Report No: PB1 U100-00-0499

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

in association with

UMGENI WATER
Corporate Services Division

MKOMAZI-MGENI TRANSFER SCHEME PRE-FEASIBILITY STUDY

MKOMAZI-MGENI TRANSFER SCHEME

MAIN REPORT

Report No 2787/7856
May 1999

NINHAM SHAND
CONSULTING ENGINEERS

Report No: PB U100-00-0499

MKOMAZI/MOOI-MGENI TRANSFER SCHEME PRE-FEASIBILITY STUDY

MKOMAZI-MGENI TRANSFER SCHEME MAIN REPORT

Approved for:

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NS Report No: 2787/7856
May 1999

MKOMAZI/MOOI-MGENI TRANSFER SCHEME PRE-FEASIBILITY STUDY
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\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

This report has been compiled as a stand-alone document summarising the background, processes, methodology and findings of the Mkomazi-Mgeni Transfer Scheme Pre-feasibility Study, and makes recommendations for the next phase of planning. Full details of the work carried out during this Study are included in the seven Supporting Reports to this Report.

The water resources of the Mgeni River System, which is the main source of water for the Durban/Pietermaritzburg metropolitan area, are already fully utilised and augmentation from the Mooi River is already taking place, with further schemes in an advanced stage of planning. There was therefore an urgent need for planning of the next phase of augmentation to commence.

In earlier studies, the Mkomazi River was identified as being the most feasible after the Mooi River to augment the Mgeni System and the main objective of this Study was to select a preferred transfer scheme on the Mkomazi for further investigation at feasibility level. The scheme should deliver treated water to a point in the vicinity of Umlaas Road. In parallel with this, the second phase Mooi-Mgeni Transfer Scheme was to be refined in preparation for the feasibility phase. Proposals for the Mkomazi-Mgeni Transfer Scheme Pre-feasibility Study were invited by the Department of Water Affairs & Forestry (DWAF) and Umgeni Water (UW) in January 1997 and Ninham Shand were appointed to carry out the Study in June 1997.

The Study was managed by three committees: A project Management Committee which was responsible for the overall management of the Study process; a Stakeholder Committee tasked with reviewing the process and acting as a conduit between the Study Team and stakeholder groups; and an Environmental Task Group (ETG) which was responsible for ensuring that Integrated Environmental Management (IEM) Procedures were followed in accordance with DWAF and UW policy.

It became apparent after a preliminary review of previous studies that scheme layouts identified in these studies would not be appropriate for the delivery of water to Umlaas Road and it was decided to review the options previously proposed and to identify any other development options which may be considered feasible. This component of the Study was completed prior to the Pre-feasibility phase and commenced with a Scheme Identification phase, progressing to a Reconnaissance phase in which two schemes were identified for pre-feasibility investigation.

In the Scheme Identification phase, a total of eight schemes were identified, of which three were eliminated during an initial screening process on mainly technical grounds. The remaining five schemes, all sized to generate an historical firm yield of 200 million m^3/a, were subjected to further technical and economic evaluation. This secondary screening identified significant flaws in two of the five remaining schemes, but the results of the economic *analysis were inconclusive and it was considered inappropriate to eliminate of any of these schemes without further investigation.*

The remaining five schemes were then subjected to a Pre-reconnaissance assessment, in which the schemes were refined, with particular emphasis on phasing. An environmental scoping exercise was also carried out. These schemes consist of dams, clear and raw water conveyances consisting of tunnels, pipelines and, in one case, canals, pumpstations, and water treatment works. Based on environmental and economic considerations, one of the schemes was eliminated and a second was identified as probably being environmentally unacceptable, but requiring further investigation to confirm this.

Three of the remaining schemes were assessed at Reconnaissance level, while a habitat integrity and preliminary geotechnical assessment was carried out on the fourth. The schemes were refined, with allowance made for peak demand factors. Geotechnical assessments of the dam sites and tunnel routes were carried out, as were Initial Environmental Assessments. Technically, the three primary schemes were found to be feasible, and economically the schemes lay within a relatively small range. The environmental assessment confirmed that the fourth scheme would be unacceptable. It was therefore decided to eliminate this scheme, along with the least economical of the remaining three schemes, from further investigation and to proceed to Pre-feasibility phase with two schemes, namely the Impendle Scheme and Smithfield Scheme, configured as follows:

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.*

<u>Smithfield Scheme</u>

- *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 intake 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.

For the Pre-feasibility investigations, water demands were determined on the basis of data provided by Umgeni Water. High and low scenario data was provided and a middle scenario was developed which formed the basis for the planning process.

It has historically been policy of DWAF that the needs of a donor catchment should be met before consideration can be given to transferring water to other catchments. It was consequently necessary to carry out a reconnaissance level basin study to determine the present and future water demands within the Mkomazi catchment. The study was carried out at quaternary sub-catchment level and high, middle and low scenarios were assessed. It was found that the environmental requirements, in the form of Instream Flow Requirements (IFR's) dominate, requiring approximately 30% of the natural Mean Annual Runoff. Under middle scenario future conditions, forestry, irrigation and industrial demands amount to 8%, 6% and 5% of the MAR respectively, with other demands at less than 1% each. It was found that meeting in-basin demands for future conditions reduces the yields of the proposed transfer schemes by less than 10%. A preliminary assessment of a further dam on the lower Mkomazi indicated that it will probably not be viable, as a very large storage capacity would be required to generate a significant yield.

Using a combination of demand data generated in the basin study and hydrological data and system configurations prepared for previous System Analysis studies, historical firm yields were determined for various sizes of Impendle and Smithfield Schemes. In addition, the effect of transfer capacities in excess of the firm yields was assessed and found to be minimal. Long term stochastic yield analyses were also carried out for various recurrence intervals for *present and future catchment development scenarios. These formed the basis for the sizing of the scheme components and the economic analysis respectively. Again, the reduction in yield under future conditions was less than 10%. The 1 in 100 year yield of the largest Impendle Scheme was 313 million m^3/a and the largest Smithfield scheme, 376 million m^3/a. The implications of this 20% difference are significant, as will become apparent from discussion following.*

The environmental impact assessments of the schemes were carried out in accordance with the DWAF Integrated Environmental Management (IEM) Procedures. Registration of the project in accordance with current Environmental Impact Assessment (EIA) Regulations was in progress at the time of preparation of this report.

The pre-feasibility environmental assessment of the schemes considered social and biophysical impacts of the following:

- *Environments affected by inundation;*
- *Environments affected by raw and clear water conveyances;*
- *Riverine environments affected by changes in flow regime;*
- *Estuarine environment affected by changes in flow regime;*
- *Receiving river systems affected by transfers.*

In addition, the socio economic impact of non-augmentation, as reported in a separate study, was briefly discussed.

The impacts of the Smithfield Scheme on environments affected by inundation and conveyances are more severe than the Impendle Scheme, mainly because of the two dams and the fact that more greenfields areas are affected. Social impacts will be more complex, but mitigation measures are feasible.

An Instream Flow Requirements (IFR) study was undertaken to determine the requirements to maintain the river in a desired future state. Four representative sites were selected and studied and a range of maintenance and drought flows were determined. The overall IFR amounts to approximately 30% of the MAR. Yield modelling indicates that the IFR's can be met without a severe impact on the yields of the proposed schemes.

An Estuarine Freshwater Requirements (EFR) study was undertaken to determine the flows required to maintain the ecological functions of the estuary. It was found that mouth closure was a critical issue and by correlating historical observations of closure against recorded flows, a set of maintenance and drought flows were derived. It was concluded that if the IFR at the lowest site is met, the EFR will also be met.

It was concluded that the impact of transfers on receiving streams will be negligible, except for potential geomorphological damage at the Smithfield tunnel outlet. However, this can be mitigated by appropriate design of scour protection.

It was concluded that environmentally, both schemes are regarded as acceptable, provided that recommended future work is carried out and mitigation measures are implemented.

The socio-economic impacts of shortages in supply arising from non-augmentation, determined under a separate appointment, would be very severe, both in the Mgeni System supply area and KwaZulu-Natal Province as a whole. The Gross Geographic Product (GGP) would be drastically curtailed and a total of some 5 million potential new jobs would be lost by the year 2038. It was concluded that water demand management on its own is not a viable alternative to augmentation, but, along with catchment management, it is considered vital in ensuring the long term water supply in the region.

The designs of the Impendle and Smithfield Schemes were refined at pre-feasibility level, utilising more detailed geotechnical information, updated yield analysis results and taking cognisance of environmental aspects. The refined configurations are as described on Pages 2 and 3 above.

The Impendle Dam will be a rockfill dam with a side channel spillway and the Smithfield Dam, a composite dam with a central roller-compacted concrete (RCC) gravity spillway section and rockfill embankments on the flanks.

Sedimentation is expected to be minimal in relation to the capacity of the dams and the water quality in the Mkomazi is better than in the receiving river systems. However, due to the limited capacity of the Midmar Dam outlet works, the scour outlets will have to be utilised in addition to the multi-level outlets and periodic treatment problems are anticipated. In the case of the Smithfield Scheme, high turbidities may occur periodically in the Mlazi river and consequently in the balancing dam. A direct link between the tunnel outlet and waterworks was therefore provided, allowing the balancing dam to be bypassed for most of the time.

Geological investigations indicate that the rock conditions along the tunnel routes should be suitable for excavation by tunnel boring machine (TBM) and the tunnels will be fully concrete lined.

No particular technical problems are anticipated with the Smithfield Scheme, but the Impendle Scheme is expected to have operational problems in its ultimate phase, with the complex clearwater conveyance system and limited balancing storage.

Cost estimates were prepared on the basis of current DWAF guidelines, escalated to March 1998 prices and adjusted where necessary on the basis of more current data. Particular attention was given to major cost components which are not common to the two schemes. Annual operation and maintenance costs were also determined in accordance with DWAF guidelines and energy costs were determined on the basis of the Eskom "Miniflex" tariff structure. The total capital costs of the schemes are very similar, at between R2 400 and R2 700 million. The first phase Smithfield Scheme is 12% to 20% cheaper than the first phase Impendle Scheme and cash flows will be similar.

It is envisaged that the provision of bulk electrical supply and the relocation of roads affected by the dams would be carried out in advance of the main contracts. The overall duration from the commencement of the feasibility study to the commissioning of the first phase of the selected scheme is expected to be approximately nine years.

As an additional parameter to assist in the selection of the preferred scheme, the risk of operational failure of the two schemes was assessed under a separate appointment. It was found that the risk of occurrence of an event which would lead to unacceptable curtailments in supply to Umlaas Road would be approximately 60% greater for the Impendle Scheme than for the Smithfield Scheme. However, overall probabilities are relatively low.

An economic comparison of the schemes was carried out, using the Unit Reference Value (URV) as the primary parameter for comparison. The URV is simply the Net Present Value (NPV) of capital and running costs divided by the NPV of water delivered during the selected analysis period. Discount rates of 6, 8 and 10% were used with a 50 year analysis period. It was found that with a "most likely" discount rate of 8%, the URV of the Smithfield Scheme is 11% lower than the Impendle Scheme, which is a relatively small difference considering the level of study detail. However, approximately 85% of scheme costs are made up of cost components which are common to both schemes and a 60% change to the costs of the other components would be required to make the Impendle Scheme the more economical scheme.

In order to better assess the significance of the difference in URV's between the schemes, the NPV of the total additional cost of supply resulting from the higher URV was determined for the analysis period, as was the NPV of the cost of having to implement a further augmentation scheme three years earlier. This represents a total cost of R180 million, of which only a fraction would be sufficient to compensate for the necessary environmental mitigation measures required for the Smithfield Scheme.

The overall environmental impact ratings and a comparison of the technical and economic aspects of the schemes were summarised in table form and presented to the final Stakeholder Committee Meeting.

From a socio-economic perspective, the non-augmentation option is unacceptable and should not be considered further. The environmental impact of the Smithfield Scheme was rated as Moderate/High and the Impendle Scheme as Moderate. However, the lower yield of the Impendle Scheme will require earlier augmentation, which would offset this difference somewhat. Mitigation measures have been stipulated that will reduce impacts to acceptable levels.

The technical and economic comparison of the schemes was dominated by the lower yield of the Impendle Scheme, which, in turn, results in the Impendle Scheme being significantly less economical than the Smithfield Scheme.

Taking all the above factors into account, it is recommended that the Impendle Scheme be eliminated from further investigation and that the Smithfield Scheme proceed to the next phase of investigation in a detailed Feasibility Study. This decision was ratified by the Stakeholder Committee.

It was not possible to select a preferred configuration for the Smithfield Scheme from the three configurations evaluated and this should be done in the Feasibility Study.

It is assumed that the terms of reference for the Feasibility Study will include the general requirements for investigation of all aspects to an appropriate level of detail. However, a number of aspects requiring particular attention were identified during the course of this Study, in particular:

- *Detailed surveys of ecologically sensitive areas*
- *EFR monitoring and refinement*
- *Address land restitution issues with Department of Land Affairs*
- *Enter into negotiations with affected communities and landowners regarding relocation and compensation*
- *Refine phasing of selected scheme and evaluate raising of Impendle Dam*
- *Optimise and model test dam spillways*
- *Evaluate Smithfield pressure tunnel alternative*

MKOMAZI-MGENI TRANSFER SCHEME PRE-FEASIBILITY STUDY

MAIN REPORT

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APPENDICES

MKOMAZI-MGENI TRANSFER SCHEME PRE-FEASIBILITY STUDY

MAIN REPORT

1. INTRODUCTION

This report has been compiled as a stand-alone document summarising the background, processes, methodology and findings of the Mkomazi-Mgeni Transfer Pre-feasibility Study, and makes recommendations for the next phase of planning.

Full details of the work carried out during this Study are included in the seven Supporting Reports and their appendices, as follows:

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 and Water Resources
Supporting Report No 5:	Environmental
Supporting Report No 6:	Engineering Design and Costing
Supporting Report No 7:	Economics

The findings of two parallel studies which were carried out under separate appointments by others are summarised in Supporting Report Nos 6 and 7, with the full reports included as appendices. These are: An assessment of the relative operational reliability of the schemes investigated at pre-feasibility level; and an assessment of the socio-economic impacts of non-augmentation of the Mgeni System.

2. BACKGROUND AND OBJECTIVES

2.1 Background

The water resources of the Mgeni River system, which is the main source of water for the Durban/Pietermaritzburg metropolitan area, the economic powerhouse of KwaZulu-Natal Province, are already fully utilised. The Mooi-Mgeni Transfer Scheme and the raising of Midmar Dam will shortly proceed to the design phase, but additional augmentation will be required about eight years hence.

Water resources in South Africa are now regarded as a national asset and the goal of Government is to ensure that all South Africans have access to basic water supply and sanitation services. KwaZulu-Natal is considered to be a relatively water-rich Province, evidenced in the major inter-basin transfers, both existing and planned, on the Province's major rivers. However, very sensitive management will be required at central and regional government level to avoid conflicts of interest between regional strategies and the basic needs of the inhabitants of the affected river basins. Comprehensive and careful planning of the development of these water resources is therefore essential and it is with this in mind that the current planning initiative was commissioned by the Department of Water Affairs & Forestry (DWAF) and Umgeni Water.

The Mkomazi is one of the nine major rivers in the Province with a catchment area greater than 1 000 km^2 and is therefore an extremely important water resource in the region. Its potential is currently largely untapped, with approximately 85% of its virgin Mean Annual Runoff (MAR) of 1 070 million m^3/a flowing to the Indian Ocean. The locality of the catchment and its sub-catchments are shown in **Figures 2.1** and **2.2** respectively.

In the Umgeni River System Analysis (DWAF & Umgeni Water, 1994a), transfer schemes from the Mooi and Mkomazi Rivers were identified as being the most feasible to augment the Mgeni system. A number of other alternatives were identified and evaluated, but were found to be too small and/or uneconomical to be viable. The Mooi-Mgeni Transfer Scheme was subsequently investigated in more detail (DWAF & Umgeni Water, 1995) and recommendations for development of a first phase scheme were made. Schemes on the other major rivers that could potentially be tapped, namely the Bushmans, Mzimkhulu and Mzimvubu, would all involve far greater capital and running costs than the Mkomazi, due to their distance from the demand node and their relative elevations.

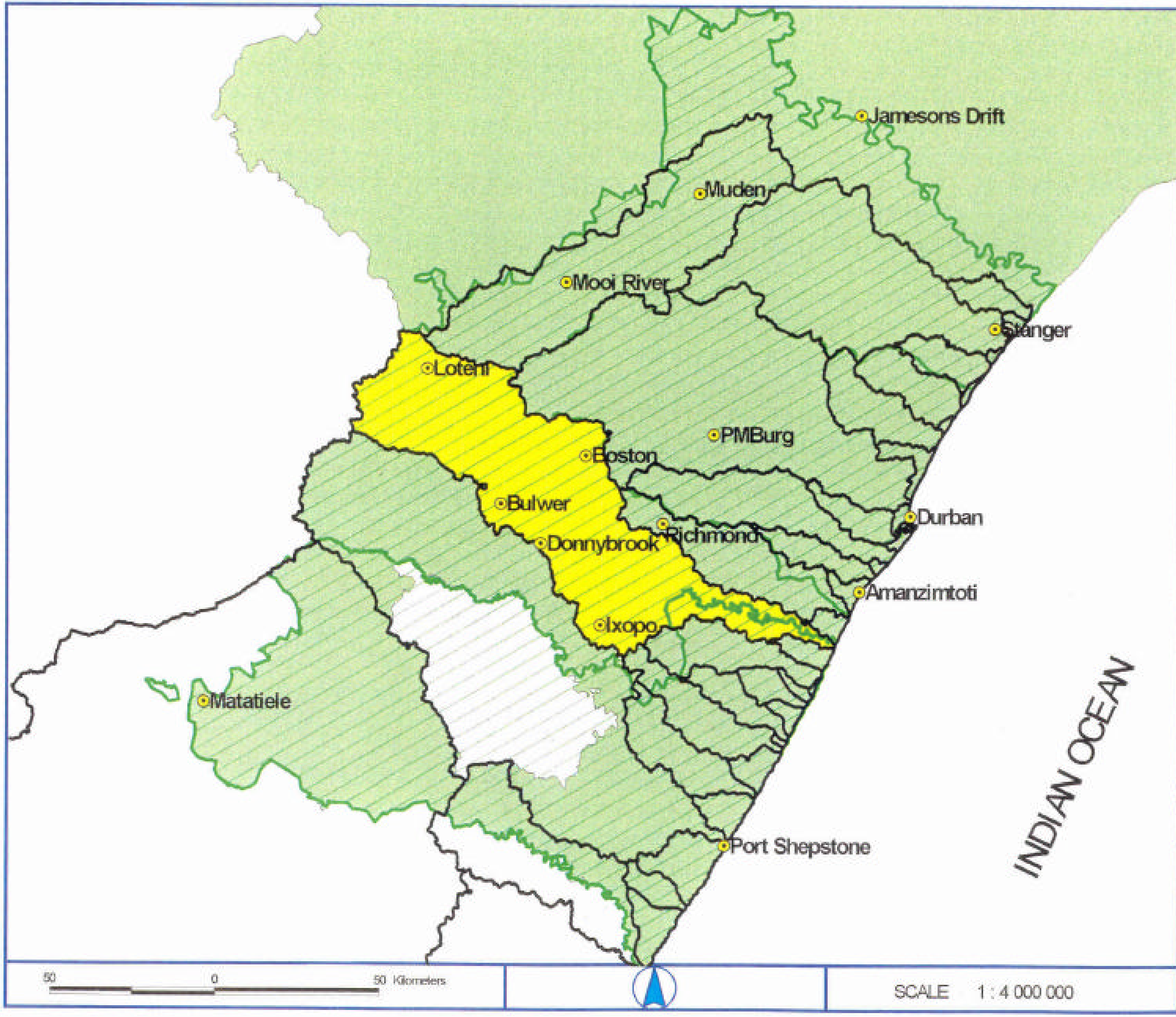
2.2 Objectives of this Study

According to the original January 1997 Terms of Reference, the ultimate objective of this Study was to identify the next augmentation scheme for the Mgeni System after the first phase of the Mooi-Mgeni Transfer Scheme is fully utilised. Such a scheme would be either on the Mooi or Mkomazi Rivers. However, during the course of the Study, it became apparent that the second phase Mooi-Mgeni Transfer Scheme should be implemented as a matter of course, both because of economic considerations and the fact that a scheme on the Mkomazi could not be implemented in time to avoid risks of significant shortfalls in supply in the Mgeni System. Consequently, the objectives of the Study shifted to identifying the preferred Mkomazi Scheme for further investigation at feasibility level, along with refining the second phase Mooi-Mgeni Transfer Scheme in preparation for the feasibility phase. The Mooi-Mgeni Transfer Scheme is described in a parallel suite of reports (see the Report Structure at the front of this report).

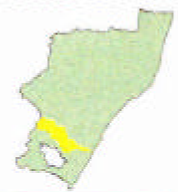
MAP TITLE

Catchment

LEGEND



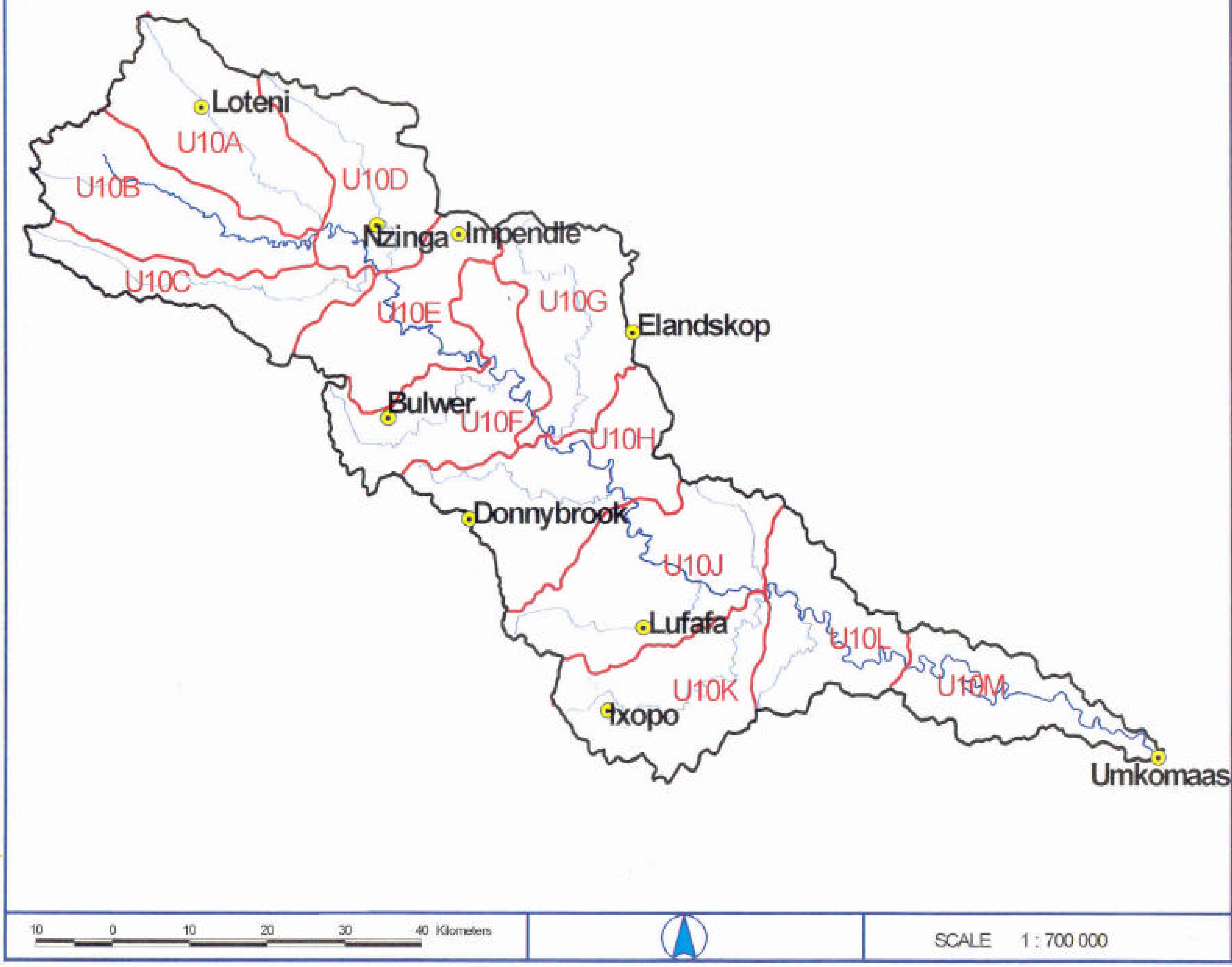
LOCALITY PLAN

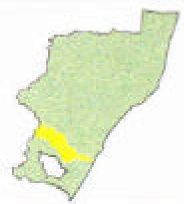


Mkomazi-Mgeni Transfer Scheme
Pre-Feasibility Study

SCALE 1 : 4 000 000

FIGURE 2.1





MAP TITLE

Mkomazi Catchment

LEGEND

Towns / Villages

Rivers

Quaternary Catchments

Mkomazi Catchment

Mkomazi-Mgeni Transfer Scheme
Pre-Feasibility Study

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SCALE 1 : 700 000

FIGURE 2.2

According to the Terms of Reference, the Mkomazi-Mgeni Transfer Scheme is to supply potable water to the distribution centre at Umlaas Road and its selection should be based on economics as well as engineering, hydrological, social and environmental considerations. A scheme which would allow the deferment of capital expenditure would be particularly attractive and phasing has therefore been considered.

