DEVELOPMENT OF RECONCILIATION STRATEGIES FOR BULK WATER SUPPLY SYSTEMS ORANGE RIVER

REFERENCE

This report is to be referred to in bibliographies as:

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***DEVELOPMENT OF RECONCILLIATION STRATEGIES FOR LARGE BULK WATER SUPPLY SYSTEMS: ORANGE RIVER*: LITERATURE REVIEW REPORT**

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Report No. P RSA D000/00/18312/2

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

LITERATURE REVIEW REPORT

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1 INTRODUCTION

1.1 BACKGROUND

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

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

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

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

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

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

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

1.2 MAIN OBJECTIVES OF THE STUDY

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

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

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

1.3 STUDY AREA

As depicted in **Figure B1** of **Appendix B**, the study will focus on the water resources of the Upper and Lower Orange River Water Management Areas (WMAs), while also considering all the tributary rivers and transfers affecting the water balance of the system. This core area forms part of the Orange-Senqu River Basin, which straddles four International Basin States with the Senqu River originating in the highlands of Lesotho, Botswana in the north eastern part of the Basin, the Fish River in Namibia and the largest area situated in South Africa.

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

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

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

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

Other major tributaries into the Orange River are:

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

- The Fish River draining the southern part of Namibia.

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

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

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

1.4 PURPOSE OF THE REPORT

The Literature Review Report lists and briefly describes past reports that were reviewed with the aim of capturing relevant information that can be used in the current study and to prepare a list of augmentation schemes, management measures and planned bulk infrastructure options that were investigated in the past. The aim with the information review task was to collate information from previous studies and assessments that are relevant for the development of the reconciliation strategies for bulk water supply systems in the Orange River.

1.5 INFORMATION SOURCES

The reports that were reviewed originated from several studies of which the most important are listed below:

- Orange River System Analysis
- Orange River System Analysis Phase 2
- Vaal Augmentation Planning Studies
- Rehabilitation of Noordoewer/Vioolsdrift Irrigation Scheme
- Orange River Development Project Replanning Study
- Metolong Dam Feasibility Study
- Orange River Water Balance
- Internal Strategic Perspective Orange River (Upper & Lower Orange WMAs)
- Internal Strategic Perspective Vaal River (Upper, Middle & Lower Vaal WMAs)
- Lesotho Lowlands Water Supply Scheme Feasibility Study
- Pre-feasibility study into measures to improve the management of the Lower Orange river and to Provide for Future Developments along the Border between Namibia and south Africa
- Orange River Integrated Water Resource Management Plan
- Preliminary Transboundary Diagnostic Analysis
- Lesotho Highlands Water Project Phase II Feasibility Study
- Vaal Reconciliation Strategy Study
- Feasibility Study of the Potential for Sustainable Water Resources Development in the Molopo-Nossob watercourse
- Groundwater review of the Molopo-Nossob Basin for rural communities including assessment of national databases at the sub-basin level for possible future integration
- Comprehensive Reserve Determination Study of the Integrated Vaal River System
- Development of Reconciliation Strategies for all towns in the Central Region
- Development of Reconciliation Strategies for the area served/interacting by/with Sedibeng Water's

Vaal Gamagara Scheme as well as a Water Master Plan
- Orange River System annual operating analysis
- Support to Phase 2 of the ORASECOM Basin Wide Integrated Water Resources Management Plan (ORASECOM)
- Lesotho Water Sector Improvement Project Second Phase
- Water Reconciliation Strategy for Large Bulk Water Supply Systems: Greater Bloemfontein Area.

Relevant studies currently being or soon to be undertaken include:
- Upper Orange Validation/Verification Study (DWA)
- Orange-Senqu strategic Action Programme: Environmental flows Project by ORASECOM UNDP-GEF
- WQT Modelling and Water Resources Planning Model (WRPM) Salinity set-up for the Orange River (DWA)
- Vaal River System Classification Study (DWA)
- Acid Mine Drainage Feasibility Study (Vaal) (DWA)
- Development of a Water Conservation and Water Demand Management strategy for the Fish to Tsitsikamma Water Management Area (DWA)
- Orange River IWRM Plan by ORASECOM.

In total 115 of the most relevant reports from each study were sourced, as listed in **Table 1-1** below, and were grouped according to the above-mentioned studies and listed in chronological order within each group.

Table 1-1: List of reports reviewed

No	Title	Document No.	Author	Date	Comments
1.1 Reports: Orange River System Analysis (1991/1992)					
1	Description of the physical systems (DWA)	P D000/00/0392	MS Meyer	1992	
2	Demands and return flows DWA)	P D000/00/0492	NW Schäfer	1992	
3	Caledon-Modder River Government water scheme: Historical and future water demands and return flows (DWA)	P D000/00/1691 P D200/00/0291 P C520/00/0391	NW Schäfer	1991	
4	Caledon, Modder and Riet Rivers: Yield analysis (DWA)	P D000/00/1092 P D200/00/0192 P C500/00/0792	RS McKenzie	1992	
5	Orange River: Yield analysis up to P K Le Roux Dam (DWA)	P D000/00/1292	RS McKenzie	1993	
6	Assessment of the environmental water requirements of the Orange River mouth (DWA)	V/D400/01/E002	JG Prins	1990	
7	Assessment of the environmental water requirements of the Orange River between P K Le Roux Dam and the mouth (DWA)	V/D400/01/E002		1990	
1.2 Reports: Orange River System Analysis Phase 2 (1993)					
8	Further Analysis of the Caledon-Modder Subsystem (DWA)	P D000/00/3193	JD Rossouw	1993	
9	Evaluation of future water demands on the Orange River Project (DWA)	P D000/00/3393	M van Veelen	1993	
10	Development options to increase Hydro Power Generation and Yield of the Orange River System (DWA)	P D000/00/3493	RS McKenzie JD Rossouw	1993	
11	Orange River Integrated System Analysis (DWA)	P D000/00/3593	SJ van Vuuren JD Rossouw	1993	

No	Title	Document No.	Author	Date	Comments
12	Evaluation of possible augmentation from the Mzimvubu River: Reconnaissance Study (DWA)	P D000/00/3693	SJ van Vuuren JD Rossouw	1993	
1.3 Reports: Vaal Augmentation Planning Studies (VAPS) (1994)					
1.3.1 Overarching Reports					
13	VAPS: Reconnaissance Phase Review Report (DWA)	PC000/00/13894	BKS Inc	Aug 1994	
14	VAPS: Guidelines for Project Economic Evaluation DWA).	C000/00/15195	Ernest & Young	1995	
15	VAPS: Evaluation of Non-Augmentation Option (DWA)	PC000/00/14895	Ernst & Young/Consult 4	May 1995	
16	VAPS: Overview Report (DWA)	PC000/00/15395	BKS/DWA	June 1996	
1.3.2 Mzimvubu Transfer Options.					
17	VAPS: Mzimvubu Transfer Options: Reconnaissance Stage: Main Report (DWA Final)	PC000/00/14894	Consult 4	March 1996	
18	VAPS: Mzimvubu Transfer Options – Reconnaissance Stage : Supporting Report : Costing (DWA)	PC000/00/14894	Consult 4	Sep 1995	
19	VAPS: Mzimvubu Transfer Options: Reconnaissance Stage: Supporting Report: Dams (DWA)	PC000/00/14894 PT000/00/0494	Consult 4	Sep 1995	
20	VAPS: Mzimvubu Transfer Options: Reconnaissance Stage: Supporting Report: Design. Album of Drawing (DWA)s	PC000/00/14894 PT000/00/0494	Consult 4	May 1995	
21	VAPS: Mzimvubu Transfer Options: Reconnaissance Stage: Supporting Report: Infrastructure (DWA)	PC000/00/14894	Consult 4	Sep 1995	
1.3.3 Lesotho Highlands Water Project.					
22	VAPS: Lesotho Highlands Further Phases – Pre-Feasibility Stage : Main Report (DWA)	PC000/00/13594 PT000/00/0394	Consult 4	1995	
23	VAPS: Lesotho Highlands Further Phases – Pre-Feasibility Stage : Supporting Report – Dams (DWA)	PC000/00/13594 PD100/000394	Consult 4	1995	
24	VAPS: Lesotho Highlands Further Phases – Pre-Feasibility Stage : Supporting Report – Album of Drawings (DWA)	PC000/00/13594	Consult 4	1995	
1.3.4 Orange Vaal Transfer Scheme.					
25	VAPS: Orange-Vaal Transfer Schemes (OVTS):	C000/00/13194	Orvaal Consult	1994	

No	Title	Document No.	Author	Date	Comments
	Reconnaissance Report (DWA)				
26	VAPS: Orange Vaal Transfer Scheme: Pre-Feasibility Report. Goedemoed and Upper Caledon Options (DWA)	C000/00/13194	Orvaal Consult	1994	
27	VAPS: Orange Vaal Transfer Scheme: Prefeasibility Report (DWA	C000/00/13294	Orvaal Consult	1994	
28	VAPS: Orange Vaal Transfer Scheme: Caledon Cascades special reconnaissance report (DWA)	C000/00/13294 Spes-Recon A1	Orvaal Consult	1994	
29	VAPS: Orange Vaal Transfer Scheme: Upper Caledon and Upper Caledon Alternative Options (DWA)	C000/00/13194	Orvaal Consult	1994	
30	VAPS: Orange Vaal Transfer Scheme: Bakenkop Dam (DWA)	C000/00/13194	Orvaal Consult	1994	
31	VAPS: Orange Vaal Transfer Scheme: Bosberg Dam (DWA)	C000/00/13194	Orvaal Consult	1994	
32	VAPS: Orange Vaal Transfer Scheme: Finlaysdyk Dam (DWA)	C000/00/13194	Orvaal Consult	1994	
33	VAPS: Orange Vaal Transfer Scheme: Katjiesberg Dam (DWA)	C000/00/13194	Orvaal Consult	1994	
34	VAPS: Orange Vaal Transfer Scheme: Waterpoort Dam (DWA)	C000/00/13194	Orvaal Consult	1994	
1.4	**Reports: Rehabilitation of Noordoewer/Vioolsdrift Irrigation Scheme (1996)**				
35	Interim Report	C/12923/sb	African Namibia Inc.	1996	
1.5	**Report: VAPS Interim Studies (1998)**				
36	Reports could not be sourced (DWA)				
1.6	**Reports: Orange River Development Project Replanning Study (ORRS) (1998)**				
37	Social Overview - Orange River Basin (DWA)	PD 00/00/5095	Seneque Smith & Maughan-Brown	1995	
38	Water Demands of the Orange River Basin (DWA)	PD 00/00/4497	JD Rossouw	1997	
39	Evaluation of Irrigation Water Use Volume 1: Present Water	P D000/00/4897	Loxton Venn &	1998	

No	Title	Document No.	Author	Date	Comments
	Demand (DWA)	P Q000/00/0697 P N000/00/0697	Associates Agrimodel		
40	Evaluation of Irrigation Water Use Volume 2: Existing Irrigated Agriculture (DWA)	P D000/00/4897 P Q000/00/0697 P N000/00/0697	Loxton Venn & Associates Agrimodel	1998	
41	Evaluation of Irrigation Water Use Volume 3: Possible New Irrigation Developments (DWA)	P D000/00/4897 P Q000/00/0697 P N000/00/0697	Loxton Venn & Associates Agrimodel	1998	
42	Potential Dam Development and Hydro Power Options (DWA)	PD 000/00/4997 PN 000/00/0797 PQ 000/00/0797	BKS/Ninham Shand	1998	
43	Refinement of the instream flow requirements for the Orange River (DWA)	PD 00/00/6197	A Venter M van Veelen	1996	
44	Water Demands of the Eastern Cape region (DWA)	PD 000/00/4397 PN 000/00/0397 PQ 000/00/0397	R de Haan	1997	
45	Existing Water Infrastructure in the Eastern Cape region (DWA)	D 000/00/4197 N 000/00/0297 Q 000/00/0297	G Dyke SL Murray	1997	
46	Social Overview - Eastern Cape region (DWA)	D 00/00/5195 N 000/00/0895 Q 000/00/0895	Seneque Smith & Maughan-Brown	1995	
47	Instream Flow Requirements for the Orange River between the RSA / Lesotho border and the Gariep Dam (DWA)	PD000/00/6897		1999	
48	Agriculture Economic Analysis for Irrigation Water in the Orange and Fish River Basins (DWA)	PD 000/00/6397	J van Zyl (Agrimodel)	1998	

No	Title	Document No.	Author	Date	Comments
		PQ 000/00/1597 PN 000/00/1597			
49	Existing water infrastructure in the Orange River basin (DWA)	P D000/00/4297	JD Rossouw	1997	
50	Water Demand Management (DWA)	P D000/00/4597 P Q000/00/0497 P N000/00/0497	WF Potgieter PR Little KW Sanderson MJ Copeland RJ Rutherfoord	1998	
51	Main Report (DWA)	P D	MS Basson	1998	
1.7 Reports: Metolong Dam Feasibility Study (2003)					
52	Section 2 Water Demands, Section 3 Hydrology & water resources		CEC	2003	Study done by Lesotho
53	Section 5 Dam studies, Section 6 Water supply & Transmission, Section 7 pump stations, Section 12 Infrastructure		CEC	2003	Study done by Lesotho
1.8 Reports: Orange River Water Balance (2003)					
54	Orange River Water Balance (DWA)	PD 000/00/4903	HG Maré	2003	
1.9 Reports: Internal Strategic Perspective Orange River (Upper & Lower Orange WMAs) (2004)					
55	Internal Strategic Perspective Orange River Upper Orange Management Area (DWA)	P WMA 13/000/00/0304	PDNA WRP Consulting Engineers WMB Kwezi V3	2004	
56	Internal Strategic Perspective Orange River Overarching (DWA)	P RSA D000/00/0104	PDNAWRP Consulting Engineers WMB Kwezi V3	2004	

No	Title	Document No.	Author	Date	Comments
57	Internal Strategic Perspective Orange River Lower Orange Management Area (DWA)	P WMA 14/000/00/0304	PDNA WRP Consulting Engineers WMB Kwezi V3	2004	
1.10 Reports: Internal Strategic Perspective Vaal River (Upper, Middle & Lower Vaal WMAs) (2004)					
58	Vaal River System: Overarching (DWA)	P RSA C000/00/0103	PDNA WRP WMB Kwezi-V3	2004	
1.11 Reports: Lesotho Lowlands Water Supply Scheme Feasibility Study (2004)					
59	Water Resource Assessment of Final Development Options		WRP Consulting Engineers	2004	
1.12 Reports: Pre-feasibility study into Measures to improve the Management of the Lower Orange river and to Provide for Future Developments along the Border between Namibia and South Africa (LORMS 2005)					
60	Legal, Institutional, Water Sharing, Management and Dam Operation	PB D000/00/4603	LOR Consultants	2005	Combined RSA Namibia Study
61	Specialist Report on the Environmental Flow Requirements– Riverine	PB D000/00/4503	LOR Consultants	2005	Combined RSA Namibia Study
62	Specialist Report on the Determination of the Preliminary Ecological Reserve on a Rapid Level for Orange River Estuary	PB D000/00/4503	LOR Consultants	2005	Combined RSA Namibia Study
63	Water Requirements	PB D000/00/4202	LOR Consultants	2005	Combined RSA Namibia Study
64	Hydrology, Water Quality and Systems Analysis (Volume A & B)	PB D000/00/4303	LOR Consultants	2005	Combined RSA Namibia Study
65	Water Conservation and Demand Management	PB D000/00/4903	LOR Consultants	2005	Combined RSA Namibia Study
66	Dam Development Options and Economic Analysis - Volume 1 & 2	PB D000/00/4403	LOR Consultants	2005	Combined RSA Namibia Study
67	Environmental Assessment of the Proposed Dam Sites on	PB D000/00/4503	LOR Consultants	2005	Combined RSA Namibia Study

No	Title	Document No.	Author	Date	Comments
	the Orange River				
68	Vioolsdrift/Noordoewer Joint Irrigation Scheme: Assessment of Viability	PB D000/00/4803	LOR Consultants	2005	Combined RSA Namibia Study
69	Public Consultation	PB D000/00/4703	LOR Consultants	2005	Combined RSA Namibia Study
70	Main Report & Synopsis	PB D000/00/4703	LOR Consultants	2005	Combined RSA Namibia Study
1.13	**Reports: Development of a Catchment Management Strategy (CMS) for the Modder and Riet Rivers in the Upper Orange Water Management area (2006)**				
71	Catchment Management Strategy (DWA)	H1275	M van Veelen T Baker	2006	
1.14	**Reports: Orange river Integrated Water Resource Management Plan (ORASECOM 2007)**				
72	Review of Existing Infrastructure in the Orange River catchment		AJeleni H Mare	2007	ORASECOM Study
73	Review of Surface Hydrology in the Orange River Catchment		HG Mare	2007	ORASECOM Study
74	Review of Groundwater Resources in the Orange River catchment		A Viles	2007	ORASECOM Study
75	Environmental Considerations Pertaining to the Orange River		R Heath C Brown	2007	ORASECOM Study
76	Summary of Water Requirements from the Orange River		HG Mare	2007	ORASECOM Study
77	Water Quality in the Orange River		T Coleman A van Niekerk	2007	ORASECOM Study
78	Demographic and Economic Activity in the four Orange basin States		D Hall G Jennings	2007	ORASECOM Study
79	Institutional Structures in the four Orange Basin States		R Tompkins	2007	ORASECOM Study
80	Legislation and Legal Issues Surrounding the Orange River catchment		U Hiddema G Erasmus	2007	ORASECOM Study
81	Summary Report			2007	ORASECOM Study

No	Title	Document No.	Author	Date	Comments
1.15	**Reports: Preliminary Transboundary Diagnostic Analysis (ORASECOM 2008)**				
82	Preliminary Transboundary Diagnostic Analysis		Tethys Environmental Consultants Southern African Institute for Environmental Assessment	2008	ORASECOM Study
1.16	**Reports: Lesotho Highlands Water Project 2 Feasibility Study (2008)**				
83	Hydrology Supporting	HWC 001/205A-2007 P RSA D000/00/5107A	Consult 4 Consortium SEED Consult	2008	
84	Infrastructure Supporting Report	LHWC 001/210-2007 P RSA D000/00/5607	Consult 4 Consortium SEED Consult	2008	
85	Instream Flow Requirements	LHWC 001/218-2007 P RSA D000/00/6407	Consult 4 Consortium SEED Consult	2008	
86	Legal Studies	LHWC 001/221-2007 P RSA D000/00/6907	Consult 4 Consortium SEED Consult	2008	
87	System Analysis Supporting Report	LHWC 001/205B-2007 P RSA D000/00/5107 B	Consult 4 Consortium SEED Consult	2008	
88	MAIN REPORT	LHWC 001/224/2007 P RSA D000/00/7007	Seed Consult	2008	
1.17	**Reports: Taung Dam Utilisation Feasibility Study (2008)**				
89	Main Report (DWA)	P WMA 10/C31/00/0408	AJ Smook	2008	

No	Title	Document No.	Author	Date	Comments
1.18 Report: Metolong Dam Environmental and Social Impact Assessment (2008)					
90	Instream Flow Assessment		Southern Waters Ecological Research and Consulting	2008	Study done by Lesotho
1.19 Reports: Vaal Recociliation Strategy Study (2009)					
91	Second Stage Reconciliation Strategy (DWA)	P RSA C000/00/4406/08	DDM Golder SRK WRP Zitholele	2009	
1.20 Reports: Feasibility Study of the Potential for Sustainable Water Resources Development in the Molopo-Nossob watercourse (2009)					
92	Main Report	007/2009	M van Veelen T Baker	2009	ORASECOM Study
1.21 Reports: Groundwater review of the Molopo-Nossob Basin for rural communities including assessment of national data basis at the sub-basin level for possible future integration (2009)					
93	Draft Final Report		L Carlsson	2009	ORASECOM Study
1.22 Reports: Assessment of Potential for Development and use of Marginal Waters (ORASECOM 2009)					
94	Final Report	002/2009	Ninham Shand Golder Associates Africa Sechaba Consultants	2009	ORASECOM Study
1.23 Reports: Orange River System: Real-time Operating System for the Lower Orange River (2009)					
95	Main Study Report (DWA)	P WMA 14/000/00/0507	A du P le Grange CJ Briers J Hallowes	2009	
1.24 Reports: Vaal River WRDP:Comparitive Study between LHWP Phase 2 and Tukela Water Project (2010)					
96	Main Report (DWA)	P RSA C000/00/12009/1	ACER BKS DMM Golder WRP	2010	

No	Title	Document No.	Author	Date	Comments
1.25 Reports: Comprehensive Reserve Determination Study of the Integrated Vaal River System (2010)					
97	Water Resource Modelling Report (DWA)	RDM/ C000/01/CON/0607	DDM Hydrosol WRP	2010	
1.26 Reports: Development of Reconciliation Strategies for all towns in the Central Region (2011)					
98	Total of 295 Towns (DWA)		WRP	2011	
1.27 Reports: Development of Reconciliation Strategies for the area served/interacting by/with Sedibeng's water's Vaal Gamagara Scheme as well as a Water Master Plan (2011).					
99	Feasibility Study Main Report	245460/08	KV3 WRP Golder GLS ICP DPA	2011	
1.28 Reports: Orange River System annual operating analysis (2011)					
100	Orange River System 2011/2012 System Analysis (DWA)	P RSA C000/00/12410	HG Mare C Seago	2011	
1.29 Reports: Support to Phase 2 of the ORASECOM Basin Wide Integrated Water Resources Management Plan (2011)					
101	Water Resource Modelling of the Orange Senqu basin: Stregths and Weaknesses of Existing Models	005/2011	C Seago	2011	
102	Extension and Expansion of the Hydrology of the Orange Senqu Basin	006/2011	B Haasbroek S Crerar HG Mare B Pitman G de Jager R McKenzie	2011	
103	Development of a Water Quality Monitoring Programme and data Management Framework	007/2011	T Coleman P Moodley	2011	
104	Development of Specifications for the Water Quality Model	006/2011	C Herold	2011	
105	Climate Change in the Orange-Senqu Basin	009/2011	S Crerar J Volkholz J Lutz	2011	
106	Irrigation GIS Database Interactive Database and irrigation Scenario Tools	012/2011	T Chidley H Beuster G Howard	2011	

No	Title	Document No.	Author	Date	Comments
107	The Promotion of Water Conservation and Water Demand Management in the Irrigation Sector	011/2011	N de Wet J Rutherfoord T Basson S Crerar	2011	
108	Project Executive Summary	013/2011		2011	
1.30 Reports: Lestoho Water Sector Improvement Project Second Phase (2012)					
109	Final Report	LWSIP II/06/02/2011	WRP	2012	
1.31 Reports: Water Reconciliation Strategy for Large Bulk Water Supply Systems: Greater Bloemfontein Area (2012)					
110	Final Interventions Report (DWA)	P WMA 14/C520/00/0910/03	Aurecon GHT Consulting Scientists ILISO Consulting	2012	
111	Water Quality Assessment Report (DWA)	P WMA 14/C520/00/0910/04	Aurecon GHT Consulting Scientists ILISO Consulting	2012	
112	Reconciliation Strategy Report (DWA)	P WMA 14/C520/00/0910/05	Aurecon GHT Consulting Scientists ILISO Consulting	2012	
1.32 Report: Mzimvubu Water Transfer to Fish River (2005)					
113	Mzimvubu River Basin - Water Utilization Opportunities (DWA)	P WMA 12/000/00/0505	ECH Sellick	April 2005	
1.33 Report: Algoa Water Resources Bridging Study (2010)					
114	Algoa Water Resources Bridging Study: Water Resources and System Modelling (DWA)	P WMA 15/K90/00/1909	HG Maré & C Seago	October 2010	

No	Title	Document No.	Author	Date	Comments
1.34 Report: Water Reconciliation Strategy Study for the Algoa Water Supply Area(2011)					
115	Water Reconciliation Strategy Study for the Algoa Water Supply Area (DWA)	WMA 15/M00/00/1409/04	Aurecon, AfriCoast Engineers, Palmer Development Group, Groundwater Africa, MGP Consulting, Scherman Colloty & Associates	April 2011	

1.6 REPORT LAYOUT (WRP DONE)

Chapter two of the report describes pertinent information from the reports of past studies, covering each study under a main heading. The sub-sections give a concise description of each of the reports with the focus on the conclusions and recommendations that were made in the report.

Chapter three provide a summary of the most important information that need to be considered in the tasks of the current study for the development of the reconciliation strategy.

2 SUMMARY OF PERTINENT INFORMATION FROM THE REPORTS

2.1 ORANGE RIVER SYSTEM ANALYSIS (1991/92)

2.1.1 Overview

The Orange River System Analysis was undertaken to ensure the economic utilization and allocation of the Orange River water sources. One of the primary aims of this study was to evaluate the impact of the LHWP different phases on the current system and the yield capability at the dams. The analysis involved an assessment of the historical water use in conjunction with the stream flow in order to establish the natural historic hydrology. This hydrology was then used to determine the current yield available from the system taking into account the current demands at the time. Stochastic hydrology was used to determine the reliability of the yield that was determined.

Planning scenarios for future schemes were assessed and future yields were determined using future demands.

2.1.2 Description of the Physical Systems

Report Title: ORANGE RIVER SYSTEM ANALYSIS: Description of the Physical Systems. Report No. PD 000/00/0392. Department of Water Affairs Directorate of Project Planning. Prepared by BKS Incorporated, Author MS Meyer (November 1992).

2.1.2.1 General Description of the Systems

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

The Caledon River, forming the north-western boundary of Lesotho with the Republic of South Africa (RSA) and the Senqu River in Lesotho are the major tributaries of the Orange River. The Caledon and the Orange Rivers have their confluence in the upper reaches of the Hendrik Verwoerd Dam.

Other major tributaries into the Orange River are:

- The Kraai River draining from the North Eastern Cape;
- The Vaal River joining the Orange River at Douglas
- The Ongers and Sak rivers draining from the northern parts of the Karoo;
- The Kuruman and Molopo rivers draining the Cape Province north of the Orange River as well as the southern parts of Botswana; and
- The Fish River draining the southern part of Namibia.

The Vaal River joining the Orange River at Douglas and its tributaries were not analysed as part of the Orange River System and are dealt with in a separate study, the Vaal River System Analysis. The Modder- and Riet Rivers, draining the southern part of the Orange Free State, discharge into the Vaal River just upstream of the confluence with the Orange River. The Modder- and Riet Rivers were excluded from the Vaal River System Analysis Study and it was decided by the Department of Water Affairs to include these two rivers in this study. The water supply from these rivers is supplemented by transfers from the Orange River.

The water supply from the two rivers in the Eastern Cape, the Great Fish and Sundays Rivers, as well as the water supply to Port Elizabeth are supplemented with water transferred from the Orange River via the Orange-Fish Tunnel. Only the demands from the Eastern Cape were used in the analyses. The Eastern Cap sub-system was not analysed as part of the Orange River System.

2.1.2.1.1 Caledon River

The two major dams within the Caledon catchment are the Welbedacht Dam and the Knellpoort Dam. The Welbedacht Dam is situated on the Caledon River while the Knellpoort Dam is situated on the Rietspruit, a tributary of the Caledon River. The Knellpoort Dam is operated as an off-channel storage dam by pumping water from the Caledon River into the dam.

The Knellpoort Dam was built to augment the storage capacity of Welbedacht Dam and to transfer water to the upper reaches of the Modder River. The storage capacity of Welbedacht Dam has reduced significantly due to siltation.

Water from the Welbedacht Dam is pumped to the Welbedacht water purification works from where potable water is pumped to supplement the water supply from the Modder River to Bloemfontein. Water is also supplied from this system to Dewetsdorp and Botshabelo.

2.1.2.1.2 Senqu River (Lesotho Highlands Water Project)

The Orange River is called the Senqu River in Lesotho, The Senqu River, with its tributaries, drains most of the Lesotho Highlands. As the Orange River, the Senqu has its confluence with the Caledon River in the RSA in the upper reaches of the HF Verwoerd Dam. The first phase of the Lesotho Highlands Water Project (LHWP) was then under construction to supply water to the Vaal River System and to generate electricity.

Most of the tributaries within Lesotho will be controlled by the LHWP once all the proposed phases have been developed. The Kraai River drains from the North Eastern Cape into the Orange River, downstream of Lesotho and upstream of Hendrik Verwoerd Dam.

2.1.2.1.3 Upper Orange River

The Upper Orange River as defined in this report comprises the Orange River from the confluence with the Caledon River to the confluence with the Vaal River. The two largest dams in the RSA, i.e. the Hendrik Verwoerd and PK Le Roux Dams are situated in this section of the Orange River. These two dams are utilized for river flow control, flood control, hydro power generation and storage of water for urban and irrigation use. The Torquay Dam has been planned to be built as a future option close to the confluence with the Vaal River.

Water is transferred from the Hendrik Verwoerd Dam via the Orange-Fish tunnel to supplement to irrigation and urban water dams along the Great Fish and Sundays rivers, as well as in Port Elizabeth. Water is also transferred from PK Le Roux Dam to supplement the irrigation demands along the Riet River. The third transfer scheme comprises the transfer of water from the Orange River along Marksdrift into the Douglas Weir on the Vaal River.

2.1.2.1.4 Lower Orange River

The Lower Orange River as defined in this report comprises the Orange River from the confluence with the Vaal River to the Atlantic Ocean. The major tributaries draining into this section of the Orange River are:

- the Ongers and Sak Rivers from the northern Karoo;
- the Kuruman and Molopo rivers from the Cape Province north of the Orange and the southern part of Botswana; and
- The Fish River from the southern part of Namibia.

These rivers are draining arid and semi-arid areas.

Water is abstracted for irrigation along the river at various points, for urban use and for stock watering in the Kalahari.

