REPORT NUMBER: P RSA A000/00/9009

Department of Water Affairs

Chief Directorate: Integrated Water Resource Planning
Directorate: Options Analysis

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

Project No. WP9528

PRE-FEASIBILITY STAGE REPORT 3
TECHNICAL MODULE PRE-FEASIBILITY STAGE GUIDELINES FOR PRELIMINARY SIZING, COSTING AND ENGINEERING ECONOMIC EVALUATION OF DEVELOPMENT OPTIONS

Lead Consultant: Africon

In association with: KV3, VELA VKE

LIST OF REPORTS

REPORT NO	DESCRIPTION	REPORT NAME
FEASIBILITY STAGE		
P RSA A000/00/8109	Main Report	MCWAP FEASIBILITY STUDY TECHNICAL MODULE SUMMARY REPORT
P RSA A000/00/8409	Supporting Report 8A	GEOTECHNICAL INVESTIGATIONS PHASE 1
P RSA A000/00/8709	Supporting Report 8B	GEOTECHNICAL INVESTIGATIONS PHASE 2
P RSA A000/008509	Supporting Report 9	TOPOGRAPHICAL SURVEYS
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PRE-FEASIBILITY STAGE		
P RSA A000/00/8809	Supporting Report 1	WATER REQUIREMENTS
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P RSA A000/00/9309	Supporting Report 6	WATER TRANSFER SCHEME OPTIONS
P RSA A000/00/9409	Supporting Report 7	SOCIAL AND ENVIRONMENTAL SCREENING
INCEPTION STAGE		
P RSA A000/00/9609	Inception	INCEPTION REPORT

REFERENCE

This report is to be referred to in bibliographies as:

Department: Water Affairs, South Africa, 2008. Mokolo Crocodile (West) Water Augmentation Project (MCWAP) Feasibility Study. Pre-Feasibility Stage: Report 3: Guidelines for Preliminary Sizing, Costing and Economic Evaluation of Development Options. Prepared by Africon in association with Kwezi V3 Engineers, Vela VKE, WRP Consulting Engineers and specialists.

DWA Report No. **P RSA A000/00/9009**

REPORT DETAILS PAGE

Project name:	***Mokolo and Crocodile River (West) Water Augmentation Project (MCWAP)***
Report Title:	**Pre-Feasibility Study Report 3 – Guidelines for Preliminary Sizing, Costing and Economic Evaluation of Development Options Report**
Author:	***Project Team***
DWA report reference no.:	***P RSA A000/00/9009***
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PSP

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DEPARTMENT OF WATER AFFAIRS (DWA)
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PREFACE

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

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

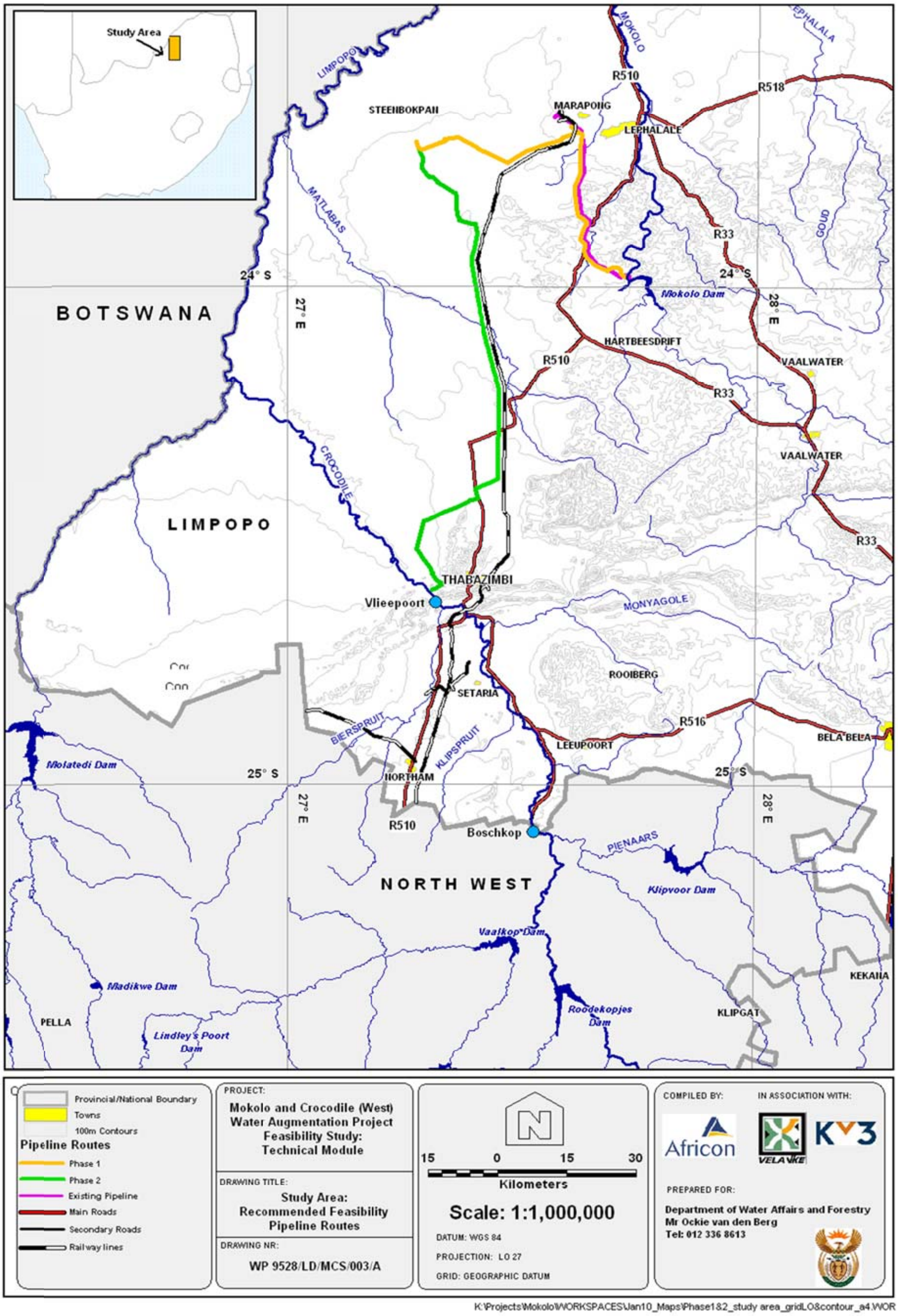
The development of new power stations is of high strategic importance with tight timeframes. Commissioning of the first generation unit will start in September 2010 and additional water needs to be available by mid-2011 according to the expected water requirements. A solution addressing the water needs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

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

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

The Technical Module has been programmed to be executed at a Pre-feasibility level of investigation to identify different options and recommend the preferred schemes, which was followed by a Feasibility level investigation of the preferred water schemes. Recommendations on the preferred options for Phase 1 and Phase 2 Schemes were presented to DWA during October 2008 and draft reports were submitted during December 2008. The Feasibility Stage of the project commenced in January 2009 and considered numerous water requirement scenarios, project phasing and optimisation of pipeline routes. The study team submitted a draft Feasibility report during October 2009 to the MCWAP Main Report in November 2009.

This report (Report 3 – Guidelines for Preliminary Sizing, Costing and Economic Evaluation of Development Options, P RSA A000/00/9009) covers the infrastructure planning criteria that was used in the Feasibility Study towards the evaluation of development options and selection of the preferred alternative.


Study Area
BOTSWANA
LIMPOPO
NORTH WEST
STEENBOKPAN
MARAPONG
LEPHALALE
R510
R518
R33
24° S
25° S
27° E
28° E
Mokolo Dam
HARTBEESDRIFT
VAALWATER
THABAZIMBI
Vlieepoort
ROOIBERG
SETARIA
R516
BELA BELA
LEEUPOORT
NORTHAM
Boschkop
Molatedi Dam
Klipvoor Dam
Vaalkop Dam
Madikwe Dam
Roodekopjes Dam
Lindley's Poort Dam
PELLA
KLIPGAT
KEKANA
LIMPOPO
MATLABAS
CROCODILE
MOKOLO
MONYAGOLE
BIERSPRUIT
KLIPSPRUIT
PIENAARS
GOUD
Provincial/National Boundary
Towns
100m Contours
Pipeline Routes
Phase 1
Phase 2
Existing Pipeline
Main Roads
Secondary Roads
Railway lines
PROJECT:
Mokolo and Crocodile (West) Water Augmentation Project Feasibility Study: Technical Module
DRAWING TITLE:
Study Area: Recommended Feasibility Pipeline Routes
DRAWING NR:
WP 9528/LD/MCS/003/A
15 0 15 30
Kilometers
Scale: 1:1,000,000
DATUM: WGS 84
PROJECTION: LO 27
GRID: GEOGRAPHIC DATUM
COMPILED BY:
IN ASSOCIATION WITH:
Africon
VELA VKE
KV3
PREPARED FOR:
Department of Water Affairs and Forestry
Mr Ockie van den Berg
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MOKOLO AND CROCODILE RIVER (WEST) WATER AUGMENTATION PROJECT FEASIBILITY STUDY

TECHNICAL MODULE

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LIST OF ABBREVIATIONS

AAD	Average Annual Demand
CPAF	Contract Price Adjustment Factors
DWA	Department of Water Affairs
LHFP	Lesotho Highlands Further Phases
LORMS	Lower Orange River Management Study
O&M	Operation and Maintenance
MCWAP	Mokolo and Crocodile River (West) Water Augmentation Project
NOC	Non-overspill Crest
NPSH	Net Positive Suction Head
P&G	Preliminary & General
PMF	Probable Maximum Flood
RDD	Recommended Design Discharge
RDF	Recommended Design Flood
RMF	Regional Maximum Flood
SANCOLD	South African National Committee on Large Dams
SED	Safety Evaluation Discharge
SEF	Safety Evaluation Flood
URV	Unit Reference Value
VAPS	Vaal Augmentation Planning Study
VAT	Value Added Tax
VRESAP	Vaal River Eastern Sub-system Augmentation Project
WMA	Water Management Area

1. INTRODUCTION

During the execution of the Vaal Augmentation Planning Study (VAPS) (mid-1990s), the Project Planning Division of the Department of Water Affairs (DWA) recognised that the standard methodology developed during that study for the sizing and costing of water resource project components and for the economic evaluation of water resource development options would be a valuable tool for subsequent planning studies. It was accordingly decided to capture the guidelines in a single document which could be made available to planning professionals both within the Department and those consultants appointed by the Department to undertake specific assignments.

Costing and sizing guidelines were compiled during the VAPS. The purpose of the guidelines was to provide a standard framework for first pass comparative costing and project engineering economic evaluation of water resources development options. The guidelines stipulated in this document are based on the VAPS guidelines (**DWA Report No. PC 000/00/14394: January 1996**) suitably updated to April 2008 prices. The necessary amendments were made to cater only for those items required in this study. Refer to Report 3 – Technical Module: Guidelines for Preliminary Sizing, Costing and Economic Evaluation of Development Options for more detail.

These guidelines are merely planning tools and should not be seen as suitable for detailed designs, engineer's estimates or tender documentation. It is expected that as additional information is obtained on the Schemes (Phases 1 and 2) under investigation, the models provided in these guidelines would be expanded to more accurately reflect the actual circumstances.

2. LEVEL OF DETAIL REQUIRED FOR THE DIFFERENT PLANNING PHASES

The benefit of investigating development options through a predetermined sequence, of increasingly more detailed planning phases, is that it allows decision makers the opportunity to terminate the investigation of identified sub-optimal options without incurring unnecessary expenditure in taking them to a greater than necessary degree of detail.