2.3 Typical Study and Implementation Process

Typically, the process from the initial identification of the need for a scheme through to the commissioning of a scheme is as follows:

Scheme Identification Phase

All apparent technically viable alternative schemes, which could meet the identified needs, are identified and evaluated at a scoping level to confirm their viability and appropriateness. Some schemes may be eliminated from further investigation at this stage and the remainder recommended for further study.

Reconnaissance Phase

Schemes recommended in the Scheme Identification Phase are screened on the basis of technical feasibility, economic evaluation and social and environmental impacts to select preferably not more than two layouts for further study.

Pre-Feasibility Phase

The schemes selected in the Reconnaissance Phase are subjected to more exhaustive studies of the technical feasibility, social and environmental acceptability, and economic and financial viability to determine the best layout for further study.

Feasibility Phase

The feasibility of the scheme selected in the Pre-feasibility Phase is confirmed by carrying out detailed studies of the technical feasibility, social and environmental issues and economic and financial viability, to a level of detail where approval for the implementation of the scheme can be obtained from the relevant authorities. Firm budgets are determined to enable funding to be procured.

Implementation Phase

Detailed design is carried out and tender documents prepared, compensation of affected parties takes place and an environmental management plan is drawn up. Tenders are invited and evaluated, a contractor appointed and the construction of the scheme proceeds. This phase culminates in the commissioning of the scheme.

In this Study, the investigations of potential Mkomazi-Mgeni Transfer Schemes commenced with Scheme Identification and concluded with the Pre-feasibility phase, with the level of detail for each stage being in accordance with the recommendations set out in the DWAF VAPS Guidelines (DWAF, 1994c).

2.4 Management Structure

A diagram of the project management structure for this Study is given in **Figure 2.3**.

The ***Project Management Committee*** comprised representatives of the two Client bodies, the Study Leader, the Study Manager and, on an ad hoc basis, team leaders of specific tasks. This committee was responsible for the overall management of the Study process. Various technical working group meetings were also convened on an ad hoc basis to clarify specific technical issues.

The ***Stakeholder Committee*** comprised representatives from all interested and affected groups, although attendance at meetings by several of the stakeholder representatives was poor. Nonetheless, all pertinent documentation was sent to all representatives, irrespective of their attendance. Note that, as is appropriate at pre-feasibility stage, representation took the form of umbrella body representation, rather than individual representation.

The task of the Stakeholder Committee was to review the scope of work and recommendations of the Study Team at appropriate stages, to ensure that the needs of the interested and affected parties were being adequately addressed, to provide feedback to their constituency and to provide input to the Study through their local knowledge. A total of six meetings were held and two newsletters in both English and Zulu were produced and distributed.

The ***Environmental Task Group*** or ***ETG*** comprised members of the Project Management Committee and Study Team, along with various stakeholders and specialists directly involved with environmental issues. Their primary task was to ensure that the Integrated Environmental Management (IEM) Procedure of the

Department of Environment Affairs and Tourism was being followed. A total of four meetings were held.

A list of members of all the above committees is included in **Appendix A**.

A list of issues raised in the various committee meetings, as well as record of decisions taken, is included in **Appendix B**.

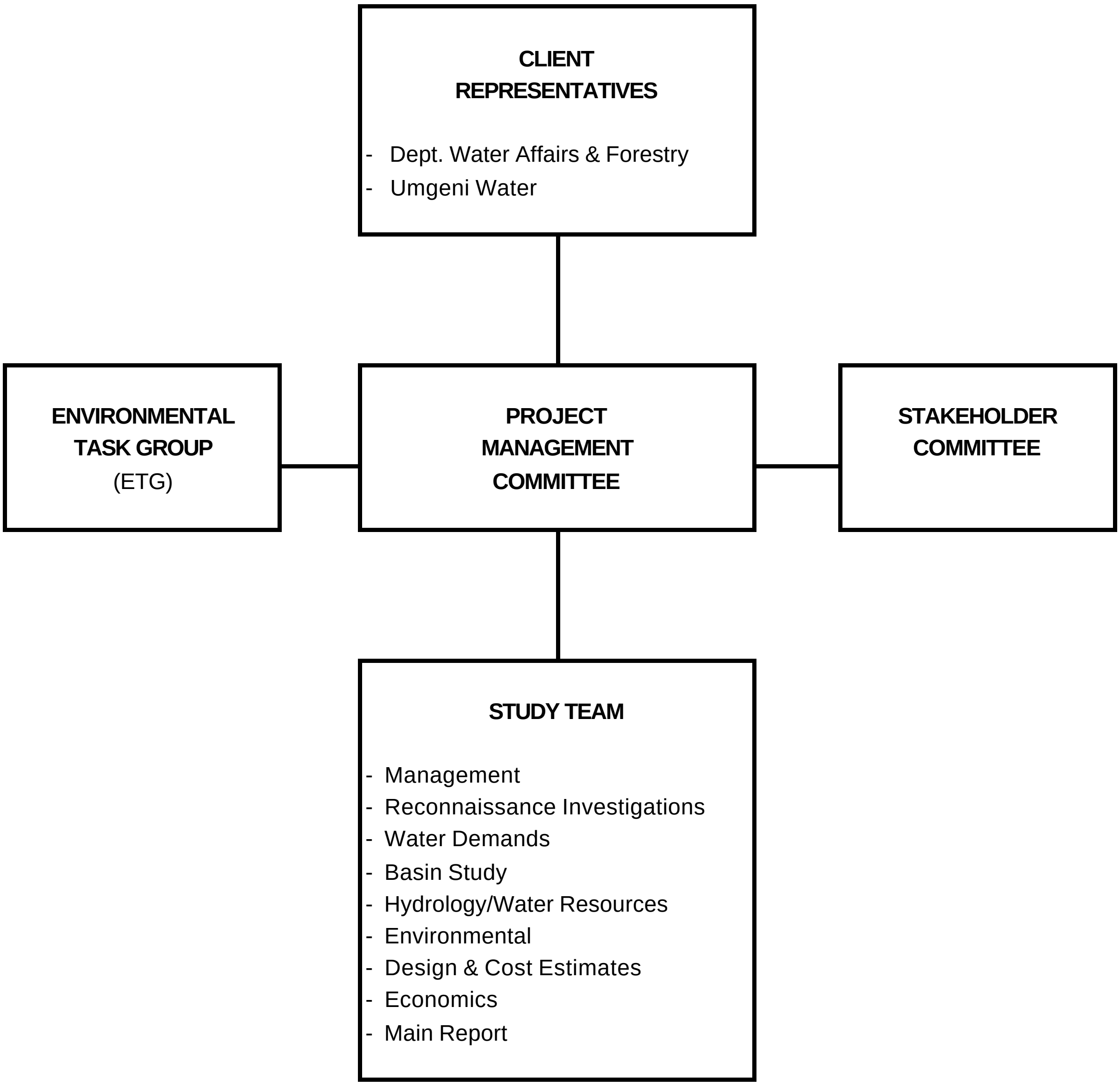


FIGURE 2.3: PROJECT MANAGEMENT STRUCTURE

3. RECONNAISSANCE INVESTIGATIONS (See Supporting Report No 1)

3.1 Introduction

The objective of this first phase of the Mkomazi-Mgeni Transfer Scheme Pre-Feasibility Study was to select the optimal transfer schemes for the Mkomazi by identifying and evaluating a number of potential schemes, all delivering clear water to Umlaas Road, eliminating those that clearly have little merit, and carrying out a reconnaissance investigation of the remaining schemes.

It became apparent after a preliminary review of previous studies that in view of the requirement that water from the proposed transfer scheme was to be delivered to a demand node at Umlaas Road, only one of the two Mkomazi schemes identified in the Mgeni River System Analysis Study (DWAF & Umgeni Water, 1994b) would be feasible in the configuration proposed in that study. Taking this and subsequent discussions with Umgeni Water and DWAF on other alternatives into account, it was decided to review all the development options that had been previously proposed for the Upper Mkomazi-Mgeni Transfer and to investigate any other development options that may be considered feasible. These were to be subjected to an initial screening process prior to proceeding to the next level of detail of investigation. This process thus moved through a scheme identification phase, a pre-reconnaissance phase and a reconnaissance phase, culminating in the recommendation of two schemes for pre-feasibility investigation.

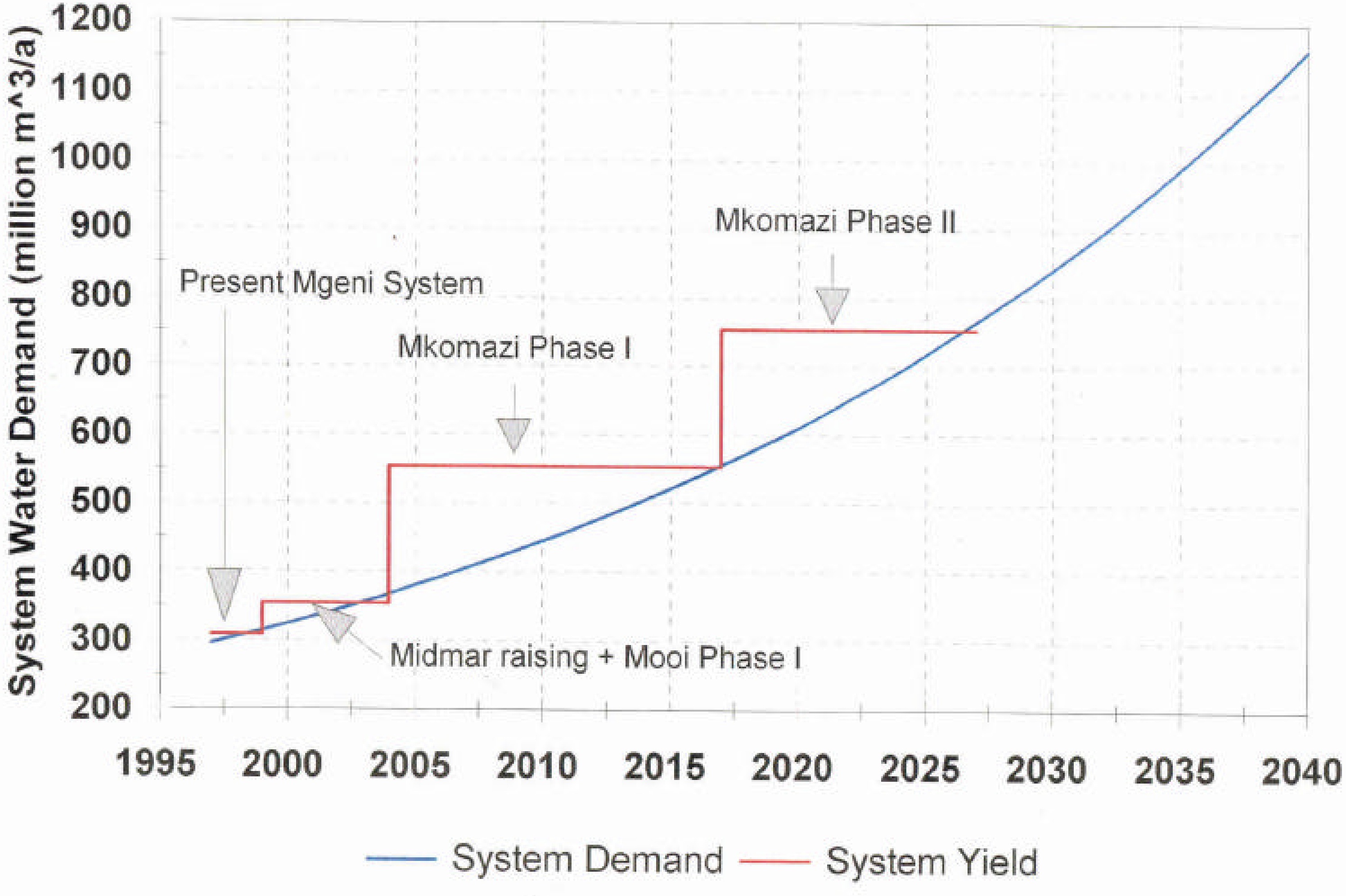
3.2 Water Demands

The first task of this phase of the Study was to determine present and projected future water demands in the portion of the Mgeni System which is to be supplied from the proposed transfer schemes. Data was obtained from BKS and Umgeni Water for the inland and coastal systems and average growth rates were selected to approximate the figures supplied. It should be noted that the Durban Metro demands assuming stringent demand management measures in place were still under discussion during the reconnaissance phase of the Study, but were taken into account in the pre-feasibility phase.

Net demands from the proposed transfer schemes were calculated by subtracting the Mgeni System yield, assuming the Midmar Dam is raised and Phase 1 of the Mooi-Mgeni Transfer Scheme is in place, from the total system demand. The demand and yields of the Mgeni System and two possible phases of Mkomazi Schemes are shown in **Figure 3.1**.

FIGURE 3.1

PROJECTED MGENI SYSTEM DEMAND



3.3 Scheme Identification Phase

3.3.1 General

As indicated in Section 3.1, it became apparent at an early stage of the Study that consideration should be given to other potential schemes on the Mkomazi River before proceeding to more detailed evaluation of selected schemes. In this phase of investigation, only first phase schemes with yields of 200 million m^3/a were considered, with a total of eight potential schemes being identified. The scheme layouts are shown in **Figure 3.2**.

3.3.2 Scheme descriptions and initial screening

A total of eight schemes were identified, as described below, of which three were eliminated during an initial screening process.

Impendle Scheme (Scheme 1)

This scheme was originally identified by DWAF and for the purposes of this study, it was assumed that the scheme would be configured as follows:

- Rockfill dam with side channel spillway and capacity of 200 million m^3, near Inzinga River confluence.
- Gravity tunnel to Midmar Dam.
- Pipeline and low lift pumpstation to extension of Midmar Waterworks.
- Clearwater gravity conveyance (existing and upgraded pipelines and Midmar Tunnel) to Umlaas Road.

Clayborne Scheme (Scheme 2)

This scheme was identified by Umgeni Water and modified to include limited pumping not allowed for in the original configuration. The selected configuration is as follows:

- Rockfill dam with side channel spillway and capacity of 170 million m^3, approximately 10 km downstream of Impendle.
- 66 km of canals and 8 km of gravity tunnels to Lovu River near Richmond, including a low lift pumpstation and shaft.
- Waterworks and gravity pipeline to Umlaas Road.

Smithfield-Richmond Scheme (Scheme 3A)

This scheme was identified in the System Analysis Study, but required major modification to deliver water to Umlaas Road. Its revised configuration is as follows:

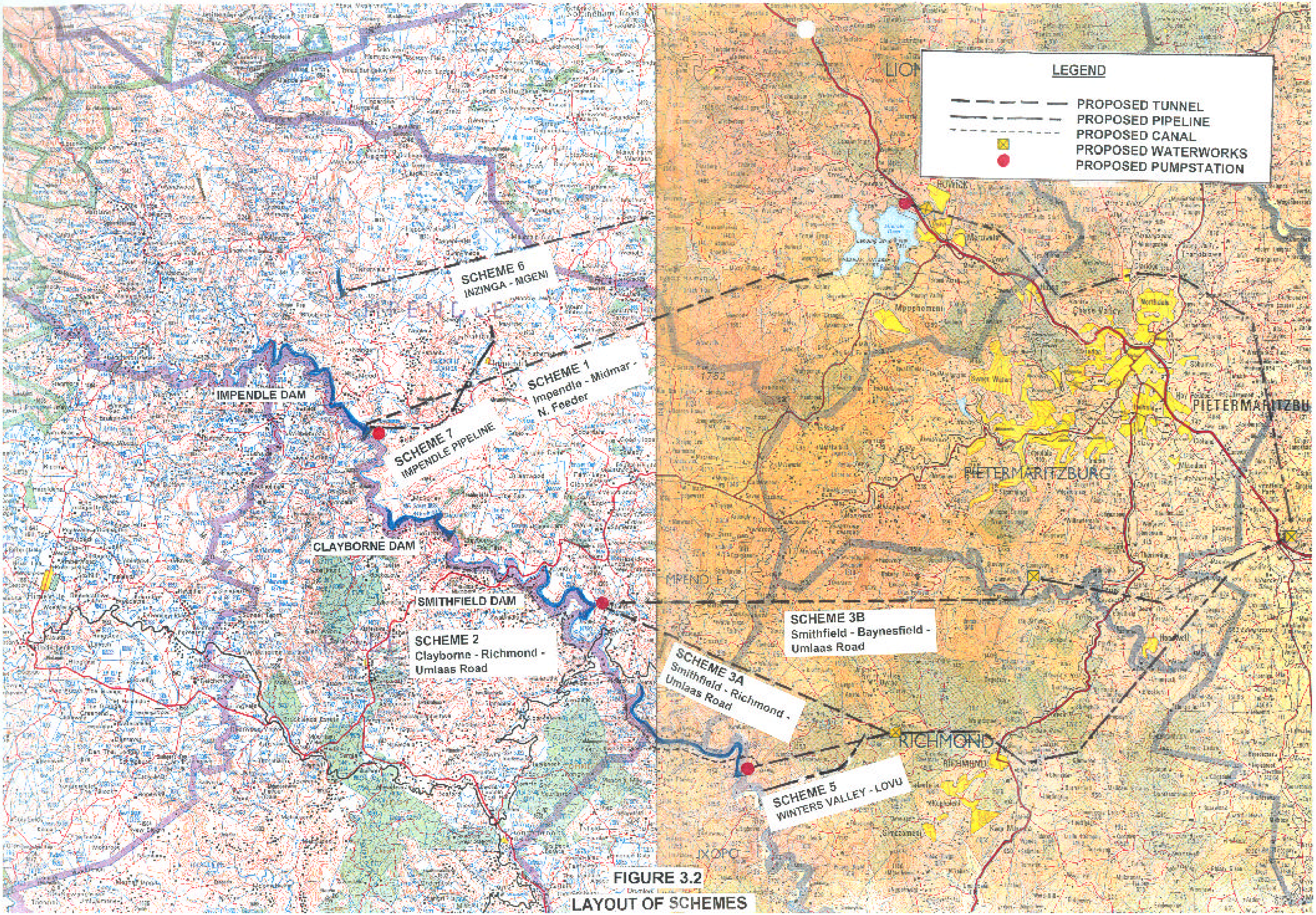


FIGURE 3.2
LAYOUT OF SCHEMES

- Rockfill dam with side channel spillway and capacity of 170 million m^3 at Smithfield.
- Pumpstation and shaft (85 m head) feeding 25 km gravity tunnel to Lovu River near Richmond.
- Waterworks and pipeline as per Clayborne Scheme.

Smithfield-Baynesfield Scheme (Scheme 3B)

This scheme is a variation of Scheme 3A, as follows:

- Rockfill dam as above.
- Pumpstation and shaft (25 m head) feeding a 32 km gravity tunnel to Mlazi River at Baynesfield.
- Waterworks and pipeline to Umlaas Road.

Ndonyane Scheme (Scheme 4)

This scheme was not previously identified. Its configuration is as follows:

- Rockfill dam with side channel spillway and capacity of 160 million m^3 at Ndonyane.
- Pumpstation and shaft (340 m head) feeding 14 km gravity tunnel to Lovu River near Richmond.
- Waterworks and clearwater conveyance as per Scheme 3A.

Winters Valley-Lovu (Scheme 5)

This scheme was identified by Umgeni Water and is configured as follows:

- Weir on the Mkomazi at Winters Valley.
- Canal and multiple stage pumping via a pipeline across the divide between the Mkomazi and Lovu catchments.
- Waterworks and clearwater conveyance as per Scheme 3A.

This scheme was eliminated as it relies on run-of-river, which cannot supply a regional waterworks and related conveyance infrastructure at sufficiently high levels of assurance to be viable.

Inzinga-Mgeni (Scheme 6)

This scheme was not previously identified and consists of the following:

- Dam on Inzinga River near Brooklyn.
- Gravity tunnel 24 km long to upper reaches of Mgeni River.
- Waterworks and clearwater conveyance system as per Scheme 1.

This scheme was eliminated as its yield would be too small to justify the capital cost of a 24 km tunnel. There would also be environmental problems associated with transfers into the Mgeni Vlei.

Impendle Pipeline (Scheme 7)

As an alternative to Scheme 1, DWAF suggested that a smaller scheme without a tunnel should be considered. The configuration is as follows:

- Small dam at Impendle site.
- Pumpstation and pipeline (head 600 m) across watershed to Mgeni catchment.
- Waterworks and clearwater conveyance as per Scheme 1.

This scheme was eliminated on the basis of the extremely high pumping head. There would also be environmental problems associated with discharging water into sensitive vlei areas.

3.3.3 Hydrology and water resources

Yield analyses for the Impendle and Smithfield schemes were carried out by BKS, using the recently revised catchment hydrology. Sub-catchment boundaries had been set up to match the dam sites proposed in the 1994 System Analysis Study and it was therefore a relatively simple matter to set up the yield model for the two schemes. At this stage, historical firm yields of the individual schemes only were determined.

