereafter the pipeline will follow the northern side of the N3 to a point near the proposed terminal reservoir, where it will cross the N3 within jacked sleeves. Two 1 650 mm diameter pipelines will be required to handle the ultimate yield of the scheme with a 25% peak factor at acceptable velocities of approximately 3 m/s. The pipeline crosses numerous roads and has one major river crossing (Msunduzi River), which would be constructed in the first phase to accommodate both pipelines.

Very high pressures will be encountered along sections of the pipeline, even with a break pressure tank at Whispers, which should receive special attention at feasibility stage. Pipe wall thicknesses were determined in accordance with the VAPS Guidelines.

The existing Northern Feeder servitude is wide enough for two pipelines. If it is assumed that the pipeline currently being designed is implemented, the servitude width will be inadequate for the ultimate scheme with three pipelines and allowance was therefore made for widening of the servitude by 15 m.

2.6.2 Tunnels

Stuckenberg Tunnel

It has previously been proposed that a tunnel be constructed under and behind Stuckenberg Ledge on the 251 pipeline route. This was investigated by Keeve Steyn Inc, at pre-feasibility level (Umgeni Water, 1996), and is being studied at a higher level of detail at the time of writing this report. The proposed tunnel would be constructed to provide security of supply around the unstable geological zone along this ledge, that has is the past been the cause of pipe failure through slips. The final configuration of the tunnel has not yet been confirmed, and the details as given in the Keeve Steyn Inc. report have been therefore been assumed for the purposes of this investigation.

A reverse grade, gravity pressure, 3.6 m x 3.6 m drill and blast tunnel 2 km long has been assumed, fully concrete lined with steel liners at the inlet and outlet portals and waterproof membrane where required. The portal structures will accommodate all three pipelines of the ultimate configuration, with isolating butterfly valves.

It should be noted that a final decision has not yet been made as to whether the tunnel will be constructed as part of an earlier upgrade or as part of the Mkomazi-Mgeni Transfer Scheme. Consequently, scenarios both including and excluding the costs of the Stuckenberg tunnel were evaluated in the economic analysis (See Supporting Report No 7: Economics).

Ferncliffe Tunnel

The reason for the proposed utilisation of the Ferncliffe Tunnel is that the existing Midmar Tunnel is designed to pass only 1 000 Mℓ/day. The residual head from the Midmar Waterworks will be used to drive the additional flow required through the Ferncliffe Tunnel, upgraded to a potable water pressure tunnel. This will be accomplished through the installation of 1 800 mm diameter steel liners at the inlet and outlet portals, and at an intermediate low cover point, over a total length of 1 050 m. The remainder of the tunnel will be upgraded using rockbolts, mesh and shotcrete, as required. The proposals to upgrade the Ferncliffe Tunnel are, however, subject to an inspection of the facility, as there is no recent record available of the tunnel condition, and access to the tunnel for the purposes of this Study was not possible with the current water demand situation.

The inlet structure will be modified to accept the 1 800 mm diameter inlet line with an isolating butterfly valve, and the outlet will include an isolating valve and single line to tie in with the tunnel outlet control structure.

2.6.3 Structures

Midmar/Ferncliffe Tunnel Control Structure

A control structure will be required at the outlet of the Midmar and Ferncliffe Tunnels, to provide a common free water surface, (see **Figure A1.19**). With a flow of 1 000 Mℓ/day through the Midmar Tunnel and the remaining 540 Mℓ/day through the upgraded Ferncliffe Tunnel, the control structure will operate close to the overt of the Midmar Tunnel, as this is driven by the free water surface from the Midmar Reservoir.

Flow through the Ferncliffe Tunnel will discharge into the control structure through a 1 000 mm diameter sleeve valve to the same downstream water level as the Midmar Tunnel. The structure will be high enough to match the free water surface level at the Midmar reservoir in the event of no flow in the system, and will include a spill facility discharging into the Town Bush stream.

The current control system for the Midmar Aqueduct will require significant modifications to provide sufficient control of the upgraded system, probably with fast response times on control valves, especially at the tunnel outlet control structure. This problem has not been considered in detail and should be considered as a significant drawback of this option. The stability of the ground in the area of the tunnel outlets may also be problematic and needs to be considered in the design of this structure, at a later stage of investigation.

Whispers Break Pressure Tank

A break pressure tank will have to be provided at Whispers, as is the case with the Northern Feeder design currently being undertaken by Umgeni Water. Allowance has been made for a 20 Mℓ reinforced concrete structure, with isolating butterfly valves and sleeve valves for control.

Umlaas Road Reservoir

According to the Terms of Reference for this Study, water is to be delivered to a point at Umlaas Road. During the reconnaissance phase of the study, a suitable site at an appropriate elevation was identified immediately to the south of the N3, approximately 1 km from the existing Umlaas Road waterworks. This is approximately 40 m lower than the alternative site adjacent to the waterworks and has more favourable topography for the construction of a large reservoir.

The selection of the size of reservoir was based on providing only a few hours' storage. As this point is still some distance from the main demand centres, provision of a large storage volume at Umlaas Road instead of closer to the demand centres would necessitate larger pipelines between Umlaas Road and these points to handle peak demands, with cost implications. The reservoir is also common to both schemes under consideration, and changes to the reservoir size and cost would therefore not affect the relative economics of the schemes.

The 200 Mℓ reservoir has been designed as a 180 x 180 m reinforced concrete structure with a water depth of 8 m. The reinforced concrete roof would be supported on columns at 6 m centres. It would be partially excavated, with the excavated material being used as mostly as fill around the outside of the structure.

2.7 Advance Infrastructure

All infrastructure directly related to the construction of the scheme, including the provision of accommodation for the Contractors' personnel and all on-site services, was deemed to be provided by the Contractors and included in the Preliminary and General items (P&G's). It is assumed that supervisory staff will be accommodated in the nearest town and will commute to site, as per current DWAF policy.

The provision of advance infrastructure is therefore limited to the following:

- Construction of the main access roads to the dam site, which will replace those roads which will be inundated by the dam, as well as the upgrading of minor roads to the intermediate and outlet tunnel portals. The permanent roads are shown in **Figure A1.1**.

- Provision of bulk electrical supply to the tunnel portal sites, from where power to the dam site will also be drawn. It should that the power requirements for TBM's are significant, at approximately 5 MVA.

3. DESIGN ASPECTS OF THE SMITHFIELD SCHEME

3.1 Scheme Description

Details of the Smithfield Scheme are given in **Table 3.1a, b** and **c**. Note that these are for the selected scheme configurations, the derivation of which is described below. All detailed drawings of the scheme are included in **Appendix A2**. The scheme consists of an initial dam on the Mkomazi River near Smithfield, with a pumpstation and transfer tunnel to the Mlazi River near Baynesfield and conveyance and treatment infrastructure supplying potable water to a proposed reservoir at Umlaas Road. A second dam will be constructed at the Impendle Site, as described in Section 2.2, as the topography of the Smithfield site limits the size of dam which can be constructed there and sufficient storage cannot be provided there to maximise the utilisation of the Mkomazi.

All of the infrastructure for this scheme is new, with the exception of the Baynesfield Dam, which will be raised and utilised for balancing storage. The three scheme configurations evaluated are as follows:

Scheme 1A: A dam at Smithfield, with related conveyance and treatment infrastructure, followed by a dam at Impendle with a capacity equivalent to 1,5 times the MAR.

Scheme 1B: A dam at Smithfield, with related conveyance and treatment infrastructure, followed by a dam at Impendle with a 1,0 MAR capacity.

Scheme 1C: A dam at Smithfield, with related conveyance and treatment infrastructure, followed by a dam at Impendle with an initial capacity of 1,0 MAR, later raised to a 1,5 MAR capacity,

The scheme will be implemented in phases and the main scheme components for the ultimate scheme are as follows:

- A dam on the Mkomazi River, approximately midway between the Lundy's Hill bridge and Deepdale (Smithfield Dam).

- A second dam on the Mkomazi River, a short distance downstream of the Nzinga River confluence (Impendle Dam), possibly implemented in two phases by raising, releasing water down the Mkomazi River to the lower dam for transfer.

- A multi-level outlet tower in the Smithfield Dam basin, incorporating a pumpstation, feeding twin pipelines to a free water surface tunnel, discharging near Baynesfield, either into a balancing dam or a pipeline to a proposed waterworks.

- Raising of the existing Baynesfield Dam for raw water balancing storage.

- Twin pipelines from Baynesfield Dam and the tunnel outlet to a new waterworks.

- Twin pipelines from the waterworks to a proposed clear water reservoir immediately to the south of the N3 freeway at Umlaas Road.

Conveyance infrastructure downstream of Umlaas Road was excluded from consideration in this study.

As indicated previously, the conveyance and treatment infrastructure is sized for the 1 in 100 year scheme yield. In addition, allowance was made for a 25% peak factor in all conveyance and treatment infrastructure. The Baynesfield dam has insufficient storage capacity to handle fluctuations in demand and it was therefore also necessary to also consider peaks when sizing the raw water transfer infrastructure.

TABLE 3.1a

SMITHFIELD SCHEME 2A - IMPENDLE DAM RAISED TO 1,5 MAR			
	Phase 1	**Phase 2**	**Phase 3**
Transfer Capacity (Peak)	5,6 m^3/s (7,0 m^3/s)	11,7 m^3/s (14,6 m^3/s)	13,0 m^3/s (16,2 m^3/s)
Transfer Route and Description	Smithfield Dam-pumpstation-shaft-tunnel to existing dam (raised) near Baynesfield-new waterworks near Baynesfield-gravity pipeline-Umlaas Road reservoir		
Dam: Name Type Spillway Crest Level; **FSL**; River Bed Level Minimum operating level Height of wall Surface area at FSL Storage capacity at FSL 1:100 year stochastic yield	Smithfield Composite RCC gravity dam with rockfill flanks 923 masl; **915 masl**; 854 masl 875 masl 69 m 583 ha 137 million m^3 (25% MAR) 177 million m^3/a	Impendle for raising Rockfill embankment with clay core Side channel 1 192 masl; **1 184 masl**; 1 100 masl 1 123 masl 92 m 1 934 ha 535 million m^3 (100% MAR) Total 369 million m^3/a	Impendle raised Rockfill embankment with clay core Side channel 1 205 masl; **1 197 masl**; 1 100 masl 1 123 masl 105 m 2 580 ha 830 million m^3 (150% MAR) Total 409 million m^3/a
Tunnel/Shaft: Route Length Diameter Description Typical rock formation Average gradient Inlet invert level Outlet invert level Intake works	From Smithfield Dam to Baynesfield Dam on the Mlazi River 32,9 km 3,5 m bored (3,0 m lined) Bored tunnel, fully concrete lined. Free surface flow. Drill and blasted shaft Sandstones and siltstones, with dolerite intrusions 1 in 580 940 masl 885 masl Multi-level intake structure		
Pumpstation: Location Capacity Maximum/Average head	Smithfield 7,0 m^3/s 71 m/48 m	Smithfield (upgrade) 16,2 m^3/s 71 m/48 m	
Pipelines: Route General	Clear water: Gravity main from Baynesfield waterworks to reservoir at Umlaas Road Raw water: Gravity from tunnel outlet to waterworks via Baynesfield Dam outlet All pipelines are buried		
Diameter Length (total)	1 800 mm to 1 900 mm 26,3 km	1 800 mm to 1 900 mm 26,3 km	
Waterworks: Description Capacity prior to upgrade Upgraded capacity	New waterworks near Baynesfield Nil 606 Ml/d	Upgrade of Baynesfield Waterworks 606 Ml/d 1 400 Ml/d	
Features	Smithfield built to maximum height topography allows and avoids flooding of road to Bulwer at Lundy's Hill. Pumping required to minimise tunnel length. No obvious stability problems identified.		

TABLE 3.1b

SMITHFIELD SCHEME 2B - IMPENDLE DAM 1,0 MAR			
	Phase 1	**Phase 2**	**Phase 3**
Transfer Capacity (Peak)	5,6 m^3/s (7,0 m^3/s)	5,9 m^3/s (7,3 m^3/s)	11,7 m^3/s (14,6 m^3/s)
Transfer Route and Description	Smithfield Dam-pumpstation-shaft-tunnel to existing dam (raised) near Baynesfield-new waterworks near Baynesfield-gravity pipeline-Umlaas Road reservoir		
Dam: Name Type Spillway Crest Level; **FSL**; River Bed Level Minimum operating level Height of wall Surface area at FSL Storage capacity at FSL 1:100 year stochastic yield	Smithfield Composite RCC gravity dam with rockfill flanks 923 masl; **915 masl**; 854 masl 875 masl 69 m 583 ha 137 million m^3 (25% MAR) 177 million m^3/a	Impendle Rockfill embankment with clay core Side channel 1 192 masl; **1 184 masl**; 1 100 masl 1 123 masl 92 m 1 934 ha 535 million m^3 (100% MAR) Total 369 million m^3/a	
Tunnel/Shaft: Route Length Diameter Description Typical rock formation Average gradient Inlet invert level Outlet invert level Intake works	From Smithfield Dam to Baynesfield Dam on the Mlazi River 32,9 km 3,5 m bored (3,0 m lined) Bored tunnel, fully concrete lined. Free surface flow. Drill and blasted shaft Sandstones and siltstones, with dolerite intrusions 1 in 580 940 masl 885 masl Multi-level intake structure		
Pumpstation: Location Capacity Maximum/Average head	Smithfield 7,3 m^3/s 71 m/48 m		Smithfield (upgrade) 14,6 m^3/s total 71 m/48 m
Pipelines: Route General	Clear water: Gravity main from Baynesfield waterworks to reservoir at Umlaas Road Raw water: Gravity from tunnel outlet to waterworks via Baynesfield Dam outlet All pipelines are buried		
Diameter Length (total)	1 800 mm to 1 900 mm 26,3 km		1 800 mm to 1 900 mm 26,3 km
Waterworks: Description Capacity prior to upgrade Upgraded capacity	New waterworks near Baynesfield Nil 630 Ml/d		Upgrade of Baynesfield Waterworks 630 Ml/d 1 260 Ml/d
Features	Smithfield built to maximum height topography allows and avoids flooding of road to Bulwer at Lundy's Hill. Pumping required to minimise tunnel length. No obvious stability problems identified.		

TABLE 3.1c

SMITHFIELD SCHEME 2C - IMPENDLE DAM 1,5 MAR (NOT RAISED)			
	Phase 1	**Phase 2**	**Phase 3**
Transfer Capacity	5,6 m³/s (7,0 m³/s)	Total 6,5 m³/s (8,1 m³/s)	13,0 m³/s (16,2 m³/s)
Transfer Route and Description	Smithfield Dam-pumpstation-shaft-tunnel to existing dam (raised) near Baynesfield-new waterworks near Baynesfield-gravity pipeline-Umlaas Road reservoir		
Dam: Name Type Spillway Crest Level; **FSL**; River Bed Level Minimum operating level Height of wall Surface area at FSL Storage capacity at FSL 1:100 year stochastic yield	Smithfield Composite RCC gravity dam with rockfill flanks 923 masl; **915 masl**; 854 masl 875 masl 69 m 583 ha 137 million m³ (25% MAR) 177 million m³/a	Impendle Rockfill embankment with clay core Side channel 1 205 masl; **1 197 masl**; 1 100 masl 1 123 masl 105 m 2 580 ha 830 million m³ (150% MAR) Total 409 million m³/a	
Tunnel/Shaft: Route Length Diameter Description Typical rock formation Average gradient Inlet invert level Outlet invert level Intake works	From Smithfield Dam to Baynesfield Dam on the Mlazi River 32,9 km 3,5 m bored (3,0 m lined) Bored tunnel, fully concrete lined. Free surface flow. Drill and blasted shaft Sandstones and siltstones, with dolerite intrusions 1 in 580 940 masl 885 masl Multi-level intake structure		
Pumpstation: Location Capacity Maximum/Average head	Smithfield 7,0 m³/s 71 m/48 m	Smithfield (upgrade) 16,2 m³/s total 71 m/48 m	
Pipelines: Route General	Clear water: Gravity main from Baynesfield waterworks to reservoir at Umlaas Road Raw water: Gravity from tunnel outlet to waterworks via Baynesfield Dam outlet All pipelines are buried		
Diameter Length (total)	1 800 mm to 1900 mm 26,3 km		1 800 mm to 1 900 mm 26,3 km
Waterworks: Description Capacity prior to upgrade Upgraded capacity	New waterworks near Baynesfield Nil 606 Ml/d	Upgrade of Baynesfield Waterworks 606 Ml/d 1 400 Ml/d	
Features	Smithfield built to maximum height topography allows and avoids flooding of road to Bulwer at Lundy's Hill. Pumping required to minimise tunnel length. No obvious stability problems identified.		

3.2 Dam Design

3.2.1 Introduction

The design of the Impendle Dam will be as described in Section 2.2 of this report. The only difference is that instead of the outlet works delivering water directly to the transfer tunnel, water will be released into the river to Smithfield. There may be some potential for hydroelectric power generation, which should be considered at feasibility stage, but ecological constraints will cap flows to levels which may render power generation uneconomical. Details of the 1,5 MAR dam are shown in **Figures A2.1** and **A2.2**.

The proposed Smithfield Dam is located on the Mkomazi River at co-ordinates 29E46'30" S 29E56'30" E in the Polela district about 16 km east of Bulwer. The catchment area of the dam is 2 054 km^2 and the natural MAR is 730 million m^3. The selected centreline is the most upstream one of three centrelines within a 1,5 km reach of the Mkomazi river which were considered in the reconnaissance phase of the Study (see Supporting Report No 1: Reconnaissance Investigations). This site requires significantly less material in the dam wall than the other sites considered. A plan of the site is shown in **Figure A2.4**.

The site at this centreline is roughly symmetrical. The river bed is at elevation 857 masl and approximately 50 m wide. The flanks rise steeply on both sides for about 25 to 30 m above the river level. Above this level the flanks flatten out along two ridges which are followed by the embankment sections of the dam. The alignment of the ridges results in the centreline of the dam having a shallow S shape. For a dam having a full supply level at 915 masl, the highest dam that could be practically be constructed at Smithfield, a saddle dam will be required to prevent spillage over the saddle situated about 1 km to the north east of the site. The saddle dam would have a maximum height of about 11 m.

The depth/area/capacity relationships of the basin are given in **Figures A2.20** and **A2.21.**

3.2.2 Geotechnical aspects

The engineering geology of the proposed Smithfield Dam site was investigated by the Council for Geoscience and is presented in a report (Council for Geoscience, 1998) included in a separately bound appendix to this report (**Appendix G**), together with the other Engineering Geological reports prepared for this Study. The investigations included surface inspections and limited core drilling.

The area is underlain by sedimentary strata of the Karoo Supergroup which have been intruded by younger dolerite sills and dykes. At the dam site a relatively thick dolerite sill has been eroded through by the Mkomazi river to expose indurated mudstones in the river bed. The dolerite sill extends up each flank for about 25 m in height from 5 m above the river to about 30 m above the river. This hard rock forms the steep sides to the river valley. Above the dolerite sill the valley slopes are flatter where they are underlain by siltstones and thin interbedded sandstones. The sedimentary rocks are generally sub-horizontally bedded and relatively undisturbed. Four boreholes were drilled at this site. On the upper right flank the siltstones are deeply weathered and overlain by recent unconsolidated sediments (possibly colluvium) consisting of sandy clay and gravel to a depth of 12 m that could form pervious horizons that may have to be sealed by the proposed embankment cut off.

No boreholes were drilled at the site of the saddle dam but examination of the surface exposures in this area indicate that relatively undisturbed weathered siltstones and thin sandstone beds occur in this area. The saddle ridge is wide and is not expected to present a problem with respect to seepage or instability.

Fairly extensive deposits of material suitable for use as imperious core material have been located in the dam basin and on the right flank of the river valley. A 25 m thick dolerite sill forms a prominent nose on the left bank of the river in the dam basin about 0,5 km from the dam centreline. This deposit could be developed as a quarry for rockfill, filter sand and concrete aggregate. There do not appear to be large deposits of natural sand suitable for filters or fine aggregate for concrete in the vicinity of the dam site.

The quarry site has not been drilled, nor has the site of the saddle dam. Further, more detailed drilling and material investigations will have to be done in the feasibility phase of investigation.

3.2.3 Water quality and sedimentation

A study was undertaken by Umgeni Water to assess the probable water quality in the proposed dam. The findings of the study relevant to this scheme are summarised below and the full report is included in **Appendix H** to this report.

The water quality of the Mkomazi is generally good, showing a gradual deterioration towards the estuary. Nutrient levels are low and turbidities vary significantly. Water quality is generally better than that of the receiving river system, namely the Mlazi River at Baynesfield. Very high turbidities can be expected at times in the Mlazi River due to the current land use in the catchment. For this reason, it is recommended that a direct link be provided between the transfer tunnel portal and the waterworks, and that the Baynesfield Dam only be utilised for balancing storage when required, thus reducing potential treatment problems.

With the relatively large reservoir volumes being proposed on the Mkomazi, a large degree of settlement of suspended solids will occur upstream of the transfer intake tower and the turbidity of transferred water will therefore be low.

Both reservoirs will almost certainly stratify during the summer, when low dissolved oxygen concentrations and temperatures will be encountered in the water column below the thermocline. Whilst this will not pose treatment problems, as the transferred water will have sufficient time to become oxygenated in the free water surface transfer tunnel before it is abstracted, release of this cold, anaerobic water from either dam into the river would cause significant ecological damage. It is therefore necessary to provide multi-level draw-off facilities to allow the abstraction of warmer, aerobic water from near the surface. It was deemed appropriate to also allow for multi-level abstraction facilities for water transfer at this stage of planning, but this may not be necessary and should be reviewed at feasibility stage.

Estimates of sedimentation rates for the dam were prepared by Professor Albert Rooseboom and the general findings of his report are summarised in Section 2.2.3 of this report. A copy of his report is included in **Appendix C** and the sedimentation rates for the dams are given in **Table 3.2** below. Note that the volumes given for Smithfield Dam are based on the assumption that Impendle Dam will be commissioned 7 years after Smithfield Dam, with the Smithfield Dam commissioning year taken as the base year.

Table 3.2: Estimated Sedimentation Rates for Impendle and Smithfield Dams

	Sediment Volumes	
	Yield 150 t/km^2.a	**Yield 300 t/km^2.a**
Smithfield		
After 20 years	2,9 million m^3	5,8 million m^3
After 50 years	3,0 million m^3	6,0 million m^3
Impendle		
After 20 years	3,9 million m^3	7,8 million m^3
After 50 years	7,3 million m^3	14,8 million m^3

It can be concluded that sedimentation is insignificant in comparison to the proposed dam volumes and can easily be accommodated within the dead storage below the minimum operating levels.

3.2.4 Selection of dam type

The proposed Smithfield Dam will consist of a central roller compacted concrete (RCC) gravity dam founded on the sound indurated mudstone and dolerite in the river section. Above elevation 854 masl the flatter slopes and the poor founding conditions make extension of the concrete gravity section uneconomical and embankment sections are proposed. As there is an abundance of good quality doleritic rock in the vicinity of the dam site, it is proposed that the embankment sections of the main dam and the saddle dam be constructed as rockfill dams with central clay cores.

The site is not suitable for an embankment with a side channel or bywash spillway, due to the poor founding conditions on the flanks. Sufficient spillway length can be accommodated within the valley and alternatives such as a trough spillway are therefore superfluous.

Plans and sections showing the proposed layout of the dam and saddle dam are shown in **Figures A2.3, A2.4, A2.6, A2.7** and **A2.8**

3.2.5 Gravity section design

The design of the gravity portion of the dam which includes the spillway was based on the VAPS Guidelines (DWAF, 1994), with a vertical upstream slope and 1:0,7 downstream slope. The concrete gravity spillway section is 130 m long and thus overlaps the lower portions of the steeper valley slopes. The non-overspill portions of the gravity section of the dam have the same downstream slope as the spillway and a 1:0,1 downstream slope. They extend on each flank to the upper flatter slopes, tapering below embankment fill level into concrete tongue walls. (**Figures A2.5** and **A2.6**)

The concrete gravity section and tongue walls are expected to be constructed in roller compacted concrete (RCC) with conventional concrete for the facing, spillway crest and guide walls. The spillway crest will be at 915 masl, 58 m above river bed level and the non-overspill crest at 923 masl. The non overspill sections, including the tongue walls will be 105 m long on the right flank and 97 m long on the left flank.

Assumed founding levels for the concrete structure are as recommended in the geological report. Provision was made for both curtain and blanket grouting.

3.2.6 Embankment design

The typical rockfill embankment cross section as given in the VAPS Guidelines was adopted, as for the Impendle Dam (See **Figure A2.7**). The maximum height of the rockfill embankment section of the dam will be about 25 m at the left bank tongue wall. These embankment sections will extend for 425 m on the right flank and 355 m on the left flank. It may be necessary for a deep cut-off to be provided under the embankment in the vicinity of Borehole 4 where 11 m of transported sandy gravelly clay deposits overlie the insitu weathered siltstone. This is expected to occur over a limited extent but requires further detailed investigation.

In order to achieve the maximum storage that is possible at the Smithfield site, a dam will have to be constructed along the saddle about 1 km to the north of the main dam (See **Figure A2.3**). This saddle dam will have a maximum height of 11 m and will be about 650 m long. A typical rockfill section with a central clay core has been chosen for this dam.

There is an abundance of good quality doleritic rock in the vicinity of the dam site which could be used for rockfill. Tunnel spoil and poorer quality rock from quarry overburden could be used in the inner zones and transitions of the embankment shells. Indications are that there is sufficient material available nearby for the clay cores. It envisaged that the bulk of filter materials will have to be crushed.

3.2.7 Spillway

As indicated in Section 2.2.6, flood magnitudes at Smithfield were determined by the DWAF Directorate of Hydrology based on a statistical analysis of flow records of streamflow gauge U1H005 and extrapolated to the Impendle and Smithfield sites on the basis of their relative catchment areas. In addition, Regional Maximum Floods (RMF's) were determined. This report is presented in **Appendix B**.

In accordance with the VAPS Guidelines and in line with the current SANCOLD Guidelines (SANCOLD, 1991), the spillway should be sized to pass the Safety Evaluation Discharge (SED), where the SED is based on the RMF for the adjacent region with a K-value numerically one step greater than that of the region in which the dam lies, that is $RMF_{+Ä}$. In the case of the Smithfield Dam, the K-value for the SED is 5,2. The Recommended Design Flood (RDF) would be the 1 in 200 year flood. The flood magnitudes and spillway surcharges, assuming a spillway length of 130 m, for various return periods are given in **Table 3.3**. Note that flood routing was not assessed at this stage.

Table 3.3: Results of Flood Analysis for Smithfield Dam

Recurrence Interval (Years)	1:2	1:10	1:20	1:50	RDF 1:200	RMF	SED
Flood Peak (m^3/s)	390	1 000	1 310	1 750	2 540	4 520	5 620
Flood surcharge with 130 m long spillway (m)					4,3	6,3	7,3

As can be seen from the above, a 130 m long spillway with a discharge coefficient of 2,2 will pass the SED with a surcharge of 7,3 m. Allowance was therefore made for a total freeboard of 8 m, leaving a dry freeboard of 0,7 m to the crest of the dam. This could possibly be reduced slightly, subject to a more rigorous flood analysis, including routing.

The specific discharge over the spillway under RDF conditions will be 20 m^3/s.m, which is well within acceptable limits. However, under SED conditions the unit discharge will be 43,0 m^3/s.m, which is higher than the norm of 30 m^3/s.m and may result in some damage by cavitation, although it should be noted that this would be only under extreme flood conditions. To account for the reduced effectiveness for energy dissipation of the stepped spillway under such high specific discharges, a 20 m wide reinforced concrete apron is provided, which is relatively wide for dam with a stepped spillway. A longer spillway cannot readily be provided due to topographical constraints, but the spillway length versus freeboard provision should be optimised in detail at feasibility stage.

3.2.8 River diversion and outlet works

As the centre section of the Smithfield dam will be constructed in RCC, river diversion can be achieved by simply leaving an opening in the dam, which would later be closed off using stoplogs, filled with pumped concrete and grouted. An opening size of 7 x 7 m would probably be adequate for this purpose. The diversion block would be constructed of mass and reinforced concrete ahead of RCC placing operations, to minimise disruption.

The intake for the transfer tunnel will be located upstream in the dam basin and is described in Section 3.4 of this report. The outlet works for the Smithfield dam will therefore only be used for releases of compensation and IFR flows into the river.

A multi-level intake structure will be provided on the upstream side of the dam, constructed in reinforced concrete ahead of RCC placing operations. The outlet is sized to empty the reservoir from FSL to 10% of its capacity in 30 days, assuming no inflow (see **Figure A2.19**). IFR releases of up to 50 m^3/s can be made.

The intake structure will be provided with trash racks and fine GRP screens and will house twin 1 600 mm diameter pipes with staggered intakes at 4 m centres, each equipped with a butterfly valve. Two 1 800 mm diameter scour pipes will be provided at elevation 872 m masl, also fitted with butterfly valves. Slab gates will be provided on the upstream side of the intakes for maintenance of valves and pipework. Details are shown in **Figure A2.9**.

The intake pipes are connected to 1 800 mm diameter pipes through the dam wall to the outlet house, where each outlet pipe has an 800 mm diameter branch. Both branches are fitted with butterfly valves and the 1 800 mm and 800 mm diameter branches are fitted with 1 000 mm and 400 mm diameter sleeve valves respectively. Details of the outlet house are shown in **Figure A2.10**.

3.3 Transfer Tunnel Design

3.3.1 Introduction

The relative elevations of the dam and waterworks in the Smithfield Scheme are such that a gravity transfer, as in the case of the Impendle Scheme, is not possible. For the Smithfield transfer option, no screening process was carried out on the tunnel configuration, as it was considered that pumping into a tunnel would preclude a pressure alternative, as discussed further in Section 3.3.4.

The general assumptions with regard to TBM size, lengths of TBM drives and tunnel lining, as discussed in Section 2.3.1 under the Impendle option, apply again in the case of the Smithfield Scheme.

In the latter stages of the study, the possibility was identified of constructing a larger diameter pressure tunnel, with an underground pumpstation located at the delivery end of the tunnel. The system could operate under gravity when the dam is relatively full. Pumping costs would therefore be reduced, but capital costs would be higher. This option was not evaluated in further detail in this study, but should be considered in the feasibility phase. A description and conceptual layout in included in **Appendix E**.

3.3.2 Engineering geology

General

A preliminary report titled "First Engineering Geological Reconnaissance Report" (Council for Geoscience, 1997b), details the most recent information available on the transfer tunnel. A pre-feasibility investigation was carried on the dam site (Council for Geoscience, 1998), but not on the tunnel route. This is in accordance with the Terms of Reference for the Study.

The bulk of the proposed tunnel route (22 km), from the inlet to approximately 11 km from the outlet, will be excavated in rocks of the Volksrust formation (67%). The remaining portion at the outlet end is expected to be driven in rocks of the Vryheid formation (4,5 km or 14%) and of the Pietermaritzburg formation (6,4 km or 19%). These rocks all form part of the Ecca group of the Karoo sequence.

These rocks comprise siltstones and sandstones. The tunnel route is also intersected by intruded dolerite dykes and sills. The extent to which the dolerites are expected to intersected at tunnel invert level is unknown. For costing purposes an estimate was made based on the Impendle geological report.

Inlet portal

The proposed position of the tunnel inlet is discussed in the report by the Council for Geoscience. It is expected that the portal will be in rocks of the Volksrust formation which have been disturbed by dolerite dykes. Further investigation of this portal position, if opted for, will need to be undertaken.

Outlet Portal

The outlet portal is expected to be excavated in rocks of the Pietermaritzburg formation. As indicated in the Council for Geoscience report, a large open excavation will be necessary.

Geohydrology

The potential for high water inflows exist, particularly at the dolerite contact zones. As for the Impendle option this is problematic for downgrade drives, thus the additional risk and associated works to allow for pumping have been allowed for in the costing.

Expected tunnelling conditions

With the exception of the areas close to the portals, the tunnel is expected to be excavated within an unweathered rock mass. Siltstone, mudstone, sandstone and dolerite, and combinations of these rock types will be encountered across the tunnel section.

As with the Impendle option the dolerite intrusions could have a blocky structure which may lead to instability problems and certain of the sedimentary rocks are known to be susceptible to slaking. These problems can be overcome by the installation of the correct primary support.

A preliminary estimate of the rock classes to be encountered was completed for preliminary costing purposes. A more accurate assessment will need to be made for further study purposes, following more detailed investigations including borehole drilling.

3.3.3 Tunnel alignment

The use of 3,5 m diameter TBM's again requires intermediate access, as the length of tunnel drives has to be restricted. Three TBM drives of 3,5 m diameter would be required. If larger diameter TBM's were to be used, two drives could be feasible, one from the inlet and one from the outlet. Further investigation is required at feasibility stage into the option of larger diameter tunnels.

As the Smithfield-Baynesfield transfer scheme is the preferred option for the Smithfield Dam site, only this tunnel alignment has been considered. The portal positions and tunnel alignments will need to be refined in the feasibility stage.

A longitudinal section of the tunnel and details of portal structures is given in **Figure A2.17**.

Inlet portal

An intake tower in the proposed dam, from where water will be pumped up to the tunnel inlet portal appears to be the most feasible option, as discussed in Section 3.4. The proposed tower is located on a bend in the Mkomazi River approximately 1 800 m upstream from the dam wall. The inlet portal site is located on the farm Smithfield, with the following coordinates (Lo 31E):

Y : +111 350
X : +3 294 050
Invert level 940 masl.

This position is on the north bank of the river, approximately 95 m above the river bed. The site has a relatively steep slope (1:2,5), thus gaining cover quickly. A relatively small open excavation and short drill and blast adit is anticipated to allow access to competent rock.

This portal position will require access to be gained from the south. Working area for the tunnel construction site is available on the south side of the portal, which will have to be located so as not to interfere with the proposed borrow area for the dam wall.

Depending on the final option of tunnel excavation, approximately 65 000 m^3 of spoil material will be generated from the tunnel. This is assuming a 3,5 m diameter 6 500 m TBM drive. If the option of a 4,5 m diameter TBM were to be implemented, this spoil volume would increase to approximately 105 000 m^3. This excavated material can be spoiled in the dam basin below MOL or used in the dam embankments, thus negating unsightly spoil dumps.

Outlet portal

Various options were considered for the outlet portal site on the slopes south of the existing Baynesfield Dam on the Mlazi River. The outlet portal on the farm Nooitgedacht has an invert level dictated by the hydraulic grade line (free water surface), and has the following approximate coordinates (Lo 31E):

Y : +68 800
X : +3 293 900
Invert level 885 masl

The proposed tunnel portals on the gentle slope above the dam. As the slopes at the 885 masl elevation are fairly flat (1:8) a relatively large open excavation will be required to expose competent rock. This temporary excavation to allow a section of "cut and cover" tunnel is expected to be approximately 200 000 m^3. The excavation will be backfilled on completion of the tunnel works. In order to gain cover quickly and tunnel perpendicular to the contours, a horizontal curve has been incorporated at this portal.

Working area for the tunnel construction site is available at the portal site. A working area of approximately 5 ha will be required. Access to the working area will need to be gained via the existing district and farm roads.

Depending on the final option of tunnel excavation, approximately 130 000 m^3 of spoil material will be generated from the tunnel. This is assuming a 3,5 m diameter, 12 950 m long TBM drive from the outlet. If the option of a 4,5 m diameter TBM were to be implemented, this spoil volume would increase to approximately 265 000 m^3, due to the larger diameter and longer tunnel. This excavated material will have to be spoiled in the valleys adjacent to the portal site. These are not ideal sites, but with the necessary drainage measures and landscaping, these spoil dumps can be incorporated into the relief.

Tunnel alignment

As with the Impendle Scheme, various intermediate portal sites, up- and downgrade drives, and number of TBM drives were considered.

i) 2 No 3,5 m diameter TBM's, one downgrade from the inlet and one upgrade from the outlet

ii) 2 No 3,5 m diameter TBM's, one upgrade from the outlet and one upgrade from a central point

iii) 3 No 3,5 m diameter TBM's, one downgrade from the inlet, one upgrade from the outlet and one downgrade from an approximate 1/3 point.

iv) 3 No 3,5 m diameter TBM's, one upgrade from the outlet, one upgrade and one downgrade an approximate **a** point.

These options were advanced to a similar level of detail which allowed comparative costing, including programming and the determination of setup costs and time related P&G costs, to be considered.

Option iii) proved to be the most economical and practical solution for the 3,5 m diameter tunnel option, and is detailed as follows.

C 6 500 m downgrade drive from the inlet
C 12 950 m upgrade drive from the outlet
C 12 950 m upgrade drive from an intermediate position

The tunnel alignment assumes a direct route from the inlet to the outlet with a total length of 32 900 m.

This route has been chosen with an intermediate adit position at the Elands River. Adit positions are available closer to the **a** point, but due to the low cover at the crossing under the Elands River (45 m), this intermediate position is favoured as the excavation under the river will most likely need to be completed by conventional drill and blast means.

This option thus requires two of the drives to be downgrade, thus increasing the risk associated with high groundwater inflows.

Intermediate portal

An intermediate adit, sloping down to the tunnel invert at a grade of 1:10 for a length of 350 m, with an excavated profile of 5,5 m wide by 6 m high is proposed.

As stated above, the crossing under the Elands River has been assumed to be excavated by drill and blast means as this may be a high risk crossing by virtue of its low cover. It is therefore logical to incorporate one of the TBM accesses at the same point, negating the need for a further adit. The approximate co-ordinates of this adit are as follows (Lo 31E):

Y :	+94 600
X :	+3 295 050
Invert level	970 masl.

This position is on a south facing slope from where the adit slopes at 1:10 down to the tunnel invert at 929 masl. The adit length is approximately 350 m. The intermediate adit site has a gentle slope of 1:8, not ideal for portal conditions, but as the adit is inclined downwards, cover is quickly gained.

Due to the nature of the slope the open excavation will require approximately 200 000 m^3 of excavation. This excavation can be backfilled on completion with a section of “cut and cover” tunnel if maintenance access through this adit is required.

Working area for the adit and tunnel construction site will need to be made available adjacent to the portal. A working area of approximately 5 ha will again be needed. Access to the working area will need to be gained via the existing road network.

Approximately 145 000 m^3 of spoil material will be generated from the adit and tunnel. This is assuming a 3,5 m diameter 12 950 m TBM drive, a 6 x 5,5 m adit for 350 m and the 4 m x 4 m “lazy D” shaped excavation under the Elands River. This excavated material can be spoiled in the valleys adjacent to the portal site. This volume would increase to approximately 275 000 m^3 if the 4,5 m diameter tunnel were opted for.

3.3.4 Hydraulics and portal structures

The option of a pressure flow tunnel between Smithfield Dam and the Baynesfield Waterworks was not considered in detail, as this would immediately result in increased pumping head and cost. It was decided that only a free surface flow tunnel would be considered.

Based on the yield of the combined system, the maximum transfer flow rate is set at 13 m^3/s. With transfer being directly to a waterworks and minimal available storage at the works, a peak factor of 1,25 has been used, giving a peak flow of 16,3 m^3/s.

A steeper grade than that proposed during the reconnaissance phase has been designed for, to accommodate this peak flow. Along with the final positioning of the proposed waterworks, this has resulted in the inlet level of the tunnel being set at 940 masl, with the tunnel outlet fixed at 885 masl.

For the hydraulic design of the tunnel an 80% maximum depth factor was allowed for at peak flows (2,3 m depth over the segment), requiring a slope of 1:570 to achieve this condition. Higher Froude numbers (of the order of Fr = 0.73) tend to occur at lower flows which could indicate the onset of undulating flow, but this is in the range of low flow depths and is considered acceptable.

The inlet portal structure will consist of isolating valves and energy dissipation chamber, and a transition section with the tunnel invert at 940 masl. Flow control will be provided at the pumpstation with variable speed motors on certain of the pumps (see Section 3.4.2).

The outlet structure will consist of an enclosed transition section between the tunnel and inlets to the twin 1 800 mm diameter pipelines feeding the waterworks. Isolating butterfly valves will be provided on the pipelines. An overflow weir and energy dissipation structure will be provided for emergency spill to the balancing dam or for diversion of flow in the event of shutdown of the pipelines.

3.3.5 *Tunnel construction methods*

Little information is currently available on the rock to be excavated along the tunnel route. However sufficient information is available to suggest that the tunnel will be suitable for excavation by hard rock tunnel boring machines, based on experience gained in construction on the Midmar Tunnel and information obtained from the investigation of the proposed Wellington Tunnel as part of the Mooi-Mgeni transfer Scheme and the Impendle transfer option.

Due to the length of the transfer tunnel, the use of TBM's will be far more economical than conventional tunnelling methods. The option of 3,5 m diameter machines excavating on three headings, or 4,5 m machines excavation on two headings will need to be investigated further. Special precautions will have to be taken for machines operating on downgrade drives.

The same lining philosophy as the Impendle option applies to this tunnel. The tunnel has been assumed to require full concrete lining to a lined diameter of 3 m. As the tunnel is a free surface tunnel, no steel liners are expected to be required.

As with the lining, the same philosophy for rock support as the Impendle Tunnel applies.

3.4 Pumpstation Design

3.4.1 *Initial screening process*

As part of the process of siting the pumpstation, a screening was carried out of the various options available, summarised as follows :

i) Downstream of the dam, at a dedicated offtake weir.
ii) At the toe of the dam.
iii) Within the dam basin, in a combined dam outlet / pumpstation tower, at the dam wall.
iv) In a dedicated pumpstation, upstream of the dam wall, with a separate intake tower.

Pumpstation downstream of dam at dedicated weir.

A site was considered approximately 4,5 km downstream of the dam, on the left bank of the river. An offtake weir would be constructed to divert water into the pumpstation forebay, with a link pipeline connecting the pumpstation to the tunnel inlet portal.

The option would allow a shortening of the transfer tunnel by approximately 1,5 km, with consequent savings. However, the option was excluded for the following reasons:

- The siting of the pumpstation away from the dam immediately negates the advantage of head of water in the dam on the upstream side of the pumps, with a resulting increase in average pumped head.
- The cost of 2 000 m of twin 1 800 mm diameter pipe, along with the capital cost of the weir (although this can be offset against the cost of an intake tower).
- An analysis of pumping costs indicates that, over the lifetime of a scheme, approximately R5 million is added to the cost of pumping for every 1 m of head due to friction with longer pipelines.
- The advantage of a shorter tunnel is somewhat offset by difficult portal conditions in the vicinity of the inlet for this alignment.

Pumpstation at the toe of the dam

The pumpstation would be located on a platform at the toe of the dam, linked directly to the outlet works of the dam, with a pipeline leading up the side of the valley and to the tunnel inlet portal. This option was excluded for the following reasons:

- Space will be limited at the base of the dam.
- The cost of 1 500 m of twin 1 800 mm diameter pipelines.
- The cost of additional pumping head for longer delivery mains over the lifetime of the scheme, as discussed above, also applies in this case.
- Difficult portal conditions at the inlet for this modified tunnel alignment.

Combined tower

The intake tower of the dam would include both the outlet works for the dam, and the pumpstation itself. This option was excluded for similar reasons to those of the option with the pumpstation at the toe of the dam.

This left the option of a dedicated tower, either linked to an underground pumpstation or containing the pumpstation within the tower itself. This would be located on a bend in the river approximately 1 800 m upstream of the dam wall. A multi-level offtake tower would feed water to a series of pipes through a link tunnel to a shaft and underground pumpstation, with twin 1 800 mm diameter rising mains delivering water to the tunnel intake. Qualitative consideration of this option indicated that it would be cheaper to construct a twin intake tower containing a multi-level offtake section and a wet well pump bay. This option weighs the cost of this more complex tower against the cost of the underground hall, lined shaft and link tunnel of the alternative configuration.

3.4.2 Intake structure and pumpstation design

No specific geotechnical investigations were carried out for the intake tower/pumpstation, but a visual inspection of the site indicates that competent rock should be encountered at or close to the surface.

The layout consists of a contiguous multi-level intake tower and wet well pumpstation. Intakes are located at three levels, staggered around the tower to avoid need for nested screens and service gates. Each offtake can be isolated by a slab gate. The offtakes are fitted with trashracks and screens. The limited perimeter of the tower allows only three offtake levels, which could affect the water quality for delivery. This problem is offset by the fact that severe turbulence and mixing will occur at the tunnel intake, and a free water surface over distance of nearly 33 km should allow the water to aerate sufficiently prior to reaching the waterworks.

The common intake wet well supplies a pump well, split to allow maintenance and removal of pumps. Slab gates separate the intake well from the pump well.

For design and costing, 6 No multi-stage vertical spindle pumps were assumed. 1 000 mm diameter rising columns will lead to twin 1800 mm diameter rising mains, mounted within the tower access bridge. The motors and electrical gear will be installed above NOC level (923 masl). The motors will be fitted with variable speed controllers to allow fine adjustments to be made to the waterworks supply. Twin radial cranes are provided on top structure for maintenance.

The pumps provided will transfer the peak flow of 16,3 m^3/s with all six pumps operational, with the normal maximum flow of 13 m^3/s handled by five pumps. This configuration should be optimised at feasibility phase. In the first phases of the scheme, 4 No pumps will be installed.

An access bridge will be provided, with an embankment constructed from tunnel spoil material allowing shortening of the bridge.

Figure A2.18 shows the final pumpstation and intake configuration selected.

3.5 Balancing Dam and Raw Water Pipelines

Unlike the Impendle Scheme, there is no significant raw water balancing storage at the delivery end of the transfer tunnel. The existing Baynesfield Dam on the Mlazi River close to the outlet portal, with a capacity of 2 million m^3, provides the possibility for approximately 1 million m^3 of balancing storage, equivalent to one day's storage at average ultimate transfer. In order to achieve this, a new inlet structure would be constructed and the dam would be raised by 0,5 m. Appropriate agreements would have to be put in place with the owners of the dam, and some augmentation from the Mkomazi may be required to make up for lost storage, but these volumes will be negligible compared to the yield of the scheme. Initial indications are that the owners of the dam, the Mlazi Irrigation Board, would be amenable to such an arrangement, but this matter will require attention at feasibility stage.

Due to potential high turbidities in the Mlazi River at times, which would increase treatment costs, it is envisaged that the dam will only be used to absorb peaks and that the waterworks will generally be supplied directly from the tunnel.

The proposed waterworks will be supplied from the tunnel outlet structure via twin 1 800 mm pipelines. Link pipelines, also 1 800 mm diameter, will be provided between the dam and the tunnel-waterworks pipelines.

3.6 Water Treatment Works

The waterworks will be constructed on gently sloping ground to the south-west of the Baynesfield Estate. It will have an ultimate capacity of 1 400 Mℓ/d, capable of treating the 1:100 year scheme yield with the required 25% peak factor. Its design is identical to that of the Impendle Scheme, as described in Section 2.5.

3.7 Clearwater Conveyance

3.7.1 Pipelines

From the proposed waterworks to the reservoir at Umlaas Road, twin 1 900 mm diameter pipelines, implemented in phases, with a total length of 21 km are proposed. A high point approximately 8 km from Umlaas Road requires that 1 900 mm rather than 1 800 mm diameter pipelines are used. Pressures are moderate and pipe wall thicknesses were determined in accordance with the VAPS guidelines.

The topography of the route is characterised by relatively gentle slopes. The pipelines cross various roads and one major rail crossing will have to be provided at Umlaas Road. There is only one major river crossing (Mlazi River), which would be constructed in the first phase to accommodate both pipelines. A plan of the route is shown in **Figure A2.15**.

3.7.2 Umlaas Road reservoir

The Umlaas Road Reservoir would be as described in Section 2.6.3, except that the inlet pipework and valves would be larger to accommodate the incoming 1 900 mm diameter pipelines.

.

3.8 Advance Infrastructure

As with the Impendle Scheme, all infrastructure directly related to the construction of the scheme, including the provision of accommodation for the Contractors' personnel and all on-site services, is deemed to be provided by the Contractors and included in the Preliminary and General items (P&G's). It is assumed that supervisory staff will be accommodated in the nearest town and will commute to site.

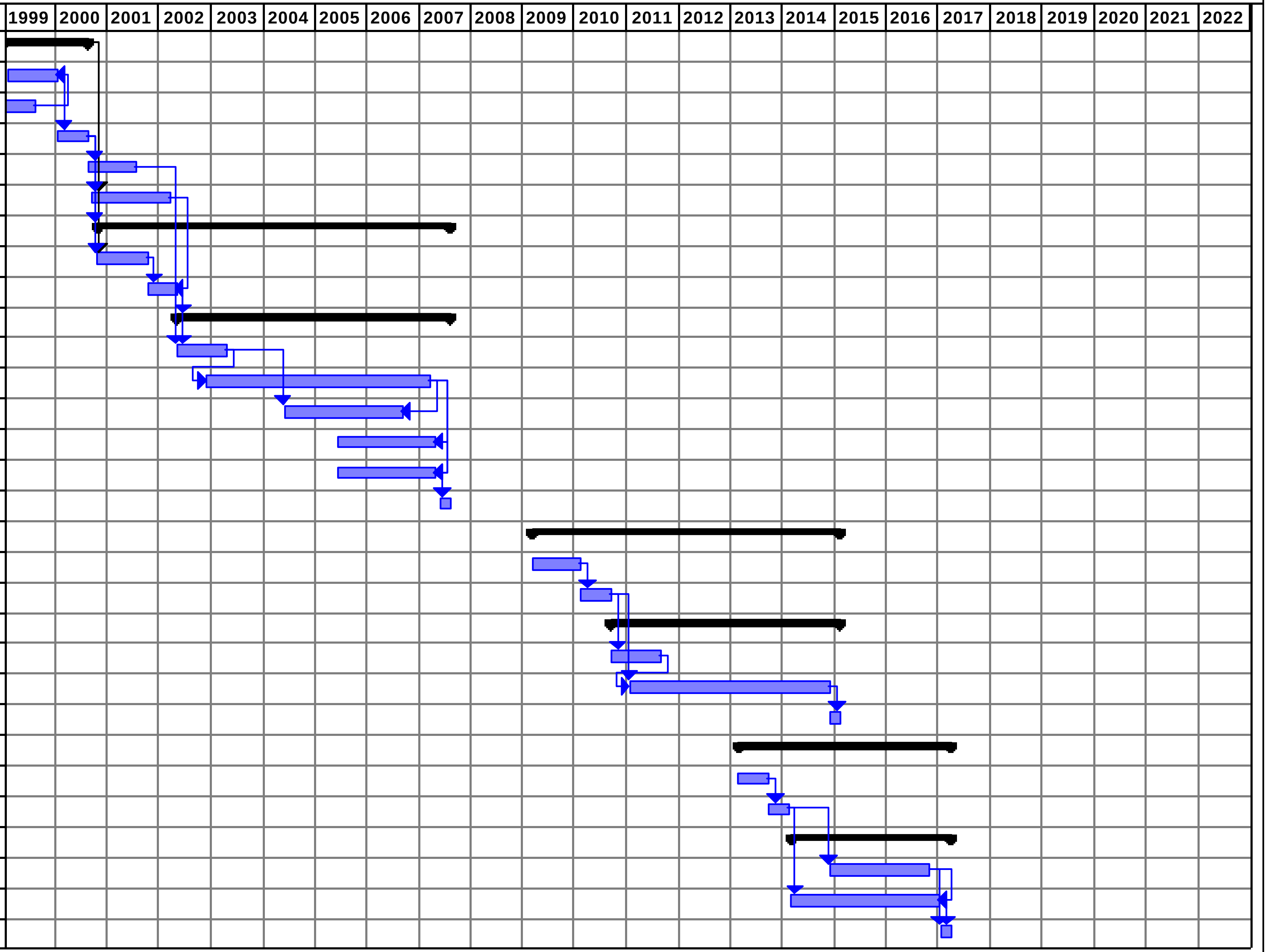
The provision of advance infrastructure is therefore limited to the following:

- Construction of the main access roads to the dam site, which will replace those roads which will be inundated by the dam, as well as the upgrading of minor roads to the intermediate and outlet tunnel portals. The permanent roads are shown in **Figures A1.1** and **A2.3**.

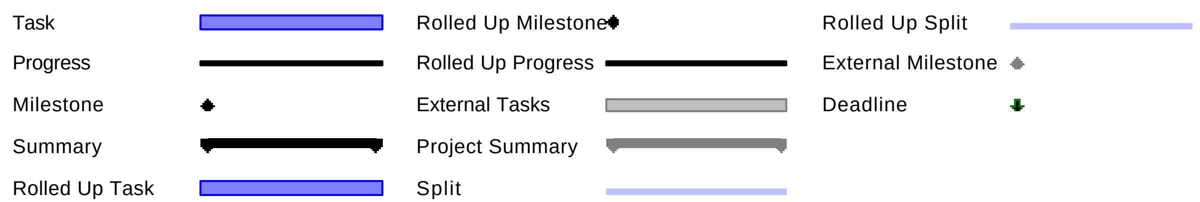
- Provision of bulk electrical supply to the tunnel portal sites, from where power to the dam site will also be drawn. It should be noted that bulk power is currently available closer to the portals than is the case with the Impendle Scheme

SCHEME 2C IMPLEMENTATION PROGRAMME

ID	Task Name	Duration
1	**Feasibility Study**	**83.6 wks**
2	Study and Report	50 wks
3	Geotech.Investigations	30 wks
4	Approval	30 wks
5	Property Aquisition	50 wks
6	FUNDING	80 wks
7	**PHASE 1**	**354.8 wks**
8	Design	50 wks
9	Tender and award	30 wks
10	**Construct**	**274.8 wks**
11	Infrastructure	50 wks
12	Tunnel	225 wks
13	Smithfield Dam	120 wks
14	Water Works	100 wks
15	Conveyance Systems	100 wks
16	Comission Phase 1	10 wks
17	**PHASE 2**	**310 wks**
18	Design	50 wks
19	Tender and award	30 wks
20	**Construct**	**230 wks**
21	Infrastructure	50 wks
22	Impendle dam 1.5 MAR	200 wks
23	Comission Phase 2	10 wks
24	**PHASE 3**	**212.2 wks**
25	Design	30 wks
26	Tender and award	20 wks
27	**Construct**	**160 wks**
28	Water Woks upgrade	100 wks
29	Conveyance systems upgrade	150 wks
30	Comission Phase 3	10 wks



Project: MKOMAZI-MGENI PRE-FEASIBILITY STUDY
Date: Tue 03/02/04

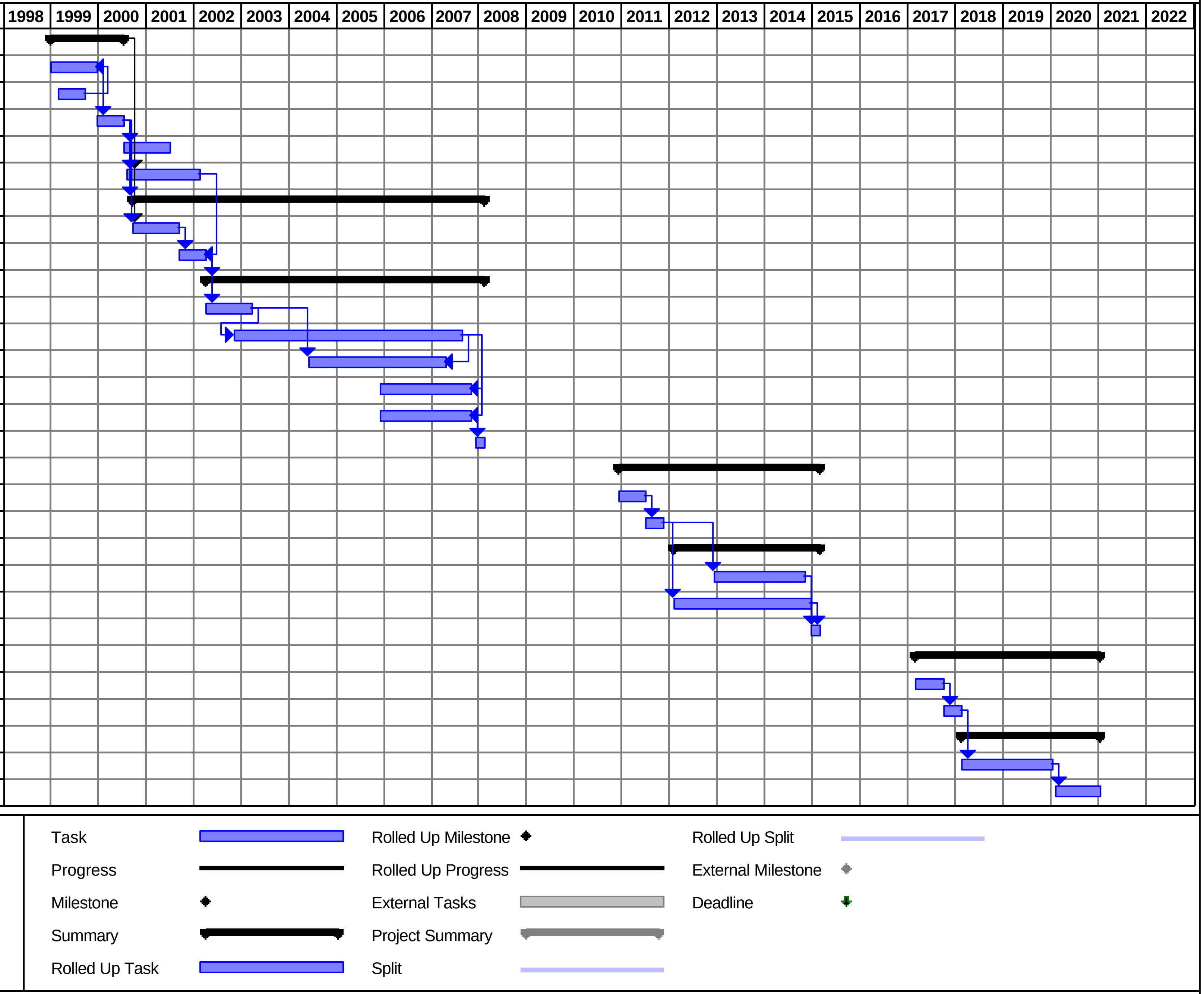


IMPLEMENTATION PROGRAMME: SMITHFIELD SCHEME

FIGURE 4.1

SCHEME 1A IMPLEMENTATION PROGRAMME

ID	Task Name	Duration
1	**Feasibility Study**	**80 wks**
2	Study and Report	50 wks
3	Geotech.Investigations	30 wks
4	Approval	30 wks
5	Property Aquisition	50 wks
6	FUNDING	80 wks
7	**PHASE 1**	**384.6 wks**
8	Design	50 wks
9	Tender and award	30 wks
10	**Construction**	**304.6 wks**
11	Infrastructure	50 wks
12	Transfer Tunnel	250 wks
13	Dam, 1.0 MAR	150 wks
14	Water Works	100 wks
15	Conveyance Systems	100 wks
16	Comission Phase 1	10 wks
17	**PHASE 3**	**221 wks**
18	Design	30 wks
19	Tender and award	20 wks
20	**Construct**	**160 wks**
21	Water Works upgrade	100 wks
22	Conveyance Systems	150 wks
23	Comission Phase 2	10 wks
24	**PHASE 2**	**202.6 wks**
25	Design	30 wks
26	Tender and award	20 wks
27	**Construct**	**152.6 wks**
28	Raise dam to 1.5 MAR	100 wks
29	Comission and fill dam	50 wks



Project: MKOMAZI-MGENI PRE-FEASIBILITY STUDY
Date: Tue 03/02/04

IMPLEMENTATION PROGRAMME: IMPENDLE SCHEME

FIGURE 4.2

4. CONSTRUCTION ASPECTS

4.1 Construction Infrastructure

As indicated in Sections 2.7 and 3.8, all construction infrastructure, with the exception of main access roads to the sites and bulk electrical supply, has been assumed to be the responsibility of the Contractors on the various scheme components. It is envisaged that the advance infrastructure would be implemented ahead of the contracts for the various scheme components, to avoid delays.

4.2 Programme of Implementation

4.2.1 General

Programmes for the implementation of the Smithfield and Impendle Schemes are given in **Figures 4.1** and **4.2**. Note that the overall programme for the implementation of the first phases of the three configurations of each of these schemes will be the same.

Overall durations from the commencement of the next phase of study to the commissioning of the first phase of the Impendle and Smithfield Schemes are expected to be 9 years and 8,5 years respectively.

4.2.2 Preliminary work

Prior to the commencement of the detail design of the various scheme components, the following tasks will need to be completed:

- Further geotechnical investigations of the dam sites, tunnel and pipeline routes, tunnel portals, waterworks sites and reservoir site.
- A detailed feasibility study, which could run partially in parallel with the geotechnical investigations.
- Procurement of funding for the selected project. This could run partially in parallel with the detail design if sufficient funding is available for this.

The detail design and tender process is expected to take approximately 18 months for the first phases of the schemes, and as little as 12 months for the final phases.

4.2.3 *Dams*

The construction of the dams will not be on the overall critical path of the first phase construction programmes. It should be noted that the programmes for the dams would be affected by the timing of commencement of construction, due to the fact that river diversion could probably only be achieved during the dry season. The closure of the diversion will also have to be carried out during the dry season.

It is expected that the construction of the Impendle 1,5 MAR dam would take approximately 3 years to complete and the Smithfield Dam 2,5 years.

4.2.4 *Tunnels*

As can be seen in **Figures 4.1** and **4.2**, tunnel construction is on the critical path for both schemes.

Construction of the transfer tunnels will commence with the portal developments and adit excavations. These activities can be completed, for the most part, during the lead in period before the TBM's are assembled on site. This lead in period comprises the procurement, transport and assembly of the TBM which generally takes approximately one year.

Advance rates of TBM excavation and concrete lining have been assumed to be:

- 130 m per week, per heading for TBM excavation
- 175 m per week, per heading for concrete tunnel lining.

These advance rates have been based on experience gained in construction of the Midmar Tunnel and the Lesotho Highlands project. A finishing period has been allowed for to complete portal structures etc.

Based on the above, the Impendle transfer tunnel is expected to take 5 years to complete. The Smithfield tunnel is expected to take 4,5 to 5 years to complete.

If a 4,5 m diameter segmentally lined tunnel were to be constructed in one pass, the estimated construction period for the Impendle scheme would be approximately 3,5 years, and for the Smithfield scheme between 3 and 3,5 years.

4.2.5 *Other infrastructure*

None of the other conveyance or treatment infrastructure is on the critical path and should be programmed so as to delay capital expenditure for as long as possible.

5. COST ESTIMATES

5.1 General

The structure of cost models, methods used for the calculation of quantities and the unit rates are based on the VAPS Guidelines (DWAF, 1994), except where otherwise indicated. VAPS unit rates were escalated by 34% from May 1994 to March 1998 prices, adjusted where necessary on the basis of more current information. Particular attention was given to major cost components which are not common to the two schemes, with a more generalised approach adopted for common components, such as water treatment works, and minor items, such as the Midmar pumpstation.

Preliminary and General allowances used were generally lower than those in the VAPS guidelines, as these were based on projects in Lesotho, where sites are significantly more remote than those being considered here.

Detailed cost estimates are included in **Appendix E** and summarised in **Table 5.1a** and **b**.

5.2 Calculation of Quantities

5.2.1 Dams

Founding levels were determined on the basis of geological reports, and embankment and concrete quantities calculated accordingly. Allowance was made for curtain grouting with a depth of two thirds of the height of dam and holes at 3 m centres. Blanket grouting was assumed to be 5 m deep at 3 m centres over the footprint of the concrete section or core trench. A drainage curtain is provided under the concrete gravity section to a depth of half the height of the dam with holes at 5 m centres. Internal drains are provided with a similar spacing.