It is difficult to make clear distinctions between Reconnaissance Level, Pre-feasibility Level and Feasibility Level planning studies. Planning studies are commissioned for various purposes and largely due to the availability and cost of obtaining information, the number and competitiveness of the development options from which the planner must make a selection, and the time constraints imposed on the study result in more than one level of detail being addressed in a particular planning study.

The broad definitions of the three levels of study have been taken to be the following:

2.1 Reconnaissance Level Planning Study

An initial exploratory study to conduct a preliminary examination of an area in order to obtain and evaluate existing information and identify likely schemes and layouts.

This level of study comprises a desk study of available mapping and existing reports and data bases with only limited verification and field work.

Generally applicable to studies where the accuracy and detail of the results are not likely to be determinant with respect to a final decision.

2.2 Pre-feasibility Level Planning Study

A precursor to the feasibility study in which resource and constraints of the likely final scheme, as well as the most beneficial layouts are identified for final optimisation.

This level of study requires field work to obtain accurate information and data and often requires considerable verification. Drilling and sampling are not usually required at this stage.

The level of accuracy and detail resulting from the study are, however, not considered sufficient for the purpose of detail design of works and will require further investigation and final optimisation for that purpose.

2.3 Feasibility Level Planning Study

An intensive investigation and optimisation of the most beneficial layouts of the final scheme resulting in one best layout with final specifications of major dimensions.

The results of this study must be of sufficient detail and accuracy to define the detail design of the scheme.

2.4 MCWAP Study Level of Detail

The nature of this MCWAP study has resulted in a multi-level approach with some components such as the water requirement being considered at a full feasibility level, at the onset of the study. Other components are in the process of being developed systematically from reconnaissance level to feasibility level. Components not yet at the feasibility level are constrained mainly by a lack of survey or geotechnical detail.

The multi-level MCWAP study was accepted by the client due to time constraints whereby the engineering aspects would be re-evaluated in greater detail in later studies once the geotechnical investigations and topographical surveys have been completed.

At any level of investigation, the objective is to carry out sufficient work to enable proper comparisons of alternatives to be made so that the correct decisions can be made and a cost estimate at a sufficient level of confidence is available before the design phase commences. This procedure also reduces the expenditure investigating layouts or components which are eventually rejected in favour of the selected scheme.

The aim of the reconnaissance level investigation is to provide a sufficiently consistent basis for comparison of the individual development options for further analysis at a pre-feasibility level of detail. The following table indicates the approximate level of detail considered in this particular study.

Table 2-1: Recommended Level of Detail of Different Study Stages

Type of investigation	Component	Identification of Development Options	Level of Detail	
			Reconnaissance	Pre-feasibility
Objective		Identify all apparently technically viable alternative layouts which can meet the needs in terms of yield and delivery dates.	Select typically not more than 4 basic layouts and desirably not more than 2 layouts for further study. **Notes:** Selection will be on the basis of technical feasibility, engineering economic evaluation and social and environmental impact. Range of layouts would typically include 2 or 3 dam sites and 2 or 3 conveyance routes in various combinations.	Select the best layout for further study on the basis of technical feasibility, social and environmental acceptability, plus engineering economic and financial viability.
Survey	Layout	1:250 000 mapping for layout configurations	1:50 000	1:10 000
	Dam Basin	1:50 000 mapping for capacity	1:50 000	1:10 000/ 1:50 000 min①
	Dam Site	1:10 000 for prelim quantities	1:10 000	1:10 000 plus X-Section or 1:1 000
	Pipeline Route	1:50 000	1:50 000	1:50 000
	Canal Route	1:50 000	1:50 000	1:10 000
	Tunnel Route	1:50 000	1:50 000	1:50 000 but 1:1 000 for adit/portals

Type of investigation	Component	Identification of Development Options	Level of Detail	
			Reconnaissance	Pre-feasibility
	Civil Works	1:10 000 if significant component of cost	1:10 000 ①	1:10 000/ 1:1 000①
Geotechnical	Dam Basin	Published geological maps and reports	Published information, aerial photography and walkover site inspections.	Surface geological mapping. Limited trenching to facilitate mapping. Limited drilling possible to identify critical features which could restrict the feasible options. No laboratory testing.
Sizing & Layout	Dam Pipeline Canal Tunnels Civil Works/ Infrastructure	Typical sizing adopted to give “all in” quantities.	Sizing based on recommended criteria.	Preliminary design based on best information.
Cost Estimates	Dam Pipeline Pump Station Canal Tunnels Civil Works Temporary / Miscellaneous Works P&G	Rate/m³ of wall Rate/km/diameter Rate/KW Rate/km/capacity Rate/km/diameter Lump sum	Unit rates for major items on basis of historical information with a % allowance for miscellaneous items, temporary words and P&G.	Resource based cost estimates for major activities and adjustment of miscellaneous items, temporary works and P&G for specific site considerations.
Regional Economics		N/A	N/A	Assessment required. ②
Environmental Impact	Dam Basin Dam Site Pipeline Route Canal Route Tunnel Route Pump Station Site Temporary and Permanent Works Civil Works/ Infrastructure	Desk Study	Geographic overview to identify: - sensitive and non-sensitive areas. This is a desk study with overview field trip. Purpose is to: - identify any fatal flaws - qualitative assessment of time and cost implications of impacts	Initial project specific assessment to identify: - time and cost implications of impacts. ROIP required, together with ranking of impacts. Limited field work.

Type of investigation	Component	Identification of Development Options	Level of Detail	
			Reconnaissance	Pre-feasibility
Environmental Water Requirements	Natural streams	See note ②	Overview of available information. Site investigation and assessment based on related experience. Possible IFR assessment. ③	Detailed assessment of in-stream flow requirements early in Pre-feasibility. (Guidelines not followed strictly in Pre-feasibility.)④
Social Impact	Dam Basin Dam Site Pipeline Route Canal Route Tunnel Route Pump Station Site Temporary and Permanent Works Civil Works/ Infrastructure	See note ②	Overview to identify: - time and cost implications of impacts.	Detailed assessment ④
Hydrology		Published hydrology	First level patching analysis and naturalisation.	Detailed hydrological studies.
Yield analysis		Historic analysis based on above hydrology.⑤	Primary historic analyses. Possible long term stochastic analyses in specific cases.⑤	Long term stochastic analyses. Scheduling with planning model, using short term characteristics.⑤

① 1:50 000 Mapping was used for these items as 1:10 000 mapping was not available for all sites concerned.

② Not done for pre-feasibility stage.

③ IFR assessment is based on available information.

④ Not done.

⑤ Done for Mokolo Dam, but not for dam in Crocodile River (West). Published regional hydrologic characteristics for dam in Crocodile River (West) were used.

Notes: Civil works includes tunnel inlets and outlets, pump stations, inlet towers, etc.

On completion of the Pre-Feasibility stage the project team will consider only selected options and develop it to feasibility level. At the end of the pre-feasibility stage the project team need to review this and revise it to reflect what was actually done, since above table only includes recommendations.

3. COMPONENT SIZING CRITERIA

This section provides the guidelines that were used for size of the main parameters for the following components that are applicable to this particular study:

1. Mass Concrete Dams (conventional construction).
2. Embankment Dams (Earthfill).
3. Concrete Weirs.
4. Conveyance losses.
5. Tunnels.
6. Canals (including siphons at canal intake).
7. Pipelines (including road, river and rail crossings).
8. Pump Stations (including electricity requirements)).
9. Social and Environmental costs.
10. Economic Life and Operation and Maintenance costs (excluding electricity).

3.1 Mass Concrete Dams

All proposed concrete dams were considered as mass gravity concrete dams except where better information was available. Past experience has shown that where other types of concrete dam walls may be more economical, their respective costs are generally close to that of a mass gravity wall, assuming that sufficient materials are available. The optimisation of the type of dam and spillways to reduce the cost would then be addressed at the next level of detail.

3.1.1 Definition

The following criteria were applied to dams that will be classified as Category II or III dams in terms of the dam safety regulations. Smaller structures should be treated according to the criteria for weirs.

3.1.2 Flood Determination and Spillway Sizing

3.1.2.1. Flood Magnitudes

i) Recommended Design Discharge (RDD)

Use Table 3-1 to determine the RDD.

Table 3-1: Recommended RDD Values①

Dam Size Class	Hazard Rating		
	Low	**Significant**	**High**
Small	0,5 Q_{50} – Q_{50}	Q_{100}	Q_{100}
Medium	Q_{100}	Q_{100}	Q_{200}
Large	Q_{200}	Q_{200}	Q_{200}

① Table 5-1 on page 28 of SANCOLD Guidelines on Safety in Relation to Floods - Report No. 4, 1991[(1)]

ii) Safety Evaluation Discharge (SED) - Use Table 3-2 to determine the SED.

Table 3-2: Recommended SED Values ①

Dam Size Class	Hazard Rating		
	Low	**Significant**	**High**
Small	$RMF_{-\Delta}$	$RMF_{-\Delta}$	RMF
Medium	$RMF_{-\Delta}$	RMF	$RMF_{+\Delta}$
Large	RMF	$RMF_{+\Delta}$	$RMF_{+\Delta}$

① Table 5.2 on page 30 of SANGOLD Guidelines on Safety in Relation to Floods – Report No. 4, 1991

iii) Diversion Flood:

Use the 1:10 year flood for concrete dams with no allowance for flood attenuation.

Use the 1:20 year flood for earth and rockfill dams with no allowance for flood attenuation.

3.1.2.2. Flood Attenuation

Use the following Görgens flood attenuation formula to obtain the Recommended Design Flood (RDF) (attenuated RDD) as SEF (attenuated SED):

$$\frac{Q\ out}{Q\ in} = 0{,}99 - 5{,}56 \times \frac{Area\ reservoir}{Area\ catchment}$$

3.1.2.3. Freeboard

i) Wet freeboard:

Use the flood surcharge when routing the attenuated design flood calculated by means of:

Q out = $2{,}0h^{1,5}$ L (m³/s) where h = flood surcharge (m), gurring the velocity head

L = overspill length (m)

ii) Total freeboard:

Use the maximum of the following:

1. Wet freeboard (including velocity head) + 3 m.

2. The flood surcharge when using the attenuated SED and the discharge formula in (ii) above.

3.1.3 Dead Storage

A dead storage volume was allowed for future sedimentation, based on an estimate of the sediment accumulation over the economic life span of the dam (45 years).

3.1.4 Spillway Aprons

An allowance was made for a concrete apron 1 m thick with a length equal to (10 + H/5) m, where H is the difference between the apron invert and the non-overspill crest (NOC) level of the dam. Roller buckets were site specific. Surface reinforcing in both directions at 0.1% of the area of the cross-section will be required.

3.1.5 Spillway Training Walls

Where composite dams with earth flanks have been used, training walls from the NOC level to 5 m below the full supply level on the upstream side and to the apron retaining walls on the downstream side have been allowed for.

3.1.6 Apron Retaining Walls

Mass concrete retaining walls 4 m high running the length of the apron and butting up against the non-overspill wall have been allowed.

3.1.7 Typical Cross Section

Figures 3-1 and 3-2 were used to determine quantities for concrete, excavations and foundation preparation. No adjustments were made for the spillway, galleries or energy dissipaters (splitters).

The following excavation dimensions were assumed:

- Strip depth : 2 m (as per sketch); and
- Foundation depth below strip depth : H/25, max 5 m.

3.1.8 River Outlet

The river outlet is assumed to be built into the dam wall consisting of a 5 m × 5 m square dry well with walls at least 1 m thick and reinforcing in both directions at 0.1% on average of the area of the cross-section (Reinforcing is required by the cost model).