2.1.2.1.5 Modder River

The Modder River has its source in the south-eastern Orange Free State and generally flows in a western direction north of Bloemfontein to the confluences with the Riet River. The three major dams in the catchment are:

- Rustfontein Dam on the Modder River. This dam was built to supplement the water supply to Bloemfontein.
- Krugersdrift Dam on the Modder River. This dam provides storage for irrigation usage downstream.
- Groothoek Dam on the Klein Modder River. This dam provides water for urban usage in Thaba'Nchu.

Potable water is transferred into the catchment from Welbedacht Dam on the Caledon River to supplement the water supply to Bloemfontein, Dewetsdorp and Botshabelo. Water will also be transferred from the Caledon River, via the Knellpoort Dam and the proposed Novo pumping station, to the upper reaches of the Modder River. This water will supplement the yield from the Rustfontein Dam. Potable water for Bloemfontein is also supplied from the purification works at Maselspoort. Raw water for this purifications works in abstracted from the Modder River at the Mockes Dam.

2.1.2.1.6 Riet River

The Riet River has its source in the southern Free State and drains after its confluence with the Modder River, into the Vaal River just upstream of the confluence of the Vaal River with the Orange River. The major dams in the catchment are the Tierpoort Dam on the Kaffir River and the Kalkfontein Dam on the Riet River. Both dams are primarily used for irrigation purposes. The irrigation demands along the Riet River are supplemented with water transferred from PK Le Roux Dam on the Orange River.

2.1.2.1.7 Eastern Cape (Orange-Fish Tunnel)

The water demands along the Great Fish and Sundays Rivers as well as in Port Elizabeth is supplemented with water transferred from Hendrik Verwoerd Dam via the Orange Fish Tunnel. The water is discharged from the Orange-Fish tunnel into the Teebus Spruit, a tributary to the Great Fish River. Through a series of weirs, tunnels, canals and pipelines water is transferred from the Great Fish River to the Little Fish River, to the Sundays River and finally to Port Elizabeth. Along all the above rivers the Orange River water supplements the water supply for irrigation.

The Eastern Cape system is analysed as a demand centre from Hendrik Verwoerd Dam (Now Gariep Dam) and it is discussed only briefly in this report. The details of the system will be discussed in a supplementary report.

2.1.2.1.8 Minor Tributaries

Tributaries such as the Ongers, Sak, Kuruman, Molopo and Fish (Namibia) Rivers are draining arid and semi-arid regions. The flows in these rivers are very infrequent and it is expected their flows will contribute to the Orange River's flow only during periods of relative high flows in the Orange River. All inflows into the Orang River from tributaries downstream of the confluence with the Vaal River are therefore ignored in the hydrology and yield analyses. A hydrology study was however done for the Fish River (Namibia).

The local irrigation schemes, such as those along the Sak and Ongers Rivers (Smart Syndicate Dam) are therefore not discussed in this report. During the original planning phases of the Orange River Development Project however, transfer canals from PK Le Roux Dam to the Sak and Ongers Rivers were envisaged. Yield analyses however indicated that with LHWP fully developed the water resources are limited. These schemes are also not economically viable. Development of these schemes is therefore not envisaged in the foreseeable future.

2.1.2.2 Detailed Description of Transfer Scheme

The various interbasin transfer schemes are discussed briefly in the sections above. In this section each of the major systems that are modelled in the analyses is discussed in detail. Details of the capacities of the various components, i.e. pumping capacities, pipe sizes and lengths, height/area/capacity relationships for the dams are given in the appendices to that report.

2.1.2.2.1 The Caledon-Modder Transfer System

A description of the existing system and future options is presented in the following paragraphs.

Interbasin transfer

The Caledon River forms, for most of its length, the north-western border of Lesotho, between Lesotho and the Republic of South Africa. The major dam on the Caledon River is Welbedacht Dam. The Knellpoort Dam is built on the Rietspruit and is operated as an off-channel storage dam by pumping water from the Caledon River into the dam.

The Caledon-Modder River Transfer Scheme consists of two subsystems: the Caledon-Bloemfontein Water Supply Scheme and Caledon-Modder Transfer Scheme.

The Caledon-Bloemfontein Water Supply Scheme facilitates abstraction of water from Welbedacht Dam. After purification it is pumped to Bloemfontein via a 6,55 km pressure pipeline and a 105,5 km gravity pipeline. Potable water is also supplied to Dewetsdorp, Botshabelo and other minor consumers by means of secondary pipelines branching off the main pipeline.

Sediment deposition has decreased the yield from Welbedacht Dam significantly. The decrease led to the construction of Knellpoort Dam, which is to supplement the yield of the capacity of the Welbedacht Dam and to supply water to the upper reaches of the Modder River. The storage capacity of Welbedacht Dam reduced from the original 115 million m³ in 1973 to 17 million m³ in 1990 due to severe siltation. Water is pumped via the Tienfontein pumping station from the Caledon River to the Knellpoort Dam on the Rietspruit, a tributary of the Caledon River. The Knellpoort Dam has a capacity of 125 million m³. At present it is utilised to supplement the storage capacity of Welbedacht Dam only. A further option is to transfer water from Knellpoort Dam, via the Novo pumping station, rising main and canal, to the upper reaches of the Modder River.

Dams on the Modder River

The Modder River is a main tributary of the Riet River, and drains the central Orange Free State. The largest dams in the Modder River catchment are Rustfontein, Groothoek and Krugersdrift. The Rustfontein Dam will be supplemented by the Caledon-Modder Transfer Scheme and could in future supply water to Botshabelo, Thaba N'chu and Bloemfontein. Groothoek Dam supplies water to Thaba N'chu and Krugersdrift Dam supplies irrigation water to irrigation farmers downstream of the dam.

Major dams in the Caledon and Modder River catchments are listed in **Table 2.1.**

Future options

Future options for this subsystem consist of the possible raising of the Krugersdrift Dam and the Interbasin transfer scheme from the Caledon River to the Modder River.

The Caledon-Modder Transfer Scheme via the Novo pumping station from Knellpoort Dam can be developed in phases up to a total transfer capacity of 4 m^3/s.

Abstraction from Knellpoort Dam and interbasin transfer will be facilitated by the Novo Pumping Station. Water will be transferred from Knellpoort Dam to the upper Modder River via a 29,7 km pipeline and 12 km canal. The physical information and a schedule for the future extension of this transfer scheme are included in **Table 2.3.**

The two dams, Rooiwald and N'gakansispoort Dams, have been proposed by Bophuthatswana to supply water for urban use to the Thaba N'chu area.

The increase in return flows, due to rapid urban development in the Bloemfontein – Botshabelo – Thaba N'chu area will increase the base flow of the Modder River. The option to raise the Krugersdrift Dam has been investigated. The increases storage capacity together with the increase in base flow will improve the assurance of supply from the dam.

Physical characteristics

A summary of the physical details of the major reservoirs, consisting of information regarding the full supply level (FSL), minimum operating level (MOL), live storage, surface area at full supply level and incremental catchment, is presented in the table below.

Table 2-1: Summary of Physical Details of Dams in the Caledon-Modder River Subsystem

Dam	FSL (masl)	MOL (masl)	Live* Storage (million m^3)	Surface Area (km^2)	Incremental catchment (km^2)
Knellpoort	1 452,10	1 432,60	130,2	9,76	798
Welbedacht	1 402,90	1 385,22	17,1	12,55	15 245
Rustfontein	1 373,03	1 356,27	72,7	11,58	940
Groothoek	1 495,00	1 484,75	11,7	2,49	118
Krugersdrift	1 248,13	1 229,85	75,5	18,78	4 511

* Based on latest survey data

Sediment deposition has decreased the capacity of Welbedacht Dam significantly. The sedimentation history of Welbedacht Dam is summarized in the table below.

Table 2-2: Sedimentation history of Welbedacht Dam

Date of Hydro Survey	Capacity (million m^3)	Sediment	
		Volume	Percentage

		(million m³)	
1973	115,166	0	0,0
1976	77,703	37,463	32,3
1978	62,811	52,355	45,3
1981	55,662	59,504	51,5
1982	56,877	58,289	50,5
1986	39,652	75,514	65,5
1987	38,327	76,839	66,7
1988	37,132	78,034	67,8
1991	17,123	98,043	85,1

Detail information regarding canals, pipelines and pumps of the two transfer schemes was summarized in appendices, but is not repeated here. Relevant information regarding pipe diameters and capacities are shown in the table below.

Table 2-3: Pipe diameters: Caledon-Modder River Subsystem and Welbedacht Dam

Pipeline	Diameter (mm)	Design Capacity (m³/a)	Date of Future Extension
1. Welbedacht-Bloemfontein Transfer Scheme			
Rising Main	1 220	1,68	-
Gravity Pipeline	1 170	1,68	
2. Caledon-Modder River Transfer System			
Tienfontein	1 620	3,00	1991
Pumping Station	1 242 1 620 1 245	2,00 3,00 2,00	2005 2015 2025
Novo Pumping Station (Proposed)	1 245 1 245	3,00 3,00	1992 2015

2.1.2.2.2 Orange Riet Transfer Scheme

Water is transferred from the PK Le Roux Dam on the Orange River to the irrigation areas along the Riet River.

Water is pumped from the Van der Kloof Canal, on the right bank of the Orange River, via the Scheiding pumping station and the Sarel Hayward Canal to the Riet River Settlement near Jacobsdal. The Riet River Settlement forms part of the Riet River Government Water Scheme.

The Sarel Hayward Canal has a total length of about 112 km and the capacity of the first 73 km of the canal is 6 m³/s and the remainder 13 m³/s. The planned final capacity of the system is 24 m³/s.

2.1.2.2.3 Lesotho Highlands Water Project

The first phase of the Lesotho Highlands Water Project (LHWP) was then under construction. The purpose of this project was to meet the growing water demands from the Vaal River System and to generate hydro power for Lesotho. Water will be transferred from the Senqu River and its tributaries to the upper reaches of the Ash River, a tributary to the Vaal River

The Phase 1A of the LHWP was to comprise the following:

- The Katse Dam on the Senqu River. The minimum operating level (MOL) for this dam will change from 1 989 m for Phase I to 2 002,5 m for Phase II;
- The Transfer Tunnel from Katse Dam to the ‘Muela Hydro Power Station;
- The Hydro Power station at ‘Muela;
- The Delivery Tunnel from ‘Muela to the upper reaches of the Ash River in the RSA; and
- The Matsoka Weir and transfer tunnel to the Katse Dam.

The Mohale Dam and the transfer tunnel to the Katse Dam were then planned to form Phase 1B. The capacity of Mohale Dam will be 722 million m³.

The second and further phases of the LHWP were at that time planned to comprise the following dams:

- The Mashai Dam with a capacity of 2 433 million m³;
- The Tsoelike Dam with a storage capacity of 1 254 million m³; and
- The Ntoahae Dam with a storage capacity of 653 million m³.

All three these dams would be downstream of Katse Dam and the water will progressively be pumped from the downstream dam to the dam upstream and finally to Katse Dam. The water will then be transferred to the RSA from Katse Dam. The further phases will also entail the doubling of the transfer and delivery tunnels between Katse Dam and the RSA.

2.1.2.2.4 Orange-Vaal Transfer Scheme

The Orange-Vaal transfer system was originally built as an emergency scheme to overcome water shortages and salinity problems at the Douglas Government Water Scheme. The scheme consists of a pumping station on the Orange River at Marksdrift, a rising main and a 22 km canal terminating at the Douglas Weir on the Vaal River. The system had a capacity of 7 m³/s at that time.

2.1.2.2.5 Minor Abstraction Systems

Various abstraction schemes for irrigation, urban usage and stock watering exist along the lower Orange River.

(a) Kalkfontein Irrigation Canal

The Riet River Scheme is situated in the southern Orange Free State, the storage unit being the Kalkfontein Dam on the Riet River. The dam supplies water mainly for irrigation on riparian farms along both banks of the river downstream of the dam, and also to the towns Kalkfontein and Jacobsdal. The main canal, which runs from the Kalkfontein Dam along the left bank of the Riet River, is 123 km long and has an initial carrying capacity of 7,1 m³/s. The original basic canal system was completed in 1942; a portion of the canal near the dam consists of a 3 350 m long tunnel to avoid a number of steep cliffs along the river. At several places there are siphons through the river to branch canals serving the irrigable area on the right bank of the river.

(b) Buchuberg Government Water Scheme

The Buchuberg Government Water Scheme comprises the concrete gravity-section Buchuberg Dam across the Orange River, 150 km by road upstream of Upington built by the Department of Water Affairs as a drought relief work and completed in 1931. The scheme also comprises the 172 km long main canal on the south bank, originally completed in 1934 but subsequently enlarged to the current capacity of 9,76 m³/s. The branch canal and syphon conveys water across the river to the Gariep Settlement on the north bank.

(c) Upington Islands Government Water Scheme

Many large islands exist in the Upington part of the Orange River, and irrigation in this area began as far back as 1883 when the first canal was constructed. The upstream intake for the Scheme is at the Rouxville West Island group. The south bank canal, with an initial capacity of about 10 m³/s, extends a fair distance downstream of Upington. Both banks of the river and the islands are irrigated and water is supplied via a maze of secondary canals and syphons.

(d) Kalahari-West Rural Water Supply System

The supply system became necessary as a result of several years of critical drought in these parts and the accompanying state of emergency. The scheme comprises a main pumping station at the Upington municipal reservoir with a capacity of 51 ℓ/s, conveying water through a rising main of 20 km long and a diameter of 250 mm to the main reservoir on the watershed near Spitskop. From the main reservoir, with a storage capacity of 2 500 m³, the water flows under gravity through a 250 mm diameter pipeline to a balancing reservoir with a storage capacity of 100 m³ on the farm Norokei. A booster pumping station with a capacity of 22,5 ℓ/s supplies the water past this point to the primary distribution system consisting of nine reservoirs with capacities varying from 730 m³ and pipelines with a total length of approximately 330 km and diameters ranging from 250 mm to 110 mm. A second booster pumping station distributes the water to the remainder of the area at a maximum capacity of 16,4 ℓ/s. The secondary distribution system consists of approximately 105 km of pipelines with diameters ranging from 1190 mm to 50 mm, and three reservoirs, each with a capacity of 80 m³.

(e) Kakamas Government Water Works

Irrigation in the Kakamas area started in the late nineteenth century and takes place on various islands in the Orange River as well as on the alluvial flood banks on either side of the river. Construction of the South-Furrow Canal Scheme commenced in July 1898, and construction of the North-Furrow commenced ion 1908. At The end of 1914 some 340 settlers had already been placed on the Kakamas settlement. The intake capacity of the South-Furrow canal is 6,81 m³/s, and water was originally diverted into it by means of a low weir in a creek on the left bank upstream of Neusberg. The intake capacity of the North-Furrow is 7,45 m³/s. In future the water for both these canals will be abstracted from the Neusberg Weir presently under construction. The Rhenosterkop canal is diverted at the end of the South-Furrow by means of a concrete weir which is built between the left bank and Paarden Island and has an intake capacity of 8,79 m³/s.

(f) Springbok Regional Water Supply Scheme

The Springbok Regional Water Supply Scheme was necessitated by the insufficient existing water resources which comprised mainly boreholes and water drawn from the mine shaft. The scheme was designed to supply purified water from the Orange River to the various settlements and mines in the region. The works consist of abstraction works along the Orange River at Henkriesmond, purification works at Henkries, several pump stations, and pipelines to terminal reservoirs built where the various bulk consumers are. The construction of this scheme was commenced in 1970, and the last construction work on the scheme comprised the pipeline to Kleinsee.

2.1.3 Demands and Return Flows

Report Title: ORANGE RIVER SYSTEM ANALYSIS: Demands and Return Flows. Report No. PD 000/00/0491. Department of Water Affairs Directorate of Project Planning. Prepared by BKS Incorporated, Author NW Schäfer (November 1992).

Irrigation is by far the major consumer of water in the Orange River System. In 1988 and total area of 1 213 km^2 (121 300 ha) was estimated to be irrigated with Orange River water. This however excludes the area irrigated in the Eastern Cape with water transferred through the Orange Fish tunnel. An average requirement of 10 750 m³/ha/a was estimated resulting in a total requirement of 1 304 million m³/a.

A summary of the irrigation areas and **Error! Reference source not found.**requirements is given in **Table 2-5**

Table 2-4: Summary of the estimated areas under irrigation at 1988 development levels along various river sections of the Orange River System

River Section	Area (ha)
Modder River upstream of Krugersdrift Dam	4 400
Riet River upstream of Kalkfontein Dam	7 700
Modder River downstream of Krugersdrift Dam	3 400
Riet river downstream of Kalkfontein Dam	7 750
Lower Riet River	2 640
Caledon River upstream of Welbedacht Dam	3 680
Caledon tributaries	3 850
Kraai River	2 500
Stormberg River	1 500
Orange River upstream of Gariep Dam	4 100
Caledon River downstream of Welbedacht Dam	4 850
Orange River upstream of Vanderkloof Dam	1 400
Vanderkloof Dam to Orange Vaal confluence	9 660
Orange Vaal confluence to Prieska	10 520
Prieska to Boegoeberg Dam	2 000
Boegoeberg Dam to Upington	8 512
Upington to Augrabies falls	17 901
Augrabies falls to Vioolsdrift	2 357
Vioolsdrift to Orange-Fish confluence	205
Fish-Orange confluence to Alexander Bay	750
Ramah branch canal	5 200
Sarel Hayward Canal (Orange Riet canal)	10 830
Orange Vaal Canal	5 640
Total	**121 335**

Table 2-5: Summary of the estimated crop water requirements along various river sections of the Orange River System

River Section	Requirement (m³/ha/a)
Riet and Modder Rivers	11 000
Caledon River upstream of Welbedacht Dam	7 500
Caledon River downstream of Welbedacht Dam	9 000
Orange River upstream of Gariep Dam	8 000

River Section	Requirement (m³/ha/a)
Kraai River	8 000
Stormberg River	8 000
Orange River upstream of Vanderkloof Dam	11 000
Orange River downstream of Vanderkloof River	11 000
Orange Riet canal	11 000
Orange Vaal canal	10 000
Brak and Ongers rivers	13 000
Middle Orange River	13 000
Lower Orange River	15 000
Namaqualand	15 000

The total urban/industrial use is much lower and was estimated at 71 million m³/a for the 1988 development level. This demand however excludes the Eastern Cape urban requirements. The historic growth as well as future demand projections was also considered in this report

Table 2-6: Summary of the estimated urban/industrial 1988 water requirements of towns in the Orange River Basin

Consumer	Requirement (m³/a)
Bloemfontein	31.300
Dewetsdorp	0.1750
Koffiefontein	1.3000
Clocolan	0.3400
Ficksburg	1.6785
Aliwal North	2.0000
Burgersdorp	0.5900
Zastron	0.5000
Kakamas	0.8019
Keimoes	0.6825
Oranjemund	7.0000
Pelladrift Water Board	4.5500
Prieska	0.0006
Upington	10.0000
Hopetown	0.3000
Douglas	0.9000
Groblershoop	0.3500
Karos-Geelkoppan Rural Supply	0.0600
Kalahari West Rural supply	0.4000
Springbok Water Board	3.6000
Rosh Pinah Mine	1.2000
Alexander Bay	1.5000
Various small users	1.2000
Total	**71.0279**

At 1990 development level only 450 million m³/a was transferred to the Eastern Cape through the Orange-Fish Tunnel. It is however expected that this will increase to 840 million m³/a by 2005 (approximately 50 000 ha). This calculation allowed for 25% conveyance losses. To this another 25 million m³/a need to be added for urban/industrial requirements. This includes urban centres such as Port Elizabeth, Grahamstown, Cradock and Kirkwood.

This report further contains information on the LHWP, irrigation and urban return flows, evaporation and environmental requirements.

2.1.4 Caledon Modder Government Water Scheme: Historical and Future Water Demands and return Flows

This report focusses only on the demands and return flows relating to the Caledon Modder water supply system used to supply Bloemfontein, Botshabelo and several smaller towns with water. This system forms an integral part of the larger Orange River system and is used to support the largest urban consumer of water in the Orange River.

The projected urban/industrial demands for the scheme was projected from 1990 as 43.2 million m³/a of which 36.3 million m³/a is for Bloemfontein, 3 million m³/a for Botshabelo and 3.9 million m³/a for the rest of the small towns. The total requirement was expected to grow to 70 million m³/a by the year 2000. Details of the historic water use since 1974/75 are included in the reports as well as on return flows. Information and applicable dates for the Tienfontein pump station and Novo Transfer Scheme are available in this report.

2.1.5 Caledon Modder and Riet Rivers: Yield Analysis

This report provides details of the analyses carried out for the Caledon Modder and Riet River yield analyses. Yield analyses were carried out for the following sub-systems:

- The Caledon/Modder sub-system supplying water to the Greater Bloemfontein area and Botshabelo. This sub-system includes Knellpoort Dam, Welbedacht Dam, Rustfontein Dam and Mockes Dam.
- Krugersdrift Dam in the Modder River downstream of Mockes Dam. Analyses also looked at the effect of the increasing demands and return flows of Bloemfontein located upstream of Krugersdrift on the yield of Krugersdrift Dam.
- The yields from Kalkfontein and Tierpoort dams, both in the Riet River.

A large number of different scenarios and operating rules were analysed for the Caledon/Modder sub-system. These analyses clearly showed that the operating rule followed had a significant effect on the system yield. Depending on the capacity of the Tienfontein pump station and the Novo transfer scheme as well as the operating rule used, the historic firm yield varied from as low as 40.4 million m³/a to as high as 151.5 million m³/a.

The historic firm yield at current (1990) development level for Krugersdrift Dam was found to be 15 million m³/a. This increased to 24.8 million m³/a when the dam was raised. The yield from Krugersdrift Dam will however reduce over time as the Bloemfontein demand increases and can be as low as 13.7 million m³/a when the final phase of the Novo transfer scheme are completed.

The historic firm yields at 1990 development level for Tierpoort and Kalkfontein Dams were found to be 2 million m³/a and 30.1 million m³/a respectively. The current demands imposed on these dams are 11.4 million m³/a for Tierpoort Dam and 56.4 million m³/a for Kalkfontein Dam. Both dams are therefore significantly over allocated.

Recommendations from this report include the following:

- Caledon River water should be used whenever possible to support the Bloemfontein Demands.
- The bulk distribution system for Bloemfontein should be upgraded and in particular the capacity of Brandkop Reservoir be increased to enable better utilisation of the Welbedacht water purification works.
- A detailed investigation on the Bloemfontein bulk water distribution system to identify any system restrictions and the most sufficient solutions for future upgrading.

- A series of detailed stochastic analyses to confirm the proposed staged implementation of the proposed Novo Transfer Scheme.
- A series of detailed stochastic analyses to confirm the proposed rule curve levels to be used for Knellpoort Dam.

2.1.6 Orange River: Yield Analysis up to PK le Roux Dam

The primary aim of the system analysis described in this report is to determine the influence of different phases of the LHWP on the yield from the ORP dams. When all possible phases of the LHWP are developed it will result in a total transfer to the upper Vaal from the LHWP of in excess of 2 200 million m³/a. Such a large transfer will obviously have a significant influence on the water available to downstream users, and in particular to Gariep and Vanderkloof dams. Results from the analyses are summarised in **Table 2-7** below.

Table 2-7: Historic Firm yields for different LHWP phases

Phase of LHWP	Historic Firm yield (million m³/a)		
	Total at Vanderkloof	From Lesotho	Total
Natural	4 806	0	4 806
Current	4 456	0	4 456
1a	4 027	539	4 566
1m	3 966	603	4 569
1b	3 776	915	4 691
2	3 323	1 577	4 900
3	3 033	1 955	4 988
4	2 901	2 123	5 024
5	2 755	2 347	5 102

Note: The total yield at Vanderkloof include the yield from Gariep and the 450 million m³/a transferred to the Eastern Cape as well as the 250 million m³/a transferred through the Orange Riet canal.

The point of overriding importance is that the availability of water from the ORP will be severely reduced when all the phases of the LHWP are developed. Based on the results from this report a shortage of 842 million m³/a by the year 2030 when the all the phases of the LHWP are developed. Previous estimates from a study carried out in 1986 and documented in the report PD 000/00/1389 showed a surplus of 1 078 million m³/a by the year 2030 when the all the phases of the LHWP are developed.

The results from this study clearly underline the need for a comprehensive re-planning of the ORP and the utilisation of Orange River water in general. In such a planning study the demands of all consumer sectors including the environmental and Namibian demands must be taken into account.

The study also highlighted the importance of river losses downstream of Vanderkloof Dam. It was recommended that a detailed study of the river losses be undertaken during subsequent investigations.

2.2 ORANGE RIVER SYSTEM ANALYSIS: PHASE II (1993)

2.2.1 Overview

In light of the results from Phase I of the Orange River System Analysis Study the DWAF decided to evaluate certain aspects of the Orange River System in more detail as part of Phase II of the study. The aims of Phase II included the following:

- To refine estimates of how much water can be transferred from the Upper Orange by means of the LHWP to the Vaal, by taking into account the other demands that will be placed on the ORP.
- To carry out further investigations that were identified as essential to allow the future integrated

planning of the LHWP and the ORP; and

- And to address specific aspects such as environmental demands, river losses, hydro-power generation and the possible augmentation of the system from water available in the Mzimvubu River.

2.2.2 Further Analysis of the Caledon-Modder Sub-system

Some work was done on the Caledon-Modder sub-system as part of the Orange River System Analysis. The existing supplies at the time to Bloemfontein and other users in the BloemWater's distribution area will in the near future have to be upgraded in order to maintain the water supply to the users.

To be able to do this it might be required to extend the treatment works at Welbedacht Dam and or supplement the yield of Rustfontein Dam. With spare treatment capacity in the Modder sub-system it is expedient to exploit this first by supplementing the yield of Rustfontein Dam. The proposed Novo Transfer Scheme has in the past been identified as the best alternative to supplement the supply of water to users in the Caledon-Modder sub-system. This scheme consists of a pump station at Knellpoort Dam as well as a pipeline and a canal to the upper reaches of the Modder River upstream of Rustfontein Dam.

The physical capacity of the then existing Welbedacht-Bloemfontein pipeline was 145 Mℓ/day (52.95 million m^3/a or 1.678 m^3/s), but on a monthly average only 128 Mℓ/day is possible due to peaking factors (46.75 million m^3/a or 1.481 m^3/s). The implementation date for the proposed Novo Transfer Scheme with a 128 Mℓ/day Welbedacht-Bloemfontein pipeline was determined as 1996.

A second analysis was performed for a capacity of 160 Mℓ/day for the Welbedacht-Bloemfontein pipeline, which is the maximum capacity of both the treatment works as well as a boosted Welbedacht-Bloemfontein pipeline. Under this conditions the implementation date for the proposed Novo Transfer Scheme was determined as 2001.

2.2.3 Evaluation of future water demands on the Orange River Project

At the time of this study it was essential to establish the then current and future demands on the ORP and to compare these with the firm yield after each of the phases of the LHWP have been implemented.

Irrigation is by far the largest consumptive user of water from the ORP, and represented 85% of the then current (1990) consumptive demand (excluding river losses and return flows). The current irrigation demand at the time represented 41% of the yield then of the ORP. When taking into account development already under construction or scheduled for construction as well as the development of an additional 6 300ha on the Namibian Side, it will represent 54% of the ORP yield. The irrigation demands imposed on the ORP is summarised in **Table 2-8**.

Table 2-8: Summarised irrigation demands

Description	Current levels (1990)		Potential levels	
	Area (ha)	Demand (million m^3/a)	Area (ha)	Demand (million m^3/a)
Directly from ORP Dams				
Scheduled	70 720	810.2	87 876	997.4
Section 56(3)	650*	8.1	650*	8.1
Losses		185.9		215.2
Sub-total	**71 370**	**1 004.2**	**88 526**	**1 220.7**
Below the Vanderkloof Dam				
Scheduled	59 086	758.7	86 610	1 116.4

Description	Current levels (1990)		Potential levels	
	Area (ha)	Demand (million m^3/a)	Area (ha)	Demand (million m^3/a)
Section 56(3)	240*	3.5	240*	3.5
Losses		64.3		87.9
Sub-total	**59 326**	**826.5**	**86 850**	**1 207.8**
Total	**130 696**	**1 830.7**	**175 376**	**2 428.5**

Note: *Estimate

The urban demands from the ORP are summarised in **Table 2-9**. In all cases the highest value of the projected demand or the allocated amount was used for the future demand, except in the case of Bloemfontein and Port Elizabeth, where the projected 2020 demand was used.

Table 2-9: Summarised urban demands

Area/River reach		1990 Demand (million m^3/a)	2020 Demand (million m^3/a)
Caledon River upstream of Welbedacht		9.0	19.7
Orange River upstream of Gariep Dam		6.1	7.9
	Sub-total	**15.1**	**27.6**
Riet/Modder River (towns supplied from ORP)		1.0	1.8
Bloemfontein (portion supplied from Caledon River)		34.3	128.9
Port Elizabeth		9.1	58.9
Caledon River downstream of Welbedacht Dam		1.0	1.0
Fish/Sundays		5.1	23.7
	Sub-total	**49.5**	**212.5**
Orange River:	Gariep to Orange -Vaal	2.9	4.0
	Orange/Vaal to Boegoeberg	0.6	1.7
	Boegoeberg to Neusberg	12.2	22.4
	Neusberg to Vioolsdrift	9.3	16.4
	Vioolsdrift to River mouth	9.8	14.1
	Sub-total	**34.8**	**58.6**
	Grand Total	**100.4**	**300.5**

If the allocated amounts to Bloemfontein (166 million m^3/a) and Port Elizabeth (207 million m^3/a) were used, the ultimate future urban demand on the ORP will be 486 million m^3/a.

Apart from the urban demands there were a number of industrial users who have been granted permission to withdraw water from the Orange according to Section 56(3) of the water act. This amounts to 5.2 million m^3/a.

An amount of 1 million m^3/a was allowed for stock watering from the ORP.

At the time the environmental requirements between Vanderkloof Dam and the river mouth was estimated at 200 million m^3/a. River losses was then estimated to be in the order of 800 million m^3/a. The River Losses study was at that time not yet completed.