Allowance was made for mass and reinforced concrete quantities for the Smithfield river diversion opening.

5.2.2 Tunnels

Quantities for items in the tunnel cost models, such as rock class, support, dealing with water and grouting, have been based on experience gained in the construction of the Midmar Tunnel, and estimated quantities for the Wellington Tunnel as part of the proposed Mooi-Mgeni Transfer Scheme.

A preliminary estimate of the lengths of steel liners and waterproof membrane required was made based on depth of cover and available geotechnical reports.

5.2.3 Pipelines

Cost models from recently constructed pipelines of similar diameter were used to determine typical quantities for items such as clearing, excavation and backfilling, cathodic protection etc.

Quantities for structures were taken off line drawings of typical air and scour valve structures.

5.2.4 Pumpstations and structures

Quantities for structures, including the Smithfield pumpstation, were calculated on the basis of layout and sections taken from drawings at the current level of investigation.

Reinforcement mass was calculated on the basis of 170 kg/m^3 of structural concrete for major structures, such as the Impendle Dam intake tower and the Smithfield transfer tunnel intake tower and pumpstation. 80 to 100 kg/m^3 was assumed in smaller structures.

In the case of the Midmar pumpstation, relatively recent construction prices are available and the new facility would be very similar in layout. A detailed cost model was therefore not prepared.

5.2.5 Water treatment works

Detailed cost models were not prepared for the water treatment works, as they are common components to both schemes, with similar quality water being treated and sites which are not anticipated to be problematic. See Section 5.3.5 for details of the derivation of costs.

5.3 Unit Rates

5.3.1 Dams

Unit rates for earthfill and RCC were based on rates determined for the iSithundu Dam in the Mvoti River Dam Feasibility Study, escalated by 13% from June 1996 to March 1998 prices. Other rates are based on escalated VAPS rates.

All built-in pipework and specials were assumed to be stainless steel, and other pipework, coated 3Cr-12, with rates determined accordingly. Valve costs were obtained from suppliers.

5.3.2 *Tunnels*

The unit rates for the construction of the tunnels were based on the following:

- Escalated VAPS rates
- Escalated Midmar Tunnel rates
- Escalated Lesotho Highlands rates (Mohale).

Rates were derived by comparing the above, to obtain balanced rates for the various major items.

Preliminary and General Charges were based on the duration of the activities for the various options, and averaged out at approximately 40% of the cost of the works.

5.3.3 *Pipelines*

Unit rates were developed from pipeline costs of recently constructed schemes in the same area as the proposed development. These are considered to be more appropriate than those developed in the VAPS model. All proposed pipelines will be cement mortar lined, Sintakote coated steel.

Pipe supply and deliver rates were confirmed with suppliers, and a 20% contingency added to counteract low prices quoted, probably as a result of the currently depressed construction industry.

Preliminary and general, miscellaneous and contingency rates considered appropriate to the relevant schemes were applied. A lower P&G was applied than those provided for in the VAPS cost models, including the provision of services, due to the less remote nature of the sites than those in Lesotho.

5.3.4 *Pumpstations and structures*

Prices for pumps, valves and related equipment were obtained from suppliers. VAPS rates were used for other items.

As indicated in Section 5.2.4, a detailed cost estimate was not prepared for the Midmar pumpstation. Instead, the construction costs of the existing pumpstation, provided by Umgeni Water (Umgeni Water, 1998c), were adjusted proportionally to the capacity of the proposed pumpstation and escalated from October 1996 to March 1998 prices.

5.3.5 Water treatment works

As indicated in Section 5.2.5, a detailed cost estimate was not prepared for the waterworks. Instead, an all-in price based on capacity was used, as provided by Umgeni Water (Umgeni Water, 1997). This all-in price was verified against recent prices on other large waterworks.

5.3.6 Advance infrastructure

Advance infrastructure provision is limited to roads and bulk electrical supply. All in unit rates per km were determined for the roads, assuming gravel surfaces and taking cognisance of the topography being traversed. The cost of bulk electrical supply was based on information provided by Eskom.

5.4 Social Costs

Details of the derivation of the social costs are provided in Supporting Report No 5: Environmental. Allowance was made for land acquisition for the dams and conveyances, as well as relocation of homesteads and graves, purchase of formal farm buildings and compensation for crops in the field. In the case of pipeline servitudes, 30% of land value is paid, in accordance with Umgeni Water procedures, as the land can be utilised subject to certain limitations

5.5 Operation and Maintenance Costs

Annual operation and maintenance costs were determined as recommended in the VAPS Guidelines, namely as a percentage of the capital costs, as follows:

Civil components
Dams, pipelines, pumpstations, waterworks and sundry structures: 0,25% of value of civil component of overall capital cost.
Tunnels: 0,1% of value of civil component of overall capital cost.

Mechanical and electrical components
Dams, pipelines, tunnels, waterworks and sundry structures: 4,0% of value of mechanical and electrical component of overall capital cost.

Pumpstations: As for other components, plus 15% of value of mechanical and electrical component of overall capital cost every 15 years for periodic refurbishment.

5.6 Pumping Costs

Pumping costs have been calculated for the Smithfield and Midmar pumpstations on the basis of the “Miniflex” tariff provided by Eskom. Umgeni Water's demand pattern suits the price structure of this tariff, it has been assumed that this option will in future be used. The basis of the tariff is that there is no demand charge, with the principal component being the energy charges plus add-ons such distance surcharge and monthly rental.

Using the Miniflex charge structure, an average unit energy charge (c/kWh) was calculated for a year. Energy costs were calculated on a monthly and annual basis, based on the maximum and minimum operating levels and friction head. The pump and motor efficiencies were selected according to the VAPS guidelines, and a 20% contingency on the power costs has been allowed for.

TABLE 5.1a: COST ESTIMATES: IMPENDLE SCHEME

IMPENDLE SCHEME 1A - RAISED TO 1,5 MAR DAM

		Phase 1	Phase 2	Phase 3	Total
Capital Costs:	Dam	R 321 million		R 116 million	R 437 million
(Mar '98 prices):	Tunnel	640 million	R 40 million		680 million
	Pumpstation	20 million	20 million		40 million
	Waterworks	287 million	247 million		534 million
	Pipelines	317 million	302 million		619 million
	Infrastructure	13 million			13 million
	Social & Environmental	10 million			10 million
	Engineering Fees	192 million	73 million	14 million	279 million
	TOTAL	**R1 800 million**	**R682 million**	**R130 million**	**R2 612 million**
Running Costs:	Pumping	R 1,7 million/a	R 1,3 million/a	R 0,4 million/a	R 3,4 million/a
(Mar '98 prices):	Operation & Maint.	7,0 million/a	5,2 million/a	0,3 million/a	12,5 million/a
	TOTAL	**R8,7 million/a**	**R6,5 million/a**	**R0,7 million/a**	**R15,9 million/a**

IMPENDLE SCHEME 1B - 1,0 MAR DAM

		Phase 1	Phase 2	Total
Capital Costs:	Dam	R 310 million		R 310 million
(Mar '98 prices):	Tunnel	640 million	R 40 million	680 million
	Pumpstation	17 million	17 million	34 million
	Waterworks	256 million	216 million	472 million
	Pipelines	312 million	297 million	609 million
	Infrastructure	13 million		13 million
	Social & Environmental	10 million		10 million
	Engineering Fees	186 million	68 million	254 million
	TOTAL	**R1 744 million**	**R638 million**	**R2 382 million**
Running Costs:	Pumping	R 1,5 million/a	R 1,5 million/a	R 3,0 million/a
(Mar '98 prices):	Operation & Maint.	6,5 million/a	4,6 million/a	11,1 million/a
	TOTAL	**R8,0 million/a**	**R6,1 million/a**	**R14,1 million/a**

IMPENDLE SCHEME 1C - 1,5 MAR DAM

		Phase 1	Phase 2	Total
Capital Costs:	Dam	R 384 million		R 384 million
(Mar '98 prices):	Tunnel	640 million	R 40 million	680 million
	Pumpstation	20 million	20 million	40 million
	Waterworks	287 million	247 million	534 million
	Pipelines	317 million	302 million	619 million
	Infrastructure	13 million		13 million
	Social & Environmental	10 million		10 million
	Engineering Fees	199 million	73 million	272 million
	TOTAL	**R1 870 million**	**R682 million**	**R2 552 million**
Running Costs:	Pumping	R 1,7 million/a	R 1,7 million/a	R 3,4 million/a
(Mar '98 prices):	Operation & Maint.	7,2 million/a	5,2 million/a	12,4 million/a
	TOTAL	**R8,9 million/a**	**R6,9 million/a**	**R15,8 million/a**

Note: Costs for Phases 2 and 3 represent incremental costs only

TABLE 5.1b: COST ESTIMATES: SMITHFIELD SCHEME

SMITHFIELD SCHEME 2A - IMPENDLE DAM RAISED TO 1,5 MAR

		Phase 1	Phase 2	Phase 3	Total
Capital Costs:	Dam	R 228 million	R 321 million	R 116 million	R 665 million
(Mar '98 prices)	Tunnel	543 million			543 million
	Pumpstation	68 million	20 million		88 million
	Waterworks	273 million	351 million		624 million
	Pipelines	212 million	209 million		421 million
	Infrastructure	14 million	13 million		27 million
	Social & Environmental	4 million	10 million		15 million
	Engineering Fees	161 million	110 million	14 million	285 million
	TOTAL	**R1 503 million**	**R1 035 million**	**R 130 million**	**R2 668 million**
Running Costs:	Pumping	R 3,8 million/a	R 5,0 million/a	R 1,1 million/a	R 9,9 million/a
(Mar '98 prices)	Operation & Maint.	6,8 million/a	7,7 million/a	0,3 million/a	14,8 million/a
	TOTAL	**R10,6 million/a**	**R12,7 million/a**	**R1,4 million/a**	**R24,7 million/a**

SMITHFIELD SCHEME 2B - IMPENDLE DAM 1,0 MAR

		Phase 1	Phase 2	Phase 3	Total
Capital Costs:	Dam	R 228 million	R 310 million		R 538 million
(Mar '98 prices)	Tunnel	543 million			543 million
	Pumpstation	71 million		R 17 million	88 million
	Waterworks	304 million		263 million	513 million
	Pipelines	212 million		209 million	421 million
	Infrastructure	14 million	13 million		27 million
	Social & Environmental	4 million	10 million		14 million
	Engineering Fees	165 million	39 million	59 million	263 million
	TOTAL	**R1 541 million**	**R 372 million**	**R 547 million**	**R2 407 million**
Running Costs:	Pumping	R 3,8 million/a	R 0,5 million/a	R 4,4 million/a	R 8,7 million/a
(Mar '98 prices)	Operation & Maint.	7,3 million/a	1,4 million/a	4,9 million/a	13,6 million/a
	TOTAL	**R11,1 million/a**	**R 1,9 million/a**	**R9,3 million/a**	**R22,3 million/a**

SMITHFIELD SCHEME 2C - IMPENDLE DAM 1,5 MAR

		Phase 1	Phase 2	Phase 3	Total
Capital Costs:	Dam	R 228 million	R 384 million		R 612 million
(Mar '98 prices)	Tunnel	543 million			543 million
	Pumpstation	68 million	20 million		88 million
	Waterworks	273 million	351 million		624 million
	Pipelines	212 million		R 209 million	421 million
	Infrastructure	14 million	13 million		27 million
	Social & Environmental	4 million	10 million		14 million
	Engineering Fees	161 million	92 million	25 million	278 million
	TOTAL	**R1 503 million**	**R 871 million**	**R 234 million**	**R2 608 million**
Running Costs:	Pumping	R 3,8 million/a	R 1,1 million/a	R 5,0 million/a	R 9,9 million/a
(Mar '98 prices)	Operation & Maint.	6,8 million/a	7,1 million/a	0,7 million/a	14,6 million/a
	TOTAL	**R10,6 million/a**	**R 8,7 million/a**	**R5,7 million/a**	**R24,5 million/a**

Note: Costs for Phase 2 represent incremental costs only

6. RECOMMENDATIONS FOR SPECIAL ATTENTION AT FEASIBILITY STAGE

It is assumed that all activities normally associated with a feasibility study will be included in the terms of reference for the feasibility study as a matter of course. This would include more detailed geotechnical investigations (including waterworks and reservoir sites and pipeline routes), flood analyses, etc. Only issues identified as requiring particular attention are therefore listed, as follows:

- Refine phasing of all components to optimise the selected scheme layout.

- Review sediment volumes and distribution in dam basins.

- Geotechnical
  - In addition to general exploratory drilling, etc, carry out a geohydrological investigation of the tunnel routes.
  - Carry out material investigations and testing of quarries in particular, including concrete aggregate durability tests.
  - Investigate stability for Midmar/Ferncliffe outlet control structure.

- Dam Design
  - Optimise spillway lengths and model test.
  - Investigate river diversion and programme implications thereof in more detail (both dams).
  - Optimise concrete gravity/embankment lengths at Smithfield.
  - Review desirability of raising Impendle.

- Tunnel Design
  - Evaluate Smithfield pressure tunnel and underground pumpstation option in detail.
  - Assess risks of groundwater inflows with downgrade drives (both schemes).
  - Review preferred TBM diameter (3,5 m or 4,5 m) (both schemes).
  - Evaluate interface between tunnel and dam construction activities and programmes, with a view to maximising common access roads, facilities, etc. (both schemes).
  - Carry out detailed hydraulic analysis of potable water aqueduct system between Midmar Waterworks and Northern feeder, including operating system (Impendle Scheme).
  - Inspect Ferncliffe Tunnel (Impendle Scheme).

- Pumpstation Design
  - Confirm redundancy requirements (both schemes).
  - Evaluate whether multi-level intakes are required for the Smithfield pumpstation

- Balancing Storage
  - Review long term serviceability of Midmar outlet works under ultimate flow conditions (Impendle Scheme).
  - Enter into negotiations with Umlazi River Irrigation Board for the joint use of Baynesfield Dam (Smithfield Scheme).

- Waterworks Design
  - Take potential poor quality scour water into account in Midmar Waterworks process design (Impendle Scheme).

7. OPERATIONAL RISK ASSESSMENT

During the latter stages of this Study, it became apparent that factors other than technical issues, economics and environmental impacts may have to be considered in order to select a preferred scheme for the feasibility phase of planning. It was apparent that the configurations of the two schemes were such that there may be significantly different risks of operational failure for the two schemes and Umgeni Water commissioned a parallel study to assess these risks. An assessment using probabilistic fault-event tree techniques was undertaken by SRK Consulting and the full report of their study is included in a separately bound appendix to this Report (**Appendix H**). The findings of their report are summarised below.

In terms of the context of the study and in relation to the level of detail of the design data (Pre-Feasibility), the approach adopted was to focus on the key issues contributing to failure and to assess if there is a clear cut preference between the two schemes. A relative assessment of probability as opposed to an absolute assessment of probability could be used in the risk analysis. This enabled a reduction in the number of variables considered as well as allowing some flexibility in the accuracy of the probabilities assigned.

Fault trees were developed for each of the schemes in conjunction with key personnel from SRK, Umgeni Water, DWAF, NS and KSI. Two workshops were held at which the fault tree logic and probability assignments were discussed and agreed.

The fault event tree combines probabilities of faults and events to provide the probability of a top event, which was defined as follows:

> *The occurrence of maximum allowable curtailment of water transfer from the Mkomazi Impendle/Smithfield dam/s to the outlet of Umlaas Road in the Mgeni System as a consequence of a physical failure of the Mkomazi-Mgeni water transfer infrastructure for a period of at least five days at the time of full system supply (approximately 2025).*

The results of the analyses (top event and Primary Faults only) for the two schemes are shown in **Tables 8.1** and **8.2**.

It can be seen from the results that the Smithfield option has a lower probability of occurrence of the top event than the Impendle option, at approximately 1: 150 years against the 1:100 years of Impendle.

According to the analysis, the most vulnerable component of the Smithfield Scheme is the pumpstation, due to possible major power outages, as well as the rising main, due to possible waterhammer. The Impendle Scheme has a number of vulnerable areas, in particular, failure of a clear water pipeline causing the failure of adjacent pipelines and failure of the Stuckenberg or Midmar Tunnel. It is also apparent that the scheme with the greatest number of components in series is the more likely to fail. However, in neither scheme is there a single component which can be identified as the major cause of failure.

An issue which was identified in both schemes is the potential for unplanned maintenance events to last longer than 5 days, particularly in elements which do not have a back-up, such as the Smithfield Transfer Tunnel and the Midmar and Stuckenberg Tunnels. Careful scheduling of maintenance will be required once the schemes begin to reach peak capacity.

Table 8.1: Summary of Probabilities for Smithfield Scheme

Item No	Description	Calculated Probability	Occurs once in 'X' years
TE	Top Event	6.49E-03	154
TF2	Storage Failure of Smithfield Dam	6.54E-05	15287
TF3	Abstraction Failure of Intake Tower and Pumps	2.09E-03	478
TF4	Burst of Raising Main Pipeline	1.52E-03	656
TF5	Complete lack of Water Transfer Through Smithfield Tunnel	7.70E-04	1299
TF6	Burst of Baynesfield Raw Water Pipeline	3.98E-04	2515
TF7	Complete lack of Water Purification At Baynesfield Waterworks	6.26E-04	1596
TF8	Burst of Baynesfield Clear Water Pipelines	9.80E-04	1020
TF9	Complete lack of Water Transfer Through Umlaas Road Outlet	5.60E-05	17858

Table 8.2: Summary of Probabilities for Impendle Scheme

Item No	Description	Calculated Probability	Occurs once in 'X' years
TE	Top Event	1.04E-02	96
TF5	Storage Failure of Midmar Dam	9.46E-05	10568
TF6	Abstraction Failure through Midmar Dam Outlet	7.90E-04	1266
TF7	Burst of Midmar Dam Outlet Pipelines	2.27E-04	4409
TF8	Complete lack of Water Purification at Midmar Waterworks	4.03E-04	2482
TF9	Burst of Midmar Raw Water Pipelines	3.11E-04	3220
TF10	Complete lack of Water Purification at Midmar Waterworks	6.26E-04	1596
TF11	Burst of Waterworks Pipelines	1.44E-03	696
TF12	Complete lack of Water Transfer Through Stuckenberg Tunnel	1.28E-03	782
TF13	Burst of Stuckenberg Pipelines	1.70E-04	5686
TF14	Complete lack of Water Transfer Through Midmar Reservoir	1.82E-04	5495
TF15	Complete lack of Water Transfer Through Midmar Tunnel	1.28E-03	783
TF17	Burst of Tunnel Outlet Pipelines	2.65E-04	3780
TF18	Complete lack of Water Transfer Through Midmar BPT	4.34E-04	2304
TF19	Burst of Midmar Pipelines	2.17E-03	461
TF20	Complete lack of Water Transfer Through Whispers BPT	5.60E-05	17858
TF21	Burst of Whispers Pipelines	6.69E-04	1495
TF22	Complete lack of Water Transfer Through Umlaas Road Outlet	5.60E-05	17858

8. CONCLUSIONS AND RECOMMENDATIONS

8.1 Technical

Based on the information available for the preparation of the above preliminary designs, it has been ascertained that all schemes evaluated during this phase of the Study are technically feasible, although there are some areas of concern. The Smithfield Scheme has no obvious flaws, but the Impendle Scheme has the following potential problems:

- The capacity if the Midmar Dam outlet works is limited and modifications will be required to be able to abstract sufficient water. These will be difficult to implement, as the existing draw off facilities are already under demand pressure. The long term serviceability of the existing pipework and valves under relatively high velocity service conditions is also cause for concern.
- Some water will have to be drawn from the scour outlets, which will be of a poorer quality than that drawn from the multi-level outlets. This will pose treatment problems and will have cost implications.
- The condition of the Ferncliffe Tunnel, which will have to be utilised for clear water transfer in the latter phases of the scheme, is unknown, and may be worse than anticipated.
- The parallel operation of the Ferncliffe and Midmar Tunnels will require a sophisticated control system, with appropriate redundancy.
- The working area available along portions of the pipeline routes is limited and special care will have to be taken during construction to avoid damage and disturbance to adjacent property.

There is no clear technical preference for any of the three configurations of the two schemes, although the raising of Impendle Dam may pose some difficulties. This issue will probably be decided on the basis of economics.

8.2 Costs

The overall costs of all phases of the equivalent Impendle and Smithfield Schemes are very similar, in fact within the range of accuracy which could be expected at this level of detail. The first phase Smithfield Schemes are between 12 and 20%

cheaper than the Impendle Schemes, due mainly to the lower dam, tunnel and pipeline costs. The cash flows of the schemes are similar, as indicated in Supporting Report No 7: Economics.

In view of the above and considering the level of detail of the current Study, it would be inappropriate to eliminate either scheme on the basis of cost.

8.3 Operational Risk

The results of the SRK operational reliability risk assessment (Umgeni Water, 1998a) summarised in Section 7 indicate that the risk of the occurrence of maximum allowable curtailment (50%) of delivery of water from the Impendle Scheme to the outlet of the proposed Umlaas Road Reservoir is 60% greater than that of the Smithfield scheme. However, this risk is 1:96 years, which is similar to the hydrological risk and is therefore not unacceptable.

A further issue to be considered, however, is that in the event of a failure of a scheme component which is common to both the existing potable water transfer system from the Midmar Waterworks and the proposed Impendle Scheme, none of the areas currently being supplied from this source, including Pietermaritzburg, could be supplied. In the case of the Smithfield Scheme, a small quantity of water could still be supplied to Umlaas Road in the event of a failure of a scheme component and a large proportion of Pietermaritzburg could still be supplied in the event of failure of the existing system if a booster pumpstation is provided.

8.4 Recommendations

Based on the technical aspects, costs and operational risks, it can be concluded that the Smithfield Scheme is preferable to the Impendle Scheme. However, based on these issues alone, it would be unwise to eliminate the Impendle Scheme and consideration should first be given to relative environmental impacts and the economics of the schemes before a final decision is made. The preferred scheme size and configuration should also be determined on the basis of economics, and if this is not possible at the current level of study detail, a final decision should be made during feasibility phase. This applies particularly to the raising of Impendle Dam.

It is assumed that the feasibility study will be carried out to an appropriate level of detail, but there are a number of issues which require particular attention, as listed in Section 6. These should be included in the terms of reference for the feasibility study.

REFERENCES

Council for Geoscience (1997a), **UPPER MKOMAZI-MGENI TRANSFER SCHEME: IMPENDLE DAM SITE AND TRANSFER TUNNEL: IMPENDLE AND LIONS RIVER DISTRICTS: ENGINEERING GEOLOGICAL REVIEW,** *Geological Survey, Report No 1997-0342 (November 1997).*

Council for Geoscience (1997b), **UPPER MKOMAZI-MGENI TRANSFER SCHEME: SMITHFIELD DAM SITES AND TRANSFER TUNNEL ALIGNMENTS: IMPENDLE AND POLELA DISTRICTS: FIRST ENGINEERING GEOLOGICAL RECONNAISSANCE REPORT,** *Geological Survey, Report No 1997-0118, (October 1997).*

Council for Geoscience (1998), **UPPER MKOMAZI-MGENI TRANSFER SCHEME: SMITHFIELD DAM SITE: IMPENDLE AND POLELA DISTRICTS: FIRST ENGINEERING GEOLOGICAL PRE-FEASIBILITY REPORT,** *Geological Survey, Report No 1998-0037, (February 1998).*

Department of Water Affairs and Forestry (1994), **VAAL AUGMENTATION PLANNING STUDY: GUIDELINES FOR THE PRELIMINARY SIZING, COSTING AND ENGINEERING EVALUATION OF PLANNING OPTIONS,** *Report No PC 000/00/14394 (August 1994)*.

South African National Committee on Large Dams (1991), **GUIDELINES ON SAFETY IN RELATION TO FLOODS,** *Safety Evaluation of Dams, Report No 4 (August 1991).*

Umgeni Water (1996), **MIDMAR WATER TRANSFER PRE-FEASIBILITY STUDY,** Final Report, Keeve Steyn Inc (July 1996).

Umgeni Water (1997), **PRICES FOR WATER TREATMENT WORKS,** *Personal communication with Mr D Hodginson (31 July 1997).*

Umgeni Water (1998a), **COMPARATIVE OPERATIONAL RELIABILITY ASSESSMENT OF TWO TRANSFER OPTIONS FOR THE PROPOSED MKOMAZI-MGENI TRANSFER SCHEME,** *Report by SRK Consulting (November 1998).*

Umgeni Water (1998b), **COMMENT TO NINHAM SHAND ON THE WATER QUALITY IMPLICATIONS OF TREATING ABSTRACTED AND SCOUR RELEASE WATER AFTER THE RAISING OF MIDMAR DAM WALL BY 4,5 METRES,** *Water Quality Planning, Scientific Services, Umgeni Water (July 1998).*

Umgeni Water (1998c), **PRICE OF MIDMAR PUMPSTATION,** *Personal Communication with Mr D Hodkinson (June 1998).*

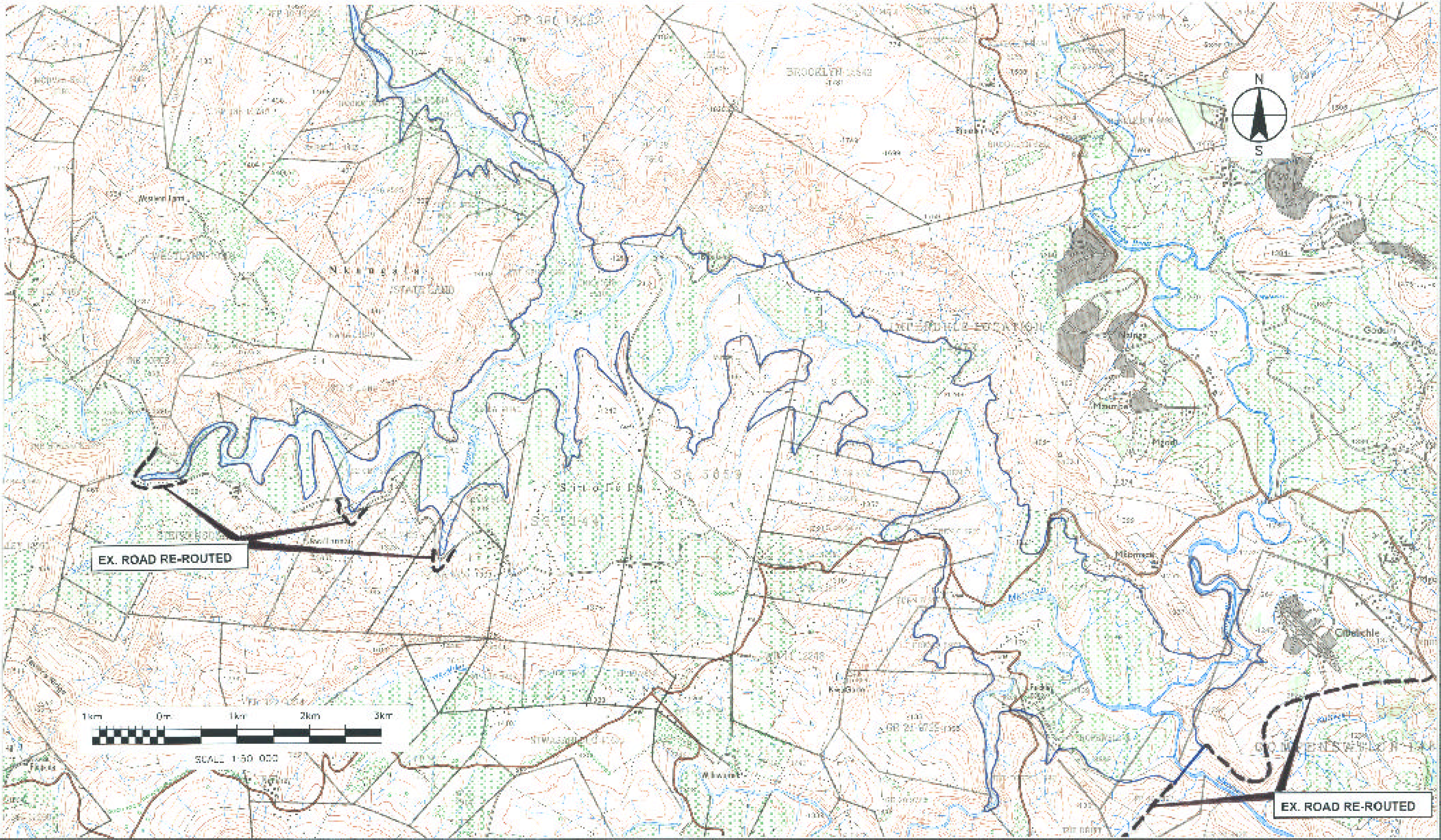
A P P E N D I C E S

APPENDIX A

DRAWINGS

APPENDIX A1 - IMPENDLE SCHEME DRAWING LIST

No	Description	Figure No
1	Impendle Dam Basin at FSL 1197masl	A1.1
2	Impendle Dam - Plan	A1.2
3	Impendle Dam - Downstream Elevation	A1.3
4	Impendle Dam - Typical Maximum Section	A1.4
5	Impendle Dam - Section Along Spillway Channel	A1.5
6	Impendle Dam - Section Through Outlet Works	A1.6
7	Impendle Dam - Details of Intake Tower	A1.7
8	Impendle Dam - Details of Outlet House	A1.8
9	Impendle Dam - Section Through Diversion / Access Tunnel	A1.9
10	Impendle Tunnel Alignment	A1.10
11	Impendle Tunnel Inlet	A1.11
12	Impendle Tunnel Intermediate Adit	A1.12
13	Impendle Tunnel Outlet	A1.13
14	Midmar Potable Water Aqueduct - Plan	A1.14
15	Northern Feeder Pipeline - Plan	A1.15
16	Impendle Scheme: Longitudinal Section of Conveyance	A1.16
17	Impendle Tunnel: Free Surface Flow Option: Longsection & Structures	A1.17
18	Impendle Tunnel: Pressure Flow Option: Longsection & Structures	A1.18
19	Midmar Aqueduct: Midmar / Ferncliff Tunnel: Outlet Control Structure	A1.19
20	Impendle Dam Reservoir Drawdown	A1.20
21	Impendle Stage Capacity Curve	A1.21
22	Impendle Stage Area Curve	A1.22



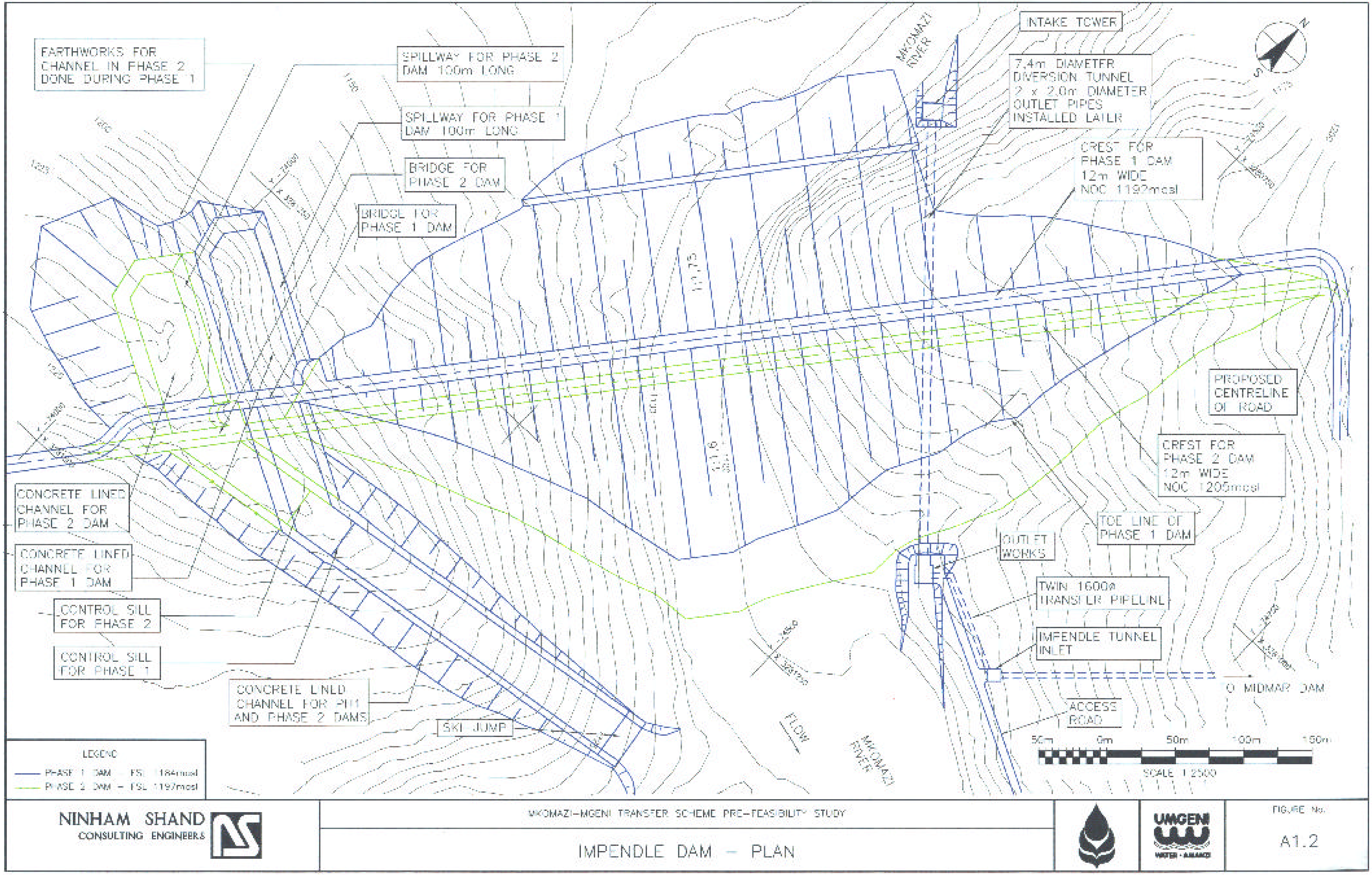
NINHAM SHAND CONSULTING ENGINEERS

MKOMAZI–MGENI TRANSFER SCHEME PRE-FEASIBILITY STUDY

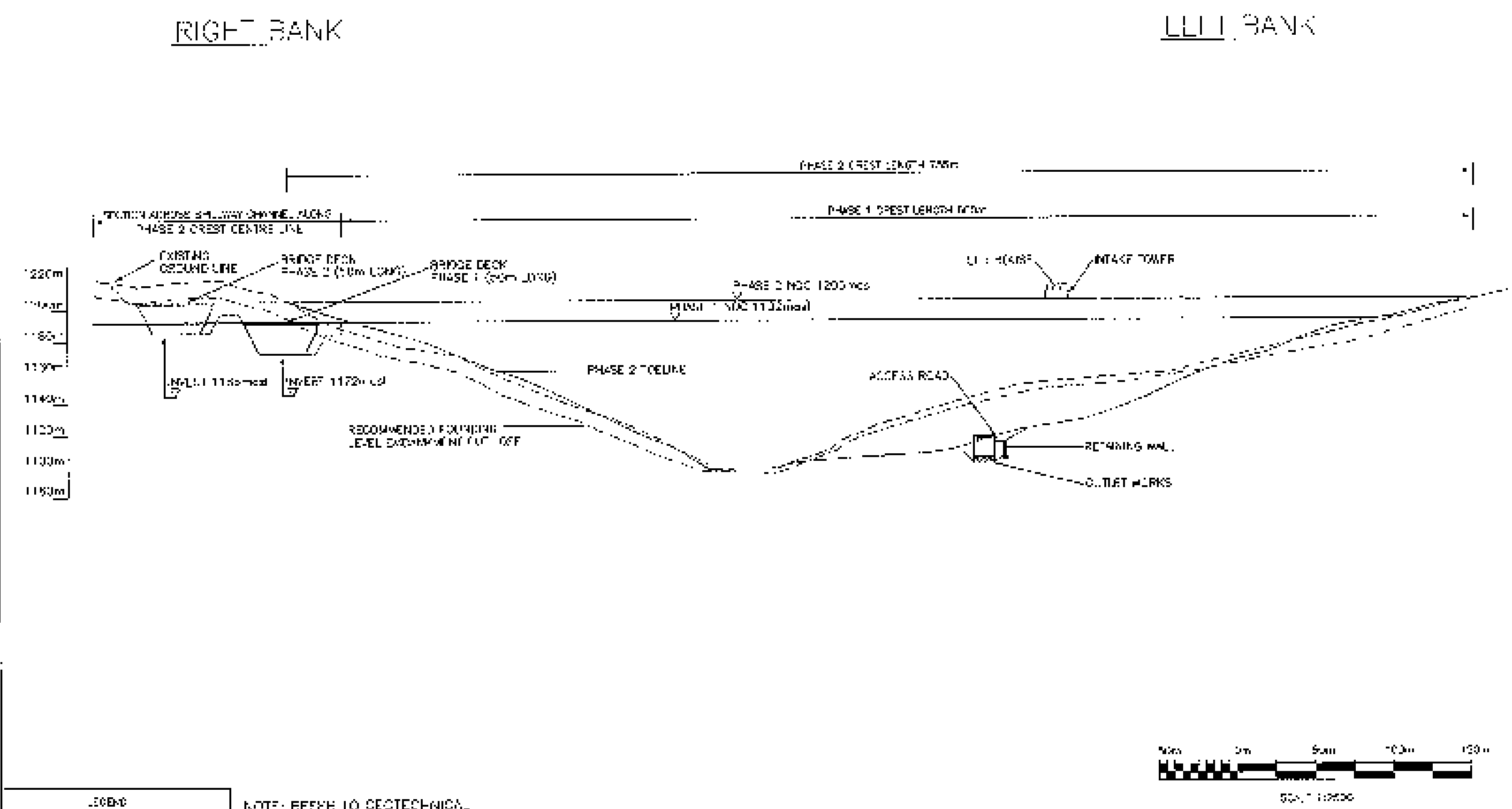
IMPENDLE DAM BASIN AT FSL 1197masl

UMGENI WATER • AMANZI

FIGURE No. A1.1



EARTHWORKS FOR CHANNEL IN PHASE 2 DONE DURING PHASE 1
SPILLWAY FOR PHASE 2 DAM 100m LONG
SPILLWAY FOR PHASE 1 DAM 100m LONG
BRIDGE FOR PHASE 2 DAM
BRIDGE FOR PHASE 1 DAM
MKOMAZI RIVER
INTAKE TOWER
7,4m DIAMETER DIVERSION TUNNEL 2 x 2,0m DIAMETER OUTLET PIPES INSTALLED LATER
CREST FOR PHASE 1 DAM 12m WIDE NOC 1192masl
PROPOSED CENTRELINE OF ROAD
CREST FOR PHASE 2 DAM 12m WIDE NOC 1205masl
TOE LINE OF PHASE 1 DAM
OUTLET WORKS
TWIN 1600ø TRANSFER PIPELINE
IMPENDLE TUNNEL INLET
TO MIDMAR DAM
ACCESS ROAD
CONCRETE LINED CHANNEL FOR PHASE 2 DAM
CONCRETE LINED CHANNEL FOR PHASE 1 DAM
CONTROL SILL FOR PHASE 2
CONTROL SILL FOR PHASE 1
CONCRETE LINED CHANNEL FOR PH1 AND PHASE 2 DAMS
SKI JUMP
FLOW
MKOMAZI RIVER
LEGEND
PHASE 1 DAM – FSL 1184masl
PHASE 2 DAM – FSL 1197masl
50m 0m 50m 100m 150m
SCALE 1:2500
NINHAM SHAND CONSULTING ENGINEERS
MKOMAZI–MGENI TRANSFER SCHEME PRE-FEASIBILITY STUDY
IMPENDLE DAM – PLAN
UMGENI WATER · AMANZI
FIGURE No.
A1.2



LEGEND

.... PHASE 1 DAM – FSL 1184masl
—— PHASE 2 DAM – FSL 1197masl

NOTE: REFER TO GEOTECHNICAL REPORT NO. 1107/6342 FOR GEOTECHNICAL DETAILS

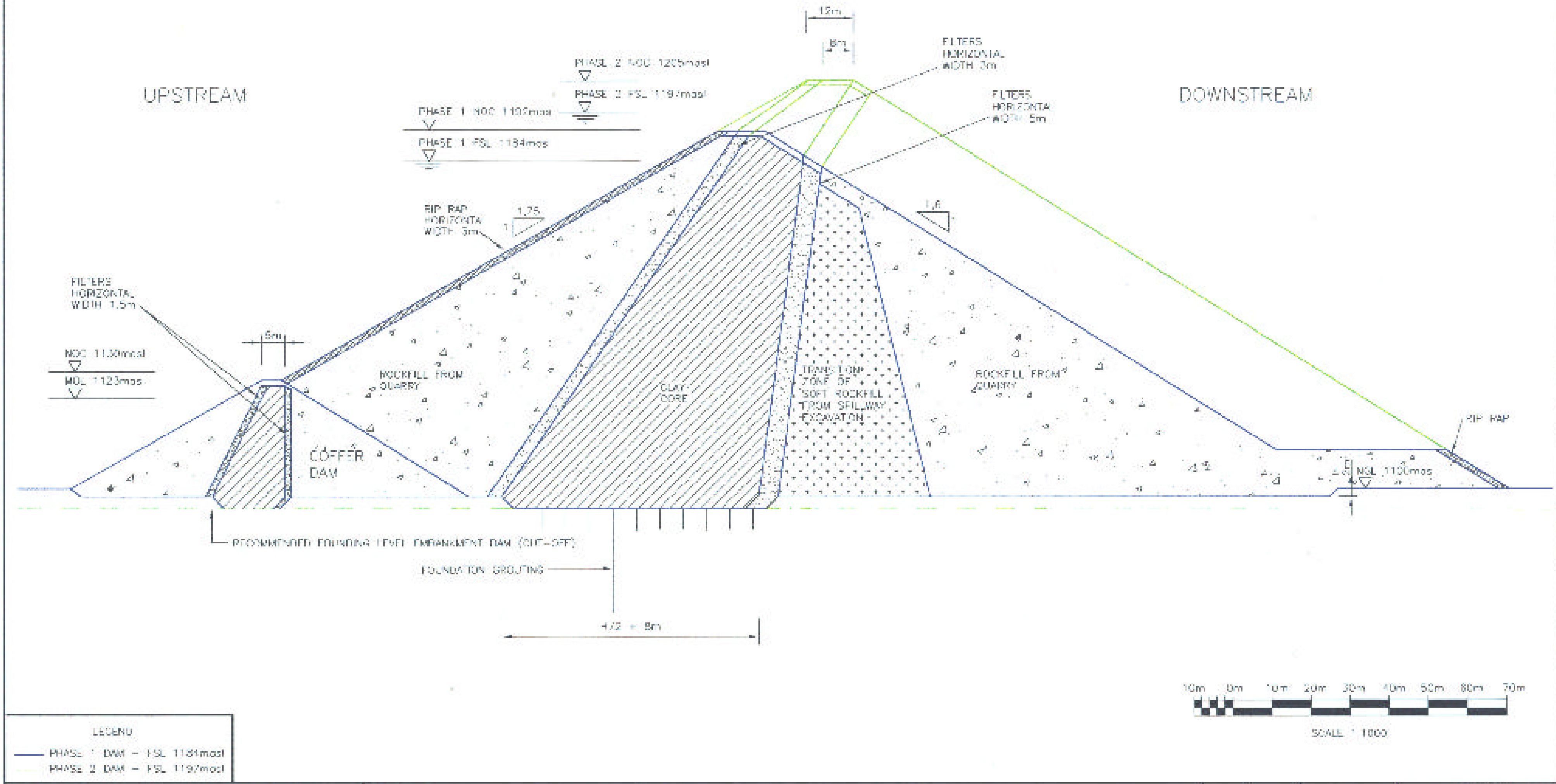
NINHAM SHAND
CONSULTING ENGINEERS

MOOI-MGENI TRANSFER SCHEME PRE-FEASIBILITY STUDY

IMPENDLE DAM – DOWNSTREAM ELEVATION

UMGENI WATER

FIGURE No.
A1.5



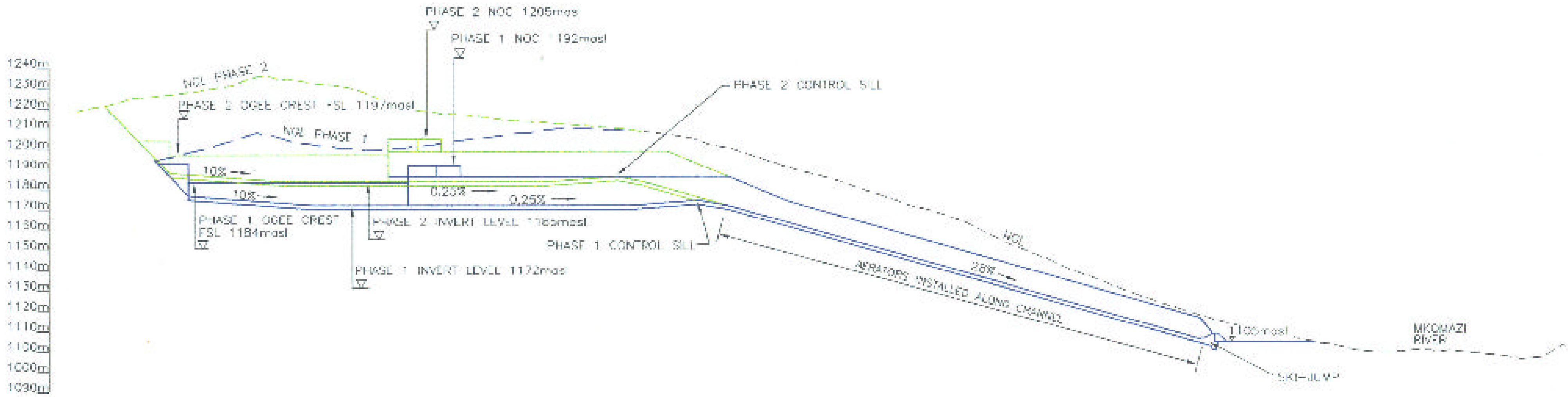
NINHAM SHAND CONSULTING ENGINEERS

MKOMAZI-MGENI TRANSFER SCHEME PRE-FEASIBILITY STUDY

IMPENDLE DAM – TYPICAL MAXIMUM SECTION

UMGENI WATER · AMANZI

FIGURE No. A1.4



LEGEND

PHASE 1 DAM – FSL 1184masl

PHASE 2 DAM – FSL 1197masl

50m 0m 50m 100m 150m

SCALE 1:2000

NINHAM SHAND CONSULTING ENGINEERS

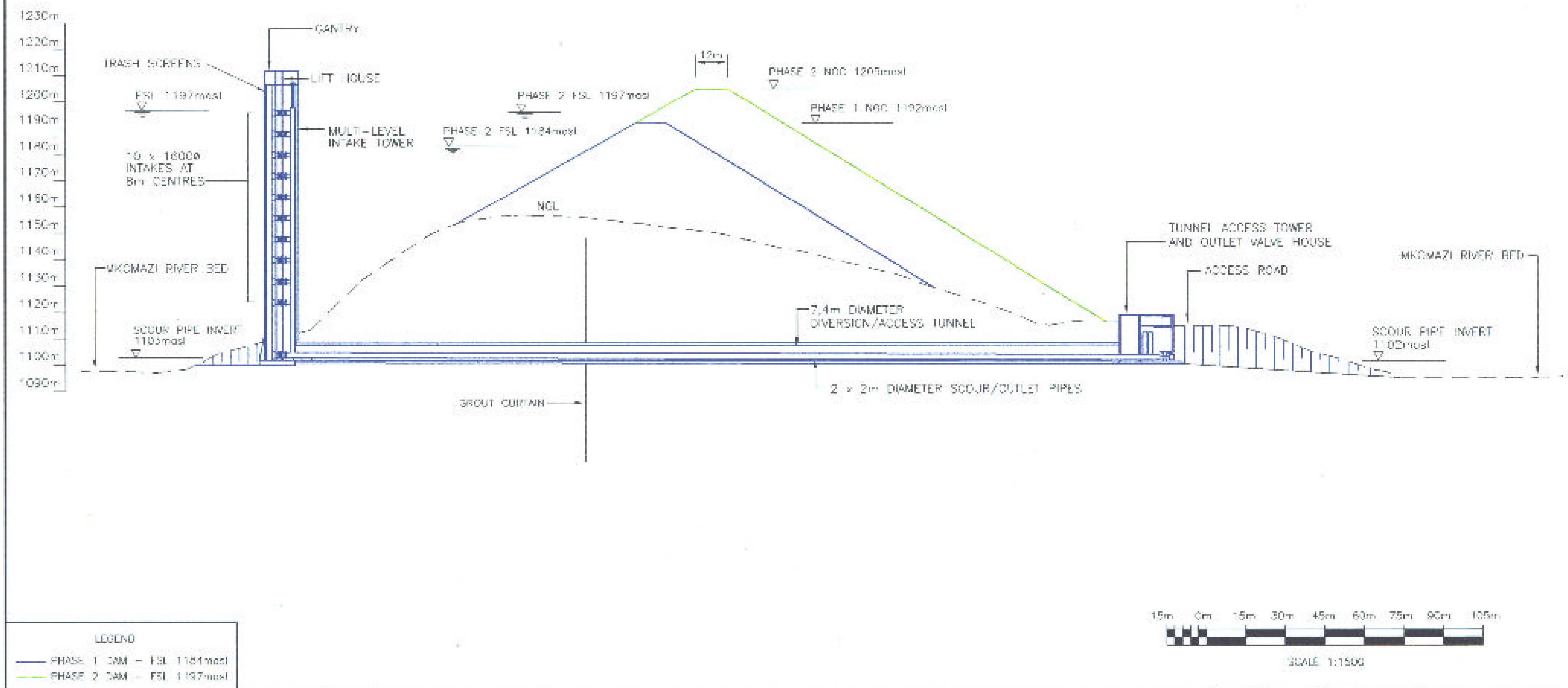
MKOMAZI-MGENI TRANSFER SCHEME PRE-FEASIBILITY STUDY

IMPENDLE DAM – SECTION ALONG SPILLWAY CHANNEL

UMGENI WATER • AMANZI

FIGURE No.

A1.5



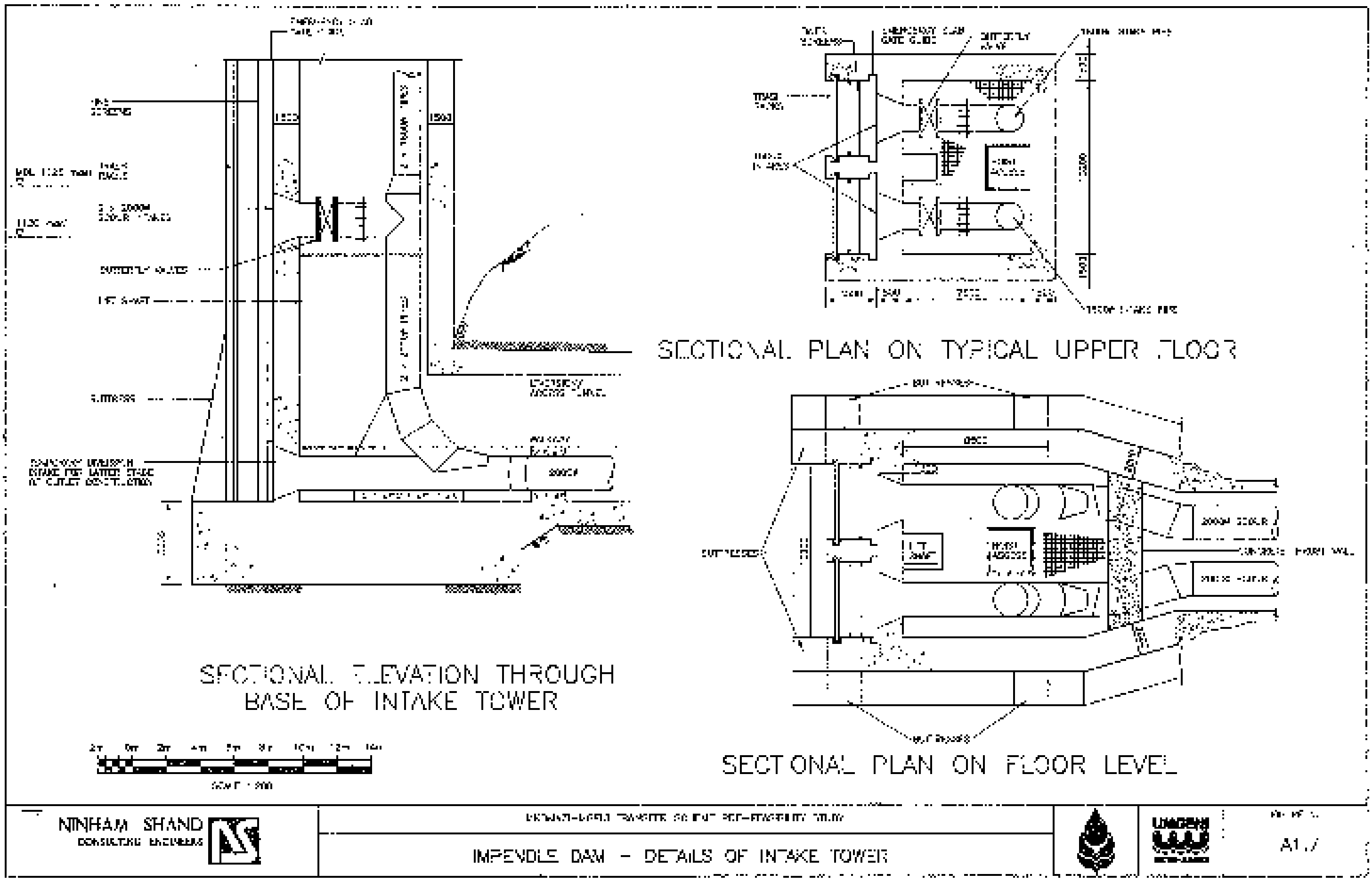
NINHAM SHAND CONSULTING ENGINEERS

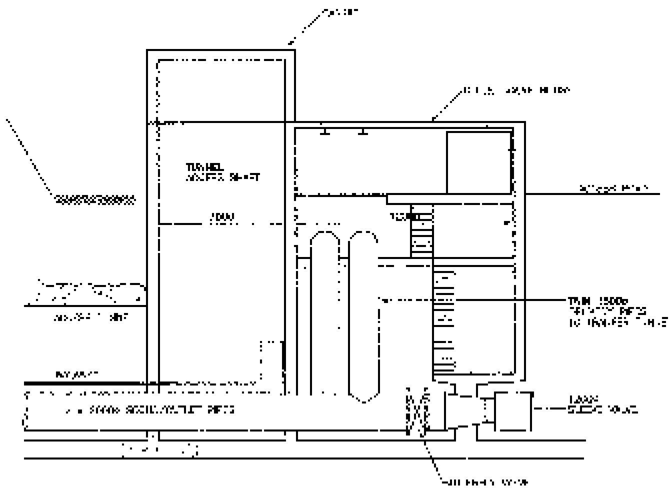
MKOMAZI-MGENI TRANSFER SCHEME PRE FEASIBILITY STUDY

IMPENDLE DAM - SECTION THROUGH OUTLET WORKS

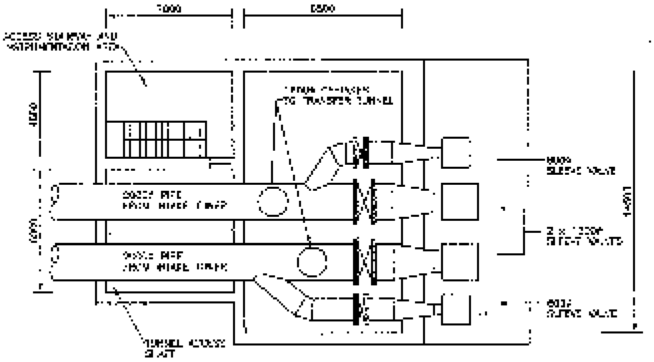
UMGENI WATER

FIGURE No. A1.6


SECTIONAL ELEVATION THROUGH BASE OF INTAKE TOWER
SECTIONAL PLAN ON TYPICAL UPPER FLOOR
SECTIONAL PLAN ON FLOOR LEVEL
BUTTRESSES
LIFT SHAFT
BUTTERFLY VALVES
2000Ø
1500
2500
NINHAM SHAND
CONSULTING ENGINEERS
IMPENDLE DAM - DETAILS OF INTAKE TOWER
A1.7