3.1.9 Multiple Level Intake Tower

A multiple level intake tower was considered at only one site (Bakenkop) and was priced site specific.

3.1.10 Foundation Grouting

Allowance was made for a grout curtain with holes spaced at 2 m intervals to a depth of 3/4H.

Over reaches of the dam where H > 30 m allowance was made for three rows of consolidation grout holes spaced at 1 m to a depth of H/10.

Drainage holes were ignored.

3.1.11 Construction Joints

Construction joints were allowed for at 15 m intervals.

3.1.12 Mechanical Items

The amounts (at April 2008 prices) allowed for mechanical outlets are to satisfy the requirements of the Dam Safety Office and exclude inlets and outlets as may be required for operation:

Cranes and hoists	:	allow R 1 300 000 for dams up to 50 m high
		allow R 2 500 000 for dams up to 100 m high
		allow R 3 900 000 for dams above 100 m high

River outlets (valves and gates) allow the following:

Dam capacity up to 50 × 10^6 m³	=	R	2 500 000
Dam capacity 50 to 100 × 10^6 m³	=	R	3 900 000
Dam capacity 100 to 150 × 10^6 m³	=	R	5 200 000
Dam capacity over 150 × 10^6 m³	=	R	6 500 000

Structural steel screens and guides: allow R 1 300 000.

3.1.13 Purchase Line

The purchase area under the level pool safety evaluation flood level + 1 m was allowed for.

3.1.14 Security Fencing

Security fencing has been allowed for around the dam wall and associated structures.

3.2 Embankment Dams

In addition to the guidelines provided for mass concrete dams the following apply.

3.2.1 Definitions

Embankments include the following:

- Earthfill embankment with impervious core.
- Rockfill embankment with impervious core.
- Rockfill embankment with reinforced concrete upstream face.

3.2.2 Flood Determination

Flood magnitudes SEF and RDF to be based on SANCOLD Guidelines on Safety in relation to Floods – Report No. 4, 1991.

Diversion flood to be the 1:20 year recurrence interval flood with no attenuation assumed.

3.2.3 Freeboard

Total Freeboard above Full Supply Level (FSL) was the greater of:

- For SEF = Flood surcharge
- For RDF = Flood surcharge + 3m

When using the RMF approach, to determine the Safety Evaluation Flood (SEF) for dams over 50 m high, the total freeboard allowances (RMF x factor + 1 m).

3.2.4 Spillway Location and Sizing

Either central mass concrete overflow sections (refer to Section 3.1 above) or lateral (side channel) overflow with ogee crest and concrete lined chute. Maximum convergence 1:8.

For floods greater than the RDF, a separate higher level emergency spillway overflow and chute with reduced concrete lining was considered.

The appropriate sizing of a side overflow side channel spillway is as follows:

- Head over spillway = H
- Top width of trapezoidal channel = 6H
- Bottom width of trapezoidal channel = 3H
- Depth of invert below ogee level = 3H
- Height of control sill at entrance = 0,5H to rectangular chute.

Side channel spillways could be tapered and these dimensions suggest the maximum section.

3.2.5 Typical Dimensions for Embankment

Table 3-3: Crest Width and Slope

Dam Type	Crest Width	U/S Slope	D/S Slope	Top Core Width	Core Slopes U/S and D/S
Earthfill	H/5: Max 15 m Min 5 m	1:3,0	1:2,5	H/8: Max 10 m Min 3 m	1:0,5 each face
Rockfill	H/5: Max 15 m	1:1,75	1:1,6	H/8: Max 10 m	1:0,25 each face

Dam Type	Crest Width	U/S Slope	D/S Slope	Top Core Width	Core Slopes U/S and D/S
	Min 6 m			Min 5 m	
Concrete Faced Rockfill	H/5: Max 15 m Min 8 m	1:1,4	1:1,4	Not applicable	Not applicable

3.2.6 Special Zones

3.2.6.1. Earthfill Embankment

- Riprap on U/S face: Thickness normal to slope H/50, min 600 mm, max 5 m.
- Zoned filter under riprap: Total thickness normal to slope H/50, min 600 mm, max 1 000 mm.
- Filter D/S of core: Thickness H/25, max 4 000 mm.
- Blanket filter on foundation: Thickness 1 000 mm min, 2 000 mm max.

3.2.6.2. Rockfill Embankment

- Filter U/S of core: Thickness H/25, max 3 000 mm.
- Composite filter D/S of core: Thickness H/12, max 6 000 mm.

3.2.6.3. Concrete Faced Rockfill Embankment

- Bedding and drainage zone for facing concrete: Horizontal thickness 5 m.

3.2.7 Excavation Depth for Assessment of Quantities

Table 3-4: Excavation Depths

Dam Type	Unsuitable Material in Footprint	Material in Core Trench
Earthfill	0,5 m	H/15, min 2,0 m, max 5,0 m
Rockfill	2,0 m	H/25, min 1,0 m
Concrete Faced Rockfill	2,0 m	Plinth 3,0 m

Note: Assume excavation in rockfill core and plinth to be hard.

3.2.8 Foundation Grouting

- Blanket grouting: over invert of core trench and perimeter plinth: 5.0 m deep @ 2.0 m centres.
- Curtain grouting: on centreline of core trench or perimeter plinth: 0,75H and spacing 2.0 m centres.

3.2.9 Reinforced Concrete Facing

- Slab thickness: 0,01H, tapered, min 350 mm at crest.
- Perimeter plinth: 4,0 m x 1.5 m dowelled.
- Vertical joint spacing in facing slab: 15.0 m max width, with rubber water stops continuous in up slope direction.

3.2.10 Intake and Outlet Works

Provision of free standing tower, or concrete lined vertical shaft:

- Min diameter 2.0 m, max diameter 6.0 m.
- Dual gate/valve system.
- Stoplogs and screens.
- Bridge access to tower.
- Diversion tunnels through abutment for dams over 50 m height.

Outlet works sized to lower reservoir from full to 10% capacity in 90 days, excluding any inflows.

Stoplogs and operating gates to be accessible from above maximum water level.

3.2.11 Reservoir Basin Purchase Lines

Purchase area below the level pool safety evaluation flood level + 1.0 m.

3.3 Concrete Weirs

3.3.1 Definition of a Weir

For the purpose of applying these guidelines, a weir is considered to be a dam that is classified as a Category I dam in terms of the dam safety regulations. However, at both the Boschkop and Vlieëpoort weir sites on the Crocodile River (West), the 1:100 year flood depths exceed 12 m. If the top of the structure at the pumps is taken above the 1:100 year flood level because of the hazard rating, these weirs will be categorized as of medium size. The weirs are, however, low (FSL) and sunny day failures should not have a major impact on the river downstream. The loss of lives rating would be minimal to significant (say < 10 lives) at most, but the economic and strategic loss rating is very high, due to the impact on the Crocodile River (West) Transfer Scheme. These weirs have therefore been classified as Category II structures, based on the SANCOLD guidelines[(1).] This classification justifies the use of the Possible Maximum Flood (PMF) for the SEF and the 1:200 flood as the RDF.

3.3.2 Flood Determination and Spillway Sizing

3.3.2.1. Flood Magnitudes

Based on the December 1991 edition of "Guidelines on Safety in Relation to Floods" by SANCOLD [(1)]:

- Recommended Design Discharge (RDD) : 1:50 year flood
- Safety Evaluation Discharge (SED) : Regional Maximum Flood (RMF) for the next lower region than the weir site.

3.3.2.2. Flood Attenuation

Ignore any flood attenuation.

3.3.2.3. Freeboard

The total freeboard provided, measured from the spillway crest, shall be the greater of:

i) The flood surcharge + 1.5 m when passing the un-attenuated RDD; or
ii) The flood surcharge when passing the un-attenuated SED for any embankment sections or 0.5 m less than the flood surcharge when passing the un-attenuated SED for any concrete sections.

3.3.2.4. Spillway Aprons

Allow for a concrete apron 1 m thick with nominal surface reinforcing of 0.1% of the area of the cross-section in both directions.

Allow for an apron length equal to the height difference between the apron invert and the NOC level, provided that the apron is founded on sound rock.

3.3.2.5. Construction Floods and Cofferdams

The construction period for weirs will generally be much shorter than for dams.

Based on the aforementioned SANCOLD guidelines use:

- 1:5 year flood for a 1 year river construction period; and
- 1:10 year flood for a 2 year or longer river construction period.

The cofferdams need have no freeboard above the water surface when passing the aforementioned construction floods.

Figure 3-1: Typical Cross Section through Embankment Dam Non-overspill Crest

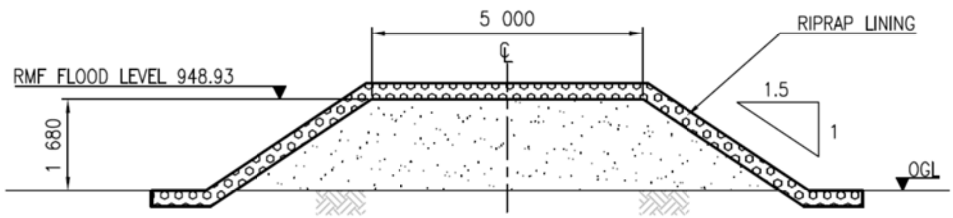
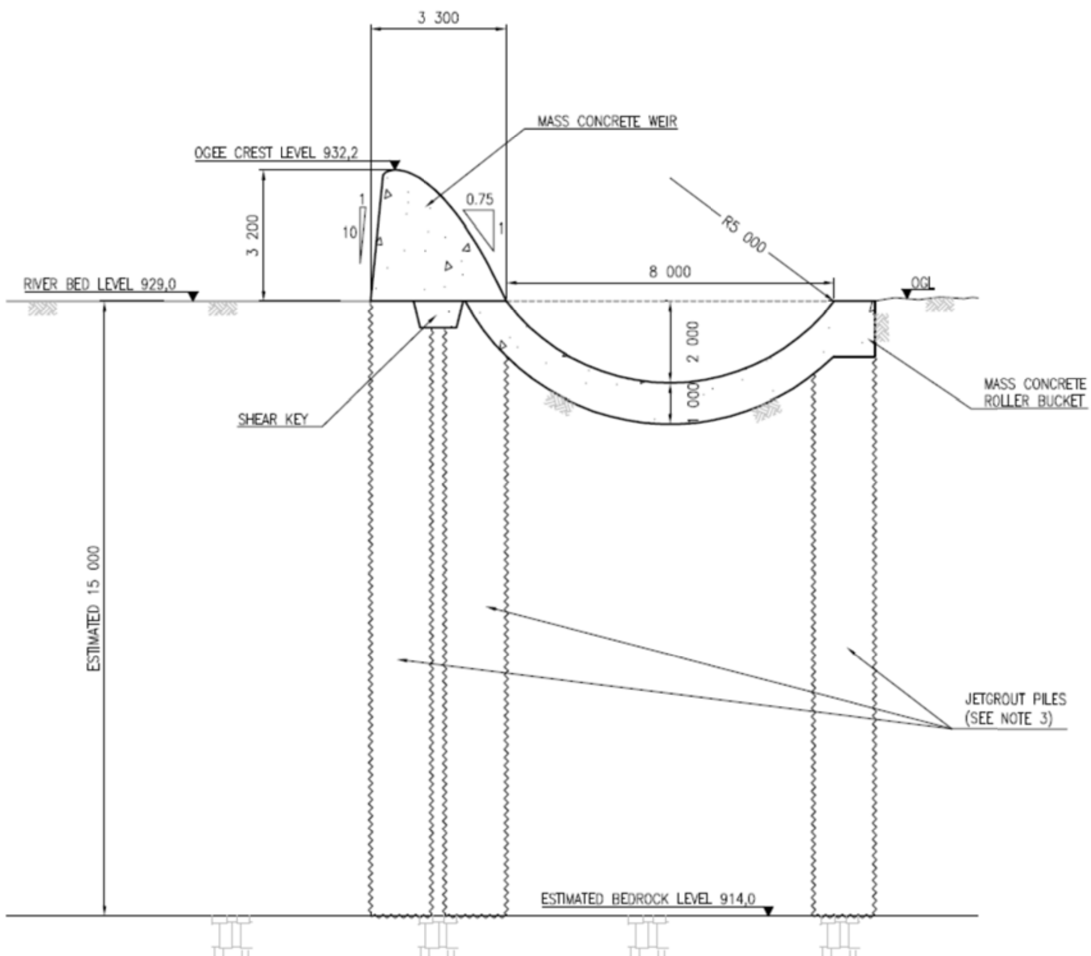


Figure 3-2: Typical Cross Section through Weir Spillway



3.3.3 Foundation Grouting and Drainage

Allow for a grout curtain with holes spaced 2.0 m apart.