Return flows from small irrigation schemes were estimated at 10% of the quota and for large schemes at 20% of the quota. The potential return flows are summarised in **Table 2-10**.

Table 2-10: Potential irrigation return flow volumes

Description	% of quota	Return flows (million m³/a)	
		Current levels	Potential levels
Downstream of Welbedacht	10	2.9	2.9
Gariep to Vanderkloof Dam	10	1.9	2.2
Sub-total		4.8	5.1
Vanderkloof main Canal*	20	2.2	2.2
Ramah Canal	20	10.1	10.1
Orange Vaal Transfer Scheme**	20	3.3	3.3
Other Schemes	20	71.9	99.6
River abstractions	10	33.3	49.2
Sub-total		**120.8**	**164.4**
Total		**125.6**	**169.5**

Notes: * Orange Riet Canal and Riet River not included.
**Return flows upstream of Douglas Weir not included

The total demand imposed on the ORP system at the then current development level was calculated to be 2 965.2 million m³/a with the net demand after taking return flows into account being 2 836.5 million m³/a. The 2020 demand was estimated to be 3 749.8 million m³/a with a net demand of 3 574.3 million m³/a. In the calculation of the future demands no additional irrigation schemes apart from the development of some 6 300ha on the northern bank of the Orange River in Namibia were taken into account as well as normal growth in the urban demands.

Up to the implementation of Phase 1a of LHWP, the ORP will still be able to supply the 2020 ORP demand. After the implementation of Phase 1b power generation will have to be stepped down. After Phase 2 the ORP will no longer be able to supply the consumptive demand. The projected surplus and shortfalls are summarised in **Table 2-11**.

Table 2-11: Projected shortfalls in water supply from the ORP for various phases of the LHWP

LHWP Phase	Yield (million m³/a)	Consumptive demand in 2020 (million m³/a)	Power Generation demand in 2020 (million m³/a)	Surplus (Shortfall) (million m³/a)	
				Consumptive Demand only	With Power Generation
	4 492	3 575	750	917	167
1(a)	4 063	3 575	750	488	(262)
1(m)	4 063	3 575	750	427	(323)
1(b)	3 812	3 575	750	237	(513)
2	3 359	3 575	750	(216)	(966)
3	3 069	3 575	750	(506)	(1 256)
4	2 937	3 575	750	(638)	(1 388)
5	2 791	3 575	750	(784)	(1 534)

2.2.4 Development options to increase Hydro Power Generation and Yield of the Orange River System

Hydro-power generation at Gariep and Vanderkloof dams is of major importance both to Eskom and the country as a whole. Due the importance and high value of the hydro-power it was decided to provide an outline of the hydro-power generated at the two dams.

The main components considered in the second phase analyses included the following:

- The influence of demand distributions.
- The influence of compensation releases during periods of no power generation.
- The influence of increased storage at Gariep and Vanderkloof dams.
- The influence of a seasonal storage dam downstream of Vanderkloof Dam (i.e. Torquay Dam)
- The influence of the Lesotho Highlands Water Project.

Hydro-power at Gariep dam cannot be generated below the 1 231.4m, with a remaining storage of 699.2 million m³. At Vanderkloof Dam a similar situation exists and hydro-power cannot be generated below the level of 1 150.9 m at a remaining storage of 1 230.5 million m³.

The main conclusions from the analyses carried out were the following:

- Changing the minimum operating level from the dead storage to minimum draw down level for hydro-power generation purposes resulted in a decrease in yield of 15% from 4 449 to 3 866 million m³/a.
- Using a variable demand pattern instead of a constant demand pattern increased the yield from 3 866 to 3 901 million m³/a. The hydro-power generation dropped from 96 to 97 MWc.
- Increasing the storage capacity at both dams, first Vanderkloof by 21.1% and then only Gariep by 40.8% and finally both dams, resulted in an increase in yield of 3%, 11% and 14% from 3 901 million m³/a to 4 029, 4 315 and 4 429 million m³/a respectively. The increase in the maximum energy for these three scenarios was 4%, 16% and 22% respectively from 97 to 101, 113 and 118 MWc.
- The compensation releases had no effect on the system yield and a small effect on the maximum power.
- The LHWP had a significant impact on the yield as well as on the energy. The results are summarised in **Table 2.11.**
- The inclusion of Torquay Dam had definite advantages, especially for hydro-power generation.
- It was recommended that detailed cost analyses be undertaken to determine the advantage of raising Gariep and Vanderkloof dams as well as for Torquay Dam to increase the yield and power generation ability.

2.2.5 Integrated System Analysis

The objective of the integrated system analysis was to assess the influence of the present and future demands of the consumers in the catchment on the yield characteristics of the existing storage facilities.

System constraints that were included in the analysis are continues abstraction at Welbedacht purification plant of 1.157 m³/s which was increased to 4.5 m³/s coinciding with the implementation of phase 1b of the LHWP. A transfer of 29 m³/s from Katse Dam to the Vaal as provided for. Vanderkloof and Gariep dams were drawn down equally. The minimum operating levels in Vanderkloof (1 150.9 m) and Gariep Dam (1 231.4 m) was set to the lowest level for power generation at the two dams.

Analyses were performed for the current system a) with present (1992) water demands, b) with future (2020) water demands, c) in conjunction with the LHWP Phase 1b and d) with LHWP Phase 5. Influences of the development up to the Orange River Mouth were modelled. The results indicated that the risk of non-supply to all the consumers will substantially increase should any development beyond LHWP Phase 1B be implemented and that it is therefore essential to evaluate alternative sources to sustain the supply to the Gauteng area or to evaluate supplementation schemes for the consumers in the Orange River Basin.

2.2.6 Evaluation of possible augmentation from the Mzimvubu River: Reconnaissance Study

Report Title: EVALUATION OF POSSIBLE AUGMENTATION FROM THE MZIMVUBU: RECONNAISSANCE STUDY.

2.2.6.1 **Background:**

The results from the Orange River System Analysis Study: Phase 1, indicated amongst others that the yield of Hendrik Verwoerd and PK Le Roux Dams would be adversely affected by the implementation of the development phases, after Phase 2, of the Lesotho Highlands Water Project. As part of Phase 2 of the Orange River System Analysis Study, the possible augmentation of the water supply in the Orange and/or Vaal River catchments from the Mzimvubu River was investigated.

The purpose of the report was to describe the Mzimvubu catchment and to investigate the possibility of water transfer to the Orange and/or Vaal River Basin.

2.2.6.2 **Water Resources of the Mzimvubu Basin**

The Mzimvubu Basin covers an area of 20 060 km^2, of which 70% lies within Transkei and 30% in South Africa. The MAP of the Basin is generally above 800 mm and the MAR is approximately 2 000 x $10^6 m^3$. The topography varies from the Drakensberg mountains, through the central plateau to a hilly coastal belt at the Indian Ocean. The Mzimvubu Basin river system comprises the Mzimvubu River and its four main tributaries the Tsitsa, Tina, Kinira and the Mzintlava Rivers. The Basin was at that time relatively undeveloped, and the water use low (72 x $10^6 m^3/a$).

The Mzimvubu Basin has large resources that are not fully utilized at present which could be utilized for local development or transfer to adjoin catchments. Previous studies have also shown that there is a good potential for the generation of hydro-electric power in the Basin.

Yield analyses at four possible dam sites, the Kinira, Mpindweni, Ntabelanga and Mbokazi Dam in the Mzimvubu catchment were done. Yield figures are for standalone dams. The future local water demands have been taken into consideration in determining the volumes of water available for transfer. Because of the relatively few known demand and growth factors in this area, the yields that were calculated were conservative. **Table 2-12** presents the availability of water for transfer for various levels of local development.

Table 2-12: Water available for transfer – $10^6 m^3/a$

Dam sites	Ntabelanga	Mpindweni	Kinira	Mbokazi*
River	Tsitsa	Tina	Mzimvubu	Mzimvubu
Area (km^2)	1 980	2 313	6 814	19 587
MAR ($10^6 m^3$)	465	439	740	2 770

Dam sites	Ntabelanga	Mpindweni	Kinira	Mbokazi*
MAP (mm)	912	869	785	838
Firm yield ($10^6 m^3/a$)	324	324	426	1 980
2000 – Low demand	223	257	292	1 486
[m^3/s]	[7.1]	[8.1]	[9.2]	[47.1]
High demand	189	221	201	1 246
[m^3/s]	[6.0]	[7.0]	[6.4]	[39.5]
2000 – Low demand	206	240	254	1 225
[m^3/s]	[6.5]	[7.6]	[8.0]	[38.9]
High demand	135	182	184	651
[m^3/s]	[4.3]	[5.8]	[5.8]	[20.6]

* The yield for Mbokazi Dam has been calculated as if there were no upstream dams.

2.2.6.3 Identification of Transfer Options

Various previous desk studies had been done to investigate the development potential in the Mzimvubu basin. These studies concentrated on power generation and water transfer schemes. With these studies as background and taking the possible shortfalls in the Orange River into account, three basic transfer schemes were identified. Major components, such as dam sites and transfer routs coincide with the previous schemes.

The three transfer schemes that have been identified are:

- The Mzimvubu-Kraai Transfer Scheme, to supplement shortfalls in the Orange Rive system if the LHWP is developed to its final phases;
- The Mzimvubu-Tugela/Vaal Transfer Schemes, could supplement the supply in the Vaal System, if the LHWP is not developed to its final Phases; and
- The Mzimvubu-LHWP Transfer Scheme, where water could be transferred from the Mzimvubu to the Vaal System via the LHWP or be released to the Orange River system.

Based on the costing at that time, the ranking using URV as the criteria was:

Alternative A: Mzimvubu-Kraai
Alternative B: Mzimvubu-Tugela
Alternative C: Mzimvubu-LHWP

2.2.6.4 Recommendations

In view of the availability of water for transfer and the favourable unit reference values, it was recommended that the viability to transfer water from the Mzimvubu be investigated in more detail.

Specific recommendations were as follow:

- The Vaal River Augmentation studies should be taken into consideration in any further studies on transfer schemes from the Mzimvubu Basin.
- The hydrology of the Mzimvubu Basin has to be reviewed and updated.
- The present and future water demands of developments in the Mzimvubu catchment should be determined.
- The incorporation of Hydro power and pumped storage schemes into the transfer scheme should be investigated.

2.3 VAAL AUGMENTATION PLANNING STUDIES (1994)

2.3.1 Overview

The purpose of the Vaal Augmentation Planning Study (VAPS) was to determine the most feasible source of water to further augment the water resources of the Vaal River System. At the time of the study (1994 to 1996) it was expected that the growth in the water requirements would be substantial and that that infrastructural intervention would be inevitable.

Four main alternatives were considered:

- Lesotho Highlands Water Project (LHWP)
- Orange Vaal Transfer Scheme (OVTS)
- Tugela Water Project (TWP)
- Mzimvubu Transfer Option (MZTO)

The TWP only affects the Tugela and Vaal systems, and is not assessed in this report. The LHWP, OVTS and MZTO affect the Orange as either a donor catchment (LHWP) and ORRS or a receiving catchment (MZTO).

The VAPS study produced several reports of an over-arching nature which cover general subjects relating to augmentation as covered in **Section 2.3.2**. The reports on each of the augmentation sources are covered in the **Sections 2.3.3** to **2.3.5**.

2.3.2 Overarching Reports

2.3.2.1 Reconnaissance Phase Review

Report Title: VAPS: RECONNAISSANCE PHASE REVIEW REPORT. Report Number PC000/00/13894. Compiled by BKS Inc. for the Department of Water Affairs and Forestry, August 1994.

- The aim of the document was to consider all possible development options identified in the reconnaissance phase of the four separate studies and to select the most promising schemes to be assessed at pre-feasibility level of detail. The report was compiled after the reconnaissance phase of the VAPS was completed and a meeting was held with a panel of reviewers to review the completed work and identify what further investigations needs to be undertaken.

- The main recommendations relevant to the current re-conciliation study that were extracted from the reconnaissance studies and the review process are as listed below:
    - The Thukela options should be re-evaluated in terms of the integration of options to define a long term total development scenarios.
    - Consistency in assessment approaches of future work is required with respect to transfer losses, allowances for over sizing of infrastructure components to allow for down-time and the quantification of benefits for the source basin from where the water is transferred.
    - A major potential social risk was identified for the Lesotho Highlands Water Project with respect to compensation. It was indicated that the success of the compensation programme that was underway (at that time) for the first phase of the project would be extremely important.
    - It was identified that more than one delivery route, or a split delivery, should be considered for the Mzimvubu options. It was sited that this would enhance the flexibility and security of the supply from this source.
    - The need to maintain flexibility in the implementation of options to accommodate altering circumstances was identified as an important planning criterion.

- It was agreed that the source basin of each option must allow for services according to the Reconstruction and Development Plan (RDP) compiled by the government.
- The royalties and compensation methods should be developed further.

- Other aspects mentioned in the document that have relevance to the re-conciliation study are as follows:
  - Water conservation and demand management could postpone the date when the schemes need to be implemented.
  - Labour intensive construction methods should be considered for the implementation of the augmentation schemes.
  - The Zambezi Scheme remains to be very expensive relative to the options that were assessed in the VAPS reconnaissance phase study.
  - The importance of accounting for the filling time of proposed dams was identified as an important aspect to take into account in the planning process.
  - The energy costs associated with schemes were cited as being a large portion of the overall costs and it was identified that some optimisation should be considered in future studies. The possibility of allowing Eskom to influence the operating procedures of schemes could reduce the pumping costs.

2.3.2.2 **VAPS: Legal Aspects**

Report Title: VAAL AUGMENTATION PLANNING STUDY-LEGAL ASPECTS. Report Number PC000/00/14294. Compiled by BKS *et al* for the Department of Water Affairs and Forestry, 1994.

The document consists of five parts (called interim reports in the document). It addresses diverse legal matters relating to the implementation of the further phases of the Lesotho Highlands Water Project or their impact with regard to any alternative project configuration or other possible strategies. The first three interim reports as well as part of the fifth deal with the interpretation of discrete aspects of the Treaty on the Lesotho Highlands Water Project. The fourth deals with environmental, social and cultural issues and the remainder of the fifth report are devoted to the question of accommodating Namibian interests with regard to the implementation of the project.

No option as far as the augmentation of water in the Vaal River catchment is identified in the document.

Although not an option, the document deals with the question whether or not the government of the Republic of South Africa is bound in terms of the Treaty to proceed with any of the phases of the project after Phase 1B as well as the potential obligations which may be incurred by the government of the Republic of South Africa should South Africa decide not to proceed with the implementation, especially with respect to the impact on royalty payments.

2.3.2.3 **VAPS: Overview Report**

Report Title: VAPS: OVERVIEW REPORT. Report Number C000/00/15395. Compiled by Orval Consult for the Department of Water Affairs and Forestry, 1995.

The purpose of this report is to discuss the water supply situation in Vaal River System supply area, the overview of possible solutions (i.e. non-augmentation, demand management and augmentation of resources (Lesotho Highlands Further phase, Orange-Vaal canal scheme, Caledon cascade scheme, Tugela-Vaal transfer scheme, Mzimvubu transfer options, Orange-Vaal Weirs Scheme).

The primary aim of the VAPS was to decide on the best scheme after Phases 1A and B of the LHWP to augment the water resources serving the Vaal River supply area. From the arguments and recommendations, the main recommendations of the VAPS were:

1. Do a feasibility study of the Tugela Southern Tributaries Transfer Scheme as an option for augmentation.
2. Delay the final choice between further phases of LHWP and an Orange-Vaal Canal Scheme until after the Orange River re-planning Study has been completed.
3. Discard the Caledon Cascade Scheme and the Orange-Vaal Weirs Scheme due to high costs.

2.3.3 Mzimvubu Transfer Options Report

2.3.3.1 Mzimvubu Transfer Option: Reconnaissance Stage Main Report (Final)

Report Title: VAPS: MZIMVUBU TRANSFER OPTIONS. RECONNAISSANCE MAIN REPORT (FINAL). Report Number PC000/00/14894. Compiled by Consult 4 for the Department of Water Affairs and Forestry, August 1996.

This reconnaissance study followed on the pre-reconnaissance report and refined the work in that report. This report summarises the findings of the other reports which are listed and which were reviewed but are not only the dams are not discussed here.

Three possible options have been identified to transfer water from the Mzimvubu and thus augment the supplies in one of the resource basins. The three options are:

a) OVTS Transfer (Kraai Option)

Water delivered to the Bell River would flow into the Kraai River and hence to the Orange River to the proposed Goedemoed Weir. Water abstracted at the Goedemoed Weir would be conveyed via a system of pumps, rising mains canals, syphons and tunnels, 515 km long in all, to a tributary of the Liebenbergsvlei River.

An alternative proposal for the Orange Vaal transfer is known as the Caledon Cascades scheme. If this proposal had been implemented, Mzimvubu water could also be transferred together with Caledon/Orange River water by sequential pumping from weir to weir up the Caledon River. Costs involved would relate to providing increased pumping capacity, raising the weirs marginally, and canals for the conventional transfer sections.

b) Lesotho Highlands (Tsoelike Option)

At this stage, it appears unlikely that Tsoelike Dam will be required as part of the extensions to the Lesotho Highlands Scheme. The preferred delivery route for water from the Mzimvubu Basin would be directly to Mashai Dam and hence to Katse Dam and Muela en route to the Axle River. A booster pump station would be required on the leg to Mashai and a pump station for the Mashai to Katse section. Tunnels are required throughout.

c) TVTS Transfer (Tugela Option)

Water delivered to Bucklands Dam on the Mkomazi River would gravitate from Bucklands Dam through a 110 m long tunnel to a point on the right bank of the Mlambonja River, then be syphoned to the left bank from where a canal and a second syphon would convey water across the Tugela River between Driel Barrage and Woodstock Dam. Near Woodstock Dam wall a pumping station would raise the water 80 m into a 29 km long canal to the farm Waterkloof. The transfer pumping station would be situated at Waterkloof and would pump water 444 m high over the escarpment to the headwaters of the Oubergspruit, a tributary of the Wilge River.

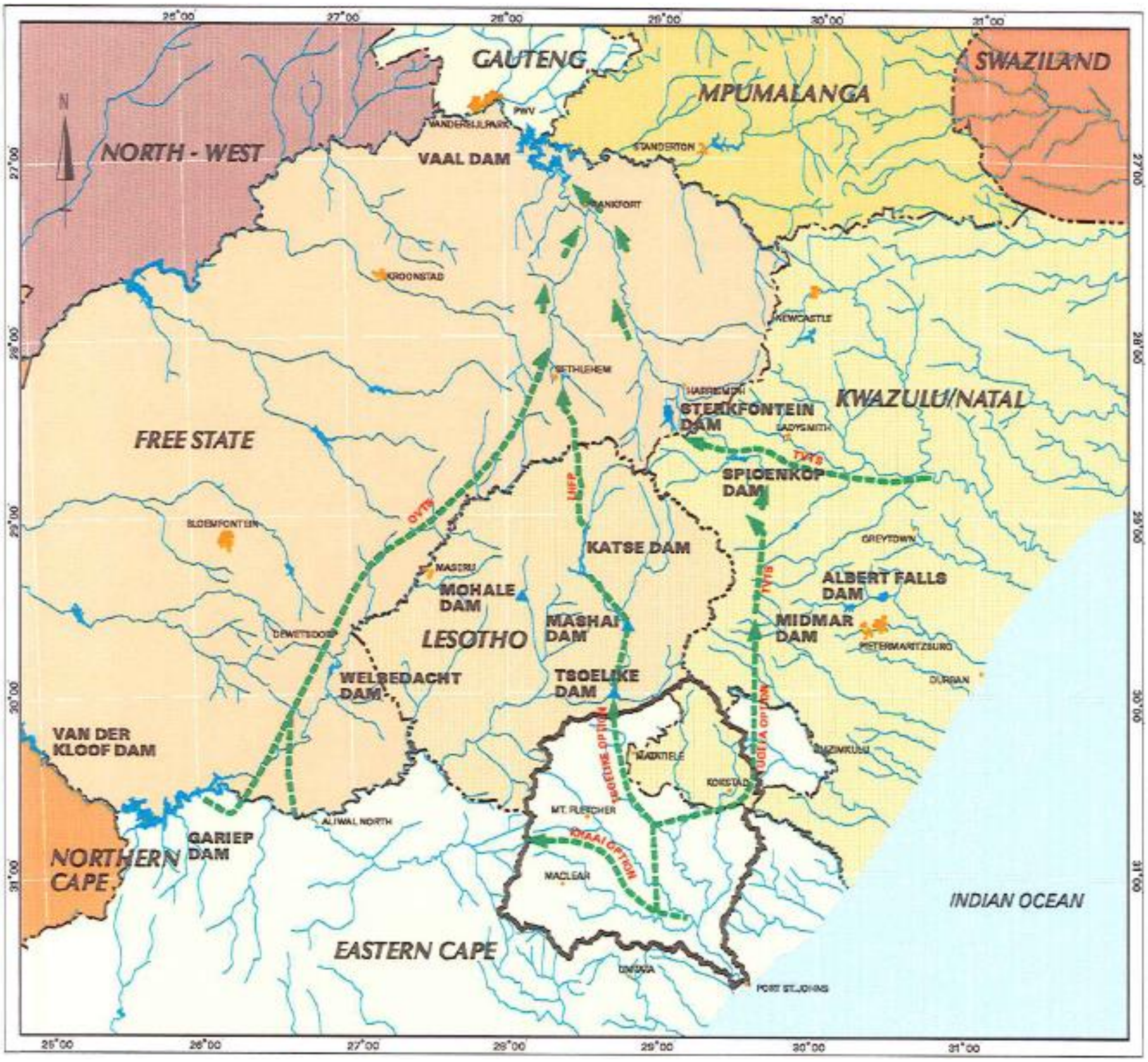


Figure 2-1: Mzimvubu Transfer Options to the Vaal System

The most significant aspects are summarised in the following sections.

2.3.3.2 Water Demand

The ecological water demand was work shopped and set at 37%. This was mainly due to requirements at the estuary. The other values were refined and some showed little or no change. The demands in the Mzimvubu Basin (given in million m³/annum) are:

- Domestic/Industrial (high) = 50.0
- Stock Watering (low) = 16.0
- Irrigation (low) = 149.0
- Reduction due to afforestation = 139.0
- Total consumptive use = 354.0
- Ecological requirement (37% of MAR) = 1076.0

TOTAL DEMAND (49% of MAR) = 1430.0

2.3.3.3 Water availability

The naturalised MAR of the basin was revised to 2 894 million m³/annum. Taking all factors into account the exploitable maximum yield for transfer is approximately 40 m³/s. This would require a 2.5 MAR active storage in the scheme. The schemes were also assessed for 20 m³/s to check for the consistency of lower yields.

2.3.3.4 Social Impact

All three schemes would impact on the social areas to a similar level for a scheme capability of 40 m³/s. Some 79000 people would be affected including 337 households and 23 870 ha of land.

For the smaller 20 m³/s schemes the numbers are 52000 people, 315 households and 15 510 ha for the Kraai options; 47 000 people, 320 households and 14 700 ha for the Tsoelike option and 35 000 people, 260 households and 13 300 ha for the Tugela option.

A scheme of this magnitude would however provide great benefits. Negative impacts should however be mitigated where possible.

2.3.3.5 Scheme Costs

The scheme costs are summarised in the table below. The Kraai option is however broken up into two sub-options referred to as the Kraai/Goedemoed option and the Kraai/Caledon Cascades option. The main difference being the proposed conveyance system to transfer water to the Vaal. The Kraai/Goedemoed option could provide water to the lower Orange as an alternative option.

Table 2-13: Cost Breakdown between Mzimvubu Basin and Onward Delivery (R million)

Scheme	Mzimvubu Basin		Onward Delivery		Total	
	CAPEX	Power (annual)	CAPEX	Power (annual)	CAPEX	Power (annual)
Scheme capability of 40m³/s						
Kraai/Goedemoed	13947	417.0	6316	204.8	20263	621.8
Kraai/Caledon	13947	417.0	3547	217.1	17493	634.1
Tsoelike/LHFP	14631	376.0	6316	228.7	20942	604.2
Tugela/TVTS	16019	276.1	4658	200.7	20677	476.8
Scheme capability of 20 m³/s						
Kraai/Goedemoed	8253	169.0	4450	101.3	12703	270.3
Kraai/Caledon	8253	169.0	2496	108.5	10749	277.5
Tsoelike/LHFP	7734	162.6	3816	100.4	11551	262.9
Tugela/TVTS	8395	80.6	3282	120.1	11677	210.7

To compare the schemes the unit reference values were compared and are shown in the table below.

Table 2-14: Unit Reference Values (URV)

Option	Yield		Cost		URV (R/m³)
	Yield (m³/s)	Annual (10^6m³)	CAPEX (Rbn)	Power NPV (Rm)	
Kraai/Goedemoed	35.2	4030	20.26	12375	3.07
Kraai/Caledon	38.2	4241	17.49	10837	2.56
Tsoelike/LHFP	39.7	4342	20.95	12907	2.97
Tugela/TVTS	41.3	4445	20.68	12443	2.80

2.3.3.6 Conclusion

Conclusions from the study are:

- Although the Kraai/Caledon Cascades option was the most economical political and social issues in especially Lesotho could put this option in doubt. It was thus not recommended.
- The Tugela option is the most economical, followed by the Tsoelike option (6% more than the Tugela option) and the Kraai/Goedemoed option (9.6% more than the Tugela option).
- The cost of supplying water from the Mzimvubu is extremely high, being more than double the cost of that from the Tugela or the Orange River. The high cost should prompt a review of other sources or options. One option could be the reallocation of water rights in the Orange River.
- Social impacts on all three options are similar. Economic spin-offs could benefit an economically deprived region of South Africa.
- Environmental impacts are similar for all three schemes.
- There is no clear indication of any viable hydro-power development. Some sections of schemes may however benefit from local schemes or pumped storage options.
- The ecological reserve must still be refined.
- The optimisation of scheme components is provisional. The required 2.5 MAR active storage is near the upper limit.
- The Tugela/TVTS option was then the more attractive due to its considerably lower operating transfer cost than the other two options, lowest annual power cost due to the lower static head, potential flexibility through a possible supply to the Pietermaritzburg/Durban area and the potential of increasing the supply by developing water resources in rivers along the route in southern KwaZulu-Natal.

2.3.3.7 Matters requiring immediate attention

The following issues required immediate attention;

- Hydrology. Improve river and rain gauging network. The lack of more information does impact on confidence levels regarding the hydrology.
- Environmental. . Install water level recorder in the Mzimvubu estuary.
- Local development. During the study a need to address local development was identified. This included forestry and irrigation development for which there is a great potential.
- Should the preferred option be pursued the layout must be reviewed.
- The cost of an Mzimvubu transfer scheme should draw increased attention to other alternatives to manage water demands in the Vaal river basin.

2.3.3.8 Recommendations

The following recommendations were made;

- During pre-feasibility the best option should be confirmed. Also include the rivers of southern KwaZulu-Natal.
- Investigate the potential for hydro-power. There could be potential for pumped storage options and small hydro on the Kraai option.
- Due to the high annual energy cost appropriate cost structures must be discussed with ESKOM.
- Planning and engineering should be done in conjunction with social assessments.
- The sizing and location of scheme components should minimise impact on communities.

2.3.4 Lesotho Highlands Further Phases

Report Titles:

(A) RECONNAISSANCE STAGE. MAIN REPORT. Compiled by Consult 4. DWAF Report

Number PC000/00/13494, 1994.

(B) PRE-FEASIBILITY STAGE. MAIN REPORT. Compiled by Consult 4. DWAF Report Number PC000/00/13594, 1995.

2.3.4.1 **Overview**

These reports all relate to the augmentation of the Vaal River system by further development of the Lesotho Highlands Water Project (LHWP). This is referred as the Lesotho Highlands Further Phases (LHFP).

The LHWP Phase IA, consisting of the Katse Dam and the transfer tunnel via Muela to the Axle (now known as Ash) River, was completed in 1998. The Muela tunnel has break about 45km from Katse where a hydro-power station is located at Muela. Phase IB, consisting of the Mohale Dam and Matsoku Weir from where water is a transferred via a tunnel to Katse Dam, was completed recently.

A number of additional dam sites and conveyance systems have been identified for LHFP. During the reconnaissance study 19 potential layout options where identified and assessed for further investigation. This layout provided yields from 14 m³/s to 48 m³/s and was based on historic firm yield estimates. Of the 19 original layouts:

- 13 were discarded during the reconnaissance study; and
- 6 were assessed in more detail during the prefeasibility study.

For the pre-feasibility study the yields, defined with an assurance level of 1:100 years, include the losses from the outfall to Vaal Dam. The LHFP study also took the possible transfers from the Mzimvubu River into account in the sizing of conveyance systems.

2.3.4.2 **Hydrology**

The most significant aspects from these studies are the impact of the yield definition and more stringent environmental requirements have on the actual yield. Previous studies did not include the losses from the outfalls to Vaal Dam and environmental releases where on a nominal compensation release of 0.5 m³/s. The yields for the various layouts are shown in the table below.

Table 2-15: Yield results

Layout	Dam	Historic Firm Yield			Long Term Characteristic Yield (m³/s)					
		Recon Study	Pre-feasibility		1:50 yr.		1:100 yr.		1:100 yr. include losses to Vaal Dam	
			Low IFR	High IFR	Low IFR	High IFR	Low IFR	High IFR	Low IFR	High IFR
	Phase I-Katse, Mohale, Matsoku	28.7	28.3	28.3	27.9	27.9	26.3	26.3	N/A	N/A
3	Polihali		12.9	12.2	13.0	11.7	12.4	11.1	10.9	9.6
6 & 7	Mashai	21.9	20.4	15.6	20.6	15.8	20.6	15.5	19.7	14.6
11	Polihali & Taung	22.4	12.9 8.0	12.2 5.5	13.0 8.0	11.7 6.3	12.4 7.9	11.1 5.4	18.8	15.0
12 & 13	Mashai & Tsoelike	21.9 11.6	20.4 10.5	15.6 8.7	20.6 10.1	15.8 8.9	20.3 9.8	15.5 8.6	28.4	22.4

The Long Term Characteristic Yield (LTCY) is based on 400 stochastically generated flow sequences. The above also includes the analysis for the two environmental scenarios.