SECTIONAL ELEVATION OF OUTLET HOUSE

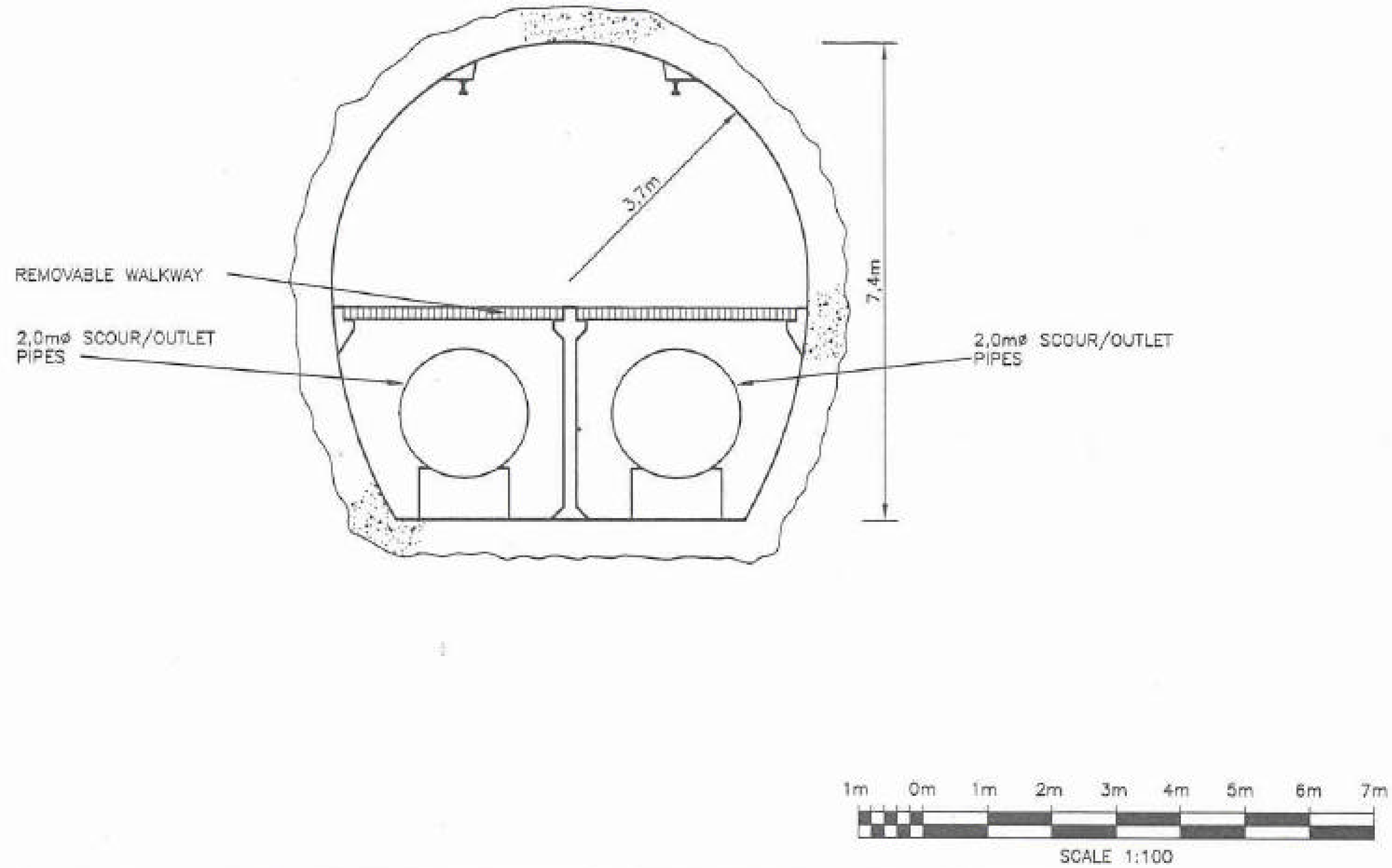


SECTIONAL PLAN OF OUTLET HOUSE

NINHAM SHAND
CONSULTING ENGINEERS

IMPENDLE DAM – DETAILS OF OUTLET HOUSE

FIGURE No.
A1.8



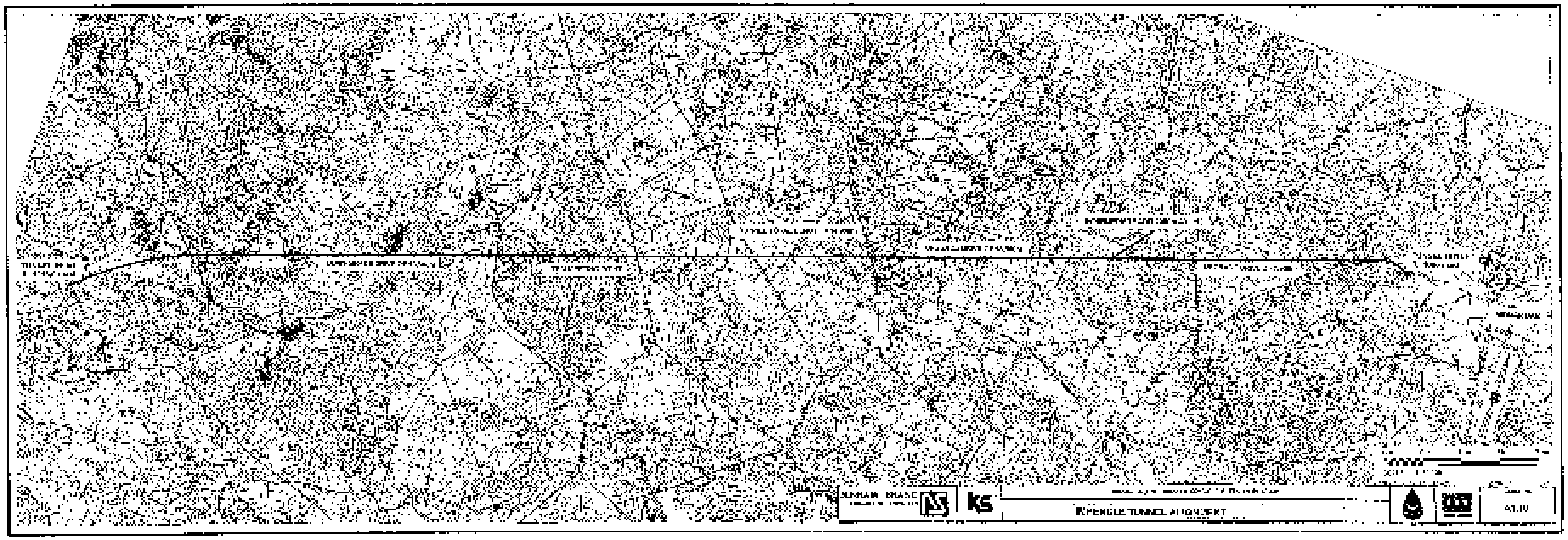
NINHAM SHAND CONSULTING ENGINEERS

MKOMAZI–MGENI TRANSFER SCHEME PRE–FEASIBILITY STUDY

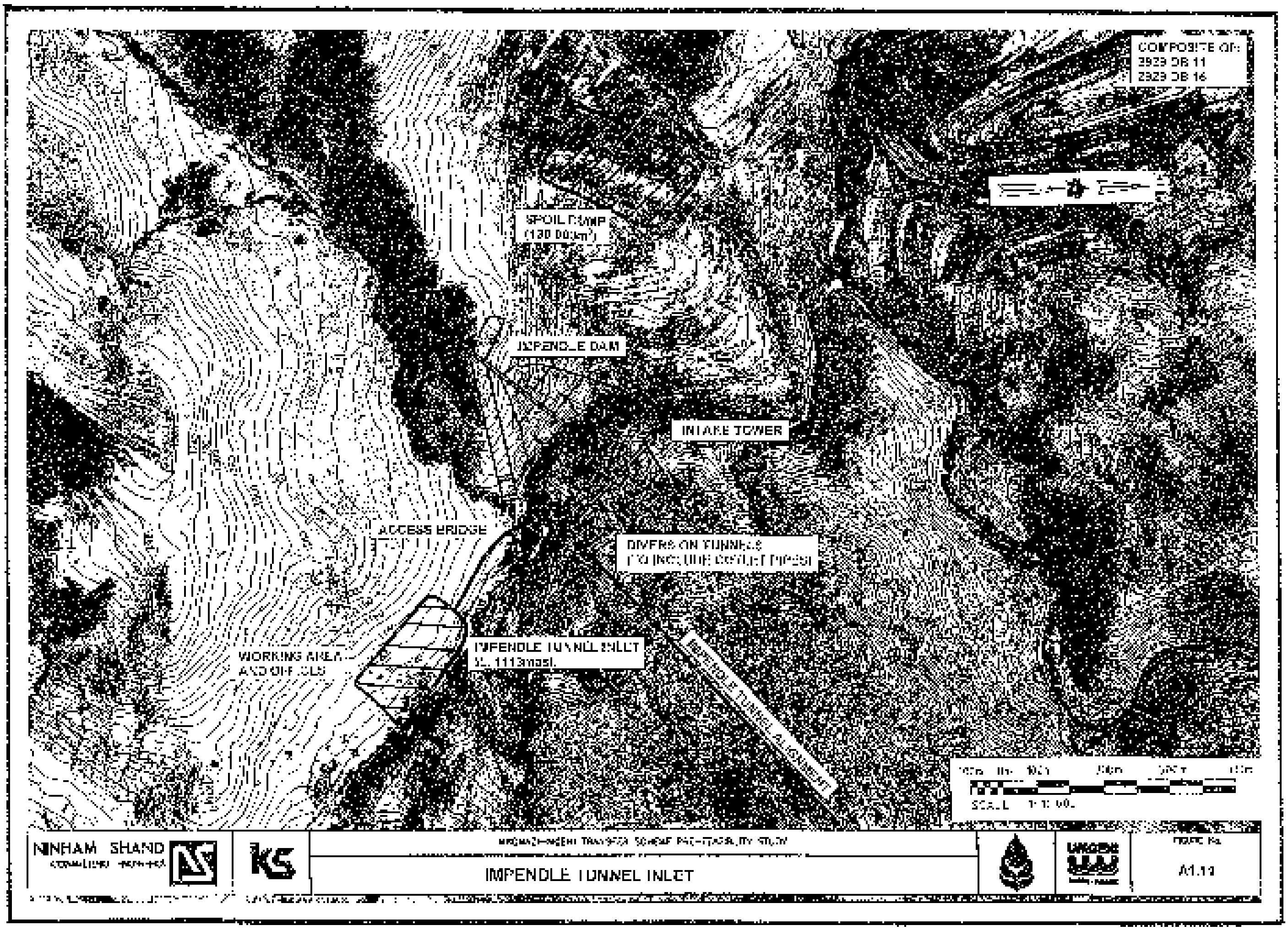
IMPENDLE DAM – SECTION THROUGH DIVERSION/ACCESS TUNNEL

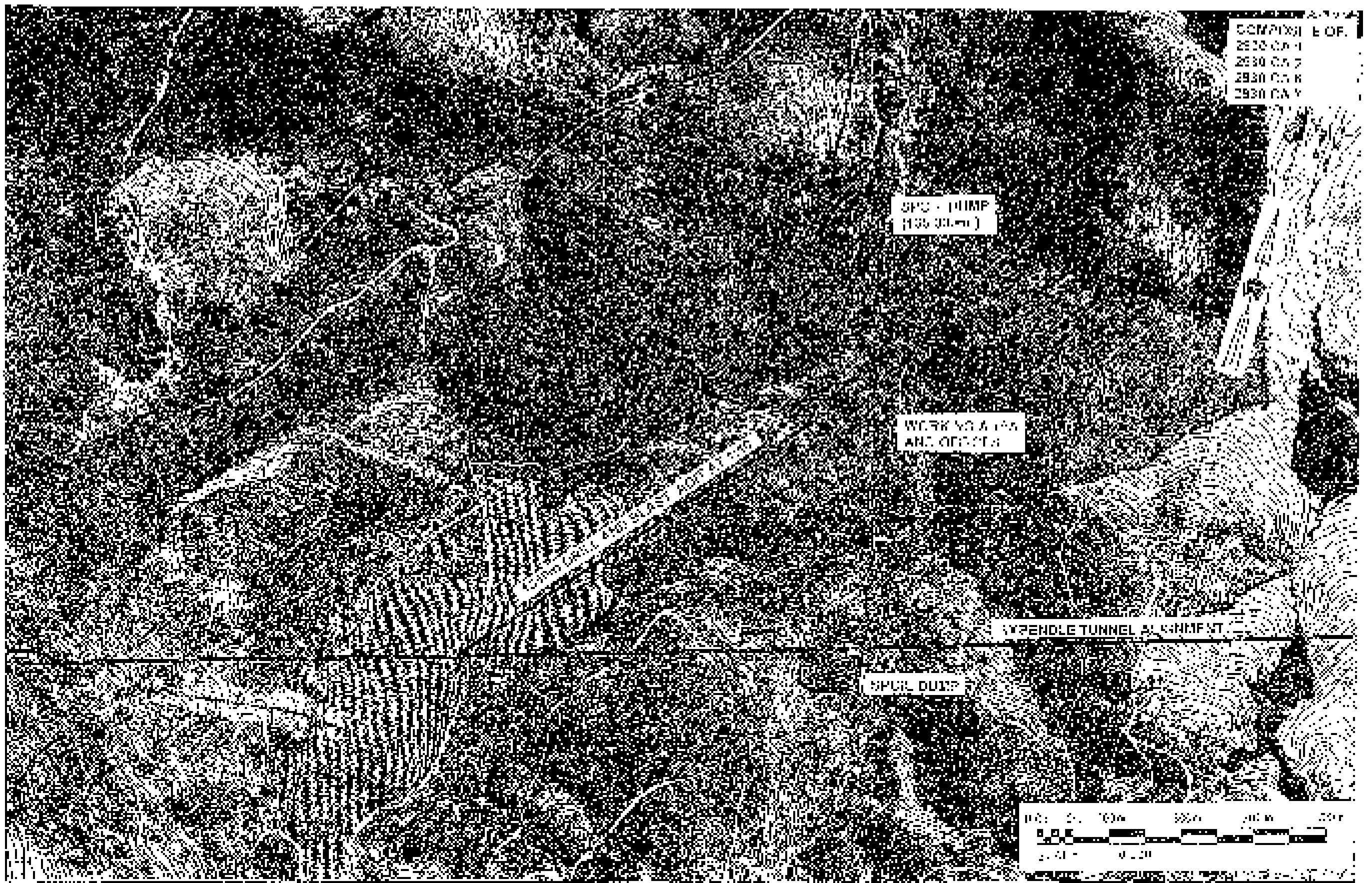
UMGENI

FIGURE No. A1.9



KS
TUNNEL ALIGNMENT


COMPOSITE OF:
2929 DB 11
2929 DB 16
SPOIL DUMP
IMPENDLE DAM
INTAKE TOWER
ACCESS BRIDGE
WORKING AREA
IMPENDLE TUNNEL INLET
NINHAM SHAND
KS
IMPENDLE TUNNEL INLET
A1.11

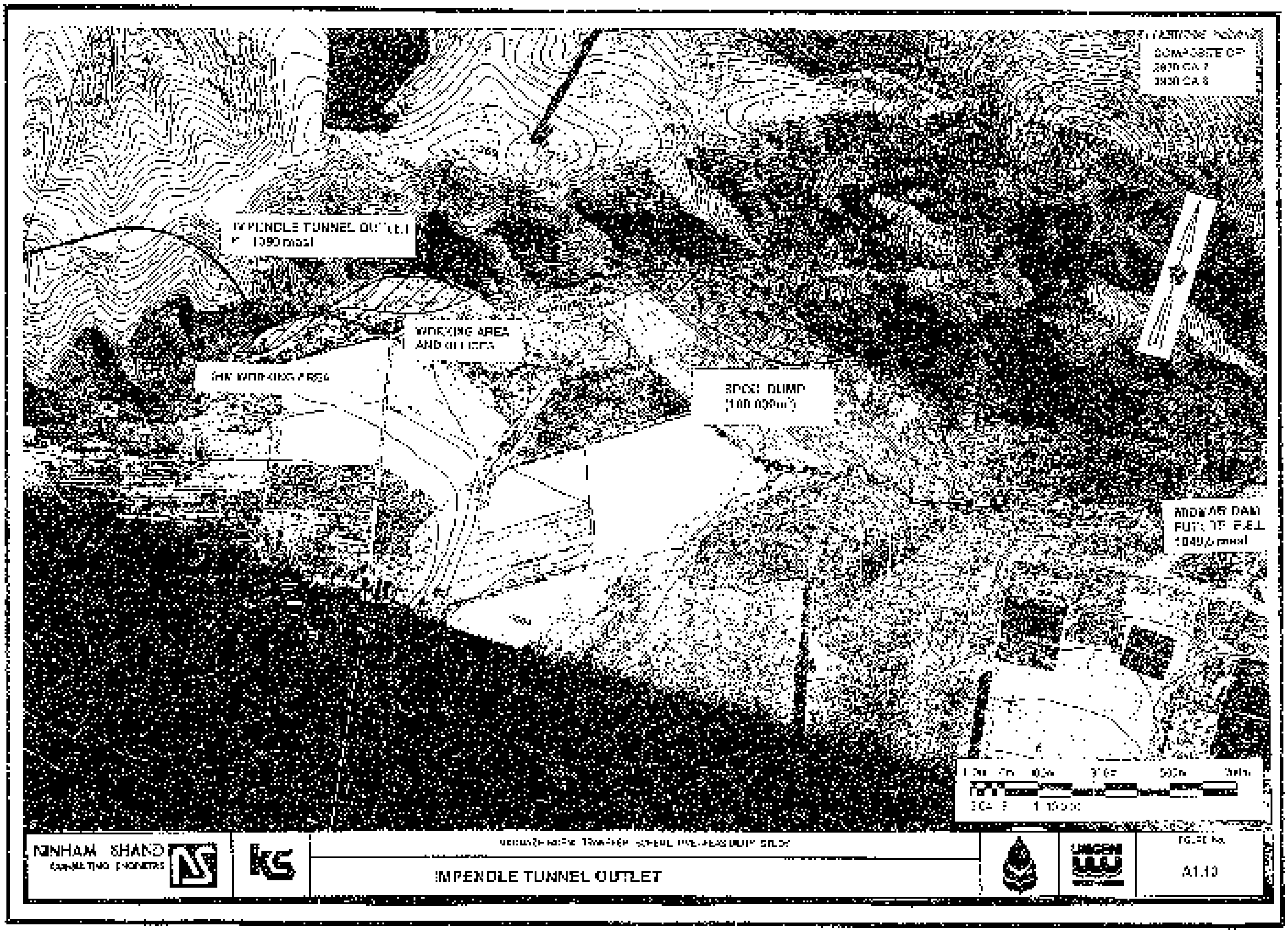


NINHAM SHAND
CONSULTING ENGINEERS

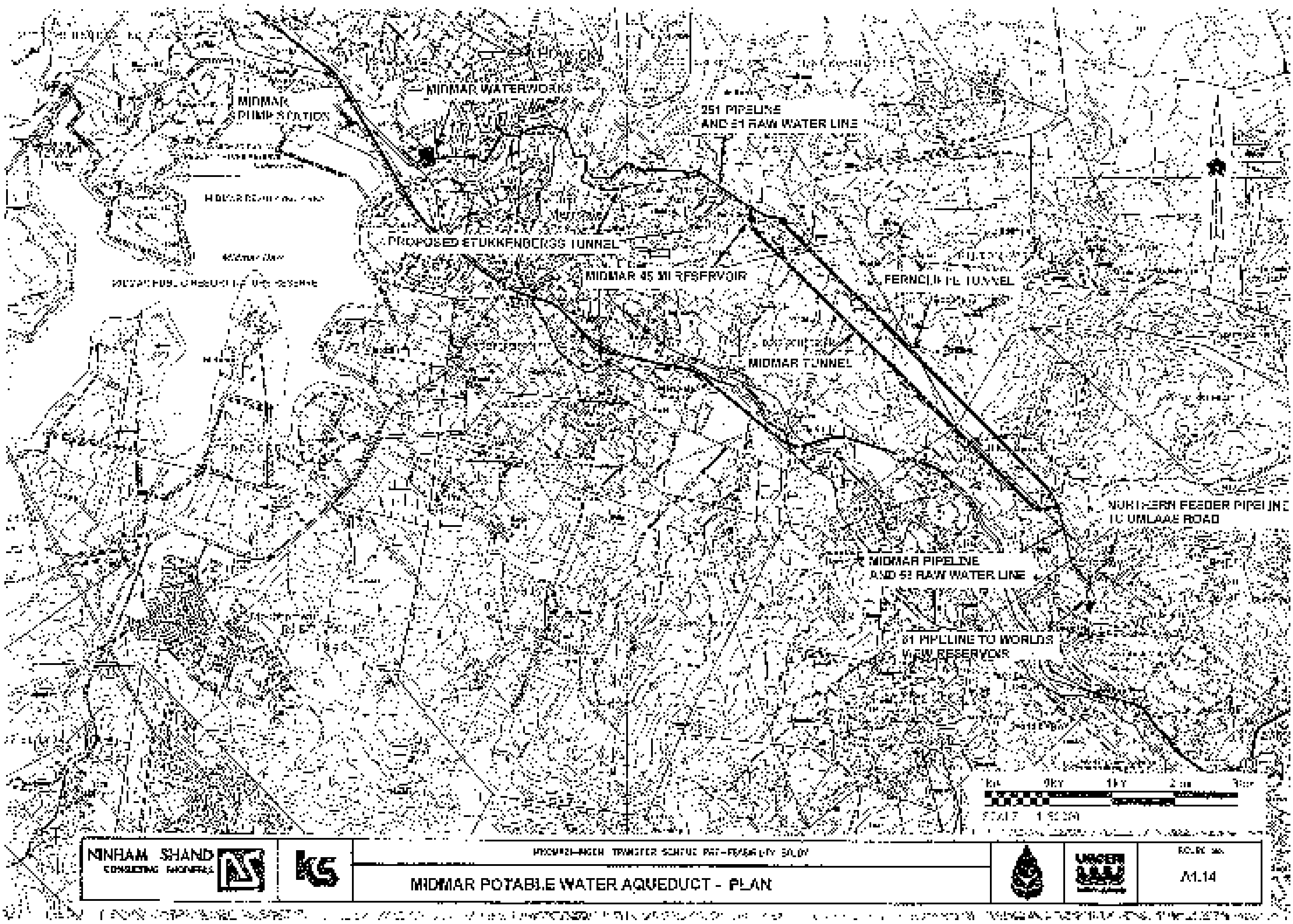
KS

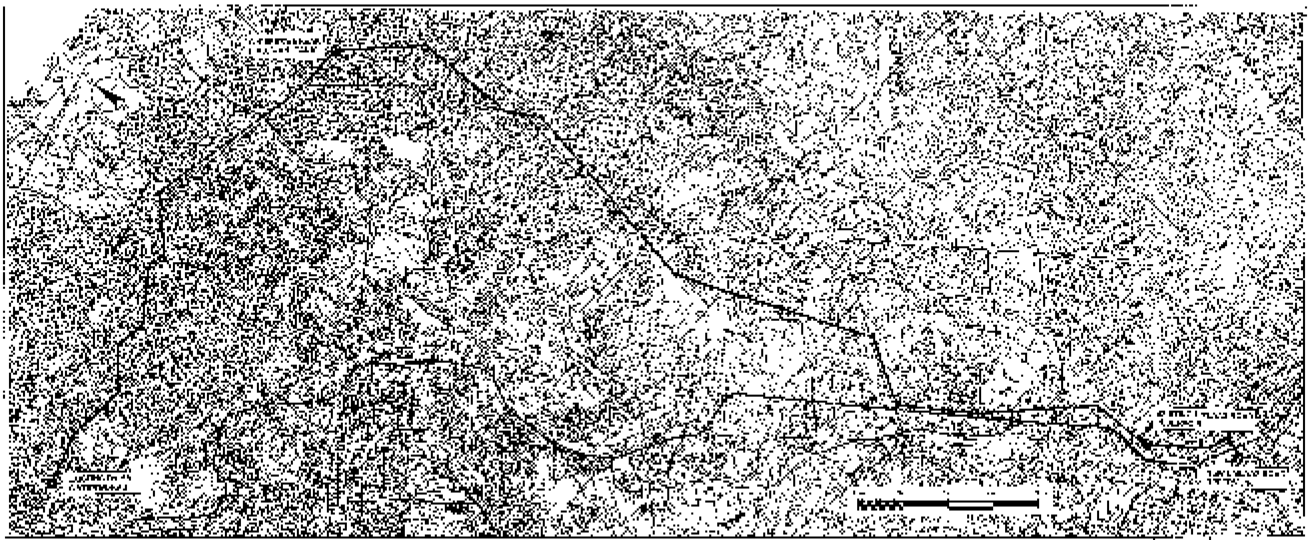
IMPENDLE TUNNEL INTERMEDIATE ADIT

A1.12

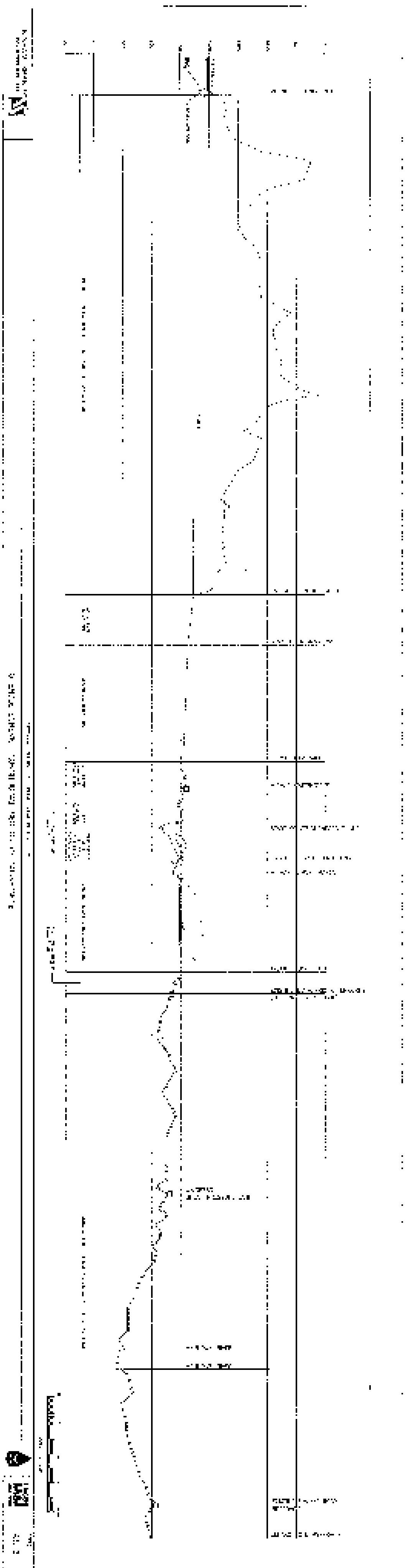


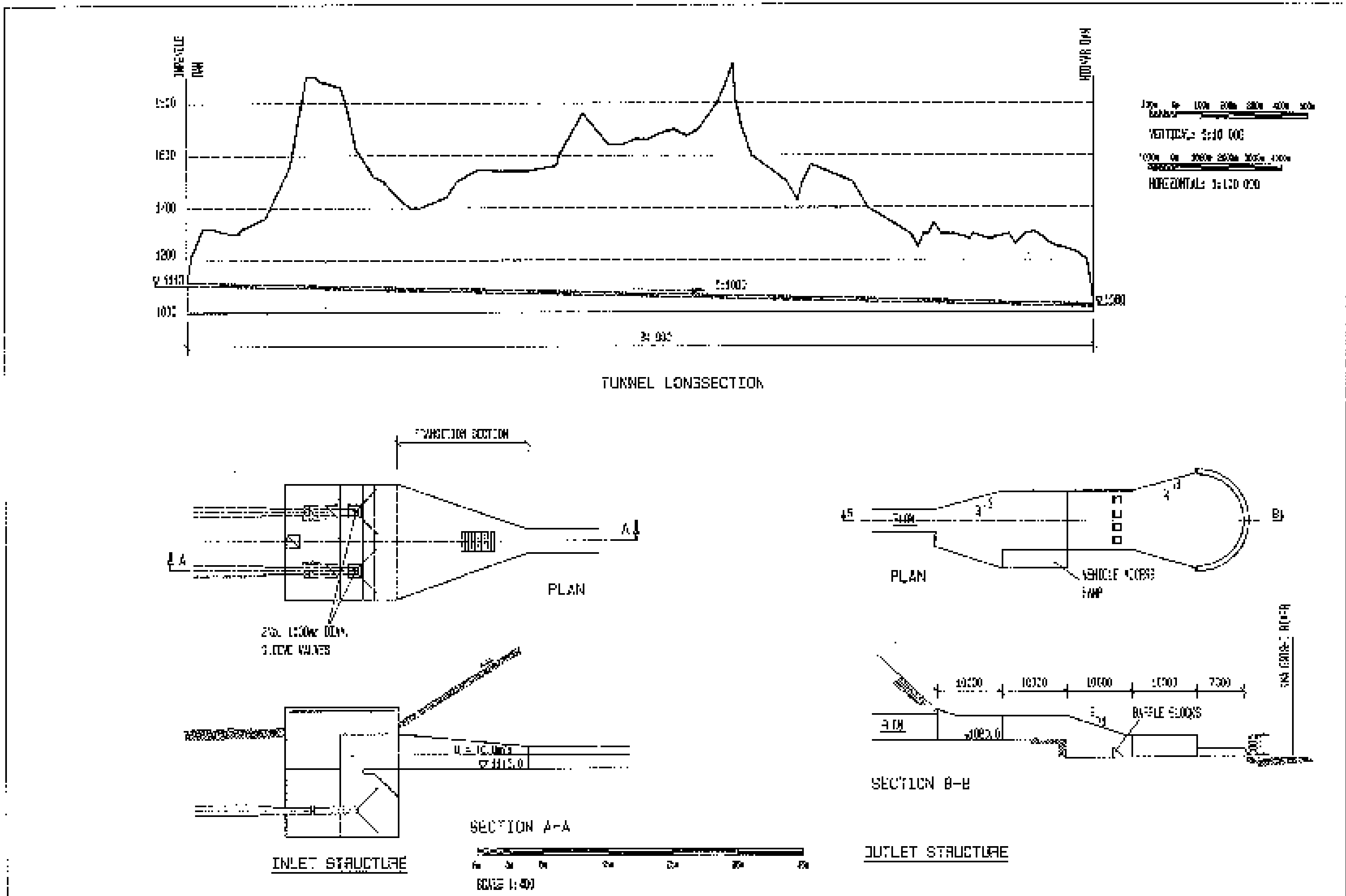
WORKING AREA
SPOIL DUMP
NINHAM SHAND
IMPENDLE TUNNEL OUTLET
A1.10


MIDMAR PUMP STATION
MIDMAR WATERWORKS
251 PIPELINE
AND 51 RAW WATER LINE
PROPOSED STUKKENBERGS TUNNEL
MIDMAR 45 Ml RESERVOIR
FERNCLIFFE TUNNEL
MIDMAR TUNNEL
NORTHERN FEEDER PIPELINE
TO UMLAAS ROAD
MIDMAR PIPELINE
AND 53 RAW WATER LINE
81 PIPELINE TO WORLDS
VIEW RESERVOIR
NINHAM SHAND
CONSULTING ENGINEERS
KS
MIDMAR POTABLE WATER AQUEDUCT - PLAN
A1.14



NORTHERN FEEDER PIPELINE – PLAN





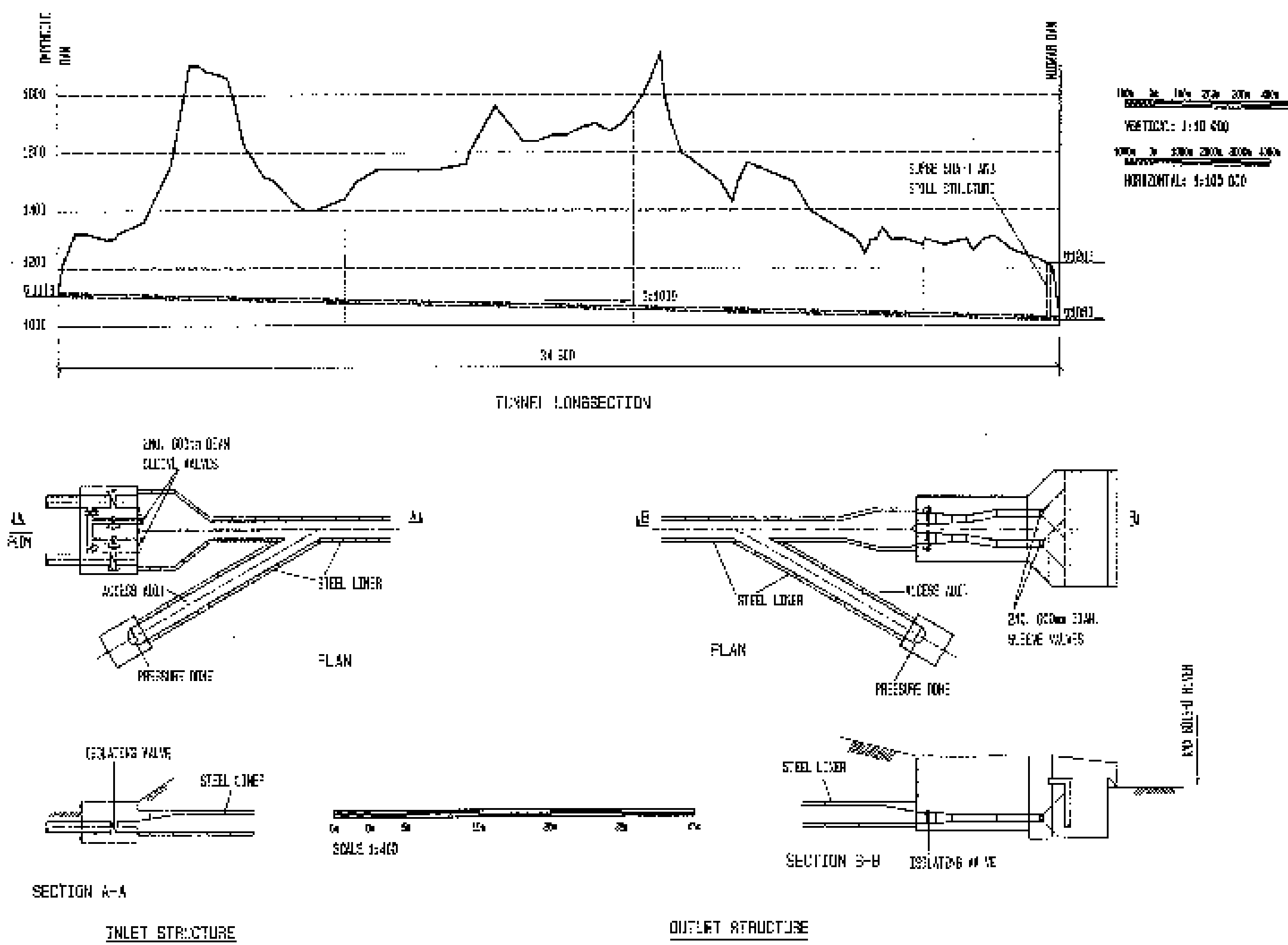
NINHAM SHAND CONSULTING ENGINEERS

KS

MKOMAZI-MGENI TRANSFER SCHEME PRE-FEASIBILITY STUDY

IMPENDLE TUNNEL, FREE SURFACE FLOW OPTION, LONGSECTION AND STRUCTURES

A1.17



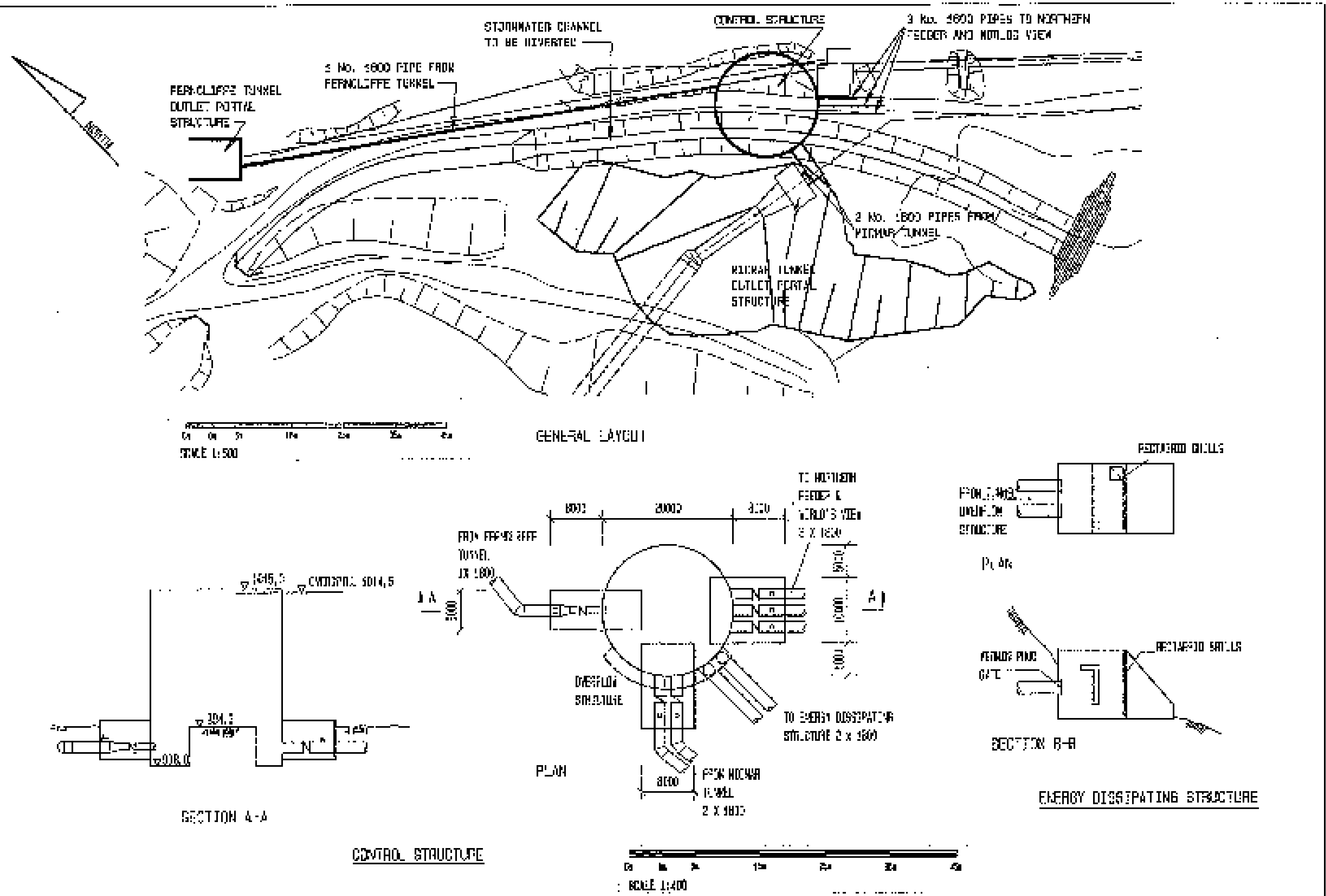
NINHAM SHAND CONSULTING ENGINEERS

KS

MKOMAZI-MGENI TRANSFER SCHEME PRE-FEASIBILITY STUDY

IMPENDLE TUNNEL, PRESSURE FLOW OPTION, LONGSECTION AND STRUCTURES

FIGURE No. A1.13



NINHAM SHAND

KS

MOOI-MGENI TRANSFER SCHEME PRE-FEASIBILITY STUDY

MIDMAR AQUEDUCT. MIDMAR / FERNCLIFFE TUNNEL - OUTLET CONTROL STRUCTURE

FIGURE No. A4.19

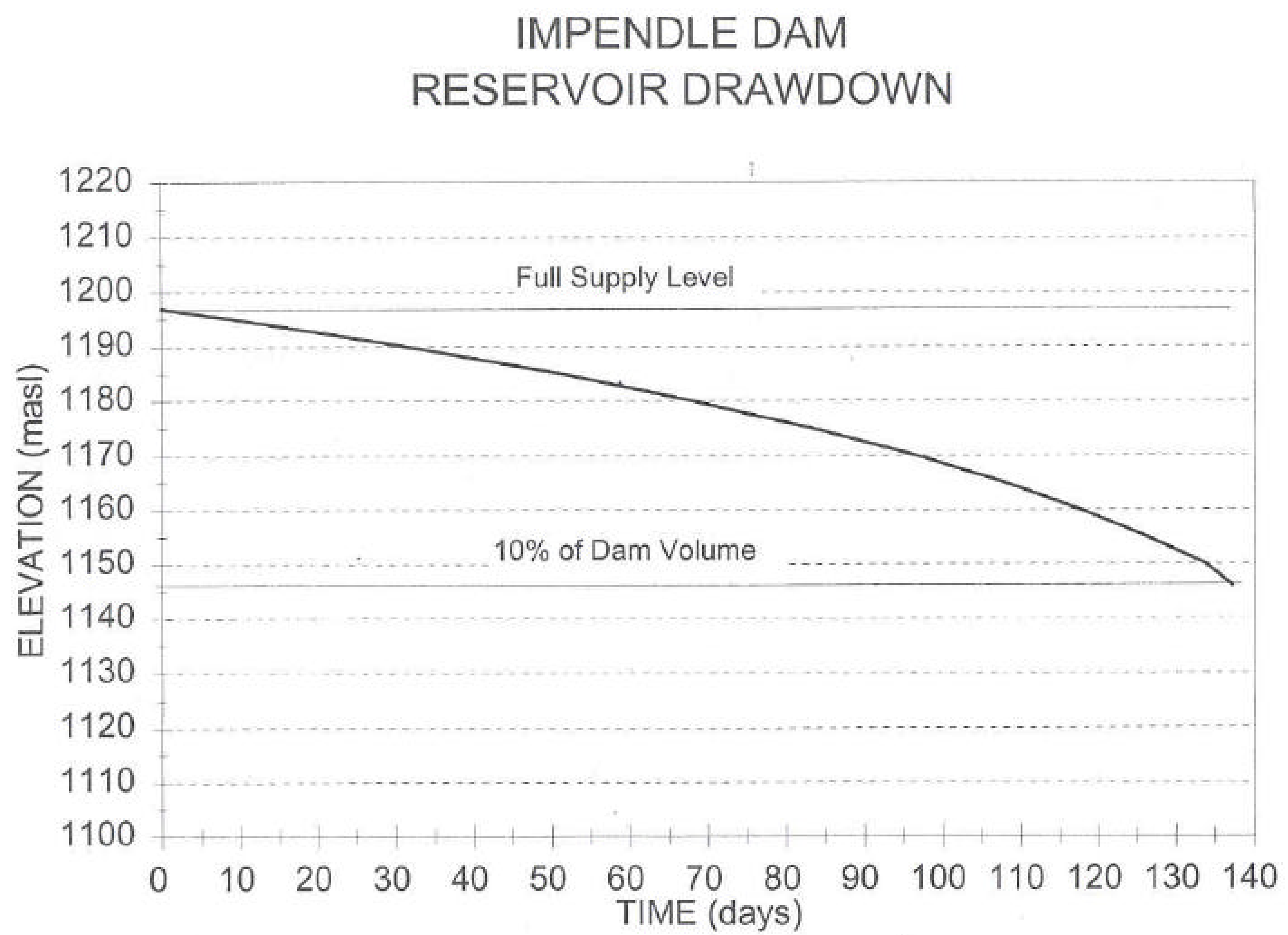

IMPENDLE DAM
RESERVOIR DRAWDOWN
Full Supply Level
10% of Dam Volume
ELEVATION (masl)
1220
1210
1200
1190
1180
1170
1160
1150
1140
1130
1120
1110
1100
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140
TIME (days)

FIGURE A1.20

IMPENDLE DAM
STAGE - CAPACITY CURVE

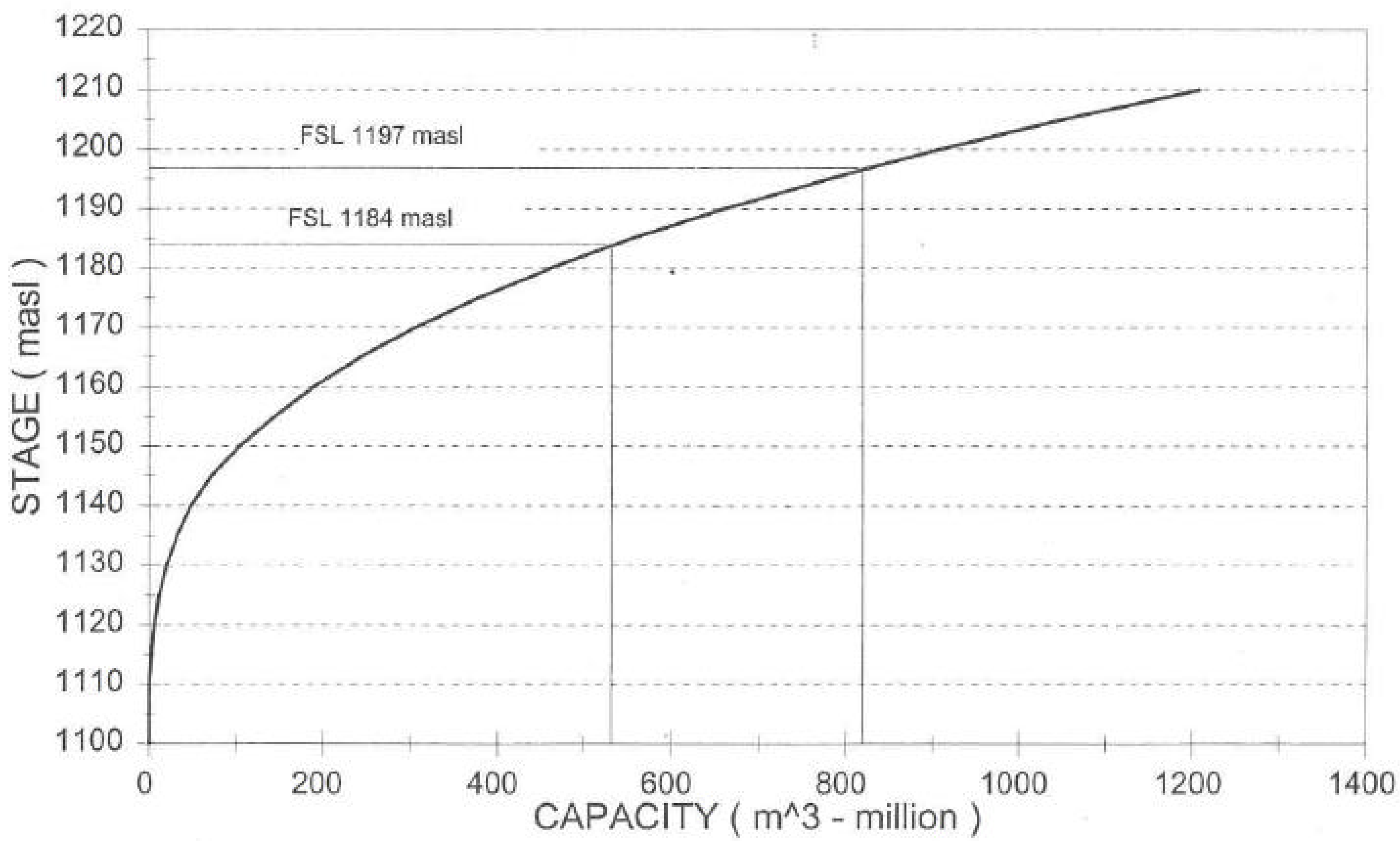


FIGURE A1.21

IMPENDLE DAM
STAGE - AREA CURVE

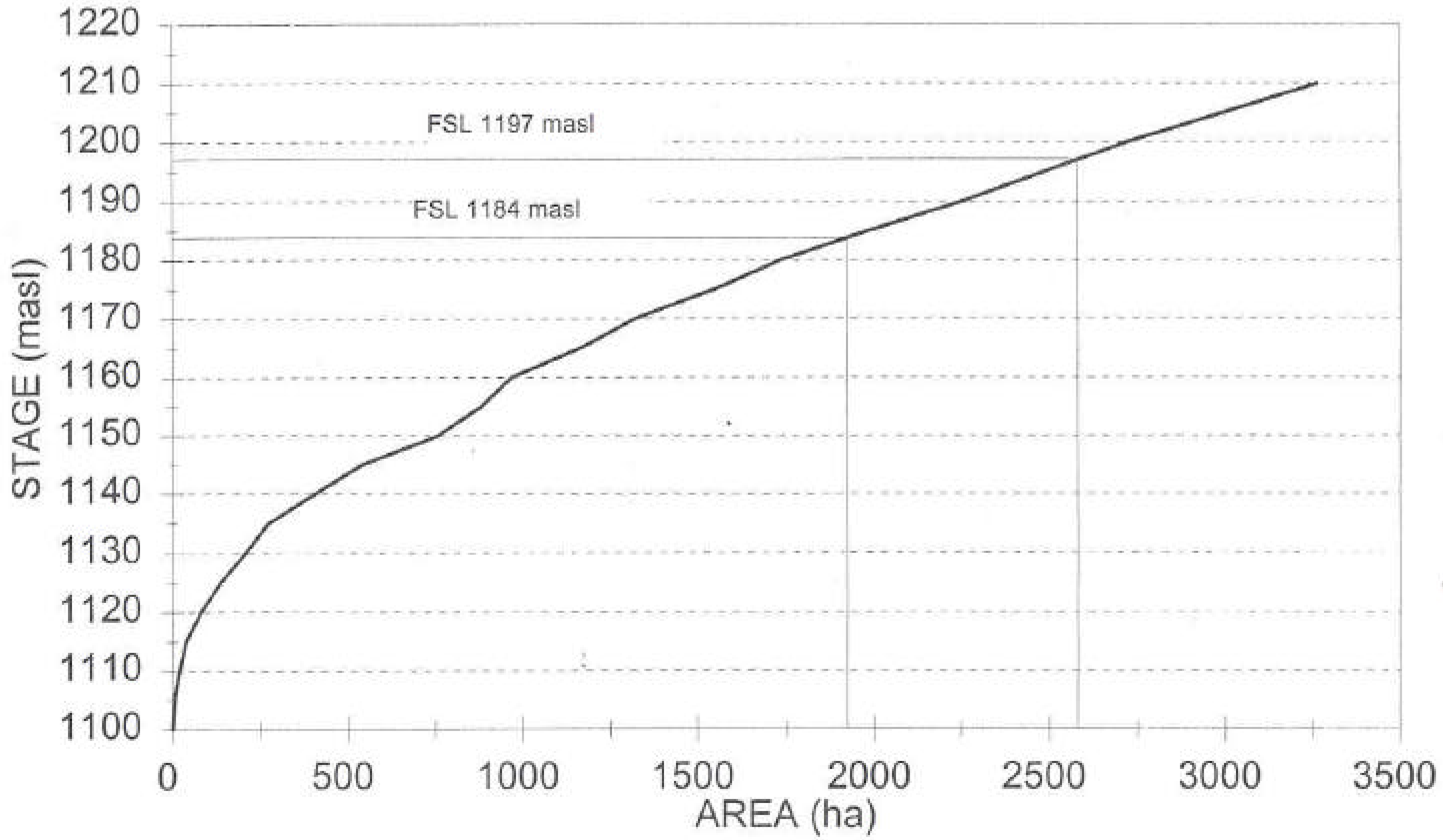
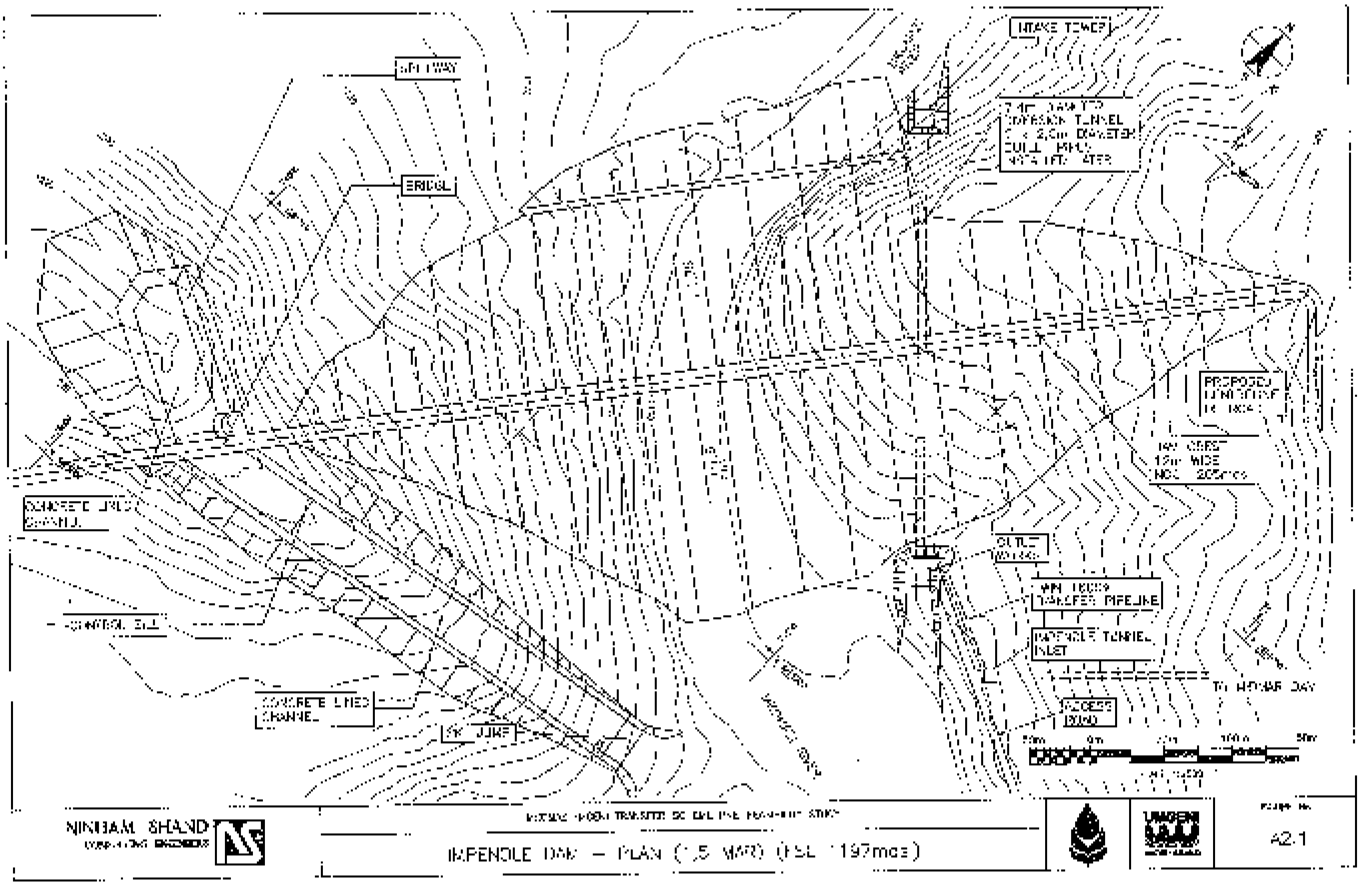


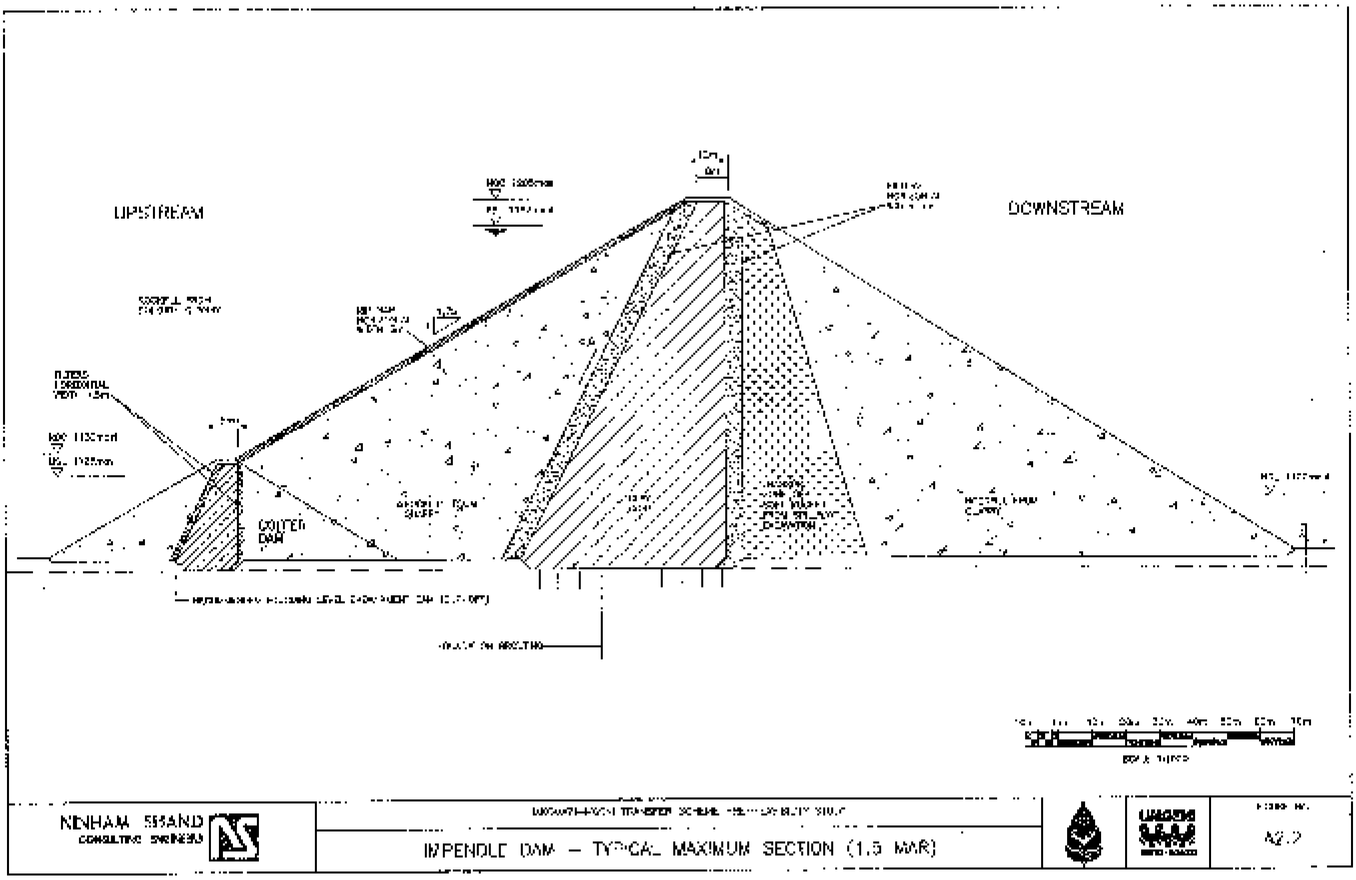
FIGURE A1.22

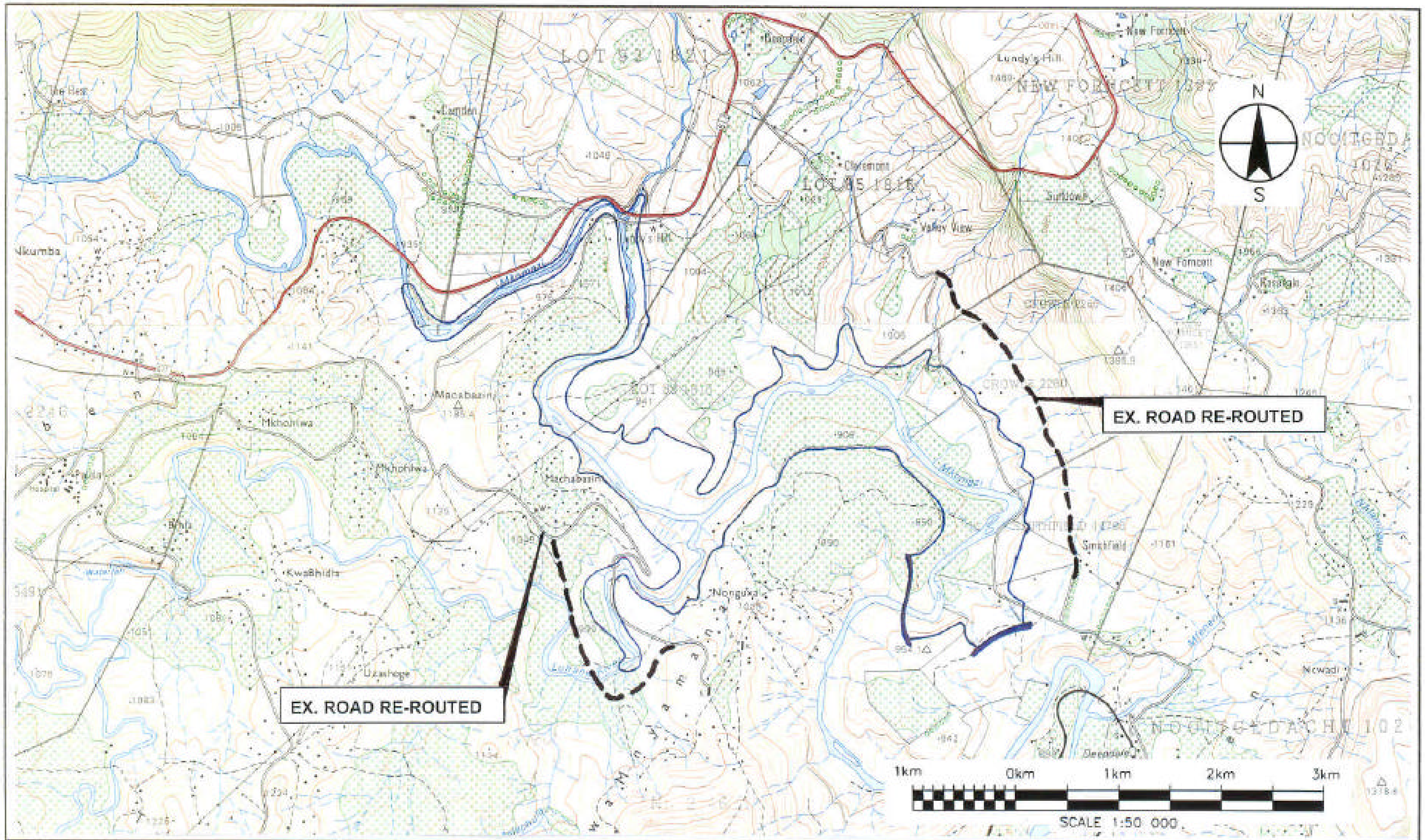
APPENDIX A2 - SMITHFIELD SCHEME DRAWING LIST

No	Description	Figure No
1	Impendle Dam - Plan (1,5 MAR)	A2.1
2	Impendle Dam - Typical Maximum Section (1,5 MAR)	A2.2
3	Smithfield Dam Basin at FSL 915masl	A2.3
4	Smithfield Dam - Plan	A2.4
5	Smithfield Dam - Downstream Elevations	A2.5
6	Smithfield Dam - Typical Concrete Sections	A2.6
7	Smithfield Dam - Typical Rockfill Embankment Section	A2.7
8	Smithfield Dam - Typical Section of Saddle Dam	A2.8
9	Smithfield Dam - Details of Inlet Structure	A2.9
10	Smithfield Dam - Details of Outlet House	A2.10
11	Baynesfield Clear Water Pipeline - Plan	A2.15
12	Smithfield Scheme: Longitudinal Section of Conveyance	A2.16
13	Smithfield Tunnel: Longsection and Structures	A2.17
14	Smithfield Dam Intake Structure	A2.18
15	Smithfield Dam Reservoir Drawdown	A2.19
16	Smithfield Stage Capacity Curve	A2.20
17	Smithfield Stage Area Curve	A2.21



SPILLWAY
BRIDGE
INTAKE TOWER
CONCRETE LINED CHANNEL
CONTROL SILL
SKI JUMP
OUTLET WORKS
IMPENDLE TUNNEL INLET
ACCESS ROAD
NINHAM SHAND
A2.1