Ignore drainage holes but work on a grout curtain depth equal to the water depth at FSL above the founding level, with a minimum grout curtain depth of 5.0 m. The grout curtain is to extend along the flanks to where the founding level reaches FSL + 1.0 m.

3.3.4 Excavation Depths

The excavation depths to be adopted must be assessed on an individual basis for each weir.

3.3.5 Reservoir Purchase Lines

Allow to purchase the area below the level of the un-attenuated SED + 1.0 m

3.4 Canals

3.4.1 Design Capacity

3.4.1.1. The Design Capacity

Calculation for determining the design flow to allow for a downtime period of 28 days per year for planned and unplanned closures:

- Q design = (Q AAD[(1)] x 1.3) + Evaporation losses + Seepage losses if there is a balancing dam at the end of the canal section.
- Evaporation Losses = Maximum Gross = 1 800 mm/a.
- Seepage Losses = 0.35 ℓ/s/1 000 m² of wetted perimeter –
- AAD – Average Annual Demand

3.4.1.2. Evaporation Losses

Maximum gross monthly open water evaporation applied to the top water width of the canal.

3.4.1.3. Seepage from Canal

Minimum of 0,55 ℓ/s/1 000 m² of wetted perimeter.

3.4.2 Canal Cross-section

3.4.2.1. Shape

Trapezoidal canal sections were used, taking into consideration the following cost factors:

- minimum wetted perimeter;
- geological conditions;
- ground water table and uplift forces;
- construction technology;

- under-drainage outlet costs; and
- seepage.

Although the proportion b/y = 0,6 where b = bed width and y = design flow depth, provides for the smallest wetted perimeter, it has been proven in practice that the most cost effective section would have a ratio of b/y = 1,0 for small canals, and b/y = (1,0 to 2,0 or higher) for large canals.

3.4.2.2. Friction Factor and Slope

- Manning "n" = 0,015.
- Slide slopes of trapezoidal section 1:1,5.

3.4.2.3. Velocities

Velocities in the canal were allowed to reach approximately 1 m/s, but mostly fell in the range of 0,8 m/s to 1,5 m/s. A Froude number < 0,8 was adopted. Where high proportions of rock excavation or sedimentation problems were expected, engineering judgment should be used.

3.4.2.4. Freeboard

Freeboard to accommodate a flow 20% in excess of the design flow (Q design) plus the velocity head component:

- $V^2/2g$
- Where V = mean canal velocity corresponding to the 20% overload flow.

3.4.2.5. Lining Type and Design

Costs were based on a concrete lining taken to the top of the canal cross section.

LINING DEPTH (m)	CONCRETE THICKNESS (mm)	REINFORCEMENT
< 0,5	60	Ref no 100
0,5 – 1,5	75	Ref no 100
1,5 – 4,0	100	Ref no 193
> 4,0	115 to 125	Ref no 193 to 245

3.4.2.6. Trimming and Backfilling

150 mm of over-excavation below canal lining and backfilled with selected compacted material.

Where potentially expansive soils occur: over-excavation to a depth of 2 m and laterally 1 m outside the lining on both sides of the canal and replace with selected compacted backfill was allowed for.

3.4.2.7. Joints and Joint Sealant

Transverse joints at 2.5 m centres and longitudinal joints at maximum intervals of 5 m were adopted to accommodate labour intensive construction methods.

Suitable sealant according to DWA specification.

3.4.2.8. Under Drainage and Flotation Forces

The interface between the top edge of the lining and the fill was covered with a 60 mm wide strip of 0.25 mm plastic sheet along the whole length of both sides of the canal.

2 x 150 mm (or larger) under drainage pipes installed at the bottom edges were adopted.

Outlets at an average spacing of 50 m were adopted.

3.4.2.9. Open Cuts and Embankments

Slide slopes for open cuts: 1:1,5 in soft materials. In hard materials discretion and engineering judgment was used.

3.4.2.10. Berms

2 m Wide provided at 7.5 m vertical intervals where cut depth exceeds 10 m.

3.4.2.11. Embankments

Slide slopes 1:2 and compacted.

3.4.3 Canal Servitude

- Up to 8 m³/s 40 m servitude
- 8 m³/s to 12 m³/s 45 m servitude
- 12 m³/s to 24 m³/s 50 m servitude

3.4.4 Fencing and Gates

Canals away from population concentration, but subject to infrequent visits with access from farms or public roads, 100 m upstream of inlet structures and 100 m downstream of outlet structures – DWA class B fencing.

3.5 Pipelines

3.5.1 General

For the Pre-feasibility Stage, it was assumed that all pipes to be fabricated in grade X 42 – 300 WA spiral welded mild steel for the Pre-feasibility Study. This will be revisited during the feasibility stage where optimizing of the system will take place.

It was assumed that corrosion protection is Sintakote external and epoxy internal lining

It was assumed that joints are butt welded for diameters 600 mm and larger. For smaller diameters Viking-Johnson couplings were assumed.

All pipes were assumed to be buried, except where extreme topography or physical obstructions suggested otherwise. See Figure 3-4 for excavation dimensions.

The pipeline capacities and sizing allow for water losses (as previously described) where relevant.

3.5.2 Pipeline Servitudes

Servitudes are typically 40 – 50m wide during construction and reducing to 20 – 30m permanent.

3.5.3 Friction Loss

The friction loss is based on the Colebrook-White and Darcey-Weisbach formulae with an effective roughness of 0.5 mm for an epoxy lined pipe over the economic life-span of the pipeline (45 years).

3.5.4 Operational Period

The operational period is based on the following assumptions:

- Pipelines — 18 days downtime per annum.
- 24-hour pumping per day.

3.5.5 Secondary Head Losses

Secondary losses of 0.25 m/km of pipe have been assumed to cater for bends, valves, etc.

3.5.6 Peak Flow Factor

Considering the Reliability and Redundancy requirements the design flow was calculated with due allowance for a downtime period of up to 18 days continuous per year for planned and unplanned closures, consumer peaks as well as a storage dam re-fill peak of 120% for pipelines.

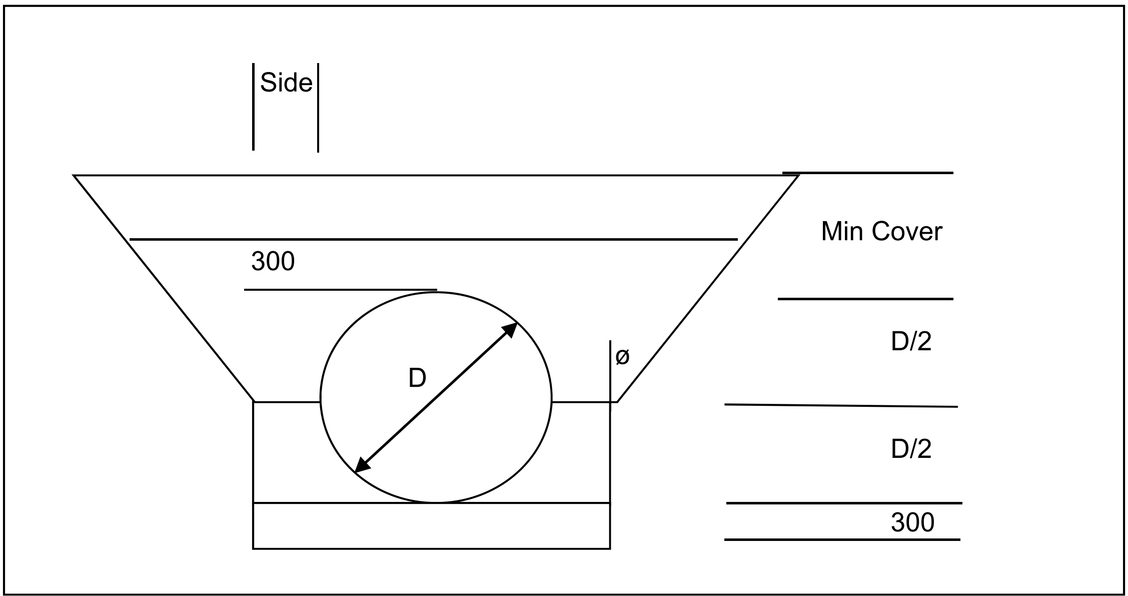
3.5.7 Flow Velocities

Flow velocities were fixed between 1 and 2.5 m/s at peak flow, with 1.8 m/s accepted as the norm, for purposes of sizing pipelines.

3.5.8 Residual Pressure

A residual pressure of 15 m at the delivers end of the rising and gravity mains of 15 m has been assumed to ensure a discharge pressure and allow for inaccuracies in static heads determined from the 1:50 000 mapping that formed the only basis for establishing the longitudinal profiles of the pipelines.

Figure 3-3: Typical Pipeline Excavation Detail



3.5.9 Maximum Pipe Diameter

The maximum diameter allowed is 2.4 m where this restriction dictated flow velocities, in excess of 3 m/s then multiple pipes of equal diameter were used.

3.5.10 Wall Thickness

The pipe wall thickness is to be determined using the formula:

$$t = \frac{P \times D}{290}$$ where

t = wall thickness in mm

D = outside diameter of pipe in mm

P = normal working pressure (excluding water hammer) in MPa

The formula allows for normal surge protection.

Wall thickness was chosen to be between the limits:

t min = D/180, and

t max = 22 mm.

Minimum yield strength of the steel is 290 MPa.

3.5.11 Pipe Bedding and Backfill

Rates for selected backfill allowed only for selection where excavation is in soft material, while screening was be included with intermediate material and importation of selected backfill in case of rock excavation.

Compaction was assumed to be to 90% of Mod AASHTO maximum dry density.

3.5.12 Energy Dissipation at Rising Main Outlets

Allowance is made for energy dissipation on the rising main outlets by means of flow control valves.

3.5.13 Gravity Pipeline

Gravity pipelines discharging into dams were assumed to be controlled by a sleeve valve, seated in a valve chamber, discharging onto a concrete apron.

Gravity pipelines discharging into canals were assumed to be controlled via a pressure/flow reducing valve seated in a valve chamber.

Standby valve capacity of 100% was provided at the outlet. The number of sleeve valves does not have to be the same as the number of pumps feeding the rising main since the sleeve valves are adjustable.

3.5.14 Valves

3.5.14.1. Isolating Valves

One butterfly valve was allowed for every 5 km.

3.5.14.2. Air Valves

One double orifice air valve was allowed for every kilometre. The valve diameter was not less than 1/6 of the pipeline diameter. Where this standard required an air valve diameter larger than 300 mm, multiple valves were allowed for.