2.3.4.3 **Dams**

The dam sites assessed were the Polihali, Taung, Mashai and Tsoelike. The sites at Ntoahae and Malatsi were discarded early on in the feasibility study. The IFR and new yield requirements made these sites, comprising phase IV of the LHWP, economically not viable.

Dam types assessed were earth and rock fill embankments, concrete clad rock fill dams and roller compacted concrete gravity dams. Arch dams were not considered due to limited foundation information. All the sites and dam types assessed are technically feasible.

2.3.4.4 **Tunnels**

Tunnels assessed were;

- To Axle River – Tunnel from Mashai to Katse, Katse to Muela and Muela to Axle River. The tunnel from Mashai Dam to Katse Dam will be a pumped tunnel. The tunnel from Katse to Muela and on to Axle will run adjacent to the phase I tunnel.
- To Axle River – Tunnel from Mashai to Muela and Muela to Axle River. The tunnel from Mashai/Taung will be a gravity section to the Muela power station tail pond. From Muela to the Axle River the tunnel will run adjacent to the phase I tunnel.
- To Elands River – Polihali to Elands River. Gravity line from Polihali to Elands River headwaters east of Fika Patso Dam.
- To Elands River – Tunnel from Taung to Polihali and from Polihali to Elands River. Water from Taung will be pumped to Polihali. From Polihali to Elands River it will be a gravity section.

2.3.4.5 **Hydro power**

Hydro power potential exists at the Muela and Elands outfalls but based on the then current power cost (1995) these were not economically viable.

2.3.4.6 **Mzimvubu Transfers**

Components in the LHFP were assessed to include a 40 m^3/s transfer from the Mzimvubu River catchment.

2.3.4.7 **Environmental and Social impacts**

The studies indicated that none of the dams had environmental impacts that would render the project unacceptable. The most significant impacts are the social impacts associated with resettlement and loss of productive resources. The impacts must be managed properly to ensure that mistakes made during Phase IA are not repeated as failure may constitute a fatal flaw during the implementation.

Three IFR sites were investigated during a workshop and their requirements established. This is subject to further refinement.

2.3.4.8 **Summary of Selected Layouts**

The relevant layout parameters are listed in the table below. The schemes are assessed for high (H) and low (L) IFR releases.

Table 2-16: Yield results and Unit Reference Values

Scheme	Yield (m^3/s)	CAPEX ($Rx10^6$)	Energy ($R\ x10^6$)	URV (c/m^3)
Polihali to Elands (L)	10.9	1657	0	101.0
Polihali to Elands (H)	9.6	1813	0	126.9
Med Mashai via Katse to Axle (H)	10.0	1773	238	133.0
Med Mashai via Katse to Axle (H**)	10.0	1041	237.9	85.5
Mashai via Katse to Axle (6H)	14.6	2327	127	127.7
Mashai via Muela to Axle (7H)	14.6	2735	0	136.8
Mashai via Katse to Axle (6.1L)	14.1	1833	238	100.4
Mashai via Katse to Axle (6L)	19.7	2319	164	92.5
Mashai via Muela to Axle (7L)	19.7	2609	188	101.5
Taung to Polihali to Elands (L)	18.8	2623	48	101.1
Taung to Polihali to Elands (H)	22.4	3105	217	110.7
Tsoelike to Mashai via Muela to Axle (H)	22.4	3748	16	124.9
Tsoelike to Mashai via Katse to Axle (12L)	28.4	3496	295	104.8
Tsoelike to Mashai via Katse to Axle (13L)	28.4	4050	54	112.1

2.3.4.9 **Conclusion and Recommendations**

The yields that can be provided vary between 10 m³/s to 29 m³/s. Although the final selection depends on the volume of water available for transfer, Layout 6, Mashai pumping to Katse, has the lowest URV for all four scenarios, provides the most flexibility for the range of yields and could include the Mzimvubu transfers if the conveyances are sized accordingly.

2.3.5 Orange Vaal Transfer Scheme

2.3.5.1 **Reconnaissance Report**

Report Title: VAPS: ORANGE-VAAL TRANSFER SCHEMES (OVTS): RECONNAISSANCE REPORT. DWA Report Number C 000/00/13194. Compiled by Orval Consult for the Department of Water Affairs and Forestry, 1994.

This report investigated the option of augmenting the Vaal River Systems from the Orange River. Each of the development options investigated in the OVTS can be grouped into one of three categories:

1. A conventional pump station, rising main, tunnel and canal type conveyance system from the Hendrik Verwoerd Dam through the middle of the Orange Free State. The Verwoerd Dam Western Option (VDWO) falls into this category.
2. A conventional pump station, rising main, tunnel and canal type conveyance system following a route close to the eastern border of the Orange Free State. The Verwoerd Dam Eastern Option (VDEO), Goedemoed Option (GO), Aloedal Option (AO), Bakenkop Option (BO), Finlays dyk Option (FO), Makhaleng Option (MO), Upper Caledon Option (UCO), Upper Caledon Alternative Option (UCAO), all fall into this category.
3. A cascade type conveyance system where dams are built in suitable positions in the Caledon River and whereby the flow can be reversed by pumping in an upstream direction from each downstream dam into the immediate upstream dam. The Caledon Cascades Scheme (CCS) falls into this category.

It was recommended that the following development options be investigated at pre-feasibility level:

1. Caledon Cascades Schemes with the upper Caledon Option;
2. Aloedal option; and
3. Goedemoed option

2.3.5.2 **Pre-Feasibility Report (May 1995)**

Report Title: VAPS: ORANGE VAAL TRANSFER SCHEME: PRE-FEASIBILITY REPORT. Report Number C000/00/13294 Pre-Feasibility Main. Compiled by Orval Consult for the Department of Water Affairs and Forestry, 1994.

This executive summary deals with the findings of the OVTS. It can be expected that any unutilised water in the Orange River System will have to be used to augment the water supplies of the Vaal River system. This can be done by abstraction from the upper reaches of the Caledon River, by further phases of the LHWP or by a transfer from the upper reaches of the Orange River.

The Caledon cascade scheme can only be considered for water transfers significantly larger than 25 m³/s.

2.3.5.3 Caledon Cascades Special Reconnaissance Report

Report Title: VAPS: ORANGE VAAL TRANSFER SCHEME: CALEDON CASCADES SPECIAL RECONNAISSANCE REPORT (May 1995): Revised cascade scheme looking at water supply, cascade system and upper end conveyance. Report Number C000/00/13294 Spes-Recon A1. Compiled by Orval Consult for the Department of Water Affairs and Forestry, 1994.

This report shows that the Caledon Cascade scheme remains a financially attractive option and no fatal flaws could be identified. A big advantage of the CCS is the relatively low incremental cost of increasing the volume of water to be transferred.

It is recommended in this report that the study be allowed to proceed to the next level of detail, focussing on the important issues and in particular the social issues, sedimentation model studies, detailed flood water level analyses and the involvement of Lesotho.

2.4 ORANGE RIVER DEVELOPMENT PROJECT REPLANNING STUDY (1998)

2.4.1 Overview

The Orange River Development Project Replanning Study (ORRS) was commissioned to determine a strategy for the most beneficial utilisation and optimal development of the water resources of the Orange River as recommended in the Orange River System Analysis Study.

It is recognised that further development of the resource will become necessary in due course and investigation of the options in this respect will form an important part of the study. The first priority, however, is for appropriate water conservation and demand management strategies to be devised and effectively implemented before any new works are constructed. Rather than firm development plans, a framework strategy is required to direct the utilisation and development of the resource towards ultimately achieving the greatest overall benefits for all.

The Orange is an international river and its waters must be shared by the basin states. On the other hand, South African water law views water in the country as a national asset to be utilised equitably by all. The study was therefore conducted with due regard to regional, national and international considerations. Existing and potential South African developments within the Orange River basin were considered, as well as the possible transfer of water to other basins. The existing and potential future needs of Lesotho and Namibia were also taken into account.

Apart from the normal technical evaluation, specific attention was also given to social, environmental, broad economic and transboundary issues. The public and stakeholders were informed and consulted throughout the study by means of a well-planned public involvement programme.

2.4.2 Water Demands of the Orange River Basin

This report summarises the water demands for the Orange River Development Project Replanning Study. The water demands have been grouped into different user categories, irrigation, urban (including industrial, mining and stock watering) and environmental losses and also include river losses (evaporation losses from the river surface area) and conveyance losses. Two separate reports on water demands were prepared, one for the Orange River basin and one for the Eastern Cape. This report focusses on the demands in the Orange River basin.

The future irrigation demands were determined for different irrigation areas, but a final decision on the allocation of that water will only be taken once the water availability in the Orange River system has been calculated. The irrigation demands for the years 2000, 2010, 2020 and 2030 were thus assumed the same as for 1994 for the compilation of the total water demands. The future urban demands, including the industrial, mining and stock watering demands, were updated and are included in this report. The environmental demands, as well as the river losses and conveyance losses, were assumed to be the same in future as for 1994.

Table 2-17: Summary of total water demands for the Orange River Development Project (million m³/a)

Description	1994	2000	2010	2020	2030
Area 1: Upstream of Gariep	343.8	364.3	398.7	433.1	473.3
Area 2: Gariep to Orange Vaal confluence	1 280.1	1 284.4	1 284.9	1 285.5	1 330.8
Area 4: Orange Vaal confluence to 20° latitude	960.8	962.6	965.6	968.7	971.7
Area 5: 20° latitude to Orange River mouth	854.7	887.9	924.4	927.8	930.7
Total Orange River (Areas 1, 2, 4 & 5)	**3 439.4**	**3 499.2**	**3 573.6**	**3 615.1**	**3 706.5**
Area 3: Modder Riet catchment	66.4	67.2	68.3	69.4	70.7
Total Water Demand	**3 505.8**	**3 566.4**	**3 641.9**	**3 684.5**	**3 777.2**

The projected demands for the greater Bloemfontein area will ultimately be supplied from the Caledon basin and such demands are included under Area 1 of **Table 2-17**.

A summary of the total demands per user group is given in **Table 2-18** below.

Table 2-18: Summary of total water demands (per user group) for the Orange River Development Project (values given in million m³/a)

Description	1994	2000	2010	2020	2030
Irrigation	2 024.3	2 024.3	2 024.3	2 024.3	2 024.3
Urban	141.8	202.4	277.9	320.5	413.2
River losses / requirement	960.1	960.1	960.1	960.1	960.1
Environmental requirement	306.5	306.5	306.5	306.5	306.5
Conveyance losses	73.1	73.1	73.1	73.1	73.1
Total water demand	**3 505.8**	**3 566.4**	**3 641.9**	**3 684.5**	**3 777.2**

From the table above it is clear that the bulk of the water is used for irrigation purposes. This is followed by the river losses or requirements and the environmental requirements. The river losses in fact is also an environmental requirement of a sort as it is required to support natural losses or requirements from the river such as evaporation, evapotranspiration from natural riparian vegetation and seepage. The demands summarised for this study seems to be more than double that documented in the Orange System Analysis Study.

One of the inputs required by the WRPM when analysing the integrated system, is a set of guidelines of how to implement water restrictions in the catchment, if necessary. The method of allocating the supply of available water to users, on the basis of current supply characteristics of the various components of a system, is built into the WRPM. This requires that the different water users should be grouped together into user categories and these categories should be classified according to priority for water supply. User categories considered for the Orange River Replanning Study are urban, industrial, strategic industries, mining, irrigation and environmental. The urban and industrial users are grouped together due to the fact that it is difficult to split the total water demand of a municipality into these two user categories.

The user categories are each split into different levels of assurance of supply. In the ORRS it was decided to split each of these user categories into three levels of assurance of supply, namely low (95% assurance of supply), medium (99% assurance of supply), and high (99,5% assurance of supply). In this way a portion of the demand of a specific user category (say urban) can be supplied at a high level of assurance (e.g. domestic consumption), while the remaining portion of the demand can be supplied at a lower level of assurance (e.g. garden watering).

Table 2-19: Proposed priority classification for the ORRS Study

System and user category	Priority Classification (%)			
	Low (90% assurance) (1:10 year)	Medium (95% assurance) (1:20 year)	Intermediate (99% assurance) (1:100 year)	High (99.5% assurance) (1: 200 year)
Irrigation	Percentage split varies from crop to crop (See **Table 2.16** Below)			
Urban and Mining	0	20	30	50
River losses	0	0	0	100
Environmental	0	36	66	0
Conveyance loss	0	0	0	100
Curtailment level 0	1	2	3	4

Table 2-20: Proposed priority classification for different crops

System and user category	Priority Classification (%)			
	Low (90% assurance) (1:10 year)	Medium (95% assurance) (1:20 year)	Intermediate (99% assurance) (1:100 year)	High (99.5% assurance) (1: 200 year)
Annual crops				
Maize	100	0	0	0
Wheat	100	0	0	0
Cotton	100	0	0	0
Beans/Peas	100	0	0	0
Groundnuts	100	0	0	0
Fodder	100	0	0	0
Vegetables	50	50	0	0
Perennial fodder				
Lucerne	100	0	0	0
Perennial fruits / nuts				
Dates	30	50	20	0
Citrus	30	30	40	0
Grapes	30	40	30	0
Curtailment level 0	1	2	3	4

2.4.3 Evaluation of Irrigation Water Use Volume 1: Present Water Demand

2.4.3.1 River Systems

The study area included two major river systems, the Orange River and two major Eastern Cape river catchments.

The rivers were subdivided into "river reaches" for the purpose of determining irrigation water demands. The Orange River system consists of 22 reaches and the Fish and Sundays River sections of the Eastern Cape system contains 15 reaches. A description of each river reach and its irrigation activities is given in the report.

2.4.3.2 Irrigation Requirements and Water Demand

- **Water demand calculations**

Current and possible future agricultural irrigation activities in the river reaches were identified. Using the programme, Cropwat (FAO, 1992), crop water use and irrigation requirements were derived from the evapo-transpiration occurring from each crop during its life. Other climatic influences as well as factors such as irrigation type and efficiency and the need for extra water for leaching of excess salts from the soil were taken into account.

- **Cropping patterns**

Overall cropping patterns for the Orange River system and the Eastern Cape Rivers are given in the Table below. The detailed cropping patterns by river reach are given in the report.

Table 2-21: **Cropping patterns for the Orange River system and Eastern Cape Rivers**

River System	Cropping pattern (expressed as % of total crop area)								
	Lucerne	Fodder + pasture	Maize	Wheat	Cotton	Legumes	Vegetables + potato	Grape	Fruit + citrus
Orange River	11,2	4,4	18,1	33,9	6,4	5,2	2,7	17,5	0,6
Eastern Cape	49,1	11,0	14,1	4,3	-	-	4,5	-	17,0

- **Current water demand**

The water demand data for each of the 22 river reaches in the Orange River system and 15 river reaches in the Eastern Cape system are given in the report. Total current water allocations (scheduled irrigation hectares x water quota) are compared with the calculated estimates for overall irrigation requirement and water demand in the **Table 2.22.**

Table 2-22: Overall irrigation requirements and water demands for the Orange River and Eastern Cape systems

River system	Water allocation (m^3x10^6/a)	Water demand (Cropwat) (m^3x10^6/a)	Average water quota ($m^3/ha/a$)	Average irrigation requirement (Cropwat) ($m^3/ha/a$)
Orange River	1 221	1 382	11 560	13 243
Eastern Cape	570	719	11 966	15 100
TOTAL	1 791	2 101	11 685	13 825

- **Possible future water demand**

Water demands were calculated for the possible new irrigation developments (both small farmer/community and commercial) identified during the course of the study. Calculations were based on prevailing water quotas. These are summarized in the table below.

Table 2-23: Possible new irrigation development

	Water allocation (m^3x10^6/a)	Level of irrigation development		
		Rating A	Rating A+B	Rating A+B+C
		Total water demand (m^3x10^6/a)		
Orange River:				
Current water allocation	1221,10	-	-	-
Possible new developments: *Social* *Commercial*	 - -	 65,02 126,00	 86,08 155,45	 - -
Current + new social	-	1286,12	1307,18	-
Current + new commercial	-	1347,10	1376,55	
Current + new social + new commercial	-	1412,12	1462,63	-
Eastern Cape:				
Current water allocation	569,96	-	-	-
Water rights unscheduled	57,06	-	-	-
Possible new developments: *Social* *Commercial*	 - -	 16,75 -	 46,20 -	 49,80 -
Current +water rights unscheduled + new social	-	643,77	673,22	676,82
Current +water rights unscheduled +new commercial	-	627,02	627,02	627,02
Current +water rights unscheduled + new social + new commercial	-	643,77	673,22	676,82

2.4.4 Evaluation of Irrigation Water Use Volume 2: Existing Irrigated Agriculture

2.4.4.1 River reaches and agro-economic groups

The 22 demarcated river reaches that make up the Orange River and the 15 that make up the Eastern Cape systems were originally defined in terms of engineering and water-balance modelling requirements. For the purpose of agricultural analysis, the river systems have been combined into groupings more applicable to agriculture – termed agro-economic groupings.

The main basis for this grouping was average gross margin per unit water consumption (quota basis). Average gross margins (R/1000m3/a) for the various cropping systems, applicable to each river reach, were assessed, and areas with similar cropping patterns and returns were combined. An additional consideration was geographic location.

Where, for example, reaches with similar economic performance were not located adjacent to each other, they were placed in separate groups.

2.4.4.2 Cropping patterns within groups

The table below illustrates the relative proportions of the three main categories of crops found within the study area (field crops, fodder crops and orchard crops). The table shows the dominance of field crops and fodder crops in both the Orange River system and the Eastern Cape region. The only significant exceptions in the Orange River system are the deciduous fruits grown in the eastern, temperate Caledon River region (agroeconomic group G1) and the grape growing areas of the hot, dry lower Orange region (agro-economic groups G6 – G9). In the Eastern Cape, the citrus growing areas of the Sundays River valley (agro-economic group G6) are the dominant exception.

Table 2-24: Distribution of cropping enterprises according to region

Region	Crop Type %(ha)						Total land use	
	Annual/Cash		Fodder		Orchard			
	%	ha	%	ha	%	ha	%	ha
Orange River	60	63 249	19	19 787	21	22 598	100	105 634
Eastern Cape	20	9 535	62	29 706	18	8 392	100	47 634

2.4.4.3 Economic value of crops: present and potential

Many of the crops grown under irrigation (at the time of the study) provide low financial returns, both per hectare and per cubic metre of water consumed.

The efficiency of agricultural irrigation water use may be improved in all river reaches and agro-economic groups through increased production returns. Increases in the yields of annual field crops and perennial crops may be achieved by means of general improvements in standards of management and agronomic practices without any significant change in cropping pattern.

The general improvement in production, by the top 15% of farmers in each river reach, ranges between 10% and 20%. This level of improvement might be insufficient to cope with significant increases in water prices in the future. The gradual introduction of high-value crops, particularly perennial fruit and nut crops, is therefore to be considered as an appropriate initiative in the medium to long term for significant improvement in agricultural productivity and increased water use efficiency.

Many of the climatic zones within the study area are similar to other areas in the world where high-value crops have been successfully adopted. An exercise was undertaken, therefore, to investigate a range (not exclusive) of potential new crops in terms of their marketing possibilities, climatic adaptability and regional comparative advantages and constraints.

2.4.4.4 High-value crops

The impact of replacing a proportion of existing `low-value' crops, grown in each agro-economic group, with a blend of `high-value' crops, was investigated. A standard approach was used, in which 25% of low value crops were `replaced' by a blend of five suggested crops. In most cases, the low value crops comprised annual cash crops. The positive financial impact of adding high value crops to the existing average crop mix, for each of the agro-economic groups, is shown in Figures S.(i) and S.(ii) in terms of annual gross margin per unit of irrigation water used (R/1000m3/a). The alternative high value crop option is compared with the present average gross margins and the potential gross margin (top 15% of existing farmers).

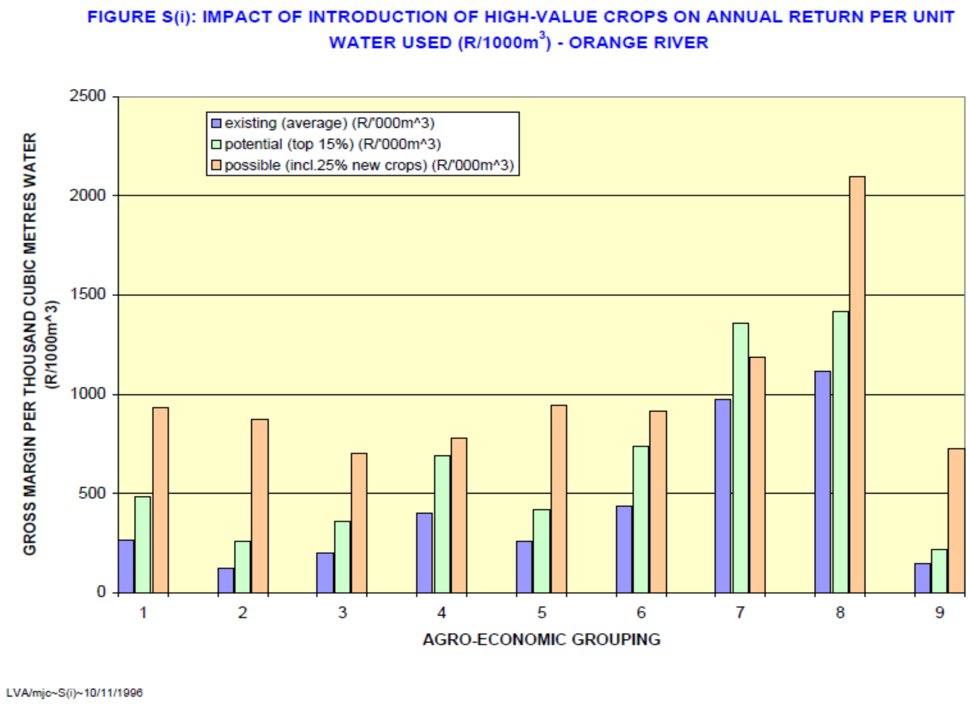


Figure 2-2: Impact of Introduction of Gigh value Crops on annual return per unit water used (R/1000m^3) Orange River

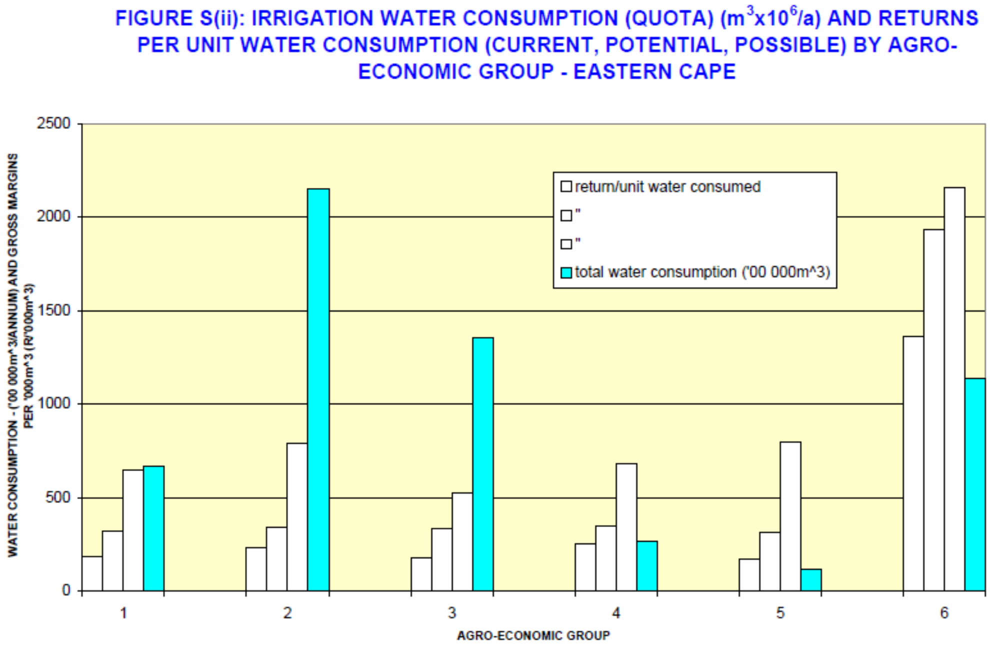


Figure 2-3: Irrigation water consumption (quota million m3/a) and returns per unit water consumption (Current, Potential, Possible) by Agro Economic Group – Eastern Cape

2.4.5 Evaluation of Irrigation Water Use Volume 3: Possible New Irrigation Developments

Assembly of agricultural irrigation data during the reconnaissance and prefeasibility phases of the study included the identification and investigation of possible new irrigation developments in the Orange River and Eastern Cape. These developments included:

- Expansion of existing irrigation schemes,
- Newly identified irrigation developments, and
- Previously investigated/planned irrigation projects.

A total of 18 336 ha of possible new irrigation development is listed for the Orange River system and 10 250 ha for the Eastern Cape system.

A priority development rating (A, B, C, D) was allocated to each potential irrigation development by representatives of the study team, Department of Water Affairs and Forestry, Department of Agriculture and irrigation farmers. In view of the priorities of the land reform process, particular attention was paid to areas with irrigation potential where Orange River water could be used for the upliftment of previously disadvantaged communities.

The additional total water demand required for these new irrigation areas, using prevailing water quotas, would be 245 m3x106/a for Orange River and 107 m3x106/a for Eastern Cape.

An overall summary of possible future water demands, incorporating current allocations, unscheduled water rights and possible new irrigation developments, is provided at three development levels. The development categories, "social" and"commercial" were also differentiated.

In view of the limited availability of water as a resource and the need to allocate this water on a national priority basis, including agriculture, industry and domestic, it was concluded that it was unlikely that consideration would be given to irrigation expansion on any significant scale and particularly not to lower priority irrigation development ratings. National policy will also ensure that if limited irrigation expansion is allowed, the focus will be on development projects for previously disadvantaged communities.

2.4.6 Social Overview - Orange River Basin

The objective of the socio-economic assessment was to evaluate social aspects of water demand in the Fish and Sundays River catchments, with a view to identifying key issues that need to be considered in the replanning process. Furthermore, the assessment provided an overview of the extent of domestic water demand by analysing the distribution of population and settlement as well as profile of institutions that are involved in water issues and therefore have a potential interest in the outcome of the replanning process.

In as far as water demands was concerned, the assessment pointed out that water demand was expected to increase from 52 500 to 80 000 mega litres per annum by 2010, assuming a rate of 60 litres per person per day. Although the quantity of domestic water demand was significantly smaller than agricultural and industrial water demands, it anticipated an unevenly large importance in view of the scale of expectation around the RDP targets, i.e. 25 litres (minimum) and 60 litres (maximum) per person per day. The assessment further held that if these targets were to be met, then demand levels would increase by 0,5 % and 7,25 % respectively.

The distribution of need was found to differ within the two river catchments indicated in the diverse geographic sectors that seemed to have the greatest backlog in water services. These included the following:

- the underdeveloped townships that occurred through-out the two river catchments overloaded by historical neglect in terms of service provision as well as rural –urban migration;
- The underdeveloped rural areas of the former Ciskei. Similar to the urban areas, these areas also burdened with poor service provision and rapid population growth; and
- The drought-stricken Karoo districts located in the middle and upper reaches of the two river catchments, which had experienced acute agricultural decline and depopulation.
- In addition to water needs, there were certain identified areas within the two catchments where the provision of water, if linked to socio-economic development strategies, could potentially generate growth and combat poverty. These are highlighted as follows:
- The lower Fish River, where pressures exist for the present irrigation scheme supplying small-scale farmers to be expanded to its fullest capacity to maximise opportunities for emerging black farmers.
- The middle reaches of the Fish River, where initiatives are underway to develop urban agricultural opportunities in towns like Cradock, Somerset East and Cookhouse, based around irrigation and intensive food crop cultivation.
- the lower Sundays River, where potentials exist for developing small-scale agricultural opportunities around the existing irrigation scheme in the Kirkwood district, and for expanding irrigation schemes downstream of Barkly Bridge. One of the possibilities highlighted involved linkage to a land reform programme to provide opportunities to small-scale emerging black farmers.
- Similar possibilities have been proposed for the upper Sundays River, where the lack of water had prohibited the irrigation scheme at Graaff-Reinet and Kendrew from being realised. If finance was to be made available, the possibility had been suggested of linking the transfer of water into the upper

reaches of the Sundays River with land reforms that could provide small-scale irrigation farming opportunities along the banks of the Sundays River.

2.4.7 Refinement of the in stream flow requirements for the Orange River

The purpose of the Orange River Replanning Study (ORRS) is to evaluate the water resource developments that have already taken place in the Orange River basin and to determine the extent of the surplus water available. The study will then focus on addressing how the available resources should be allocated. The water rights of Namibia and Lesotho will be taken into account together with the numerous social and environmental demands.

The Orange River Environmental Task Group (ORETG) was formed with the objective to facilitate interdisciplinary inputs in respect of the environmental issues resulting from the increased water resources development of the Orange River. The task group forms part of an overall committee, and together with the Eastern Cape Environmental Task Group addresses the environmental water demands as part of the overall study. The ORETG started by defining environmental management objectives which would be used to determine the water demand.

The desired future state of the Orange River Mouth should be equivalent to the conditions experienced before 1984, i.e. before the decline in the water level started. The level of development should ensure that the Orange River System, from the Vanderkloof Dam to the Orange River Mouth, should meet sustainable natural resource utilization goals.

2.4.7.1 In-stream Flow Requirement for the river

The in-stream flow requirements for the river can be divided into two distinctly different aspects, namely:

- maintaining a minimum flow to ensure short-term survival of aquatic life forms, and
- Maintaining a seasonal flow pattern to ensure the long-term survival of the aquatic ecosystem. This includes the riparian vegetation.