UPSTREAM
DOWNSTREAM
COFFER DAM
NINHAM SHAND
CONSULTING ENGINEERS
IMPENDLE DAM – TYPICAL MAXIMUM SECTION (1.5 MAR)
A2.2

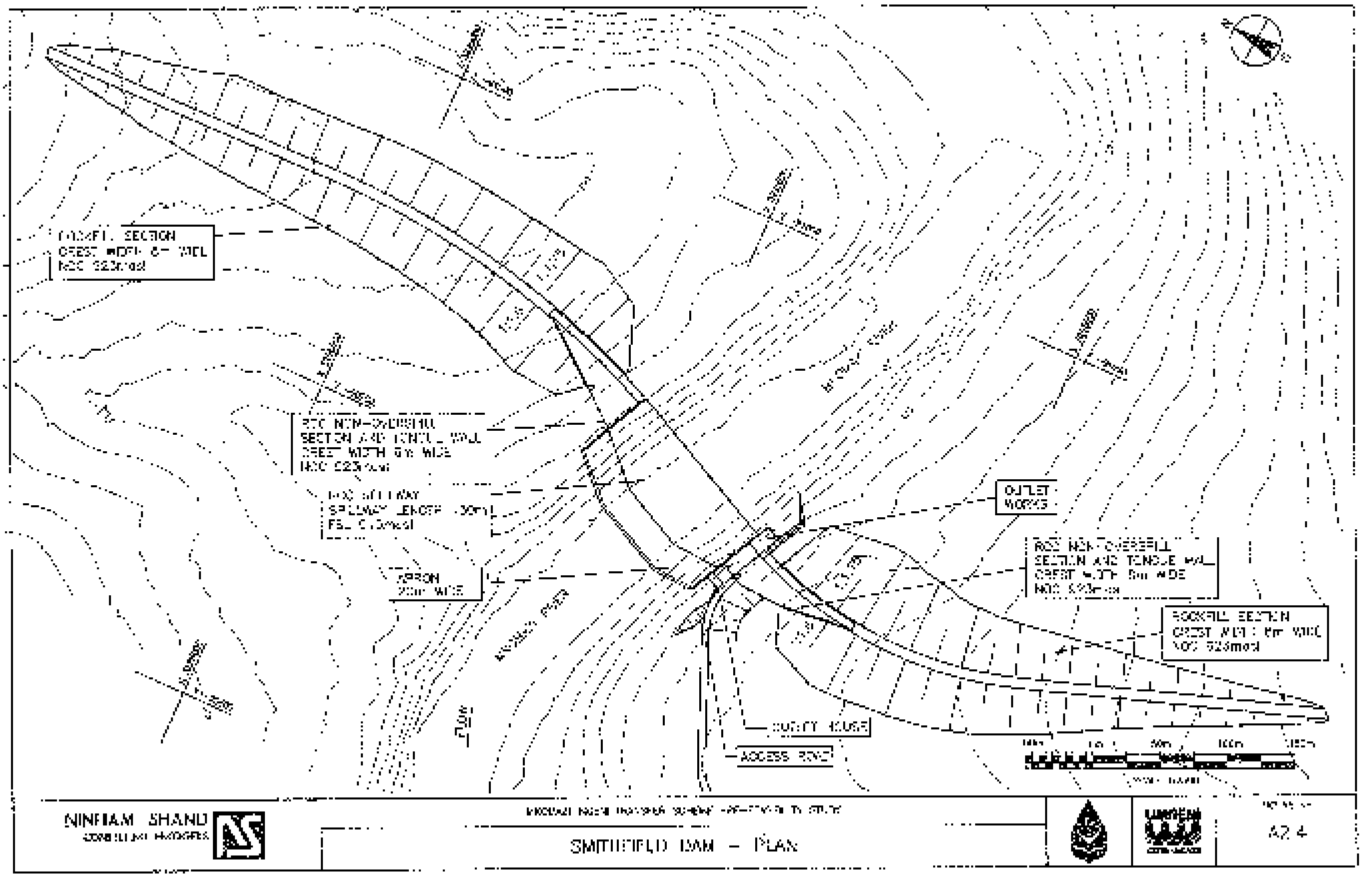


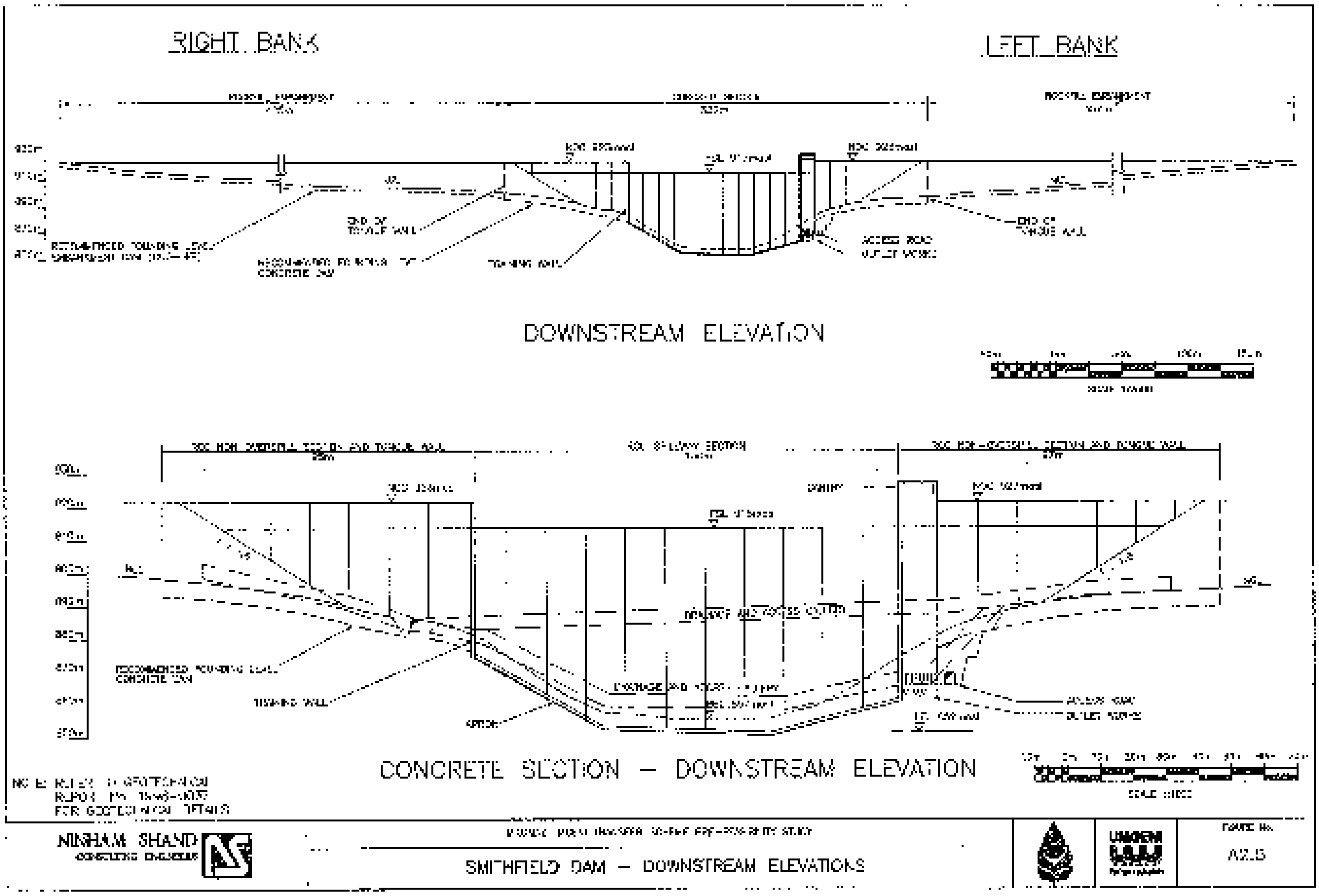
NINHAM SHAND CONSULTING ENGINEERS

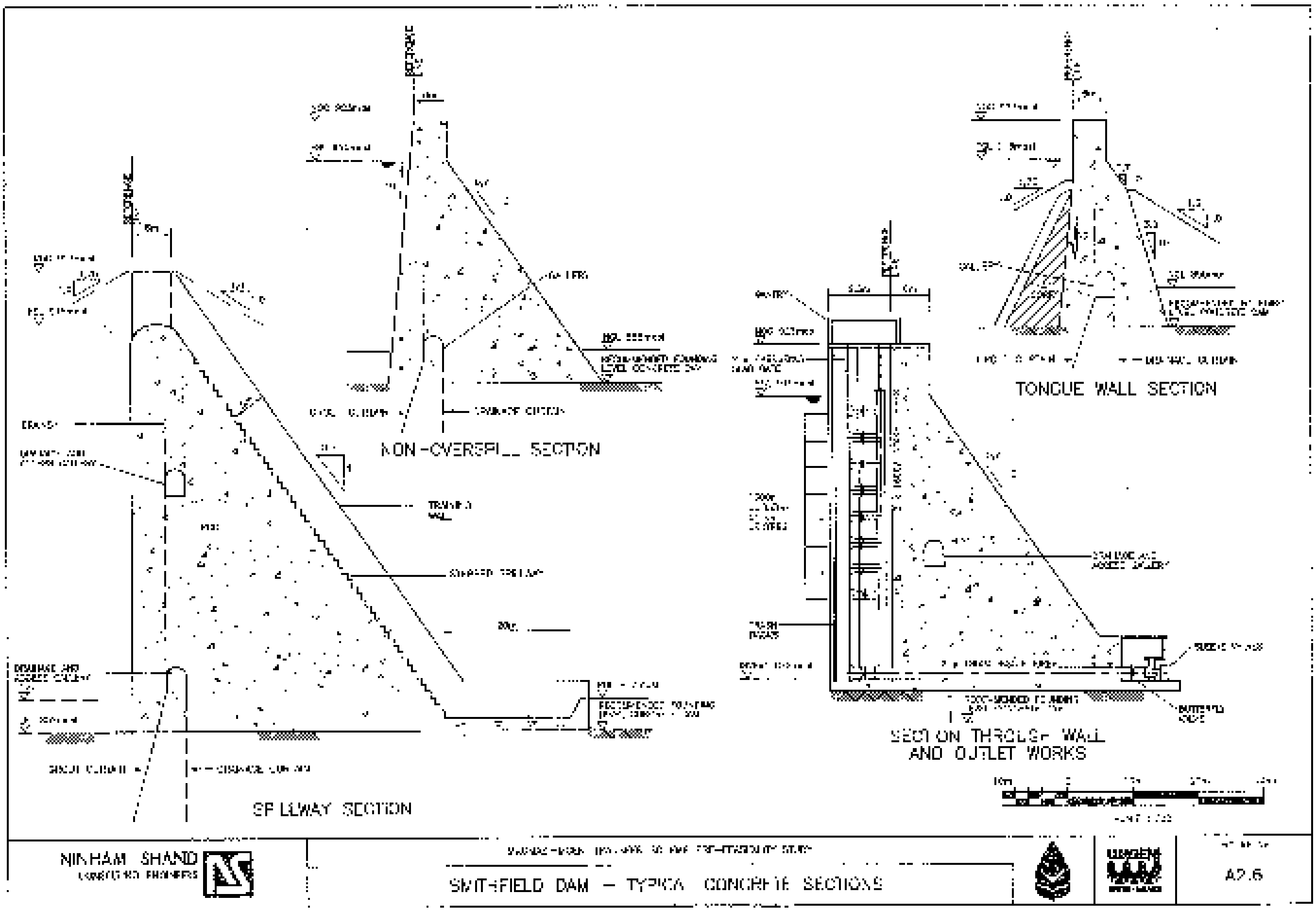
MKOMAZI–MGENI TRANSFER SCHEME PRE–FEASIBILITY STUDY

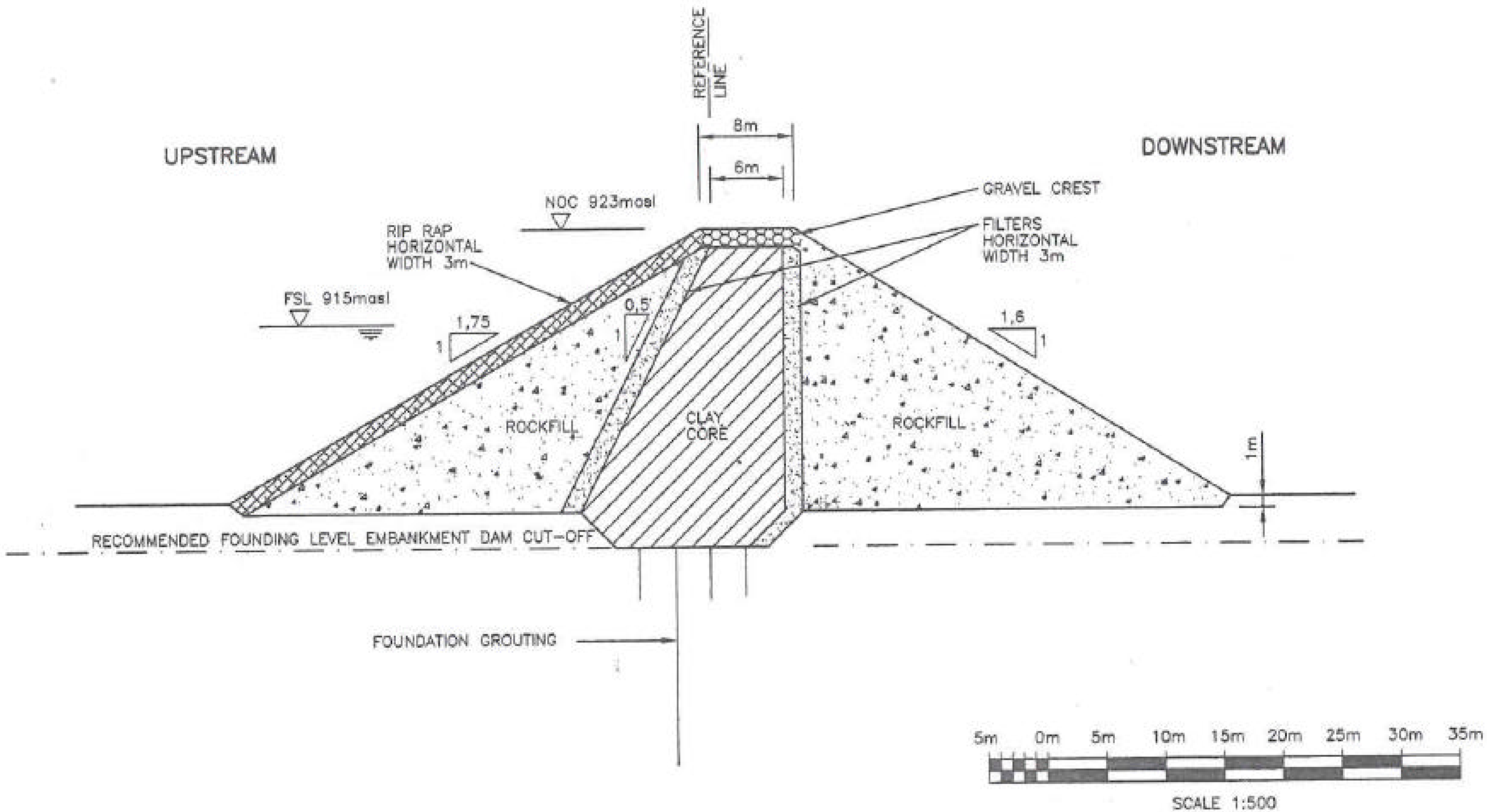
SMITHFIELD DAM BASIN – AT FSL 915masl

FIGURE No. A2.3


ROCKFILL SECTION
RCC NON-OVERSPILL SECTION AND TONGUE WALL
RCC SPILLWAY
APRON
OUTLET WORKS
ROCKFILL SECTION
ACCESS ROAD
FLOW
NINHAM SHAND
SMITHFIELD DAM – PLAN
A2.4


RIGHT BANK
LEFT BANK
DOWNSTREAM ELEVATION
CONCRETE SECTION – DOWNSTREAM ELEVATION
NINHAM SHAND
SMITHFIELD DAM – DOWNSTREAM ELEVATIONS


SPILLWAY SECTION
NON-OVERSPILL SECTION
TONGUE WALL SECTION
SECTION THROUGH WALL
AND OUTLET WORKS
GALLERY
STEPPED SPILLWAY
NINHAM SHAND
CONSULTING ENGINEERS
SMITHFIELD DAM — TYPICAL CONCRETE SECTIONS
A2.6



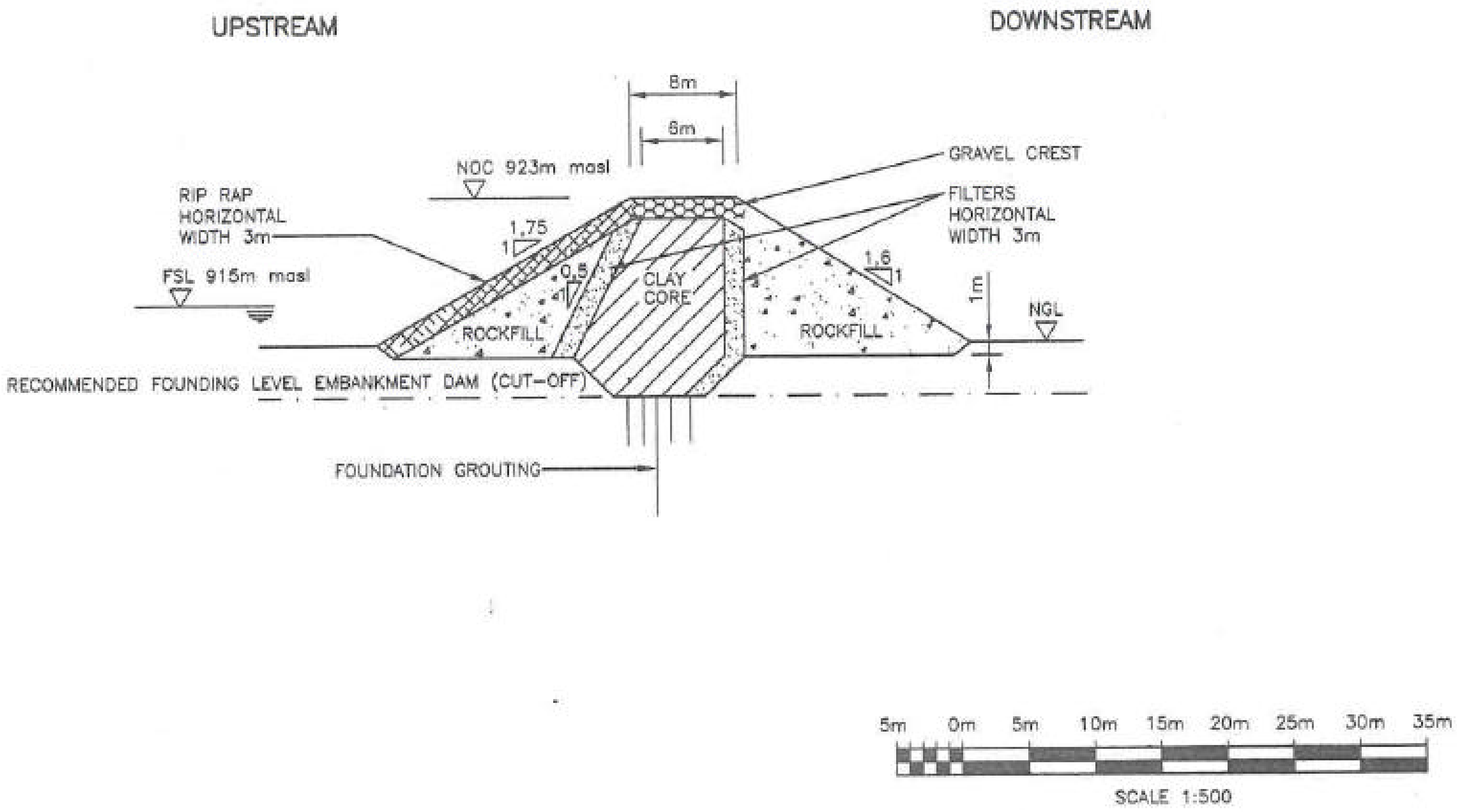
NINHAM SHAND CONSULTING ENGINEERS

MKOMAZI–MGENI TRANSFER SCHEME PRE–FEASIBILITY STUDY

SMITHFIELD DAM – TYPICAL ROCKFILL EMBANKMENT SECTION

UMGENI WATER · AMANZI

FIGURE No. A2.7

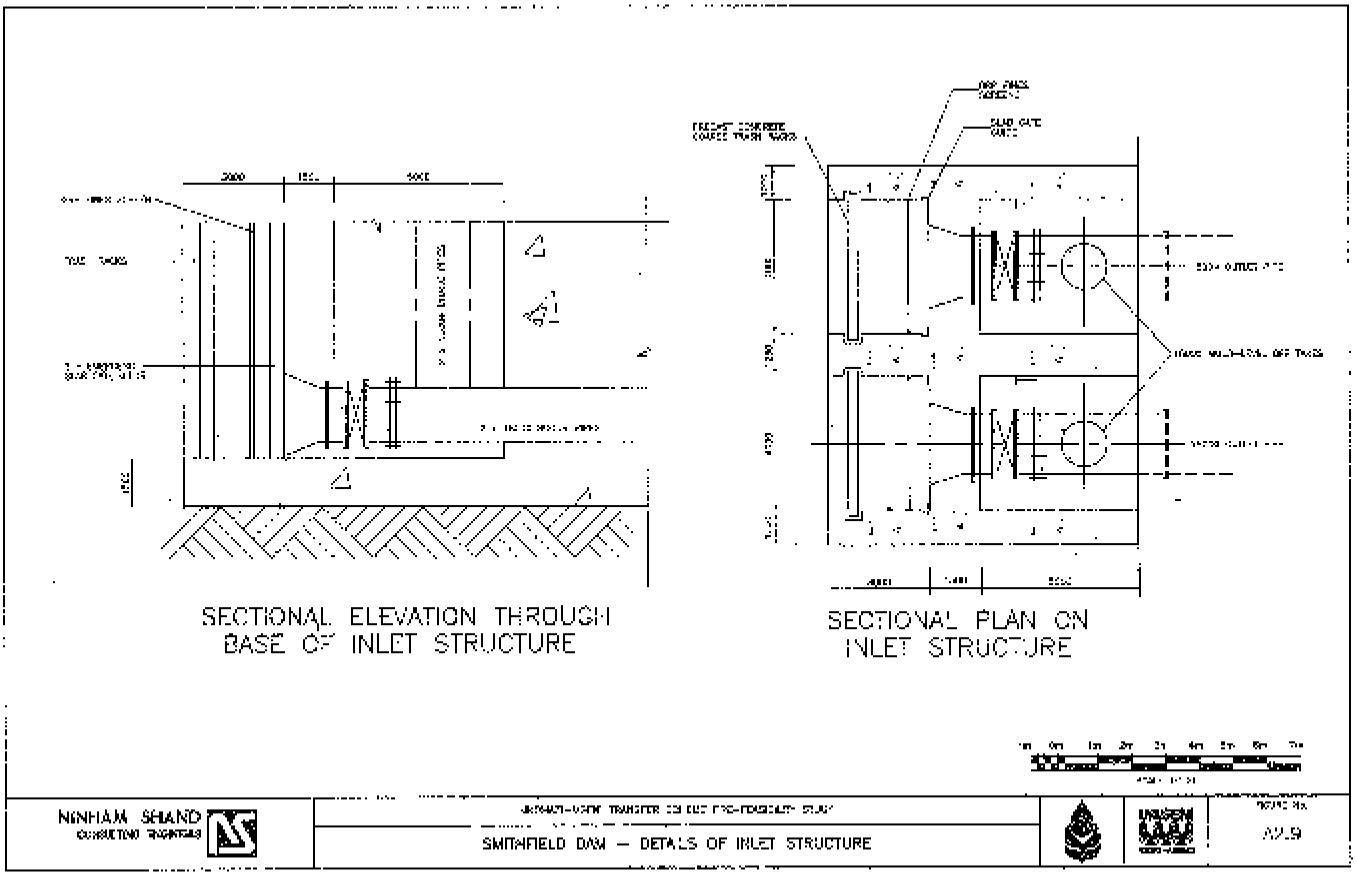


NINHAM SHAND CONSULTING ENGINEERS

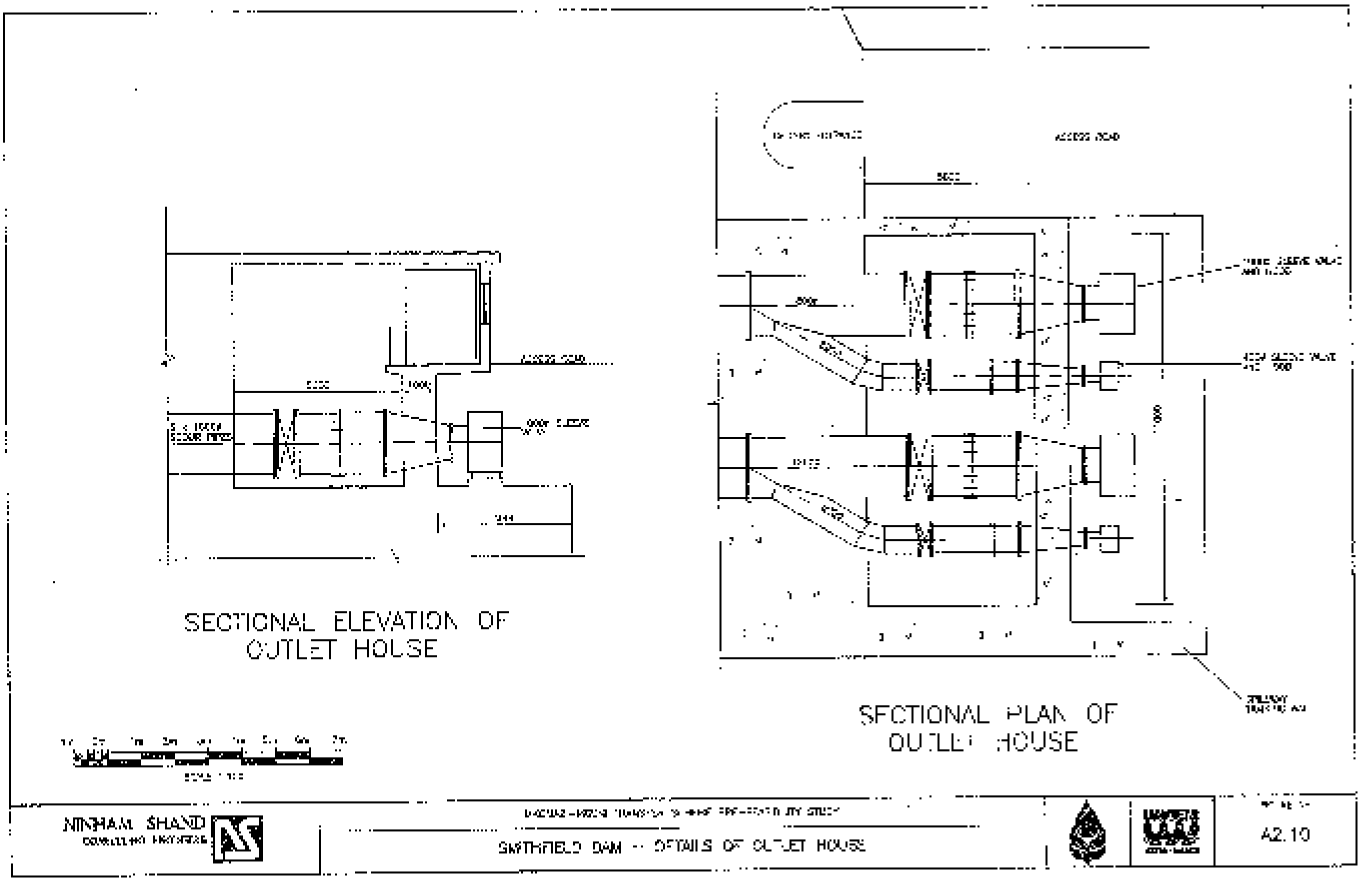
MKOMAZI–MGENI TRANSFER SCHEME PRE–FEASIBILITY STUDY

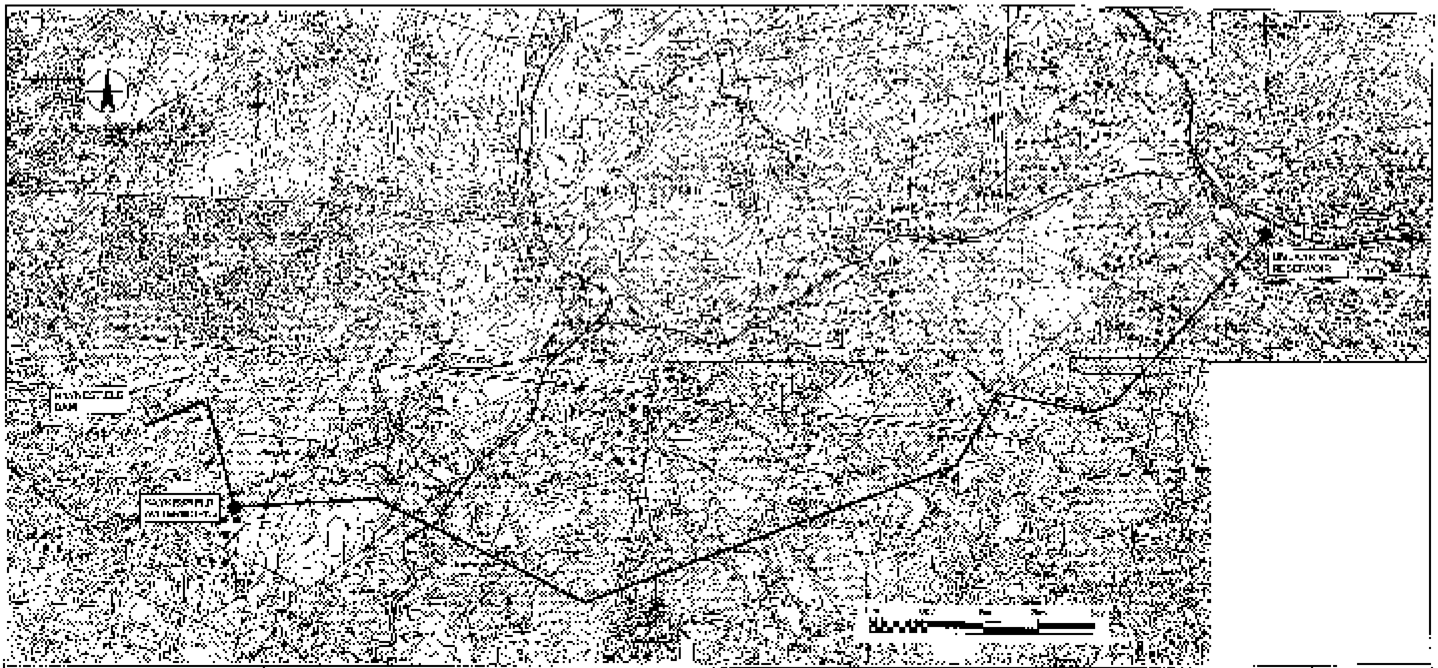
SMITHFIELD DAM – TYPICAL SECTION OF SADDLE DAM

FIGURE No. A2.8



SECTIONAL ELEVATION THROUGH BASE OF INLET STRUCTURE
SECTIONAL PLAN ON INLET STRUCTURE
NINHAM SHAND
SMITHFIELD DAM — DETAILS OF INLET STRUCTURE

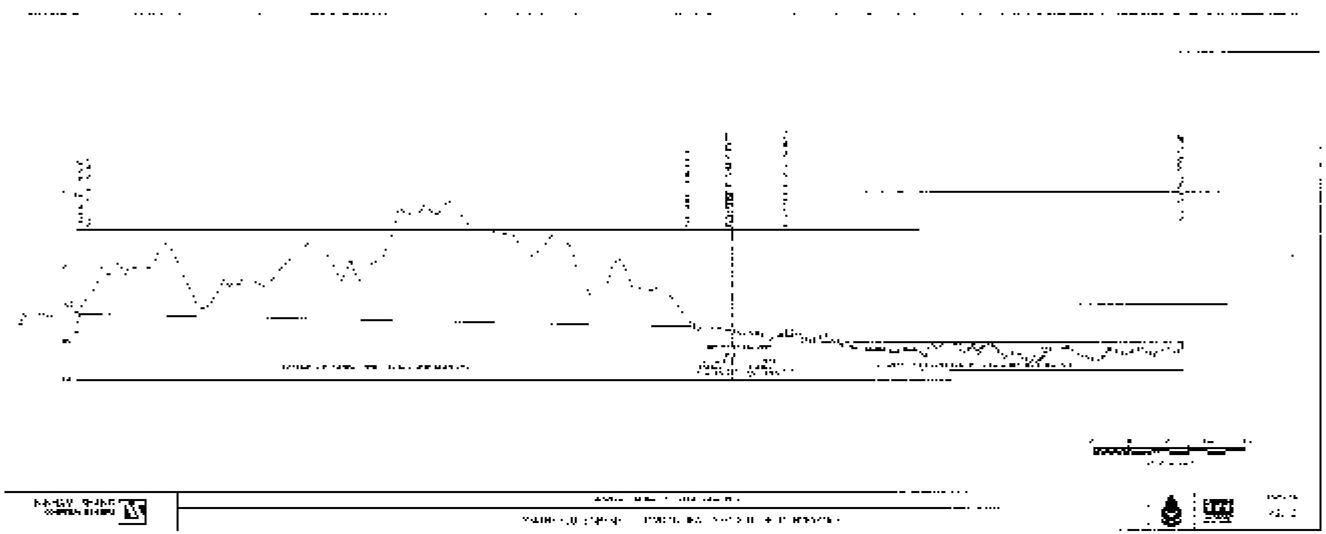

ACCESS ROAD
SECTIONAL ELEVATION OF OUTLET HOUSE
SECTIONAL PLAN OF OUTLET HOUSE
NINHAM SHAND
SMITHFIELD DAM -- DETAILS OF OUTLET HOUSE
A2.10

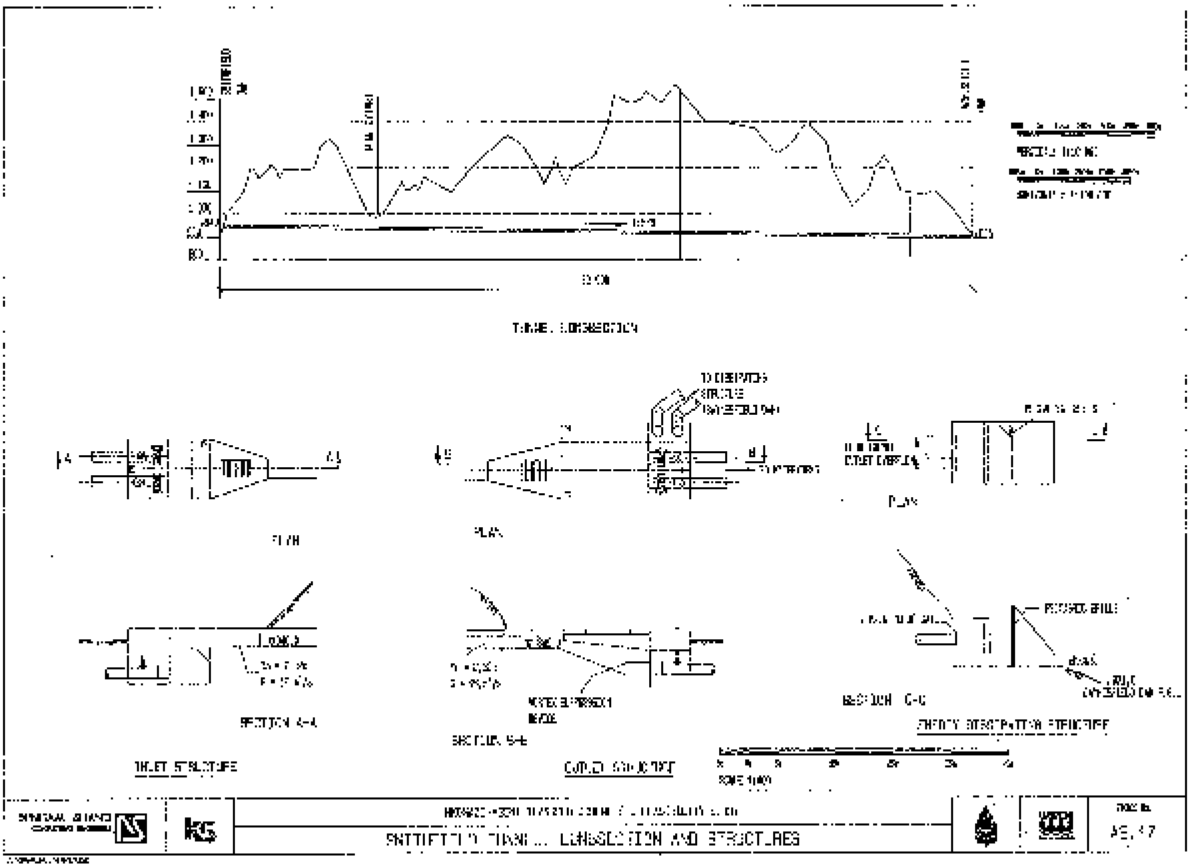


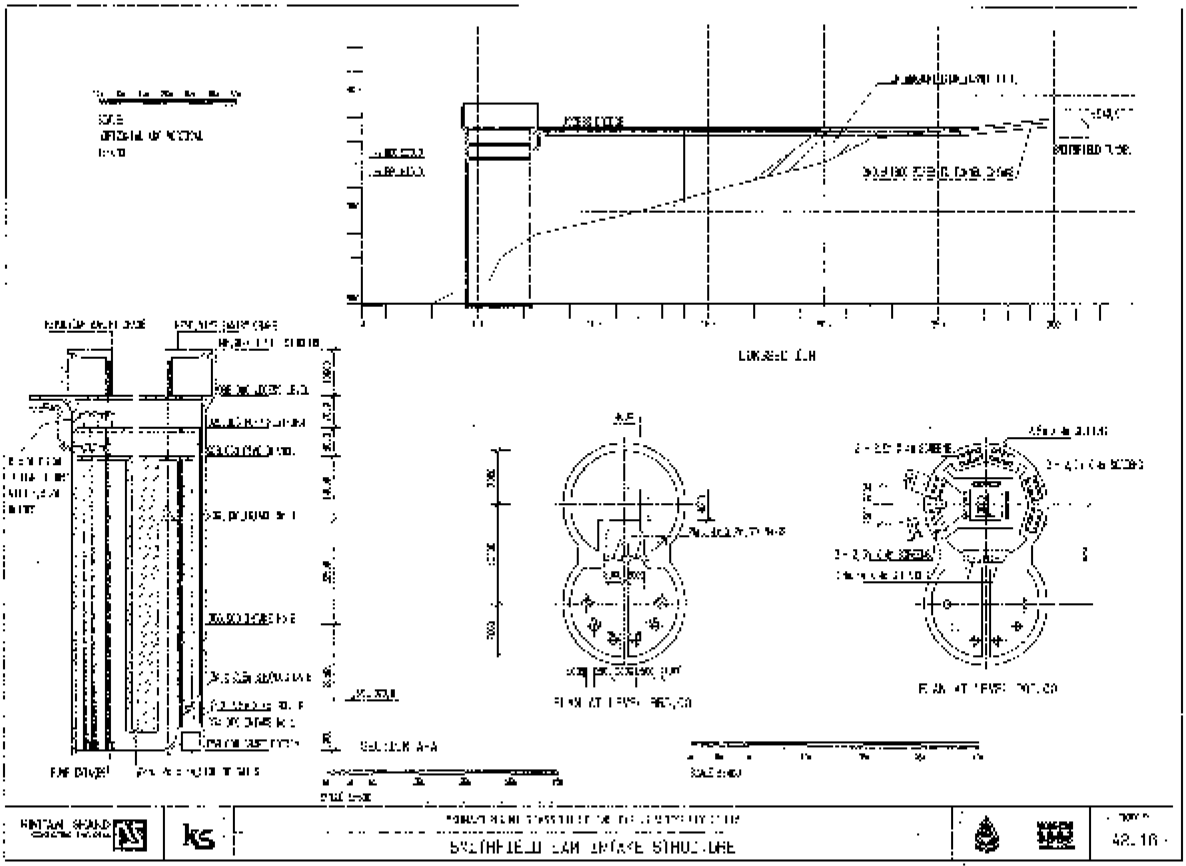
NINHAM SHAND

WAYNESFIELD CLEAR WATER PIPELINE – PLAN

A2. 5




PLAN
PLAN
PLAN
SECTION A-A
SECTION B-B
SECTION C-C
INLET STRUCTURE
OUTLET STRUCTURE
ENERGY DISSIPATION STRUCTURE



SECTION A-A
PLAN AT LEVEL
42.16


SMITHFIELD DAM
RESERVOIR DRAWDOWN
Full Supply Level
10% of Dam Volume
ELEVATION (masl)
920
910
900
890
880
870
860
850
0
5
10
15
20
25
30
35
TIME (days)

FIGURE A2.19

SMITHFIELD DAM
STAGE - CAPACITY CURVE

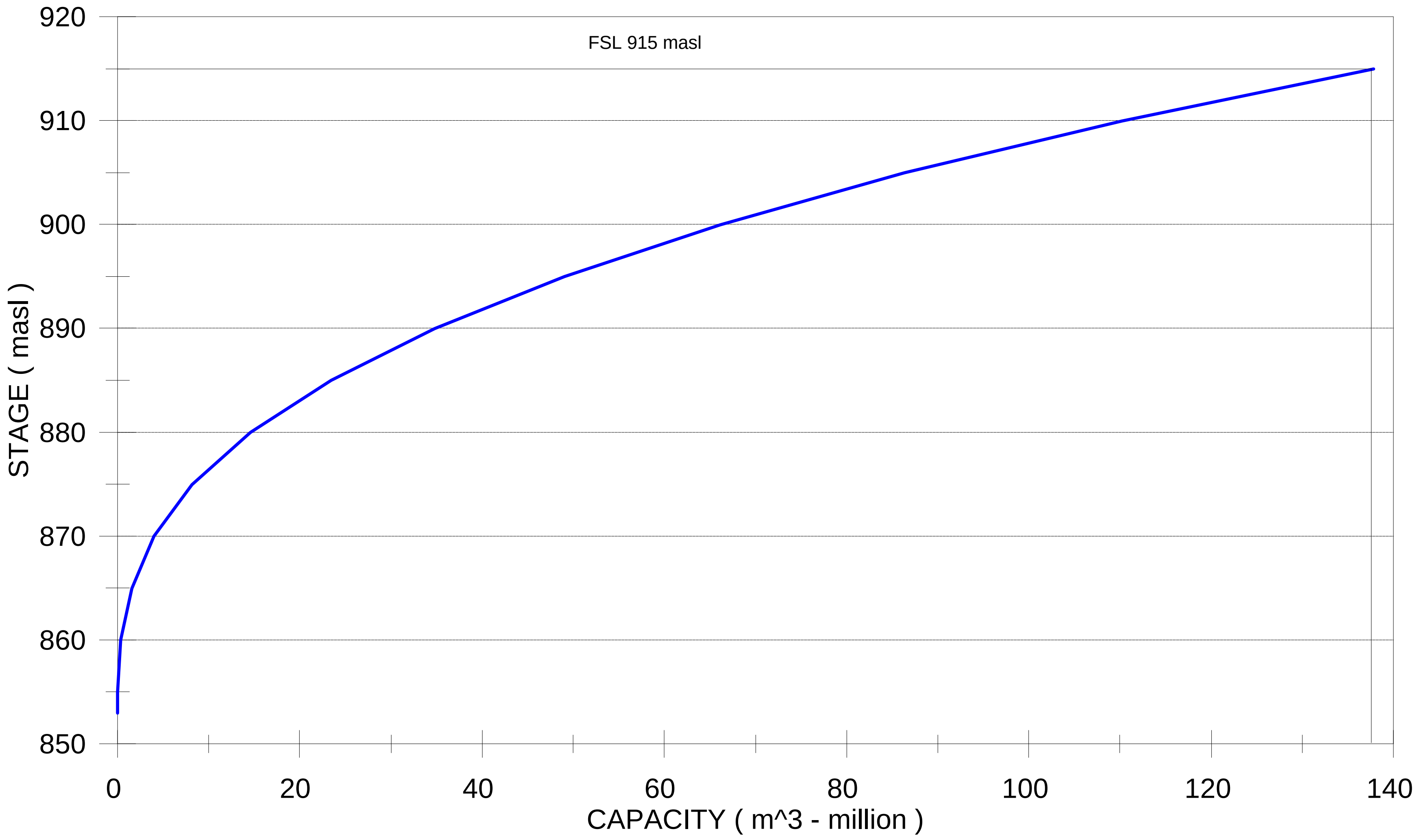


FIGURE A2.20

SMITHFIELD DAM

STAGE - AREA CURVE

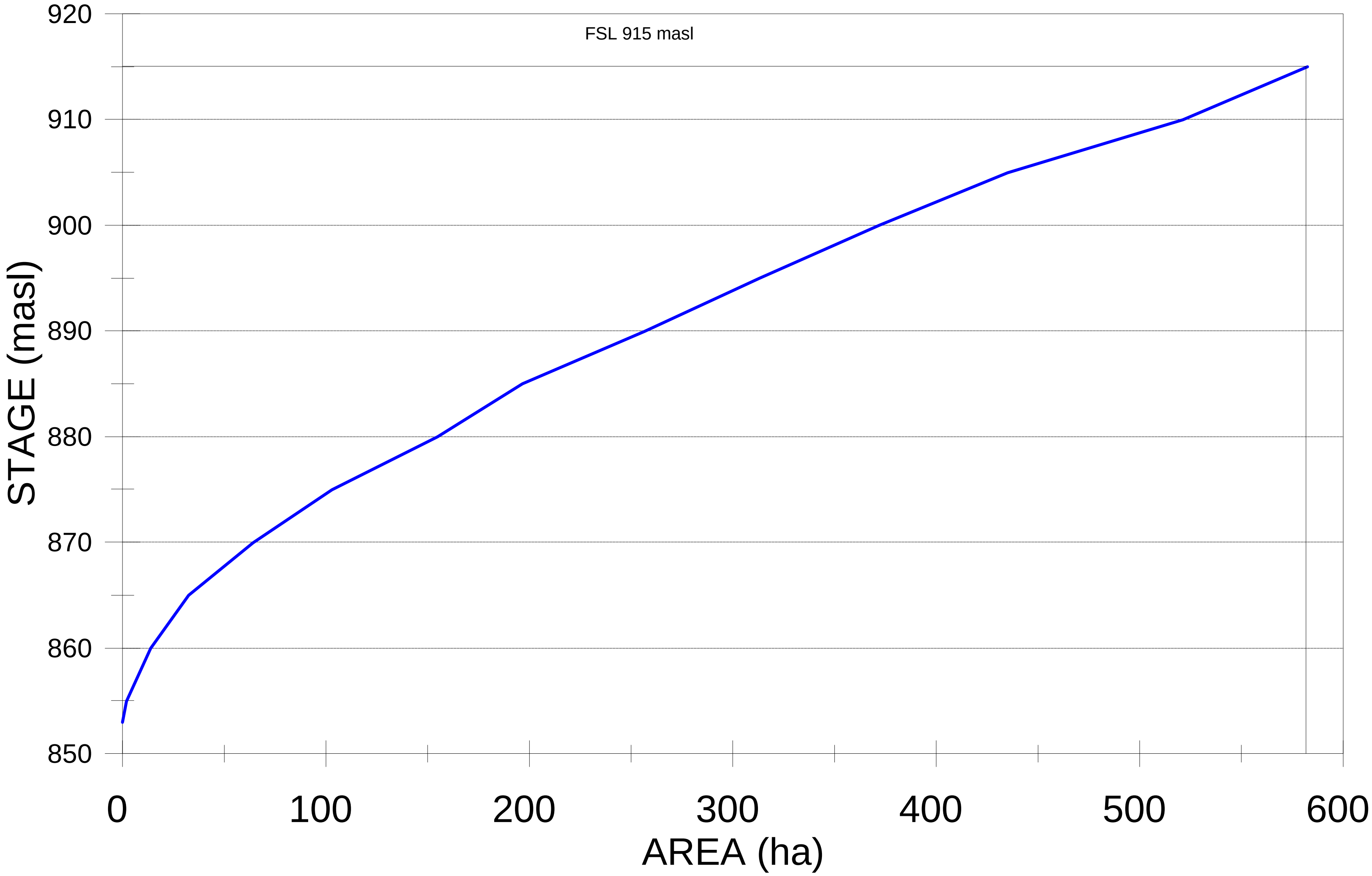


FIGURE A2.21

APPENDIX B

FLOOD HYDROLOGY

DEPARTEMENT VAN WATERWESE EN BOSBOU
DEPARTMENT OF WATER AFFAIRS AND FORESTRY
LEFAPHA LA METSI LE DIKGWA
UMNYANGO WEZAMANZI NEZAMAHLATHI

DW1

RESIDENSIEGEBOU/BUILDING, SCHOEMANSTRAAT 185 SCHOEMAN STREET, PRETORIA

F (012) 326-1488
~~(012) 326-1780 326-2715 323-4472~~

E- Charles@dwaf.pwv.gov.za

P/B X313
PRETORIA
0001

C.R. Linström
012 – 3387877
7856/15A-01

NINHAM SHAND Consulting engineers
163 Loop Street
Pietermaritzburg
3201

Attention: Peter Blersch, PrEng

IMPENDLE AND SMITHFIELD DAM PRE-FEASIBILITY STUDY: FLOOD DETERMINATION

In reference to your letter dated 17/11/97 (7856/15A) hereby the results of the flood frequency analysis for the pre-feasibility study.

The required flood magnitudes were calculated using a statistical analysis on flow gauging station U1H005. These values were then extrapolated using the following formula with relevant catchment sizes (U1H005 : 1744 km^2; Impendle Dam : 1410 km^2; Smithfield Dam : 2041 km^2):

$$Q_T = Q_{To}\sqrt{\frac{A_x}{A_o}}$$

The MIPI and HRU 1/71 methods produced similar results, although marginally lower, than the statistical methods. Thus the statistical results were considered to be adequate for the pre-feasibility study.

Proposed Impendle Dam: 29°39'00"S 29°46'00"E						
Exceedance Probability (%)	**50**	**10**	**5**	**2**	**0.05**	**RMF**
Flood Peaks (m^3/s)	320	830	1080	1460	2110	3760

Proposed Smithfield Dam: 29°46'45"S 29°56'15"E						
Exceedance Probability (%)	**50**	**10**	**5**	**2**	**0.05**	**RMF**
Flood Peaks (m^3/s)	390	1000	1310	1750	2540	4520

/ DIRECTOR: HYDROLOGY
Date: 4/2/98

Cc Mr J Geringer, DWAF, Pretoria

Ordinates of hydrographs

Impendle Dam		Smithfield Dam	
Time (hour)	Flow (m^3/s)	Time (hour)	Flow (m^3/s)
0.00	0.0	0.00	0.0
0.60	34.3	0.90	63.9
1.20	89.2	1.80	133.4
1.80	125.7	2.70	143.4
2.40	158.8	3.60	175.4
3.00	203.4	4.50	272.1
3.60	272.7	5.40	447.6
4.20	375.6	6.30	695.6
4.80	516.7	7.20	997.2
5.40	695.0	8.10	1326.0
6.00	904.3	9.00	1654.0
6.60	1134.1	9.90	1954.3
7.20	1370.0	10.80	2204.8
7.80	1595.7	11.70	2389.9
8.40	1794.6	12.60	2501.5
9.00	1951.9	13.50	2540.0
9.60	2057.2	14.40	2513.4
10.20	2107.5	15.30	2437.0
10.80	2110.0	16.20	2331.7
11.40	2085.5	17.10	2222.1
12.00	2072.1	18.00	2134.2
12.60	1989.8	18.90	2014.1
13.20	1830.7	19.80	1853.1
13.80	1684.3	20.70	1704.9
14.40	1549.6	21.60	1568.6
15.00	1425.7	22.50	1443.2
15.60	1311.7	23.40	1327.8
16.20	1206.9	24.30	1221.6
16.80	1110.4	25.20	1124.0
17.40	1021.6	26.10	1034.1
18.00	939.9	27.00	951.4
18.60	864.8	27.90	875.3
19.20	795.6	28.80	805.3
19.80	732.0	29.70	741.0
20.40	673.5	30.60	681.7
21.00	619.6	31.50	627.2
21.60	570.1	32.40	577.1
22.20	524.5	33.30	530.9
22.80	482.6	34.20	488.5
23.40	444.0	35.10	449.4
24.00	408.5	36.00	413.5
24.60	375.8	36.90	380.4
25.20	345.8	37.80	350.0
25.80	318.1	38.70	322.0
26.40	292.7	39.60	296.3
27.00	269.3	40.50	272.6
27.60	247.8	41.40	250.8
28.20	227.9	42.30	230.7
28.80	209.7	43.20	212.3

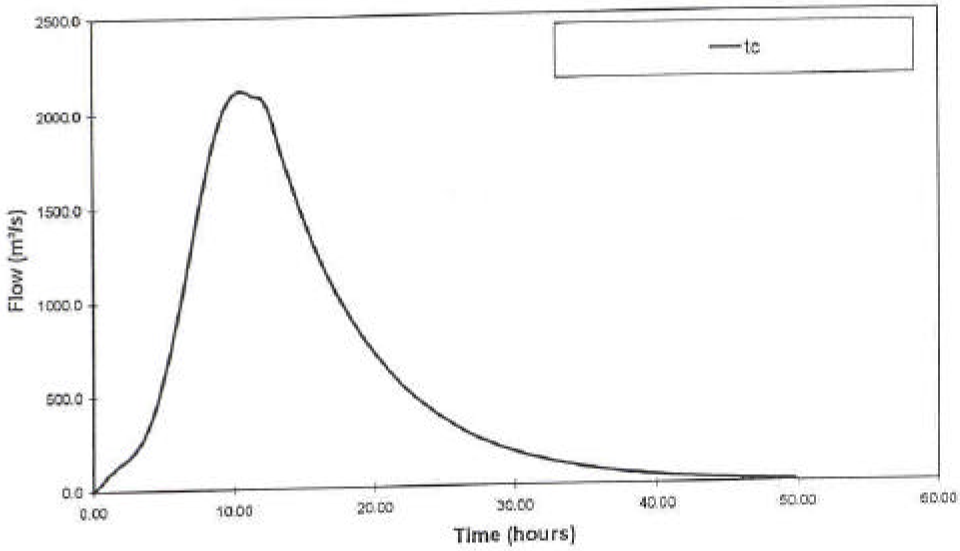
Ordinates of hydrographs - CONTINUED

Impendle Dam		Smithfield Dam	
Time (hour)	Flow (m^3/s)	Time (hour)	Flow (m^3/s)
29.40	193.0	44.10	195.3
30.00	177.5	45.00	179.7
30.60	163.3	45.90	165.3
31.20	150.3	46.80	152.1
31.80	138.3	47.70	139.9
32.40	127.2	48.60	128.8
33.00	117.0	49.50	118.5
33.60	107.7	50.40	109.0
34.20	99.1	51.30	100.3
34.80	91.1	52.20	92.3
35.40	83.9	53.10	84.9
36.00	77.2	54.00	78.1
36.60	71.0	54.90	71.9
37.20	65.3	55.80	66.1
37.80	60.1	56.70	60.8
38.40	55.3	57.60	56.0
39.00	50.9	58.50	51.5
39.60	46.8	59.40	47.4
40.20	43.1	60.30	43.6
40.80	39.6	61.20	40.1
41.40	36.4	62.10	36.9
42.00	33.5	63.00	33.9
42.60	30.8	63.90	31.2
43.20	28.4	64.80	28.7
43.80	26.1	65.70	26.4
44.40	24.0	66.60	24.3
45.00	22.1	67.50	22.4
45.60	20.3	68.40	20.6
46.20	18.7	69.30	18.9
46.80	17.2	70.20	17.4
47.40	15.8	71.10	16.0
48.00	14.6	72.00	14.8
48.60	13.4	72.90	13.6
49.20	12.3	73.80	12.5
49.80	11.3	74.70	11.5
50.40	10.4	75.60	10.6
51.00	9.6	76.50	9.7
51.60	8.8	77.40	8.9
52.20	8.1	78.30	8.2
52.80	7.5	79.20	7.6
53.40	6.9	80.10	7.0
54.00	6.3	81.00	6.4
54.60	5.8	81.90	5.9
55.20	5.4	82.80	5.4
55.80	4.9	83.70	5.0
56.40	4.5	84.60	4.6
57.00	4.2	85.50	4.2
57.60	3.8	86.40	3.9
58.20	3.5	87.30	3.6
58.80	3.3	88.20	3.3

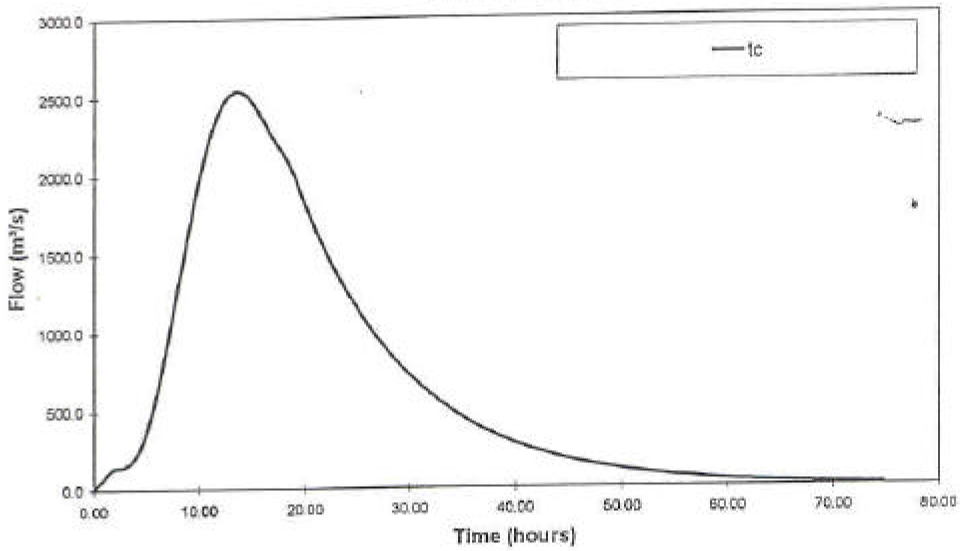
Ordinates of hydrographs - CONTINUED

Impendle Dam		Smithfield Dam	
Time (hour)	Flow (m^3/s)	Time (hour)	Flow (m^3/s)
59.40	3.0	89.10	3.0
60.00	2.8	90.00	2.8
60.60	2.5	90.90	2.6
61.20	2.3	91.80	2.4
61.80	2.1	92.70	2.2
62.40	2.0	93.60	2.0
63.00	1.8	94.50	1.8
63.60	1.7	95.40	1.7
64.20	1.5	96.30	1.6
64.80	1.4	97.20	1.4
65.40	1.3	98.10	1.3
66.00	1.2	99.00	1.2
66.60	1.1	99.90	1.1
67.20	1.0	100.80	1.0
67.80	0.9	101.70	0.9
68.40	0.9	102.60	0.9
69.00	0.8	103.50	0.8
69.60	0.7	104.40	0.7
70.20	0.7	105.30	0.7
70.80	0.6	106.20	0.6
71.40	0.6	107.10	0.6
72.00	0.5	108.00	0.5
72.60	0.5	108.90	0.5
73.20	0.4	109.80	0.4
73.80	0.4	110.70	0.4
74.40	0.4	111.60	0.4
75.00	0.3	112.50	0.3
75.60	0.3	113.40	0.3
76.20	0.3	114.30	0.3
76.80	0.3	115.20	0.3
77.40	0.2	116.10	0.2
78.00	0.2	117.00	0.2
78.60	0.2	117.90	0.2
79.20	0.2	118.80	0.2
79.80	0.2	119.70	0.2

0.5 % Exceedence Probability Hydrograph
Impendle Dam



0.5 % Exceedence Probability Hydrograph
Smithfield Dam



APPENDIX C

REPORT ON SEDIMENTATION

Mkomazi Pre-Feasibility Study

Sedimentation

Report by

A Rooseboom

Sigma Beta **August 1996**

Introduction

As part of the Mkomazi Pre-Feasibility Study estimates were prepared of expected sedimentation rates for the reservoirs are being considered.

The alternative dams which are being considered are:

(i) Impendle Dam with a catchment of 1 422 km^2 and a trap efficiency of near 100%

$$\left(\frac{\text{MAR}}{\text{Capacity}} = \frac{560}{680} = 0{,}82 \right)$$

(ii) Smithfield Dam with a catchment of 2 054 km^2 and an initial trap efficiency of some 90%

$$\left(\frac{\text{MAR}}{\text{Capacity}} = \frac{680}{170} = 4 \right)$$

The Smithfield Dam if it were to be built, is to be followed some 10 years later by the Impendle Dam.

Rates of sedimentation were therefore determined for Impendle Dam and for Smithfield Dam (without Impendle Dam in place).

In order to assess conditions within the catchments, I visited representative parts of the catchments on 17th and 18th February 1998.

Basic Sediment Yield Potential of Catchments

The basic yield potential of the soils within the catchments have been classified predominantly as 12 and 15 on a scale of 20 with 20 the lowest yield potential. (1992 Sediment Yield Map of Southern Africa: A Rooseboom et al; WRC Report 297/2/92).

The basically low sediment yield potential also became evident during my field trip. Even though localised patches of serious erosion are found, the general impression is that of largely stable soils and reasonable vegetation cover.

Expected Yield Figures

According to the 1992 sediment yield map, the expected yield for the catchment is 155 t/km^2.a given that the catchments fall within region 4 on the map. If the equivalent yield figure is calculated for the catchments in terms of the bordering region 9, then the median statistical yield is 185 t/km^2.a.

Actual recorded yield values for the dams closest to these catchments are:

Midmar	10 t/km^2.a
Shongweni	231 t/km^2.a
Albert Falls	31 t/km^2.a
Wagendrift	91 t/km^2.a
Henley	42 t/km^2.a
Craigie Burn	29 t/km^2.a

Given the conditions of the catchments and the figures at hand, a likely sediment yield of 150 t/km^2.a is accepted together with a maximum foreseeable yield of 300 t/km^2.a.

The corresponding sedimentation rates for the reservoirs are thus as follows:

	Sediment Volumes	
Impendle	**Yield 150 t/km^2.a**	**Yield 300 t/km^2.a**
After 20 years	5,2 x 10^6m^3	10,4 x 10^6m^3
After 50 years	7,9 x 10^6m^3	15,8 x 10^6m^3 opening
Smithfield (without Impendle)	**Yield 150 t/km^2.a**	**Yield 300 t/km^2.a**
After 20 years	6,8 x 10^6m^3	13,5 x 10^6m^3
After 50 years	10,3 x 10^6m^3	20,5 x 10^6m^3

Sedimentation therefore does not seem to pose a serious threat to the storage capacities of these reservoirs.

Sediment Loads at the Estuary

It is necessary to provide estimates of the sediment loads at the estuary for environmental studies.

The following yield values and corresponding loads have been estimated for the total catchment of 4 387 km^2 and for the catchments above and below the dams.

Catchment	**Area km^2**	**Yield t/km^2.a**	**Sediment Load 10^6t/a**
Total (Pristine conditions)	4387	20	0,09
Impendle (Present)	1422	150	0,21
Smithfield (Incremental, Present)	632	150	0,09
Below Smithfield (Present)	2333	180	0,42
Total (Present)	4387	166	0,73

Although there is a great deal of uncertainty about the estimated values, it is likely that the dams will not reduce the sediment loads to less than those which were transported under pristine conditions.

It is likely that the sand content of the sediment load is less than 25%. A more reliable estimate will only be possible if soil samples from different parts of the catchment were to be analysed.

backup\7856\pcb\reports\sr6_mkom_app c.

APPENDIX D

REPORT ON TREATMENT OF MIDMAR DAM SCOUR RELEASE

UMGENI
WATER · AMANZI

Managing Water for Life

WQP 12/98

COMMENT TO NINHAM SHAND ON THE WATER QUALITY IMPLICATIONS OF TREATING ABSTRACTED AND SCOUR RELEASE WATER AFTER THE RAISING OF MIDMAR DAM WALL BY 4.5 METRES

WATER QUALITY PLANNING
SCIENTIFIC SERVICES
UMGENI WATER

JULY 1998

COMMENT TO NINHAM SHAND ON THE WATER QUALITY IMPLICATIONS OF TREATING ABSTRACTED AND SCOUR RELEASE WATER AFTER THE RAISING OF MIDMAR DAM WALL BY 4.5 METRES

1. BACKGROUND

The Midmar dam wall is due to be raised by 4.5 m from a FSL water depth of 22.9 m to 27.4 m to increase the storage and receive water transfers from the Mooi, and possibly the Mkomazi river catchments. The purpose is to augment the potable water supply to the Mgeni system which is essentially the greater Pietermaritzburg and Durban areas. Construction at the wall is scheduled to commence in January 1999 and be completed in April 2001. The existing full supply storage volume of 178 million m^3 will increase by 44% to 255 million m^3 with a concomitant increase in water surface area from 15.64 km^2 to 18.66 km^2, a 19% increase. The mean depth in the dam will increase from 11.4 m to 13.7 m.

Ninham Shand (Peter Blersch) requested information on the water quality implications for treatment of scour water released from the dam to augment water abstracted from the normal level abstraction pipe, as the supply to the WW from this latter source would eventually become limiting. At certain times of the year, scour water would be anoxic due to thermal stratification and depletion of dissolved oxygen in the water column of the dam, which would have water treatment implications. To assess the change in water quality, the quality of scour water has been compared with that of water abstracted from a level pipe. Additionally, dissolved oxygen profiles for the dam have been examined to determine typical patterns which could be assumed to prevail when the wall is raised, and the implications for using the existing abstraction level drawoff are discussed.

2. SCOUR AND ABSTRACTION LEVEL WATER QUALITY

Data from routine monitoring of Midmar dam from 1988 to the present were extracted and assessed to characterise scour release water quality and that drawn from an abstraction level for treatment. However, there were periods when the water of the Midmar dam outflow consisted of a mixture of scour release water and overflow from the dam. To exclude this data, the dam level record was examined and data for months when overflow occurred were not included in the data set. As a result, approximately half of the data had to be excluded. This is considered to be a worst case water quality scenario as dam overflow water would dilute higher concentrations of iron, manganese and turbidity, but on the other hand there may be higher concentrations of algae present. To make the comparison of scour water with abstracted water quality more valid, only abstracted water data for the same periods were selected.

Percentile analysis was performed on the data sets for water quality variables that have water treatment implications, namely, *E. coli*, pH, colour, turbidity, total aluminium, iron, manganese, suspended solids and total organic carbon (TOC). The results are shown in Table 1 and have been divided up into summer (October - March) and winter (April - September) periods since scour water quality will be affected by stratification in summer and turnover (mixing) in winter. In spite of the data exclusions because of dam overflow occurring, the data sets are quite large as shown by number of results ranging from 102 to 147, which increases the confidence in the results. For ease of viewing, the summer results, which show the greatest differences in quality, for the more important variables are shown graphically in Figures 1 and 2.

The Process Services Senior Scientist for Water Treatment (Peter Thompson) was provided with the data for comment on the treatment implications which are included in the summary below.

2.1 Summer period

Chlorine demand

The summer data show higher concentrations of *E.coli*, turbidity, iron and manganese for the scour compared to water abstracted for treatment. There would thus be an associated increase in the chlorine demand of the water when the ratio of scour:abstracted water increases. This could possibly double the chlorine demand with an associated doubling of the costs of pre-chlorination. There are stoichiometric relationships for the ratio of iron, manganese and chlorine. However, these cannot be applied as it is not certain whether the iron and manganese would be in a reduced form. Laboratory scale tests would need to be conducted by Process Services to determine the effect on chlorine demand. These tests can only be done in summer when stratification had taken place.

Coagulant demand

The turbidity and suspended solids values of the scour water are also higher than the abstracted water and thus an associated increase in the coagulant demand could be expected. However, as bentonite is sometimes added to Midmar water to aid flocculation due to low turbidity, a decrease in the bentonite demand could be expected. These effects would therefore also have to be determined by conducting laboratory scale tests.

Dissolved oxygen

The dissolved oxygen concentrations in the scour water would be low (<2 mg/l), and therefore it could be expected that the iron and manganese would be in the reduced forms. This is most likely to be the case particularly since there will be an extra depth of 4.5 m. The effect on water treatment could be quite drastic and the process would then have to modified. Modifications would need to include a system for raising the scour water pH to between 8 and 9.5 before oxidation. Existing systems use chlorine for pre-chlorination and this could be used for the oxidation of the iron and manganese. However, if chlorine did not work, a stronger oxidising agent such as potassium permanganate or ozone would need to be included in the process. A pH correction unit process would also be needed after filtration. Additionally, reduced forms of sulphur such as hydrogen sulphide could also be present which would need to be oxidised in the same manner.

2.1 Winter period

The winter data for scour water show higher concentrations for *E.coli* and iron. The only influence on water treatment during this period may be an increase in the chlorine and coagulant demand.

The capital and operating costs for these changes can be estimated, however more time would be needed to include this work in the Process Services work schedule.