3.5.14.3. Drain Valves

Allowance was made for two gate valves every 5 km gate valve and one sleeve valve every 5 km for heads greater than 60 m. The valve diameter allowed for was not less than 1/3 of the pipe diameter, up to a maximum valve diameter of 900 mm.

3.5.15 Surge Protection

One non-return valve every 5 km was allowed for.

3.5.16 Break Pressure Reservoir

Break pressure reservoirs were provided at the end of the rising mains and allowed for four (4) hours pumped storage capacity.

3.5.17 Road, River and Rail Crossings

The national and major provincial roads crossings, as well as the rail crossings pipe jacking was allowed for across the full width of the servitude.

3.5.18 Operating Pressure

The maximum operating pressure was limited to 350 m to ensure that the surge pressures would be within 400 m. This would also ensure that Table 40 flanges were not exceeded.

3.6 Pump Stations

The criteria that were adopted are set out below.

3.6.1 Parameters for Energy Calculations

Efficiency of pumps : 90%
Efficiency of motors : 97%

This does not apply for the submersible grit pumps where the efficiencies will be a bit lower.

- Maximum allowable loss in efficiency between major overhauls : 3%
- Average loss in efficiency used for energy calculations : 1,5%
- Overall efficiency : (0,90 × 0,97 × (1 - 0,015)) × 100% : 86,0%
- Power factor (MW/MVA) : 0,96

Major overhaul were allowed for every 15 years. Shorter period of time for water containing silt, sand or other abrasive media.

Provision was made as a lump sum for the supply of electricity to site. This was site specific and provided for all costs expected up to the pump station.

3.6.2 Number of Pump Sets and Standby Capacity

- Breakdown allowance: 5% per annum or 18 days per year (resulting from power failures, pump/motor/switchgear breakdown).

- Limitation on pump size: minimum of two duty pump sets plus one standby pump set, but not less than 25% of the number of duty pump sets.

3.6.3 Type/Size of Motor

Up to 10 000 kW, operating at 11 kV.

Safety factor: motors were sized 10% in excess of calculated power absorbed by pump.

3.6.4 Costing of Pump Stations

The cost model (based on the total installed motor size) for the mechanical and electrical components are given in Section 4.3.

The breakdown of major cost components of the pump stations is given in Table 3-5.

Table 3-5: Breakdown of Major Cost Components for High Lift Pump Stations

Component	Min (%)	Max (%)	Average (%)	Average for Large Pump Stations (%)
Civil	20	45	35	30
Mechanical	35	60	50	50
Electrical	10	25	15	20

Note that the breakdown of the major cost components for the abstraction works will be different from the pump stations.

The total cost includes the following cost elements:

Electrical	:	switchgear, high and low voltage equipment and all cabling. (It excludes Eskom transmission cables, switch yard and transformers).
Mechanical	:	pump and motor sets inclusive of standby capacity, valves, pipework inside pump station up to and including standard suction and delivery manifolds and overhead crane. As part of the mechanical cost two complete rotating elements (impeller, shaft and bearings) are included at 20% of the cost of the pump.
Civil	:	pump basement (substructure), superstructure, including area for switch and control gear, workshop (electrical/mechanical), stores, office area and ablution facilities. *It excludes forebays and emergency storage, which form part of the other separately costed components.*

3.6.5 Mechanical (further breakdown of costs):

Pumps and motors	:	60% of total mechanical cost
Valves	:	25% of total mechanical cost
Pipework	:	15% of total mechanical cost

Note that the breakdown of the mechanical cost is different for the submersible pumps.

The total cost excludes landscaping, miscellaneous, preliminary and general planning, design and supervision, and VAT, which is added separately for each pump station.

Additional site specific costs that were allowed at pump stations were:

- Power transmission lines from Eskom grid to pump station
- Access roads
- Special site conditions such as rock excavation, poor ground conditions, etc.
- Cost of relocation and land acquisition.

3.6.6 Sizing of Forebay and Emergency Storage

Forebay volume	:	minimum volume 4 hour of pump station design flow (to be optimised in later phases of study).
Balancing storage volume	:	volume shall be sufficient to accommodate fluctuations in river flow conditions over a 5 day period (or as determined) in the case of the Crocodile river

3.6.7 Head Losses

Intake screen	:	0,20 m
Suction losses	:	0,35 m
Delivery losses	:	2,45 m
Manifold losses	:	0,40 m
Forebay drawdown	:	0,60 m (where applicable)
Total loss	:	4,00 m per pump station

3.6.8 Pump Station Layout

Pumps and pipework inside pump station were installed low enough to ensure that the net positive suction head (NPSH) required by the pumps will be achieved.

Pump stations to include switch and control gear rooms, electrical and mechanical workshops, stores, control room/office area and ablution facilities, in addition to the pump basement and loading bay.

3.6.9 Telemetry

A telemetry system is to be allowed for on the rising mains as part of the pump station costs.

3.7 Social, Environmental and Administration Costs

3.7.1 Social and Compensation Costs

In the economic analysis, social and compensation costs were treated as a lump sum disbursement taking place during the second year of construction.

The number of people affected and relocated was reflected separately. The acquisition of land was handled as site specific with a rate per hectare for the specific area.

Structures were costed separately using current market costs.

3.7.2 Environmental and Social Studies

Not costed as this is done as a separate study.

3.7.3 Administration Costs

No allowance has been made for administration costs as the project will be managed / administered by DWA who already has the necessary structures/systems for such a project in place.

3.8 Redemption Periods, and Operation and Maintenance Costs

The redemption periods and operation and maintenance costs for the respective items are listed in the table below.

Table 3-6: Redemption Periods and Operation and Maintenance Costs

Component	Redemption Period	Annual Operation and Maintenance and Costs (excluding Energy)
Dams:		
- Civil works	45 years	0,25% p.a.
- Mechanical and Electrical	45 years	4,0% p.a.
Pipelines and Canals:		
- Civil works	45 years	0.50% p.a.
- Mechanical and Electrical	45 years	4,0% p.a.
Pumping Stations:		
- Civil works	45 years	0,25% p.a.
- Mechanical and Electrical	45 years	4,0% p.a.

Major overhauls of 15% of the initial capital cost of all mechanical and electrical equipment were provided for every 15 years.

4. COST MODELS

Simple spread sheet cost models were developed for each of the following engineering components:

- Main Concrete Dams and Weirs (See Section 4.1)
- Embankment (Earthfill) Dams
- Pipelines
- Pump Stations
- Canals

The cost models were based on those developed for the 1996 VAPS Study[5]. These cost models consist of a Bill of Quantities with parametric unit cost rates for each of the direct cost pay items considered to be representative of the main cost items. The parametric unit rates were developed to include for the typical costs of those items that are not measured at his level of study detail. Percentage allowances were made for non-measured cost items which include Preliminary and General (P&G), landscaping, miscellaneous, contingency, planning and design supervision items.

The “Pay Ref.” column is used to cross-reference the item description in the cost model with the corresponding item in the Method of Measurement given in Section 5.

The base date for the rates given in the models is **April 2008**. Where required, historic cost rates were escalated to the base date using the Contract Price Adjustment Factors (CPAF) published by SAFCEC [6].

4.1 Mass Concrete Dam and Weir Cost Model

The Dam and Weir Cost Model was based on the dam cost model generated for the 1996 VAPS Study[5]. Where it was considered appropriate, additional measured direct cost items were added to enhance the reliability of the calculated cost.

The parametric cost rates used in the cost model were calculated using the original rates calculated for the 1996 VAPS Study[5]. These were considered the most appropriate rates for use in this costing exercise.

The base date of the VAPS rates was April 1994. The escalation factor to April 2008 was calculated to be 3.952.

As an exercise, the rates shown in the following table were also used to check the cost estimated using the VAPS rates for a typical MCWAP dam. The Lesotho Highlands Further Phases (LHFP) and Lower Orange River Management Study (LORMS) rates compared well with the VAPS rates. However, the Mooi-Mgeni[7] rates were of a completely different order.

Table 4-1: Cost Estimates, using the VAPS rates for a Typical MCWAP Dam

Rate	Base Date	Amount (April 08)	Difference to VAPS Estimate April 08)
VAPS Study	April 1994	R 791,370,870	0.0%
LHFP Study	January 2006	R 724,384,103	- 8.5 %
LORMS Study	April 2004	R 790,126,815	- 0.2%
Mooi Mgeni River Transfer Scheme Phase 2 Feasibility Study	April 2008	R 1,825,603,689	+ 130.7%

The major difference was found to be in the rates used for "Preparation of Solum". A comparison of these rates is shown in the table below. It is believed that the basis of the quantities measured may be different but no further details were available to check if this was indeed the case. As such, the Mooi Mgeni[(7)] rates could not be used with confidence and were discarded.

Table 4-2: "Preparation of Solum" – Comparison of Rates

No	Pay Ref	Description	Unit	VAPS Rate	LHFP Rate	LORMS Rate	Mooi Mgeni Rate
				01-April-08	01-April-08	01-April-08	01-April-08
4	**4.0**	**Preparation of solum**					
	4.1	a) all materials	m^2	20	14	15	122
	4.2	b) extra over for rock	m^2	20	14	15	612

Table 4-3: MCWAP Dam Cost Model

MCWAP DAM COST MODEL

No	Pay Ref	Description	Unit	QUANTITY	RATE (Mar 08)	AMOUNT (Mar 08)
1	1.0	**Clearing**				
	1.1	a) Sparse	ha		5,533	
	1.2	b) Bush	ha		16,598	
	1.3	c) Trees	ha		27,664	
2	2.0	**River Diversion**	Sum		1,725,000	
3	3.0	**Excavation**				
	3.1	(a) Bulk				
	3.1.1	(i) all materials	m^3		40	
	3.1.2	(ii) extra over for rock	m^3		71	
	3.2	(b) Confined				
	3.2.1	(i) all materials	m^3		59	
	3.2.2	(ii) extra over for rock	m^3		99	
4	4.0	**Preparation of solum**				
	4.1	a) all materials	m^2		20	
	4.2	b) extra over for rock	m^2		20	
5	5.0	**Drilling & Grouting**				
	5.1	(a) Curtain grouting	m drill		443	
	5.2	(b) Consolidation grouting	m drill		443	
	5.3	(c) Jet grouting	m drill		4,370	
6	6.0	**Embankment**				
	6.1	(a) Earthfill	m^3		47	
	6.2	(b) Filters	m^3		174	
	6.3	(c) Rip-rap	m^3		95	
	6.4	(d) Overhaul beyond 5km	m^3.km		4	
	6.5	(e) Waterproof Membrane System	m^2		100	
	6.6	(f) Geofabric	m^2		30	
7	7.0	**Concrete works**				
	7.1	a) Formwork				
	7.1.1	(i) Gang formed	m^2		257	
	7.1.2	(ii) Intricate	m^2		316	
	7.2	(b)Concrete				
	7.2.1	(i) Mass	m^3		1,156	
	7.2.2	(ii) Structural	m^3		1,482	
	7.3	(c) Reinforcing	t		12,350	
		SUB-TOTAL				
8	8.0	**Mechanical Items**				
	8.1	(a) Pipes, Valves & Gates	Sum		4,725,000	
	8.2	(b) Cranes & hoists	Sum		600,000	
	8.3	(c) Structural steelwork	t		19,760	
9	9.0	**Fencing**	km		27,664	
10	10.0	**Landscaping** (% of 1-9)	%		5	
11	11.0	**Miscellaneous** (% of 1-9)	%		10	
		SUB TOTAL A				

No	Pay Ref	Description	Unit	QUANTITY	RATE (Mar 08)	AMOUNT (Mar 08)
12	12.0	**Preliminary & General** (% of sub-total A)	%		30	
13	13.0	**Preliminary works**				
	13.1	(a) Access road	km		350,000	
	13.2	(b) Electricity to site	Sum		250,000	
	13.3	(c) Water to site-construction (not potable)	Sum		150,000	
	13.4	(d) Railhead & materials handling	Sum			
14	14.0	**Accomodation**	Sum			
		SUB TOTAL B				
15	15.0	**Contingencies** (% of sub total B)	%		20	
		SUB TOTAL C (Civils Total)				
16	16.0	**Planning design & supervision** (% of sub-total C)	%		15	
		SUB TOTAL D				
17	17.0	**VAT** (% of sub-total D)	%		14	
		NETT PROJECT COST				
18	18.0	Cost of relocations	Sum			
19	19.0	Cost of land acquisition	Sum			
		TOTAL PROJECT COST				

4.2 Pipeline Cost Model

The Pipeline Cost Model was based on the cost model generated for the 1996 VAPS Study(5). Where it was considered appropriate, additional measured direct cost items were added to enhance the reliability of the calculated cost.