The flow requirements for the river downstream of the Augrabies Falls will dictate the releases from the Vanderkloof Dam. This will only change nominally should a dam be constructed at Boegoeberg or Vioolsdrift, and will in fact not change the overall volumes. The IFR's for the Orange River downstream of the Vanderkloof Dam can therefore be defined as shown in **Table 2-25**.

Table 2-25: Environmental flow requirements for the Orange River (million m^3)

Description	Month

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Minimum flow: Normal years (95 %) Droughts (5 %) Extreme conditions (0.5 %)	 21.4 5.4 0	 23.3 13.0 0	 26.8 13.4 2.7	 26.8 13.4 2.7	 24.2 12.1 2.4	 26.8 13.4 0	 20.7 5.2 0	 18.8 2.7 0	 15.6 2.6 0	 13.4 0 0	 13.4 0 0	 13.0 2.6 0
Flow modification to stimulate fish spawning (additional to minimum flow)	10.3	-	8.6	-	8.6							
Total: normal years droughts extreme conditions	31.7 5.4 0	23.2 13.0 0	35.4 13.4 2.7	26.8 13.4 2.7	32.8 12.1 2.4	26.8 13.4 0	20.7 5.2 0	18.8 2.7 0	15.6 2.6 0	13.4 0 0	13.4 0 0	13.0 2.6 0

2.4.7.2 In-stream Flow Requirement for the Mouth

The first and foremost managerial aspect is that the Orange River Mouth, as a Ramsar site, has certain predefined objectives. As a result of the Ramsar status the different bird species frequenting the mouth, either for breeding or feeding purposes or as a stopover on migrating routes, should be regarded as a unique feature in this estuarine ecosystem. **Table 2-26** provides a summary on the type of flow needed to create a certain environmental condition at the mouth during the various months of the year.

Table 2-26: Types of flow needed to create a certain environmental condition during the various months of the year

Month of the year	Remarks on the type of flows needed
July, August, September	Back-flooding for inundation of salt marsh. Lowest flow during August and September to initiate mouth closure.
October, November, December, January, February, March, April	Enough water to keep the mouth open to create habitat for inter-tidal birds. Maintenance flows needed once every five years for reseeding of plants, to reduce salinity, to clear sediments etc. The major maintenance flows should occur between January and March. During extended drought periods no maintenance flows are necessary.
May, June	Low flow months for conditioning of the germination of seedlings.

The following monthly volumes (million m^3) are required for the Mouth (**Table 2-27**):

Table 2-27: Water requirements for the Orange River Mouth (Mm^3/m)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total (Mm^3/a)

IFR for maintenance (95%)	Flows	32.1	31.1	32.1	32.1	29.3	32.1	31.1	24.1	15.6	9.4	9.4	9.1	287.5
IFR for drought situation (5%)	Flows	32.1	31.1	13.4	13.4	12.2	32.1	31.1	10.7	6.2	2.7	2.7	9.1	195.8
Inundation of the salt marsh*						6.3*								

Note: * Required once in every three years

2.4.7.3 Matching of IFR between the River and the Mouth

The IFR for the river and the mouth should match, as the one is dependent on the other. It is also not possible to manage the river and the mouth as separate entities, and if requirements are not compatible, this needs to be resolved. **Table 2-28** summarises the monthly IRF's for both the river and the mouth to satisfy the environmental requirements.

Table 2-28: Comparison of the IFR for the river and the mouth (Million m^3/month)

Maintenance	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
River - Maintenance flow	31.7	23.3	35.4	26.8	32.8	26.8	20.7	18.8	15.6	13.4	13.4	13.0
Mouth - Maintenance flow	32.1	31.1	32.1	32.1	29.3	32.1	31.1	24.1	15.6	9.4	9.4	9.1
River - draught	5.4	13.0	13.4	13.4	12.1	13.4	5.2	2.7	2.6	0	0	2.6
Mouth - draught	32.1	31.1	13.4	13.4	12.2	32.1	31.1	10.7	5.2	2.7	2.7	10.4

During December, February, July, August and September the environmental requirements for the river are slightly higher than those for the mouth. The relatively high environmental requirement in the river during December and February is to stimulate spawning behaviour of B. kimberleyensis and B. hospes. The low flows specified during winter for the mouth are to ensure that it closes and causes back-flooding to inundate the salt marsh. During the bird breeding season the critical element is to prevent mouth closure (during summer). This means that in winter the mouth will dictate what the maximum flow (5 m^3/s) should be, and in summer what the minimum flow (12 m^3/s) should be. During December and February the flow in the river will exceed the minimum requirements for 5 days, but this is acceptable as it will not cause significant flooding and will help to ensure that the mouth remains open. The minimum flows for the mouth during winter were also accepted for the river, as these occur during relatively cool months (July, August and September) and should not cause undue stress in the river.

Table 2-29: Environmental requirements for the Orange River and Orange River Mouth (Million m^3) for normal flow conditions

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Environmental requirement	32.1	31.1	35.4	32.1	32.8	32.1	31.1	24.1	15.6	9.4	9.4	9.1	294.3

Table 2-30: Environmental requirements for the Orange River and Orange River Mouth (Million m^3) for during draught conditions

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Environmental requirement	32.1	31.1	13.4	13.4	12.2	32.1	31.1	10.7	5.2	2.7	2.7	10.4	197.1

The principle is therefore that the flows shown in the two tables above should reach the mouth, under which conditions all environmental requirements will be met. It should be noted that the larger floods (1 in 5 years and more) were not included in the demand figures, as they are accepted to occur naturally even with the dams in place.

2.4.7.4 Conclusions

The current objective is to maintain a low flow during winter, which will allow the mouth to close, under which conditions the salt marsh will be inundated by means of back-flooding. The IFR for the mouth has increased from 244 to 294 million m^3/a. Most of this water is required in summer in order to keep the mouth open. The minimum flow which is required to ensure that the mouth remains open is 12 m^3/s. The maximum flow which can be tolerated to ensure that the mouth closes in winter is 5 m^3/s. There is therefore a fairly large "grey" area where the dynamics of the system are not well-known. It is clear that the IFR for the mouth would reduce drastically, should it prove possible to maintain an open mouth condition with 9 m^3/s instead of 12 m^3/s. This aspect needs careful consideration, especially if it is kept in mind that the water for the mouth has to be supplied from dams which are situated more than 1 000 km upstream.

2.4.8 Water Demands of the Eastern Cape region

This report covers the water demands in that portion of the Eastern Cape influenced by the Orange River Project (ORP), mainly in the Fish and Sundays River Basins. Although irrigation water demands constitute the greatest portion, by far, of these demands, the irrigation demands are only briefly referred to in summary as they are extensively described in another report of the Orange River Development Project Replanning Study.

The main emphasis of this report is on the urban demands of the region where existing demands are recorded and future demands estimated to the year 2030. Water demands of these communities which conceivably could be provided with the Orange River Project (ORP) are also quantified, as are other rural demands.

2.4.8.1 Urban Areas

Port Elizabeth and Grahamstown are the two largest towns in this area and both receive a part of their supply from the ORP, although they draw a much higher proportion from local sources at present. Other towns dependent on ORP water are Cradock, Cookhouse, Kirkwood and Addo.

Because of its substantial influence, Port Elizabeth, including the urban areas within the Port Elizabeth supply area, was separately dealt with. The two scenarios for Port Elizabeth are shown in **Table 2-31.**

At present Port Elizabeth's local sources have a supply capacity of 56 million m^3/a and the combined local supply capacity of the other towns is just over 2 million m^3/a. This and the potential for Port Elizabeth to develop further local sources affect the demands placed on the ORP.

A further influence is that potentially other towns may also in future draw water from the ORP. These towns include Adelaide, Alicedale, Bedford, Riebeek East, Alexandria, Kenton-on-Sea, Graaff-Reinet, Hofmeyr, Peddie, Steynsburg, Tarkastad, Victoria East and Pearston. Assuming, conservatively, that all future growth in these towns was ORP sourced, then the additional demand which could be placed on the ORP is as shown in **Table 2-31**.

Table 2-31: Present and Forecast Demand (million m³/a) of Urban Areas Presently Supplied from the ORP

Year	Port Elizabeth Supply Area Growth Scenario		All Urban areas Growth Scenario	
	Probable	High	Probable	High
1993/1994	61	61	67	67
2000	82	83	89	92
2010	105	111	114	123
2020	136	149	146	164
2030	175	199	187	221

Based on the probable scenarios indicated below, four future urban demand scenarios were suggested. The "Scheepersvlakte infrastructure" referred to in the descriptions of the scenarios below is the supply and purification system for Port Elizabeth of its ORP supply. In all four of the scenarios it is assumed that all growth in centres presently supplied other than Port Elizabeth will be met from the ORP.

Table 2-32: Possible Demand (million m³/a) on the ORP of Centres not presently linked to the Scheme

Scenario	2000	2010	2020	2030
High	3	6	9	15
Probable	2	4	5	7

The assumptions made were as follows:

1. After the Scheepersvlakte infrastructure is utilised to the maximum extent of existing capacity (20 million m³/annum) that all future growth for the Port Elizabeth supply would be met from local sources.
2. After the Scheepersvlakte infrastructure is utilised up to the maximum extent of the existing capacity that local sources (Guernakop Dam and the Groot-Tsitsikamma-Krom River sources with a capacity of 60.6 million m³/annum) would be developed. Thereafter further supplies would be drawn from the ORP.
3. That all future growth for the Port Elizabeth supply would be met from the ORP.
4. That all future growth for Port Elizabeth and the areas which have potential to be supplied from the ORP are supplied with ORP water.

The forecast demand figures for these scenarios are given in **Table 2-33.**

Table 2-33: Future Urban Demand Scenarios on ORP (Based on Probable Scenario)

Scenario	Forecast Demand (million m³/a)				
	1995	2000	2010	2020	2030
1	16.3	25.9	27.0	28.1	29.4
2	16.3	25.9	27.0	28.1	68.2
3	16.3	31.5	56.3	88.0	128.8
4	16.3	34.1	60.2	93.3	135.8

2.4.8.2 Rural Communities

There are a number of rural communities in the former Ciskei portion of the region located on the east bank of the Fish River near its mouth. The present population of these communities, which number about 40, is just over 50 000 people with a demand of just over 1 million m³/annum based on the RDP standard of

60 R/c/d.

2.4.8.3 Irrigation Demands

These demands total about 570 million m³/a as shown in **Table 2-44** and as such, are the dominant water demands for the Eastern Cape region on the ORP.

Table 2-34: Irrigation Demands

Region (River reaches)	Scheduled Irrigation Area (ha)	Water Quota (m³/ha/a)	Water Allocation (million m³/a)	Water Rights not Scheduled (ha)
Upper Great Fish	18 912.3	13 500	255.3	984
Middle Great Fish	11 810.9	12 500	147.6	264
Little Fish/Skoenmakers	3 308.0	12 500	41.4	1 663
Lower Great Fish	925.2	12 500	11.6	0
Lower Sundays	12 676.8	9 000	114.1	2 186
Total	**47 633.2**		**570.0**	**5 097**

2.4.9 Existing Water Infrastructure in the Eastern Cape Region

2.4.9.1 Overview

The development of water infrastructure in the Fish and Sundays River basins has occurred in two phases:

- Original irrigation scheme and ancillary works in the two main stem and certain tributary river valleys.
- Augmentation schemes developed as part of the original Orange River Project and its subsequent extensions which rely largely on the availability of Orange River water.

The augmentation schemes along the Great Fish and Lower Sundays Rivers were integrated with pre-existing water infrastructure.

There are three main water supply schemes in the region namely:

(i) The Fish-Sundays River Canal Scheme
(ii) The Lower Sundays River Government Water Scheme, including extension to Port Elizabeth.
(iii) The Lower Fish River Government Water Scheme.

A layout of the main water-supply schemes is given in.

Irrigation schemes exist in the catchments of the Great Fish River and Sundays River. These are Van Ryneveldspas Dam just upstream of Graaff-Reinet in the Sundays River, Kommandodrift Dam and Lake Arthur in the Tarka River (tributary of Great Fish River), Kat River Dam on the Kat River (also a tributary of the Great Fish River).

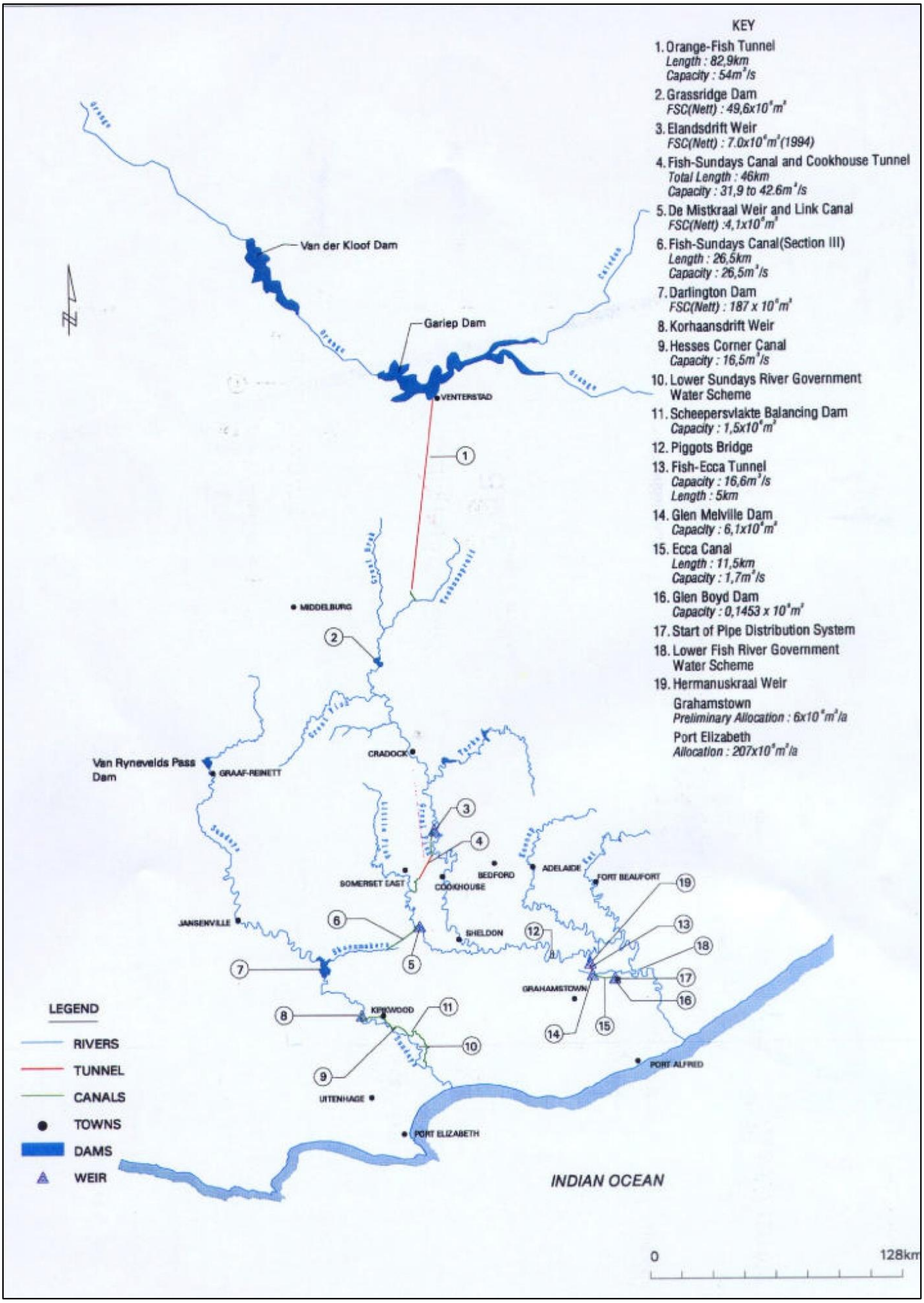


Figure 2-4: Orange River Development Project Replanning Study: Geographical Layout of Eastern cape Scheme

The key feature of all three schemes is the Orange-Fish Tunnel completed in 1975, which diverts water from the Orange River to the Teebus Spruit and thence to the Great Fish and Sundays Rivers. The water flows from the tunnel outlet to the Grassridge Dam on the Great Brak River, a tributary of the Great Fish River. Detail of the tunnel is listed below.

Table 2-35: General Data: Orange-Fish Tunnel

General Data: Orange-Fish Tunnel	
Length	82,9 km
Diameter	5,4 m
Capacity (at least 100 % of FSC of Gariep Dam	54 m³/s
Capacity (at 28 % of FSC of Gariep Dam)	46 m³/s

2.4.9.2 Fish Sundays River Canal Scheme

Water is released from Grassridge Dam down the Great Fish River such that water may be abstracted at several points to supply the various irrigation boards before reaching the Elandsdrift Weir. Details of the Grassridge Dam are shown in the table below.

Irrigation water distribution in most of the large schemes and in all the small schemes is via earth canals. Canal losses are therefore significant in the study area, and irrigation return flows are recognised as a significant part of the water balance.

Table 2-36: General Data: Grassridge Dam

General Data: Grassridge Dam	
Type	Earth fill
Owner	DWAF
Full Supply Level	1 057,84 m
Gross Capacity	49,604 million m³
Net Capacity	49,603 million m³
Dead Storage Volume	0,001 million m³
Dead Storage Level	1 049,60 m
Spillway Type	Broad crested concrete
Capacity of Old Outlet	ca 17 m³/s
Capacity of New Outlet	cfa 60 m³/s

Water is then diverted from the Great Fish River at the Elandsdrift Weir into a 108 km aqueduct. The Cookhouse Tunnel, the main feature of the aqueduct, discharges the water into the Little Fish River. The De Mistkraal Weir situated on the Little Fish River transfers to the Skoenmakers Canal and into Darlington Dam. Details of these structures follow below.

Table 2-37: General Data: Elandsdrift Weir

General Data: Elandsdrift Weir	
Type	Earth fill / Concrete
Owner	DWAF
Full Supply Level	742,19 m
Gross Capacity	0,74 million m³
Net Capacity	9,74 million m³
Dead Storage Volume	0,001 million m³
Dead Storage Level	732,39 m
Spillway Type	Rounded crested concrete
Approximate TDS	450 – 500 mg/ℓ (Crafford Pers Com, 1994)

Table 2-38: General Data: Cookhouse Tunnel

General Data: Cookhouse Tunnel	
Length	13,7 km
Diameter	9,6 m
Gradient	1:2 000

The total length of canal and tunnel from Elandsdrift Weir to the point of discharge into the Little Fish River is some 46 km, and the capacity varies along the length from 42,6 m³/s at the Elandsdrift end done to 31,9 m³/s at the discharge chute into the Little Fish River.

Table 2-39: General Data: De Mistkraal Weir

General Data: De Mistkraal Weir	
Type	Gravity concrete
Owner	DWAF
Full Supply Level	550,96 m
Surface Area at FSL	79 ha
Gross Capacity	7,007 million m³
Net Capacity	3,079 million m³
Dead Storage Level	1,019 million m³
Spillway Type	Rounded crested concrete
Spillway Length	195 m
Max Height above Foundation	27 m
Catchment Area	1 879 km²
1:200 Year Flood	2 000 m³//s
High Flood Level	553,95 m

2.4.9.2.1 Skoenmakers Canal

The canal (26,5 km in length) is reported to have a design capacity of 26,5 m³/s and was constructed in 1978 to facilitate the transfer of water from the Little Fish River to Darlington Dam.

2.4.9.3 Lower Sundays River Canal Scheme

Water from Darlington Dam is released into the Sundays River, diverted into the Sundays Canal at Korhaansdrift Weir from where it flows to the Scheepersvlakte Dam from whence it is transported to the Nooitgedacht purification works on the right bank of the Sundays River by gravity pipeline. From there it is conveyed to Motherwell Reservoir by gravity pipeline to serve users in the urban areas of Port Elizabeth. Details of these structures follow below.

Table 2-40: General Data: Darlington Dam

General Data: Data Darlington Dam	
Type	Concrete
Owner	Currently DWAF – To be transferred to SRIB
Full Supply Level	247,2 m
Gross Capacity	187,278 million m³
Net Capacity	187,278 million m³
Dead Storage Volume	0,001 million m³
Dead Storage Level	235,68 m
Spillway Type	Rounded crested concrete

2.4.9.3.1 Korhaansdrift Diversion Weir

The Korhaansdrift Weir, commissioned in 1902, diverts water from the Sundays River into a canal system which originally ended at Hesse's Corner. The length of this canal is 18,7 km and the original design capacity was 10,7 m³/s, but this was upgraded to 22,7 m³/s under the new development.

The canal outlet capacity of Korhaansdrift Weir is 36 m³/s (W.P.C-86).

2.4.9.3.2 Hesse's Corner Canal and Tunnels

This canal starts at Hesse's Corner, the end of the existing canal from Korhaansdrift Weir, and completes the transfer of water from the Korhaansdrift Weir to the Scheepersvlakte Dam (see below). The canal's capacity varies between Korhaansdrift and the Scheepersvlakte Dam, ranging from 13 m³/s to 22,7 m³/s.

2.4.9.3.3 Scheepersvlakte Dam

Commissioned in 1990, the Scheepersvlakte Dam is balancing dam, having a capacity of approximately 1,5 million m³ . The dam was built as an extension to the Lower Sundays River Government Water Scheme and is owned by the Department of Water Affairs and Forestry (DWAF). It is the starting point of the pipeline which conveys Fish-Sundays water to the Port Elizabeth metropolitan area.

2.4.9.3.4 Scheepersvlakte to Nooitgedacht Pipeline

This is a 9,1 km long 14 700 mm diameter steel gravity main designed to convey 290 Mℓ/day, with development taking place in four modular stages o 70 Mℓ/day each. The first Mℓ/day stage was commissioned in 1993.

The following further components of infrastructure were constructed to facilitate the supply of Orange-Fish-Sundays water to Port Elizabeth.

- The 105 Mℓ/day steel rising main (14 km long, diameter = 1 000 mm) from Nooitgedacht to Grassridge Reservoir.
- The 23 Mℓ Grassridge Reservoir.
- The 105 Mℓ/day gravity main (18,7 km long, diameter = 1 100 mm) from the Grassridge Reservoir to the Motherwell Reservoir.

2.4.9.4 Lower Fish River Government Water Scheme

Water is also released from Elandsdrift Weir into the Great Fish River to supply users from the Lower Fish River Scheme (which consists of the Hermanuskraal diversion weir in the Great Fish River and a tunnel to divert water to the Glen Melville Dam on the Ecca River), and to serve users in the Grahamstown area. The distribution system consists of the Glen Boyd balancing dam and canals and pipelines to the irrigable land on both sides of the river. Details of structures downstream of Elandsdrift Weir are listed below. Elandsdrift Weir's detail is tabled under (i).

Table 2-41: General Data: Hermanuskraal

General Data: Hermanuskraal Weir	
Type	Concrete
Maximum height above river bed	5 m
Overspill crest length	45 m
Design Flood	7 600 m^3/s (1:100 year flood)
Gross Capacity	1,2 million m^3
Full Supply Level	260,5 m
Full Supply Area	26 ha
Right abutment crest	262 m
Lowest drawdown	255,5 m
Flow at RL 262 m	190 m^3/s
Flow at RL 265 m	1 200 m^3/s

Table 2-42: General Data: Fish-Ecca Tunnel

General Data: Fish-Ecca Tunnel	
Capacity	16,6 m^3/s
Length	5 km
Normal Diameter	3 m

Table 2-43: General Data: Glen Melville Dam

General Data: Glen Melville Dam	
Owner	DWAF
Gross Capacity	6,50 million m^3
Net Capacity	6,13 million m^3
Full Supply Level	225 m
Full Supply Area	76 ha
Maximum Height above river bed	26 m
Crest length of dam	390 km
Catchment area	55 km^2
Design Flood, PME	1 350 m^3/s
1:100 year flood	250 m^3/s
Spillway Length	100 m

Table 2-44: General Data: Ecca Canal

General Data: Ecca Canal

General Data: Ecca Canal	
Cross Section	Parabolic
Capacity	1,7 m^3/s
Length	11,5 km
Number of irrigation off-takes	13

2.4.9.4.1 Glen Boyd Balancing Dam

The dam was commissioned in 1992.

Table 2-45: General Data: Glen Boyd Dam

General Data: Glen Boyd Dam	
Gross Capacity	0,149 million m^3
Net Capacity	0,145 million m^3
Full Supply Area	3,2 ha
Catchment Area	1,2 km^2
Full Supply Level	161 m
Potential Maximum Flood	240 m^3/s
1:100 year flood	24 m^3/s
Spillway discharge at RL 163 m	285 m^3/s

2.4.9.4.2 Distribution Pipelines

The physical dimensions of the pipelines are as follows:

- Irrigation pipelines 1 1 200 m
- Pipeline length 12,5 km
- Number of Irrigation off-takes 15
- River discharge through 200 mm ø valve 0,18 m^3/s

2.4.10 Social Overview - Eastern Cape region

The objective of the socio-economic assessment was to evaluate social aspects of water demand in the Fish and Sundays River catchments, with a view to identifying key issues that need to be considered in the replanning process. Furthermore, the assessment provided an overview of the extent of domestic water demand by analysing the distribution of population and settlement as well as profile of institutions that are involved in water issues and therefore have a potential interest in the outcome of the replanning process.

In as far as water demands was concerned, the assessment pointed out that water demand was expected to increase from 52 500 to 80 000 mega litres per annum by 2010, assuming a rate of 60 litres per person per day. Although the quantity of domestic water demand was significantly smaller than agricultural and industrial water demands, it anticipated an unevenly large importance in view of the scale of expectation around the RDP targets, i.e. 25 litres (minimum) and 60 litres (maximum) per person per day. The assessment further held that if these targets were to be met, then demand levels would increase by 0,5 % and 7,25 % respectively.

The distribution of need was found to differ within the two river catchments indicated in the diverse geographic sectors that seemed to have the greatest backlog in water services. These included the following:

- the underdeveloped townships that occurred through-out the two river catchments overloaded by historical neglect in terms of service provision as well as rural –urban migration;

- The underdeveloped rural areas of the former Ciskei. Similar to the urban areas, these areas also burdened with poor service provision and rapid population growth; and
- The drought-stricken Karoo districts located in the middle and upper reaches of the two river catchments, which had experienced acute agricultural decline and depopulation.

In addition to water needs, there were certain identified areas within the two catchments where the provision of water, if linked to socio-economic development strategies, could potentially generate growth and combat poverty. These are highlighted as follows:

- The lower Fish River, where pressures exist for the present irrigation scheme supplying small-scale farmers to be expanded to its fullest capacity to maximise opportunities for emerging black farmers.
- The middle reaches of the Fish River, where initiatives are underway to develop urban agricultural opportunities in towns like Cradock, Somerset East and Cookhouse, based around irrigation and intensive food crop cultivation.
- the lower Sundays River, where potentials exist for developing small-scale agricultural opportunities around the existing irrigation scheme in the Kirkwood district, and for expanding irrigation schemes downstream of Barkly Bridge. One of the possibilities highlighted involved linkage to a land reform programme to provide opportunities to small-scale emerging black farmers.

Similar possibilities have been proposed for the upper Sundays River, where the lack of water had prohibited the irrigation scheme at Graaff-Reinet and Kendrew from being realised. If finance was to be made available, the possibility had been suggested of linking the transfer of water into the upper reaches of the Sundays River with land reforms that could provide small-scale irrigation farming opportunities along the banks of the Sundays River.

2.4.11 In-stream Flow Requirements for the Orange River between the RSA / Lesotho border and the Gariep Dam

The IFR as given in this report was determined before the most recent methodology to be used in the determination of IFR's, was available. Although this report was finalised as part of the set of reports prepared for the ORRS, the IFR's are not considered as the final recommended IFR. The DWAF will carry out further work in this regard.

2.4.12 Agriculture Economic Analysis for Irrigation Water in the Orange and Fish River Basins

This report was completed in 1998 and consequently the financial data is out of date. However the approach applied in the report is still relevant to today's situation. This review excludes the Eastern Cape component of the report.

The report consists of three sections. An introduction is given in the first section. The second section comprises analyses of the crop gross margins and employment opportunities per volume of water used in the various river reaches. In the third section, comparisons are made of the financial results of various farming models, with the specific aim being able to determine the contributions of irrigated lands and the role of fodder production in particular.

2.4.12.1 Gross Margin per Water Volume

2.4.12.1.1 Existing crop yields

A total of 105 013 ha were shown to be irrigated from the Orange River. The average water requirement is 12 994 m3 per ha. Annual field crops comprised 66 % of the total area, with orchard crops at 18 % and fodder crops 16 %.

Range in Gross margins per m3 of irrigation water used: Orange River R0,083 in the more extensive areas to more than R1,37 in the intensive table grape production areas near Upington.

2.4.12.1.2 Potential crop yields

Substantial increases in crop yields are possible in most reaches, provided optimum production practices are applied. Gross margins per water volume in the more extensive river reaches could therefore be doubled, with less proportionate increases in the existing high value reaches.

Market conditions permitted, high valued crops can be incorporated in the cropping programmes in many river reaches. This will result in higher gross margins per water volume required.

2.4.12.1.3 Labour Days per Volume

Labour requirements for crop production range between 1,3 days per 1 000 m3 in reaches with large contributions of annual crops and fodder crops in the overall cropping programme, to 20 days per 1 000 m3 at reaches with relative high percentages orchard crops. At the potential crop yields, additional employment opportunities will be created. Employment opportunities will be stimulated with the inclusion of high value crops in the cropping programme.

River Reaches with Low Gross margin and Labour day values

River reaches with low values in both gross margins and labour days per water volume:

- An irrigated area of 17 300 ha, or 11 % of the total irrigated areas,
- Use 12 % of the total irrigation water,
- Produce only 5 % of the total gross margin in the study area.

Features of the low-valued reaches

- Predominantly situated along the upper reaches of the Orange River.
- Usually relative large fodder production areas.
- Livestock production plays an important role in the farming activities.