3. ABSTRACTION WATER QUALITY IMPLICATIONS

The current status at Midmar dam is that there are four level drawoffs at depths below FSL of 3.6 m, 9.6 m, 16.6 m and 21.6 m, but the latter is reported to be silted up. The upper level at 3.6 m is normally used for abstraction in summer. However, when the dam wall is raised by 4.5 m, the depths of the drawoffs will fall to 8.1 m, 14.1 m and 21.1 m with respect to FSL. A possible problem during summer stratification may be that even when using the uppermost level, low dissolved oxygen concentration water may be abstracted with the attendant water treatment problems as discussed above.

The dissolved oxygen profiles, measured weekly, since 1990 have been examined to determine for each year when the dam was most strongly stratified, ie: profile where the lowest dissolved oxygen concentration was closest to the surface. The results are shown in

Table 2 as dissolved oxygen concentrations at 2 m depth intervals. They show that at a depth of 8 m, the approximate depth of the highest drawoff when the dam wall is raised, the concentrations ranged from a high of 6.9 mg/ℓ down to 2 mg/ℓ, while at 10 m depth they ranged from 6.1 mg/ℓ down to 1 mg/ℓ. For ease of viewing, the dissolved oxygen concentrations are shown at 4 m intervals in Figure 3.

If it can be assumed that similar dissolved oxygen and temperature stratification will prevail in the dam when the wall is raised, and this is likely to be the case, then abstracted water from 8.1 m would vary in dissolved oxygen concentration down to 2 mg/ℓ, which is not desirable from a water treatment point of view. It is even possible than lower dissolved oxygen concentrations may occur at this depth as shown by the data for 10 m. Current treatment of water at approximately the 4 m depth shows dissolved oxygen concentrations of between 6 mg/ℓ and 8 mg/ℓ which is entirely satisfactory.

Dissolved oxygen and temperature stratification in the dam is shown for a typical year in Figures 4 and 5 respectively, except that, as assumed above, the profiles would simply extend to a depth of 28 m. For these predicted profiles, the values for the lowest depths of the profiles have been assumed for the extra 4.5 m depth. The abstraction levels with the wall raised are shown together with a proposed new level for abstraction at 4 m depth. The lowered dissolved oxygen concentrations at a depth of 8 m, at the greatest intensity of stratification in January and February are clearly evident, as opposed to the higher concentrations at 4 m. As may be seen, stratification commenced in October with turnover occurring in May. From May to September, abstraction from a lower level, such as 8 m, would not be a problem from a dissolved oxygen point of view.

The temperature isopleths in Figure 5 show a similar pattern with maximum temperature differential from January to March and isothermal conditions starting in May. Temperature stratification precedes dissolved oxygen stratification and is the driving force.

4. SUMMARY

Comparison between scour release water and water abstracted from a level drawoff for Midmar dam show the scour water to be a poorer quality for a number of critical water treatment variables. Based on the information available, should scour water be drawn for treatment when the dam is stratified, the chlorine dose required could double and the coagulant dose required would increase. Laboratory tests would need to be carried out to more accurately estimate the requirements. At times when scour water has low dissolved oxygen concentrations and reduced iron and manganese species are present, the treatment process may be drastically affected, requiring strong oxidation. In winter the general effects would be less.

From consideration of dissolved oxygen profiles in the dam since 1990, concentrations as low as 2 mg/ℓ have been found at a depth of 8 m, which is the approximate depth (8.1 m) that the highest abstraction level will be when the dam wall is raised by 4.5 m. Treatment of such low dissolved oxygen concentration water could be problematic and is not desirable.

5. RECOMMENDATIONS

- Treatment of scour release water is not recommended, but if this practice is to be carried out then some laboratory tests will be needed for assessment of additional treatment processes required.
- The cost of the extra water treatment required to treat scour water should be compared with the cost of the infrastructure required to increase the level abstraction.
- A new abstraction level at 4 m depth from FSL is recommended when the dam wall is raised to ensure that aerobic water is drawn off for treatment.

6. ACKNOWLEDGEMENTS

- To Peter Thompson of Process Services for comment on possible water treatment problems.
- To Asha Ramjatan for production of the temperature and dissolved oxygen isopleth figures.

Dean Simpson
Scientist, Water Quality Planning

Table 1: Comparison of Midmar dam scour release and raw water abstraction quality

SCOUR RELEASE PERCENTILES IN SUMMER									
	E. COLI	pH	COLOUR	TURB	Total Al	Fe	Mn	SS	TOC
	/100 mℓ		° Hazen	NTU	µg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ
0%	1	6.2	2	11	0	0.30	0.01	5	0.9
5%	4	6.8	8	19	0	0.62	0.02	8	1.5
10%	6	6.9	9	24	0	0.72	0.02	10	1.8
25%	12	7.2	12	27	89	0.84	0.03	14	2.0
50%	24	7.5	19	31	144	1.06	0.05	20	2.4
75%	56	7.8	24	36	212	1.28	0.07	27	2.8
90%	120	8.1	30	41	293	1.47	0.16	33	3.4
95%	201	8.2	32	44	346	1.52	0.24	37	3.7
100%	880	8.7	46	105	511	1.73	0.32	75	7.8
n	117	115	117	117	117	117	117	117	116

RAW WATER ABSTRACTION IN SUMMER									
	ECOLI	pH	COLOUR	TURB	T Al	Fe	Mn	SS	TOC
	/100 mℓ		° Hazen	NTU	µg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ
0%	0	6.9	0	4	0	0.00	0.00	0	0.0
5%	0	7.1	6	7	0	0.13	0.01	4	1.1
10%	0	7.3	7	9	0	0.33	0.01	4	1.7
25%	0	7.4	10	14	63	0.59	0.02	6	1.9
50%	1	7.5	17	19	120	0.80	0.02	12	2.3
75%	4	7.7	23	27	180	0.97	0.04	20	2.6
90%	10	7.9	26	33	260	1.11	0.06	27	3.3
95%	19	7.9	29	36	304	1.20	0.10	32	3.6
100%	104	8.6	78	105	482	2.01	0.24	91	5.0
n	136	137	138	137	137	136	137	138	132

SCOUR RELEASE PERCENTILES IN WINTER									
	E. COLI	pH	COLOUR	TURB	Total Al	Fe	Mn	SS	TOC
	/100 mℓ		° Hazen	NTU	µg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ
0%	0	6.8	4	8	0	0.32	0.01	5	0.9
5%	2	7.1	8	10	0	0.40	0.01	6	1.4
10%	3	7.2	10	12	0	0.47	0.02	7	1.8
25%	6	7.4	11	13	68	0.65	0.02	9	2.1
50%	10	7.5	16	17	96	0.81	0.03	12	2.4
75%	28	7.8	24	24	157	0.99	0.03	16	2.8
90%	72	8.0	28	30	250	1.15	0.07	22	3.2
95%	151	8.0	29	34	362	1.28	0.13	24	3.3
100%	600	8.2	39	50	1269	2.35	0.26	32	6.4
n	127	127	123	124	126	126	126	123	102

RAW WATER ABSTRACTION IN WINTER									
	ECOLI	pH	COLOUR	TURB	T Al	Fe	Mn	SS	TOC
	/100 mℓ		° Hazen	NTU	µg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ
0%	0	6.8	0	3	0	0.00	0.00	0	0.0
5%	0	7.3	6	7	0	0.21	0.01	4	0.9
10%	0	7.4	8	9	33	0.31	0.01	4	1.6
25%	0	7.6	10	13	63	0.47	0.02	6	1.9
50%	0	7.7	14	18	120	0.66	0.02	10	2.3
75%	1	7.9	21	25	191	0.84	0.03	16	2.7
90%	2	8.0	27	32	289	0.98	0.07	25	3.3
95%	4	8.0	30	40	354	1.29	0.11	30	3.7
100%	6	8.2	50	189	1607	2.21	0.25	66	5.7
n	145	147	146	145	140	147	147	144	118

FIGURE 1: E. COLI, TURBIDITY AND IRON PERCENTILE VALUES COMPARING SCOUR AND ABSTRACTION WATER QUALITY FOR MIDMAR DAM

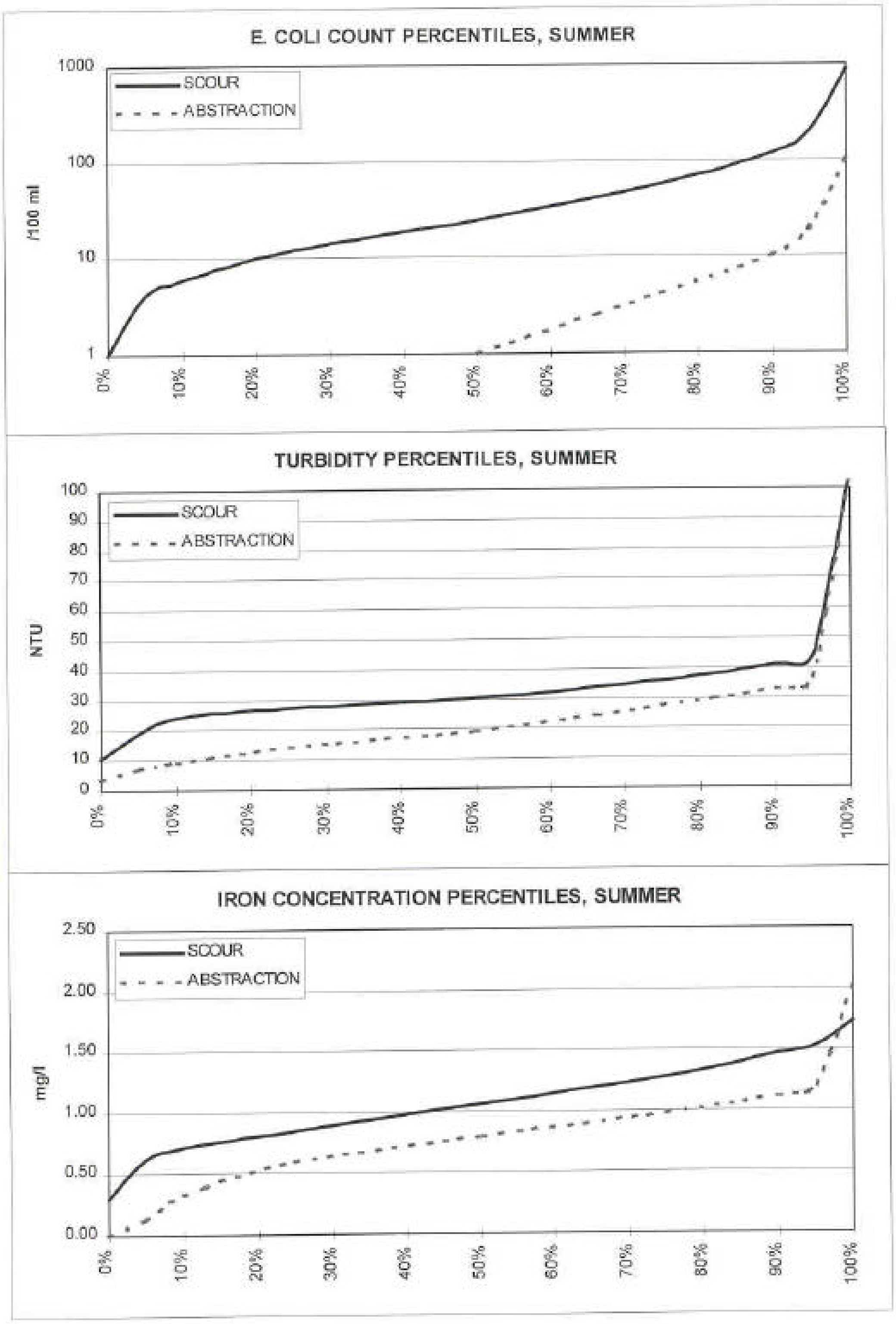


FIGURE 2: MANGANESE, SUSPENDED SOLIDS AND TOC PERCENTILE VALUES COMPARING SCOUR AND ABSTRACTION WATER QUALITY FOR MIDMAR

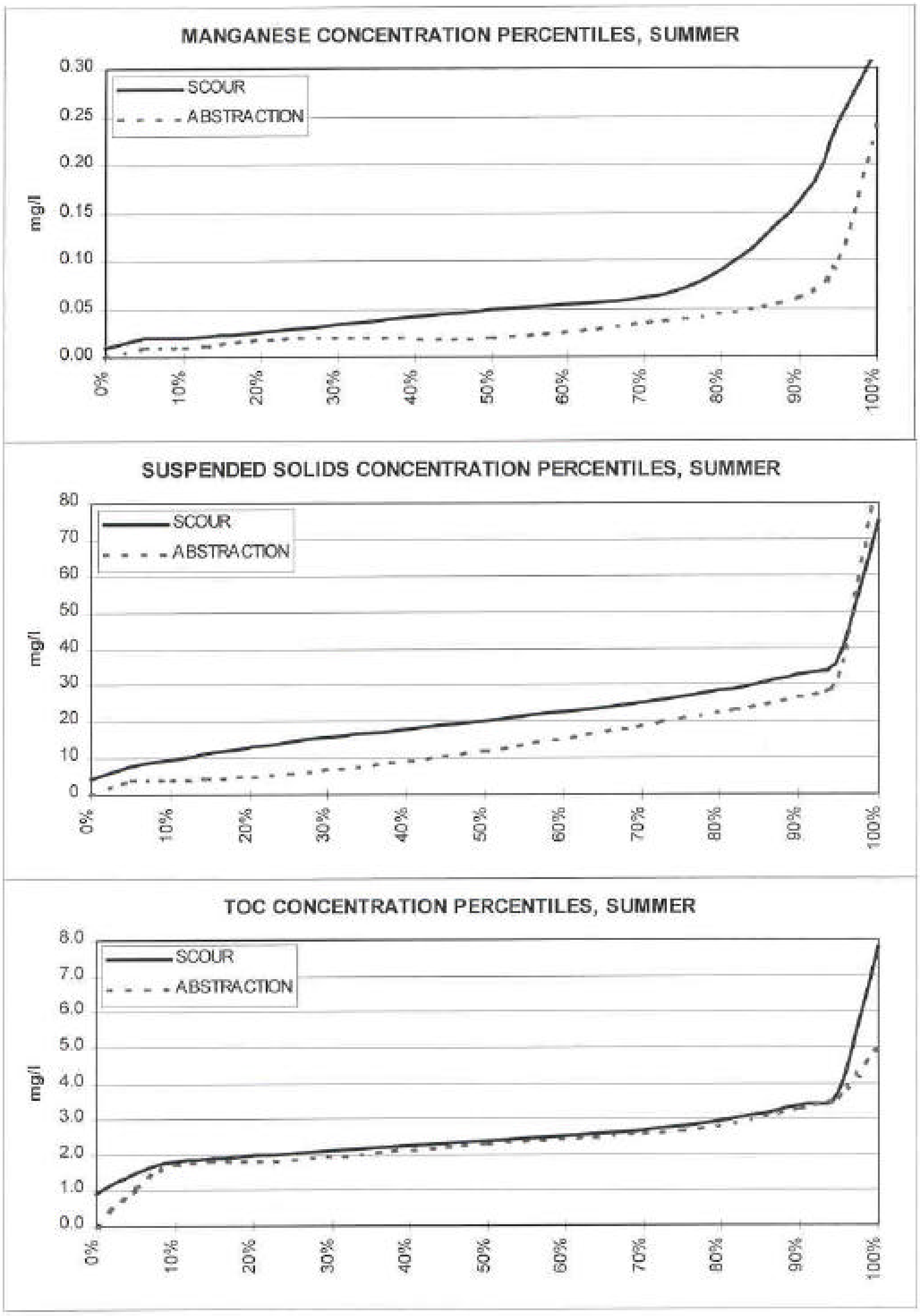


Table 2: Midmar dam annual minimum dissolved oxygen profiles, mg/ℓ, and month of occurrence

MONTH	MARCH	MARCH	JAN.	JAN.	MARCH	FEB.	FEB.	FEB.	FEB.
DEPTH	1990	1991	1992	1993	1994	1995	1996	1997	1998
0m	8.6	6.5	8	7.5	6.2	7.3	7.8	7.9	6.7
2m	8.3	7.1	7.8	7.6	6.3	7.8	7.6	7.7	6.7
4m	7.8	7.4	7.5	6.7	6.1	7.5	6.7	7.5	6.7
6m	7.4	7.2	3.1	5.2	5.5	7.2	4.9	7.4	5.2
8m	6.9	4.6	2.6	3.3	3.6	4	3.2	3.3	2
10m	6.1	1.7	1.1	2.9	1	1.3	2.3	1.5	1
12m	4.3	1.6	1	2.8	0.6	1	2.2	1	0
14m	2.8	1.3	0.9	2.8	0.2	0.7	2.4	0.5	0
16m	1.6	0.2	0.9	2.8	0.2	0.5	2.5	0.3	0
18m	1.4	0.2	0.9		0.2				
20m	1.4	0.2	0.9		0.2				

Figure 3: Midmar dam annual minimum dissolved oxygen profiles at different depths

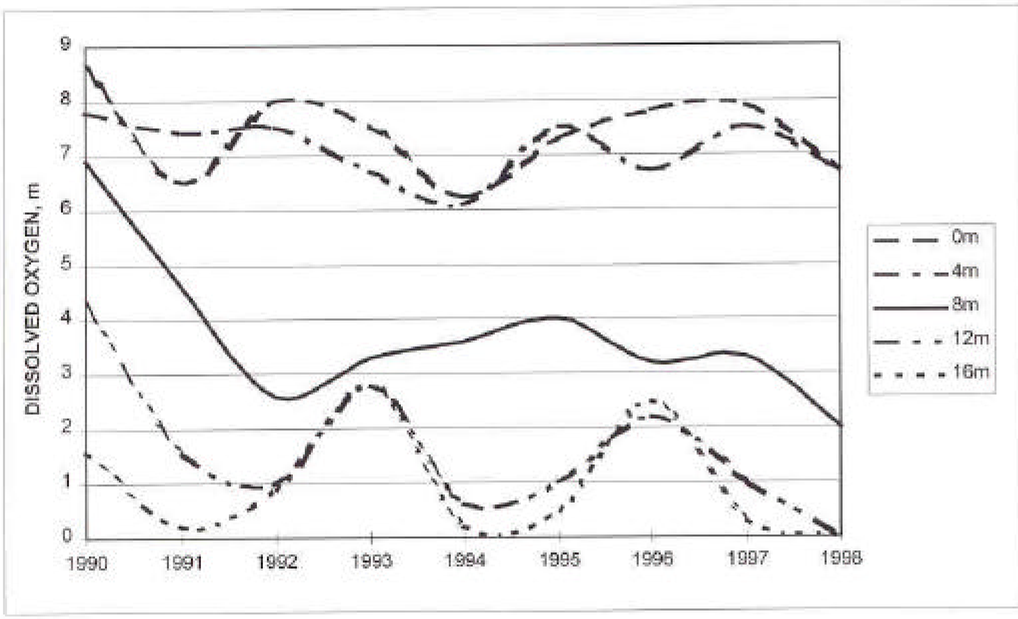


Figure 4 : DO Isopleth (mg/ℓ), Midmar main basin site 36.1

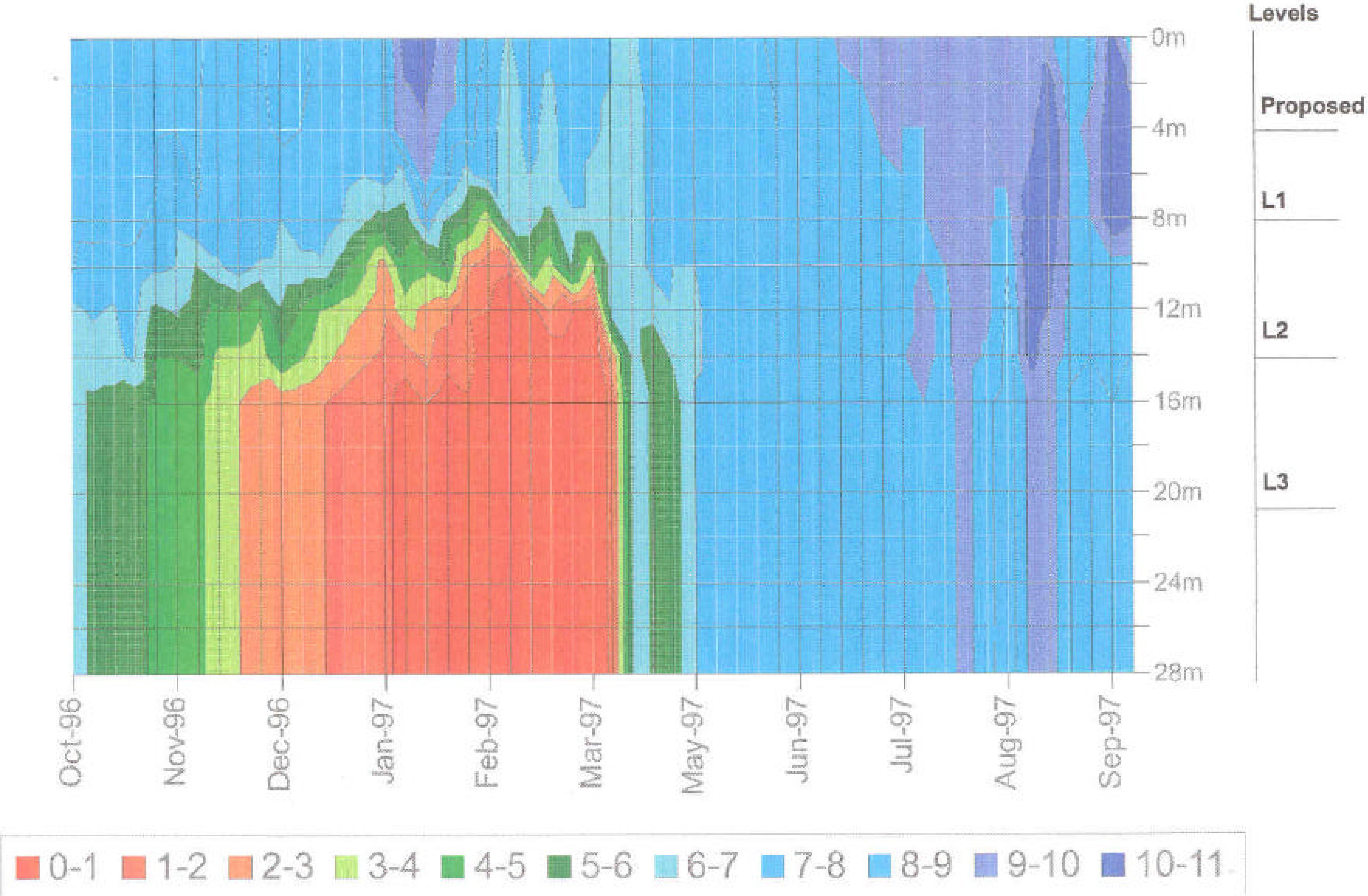
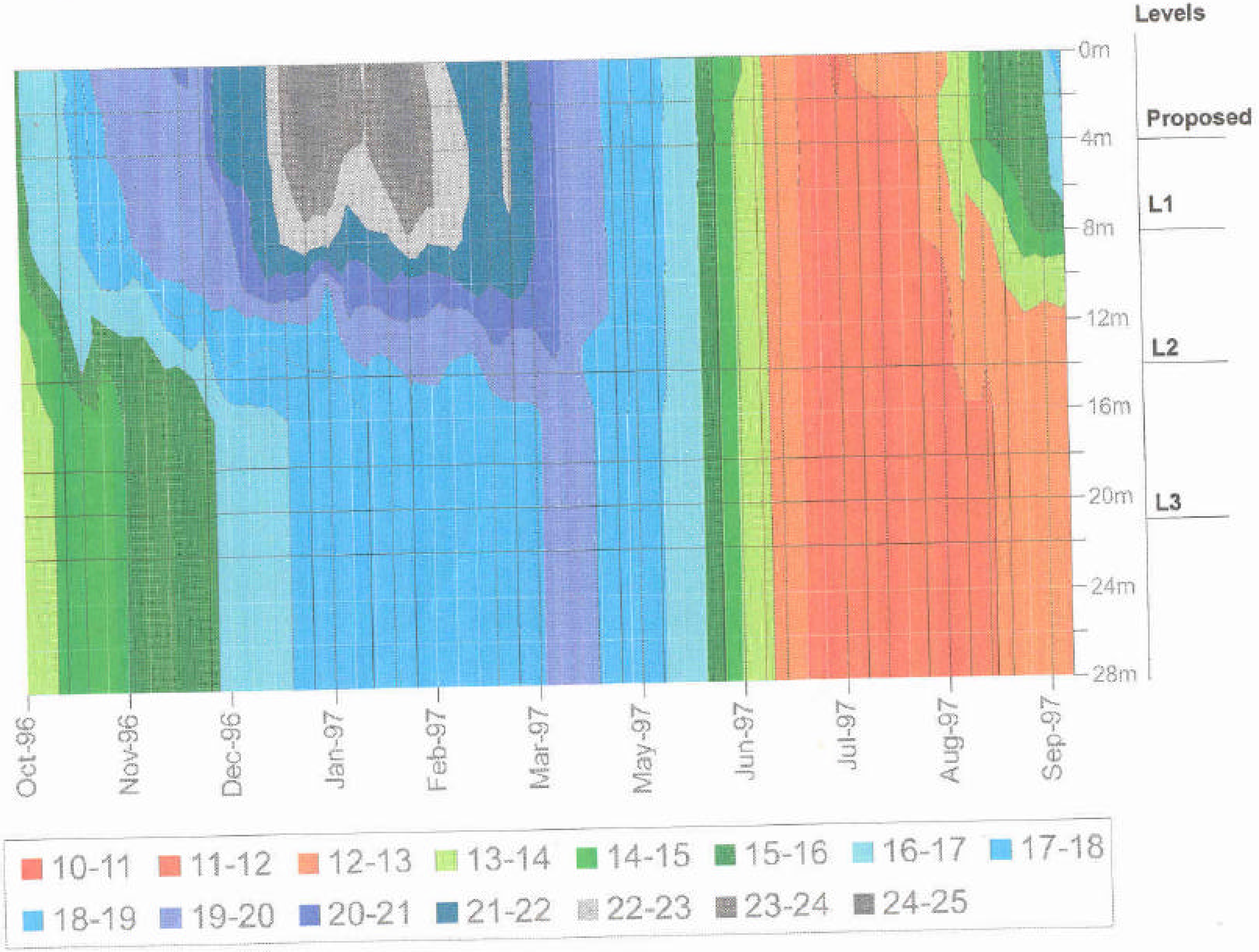


Figure 5 : Temperature Isopleth (°C), Midmar main basin site 36.1



APPENDIX E

SMITHFIELD TRANSFER TUNNEL

PRESSURE OPTION

MKOMAZI-MGENI TRANSFER PREFEASIBILITY STUDY
Smithfield-Baynesfield transfer alternative

Description of scheme

The configuration of the currently selected scheme includes the following :

- A gravity pressure tunnel linking the Smithfield Dam intake to the Baynesfield Dam.
- A pumpstation in the Smithfield intake tower, pumping to a tunnel elevation of 940 masl, with an average pumping head of about 50 m.
- Twin 1900 mm diameter steel pipelines from the tunnel outlet to the Baynesfield Waterworks.
- This configuration requires pumped flow at all times, as the tunnel invert is above the NOC of Smithfield Dam.

The alternative configuration consists of the following : (See attached drawing)

- A gravity pressure tunnel at a lower elevation. (Inlet invert = 860 masl, 10 m below the Smithfield Dam MOL. Outlet invert = 850 masl).
- A 2.5 m or 3.0 m diameter surge shaft at the downstream end of the tunnel, daylighting above the NOC of Smithfield Dam (1205 masl).
- An underground pumpstation at the tunnel outlet, constructed in an enlarged TBM erection chamber at the bottom of a 1:10 adit.
- Alternative routing of flow through pumps or through gravity mains within pumpstation.
- Access to downstream end of tunnel would be provided from within pumpstation.
- Larger diameter TBM's would probably allow 2 No drives, one from the downstream end and one from an intermediate adit, from where access would be gained for inspection and maintenance.
- Twin 1900 mm diameter steel pipelines installed in the adit to Baynesfield Dam and the new Baynesfield Waterworks.

Hydraulics and operation

- This tunnel would have to be 4.5 m diameter bored, 4.0 m diameter lined, for headloss reasons. At peak flow of Q = 16.3 m^3/s the hydraulic grade line is approximately parallel to the tunnel. This larger tunnel diameter is critical to the success of this option.
- For Smithfield Dam levels above approximately 900 masl, flow will pass through the tunnel and link pipelines to the Waterworks, with a minimum residual head of about 6 m at the Waterworks inlet, required to allow flash mixing at this point.
- For Smithfield Dam operating levels below 900 masl, pumping from the tunnel outlet will be required to generate sufficient head at the Waterworks.
- Control at the Waterworks inlet will be dual, with sleeve valves or open pipe outlet depending on whether flow is gravity or pumped.

Pumping costs

- Reduced head on pumpstation to drive flow to waterworks.
- Pumping only required when Smithfield Dam is below approximately 900 masl (Q = 16 m^3/s) or 895 masl (Q = 13 m^3/s).
- Reduced cost of pumping with reduced pumping duration annually.
- Reduced maintenance on pumps with less wear and tear.
- Maintenance on the pumps can be carried out during non pumping periods.
- Pumps will be fitted with variable speed control to optimise energy consumption

Conclusion and Recommendation

This alternative now provides two options for the Smithfield transfer, which have differing parameters in terms of tunnel sizes, pumping costs, operational difficulties etc. The issue of larger tunnel sizes is discussed in the prefeasibility reports, in that this should be considered for any option selected, at the next stage of investigation. A larger tunnel diameter (of 4.5 m) is fundamental to the success of this alternative.

With the primary objective of the prefeasibility investigation to determine the initial feasibility and allow selection of either the Smithfield or the Impendle scheme, the cost implications of this alternative are not expected to alter this decision.

If the Smithfield option is opted for over the Impendle scheme, and a larger tunnel diameter is viable and cost effective, then this configuration should be considered further at feasibility stage as an alternative to the configuration discussed in the main body of the report. The primary reason for this line of thinking is that larger tunnels may well prove preferable, in which case this configuration will possibly be more cost effective.

APPENDIX F1

DETAILED COST ESTIMATES

IMPENDLE SCHEME

Scheme 1A

Scheme 1B

Scheme 1C

SCHEME 1A

SCHEME 1A PHASE 1
COST MODEL : ITEM 1 IMPENDLE DAM FOR RAISING FSL=1184masl (1.0MAR)

No	Description	Unit	Rate Mar '98	Quantity	Amount
1.	Site and basin clearing	ha	1,875	1,845	3,457,800
2.	River diversion				
	(a) Diversion Tunnel 350m long	Sum			11,000,000
	(b) Coffer Dams	Sum			8,608,231
	(c) Structural Concrete for Diversion Works	Sum			2,825,260
	(d) Foundation Prep. and Dealing with Water	Sum			50,000
3.	Excavation				
	(a) all materials	m3	13	366,192	4,903,316
	(b) extra over for rock	m3	24	123,092	2,966,506
4.	Preparation of solum				
	(b) for embankment	m2	8	70,543	566,457
	(c) core trench	m2	16	26,538	426,462
5.	Drilling and Grouting				
	(a) curtain grouting	m Drill	150	7,021	1,052,974
	(b) consolidation grouting	m Drill	150	4,224	633,493
6.	Embankment				
	(a) Earthfill Core	m3	18	1,114,362	20,192,241
	(b) rockfill	m3	28	2,355,391	66,681,130
	(c) filters	m3	59	189,665	11,175,050
	(d) rip-rap	m3	33	92,188	3,086,442
	(e) road layerworks	m2	80	4,900	392,000
7	SPILLWAY				
	(a) Excavation e/o to quarry	m3	10	1,030,000	10,300,000
	(b) Formwork	m3	67	24,205	1,620,500
	(c) Structural Concrete	m3	319	37,171	11,871,200
	(d) Mass Concrete	m3	248	10,523	2,610,000
	(e) Anchors and steel rebars	t	3,348	2,536	8,490,000
	(f) Drill for Anchors	m Drill	50	90,000	4,500,000
	(g) Road Bridge over Spillway	Sum			1,800,000
8	OUTLET STRUCTURE				
	(a) civil	Sum			6,970,000
	(b) mechanical/electrical	Sum			9,704,500
	(c) Pipework	Sum			15,335,500
	(d) Measuring weir	Sum			500,000
9	Landscaping (% of 1-8)	%	5%	211,719,064	10,585,953
10	Miscellaneous (% of 1-8)	%	10%	211,719,064	21,171,906
	Subtotal A (carried forward)				243,476,924
11	Preliminary, General and Preliminary works (% of Subtotal A)	%	20%	243,476,924	48,695,385
	Subtotal B				292,172,308
12	Contingencies (% of Subtotal B)	%	10%	292,172,308	29,217,231
	Subtotal C				321,389,539
13	Planning design & supervision, fees, time cost & transport (% of Subtotal C)	%	15%	321,389,539	48,208,431
	Subtotal D				369,597,970
14	VAT (% of Subtotal D)	%	14%	369,597,970	51,743,716
	TOTAL PROJECT COST				421,341,686

SCHEME 1A PHASE 1
COST MODEL : ITEM 2 Tunnel from Impendle Dam to Midmar Dam
Pressure flow
TBM Tunnel 3,5 m diameter
D & B Tunnel 5,5 by 6 m high

Tunnel Length: 34900m
1 Up from outlet TBM - 7900m
1 Up from 2/3 point - 13500m
1 Down from inlet - 13500m
1 DB Adit - 1350m at 1:10

No	Description	Unit	Rate	Quantity	Amount
1	Portal excavations				
	a. Inlet portal	Sum	3,000,000	1	3,000,000
	b. Outlet portal	Sum	2,000,000	1	2,000,000
	b. Intermediate	Sum	2,500,000	1	2,500,000
2	Tunnel Excavation				
	TBM				
	b. Rock Class II	m3	340	57,081	19,407,674
	c. Rock Class III	m3	350	218,252	76,388,335
	d. Rock Class IV	m3	400	53,724	21,489,466
	e. Rock Class V	m3	1,000	6,715	6,715,458
	D & B (Adits)				
	c. Rock Class III	m3	180	36,531	6,575,580
	d. Rock Class IV	m3	200	7,128	1,425,600
	e. Rock Class V	m3	550	891	490,050
3	Extra for down grade drive	m	1,500	13,500	20,250,000
4	Extra for length of drive over 10 km	m	1,000	7,000	7,000,000
5	Turning Chamber	No	250,000	2	500,000
6	Dealing with Water	m	15	36,250	543,750
7	Shafts				
	a. Ventilation	m	3,000	1,000	3,000,000
	b. Surge	m	8,000	130	1,040,000
8	Rock support				
	a. i) Rockbolts - TBM	m	250	34,900	8,725,000
	a. ii) Rockbolts - D & B	m	380	1,350	513,000
	b. Shotcrete	m3	1,400	731	1,023,806
9	Concrete				
	a. Linings	m3	550	77,431	42,587,161
	b. Overbreak concrete : TBM	m2	100	377,973	37,797,287
	c. Overbreak concrete : DBT	m2			
	d. Concrete - D & B Invert blinding	m3	400	2,025	810,000
	e. Concrete : Structures	m3	380	650	247,000
10	Formwork				
	a. Smooth curved in tunnel	m2	150	282,727	42,409,011
	b. Structures	m2	155	3,200	496,000
11	Reinforcement	ton	3,000	52	156,000
12	Pre-cast concrete inverts	m	290	34,375	9,968,750
	SUBTOTAL : MEASURED ITEMS				**317,058,927**

SCHEME 1A PHASE 1
COST MODEL : ITEM 2 Tunnel from Impendle Dam to Midmar Dam

IMPENDLE TUNNEL - PRESSURE FLOW

No	Description	Unit	Rate	Quantity	Amount
	SUBTOTAL : MEASURED ITEMS				**317,058,927**
13	Grouting				
	i) Cavity	m	200	34,375	6,875,000
	ii) Consolidation/Fissure	m	7	34,375	240,625
14	Waterproof lining				
	a. Steel liners	m	26,000	525	13,650,000
	b. Waterproof membrane	m2	300	9,100	2,730,000
15	Intake Pipeline : Twin 1600 dia pipeline	m	14,000	250	3,500,000
16	Miscellaneous	%	10	**344,054,552**	34,405,455
	SUBTOTAL A				**378,460,007**
17.1	P & G Fixed	Sum	1	27,000,000	27,000,000
17.2	P & G Time Related - Establishment	Sum	1	9,800,000	9,800,000
17.3	P & G Time Related - TBM Excavation	Sum	1	68,200,000	68,200,000
17.4	P & G Time Related - Adit Excavation	Sum	1	10,400,000	10,400,000
17.5	P & G Time Related - Lining	Sum	1	38,150,000	38,150,000
18	Preliminary works		Incl. P&G		
19	Accommodation		Incl. P&G		
	SUBTOTAL B				**532,010,007**
20	Contingencies (% of Subtotal B)	%	10	532,010,007	53,201,001
	SUBTOTAL C				**585,211,007**
21	Planning, design and supervision (% of Subtotal C)	%	12	585,211,007	70,225,321
	SUBTOTAL D				**655,436,328**
22	VAT (% of Subtotal D)	%	14	655,436,328	91,761,086
	TOTAL PROJECT COST				**747,197,414**

Construction Period = 62 months
5.2 years

SCHEME 1A PHASE 1
COST MODEL : ITEM 3 ADDITIONAL PIPEWORK AT MIDMAR DAM OUTLET

No	Description	Unit	Rate Mar '98	Quantity	Amount
1.	Supply and Fit/Lay Pipework	Sum			1,078,027
2.	Mechanical component (a) 1200 Dia. Mag-Flow Meter (b) Valves	 Sum Sum			 400,000 918,000
	Subtotal A (carried forward)				2,396,027
3	Electrical component (% of 2(a) and 2(b)	%	15%	1,318,000	197,700
4	Miscellaneous Civils (% of Subtotal A)	%	10%	2,396,027	239,603
	Subtotal B (carried forward)				2,833,330
5	Preliminary, General and Preliminary works (% of Subtotal B)	%	20%	2,833,330	566,666
	Subtotal C				3,399,996
6	Contingencies (% of Subtotal C)	%	10%	3,399,996	340,000
	Subtotal D				3,739,995
7	Planning design & supervision, fees, time cost & transport (% of Subtotal D)	%	15%	3,739,995	560,999
	Subtotal E				4,300,994
8	VAT (% of Subtotal E)	%	14%	4,300,994	602,139
	TOTAL PROJECT COST				4,903,134

SCHEME 1A PHASE 1
COST MODEL : ITEM 4 Midmar Pumpstation upsized by 580 Ml/day

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Mechanical and Electrical	%	64	13,239,458	8,473,253
2	Civils	%	36	13,239,458	4,766,205
	SUB TOTAL A				13,239,458
3	Landscaping (% of Sub total A)	%	2	13,239,458	264,789
4	Miscellaneous (% of Sub total A)	%	10	13,239,458	1,323,946
	SUB TOTAL B				14,828,193
5	Preliminary and General	%	20	14,828,193	2,965,639
6	Preliminary Works		Incl. P&G		
7	Accomodation		Incl. P&G		
	SUB TOTAL C				17,793,831
8	Contingencies (% of Sub total C)	%	10	17,793,831	1,779,383
	Sub Total D				19,573,214
9	Planning design & Supervision (% of Sub total D)	%	12	19,573,214	2,348,786
	Sub Total E				21,922,000
10	VAT (% of Sub total E)	%	14		3,069,080
	TOTAL PROJECT COST				**24,991,080**

Note : Pumpstation costs based on actual construction costs of existing large pumpstation escalated

SCHEME 1A PHASE 1
COST MODEL : ITEM 5 Pipeline from Midmar Dam to Midmar Waterworks
1800mm diameter pipeline 1900m long

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	4.0	48,000
1.2	(b) bush	ha	20,000	0.5	10,000
2	Road and Railway Crossings	Sum			1,700,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m³	35	16500	577,500
3.2	(b) Extra over for rock	m³	50	1650	82,500
3.3	(c) Bed preparation (Bedding)	m	70	8900	623,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	3,500	1900	6,650,000
4.2	(b) Laying and Jointing (% of(a))	%	20		1,330,000
4.3	(d) Cathodic Protection	km	50,000	1.9	95,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m³	850	150	127,500
6	Reinforcing	t	3,000	12.0	36,000
7	Mechanical Items				
7.1	(a) Structural Steelwork	t	8,000	3	24,000
	SUB TOTAL A				11,303,500
8	Landscaping (% of Sub total A)	%	5		565,175
9	Miscellaneous (% of Sub total A)	%	5		565,175
	SUB TOTAL B				12,433,850
10	Preliminary and General	%	15		1,865,078
11	Preliminary Works		Incl. P&G		
12	Accomodation		Incl. P&G		
	SUB TOTAL C				14,298,928
13	Contingencies (% of Sub total C)	%	15		2,144,839
	Sub Total D				16,443,767
14	Planning design & Supervision (% of Sub total D)	%	12		1,973,252
	Sub Total E				18,417,019
15	VAT (% of Sub total E)	%	14		2,578,383
	TOTAL PROJECT COST				**20,995,401**

SCHEME 1A PHASE 1
COST MODEL : ITEM 6 Midmar Waterworks upsized by 580 Ml/day

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Mechanical and Electrical	%	30	166,817,167	50,045,150
2	Civils	%	70	166,817,167	116,772,017
	SUB TOTAL A				166,817,167
3	Landscaping (% of Sub total A)	%	2	166,817,167	3,336,343
4	Miscellaneous (% of Sub total A)	%	10	166,817,167	16,681,717
	SUB TOTAL B				186,835,227
5	Preliminary and General	%	20	186,835,227	37,367,045
6	Preliminary Works		Incl. P&G		
7	Accomodation		Incl. P&G		
	SUB TOTAL C				224,202,273
8	Contingencies (% of Sub total C)	%	10	224,202,273	22,420,227
	Sub Total D				246,622,500
9	Planning design & Supervision (% of Sub total D)	%	12	246,622,500	29,594,700
	Sub Total E				276,217,200
10	VAT (% of Sub total E)	%	14		38,670,408
	TOTAL PROJECT COST				**314,887,608**

Note : Waterworks costs based on actual construction costs of existing large waterworks escalated.

SCHEME 1A PHASE 1
COST MODEL : ITEM 7 Pipeline from Midmar Waterworks to Stukkenbergs Tunnel
1800 mm diameter pipeline - 3000 m long

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	6.0	72,000
1.2	(b) bush	ha	20,000	1.0	20,000
2	Road and River Crossings	Sum			2,200,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m³	35	26,000	910,000
3.2	(b) Extra over for rock	m³	50	2,600	130,000
3.3	(c) Bed preparation (Bedding)	m	70	14,000	980,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	3,500	3000	10,500,000
4.2	(b) Laying and Jointing (% of(a))	%	20		2,100,000
4.3	(c) E/O for steep slopes	m	2,000	100	200,000
4.4	(d) Cathodic Protection	km	50,000	3.0	150,000
4.5	(e) E/O for removal of existing line	m	195	3000	585,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m3	850	160	136,000
5.2	(b) Headwalls on steep slopes	m3	550	100	55,000
6	Reinforcing	t	3,000	13.0	39,000
7	Mechanical Items				
7.1	(a) Valves etc	Sum			200,000
7.2	(b) Structural steelwork	t	8,000	3	24,000
	SUB TOTAL A				18,301,000
8	Landscaping (% of Sub total A)	%	5		915,050
9	Miscellaneous (% of Sub total A)	%	5		915,050
	SUB TOTAL B				20,131,100
10	Preliminary and General	%	15		3,019,665
11	Preliminary Works		Incl. in P&G		
12	Accomodation		Incl. in P&G		
	SUB TOTAL C				23,150,765
13	Contingencies (% of Sub total C)	%	15		3,472,615
	Sub Total D				26,623,380
14	Planning design & Supervision (% of Sub total D)	%	12		3,194,806
	Sub Total E				29,818,185
15	VAT (% of Sub total E)	%	14		4,174,546
	TOTAL PROJECT COST				**33,992,731**

SCHEME 1A PHASE 1
COST MODEL : ITEM 8 STUKKENBERGS TUNNEL - PRESSURE
D & B 3.6 m x 3.6 m

Tunnel Length: 2025 m
Drill and blast

No	Description	Unit	Rate	Quantity	Amount
1	Portal excavations				
	a. Inlet portal	Sum	2,000,000	1	2,000,000
	b. Outlet portal	Sum	2,000,000	1	2,000,000
2	Tunnel Excavation	m	6,500	2,025	13,162,500
3	Rock support				
	a. Support class A	m	50	615	30,750
	b. Support class B	m	100	615	61,500
	c. Support class C	m	170	615	104,550
	d. Support class D	m	980	105	102,900
	e. Support class E	m	3,300	100	330,000
4	Waterproof lining				
	a. Steel liners	m	3,300	100	330,000
	b. Waterproof membrane	m	6,000	1,950	11,700,000
5	Miscellaneous	%	10	29,822,200	2,982,220
	SUBTOTAL A				**32,804,420**
6.1	P & G Fixed	Sum	1	5,725,000	5,725,000
6.2	P & G Time Related - Establishment	Sum	1	1,035,000	1,035,000
6.3	P & G Time Related - Excavation	Sum	1	5,750,000	5,750,000
6.4	P & G Time Related - Lining	Sum	1	4,600,000	4,600,000
7	Preliminary works		Incl. in P&G		
8	Accommodation		Incl. in P&G		
	SUBTOTAL B				**49,914,420**
9	Contingencies (% of Subtotal B)	%	10	49,914,420	4,991,442
	SUBTOTAL C				**54,905,862**
10	Planning, design and supervision (% of Subtotal C)	%	12	54,905,862	6,588,703
	SUBTOTAL D				**61,494,565**
11	VAT (% of Subtotal D)	%	14	61,494,565	8,609,239
	TOTAL PROJECT COST				**70,103,805**

Construction Period = 24 months
2.0 years

SCHEME 1A PHASE 1
COST MODEL : ITEM 9 Pipeline from Stukkenberg Tunnel to Midmar Reservoir
1800 mm diameter pipeline - 1100 m long

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	2.2	26,400
1.2	(b) bush	ha	20,000	0.3	5,000
2	Road and River Crossings	Sum			500,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m3	35	10000	350,000
3.2	(b) Extra over for rock	m3	50	1000	50,000
3.3	(c) Bed preparation (Bedding)	m	70	5100	357,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	3,500	1100	3,850,000
4.2	(b) Laying and Jointing (% of(a))	%	20		770,000
4.3	(d) Cathodic Protection	km	50,000	1.1	55,000
4.4	(e) E/O for removal of existing line	m	195	1100	214,500
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m3	850	60	51,000
6	Reinforcing	t	3,000	5.0	15,000
7	Mechanical Items				
7.1	(a) Valves etc	Sum			210,000
7.2	(b) Structural steelwork	t	8,000	1	8,000
	SUB TOTAL A				6,461,900
8	Landscaping (% of Sub total A)	%	5		323,095
9	Miscellaneous (% of Sub total A)	%	5		323,095
	SUB TOTAL B				7,108,090
10	Preliminary and General	%	15		1,066,214
11	Preliminary Works		Incl. in P&G		
12	Accomodation		Incl. in P&G		
	SUB TOTAL C				8,174,304
13	Contingencies (% of Sub total C)	%	15		1,226,146
	Sub Total D				9,400,449
14	Planning design & Supervision (% of Sub total D)	%	12		1,128,054
	Sub Total E				10,528,503
15	VAT (% of Sub total E)	%	14		1,473,990
	TOTAL PROJECT COST				**12,002,493**

SCHEME 1A PHASE 1
COST MODEL : ITEM 10 Midmar Reservoir
Installation of sleeve valves, instrumentation and software

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Supply of 2 No 1000 mm diam., 600 Kpa, sleeve valves.	No	100,000	2	200,000
2	Installation of valves	%	20		40,000
3	Supply, manufacture and installation of spindle, actuator and headstock arrangement.	No	83,000	2	166,000.00
4	Instrumentation and software development Estimated only	Sum			1,000,000
	SUB TOTAL A				1,406,000
5	Landscaping (% of Sub total A)		None required		
6	Miscellaneous (% of Sub total A)	%	5		70,300
	SUB TOTAL B				1,476,300
7	Preliminary and General	%	10		147,630
8	Preliminary Works		Incl. in P&G		
9	Accomodation		Incl. in P&G		
	SUB TOTAL C				1,623,930
10	Contingencies (% of Sub total C)	%	15		243,590
	Sub Total D				1,867,520
11	Planning design & Supervision (% of Sub total D)	%	12		224,102
	Sub Total E				2,091,622
12	VAT (% of Sub total E)	%	14		292,827
	TOTAL PROJECT COST				**2,384,449**

PHASE 1A PHASE 1
COST MODEL : ITEM 11 Pipeline from Midmar Tunnel Outlet to Northern Feeder
1600 mm diameter pipeline - 1400 m long

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	2.8	33,600
1.2	(b) bush	ha	20,000	0.25	5,000
2	Road and River Crossings	Sum			500,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m3	35	11000	385,000
3.2	(b) Extra over for rock	m3	50	1100	55,000
3.3	(c) Bed preparation (Bedding)	m	70	4700	329,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	2,800	1400	3,920,000
4.2	(b) Laying and Jointing (% of(a))	%	20		784,000
4.3	(d) Cathodic Protection	km	50,000	1.4	70,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m3	850	80	68,000
6	Reinforcing	t	3,000	6.0	18,000
7	Mechanical Items				
7.1	(a) Valves etc	Sum			250,000
7.2	(b) Structural steelwork	t	8,000	1.5	12,000
8	Upgrade DV Harris offtake	Sum			300,000
	SUB TOTAL A				6,729,600
9	Landscaping (% of Sub total A)	%	5		336,480
10	Miscellaneous (% of Sub total A)	%	5		336,480
	SUB TOTAL B				7,402,560
11	Preliminary and General	%	15		1,110,384
12	Preliminary Works		Incl. in P&G		
13	Accomodation		Incl. in P&G		
	SUB TOTAL C				8,512,944
14	Contingencies (% of Sub total C)	%	15		1,276,942
	Sub Total D				9,789,886
15	Planning design & Supervision (% of Sub total D)	%	12		1,174,786
	Sub Total E				10,964,672
16	VAT (% of Sub total E)	%	14		1,535,054
	TOTAL PROJECT COST				**12,499,726**

SCHEME 1A PHASE 1

COST MODEL : ITEM 12 NORTHERN FEEDER PIPELINE TO UMLAAS ROAD RESERVOIR

37.9 km of 1650mm diameter

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	108.0	1,296,000
1.2	(b) bush	ha	20,000	6.0	120,000
2	Road and River Crossings	Sum			4,400,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m³	35	376600	13,181,000
3.2	(b) Extra over for rock	m³	50	37660	1,883,000
3.3	(c) Bed preparation (Bedding)	m	70	37900	2,653,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	3,000	37900	113,700,000
4.2	(b) Laying and Jointing (% of(a))	%	20		22,740,000
4.3	(c) E/O for steep slopes	m	2,000	1000	2,000,000
4.4	(d) Cathodic Protection	km	50,000	37.9	1,895,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m³	850	300	255,000
5.2	(b) Headwalls on steep slopes	m³	550	150	82,500
6	Reinforcing	t	3,000	103.5	310,500
7	20 Ml Balancing / Break Pressure Reservoir	Sum			4,500,000
8	Mechanical Items				
8.1	(a) Valves etc	Sum			2,150,000
	SUB TOTAL A				171,166,000
9	Landscaping (% of Sub total A)	%	5		8,558,300
10	Miscellaneous (% of Sub total A)	%	5		8,558,300
	SUB TOTAL B				188,282,600
11	Preliminary and General	%	15		28,242,390
12	Preliminary Works		Incl. in P&G		
13	Accomodation		Incl. in P&G		
	SUB TOTAL C				216,524,990
14	Contingencies (% of Sub total C)	%	15		32,478,749
	Sub Total D				249,003,739
15	Planning design & Supervision (% of Sub total D)	%	12		29,880,449
	Sub Total E				278,884,187
16	VAT (% of Sub total E)	%	14		39,043,786
	TOTAL PROJECT COST				**317,927,973**

SCHEME 1A PHASE 1
COST MODEL : ITEM 13 UMLAAS ROAD RESERVOIR 200Ml

No	Description	Unit	Rate Mar '98	Quantity	Amount
1.	Excavation to spoil	m3	15	35,000	525,000
2.	Cut to Fill	m3	20	30,000	600,000
3.	Mass Concrete	Sum			1,953,000
4	Structural Concrete	Sum			7,259,800
5	Formwork and Shuttering	Sum			8,206,600
6	Reinforcement	Sum			5,111,600
	PIPEWORK				
7	(a) civil	Sum			310,805
8	(b)mechanical/electrical	Sum			1,407,186
9	Miscellaneous	Sum			4,931,260
	Subtotal A (carried forward)				30,305,251
10	Preliminary, General and Preliminary works (% of Subtotal A)	%	20%	30,305,251	6,061,050
	Subtotal B				36,366,301
11	Contingencies (% of Subtotal B)	%	10%	36,366,301	3,636,630
	Subtotal C				40,002,931
12	Planning design & supervision, fees, time cost & transport (% of Subtotal C)	%	15%	40,002,931	6,000,440
	Subtotal D				46,003,371
13	VAT (% of Subtotal D)	%	14%	46,003,371	6,440,472
	TOTAL PROJECT COST				52,443,843

PHASE 1A PHASE 1
COST MODEL : ITEM 14 Advanced infrastructure Costs for Impendle Dam

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Preliminary Works				
1.1	(a) Access Roads	km	800,000	12.5	10,000,000
1.2	(b) Electricity to Site	Sum			1,770,000
	SUB TOTAL A				11,770,000
2	Contingencies (% of Sub total A)	%	10		1,177,000
	Sub Total B				12,947,000
3	Planning design & Supervision (% of Sub total B)	%	12		1,553,640
	Sub Total C				14,500,640
4	VAT (% of Sub total C)	%	14		2,030,090
	TOTAL PROJECT COST				**16,530,730**

SCHEME 1 A PHASE 2
COST MODEL : ITEM 1 Add. pipework at Midmar Dam Outlet

No	Description	Unit	Rate Mar '98	Quantity	Amount
1.	Supply and Fit/Lay Pipework	Sum			736,442
	Mechanical component				
2.	(a) 1200 Dia. Mag-Flow Meter	Sum			400,000
	(b) Valves	Sum			328,853
	Subtotal A (carried forward)				1,465,295
3	Electrical component (% of 2(a) and 2(b)	%	15.0%	728,853	109,328
4	Miscellaneous Civils (% of Subtotal A)	%	10%	1,465,295	146,530
	Subtotal B (carried forward)				1,721,152
5	Preliminary, General and Preliminary works (% of Subtotal B)	%	20%	1,721,152	344,230
	Subtotal C				2,065,383
6	Contingencies (% of Subtotal C)	%	10%	2,065,383	206,538
	Subtotal D				2,271,921
7	Planning design & supervision, fees, time cost & transport (% of Subtotal D)	%	15%	2,271,921	340,788
	Subtotal E				2,612,709
8	VAT (% of Subtotal E)	%	14%	2,612,709	365,779
	TOTAL PROJECT COST				2,978,489

SCHEME 1A PHASE 2
COST MODEL : ITEM 2 Midmar Pumpstation upsized by 580 Ml/day

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Mechanical and Electrical	%	64	13,239,458	8,473,253
2	Civils	%	36	13,239,458	4,766,205
	SUB TOTAL A				13,239,458
3	Landscaping (% of Sub total A)	%	2	13,239,458	264,789
4	Miscellaneous (% of Sub total A)	%	10	13,239,458	1,323,946
	SUB TOTAL B				14,828,193
5	Preliminary and General	%	20	14,828,193	2,965,639
6	Preliminary Works		Incl. in P&G		
7	Accomodation		Incl. in P&G		
	SUB TOTAL C				17,793,831
8	Contingencies (% of Sub total C)	%	10	17,793,831	1,779,383
	Sub Total D				19,573,214
9	Planning design & Supervision (% of Sub total D)	%	12	19,573,214	2,348,786
	Sub Total E				21,922,000
10	VAT (% of Sub total E)	%	14		3,069,080
	TOTAL PROJECT COST				**24,991,080**

Note : Pumpstation costs based on actual construction costs of existing large pumpstation escalated

SCHEME 1A PHASE 2
COST MODEL : ITEM 3 Add. Pipeline from Midmar Dam to Midmar Waterworks
1800mm diameter pipeline 1900m long

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	4.0	48,000
1.2	(b) bush	ha	20,000	0.5	10,000
2	Road and Railway Crossings	Sum			1,700,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m^3	35	16500	577,500
3.2	(b) Extra over for rock	m^3	50	1650	82,500
3.3	(c) Bed preparation (Bedding)	m	70	8900	623,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	3,500	1900	6,650,000
4.2	(b) Laying and Jointing (% of(a))	%	20		1,330,000
4.3	(d) Cathodic Protection	km	50,000	1.9	95,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m^3	850	150	127,500
6	Reinforcing	t	3,000	12.0	36,000
7	Mechanical Items				
7.1	(b) Structural steelwork	t	8,000	3	24,000
	SUB TOTAL A				11,303,500
8	Landscaping (% of Sub total A)	%	5		565,175
9	Miscellaneous (% of Sub total A)	%	5		565,175
	SUB TOTAL B				12,433,850
10	Preliminary and General	%	15		1,865,078
11	Preliminary Works		Incl. in P&G		
12	Accomodation		Incl. in P&G		
	SUB TOTAL C				14,298,928
13	Contingencies (% of Sub total C)	%	15		2,144,839
	Sub Total D				16,443,767
14	Planning design & Supervision (% of Sub total D)	%	12		1,973,252
	Sub Total E				18,417,019
15	VAT (% of Sub total E)	%	14		2,578,383
	TOTAL PROJECT COST				**20,995,401**

SCHEME 1A PHASE 2
COST MODEL : ITEM 4 Midmar Waterworks upsized by 580 Ml/day

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Mechanical and Electrical	%	30	166,817,167	50045150
2	Civils	%	70	166,817,167	116772017
	SUB TOTAL A				166,817,167
3	Landscaping (% of Sub total A)	%	2	166,817,167	3336343
4	Miscellaneous (% of Sub total A)	%	10	166,817,167	16681717
	SUB TOTAL B				186,835,227
5	Preliminary and General	%	20	186,835,227	37367045
6	Preliminary Works		Incl. in P&G		
7	Accomodation		Incl. in P&G		
	SUB TOTAL C				224,202,273
8	Contingencies (% of Sub total C)	%	10	224,202,273	22420227
	Sub Total D				246,622,500
9	Planning design & Supervision (% of Sub total D)	%	12	246,622,500	29594700
	Sub Total E				276,217,200
10	VAT (% of Sub total E)	%	14	276,217,200	38,670,408
	TOTAL PROJECT COST				**314,887,608**

Note : Waterworks costs based on actual construction costs of existing large waterworks escalated.