The parametric cost rates used in the Cost Model were calculated using the Vaal River Eastern Sub-System Augmentation Project (VRESAP) Contract V020 Bill of Quantities(8). This is considered the most recent relevant costs for a pipeline construction project of this type and scale. The only exception was for the cost of supplying steel pipe (Pay Ref 4.). In this case current quotes were obtained from pipe suppliers.

The base date of the VRESAP rates was January 2006. The escalation factor to April 2008 was calculated to be 1.211.

Table 4-4: MCWAP Pipeline Cost Model

MCWAP PIPELINE COST MODEL

No	Pay Ref	Description	Unit	QUANTITY	RATE (Mar 08)	AMOUNT (Mar 08)
1	1.0	Route Clearing & grubbing				
	1.1	(a) Sparse, bush & trees	Ha		10,300.00	-
	1.2	(b) Other	Ha			
2	2.0	Road, river and rail crossings				
	2.1	(a) national & provincial road	no		700,000.00	-
	2.2	(b) gravel road	no		700,000.00	-
	2.3	(c) river	no		1,250,000.00	-
	2.4	(d) rail	no		1,800,000.00	-
3	3.0	Trench Excvation & backfill				
	3.1	(a) Excavation				
	3.1.1	All materials	m³		50.00	-
	3.1.2	E/O Hard	m³		100.00	-
	3.2	(b) Bedding				
	3.2.1	From trench	m³		135.00	-
	3.2.2	From commercial sources	m³		235.00	-
	3.3	(c) Bedding Cradle & Fill Blanket				
	3.3.1	From trench	m³		210.00	-
	3.3.2	From commercial sources	m³		245.00	-
	3.4	(d) Main Fill				
	3.4.1	From trench	m³		55.00	-
	3.5	(e) Spoil	m³		45.00	-
4	4.0	Pipelines				
	4.1	(a) Supply of steel pipe: D/t ratio as specified. Sintakote external coating and epoxy internal lining				
		Dia (mm) Grade D/t				
	4.1.1	2000 API Grade X42 160	m		From Pipeline Price Schedule	
	4.1.2	0 API Grade X42 160	m			
	4.1.3	0 API Grade X42 160	m			
	4.2	(b) Laying & jointing (% of a)			20.00%	-
	4.3	(c) Air valve, Isolating Valve, Scour Valve, Access All valve types, incl chamber - civil & mechanical components	m		775.00	-
	4.4	(d) Cathodic Protection	m		390.00	
		SUB-TOTAL A				-
5.	5.0	Landscaping & EIA Remediation (% of Sub-total A)	%		5.00%	-
6.	6.0	Miscellaneous (% of Sub-total A)	%		10.00%	-
		SUB TOTAL B				-
7.	7.0	Preliminary & General (% of Sub-total B)	%		30.00%	-
8.	8.0	Preliminary works				
	8.1	(a) Access road	km		350,000.00	-
	8.2	(b) Electricity to site	Sum			
	8.3	(c) Water to site - construction (not potable)	Sum			
	8.4	(d) Railhead & materials handling	Sum			
9.	9.0	Accommodation	Sum			
		SUB TOTAL C				-
10.	10.0	Contingencies (% of Sub-total C)	%		10.00%	-
		SUB TOTAL D				-
11.	11.0	Planning design & supervision (% of Sub-total D)	%		15.00%	-
		SUB TOTAL E				-
12.	12.0	VAT (% of sub total E)	%		14.00%	-
		NETT PROJECT COST				-
13.	13.0	Cost of relocations	Sum			
14.	14.0	Cost of land acquisition	Sum			
		TOTAL PROJECT COST				-

4.3 Pump Station Cost Models

The Pump Station Cost Model was based the cost model generated for the 1996 VAPS Study[5]. The Mechanical and Electrical cost component was estimated from a graph developed from similar pump station costs obtained from DWA.

Table 4-5: MCWAP Pump Station Cost Model

MCWAP PUMP STATION COST MODEL

No	Pay Ref	Description	Unit	RATE (Mar 08)	QUANTITY	AMOUNT (Mar 08)
1	1.0	Mechanical and Electrical (from graph)	Sum			
2	2.0	Civils				
	2.1	(a) (% of 1)	%	43%		
	2.2	(b) Permanent access road	km	3,000,000		
		SUB-TOTAL A				
3	3.0	Landscaping (% of Sub-total A)	%	5		
4	4.0	Miscellaneous (% of Sub-total A)	%	10		
		SUB TOTAL B				
5	5.0	Preliminary & General (% of sub-total B)	%	30		
		SUB TOTAL C				
6	6.0	Contingencies (% of sub total C)	%	10		
		SUB TOTAL D				
7	7.0	Planning design & supervision fees, time cost & transport (% of sub total D)	%	15		
		SUB TOTAL E				
8	8.0	VAT (% of sub total E)	%	14		
		NETT PROJECT COST				
9	9.0	Cost of relocations	Sum			
10	10.0	Cost of land acquisition	Sum			
11	11.0	Cost of ESKOM transmission lines to site + Connection fee	Sum			
		TOTAL PROJECT COST				

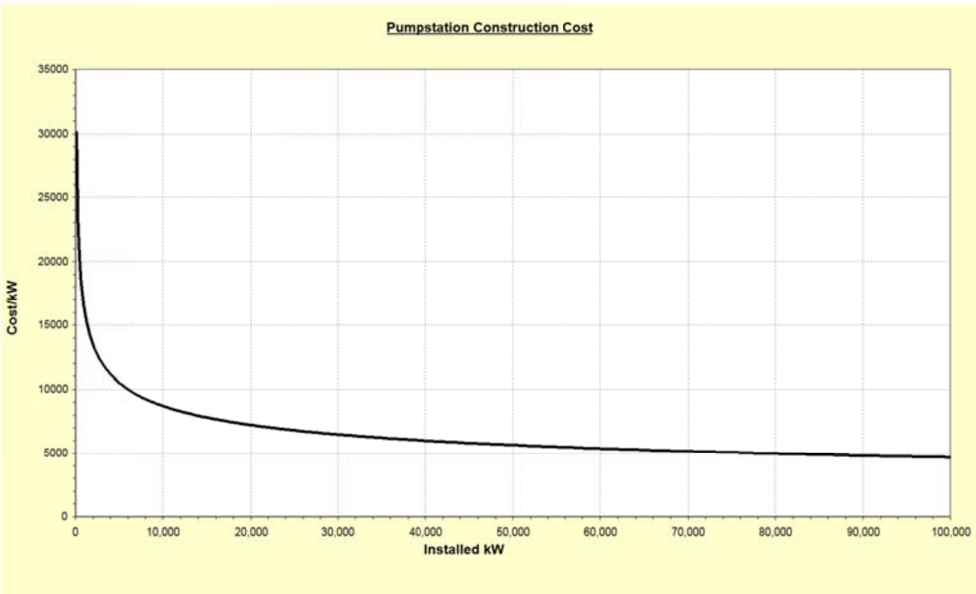


Figure 4-1: Pump Station Construction Cost

4.4 Canal Cost Model

The Canal Cost Model was based on the canal cost model generated for the 1996 VAPS Study(5). Where it was considered appropriate, additional measured direct cost items were added to enhance the reliability of the calculated cost.

The parametric cost rates used in the cost model were calculated using the original rates calculated for the 1996 VAPS Study(5). These were considered the most appropriate rates for use in this costing exercise.

The base date of the VAPS rates was April 1994. The escalation factor to April 2008 was calculated to be 3,952.

Table 4-6: MCWAP Canal Cost Model

MCWAP CANAL COST MODEL

No	Pay Ref	Description	Unit	RATE (Mar 08)	QUANTITY	AMOUNT (Mar 08)
1	1.0	**Site clearing**				
	1.1	(a) Sparse	ha	5,535		
	1.2	(b) Bush	ha	16,600		
	1.3	(c) Trees	ha	27,665		
2	2.0	**Benching (forming the terrace)**	Sum			
	2.1	(a) all materials	m^3	36		
	2.2	(b) extra over for rock	m^3	83		
3	3.0	**Canal excavation**				
	3.1	(a) all materials	m^3	40		
	3.2	(b) extra over for rock	m^3	111		
4	4.0	**Canal fill**				
	4.1	(a) from excavation	m^3	44		
	4.2	(b) from borrow	m^3	60		
	4.3	(c) selected layer to 90% modified AASHTO	m^3	160		
	4.4	(d) overhaul beyond 10km	m^3/km	4		
5	5.0	**Trimming over canal perimeter**	m^2	16		
6	6.0	**Canal lining**				
	6.1	(a) concrete (including joints)	m^3	1,385		
	6.2	(b) mesh reinforcing	ton	13,850		
	6.3	(c) ground water drainage under canal lining	per m^2 of canal	20		
7	7.0	**Structures**				
	7.1	(a) excavation-soft	m^3	48		
	7.2	(b) rock extra over	m^3	210		
	7.3	(c) concrete	m^3	1,225		
	7.4	(d) formwork-intricate	m^2	317		
	7.5	(e) reinforcing	t	9,880		
		SUB-TOTAL				
8	8.0	**Fencing**	km	27,670		
9	9.0	Canal road 5m wide (m length canal)	m	350		
10	10.0	**Landscaping** (% of 1-9)	%	10		
11	11.0	**Miscellaneous** (% of 1-9)	%	10		
		SUB TOTAL A				
12	12.0	**Preliminary & General** (% of sub-total A)	%	30		
13	13.0	**Preliminary works**				
	13.1	(a) Access road	km	350,000		
	13.2	(b) Electricity to site	Sum			
	13.3	(c) Water to site-construction (not potable)	Sum			
	13.4	(d) Railhead & materials handling	Sum			
14	14.0	**Accomodation**	Sum			
		SUB TOTAL B				
15	15.0	**Contingencies** (% of sub total B)	%			
		SUB TOTAL C				
16	16.0	**Planning design & supervision** (% of sub-total C)	%			
		SUB TOTAL D				
17	17.0	**VAT** (% of sub-total D)	%			
		NETT PROJECT COST				
18	18.0	Cost of relocations	Sum			
19	19.0	Cost of land acquisition	Sum			
		TOTAL PROJECT COST				

5. METHOD OF MEASUREMENT

There are cost models for the following sections of the study:

1) Mass Concrete Dams and Weirs
2) Pipelines
3) Pump Stations
4) Canals

The cost models have been standardised measuring direct cost items and Preliminary and General items and items for design, supervision and contingencies.

It is assumed that cost estimates are based upon limited detail at the pre-feasibility stage. The cost models have thus been reduced to a few items only and most of these items embrace other activities. It is intended that parametric rates shall be used for measurement and cost estimation as described in the following paragraphs.