For the Clayborne and Ndonyane Schemes, the yields determined for the Impendle and Smithfield Dams were adjusted to match the estimated MAR's at these sites.

All dams were sized for an historical firm yield of 200 million m^3/a.

3.3.4 Engineering, costing and economics

Schemes 1 to 4 described above were investigated at a level of detail in accordance with the DWAF VAPS Guidelines for scheme identification phase. Cost estimates were prepared on the same basis.

Based on information available at the time and a visit to the sites, it was concluded that none of the dam sites would be suitable for a concrete structure. Rockfill dams with side channel spillways and multi-level intake structures feeding reinforced outlet conduits were assumed.

All tunnels were designed as free water surface gravity tunnels and all but short tunnels were assumed to be bored. Concrete lining was provided throughout.

Cost estimates for dams, tunnels, canals and pumpstations were based on VAPS cost models, escalated to August 1997 prices. Pipeline and water treatment works costs were based on information provided by Umgeni Water. Running costs were also calculated according to the Guidelines, but treatment costs were not considered, as these would be common to all schemes.

Economic analyses for the period up to 2053 were carried out, assuming commissioning in 2004. The Net Present Value (NPV) of costs and Unit Reference Value (URV) of each scheme was determined for discount rates of 6, 8 and 10 %. The URV is calculated as the URV of all costs for the analysis period divided by the NPV of water delivered during the same period.

The results of the analyses are given in **Table 3.1**.

TABLE 3.1: COSTS AND ECONOMICS: SCHEME IDENTIFICATION PHASE

SCHEME	CAPITAL COST (R000)	RUNNING COSTS (R000/a)	NET PRESENT VALUE OF COSTS (R000) @ DISCOUNT RATES			UNIT REFERENCE VALUE (c/m^3) @ DISCOUNT RATES		
			6%	8%	10%	6%	8%	10%
1. Impendle	1 474 000	7 856	1 238 822	1 122 980	1 026 473	82,3	118,3	163,6
2. Clayborne	1 457 000	13 273	1 242 658	1 105 020	994 446	82,6	116,4	158,5
3A. Smithfield-Richmond	1 271 000	23 541	1 172 608	1 020 829	906 386	77,9	107,6	144,5
3B. Smithfield-Baynesfield	1 321 000	10 918	1 120 631	1 001 808	905 774	74,5	105,5	144,4
4. Ndonyane	1 384 000	26 268	1 276 359	1 107 357	980 162	84,8	116,7	156,2

Note: 1. All costs are based on an August 1997 base date.
2. Costs exclude VAT.
3. Analysis period of 50 years from commissioning date of schemes (2004).

3.3.5 Secondary screening and conclusions

As can be seen in **Table 3.1**, the capital costs and URV's of the five schemes are within 12% of each other and considering the level of detail of the cost estimates, it would be inappropriate to eliminate any of these schemes on the basis of economics at this stage.

Positive and negative aspects of all eight schemes are summarised in **Table 3.2**. Of these, the most significant are the major ecological and social impact of the Clayborne canal, the risk of slope failure blocking the canal for extended periods, and the high pumping head and relatively pristine dam basin of the Ndonyane Scheme. However, it was concluded that there were insufficient grounds for the elimination of any of the remaining five schemes, which were carried forward to the next phase of the Study.

TABLE 3.2: SCHEME COMPARISON: SCHEME IDENTIFICATION PHASE

SCHEME	ADVANTAGES	DISADVANTAGES
1: Impendle	C Very limited pumping C Probably least impact on estuary C Least impact of conveyance and waterworks C Centralised system simplifies operation	C Highest capital cost and Unit Reference Value C Yield limited by MAR C Centralised system entails greater risks
2: Clayborne	C Limited pumping C Scope for supplying irrigation along canal route	C Second highest capital cost and third highest URV C Limited scope for phasing of canal C High social and environmental impacts of canal C High maintenance costs of canal
3A: Smithfield-Richmond	C Lowest capital cost and second lowest URV C Greater yield than Impendle	C Relatively high pumping head C Maximum size limited by topography C Second dam required for future phases
3B: Smithfield-Baynesfield	C Second lowest capital cost and lowest URV C Greater yield than Impendle C Low pumping head	C Maximum size limited by topography C Second dam required for future phases
4: Ndonyane	C Potentially highest yield of schemes evaluated	C Very high pumping head C Relatively high capital cost and second highest URV C Dam basin relatively pristine
5: Winters Valley-Lovu	C Low capital cost	C Very high pumping head C Inadequate assurance of supply for scheme to be viable
6: Inzinga-Mgeni		C Inadequate yield vs. capital cost for scheme to be viable
7: Impendle Pipeline	C Low capital cost	C Unacceptably high pumping head C Unacceptable negative impact on receiving stream C Low yield

Note: Shading indicates schemes which were eliminated from further investigation and points considered critical are underlined.

3.4 Pre-Reconnaissance Assessment

3.4.1 General

This phase of the study concentrated on refining the five schemes selected in the Scheme Identification phase, with particular emphasis on phasing of the schemes. Initial environmental impact assessments were also carried out.

3.4.2 Hydrology and water resources

The same hydrology as that used in the Scheme Identification phase was utilised. However, for the phased Smithfield Scheme, a second phase dam was required at Impendle and the yield for this combination of dams was determined by BKS. The results of this and the original analysis are given in **Figure 3.3**.

3.4.3 Review of schemes

Impendle Scheme (Scheme 1)

The revised scheme consists of a dam implemented in three phases by raising to an ultimate capacity of 680 million m^3, yielding 340 million m^3/a. Allowance was made in the third phase yield for 40 million m^3 of releases for the Instream Flow Requirements (IFR). The pumpstation, waterworks and pipelines would also be phased and the tunnel route was refined and shortened.

Clayborne Scheme (Scheme 2)

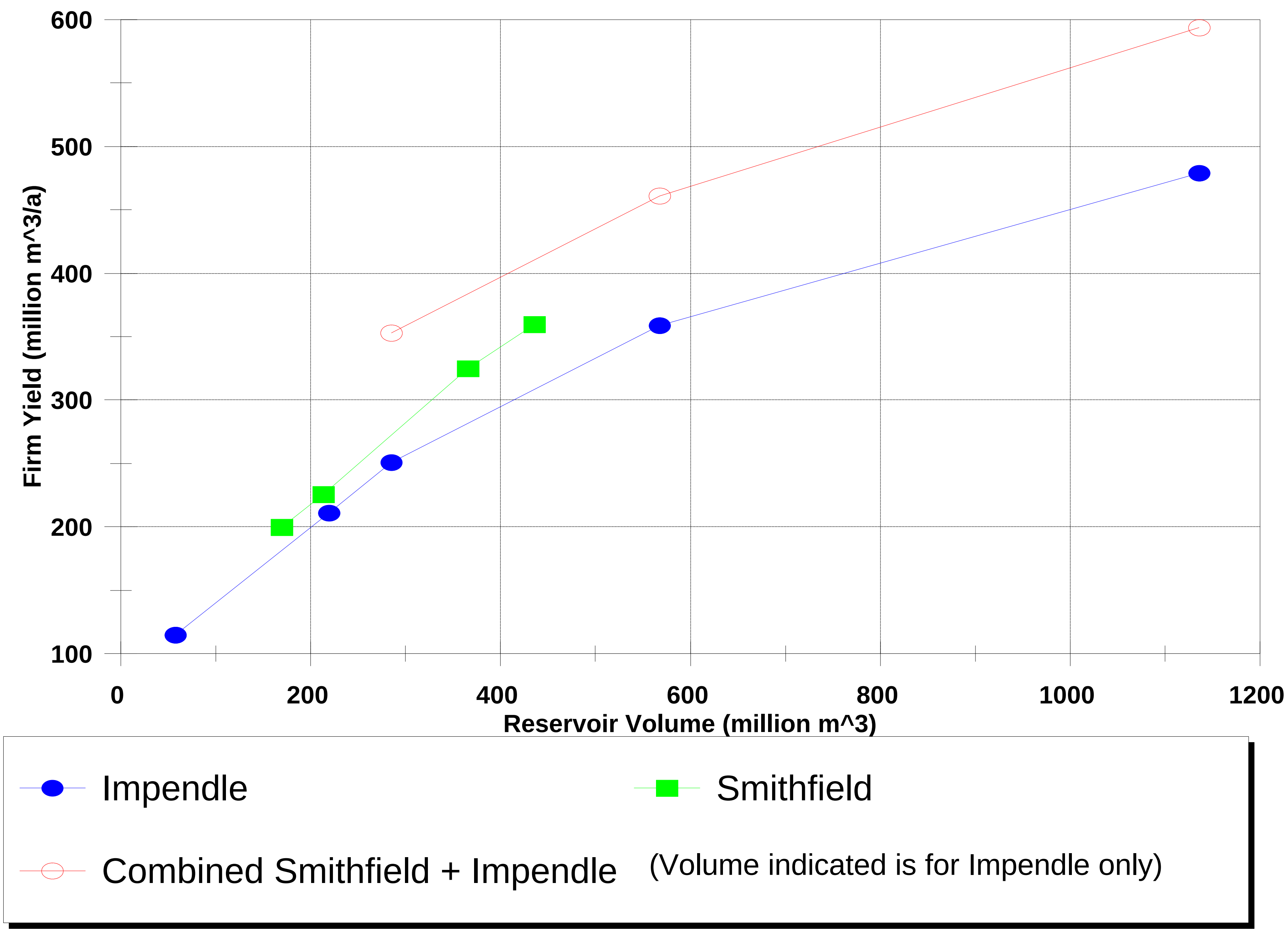
In view of potential fatal ecological and social flaws with the scheme, as well as the potential stability problems on the left flank of the dam and the difficulty in raising the canal, it was not considered worthwhile refining the scheme, but rather to accept the original layout.

Smithfield-Richmond Scheme (Scheme 3A)

Due to topographical constraints, the maximum practical capacity that can be attained at the Smithfield Dam site is limited to approximately 170 million m^3. Consequently, for further phasing, additional storage has to be provided at some point upstream of Smithfield. Impendle was identified as the preferred site.

The revised scheme consists of an initial dam at Smithfield with a 560 million m^3 second phase dam at Impendle, yielding 200 and 410 million m^3/a respectively, including a 50 million m^3/a IFR allowance in the second phase combined yield.

FIGURE 3.3: HISTORICAL FIRM YIELD



Water would be released down river from Impendle to Smithfield in the second phase. Treatment and conveyance infrastructure would be as per the original scheme, but implemented in phases.

Smithfield-Baynesfield Scheme (Scheme 3B)

The configuration of the dams would be identical to Scheme 3A. Other infrastructure as previously described, but will be phased.

Ndonyane (Scheme 4)

The revised scheme consists of a dam implemented in two phases by raising to an ultimate capacity of 560 million m^3, yielding 410 million m^3/a respectively, including a 50 million m^3 IFR allowance in the second phase. Other infrastructure will be phased.

3.4.4 Engineering, costing and economics

The basis for the engineering design and cost estimates is generally the same as for the Scheme Identification phase. However, tunnel costs were re-calculated using escalated unit rates from the Mooi-Mgeni Transfer Scheme study. The methodology for the economic analysis was the same as for the Scheme Identification phase, but the sensitivity to lower water demands was also determined. The results of the analysis are given in **Table 3.3**.

3.4.5 Environmental

The pre-reconnaissance environmental assessment comprised a site visit and an initial scoping exercise.

Information on the ecological and social aspects of the dam basin gathered during the site visit were presented to the Environmental Task Group (ETG), along with appropriate engineering background to the schemes. The ETG concluded that:

- The Clayborne Scheme should not proceed due mainly to the ecological and social impact of the canal.
- The Ndonyane Dam may result in the inundation of a valuable and important resource base. A Habitat Integrity Assessment was requested to confirm the magnitude of this.

TABLE 3.3: COSTS AND ECONOMIC COMPARISON: PRE-RECONNAISSANCE PHASE

SCHEME	CAPITAL COSTS ® Million)			URV (ALL PHASES) @ DISCOUNT RATE (c/m³)			URV (1ST PHASE ONLY) @ DISCOUNT RATE			URV (WATER DEMAND GROWTH = 2,5%) @ DISCOUNT RATE		
	Ph 1	Ph 2	Ph 3	6%	8%	10%	6%	8%	10%	6%	8%	10%
1: Impendle	1 114	508	478	67,2	94,4	128,4	96,9	133,3	176,7	90,2	132,6	188,6
2: Clayborne	1 457			82,6	116,4	158,5	82,6	116,4	158,5	-	-	-
3A: Smithfield-Richmond	1 191	867		65,6	90,6	122,7	72,1	100,1	134,9	85,8	125,0	177,7
3B: Smithfield-Baynesfield	1 142	746		57,2	81,2	112,3	64,9	92,0	125,9	76,1	113,7	164,5
4: Ndonyane	1 318	997		78,0	105,5	140,7	84,5	115,1	153,1	100,4	143,6	201,4

Note:
1. All costs are based on an August 1997 base date.
2. Costs exclude VAT.
3. Analysis period of 50 years from commissioning date of schemes (2004).

TABLE 3.4: SCHEME COMPARISON: PRE-RECONNAISSANCE PHASE

SCHEME	ADVANTAGES	DISADVANTAGES
1: Impendle	C Very limited pumping C Probably least impact on estuary C Least environmental impact of conveyance and waterworks C Centralised system simplifies operation	C Third highest URV C Yield limited by MAR C Centralised system entails greater risks
2: Clayborne	C Limited pumping C Scope for supplying irrigation along canal route	C Highest URV C Limited scope for phasing of canal C Unacceptably high social and environmental impacts of canal C High maintenance costs of canal and risk of interruption of supply due to instability C Possible instability on dam site
3A: Smithfield-Richmond	C Second lowest URV C Greater yield than Impendle	C Relatively high pumping head C Maximum size limited by topography C Second dam required for future phases
3B: Smithfield-Baynesfield	C Lowest URV C Greater yield than Impendle C Low pumping head	C Maximum size limited by topography C Second dam required for future phases
4: Ndonyane	C Potentially highest yield of schemes evaluated	C Very high pumping head C Highest capital cost and second highest URV C Dam probably has greatest environmental impact

Note: Shading indicates schemes which were eliminated from further investigation and points considered critical are underlined.

3.4.6 Selection of schemes for reconnaissance investigation

The advantages and disadvantages of the various schemes are listed in **Table 3.4**. On the basis of the Pre-reconnaissance investigations, the Clayborne Scheme was eliminated from further investigation, for environmental and economic reasons.

In the case of the Ndonyane Scheme, it was found to be the least economical of the phased schemes and environmental concerns were raised. Subsequently, a geotechnical investigation indicated that the site was less favourable than the Smithfield and Impendle sites. However, a final decision of its elimination was made dependent on further investigations.

The following schemes were therefore selected for further investigation at reconnaissance level:

- Impendle Scheme
- Smithfield-Richmond Scheme
- Smithfield-Baynesfield Scheme
- Ndonyane Scheme (Habitat Integrity Assessment only, unless the technical or economic viability of the other schemes change significantly)

3.5 Reconnaissance Investigation

3.5.1 Water demands and water resources

It was not considered necessary to revise water demand projections or scheme yields determined in the Scheme Identification and Pre-reconnaissance phases for the Reconnaissance phase.

3.5.2 Engineering aspects

General

A number of modifications were made to the selected schemes in this phase of the Study and various aspects were investigated in more detail. Scheme details are provided in **Appendix C** and layouts are shown in **Figure 3.4**.

The preferred delivery point for clear water was initially near the existing reservoir at Umlaas Road at elevation 840 masl. However, a better site for a reservoir was identified nearby at an elevation of 804 masl, from where water could still gravitate to the Durban system. This site was approved by Umgeni Water after consultation with Durban Metro.

In the initial phases of the Study, it was assumed that clear water would be delivered at a constant rate equivalent to the historical firm yield of the schemes. In this phase, it was considered appropriate to allow for a peak factor of 25% in all infrastructure, except in the case of the Impendle raw water transfer, where the storage available in Midmar Dam can be utilised to balance peaks.

Reconnaissance level geotechnical information was provided by the Council for Geoscience, based on previous reports and other available data, as well as site visits.

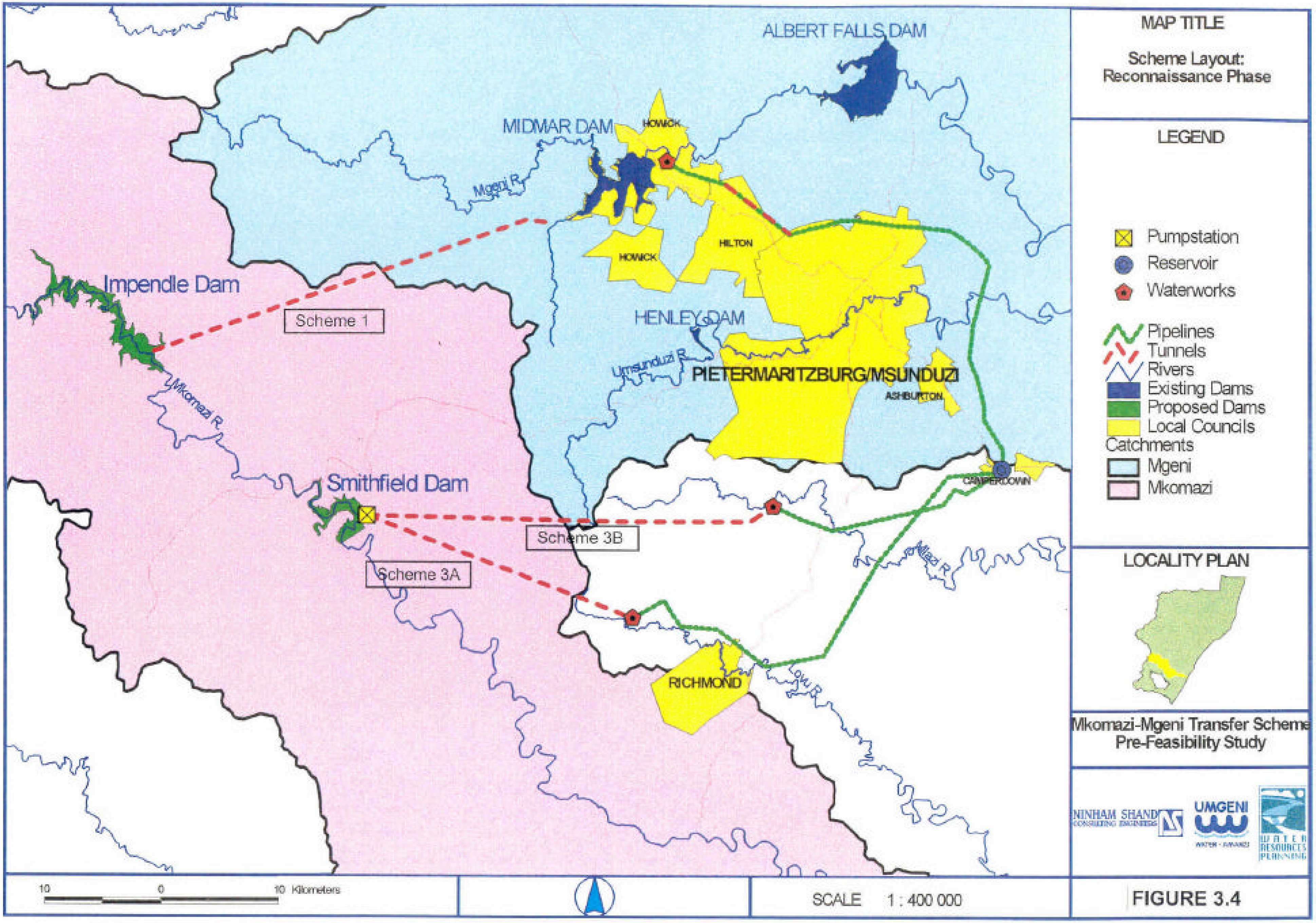

MAP TITLE
Scheme Layout:
Reconnaissance Phase
LEGEND
Pumpstation
Reservoir
Waterworks
Pipelines
Tunnels
Rivers
Existing Dams
Proposed Dams
Local Councils
Catchments
Mgeni
Mkomazi
LOCALITY PLAN
Mkomazi-Mgeni Transfer Scheme
Pre-Feasibility Study
NINHAM SHAND CONSULTING ENGINEERS
UMGENI WATER · AMANZI
WATER RESOURCES PLANNING
ALBERT FALLS DAM
MIDMAR DAM
HOWICK
HILTON
HENLEY DAM
Mgeni R.
Umsunduzi R.
PIETERMARITZBURG/MSUNDUZI
ASHBURTON
CAMPERDOWN
Impendle Dam
Mkomazi R.
Scheme 1
Smithfield Dam
Scheme 3B
Scheme 3A
Mlazi R.
Lovu R.
RICHMOND
10 0 10 Kilometers
SCALE 1 : 400 000

FIGURE 3.4

Impendle Scheme

The geotechnical information provided confirmed that the selected dam type was appropriate. The impact of the dam on infrastructure was evaluated.

Smithfield-Richmond Scheme

A preferred site for the Smithfield Dam was identified approximately 1,5 km upstream of the original site, which significantly reduces fill volume. Geotechnical investigations confirmed the suitability of this site.

A raw water balancing dam was provided on the Lovu River and the waterworks was moved to suit the location and elevation of the balancing dam. Pipeline routes were reviewed and a problem area was identified, where deep excavations will be required. The impact of the dams on infrastructure was also assessed.

Smithfield-Baynesfield Scheme

The configuration of the storage dams were as per the Smithfield-Richmond Scheme and similar allowances were made for a raw water balancing dam on the Mlazi River. The waterworks position was adjusted accordingly and pipeline routes were reviewed.

3.5.3 Environmental aspects

Initial Environmental Assessments (ROIP's) were undertaken by DWAF for the Impendle and Smithfield Schemes and a Habitat Integrity Assessment was carried out at the Ndonyane Dam site. The main findings were as follows:

Impendle Scheme

The social impacts of the scheme are particularly significant, with the overall socio-economic impact being rated as severe, due mainly to the loss of arable land and relocation of a settlement which will be required. The incremental impact of the larger dam than for the Smithfield Scheme is significant. The ecological impacts were related to loss of habitat and primarily the change in flow regime.

Smithfield Schemes

Both Smithfield schemes involve the same dam basins and area of inundation, the differences between the schemes being their conveyance routes. A number of potential social problems related to loss of arable land, disruption of access routes and inundation of dwellings were identified and the overall impact was rated as generally problematic. The ecological impacts were similar to the Impendle Scheme.

Ndonyane Scheme

The habitat integrity assessment confirmed that the Ndonyane Dam basin has a significantly more valuable and important resource base than the other schemes. It is relatively pristine and has exceptional scenic and aesthetic value.

Overall Assessment

The overall assessment is that the social impacts of the Impendle Scheme dominate and are severe. Mitigation may be problematic, but will be feasible. Ecological impacts of the Smithfield scheme are more severe than Impendle, but not critical. The Ndonyane Scheme is not favoured.

3.5.4 Costing and economics

Revised cost estimates were prepared for the schemes. The approach was generally similar to the previous phases, with the most significant changes being in pipeline costs, due to the larger diameters required and the revised unit rates used. Economic analyses were carried out on the three schemes as before and the results are summarised in **Table 3.5**.