Consequences of these results and features

In the financial evaluation of these reaches, a total farm analysis will be necessary to determine the relative contributions of all the farming enterprises.

2.4.12.1.4 Characteristics of Farming Operations Adjacent to the Fish River and Upper Reaches of the Orange River

A broader analysis was undertaken to enlighten the general situation on farms in the low value areas.

- Farming operations in the upper reaches of the Orange River depend highly significantly on the contributions from irrigated lands.
- Units with small natural grazing areas (below 600 ha), will not survive financially unless at least 30 ha irrigated lands are available.
- Irrigation areas of 14 ha can change medium sized natural grazing units (± 2 000 ha) into a profitable position, but will only be able to service limited debts.
- Large natural grazing areas (more than 5 000 ha) are capable of producing adequate financial surpluses. Models with large natural grazing areas and large irrigated lands, yield acceptable financial returns. Returns from the irrigated lands can be increased when less intensive small stock production systems are followed. Producer price levels of wool and mohair will dictate the intensity of SSU on irrigated lands. When 60 ha irrigated lands are added to large natural grazing areas, positive cash flow positions are possible.
- Long-term sustainability of mixed farming operations in the study area depends heavily on efficient production practices. Efficient irrigation operations not only contribute to improved financial returns, but it is an important precondition in the effective use of limited water resources.
- Decommissioning of irrigation areas will result in decreases in job opportunities in the order of 16,9 workers per 100 ha irrigation land.
- Reduction of irrigation quotas will result in the termination of small to medium sized natural grazing units with small irrigation areas. The consequences of a possible reduction in water quotas in the Eastern Cape and other extensive production areas adjacent to the Orange River, extend beyond disposable water surpluses to be applied for other areas/users, and will also have socio economic affects.
- These typical characteristics have serious consequences for establishing new commercial farmers and will increase the entry barriers for the prospective farmers, e.g.,
- Relative large grazing areas will be required to support a farmer and his family.
- Potential financial results limit the extent of possible external financing. This situation will require larger financial assistance from Government.
- With the inclusion of irrigated areas, smaller natural grazing areas will be required, external loans can be at higher levels and with limited dependence on the State

2.4.13 Existing water infrastructure in the Orange River Basin

2.4.14 Water Demand Management

2.4.14.1 Introduction

This study was undertaken in two phases. During the reconnaissance phase, the study focussed on a literature survey during which the principle elements of Water Demand Management and Water Conservation were identified and evaluated. The pre-feasibility phase then focussed on the following:

- review of the main principles and past experience with Water Demand Management;
- describe current water users and assess the water loss from the study area;
- identify and evaluate Water Conservation measures;
- discuss intervention mechanisms in Water Conservation Management; and
- Identify Water Conservation Strategies.

2.4.14.2 Principle water users

The impact of demand management has been evaluated on the following users:

- Urban and rural water demand
- Mining water demands
- Environmental water demands
- Hydro Power water demands
- Irrigation water demand

2.4.14.3 Water Conservation measures

Past experience in South Africa indicates that pricing is probably the most effective way to obtain consumer response to a call for effective utilization of water. With an increase in demands, especially in urban areas, this procedure will have to be managed with great sensitivity.

Based on current water use, water conservation measures on urban and rural water supply are unlikely to have any noticeable effect in terms of potential saving of water. Nevertheless, it is important that water is effectively used. It is therefore recommended that all urban centres especially the major ones e.g. Bloemfontein and Port Elizabeth take steps to ensure than an effective water demand management programme is implemented. This will include training and education of consumers to promote the effective use of the water.

2.4.14.4 Irrigation demand management

It is estimated that a 10% increase in current irrigation efficiency would reduce overall irrigation demand by 190 million m^3/a. This volume is equal to the expected growth in urban and industrial use until the year 2010. In view of the large potential savings in irrigation water, this study focussed on the management of this demand as an essential component of the water conservation strategy.

The following aspects can be regarded most significant in dealing with the in-field irrigation management:

- Water requirements - The study has made use of Cropwat to estimate water requirements for specific crops. Comparing these theoretical calculations with farmer water allocations (quotas), limited scope exists to reduce the use of water if current cropping patterns are maintained.
- Leaching - Irrigation water contains salts, which accumulate in the soil over a period of time. Additional water is required to drain these wastes before harmful effects set in. This additional water for leaching is therefore not considered wasteful as it is performing a vital function and re-enters the system as return flow, with the likelihood of further downstream utilisation. Proper irrigation scheduling should therefore incorporate sufficient water for leaching into the irrigation programme.
- Quotas - The quota system is a tool to effectively plan storage and distribution system capacities and to regulate consumption within water control areas. The disadvantage of this system is that it does not leave an incentive to save water through better management, changed cropping patterns or to adopt a less wasteful application system. The system must allow farmers to apply their irrigation water judiciously through the effective application of limited amounts of water at realistic prices.
- On-Farm application strategy - Farmers must have a good idea of seasonal water requirements and must fully understand the water allocation system and programme. Farmers tend to over-estimate crop water requirements, both seasonally and with respect to day to day applications due to surplus water releases. The existing rigid bulk supply system acts to buffer this inclination to over-irrigate. Evidence of considerable and widespread over-watering already exists which is resulting in water-tables rising and salinization increasing. This approach will change in future due to extended allocation of water from the Orange River.

2.4.14.5 Recommendations

Substantial scope exists for saving water through the implementation of a proper strategy to improve efficiency of water supply. Short, medium and long-term goals have been identified and are summarised below. Although these goals are aimed more to irrigation water use, similar principles will apply to other (urban and mining) users.

The high costs to develop, operate and maintain bulk water supply will necessitate significant water tariff increases. Unless high value crops are introduced, this may result in the reduction of irrigation farming in certain river stretches where low value farming is currently being practised.

Some practical pre-requisites for improvement of water use efficiency are as follows:

- **Co-operation**: Co-operation is fundamental for success. DWAF/ Department of Agriculture and water authority/user relationships are important. There is a common purpose in conserving water which will require a joint vision from all parties.
- **Data base**: A comprehensive data base is required of all activities/ actions/ infrastructure/ resources/ enterprises etc. in order to plan and manage the supply systems properly.
- **Water allocation**: A revision of quotas and allocation rationale is needed to better plan equitable water apportionment. The basic need for domestic use in the catchment should receive priority.
- **Water valuation**: Water needs to be priced according to its value as a potential generator of wealth.
- **Control of salinity/drainage**: Monitoring, quality control and rectification strategies need to be in place.
- **Technical support**: R & D and extension should be geared to facilitate changes in areas where new cropping ventures are indicated. This is particularly important for new emergent/small scale farmers.
- **Strategy formulation**: Poor efficiency and deficiencies in existing water conservation mechanisms should be addressed through comprehensive planning both inter and intra sectorial.

It is therefore recommended that the proposed goals to improve efficiency be implemented within the framework of the practical pre-requisites listed above. A feasibility study with regard to water conservation should be launched to quantify the volume of potential savings through a well-defined water conservation strategy.

2.4.15 Main Report

2.4.15.1 Purpose and Approach

The Orange River Development Project Replanning Study (ORRS) was commissioned to determine a strategy for the most beneficial utilisation and optimal development of the water resources of the Orange River. This had to be based on a thorough assessment of the water resources of the basin, together with a perspective of how this may be impacted upon in future. It is recognised that further development of the resource will become necessary in due course and investigation of the options in this respect will form an important part of the study. The first priority, however, is for appropriate water conservation and demand management strategies to be devised and effectively implemented before any new works are constructed. Rather than firm development plans, a framework strategy is required to direct the utilisation and development of the resource towards ultimately achieving the greatest overall benefits for all.

2.4.15.2 Study Area

The ORRS is essentially a South African study which aims to provide knowledge on how the South African share of Orange River water can best be utilised in the country. The study area includes the whole of the Orange River Basin inside South Africa, with the exception of the Vaal River Basin which has been the subject of several other studies. Given the international nature of the river, the South African utilisation plans must eventually be integrated with similar plans of the other basin states. However, in addressing the South African situation in the ORRS, it was necessary to consider the overall resource. This includes runoff generated in Lesotho and Namibia, as well as the estimated water use by these countries. The study area also includes the Eastern Cape area which is supplied with water through the Orange-Fish Tunnel.

2.4.15.2.1 Current water use

Irrigation is by far the largest user of water from the Orange River, accounting for close to 90 percent of the use of water, other than environmental. In 1995 South African water use was about 2 000 million m^3 per year for irrigation and 125 million m^3 per year for urban and industrial purposes. After full implementation of Phase 1 of the LHWP, irrigation use will still dominate.

2.4.15.2.2 Losses

River losses are a natural phenomenon and are particularly pronounced in the case of the Orange River, where water is conveyed to users as far as 1 400km from the point of release. Annual losses were estimated at about 700 million m^3. Significant losses also occur from irrigation canals and distribution systems.

2.4.15.2.3 Efficiency of use

Various elements of inefficiency were identified, mainly with respect to the measurement, conveyance and application of irrigation water. Evidently the most important factor contributing to the low efficiency of water use is the exceptionally low tariff at which water is supplied to irrigation farmers. In 1995 the average irrigation water tariff was 2 cents per m^3, while the cost of that water was estimated at more than 50 cents per m^3.

2.4.15.2.4 Cropping patterns

It was found that about 70 percent of the irrigation water along the Orange River, and close to 90 percent of that in the Fish/Sundays basin is used for the irrigation of low value annual and fodder crops, with the balance going to the intensive production of high value crops such as grapes and citrus. Potential exists for high value crops to be introduced throughout the study area and it was evident that substantially greater financial and employment benefits could be gained from irrigation. It is therefore likely that there will be a shift from the irrigation of low value crops to higher value crops, as the price of water increases.

2.4.15.2.5 Economic value of water

The comparison on a national basis of the economic production per unit of water used by the different sectors of the economy, considering both direct and indirect effects related to water use, showed that the agricultural sector produces a substantially lower output and creates less employment per unit of water than any other sector. This does not imply that water should be taken away from agriculture, but rather that industrial activity should not be limited by a lack of water in favour of irrigated agriculture.

2.4.15.2.6 Social implications of water use

The investigation into the national and regional social implications of water allocation highlighted the diverse nature of the positive and negative social impacts associated with the allocation of water. From a national perspective, the transfer of at least part of the water available from the Orange River to the Vaal River System holds enormous benefits for the country as a whole in terms of increased potential for economic growth, and the resulting employment creation and other social benefits. In absolute terms, the national long-term socio-economic benefits of a shift in water use to urban/industrial areas significantly outweigh the social benefits of using available water for irrigation of low value crops.

2.4.15.2.7 Future uses for water

There are several user sectors in South Africa that could use more water from the Orange River, with their combined potential requirements well in excess of what the river can yield. Water for the establishment of new irrigation farmers from previously disadvantaged groups, as well as water for the augmentation of supplies to the Vaal River System is of particular importance.

2.4.15.2.8 Yield of existing system

The historic firm yield of the Orange River at current development levels and with the inclusion of Phase 1 of the LHWP, is 4 624 million m^3 per year. Of this, the ORP represents about 3 964 million m^3 per year, an estimated 274 million m^3 per year of which is still unutilised. It is important to note that in the estimation of the water available, it was assumed that the operation of the system will be managed efficiently and that abstractions will be equal to the quota allowances. Should abstractions be in excess of the quotas, as is believed to occur in some cases, or should inefficient releases occur, the water available will be reduced accordingly.

2.4.15.2.9 Resource potential

Substantial scope for further development of the Orange River will still exist after completion of Phase 1 of the LHWP and full utilisation of the current infrastructure. About 1 735 million m^3 per year (55 m^3/s) additional water could be abstracted from the Orange River on an environmentally sustainable basis. Due to uncertainties which exist, as well as the knowledge that circumstances are likely to change in future, this should only be regarded as a present indication of the full potential of the river. Harnessing this additional potential will require that the river be further developed and managed in a systems context, with new storage to be created in both the upper and lower parts of the river.

2.4.15.2.10 Development options

Many possible developments for increasing the yield of the Orange River System were investigated. Although no single option can fully harness the resource, various combinations of development options were identified for realising the remaining potential of the Orange River. These consist of small developments to improve the utilisation of the existing infrastructure, as well as possible large dams.

The most promising development options include:
- utilising low level storage in the Vanderkloof Dam
- re-regulating dams at Vioolsdrift and/or Boegoeberg to improve operational efficiency
- a large dam at one of these sites to increase the system yield
- a dam at Bosberg to increase the yield and to facilitate water transfer to the Vaal River
- a larger dam at Bosberg (the Boskraai Dam) would also dam the Kraai River
- A dam at Mashai in Lesotho, as previously identified, also remains an option.

No significant opportunities for further resource development exist as far as the Eastern Cape Rivers are concerned.

2.4.15.2.11 Transfers to Vaal River System

Of significance was the realisation that the full potential for transfer of water from the Orange River to the Vaal River System could not be realised from further development of the LHWP only. If such large volumes are to be transferred in future, it will have to be done from a point downstream of Lesotho, such as the proposed Boskraai Dam. The full transfer potential may be realised from Boskraai Dam without a further LHWP component.

After Phase 1 of the LHWP, further transfers via extensions to that project are limited to about 630 million m^3 per year (20 m^3/s), while the full additional yield potential of 1 735 million m^3 per year (55 m^3/s) can be transferred from Boskraai. Should it ever be necessary for more water to be transferred to the Vaal River System, a maximum of 2 840 million m^3 per year (90 m^3/s) can be abstracted at this site. This quantity of water can be made available for transfer, only if downstream irrigation is reduced.

2.4.15.2.12 Hydropower

Hydropower is generated at the Vanderkloof and Gariep dams with water released for other purposes, as well as with surplus water, as long as a situation of surplus exists. The ORRS analyses showed that the power generating capacity as originally planned will still be available after full implementation of the LHWP Phase 1. Further development of the river, such as utilisation of low level storage at the Vanderkloof Dam and eventual further transfer of water out of the Orange River upstream of the hydropower installations, will however reduce the generating potential. On the other hand, intermittent generation causes flow surges which negatively impact on the riverine ecology, as well as on downstream abstractions from the river. It is necessary that the agreement between the DWAF and Eskom be reviewed and revised to allow for changed circumstances and to conform to the new National Water Act.

2.4.15.2.13 Water quality

The quality of water in the Orange River has always been relatively good as most of the water originates in Lesotho, where the geology is such that the water generally has a low salt concentration. However, the analyses have shown that some deterioration of water quality is likely to occur as further development takes place, but that the quality should remain within acceptable limits. It is nevertheless advisable that the situation be monitored and that possible mitigation measures are introduced in future.

In the Great Fish and Sundays Rivers the water is of natural high salinity, and Orange River water is therefore transferred to the Eastern Cape not only to augment the supplies, but also for blending purposes. The comprehensive ORRS analyses showed that some refinements in operating strategies would be beneficial, but that no major reduction in blending volumes would be achievable. The only significant reduction in the need to use Orange River water would be directly associated with a reduction of irrigation, especially along the upper Fish River.

2.4.15.2.14 Environmental and social impacts of new Infrastructure

Although developments along the Orange River have had significant impacts on the natural environment, as well as the ecology of the river, important conservation areas remain. Significant potential impacts were identified at some of the proposed dam sites, which should be appropriately considered and mitigated, should these dams be built. Key issues include:

- desires and perceptions of interested and affected parties
- relocation of people
- conservation of unique ecosystems
- tourism in scenically dramatic semi-desert areas
- Important archaeological sites.

2.4.15.2.15 International co-operation

There are complex technical and political issues pertaining to the management and equitable sharing of the resources of the Orange River. These need to be addressed jointly by the co-basin states within the framework of the Protocol on Shared Watercourse Systems in the SADC Region. At least two of the development options proposed for further consideration, the Mashai and Vioolsdrift dams involve foreign territory and will require direct co-operation with Lesotho or Namibia respectively.

2.4.15.3 Strategy for Development and utilisation of the Orange River

The broad strategy for the management of the Orange River should be to promote effective and efficient utilisation on a sustainable basis and to achieve the greatest social, environmental and economic benefit from each cubic metre of water used, to the overall good of all. This includes the following components:

2.4.15.3.1 Better utilisation of water

Before any further development of the resource is embarked upon, it is essential that steps be taken and actual progress made with respect to the better utilisation of water already available. In particular, the national strategy with respect to water conservation and demand management needs to be adhered to.

The core factor in support of the strategy to ensure the efficient and most beneficial use of water, specifically by the irrigation sector, is the application of a well-structured pricing policy. To facilitate the shift in water use from low value applications to more beneficial and higher value applications, trading of water should be allowed. Full details of the pricing policy, with indications as to how the price of water may change in future, as well as the regulations with respect to the trading of water, should be made available to users, enabling appropriate advance planning by them. Should water be strategically priced and trading of water is allowed, subject to appropriate licensing and abstraction control, the use of water will automatically gravitate towards more beneficial applications. Natural growth in water use could therefore be allowed as long as water is available or can be developed.

2.4.15.3.2 Short term strategy

Part of the current surplus of 274 million m^3 per year will be needed to meet the normal growth in urban/industrial requirements for water, mainly by users in the vicinity of the Orange River and in the Eastern Cape already supplied from the Orange River. In support of Government programmes to provide opportunities for the upliftment of previously disadvantaged people, there is also a great need for water to be made available for the establishment of emerging irrigation farmers.

One option would be to allow the surplus to be taken up through normal growth in any sector(s), where ever the need may first arise. Whereas water for emerging farmers should be at a subsidised price, additional water for commercial irrigation, urban/industrial use and possible other users should be at the full price.

Alternatively, the surplus water may be reserved primarily for the establishment of emerging farmers. Other additional users will then be dependent mainly on water made available from new infrastructure. As an interim measure, part of the available surplus may be supplied to these users, but at a price equivalent to water from the next resource development.

2.4.15.3.3 Medium and long term strategy

Once full utilisation of the surplus is reached, additional water at relatively low cost can be made available through the utilisation of low level storage at Vanderkloof Dam (305 million m^3 per year) and through the construction of a small balancing dam at Vioolsdrift and possibly Boegoeberg (220 million m^3 per year), provided the cost of water from these developments can be afforded by intended users.

The next step of development will require extensive capital investment for the construction of one or more large dams and conveyance systems. The price of water from these schemes will be relatively high and is likely to be affordable only to large urban/industrial users where a high growth in water requirements is experienced and ability to pay is high. The water is unlikely to be affordable to irrigators who produce low income crops.

The effects of the national water conservation strategy and proposed pricing policy on the use of water from the Orange River will become quantifiable only over time. It is, therefore, not possible for a firm resource development plan to be formulated at this stage. Smaller resource developments should therefore be implemented as the needs arise, provided that the potential feasibility of future large schemes are not jeopardised. A framework is therefore proposed, within which development can take place, but which requires review at least when the next major development is to take place. This will ensure that future flexibility for development and management of the resource is retained.

2.4.15.4 Recommendations

It is evident from the ORRS that a substantial quantity of water can still be made available from the existing infrastructure on the Orange River, provided that efficient use of water is achieved and properly managed. Significant potential for further development of the resource also exists. The projections further indicate that it will be several decades before full development of the resource is approached. This will allow for incremental decisions to be taken with respect to future developments and the use of water, as well as the phasing of development based on prevailing circumstances at any future time. The strategic framework is therefore targeted at achieving improved utilisation of water and ensuring that development decisions are flexible enough to allow the full beneficial utilisation of the resource in future, even if circumstances should change.

2.4.15.4.1 Improved management

A fundamental assumption for the determination of the water available for further use, is that abstractions will be within the limits of the quotas (licenses) issued. There are strong indications that in many cases, actual irrigation abstractions exceed the quota allowances, which could result in shortages being experienced by other users and possible damage to the estuary, when sufficient water should still have been available. Improved measurement and control over abstractions is therefore required as a priority.

In general, significantly greater utility can be achieved from water used in the irrigation sector, both in terms of financial production per unit of water as well as the employment opportunities created. The introduction of an effective pricing strategy is recommended to induce a shift in the use of water from low value applications to more beneficial high value uses.

In terms of the National Water Act of 1998, the quotas for irrigation water are to be replaced by water use licenses. It is important that the licenses be volume based and that the license conditions be purposefully structured to promote more beneficial use of water. In conjunction with an appropriate pricing strategy (which would determine realistic minimum prices for water) the trading of water can, through normal market forces, contribute greatly to more beneficial use of water. The rules for the trading of water use licenses, possibly also between basins, should be clearly defined.

The proposed changes to the quota system and pricing of water, will act in support of water conservation in agricultural irrigation, which should be promoted and supported by government. The potential for irrigation water conservation and demand management should be analysed as a first step towards the development of a comprehensive strategy in general, and for the Orange River supply region in particular.
A standard approach for water to be measured at the point of abstraction from the river is recommended. This will imply that users/water use associations take responsibility for all water losses. Successful implementation will require that the measurement and monitoring of water use be upgraded.

The existing agreement between DWAF and Eskom should also be reviewed in the light of the changed circumstances, and be revised accordingly.

2.4.15.4.2 Water requirements and allocation

It is recommended that the in-stream flow requirements and estuarine freshwater requirements, as determined for the respective rivers, be accepted in the interim as the Ecological Reserves. These should be implemented, and the results monitored to facilitate the comprehensive determination of the Reserves in due course.

Sufficient water is available from the Orange River, now and in the foreseeable future, to supply the domestic/urban/industrial requirements in the Orange River basin and in the Eastern Cape area, served through the Fish and Sundays rivers. License conditions for these users should specify the implementation of appropriate water conservation and demand management measures. Water for the establishment of new irrigation farmers from disadvantaged backgrounds, as well as for possible community gardens, can also be made available from the existing infrastructure, for the purpose of social upliftment. A clear definition is required with respect to who would qualify for irrigation under this category. Suitable license conditions should be formulated, and it is recommended that limitations be placed on the trading of such water.

It is recommended that no further water be made available for commercial irrigation, until the pricing strategy has been finalised.

2.4.15.4.3 Resource development

Further stochastic analyses should be performed to determine the probabilistic yield capability of the existing system, as well as for selected development scenarios. Long-term analyses for planning purposes, as well as short-term operational analyses are required.

Access to low level storage at the Vanderkloof Dam offers the lowest cost option for increasing the yield of the Orange River system. Downstream users can already be supplied by means of low-level river outlets, while pumps would be required for supplying the Vanderkloof and Riet River irrigation schemes during periods of severe drought. It is recommended that the feasibility and timing of a permanent or emergency pumping station be further investigated.

Considering the obvious benefits of improving the operational efficiency of the system below the Vanderkloof Dam by regulating excess releases along the Lower Orange River and the favourable position of a possible Vioolsdrift Dam in this regard, further investigation of this option is recommended. As a large dam may later be required at this site, this option should be investigated at the same time.

As an alternative to a dam at Vioolsdrift, the feasibility of a dam at Boegoeberg should be investigated. An assessment of the balancing effect of the possible Vioolsdrift or Boegoeberg dams on the salinity in the lower Orange River should form part of the investigation. A dam at Boskraai will be essential to harness the full potential of the Orange River, as well as for transfers to the Vaal River in excess of about 20 m^3/s (in addition to LHWP 1). Although it is likely to be many years before this dam is required, it is advisable to bring investigations at least to a full prefeasibility level to provide a proper basis for comparison with the LHWP II options.

A possible dam at Mashai, as well as the size and operating rules of such a dam, will have a direct bearing on the developments downstream. It is therefore important that priority be given by South Africa and Lesotho to a decision in this regard.

A detailed comparison is required between meeting the growth in water requirements of Port Elizabeth from the development of local resources or from the increased use of Orange River water. It is foreseen that both these options will eventually have to be resorted to.

Several uncertainties still remain regarding the factors which would impact on the sizing of the aqueduct from Boskraai Dam to the Vaal River. Considering this, as well as the inflexibility of the aqueduct to increasing the capacity after construction, it is recommended that a decision on the required transfer capacity be postponed for as long as possible.

The impact of the various development and management scenarios on the hydropower generating capacity need to be assessed in detail for evaluation against the benefits of water supply. A balancing weir at Havenga Bridge is needed to attenuate flow surges, which result from the highly variable turbine releases at the Vanderkloof Dam.

2.4.15.5 **International Co-operation**

The implementation of many of the recommendations would affect water use and water resource management in Lesotho and Namibia, while some of the proposed developments also fall partly or totally within the territory of these countries. It is therefore essential that the ORRS be integrated with corresponding planning in these two countries as co-riparian states, and a joint development and management strategy for the river is recommended.

2.5 METOLONG DAM FEASIBILITY STUDY (2003)

2.5.1 Section 2 Water Demands, Section 3 Hydrology & water resources

2.5.1.1 **Provisional Demand Projection for Maseru to 2010**

By projecting the baseline demand to 2010 (associated with the implementation of the Maseru Peri-Urban project), and inserting the industrial demand figures from LNDC, the demand trend as shown in **Table 2-46** is indicated. Note that the present system capacity will not allow meeting this demand throughout this period, particularly in the years 2005 to 2007 prior to the inauguration of the supply from Metolong Dam. The projected timing and rate of industrial expansion may be delayed unless additional supply can be made available from alternative sources.

Table 2-46: Projected demand for Maseru up to 2010

(All demand figures in Mℓ/day and include distribution water losses)

Year of Projection	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Baseline Demand	24.53	25.51	26.53	27.59	28.69	31.44	34.30	37.27	40.36	43.57	46.92
Industrialisation	0.72	1.44	2.52	7.44	12.84	18.24	20.88	23.40	25.44	28.20	30.60
Total Demand	**25.25**	**26.95**	**29.05**	**35.03**	**41.53**	**49.68**	**55.18**	**60.67**	**65.80**	**71.77**	**77.52**

Note: 1) Baseline Demand includes approximately 3.5 Mℓ/day of industrial demand already in existence in 2000, and allows for internal increase of this demand by 5% per annum.

2) Industrialisation Demand follows the peak demand projections of LNDC, allowing for a volumetric reduction of 30% from the peak demand figures.

2.5.1.2 **Provisional Demand Projection for Maseru, 2010 – 2020**

For the baseline demand projection, a steady demand growth at an annual rate of 4% per annum has been postulated following 2010. In the high demand model this has been increased to 4.5% due to the knock-on effect of industrialisation. Even in the scenario that the national population increases at a compound rate of only 1.4% per annum over the period 2000 to 2020, the population of Maseru Urban Area is projected to increase by at least 4.0 % per annum over the same period due to the persistent trend of urbanisation.

The demand projection for the Medium ('most likely') demand Scenario to the year 2020 is as shown in **Table 2-47**. Please also note the possible impact should industrialisation be diminished or reversed. The baseline demand figure for the year 2020 is 69.5 Mℓ/day. This is practically the same as that in the project ToR (70 Mℓ/day), thus indicating that the ToR figures may represent a pre-industrialisation projection.

Table 2-47: Projected demand for Maseru up to 2020

(All demand figures in Ml/day and include distribution water losses)

Year of Projection	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Baseline Demand	48.79	50.74	52.77	54.89	57.08	59.36	61.74	64.21	66.78	69.45
Industrialisation	31.80	32.76	33.72	34.68	35.40	36.84	38.28	39.72	40.92	42.12
Total Demand	**80.59**	**83.50**	**86.49**	**89.57**	**92.48**	**96.20**	**100.02**	**103.93**	**107.70**	**111.57**

Values from other alternative demand scenarios developed by the study are presented in **Table 2-48.** The high divergence (up to a factor of 2 times) between the historically-based trend as per ToR and those generated using planning data indicate the magnitude of the risk should the planned industrial demand not materialise or not be sustainable.

Table 2-48: Comparative Values for Maseru Demand Scenarios

Demand Scenario	Year 2010 (Mℓ/d)	Year 2020 (Mℓ/d)	Key Assumptions
ToR	50	70	No planning or theoretical basis, neutral projection of historic data
Low	69.91	88.84	Uses LNDC figures, with exception of only Phase I development at Tikoe. Applies 30% reduction in volume for peak/averaged adjustment and water reuse.
Medium	77.52	111.57	Uses LNDC figures, with 30% reduction in volume for peak/averaged adjustment and water reuse.
High	88.94	126.75	Uses LNDC figures, with only 10% reduction in industrial demand volume.

2.5.1.3 Important Conclusions regarding the Maseru Water Demand Projection

The demand projection included in the Terms of Reference predated the phenomenon of industrial expansion in Maseru. Whereas the domestic demand of Maseru can be predicted with a fair degree of confidence, the potential of rapid and large-scale industrial expansion in Lesotho, and the uncertain nature of the activities to be undertaken, result in a wide range of possible water demand projections.

Reflecting various degrees of economic expansion, the projected demand in 2020 ranges from 1.27 times (Low Demand case) to 1.8 times (High Demand case) that predicted in the Terms of Reference. Whichever scenario is the case, it is clear that the growth in the Domestic portion of the Gross National Product will involve a shift in the base of production from South Africa to Lesotho and this will involve localisation of water demand for production.