SCHEME 1A PHASE 2
COST MODEL : ITEM 5 Add. Pipeline from Midmar Waterworks to Stukkenberg Tunnel
1800 mm diameter pipeline - 3000 m long

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	6.0	72,000
1.2	(b) bush	ha	20,000	1.0	20,000
2	Road and River Crossings	Sum			700,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m3	35	26000	910,000
3.2	(b) Extra over for rock	m3	50	2600	130,000
3.3	(c) Bed preparation (Bedding)	m	70	14000	980,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	3,500	3000	10,500,000
4.2	(b) Laying and Jointing (% of(a))	%	20		2,100,000
4.3	(c) E/O for steep slopes	m	2,000	100	200,000
4.4	(d) Cathodic Protection	km	50,000	3.0	150,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m3	850	160	136,000
5.2	(b) Headwalls on steep slopes	m3	550	100	55,000
6	Reinforcing	t	3,000	6.0	18,000
7	Mechanical Items				
7.1	(a) Valves etc	Sum			200,000
7.2	(b) Structural steelwork	t	8,000	3	24,000
	SUB TOTAL A				16,195,000
8	Landscaping (% of Sub total A)	%	5		809,750
9	Miscellaneous (% of Sub total A)	%	5		809,750
	SUB TOTAL B				17,814,500
10	Preliminary and General	%	15		2,672,175
11	Preliminary Works		Incl. in P&G		
12	Accomodation		Incl. in P&G		
	SUB TOTAL C				20,486,675
13	Contingencies (% of Sub total C)	%	15		3,073,001
	Sub Total D				23,559,676
14	Planning design & Supervision (% of Sub total D)	%	12		2,827,161
	Sub Total E				26,386,837
15	VAT (% of Sub total E)	%	14		3,694,157
	TOTAL PROJECT COST				**30,080,995**

SCHEME 1A PHASE 2
COST MODEL : ITEM 6 Add. Pipeline from Stukkenberg Tunnel to Midmar Reservoir
1800 mm diameter pipeline - 1100 m long

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	2.6	31,200
1.2	(b) bush	ha	20,000	0.25	5,000
2	Road and River Crossings	Sum			500,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m3	35	11000	385,000
3.2	(b) Extra over for rock	m3	50	1100	55,000
3.3	(c) Bed preparation (Bedding)	m	70	6000	420,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	3,500	1300	4,550,000
4.2	(b) Laying and Jointing (% of(a))	%	20		910,000
4.3	(c) E/O for steep slopes	m			
4.4	(d) Cathodic Protection	km	50,000	1.3	65,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m3	850	60	51,000
5.2	(b) Headwalls on steep slopes	m3			
6	Reinforcing	t	3,000	5.0	15,000
7	Mechanical Items				
7.1	(a) Valves etc	Sum			210,000
7.2	(b) Structural steelwork	t	8,000	1	8,000
	SUB TOTAL A				7,205,200
8	Landscaping (% of Sub total A)	%	5		360,260
9	Miscellaneous (% of Sub total A)	%	5		360,260
	SUB TOTAL B				7,925,720
10	Preliminary and General	%	15		1,188,858
11	Preliminary Works		Incl. in P&G		
12	Accomodation		Incl. in P&G		
	SUB TOTAL C				9,114,578
13	Contingencies (% of Sub total C)	%	15		1,367,187
	Sub Total D				10,481,765
14	Planning design & Supervision (% of Sub total D)	%	12		1,257,812
	Sub Total E				11,739,576
15	VAT (% of Sub total E)	%	14		1,643,541
	TOTAL PROJECT COST				**13,383,117**

SCHEME 1A PHASE 2
COST MODEL : ITEM 7 Upgrade existing Ferncliffe tunnel
Inlet pipework, upgrade and lining

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Steel pipe liners				
1.1	(a) Supply of pipes to site - 1800 mm diam.	m	3,500	1050	3,675,000
1.3	(b) Installation and grouting	%	300		11,025,000
2	Shotcreting : 100 mm	m3	1,500	2800	4,200,000
3	Concrete including Formwork				
	Inlet and outlet portal chambers	m3	850	101	85,850
4	Reinforcing	t	3,500	9	31,500
5	Mechanical Items				
5.1	(a) Valves / pressure doors etc	Sum		180,000	180,000
5.2	(b) Structural steelwork	t	8,000	0.5	4,000
	SUB TOTAL A				19,201,350
6	Landscaping (% of Sub total A)	%	5		960,068
7	Miscellaneous (% of Sub total A)	%	5		960,068
	SUB TOTAL B				21,121,485
8	Preliminary and General	%	20		4,224,297
9	Preliminary Works		Incl. in P&G		
10	Accomodation		Incl. in P&G		
	SUB TOTAL C				25,345,782
11	Contingencies (% of Sub total C)	%	15		3,801,867
	Sub Total D				29,147,649
12	Planning design & Supervision (% of Sub total D)	%	12		3,497,718
	Sub Total E				32,645,367
13	VAT (% of Sub total E)	%	14		4,570,351
	TOTAL PROJECT COST				**37,215,719**

SCHEME 1A PHASE 2
COST MODEL : ITEM 7+ Midmar/Ferncliffe outlet control structure
Outlet pipework and control structure

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Earthworks				
1.1	(a) Clearing and grubbing	ha	12,000	0.2	2,400
1.2	(b) Excavation - soft	m3	20	3000	60,000
2	Concrete - structural	m3	380	1475	560,500
3	Formwork				
3.1	(a) Smooth vertical	m2	155	3760	582,800
3.2	(b) Smooth horizontal	m2	155	506	78,430
4	Reinforcing	t	3,000	118	354,000
5	Mechanical items				
5.1	Valves etc	Sum			850,000
5.2	Structural steelwork	t	8,000	3	24,000
5.3	Pipework to spill structure	Sum			2,000,000
5.4	Pipework from tunnels	Sum			2,000,000
6	Miscellaneous				
6.1	Joints	m	100	100	10,000
6.2	Instrumentation and software	Sum			1,000,000
	SUB TOTAL A				7,522,130
7	Landscaping (% of Sub total A)	%	5		376,107
8	Miscellaneous (% of Sub total A)	%	5		376,107
	SUB TOTAL B				8,274,343
9	Preliminary and General	%	15		1,241,151
10	Preliminary Works		Incl. in P&G		
11	Accomodation		Incl. in P&G		
	SUB TOTAL C				9,515,494
12	Contingencies (% of Sub total C)	%	15		1,427,324
	Sub Total D				10,942,819
13	Planning design & Supervision (% of Sub total D)	%	12		1,313,138
	Sub Total E				12,255,957
14	VAT (% of Sub total E)	%	14		1,715,834
	TOTAL PROJECT COST				**13,971,791**

SCHEME 1A PHASE 2
COST MODEL : ITEM 8 Add. Pipeline from Midmar Tunnel Outlet to Northern Feeder
1600 mm diameter pipeline - 1400 m long

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	2.8	33,600
1.2	(b) bush	ha	20,000	0.25	5,000
2	Road and River Crossings	Sum			500,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m3	35	11000	385,000
3.2	(b) Extra over for rock	m3	50	1100	55,000
3.3	(c) Bed preparation (Bedding)	m	70	4700	329,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	2,800	1400	3,920,000
4.2	(b) Laying and Jointing (% of(a))	%	20		784,000
4.3	(d) Cathodic Protection	km	50,000	1.4	70,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m3	850	80	68,000
5.2	(b) Headwalls on steep slopes	m3			
6	Reinforcing	t	3,000	8.0	24,000
7	Mechanical Items				
7.1	(a) Valves etc	Sum			250,000
7.2	(b) Structural steelwork	t	8,000	1.5	12,000
	SUB TOTAL A				6,435,600
8	Landscaping (% of Sub total A)	%	5		321,780
9	Miscellaneous (% of Sub total A)	%	5		321,780
	SUB TOTAL B				7,079,160
10	Preliminary and General	%	15		1,061,874
11	Preliminary Works		Incl. in P&G		
12	Accomodation		Incl. in P&G		
	SUB TOTAL C				8,141,034
13	Contingencies (% of Sub total C)	%	15		1,221,155
	Sub Total D				9,362,189
14	Planning design & Supervision (% of Sub total D)	%	12		1,123,463
	Sub Total E				10,485,652
15	VAT (% of Sub total E)	%	14		1,467,991
	TOTAL PROJECT COST				**11,953,643**

SCHEME 1A PHASE 2

COST MODEL : ITEM 9 ADD. NORTHERN FEEDER PIPELINE TO UMLAAS ROAD RESERVOIR

37.5 KM OF 1650mm DIAMETER

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	108.0	1,296,000
1.2	(b) bush	ha	20,000	6.0	120,000
2	Road and River Crossings	Sum			3,650,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m³	35	376600	13,181,000
3.2	(b) Extra over for rock	m³	50	37660	1,883,000
3.3	(c) Bed preparation (Bedding)	m	70	37900	2,653,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	3,000	37900	113,700,000
4.2	(b) Laying and Jointing (% of(a))	%	20		22,740,000
4.3	(c) E/O for steep slopes	m	2,000	1000	2,000,000
4.4	(d) Cathodic Protection	km	50,000	37.9	1,895,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m³	850	300	255,000
5.2	(b) Headwalls on steep slopes	m³	550	150	82,500
6	Reinforcing	t	3,000	103.5	310,500
7	Mechanical Items				
7.1	(a) Valves etc	Sum			1,400,000
	SUB TOTAL A				165,166,000
8	Landscaping (% of Sub total A)	%	5		8,258,300
9	Miscellaneous (% of Sub total A)	%	5		8,258,300
	SUB TOTAL B				181,682,600
10	Preliminary and General	%	15		27,252,390
11	Preliminary Works		Incl. in P&G		
12	Accomodation		Incl. in P&G		
	SUB TOTAL C				208,934,990
13	Contingencies (% of Sub total C)	%	15		31,340,249
	Sub Total D				240,275,239
14	Planning design & Supervision (% of Sub total D)	%	12		28,833,029
	Sub Total E				269,108,267
15	VAT (% of Sub total E)	%	14		37,675,157
	TOTAL PROJECT COST				**306,783,425**

SCHEME 1A PHASE 3
COST MODEL : ITEM 1 IMPENDLE DAM (RAISING FROM 1184masl TO FSL 1197masl)

No	Description	Unit	Rate Mar '98	Quantity	Amount
1.	Site and basin clearing	ha	1,875	769	1,440,750
2	Excavation				
	(a) all materials	m3	13	231,079	3,094,145
	(b) extra over for rock	m3	24	23,210	559,349
3	Preparation of solum				
	(b) for embankment	m2	8	22,780	182,926
	(c) core trench	m2	16	464	7,458
4	Drilling and Grouting				
	(a) curtain grouting	m Drill	150	1,275	191,238
	(b) consolidation grouting	m Drill	150	168	25,179
5	Embankment				
	(a) Earthfill Core	m3	18	183,470	3,324,475
	(b) rockfill	m3	28	1,569,196	44,423,929
	(c) filters	m3	59	52,649	3,102,104
	(d) rip-rap	m3	33	25,591	856,772
	(e) road layerworks	m2	80	5,460	436,800
6	SPILLWAY				
	(a) Excavation e/o to quarry	m3	10	80,000	800,000
	(b) Formwork	m3	67	15,108	1,011,500
	(c) Structural Concrete	m3	319	18,645	5,954,600
	(d) Mass Concrete	m3	248	4,234	1,050,000
	(e) Anchors and steel rebars	t	3,348	1,228	4,110,000
	(f) Drill for Anchors	m Drill	50	34,000	1,700,000
	(g) Road Bridge over Spillway	Sum			1,900,000
	(h)Demolish Phase 1 Structs	Sum			500,000
8	OUTLET STRUCTURE				
	(a) civil	Sum			1,046,000
	(b) mechanical/electrical	Sum			172,000
	(c) Pipework	Sum			502,000
9	Landscaping (% of 1-8)	%	5%	76,391,225	3,819,561
10	Miscellaneous (% of 1-8)	%	10%	76,391,225	7,639,122
	Subtotal A (carried forward)				87,849,908
11	Preliminary, General and Preliminary works (% of Subtotal A)	%	20%	87,849,908	17,569,982
	Subtotal B				105,419,890
12	Contingencies (% of Subtotal B)	%	10%	105,419,890	10,541,989
	Subtotal C				115,961,879
13	Planning design & supervision, fees, time cost & transport (% of Subtotal C)	%	15%	115,961,879	17,394,282
	Subtotal D				133,356,161
14	VAT (% of Subtotal D)	%	14%	133,356,161	18,669,863
	TOTAL PROJECT COST				152,026,023

SCHEME 1A
PUMPING COSTS

Power costs : Miniflex structure

Rates obtained from Eskom.

Basic charge	per month	53.05
Demand charge	No demand charge - assumed that Umgeni Water will go to Miniflex structure as proposed for Mearns scheme.	

Energy charges :

High demand : April - September (c/kWh)

Peak	c/kWh	30.54
Standard	c/kWh	11.23
Off-peak	c/kWh	6.44
Average	*c/kWh*	*16.07*

Low demand : October - March (c/kWh)

Peak	c/kWh	27.49
Standard	c/kWh	10.08
Off-peak	c/kWh	5.80
Average	*c/kWh*	*14.46*

Weighted annual average rate : (12 months - assume constant pumping all year round)
Rate 15.26 c/kWh

Parameter		Unit	Scheme 1a		
			Phase 1	Phase 2	Phase 3
FSL		masl			
Min operating level		masl			
Average operating level		masl			
Inlet		masl			
Flow		**m3/s**	**5.30**	**9.43**	**10.60**
Friction head *		m			
Total head	Min	m	8	8	8
	Max	m	32	32	32
	Average	m	20	20	20
Pump efficiency **			0.90	0.90	0.90
Motor efficiency **			0.97	0.97	0.97
Power requirement		MW	1.19	2.12	2.38
Monthly energy ***		MWh	872	1551	1744
Total pumped per month * **		**m3.10E6**	**13.97**	**24.85**	**27.93**
Total pumped per annum		**m3.10E6**	**167.60**	**298.20**	**335.20**
<u>*Monthly charges*</u>					
Energy charge			133,083	236,786	266,165
Reactive energy charge		Not considered - high efficiency (pf=0.96) gives low reactiv			
Basic charge			53	53	53
	Subtotal		133,136	236,840	266,218
Transmission surcharge (1%)			1,331	2,368	2,662
Voltage discount (5%)			-6,657	-11,842	-13,311
	Subtotal		**127,810**	**227,366**	**255,569**
Contingency (20%)			**25,562**	**45,473**	**51,114**
	Total per month		**153,372**	**272,839**	**306,683**
	Total per annum		**1,840,466**	**3,274,070**	**3,680,200**
Unit cost		**c/m3**	**1.10**	**1.10**	**1.10**

Check (c/m3/100m)		5.49	5.49	5.49

* Based on 250 m long, twin 1800 mm diam line (n = 0.012)
** VAPS recommendation
*** 30.5 days per month

SCHEME 1B

SCHEME 1B PHASE 1
COST MODEL : ITEM 1 IMPENDLE DAM FSL =1184masl (1.0 MAR)

No	Description	Unit	Rate Mar '98	Quantity	Amount
1.	Site and basin clearing	ha	1,875	1,025	1,921,000
2.	River diversion				
	(a) Diversion Tunnel 350m long	Sum			11,000,000
	(b) Coffer Dams	Sum			8,608,231
	(c)Structural Concrete to Diversion Works	Sum			2,825,260
	(d) Foundation Prep. and Dealing with Water	Sum			500,000
3.	Excavation				
	(a) all materials	m3	13	340,094	4,553,858
	(b) extra over for rock	m3	24	114,319	2,755,084
4.	Preparation of solum				
	(b) for embankment	m2	8	73,584	590,882
	(c) core trench	m2	16	21,840	350,967
5.	Drilling and Grouting				
	(a) curtain grouting	m Drill	150	6,651	997,420
	(b) consolidation grouting	m Drill	150	3,476	521,348
6.	Embankment				
	(a) Earthfill Core	m3	18	827,124	14,987,484
	(b) rockfill	m3	28	2,527,698	71,559,143
	(c) filters	m3	59	189,665	11,175,050
	(d) rip-rap	m3	33	92,188	3,086,442
	(e) road layerworks	m2	80	4,900	392,000
7	SPILLWAY				
	(a) Excavation e/o to quarry	m3	10	710,000	7,100,000
	(b) Formwork	m3	67	20,022	1,340,500
	(c) Structural Concrete	m3	319	33,792	10,792,000
	(d) Mass Concrete	m3	248	10,523	2,610,000
	(e) Anchors and steel rebars	t	3,348	2,330	7,800,000
	(f) Drill for Anchors	m Drill	50	88,000	4,400,000
	(g) Road Bridge over Spillway	Sum			1,900,000
8	OUTLET STRUCTURE				
	(a) civil	Sum			6,970,000
	(b) mechanical/electrical	Sum			9,704,500
	(c) Pipework	Sum			15,335,500
	(d) Measuring weir	Sum			500,000
9	Landscaping (% of 1-8)	%	5%	204,276,669	10,213,833
10	Miscellaneous (% of 1-8)	%	10%	204,276,669	20,427,667
	Subtotal A (carried forward)				234,918,169
11	Preliminary, General and Preliminary works (% of Subtotal A)	%	20%	234,918,169	46,983,634
	Subtotal B				281,901,803
12	Contingencies (% of Subtotal B)	%	10%	281,901,803	28,190,180
	Subtotal C				310,091,983
13	Planning design & supervision, fees, time cost & transport (% of Subtotal C)	%	15%	310,091,983	46,513,797
	Subtotal D				356,605,781
14	VAT (% of Subtotal D)	%	14%	356,605,781	49,924,809
	TOTAL PROJECT COST				406,530,590

SCHEME 1B PHASE 1
COST MODEL : ITEM 2 Tunnel from Impendle Dam to Midmar Dam
Pressure flow
TBM Tunnel 3,5 m diameter
D & B Tunnel 5,5 by 6 m high

Tunnel Length: 34900m
1 Up from outlet TBM - 7900m
1 Up from 2/3 point - 13500m
1 Down from inlet - 13500m
1 DB Adit - 1350m at 1:10

No	Description	Unit	Rate	Quantity	Amount
1	Portal excavations				
	a. Inlet portal	Sum	3,000,000	1	3,000,000
	b. Outlet portal	Sum	2,000,000	1	2,000,000
	b. Intermediate	Sum	2,500,000	1	2,500,000
2	Tunnel Excavation				
	TBM				
	b. Rock Class II	m3	340	57081	19,407,674
	c. Rock Class III	m3	350	218252	76,388,335
	d. Rock Class IV	m3	400	53724	21,489,466
	e. Rock Class V	m3	1,000	6715	6,715,458
	D & B (Adits)				
	c. Rock Class III	m3	180	36,531	6,575,580
	d. Rock Class IV	m3	200	7,128	1,425,600
	e. Rock Class V	m3	550	891	490,050
3	Extra for down grade drive	m	1,500	13,500	20,250,000
4	Extra for length of drive over 10 km	m	1,000	7,000	7,000,000
5	Turning Chamber	No	250,000	2	500,000
6	Dealing with Water	m	15	36,250	543,750
7	Shafts				
	a. Ventilation	m	3,000	1,000	3,000,000
	b. Surge	m	8,000	130	1,040,000
8	Rock support				
	a. i) Rockbolts - TBM	m	250	34,900	8,725,000
	a. ii) Rockbolts - D & B	m	380	1,350	513,000
	b. Shotcrete	m3	1,400	731	1,023,806
9	Concrete				
	a. Linings	m3	550	77,431	42,587,161
	b. Overbreak concrete : TBM	m2	100	377,973	37,797,287
	c. Overbreak concrete : DBT	m2			
	d. Concrete - D & B Invert blinding	m3	400	2,025	810,000
	e. Concrete : Structures	m3	380	650	247,000
10	Formwork				
	a. Smooth curved in tunnel	m2	150	282,727	42,409,011
	b. Structures	m2	155	3,200	496,000
11	Reinforcement	ton	3,000	52	156,000
12	Pre-cast concrete inverts	m	290	34,375	9,968,750
	SUBTOTAL : MEASURED ITEMS				**317,058,927**

SCHEME 1B PHASE 1
COST MODEL : ITEM 2 Tunnel from Impendle Dam to Midmar Dam

IMPENDLE TUNNEL - PRESSURE FLOW

No	Description	Unit	Rate	Quantity	Amount
	SUBTOTAL : MEASURED ITEMS				**317,058,927**
13	Grouting				
	i) Cavity	m	200	34,375	6,875,000
	ii) Consolidation/Fissure	m	7	34,375	240,625
14	Waterproof lining				
	a. Steel liners	m	26,000	525	13,650,000
	b. Waterproof membrane	m2	300	9,100	2,730,000
15	Intake Pipeline : Twin 1600 dia pipeline	m	14,000	250	3,500,000
16	Miscellaneous	%	10	**344,054,552**	34,405,455
	SUBTOTAL A				**378,460,007**
17.1	P & G Fixed	Sum	1	27,000,000	27,000,000
17.2	P & G Time Related - Establishment	Sum	1	9,800,000	9,800,000
17.3	P & G Time Related - TBM Excavation	Sum	1	68,200,000	68,200,000
17.4	P & G Time Related - Adit Excavation	Sum	1	10,400,000	10,400,000
17.5	P & G Time Related - Lining	Sum	1	38,150,000	38,150,000
18	Preliminary works		Incl. in P&G		
19	Accommodation		Incl. in P&G		
	SUBTOTAL B				**532,010,007**
20	Contingencies (% of Subtotal B)	%	10	532,010,007	53,201,001
	SUBTOTAL C				**585,211,007**
21	Planning, design and supervision (% of Subtotal C)	%	12	585,211,007	70,225,321
	SUBTOTAL D				**655,436,328**
22	VAT (% of Subtotal D)	%	14	655,436,328	91,761,086
	TOTAL PROJECT COST				**747,197,414**

Construction Period = 62 months
5.2 years

SCHEME 1B PHASE 1
COST MODEL : ITEM 3 Additional Pipework at Midmar Dam Outlet

No	Description	Unit	Rate Mar '98	Quantity	Amount
1.	Supply and Fit/Lay Pipework	Sum			1,078,027
2.	Mechanical component (a) 1200 Dia. Mag-Flow Meter (b) Valves	 Sum Sum			 400,000 918,000
	Subtotal A (carried forward)				2,396,027
3	Electrical component (% of 2(a) and 2(b)	%	15%	1,318,000	197,700
4	Miscellaneous Civils (% of Subtotal A)	%	10%	2,396,027	239,603
	Subtotal B (carried forward)				2,833,330
5	Preliminary, General and Preliminary works (% of Subtotal B)	%	20%	2,833,330	566,666
	Subtotal C				3,399,996
6	Contingencies (% of Subtotal C)	%	10%	3,399,996	340,000
	Subtotal D				3,739,995
7	Planning design & supervision, fees, time cost & transport (% of Subtotal D)	%	15%	3,739,995	560,999
	Subtotal E				4,300,994
8	VAT (% of Subtotal E)	%	14%	4,300,994	602,139
	TOTAL PROJECT COST				4,903,134

SCHEME 1B PHASE 1
COST MODEL : ITEM 4 Midmar Pumpstation upsized by 509 Ml/day

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Mechanical and Electrical	%	64	11,578,838	7,410,457
2	Civils	%	36	11,578,838	4,168,382
	SUB TOTAL A				11,578,838
3	Landscaping (% of Sub total A)	%	2	11,578,838	231,577
4	Miscellaneous (% of Sub total A)	%	10	11,578,838	1,157,884
	SUB TOTAL B				12,968,299
5	Preliminary and General	%	20	12,968,299	2,593,660
6	Preliminary Works		Incl. in P&G		
7	Accomodation		Incl. in P&G		
	SUB TOTAL C				15,561,959
8	Contingencies (% of Sub total C)	%	10	15,561,959	1,556,196
	Sub Total D				17,118,155
9	Planning design & Supervision (% of Sub total D)	%	12	17,118,155	2,054,179
	Sub Total E				19,172,333
10	VAT (% of Sub total E)	%	14		2,684,127
	TOTAL PROJECT COST				**21,856,460**

Note : Pumpstation costs based on actual construction costs of existing large pumpstation escalated

SCHEME 1B PHASE 1
COST MODEL : ITEM 5 Pipeline from Midmar dam to Midmar Waterworks
1600mm diameter pipeline 1900m long

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	3.8	45,600
1.2	(b) bush	ha	20,000	0.5	10,000
2	Road and Railway Crossings	Sum			1,700,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m³	35	14930	522,550
3.2	(b) Extra over for rock	m³	50	1493	74,650
3.3	(c) Bed preparation (Bedding)	m	70	8010	560,700
4	Pipelines				
4.1	(a) Supply of pipes to site	m	2,800	1900	5,320,000
4.2	(b) Laying and Jointing (% of(a))	%	20		1,064,000
4.3	(d) Cathodic Protection	km	50,000	1.9	95,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m³	850	150	127,500
6	Reinforcing	t	3,000	12.0	36,000
7	Mechanical Items				
7.1	(b) Structural steelwork	t	8,000	3	24,000
	SUB TOTAL A				9,580,000
8	Landscaping (% of Sub total A)	%	5		479,000
9	Miscellaneous (% of Sub total A)	%	5		479,000
	SUB TOTAL B				10,538,000
10	Preliminary and General	%	15		1,580,700
11	Preliminary Works		Incl. in P&G		
12	Accomodation		Incl. in P&G		
	SUB TOTAL C				12,118,700
13	Contingencies (% of Sub total C)	%	15		1,817,805
	Sub Total D				13,936,505
14	Planning design & Supervision (% of Sub total D)	%	12		1,672,381
	Sub Total E				15,608,886
15	VAT (% of Sub total E)	%	14		2,185,244
	TOTAL PROJECT COST				**17,794,130**

SCHEME 1B PHASE 1
COST MODEL : ITEM 6 Midmar Waterworks upsized by 509 Ml/day

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Mechanical and Electrical	%	30	145,893,364	43,768,009
2	Civils	%	70	145,893,364	102,125,355
	SUB TOTAL A				145,893,364
3	Landscaping (% of Sub total A)	%	2	145,893,364	2,917,867
4	Miscellaneous (% of Sub total A)	%	10	145,893,364	14,589,336
	SUB TOTAL B				163,400,568
5	Preliminary and General	%	20	163,400,568	32,680,114
6	Preliminary Works		Incl. in P&G		
7	Accomodation		Incl. in P&G		
	SUB TOTAL C				196,080,682
8	Contingencies (% of Sub total C)	%	10	196,080,682	19,608,068
	Sub Total D				215,688,750
9	Planning design & Supervision (% of Sub total D)	%	12	215,688,750	25,882,650
	Sub Total E				241,571,400
10	VAT (% of Sub total E)	%	14	241,571,400	33,819,996
	TOTAL PROJECT COST				**275,391,396**

Note : Waterworks costs based on actual construction costs of existing large waterworks escalated.

SCHEME 1B PHASE 1
COST MODEL : ITEM 7 Pipeline from Midmar Waterworks to Stukkenberg Tunnel
1700mm daimeter pipeline-3000m long

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	5.8	69,600
1.2	(b) bush	ha	20,000	1.0	20,000
2	Road and River Crossings	Sum			2,200,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m³	35	24,772	867,020
3.2	(b) Extra over for rock	m³	50	2,477	123,860
3.3	(c) Bed preparation (Bedding)	m	70	12,600	882,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	3,150	3,000	9,450,000
4.2	(b) Laying and Jointing (% of(a))	%	20		1,890,000
4.3	(c) E/O for steep slopes	m	2,000	100	200,000
4.4	(d) Cathodic Protection	km	50,000	3.0	150,000
4.5	(e) E/O for removal of existing line	m	195	3,000	585,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m³	850	160	136,000
5.2	(b) Headwalls on steep slopes	m³	550	100	55,000
6	Reinforcing	t	3,000	13	39,000
7	Mechanical Items				
7.1	(a) Valves etc	Sum			200,000
7.2	(b) Structural steelwork	t	8,000	3	24,000
	SUB TOTAL A				16,891,480
8	Landscaping (% of Sub total A)	%	5		844,574
9	Miscellaneous (% of Sub total A)	%	5		844,574
	SUB TOTAL B				18,580,628
10	Preliminary and General	%	15		2,787,094
11	Preliminary Works		Incl. in P&G		
12	Accomodation		Incl. in P&G		
	SUB TOTAL C				21,367,722
13	Contingencies (% of Sub total C)	%	15		3,205,158
	Sub Total D				24,572,881
14	Planning design & Supervision (% of Sub total D)	%	12		2,948,746
	Sub Total E				27,521,626
15	VAT (% of Sub total E)	%	14		3,853,028
	TOTAL PROJECT COST				**31,374,654**

SCHEME 1B PHASE 1
COST MODEL : ITEM 8 STUKKENBERGS TUNNEL - PRESSURE
D & B 3.6 m x 3.6 m

Tunnel Length: 2025 m
Drill and blast

No	Description	Unit	Rate	Quantity	Amount
1	Portal excavations				
	a. Inlet portal	Sum	2,000,000	1	2,000,000
	b. Outlet portal	Sum	2,000,000	1	2,000,000
2	Tunnel Excavation	m	6,500	2,025	13,162,500
3	Rock support				
	a. Support class A	m	50	615	30,750
	b. Support class B	m	100	615	61,500
	c. Support class C	m	170	615	104,550
	d. Support class D	m	980	105	102,900
	e. Support class E	m	3,300	100	330,000
4	Waterproof lining				
	a. Steel liners	m	3,300	100	330,000
	b. Waterproof membrane	m	6,000	1,950	11,700,000
5	Miscellaneous	%	10	29,822,200	2,982,220
	SUBTOTAL A				**32,804,420**
6.1	P & G Fixed	Sum	1	5,725,000	5,725,000
6.2	P & G Time Related - Establishment	Sum	1	1,035,000	1,035,000
6.3	P & G Time Related - Excavation	Sum	1	5,750,000	5,750,000
6.4	P & G Time Related - Lining	Sum	1	4,600,000	4,600,000
7	Preliminary works		Incl. in P&G		
8	Accommodation		Incl. in P&G		
	SUBTOTAL B				**49,914,420**
9	Contingencies (% of Subtotal B)	%	10	49,914,420	4,991,442
	SUBTOTAL C				**54,905,862**
10	Planning, design and supervision (% of Subtotal C)	%	12	54,905,862	6,588,703
	SUBTOTAL D				**61,494,565**
11	VAT (% of Subtotal D)	%	14	61,494,565	8,609,239
	TOTAL PROJECT COST				**70,103,805**

Construction Period = 24 months
2.0 years

SCHEME 1B PHASE1
COST MODEL : ITEM 9 Pipeline from Stukkenberg Tunnel to Midmar Reservoir
1700mm daimeter pipeline-1100m long

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	2.0	24,000
1.2	(b) bush	ha	20,000	0.30	6,000
2	Road and River Crossings	Sum			500,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m³	35	9083	317,905
3.2	(b) Extra over for rock	m³	50	908.3	45,415
3.3	(c) Bed preparation (Bedding)	m	70	4590	321,300
4	Pipelines				
4.1	(a) Supply of pipes to site	m	3,150	1100	3,465,000
4.2	(b) Laying and Jointing (% of(a))	%	20		693,000
4.3	(d) Cathodic Protection	km	50,000	1.1	55,000
4.4	(e) E/O for removal of existing line	m	195	1100.0	214,500
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m³	850	60	51,000
6	Reinforcing	t	3,000	5.0	15,000
7	Mechanical Items				
7.1	(a) Valves etc	Sum			210,000
7.2	(b) Structural steelwork	t	8,000	1	8,000
	SUB TOTAL A				5,926,120
8	Landscaping (% of Sub total A)	%	5		296,306
9	Miscellaneous (% of Sub total A)	%	5		296,306
	SUB TOTAL B				6,518,732
10	Preliminary and General	%	15		977,810
11	Preliminary Works		Incl. in P&G		
12	Accomodation		Incl. in P&G		
	SUB TOTAL C				7,496,542
13	Contingencies (% of Sub total C)	%	15		1,124,481
	Sub Total D				8,621,023
14	Planning design & Supervision (% of Sub total D)	%	12		1,034,523
	Sub Total E				9,655,546
15	VAT (% of Sub total E)	%	14		1,351,776
	TOTAL PROJECT COST				**11,007,322**

SCHEME 1B PHASE 1
COST MODEL : ITEM 10 Midmar Reservoir
Installation of sleeve valves, instrumentation and software

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Supply of 2 No 1000 mm diam., 600 Kpa, sleeve valves.	No	100,000	2	200,000
2	Installation of valves	%	20		40,000
3	Supply, manufacture and installation of spindle, actuator and headstock arrangement.	No	83,000	2	166,000.00
4	Instrumentation and software development Estimated only	Sum			1,000,000
	SUB TOTAL A				1,406,000
5	Landscaping (% of Sub total A)		None required		
6	Miscellaneous (% of Sub total A)	%	5		70,300
	SUB TOTAL B				1,476,300
7	Preliminary and General	%	10		147,630
8	Preliminary Works		Incl. in P&G		
9	Accomodation		Incl. in P&G		
	SUB TOTAL C				1,623,930
10	Contingencies (% of Sub total C)	%	15		243,590
	Sub Total D				1,867,520
11	Planning design & Supervision (% of Sub total D)	%	12		224,102
	Sub Total E				2,091,622
12	VAT (% of Sub total E)	%	14		292,827
	TOTAL PROJECT COST				**2,384,449**

PHASE 1B PHASE 1
COST MODEL : ITEM 11 Pipeline from Midmar Tunnel Outlet to Northern Feeder
1600 mm diameter pipeline - 1400 m long

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	2.8	33,600
1.2	(b) bush	ha	20,000	0.25	5,000
2	Road and River Crossings	Sum			500,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m3	35	11000	385,000
3.2	(b) Extra over for rock	m3	50	1100	55,000
3.3	(c) Bed preparation (Bedding)	m	70	4700	329,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	2,800	1400	3,920,000
4.2	(b) Laying and Jointing (% of(a))	%	20		784,000
4.3	(d) Cathodic Protection	km	50,000	1.4	70,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m3	850	80	68,000
6	Reinforcing	t	3,000	6.0	18,000
7	Mechanical Items				
7.1	(a) Valves etc	Sum			250,000
7.2	(b) Structural steelwork	t	8,000	1.5	12,000
8	Upgrade DV Harris offtake	Sum			300,000
	SUB TOTAL A				6,729,600
9	Landscaping (% of Sub total A)	%	5		336,480
10	Miscellaneous (% of Sub total A)	%	5		336,480
	SUB TOTAL B				7,402,560
11	Preliminary and General	%	15		1,110,384
12	Preliminary Works		Incl. in P&G		
13	Accomodation		Incl. in P&G		
	SUB TOTAL C				8,512,944
14	Contingencies (% of Sub total C)	%	15		1,276,942
	Sub Total D				9,789,886
15	Planning design & Supervision (% of Sub total D)	%	12		1,174,786
	Sub Total E				10,964,672
16	VAT (% of Sub total E)	%	14		1,535,054
	TOTAL PROJECT COST				**12,499,726**

SCHEME 1B PHASE 1

COST MODEL : ITEM 12 NORTHERN FEEDER PIPELINE TO UMLAAS ROAD RESERVOIR

37.9 km of 1650mm diameter

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	108.0	1,296,000
1.2	(b) bush	ha	20,000	6.0	120,000
2	Road and River Crossings	Sum			4,400,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m³	35	376,600	13,181,000
3.2	(b) Extra over for rock	m³	50	37,660	1,883,000
3.3	(c) Bed preparation (Bedding)	m	70	37,900	2,653,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	3,000	37,900	113,700,000
4.2	(b) Laying and Jointing (% of(a))	%	20		22,740,000
4.3	(c) E/O for steep slopes	m	2,000	1000	2,000,000
4.4	(d) Cathodic Protection	km	50,000	37.9	1,895,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m³	850	300	255,000
5.2	(b) Headwalls on steep slopes	m³	550	150	82,500
6	Reinforcing	t	3,000	103.5	310,500
7	20 Ml Balancing / Break Pressure Reservoir	Sum	4,500,000	1.0	4,500,000
8	Mechanical Items				
8.1	(a) Valves etc	Sum			2,150,000
	SUB TOTAL A				171,166,000
9	Landscaping (% of Sub total A)	%	5		8,558,300
10	Miscellaneous (% of Sub total A)	%	5		8,558,300
	SUB TOTAL B				188,282,600
11	Preliminary and General	%	15		28,242,390
12	Preliminary Works		Incl. in P&G		
13	Accomodation		Incl. in P&G		
	SUB TOTAL C				216,524,990
14	Contingencies (% of Sub total C)	%	15		32,478,749
	Sub Total D				249,003,739
15	Planning design & Supervision (% of Sub total D)	%	12		29,880,449
	Sub Total E				278,884,187
16	VAT (% of Sub total E)	%	14		39,043,786
	TOTAL PROJECT COST				**317,927,973**

SCHEME 1B PHASE 1
COST MODEL : ITEM 13 UMLAAS ROAD RESERVOIR 200 Ml

No	Description	Unit	Rate Mar '98	Quantity	Amount
1.	Excavation to spoil	m3	15	35,000	525,000
2.	Cut to Fill	m3	20	30,000	600,000
3.	Mass Concrete	Sum			1,953,000
4	Structural Concrete	Sum			7,259,800
5	Formwork and Shuttering	Sum			8,206,600
6	Reinforcement	Sum			5,111,600
	PIPEWORK				
7	(a) civil	Sum			310,805
8	(b)mechanical/electrical	Sum			1,407,186
9	Miscellaneous	Sum			4,931,260
	Subtotal A (carried forward)				30,305,251
10	Preliminary, General and Preliminary works (% of Subtotal A)	%	20%	30,305,251	6,061,050
	Subtotal B				36,366,301
11	Contingencies (% of Subtotal B)	%	10%	36,366,301	3,636,630
	Subtotal C				40,002,931
12	Planning design & supervision, fees, time cost & transport (% of Subtotal C)	%	15%	40,002,931	6,000,440
	Subtotal D				46,003,371
13	VAT (% of Subtotal D)	%	14%	46,003,371	6,440,472
	TOTAL PROJECT COST				52,443,843

PHASE 1B PHASE 1
COST MODEL : ITEM 14 Advanced infrastructure Costs for Impendle Dam

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Preliminary Works				
1.1	(a) Access Roads	km	800,000	12.5	10,000,000
1.2	(b) Electricity to Site	Sum			1,770,000
	SUB TOTAL A				11,770,000
2	Contingencies (% of Sub total A)	%	10		1,177,000
	Sub Total B				12,947,000
3	Planning design & Supervision (% of Sub total B)	%	12		1,553,640
	Sub Total C				14,500,640
4	VAT (% of Sub total C)	%	14		2,030,090
	TOTAL PROJECT COST				**16,530,730**

SCHEME 1B PHASE 2
COST MODEL : ITEM 1 Add. pipework at Midmar Dam Outlet

No	Description	Unit	Rate Mar '98	Quantity	Amount
1.	Supply and Fit/Lay Pipework	Sum			736,442
	Mechanical component				
2.	(a) 1200 Dia. Mag-Flow Meter	Sum			400,000
	(b) Valves	Sum			328,853
	Subtotal A (carried forward)				1,465,295
3	Electrical component (% of 2(a) and 2(b)	%	15%	728,853	109,328
4	Miscellaneous Civils (% of Subtotal A)	%	10%	1,465,295	146,530
	Subtotal B (carried forward)				1,721,152
5	Preliminary, General and Preliminary works (% of Subtotal B)	%	20%	1,721,152	344,230
	Subtotal C				2,065,383
6	Contingencies (% of Subtotal C)	%	10%	2,065,383	206,538
	Subtotal D				2,271,921
7	Planning design & supervision, fees, time cost & transport (% of Subtotal D)	%	15%	2,271,921	340,788
	Subtotal E				2,612,709
8	VAT (% of Subtotal E)	%	14%	2,612,709	365,779
	TOTAL PROJECT COST				2,978,489

SCHEME 1B PHASE 2
COST MODEL : ITEM 2 Midmar Pumpstation upsized by 509 Ml/day

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Mechanical and Electrical	%	64	11,578,838	7,410,457
2	Civils	%	36	11,578,838	4,168,382
	SUB TOTAL A				11,578,838
3	Landscaping (% of Sub total A)	%	2	11,578,838	231,577
4	Miscellaneous (% of Sub total A)	%	10	11,578,838	1,157,884
	SUB TOTAL B				12,968,299
5	Preliminary and General	%	20	12,968,299	2,593,660
6	Preliminary Works		Incl. in P&G		
7	Accomodation		Incl. in P&G		
	SUB TOTAL C				15,561,959
8	Contingencies (% of Sub total C)	%	10	15,561,959	1,556,196
	Sub Total D				17,118,155
9	Planning design & Supervision (% of Sub total D)	%	12	17,118,155	2,054,179
	Sub Total E				19,172,333
10	VAT (% of Sub total E)	%	14		2,684,127
	TOTAL PROJECT COST				**21,856,460**

Note : Pumpstation costs based on actual construction costs of existing large pumpstation escalated

SCHEME 1B PHASE 2
COST MODEL : ITEM 3 Add. Pipeline from Midmar dam to Midmar Waterworks
1600mm diameter pipeline 1900m long

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	3.8	45,600
1.2	(b) bush	ha	20,000	0.5	10,000
2	Road and Railway Crossings	Sum			1,700,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m³	35	14930	522,550
3.2	(b) Extra over for rock	m³	50	1493	74,650
3.3	(c) Bed preparation (Bedding)	m	70	8010	560,700
4	Pipelines				
4.1	(a) Supply of pipes to site	m	2,800	1900	5,320,000
4.2	(b) Laying and Jointing (% of(a))	%	20		1,064,000
4.3	(d) Cathodic Protection	km	50,000	1.9	95,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m³	850	150	127,500
6	Reinforcing	t	3,000	12.0	36,000
7	Mechanical Items				
7.1	(b) Structural steelwork	t	8,000	3	24,000
	SUB TOTAL A				9,580,000
8	Landscaping (% of Sub total A)	%	5		479,000
9	Miscellaneous (% of Sub total A)	%	5		479,000
	SUB TOTAL B				10,538,000
10	Preliminary and General	%	15		1,580,700
11	Preliminary Works		Incl. in P&G		
12	Accomodation		Incl. in P&G		
	SUB TOTAL C				12,118,700
13	Contingencies (% of Sub total C)	%	15		1,817,805
	Sub Total D				13,936,505
14	Planning design & Supervision (% of Sub total D)	%	12		1,672,381
	Sub Total E				15,608,886
15	VAT (% of Sub total E)	%	14		2,185,244
	TOTAL PROJECT COST				**17,794,130**

SCHEME 1B PHASE 2
COST MODEL : ITEM 4 Midmar Waterworks upsized by 509 Ml/day

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Mechanical and Electrical	%	30	145,893,364	43,768,009
2	Civils	%	70	145,893,364	102,125,355
	SUB TOTAL A				145,893,364
3	Landscaping (% of Sub total A)	%	2	145,893,364	2,917,867
4	Miscellaneous (% of Sub total A)	%	10	145,893,364	14,589,336
	SUB TOTAL B				163,400,568
5	Preliminary and General	%	20	163,400,568	32,680,114
6	Preliminary Works		Incl. in P&G		
7	Accomodation		Incl. in P&G		
	SUB TOTAL C				196,080,682
8	Contingencies (% of Sub total C)	%	10	196,080,682	19,608,068
	Sub Total D				215,688,750
9	Planning design & Supervision (% of Sub total D)	%	12	215,688,750	25,882,650
	Sub Total E				241,571,400
10	VAT (% of Sub total E)	%	14		33,819,996
	TOTAL PROJECT COST				**275,391,396**

Note : Waterworks costs based on actual construction costs of existing large waterworks escalated.

SCHEME 1B Phase 2
COST MODEL : ITEM 5 Add. Pipeline from Midmar Waterworks to Stukkenberg Tunnel
1700mm daimeter pipeline-3000m long

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	5.8	69,600
1.2	(b) bush	ha	20,000	1.0	20,000
2	Road and River Crossings	Sum			700,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m^3	35	24772	867,020
3.2	(b) Extra over for rock	m^3	50	2477	123,860
3.3	(c) Bed preparation (Bedding)	m	70	12600	882,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	3,150	3000	9,450,000
4.2	(b) Laying and Jointing (% of(a))	%	20		1,890,000
4.3	(c) E/O for steep slopes	m	2,000	100	200,000
4.4	(d) Cathodic Protection	km	50,000	3.0	150,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m^3	850	160	136,000
5.2	(b) Headwalls on steep slopes	m^3	550	100	55,000
6	Reinforcing	t	3,000	6.0	18,000
7	Mechanical Items				
7.1	(a) Valves etc	Sum			200,000
7.2	(b) Structural steelwork	t	8,000	3	24,000
	SUB TOTAL A				14,785,480
8	Landscaping (% of Sub total A)	%	5		739,274
9	Miscellaneous (% of Sub total A)	%	5		739,274
	SUB TOTAL B				16,264,028
10	Preliminary and General	%	15		2,439,604
11	Preliminary Works		Incl. in P&G		
12	Accomodation		Incl. in P&G		
	SUB TOTAL C				18,703,632
13	Contingencies (% of Sub total C)	%	15		2,805,545
	Sub Total D				21,509,177
14	Planning design & Supervision (% of Sub total D)	%	12		2,581,101
	Sub Total E				24,090,278
15	VAT (% of Sub total E)	%	14		3,372,639
	TOTAL PROJECT COST				**27,462,917**

SCHEME 1B PHASE 2
COST MODEL : ITEM 6 Add. Pipeline from Stukkenberg Tunnel to Midmar Reservoir
1700mm daimeter pipeline-1300m long

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	2.3	27,600
1.2	(b) bush	ha	20,000	0.25	5,000
2	Road and River Crossings	Sum			500,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m³	35	10735	375,725
3.2	(b) Extra over for rock	m³	50	1073.5	53,675
3.3	(c) Bed preparation (Bedding)	m	70	5400	378,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	3,150	1300	4,095,000
4.2	(b) Laying and Jointing (% of(a))	%	20		819,000
4.3	(d) Cathodic Protection	km	50,000	1.3	65,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m³	850	60	51,000
6	Reinforcing	t	3,000	5.0	15,000
7	Mechanical Items				
7.1	(a) Valves etc	Sum			210,000
7.2	(b) Structural steelwork	t	8,000	1	8,000
	SUB TOTAL A				6,603,000
8	Landscaping (% of Sub total A)	%	5		330,150
9	Miscellaneous (% of Sub total A)	%	5		330,150
	SUB TOTAL B				7,263,300
10	Preliminary and General	%	15		1,089,495
11	Preliminary Works		Incl. in P&G		
12	Accomodation		Incl. in P&G		
	SUB TOTAL C				8,352,795
13	Contingencies (% of Sub total C)	%	15		1,252,919
	Sub Total D				9,605,714
14	Planning design & Supervision (% of Sub total D)	%	12		1,152,686
	Sub Total E				10,758,400
15	VAT (% of Sub total E)	%	14		1,506,176
	TOTAL PROJECT COST				**12,264,576**

SCHEME 1B PHASE 2
COST MODEL : ITEM 7+ Midmar/Ferncliffe outlet control structure
Outlet pipework and control structure

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Earthworks				
1.1	(a) Clearing and grubbing	ha	12,000	0.2	2,400
1.2	(b) Excavation - soft	m3	20	3000	60,000
1.3	(c) Excavation - rock	m3	50		
2	Concrete - structural	m3	380	1475	560,500
3	Formwork				
3.1	(a) Smooth vertical	m2	155	3760	582,800
3.2	(b) Smooth horizontal	m2	155	506	78,430
4	Reinforcing	t	3,000	118	354,000
5	Mechanical items				
5.1	Valves etc	Sum			850,000
5.2	Structural steelwork	t	8,000	3	24,000
5.3	Pipework to spill structure	Sum			2,000,000
5.4	Pipework from tunnels	Sum			2,000,000
6	Miscellaneous				
6.1	Joints	m	100	100	10,000
6.2	Instrumentation and software	Sum			1,000,000
	SUB TOTAL A				7,522,130
7	Landscaping (% of Sub total A)	%	5		376,107
8	Miscellaneous (% of Sub total A)	%	5		376,107
	SUB TOTAL B				8,274,343
9	Preliminary and General	%	15		1,241,151
10	Preliminary Works			Incl. in P&G	
11	Accomodation			Incl. in P&G	
	SUB TOTAL C				9,515,494
12	Contingencies (% of Sub total C)	%	15		1,427,324
	Sub Total D				10,942,819
13	Planning design & Supervision (% of Sub total D)	%	12		1,313,138
	Sub Total E				12,255,957
14	VAT (% of Sub total E)	%	14		1,715,834
	TOTAL PROJECT COST				**13,971,791**

SCHEME 1B PHASE 2
COST MODEL : ITEM 8 Add. Pipeline from Midmar Tunnel Outlet to Northern Feeder
1600 mm diameter pipeline - 1400 m long

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	2.8	33,600
1.2	(b) bush	ha	20,000	0.25	5,000
2	Road and River Crossings	Sum			500,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m3	35	11000	385,000
3.2	(b) Extra over for rock	m3	50	1100	55,000
3.3	(c) Bed preparation (Bedding)	m	70	4700	329,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	2,800	1400	3,920,000
4.2	(b) Laying and Jointing (% of(a))	%	20		784,000
4.3	(d) Cathodic Protection	km	50,000	1.4	70,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m3	850	80	68,000
6	Reinforcing	t	3,000	8.0	24,000
7	Mechanical Items				
7.1	(a) Valves etc	Sum		100,000	250,000
7.2	(b) Structural steelwork	t	8,000	1.5	12,000
	SUB TOTAL A				6,435,600
8	Landscaping (% of Sub total A)	%	5		321,780
9	Miscellaneous (% of Sub total A)	%	5		321,780
	SUB TOTAL B				7,079,160
10	Preliminary and General	%	15		1,061,874
11	Preliminary Works		Incl. in P&G		
12	Accomodation		Incl. in P&G		
	SUB TOTAL C				8,141,034
13	Contingencies (% of Sub total C)	%	15		1,221,155
	Sub Total D				9,362,189
14	Planning design & Supervision (% of Sub total D)	%	12		1,123,463
	Sub Total E				10,485,652
15	VAT (% of Sub total E)	%	14		1,467,991
	TOTAL PROJECT COST				**11,953,643**

SCHEME 1B PHASE 2
COST MODEL : ITEM 9 ADD. NORTHERN FEEDER PIPELINE TO UMLAAS ROAD RESERVOIR
37.5 KM OF 1650mm DIAMETER

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	108.0	1,296,000
1.2	(b) bush	ha	20,000	6.0	120,000
2	Road and River Crossings	Sum			3,650,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m^3	35	376600	13,181,000
3.2	(b) Extra over for rock	m^3	50	37660	1,883,000
3.3	(c) Bed preparation (Bedding)	m	70	37900	2,653,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	3,000	37900	113,700,000
4.2	(b) Laying and Jointing (% of(a))	%	20		22,740,000
4.3	(c) E/O for steep slopes	m	2,000	1000	2,000,000
4.4	(d) Cathodic Protection	km	50,000	37.9	1,895,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m^3	850	300	255,000
5.2	(b) Headwalls on steep slopes	m^3	550	150	82,500
6	Reinforcing	t	3,000	103.5	310,500
7	Mechanical Items				
7.1	(a) Valves etc	Sum			1,400,000
	SUB TOTAL A				165,166,000
8	Landscaping (% of Sub total A)	%	5		8,258,300
9	Miscellaneous (% of Sub total A)	%	5		8,258,300
	SUB TOTAL B				181,682,600
10	Preliminary and General	%	15		27,252,390
11	Preliminary Works		Incl. in P&G		
12	Accomodation		Incl. in P&G		
	SUB TOTAL C				208,934,990
13	Contingencies (% of Sub total C)	%	15		31,340,249
	Sub Total D				240,275,239
14	Planning design & Supervision (% of Sub total D)	%	12		28,833,029
	Sub Total E				269,108,267
15	VAT (% of Sub total E)	%	14		37,675,157
	TOTAL PROJECT COST				**306,783,425**

SCHEME 1B
PUMPING COSTS

Power costs : Miniflex structure

Rates obtained from Eskom.

Basic charge	per month	53.05
Demand charge	No demand charge - assumed that Umgeni Water will go to Miniflex structure as proposed for Mearns scheme.	

Energy charges :

High demand : April - September (c/kWh)

Peak	c/kWh	30.54
Standard	c/kWh	11.23
Off-peak	c/kWh	6.44
Average	*c/kWh*	*16.07*

Low demand : October - March (c/kWh)

Peak	c/kWh	27.49
Standard	c/kWh	10.08
Off-peak	c/kWh	5.80
Average	*c/kWh*	*14.46*

Weighted annual average rate : (12 months - assume constant pumping all year round)

Rate 15.26 c/kWh

Parameter		Unit	Scheme 1B	
			Phase 1	Phase 2
FSL		masl		
Min operating level		masl		
Average operating level		masl		
Inlet		masl		
Flow		**m3/s**	**4.35**	**8.70**
Friction head *		m		
Total head	Min	m	8	8
	Max	m	32	32
	Average	m	20	20
Pump efficiency **			0.90	0.90
Motor efficiency **			0.97	0.97
Power requirement		MW	0.98	1.95
Monthly energy ***		MWh	715	1431
Total pumped per month * **		**m3.10E6**	**11.46**	**22.92**
Total pumped per annum		**m3.10E6**	**137.49**	**274.99**
<u>Monthly charges</u>				
Energy charge			109,178	218,356
Reactive energy charge		Not considered - high efficiency (pf=0.96) gives low reactive energy charge		
Basic charge			53	53
	Subtotal		109,231	218,409
Transmission surcharge (1%)			1,092	2,184
Voltage discount (5%)			-5,462	-10,920
	Subtotal		**104,862**	**209,673**
Contingency (20%)			**20,972**	**41,935**
	Total per month		**125,834**	**251,607**
	Total per annum		**1,510,009**	**3,019,284**
Unit cost		**c/m3**	**1.10**	**1.10**
Check (c/m3/100m)			5.49	5.49

* Based on 250 m long, twin 1800 mm diam line (n = 0.012)
** VAPS recommendation
*** 30.5 days per month

SCHEME 1C

SCHEME 1C PHASE 1
COST MODEL : ITEM 1 IMPENDLE DAM FSL=1197masl (1.5 MAR)

No	Description	Unit	Rate Mar '98	Quantity	Amount
1.	Site and basin clearing	ha	1,875	1,025	1,921,000
2.	River diversion				
	(a) Diversion Tunnel 350m long	Sum			11,000,000
	(b) Coffer Dams	Sum			8,608,231
	(c) Structural Concrete to Diversion Works	Sum			2,825,260
	(d) Foundation Prep. and Dealing with Water	Sum			500,000
3.	Excavation				
	(a) all materials	m3	13	430,029	5,758,095
	(b) extra over for rock	m3	24	144,550	3,483,647
4.	Preparation of solum				
	(b) for embankment	m2	8	94,471	758,604
	(c) core trench	m2	16	25,854	415,478
5.	Drilling and Grouting				
	(a) curtain grouting	m Drill	150	8,296	1,244,212
	(b) consolidation grouting	m Drill	150	4,115	617,177
6.	Embankment				
	(a) Earthfill Core	m3	18	1,145,153	20,750,167
	(b) rockfill	m3	28	3,813,313	107,954,889
	(c) filters	m3	59	242,314	14,277,155
	(d) rip-rap	m3	33	117,778	3,943,214
	(e) road layerworks	m2	80	5,460	436,800
7	SPILLWAY				
	(a) Excavation e/o to quarry	m3	10	780,000	7,800,000
	(b) Formwork	m3	67	19,343	1,295,000
	(c) Structural Concrete	m3	319	30,936	9,880,000
	(d) Mass Concrete	m3	248	10,281	2,550,000
	(e) Anchors and steel rebars	t	3,348	2,240	7,500,000
	(f) Drill for Anchors	m Drill	50	75,000	3,750,000
	(g) Road Bridge over Spillway	Sum			1,900,000
8	OUTLET STRUCTURE				
	(a) civil	Sum			8,016,000
	(b) mechanical/electrical	Sum			9,745,000
	(c) Pipework	Sum			15,545,000
	(d) Measuring weir	Sum			500,000
9	Landscaping (% of 1-8)	%	5%	252,974,930	12,648,746
10	Miscellaneous (% of 1-8)	%	10%	252,974,930	25,297,493
	Subtotal A (carried forward)				290,921,169
20	Preliminary, General and Preliminary works (% of Subtotal A)	%	20%	290,921,169	58,184,234
	Subtotal B				349,105,403
21	Contingencies (% of Subtotal B)	%	10%	349,105,403	34,910,540
	Subtotal C				384,015,943
22	Planning design & supervision, fees, time, cost & transport (% of Subtotal C)	%	15%	384,015,943	57,602,391
	Subtotal D				441,618,335
23	VAT (% of Subtotal D)	%	14%	441,618,335	61,826,567
	TOTAL PROJECT COST				503,444,902

SCHEME 1C PHASE 1
COST MODEL : ITEM 2 Tunnel from Impendle Dam to Midmar Dam
Pressure flow
TBM Tunnel 3,5 m diameter
D & B Tunnel 5,5 by 6 m high

Tunnel Length: 34900m
1 Up from outlet TBM - 7900m
1 Up from 2/3 point - 13500m
1 Down from inlet - 13500m
1 DB Adit - 1350m at 1:10

No	Description	Unit	Rate	Quantity	Amount
1	Portal excavations				
	a. Inlet portal	Sum	3,000,000	1	3,000,000
	b. Outlet portal	Sum	2,000,000	1	2,000,000
	b. Intermediate	Sum	2,500,000	1	2,500,000
2	Tunnel Excavation				
	TBM				
	b. Rock Class II	m3	340	57,081	19,407,674
	c. Rock Class III	m3	350	218,252	76,388,335
	d. Rock Class IV	m3	400	53,724	21,489,466
	e. Rock Class V	m3	1,000	6,715	6,715,458
	D & B (Adits)				
	c. Rock Class III	m3	180	36,531	6,575,580
	d. Rock Class IV	m3	200	7,128	1,425,600
	e. Rock Class V	m3	550	891	490,050
3	Extra for down grade drive	m	1,500	13,500	20,250,000
4	Extra for length of drive over 10 km	m	1,000	7,000	7,000,000
5	Turning Chamber	No	250,000	2	500,000
6	Dealing with Water	m	15	36,250	543,750
7	Shafts				
	a. Ventilation	m	3,000	1,000	3,000,000
	b. Surge	m	8,000	130	1,040,000
8	Rock support				
	a. i) Rockbolts - TBM	m	250	34,900	8,725,000
	a. ii) Rockbolts - D & B	m	380	1,350	513,000
	b. Shotcrete	m3	1,400	731	1,023,806
9	Concrete				
	a. Linings	m3	550	77,431	42,587,161
	b. Overbreak concrete : TBM	m2	100	377,973	37,797,287
	c. Overbreak concrete : DBT	m2			
	d. Concrete - D & B Invert blinding	m3	400	2,025	810,000
	e. Concrete : Structures	m3	380	650	247,000
10	Formwork				
	a. Smooth curved in tunnel	m2	150	282,727	42,409,011
	b. Structures	m2	155	3,200	496,000
11	Reinforcement	ton	3,000	52	156,000
12	Pre-cast concrete inverts	m	290	34,375	9,968,750
	SUBTOTAL : MEASURED ITEMS				**317,058,927**

SCHEME 1C PHASE 1
COST MODEL : ITEM 2 Tunnel from Impendle Dam to Midmar Dam

IMPENDLE TUNNEL - PRESSURE FLOW

No	Description	Unit	Rate	Quantity	Amount
	SUBTOTAL : MEASURED ITEMS				**317,058,927**
13	Grouting				
	i) Cavity	m	200	34,375	6,875,000
	ii) Consolidation/Fissure	m	7	34,375	240,625
14	Waterproof lining				
	a. Steel liners	m	26,000	525	13,650,000
	b. Waterproof membrane	m2	300	9,100	2,730,000
15	Intake Pipeline : Twin 1600 dia pipeline	m	14,000	250	3,500,000
16	Miscellaneous	%	10	**344,054,552**	34,405,455
	SUBTOTAL A				**378,460,007**
17.1	P & G Fixed	Sum	1	27,000,000	27,000,000
17.2	P & G Time Related - Establishment	Sum	1	9,800,000	9,800,000
17.3	P & G Time Related - TBM Excavation	Sum	1	68,200,000	68,200,000
17.4	P & G Time Related - Adit Excavation	Sum	1	10,400,000	10,400,000
17.5	P & G Time Related - Lining	Sum	1	38,150,000	38,150,000
18	Preliminary works		Incl. P&G		
19	Accommodation		Incl. P&G		
	SUBTOTAL B				**532,010,007**
20	Contingencies (% of Subtotal B)	%	10	532,010,007	53,201,001
	SUBTOTAL C				**585,211,007**
21	Planning, design and supervision (% of Subtotal C)	%	12	585,211,007	70,225,321
	SUBTOTAL D				**655,436,328**
22	VAT (% of Subtotal D)	%	14	655,436,328	91,761,086
	TOTAL PROJECT COST				**747,197,414**

Construction Period = 62 months
5.2 years

SCHEME 1C PHASE 1
COST MODEL : ITEM 3 Additional pipework at Midmar Dam Outlet

No	Description	Unit	Rate Mar '98	Quantity	Amount
1.	Supply and Fit/Lay Pipework	Sum			1,078,027
2.	Mechanical component (a) 1200 Dia. Mag-Flow Meter (b) Valves	 Sum Sum			 400,000 918,000
	Subtotal A (carried forward)				2,396,027
3	Electrical component (% of 2(a) and 2(b)	%	15%	1,318,000	197,700
4	Miscellaneous Civils (% of Subtotal A)	%	10%	2,396,027	239,603
	Subtotal B (carried forward)				2,833,330
5	Preliminary, General and Preliminary works (% of Subtotal B)	%	20%	2,833,330	566,666
	Subtotal C				3,399,996
6	Contingencies (% of Subtotal C)	%	10%	3,399,996	340,000
	Subtotal D				3,739,995
7	Planning design & supervision, fees, time cost & transport (% of Subtotal D)	%	15%	3,739,995	560,999
	Subtotal E				4,300,994
8	VAT (% of Subtotal E)	%	14%	4,300,994	602,139
	TOTAL PROJECT COST				4,903,134

SCHEME 1C PHASE 1
COST MODEL : ITEM 4 Midmar Pumpstation upsized by 580 Ml/day

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Mechanical and Electrical	%	64	13,239,458	8,473,253
2	Civils	%	36	13,239,458	4,766,205
	SUB TOTAL A				13,239,458
3	Landscaping (% of Sub total A)	%	2	13,239,458	264,789
4	Miscellaneous (% of Sub total A)	%	10	13,239,458	1,323,946
	SUB TOTAL B				14,828,193
5	Preliminary and General	%	20	14,828,193	2,965,639
6	Preliminary Works		Incl. in P&G		
7	Accomodation		Incl. in P&G		
	SUB TOTAL C				17,793,831
8	Contingencies (% of Sub total C)	%	10	17,793,831	1,779,383
	Sub Total D				19,573,214
9	Planning design & Supervision (% of Sub total D)	%	12	19,573,214	2,348,786
	Sub Total E				21,922,000
10	VAT (% of Sub total E)	%	14		3,069,080
	TOTAL PROJECT COST				**24,991,080**

Note : Pumpstation costs based on actual construction costs of existing large pumpstation escalated

SCHEME 1C PHASE 1
COST MODEL : ITEM 5 Pipeline from Midmar Dam to Midmar Waterworks
1800mm diameter pipeline 1900m long

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	4.0	48,000
1.2	(b) bush	ha	20,000	0.5	10,000
2	Road and Railway Crossings	Sum			1,700,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m³	35	16500	577,500
3.2	(b) Extra over for rock	m³	50	1650	82,500
3.3	(c) Bed preparation (Bedding)	m	70	8900	623,000
4	Pipelines				
4.4	(a) Supply of pipes to site	m	3,500	1900	6,650,000
4.2	(b) Laying and Jointing (% of(a))	%	20		1,330,000
4.3	(d) Cathodic Protection	km	50,000	1.9	95,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m³	850	150	127,500
6	Reinforcing	t	3,000	12.0	36,000
7	Mechanical Items				
7.1	(a) Structural steelwork	t	8,000	3	24,000
	SUB TOTAL A				11,303,500
8	Landscaping (% of Sub total A)	%	5		565,175
9	Miscellaneous (% of Sub total A)	%	5		565,175
	SUB TOTAL B				12,433,850
10	Preliminary and General	%	15		1,865,078
11	Preliminary Works		Incl. P&G		
12	Accomodation		Incl. P&G		
	SUB TOTAL C				14,298,928
13	Contingencies (% of Sub total C)	%	15		2,144,839
	Sub Total D				16,443,767
14	Planning design & Supervision (% of Sub total D)	%	12		1,973,252
	Sub Total E				18,417,019
15	VAT (% of Sub total E)	%	14		2,578,383
	TOTAL PROJECT COST				**20,995,401**

SCHEME 1C PHASE 1
COST MODEL : ITEM 6 Midmar Waterworks upsized by 580 Ml/day

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Mechanical and Electrical	%	30	166,817,167	50,045,150
2	Civils	%	70	166,817,167	116,772,017
	SUB TOTAL A				166,817,167
3	Landscaping (% of Sub total A)	%	2	166,817,167	3,336,343
4	Miscellaneous (% of Sub total A)	%	10	166,817,167	16,681,717
	SUB TOTAL B				186,835,227
5	Preliminary and General	%	20	186,835,227	37,367,045
6	Preliminary Works		Incl. P&G		
7	Accomodation		Incl. P&G		
	SUB TOTAL C				224,202,273
8	Contingencies (% of Sub total C)	%	10	224,202,273	22,420,227
	Sub Total D				246,622,500
9	Planning design & Supervision (% of Sub total D)	%	12	246,622,500	29,594,700
	Sub Total E				276,217,200
10	VAT (% of Sub total E)	%	14		38,670,408
	TOTAL PROJECT COST				**314,887,608**

Note : Waterworks costs based on actual construction costs of existing large waterworks escalated.