3.5.5 Recommendations for Pre-feasibility Study

The main advantages and disadvantages of each scheme are summarised in **Table 3.6**.

Technically, all three schemes selected in the pre-reconnaissance phase were found to be feasible, although problems were encountered with the pipeline between Richmond and Umlaas Road which would necessitate deep excavation. Economically, the URV's of the three scheme lie within a small range, with the Smithfield-Richmond Scheme being least favourable.

The Smithfield schemes would have a greater ecological impact than Impendle, due mainly to their effect on the downstream flow regime and the two dams. The Impendle scheme would have relatively severe social impacts, which would also apply, but to a lesser extent, with the second phase of the Smithfield schemes. However, it was agreed that no fatal ecological or social flaws were apparent. In the case of the Ndonyane scheme, which was provisionally eliminated in the Pre-reconnaissance phase, the Habitat Integrity Assessment confirmed that the dam would inundate a valuable and important resource base.

It was therefore proposed to and agreed by the ETG and Stakeholder Committee that only the Impendle and Smithfield-Baynesfield schemes should be investigated further at Pre-Feasibility level.

TABLE 3.5: ECONOMIC COMPARISON: RECONNAISSANCE PHASE

SCHEME	COMMISSIONING DATE			CAPITAL COST (All phases) (R000)	RUNNING COST (All phases) (R000)	NET PRESENT VALUE OF COSTS (R000) @ DISCOUNT RATES			UNIT REFERENCE VALUE (c/m³) @ DISCOUNT RATES		
	Ph 1	Ph 2	Ph 3			6%	8%	10%	6%	8%	10%
1. Impendle	2004	2012	2018	2 285 000	712 000	1 463 000	1 234 000	1 062 000	72,3	101,0	136,7
3A. Smithfield-Richmond	2004	2018	-	2 394 000	1 954 000	1 660 000	1 352 000	1 136 000	75,4	103,2	138,6
3B. Smithfield-Baynesfield	2004	2018	-	2 135 000	1 200 000	1 440 000	1 201 000	1 029 000	65,4	91,7	125,5

Note:
1. All costs are based on an August 1997 base date.
2. Costs exclude VAT.
3. Costs, NPV's and URV's are for all phases of schemes.
4. Analysis period of 50 years from commissioning date of schemes (2004).

TABLE 3.6: SCHEME COMPARISON: RECONNAISSANCE PHASE

SCHEME	ADVANTAGES	DISADVANTAGES
1: Impendle	C Very limited pumping C Low running costs C Impact of waterworks and conveyance system minimised by using Midmar site and northern feeder C Infrastructure is centralised: Ease of operation C More scope for spin-off development of rural areas C Second lowest Unit Reference Value (URV)	C Yield limited by Mean Annual Runoff C Probable technical difficulties in raising dam C Relatively high initial capital cost C Vulnerability of centralised infrastructure
3A: Smithfield-Richmond	C Larger yield than Impendle Scheme C Would create more permanent employment than Impendle Scheme	C Requires two dams: Greater environmental impact C Requires major excavation at high point on pipeline route C Waterworks site not ideal topographically C Relatively high pumping head C Highest URV
3B: Smithfield-Baynesfield	C Larger yield than Impendle C Relatively low pumping head and running costs C Pipeline route and waterworks site not problematic C Lowest URV C Would create more permanent employment than Impendle Scheme	C Requires two dams: Greater environmental impact

Note: 1. Shading indicates schemes which were eliminated from further investigation.

4. MGENI SYSTEM WATER DEMANDS (See Supporting Report No 2)

4.1 Background

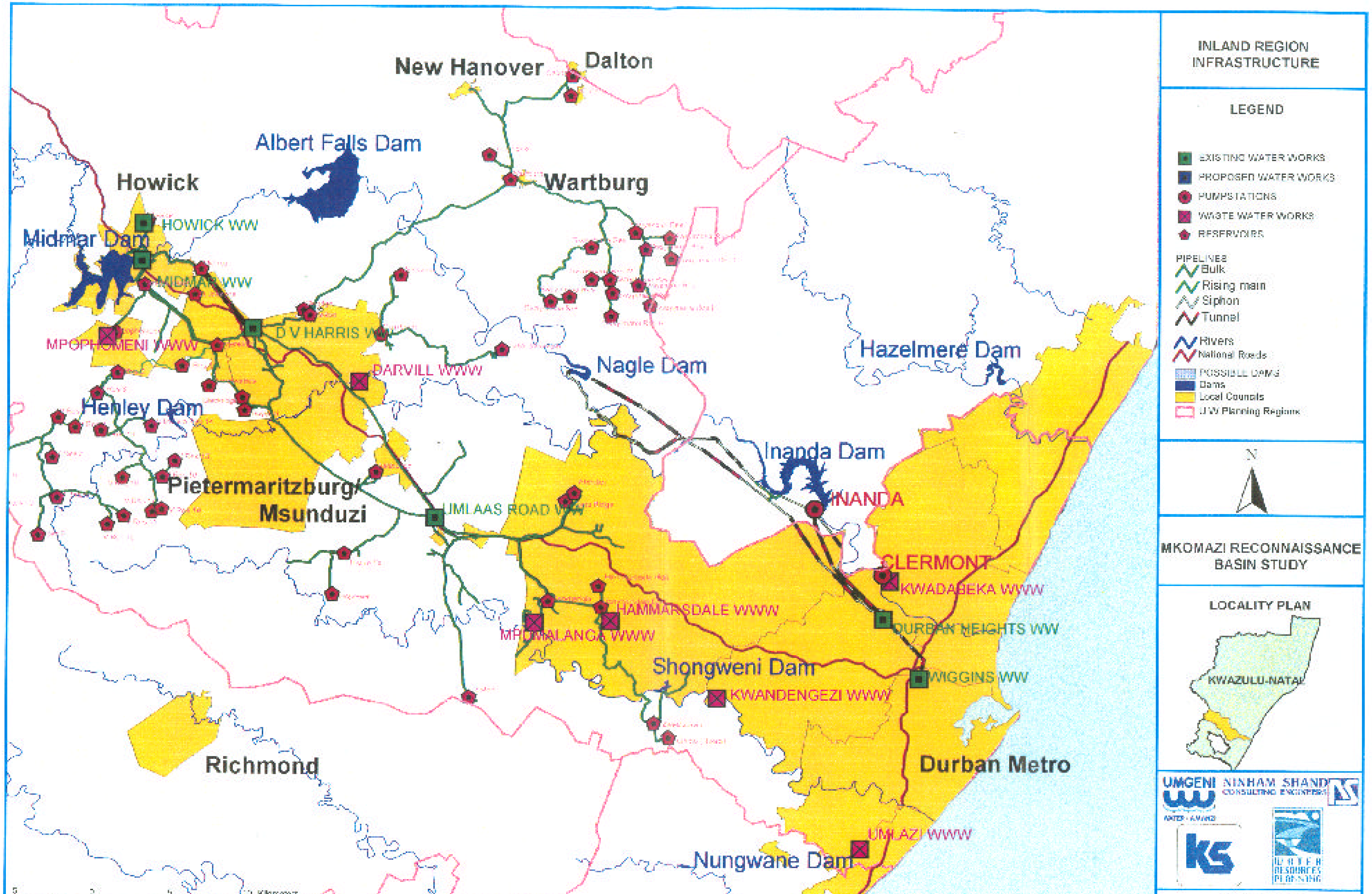
This section of the report describes the water demands in the area of supply to be augmented by the proposed transfer schemes, namely the Mgeni System. Establishing these demands is required in order to determine the timing of implementation of the proposed augmentation schemes on the Mkomazi River and to carry out economic comparisons of these proposed schemes. In accordance with the Terms of Reference for the Study, projected demands were obtained from existing sources, rather than deriving them from primary data.

In the reconnaissance phase of this Study, implementation dates of proposed schemes and economic comparisons were based on demand estimates by BKS and Umgeni Water. However, with the recent emphasis of DWAF on water demand management, the projected demand picture has changed somewhat, as described in Section 4.3 below.

The Mgeni System demands can be divided into two broad areas, namely the Inland Region (Upper Mgeni System) and the Lower Mgeni System (Durban Heights and Wiggins Systems). The Upper Mgeni System draws water from Midmar Dam and the Lower Mgeni System from Nagle and Inanda Dams. The Upper Mgeni system is currently augmented by a limited transfer scheme from the Mooi River, which will be extended in the near future, along with the raising of Midmar Dam. A diagram of the bulk water infrastructure is given in **Figure 4.1**.

4.2 Demand Scenarios

There is significant uncertainty surrounding future water demands in the Mgeni System, with historical growth trends having been variable and factors such as the drought in the early 1980's having an impact. This makes projections based on historical growth unreliable and alternative methods based on known factors which may influence demand have to be used. However, to compensate for this uncertainty, which could have an impact on the selection of the preferred Mkomazi transfer scheme, it was necessary to evaluate the proposed transfer schemes for a range of demand scenarios. High and low demand scenarios were provided by Umgeni Water and are described in Section 4.3 below. A third, middle scenario, which is simply the average of the two extremes, was also developed and forms the basis for most of scheme comparisons during the Pre-feasibility phase of the Study, although sensitivity to the different demand scenarios was evaluated.



INLAND REGION INFRASTRUCTURE
LEGEND
EXISTING WATER WORKS
PROPOSED WATER WORKS
PUMPSTATIONS
WASTE WATER WORKS
RESERVOIRS
PIPELINES
Bulk
Rising main
Siphon
Tunnel
Rivers
National Roads
POSSIBLE DAMS
Dams
Local Councils
UW Planning Regions
N
MKOMAZI RECONNAISSANCE BASIN STUDY
LOCALITY PLAN
KWAZULU-NATAL
UMGENI
NINHAM SHAND CONSULTING ENGINEERS
New Hanover
Dalton
Albert Falls Dam
Wartburg
Howick
HOWICK WW
Midmar Dam
MIDMAR WW
D V HARRIS WW
MPOPHOMENI WWW
DARVILL WWW
Nagle Dam
Hazelmere Dam
Henley Dam
Inanda Dam
INANDA
Pietermaritzburg/ Msunduzi
UMLAAS ROAD WW
CLERMONT
KWADABEKA WWW
HAMMARSDALE WWW
MPUMALANGA WWW
DURBAN HEIGHTS WW
Shongweni Dam
WIGGINS WW
KWANDENGEZI WWW
Richmond
Durban Metro
UMLAZI WWW
Nungwane Dam
Kilometers

FIGURE 4.1

4.3 Demand Projections

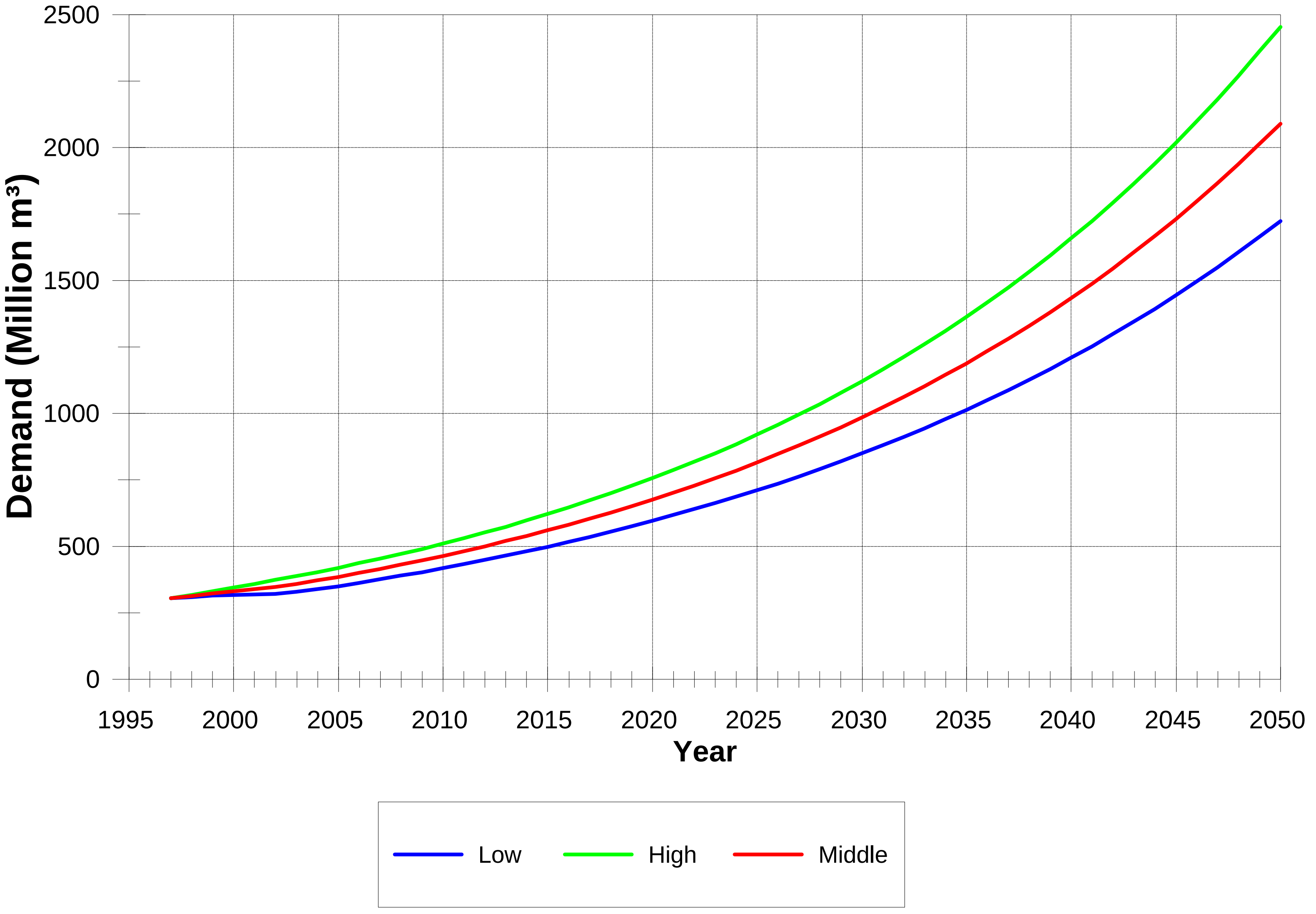
The Inland Region has experienced a relatively high growth of 7% per annum over the past nine years and 5% over the past five years. Taking the impact of the drought prior to this period, as well as anticipated rapid growth in Vulindlela, Pinetown and rural areas below Hammarsdale into account, Umgeni Water predicts that the future annual growth in water demand in this region will be around 4%.

The combined Durban Heights and Wiggins Systems have experienced a compounded growth rate of approximately 7% per annum over the past ten years reducing to 4,5% over the past five years. The rapid initial growth can be attributed to the recovery after the drastic curtailments during the 1982/83 drought. The projected future growth rate is between 3 and 4%. Durban Metro has indicated that it is implementing a drastic programme to reduce unaccounted-for water in some of the areas it has recently taken over responsibility for. They maintain that their demand growth will reduce to 0% over the next five years, whereafter growth in demand should increase to between 3 and 4% per annum. However, there is some concern that basing the planning of augmentation schemes on the projected success of these demand management measures carries some risk, in view of the relatively long lead times required for the implementation of such schemes should growth in demand exceed projections. A second demand scenario, considered to be an upper limit, was therefore developed by Umgeni Water on the basis of unconstrained growth.

Umgeni Water, in consultation with Durban Metro and other customers, has thus developed two distinct sets of demand projections up to 2015 for the Mgeni System as a whole. These were extrapolated to 2050 at the average growth rates over the period 2010 to 2015 to yield the high and low scenarios shown in **Figure 4.2**. The third or middle scenario is the average of the two extremes, as indicated in Section 3.2 above.

The net demands to be supplied from the proposed Mkomazi Transfer Schemes are dependent on decisions regarding proposed augmentation schemes from the Mooi River. However, schemes on the Mkomazi River could realistically probably not be implemented in less than 10 years, by which stage Midmar Dam would have to be raised and both phases of the proposed Mooi River augmentation schemes would have to be implemented to maintain an acceptable assurance of supply. The net demands to be met from the proposed Mkomazi Schemes would therefore be equal to the gross demand shown in **Figure 4.2**, less the 1:100 year yield of the Mgeni system augmented as described above, ie 397 million m^3/a.

FIGURE 4.2: MGENI SYSTEM WATER DEMANDS



Source : Umgeni Water (May 1998)

5. RECONNAISSANCE BASIN STUDY (See Supporting Report No 3)

5.1 Background

During the course of the Reconnaissance phase of the Study, it was noted that to date no attempt had been made to quantify the present and future water demands within the Mkomazi River basin. It has historically been policy of the Department of Water Affairs and Forestry that the demands of a donor catchment should be met before water can be transferred to another catchment, that is, water cannot be transferred to another catchment to the detriment of the inhabitants of the donor catchment. An additional study to determine the present and future water demands within the Mkomazi basin was therefore initiated. This study was carried out at a reconnaissance level, making use of existing sources of data, with collection of primary data specifically excluded. There will be adequate opportunity for refinement of the Basin Study during the feasibility phase of planning, should this be deemed necessary.

It was decided that the study should be carried out at quaternary sub-catchment level (see **Figure 2.2**). Three demand scenarios were evaluated, high road, low road and middle road, with the middle road scenario forming the basis of the current phase of planning and the other two scenarios being evaluated with a view to assessing sensitivity. The following user sectors were assessed:

- Domestic (Rural and urban)
- Agriculture (Irrigation and livestock)
- Forestry
- Industrial
- Environmental

5.2 Data Gathering and Processing

5.2.1 Domestic demands

Population data at quaternary sub-catchment level for the determination of domestic demands was provided by Umgeni Water, prepared under a separate appointment by Scott Wilson Planning and Development Resources. The figures were modelled using 1991 census data as a basis and high middle and low growth scenarios were assessed, with the low growth scenario incorporating the effect of the Aids epidemic on future population growth. Figures were split into urban and non-urban sectors.

Unit demands were determined for a three scenarios using National Housing Board guidelines, ranging from 100 to 200 ℓ per capita per day for urban demands, with a middle scenario figure of 150 ℓ/c/d, and 8 to 60 ℓ/c/d for rural demands, with a middle scenario figure of 30 ℓ/c/d. Population and unit demand figures were matched by scenario to determine the demand figures for each sub-catchment.

The availability of groundwater was considered for supplying rural demands. Groundwater potential data was provided by Umgeni Water in the form of harvest potential in m^3/km^2/annum. It was assumed that on average, 10% of the total area of each sub-catchment would lie within a viable distance of rural communities for groundwater harvesting, and safe abstraction volumes were determined accordingly.

5.2.2 Agriculture

Irrigation

Present irrigation development determined by BKS in the Mkomazi/Mgeni/Mooi River Hydrology and Yield Update (DWAF& Umgeni Water, 1998) was adopted for the purposes of this study. Whilst future irrigation demands based on potential irrigable areas were determined for the Mooi River catchment in the 1994 Mgeni River System Analysis Study, a similar exercise was not carried out in the Mkomazi River catchment. A maximum potential increase of irrigation of approximately 100% was determined in the Mooi catchment and a similar approach was adopted for the high scenario in the Mkomazi catchment. By comparing the topography, MAP and status of current irrigation development within each Mkomazi sub-catchment with those of the Mooi, a maximum probable increase in irrigation areas was determined, at 110% of the present area.

For the middle scenario, each sub-catchment was assessed on its own merits in discussion were held with Mr R Bennett of the Bio-Resource Centre at Cedara. Bio-Resource Unit maps were used as supporting data in this assessment. The total increase in irrigation area was found to be 54%.

A low scenario was developed by assuming half of the middle road increases.

Livestock

Livestock figures at magisterial district level were obtained from the State Veterinary Services and allocated to quaternary sub-catchments using map overlays. Unit demands were based on daily consumption for large stock units. Growth in livestock demand was assumed to follow the growth in population in the Umgeni Water operational area, where the main markets would lie. Only a single scenario was evaluated.

5.2.3 Forestry

Details of current forestry areas and permits were obtained from the DWAF, and current forestry areas based on video imagery from Umgeni Water. The DWAF figures for current afforested areas were found to be generally higher than the Umgeni Water figures and were used as a baseline for the high scenario, to which was added the greater of all currently registered permit applications or the allowable additional area based on DWAF runoff reduction limits.

For the middle scenario, the Umgeni Water data was taken as the baseline. To this was added approved permitted areas and probable increments which would be permitted by DWAF. The low scenario was taken as the Umgeni Water areas plus approved permitted areas.

5.2.4 Industrial

The only significant industrial demand in the catchment is SAPPI/SAICCOR, situated near the mouth. It was assumed that this demand will remain constant.

5.2.5 Environmental

The provisional environmental reserve is given in the form of Instream Flow Requirements (IFR) and Estuarine Freshwater Requirements (EFR), which were developed as part of the environmental component of the Study described in Section 7 of this Report.

IFR's to maintain the river in a specific Desired Future State were determined at four representative sites along the river, the most downstream site (IFR Site 4), being situated a few kilometres upstream of Goodenough Weir. Downstream of IFR 4 the river becomes significantly more degraded and the EFR becomes dominant. The EFR study found that the ecological health of the estuary is greatly affected by the frequency and duration of mouth closure.

5.3 Hydrological Modelling

5.3.1 Introduction

A detailed discussion of the hydrological and water resources aspects of the Study is provided in Section 6 and in Supporting Report No 4.

In previous studies undertaken by BKS, the Mkomazi River catchment was divided into four sub-catchments to match possible dam sites. However, it was agreed that for the purposes of this Study, in-basin demands should be determined at quaternary sub-catchment level. It was therefore necessary to disaggregate the BKS hydrology into the 12 sub-catchments in order to be able to model the impact of forestry and irrigation at this level.

5.3.2 Disaggregation of hydrology

The naturalised runoff sequences for the four modelling sub-catchments were disaggregated into quaternary sub-catchments on the basis ratios of catchment area and the MAP of the modelling and quaternary sub-catchments.

Forestry demands were disaggregated to quaternary level using the ratios of forestry per quaternary and modelling sub-catchment, as were irrigation demands. The proportions of mainstream and diffuse irrigation were also applied on the same basis.

5.3.3 Modelling of future forestry and irrigation demands

Afforestation would have an impact on the availability of water for irrigation. The same scenarios of afforestation and irrigation were therefore modelled together for consistency, ie high afforestation with high irrigation, etc. The BKS AFFDEM program was used for modelling forestry demands, and disaggregated BKS WRSM90 configurations were used to determine irrigation demands.

5.4 Demand Sector Results

Middle scenario demands by sector for present and future (2040) development conditions are given in Table 5.2.

Domestic Demands

As indicated in Section 5.2.1, groundwater was considered as a potential source of supply ahead of surface sources for rural demands, but not for urban demands. However, if the full rural demand in a particular sub-catchment cannot be met from groundwater sources, it was assumed that the full demand will be supplied from surface sources. Overall, the middle scenario 2040 domestic demand is reduced from 3,0 to 2,2 million m^3/a through the utilisation of groundwater. This represents only 0,2% of the natural MAR of the Mkomazi River.

Agriculture

Total future irrigation demands range from 59,4 to 105,3 million m^3/a, with the middle scenario demand projected as 69,1 million m^3/a, or 6,5% of the MAR. This is the second largest demand sector after the environment.