The cost models shall include a payment reference (Pay Ref) column where reference is made to the Method of Measurement clauses:

Table 5-1: Cost Models: Payment Reference to Method of Measurement Clauses

Pay Ref	Description
Dam – Pay Ref 1.1, 1.2, 1.3 Pipeline – Pay Ref 1.1, 1.2 Canal – Pay Ref 1.1, 1.2, 1.3	**Site Clearance** Clearing and grubbing of areas where excavation or placing of fill or where right of way clearance is required shall be measured but not for dam basins. Dam basins are covered in the percentage for miscellaneous. The area cleared for the dam construction will consist of the wetted perimeter of the valley multiplied by 100 m upstream and 100 m downstream of the centre line of the dam wall. The unit shall be **hectare (ha)**. Clearing shall be divided into three categories with each area being dealt with individually: • Sparse where only grass and roots are removed, transported to areas specified for disposal. • Bush, where the density of small trees and bush requires the use of a bulldozer. This is based on a percentage of the cleared area. • Trees, where plantations and the like are encountered which requires cutting of trees, removal by crane, trailer or logging equipment before a bulldozer can be used to remove stumps and roots. This based on a percentage of the cleared area.
Dam – Pay Ref 2.0	**River Diversion** The item is provided to cover activities associated with a river diversion, whether open channel or tunnel. The work involved in creating a sum for a diversion will have its own small bill of quantities or calculation. The unit shall be **lump sum**.
Canal – Pay Ref 2.1	**Excavation** *Benching* Benching for canals, pipeline or syphons is an item for forming a terrace from existing ground level down to a platform or terrace from which the canal profile, pipeline or syphon trench is excavated. The activity shall include excavation, generally placing the material alongside the canal, pipe trench or

Pay Ref	Description
	syphon excavation, but it shall also include for loading and transporting surplus material or unsuitable material to spoil dumps. The excavation shall assume that the material is soft. The unit for excavation, transport, etc. shall be **m³** and the free haul distance shall be 3 km.
Canal – Pay Ref 3.1	*Canal Excavation* Canal excavation shall be measured from terrace level to the profile shown on the drawings, which is 150 mm below the underside of the concrete canal lining. The activity shall include placing and compacting the excavated material in embankments either side of the canal, or disposing of surplus material, or disposal of material which is unsuitable upon which a canal can be constructed or unsuitable for fill in embankments. The excavation shall assume that the material is soft. The unit for excavation, transport etc shall be **m³** and the free haul distance shall be 3 km.
Dam – Pay Ref 3.1.1, 3.2.1	*Dam and structure excavation* Excavation for dams and structures shall be measured net plan area, and there are separate items for soft material and extra over for rock. The unit shall be **m³**.
Dam – Pay Ref 3.1.2, 3.2.2 Pipeline – Pay Ref 3.1.2 Canal – Pay Ref 2.2, 3.2	*Extra over for rock* A separate item is provided for excavation in hard material which requires the use of drilling and blasting with explosives. The rate must include for any overbreak which may occur. The unit for extra over for rock shall be **m³**.
Canal – Pay Ref 5.0	*Trimming over canal perimeter* The item includes all activities required for preparing the surface of the selected layer to the profile shown on the drawings prior to placing the concrete lining. The selected layer is measured separately. The unit for trimming shall be **m²**.
Pipeline – Pay Ref 3.1.1	*Pipeline trench excavation* Trench excavation and backfilling for pipelines and syphons shall be measured to the width and depth shown on the drawings. The volumes calculated from the cross sections shall include for battering back of excavated side and shall be measured from the terrace level or from natural ground level if no terrace is formed. The excavation shall assume that the material is soft. The unit shall be **m³**.
Dam – Pay Ref 4.1, 4.2	*Preparation of solumn of dam or final foundation preparation* This item shall include for all activities to prepare the surface of the excavated foundation level, where required by the dam specification, to receive the earth or rockfill materials comprising the embankment or concrete in the dam wall.

Pay Ref	Description
	The excavation shall assume that the material is soft and an extra over item has been allowed for rock. The unit shall be **m²**.
Canal – Pay Ref 7.1, 7.2	*Structures* Excavation for structures shall be measured to the width and depth shown on the drawings. The volumes calculated shall include for battering back of excavated side and shall be measured from the terrace level or from natural ground level if no terrace is formed. The excavation shall assume that the material is soft and an extra over item has been allowed for rock. The unit shall be **m³**.
Canal – Pay Ref 4.1, 4.2	**Filling** *Canal Fill* Canal fill shall be measured wherever fill is required to form the canal profile. For instance where the entire canal is constructed on an embankment or where the volume of fill in an embankment either side of a canal exceeds the volume of excavation at that canal chainage. It will also be required where undercutting has taken place to remove unsuitable material below the canal. Where one or two embankment fills are constructed to form the canal profile, only the nett volume of the fill shall be measured. The fill shall be measured separately if it comes from borrow pits. The unit for canal fill shall be **m³** and its free haul distance shall be 10 km.
Canal – Pay Ref 4.3	A selected layer of material obtained from a borrow pit and placed 150 mm thick under the perimeter of the canal shall be placed throughout the length of the canal. The design criteria and drawings show this layer to be compacted to 90% Modified AASHTO. The unit for selected layer with a freehaul distance of 10 km, is **m³.**
Canal – Pay Ref 4.4	Overhaul on imported or selected material, unit **m³/km**.
Dam – Pay Ref 6.1	*Embankment Fill* Embankment fills for dams, weirs or cofferdams constructed of fill obtained from quarries shall include for drilling and blasting in a quarry using explosives, excavating and haulage of up to 5 km and depositing in embankment, spreading, watering and compacting to specification. The unit shall be **m³** of rockfill placed.
Dam – Pay Ref 6.2	Filter materials required in dams, weirs or cofferdams shall be obtained from natural deposits or by crushing and screening rock obtained in a quarry, for haulage up to 5 km and depositing in the embankment in zones as shown on the drawings. The unit shall be **m³** of filter material placed.
Dam – Pay Ref 6.3	Rip Rap shall be placed as required in thickness shown on the drawings and shall be obtained from borrowpits, and shall include for haulage up to 5 km.

Pay Ref	Description
   Dam – Pay Ref 6.4 Dam – Pay Ref 6.5 Dam – Pay Ref 6.6	The unit shall be **m^3** of rip rap placed. Overhaul of fill material for placing in embankment shall be measured over the free haul distance, the unit is **m^3/km**. Waterproof Membrane System shall include for the supply and installation of the plastic membrane, the geofabric backing and the sand bedding as required in the dam basin. The unit of measurement is **m^2.** Geofabric shall include for the supply and installation of the geofabric artificial filter below the rip-rap placed in weirs. The unit of measurement is **m^2.**
Dam – Pay Ref 5.1, 5.2, 5.3	**Drilling and Grouting (Foundation Treatment)** Activities of drilling and grouting for curtain, consolidation and jet grouting shall be measured as depth of hole drilled and injected with cementitious grout. The unit shall be **linear metre** (m).
Dam – Pay Ref 7.1.1, 7.1.2 Tunnel – Pay Ref 7.1, 7.2 Canal – Pay Ref 7.4	**Formwork** Where shuttering is required to form concrete, then the surface area of concrete formed shall be measured in square metres (**m^2**). The following categories of formwork are measured separately: • Formwork gang formed - (vertical, sloping or horizontal). • Formwork to structures - intricate. • Formwork inside tunnel or syphon-curved. No formwork shall be measured for construction joints. This will be included in the mass concrete rate.
Dam – Pay Ref 7.2.1, 7.2.2 Tunnel – Pay Ref 6.1, 6.2, 6.3, 6.4, 9.0 Canal – Pay Ref 6.1, 7.3	**Concrete** Concrete shall be of grade 30 MPa in all structures and measured in **m^3**. The following categories of concrete are measured separately: • Structural concrete (formwork and reinforcement measured separately) • Concrete in canal lining, minimum thickness 100 mm, including forming joints (reinforcement measured separately). • Concrete in tunnel lining, to specified thickness (formwork and reinforcement measured separately) • Concrete in dam (reinforcement measured separately) • Overbreak concrete in tunnels shall be measured separately and the unit is **m^2** of tunnel circumference on the specified tunnel lining back face. • Invert concrete in tunnels shall be measured separately and the unit is per **linear metre** (m) of tunnel. This shall include all formwork, concrete and reinforcement.
Dam – Pay Ref 7.3 Tunnel – Pay Ref 5.3, 8.0 Canal – Pay Ref 6.2, 7.5	**Reinforcement** Steel rod reinforcement in structures shall be cut, bent and fixed in position in accordance with the specification and drawings and is assumed to be high yield deformed bar. The unit for reinforcement shall be **tonne** (t). Mesh reinforcement in canals and tunnel linings shall be specified kg/m^2 and measured net area placed. The unit for mesh reinforcement shall be **m^2** for tunnels and **tonne** (t) for canals.

Pay Ref	Description
Pipeline – Pay Ref 2.1, 2.2, 2.3, 2.4	**<u>Pipelines</u>** *<u>Road, River and Rail Crossings</u>* River and road crossings will require diversion and deviation works and the extra costs will be allowed for in the provision of a **lump sum per crossing**. A separate calculation should be made and costed for this work. The following categories of crossing shall be measured separately: • National and Provincial Road • Gravel Road • River • Rail
Pipeline – Pay Ref 3.2.1, 3.2.2, 3.3.1, 3.3.2, 3.4.1	*<u>Bedding</u>* Following the excavation of a trench for pipelines, bedding material shall be placed from an approved source to dimensions shown on the drawings. Bed preparation shall be measured in $\mathbf{m^3}$. The following categories of bedding shall be measured separately: • Bedding • Bedding Cradle and Fill Blanket • Main Fill Separate items shall be measured for material sourced from the trench excavation and material from commercial sources.
Pipeline – Pay Ref 3.5	*<u>Spoil</u>* All additional material that will require to be spoiled shall be measured in $\mathbf{m^3}$.
Pipeline – Pay Ref 4.1	*<u>Pipelines</u>* Steel pipelines shall be specified for each diameter and wall thickness supplied to site. The rate shall include for joints and specials and for internal and external corrosion protection. The unit shall be **linear kilometre** (km).
Pipeline – Pay Ref 4.2	Laying and jointing of pipelines shall be measured separately and shall include for all activities of taking pipes from delivery points on site and installing in the trench with welding, making good of corrosion protection and testing as required. The unit shall be expressed as a **percentage** of the pipe supply item (%).
Pipeline – Pay Ref 4.3	*<u>Valve Chambers</u>* Valve chambers shall include all civil, structural and mechanical components required. The unit of measurement shall be **linear metre** (m) of constructed pipeline.
Pipeline – Pay Ref 4.4	*<u>Cathodic Protection</u>* Cathodic protection shall be measured where required. The unit of measurement shall be **linear metre** (m).
Canal – Pay Ref 6.3	**<u>Canals</u>** *<u>Ground Water Drainage Under Canal Lining</u>* This activity shall include the following: • Pitch fibre 100mm diameter slotted pipe wrapped in filter fabric • Plastic sheeting (to the specified grade and thickness) provided over pitch fibre pipe under the drain and under the berm at the top of the canal lining. To be provided on both sides as shown on the drawings. The unit of measurement shall be $\mathbf{m^2}$ of canal.