SCHEME 1C PHASE 1
COST MODEL : ITEM 7 Pipeline from Midmar Waterworks to Stukkenbergs Tunnel
1800 mm diameter pipeline - 3000 m long

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	6.0	72,000
1.2	(b) bush	ha	20,000	1.0	20,000
2	Road and River Crossings	Sum			2,200,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m³	35	26,000	910,000
3.2	(b) Extra over for rock	m³	50	2,600	130,000
3.3	(c) Bed preparation (Bedding)	m	70	14,000	980,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	3,500	3000	10,500,000
4.2	(b) Laying and Jointing (% of(a))	%	20		2,100,000
4.3	(c) E/O for steep slopes	m	2,000	100	200,000
4.4	(d) Cathodic Protection	km	50,000	3.0	150,000
4.5	(e) E/O for removal of existing line	m	195	3000	585,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m3	850	160	136,000
5.2	(b) Headwalls on steep slopes	m3	550	100	55,000
6	Reinforcing	t	3,000	13.0	39,000
7	Mechanical Items				
7.1	(a) Valves etc	Sum			200,000
7.2	(b) Structural steelwork	t	8,000	3	24,000
	SUB TOTAL A				18,301,000
8	Landscaping (% of Sub total A)	%	5		915,050
9	Miscellaneous (% of Sub total A)	%	5		915,050
	SUB TOTAL B				20,131,100
10	Preliminary and General	%	15		3,019,665
11	Preliminary Works		Incl. in P&G		
12	Accomodation		Incl. in P&G		
	SUB TOTAL C				23,150,765
13	Contingencies (% of Sub total C)	%	15		3,472,615
	Sub Total D				26,623,380
14	Planning design & Supervision (% of Sub total D)	%	12		3,194,806
	Sub Total E				29,818,185
15	VAT (% of Sub total E)	%	14		4,174,546
	TOTAL PROJECT COST				**33,992,731**

SCHEME 1C PHASE 1
COST MODEL : ITEM 8 STUKKENBERGS TUNNEL - PRESSURE
D & B 3.6 m x 3.6 m

Tunnel Length: 2025 m
Drill and blast

No	Description	Unit	Rate	Quantity	Amount
1	Portal excavations				
	a. Inlet portal	Sum	2,000,000	1	2,000,000
	b. Outlet portal	Sum	2,000,000	1	2,000,000
2	Tunnel Excavation	m	6,500	2025	13,162,500
3	Rock support				
	a. Support class A	m	50	615	30,750
	b. Support class B	m	100	615	61,500
	c. Support class C	m	170	615	104,550
	d. Support class D	m	980	105	102,900
	e. Support class E	m	3,300	100	330,000
4	Waterproof lining				
	a. Steel liners	m	3,300	100	330,000
	b. Waterproof membrane	m	6,000	1950	11,700,000
5	Miscellaneous	%	10	29,822,200	2,982,220
	SUBTOTAL A				**32,804,420**
6.1	P & G Fixed	Sum	1	5,725,000	5,725,000
6.2	P & G Time Related - Establishment	Sum	1	1,035,000	1,035,000
6.3	P & G Time Related - Excavation	Sum	1	5,750,000	5,750,000
6.4	P & G Time Related - Lining	Sum	1	4,600,000	4,600,000
7	Preliminary works		Incl. P&G		
8	Accommodation		Incl. P&G		
	SUBTOTAL B				**49,914,420**
9	Contingencies (% of Subtotal B)	%	10	49914420	4,991,442
	SUBTOTAL C				**54,905,862**
10	Planning, design and supervision (% of Subtotal C)	%	12	54905862	6,588,703
	SUBTOTAL D				**61,494,565**
11	VAT (% of Subtotal D)	%	14	61494565	8,609,239
	TOTAL PROJECT COST				**70,103,805**

Construction Period = 24 months
2.0 years

SCHEME 1C PHASE 1
COST MODEL : ITEM 9 Pipeline from Stukkenberg Tunnel to Midmar Reservoir
1800 mm diameter pipeline - 1100 m long

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	2.2	26,400
1.2	(b) bush	ha	20,000	0.3	5,000
2	Road and River Crossings	Sum			500,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m3	35	10000	350,000
3.2	(b) Extra over for rock	m3	50	1000	50,000
3.3	(c) Bed preparation (Bedding)	m	70	5100	357,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	3,500	1100	3,850,000
4.2	(b) Laying and Jointing (% of(a))	%	20		770,000
4.3	(d) Cathodic Protection	km	50,000	1.1	55,000
4.4	(e) E/O for removal of existing line	m	195	1100	214,500
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m3	850	60	51,000
6	Reinforcing	t	3,000	5.0	15,000
7	Mechanical Items				
7.1	(a) Valves etc	Sum			210,000
7.2	(b) Structural steelwork	t	8,000	1	8,000
	SUB TOTAL A				6,461,900
8	Landscaping (% of Sub total A)	%	5		323,095
9	Miscellaneous (% of Sub total A)	%	5		323,095
	SUB TOTAL B				7,108,090
10	Preliminary and General	%	15		1,066,214
11	Preliminary Works		Incl. in P&G		
12	Accomodation		Incl. in P&G		
	SUB TOTAL C				8,174,304
13	Contingencies (% of Sub total C)	%	15		1,226,146
	Sub Total D				9,400,449
14	Planning design & Supervision (% of Sub total D)	%	12		1,128,054
	Sub Total E				10,528,503
15	VAT (% of Sub total E)	%	14		1,473,990
	TOTAL PROJECT COST				**12,002,493**

SCHEME 1C PHASE 1
COST MODEL : ITEM 10 Midmar Reservoir
Installation of sleeve valves, instrumentation and software

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Supply of 2 No 1000 mm diam., 600 Kpa, sleeve valves.	No	100,000	2	200,000
2	Installation of valves	%	20		40,000
3	Supply, manufacture and installation of spindle, actuator and headstock arrangement.	No	83,000	2	166,000.00
4	Instrumentation and software development Estimated only	Sum			1,000,000
	SUB TOTAL A				1,406,000
5	Landscaping (% of Sub total A)		None required		
6	Miscellaneous (% of Sub total A)	%	5		70,300
	SUB TOTAL B				1,476,300
7	Preliminary and General	%	10		147,630
8	Preliminary Works		Incl. in P&G		
9	Accomodation		Incl. in P&G		
	SUB TOTAL C				1,623,930
10	Contingencies (% of Sub total C)	%	15		243,590
	Sub Total D				1,867,520
11	Planning design & Supervision (% of Sub total D)	%	12		224,102
	Sub Total E				2,091,622
12	VAT (% of Sub total E)	%	14		292,827
	TOTAL PROJECT COST				**2,384,449**

PHASE 1C PHASE 1
COST MODEL : ITEM 11 Pipeline from Midmar Tunnel Outlet to Northern Feeder
1600 mm diameter pipeline - 1400 m long

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	2.8	33,600
1.2	(b) bush	ha	20,000	0.25	5,000
2	Road and River Crossings	Sum			500,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m3	35	11000	385,000
3.2	(b) Extra over for rock	m3	50	1100	55,000
3.3	(c) Bed preparation (Bedding)	m	70	4700	329,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	2,800	1400	3,920,000
4.2	(b) Laying and Jointing (% of(a))	%	20		784,000
4.3	(d) Cathodic Protection	km	50,000	1.4	70,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m3	850	80	68,000
6	Reinforcing	t	3,000	6.0	18,000
7	Mechanical Items				
7.1	(a) Valves etc	Sum			250,000
7.2	(b) Structural steelwork	t	8,000	1.5	12,000
8	Upgrade DV Harris offtake	Sum			300,000
	SUB TOTAL A				6,729,600
9	Landscaping (% of Sub total A)	%	5		336,480
10	Miscellaneous (% of Sub total A)	%	5		336,480
	SUB TOTAL B				7,402,560
11	Preliminary and General	%	15		1,110,384
12	Preliminary Works		Incl. in P&G		
13	Accomodation		Incl. in P&G		
	SUB TOTAL C				8,512,944
14	Contingencies (% of Sub total C)	%	15		1,276,942
	Sub Total D				9,789,886
15	Planning design & Supervision (% of Sub total D)	%	12		1,174,786
	Sub Total E				10,964,672
16	VAT (% of Sub total E)	%	14		1,535,054
	TOTAL PROJECT COST				**12,499,726**

SCHEME 1C PHASE 1

COST MODEL : ITEM 12 NORTHERN FEEDER PIPELINE TO UMLAAS ROAD RESERVOIR

37.9 km of 1650mm diameter

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	108.0	1,296,000
1.2	(b) bush	ha	20,000	6.0	120,000
2	Road and River Crossings	Sum			4,400,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m³	35	376600	13,181,000
3.2	(b) Extra over for rock	m³	50	37660	1,883,000
3.3	(c) Bed preparation (Bedding)	m	70	37900	2,653,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	3,000	37900	113,700,000
4.2	(b) Laying and Jointing (% of(a))	%	20		22,740,000
4.3	(c) E/O for steep slopes	m	2,000	1000	2,000,000
4.4	(d) Cathodic Protection	km	50,000	37.9	1,895,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m³	850	300	255,000
5.2	(b) Headwalls on steep slopes	m³	550	150	82,500
6	Reinforcing	t	3,000	103.5	310,500
7	20 Ml Balancing / Break Pressure Reservoir	Sum			4,500,000
8	Mechanical Items				
8.1	(a) Valves etc	Sum			2,150,000
	SUB TOTAL A				171,166,000
9	Landscaping (% of Sub total A)	%	5		8,558,300
10	Miscellaneous (% of Sub total A)	%	5		8,558,300
	SUB TOTAL B				188,282,600
11	Preliminary and General	%	15		28,242,390
12	Preliminary Works		Incl. in P&G		
13	Accomodation		Incl. in P&G		
	SUB TOTAL C				216,524,990
14	Contingencies (% of Sub total C)	%	15		32,478,749
	Sub Total D				249,003,739
15	Planning design & Supervision (% of Sub total D)	%	12		29,880,449
	Sub Total E				278,884,187
16	VAT (% of Sub total E)	%	14		39,043,786
	TOTAL PROJECT COST				**317,927,973**

SCHEME 1C PHASE 1
COST MODEL : ITEM 13 UMLAAS ROAD RESERVOIR 200Ml

No	Description	Unit	Rate Mar '98	Quantity	Amount
1.	Excavation to spoil	m3	15	35,000	525,000
2.	Cut to Fill	m3	20	30,000	600,000
3.	Mass Concrete	Sum			1,953,000
4	Structural Concrete	Sum			7,259,800
5	Formwork and Shuttering	Sum			8,206,600
6	Reinforcement	Sum			5,111,600
	PIPEWORK				
7	(a) civil	Sum			310,805
8	(b)mechanical/electrical	Sum			1,407,186
9	Miscellaneous	Sum			4,931,260
	Subtotal A (carried forward)				30,305,251
10	Preliminary, General and Preliminary works (% of Subtotal A)	%	20%	30,305,251	6,061,050
	Subtotal B				36,366,301
11	Contingencies (% of Subtotal B)	%	10%	36,366,301	3,636,630
	Subtotal C				40,002,931
12	Planning design & supervision, fees, time cost & transport (% of Subtotal C)	%	15%	40,002,931	6,000,440
	Subtotal D				46,003,371
13	VAT (% of Subtotal D)	%	14%	46,003,371	6,440,472
	TOTAL PROJECT COST				52,443,843

PHASE 1C PHASE 1
COST MODEL : ITEM 14 Advanced infrastructure Costs for Impendle Dam

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Preliminary Works				
1.1	(a) Access Roads	km	800,000	12.5	10,000,000
1.2	(b) Electricity to Site	Sum			1,770,000
	SUB TOTAL A				11,770,000
2	Contingencies (% of Sub total A)	%	10		1,177,000
	Sub Total B				12,947,000
3	Planning design & Supervision (% of Sub total B)	%	12		1,553,640
	Sub Total C				14,500,640
4	VAT (% of Sub total C)	%	14		2,030,090
	TOTAL PROJECT COST				**16,530,730**

SCHEME 1C PHASE 2
COST MODEL : ITEM 1 Add. Pipework at Midmar Dam Outlet

No	Description	Unit	Rate Mar '98	Quantity	Amount
1.	Supply and Fit/Lay Pipework	Sum			736,442
2.	Mechanical component (a) 1200 Dia. Mag-Flow Meter (b) Valves	 Sum Sum			 400,000 328,853
	Subtotal A (carried forward)				1,465,295
3	Electrical component (% of 2(a) and 2(b)	%	15.0%	728,853	109,328
4	Miscellaneous Civils (% of Subtotal A)	%	10%	1,465,295	146,530
	Subtotal B (carried forward)				1,721,152
5	Preliminary, General and Preliminary works (% of Subtotal B)	%	20%	1,721,152	344,230
	Subtotal C				2,065,383
6	Contingencies (% of Subtotal C)	%	10%	2,065,383	206,538
	Subtotal D				2,271,921
7	Planning design & supervision, fees, time cost & transport (% of Subtotal D)	%	15%	2,271,921	340,788
	Subtotal E				2,612,709
8	VAT (% of Subtotal E)	%	14%	2,612,709	365,779
	TOTAL PROJECT COST				2,978,489

SCHEME 1C PHASE 2
COST MODEL : ITEM 2 Midmar Pumpstation upsized by 580 Ml/day

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Mechanical and Electrical	%	64	13,239,458	8,473,253
2	Civils	%	36	13,239,458	4,766,205
	SUB TOTAL A				13,239,458
3	Landscaping (% of Sub total A)	%	2	13,239,458	264,789
4	Miscellaneous (% of Sub total A)	%	10	13,239,458	1,323,946
	SUB TOTAL B				14,828,193
5	Preliminary and General	%	20	14,828,193	2,965,639
6	Preliminary Works		Incl. in P&G		
7	Accomodation	Sum	Incl. in P&G		
	SUB TOTAL C				17,793,831
8	Contingencies (% of Sub total C)	%	10	17,793,831	1,779,383
	Sub Total D				19,573,214
9	Planning design & Supervision (% of Sub total D)	%	12	19,573,214	2,348,786
	Sub Total E				21,922,000
10	VAT (% of Sub total E)	%	14		3,069,080
	TOTAL PROJECT COST				**24,991,080**

Note : Pumpstation costs based on actual construction costs of existing large pumpstation escalated

SCHEME 1C PHASE 2
COST MODEL : ITEM 3 Add. Pipeline from Midmar Dam to Midmar Waterworks
1800mm diameter pipeline 1900m long

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	4.0	48,000
1.2	(b) bush	ha	20,000	0.5	10,000
2	Road and Railway Crossings	Sum			1,700,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m³	35	16500	577,500
3.2	(b) Extra over for rock	m³	50	1650	82,500
3.3	(c) Bed preparation (Bedding)	m	70	8900	623,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	3,500	1900	6,650,000
4.2	(b) Laying and Jointing (% of(a))	%	20		1,330,000
4.3	(d) Cathodic Protection	km	50,000	1.9	95,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m³	850	150	127,500
6	Reinforcing	t	3,000	12.0	36,000
7	Mechanical Items				
7.1	(b) Structural steelwork	t	8,000	3	24,000
	SUB TOTAL A				11,303,500
8	Landscaping (% of Sub total A)	%	5		565,175
9	Miscellaneous (% of Sub total A)	%	5		565,175
	SUB TOTAL B				12,433,850
10	Preliminary and General	%	15		1,865,078
11	Preliminary Works		Incl. in P&G		
12	Accomodation		Incl. in P&G		
	SUB TOTAL C				14,298,928
13	Contingencies (% of Sub total C)	%	15		2,144,839
	Sub Total D				16,443,767
14	Planning design & Supervision (% of Sub total D)	%	12		1,973,252
	Sub Total E				18,417,019
15	VAT (% of Sub total E)	%	14		2,578,383
	TOTAL PROJECT COST				**20,995,401**

SCHEME 1C PHASE 2
COST MODEL : ITEM 4 Midmar Waterworks upsized by 580 Ml/day

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Mechanical and Electrical	%	30	166,817,167	50,045,150
2	Civils	%	70	166,817,167	116,772,017
	SUB TOTAL A				166,817,167
3	Landscaping (% of Sub total A)	%	2	166,817,167	3,336,343
4	Miscellaneous (% of Sub total A)	%	10	166,817,167	16,681,717
	SUB TOTAL B				186,835,227
5	Preliminary and General	%	20	186,835,227	37,367,045
6	Preliminary Works		Incl. in P&G		
7	Accomodation		Incl. in P&G		
	SUB TOTAL C				224,202,273
8	Contingencies (% of Sub total C)	%	10	224,202,273	22,420,227
	Sub Total D				246,622,500
9	Planning design & Supervision (% of Sub total D)	%	12	246,622,500	29,594,700
	Sub Total E				276,217,200
10	VAT (% of Sub total E)	%	14		38,670,408
	TOTAL PROJECT COST				**314,887,608**

Note : Waterworks costs based on actual construction costs of existing large waterworks escalated.

SCHEME 1C PHASE 2
COST MODEL : ITEM 5 Add. Pipeline from Midmar Waterworks to Stukkenberg Tunnel
1800 mm diameter pipeline - 3000 m long

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	6.0	72,000
1.2	(b) bush	ha	20,000	1.0	20,000
2	Road and River Crossings	Sum			700,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m3	35	26000	910,000
3.2	(b) Extra over for rock	m3	50	2600	130,000
3.3	(c) Bed preparation (Bedding)	m	70	14000	980,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	3,500	3000	10,500,000
4.2	(b) Laying and Jointing (% of(a))	%	20		2,100,000
4.3	(c) E/O for steep slopes	m	2,000	100	200,000
4.4	(d) Cathodic Protection	km	50,000	3.0	150,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m3	850	160	136,000
5.2	(b) Headwalls on steep slopes	m3	550	100	55,000
6	Reinforcing	t	3,000	6.0	18,000
7	Mechanical Items				
7.1	(a) Valves etc	Sum			200,000
7.2	(b) Structural steelwork	t	8,000	3	24,000
	SUB TOTAL A				16,195,000
8	Landscaping (% of Sub total A)	%	5		809,750
9	Miscellaneous (% of Sub total A)	%	5		809,750
	SUB TOTAL B				17,814,500
10	Preliminary and General	%	15		2,672,175
11	Preliminary Works		Incl. in P&G		
12	Accomodation		Incl. in P&G		
	SUB TOTAL C				20,486,675
13	Contingencies (% of Sub total C)	%	15		3,073,001
	Sub Total D				23,559,676
14	Planning design & Supervision (% of Sub total D)	%	12		2,827,161
	Sub Total E				26,386,837
15	VAT (% of Sub total E)	%	14		3,694,157
	TOTAL PROJECT COST				**30,080,995**

SCHEME 1C PHASE 2
COST MODEL : ITEM 6 Add. Pipeline from Stukkenberg Tunnel to Midmar Reservoir
1800 mm diameter pipeline - 1100 m long

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	2.6	31,200
1.2	(b) bush	ha	20,000	0.25	5,000
2	Road and River Crossings	Sum			500,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m3	35	11000	385,000
3.2	(b) Extra over for rock	m3	50	1100	55,000
3.3	(c) Bed preparation (Bedding)	m	70	6000	420,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	3,500	1300	4,550,000
4.2	(b) Laying and Jointing (% of(a))	%	20		910,000
4.3	(c) E/O for steep slopes	m			
4.4	(d) Cathodic Protection	km	50,000	1.3	65,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m3	850	60	51,000
5.2	(b) Headwalls on steep slopes	m3			
6	Reinforcing	t	3,000	5.0	15,000
7	Mechanical Items				
7.1	(a) Valves etc	Sum			210,000
7.2	(b) Structural steelwork	t	8,000	1	8,000
	SUB TOTAL A				7,205,200
8	Landscaping (% of Sub total A)	%	5		360,260
9	Miscellaneous (% of Sub total A)	%	5		360,260
	SUB TOTAL B				7,925,720
10	Preliminary and General	%	15		1,188,858
11	Preliminary Works		Incl. in P&G		
12	Accomodation		Incl. in P&G		
	SUB TOTAL C				9,114,578
13	Contingencies (% of Sub total C)	%	15		1,367,187
	Sub Total D				10,481,765
14	Planning design & Supervision (% of Sub total D)	%	12		1,257,812
	Sub Total E				11,739,576
15	VAT (% of Sub total E)	%	14		1,643,541
	TOTAL PROJECT COST				**13,383,117**

SCHEME 1C PHASE 2
COST MODEL : ITEM 7 Ugrade exisitng Ferncliff Tunnel
Inlet pipework, upgrade and lining

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Steel pipe liners				
1.1	(a) Supply of pipes to site - 1800 mm diam.	m	3,500	1050	3,675,000
1.3	(b) Installation and grouting	%	300		11,025,000
2	Shotcreting : 100 mm	m3	1,500	2800	4,200,000
3	Concrete including Formwork				
	Inlet and outlet portal chambers	m3	850	101	85,850
4	Reinforcing	t	3,500	9	31,500
5	Mechanical Items				
5.1	(a) Valves / pressure doors etc	Sum		180,000	180,000
5.2	(b) Structural steelwork	t	8,000	0.5	4,000
	SUB TOTAL A				19,201,350
6	Landscaping (% of Sub total A)	%	5		960,068
7	Miscellaneous (% of Sub total A)	%	5		960,068
	SUB TOTAL B				21,121,485
8	Preliminary and General	%	20		4,224,297
9	Preliminary Works		Incl. in P&G		
10	Accomodation		Incl. in P&G		
	SUB TOTAL C				25,345,782
11	Contingencies (% of Sub total C)	%	15		3,801,867
	Sub Total D				29,147,649
12	Planning design & Supervision (% of Sub total D)	%	12		3,497,718
	Sub Total E				32,645,367
13	VAT (% of Sub total E)	%	14		4,570,351
	TOTAL PROJECT COST				**37,215,719**

SCHEME 1C PHASE 2
COST MODEL : ITEM 7+ Midmar/Ferncliffe outlet control structure
Outlet pipework and control structure

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Earthworks				
1.1	(a) Clearing and grubbing	ha	12,000	0.2	2,400
1.2	(b) Excavation - soft	m3	20	3000	60,000
2	Concrete - structural	m3	380	1475	560,500
3	Formwork				
3.1	(a) Smooth vertical	m2	155	3760	582,800
3.2	(b) Smooth horizontal	m2	155	506	78,430
4	Reinforcing	t	3,000	118	354,000
5	Mechanical items				
5.1	Valves etc	Sum			850,000
5.2	Structural steelwork	t	8,000	3	24,000
5.3	Pipework to spill structure	Sum			2,000,000
5.4	Pipework from tunnels	Sum			2,000,000
6	Miscellaneous				
6.1	Joints	m	100	100	10,000
6.2	Instrumentation and software	Sum			1,000,000
	SUB TOTAL A				7,522,130
7	Landscaping (% of Sub total A)	%	5		376,107
8	Miscellaneous (% of Sub total A)	%	5		376,107
	SUB TOTAL B				8,274,343
9	Preliminary and General	%	15		1,241,151
10	Preliminary Works		Incl. in P&G		
11	Accomodation		Incl. in P&G		
	SUB TOTAL C				9,515,494
12	Contingencies (% of Sub total C)	%	15		1,427,324
	Sub Total D				10,942,819
13	Planning design & Supervision (% of Sub total D)	%	12		1,313,138
	Sub Total E				12,255,957
14	VAT (% of Sub total E)	%	14		1,715,834
	TOTAL PROJECT COST				**13,971,791**

SCHEME 1C PHASE 2
COST MODEL : ITEM 8 Add. Pipeline from Midmar Tunnel Outlet to Northern Feeder
1600 mm diameter pipeline - 1400 m long

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	2.8	33,600
1.2	(b) bush	ha	20,000	0.25	5,000
2	Road and River Crossings	Sum			500,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m3	35	11000	385,000
3.2	(b) Extra over for rock	m3	50	1100	55,000
3.3	(c) Bed preparation (Bedding)	m	70	4700	329,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	2,800	1400	3,920,000
4.2	(b) Laying and Jointing (% of(a))	%	20		784,000
4.3	(d) Cathodic Protection	km	50,000	1.4	70,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m3	850	80	68,000
5.2	(b) Headwalls on steep slopes	m3			
6	Reinforcing	t	3,000	8.0	24,000
7	Mechanical Items				
7.1	(a) Valves etc	Sum		100,000	250,000
7.2	(b) Structural steelwork	t	8,000	1.5	12,000
	SUB TOTAL A				6,435,600
8	Landscaping (% of Sub total A)	%	5		321,780
9	Miscellaneous (% of Sub total A)	%	5		321,780
	SUB TOTAL B				7,079,160
10	Preliminary and General	%	15		1,061,874
11	Preliminary Works		Incl. in P&G		
12	Accomodation		Incl. in P&G		
	SUB TOTAL C				8,141,034
13	Contingencies (% of Sub total C)	%	15		1,221,155
	Sub Total D				9,362,189
14	Planning design & Supervision (% of Sub total D)	%	12		1,123,463
	Sub Total E				10,485,652
15	VAT (% of Sub total E)	%	14		1,467,991
	TOTAL PROJECT COST				**11,953,643**

SCHEME 1C PHASE 2

COST MODEL : ITEM 9 ADD. NORTHERN FEEDER PIPELINE TO UMLAAS ROAD RESERVOIR

37.5 KM OF 1650mm DIAMETER

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	108.0	1,296,000
1.2	(b) bush	ha	20,000	6.0	120,000
2	Road and River Crossings	Sum			3,650,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m³	35	376600	13,181,000
3.2	(b) Extra over for rock	m³	50	37660	1,883,000
3.3	(c) Bed preparation (Bedding)	m	70	37900	2,653,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	3,000	37900	113,700,000
4.2	(b) Laying and Jointing (% of(a))	%	20		22,740,000
4.3	(c) E/O for steep slopes	m	2,000	1000	2,000,000
4.4	(d) Cathodic Protection	km	50,000	37.9	1,895,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m³	850	300	255,000
5.2	(b) Headwalls on steep slopes	m³	550	150	82,500
6	Reinforcing	t	3,000	103.5	310,500
7	Mechanical Items				
7.1	(a) Valves etc	Sum			1,400,000
	SUB TOTAL A				165,166,000
8	Landscaping (% of Sub total A)	%	5		8,258,300
9	Miscellaneous (% of Sub total A)	%	5		8,258,300
	SUB TOTAL B				181,682,600
10	Preliminary and General	%	15		27,252,390
11	Preliminary Works		Incl. in P&G		
12	Accomodation		Incl. in P&G		
	SUB TOTAL C				208,934,990
13	Contingencies (% of Sub total C)	%	15		31,340,249
	Sub Total D				240,275,239
14	Planning design & Supervision (% of Sub total D)	%	12		28,833,029
	Sub Total E				269,108,267
15	VAT (% of Sub total E)	%	14		37,675,157
	TOTAL PROJECT COST				**306,783,425**

SCHEME 1C
PUMPING COSTS

Power costs : Miniflex structure

Rates obtained from Eskom.

Basic charge	per month	53.05
Demand charge	No demand charge - assumed that Umgeni Water will go to Miniflex structure as proposed for Mearns scheme.	

Energy charges :

High demand : April - September (c/kWh)		
Peak	c/kWh	30.54
Standard	c/kWh	11.23
Off-peak	c/kWh	6.44
Average	*c/kWh*	*16.07*
Low demand : October - March (c/kWh)		
Peak	c/kWh	27.49
Standard	c/kWh	10.08
Off-peak	c/kWh	5.80
Average	*c/kWh*	*14.46*

Weighted annual average rate : (12 months - assume constant pumping all year round)

Rate 15.26 c/kWh

Parameter		**Unit**	**Scheme 1B**	
			Phase 1	**Phase 2**
FSL		masl		
Min operating level		masl		
Average operating level		masl		
Inlet		masl		
Flow		**m3/s**	**4.95**	**9.90**
Friction head *		m		
Total head	Min	m	8	8
	Max	m	32	32
	Average	m	20	20
Pump efficiency **			0.90	0.90
Motor efficiency **			0.97	0.97
Power requirement		MW	1.11	2.22
Monthly energy ***		MWh	814	1628
Total pumped per month * **		**m3.10E6**	**13.04**	**26.08**
Total pumped per annum		**m3.10E6**	**156.50**	**313.00**
<u>*Monthly charges*</u>				
Energy charge			124,269	248,538
Reactive energy charge		Not considered - high efficiency (pf=0.96) gives low reactive energy charge		
Basic charge			53	53
	Subtotal		124,322	248,591
Transmission surcharge (1%)			1,243	2,486
Voltage discount (5%)			-6,216	-12,430
	Subtotal		**119,349**	**238,647**
Contingency (20%)			**23,870**	**47,729**
	Total per month		**143,219**	**286,377**
	Total per annum		**1,718,628**	**3,436,522**
Unit cost		**c/m3**	**1.10**	**1.10**
Check (c/m3/100m)			5.49	5.49

* Based on 250 m long, twin 1800 mm diam line (n = 0.012)
** VAPS recommendation
*** 30.5 days per month

APPENDIX F2

DETAILED COST ESTIMATES

SMITHFIELD SCHEME

Scheme 2A

Scheme 2B

Scheme 2C

SCHEME 2A

SCHEME 2A PHASE 1
COST MODEL : ITEM 1 SMITHFIELD COMPOSITE DAM
FSL 915 masl

No	Description	Unit	Rate Mar-98	Quantity	Amount
1.	Site and basin clearing	ha	1,875	582	1,091,017
2.	River diversion	Sum	1,015,800		1,015,800
3.	Excavation				
	(a) all materials	m3	13	297,216	3,979,728
	(b) extra over for rock	m3	24	155,353	3,744,313
4.	Preparation of solum				
	(a) for Concrete section	m2	24	14,893	358,957
	(b) for embankment	m2	8	49,982	401,554
	(c) core trench	m2	16	34,433	553,265
5.	Drilling and Grouting				
	(a) curtain grouting	m drill	150	13,270	1,990,094
	(b) consolidation grouting	m drill	150	7,047	1,056,760
	(c) Drainage curtain	m drill	134	4,363	584,170
6.	Embankment				
	(a) earthfill,core	m3	18	326,217	5,911,048
	(b) rockfill	m3	28	593,269	16,796,940
	(c) filters	m3	59	66,989	3,946,694
	(d) rip-rap	m3	33	66,989	2,242,440
7.	Formwork				
	(a) gang formed	m2	67	35,035	2,345,593
	(b) intricate	m2	107	3,504	375,295
8.	Concrete				
	(a) roller compacted concrete	m3	211	332,657	70,072,451
	(b) mass & skin concrete	m3	248	36,962	9,167,184
	(c) structural	m3	319	5,000	1,596,825
9.	Reinforcing	t	3,348	750	2,510,625
10	Multilevel intake structure				
	(a) civil	Sum	3,996,000		3,996,000
	(b) mechanical and electrical	Sum	7,189,000		7,189,000
	(c) River outlet pipework	Sum	3,590,000		3,590,000
	(d) Measuring weir	Sum			500,000
11	Landscaping (% of 1-10)	%	5%	145,985,753	7,299,288
12	Miscellaneous (% of 1-10)	%	10%	145,985,753	14,598,575
	Subtotal A (carried forward)				166,913,616
13	Preliminary, General and Preliminary works (% of Subtotal A)	%	20%	167,883,616	33,576,723
	Subtotal B				200,490,339
14	Contingencies (% of Subtotal B)	%	10%	201,460,339	20,146,034
	Subtotal C				220,636,373
15	Planning design & supervision, fees, time cost & transport (% of Subtotal C)	%	12%	221,606,373	26,592,765
	Subtotal D				247,229,138
16	VAT (% of Subtotal D)	%	14%	248,199,138	34,747,879
	TOTAL PROJECT COST				281,977,017

SCHEME 2A PHASE 1
COST MODEL: ITEM 2 Smithfield Dam Intake Tower and Pumpstation 606 ML/day

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Earthworks				
1.1	c. Excavation - rock	m3	90	550	49,500
2	Rock support				
2.1	a. Rock anchors - 20 m long 8x8m spacing	No	1,000	10	10,000
2.2	b. Rock dowels - 4x4m spacing	No	200	100	20,000
3	Access bridge	Sum			1,500,000
4	Drilling and grouting	m	500	300	150,000
5	Formwork				
5.1	a. Smooth vertical - curved and plain	m2	155	11650	1,805,750
5.2	b. Smooth horizontal - soffits	m2	155	750	116,250
5.3	c. Intricate	m2	420	1000	420,000
6	Unformed surface finishes	m2	6	1000	6,000
7	Concrete				
7.1	Mass concrete	m3	300	1000	300,000
7.2	Structural concrete	m3	380	14500	5,510,000
8	Reinforcing	t	3,000	2450	7,350,000
9	Miscellaneous				
9.1	a. Structural steelwork	t	8,000	45	360,000
9.2	b. Building work	Sum			50,000
9.3	c. Electrical and instrumentation	Sum			1,500,000
9.4	d. Intake pipes - twin 1800 mm diam lines	m	17,500	250	4,375,000
	Subtotal A : Civil construction				23,522,500
10	Mechanical items - Gates, screens and cranes and	Sum			11,550,000
11	Mechanical items - pumps, motors and switchgear,				8,795,800
	Subtotal B : Mechanical items				20,345,800
12	Landscaping (% of Subtotal A)	%	5		1,176,125
13	Miscellaneous (% of Subtotal A + Subtotal B)	%	5		2,193,415
	Subtotal C : Total construction				47,237,840
14	Preliminary and General	%	20		9,447,568
15	Site works		Incl. in P & G		
16	Accomodation		Incl. in P & G		
	Subtotal D				56,685,408
17	Contingencies (% of subtotal D)	%	20		11,337,082
	Subtotal E				68,022,490
18	Planning design & Supervision (% of subtotal E)	%	12		8,162,699
	Sub Total F				76,185,188
19	VAT (% of Sub total F)	%	14		10,665,926
	TOTAL PROJECT COST				**86,851,115**

SCHEME 2A PHASE 1
COST MODEL : ITEM 3 Tunnel from Smithfield Dam to Baynesfield Dam

SMITHFIELD TUNNEL - FREE SURFACE FLOW

Tunnel Length: 32900m
1 Up from outlet TBM - 12950m
1 Down from 1/3 point - 12950m
1 Down from inlet - 6500m
DB Tunnel - 500m
1 DB Adit - 350m at 1:10

No	Description	Unit	Rate	Quantity	Amount
1	Portal excavations				
	a. Inlet portal	Sum	2,500,000	1	2,500,000
	b. Outlet portal	Sum	4,000,000	1	4,000,000
	b. Intermediate	Sum	2,500,000	1	2,500,000
2	Tunnel Excavation				
	TBM				
	b. Rock Class II	m3	340	52,992	18,017,439
	c. Rock Class III	m3	350	202,618	70,916,391
	d. Rock Class IV	m3	400	49,875	19,950,106
	e. Rock Class V	m3	1,000	6,234	6,234,408
	D & B (Adits)				
	c. Rock Class III	m3	180	13,981	2,516,580
	d. Rock Class IV	m3	200	2,728	545,600
	e. Rock Class V	m3	550	341	187,550
3	Extra for down grade drive	m	1,500	19,950	29,925,000
4	Extra for length of drive over 10 km	m	1,000	5,900	5,900,000
5	Turning Chamber	No	250,000	2	500,000
6	Dealing with Water	m	15	33,250	498,750
7	Shafts				
	a. Ventilation	m	3,000	650	1,950,000
8	Rock support				
	a. i) Rockbolts - TBM	m	250	32,900	8,225,000
	a. ii) Rockbolts - D & B	m	380	350	133,000
	b. Shotcrete	m3	1,400	657	919,926
9	Concrete				
	a. Linings	m3	550	74,109	40,759,784
	b. Overbreak concrete : TBM	m2	100	361,754	36,175,439
	d. Concrete - D & B Invert blinding	m3	400	525	210,000
	e. Concrete : Structures	m3	380	1,100	418,000
10	Formwork				
	a. Smooth curved in tunnel	m2	150	270,595	40,589,279
	b. Structures	m2	155	4,400	682,000
11	Reinforcement	ton	3,000	88	264,000
12	Pre-cast concrete inverts	m	290	32,900	9,541,000
	SUBTOTAL : MEASURED ITEMS				**304,059,253**

SCHEME 2A PHASE 1
COST MODEL : ITEM 3 Tunnel from Smithfield Dam to Baynesfield Dam

SMITHFIELD TUNNEL - FREE SURFACE FLOW

No	Description	Unit	Rate	Quantity	Amount
	SUBTOTAL : MEASURED ITEMS				**304,059,253**
13	Grouting				
	i) Cavity	m	200	32,900	6,580,000
	ii) Consolidation/Fissure	m	7	32,900	230,300
14	Waterproof lining				
	b. Waterproof membrane	m2	300	30,000	9,000,000
15	a. Intake Pipeline : Twin 1800 dia	m	17,500	250	4,375,000
	b. Outlet spill line : Twin 1800 dia	m	17,500	250	4,375,000
16	Miscellaneous	%	10	328,619,553	32,861,955
	SUBTOTAL A				**361,481,508**
17.1	P & G Fixed	Sum	1	27,000,000	27,000,000
17.2	P & G Time Related - Establishment	Sum	1	9,350,000	9,350,000
17.3	P & G Time Related - TBM Excavation	Sum	1	63,250,000	63,250,000
17.4	P & G Time Related - Adit Excavation	Sum	1	3,000,000	3,000,000
17.5	P & G Time Related - Lining	Sum	1	29,820,000	29,820,000
18	Preliminary works		Incl. in P&G		
19	Accommodation		Incl. in P&G		
	SUBTOTAL B				**493,901,508**
20	Contingencies (% of Subtotal B)	%	10	493,901,508	49,390,151
	SUBTOTAL C				**543,291,659**
21	Planning, design and supervision (% of Subtotal C)	%	12	543,291,659	65,194,999
	SUBTOTAL D				**608,486,658**
22	VAT (% of Subtotal C)	%	14	608,486,658	85,188,132
	TOTAL PROJECT COST				**693,674,790**

Construction Period = 56 months
4,7 years

SCHEME 2A PHASE 1
COST MODEL : ITEM 4 BAYNESFIELD DAM RAISED BY 0.5m FSL 871.5masl

No	Description	Unit	Rate Jun-96	Rate Mar '98	Quantity	Amount
1.	Site and basin clearing	ha	1,700	1,875	51	96,050
2	Excavation					
	(a) all materials	m3	12	13	3,139	42,036
	(b) extra over for rock	m3	22	24	1,065	25,663
3	Preparation of solum					
	(a) for embankment	m2	6	8	2,871	23,052
4	Embankment					
	(a) Earthfill	m3	16	18	12,277	222,460
	(b) rockfill	m3	25	28	1,794	50,790
	(c) filters	m3	63	59	163	9,611
	(d) rip-rap	m3	29	33	108	3,605
5	SPILLWAY					
	(a) Formwork	m3		67	464	31,080
	(b) Structural Concrete	m3	186	314	405	127,300
	(c) Demolish ex slab on crest	Sum				50,000
6	OUTLET STRUCTURE					
	(a) civil	Sum				580,120
	(b) mechanical/electrical	Sum				1,629,000
	(c) Pipework	Sum				1,055,659
7	Landscaping (% of 1-6)	%		5%	3,946,425	197,321
8	Miscellaneous (% of 1-6)	%		10%	3,946,425	394,642
	Subtotal A (carried forward)					4,538,389
9	Preliminary, General and Preliminary works (% of Subtotal A)	%	20%	20%	4,538,389	907,678
	Subtotal B					5,446,067
10	Contingencies (% of Subtotal B)	%	10%	10%	5,446,067	544,607
	Subtotal C					5,990,674
11	Planning design & supervision, fees, time cost & transport (% of Subtotal C)	%	15%	15%	5,990,674	898,601
	Subtotal D					6,889,275
12	VAT (% of Subtotal D)	%	14%	14%	6,889,275	964,498
	TOTAL PROJECT COST					7,853,773

SCHEME 2A PHASE 1
COST MODEL : ITEM 5 Pipeline from Smithfield tunnel outlet to Baynesfield Dam outlet
2.2 km of 1800mm diameter

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	5.0	60,000
1.2	(b) bush	ha	20,000	1.6	32,000
2	Road and River Crossings	Sum			200,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m³	35	19800	693,000
3.2	(b) Extra over for rock	m³	50	1980	99,000
3.3	(c) Bed preparation (Bedding)	m	70	2200	154,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	3,500	2200	7,700,000
4.2	(b) Laying and Jointing (% of(a))	%	20		1,540,000
4.3	(d) Cathodic Protection	km	50,000	2.2	110,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m³	850	70	59,500
6	Reinforcing	t	3,000	6.0	18,000
7	Mechanical Items				
7.1	(a) Valves etc	Sum			400,000
	SUB TOTAL A				11,065,500
8	Landscaping (% of Sub total A)	%	5		553,275
9	Miscellaneous (% of Sub total A)	%	5		553,275
	SUB TOTAL B				12,172,050
10	Preliminary and General	%	15		1,825,808
11	Preliminary Works		Incl. in P&G		
12	Accomodation		Incl. in P&G		
	SUB TOTAL C				13,997,858
13	Contingencies (% of Sub total C)	%	15		2,099,679
	Sub Total D				16,097,536
14	Planning design & Supervision (% of Sub total D)	%	12		1,931,704
	Sub Total E				18,029,240
15	VAT (% of Sub total E)	%	14		2,524,094
	TOTAL PROJECT COST				**20,553,334**

SCHEME 2A PHASE 1
COST MODEL : ITEM 5+ Pipeline from Baynesfield Dam to Baynesfield Waterworks
3.0 km of 1900mm diameter

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	8.0	96,000
1.2	(b) bush	ha	20,000	1.0	20,000
2	Road and River Crossings	Sum			100,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m³	35	34800	1,218,000
3.2	(b) Extra over for rock	m³	50	3480	174,000
3.3	(c) Bed preparation (Bedding)	m	70	3000	210,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	3,800	3000	11,400,000
4.2	(b) Laying and Jointing (% of(a))	%	20		2,280,000
4.3	(c) E/O for steep slopes	m	2,000	100	200,000
4.4	(d) Cathodic Protection	km	50,000	3.0	150,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m³	850	60	51,000
5.2	(b) Headwalls on steep slopes	m³	550	20	11,000
6	Reinforcing	t	3,000	7.0	21,000
7	Mechanical Items				
7.1	(a) Valves etc	Sum			550,000
	SUB TOTAL A				16,481,000
8	Landscaping (% of Sub total A)	%	5		824,050
9	Miscellaneous (% of Sub total A)	%	5		824,050
	SUB TOTAL B				18,129,100
10	Preliminary and General	%	15		2,719,365
11	Preliminary Works		Incl. in P&G		
12	Accomodation		Incl. in P&G		
	SUB TOTAL C				20,848,465
13	Contingencies (% of Sub total C)	%	15		3,127,270
	Sub Total D				23,975,735
14	Planning design & Supervision (% of Sub total D)	%	12		2,877,088
	Sub Total E				26,852,823
15	VAT (% of Sub total E)	%	14		3,759,395
	TOTAL PROJECT COST				**30,612,218**

SCHEME 2A PHASE 1
COST MODEL : ITEM 6 Baynesfield Waterworks 606 Ml/day

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Mechanical and Electrical	%	30	157,071,834	47,121,550
2	Civils	%	70	157,071,834	109,950,284
	SUB TOTAL A				157,071,834
3	Landscaping (% of Sub total A)	%	2	157,071,834	3,141,437
4	Miscellaneous (% of Sub total A)	%	10	157,071,834	15,707,183
	SUB TOTAL B				175,920,455
5	Preliminary and General	%	20	175,920,455	35,184,091
6	Preliminary Works		Incl. in P&G		
7	Accomodation		Incl. in P&G		
	SUB TOTAL C				211,104,545
8	Contingencies (% of Sub total C)	%	10	211,104,545	21,110,455
	Sub Total D				232,215,000
9	Planning design & Supervision (% of Sub total D)	%	12	232,215,000	27,865,800
	Sub Total E				260,080,800
10	VAT (% of Sub total E)	%	14		36,411,312
	TOTAL PROJECT COST				**296,492,112**

Note : Waterworks costs based on actual construction costs of existing large waterworks escalated.

SCHEME 2A PHASE 1
COST MODEL : ITEM 7 Pipeline from Baynsfield Waterworks to Umlaas Road
21.1 km of 1900mm diameter

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	57.0	684,000
1.2	(b) bush	ha	20,000	6.5	130,000
2	Road and River Crossings	Sum			5,900,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m³	35	244800	8,568,000
3.2	(b) Extra over for rock	m³	50	24480	1,224,000
3.3	(c) Bed preparation (Bedding)	m	70	21100	1,477,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	3,800	21100	80,180,000
4.2	(b) Laying and Jointing (% of(a))	%	20		16,036,000
4.3	(c) E/O for steep slopes	m	2,000	700	1,400,000
4.4	(d) Cathodic Protection	km	50,000	21.1	1,055,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m³	850	200	170,000
5.2	(b) Headwalls on steep slopes	m³	550	100	55,000
6	Reinforcing	t	3,000	69.0	207,000
7	Mechanical Items				
7.1	(a) Valves etc	Sum			1,400,000
	SUB TOTAL A				118,486,000
8	Landscaping (% of Sub total A)	%	5		5,924,300
9	Miscellaneous (% of Sub total A)	%	5		5,924,300
	SUB TOTAL B				130,334,600
10	Preliminary and General	%	15		19,550,190
11	Preliminary Works		Incl. in P&G		
12	Accomodation		Incl. in P&G		
	SUB TOTAL C				149,884,790
13	Contingencies (% of Sub total C)	%	15		22,482,719
	Sub Total D				172,367,509
14	Planning design & Supervision (% of Sub total D)	%	12		20,684,101
	Sub Total E				193,051,610
15	VAT (% of Sub total E)	%	14		27,027,225
	TOTAL PROJECT COST				**220,078,835**

SCHEME 2A PHASE 1
COST MODEL : ITEM 8 UMLAAS ROAD RESERVOIR 200Ml

No	Description	Unit	Rate Mar '98	Quantity	Amount
1.	Excavation to spoil	m3	15	35,000	525,000
2.	Cut to Fill	m3	20	30,000	600,000
3.	Mass Concrete	Sum			1,953,000
4	Structural Concrete	Sum			7,259,800
5	Formwork and Shuttering	Sum			8,206,600
6	Reinforcement	Sum			5,111,600
	PIPEWORK				
7	(a) civil	Sum			384,115
8	(b)mechanical/electrical	Sum			1,956,150
9	Miscellaneous	Sum			4,931,260
	Subtotal A (carried forward)				30,927,525
10	Preliminary, General and Preliminary works (% of Subtotal A)	%	20%	30,927,525	6,185,505
	Subtotal B				37,113,030
11	Contingencies (% of Subtotal B)	%	10%	37,113,030	3,711,303
	Subtotal C				40,824,333
12	Planning design & supervision, fees, time cost & transport (% of Subtotal C)	%	15%	40,824,333	6,123,650
	Subtotal D				46,947,983
13	VAT (% of Subtotal D)	%	14%	46,947,983	6,572,718
	TOTAL PROJECT COST				53,520,701

PHASE 2A PHASE 1
COST MODEL : ITEM 9 Advanced infrastructure Costs for Smithfield Dam

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Preliminary Works				
1.1	(a) Access Roads	km	800,000	13.5	10,800,000
1.2	(b) Electricity to Site	Sum			1,800,000
	SUB TOTAL A				12,600,000
2	Contingencies (% of Sub total A)	%	10		1,260,000
	Sub Total B				13,860,000
3	Planning design & Supervision (% of Sub total B)	%	12		1,663,200
	Sub Total C				15,523,200
4	VAT (% of Sub total C)	%	14		2,173,248
	TOTAL PROJECT COST				**17,696,448**

SCHEME 2A PHASE 2
COST MODEL : ITEM 1 IMPENDLE DAM FOR RAISING FSL=1184masl (1.0MAR)

No	Description	Unit	Rate Mar '98	Quantity	Amount
1.	Site and basin clearing	ha	1,875	1,845	3,457,800
2.	River diversion				
	(a) Diversion Tunnel 350m long	Sum			11,000,000
	(b) Coffer Dams	Sum			8,608,231
	(c) Structural Concrete for Diversion Works	Sum			2,825,260
	(d) Foundation Prep. and Dealing with Water	Sum			50,000
3.	Excavation				
	(a) all materials	m3	13	366,192	4,903,316
	(b) extra over for rock	m3	24	123,092	2,966,506
4.	Preparation of solum				
	(b) for embankment	m2	8	70,543	566,457
	(c) core trench	m2	16	26,538	426,462
5.	Drilling and Grouting				
	(a) curtain grouting	m Drill	150	7,021	1,052,974
	(b) consolidation grouting	m Drill	150	4,224	633,493
6.	Embankment				
	(a) Earthfill Core	m3	18	1,114,362	20,192,241
	(b) rockfill	m3	28	2,355,391	66,681,130
	(c) filters	m3	59	189,665	11,175,050
	(d) rip-rap	m3	33	92,188	3,086,442
	(e) road layerworks	m2	80	4,900	392,000
7	SPILLWAY				
	Excavation e/o to quarry	m3	10	1,030,000	10,300,000
	Formwork	m3	67	24,205	1,620,500
	Structural Concrete	m3	319	37,171	11,871,200
	Mass Concrete	m3	248	10,523	2,610,000
	Anchors and steel rebars	t	3,348	2,536	8,490,000
	Drill for Anchors	m Drill	50	90,000	4,500,000
	Road Bridge over Spillway	Sum			1,800,000
8	OUTLET STRUCTURE				
	(a) civil	Sum			6,970,000
	(b) mechanical/electrical	Sum			9,704,500
	(c) Pipework	Sum			15,335,500
	(d) Measuring weir	Sum			500,000
9	Landscaping (% of 1-8)	%	5%	211,719,064	10,585,953
10	Miscellaneous (% of 1-8)	%	10%	211,719,064	21,171,906
	Subtotal A (carried forward)				243,476,924
11	Preliminary, General and Preliminary works (% of Subtotal A)	%	20%	243,476,924	48,695,385
	Subtotal B				292,172,308
12	Contingencies (% of Subtotal B)	%	10%	292,172,308	29,217,231
	Subtotal C				321,389,539
13	Planning design & supervision, fees, time cost & transport (% of Subtotal C)	%	15%	321,389,539	48,208,431
	Subtotal D				369,597,970
14	VAT (% of Subtotal D)	%	14%	369,597,970	51,743,716
	TOTAL PROJECT COST				421,341,686

SCHEME 2A PHASE 2
COST MODEL : ITEM 2 Smithfield Dam Intake Tower and Pumpstation upsized by 795 ML/day

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Mechanical items - pumps, motors and switchgear, valves and meters				13,304,200
	Subtotal A : Mechanical items				13,304,200
2	Miscellaneous (% of Subtotal A)	%	5		665,210
	Subtotal B: Total construction				13,969,410
3	Preliminary and General	%	20		2,793,882
4	Site works		Incl. in P&G		
5	Accomodation		Incl. in P&G		
	Subtotal C				16,763,292
6	Contingencies (% of subtotal C)	%	20		3,352,658
	Subtotal D				20,115,950
7	Planning design & Supervision (% of subtotal D)	%	12		2,413,914
	Sub Total E				22,529,864
8	VAT (% of Sub total E)	%	14		3,154,181
	TOTAL PROJECT COST				**25,684,045**

SCHEME 2A PHASE 2
COST MODEL : ITEM 3 Add. Pipeline from Smithfield tunnel outlet to Baynesfield Dam outlet
2.2 km of1800mm diameter

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	5.0	60,000
1.2	(b) bush	ha	20,000	1.6	32,000
2	Road and River Crossings	Sum			200,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m³	35	19800	693,000
3.2	(b) Extra over for rock	m³	50	1980	99,000
3.3	(c) Bed preparation (Bedding)	m	70	2200	154,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	3,500	2200	7,700,000
4.2	(b) Laying and Jointing (% of(a))	%	20		1,540,000
4.4	(d) Cathodic Protection	km	50,000	2.2	110,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m³	850	70	59,500
6	Reinforcing	t	3,000	6.0	18,000
7	Mechanical Items				
7.1	(a) Valves etc	Sum			400,000
	SUB TOTAL A				11,065,500
8	Landscaping (% of Sub total A)	%	5		553,275
9	Miscellaneous (% of Sub total A)	%	5		553,275
	SUB TOTAL B				12,172,050
10	Preliminary and General	%	15		1,825,808
11	Preliminary Works		Incl. in P&G		
12	Accomodation		Incl. in P&G		
	SUB TOTAL C				13,997,858
13	Contingencies (% of Sub total C)	%	15		2,099,679
	Sub Total D				16,097,536
14	Planning design & Supervision (% of Sub total D)	%	12		1,931,704
	Sub Total E				18,029,240
15	VAT (% of Sub total E)	%	14		2,524,094
	TOTAL PROJECT COST				**20,553,334**

SCHEME 2A PHASE 2
COST MODEL : ITEM 3+ Add. Pipeline from Baynesfield Dam to Baynesfield Waterworks
3.0 km of 1900mm diameter

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	8.0	96,000
1.2	(b) bush	ha	20,000	1.0	20,000
2	Road and River Crossings	Sum			100,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m^3	35	34800	1,218,000
3.2	(b) Extra over for rock	m^3	50	3480	174,000
3.3	(c) Bed preparation (Bedding)	m	70	3000	210,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	3,800	3000	11,400,000
4.2	(b) Laying and Jointing (% of(a))	%	20		2,280,000
4.3	(c) E/O for steep slopes	m	2,000	100	200,000
4.4	(d) Cathodic Protection	km	50,000	3.0	150,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m^3	850	60	51,000
5.2	(b) Headwalls on steep slopes	m^3	550	20	11,000
6	Reinforcing	t	3,000	7.0	21,000
7	Mechanical Items				
7.1	(a) Valves etc	Sum			550,000
	SUB TOTAL A				16,481,000
8	Landscaping (% of Sub total A)	%	5		824,050
9	Miscellaneous (% of Sub total A)	%	5		824,050
	SUB TOTAL B				18,129,100
10	Preliminary and General	%	15		2,719,365
11	Preliminary Works		Incl. in P&G		
12	Accomodation		Incl. in P&G		
	SUB TOTAL C				20,848,465
13	Contingencies (% of Sub total C)	%	15		3,127,270
	Sub Total D				23,975,735
14	Planning design & Supervision (% of Sub total D)	%	12		2,877,088
	Sub Total E				26,852,823
15	VAT (% of Sub total E)	%	14		3,759,395
	TOTAL PROJECT COST				**30,612,218**

SCHEME 2A PHASE 2
COST MODEL : ITEM 4 Baynesfield Waterworks upsized by 795 Ml/day

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Mechanical and Electrical	%	30	237,614,144	71,284,243
2	Civils	%	70	237,614,144	166,329,901
	SUB TOTAL A				237,614,144
3	Landscaping (% of Sub total A)	%	2	237,614,144	4,752,283
4	Miscellaneous (% of Sub total A)	%	10	237,614,144	23761414
	SUB TOTAL B				266,127,841
5	Preliminary and General	%	20	266,127,841	53,225,568
6	Preliminary Works		Incl. in P&G		
7	Accomodation		Incl. in P&G		
	SUB TOTAL C				319,353,409
8	Contingencies (% of Sub total C)	%	10	319,353,409	31935341
	Sub Total D				351,288,750
9	Planning design & Supervision (% of Sub total D)	%	12	351,288,750	42,154,650
	Sub Total E				393,443,400
10	VAT (% of Sub total E)	%	14		55,082,076
	TOTAL PROJECT COST				**448,525,476**

Note : Waterworks costs based on actual construction costs of existing large waterworks escalated.

SCHEME 2A PHASE 2
COST MODEL : ITEM 5 Add. Pipeline from Baynsfield Waterworks to Umlaas Road
21.1 km of 1900mm diameter

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	57.0	684,000
1.2	(b) bush	ha	20,000	6.5	130,000
2	Road and River Crossings	Sum			3,500,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m³	35	244800	8,568,000
3.2	(b) Extra over for rock	m³	50	24480	1,224,000
3.3	(c) Bed preparation (Bedding)	m	70	21100	1,477,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	3,800	21100	80,180,000
4.2	(b) Laying and Jointing (% of(a))	%	20		16,036,000
4.3	(c) E/O for steep slopes	m	2,000	700	1,400,000
4.4	(d) Cathodic Protection	km	50,000	21.1	1,055,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m³	850	200	170,000
5.2	(b) Headwalls on steep slopes	m³	550	100	55,000
6	Reinforcing	t	3,000	69.0	207,000
7	Mechanical Items				
7.1	(a) Valves etc	Sum			1,400,000
	SUB TOTAL A				116,086,000
8	Landscaping (% of Sub total A)	%	5		5,804,300
9	Miscellaneous (% of Sub total A)	%	5		5,804,300
	SUB TOTAL B				127,694,600
10	Preliminary and General	%	15		19,154,190
11	Preliminary Works		Incl. in P&G		
12	Accomodation		Incl. in P&G		
	SUB TOTAL C				146,848,790
13	Contingencies (% of Sub total C)	%	15		22,027,319
	Sub Total D				168,876,109
14	Planning design & Supervision (% of Sub total D)	%	12		20,265,133
	Sub Total E				189,141,242
15	VAT (% of Sub total E)	%	14		26,479,774
	TOTAL PROJECT COST				**215,621,015**

PHASE 2A PHASE 2
COST MODEL : ITEM 6 Advanced infrastructure Costs for Impendle Dam

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Preliminary Works				
1.1	(a) Access Roads	km	800,000	12.5	10,000,000
1.2	(b) Electricity to Site	Sum			1,770,000
	SUB TOTAL A				11,770,000
2	Contingencies (% of Sub total A)	%	10		1,177,000
	Sub Total B				12,947,000
3	Planning design & Supervision (% of Sub total B)	%	12		1,553,640
	Sub Total C				14,500,640
4	VAT (% of Sub total C)	%	14		2,030,090
	TOTAL PROJECT COST				**16,530,730**

SCHEME 2A PHASE 3
COST MODEL : ITEM 1 IMPENDLE DAM (RAISING FROM 1184masl TO FSL 1197masl)

No	Description	Unit	Rate Mar '98	Quantity	Amount
1.	Site and basin clearing	ha	1,875	769	1,440,750
2	Excavation				
	(a) all materials	m3	13	231,079	3,094,145
	(b) extra over for rock	m3	24	23,210	559,349
3	Preparation of solum				
	(b) for embankment	m2	8	22,780	182,926
	(c) core trench	m2	16	464	7,458
4	Drilling and Grouting				
	(a) curtain grouting	m Drill	150	1,275	191,238
	(b) consolidation grouting	m Drill	150	168	25,179
5	Embankment				
	(a) Earthfill Core	m3	18	183,470	3,324,475
	(b) rockfill	m3	28	1,569,196	44,423,929
	(c) filters	m3	59	52,649	3,102,104
	(d) rip-rap	m3	33	25,591	856,772
	(e) road layerworks	m2	80	5,460	436,800
6	SPILLWAY				
	(a) Excavation e/o to quarry	m3	10	80,000	800,000
	(b) Formwork	m3	67	15,108	1,011,500
	(c) Structural Concrete	m3	319	18,645	5,954,600
	(d) Mass Concrete	m3	248	4,234	1,050,000
	(e) Anchors and steel rebars	t	3,348	1,228	4,110,000
	(f) Drill for Anchors	m Drill	50	34,000	1,700,000
	(g) Road Bridge over Spillway	Sum			1,900,000
	(h) Demolish Phase 1 Structs	Sum			500,000
7	OUTLET STRUCTURE				
	(a) civil	Sum			1,046,000
	(b) mechanical/electrical	Sum			172,000
	(c) Pipework	Sum			502,000
8	Landscaping (% of 1-7)	%	5%	76,391,225	3,819,561
9	Miscellaneous (% of 1-7)	%	10%	76,391,225	7,639,122
	Subtotal A (carried forward)				87,849,908
10	Preliminary, General and Preliminary works (% of Subtotal A)	%	20%	87,849,908	17,569,982
	Subtotal B				105,419,890
11	Contingencies (% of Subtotal B)	%	10%	105,419,890	10,541,989
	Subtotal C				115,961,879
12	Planning design & supervision, fees, time cost & transport (% of Subtotal C)	%	15%	115,961,879	17,394,282
	Subtotal D				133,356,161
13	VAT (% of Subtotal D)	%	14%	133,356,161	18,669,863
	TOTAL PROJECT COST				152,026,023

SCHEME 2A
PUMPING COSTS

Power costs : Miniflex structure

Rates obtained from Eskom.

Basic charge	per month	53.05
Demand charge	No demand charge - assumed that Umgeni Water will go to Miniflex structure as proposed for Mearns scheme.	