Future demands for stock watering amount to 8,6 million m^3/a, or 0,8% of the MAR.

Forestry

Total future forestry demands (or impact of forestry on runoff) range from 66,3 to 160,4 million m^3/a, with the middle scenario figure projected at 83,3 million m^3/a, or 7,8% of the MAR. This is the largest demand sector after the environment.

Industrial

The SAPPI SAICCOR demand of 50 million m^3/a, based on their permit allocation, amounts to 4,6% of the MAR. No significant future increase in industrial demand is anticipated.

Environmental

The dominant environmental requirement is that at IFR Site 4. If this is met, there will be sufficient flow at the estuary to meet the EFR, taking intermediate abstractions into account. The IFR at site 4 is 315,5 million m^3/a or 29,8% of the MAR and is by far the largest sectoral demand.

5.5 Yield Analysis

5.5.1 Introduction

In order to refine the sizes of schemes being investigated in the Pre-feasibility phase of the Study (see Sections 8 and 9), it was necessary to determine the yields of the proposed transfer schemes for future development levels, with the 2040 middle road scenario being adopted. In addition, the yield of a possible future dam at a site on the lower Mkomazi River was determined, to assess the viability of such a dam.

The following schemes were investigated:

- Impendle Dam (five different capacities)
- Smithfield Dam (one capacity)

- A system of Impendle Dam with Smithfield Dam, assuming a single capacity for Smithfield Dam and two different capacities for Impendle Dam
- A system consisting of the largest Impendle Dam with Smithfield Dam, and with three different capacities for the Lower Mkomazi Dam. (The off-channel Ngwadini Dam is dealt with separately).

The first three schemes were analysed for natural conditions, present development, and future 2040 middle scenario development. Only historical firm yields were determined for the Basin Study.

5.5.2 Methodology

The Water Resources Yield Model (WRYM) was configured to supply irrigation demand at 70% assurance and IFR demands were set up to allow for drought flows once in ten years on average. Under natural and present conditions, IFR's were assumed to only be supplied from inflows to the dams and incremental runoff between dams and the relevant IFR site, and not from the stored water in the dams.

For the future scenarios, the same proportion of the IFR's supplied from inflow to the dams under present conditions was assumed. Some of the IFR could therefore be supplied from storage.

For the analysis of the Lower Mkomazi Dam, however, it was decided that the IFR Site 4 requirements should be supplied from the dam when necessary, in view of the major abstractions of the upstream scheme.

5.5.3 Results

Results of the yield analysis are give in **Table 5.1**.

TABLE 5.1 : RESULTS OF YIELD ANALYSIS

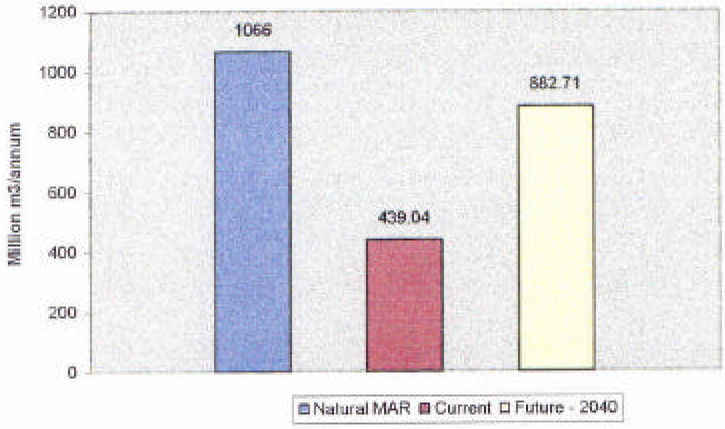
Scheme Name	Dams in Scheme	Dam Volume (Mm^3)	Firm Yield (Mm^3/a) for Development Level		
			Natural Conditions	Present Development	2040 Middle Scenario
Impendle	Impendle	135	126	124	
		270	223	206	
		543	314	293	276
		680	341	318	
		810	358	335	304
Smithfield	Smithfield	137	157	135	119
Smithfield	Impendle	543			
	Smithfield	137	397	358	335
	Impendle	810			
	Smithfield	137	454	413	388
Lower Mkomazi	Impendle	810			
	Smithfield	137			
	Lower Mk.	517		122	
Lower Mkomazi	Impendle	810			
	Smithfield	137			
	Lower Mk.	1033		186	
Lower Mkomazi	Impendle	810			
	Smithfield	137			
	Lower Mk.	1549		246	

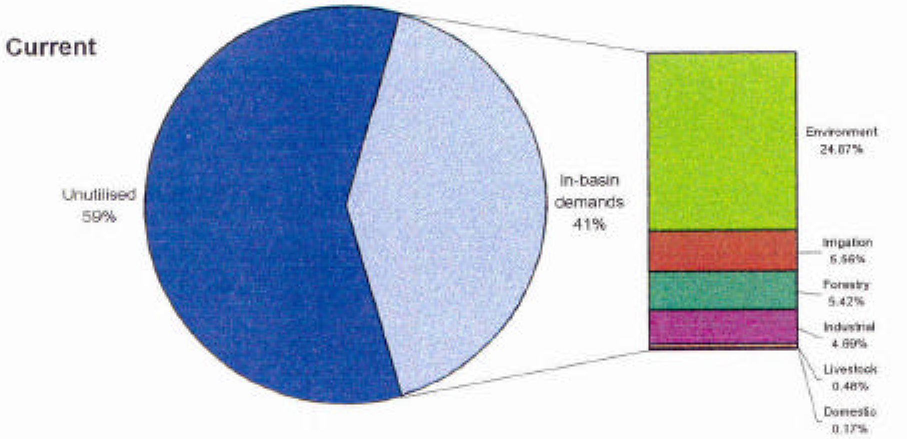
As can be seen from the above, the reduction in yield of the Impendle and Smithfield Schemes under future development conditions is relatively small, at between 4% and 9%. It can also be concluded that a dam on the lower Mkomazi in addition to a scheme on the upper Mkomazi would probably not be viable, as a very large storage capacity will have to be provided at the lower site in order to produce a significant yield.

5.6 Water Balance

To represent the various user groups in the Mkomazi River basin and their impact on available water resources, a water balance calculation was carried out for the current and future (middle) scenarios. The results are shown in **Table 5.2** and **Figure 5.1**.

FIGURE 5.1: ILLUSTRATION OF CURRENT AND FUTURE SECTOR DEMANDS





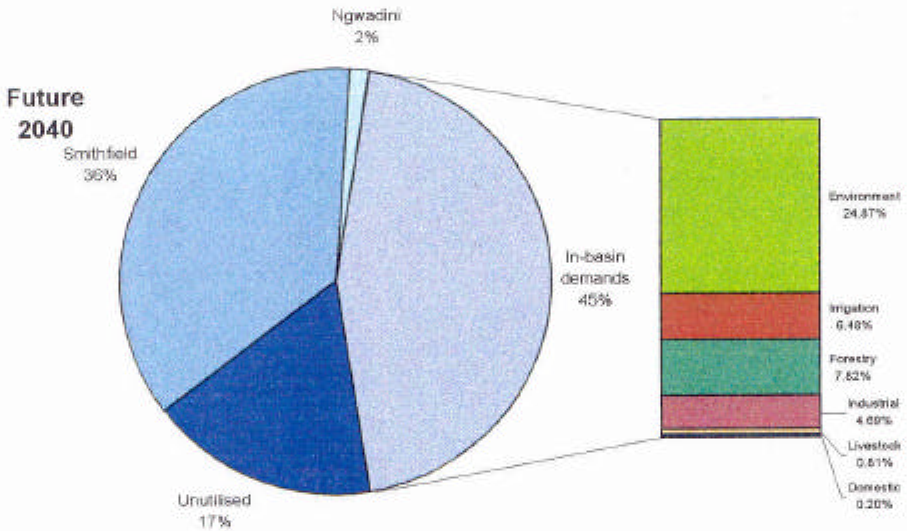


TABLE 5.2 : SECTOR DEMANDS IN RELATION TO NATURAL MAR (NATURAL MAR = 1 066 Million m^3/annum)

	Current Demands - 1995		Future Demands - 2040		Comment
	Mm^3/a	% Nat MAR	Mm^3/a	% Nat MAR	
In-basin demands					
Environment	265,12	24,87	265,12	24,87	IFR 4 demands less SAPPI/SAICCOR
Irrigation	59,25	5,56	69,10	6,48	
Forestry	57,78	5,42	83,32	7,82	
Industrial	50,00	4,69	50,00	4,69	SAICCOR
Livestock	5,10	0,48	8,60	0,81	
Domestic	1,79	0,17	2,17	0,20	Total domestic demand
Subtotal	**439,04**	**41,19**	**478,31**	**44,87**	
Available MAR	*626,97*	*58,81*	*587,69*	*55,13*	
Proposed water transfer schemes					
Ngwadini			16,40	1,54	Abstraction to off channel storage
Smithfield			119,00	11,16	Phase 1
			335,00	31,43	Phase 2 *
			388,00	36,40	Phase 3 **
Subtotal (Ngwadini + Phase 3, Smithfield)			**404,40**	**37,90**	
Total utilisation of Natural MAR					
In-basin demands	439,04	41,19	478,31	44,87	
Transfer schemes	0,00	0,00	404,40	37,90	
Total	**439,04**	**41,19**	**882,70**	**82,80**	
Unutilised	*626,97*	*58,81*	*183,30*	*17,79*	

Note: * 540 million m^3 dam at Impendle
** Impendle dam raised to 810 million m^3

From the above table, it can be seen that under current conditions in the catchment, 41% of the natural MAR is required to meet in-basin demands, with the remaining 59% being unutilised.

The future condition, which includes the increased in-basin demands and the inter-basin transfers of the proposed Ngwadini and Smithfield (Mkomazi-Mgeni) schemes, requires 45% of the MAR to meet in-basin demands and a total of 40% by transfer schemes, leaving 15% unutilised. This unutilised portion will largely be major flood flows, which could not be practically harnessed. It can therefore be concluded that under future conditions with the proposed transfer schemes in place, the Mkomazi River will be fully utilised.

6. HYDROLOGY AND WATER RESOURCES (See Supporting Report No 4)

6.1 Introduction

The hydrology component of the Study, including the derivation of hydrology for future catchment development conditions, is summarised in Section 5 of this Report. This section of the Report is therefore limited to a description of the historical and stochastic yield analyses.

6.2 Yield Analysis

6.2.1 Introduction

A yield analysis was carried out to determine the yields of the proposed transfer schemes for natural, present and projected 2040 catchment development conditions. In addition, the yield of a possible future dam on the lower Mkomazi River, referred to as the Lower Mkomazi Dam, was determined to assess the viability of such a dam.

The following schemes were investigated :

- Impendle Phase 1 Scheme (five different sizes)
- Smithfield Phase 1 Scheme (one size)
- Smithfield Phase 2 Scheme, assuming a single size for Smithfield Dam with two different sizes for Impendle Dam
- Smithfield Phase 2 Scheme (with a 1.5 MAR Impendle Dam) with three different sizes for the Lower Mkomazi Dam
- Impendle Dam (1.5 MAR) with transfer to the Mgeni System
- Smithfield Phase 2 with transfer to the Mgeni system.

The Water Resources Yield Model (WRYM) was configured for the whole Mkomazi River catchment, with the configuration for the different schemes based on the WRYM models of the Impendle and Smithfield Dam schemes as configured by BKS. The same basic WRYM model was used for the different schemes, with only minor changes made to accommodate the schemes specifics.

The historical yield analyses described in Section 5.5 were conducted for the hydrological period 1925 to 1995, inclusive. Both the firm yield (for the different schemes) and SAPPI/SAICCOR demand were met at 100 % assurance, i.e. allowing no failures at all.

6.2.2 Catchment development

As indicated in Section 5, the present development demands in the Mkomazi catchment are small in comparison to the natural MAR of 1 066 million m³/a and only moderate growths are expected, mainly in the forestry and irrigation sectors. The catchment information on the sub-catchments used for the purposes of yield modelling are given in **Table 6.1**.

The WRYM model for the future scenario was adapted slightly to accommodate additional irrigation demands and was configured to supply mainstream irrigation at an assurance of 70%. Note that farm dams are combined into a single "dummy" farm dam in each modelling sub-catchment.

TABLE 6.1 : MODELLING CATCHMENT INFORMATION

Incremental Modelling Sub-catchment				Afforestation				Irrigation			
Name	Area (km^2)	MAP (mm)	Natural Incremental MAR (Mm^3/a)	Area (km2)		Demand (Mm^3/a)		Area (km2)		Demand (Mm^3/a)	
				1996	2040	1996	2040	1996	2040	1996	2040
Impendle Dam	1422	1068	567,9	68,9	169,6	12,4	30,6	21,9	27,6	13,9	17,2
Smithfield Dam	632	1000	163,2	107,1	120,9	12,9	14,5	0,0	7,2	0,0	4,5
Lower Mkomazi Dam	2243	875	324,5	527,7	581,3	32,6	38,1	59,4	76,9	35,8	45,9
Mkomazi Mouth	91	855	11,3	7,96	2,2	0,3	0,1	0,0	0,9	0,0	0,6
Total	4388		1066,9	711,7	806,9	57,77	83,3	81,3	112,6	49,7	69,1

6.2.3 Instream flow requirements

IFR's were modelled as part of the system demands and allowance was made for an IFR drought flow once in 10 years on average.

In order to meet the demands at the respective IFR sites without any augmentation from the dams, the demands for these sites were only supplied from the inflow to Impendle Dam or Smithfield Dam and any other incremental runoff available at that site. IFR site 4 requirements were modelled with all the different schemes and scenarios, as IFR site 4 was found to be the critical IFR site of the three included in the analysis.

6.2.4 *Schemes analysed*

As indicated in Section 6.2.1, various configurations of Smithfield and Impendle Schemes were evaluated, with a view to providing sufficient data for a variety of scheme sizes to be economically evaluated. A dam on the lower Mkomazi was also assessed in order to determine the viability of a further scheme. The results of this analysis are given in **Table 5.1** in Section 5. As can be seen, the reduction in historical firm yield between present and future catchment development conditions is less than 10% in all cases.

In order to assess the effect of providing additional transfer capacity to the Mgeni System, in excess of the firm yield of the Mkomazi Schemes themselves, the historical firm yield of the combined Mgeni, Mooi and Mkomazi System yield was determined for a range of scenarios. The BKS 1998 Mooi/Mgeni System configuration was adopted, with Mearns Dam at full supply level 1387,5 masl and Spring Grove Dam at 1434,2 masl. The results of the analysis for the Impendle and Smithfield Schemes were as follows:

Impendle Scheme

With a transfer capacity equal to the historical firm yield of the Impendle Scheme, the combined system yield is 718 million m^3/a with an 810 million m^3 Impendle Dam. Increasing the transfer capacity by 10% increases the system yield by about 2% to 732 million m^3/a and all dams in the system are emptied by the end of the critical period. A further increase in transfer capacity therefore reduces the yield slightly. It can therefore be concluded that the system yield is not sensitive to transfer capacity.

Smithfield Scheme

With the transfer capacity equal to the historical firm yield of the ultimate Smithfield Scheme, with a 137 million m^3 Smithfield Dam and an 810 million m^3 Impendle Dam, the system yield is 796 million m^3, which is equal to the sum of the Mooi/Mgeni and Smithfield yields. An increase in transfer capacity results in a decrease in system yield, as would be expected.

6.2.5 *Long-term stochastic yield analysis*

Long-term stochastic yield analyses were conducted for present and future middle road levels of development, using the parameter file and stochastic hydrology produced by BKS. and based on 201 71-year sequences. The results of the long-term stochastic yield are shown in **Table 6.2**.

The reduction in the 1 in 100 year recurrence interval stochastic yield with future catchment development conditions was, apart from the initial phase of the Smithfield Scheme, again less than 10% in all cases.

TABLE 6.2 : RESULTS OF STOCHASTIC YIELD ANALYSIS

PRESENT DEVELOPMENT SCENARIO					
Scheme	**Firm Yield for Indicated Recurrence Intervals (Mm^3/a)**				
	Historic	**1:20yr**	**1:50yr**	**1:100yr**	**1:200yr**
Imp .25 MAR	120	188	169	161	155
Imp .50 MAR	204	265	240	228	218
Imp 1.00 MAR	293	349	313	296	280
Imp 1.25 MAR	318	374	337	320	302
Imp 1.50 MAR	335	395	356	336	319
Smith 137 mcm	131	208	187	177	166
Smith + 1MAR Imp	357	434	390	369	349
Smith+1.5 MAR Imp	413	480	434	409	387
FUTURE DEVELOPMENT SCENARIO					
Imp 1.00 MAR	276	323	293	275	260
Imp 1.50 MAR	304	373	334	313	296
Smith 137 mcm	112	176	159	147	136
Smith + 1MAR Imp	331	402	364	335	319
Smith+1.5 MAR Imp	385	451	405	376	356

7. ENVIRONMENTAL
(See Supporting Report No 5)

7.1 Introduction

Before implementation of a large water resource development such as an interbasin transfer scheme, it is essential to investigate the potential biophysical and social implications associated with the scheme. The Department of Water Affairs and Forestry (DWAF) has developed a procedure for the phased implementation of Integrated Environmental Management (IEM) on large water resource development projects such as the Mkomazi-Mgeni Transfer Study. This procedure, which is shown in schematic form in **Figure 7.1**, was followed during the course of this Study.

In terms of Environmental Impact Assessment (EIA) Regulations, the project should be registered with the relevant authorities. At the time of the drafting of this report, the relevant authorities had been informed, but registration had not been completed.

The Mkomazi Environmental Task Group (ETG), a technical working group, was established to oversee the environmental component and the of the Study. A Stakeholder Committee was established to involve stakeholder representatives in the development process.

Two augmentation development options were considered for the Pre-feasibility study. The scheme layouts are shown in **Figure 8.1** in Section 8 of this report. Note that environmental aspects of the Reconnaissance phase of the study are addressed in Section 2 of this Report.

- Impendle Scheme: Dam at Impendle (implemented in two phases) and conveyance through a series of tunnels and pipelines, via Midmar and the Northern Feeder route, to Umlaas Road.
- Smithfield Scheme: First phase dam at Smithfield, second phase dam at Impendle, and conveyance though a tunnel and pipeline, via a balancing dam in the Mlazi River near Baynesfield, to Umlaas Road.

In addition to these, the 'no development' option is also addressed briefly in this section:

- Non-Augmentation Scenario: The proposed Mkomazi-Mgeni Transfer Scheme is not commissioned but water demand is managed by the relative authorities.

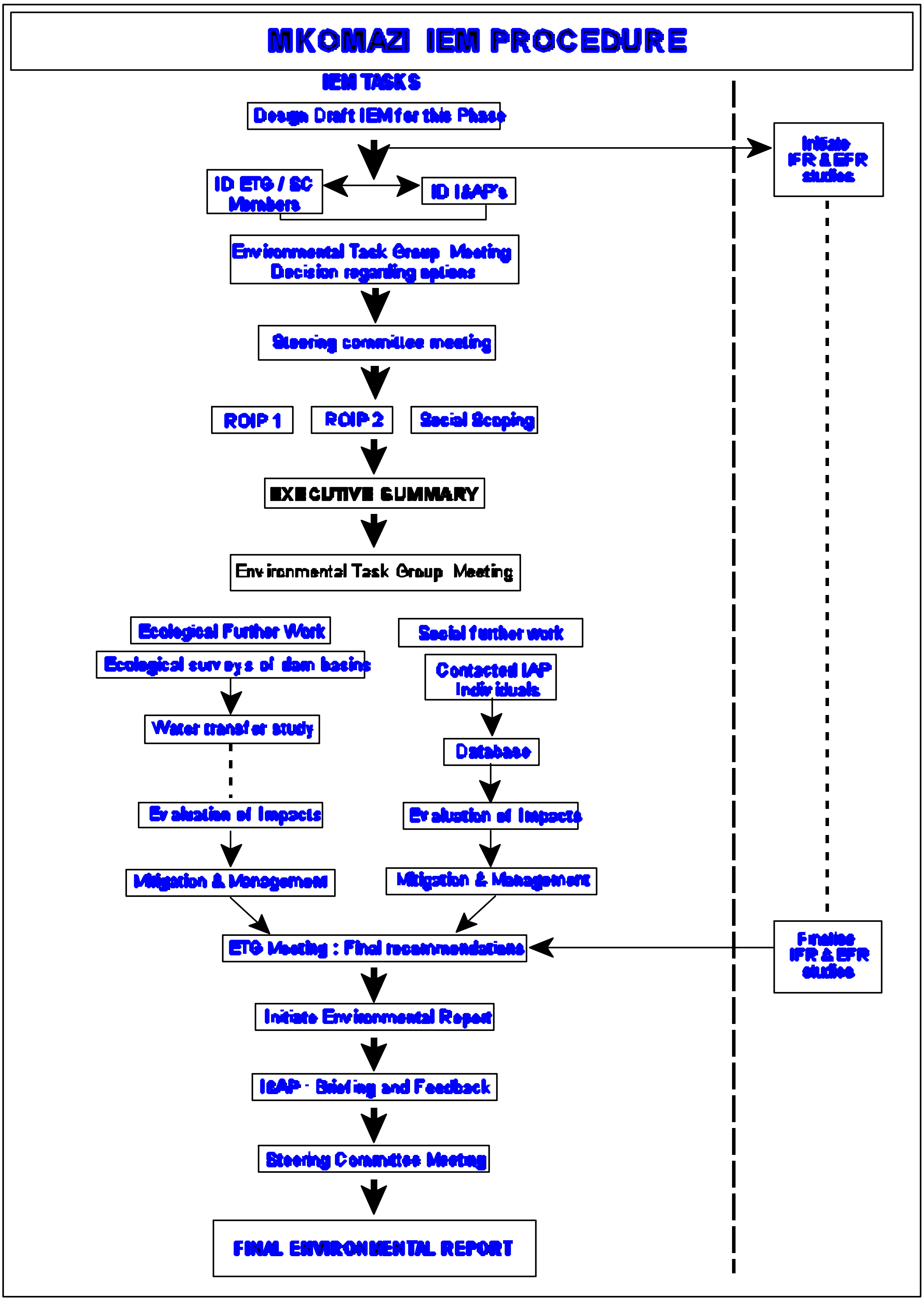


Figure 7.1: Mkomazi IEM Procedure

7.2 General Approach

The pre-feasibility environmental assessment for the Mkomazi-Mgeni Study concerned itself with the following environmental components:

- Environments affected by inundation;
- Environments affected by raw and clear water conveyances;
- Riverine environments affected by changes in flow regime;
- Estuarine environment affected by changes in flow regime;
- The receiving river systems affected by augmentation transfers; and
- Water supply areas affected by augmentation.

These aspects are discussed under their relevant headings below and are summarised in a comparative table, **Table 7.1**.

7.3 Environments Affected By Inundation

Data for the comparison of the impacts of the impoundment components of the two schemes was sourced from ROIP Reports, a pre-feasibility study of the potential impact on fauna and flora in the Smithfield and Impendle Dam basins and a pre-feasibility social impact assessment of the two schemes.