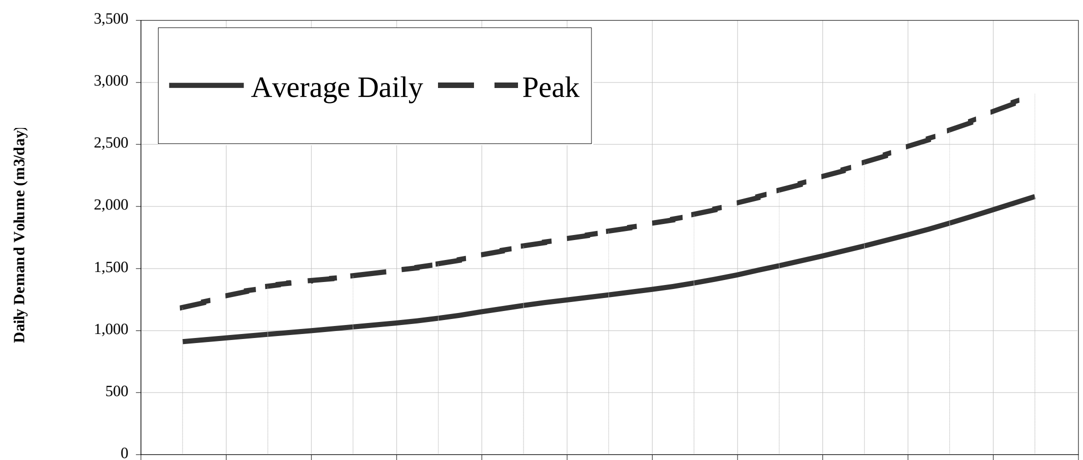
With regard to the present system capacity, the following conclusions are suggested:

- The capacity of the existing Maseru Treatment Works has already been exceeded, and has actually been in deficit since between 2000 and 2002. Increasingly, peak demands are not being met and average demand may soon not be met.
- The rehabilitation measures underway under the industrialisation program (MWSAP) will only be sufficient to allow demands to be fully met until 2004. Further source and supply measures should be in place by 2004/05.

- By the year 2010, the average daily demand of Maseru Urban Area will have reached between 50 and 90 Mℓ/day (most likely 78 Mℓ/day), and the peak demand between 65 & 120 Mℓ/day (most likely 100 Mℓ/day). The upgraded Maseru works will only be able to provide between 40% and 70% of the volume required.
- By the year 2020, the average daily demand of Maseru Urban Area is projected to reach between 70 and 127 Mℓ/day (most likely 112 Mℓ/day), and the peak demand between 90 & 165 Mℓ/day (most likely 145 Mℓ/day). By this horizon the fully developed Caledon river facilities will only be able to provide around 25% to 40% of the volume required. In the higher demand scenarios the Caledon and Metolong Schemes together may be inadequate to meet Maseru demand to the target year.
- The distribution of probability is primarily controlled by the assumptions for industrialisation.

2.5.1.4 Towns neighbouring the Metolong Project area

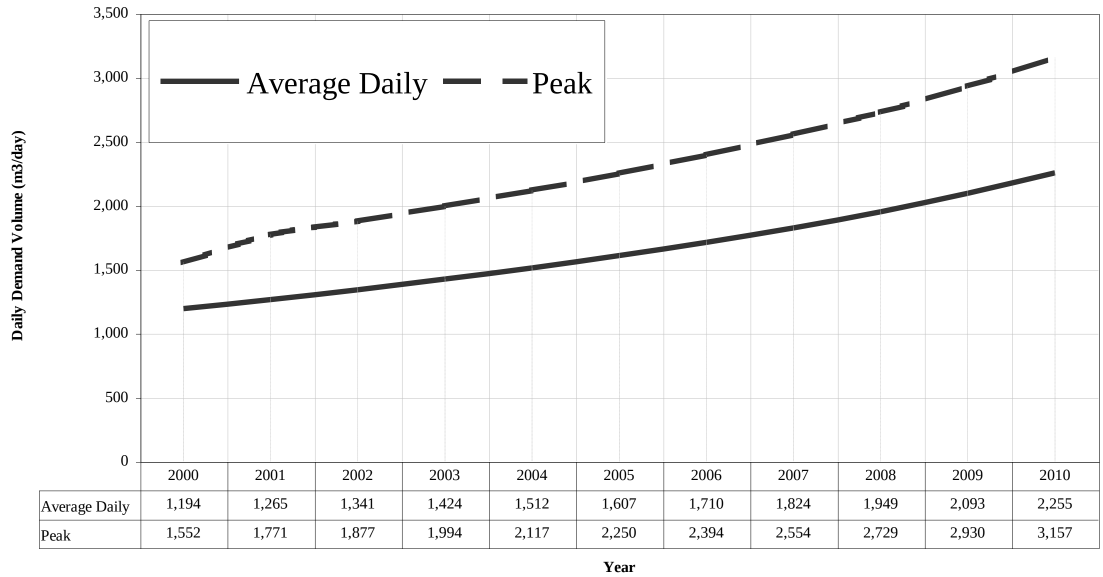
The neighbouring towns mentioned in the project Terms of Reference to be considered for supply from the proposed dam at Metolong are Mazenod, Roma and Teyateyaneng. The likely demands of these centres were individually assessed to determine the impact of the inclusion of these centres within the Metolong supply scheme. The projected demands of the neighbouring towns are presented in **Figure 2-5** to **Figure 2-7**.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Average Daily	903	962	1,023	1,092	1,194	1,279	1,375	1,514	1,674	1,858	2,072
Peak	1,174	1,347	1,432	1,529	1,672	1,791	1,925	2,120	2,344	2,601	2,901

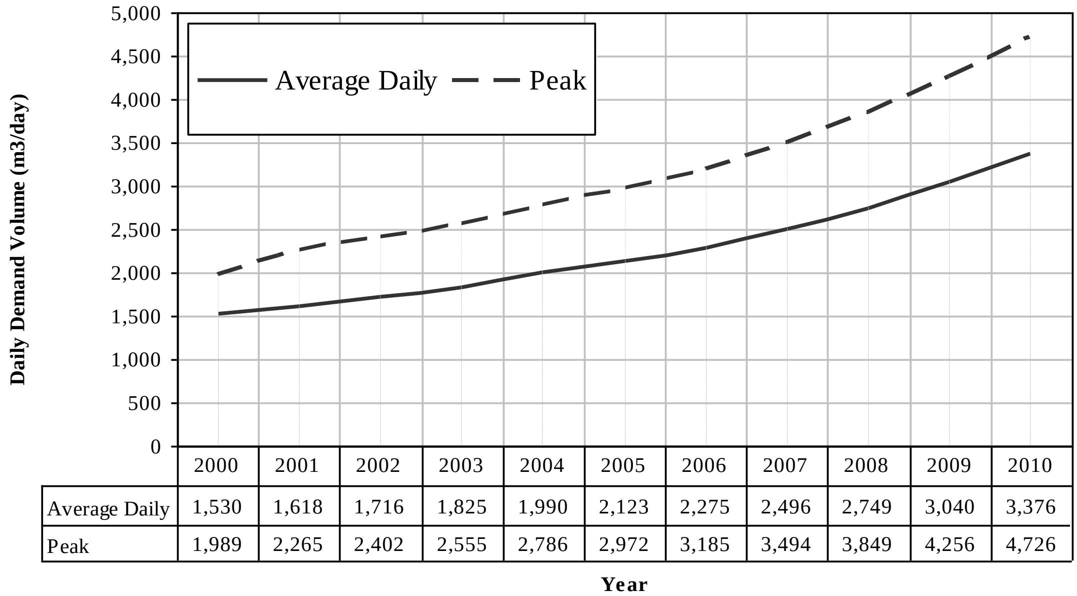
Year

Figure 2-5: Projected Water Demand for Mazenod



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Average Daily	1,194	1,265	1,341	1,424	1,512	1,607	1,710	1,824	1,949	2,093	2,255
Peak	1,552	1,771	1,877	1,994	2,117	2,250	2,394	2,554	2,729	2,930	3,157

Figure 2-6: Projected Water Demand for Roma



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Average Daily	1,530	1,618	1,716	1,825	1,990	2,123	2,275	2,496	2,749	3,040	3,376
Peak	1,989	2,265	2,402	2,555	2,786	2,972	3,185	3,494	3,849	4,256	4,726

Figure 2-7: Projected Water Demand for Teyateyaneng

2.5.1.5 Hydrological and Yield Studies

Detailed hydrological studies and catchment modelling of the South Phuthiatsana River were done. Historic and synthetic flows covering a period of 78 years from 1922 were developed. Long term rainfall records at four stations relatively close to the Metolong catchment, at Roma, Blue Mountain Pass, Botshabelo and Teyateyaneng was effective from 1922. River flow data was based on two gauging stations on the South Phuthiatsana River. The one station was at Masianokeng in the lower part of the catchment with records since 1980. The second station was at Pulane, 13 km upstream of Metolong, with records since 1991.

The station at Pulane was the most applicable in relation to the dam site location, and it was used for the catchment modelling to generate rainfall-flow relationships. The Pitman model was adopted for modelling purposes. The modelling, combined with the long term rainfall records enabled the generation of synthetic monthly flows (in volume terms) for Metolong from 1922.

The reservoir simulations involved a monthly balance of inflows and outflows at the reservoir for a range of different storages, including allowance for evaporation, spillage and releases to meet requirements for releases of environmental flows downstream (or in-stream flow requirements-IFR). A dead storage of 2 million m^3 was allowed for reservoir sedimentation. This was based on sediment data for the two river gauging stations on the river, indicating an average sedimentation rate of 0.07 million m^3/year. The yield estimates for a range of different reservoir storages are shown in **Figure 2-8**.

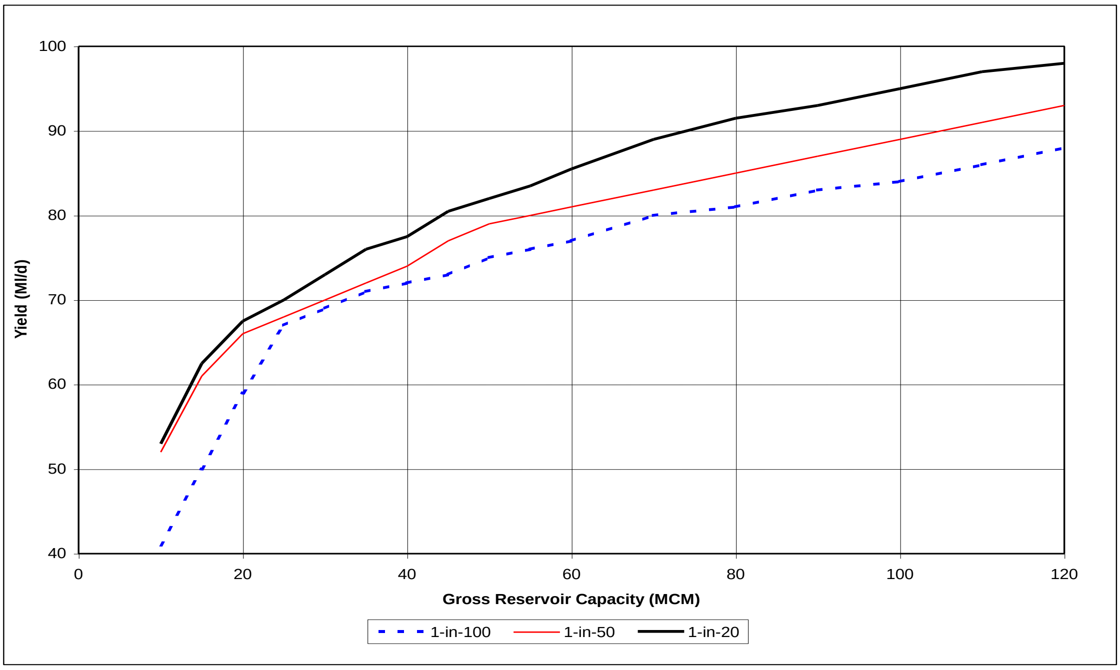


Figure 2-8: Storage-Yield Curves

The reliability target for the yield studies was 98% (1 in 50 year failure to meet the demand), required by WASA. The yields with 98% reliability are given in **Table 2-49**. The table indicates that there is a high increase in yield from zero to 70 Mℓ/day for a reservoir impounding up to 31 million m^3, while no significant increase in yield (80 Mℓ/day) is evident for reservoir storages above 52 million m^3.

Table 2-49: Yield-Storage Summary

Reservoir Storage (million m^3)	Yield (Mℓ/day)
31	70
52	80
70	83
80	85

Table 2-50 shows the demand horizons that the yields for reservoir storages of 31 and 52 million m^3 can meet in relation to the supply requirements determined in the study. It should be noted that in the derivation of these time horizons, it was assumed that a supply from Metolong commences at the beginning of 2007. The table shows that if a "High" Demand scenario is considered, there is the need for a new water source only six years after the commissioning of Metolong.

Table 2-50: Demand Horizons (Years) in Relation to Reservoir Storage

Domestic + Level of Future Industrial Development	Reservoir Storage (million m^3)	Reservoir Storage (million m^3)
	31	52
Low	2020	2024
Medium	2015	2017
High	2011	2013

2.5.2 Section 5 Dam studies, Section 6 Water supply & Transmission, Section 7 pump stations, Section 12 Infrastructure

2.5.2.1 Choice of Dam Site

At the initial stages of the Study, a comparative exercise was undertaken to confirm that the dam site at Metolong was the most favourable location on the South Phuthiatsana River. This exercise included site identification using existing 1: 50 000 scale aerial photography, site inspection, storage estimates from the 1: 50 000 scale maps and some initial topographical surveys. This led to the choice between two sites, at Metolong and a site near Qiloane, 8 km downstream, with a catchment area approximately 70 % higher with a correspondingly increased yield. These sites are shown in Drawing No.1. The catchment areas are 250 and 440 km^2 for Metolong and Qiloane respectively.

The two sites are considerably different in terms of topography and geology. Metolong is a narrow V-shaped gorge with sound hard sandstone of the Clarens Formation outcroppings over the larger part of the abutments, favouring a concrete gravity dam. The site at Qiloane is in a relatively wide (350 m) U-shaped valley within the weaker Elliot Formation with deeper overburden. In terms of direct environmental impacts, the reservoir at Metolong is entirely within an incised gorge with no habitations or farming land affected, whereas at Qiloane at least 2 km^2 of cultivated land would be lost.

Preliminary yield estimates were produced for the two sites and cost comparisons prepared based on the same yield from either location. A comparison of the two sites is given in **Table 2-51**.

This exercise confirmed Metolong as the more favourable site and, located at a 70 m higher elevation; it also offered significantly lower pumping costs for transmission to Maseru. This site has therefore been carried forward to full feasibility study.

Table 2-51: Comparative Dam Costing

DAM SITE	METOLONG	METOLONG	QILOANE
Required storage (Mm^3)	65	65	51
Dam Type	Concrete	Embankment	Embankment
Height (m)	73	78	55
Cost (Maloti x 10^6)	225	390	360
Unit Cost (M/m^3/year)	6.1	10.6	9.8

2.5.2.2 Geological and Geotechnical Studies for Metolong Dam

These studies covered the following:

- Site investigations on the proposed dam axis to establish the foundation conditions in terms of bedrock strength, jointing and permeability;
- Identification and testing of suitable sources of construction materials;
- Geological mapping of the dam site, with particular emphasis on bedding planes and other discontinuities.

The dam site is located in a narrow V-shaped gorge, 80 m deep, which the South Phuthiatsana River has incised in the Clarens Formation. This Formation comprises hard well-cemented sandstone, which outcrops over a 45 m height above the river bed on each abutment. In the upper abutments the sandstone is overlain by the Lesotho basalt, which is typically heavily fractured and moderately weathered. At the contact with the underlying sandstones, the basalt is completely weathered, approximating to a soil, over a 2 m height. At about 15 m depth below the river bed, the Elliot Formation, a weaker siltstone, underlies the Clarens Formation.

Comprehensive geological mapping of the dam site has been carried out, specifically in the context of the probable choice of a concrete dam. The priorities in relation to this have been:

- The discontinuities in the bedrock with a particular emphasis on the condition and characteristics of the horizontal or sub-horizontal bedding planes in the Clarens sandstones. This is critical in terms of sliding resistance for a concrete gravity dam;
- The possible presence of dykes and sills which could influence the dam design. Commonly these result in weak seams or layers, which can pose difficulties for the design of a concrete dam. No dykes or sills are present at or near to the Metolong dam site.

The site investigations comprised five boreholes, which confirmed suitable founding depths in the Clarens sandstone for a concrete dam of 5 m, primarily to found below the level of stress relief joints. The Clarens Formation is typically impermeable unless significant discontinuities are present. The permeability testing carried out as part of the site investigations confirmed the water tightness of this formation.

The search for construction materials has had two principal elements, possible sources of earth fill as core for an embankment dam and a location of suitable and sufficient rock, particularly for aggregates, to be quarry won and processed, for a concrete dam. In the case of the latter, the main purpose at feasibility level is to establish a possible source, so that haul distances can be taken into account in the dam costing. Several suitable dolerite or doleritic basalts sources were identified and the preferred location is about 6 km south of the dam site near the village of Ha Mofammere.

Sources of earth fill in the particular geology of the area would be from the complete weathering of the basalt lava flows. Depths of suitable material were found to be very limited in extent and at depths of less than 1 m with extensive core stones. The quantity of core material available is totally insufficient for the core zone of an embankment dam.

A programme of laboratory testing has been carried out, primarily concentrating on the rock strengths and modulus.

2.5.2.3 Metolong Dam

Topographical surveys of the dam site and reservoir area have been carried out, the latter leading to a height-storage curve for the reservoir. The reservoir is entirely contained within the incised gorge of the South Phuthiatsana River and associated side valleys. For the reservoir storages of 31 and 52 million m³, the dam heights will be 60 and 68 m respectively.

The narrow V-shaped valley and sound geology provide an excellent dam site, particularly for a concrete dam. This is further reinforced by the presence of a suitable source of concrete aggregate within 6 km of the dam site. Due to the lack of earth fill material for the core zone, an embankment dam would have to be a concrete faced rock fill dam (CFRD), with a corresponding greater cost. However the site topography and geology combined with the required spillway capacity favour a concrete gravity dam for the following reasons:

- The spillway, with a large required capacity of 2 300 m³/s, can be readily incorporated within the dam wall, whereas an embankment dam would require an independent spillway, most probably a long concrete lined chute in one abutment;
- Major diversion works can be avoided with diversion solely through an opening or culvert in the dam wall, whereas an embankment dam would require a long tunnel in one abutment, with considerably higher costs and adding a further one year to the construction programme for the dam;
- The draw-off works can be located against the upstream face of a concrete dam whereas a free-standing tower in the reservoir would be required for an embankment dam.

Concrete gravity dams have been typically in the last 20 years constructed using roller compacted concrete (RCC). RCC involves placing concrete by earthmoving methods, spreading by bulldozer and compacting in 300 mm thick layers by conventional large vibrating rollers, as for the compaction of normal earth fill dams. It does require a contractor experienced in RCC construction, of which there are now a significant number, including in RSA. Some of the principal features of RCC placing are:

- Continuous placing, if possible 24 hours a day, to avoid cold joints between layers;
- Placing quantities of up to 6000 m³/day are not unusual depending on the size of dam and construction plant employed. A typical average rate for Metolong would be 1 500 – 2 000 m³/day;
- Due to the placing methods, an RCC dam of the size proposed at Metolong would have an overall construction period of 24-27 months, whereas an embankment dam of a similar size would require a year longer. Commissioning of the Project can thus be advanced by one year.

The volume of RCC will be 168 000 and 210 000 m³ for dams impounding 31 and 52 million m³ respectively. Following typical RCC practice, this volume of RCC would be placed over 4-5 months in one season. Placing has to be in winter to enable lower concrete placing temperatures and temperature rises in the concrete, thereby avoiding shrinkage cracking. Placing at this time of year is ideal for Lesotho as it also coincides with the dry season.

The envisaged RCC mix, used as a basis for the dam costing, would have a cementitious mix comprising ordinary cement and fly-ash in the quantities of 120 and 80 kg/m³ of concrete respectively. This is a medium high paste RCC with a target characteristic strength of the concrete of 20 N/mm². Fly-ash is comparatively cheap, being obtained and processed at coal-fired power stations in the Gauteng area of RSA. Budget quotations have been obtained for cement and fly-ash delivered to Maseru to assist in the costing of the dam.

Particular features of the dam are:

- Gated central spillway, providing the least cost solution;
- Draw-off works integral within the dam wall;
- Raw water pumping station located at the immediate downstream toe of the dam, with access by vertical shaft and horizontal adit in the right (north) abutment.

In view of the importance of sound costing of the dam, the feasibility designs have been extended to the next stage of preliminary design and correspondingly the bill of quantities for the construction is more detailed than normal feasibility level. The Consultant has recently been responsible for the design and supervision of construction of an RCC dam in Jordan of a similar size to Metolong and tendered by international contractors. This has provided a sound basis for the dam costing, covering the two reservoir storages of 31 and 52 million m³.

The main dam sizing and costs for the two levels of reservoir storage considered are given in

Table 2-52.

Table 2-52: Dam Size and Costs

Description	Storage- 31 million m³ (Yield- 70 Mℓ/day)	Storage-52 million m³ (Yield- 80 Mℓ/day)
Dam Height (m)	60	68
Dam Crest Length (m)	170	210
Cost, exc. contingencies (Million)	145	173

2.5.2.4 **Abstraction and Transmission Options to Maseru**

Consideration was given to releasing water down the river and abstracting it closer to Maseru. The results showed that direct pumping from the dam has the lowest total NPV in terms of construction and operating costs, compared to the alternatives of release for abstraction downstream (Mazenod and Ha Mabitso). It also has further operational advantages, avoiding the need to handle water of variable quality. This option was selected to be carried forward to full feasibility level design and costing.

2.5.2.4.1 Water Treatment

Following the comparative evaluation described above, the treatment works design and costing at feasibility level has proceeded based on direct abstraction to a treatment works located on the right flank of the dam.

The treatment works will have an expected peak suspended solids concentration of 150 ppm. The Study cost a treatment works of 90 Mℓ/day peak capacity (70 Mℓ/day average), giving a total cost of M 77 million. For a scheme supplying 80 Mℓ/day (average), the cost of the treatment works has been adjusted in the ratio of the capacities, leading to a total cost of M 87 million.

2.5.2.4.2 Transmission System to Maseru

Leading from the comparative studies described in Section S7, the transmission system to Maseru will involve the following:

- Dam (Raw water) Pumping Station to deliver the water to the treatment works at the top of the right (north) abutment;
- 800 mm diameter raw water pipeline, 300 m long from the dam to the treatment works;
- Ha Nchela (Treated water) Pumping Station at the treatment works, pumping to a header reservoir on high ground near the village of Ha Nchela, from where the water will gravitate to Maseru;
- 27.3 km length of 800 mm diameter transmission main from the treatment works to the existing High South reservoir outside Maseru, and
- The proposed material for the transmission pipelines is ductile iron.

Table 2-53: Dam and Ha Nchela Pumping Stations

Description	Total Flow (ℓ/s)	Static Head (m)	Total Head (m)

Dam Pumping Station	940	62	67
Ha Nchela Pumping Station	890	75	138

The costs of the transmission system, including pumping stations and concrete balancing reservoirs, are indicated in **Table 2-54**. The costs of the pumping stations comprise all the mechanical and electrical plant and any associated civil works.

Table 2-54: Costs of Transmission to Maseru (Million)

Description	Cost
Raw water pipeline, 800 mm diameter, length 0.3 km	0.92
Treated water pipeline, 800 mm diameter, length 27.3 km	86.60
Header reservoir at Ha Nchela	11.18
Balancing reservoir at High South	30.10
Dam (Raw water) Pumping Station	11.80
Ha Nchela (Treated water) Pumping Station	18.38
TOTAL	**158.98**

2.5.2.4.3 Supply to Neighbouring Towns

It has been proposed that the yield from Metolong dam should also be utilized to supply the neighbouring towns of Roma and Mazenod and also Teyateyaneng if there is no suitable more economical scheme for the latter. The supply to Mazenod would include the International Airport, which is situated just south of the town. The supplies to these towns up to the year 2020 have been included in the overall demand forecasts described in Section S2.

The supplies to the towns of Roma and Mazenod will comprise the following:

- A 6.5 km long 350 mm diameter gravity pipeline branch from the 800 mm diameter treated water main to Maseru to a balancing reservoir on high ground at the village of Thaba Khupa near the Mazenod to Roma road;
- For the supply to Mazenod, a 10 km long 250 mm diameter gravity main from the balancing reservoir at Thaba Khupa;
- For the supply to Roma, a 9 km long 250 mm diameter gravity pipeline from the Thaba Khupa balancing reservoir to a pumping station (Roma Pumping Station), followed by a 4 km long pumping main.

The supply to Teyateyaneng will comprise the following:

- a pumping station (Sefikeng) at the treatment works;
- a 11 km long 300 mm diameter pumping main to a balancing reservoir near Sefikeng, and
- A 16.2 km long 300 mm diameter gravity main from the balancing reservoir to Teyateyaneng.

The construction costs of the supplies to these towns are summarized in **Table 2-55**.

Table 2-55: Costs of Supplies to Neighbouring Towns (Million)

Description	Roma	Mazenod	Teyateyaneng
Pipelines	6.29	17.04*	26.81
Pumping Stations	0.72	-	5.92

Total	7.01	17.04	32.73

* Includes the branch pipeline from the Maseru transmission main up to Thaba Khupa balancing reservoir

2.5.2.5 Infrastructure

The size of the Project will require the provision of significant infrastructure at Metolong, covering the following:

- Permanent camp with 10 houses for permanent staff, accommodation and office blocks, including power and water supply requirements;
- Power supply of 4 MW provided from the national grid by the Lesotho Electricity Corporation (LEC);
- A 4.0 km long two lane surfaced road from the existing Thaba Bosiu to Sefikeng road to the treatment works, dam and camp;
- 24 km of gravel feeder roads to the villages adjacent to the reservoir to compensate the loss of access across the river, feeding to the bridge over the dam;
- Other EIA ameliorative measures such as improved water supply to villages and fencing at selected locations along the reservoir edge.

The cost of the infrastructure has been estimated at M 63.2 million, including 10% contingency allowance. The main elements of the cost are the surfaced and gravel roads (M 25.0) million, the power supply (M 11.3 million) and the permanent camp (M 17.0 million).

2.5.2.6 Summary of Project Construction and Operating Costs

Construction and annual operating costs for the proposed Project have been estimated based on mid-2003 prices and, where applicable, an exchange rate of 1US$ to 8 Maloti. These costs have been prepared for two sizes of Project, with yields of 70 and 80 Mℓ/day respectively.

The costs of the main construction elements are summarized in **Table 2-56**, which include additional allowances for contingencies to cover for possible variations in foundation conditions actually encountered during construction and price variations. These have been taken as 15% of the construction costs for the dam and 10% for the other main construction works.

Table 2-56: Construction Costs (Maloti)

Scheme (Yield)	70 Mℓ/day	80 Mℓ/day
Supply (Mℓ/day)	68	78
Reservoir storage (million m³)	31	52
Costs: Dam	167	199
Pumping Stations	41	44
Treatment Works	85	96
Pipelines	144	144
Infrastructure	63	63
Service Reservoirs	57	57
Total Cost	**557**	**603**

Other costs are those relating to the implementation of the EIA requirements for implementation of the Project and engineering costs covering tender design and documents, detailed design site investigations and surveys and supervision of construction. Engineering costs have been based on 10% of the total construction and related costs. The EIA costs, which exclude ameliorative measures to be constructed and hence already cost under the infrastructure requirements, have at this stage been based on 5% of the principal construction and related costs. The costs allowed in the economic analyses for these elements of the Project are given in **Table 2-57**.

Table 2-57: Engineering and EIA Costs (Million)

Scheme	70 Mℓ/day	80 Mℓ/day
Engineering costs	58	61
EIA costs	30	32
Total costs	**88**	**93**

The principal annual operating costs are pumping energy costs, costs of chemicals for water treatment and costs of maintenance and operations staff. Pumping costs have been based on the latest applicable tariffs from the Lesotho Electricity Corporation and include the supplies to the three other neighbouring towns. Annual operation and maintenance costs have been taken as 5% of the total construction costs. Treatment costs have been based on the volume of treated water multiplied by a rate of M 0.15/m³. The estimated annual operating costs are summarized in **Table 2-58**, based on the time at which the Project is supplying at its maximum capacity.

Table 2-58: Annual Operating Costs (Million)

Scheme	70 Mℓ/day	80 Mℓ/day
Pumping costs	6.9	8.6
Treatment costs	3.9	4.4
Operation & Maintenance	4.0	4.2
Total annual costs	**14.8**	**17.2**

2.6 ORANGE RIVER WATER BALANCE (2003)

The Orange River Replanning Study (ORRS) was completed in 1999. This study was commissioned to determine a strategy for the most beneficial utilisation and optimal development of the water resources of the Orange River. This was based on a thorough assessment of the water resources and water use in the basin. The 1994/95 hydrological year was used in the ORRS as the base year (or current development level) for planning purposes. The water balance given in the ORRS indicated that a surplus of 274 million m³/a was available from the system at the 1994/95 development level. Since then several changes and developments occurred in the Orange River Basin. This also includes the updated hydrology that became available from the Vaal River System Analysis Update study (VRSAU). All these changes and updates will all have a direct impact on the available surplus from the Orange River System (ORS).

The main purpose of this task was therefore to determine on a reconnaissance level the long-term average surplus that is still available from the ORS system at various development levels. The results from the ORRS were used as the basis for the preparation of the updated water balance required for the ORS. Hydropower Operating Analysis (using the WRPM) is performed on an annual basis on behalf of the DWAF, to determine the surplus water available from the ORS for each year. Eskom then uses this surplus for additional hydropower generation purposes. Reports produced as part of the hydropower analyses obtain valuable information regarding changes that took place since the completion of the ORRS. During the first half of the year 2000, an operating analysis was also carried for the ORS in which further updates of water use and hydrology were given. In other separate studies the current and projected future requirements for water were recently updated for the country as a whole. This was the product of several studies such as the Water Resources Situation Assessment Studies, Demographic Study, Economic and Socio-economic studies. These studies showed a significant reduction in population growth figures, mainly as result of HIV/AIDS, which in turn resulted in substantially lower estimates of future water requirements. This mainly affected the water use from the larger urban/industrial water users such as Bloemfontein, Botshabelo and Upington. The results from these recent studies were also used for the updating of the ORS water balance.

2.6.1 Results and Conclusions

Results from this task showed that the surplus water available in the Orange River System has since the completion of the ORRS reduced significantly from 274 million m³/a at the 1995 development level to 177 million m³/a. As result of the expected growth in demands, the surplus reduced to 158 million m³/a in 2000 and to 34 million m³/a in 2025.