Pay Ref	Description
Dam – Pay Ref 8.1, 8.2, 8.3 Pump Station – Pay Ref 1.0	**Mechanical Items** Some cost models have mechanical equipment such as valves and structural steelwork. An item is provided for the cost of these mechanical items which will be allowances from experience for the type of work involved. The unit for mechanical items is **lump sum** to cover all valves gates, cranes, hoists and structural steelwork.
Pump Station – Pay Ref 2.1	**Pump Stations** *Civils* This item includes for all civil and structural work required constructing a pump station. The unit of measurement is a **percentage** (%) of the mechanical and electrical cost.
Dam – Pay Ref 10.0 Pipeline – Pay Ref 5.0 Canal – Pay Ref 10.0 Pump Station – Pay Ref 3.0	**Landscaping** The percentage allowance is to cover the cost of grassing to banks of canals and dams, and restoration of work areas after completion in accordance with environmental requirements. The allowance also includes for catchwater drains, canal right of ways and the rip rap at inlets and outlets of canal super passages or culverts. The provision of gravel on banks of dams is included in this item. The unit shall be expressed as a **percentage** (%) of the civil, electrical and mechanical construction cost.
Dam – Pay Ref 11.0 Pipeline – Pay Ref 6.0 Tunnel – Pay Ref 12.0 Canal – Pay Ref 11.0 Pump Station – Pay Ref 4.0	**Miscellaneous** The limited number of items in all cost models in the interest of simplicity means that unmeasured items have to be included in the total cost of the project as a percentage of the total of measured direct cost items. The unit shall be expressed as a **percentage** (%) of the civil, electrical and mechanical construction cost.
Dam – Pay Ref 9.0 Canal – Pay Ref 8.0	**Fencing** Both sides of the canal shall be fenced – rural specification. This also applies to fencing dam basins. The unit for fencing is **km**.
Dam – Pay Ref 12.0 Pipeline – Pay Ref 7.0 Tunnel – Pay Ref 13.0 Canal – Pay Ref 12.0 Pump Station – Pay Ref 5.0	**Preliminary and General** A percentage in each cost model is provided which covers the cost of most items of indirect nature. A few establishment type items have been excluded and given a separate cost item in the cost model. These are: The value allowed for preliminary and general items is measured as a **percentage** (%).
Dam – Pay Ref 13.1 Pipeline – Pay Ref 8.1 Tunnel – Pay Ref 14.1 Canal – Pay Ref 9.0, 13.1	**Preliminary Works** These items often included in the percentage for preliminary and general have been recognised as varying too much on a project of this size and therefore the following items are clearly defined and are to be costed individually. *Access road* These items are for the access road or roads to the construction site from the

Pay Ref	Description
Pump Station – Pay Ref 2.2	nearest public road and comprises a gravel, surfaced, all weather road 5 to 6 m wide. The cost includes all earthworks, layer works, drainage and fences that are constructed. The unit rate generally to be used is for roads in flat or undulating countryside, not hilly or with steep slopes. The unit for access roads is **km**.
Dam – Pay Ref 13.2 Pipeline – Pay Ref 8.2 Tunnel – Pay Ref 14.2 Canal – Pay Ref 13.2	*Electrical supply to site* Each site is "site specific" and no simple formula of kw demand × kilometres of overhead transmission lines is applicable. The unit for electrical supply to site is **lump sum**.
Dam – Pay Ref 13.3 Pipeline – Pay Ref 8.3 Tunnel – Pay Ref 14.3 Canal – Pay Ref 13.3	*Construction water to site* The requirements of a dam site, canal or tunnel project are different regarding water supply and consumption. Water can be extracted from a river for a dam site but canal sites, for instance, may require a temporary pipeline or provision of road tanker. The unit for construction water to site is **lump sum**. It should be noted that the cost of small quantities required for domestic use (potable water) are included in the Preliminary and General item.
Dam – Pay Ref 13.4 Pipeline – Pay Ref 8.4 Tunnel – Pay Ref 14.4 Canal – Pay Ref 13.4	*Railhead and material handling* Certain proposed schemes will have large quantities of cement for delivery to the project and upgrading of existing facilities may be required. This cost item is to be used where required for the cost of special upgrading/bypasses round residential areas etc. The unit for railhead and material handling is **lump sum**.
Dam – Pay Ref 14.0 Pipeline – Pay Ref 9.0 Tunnel – Pay Ref 15.0 Canal – Pay Ref 14.0	**Accommodation** Each project will have accommodation facilities for the supervisory and contractor's staff. The extent to which each project has to construct temporary or permanent accommodation will depend upon a number of factors including availability in local towns and the expected total of staff and workmen that have to be accommodated. The unit for accommodation is **lump sum**.
Dam – Pay Ref 15.0 Pipeline – Pay Ref 10.0 Tunnel – Pay Ref 16.0 Canal – Pay Ref 15.0 Pump Station – Pay Ref 6.0	**Contingencies** The allowance for all project costs due to unforeseen circumstances, claims and extra work is allowed as a **percentage** (%) of the total cost of direct and indirect work excluding consulting fees.
Dam – Pay Ref 16.0 Pipeline – Pay Ref 11.0 Tunnel – Pay Ref 17.0 Canal – Pay Ref 16.0 Pump Station – Pay Ref 7.0	**Planning Design and Supervision** The cost of consulting engineers' fees is allowed as a **percentage** (%) of the total of the direct and indirect work.

Pay Ref	Description
Dam – Pay Ref 17.0 Pipeline – Pay Ref 12.0 Tunnel – Pay Ref 18.0 Canal – Pay Ref 17.0 Pump Station – Pay Ref 8.0	**VAT** Value added tax is added as a percentage of the total cost of direct and indirect work and consulting fees. The unit for VAT is **percentage** (%).
Dam – Pay Ref 18.0 Pipeline – Pay Ref 13.0 Tunnel – Pay Ref 19.0 Canal – Pay Ref 18.0 Pump Station – Pay Ref 9.0	**Cost of Relocations** Each project will have an impact upon the landowners, existing services such as roads, and in some cases houses and other accommodation which will have to be relocated. The unit for relocation of services and accommodation shall be **lump sum**.
Dam – Pay Ref 19.0 Pipeline – Pay Ref 14.0 Tunnel – Pay Ref 20.0 Canal – Pay Ref 19.0 Pump Station – Pay Ref 10.0	**Cost of Land Acquisition** Land required for each project will have to be assessed regarding possible compensation and financial allowances must be made that are reasonable. The unit for acquisition is **lump sum**.
Pump Station – Pay Ref 11.0	**Cost of Eskom Transmission Lines & Connection Fee** An allowance for providing the required Eskom electrical power supply to the pump stations will need to be made. The unit for is **lump sum**.

6. PROJECT ENGINEERING ECONOMIC EVALUATION MODEL

The project economic evaluation model determines the present cost of a particular option by taking the capital and operation and maintenance costs into account. These costs are discounted against the discounted volumes of water supplied (valued at a nominal value of R1.00/m^3) over the economic life of the development option. A discount rate of 8% has been accepted to provide the relevant unit reference value (URV) against which all development options will be compared. The options were discounted for 6%, 8% and 10% to determine the sensitivity to the discount rate, the water volumes delivered and the recurrent costs such as operation and maintenance, electricity and raw water.

The following durations of the project cycle were allowed for when determining the URVs:

1) Feasibility Study and Design : 3 years

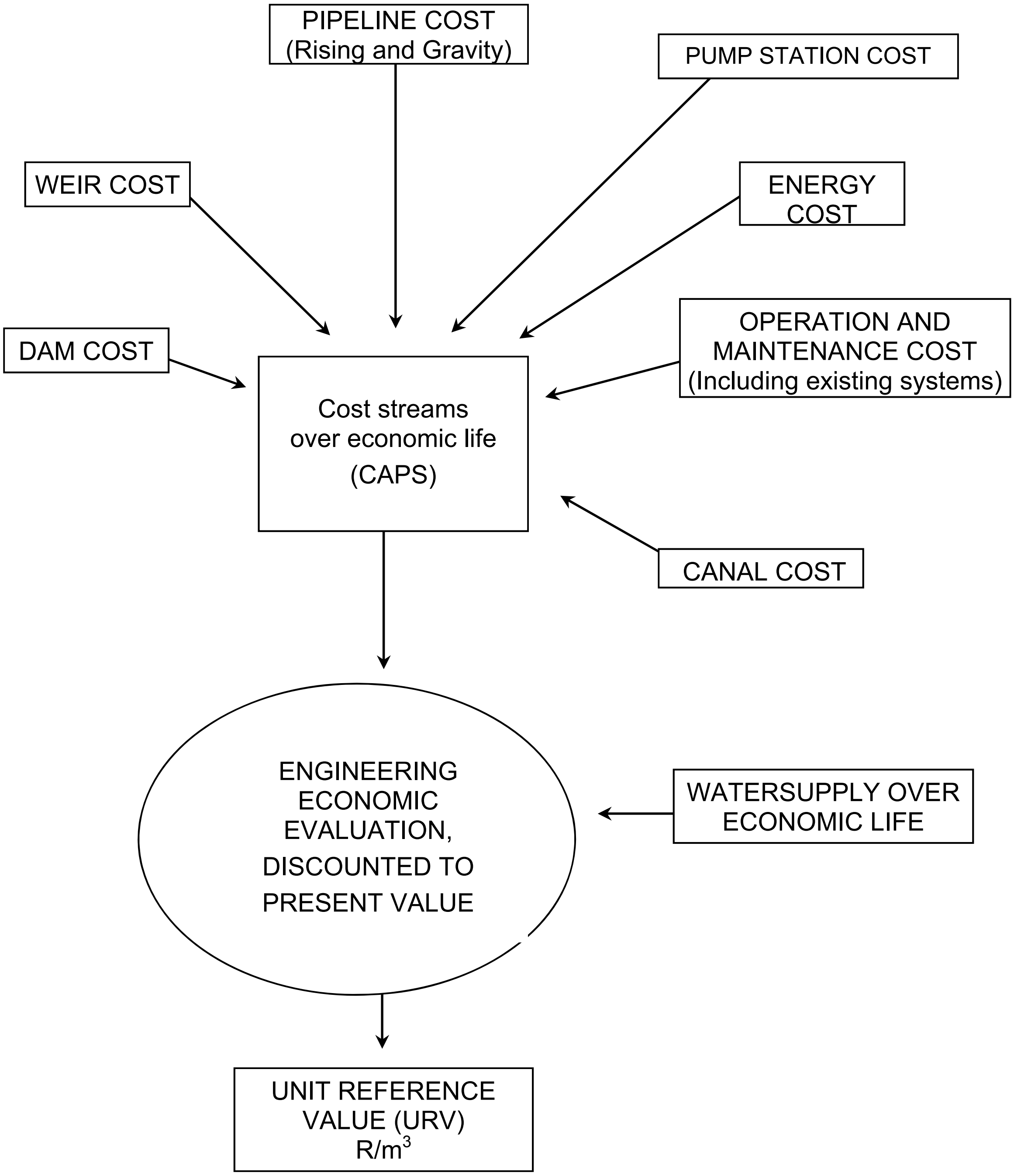
2) Construction — dam : 5 years

3) Construction — pipeline, pump stations, tanks, etc. : 2 years

4) Dam filling times (1MAR dam) : 1 year

The methodology chart below indicates the process followed and inputs used during the engineering economic evaluation.

Figure 6-1: Engineering Economic Evaluation Methodology



7. REFERENCES

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(3) (WFA, 2006)[3]

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(6) Contract Price Adjustment Figures (CPAF) figures published by SAFCEC

(7) Mooi-Mgeni rates

(8) VRESAP Contract V020 Bill of Quantities

(9) Mamelodi Sewer Tunnel rates was December 2004

REPORT DETAILS PAGE

Project name:	***Mokolo and Crocodile River (West) Water Augmentation Project (MCWAP)***
Report Title:	**Pre-Feasibility Study Report 3 – Guidelines for Preliminary Sizing, Costing and Economic Evaluation of Development Options Report**
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PSP

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