It was found that the biophysical impacts related directly to inundation by the two schemes are very similar and regarded as relatively low, with the Smithfield impact somewhat greater due to the two dams. Both areas are severely degraded. A few rare or threatened plant species occur in low numbers on both sites. Most of these could be propagated or relocated. The most significant impact (applicable to both schemes) is the loss of two Bald Ibis roosting/nesting sites at Impendle, but the Environmental Task Group did not regard this as a fatal flaw.

From a social impact perspective, both schemes could be implemented. Negative impacts could be mitigated to between low and moderate. The Smithfield Scheme would be more complex and more expensive to implement but the potential positive impacts associated with the scheme are also more significant. In relation to the overall project cost, the cost for social mitigation and optimisation measures should be fairly insignificant.

7.4 Environments Affected By Conveyances

The conveyance components of the two schemes would involve pumpstations, tunnels, pipelines, water treatment works, balancing dams and a bulk supply reservoir. Data for the comparison of impacts was sourced from the social impact assessment mentioned above, an environmental scoping of components of the conveyances and comments by Umgeni Water on potential impacts of the Impendle clear water conveyances.

The impacts of the raw water transfer tunnels would be similar and minimal for both schemes. The waterworks and pumpstation for the Impendle Scheme would be located on the same sites as existing facilities and the pipelines would generally be located along existing servitudes, which would be widened. The Smithfield waterworks and pipelines would be greenfields developments and consultation and negotiation would therefore be more problematic. However, most of the impacts are temporary in nature (associated with the construction phase) and/or the size of the affected areas are relatively limited. The greater area of greenfields affected by the Smithfield Scheme is also offset to some extent by the fact that the Impendle pipelines traverse some steep terrain and built-up areas. The overall impact rating with mitigation is low to moderate.

7.5. Riverine Environments Affected By Changes In Flow Regime

A detailed Instream Flow Requirements Study was carried out, as required by the Terms of Reference for the Study. The suite of specialist reports and Proceedings of the Specialist Meeting form the basis for the discussion below.

In terms of its present state, diversity of habitats and species, uniqueness, level of human use and reliance on the resource, the Mkomazi is a river of significant importance. For this reason, it was considered imperative that the present state and character of the river should, at least, be maintained. Impacts on the riverine environments downstream of the proposed dams relate to changes / reduction in run-off from the catchment, with consequent changes in the flow regime and potential impacts on the functioning of ecosystems and way the river is utilised.

The Instream Flow Requirement (IFR) study, carried out using the Building Block Method, made recommendations for maintenance flows and drought year flows at four representative IFR sites along the river, which amount to a maximum of 30% of the MAR at the particular site. It also provided guidelines for capping flows and, in the case of the Smithfield Scheme, the operating rule between the two dams.

The recommended IFRs have been incorporated into the design capacity of both schemes and it has been found in yield modelling that these requirements can be accommodated without affecting the viability of the proposed schemes and mitigation of the impacts to relatively low levels should be possible – if appropriate operating rules are observed. These operating rules still need to be developed.

However, the Smithfield Scheme involves two impoundments, one at Smithfield, located lower down in the catchment, and a second at Impendle. The Smithfield Scheme would impede a greater percentage of the MAR and opportunities for natural mitigation are less than that for the Impendle Scheme. Although the IFR Study provided operational guidelines for elevated flows between the two dams, there is the added risk of exceeding the capping flows for this river reach. However the yield of the Impendle Scheme is significantly lower than that of Smithfield and the possible need for a further dam on the lower Mkomazi would have a greater overall impact than the incremental impact of the Smithfield Scheme versus the Impendle Scheme.

7.6 Estuarine Environment Affected By Change In Flow Regime

A detailed Estuarine Freshwater Requirements (EFR) Study was also carried out in accordance with the Terms of Reference for the Study. The summary assessment and suite of supporting specialist reports provide information for the discussion below.

The Mkomazi Estuary is considered an important estuary due to its rarity of type, its general biological value and health, and because it is one of the few of the KwaZulu-Natal estuarine systems that is almost permanently open. However, it is also characterised by encroachment of sugarcane, the presence of alien vegetation and the existing (although relatively small) reduction in freshwater outflow due to water resource development and utilisation in the catchment area. The ecological integrity is therefore regarded as moderately modified. Based on the perceived importance of the Mkomazi Estuary it was concluded that the present state and character of the river should, at least, be maintained. The mouth should preferably be permanently open. However, it should at least remain open continuously during summer months. Should the mouth close during winter months it should only be for relatively short periods of time.

Impacts on the estuarine environment are largely related to changes / reduction in run-off from the catchment, leading to an increase in closed mouth conditions.

The observed historical behaviour of the mouth was correlated against observed flows at the U1H006 in order to derive flows required to keep the mouth open. Using this data as a basis, the EFR study provided preliminary estimates for EFR's in terms of minimum baseflows, freshettes to replenish riverine based nutrients and organic supplies, minor floods to move organic material through the estuary and major floods to reset the estuary.

It was concluded that if the EFR objectives are met, the impacts on the estuarine environment would be low. The relative impacts of the schemes were not compared, but it seems as if the Impendle Scheme, located higher in the catchment, will allow for a greater proportion of the catchment flow to be unimpeded and the larger downstream incremental catchment also provide better opportunity for natural mitigation. The risk of not meeting the EFR objectives is therefore slightly lower than in the case of the Smithfield Scheme.

As a possible worst case scenario, the IFR Site 4 flow requirements, less the SAPPI SAICCOR abstraction, were evaluated as inflows to the estuary. It was concluded that the frequency and duration of mouth closures under these conditions would not differ significantly from present conditions and would probably be acceptable.

7.7 Receiving River Systems Affected By Water Transfers

Data for the evaluation of these impacts was sourced from the ROIP on the Impact of Transfer of Water from the Mkomazi River to the Mgeni and Mlazi Catchments.

Water transfer may lead to some habitat loss in the receiving streams, but since these streams are already modified it is not regarded as a serious impact. Species likely to be transferred and to flourish probably already occur in the receiving streams. Impacts associated with the transfer of water from the Mkomazi River System to the Mgeni and Mlazi River Systems are therefore generally low and little mitigation is required. The only exception in this regard is the mitigation that would be required to address the potential geomorphological impacts of increased flow in the Mlazi River. However, the design of the proposed link pipeline and cascade between the transfer tunnel outlet portal and the balancing dam at Baynesfield has already addressed this concern and the overall impact rating is none-low.

7.8 Supply Areas Affected By Augmentation

Data for this aspect was sourced from the Graham Muller Associates report commissioned by Umgeni Water titled "Socio-Economic Impact of Outcomes Relating to the Mkomazi-Mgeni Augmentation Scheme, which is discussed in more detail in Section 9 of this Report.

The main focus of the above study was to identify the socio-economic impacts of constrained water supply in the Mgeni System supply area should the Mkomazi-Transfer Scheme not be implemented.

Assuming a direct relationship between water demand and gross geographic product (GGP), which was borne out by available historical data, it was found that achievable GGP and employment levels would be dramatically higher with commissioning of the Mkomazi-Mgeni Transfer Scheme than with the Non-Augmentation Scenario. Non-Augmentation would result in a considerable cost in terms of lost output and constraints to employment generation, with approximately 5 million potential new jobs in KwaZulu-Natal being lost by the year 2038.

Although the importance of water demand management was illustrated, the study concluded that, in the case of the Mgeni System, water demand management on its own is not a viable alternative to augmentation. Instead, water demand management and augmentation should be seen as complementing one another.

7.9 Conclusion

The summary of issues and concerns given in **Table 7.1** on the following page clearly indicates that the environmental impacts, associated with the proposed Impendle and Smithfield Transfer Schemes, could be mitigated to within acceptable levels.

Generally, the Smithfield Scheme has slightly higher impacts than in the case of the Impendle Scheme. However, the available yield of the Impendle Scheme is lower than that of Smithfield and further augmentation will be required sooner (by approximately two years), therefore, to some extent, balancing out the impacts of the two schemes.

In conclusion, both schemes are regarded as acceptable from a biophysical and social point of view, provided that the recommended future work is carried out and recommended mitigation measures are applied.

The Non-Augmentation Option proved to be problematic due to the unacceptable impacts on future economic development and employment opportunities in the water supply area, and within KwaZulu-Natal as a whole. It probably verges on being fatally flawed, with the only possible alternatives being augmentation from unconventional and expensive sources, such as desalination.

It is important to note that water demand management and catchment management would prove vital to ensure sustainable long term water supply in the region.

Table 7.1: Rating of Environmental Issues & Concerns

SUMMARY OF ENVIRONMENTAL IMPACTS AND ISSUES	***Non Augmentation Option***		*Augmentation Options*			
			Impendle		***Smithfield***	
	IMPACT RATING					
	without mitigation	with mitigation	without mitigation	with mitigation	without mitigation	with mitigation
BIOPHYSICAL IMPACTS						
Environments Affected by Inundation	-	**-**	mod-high	**low-mod**	high	**mod**
Environments Affected by Conveyances & Water Works	-	**-**	mod	**low**	mod-high	**low-mod**
Riverine Environments Affected by Changes in Flow Regime	-	**-**	high-severe	**possibly low-mod**	severe	**possibly mod**
Estuarine Environment Affected by Changes in Flow Regime	-	**-**	mod-high	**possibly low**	high	**possibly low-mod**
Receiving River Systems Affected by Augmentation Transfers	-	**-**	low	**none-low**	low	**none-low**
SOCIAL & ECONOMIC IMPACTS						
Environments Affected by Inundation	-	**-**	high	**mod**	severe	**mod-high**
	-	**-**	-	**+**	-	**++**
Environments Affected by Conveyances & Water Works	-	**-**	mod	**low**	high	**mod**
Riverine Environments Affected by Changes in Flow Regime	-	**-**	mod	**possibly none-low**	mod-high	**possibly none-low**
Estuarine Environment Affected by Changes in Flow Regime	-	**-**	?	**possibly none**	?	**possibly none**
Receiving River Systems Affected by Augmentation Transfers	-	**-**	none-low	**none-low**	none-low	**none-low**
Water Supply Areas Effected by Augmentation	**severe**			**++**		**++**

*Note: Impact ratings in this table are for the **final phases** of the development options.*

8. ENGINEERING DESIGN AND COSTING
(See Supporting Report No 6)

8.1 Introduction

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, and the engineering design and costing of these two schemes at pre-feasibility level is described in this section. Both schemes will deliver clear water to a proposed reservoir at Umlaas Road. The schemes each have three possible configurations 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. Details of the schemes and selected drawings are provided in **Appendix D** and layouts are shown in **Figure 8.1**.

It should be noted that the level of detail and methodologies used in the design and cost estimates are in accordance with the DWAF VAPS Guidelines (DWAF, 1994c) for a pre-feasibility study.

The findings of a parallel study, commissioned by Umgeni Water and undertaken by SRK, which evaluates the risk of interruptions in supply from each scheme due to a component failure, are also discussed.

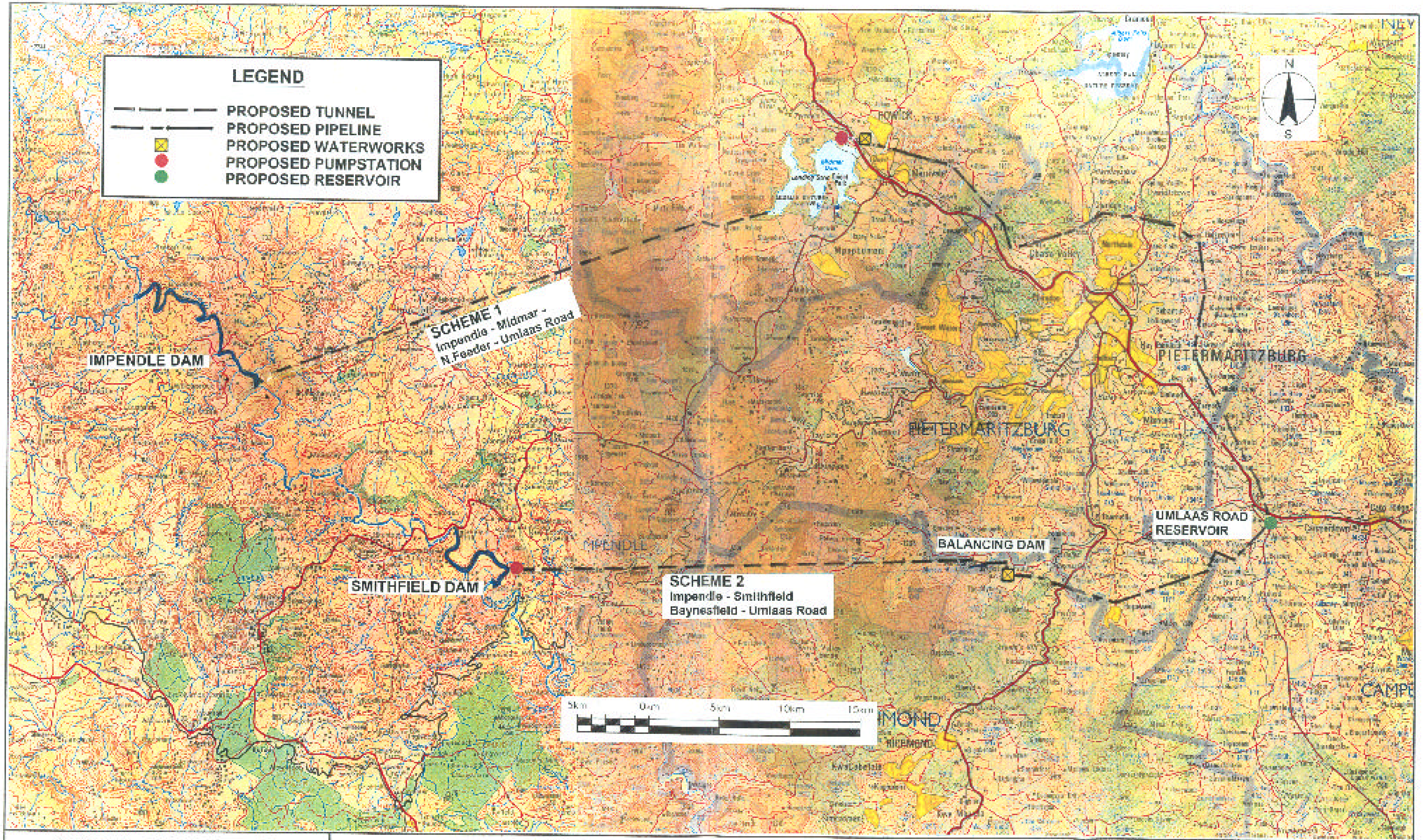
8.2 Design Aspects

8.2.1 Impendle Scheme

The most important characteristic of the Impendle Scheme is that much of the infrastructure is an extension of existing facilities, such as the waterworks and pumpstation, and also makes use of existing facilities or facilities that have or will be 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 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.



NINHAM SHAND
CONSULTING ENGINEERS

MKOMAZI–MGENI TRANSFER SCHEME PRE–FEASIBILITY STUDY

LAYOUT OF SCHEMES

UMGENI WATER • AMANZI

FIGURE No
8.1

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.

Having evaluated three potential sites and various configurations, the Impendle Dam is proposed as 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 for both the core and the rockfill available locally. At least 60% of the material from the spillway excavations should be suitable for use in the embankment. The maximum size of dam investigated has a capacity of 830 million m^3, equivalent to a height of 105 m.

Although the water quality in the Mkomazi is good, the reservoir is expected to stratify and a multi-level intake tower has been provided to allow the best quality water to be abstracted for transfer and for river releases. A tunnel will be used for river diversion and will also house the outlet pipes. Sedimentation is expected to be insignificant in relation to the reservoir capacity.

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 in the future. Various portal positions and alignments were evaluated before selecting the final alignment, which includes one intermediate portal to reduce the maximum length of drive to acceptable limits. The tunnel will be excavated by TBM to 3,5 m diameter and will be fully concrete lined. Available geotechnical information indicates that tunnelling conditions should generally be favourable, but that the potential for high groundwater inflows exist, particularly at dolerite contact zones.

It became clear during the course of the Study that the outlet capacity of Midmar Dam may be a limiting factor. Umgeni Water commissioned a separate Study, the results of which were not available at the time of writing this Report, but a preliminary analysis indicated that water would have to be abstracted from both the multi-level and scour outlets to attain the required capacity. This would involve modifications to the outlet works and periodic problems associated with the treatment of anaerobic scour water.

The pumpstation and waterworks will be constructed adjacent to the existing facilities, with linking pipelines following the most direct route. The treatment works were not considered in detail, as the treatment processes would be similar and they are common components in both schemes.

The twin clearwater pipelines, 1 600 to 1 800 mm diameter, delivering water to a 200 Mℓ reservoir at Umlaas Road, will be laid along existing or extended servitudes and care will need to be taken in certain developed areas where space is limited and along sections where the pipeline traverses very steep and potentially unstable terrain. Very high pressures will be encountered along portions of the pipeline route. It was assumed that the Stuckenberg Tunnel, which bypasses the unstable Stuckenberg Ledge, would be implemented, and the design prepared in an earlier pre-feasibility study was adopted.

The clearwater conveyance system will require very careful operation once the Midmar and Ferncliffe Tunnels are operating together, as they will be operating at their limits with very little balancing storage in the system.

Various issues requiring particular attention at feasibility stage were identified for both schemes and are discussed in Section 11 of this report

8.2.2 Smithfield Scheme

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 three scheme configurations evaluated are as follows:

Scheme 2A: 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 2B: A dam at Smithfield, with related conveyance and treatment infrastructure, followed by a dam at Impendle with a 1,0 MAR capacity.

Scheme 2C: 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 proposed Smithfield Dam will be a composite structure, with a central RCC gravity spillway section and rockfill embankments on the flanks. A saddle along the left flank of the site limits the practical maximum height of dam to approximately 70 m and a rockfill saddle dam is provided in this area. 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. As with the Impendle Dam, a multi-level intake works for river releases is provided in view of probable stratification of the reservoir. River diversion would be through an opening constructed through the RCC section, which would be concreted up and grouted on completion of the dam.

The second phase dam at Impendle would be as described in Section 8.2.1, except that the outlet works will be modified to release water down river to Smithfield, instead of into a transfer tunnel.

Again, sedimentation is expected to be insignificant in relation to the reservoir capacity.

Various alternative configurations and positions of intakes and pumpstations for water transfer were considered. The selected configuration consists of a separate multi-level intake tower, incorporating a pumpstation, situated approximately 1,8 km upstream of the dam wall. Vertical spindle pumps will be provided, with motors mounted above the non-overspill crest level of the dam. A short length of rising main links the pumpstation to the transfer tunnel portal. Access to the tower will be via a bridge, which will also carry the pipes.

Various alternative tunnel alignments were considered in parallel with alternative the intake tower and pumpstation positions. The tunnel will be a free water surface tunnel and will have one intermediate adit to keep the maximum length of drive within acceptable limits. A with the Impendle Scheme, the tunnel will be TBM excavated to 3,5 m diameter and will be fully concrete lined. Geotechnical conditions are expected to be similar to Impendle. At a late stage in the Study, the possibility of a larger diameter pressure tunnel, with a booster pumpstation located at the delivery end, was identified as worthy of consideration at feasibility stage.

Balancing storage will be provided by raising the existing Baynesfield Dam on the Mlazi River, with a direct link between the tunnel portal and waterworks also being provided. It is envisaged that water will generally be supplied directly to the waterworks and that the balancing dam will be used infrequently, as high turbidities are expected at times in the Mlazi River, with associated treatment problems.

The twin 1 800 to 1 900 mm diameter clearwater pipelines delivering water to a 200 Mℓ reservoir at Umlaas Road will be laid through relatively gently sloping and largely undeveloped terrain and no significant problems are anticipated.

8.3 Cost Estimates

The structure of cost models, methods used for the calculation of quantities and the unit rates were generally based on the VAPS Guidelines. 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 the Umlaas Road reservoir, and minor items, such as the Midmar pumpstation. Preliminary and General allowances used were generally lower than those given in the VAPS Guidelines, as these were based on projects in Lesotho, where sites are significantly more remote than those being considered here.

Annual operation and maintenance costs were determined in accordance with the Guidelines as a percentage of capital costs and energy costs were determined on the basis of the Eskom "Miniflex" tariffs.

Cost estimates for the two schemes and their three configurations are given in **Tables 8.1a** and **b**.

As can be seen from the Tables, 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, and cash flows for the schemes will be similar.

TABLE 8.1a: 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 8.1b: COST ESTIMATES: SMITHFIELD SCHEME

SMITHFIELD SCHEME 2A - IMPENDLE DAM RAISED TO 1,5 MAR					
		Phase 1	**Phase 2**	**Phase 3**	**Total**
Capital Costs: **(Mar '98 prices)**	Dam	R 228 million	R 321 million	R 116 million	R 665 million
	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: (Mar '98 prices)	Pumping	R 3,8 million/a	R 5,0 million/a	R 1,1 million/a	R 9,9 million/a
	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: **(Mar '98 prices)**	Dam	R 228 million	R 310 million		R 538 million
	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: (Mar '98 prices)	Pumping	R 3,8 million/a	R 0,5 million/a	R 4,4 million/a	R 8,7 million/a
	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: **(Mar '98 prices)**	Dam	R 228 million	R 384 million		R 612 million
	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: (Mar '98 prices)	Pumping	R 3,8 million/a	R 1,1 million/a	R 5,0 million/a	R 9,9 million/a
	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

8.4 Construction and Programming Aspects

It is assumed that all construction infrastructure, with the exception of main access roads and bulk electrical supply, would be included in the various contracts for the main scheme components. The advance infrastructure, which would include re-routing of roads affected by the dams, would be implemented ahead of the other contracts.

Overall durations from the commencement of the feasibility 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. The transfer tunnel will be on the critical path in both cases.

Prior to the commencement of detail design, further geotechnical investigations for all scheme components would be required, a feasibility study would have to be carried out and its findings approved, and funding for the selected scheme will have to be procured. The detail design and tender process would take approximately 18 months.

Implementation programmes for the two schemes are given in **Figures 8.2** and **8.3** respectively and cash flows for the most likely scheme configurations are given in **Table 8.2**.

8.5 Operational Risk Assessment

An assessment of the risk of operational failure of the two schemes was carried out under a separate Umgeni Water appointment by SRK Consulting. Assuming a top event as a curtailment of supply to Umlaas Road for at least five days and using probabilistic fault-event tree techniques, it was found that the risk of occurrence of the top event would be approximately 60% greater for the Impendle Scheme than for the Smithfield Scheme. However, the risk of curtailment remains relatively low, at approximately 1:100 years.