Energy charges :

High demand : April - September (c/kWh)		
Peak	c/kWh	30.54
Standard	c/kWh	11.23
Off-peak	c/kWh	6.44
Average	*c/kWh*	*16.07*

Low demand : October - March (c/kWh)		
Peak	c/kWh	27.49
Standard	c/kWh	10.08
Off-peak	c/kWh	5.80
Average	*c/kWh*	*14.46*

Weighted annual average rate : (12 months - assume constant pumping all year round)

Rate 15.26 c/kWh

Parameter		**Unit**	**SCHEME 2A**		
			Phase 1	**Phase 2**	**Phase 3**
FSL		masl	915	915	915
Min operating level		masl	870	870	870
Average operating level		masl	892.5	892.5	892.5
Inlet		masl	940	940	940
Flow		**m3/s**	**4.649**	**10.594**	**11.89**
Friction head *		m	0.09	0.45	0.57
Total head	Min	m	25.1	25.5	25.6
	Max	m	70.1	70.5	70.6
	Average	m	47.6	48.0	48.1
Pump efficiency **			0.90	0.90	0.90
Motor efficiency **			0.97	0.97	0.97
Power requirement		MW	2.49	5.71	6.42
Monthly energy ***		MWh	1820	4179	4701
Total pumped per month * **		**m3.10E6**	**12.25**	**27.92**	**31.33**
Total pumped per annum		**m3.10E6**	**147.01**	**335.01**	**375.99**
Monthly charges					
Energy charge			277,755	637,787	717,559
Reactive energy charge		Not considered - high efficiency (pf=0.96) gives low reactive energy charge			
Basic charge			53	53	53
	Subtotal		277,808	637,840	717,612
Transmission surcharge (1%)			2,778	6,378	7,176
Voltage discount (5%)			-13,890	-31,892	-35,881
	Subtotal		**266,696**	**612,327**	**688,908**
Contingency (20%)			**53,339**	**122,465**	**137,782**
	Total per month		**320,035**	**734,792**	**826,689**
	Total per annum		**3,840,422**	**8,817,502**	**9,920,268**
Unit cost		**c/m3**	**2.61**	**2.63**	**2.64**
Check (c/m3/100m)			5.49	5.49	5.49

* Based on 250 m long, twin 1800 mm diam line (n = 0.012)
** VAPS recommendation
*** 30.5 days per month

SCHEME 2B

SCHEME 2B PHASE 1
COST MODEL : ITEM 1 SMITHFIELD COMPOSITE DAM
FSL 915 masl

No	Description	Unit	Rate Mar-98	Quantity	Amount
1.	Site and basin clearing	ha	1,875	582	1,091,017
2.	River diversion	Sum	1,015,800		1,015,800
3.	Excavation				
	(a) all materials	m3	13	297,216	3,979,728
	(b) extra over for rock	m3	24	155,353	3,744,313
4.	Preparation of solum				
	(a) for Concrete section	m2	24	14,893	358,957
	(b) for embankment	m2	8	49,982	401,554
	(c) core trench	m2	16	34,433	553,265
5.	Drilling and Grouting				
	(a) curtain grouting	m drill	150	13,270	1,990,094
	(b) consolidation grouting	m drill	150	7,047	1,056,760
	(c) Drainage curtain	m drill	134	4,363	584,170
6.	Embankment				
	(a) earthfill,core	m3	18	326,217	5,911,048
	(b) rockfill	m3	28	593,269	16,796,940
	(c) filters	m3	59	66,989	3,946,694
	(d) rip-rap	m3	33	66,989	2,242,440
7.	Formwork				
	(a) gang formed	m2	67	35,035	2,345,593
	(b) intricate	m2	107	3,504	375,295
8.	Concrete				
	(a) roller compacted concrete	m3	211	332,657	70,072,451
	(b) mass & skin concrete	m3	248	36,962	9,167,184
	(c) structural	m3	319	5,000	1,596,825
9.	Reinforcing	t	3,348	750	2,510,625
10	Multilevel intake structure				
	(a) civil	Sum	3,996,000		3,996,000
	(b) mechanical and electrical	Sum	7,189,000		7,189,000
	(c) River outlet pipework	Sum	3,590,000		3,590,000
	(d) Measuring weir	Sum			500,000
11	Landscaping (% of 1-10)	%	5%	145,985,753	7,299,288
12	Miscellaneous (% of 1-10)	%	10%	145,985,753	14,598,575
	Subtotal A (carried forward)				166,913,616
13	Preliminary, General and Preliminary works (% of Subtotal A)	%	20%	167,883,616	33,576,723
	Subtotal B				200,490,339
14	Contingencies (% of Subtotal B)	%	10%	201,460,339	20,146,034
	Subtotal C				220,636,373
15	Planning design & supervision, fees, time cost & transport (% of Subtotal C)	%	12%	221,606,373	26,592,765
	Subtotal D				247,229,138
16	VAT (% of Subtotal D)	%	14%	248,199,138	34,747,879
	TOTAL PROJECT COST				281,977,017

SCHEME 2B PHASE 1
COST MODEL : ITEM 2 Smithfield Dam Intake Tower and Pumpstation 630 ML/day

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Earthworks				
1.1	c. Excavation - rock	m3	90	550	49,500
2	Rock support				
2.1	a. Rock anchors - 20 m long 8x8m spacing	No	1,000	10	10,000
2.2	b. Rock dowels - 4x4m spacing	No	200	100	20,000
3	Access bridge	Sum			1,500,000
4	Drilling and grouting	m	500	300	150,000
5	Formwork				
5.1	a. Smooth vertical - curved and plain	m2	155	11650	1,805,750
5.2	b. Smooth horizontal - soffits	m2	155	750	116,250
5.3	c. Intricate	m2	420	1000	420,000
6	Unformed surface finishes	m2	6	1000	6,000
7	Concrete				
7.1	Mass concrete	m3	300	1000	300,000
7.2	Structural concrete	m3	380	14500	5,510,000
8	Reinforcing	t	3,000	2450	7,350,000
9	Miscellaneous				
9.1	a. Structural steelwork	t	8,000	45	360,000
9.2	b. Building work	Sum			50,000
9.3	c. Electrical and instrumentation	Sum			1,500,000
9.4	d. Intake pipes - twin 1800 mm diam lines	m	17,500	250	4,375,000
	Subtotal A : Civil construction				23,522,500
10	Mechanical items - Gates, screens and cranes and stoplogs, including installation	Sum			11,550,000
11	Mechanical items - pumps, motors and switchgear, valves and meters	Sum			11,050,000
	Subtotal B : Mechanical items				22,600,000
12	Landscaping (% of Subtotal A)	%	5		1,176,125
13	Miscellaneous (% of Subtotal A + Subtotal B)	%	5		2,306,125
	Subtotal C : Total construction				49,604,750
14	Preliminary and General	%	20		9,920,950
15	Site works		Incl. in P&G		
16	Accomodation		Incl. in P&G		
	Subtotal D				59,525,700
17	Contingencies (% of subtotal D)	%	20		11,905,140
	Subtotal E				71,430,840
18	Planning design & Supervision (% of subtotal E)	%	12		8,571,701
	Sub Total F				80,002,541
19	VAT (% of Sub total F)	%	14		11,200,356
	TOTAL PROJECT COST				**91,202,897**

SCHEME 2B PHASE 1
COST MODEL : ITEM 3 Tunnel from Smithfield Dam to Baynesfield Dam
TBM Tunnel 3,5 m diameter
D & B Tunnel 5,5 by 6 m high

SMITHFIELD TUNNEL - FREE SURFACE FLOW

Tunnel Length: 32900m
1 Up from outlet TBM - 12950m
1 Down from 1/3 point - 12950m
1 Down from inlet - 6500m
DB Tunnel - 500m
1 DB Adit - 350m at 1:10

No	Description	Unit	Rate	Quantity	Amount
1	Portal excavations				
	a. Inlet portal	Sum	2,500,000	1	2,500,000
	b. Outlet portal	Sum	4,000,000	1	4,000,000
	b. Intermediate	Sum	2,500,000	1	2,500,000
2	Tunnel Excavation				
	TBM				
	b. Rock Class II	m3	340	52,992	18,017,439
	c. Rock Class III	m3	350	202,618	70,916,391
	d. Rock Class IV	m3	400	49,875	19,950,106
	e. Rock Class V	m3	1,000	6,234	6,234,408
	D & B (Adits)				
	c. Rock Class III	m3	180	13,981	2,516,580
	d. Rock Class IV	m3	200	2,728	545,600
	e. Rock Class V	m3	550	341	187,550
3	Extra for down grade drive	m	1,500	19,950	29,925,000
4	Extra for length of drive over 10 km	m	1,000	5,900	5,900,000
5	Turning Chamber	No	250,000	2	500,000
6	Dealing with Water	m	15	33,250	498,750
7	Shafts				
	a. Ventilation	m	3,000	650	1,950,000
8	Rock support				
	a. i) Rockbolts - TBM	m	250	32,900	8,225,000
	a. ii) Rockbolts - D & B	m	380	350	133,000
	b. Shotcrete	m3	1,400	657	919,926
9	Concrete				
	a. Linings	m3	550	74,109	40,759,784
	b. Overbreak concrete : TBM	m2	100	361,754	36,175,439
	d. Concrete - D & B Invert blinding	m3	400	525	210,000
	e. Concrete : Structures	m3	380	1,100	418,000
10	Formwork				
	a. Smooth curved in tunnel	m2	150	270,595	40,589,279
	b. Structures	m2	155	4,400	682,000
11	Reinforcement	ton	3,000	88	264,000
12	Pre-cast concrete inverts	m	290	32,900	9,541,000
	SUBTOTAL : MEASURED ITEMS				**304,059,253**

SCHEME 2B PHASE 1
COST MODEL : ITEM 3 Tunnel from Smithfield Dam to Baynesfield Dam

SMITHFIELD TUNNEL - FREE SURFACE FLOW

No	Description	Unit	Rate	Quantity	Amount
	SUBTOTAL : MEASURED ITEMS				**304,059,253**
13	Grouting				
	i) Cavity	m	200	32,900	6,580,000
	ii) Consolidation/Fissure	m	7	32,900	230,300
14	Waterproof lining				
	b. Waterproof membrane	m2	300	30,000	9,000,000
15	a. Intake Pipeline : Twin 1800 dia pipeline	m	17,500	250	4,375,000
	b. Outlet spill line : Twin 1800 dia pipeline	m	17,500	250	4,375,000
16	Miscellaneous	%	10	328,619,553	32,861,955
	SUBTOTAL A				**361,481,508**
17.1	P & G Fixed	Sum	1	27,000,000	27,000,000
17.2	P & G Time Related - Establishment	Sum	1	9,350,000	9,350,000
17.3	P & G Time Related - TBM Excavation	Sum	1	63,250,000	63,250,000
17.4	P & G Time Related - Adit Excavation	Sum	1	3,000,000	3,000,000
17.5	P & G Time Related - Lining	Sum	1	29,820,000	29,820,000
18	Preliminary works		Incl. in P&G		
19	Accommodation		Incl. in P&G		
	SUBTOTAL B				**493,901,508**
20	Contingencies (% of Subtotal B)	%	10	493,901,508	49,390,151
	SUBTOTAL C				**543,291,659**
21	Planning, design and supervision (% of Subtotal C)	%	12	543,291,659	65,194,999
	SUBTOTAL D				**608,486,658**
22	VAT (% of Subtotal D)	%	14	608,486,658	85,188,132
	TOTAL PROJECT COST				**693,674,790**

Construction Period = 56 months
4,7 years

SCHEME 2B PHASE 1
COST MODEL : ITEM 4 BAYNESFIELD DAM RAISED BY 0.5m FSL 871.5masl

No	Description	Unit	Rate Mar '98	Quantity	Amount
1.	Site and basin clearing	ha	1,875	51	96,050
2	Excavation				
	(a) all materials	m3	13	3,139	42,036
	(b) extra over for rock	m3	24	1,065	25,663
3	Preparation of solum				
	(a) for embankment	m2	8	2,871	23,052
4	Embankment				
	(a) Earthfill	m3	18	12,277	222,460
	(b) rockfill	m3	28	1,794	50,790
	(c) filters	m3	59	163	9,611
	(d) rip-rap	m3	33	108	3,605
5	SPILLWAY				
	(a) Formwork	m3	67	464	31,080
	(b) Structural Concrete	m3	314	405	127,300
	(c) Demolish ex slab on crest	Sum			50,000
6	OUTLET STRUCTURE				
	(a) civil	Sum			580,120
	(b) mechanical/electrical	Sum			1,629,000
	(c) Pipework	Sum			1,055,659
7	Landscaping (% of 1-6)	%	5%	3,946,425	197,321
8	Miscellaneous (% of 1-6)	%	10%	3,946,425	394,642
	Subtotal A (carried forward)				4,538,389
9	Preliminary, General and Preliminary works (% of Subtotal A)	%	20%	4,538,389	907,678
	Subtotal B				5,446,067
10	Contingencies (% of Subtotal B)	%	10%	5,446,067	544,607
	Subtotal C				5,990,674
11	Planning design & supervision, fees, time cost & transport (% of Subtotal C)	%	15%	5,990,674	898,601
	Subtotal D				6,889,275
12	VAT (% of Subtotal D)	%	14%	6,889,275	964,498
	TOTAL PROJECT COST				7,853,773

SCHEME 2B PHASE 1
COST MODEL : ITEM 5 Pipeline from Smithfield Tunnel outlet to Baynesfield Dam outlet
2.2 km of 1800mm diameter

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	5.0	60,000
1.2	(b) bush	ha	20,000	1.6	32,000
2	Road and River Crossings	Sum			200,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m³	35	19800	693,000
3.2	(b) Extra over for rock	m³	50	1980	99,000
3.3	(c) Bed preparation (Bedding)	m	70	2200	154,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	3,500	2200	7,700,000
4.2	(b) Laying and Jointing (% of(a))	%	20		1,540,000
4.3	(d) Cathodic Protection	km	50,000	2.2	110,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m³	850	70	59,500
5.2	(b) Headwalls on steep slopes	m³	550		
6	Reinforcing	t	3,000	6.0	18,000
7	Mechanical Items				
7.1	(a) Valves etc	Sum			400,000
	SUB TOTAL A				11,065,500
8	Landscaping (% of Sub total A)	%	5		553,275
9	Miscellaneous (% of Sub total A)	%	5		553,275
	SUB TOTAL B				12,172,050
10	Preliminary and General	%	15		1,825,808
11	Preliminary Works		Incl. in P&G		
12	Accomodation		Incl. in P&G		
	SUB TOTAL C				13,997,858
13	Contingencies (% of Sub total C)	%	15		2,099,679
	Sub Total D				16,097,536
14	Planning design & Supervision (% of Sub total D)	%	12		1,931,704
	Sub Total E				18,029,240
15	VAT (% of Sub total E)	%	14		2,524,094
	TOTAL PROJECT COST				**20,553,334**

SCHEME 2B PHASE 1
COST MODEL : ITEM 5+ Pipeline from Baynesfield Dam to Baynesfield Waterworks
3.0 km of 900mm diameter

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	8.0	96,000
1.2	(b) bush	ha	20,000	1.0	20,000
2	Road and River Crossings	Sum			100,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m³	35	34800	1,218,000
3.2	(b) Extra over for rock	m³	50	3480	174,000
3.3	(c) Bed preparation (Bedding)	m	70	3000	210,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	3,800	3000	11,400,000
4.2	(b) Laying and Jointing (% of(a))	%	20		2,280,000
4.3	(c) E/O for steep slopes	m	2,000	100	200,000
4.4	(d) Cathodic Protection	km	50,000	3.0	150,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m³	850	60	51,000
5.2	(b) Headwalls on steep slopes	m³	550	20	11,000
6	Reinforcing	t	3,000	7.0	21,000
7	Mechanical Items				
7.1	(a) Valves etc	Sum			550,000
	SUB TOTAL A				16,481,000
8	Landscaping (% of Sub total A)	%	5		824,050
9	Miscellaneous (% of Sub total A)	%	5		824,050
	SUB TOTAL B				18,129,100
10	Preliminary and General	%	15		2,719,365
11	Preliminary Works		Incl. in P&G		
12	Accomodation		Incl. in P&G		
	SUB TOTAL C				20,848,465
13	Contingencies (% of Sub total C)	%	15		3,127,270
	Sub Total D				23,975,735
14	Planning design & Supervision (% of Sub total D)	%	12		2,877,088
	Sub Total E				26,852,823
15	VAT (% of Sub total E)	%	14		3,759,395
	TOTAL PROJECT COST				**30,612,218**

SCHEME 2B PHASE
COST MODEL : ITEM 6 Baynesfield Waterworks 630 Ml/day

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Mechanical and Electrical	%	30	177,709,010	53,312,703
2	Civils	%	70	177,709,010	124,396,307
	SUB TOTAL A				177,709,010
3	Landscaping (% of Sub total A)	%	2	177,709,010	3,554,180
4	Miscellaneous (% of Sub total A)	%	10	177,709,010	17,770,901
	SUB TOTAL B				199,034,091
5	Preliminary and General	%	20	199,034,091	39,806,818
6	Preliminary Works		Incl. in P&G		
7	Accomodation		Incl. in P&G		
	SUB TOTAL C				238,840,909
8	Contingencies (% of Sub total C)	%	10	238,840,909	23,884,091
	Sub Total D				262,725,000
9	Planning design & Supervision (% of Sub total D)	%	12	262,725,000	31,527,000
	Sub Total E				294,252,000
10	VAT (% of Sub total E)	%	14	294,252,000	41,195,280
	TOTAL PROJECT COST				**335,447,280**

Note : Waterworks costs based on actual construction costs of existing large waterworks escalated.

SCHEME 2B PHASE 1
COST MODEL : ITEM 7 Pipeline from Baynsfield Waterworks to Umlaas Road Reservoir
21.1 km of 1900mm diameter

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	57.0	684,000
1.2	(b) bush	ha	20,000	6.5	130,000
2	Road and River Crossings	Sum			5,900,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m³	35	244800	8,568,000
3.2	(b) Extra over for rock	m³	50	24480	1,224,000
3.3	(c) Bed preparation (Bedding)	m	70	21100	1,477,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	3,800	21100	80,180,000
4.2	(b) Laying and Jointing (% of(a))	%	20		16,036,000
4.3	(c) E/O for steep slopes	m	2,000	700	1,400,000
4.4	(d) Cathodic Protection	km	50,000	21.1	1,055,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m³	850	200	170,000
5.2	(b) Headwalls on steep slopes	m³	550	100	55,000
6	Reinforcing	t	3,000	69.0	207,000
7	Mechanical Items				
7.1	(a) Valves etc	Sum			1,400,000
	SUB TOTAL A				118,486,000
8	Landscaping (% of Sub total A)	%	5		5,924,300
9	Miscellaneous (% of Sub total A)	%	5		5,924,300
	SUB TOTAL B				130,334,600
10	Preliminary and General	%	15		19,550,190
11	Preliminary Works		Incl. in P&G		
12	Accomodation		Incl. in P&G		
	SUB TOTAL C				149,884,790
13	Contingencies (% of Sub total C)	%	15		22,482,719
	Sub Total D				172,367,509
14	Planning design & Supervision (% of Sub total D)	%	12		20,684,101
	Sub Total E				193,051,610
15	VAT (% of Sub total E)	%	14		27,027,225
	TOTAL PROJECT COST				**220,078,835**

SCHEME 2B PHASE 1
COST MODEL : ITEM 8 UMLAAS ROAD RESERVOIR 200Ml

No	Description	Unit	Rate Mar '98	Quantity	Amount
1.	Excavation to spoil	m3	15	35,000	525,000
2.	Cut to Fill	m3	20	30,000	600,000
3.	Mass Concrete	Sum			1,953,000
4	Structural Concrete	Sum			7,259,800
5	Formwork and Shuttering	Sum			8,206,600
6	Reinforcement	Sum			5,111,600
	PIPEWORK				
7	(a) civil	Sum			384,115
8	(b)mechanical/electrical	Sum			1,956,150
9	Miscellaneous	Sum			4,931,260
	Subtotal A (carried forward)				30,927,525
10	Preliminary, General and Preliminary works (% of Subtotal A)	%	20%	30,927,525	6,185,505
	Subtotal B				37,113,030
11	Contingencies (% of Subtotal B)	%	10%	37,113,030	3,711,303
	Subtotal C				40,824,333
12	Planning design & supervision, fees, time cost & transport (% of Subtotal C)	%	15%	40,824,333	6,123,650
	Subtotal D				46,947,983
13	VAT (% of Subtotal D)	%	14%	46,947,983	6,572,718
	TOTAL PROJECT COST				53,520,701

PHASE 2B PHASE 1
COST MODEL : ITEM 9 Advanced infrastructure Costs for Smithfield Dam

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Preliminary Works				
1.1	(a) Access Roads	km	800,000	13.5	10,800,000
1.2	(b) Electricity to Site	Sum			1,800,000
	SUB TOTAL A				12,600,000
2	Contingencies (% of Sub total A)	%	10		1,260,000
	Sub Total B				13,860,000
3	Planning design & Supervision (% of Sub total B)	%	12		1,663,200
	Sub Total C				15,523,200
4	VAT (% of Sub total C)	%	14		2,173,248
	TOTAL PROJECT COST				**17,696,448**

SCHEME 2B PHASE 2
COST MODEL : ITEM 1 IMPENDLE DAM FSL =1184masl (1.0 MAR)

No	Description	Unit	Rate Mar '98	Quantity	Amount
1.	Site and basin clearing	ha	1,875	1,025	1,921,000
2.	River diversion				
	(a) Diversion Tunnel 350m long	Sum			11,000,000
	(b) Coffer Dams	Sum			8,608,231
	(c)Structural Concrete to Diversion Works	Sum			2,825,260
	(d) Foundation Prep. and Dealing with Water	Sum			500,000
3.	Excavation				
	(a) all materials	m3	13	340,094	4,553,858
	(b) extra over for rock	m3	24	114,319	2,755,084
4.	Preparation of solum				
	(b) for embankment	m2	8	73,584	590,882
	(c) core trench	m2	16	21,840	350,967
5.	Drilling and Grouting				
	(a) curtain grouting	m Drill	150	6,651	997,420
	(b) consolidation grouting	m Drill	150	3,476	521,348
6.	Embankment				
	(a) Earthfill Core	m3	18	827,124	14,987,484
	(b) rockfill	m3	28	2,527,698	71,559,143
	(c) filters	m3	59	189,665	11,175,050
	(d) rip-rap	m3	33	92,188	3,086,442
	(e) road layerworks	m2	80	4,900	392,000
7	SPILLWAY				
	(a) Excavation e/o to quarry	m3	10	710,000	7,100,000
	(b) Formwork	m3	67	20,022	1,340,500
	(c) Structural Concrete	m3	319	33,792	10,792,000
	(d) Mass Concrete	m3	248	10,523	2,610,000
	(e) Anchors and steel rebars	t	3,348	2,330	7,800,000
	(f) Drill for Anchors	m Drill	50	88,000	4,400,000
	(g) Road Bridge over Spillway	Sum			1,900,000
8	OUTLET STRUCTURE				
	(a) civil	Sum			6,970,000
	(b) mechanical/electrical	Sum			9,704,500
	(c) Pipework	Sum			15,335,500
	(d) Measuring weir	Sum			500,000
9	Landscaping (% of 1-8)	%	5%	204,276,669	10,213,833
10	Miscellaneous (% of 1-8)	%	10%	204,276,669	20,427,667
	Subtotal A (carried forward)				234,918,169
11	Preliminary, General and Preliminary works (% of Subtotal A)	%	20%	234,918,169	46,983,634
	Subtotal B				281,901,803
12	Contingencies (% of Subtotal B)	%	10%	281,901,803	28,190,180
	Subtotal C				310,091,983
13	Planning design & supervision, fees, time cost & transport (% of Subtotal C)	%	15%	310,091,983	46,513,797
	Subtotal D				356,605,781
14	VAT (% of Subtotal D)	%	14%	356,605,781	49,924,809
	TOTAL PROJECT COST				406,530,590

PHASE 2B PHASE 2
COST MODEL : ITEM 2 Advanced infrastructure Costs for Impendle Dam

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Preliminary Works				
1.1	(a) Access Roads	km	800,000	12.5	10,000,000
1.2	(b) Electricity to Site	Sum			1,770,000
	SUB TOTAL A				11,770,000
2	Contingencies (% of Sub total A)	%	10		1,177,000
	Sub Total B				12,947,000
3	Planning design & Supervision (% of Sub total B)	%	12		1,553,640
	Sub Total C				14,500,640
4	VAT (% of Sub total C)	%	14		2,030,090
	TOTAL PROJECT COST				**16,530,730**

SCHEME 2B PHASE 3
COST MODEL : ITEM 1 Smithfield Dam Intake Tower and Pumpstation upsized by 630 ML/day

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Mechanical items - pumps, motors and switchgear, valves and meters				11,050,000
	Subtotal A : Mechanical items				11,050,000
2	Miscellaneous (% of Subtotal A)	%	5		552,500
	Subtotal B: Total construction				11,602,500
3	Preliminary and General	%	20		2,320,500
4	Site works		Incl. in P&G		
5	Accomodation		Incl. in P&G		
	Subtotal C				13,923,000
6	Contingencies (% of subtotal C)	%	20		2,784,600
	Subtotal D				16,707,600
7	Planning design & Supervision (% of subtotal D)	%	12		2,004,912
	Sub Total E				18,712,512
8	VAT (% of Sub total E)	%	14		2,619,752
	TOTAL PROJECT COST				**21,332,264**

SCHEME 2B PHASE 3
COST MODEL : ITEM 2 Add. Pipeline from Smithfield Tunnel outlet to Baynesfield Dam outlet
2.2 km of 1800mm diameter

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	5.0	60,000
1.2	(b) bush	ha	20,000	1.6	32,000
2	Road and River Crossings	Sum			200,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m^3	35	19800	693,000
3.2	(b) Extra over for rock	m^3	50	1980	99,000
3.3	(c) Bed preparation (Bedding)	m	70	2200	154,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	3,500	2200	7,700,000
4.2	(b) Laying and Jointing (% of(a))	%	20		1,540,000
4.3	(d) Cathodic Protection	km	50,000	2.2	110,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m^3	850	70	59,500
6	Reinforcing	t	3,000	6.0	18,000
7	Mechanical Items				
7.1	(a) Valves etc	Sum			400,000
	SUB TOTAL A				11,065,500
8	Landscaping (% of Sub total A)	%	5		553,275
9	Miscellaneous (% of Sub total A)	%	5		553,275
	SUB TOTAL B				12,172,050
10	Preliminary and General	%	15		1,825,808
11	Preliminary Works		Incl. in P&G		
12	Accomodation		Incl. in P&G		
	SUB TOTAL C				13,997,858
13	Contingencies (% of Sub total C)	%	15		2,099,679
	Sub Total D				16,097,536
14	Planning design & Supervision (% of Sub total D)	%	12		1,931,704
	Sub Total E				18,029,240
15	VAT (% of Sub total E)	%	14		2,524,094
	TOTAL PROJECT COST				**20,553,334**

SCHEME 2B PHASE 3
COST MODEL : ITEM 2+ Add. Pipeline from Baynesfield Dam to Baynesfield Waterworks
3.0 km of 1900mm diameter

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	8.0	96,000
1.2	(b) bush	ha	20,000	1.0	20,000
2	Road and River Crossings	Sum			100,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m^3	35	34800	1,218,000
3.2	(b) Extra over for rock	m^3	50	3480	174,000
3.3	(c) Bed preparation (Bedding)	m	70	3000	210,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	3,800	3000	11,400,000
4.2	(b) Laying and Jointing (% of(a))	%	20		2,280,000
4.3	(c) E/O for steep slopes	m	2,000	100	200,000
4.4	(d) Cathodic Protection	km	50,000	3.0	150,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m^3	850	60	51,000
5.2	(b) Headwalls on steep slopes	m^3	550	20	11,000
6	Reinforcing	t	3,000	7.0	21,000
7	Mechanical Items				
7.1	(a) Valves etc	Sum			550,000
	SUB TOTAL A				16,481,000
8	Landscaping (% of Sub total A)	%	5		824,050
9	Miscellaneous (% of Sub total A)	%	5		824,050
	SUB TOTAL B				18,129,100
10	Preliminary and General	%	15		2,719,365
11	Preliminary Works		Incl. in P&G		
13	Accomodation		Incl. in P&G		
	SUB TOTAL C				20,848,465
14	Contingencies (% of Sub total C)	%	15		3,127,270
	Sub Total D				23,975,735
15	Planning design & Supervision (% of Sub total D)	%	12		2,877,088
	Sub Total E				26,852,823
16	VAT (% of Sub total E)	%	14		3,759,395
	TOTAL PROJECT COST				**30,612,218**

SCHEME 2B PHASE 3
COST MODEL : ITEM 3 Baynesfield Waterworks upsized 630 Ml/day

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Mechanical and Electrical	%	30	177,709,010	53,312,703
2	Civils	%	70	177,709,010	124,396,307
	SUB TOTAL A				177,709,010
3	Landscaping (% of Sub total A)	%	2	177,709,010	3,554,180
4	Miscellaneous (% of Sub total A)	%	10	177,709,010	17,770,901
	SUB TOTAL B				199,034,091
5	Preliminary and General	%	20	199,034,091	39,806,818
6	Preliminary Works		Incl. in P&G		
7	Accomodation		Incl. in P&G		
	SUB TOTAL C				238,840,909
8	Contingencies (% of Sub total C)	%	10	238,840,909	23,884,091
	Sub Total D				262,725,000
9	Planning design & Supervision (% of Sub total D)	%	12	262,725,000	31,527,000
	Sub Total E				294,252,000
10	VAT (% of Sub total E)	%	14	294,252,000	41,195,280
	TOTAL PROJECT COST				**335,447,280**

Note : Waterworks costs based on actual construction costs of existing large waterworks escalated.

SCHEME 2B PHASE 3
COST MODEL : ITEM 4 Add. Pipeline from Baynsfield Waterworks to Umlaas Road Reservoir
21.1 km of 1900mm diameter

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	57.0	684,000
1.2	(b) bush	ha	20,000	6.5	130,000
2	Road and River Crossings	Sum			3,500,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m³	35	244800	8,568,000
3.2	(b) Extra over for rock	m³	50	24480	1,224,000
3.3	(c) Bed preparation (Bedding)	m	70	21100	1,477,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	3,800	21100	80,180,000
4.2	(b) Laying and Jointing (% of(a))	%	20		16,036,000
4.3	(c) E/O for steep slopes	m	2,000	700	1,400,000
4.4	(d) Cathodic Protection	km	50,000	21.1	1,055,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m³	850	200	170,000
5.2	(b) Headwalls on steep slopes	m³	550	100	55,000
6	Reinforcing	t	3,000	69.0	207,000
7	Mechanical Items				
7.1	(a) Valves etc	Sum			1,400,000
	SUB TOTAL A				116,086,000
8	Landscaping (% of Sub total A)	%	5		5,804,300
9	Miscellaneous (% of Sub total A)	%	5		5,804,300
	SUB TOTAL B				127,694,600
10	Preliminary and General	%	15		19,154,190
11	Preliminary Works		Incl. in P&G		
12	Accomodation		Incl. in P&G		
	SUB TOTAL C				146,848,790
13	Contingencies (% of Sub total C)	%	15		22,027,319
	Sub Total D				168,876,109
14	Planning design & Supervision (% of Sub total D)	%	12		20,265,133
	Sub Total E				189,141,242
15	VAT (% of Sub total E)	%	14		26,479,774
	TOTAL PROJECT COST				**215,621,015**

SCHEME 2B
PUMPING COSTS

Power costs : Miniflex structure

Rates obtained from Eskom.

Basic charge	per month	53.05
Demand charge	No demand charge - assumed that Umgeni Water will go to Miniflex structure as proposed for Mearns scheme.	

Energy charges :

High demand : April - September (c/kWh)

Peak	c/kWh	30.54
Standard	c/kWh	11.23
Off-peak	c/kWh	6.44
Average	*c/kWh*	*16.07*

Low demand : October - March (c/kWh)

Peak	c/kWh	27.49
Standard	c/kWh	10.08
Off-peak	c/kWh	5.80
Average	*c/kWh*	*14.46*

Weighted annual average rate : (12 months - assume constant pumping all year round)

Rate 15.26 c/kWh

Parameter		Unit	SCHEME 2B		
			Phase 1	Phase 2	Phase 3
FSL		masl	915	915	915
Min operating level		masl	870	870	870
Average operating level		masl	892.5	892.5	892.5
Inlet		masl	940	940	940
Flow		**m3/s**	**4.65**	**5.297**	**10.594**
Friction head *		m	0.09	0.11	0.45
Total head	Min	m	25.1	25.1	25.5
	Max	m	70.1	70.1	70.5
	Average	m	47.6	47.6	48.0
Pump efficiency **			0.90	0.90	0.90
Motor efficiency **			0.97	0.97	0.97
Power requirement		MW	2.49	2.83	5.71
Monthly energy ***		MWh	1820	2075	4179
Total pumped per month * **		**m3.10E6**	**12.25**	**13.96**	**27.92**
Total pumped per annum		**m3.10E6**	**147.04**	**167.50**	**335.01**
<u>*Monthly charges*</u>					
Energy charge			277,815	316,642	637,787
Reactive energy charge		Not considered - high efficiency (pf=0.96) gives low reactive energy charge			
Basic charge			53	53	53
	Subtotal		277,868	316,696	637,840
Transmission surcharge (1%)			2,779	3,167	6,378
Voltage discount (5%)			-13,893	-15,835	-31,892
	Subtotal		**266,754**	**304,028**	**612,327**
Contingency (20%)			**53,351**	**60,806**	**122,465**
	Total per month		**320,104**	**364,833**	**734,792**
	Total per annum		**3,841,251**	**4,377,999**	**8,817,502**
Unit cost		**c/m3**	**2.61**	**2.61**	**2.63**
Check (c/m3/100m)			5.49	5.49	5.49

* Based on 250 m long, twin 1800 mm diam line (n = 0.012)
** VAPS recommendation
*** 30.5 days per month

SCHEME 2C

SCHEME 2C PHASE 1
COST MODEL : ITEM 1 SMITHFIELD COMPOSITE DAM
FSL 915 masl

No	Description	Unit	Rate Mar-98	Quantity	Amount
1.	Site and basin clearing	ha	1,875	582	1,091,017
2.	River diversion	Sum	1,015,800		1,015,800
3.	Excavation				
	(a) all materials	m3	13	297,216	3,979,728
	(b) extra over for rock	m3	24	155,353	3,744,313
4.	Preparation of solum				
	(a) for Concrete section	m2	24	14,893	358,957
	(b) for embankment	m2	8	49,982	401,554
	(c) core trench	m2	16	34,433	553,265
5.	Drilling and Grouting				
	(a) curtain grouting	m drill	150	13,270	1,990,094
	(b) consolidation grouting	m drill	150	7,047	1,056,760
	(c) Drainage curtain	m drill	134	4,363	584,170
6.	Embankment				
	(a) earthfill,core	m3	18	326,217	5,911,048
	(b) rockfill	m3	28	593,269	16,796,940
	(c) filters	m3	59	66,989	3,946,694
	(d) rip-rap	m3	33	66,989	2,242,440
7.	Formwork				
	(a) gang formed	m2	67	35,035	2,345,593
	(b) intricate	m2	107	3,504	375,295
8.	Concrete				
	(a) roller compacted concrete	m3	211	332,657	70,072,451
	(b) mass & skin concrete	m3	248	36,962	9,167,184
	(c) structural	m3	319	5,000	1,596,825
9.	Reinforcing	t	3,348	750	2,510,625
10	Multilevel intake structure				
	(a) civil	Sum	3,996,000		3,996,000
	(b) mechanical and electrical	Sum	7,189,000		7,189,000
	(c) River outlet pipework	Sum	3,590,000		3,590,000
	(d)Measuring weir	Sum	500,000		500,000
11	Landscaping (% of 1-10)	%	5%	145,985,753	7,299,288
12	Miscellaneous (% of 1-10)	%	10%	145,985,753	14,598,575
	Subtotal A (carried forward)				166,913,616
13	Preliminary, General and Preliminary works (% of Subtotal A)	%	20%	167,883,616	33,576,723
	Subtotal B				200,490,339
14	Contingencies (% of Subtotal B)	%	10%	201,460,339	20,146,034
	Subtotal C				220,636,373
15	Planning design & supervision, fees, time cost & transport (% of Subtotal C)	%	12%	221,606,373	26,592,765
	Subtotal D				247,229,138
16	VAT (% of Subtotal D)	%	14%	248,199,138	34,747,879
	TOTAL PROJECT COST				281,977,017

SCHEME 2C PHASE 1

COST MODEL : ITEM 2 Smithfield Dam Intake Tower and Pumpstation 606 ML/day

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Earthworks				
1.1	c. Excavation - rock	m3	90	550	49,500
2	Rock support				
2.1	a. Rock anchors - 20 m long 8x8m spacing	No	1,000	10	10,000
2.2	b. Rock dowels - 4x4m spacing	No	200	100	20,000
3	Access bridge	Sum			1,500,000
4	Drilling and grouting	m	500	300	150,000
5	Formwork				
5.1	a. Smooth vertical - curved and plain	m2	155	11650	1,805,750
5.2	b. Smooth horizontal - soffits	m2	155	750	116,250
5.3	c. Intricate	m2	420	1000	420,000
6	Unformed surface finishes	m2	6	1000	6,000
7	Concrete				
7.1	Mass concrete	m3	300	1000	300,000
7.2	Structural concrete	m3	380	14500	5,510,000
8	Reinforcing	t	3,000	2450	7,350,000
9	Miscellaneous				
9.1	a. Structural steelwork	t	8,000	45	360,000
9.2	b. Building work	Sum			50,000
9.3	c. Electrical and instrumentation	Sum			1,500,000
9.4	d. Intake pipes - twin 1800 mm diam lines	m	17,500	250	4,375,000
	Subtotal A : Civil construction				23,522,500
10	Mechanical items - Gates, screens and cranes and	Sum			11,550,000
11	Mechanical items - pumps, motors and switchgear,	Sum			8,795,800
	Subtotal B : Mechanical items				20,345,800
12	Landscaping (% of Subtotal A)	%	5		1,176,125
13	Miscellaneous (% of Subtotal A + Subtotal B)	%	5		2,193,415
	Subtotal C : Total construction				47,237,840
14	Preliminary and General	%	20		9,447,568
15	Site works		Incl. in P & G		
16	Accomodation		Incl. in P & G		
	Subtotal D				56,685,408
17	Contingencies (% of subtotal D)	%	20		11,337,082
	Subtotal E				68,022,490
18	Planning design & Supervision (% of subtotal E)	%	12		8,162,699
	Sub Total F				76,185,188
19	VAT (% of Sub total F)	%	14		10,665,926
	TOTAL PROJECT COST				**86,851,115**

SCHEME 2C PHASE 1
COST MODEL : ITEM 3 Tunnel from Smithfield Dam to Baynesfield Dam
TBM Tunnel 3,5 m diameter
D & B Tunnel 5,5 by 6 m high

SMITHFIELD TUNNEL - FREE SURFACE FLOW

Tunnel Length: 32900m
1 Up from outlet TBM - 12950m
1 Down from 1/3 point - 12950m
1 Down from inlet - 6500m
DB Tunnel - 500m
1 DB Adit - 350m at 1:10

No	Description	Unit	Rate	Quantity	Amount
1	Portal excavations				
	a. Inlet portal	Sum	2,500,000	1	2,500,000
	b. Outlet portal	Sum	4,000,000	1	4,000,000
	b. Intermediate	Sum	2,500,000	1	2,500,000
2	Tunnel Excavation				
	TBM				
	b. Rock Class II	m3	340	52,992	18,017,439
	c. Rock Class III	m3	350	202,618	70,916,391
	d. Rock Class IV	m3	400	49,875	19,950,106
	e. Rock Class V	m3	1,000	6,234	6,234,408
	D & B (Adits)				
	c. Rock Class III	m3	180	13,981	2,516,580
	d. Rock Class IV	m3	200	2,728	545,600
	e. Rock Class V	m3	550	341	187,550
3	Extra for down grade drive	m	1,500	19,950	29,925,000
4	Extra for length of drive over 10 km	m	1,000	5,900	5,900,000
5	Turning Chamber	No	250,000	2	500,000
6	Dealing with Water	m	15	33,250	498,750
7	Shafts				
	a. Ventilation	m	3,000	650	1,950,000
8	Rock support				
	a. i) Rockbolts - TBM	m	250	32,900	8,225,000
	a. ii) Rockbolts - D & B	m	380	350	133,000
	b. Shotcrete	m3	1,400	657	919,926
9	Concrete				
	a. Linings	m3	550	74,109	40,759,784
	b. Overbreak concrete : TBM	m2	100	361,754	36,175,439
	d. Concrete - D & B Invert blinding	m3	400	525	210,000
	e. Concrete : Structures	m3	380	1,100	418,000
10	Formwork				
	a. Smooth curved in tunnel	m2	150	270,595	40,589,279
	b. Structures	m2	155	4,400	682,000
11	Reinforcement	ton	3,000	88	264,000
12	Pre-cast concrete inverts	m	290	32,900	9,541,000
	SUBTOTAL : MEASURED ITEMS				**304,059,253**

SCHEME 2C PHASE 1
COST MODEL : ITEM 3 Tunnel from Smithfield Dam to Baynesfield Dam

SMITHFIELD TUNNEL - FREE SURFACE FLOW

No	Description	Unit	Rate	Quantity	Amount
	SUBTOTAL : MEASURED ITEMS				**304,059,253**
13	Grouting				
	i) Cavity	m	200	32,900	6,580,000
	ii) Consolidation/Fissure	m	7	32,900	230,300
14	Waterproof lining				
	b. Waterproof membrane	m2	300	30,000	9,000,000
15	a. Intake Pipeline : Twin 1800 dia pipeline	m	17,500	250	4,375,000
	b. Outlet spill line : Twin 1800 dia pipeline	m	17,500	250	4,375,000
16	Miscellaneous	%	10	328,619,553	32,861,955
	SUBTOTAL A				**361,481,508**
17.1	P & G Fixed	Sum	1	27,000,000	27,000,000
17.2	P & G Time Related - Establishment	Sum	1	9,350,000	9,350,000
17.3	P & G Time Related - TBM Excavation	Sum	1	63,250,000	63,250,000
17.4	P & G Time Related - Adit Excavation	Sum	1	3,000,000	3,000,000
17.5	P & G Time Related - Lining	Sum	1	29,820,000	29,820,000
18	Preliminary works		Incl. in P & G		
19	Accommodation		Incl. in P & G		
	SUBTOTAL B				**493,901,508**
20	Contingencies (% of Subtotal B)	%	10	493,901,508	49,390,151
	SUBTOTAL C				**543,291,659**
21	Planning, design and supervision (% of Subtotal C)	%	12	543,291,659	65,194,999
	SUBTOTAL D				**608,486,658**
22	VAT (% of Subtotal D)	%	14	608,486,658	85,188,132
	TOTAL PROJECT COST				**693,674,790**

Construction Period = 56 months
4,7 years

SCHEME 2C PHASE 1
COST MODEL : ITEM 4 COST MODEL BAYNESFIELD DAM RAISED BY 0.5m FSL 871.5masl

No	Description	Unit	Rate Mar '98	Quantity	Amount
1.	Site and basin clearing	ha	1,875	51	96,050
2	Excavation				
	(a) all materials	m3	13	3,139	42,036
	(b) extra over for rock	m3	24	1,065	25,663
3	Preparation of solum				
	(a) for embankment	m2	8	2,871	23,052
4	Embankment				
	(a) Earthfill	m3	18	12,277	222,460
	(b) rockfill	m3	28	1,794	50,790
	(c) filters	m3	59	163	9,611
	(d) rip-rap	m3	33	108	3,605
5	SPILLWAY				
	(a) Formwork	m3	67	464	31,080
	(b) Structural Concrete	m3	314	405	127,300
	(c) Demolish ex slab on crest	Sum			50,000
6	OUTLET STRUCTURE				
	(a) civil	Sum			580,120
	(b) mechanical/electrical	Sum			1,629,000
	(c) Pipework	Sum			1,055,659
7	Landscaping (% of 1-6)	%	5%	3,946,425	197,321
8	Miscellaneous (% of 1-6)	%	10%	3,946,425	394,642
	Subtotal A (carried forward)				4,538,389
9	Preliminary, General and Preliminary works (% of Subtotal A)	%	20%	4,538,389	907,678
	Subtotal B				5,446,067
10	Contingencies (% of Subtotal B)	%	10%	5,446,067	544,607
	Subtotal C				5,990,674
11	Planning design & supervision, fees, time cost & transport (% of Subtotal C)	%	15%	5,990,674	898,601
	Subtotal D				6,889,275
12	VAT (% of Subtotal D)	%	14%	6,889,275	964,498
	TOTAL PROJECT COST				7,853,773

SCHEME 2C PHASE 1
COST MODEL : ITEM 5 Pipeline from Smithfield Tunnel outlet to Baynesfield Dam outlet
2.2 km of 1800mm diameter

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	5.0	60,000
1.2	(b) bush	ha	20,000	1.6	32,000
2	Road and River Crossings	Sum			200,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m³	35	19800	693,000
3.2	(b) Extra over for rock	m³	50	1980	99,000
3.3	(c) Bed preparation (Bedding)	m	70	2200	154,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	3,500	2200	7,700,000
4.2	(b) Laying and Jointing (% of(a))	%	20		1,540,000
4.3	(d) Cathodic Protection	km	50,000	2.2	110,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m³	850	70	59,500
5.2	(b) Headwalls on steep slopes	m³	550		
6	Reinforcing	t	3,000	6.0	18,000
7	Mechanical Items				
7.1	(a) Valves etc	Sum			400,000
	SUB TOTAL A				11,065,500
8	Landscaping (% of Sub total A)	%	5		553,275
9	Miscellaneous (% of Sub total A)	%	5		553,275
	SUB TOTAL B				12,172,050
10	Preliminary and General	%	15		1,825,808
11	Preliminary Works		Incl. in P & G		
12	Accomodation		Incl. in P & G		
	SUB TOTAL C				13,997,858
13	Contingencies (% of Sub total C)	%	15		2,099,679
	Sub Total D				16,097,536
14	Planning design & Supervision (% of Sub total D)	%	12		1,931,704
	Sub Total E				18,029,240
15	VAT (% of Sub total E)	%	14		2,524,094
	TOTAL PROJECT COST				**20,553,334**

SCHEME 2C PHASE 1
COST MODEL : ITEM 5 Pipeline from Baynesfield Dam to Baynesfield Waterworks
3.0 km of 1900mm diameter

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	8.0	96,000
1.2	(b) bush	ha	20,000	1.0	20,000
2	Road and River Crossings	Sum			100,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m^3	35	34800	1,218,000
3.2	(b) Extra over for rock	m^3	50	3480	174,000
3.3	(c) Bed preparation (Bedding)	m	70	3000	210,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	3,800	3000	11,400,000
4.2	(b) Laying and Jointing (% of(a))	%	20		2,280,000
4.3	(c) E/O for steep slopes	m	2,000	100	200,000
4.4	(d) Cathodic Protection	km	50,000	3.0	150,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m^3	850	60	51,000
5.2	(b) Headwalls on steep slopes	m^3	550	20	11,000
6	Reinforcing	t	3,000	7.0	21,000
7	Mechanical Items				
7.1	(a) Valves etc	Sum			550,000
	SUB TOTAL A				16,481,000
8	Landscaping (% of Sub total A)	%	5		824,050
9	Miscellaneous (% of Sub total A)	%	5		824,050
	SUB TOTAL B				18,129,100
10	Preliminary and General	%	15		2,719,365
11	Preliminary Works		Incl. in P & G		
12	Accomodation		Incl. in P & G		
	SUB TOTAL C				20,848,465
13	Contingencies (% of Sub total C)	%	15		3,127,270
	Sub Total D				23,975,735
14	Planning design & Supervision (% of Sub total D)	%	12		2,877,088
	Sub Total E				26,852,823
15	VAT (% of Sub total E)	%	14		3,759,395
	TOTAL PROJECT COST				**30,612,218**

SCHEME 2C PHASE 1
COST MODEL : ITEM 6 Baynesfield Waterworks 606 Ml/day

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Mechanical and Electrical	%	30	157,071,834	47,121,550
2	Civils	%	70	157,071,834	109,950,284
	SUB TOTAL A				157,071,834
3	Landscaping (% of Sub total A)	%	2	157,071,834	3,141,437
4	Miscellaneous (% of Sub total A)	%	10	157,071,834	15,707,183
	SUB TOTAL B				175,920,455
5	Preliminary and General	%	20	175,920,455	35,184,091
6	Preliminary Works		Incl. in P & G		
7	Accomodation		Incl. in P & G		
	SUB TOTAL C				211,104,545
8	Contingencies (% of Sub total C)	%	10	211,104,545	21,110,455
	Sub Total D				232,215,000
9	Planning design & Supervision (% of Sub total D)	%	12	232,215,000	27,865,800
	Sub Total E				260,080,800
10	VAT (% of Sub total E)	%	14	260,080,800	36,411,312
	TOTAL PROJECT COST				**296,492,112**

Note : Waterworks costs based on actual construction costs of existing large waterworks escalated.

SCHEME 2C PHASE 1
COST MODEL : ITEM 7 Pipeline from Baynsfield Waterworks to Umlaas Road Reservoir
21.1 km of 1900mm diameter

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	57.0	684,000
1.2	(b) bush	ha	20,000	6.5	130,000
2	Road and River Crossings	Sum			5,900,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m³	35	244800	8,568,000
3.2	(b) Extra over for rock	m³	50	24480	1,224,000
3.3	(c) Bed preparation (Bedding)	m	70	21100	1,477,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	3,800	21100	80,180,000
4.2	(b) Laying and Jointing (% of(a))	%	20		16,036,000
4.3	(c) E/O for steep slopes	m	2,000	700	1,400,000
4.4	(d) Cathodic Protection	km	50,000	21.1	1,055,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m³	850	200	170,000
5.2	(b) Headwalls on steep slopes	m³	550	100	55,000
6	Reinforcing	t	3,000	69.0	207,000
7	Mechanical Items				
7.1	(a) Valves etc	Sum			1,400,000
	SUB TOTAL A				118,486,000
8	Landscaping (% of Sub total A)	%	5		5,924,300
9	Miscellaneous (% of Sub total A)	%	5		5,924,300
	SUB TOTAL B				130,334,600
10	Preliminary and General	%	15		19,550,190
11	Preliminary Works		Incl. in P & G		
12	Accomodation		Incl. in P & G		
	SUB TOTAL C				149,884,790
13	Contingencies (% of Sub total C)	%	15		22,482,719
	Sub Total D				172,367,509
14	Planning design & Supervision (% of Sub total D)	%	12		20,684,101
	Sub Total E				193,051,610
15	VAT (% of Sub total E)	%	14		27,027,225
	TOTAL PROJECT COST				**220,078,835**

SCHEME 2C PHASE 1
COST MODEL : ITEM 8 UMLAAS ROAD RESERVOIR 200Ml

No	Description	Unit	Rate Mar '98	Quantity	Amount
1.	Excavation to spoil	m3	15	35,000	525,000
2.	Cut to Fill	m3	20	30,000	600,000
3.	Mass Concrete	Sum			1,953,000
4	Structural Concrete	Sum			7,259,800
5	Formwork and Shuttering	Sum			8,206,600
6	Reinforcement	Sum			5,111,600
	PIPEWORK				
7	(a) civil	Sum			384,115
8	(b)mechanical/electrical	Sum			1,956,150
9	Miscellaneous	Sum			4,931,260
	Subtotal A (carried forward)				30,927,525
10	Preliminary, General and Preliminary works (% of Subtotal A)	%	20%	30,927,525	6,185,505
	Subtotal B				37,113,030
11	Contingencies (% of Subtotal B)	%	10%	37,113,030	3,711,303
	Subtotal C				40,824,333
12	Planning design & supervision, fees, time cost & transport (% of Subtotal C)	%	15%	40,824,333	6,123,650
	Subtotal D				46,947,983
13	VAT (% of Subtotal D)	%	14%	46,947,983	6,572,718
	TOTAL PROJECT COST				53,520,701

PHASE 2C PHASE 1
COST MODEL : ITEM 9 Advanced infrastructure Costs for Smithfield Dam

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Preliminary Works				
1.1	(a) Access Roads	km	800,000	13.5	10,800,000
1.2	(b) Electricity to Site	Sum			1,800,000
	SUB TOTAL A				12,600,000
2	Contingencies (% of Sub total A)	%	10		1,260,000
	Sub Total B				13,860,000
3	Planning design & Supervision (% of Sub total B)	%	12		1,663,200
	Sub Total C				15,523,200
4	VAT (% of Sub total C)	%	14		2,173,248
	TOTAL PROJECT COST				**17,696,448**

SCHEME 2C PHASE 2
COST MODEL : ITEM 1 IMPENDLE DAM FSL=1197masl (1.5 MAR)

No	Description	Unit	Rate Mar '98	Quantity	Amount
1.	Site and basin clearing	ha	1,875	1,025	1,921,000
2.	River diversion				
	(a) Diversion Tunnel 350m long	Sum			11,000,000
	(b) Coffer Dams	Sum			8,608,231
	(c) Structural Concrete to Diversion Works	Sum			2,825,260
	(d) Foundation Prep. and Dealing with Water	Sum			500,000
3.	Excavation				
	(a) all materials	m3	13	430,029	5,758,095
	(b) extra over for rock	m3	24	144,550	3,483,647
4.	Preparation of solum				
	(b) for embankment	m2	8	94,471	758,604
	(c) core trench	m2	16	25,854	415,478
5.	Drilling and Grouting				
	(a) curtain grouting	m Drill	150	8,296	1,244,212
	(b) consolidation grouting	m Drill	150	4,115	617,177
6.	Embankment				
	(a) Earthfill Core	m3	18	1,145,153	20,750,167
	(b) rockfill	m3	28	3,813,313	107,954,889
	(c) filters	m3	59	242,314	14,277,155
	(d) rip-rap	m3	33	117,778	3,943,214
	(e) road layerworks	m2	80	5,460	436,800
7	SPILLWAY				
	(a) Excavation e/o to quarry	m3	10	780,000	7,800,000
	(b) Formwork	m3	67	19,343	1,295,000
	(c) Structural Concrete	m3	319	30,936	9,880,000
	(d) Mass Concrete	m3	248	10,281	2,550,000
	(e) Anchors and steel rebars	t	3,348	2,240	7,500,000
	(f) Drill for Anchors	m Drill	50	75,000	3,750,000
	(g) Road Bridge over Spillway	Sum			1,900,000
8	OUTLET STRUCTURE				
	(a) civil	Sum			8,016,000
	(b) mechanical/electrical	Sum			9,745,000
	(c) Pipework	Sum			15,545,000
	(d) Measuring weir	Sum			500,000
9	Landscaping (% of 1-8)	%	5%	252,974,930	12,648,746
10	Miscellaneous (% of 1-8)	%	10%	252,974,930	25,297,493
	Subtotal A (carried forward)				290,921,169
11	Preliminary, General and Preliminary works (% of Subtotal A)	%	20%	290,921,169	58,184,234
	Subtotal B				349,105,403
12	Contingencies (% of Subtotal B)	%	10%	349,105,403	34,910,540
	Subtotal C				384,015,943
13	Planning design & supervision, fees, time, cost & transport (% of Subtotal C)	%	15%	384,015,943	57,602,391
	Subtotal D				441,618,335
14	VAT (% of Subtotal D)	%	14%	441,618,335	61,826,567
	TOTAL PROJECT COST				503,444,902

SCHEME 2C PHASE 2
COST MODEL : ITEM 2 Smithfield Dam Intake Tower and Pumpstation upsized by 795 ML/day

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Mechanical items - pumps, motors and switchgear,				13,304,200
	Subtotal A : Mechanical items				13,304,200
2	Miscellaneous (% of Subtotal A)	%	5		665,210
	Subtotal B: Total construction				13,969,410
3	Preliminary and General	%	20		2,793,882
4	Site works		Incl. in P&G		
5	Accomodation		Incl. in P&G		
	Subtotal C				16,763,292
6	Contingencies (% of subtotal C)	%	20		3,352,658
	Subtotal D				20,115,950
7	Planning design & Supervision (% of subtotal D)	%	12		2,413,914
	Sub Total E				22,529,864
8	VAT (% of Sub total E)	%	14		3,154,181
	TOTAL PROJECT COST				**25,684,045**

SCHEME 2C PHASE 2
COST MODEL : ITEM 3 Baynesfield Waterworks upsized by 795 Ml/day

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Mechanical and Electrical	%	30	237,614,144	71,284,243
2	Civils	%	70	237,614,144	166,329,901
	SUB TOTAL A				237,614,144
3	Landscaping (% of Sub total A)	%	2	237,614,144	4,752,283
4	Miscellaneous (% of Sub total A)	%	10	237,614,144	23761414
	SUB TOTAL B				266,127,841
5	Preliminary and General	%	20	266,127,841	53,225,568
6	Preliminary Works		Incl. in P & G		
7	Accomodation		Incl. in P & G		
	SUB TOTAL C				319,353,409
8	Contingencies (% of Sub total C)	%	10	319,353,409	31935341
	Sub Total D				351,288,750
9	Planning design & Supervision (% of Sub total D)	%	12	351,288,750	42,154,650
	Sub Total E				393,443,400
10	VAT (% of Sub total E)	%	14		55,082,076
	TOTAL PROJECT COST				**448,525,476**

Note : Waterworks costs based on actual construction costs of existing large waterworks escalated.

PHASE 2C PHASE 2
COST MODEL : ITEM 4 Advanced infrastructure Costs for Impendle Dam

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1 1.1 1.2	Preliminary Works (a) Access Roads (b) Electricity to Site	 km Sum	 800,000	 12.5	 10,000,000 1,770,000
	SUB TOTAL A				11,770,000
3	Contingencies (% of Sub total A)	%	10		1,177,000
	Sub Total B				12,947,000
4	Planning design & Supervision (% of Sub total B)	%	12		1,553,640
	Sub Total C				14,500,640
5	VAT (% of Sub total C)	%	14		2,030,090
	TOTAL PROJECT COST				**16,530,730**

SCHEME 2C PHASE 3
COST MODEL : ITEM 1 Add. Pipeline from Smithfield Tunnel outlet to Baynesfield Dam outlet
2.2 km of 1800mm diameter

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	5.0	60,000
1.2	(b) bush	ha	20,000	1.6	32,000
2	Road and River Crossings	Sum			200,000
4	Trench excavation and backfilling				
4.1	(a) All materials	m³	35	19800	693,000
4.2	(b) Extra over for rock	m³	50	1980	99,000
4.3	(c) Bed preparation (Bedding)	m	70	2200	154,000
5	Pipelines				
5.1	(a) Supply of pipes to site	m	3,500	2200	7,700,000
5.2	(b) Laying and Jointing (% of(a))	%	20		1,540,000
5.4	(d) Cathodic Protection	km	50,000	2.2	110,000
6	Concrete including Formwork				
6.1	(a) Valve chambers and manholes	m³	850	70	59,500
7	Reinforcing	t	3,000	6.0	18,000
8	Mechanical Items				
8.1	(a) Valves etc	Sum			400,000
	SUB TOTAL A				11,065,500
9	Landscaping (% of Sub total A)	%	5		553,275
10	Miscellaneous (% of Sub total A)	%	5		553,275
	SUB TOTAL B				12,172,050
11	Preliminary and General	%	15		1,825,808
12	Preliminary Works		Incl. in P & G		
13	Accomodation		Incl. in P & G		
	SUB TOTAL C				13,997,858
14	Contingencies (% of Sub total C)	%	15		2,099,679
	Sub Total D				16,097,536
15	Planning design & Supervision (% of Sub total D)	%	12		1,931,704
	Sub Total E				18,029,240
16	VAT (% of Sub total E)	%	14		2,524,094
	TOTAL PROJECT COST				**20,553,334**

SCHEME 2C PHASE 3
COST MODEL : ITEM 1 + Add. Pipeline from Baynesfield Dam to Waterworks
3.0 km of 1900mm diameter

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	8.0	96,000
1.2	(b) bush	ha	20,000	1.0	20,000
2	Road and River Crossings	Sum			100,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m³	35	34800	1,218,000
3.2	(b) Extra over for rock	m³	50	3480	174,000
3.3	(c) Bed preparation (Bedding)	m	70	3000	210,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	3,800	3000	11,400,000
4.2	(b) Laying and Jointing (% of(a))	%	20		2,280,000
4.3	(c) E/O for steep slopes	m	2,000	100	200,000
4.4	(d) Cathodic Protection	km	50,000	3.0	150,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m³	850	60	51,000
5.2	(b) Headwalls on steep slopes	m³	550	20	11,000
6	Reinforcing	t	3,000	7.0	21,000
7	Mechanical Items				
7.1	(a) Valves etc	Sum			550,000
	SUB TOTAL A				16,481,000
8	Landscaping (% of Sub total A)	%	5		824,050
9	Miscellaneous (% of Sub total A)	%	5		824,050
	SUB TOTAL B				18,129,100
10	Preliminary and General	%	15		2,719,365
11	Preliminary Works		Incl. in P & G		
12	Accomodation		Incl. in P & G		
	SUB TOTAL C				20,848,465
14	Contingencies (% of Sub total C)	%	15		3,127,270
	Sub Total D				23,975,735
15	Planning design & Supervision (% of Sub total D)	%	12		2,877,088
	Sub Total E				26,852,823
16	VAT (% of Sub total E)	%	14		3,759,395
	TOTAL PROJECT COST				**30,612,218**

SCHEME 2C PHASE 3
COST MODEL : ITEM 2 Add. Pipeline from Baynsfield Waterworks to Umlaas Road Reservoir
21.1 km of 1900mm diameter

No	DESCRIPTION	UNIT	RATE	QUANTITY	AMOUNT
1	Route clearing & grubbing				
1.1	(a) sparse	ha	12,000	57.0	684,000
1.2	(b) bush	ha	20,000	6.5	130,000
2	Road and River Crossings	Sum			3,500,000
3	Trench excavation and backfilling				
3.1	(a) All materials	m^3	35	244800	8,568,000
3.2	(b) Extra over for rock	m^3	50	24480	1,224,000
3.3	(c) Bed preparation (Bedding)	m	70	21100	1,477,000
4	Pipelines				
4.1	(a) Supply of pipes to site	m	3,800	21100	80,180,000
4.2	(b) Laying and Jointing (% of(a))	%	20		16,036,000
4.3	(c) E/O for steep slopes	m	2,000	700	1,400,000
4.4	(d) Cathodic Protection	km	50,000	21.1	1,055,000
5	Concrete including Formwork				
5.1	(a) Valve chambers and manholes	m^3	850	200	170,000
5.2	(b) Headwalls on steep slopes	m^3	550	100	55,000
6	Reinforcing	t	3,000	69.0	207,000
7	Mechanical Items				
7.1	(a) Valves etc	Sum			1,400,000
	SUB TOTAL A				116,086,000
8	Landscaping (% of Sub total A)	%	5		5,804,300
9	Miscellaneous (% of Sub total A)	%	5		5,804,300
	SUB TOTAL B				127,694,600
10	Preliminary and General	%	15		19,154,190
11	Preliminary Works		Incl. in P & G		
12	Accomodation	Sum	Incl. in P & G		
	SUB TOTAL C				146,848,790
13	Contingencies (% of Sub total C)	%	15		22,027,319
	Sub Total D				168,876,109
14	Planning design & Supervision (% of Sub total D)	%	12		20,265,133
	Sub Total E				189,141,242
15	VAT (% of Sub total E)	%	14		26,479,774
	TOTAL PROJECT COST				**215,621,015**

SCHEME 2C
PUMPING COSTS

Power costs : Miniflex structure

Rates obtained from Eskom.

Basic charge	per month	53.05
Demand charge	No demand charge - assumed that Umgeni Water will go to Miniflex structure as proposed for Mearns scheme.	

Energy charges :

High demand : April - September (c/kWh)		
Peak	c/kWh	30.54
Standard	c/kWh	11.23
Off-peak	c/kWh	6.44
Average	*c/kWh*	*16.07*

Low demand : October - March (c/kWh)		
Peak	c/kWh	27.49
Standard	c/kWh	10.08
Off-peak	c/kWh	5.80
Average	*c/kWh*	*14.46*

Weighted annual average rate : (12 months - assume constant pumping all year round)

Rate 15.26 c/kWh

Parameter		**Unit**	**SCHEME 2C**		
			Phase 1	**Phase 2**	**Phase 3**
FSL		masl	915	915	915
Min operating level		masl	870	870	870
Average operating level		masl	892.5	892.5	892.5
Inlet		masl	940	940	940
Flow		**m3/s**	**4.65**	**5.945**	**11.89**
Friction head *		m	0.09	0.14	0.57
Total head	Min	m	25.1	25.1	25.6
	Max	m	70.1	70.1	70.6
	Average	m	47.6	47.6	48.1
Pump efficiency **			0.90	0.90	0.90
Motor efficiency **			0.97	0.97	0.97
Power requirement		MW	2.49	3.18	6.42
Monthly energy ***		MWh	1820	2330	4701
Total pumped per month * **		**m3.10E6**	**12.25**	**15.67**	**31.33**
Total pumped per annum		**m3.10E6**	**147.04**	**188.00**	**375.99**
Monthly charges					
Energy charge			277,815	355,597	717,559
Reactive energy charge		Not considered - high efficiency (pf=0.96) gives low reactive energy charge			
Basic charge			53	53	53
	Subtotal		277,868	355,650	717,612
Transmission surcharge (1%)			2,779	3,557	7,176
Voltage discount (5%)			-13,893	-17,783	-35,881
	Subtotal		**266,754**	**341,424**	**688,908**
Contingency (20%)			**53,351**	**68,285**	**137,782**
	Total per month		**320,104**	**409,709**	**826,689**
	Total per annum		**3,841,251**	**4,916,508**	**9,920,268**
Unit cost		**c/m3**	**2.61**	**2.62**	**2.64**
Check (c/m3/100m)			5.49	5.49	5.49

* Based on 250 m long, twin 1800 mm diam line (n = 0.012)
** VAPS recommendation
*** 30.5 days per month

APPENDIX F3

DETAILED COST ESTIMATES

SOCIAL COSTS

SOCIAL COSTS

IMPENDLE DAM (High FSL)

Item	*Number*	*Cost per Item*	*Total*
Relocation of Homesteads	50	100 000	5 000 000
Purchase of formal farm buildings	2	250 000	500 000
Relocation of Graves	50	3 000	150 000
Compensation for "crops in the field"			50 000
Purchase of freehold land:			
arable land	150 ha	2 500	375 000
grazing land	2 000 ha	1 500	3 000 000
irrigation land	20 ha	5 000	100 000
Rural Development Programme			1 000 000
Community Education Programme			250 000
		TOTAL	**R10 425 000**

IMPENDLE DAM (Low FSL)

Item	*Number*	*Cost per Item*	*Total*
Relocation of Homesteads	30	100 000	3 000 000
Purchase of formal farm buildings	2	250 000	500 000
Relocation of Graves	30	3 000	90 000
Compensation for "crops in the field"			50 000
Purchase of freehold land:			
arable land	120 ha	2 500	300 000
grazing land	1 800 ha	1 500	2 700 000
irrigation land	20 ha	5 000	100 000
Rural Development Programme			800 000
Community Education Programme			250 000
		TOTAL	**R 7 790 000**

SMITHFIELD DAM

Item	*Number*	*Cost per Item*	*Total*
Relocation of Homesteads	2	100 000	200 000
Relocation of Graves	5	3 000	15 000
Compensation for "crops in the field"			30 000
Purchase of freehold land (below FSL and as compensation for tribal land lost)			
arable land	100 ha	2 500	250 000
grazing land	1 500 ha	1 500	2 250 000
irrigation land	10 ha	5 000	50 000
Rural Development Programme			750 000
Community Education Programme			200 000
Conveyance (20 m servitude for which 30% of land value is paid):			
arable land (30% of conveyance)	6,3 km	15,01502	9 460
grazing land (60% of conveyance)	2,1 km	8,992806	1 888
irrigation land (10% of conveyance)	12,6 km	30,03003	37 838
		TOTAL	**R3 794 186**