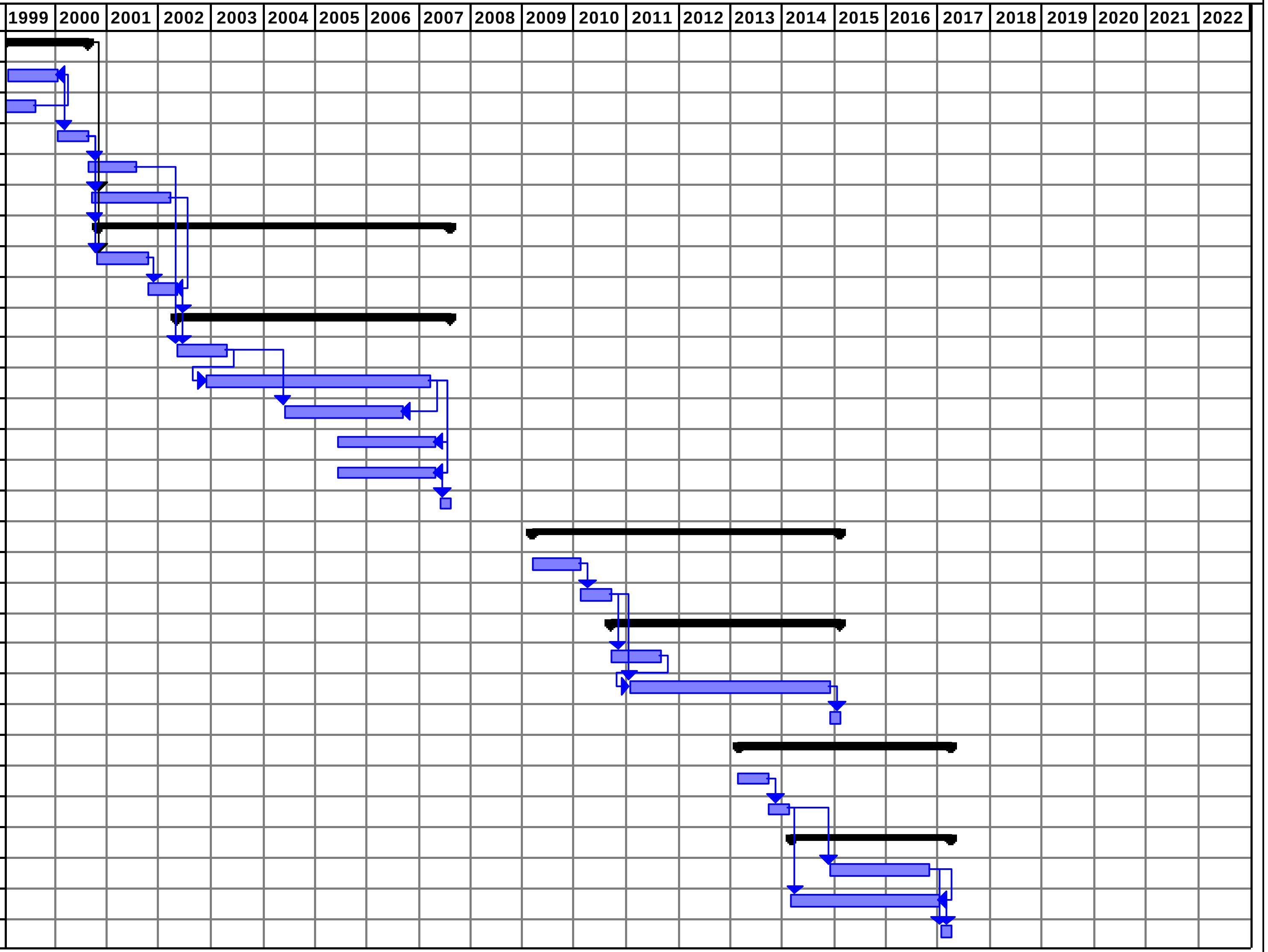
A further issue which emerged from this assessment was the potential for unplanned maintenance events lasting longer than 5 days. Careful scheduling of maintenance of elements which do not have redundancies, such as the Smithfield Transfer Tunnel and the Stuckenberg Tunnel will be required.

8.6 Conclusions

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

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: Thu 02/09/05

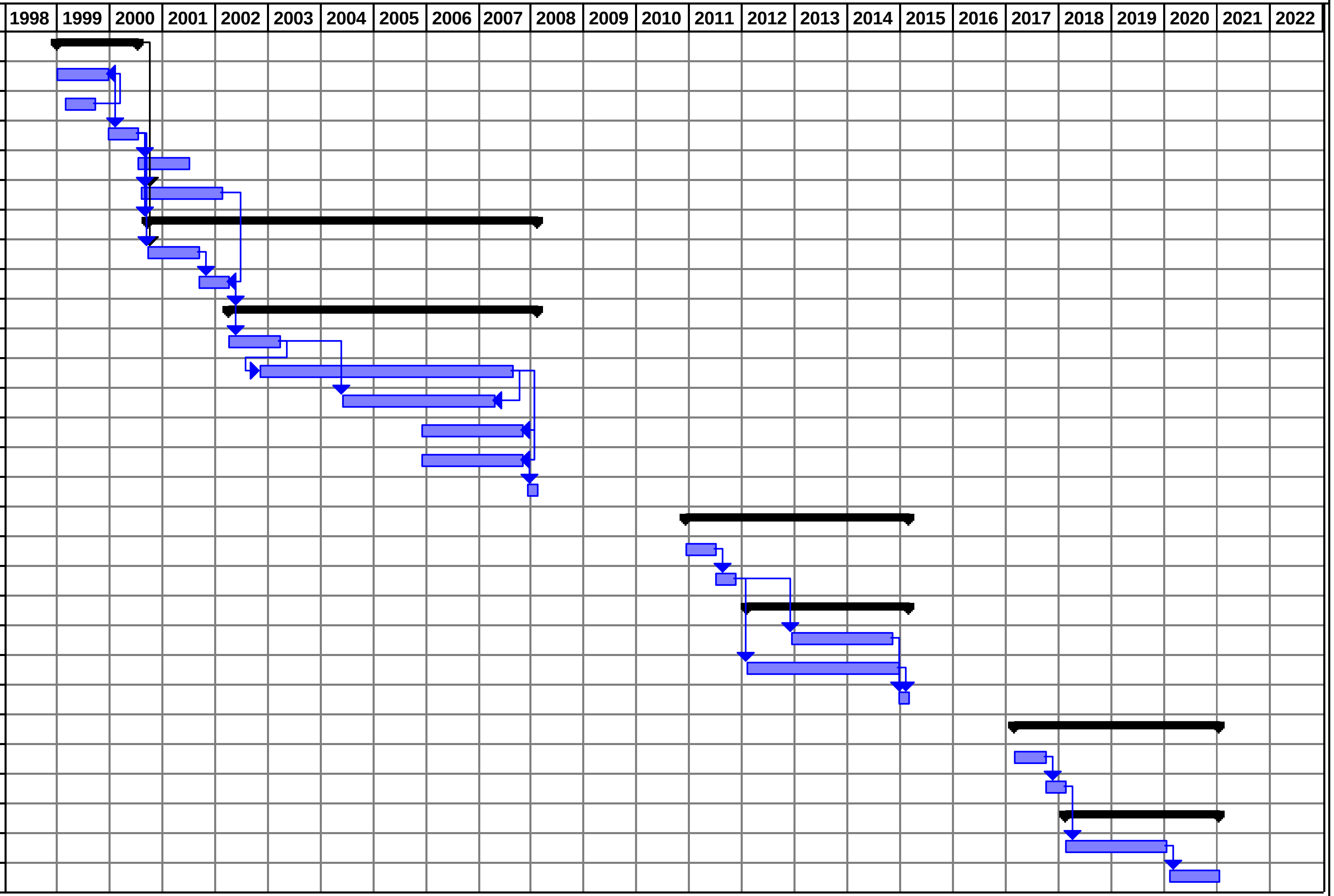
Task	Rolled Up Milestone	Rolled Up Split
Progress	Rolled Up Progress	External Milestone
Milestone	External Tasks	Deadline
Summary	Project Summary	
Rolled Up Task	Split	

IMPLEMENTATION PROGRAMME: SMITHFIELD SCHEME

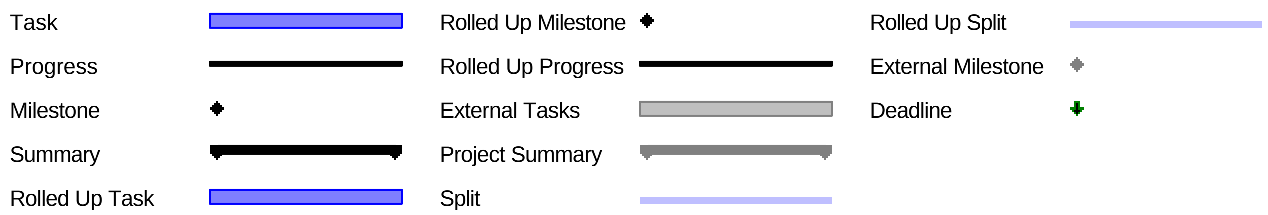
FIGURE 8.2

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 2**	**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: Thu 02/09/05



IMPLEMENTATION PROGRAMME: IMPENDLE SCHEME

FIGURE 8.3

problems, mainly of an operational nature. The risks of operational curtailment are insufficient to warrant the elimination of either scheme from further investigation, although the greater risk of the Impendle Scheme cannot be ignored. 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 and consideration should first be given to the relative environmental impacts and economics of the schemes, as discussed in Section 11. The selection of the preferred configuration of the selected scheme should be made after more detailed investigations in the feasibility phase.

Table 8.1: Cash Flows

Year	Impendle Scheme (1A)			Smithfield Scheme (2C)		
	Capital Cost ® million)	Running Cost ® million)	Total Cost ® million)	Capital Cost ® million)	Running Cost ® million)	Total Cost ® million)
2001	15,3		15,3	14,3		14,3
2002	28,5		28,5	28,4		28,4
2003	245,6		245,6	221,6		221,6
2004	128,9		128,9	112,2		112,2
2005	384,5		384,5	288,2		288,2
2006	506,6		506,6	394,9		394,9
2007	490,5		490,5	443,0		443,0
2008		7,4	7,4		7,7	7,7
2009		7,6	7,6	10,2	8,1	18,3
2010	7,6	7,7	15,3	23,5	8,6	32,1
2011	8,6	7,9	16,5	146,5	9,1	155,6
2012	137,1	8,1	145,2	111,1	9,6	120,7
2013	127,3	8,4	135,7	307,0	10,1	317,1
2014	401,2	8,6	409,8	372,6	10,6	383,2
2015		14,0	14,0	67,1	18,3	85,4
2016		14,2	14,2	67,1	18,8	85,9
2017	2,9	14,4	17,3		20,1	20,1
2018	2,9	14,7	17,6		20,7	20,7
2019	68,2	15,0	83,2		21,3	21,3
2020	55,8	15,2	71,0		22,0	22,0
2021		15,8	15,8		22,7	22,7
2022		18,2	18,2		28,3	28,3
2023		15,9	15,9		24,1	24,1
2024 °		15,9	15,9		24,6	24,6

9. ECONOMICS
(See Supporting Report No 7)

9.1 Introduction

In this section of the Report, two distinct economic components of the Study are described, firstly the socio-economic impact of non-augmentation, a separate study commissioned by Umgeni Water, and secondly the economic comparison of the two schemes identified for further investigation in the Reconnaissance phase of this Study.

9.2 Evaluation of Non-Augmentation Option

9.2.1 General

In the evaluation of the socio-economic impacts of non-augmentation, carried out by Graham Muller Associates, two scenarios were evaluated. In the first, unconstrained growth was assumed until water becomes a constraint to further growth, that is until demands in the Mgeni System exceed the system yield with augmentation from the Mooi River. In the second, it was assumed that the Mkomazi-Mgeni Transfer Scheme would be commissioned when required and that unconstrained growth is permitted until the limit of the total system yield, including the Mkomazi, is reached. Thereafter growth would be constrained, although in practice the next augmentation scheme would be commissioned.

9.2.2 Data and assumptions

The two specific indicators used to measure the socio-economic impacts were Gross Geographic product (GGP), which was found historically to follow the pattern of water demand, and formal employment, which is related to GGP. The impacts were assessed over a 40 year time frame from 1998.

Data was obtained from a variety of sources: Water demand projections assuming effective demand management in the Durban Metro area were provided by Umgeni Water; system and scheme yields were provided by BKS; GGP and employment base data was extracted from a DBSA report and projected using figures developed by Data Research Africa; population figures were provided by Scott Wilson; and GGP and employment multipliers were obtained from a DWAF manual.

9.2.3 Results and conclusions

The evaluation of the Non-augmentation scenario showed a dramatic impact on GGP and formal employment. The projected GGP in the study area in 2038 for constrained conditions is less than half of that for unconstrained conditions, with the cumulative difference over the analysis period being 27%. Even with a 20% increase in water productivity, the cumulative GGP is still 21% below the unconstrained equivalent. Non-augmentation would result in a cumulative loss of 3,3 million potential new jobs in the study area by 2038, and 5 million jobs in KwaZulu-Natal Province as a whole.

The evaluation of the Augmentation scenario showed a similarly dramatic difference in cumulative GGP of 26% compared to base (constrained) conditions. This is mainly as a result of the growth which occurs as a result of unconstrained water supply, the contribution of the construction and operation of the scheme being negligible. Potential employment levels are 34% higher than in the case of the base condition.

The consequences of loss control targets in the Durban Metro area not being met and the impacts of a delay in implementation were also evaluated. It was found that even if losses are reduced to 20% instead of the 15% target, deficits will occur which may constrain economic growth. Similarly, a delay augmentation in excess of two years will result in constrained economic development and employment.

On the basis of the above analysis, it can be concluded that without augmentation, economic growth and employment, both within the study area and in the Province as a whole, will be very severely constrained. Other alternatives, such as the relocation of industry and population, would not be viable and it is therefore recommended that the proposed augmentation proceeds as planned.

9.3 Economic Comparison of Schemes

9.3.1 Introduction

In this task, the two schemes selected for further study in the reconnaissance phase of this Study, namely the Impendle and Smithfield Schemes, were compared with a view to identifying the most economical alternative. Three configurations of each scheme were evaluated. As the selected schemes have different yields and will deliver different volumes of water to the Mgeni System during their operational lifetime, a simple comparison of actual or discounted capital costs will not necessarily indicate the most economical scheme. In order to take yields into account, the main parameter selected for comparison was the Unit Reference Values

(URV), which is simply the Net Present Value (NPV) of costs, both capital and running, for the selected analysis period, divided by the NPV of water delivered during the same period. This yields a unit cost in cents per m^3. Discount rates of 6, 8 and 10% were assessed and analyses were carried out over a 50 year period.

The first stage of economic comparison involved the calculation of URV's for each of the six possible scheme configurations, assuming the "most likely" sets of data and parameters, namely middle scenario water demands and system yields with middle scenario future catchment development conditions. In the second stage, the sensitivity to various parameters, including length of analysis period, catchment development conditions and water demands, was assessed. It should be noted that treatment and conveyance infrastructure was sized and costed on the basis of scheme yields with present catchment development conditions, but that economic analyses were carried out assuming future development conditions. This would ensure that the yield of the Mkomazi System can be maximised if projected future catchment development does not materialise.

9.3.2 Results of primary comparison

It was found that for all scenario's and parameters assessed, the Smithfield Scheme has a lower URV than the Impendle Scheme, as can be seen from the results given in **Table 9.1**. This can largely be attributed to the 20% greater yield of the Smithfield Scheme, as the costs of the two schemes are similar. For the "most likely" scenario, with a discount rate of 8%, the Smithfield Scheme has a URV 11% lower than the Impendle Scheme. Whilst this is a relatively small difference upon which to justify the elimination of a scheme at this (pre-feasibility) level of study detail, it should be noted that approximately 85% of the scheme costs are made up of cost components which are common to both schemes. It would therefore require a 60% change in the costs of the non-common components to make the Impendle Scheme more economical than the Smithfield Scheme.

The variation in URV between the different configurations within each scheme were very small and no clear preference could be identified.

In order to better assess the significance of the differences in URV between the two schemes, the Net Present Value (NPV) of the total additional cost of supply for the duration of the analysis period was determined. This amounts to approximately R140 million. It should also be noted that in the case of the Impendle Scheme, a further augmentation scheme will be required three years earlier than the Smithfield Scheme. Assuming similar costs to the first phase Mkomazi schemes, this represents an additional cost with an NPV of approximately R40 million.

9.3.3 Results of sensitivity analysis

With the most likely discount rate of 8%, it was found that for all cases evaluated, the URV of the Smithfield Schemes are a minimum of 9% lower than the equivalent Impendle Schemes and in view of the extent of common scheme components, it seems extremely unlikely that changes to cost estimates will bring about a material change to the outcome of this analysis.

9.3.4 Conclusions

It is therefore recommended that on the basis of the economic analysis, the Impendle Scheme should be eliminated from further study and that the Smithfield Scheme be taken forward to the feasibility phase of planning. However, the preferred configuration of the Smithfield Scheme could not be determined and it is recommended that the optimisation of the scheme components, as well as determining the desirability or otherwise of the raising of Impendle Dam, be carried out during the feasibility study.

TABLE 9.1: PRIMARY ECONOMIC COMPARISON

SCHEME	**CAPITAL COST ® million)**				**ANNUAL RUNNING COSTS ® million)**	**UNIT REFERENCE VALUE (c/m^3) @ DISCOUNT RATES**		
	Phase 1	**Phase 2**	**Phase 3**	**Total**		**6%**	**8%**	**10%**
1A: Impendle (raised) (Commissioning date) *Yield*	R 1 800 (2008) *157*	R 682 (2015) *119*	R 130 (2021) 38	R 2 611 *313*	R 16	83	114	152
1B: Impendle (1 MAR) (Commissioning date) *Yield (mcm)*	R 1 744 (2008) *138*	R 638 (2015) *138*		R 2 382 *275*	R 14	84	116	154
1C: Impendle (1,5 MAR) (Commissioning date) *Yield (mcm)*	R 1 870 (2008) *157*	R 682 (2015) *157*		R 2 551 *313*	R 16	83	115	154
2A: Smithfield (Impendle raised) (Commissioning date) *Yield (mcm)*	R 1 503 (2008) *147*	R 1035 (2015) *188*	R 130 (2023) *41*	R 2 667 *376*	R 25	75	103	138
2B: Smithfield (Impendle 1 MAR) (Commissioning date) *Yield (mcm)*	R 1 541 (2008) *147*	R 372 (2015) *21*	R 547 (2016) *168*	R 2 460 *335*	R 22	76	103	137
2C: Smithfield (Impendle 1,5 MAR) (Commissioning date) *Yield (mcm)*	R 1 573 (2008) *147*	R 455 (2015) *41*	R 580 (2017) *188*	R 2 607 *376*	R 25	74	102	135

Note:
1. All costs are based on June 1998 base date.
2. Costs exclude VAT.
3. Running costs and URV's given are for all phases of schemes.
4. Yields given are 1 in 100 year incremental scheme yields for future catchment development conditions.

10. CONCLUSIONS AND RECOMMENDATIONS

10.1 Scheme Comparison

The relative environmental impact ratings of the Smithfield and Impendle Schemes are given in **Table 10.1** and a comparison of the technical and economic aspects is provided in **Table 10.2**. These tables were presented at the final Stakeholder Committee Meeting on 11 November 1998.

It is clear from the environmental impact ratings that the Non-augmentation option is not worthy of further consideration. Overall, the Smithfield Scheme has a marginally higher impact rating, but this is still only Moderate-High versus Moderate for the Impendle Scheme. The higher rating can be attributed to the fact that two dams will have to be constructed and that the conveyance and treatment infrastructure involves greenfields development. However, the lower yield of the Impendle Scheme will require augmentation earlier than the Smithfield Scheme and the potential exists, albeit small, of a future dam on the lower Mkomazi, which would definitely not be viable in the case of the Smithfield Scheme. The construction of such a dam would reverse the relative ratings.

The technical and economic comparison of the schemes is dominated by the lower yield of the Impendle Scheme, which, in turn results in the Impendle Scheme being less economical than the Smithfield Scheme. The higher URV of the Impendle Scheme and the need to implement the next augmentation scheme earlier result in a total additional Net Present Value of costs of approximately R180 million. Clearly, very significant ecological and social mitigation measures could be put in place in order to reduce the impacts of the Smithfield Scheme for a fraction of this cost. It should also be noted that the Smithfield Scheme provides greater flexibility with respect to possible future transfers from the Mzimkhulu River.

10.2 Recommendations

In the light of the above, it is recommended that the Impendle Scheme be eliminated from further investigation and that the Smithfield Scheme be taken forward to the next phase of investigation in a detailed Feasibility Study. This decision was ratified by the current Stakeholder Committee at their final meeting for the current study phase.

It was not possible to select a preferred configuration from the three Smithfield Scheme configurations investigated. The final sizing and related phasing should be optimised during the Feasibility Study. Detailed recommendations of issues requiring specific attention during the Feasibility Study are given in Section 11 of this Report.

Table 10.1: Environmental Impact Ratings

Component	No Development	Scheme A (Impendle)	Scheme B (Smithfield)
Social			
Basins (including Recreation)		Significant impacts on Makhuzeni community as basin relatively densely settled. **3**	Incremental impacts associated with inundation of Smithfield basin relatively low but potential for densification high. However, combined impacts of both basins high. **3,5**
Transfer Infrastructure		Predominantly an upgrade of existing infrastructure ie. brown-fields development. **1,5**	Extensive green-fields development. Predominantly low density agricultural land-use. **2**
Waterworks		Upgrade of existing facility. **0,5**	Development of new facility. **1**
Employment	Impact on GGP and employment **4,5**	Minimal	Minimal
Bio-physical			
Basins		Basin extensively modified **1,5**	Basins extensively modified. **2**
IFR's and EFR's		Dam designed to meet requirements. Location in upper catchment also reduces impacts. **1,5**	Dams designed to meet requirements. Operation of two dams introduces some complexities and location lower down in catchment reduces ability of mitigation through incremental run-off. **2**
Transfer Infrastructure		Relatively modified landscape - mostly brownfields development. **1,5**	Mostly green-fields development, however, landscape modified through agricultural activities. **2**
Waterworks		Upgrade of existing works. **0,5**	Development of new works. **1**
Overall Rating	**4,5**	**2,0**	**2,5**

Impact Rating Scale (incorporates components of magnitude and significance)
1 = low;
2 = moderate;
3 = high;
4 = very high;
5 = fatally flawed

Table 10.2: Scheme Comparison: Technical and Economic

IMPENDLE SCHEME		SMITHFIELD SCHEME	
Issue	**Significance**	**Issue**	**Significance**
20% less ultimate yield than Smithfield	4	Higher pumping head/greater dependence on pumping	2
Potential instability at Midmar/Ferncliffe Tunnel outlet	2	No surcharge capability	1
No redundancy in supply to Pietermaritzburg and Umlaas Road	4	Requires entirely new operational infrastructure	2
Complex ultimate operating system	3	Possible problems with tunnel maintenance downtime due to limited balancing storage	3
Greater risk of failure to supply	3		
10 % greater Unit Reference Value	4		

Note:
1. For each issue, the scheme with the better characteristics for that particular issue is taken as the benchmark and the significance of the difference is rated for the less favourable scheme.
2. The significance of the issues are rated on a scale of 1 to 5.

11. REQUIREMENTS FOR FURTHER STUDY

It is assumed that the terms of reference for the next phase of investigation of the selected scheme, namely the Feasibility Study, will include general requirements for investigation of all aspects to an appropriate level of detail. However, during the course of this Study, a number of specific issues which require particular attention were identified. The most significant of these are the following:

General

- Monitor demands in the Mgeni System supply area to refine timing of schemes.

Environmental

- Sensitive areas must be surveyed in more detail to identify medicinal, rare and threatened plant specimens for propagation and relocation, and fauna for possible relocation.
- Investigate the need for fish ladders and/or eelways.
- Proceed with initiatives to set the Ecological Reserve.
- Analyse information from recently installed water level recorder at the estuary and correlate earlier assessments of processes and requirements.
- Further sampling of fish, invertebrate survey and monitoring of birds in the estuary.
- Negotiations must be entered into with affected communities and landowners regarding relocation and compensation
- Address land restitution issues through liaison with the Department of land Affairs
- Facilitate direct involvement of affected communities in further planning phases

Engineering and economics

- Refine phasing of selected scheme 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.
- Enter into negotiations on the joint use of the Baynesfield Dam.

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Department of Water Affairs & Forestry and Umgeni Water (1995), **MOOI-MGENI TRANSFER FEASIBILITY STUDY: MAIN REPORT***, Report by Keeve Steyn Inc, Report No PV200/00/1295 (November 1995)*

Department of Water Affairs & Forestry and Umgeni Water (1998), **MKOMAZI/MGENI/MOOI RIVER HYDROLOGY AND YIELD UPDATE**, *BKS Inc, January 1998, Draft report.*

APPENDICES

APPENDIX A

LIST OF COMMITTEE MEMBERS

A1: PROJECT MANAGEMENT COMMITTEE

Mr J Geringer	: DWAF, Pretoria
Mr G David	: DWAF, Pretoria
Mr W Schäfer	: Umgeni Water
Mr S Gillham	: Umgeni Water
Mr A Tanner	: Ninham Shand
Mr P Blersch	: Ninham Shand

Various other members of the Client Bodies and the Study Team attended Project Management Committee Meetings on an ad-hoc basis.

A2: ETG COMMITTEE

Mr M Taylor	: Town & Regional Planning Commission (Chairperson)
Ms M D Louw	: IWR Environmental
Mr J Geringer	: DWAF, Pretoria
Mr. W Addison	: Natal Conservancies Organisation
Ms J Davey	: Scott Wilson
Mr J David	: DWAF, Pretoria
Mr A Tanner	: Ninham Shand
Ms M Els	: Ninham Shand
Mr M J Munro	: DWAF, Pretoria
Mr P C Blersch	: Ninham Shand
Mr S W Gillham	: Umgeni Water
Mr W Schäfer	: Umgeni Water
Mr D E Simpson	: Umgeni Water
Mr M Haynes	: Umgeni Water
Mr D B Nothnagel	: iNdlovu Regional Council
Mr G C Anderson	: Natal Museum
Mr C D Tylcoat	: DWAF, KZN
Ms C Murphy	: Natal Parks Board
Mr D Airey	: SAPPI SAICCOR
Mr R Philip	: DWAF, KZN
Mr H Karodia	: DWAF, KZN
Mr NHG Jacobson	: IWR Environmental
Prof J H O'Keeffe	: IWR, Rhodes University
Dr C Dickens	: Umgeni Water
Mr G Huggins	: Scott Wilson
Ms J Davey	: Scott Wilson
Mr N Kemper	: IWR Environmental
Mr J Alletson	: Msinsi Trust
Mr K Cooper	: Wildlife & Environment Society
Mr B Wahl	: Natal Museum
Mr M Calverley	: SARA
Mr L Calverley	: SARA
Mr A Whitfield	: JLB Smith Institute
Mr R N Porter	: KwaZulu-Natal Nature Conservation
Mr E Cele	: Department of Economic Affairs & Tourism

A3. STAKEHOLDER COMMITTEE

Mr J Geringer	: DWAF, Pretoria
Mr J G David	: DWAF, Pretoria
Mr J Perkins	: DWAF, Durban
Mr W Schäfer	: Umgeni Water
Mr S Gillham	: Umgeni Water
Mr D M Taylor	: TRPC
Mr R Turner	: DLG&H, Pmb
Mr P G Louwrens	: KZNPA, Durban
Mr N Kemper	: IWR Environmental
Mr J D Black	: KWANALU
Mr P Gardiner	: Mondi Forests
Dr J Scotcher	: SAPPI Forests
Mr C Boake	: SAPPI Forests
Mr D D Airey	: SAPPI SAICCOR
Mr R N Porter	: KZN Nature Conservation
Mr L Howard	: iNdlovu Regional Council
Mr I E Anderson	: Ugu Regional Council
Mr M Newton	: Ilembe Regional Council
Mr Y Goga	: PMB-Msunduzi TLC
Mr E Cele	: KZN Dept. of Economic Affairs & Tourism
Mr B Shabalala	: KZNPA: Traditional & Environmental Affairs
Mr S K Armour	: Dept. of Agriculture, Pmb
Dr F Kars	: Dept. of Agriculture, South-West
Mr A Ferguson	: KZN Local Government Association
Mr F Stevens	: Durban Metro Water & Waste
Mr J F Oliver	: KZN Canoe Union
Mr P Sapsford	: Department of Land Affairs
Mrs J Davey	: Scott Wilson, Pmb
Mr D B Hawkins	: Trubshawe Communications
Mr A Tanner	: Ninham Shand
Mr P C Blersch	: Ninham Shand

APPENDIX B

LISTS OF ISSUES RAISED AND DECISIONS TAKEN

MKOMAZI-MGENI TRANSFER PRE-FEASIBILITY STUDY

ISSUES IDENTIFIED AS AT 1998-11-11

Issue	Raised by Whom	Date	Action	Date
Moratorium on forestry permits in the Mgeni Catchment	Wildlife & Environment Society	97-08-27	Concerns reported to DWAF's Regional Director. Moratorium in place.	97-09
Moratorium on forestry permits in the Mkomazi Catchment	Wildlife & Environment Society	97-08-27	Impacts of afforestation on runoff assessed in Mkomazi Basin Study: Impacts at current DWAF limits appear reasonable	98-08
Demand management in the Mgeni system	Wildlife & Environment Society	97-08-27	Already being implemented. Allows only a small delay in implementation of augmentation schemes. Covered in non-augmentation study.	98-09
Is it necessary to dam the Mkomazi at all?	Wildlife & Environment Society, SARA	97-08-27	Alternative augmentation options evaluated. Non-augmentation found unacceptable.	98-09
Impact of proposed schemes on South Coast Bulk Water Supply Scheme	Ugu Regional Council	97-09-16	Letter replied to by DWAF. Addressed in Mkomazi water resources assessment	97-11-06 98-09
Involvement of politicians at Stakeholder Meeting	Various Stakeholders	97-10-24	Newsletter to be distributed via Stakeholder Reps.	Ongoing
Future water use and reserve of the Mkomazi	ETG Members	97-10-23	Addressed in Mkomazi Basin Study	98-08
Plans for further long term development of Mkomazi	ETG Members	97-10-23	Addressed in Mkomazi Basin Study: Probably not viable	98-08
Compliance of environmental aspects of study with new Environmental Act	Umgeni Water	97-10-23	DWAF to register project	Pending
Concern over Forestry being unfairly singled out	FOA	97-10-24	Addressed in the Mkomazi Basin Study	98-08
Stakeholders to be kept informed throughout planning and implementation phases	Umgeni Water	98-03-05	Client(s) to ensure that this occurs	Ongoing
Consideration should be given to compensation of landowners as soon as decision is made to implement scheme	Umgeni Water	98-03-05	Policy decision to be considered by DWAF and Umgeni Water	Pending
Canoeists concerned over loss of reach of river between Lundy's Hill & Smithfield Dam wall	KZNCU	98-09-02	To be investigated and workshopped	Ongoing
Outstanding issues to be included in Feasibility Study terms of reference	Stakeholders	98-11-11	To be included in terms of reference	

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MKOMAZI-MGENI TRANSFER PRE-FEASIBILITY STUDY

DECISIONS TAKEN AS AT 1998-11-11		
Decision	**Committee**	**Date**
Include a scheme identification stage in the study	Management	9 Jul 1997
Investigate only Smithfield and Impendle options at reconnaissance level, review Ndonyane if necessary	ETG Stakeholders Management	27 Aug 1997 11 Sep 1997 9 Oct 1997
Carry out Water Resources Assessments in the Mkomazi and Mooi catchments	Management	9 Oct 1997
Eliminate Ndonyane and Smithfield Richmond Schemes from further investigation, proceed to pre-feasibility stage with Impendle and Smithfield-Baynesfield Schemes	ETG Stakeholders Management	23 Oct 1997 24 Oct 1997 20 Nov 1997
Evaluate non-augmentation option	Management Stakeholders	20 Nov 1997 24 Feb 1998
Carry out a risk assessment on the two proposed schemes	Management	11 June 1998
Proceed with Smithfield Scheme to feasibility phase, eliminate Impendle Scheme	Management Stakeholders	26 Oct 1998 11 Nov 1998

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APPENDIX C

SCHEME DETAILS: RECONNAISSANCE PHASE

RECONNAISSANCE PHASE
SCHEME 1
IMPENDLE - MIDMAR - NORTHERN FEEDER

	Phase 1	**Phase 2**	**Phase 3**
Transfer Capacity	3,6 m^3/s raw water, 4,6 m^3/s clear water (115 million m^3/a ave.)	Total 6,3 m^3/s raw water, 7,9 m^3/a clear water (200 million m^3/a ave.)	Total 10,8 m^3/s raw water, 13,5 m^3/s clear water (340 million m^3/a ave.)
Transfer Route and Description	Impendle Dam-gravity tunnel-uGqishi River-Midmar Dam-pumpstation-Midmar Waterworks-gravity pipeline/tunnel-Midmar Tunnel-gravity pipeline (Northern Feeder)-Umlaas Road reservoir		
Dam: Name	Impendle	Impendle raised	Impendle raised
Type	Rockfill with clay core	Rockfill with clay core	Rockfill with clay core
Spillway	Side channel	Side channel	Side channel
Crest Level; **FSL**; River Bed Level	1 153 masl; **1 145 masl**; 1 095 masl	1 168 masl; **1 160 masl**; 1 095 masl	1 198 masl; **1 190 masl**; 1095 masl
Minimum operating level	1 123 masl	1 123 masl	1 123 masl
Height of wall	58 m	73 m	90 m
Surface area at FSL	500 ha	1 000 ha	2 250 ha
Storage capacity at FSL	58 million m^3 (10% MAR)	200 million m^3 (35% MAR)	680 million m^3
Historical firm yield	115 million m^3/a	200 million m^3/a	380 million m^3/a
Tunnel: Route	From Impendle Dam to uGqishi River immediately upstream of Midmar Dam		
Length	35,1 km		
Diameter	3,5 m bored (3,0 m lined)		
Description	Bored tunnel, fully concrete lined with membrane for 25% of its length. Free surface flow.		
Typical rock formation	Sandstones and mudstones, with dolerite intrusions		
Average gradient	1 in 1 000		
Inlet invert level	1 115 masl		
Outlet invert level	1 080 masl		
Intake works	Multi-level intake structure		
Pumpstation: Location	Midmar	Midmar (upgrade)	Midmar (upgrade)
Capacity	4,5 m^3/s peak	8 m^3/s total peak	13,5 m^3/s total peak
Average head	10 m	10 m	10 m
Pipelines: Route	Raw water: Rising main from Midmar Dam to Midmar Water Treatment Works; Clear water: Gravity main to proposed Howick Tunnel, gravity link to existing Midmar Tunnel, gravity main from portal to reservoir at Umlaas Road, along route of proposed Northern Feeder		
General	All pipelines are buried. Proposed Northern Feeder and existing pipelines will not be utilised.		
Diameter	1 400 mm	1 900 mm	_
Length (total)	41 km	41 km	
Waterworks: Description	Upgrade of existing Midmar Waterworks	Upgrade of existing Midmar Waterworks	Upgrade of existing Midmar Waterworks
Capacity prior to upgrade	370 Ml/d average	760 Ml/d peak	1 050 Ml/d peak
Upgraded capacity	760 Ml/d peak	1 050 Ml/d peak	1 530 Ml/d peak
Features:	Gravity scheme making maximum use of existing facilities at Midmar and proposed Northern Feeder. Impendle Dam is located on a dolerite dyke. Existing geological data indicates deep excavation for dam foundation may be required. To be consistent with other schemes and as detailed geological reports not available at this stage, the deep excavation not allowed for in preliminary costing.		
Capital Costs: (Aug '97 prices): Dam	R112 million	R121 million	R294 million
Tunnel	R634 million		
Pumpstation	R6 million	R6 million	R9 million
Waterworks	R170 million	R125 million	R207 million
Pipelines	R225 million	R377 million	
TOTAL	**R1 147 million**	**R629 million**	**R510 million**
Running Costs: (Aug '97 prices): Pumping	R0,3 million/a	R0,3 million/a	R0,5 million/a
Operation & Maint.	R5,4 million/a	R4,4 million/a	R4,6 million/a
TOTAL	**R5,7 million/a**	**R4,7 million/a**	**R5,1 million/a**
Net Present Value @ 8% (period to 2053)	R1 234 million		
Unit Reference Value @ 8% (period to 2053)	R1,01		

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

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RECONNAISSANCE PHASE **SCHEME 3A** **SMITHFIELD - RICHMOND - UMLAAS ROAD**		
	Phase 1	**Phase 2**
Transfer Capacity	7,9 m³/s (200 million m³/a ave.)	Total 16,3 m³/s (410 million m³/a ave.)
Transfer Route and Description	Smithfield Dam-pumpstation-shaft-tunnel to Lovu River near Richmond-new waterworks near Richmond-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 Historical firm yield	Smithfield Rockfill with clay core Side channel 918 masl; **910 masl**; 858 masl 875 masl 60 m 700 ha 170 million m³ (25% MAR) 200 million m³/a	Impendle Rockfill with clay core Side channel 1 192 masl; **1 184 masl**; 1 095 masl 1 123 masl 97 m 2 000 ha 560 million m³ (100% MAR) Total 461million 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 Lovu River near Richmond 25,4 km 3,5 m bored (3,0 m lined) Bored tunnel, fully concrete lined with membrane for 25% of its length. Free surface flow. Raisebored shaft, steel lined Sandstones and mudstones, with dolerite intrusions 1 in 1 000 1 010 masl 980 masl Multi-level intake structure	
Pumpstation: Location Capacity Maximum/Average head	Smithfield 7,9 m³/s peak 135 m/115 m	Smithfield (upgrade) 15,8 m³/s total peak 135 m/115 m
Pipelines: Route General	Clear water: Gravity main from Richmond waterworks to reservoir at Umlaas Road All pipelines are buried	
Diameter Length (total)	1 900 mm 38 km	1 900 mm 38 km
Waterworks: Description Capacity prior to upgrade Upgraded capacity	New waterworks near Richmond Nil 690 Ml/d peak	Upgrade of Richmond Waterworks 690 Ml/d peak 1 380 Ml/d peak
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. 500 000 m³ raw water balancing dam on Lovu River near waterworks. No obvious stability problems identified.	
Capital Costs: **(Aug '97 prices)** Dam Tunnel Pumpstation Waterworks Balancing dam Pipelines TOTAL	R132 million R432 million R100 million R298 million R12million R351 million **R1325 million**	R321 million R100 million R298 million R351 million **R1 070 million**
Running Costs: **(Aug '97 prices)** Pumping Operation & Maint. TOTAL	R14,0 million/a R9,1 million/a **R23,6 million/a**	R15,2 million/a R8,7 million/a **R23,9 million/a**
Net Present Value @ 8% (period to 2053)	R1 352 million	
Unit Reference Value @ 8% (period to 2053	R1,03	

Note: Costs for Phase 2 represent incremental costs only

RECONNAISSANCE PHASE **SCHEME 3B SMITHFIELD - BAYNESFIELD - UMLAAS ROAD**			
		Phase 1	**Phase 2**
Transfer Capacity		7,9 m³/s (200 million m³/a ave.)	Total 13,0 m³/s (410 million m³/a ave.)
Transfer Route and Description		Smithfield Dam-pumpstation-shaft-tunnel to Mlazi River near Baynesfield-new waterworks near Baynesfield-gravity pipeline-Umlaas Road reservoir	
Dam:	Name	Smithfield	Impendle
	Type	Rockfill with clay core	Rockfill with clay core
	Spillway	Side channel	Side channel
	Crest Level; **FSL**; River Bed Level	918 masl; **910 masl**; 858 masl	1 192 masl; **1 184 masl**; 1 095 masl
	Minimum operating level	875 masl	1 123 masl
	Height of wall	60 m	97 m
	Surface area at FSL	700 ha	2 000 ha
	Storage capacity at FSL	170 million m³ (25% MAR)	560 million m³ (100% MAR)
	Historical firm yield	200 million m³/a	Total 461million m³/a
Tunnel/Shaft:	Route	From Smithfield Dam to Mlazi River near Baynesfield	
	Length	32 km	
	Diameter	3,5 m bored (3,0 m lined)	
	Description	Bored tunnel, fully concrete lined with membrane for 25% of its length. Free surface flow. Drill and blasted shaft	
	Typical rock formation	Sandstones and mudstones, with dolerite intrusions	
	Average gradient	1 in 1 000	
	Inlet invert level	940 masl	
	Outlet invert level	900 masl	
	Intake works	Multi-level intake structure	
Pumpstation:	Location	Smithfield	Smithfield (upgrade)
	Capacity	6,3 m³/s peak	13 m³/s total peak
	Maximum/Average head	70 m/50 m	25 m/5 m
Pipelines:	Route	Clear water: Gravity main from Baynesfield waterworks to reservoir at Umlaas Road.	
	General	All pipelines are buried.	
	Diameter	1 900 mm	1 900 mm
	Length (total)	21 km	21 km
Waterworks:	Description	New waterworks near Baynesfield	Upgrade of Baynesfield Waterworks
	Capacity prior to upgrade	Nil	690 Ml/d peak
	Upgraded capacity	690 Ml/d peak	1 380 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. 500 000 m³ raw water balancing dam on Mlazi River near Baynesfield. No obvious stability problems identified.	
Capital Costs: **(Aug '97 prices)**	Dam	R132 million	R321 million
	Tunnel	R546 million	-
	Pumpstation	R48 million	R48 million
	Waterworks	R298 million	R298 million
	Balancing dam	R1 million	-
	Pipelines	R222 million	R222 million
	TOTAL	**R1 247 million**	**R889 million**
Running Costs: **(Aug '97 prices)**	Pumping	R6,2 million/a	R6,4 million/a
	Operation & Maint.	R7,8 million/a	R7,3 million/a
	TOTAL	**R14,0 million/a**	**R13,7 million/a**
Net Present Value @ 8% (period to 2053)		R1 201 million	
Unit Reference Value @ 8% (period to 2053		R0,92	

Note: Costs for Phase 2 represent incremental costs only

APPENDIX D

SCHEME DETAILS: PRE-FEASIBILITY PHASE

PRE-FEASIBILITY PHASE
IMPENDLE SCHEME 1A - RAISED TO 1,5 MAR

	Phase 1		**Phase 2**	**Phase 3**
Transfer Capacity (Peak)	5,4 m^3/s (6,7 m^3/s)		Total 9,4 m^3/s (11,8 m^3/s)	Total 10,7 m^3/s (13,3 m^3/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 m^3 (100% MAR) 296 million m^3/a			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
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 & shotcreting, gravity pressure flow	
Pumpstation: Location Capacity Maximum/Average head	Midmar 6,7 m^3/s 32 m/20 m		Midmar (upgrade) 13,3 m^3/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 Midmar Waterworks 950 Ml/d 1 530 Ml/d	—
Features:	Largely gravity scheme, utilises existing servitudes and infrastructure as far as possible.			

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PRE-FEASIBILITY PHASE **IMPENDLE SCHEME B (SCHEME 1B) - 1,0 MAR DAM**			
	Phase 1		**Phase 2**
Transfer Capacity (Peak)	4,7 m^3/s (5,9 m^3/s)		Total 9,4 m^3/s (11,8 m^3/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 m^3 (100% MAR) 296 million m^3/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. 6,4 km 1,8 m dia (lined) Steel liners & shotcreteing, gravity pressure flow
Pumpstation: Location Capacity Maximum/Average head	Midmar 5,9 m^3/s 32 m/20 m		Midmar (upgrade) 11,8 m^3/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.		

PRE-FEASIBILITY PHASE
IMPENDLE SCHEME 1C - 1,5 MAR DAM (NOT RAISED)

	Phase 1		**Phase 2**
Transfer Capacity (Peak)	5,4 m^3/s (6,7 m^3/s)		Total 10,7 m^3/s (13,3 m^3/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 m^3 (150% MAR) 336 million m^3/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 m^3/s 32 m/20 m		Midmar (upgrade) 13,3 m^3/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.		

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PRE-FEASIBILITY PHASE
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	Smithfield	Impendle for raising	Impendle raised
	Type	Composite RCC gravity dam with rockfill flanks	Rockfill embankment with clay core	Rockfill embankment with clay core
	Spillway		Side channel	Side channel
	Crest Level; **FSL**; River Bed Level	923 masl; **915 masl**; 854 masl	1 192 masl; **1 184 masl**; 1 100 masl	1 192 masl; **1 205 masl**; 1 197 masl
	Minimum operating level	875 masl	1 123 masl	1 123 masl
	Height of wall	69 m	92 m	105 m
	Surface area at FSL	583 ha	1 934 ha	2 580 ha
	Storage capacity at FSL	137 million m^3 (25% MAR)	535 million m^3 (100% MAR)	830 million m^3 (150% MAR)
	1:100 year stochastic yield	177 million m^3/a	Total 369 million m^3/a	Total 409 million m^3/a
Tunnel/Shaft:	Route	From Smithfield Dam to Baynesfield Dam on the Mlazi River		
	Length	32,9 km		
	Diameter	3,5 m bored (3,0 m lined)		
	Description	Bored tunnel, fully concrete lined. Free surface flow. Drill and blasted shaft		
	Typical rock formation	Sandstones and siltstones, with dolerite intrusions		
	Average gradient	1 in 1 000		
	Inlet invert level	940 masl		
	Outlet invert level	885 masl		
	Intake works	Multi-level intake structure		
Pumpstation:	Location	Smithfield	Smithfield (upgrade)	
	Capacity	7,0 m^3/s	16,2 m^3/s	
	Maximum/Average head	71 m/48 m	71 m/48 m	
Pipelines:	Route	Clear water: Gravity main from Baynesfield waterworks to reservoir at Umlaas Road Raw water: Gravity from tunnel outlet to waterworks via Baynesfield Dam outlet		
	General	All pipelines are buried		
	Diameter	1 800 mm to 1 900 mm	1 800 mm to 1 900 mm	
	Length (total)	26,3 km	26,3 km	
Waterworks:	Description	New waterworks near Baynesfield	Upgrade of Baynesfield Waterworks	
	Capacity prior to upgrade	Nil	606 Ml/d	
	Upgraded capacity	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.		

PRE-FEASIBILITY PHASE

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 1 000 940 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.		

PRE-FEASIBILITY PHASE **SMITHFIELD SCHEME 2C - IMPENDLE DAM 1,5 MAR (NOT RAISED)**			
	Phase 1	**Phase 2**	**Phase 3**
Transfer Capacity	5,6 m^3/s (7,0 m^3/s)	Total 6,5 m^3/s (8,1 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 Rockfill embankment with clay core Side channel 1 192 masl; **1 205 masl**; 1 197 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 1 000 940 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 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.		