The main reasons for the difference in the current surplus and that given in the ORRS are:

- The hydrology for the Lesotho Highlands Water Project (LHWP) that was updated and extended, and resulted in lower yields for the LHWP as well as for Gariep and Vanderkloof dams.
- The difference in the total Orange River Losses as used in the ORRS in comparison with the final results from the Orange River Losses Study.
- Updated urban/industrial/mining demand projections.
- Increases in the total area irrigated in the Orange River Basin as well as in the Fish and Sundays River in the Eastern Cape.
- Increases in the irrigation quotas in some areas in the Orange River Basin.
- A certain portion of the total Orange River irrigation (Middle Orange) was not included in the ORRS irrigation figure.

Although the surplus available from the existing infrastructure at the 2000 development level appears to be a sizeable surplus it represents less than 4 % of the yield of the Orange River System, which is significantly smaller than the margin of error of the analysis.

A total of 12 000 ha was allocated to resource poor farmers, of which 4000 ha is situated within the Lower Orange WMA, 4000 ha in the Upper Orange WMA and 4000 ha within the Fish to Tsitsikamma WMA. This is expected to consume up to 140 million m³/a and almost no development in this regard has yet taken place. If these developments do take place, the surplus at 2000 development level will reduce to 18 million m³/a and a shortage of 106 million m³/a will be experienced in 2025.

The ORRS also indicated that approximately 11 000 ha of the potential additional 23 000 ha of irrigation identified in the Orange River and Fish/Sundays basins could be utilised for commercial irrigation farming and this will require in the order of 165 million m³/a of water. Included in the current water balance is already an increase of 166 million m³/a in the water use for commercial irrigation of which 45 million m³/a is as result of existing irrigation that was not included in the ORRS. It therefore seems that approximately 121 million m³/a of the 165 million m³/a for commercial irrigation farming has already been taken up.

Namibia is entitled to a quantity of 50 million m³/a on a permanent basis. This is almost in line with the Namibian demand from the Orange River for 1995 and 2000 of 53.5 million m³/a and 55.5 million m³/a respectively. South Africa is however willing to supply a maximum of 60 million m³/a in addition to this, on a temporary basis to Namibia, until 31 December 2007. The total of 110 million m³/a (50 million m³/a plus 60 million m³/a) is again almost equal to the projected demand of 111 million m³/a for Namibia at the 2025 development level. Mining is the main component responsible for the growth in the Namibian water demand projection. There are still a number of uncertainties regarding the mining developments and related water requirements. Haib Mine, which was included in the ORRS, is now on hold, while Scorpion mine is expected to go ahead. It is accepted that the 60 million m³/a temporary allocation should be sufficient to provide in the mining water requirements.

The current hydropower operating rules will also have a significant effect on the Orange River System Yield. The effect of these operating rules on the system yield has however not yet been determined. WRPM analyses for the Orange River System is currently carried out on an annual basis for DWAF, to assure that the hydro-power operating rules are not affecting the assurance of supply to the current water users. These operating rules are then adjusted to obtain the required assurance of supply to the various users. It is expected that these operating rules will be phased out over time, unless an additional scheme, such as a small Vioolsdrift Dam or the utilisation of the low-level storage in Vanderkloof Dam is put in place to increase the system yield.

The Orange River water balance as published in the NWRS draft document indicated a surplus of 477 million m³/a at the 2000 development level. This is significantly higher than the 158 million m³/a surplus as shown by this report. It is essential that the apparent differences should be clarified. For this purpose a separate task was initiated and the findings from this task are included in Appendix B of this report. The results as given in this report are however not affected and therefore remain unchanged.

2.6.2 Recommendations

It is recommended that the change in the irrigation areas and quota should be monitored on a continued basis, as this is the main water user in the Orange River System, and increases seem to be on-going.

The water demand growth curve for the Orange River system is relatively flat, and a small change in demand will therefore have a significant effect on the implementation date of the next scheme. It is of utmost importance that the annual WRPM analyses for the Orange River System should continue, so that water supply shortages in the system can be prevented as far as possible and the implementation date of the next scheme could be determined in advance.

The next scheme to be implemented to increase the system yield will possibly be the utilisation of the low-level storage in Vanderkloof Dam. This will, however, have a direct impact on the generation of hydropower at Vanderkloof Dam, as no hydropower can be generated when the water level drops below the current minimum operating level. It might be more beneficial for hydropower purposes to first investigate in a small dam at Vioolsdrift to minimise the operating losses. This must however be clarified with Eskom and will require additional analyses to better understand the advantages and disadvantages of the two options.

2.7 INTERNAL STRATEGIC PERSPECTIVE ORANGE RIVER (2004)

2.7.1 Introduction

The Overarching Internal Strategic Perspective (ISP) of the two Orange River Water Management Areas (Upper and Lower) is described in this document, and represents the Department of Water Affairs (DWAF) view on how Integrated Water Resource Management should be practiced in these two Water Management Areas (WMAs). The information in the report has been compiled from past studies.

2.7.2 Overview of the two Orange River Water Management Areas

The Orange River rises in the eastern highlands of Lesotho where it is known as the Senqu River and is the largest and longest river in South Africa. From the Upper Orange WMA, the river flows through the Lower Orange WMA where it discharges into the Atlantic Ocean some 2 300 km from its origin in Lesotho. Substantial variation in climatic conditions occurs over the two catchments.

Approximately 6 % of the country's Gross Domestic Product (GDP) originates from this area (5% from Upper Orange WMA & 1% from Lower Orange WMA). The potential for economic growth can be found in the agriculture sector converting to higher value products. Agriculture, mining, trade and Government are the main sectors contributing to the GDP in the two WMAs.

Extensive inter-catchment transfer schemes have been developed for the transfer of water within the water management area as well as to other water management areas. The most significant transfers being from Katse Dam via the Lesotho Highlands Water Project to the Upper Vaal water management area and from Gariep Dam via the Orange-Fish tunnel to the Fish to Tsitsikamma water management area.

The main storage dams in the Orange River WMAs are:

- Gariep and Vanderkloof Dams on the Orange River (Vanderkloof sub-area), which command the two largest reservoirs in South Africa. Hydropower for peaking purposes is generated at both sites.
- Armenia and Egmont Dams on tributaries in the Caledon sub-area. Welbedacht Dam lays on the main stem of the Caledon River, with Knellpoort Dam an off-channel storage dam that supplements the water supply to Bloemfontein.
- Rustfontein, Mockes and Krugersdrift Dams are situated on the Modder River, and the Tierpoort and Kalkfontein Dams on the Riet River.

Katse and Mohale dams in Lesotho are not located in the two WMAs, but have a significant impact on the available water in the Orange River, as the bulk of the water flowing in the Orange River is generated in Lesotho. Katse Dam is located in the Senqu sub-area in Lesotho and is used for the transfer of water to the Upper Vaal WMA. Mohale Dam, which was recently completed are located in the same sub-area, and started to impound water in 2003. This dam is also used to support the transfer to the Upper Vaal WMA.

2.7.3 Resource Availability (Surface & Groundwater)

Groundwater is an extremely valuable source in both WMAs and in particular in the Lower Orange WMA where approximately 60% of the water used in the tributary catchments is from groundwater. Although the total volume groundwater used is insignificant in comparison with the surface water resources, groundwater is the only source in large areas.

The Upper Orange WMA is mainly underlain by sedimentary rocks of the Karoo Supergroup intruded by dolerite dykes and sills. The aquifer types present are mainly fractured in some formations and fractured and intergranular in other formations. Borehole yields vary between 0.5 and 2.0 ℓ/s but scientifically selected boreholes on fractured fault or contact zones can yield more than 5 ℓ/s. As stated in the ISP report groundwater quality in the WMA is generally unpolluted because of the rural nature and lack of heavy industries and mining. The main impacts on groundwater quality are saltwater intrusions in the vicinity of salt pans and the agricultural practices such as fertiliser usage.

Only limited groundwater abstraction volumes were only estimated in the Bainsvlei and Petrusburg areas. In the Bainsvlei area the volume of 33 million m3/a represents 60% of the annual recharge which place this aquifer under stress. In the Petrusburg area the estimated usage is 61% also placing this area under stress. The focus was therefore on areas of high usage but it is recommended that annual recharge and usage be determined in all sub-catchments in order to identify unused resources.

The Harvest Potential Map (Seymor and Seward, 1995) calculated the annual recharge of the WMA as a whole. The Harvest Potential is determined from two parameters: groundwater recharge from rainfall and groundwater storage. The harvest potential for the WMA is then estimated at a maximum 1 020 million m3/a. This volume may vary due to variation in rainfall and the exploitation potential to utilise the resource economically. However, the total usage at present could not be more than 50% of the recharge which indicates that a large groundwater resource is still available.

It is stated in the ISP report that the groundwater/surface water interaction in the WMA is very small. Investigations in the Bainsvlei area by Van Tonder and Rudolph (2003) estimated the base flow that originated from groundwater to the Ecological Reserve, i.e. 0.26 million m3/a, or 0.4% of the annual recharge. In the Petrusburg area the base flow was estimated at 294 336 m3/a, or 1.3% of the annual recharge (Ninham Shand & GeoHydro Technologies, 2003).

The Lower Orange WMA is mainly underlain by Granites and gneisses and sedimentary rocks of the Karoo Supergroup while dolomite occurs in the Griekwastad area and Quaternary and Tertiary dune deposits are present in the extreme northern part of the WMA. Borehole yields vary between 0.1 and 2.0 ℓ/s in the granites and gneisses while yields between 0 and 5.0 ℓ/s can be expected in the other formations. The aquifers present in the WMA are mainly fractured in some formations, fractured and intergranular in other formations and intergranular in the primary aquifers.

Groundwater quality is an important factor in the development of available resources. In the Lower WMA groundwater quality vary from good in the dolomites and Beaufort Formation of the Karoo Supergroup to poor in the granites, Ecca and Dwyka sediments of the Karoo Supergroup. The groundwater quality in the primary aquifers such as the Kalahari sands and alluvial deposits along streams and rivers is variable but mostly poor quality. The most serious groundwater quality problems is high Total Dissolved Solids, Fluoride and Nitrates while unacceptable Uranium occurs in the granite and gneisses and was potentially identified as a cause for leukaemia.

Groundwater is the most important source for bulk water supply in areas located far from the surface water bulk supply network. Groundwater is used for domestic and farming in the rural areas. Data from DWA estimate the total abstraction for domestic use at 10 million m^3/a. Other users are agriculture and mining but no abstraction volumes are available. Rainfall varies from east to west and areas to the west receive as little as 100 mm per annum. The Harvest Potential Map (Seymor and Seward, 1995) calculated the annual recharge of the WMA as a whole. The Harvest Potential is determined from two parameters: groundwater recharge from rainfall and groundwater storage. The Harvest Potential is less than half of that calculated in the Upper WMA. We can therefore assume that little groundwater resources are available for further use in the Lower WMA. It is stated in the Lower Orange Groundwater Overview that under natural conditions there is seldom a connection between surface and groundwater in the Lower WMA.

The surface water resources

Fifty seven present of the natural runoff is generated in Lesotho and 33% in the Upper Orange WMA and the remaining 10% in the Lower Orange WMA. The bulk of the surface water in the Lower Orange Water Management Area is therefore found in the main stem of the Orange River, with virtually all coming from the Upper Orange Water Management Area. Most of the runoff generated in the Lower Orange is coming from the Fish River in Namibia and is only entering the main Orange River close to the river mouth.

The surface water resources of the Orange River Catchment have been the subject of various studies aimed at developing and maintaining a reliable hydrological database. The hydrological data that are currently used to operate the system typically covers the period October 1920 to September 1988. There is a fairly high level of confidence in the in the yield estimates of the surface water in the system although some of the hydrology is relatively old.

For effective Integrated Water Resources Management it is required to have a clear understanding of the current and future water resources available in the WMAs. This includes the quantities of usable water in terms of spatial distribution and any factors that may affect the yield of the system and requires an operational analysis on an annual basis. With regards to the resource availability it is required to attend to the following:

- Assess the need to update the hydrology on a continuous basis and in particular for areas with relative old hydrology and areas where a higher resolution hydrological data and system models is required for local water sources under stress.

- The hydrology for the whole system should be updated after the occurrence of a severe drought event. By 2008 it will be possible to extend the shorter hydrology records by another 20 years, which is quite a substantial extension and it recommended to at least re-evaluate the extension of the hydrology at that time if a severe drought event has not occurred before then.
- The main variables that impacts on the salinity loads in the system should be assessed on a continuous basis to establish the need to update the TDS model and to commission studies accordingly.

2.7.4 Water Requirements

Present land use in the area is mostly under natural vegetation with livestock farming (sheep, goats, cattle and some game) with large parts falling within conservation areas. Extensive areas under dry land cultivation, mostly for the production of grains, are found in the north-eastern parts of the water management areas. Large areas under irrigation for the growing of grain, fodder crops, grapes etc. have been developed along the main rivers, mostly downstream of dams.

Irrigation is by far the dominant water use sector in the Orange River WMAs, representing 88% of the total gross water use of 1 996 million m³/a estimated for the year 2000. This figure excludes the transfers out of the WMAs. Only 12% are used by the urban, industrial, mining and rural sectors. Transfers from the Orange amounts to 2 159 million m³/annum and is mainly from the Upper Orange WMA and Lesotho. Expected future growth will mainly be as result of 12 000 ha allocated to resource poor farmers and limited growth in urban/ industrial and mining sectors which will mainly be as result of developments in the Bloemfontein, Thaba'Nchu area. The projected requirement for 2025 is 2 134 million m³/a excluding the transfers. New transfer schemes out of this area are not expected before 2025.

2.7.5 Water Balance Reconciliation

The supply situation in the Orange River System is such that there is a surplus of 333 million m³/a in the system at the year 2000 development level. This surplus reduce significantly to 158 million m³/a by 2003 with the commissioning of Phase 1B of the Lesotho Highlands Project and will diminish over the next fifteen to twenty years due to the development of the 12 000 ha allocated to resource poor farmers and the natural growth in urban / industrial and mining requirements. At 2025 development level a deficit of almost 50 million m³/a is expected. The surplus is currently used for hydropower generation for Eskom; however, recent analysis indicated that the projected risk of curtailments in the water supply to the consumptive users is such that relatively small allocations can be made for power generation purposes. The utilisation of this surplus by Eskom does not only include the releasing of the available surplus through the hydropower turbines but also operating rules that benefit hydropower generation. These rules typically include the release pattern from Gariep Dam, the storage control curves in both Gariep and Vanderkloof dams, etc. As the surplus in the system reduces over time it will therefore be required to gradually move away from the rules that benefit hydropower generation to ensure that the existing users are supplied at the required risk levels.

Based on the given water balance information, which indicated that intervention measures may be required in the next 15 to 20 years, reconciliation can be obtained through any of or combinations of the following options:

- Reduction in operational losses in the Orange River System, which are currently estimated at 270 million m³/a. The operating losses can be reduced through improved release management and/or by constructing an operating dam in the Lower Orange.
- Water conservation and demand management measures. This would focus on irrigation as the largest water user sector in the system. It is however perceived that most savings will be taken up by the users themselves to expand their irrigated areas.

- Utilise the storage volume below the current minimum operating level in Vanderkloof Dam. The effect on hydropower as result of this possible option can be significant and is currently being determined and discussed with Eskom.
- Construction of Boskraai Dam in the Orange River between Gariep Dam and the Lesotho border or Mashai Dam in the Senqu. The main emphasis on these dams is to transfer water to the Vaal System but they can also be used to improve the water supply situation on the Orange River.
- Additional options from the current Lower Orange Management Study (LORMS) also include the utilising of spills from the Vaal by means of real time modelling and a storage dam at Vioolsdrift or Boegoeberg.

2.7.6 Water Quality

Water quality of the surface water in the Upper Orange is generally good except for the high sediment load in the Caledon and the salinity problems in the Lower Riet. The water quality in the Lower Orange has, however, been severely impacted upon by extensive upstream developments. It is possible that the water quality problems in the Orange is coming from the Vaal as water quality in the Vaal becomes worse as one proceed along the Vaal. Under normal operating conditions very little water from the Vaal reach the Orange River and it is mainly under flood conditions that large volumes will enter the Orange. Potentially toxic cyanobacterial bloom events are also occurring in the central region of the Orange River. The water quality issues in the catchment at the over-arching level relate to the management of the water quality passed down between WMAs and can therefore not be solved on a WMA basis alone.

An integrated water quality management tool needs to be developed for the Orange River Basin to allow for the rational assessment of the factors that impact on water quality. This is a complex system and water quality will have to be modelled in more detail.

2.7.7 Ecological Reserve Determination

The in-stream and estuarine flow requirements were determined for the Orange River downstream of Vanderkloof Dam in the Orange River Replanning Study (ORRS) (more or less at intermediate level but the methodology differ from that currently used). These ecological requirements (±280 million m³/a) are currently being released from Vanderkloof Dam. As part of the Lower Orange River Management Study (LORMS), modified Desktop level estimates of the environmental requirements were made for the section of the Orange River from the Vanderkloof Dam to the Orange River mouth as well as for the estuary. These in-stream and estuarine flow requirements are used in the current Lower Orange River Management Study (LORMS) to perform sensitivity analysis. Analysis from the LORMS showed a reduction in the system yield of approximately 100 million m³/a when the modified desktop level environmental flow requirements are used in place of the ORRS environmental flow requirements. A comprehensive Reserve must however still be determined for the Orange River. In the meantime it is essential that proper monitoring must be set in place to monitor the ecological health of the river and the estuary and to collect sufficient data as required for a proper Reserve determination.

Lesotho has determined and implemented updated IFRs for the Senqu River in Lesotho. The updated releases are more than that specified in the original Treaty between RSA and Lesotho on the LHWP and will most likely increase the Orange River System yield by about 30 to 60 million m³/a while transfers to the Vaal will decrease.

2.7.8 Water Use Management

The operation of this system requires continuous analysis of the projected water requirements, return flows and available surplus as well as communication and liaison with the major users. The system is also operated to manage water quality (TDS) by using blending or dilution. The system therefore requires continuous management of the existing and planned water resource systems to optimally manage the system from an operating cost, water quality and assurance of supply point of view. Groundwater resources play an important role in the supply of local water requirements in the Orange River system and are therefore discussed in the individual WMA ISP documents.

Essential to the operation and planning of the Orange River System is the record keeping and feedback of water use information, return flow volumes and losses. The lack of accurate water use information for irrigation schemes and low flows in the Orange River main stem has been cited as a cause of concern.

2.7.9 International aspects and implications

The National Departments are responsible to draft and implement strategies and policies regarding international shared river basins. The most important international connections that affects the Orange River System is the Lesotho Highlands Water Project (LHWP), which transfers water from Lesotho and the section of the Orange River along the RSA / Namibia border, where water is abstracted by RSA and Namibian users. Two thirds of the total yield realised by the dams in Lesotho and in the Upper Orange WMA, is transferred to the Upper Vaal and Fish to Tsitsikamma WMAs, and released to the Lower Orange WMA for use by the RSA and Namibia.

The Government of Lesotho has recently commissioned a study to investigate the feasibility of schemes to supply in local water requirements. The impacts of these possible water resource developments in the Lesotho Lowlands on the water balance of the Orange River system must be assessed. The possibility of combined utilisation of future water resource developments should be considered.

Current Namibian requirements are in line with the existing proposed 50 million m³/a permanent allocation to Namibia and 60 million m³/a temporary allocation until 31 December 2007. There are however uncertainties with regards to the growth in the water requirements for Namibia and an agreement with regards to the maximum abstraction and payment of water abstractions by Namibia from the Orange River, needs to be formalised.

It is important to ensure that international water use is based on sound agreements among shared basin states and that current and future water use data are exchanged to facilitate efficient planning and management. The existing agreements and results from the LORMS and Lesotho Lowland study should be used for guidance in this regard.

The communications of issues or future planning will be done at the national level through the appropriate government Department.

2.7.10 System Operation

The utilisation of the water resource is optimised by allowing maximum hydropower generation, without adversely impacting on the long-term reliability of supply to the users in the system. For this purpose operating analysis are undertaken on an annual basis to determine the surplus available in the Orange River System which can be used for the generation of hydro-power over and above that released for normal downstream requirements.

As long as there is still a surplus available in the Orange River System, it would be possible to apply operating rules that benefit hydropower generation without impacting on the reliability of supply of the other users. These operating rules will however have to be adjusted over time to compensate for the increasing transfer from the LHWP and the growth in demands that is imposed on the system.

2.7.11 Monitoring and Information Systems

There are a number of shortcomings that have been identified in the monitoring system. These include water quality, flow measurements to gauge power generation releases, river losses, flows at the Orange River mouth, low flows along the main stem of the Orange River mainly in the Lower Orange, and bio-monitoring. A comprehensive water monitoring system needs to be developed to address all the monitoring requirements in the Orange River System.

2.8 INTERNAL STRATEGIC PERSPECTIVE VAAL RIVER (2004)

2.8.1 Introduction

The Overarching Internal Strategic Perspective (ISP) of the three Vaal Water Management Areas (Upper, Middle and Lower), is described in this document, and represents the Department of Water Affairs' (DWAF) view on how Integrated Water Resource Management should be practiced in these Water Management Areas (WMAs). The information in the report has been compiled from past studies.

2.8.2 Overview of the three Vaal Water Management Areas

The land use in the Upper Vaal WMA is characterised by the sprawling urban and industrial areas in the northern and western parts of the WMA. There is also extensive coal and gold mining activities located in the Upper Vaal water management area. These activities are generating substantial return flow volumes in the form of treated effluent from the urban areas and mine dewatering that are discharged into the river system. These discharges are having significant impacts on the water quality in the main stem of the Vaal River, throughout all three the water management areas.

The Upper Vaal WMA is economically important, contributing nearly 20% of the GDP of South Africa, which is the second largest contribution to the national wealth amongst all nineteen of the WMAs in the country. The potential for future economic growth in this WMA remains strong. Growth will largely be attracted to the already strong urban and industrial areas in the Johannesburg-Vereeniging-Vanderbijlpark complex.

The Middle Vaal WMA is rural in nature with the land use characterised by extensive dry land agriculture. Irrigation is practiced downstream of dams along the main tributaries as well as at locations along the Vaal River. The largest urban areas are Klerksdorp, Welkom and Kroonstad. The economy of the Middle Vaal WMA contributes about 4% of the GDP of South Africa with the most dominant economic activity being the mining sector, generating more than 45% of the GDP in the WMA. Few of the gold mines in the area have a secure future beyond 2010, although the reserve base could support mining up to the year 2030. The future of gold mining will be strongly influenced by the gold price, exchange rate, operating costs and the tax regime. The declining trend experienced in the recent past is however expected to continue in future in the mining sector. As in the Upper Vaal WMA, mine dewatering and the subsequent discharge to the river system impacts on the water quality.

The land use in the Lower Vaal WMA is primary livestock farming, with some dry land cultivation in the north east. Intensive irrigation is practiced at Vaalharts as well as locations along the Vaal River. Diamond bearing intrusions occur near Kimberley (the most important urban area) and alluvial diamonds are found near Bloemhof. Iron ore and other minerals are found in the south-eastern parts of the WMA.
Due to the extensive development in the Vaal River System and Crocodile (West) WMA, which are supplied from the Upper Vaal WMA, the local surface water resources in all three the Vaal WMAs have been fully exploited, more than three decades ago. It was therefore necessary to augment the supply by developing various schemes transferring water from the Thukela and Usutu to Mhlathuze WMAs, as well as from the Kingdom of Lesotho through the Lesotho Highlands Water Project (LHWP).

2.8.3 Water Availability

The surface water availability in the Vaal River System is estimated through a set of water resource models, each fulfilling a particular function in the management of the water resources. Combined, these models serve as a decision support tool that contains a large and comprehensive database of hydrological and physical system characteristics, required to simulate the water resource systems as realistically as possible. The network configuration of the models extends as far as necessary to include all the river systems, which supply the Vaal River System by means of transfers. This water resources modelling and physical network cuts across Provincial, WMA and International boundaries in order to simulate all the interdependencies that exist due to the inter-basin transfers.

The models include water quantity, and water quality in the form of Total Dissolved Solids (TDS) or salinity modelling. The hydrology and water requirement inputs to the models have recently been updated and the water quality model recalibrated. These models are applied to determine the water balance, assess operating rules, and assess the need for restrictions during drought periods and to evaluate water quality management options such as blending and/or dilution. The models are also used to determine the implementation dates for future augmentation schemes. These models were used to determine the water availability for the water balance calculations.

2.8.4 Water Requirements

The water requirement scenarios that are currently used for planning originate from the development of the National Water Resources Strategy (NWRS). The total water requirements in the Upper, Middle and Lower Vaal WMAs are 2424, 872 and 643 million m^3/annum respectively. Limited growth in the water requirements is projected for the Middle and Lower Vaal WMAs with the major growth projected for the Upper Vaal WMA. The total water requirements for the Upper Vaal are projected to reach 2 903 million m^3/annum by the year 2025, for the base growth scenario.

There are indications that the registered water use, mainly for irrigation purposes, is substantially more than what is currently used in the water resource models. It is therefore essential to compare the data in the model with the verified use once the verification process is completed.

On an annual basis the recorded water uses are compared to the scenarios and adjustments are made to the short-term projected values where appropriate. During this process, large bulk users such as Eskom, Sasol, Sedibeng Water, Midvaal Water and Rand Water also produce revised water requirement scenarios that are evaluated and considered in the analysis. This process is essential for coherent water resource management and ensures that changes in water use trends are detected on time.

The water requirement scenarios of the Vaal WMAs and other related supply areas must be updated at regular intervals, preferably five yearly. This must be co-ordinated with overall scenarios of population and economic growth for the whole country.

2.8.5 Water Balance Reconciliation

The water balance for the Vaal River System as a whole indicates that for the year 2000, an overall surplus in supply of 19 million m^3/annum is available. With the commissioning of Phase 1b of the LHWP (Mohale Dam and transfer tunnel) during the latter part of the year 2003, an additional 320 million m^3/annum (after allowances for transfer losses) is available. This surplus is expected to be gradually depleted over time (to supply the growing water requirements) until a deficit of about 44 million m^3/annum is projected for the year 2025 using the base water requirement scenarios.

What is important to recognise is that this estimated excess in supply is qualified as “conditional” since it is only available if all the transfers are fully operational. In practice the volume of water conveyed through the Thukela-Vaal Transfer scheme will be determined annually, effectively operating the system such that the water demands are in balance with the supply and pumping costs kept to a minimum. The quantity transferred will thus increase over time in line with the growth in the water requirements.

A further important perspective is that, although the system as a whole will experience surplus conditions over the medium to long term, this surplus is not available in Grootdraai Dam and supporting systems (also referred to as the Eastern Sub-system) due to the physical location of some of the transfer schemes. A pre-feasibility study into the need for augmentation of the Eastern Sub-system showed that further augmentation of this sub-system will be required by the year 2010, or earlier. A number of options have been assessed as possible schemes to augment the supply and the latest recommendation is that a pipeline should be constructed to convey water from Vaal Dam to support the water requirements of the Eastern Sub-system.

The perspective on possible reconciliation options for the Vaal River System is as follows:

- Due to the relative low growth rate of the projected water requirements (projected demand curve is relative flat) the impact of even small savings through Water Conservation and Demand Management could result in a substantial postponement of the date that augmentation would be required (i.e. delay the date from 2025 to say 2030 or beyond). It must be noted that, due to the lack of system wide planning information on possible future WDCM measures, the water balance situation presented above do not allow for the impacts of WCDM. This was identified as a gap in the current knowledge and a study is being proposed to collate all planning information on WCDM.
- Previous studies indicated that either the Thukela Water Project or a further phase of the LHWP could be implemented as the next water resource development options to augment the supply.
- Currently the Comprehensive Reserve has not been determined for the Vaal River System. Since the two factors, releases for the Reserve and WCDM measures are at the opposite sides of the water balance equation, it may be possible (in the short to medium term) to maintain a balance between these two variables by allowing releases for the Reserve to be made with the savings that is achieved by WCDM measures. The first step towards such a strategy would be to obtain reliable planning information on both WCDM and Reserve implication, so that sound motivations and informed decisions can be taken on the way forward.

2.8.6 Water Quality Management

The water quality varies from poor in the highly developed areas to good in the less developed areas. The water quality is impacted on by point discharges from industries, wastewater treatment works, mine dewatering, irrigation return flows and diffuse sources such as runoff from mining and industrial complexes, agriculture and urban areas. The area is also subject to atmospheric deposition due to emissions from coal fired power stations and industry in and around the catchment.

The current approach adopted in managing water quality is to apply the steps presented below on a sub-catchment basis. The first step is to carry out a situation assessment during which Interim Water Quality Objectives (WQO) are established and water quality variables of concern and sources of pollution are identified. The WQO are based on the water quality requirements of the user sectors as well as from the ecology. The subsequent phases in the process, following the situation assessment, are to develop water quality management plans or catchment management strategies. During this phase water management interventions such as source control, treatment and dilution are assessed. These phases also involve the revisiting of the WQO in an iterative manner to reach a balance between the water user requirements and achievable management strategies that do not impede continued economic growth.

The cascading characteristic of the three Vaal WMAs has the consequence that the water quality of the main stem of the Vaal River in the downstream WMAs is impacted on, not only by the activities in the WMA itself, but also by the water received from upstream. In addition, the water quality in the Vaal River will also impact on the water quality of the Orange River in the Lower Orange WMA. Due to this inter-dependency it was identified that the current process of managing water at sub-catchment level should be expanded to integrate management activities across sub-catchments, to meet shared water quality objectives in major tributaries as well as in the main stem of the Vaal River.

In order to deal with the challenges posed by the interdependencies among the Vaal WMAs it is required to commission the development of an Integrated Water Resource Management Strategy for the Vaal and Orange River systems. Such a study need to integrate the WQOs of the sub-catchments, consider the opportunities of implementing the proposed Departmental Waster Discharge Charge System and assess options for water quality management.

2.8.7 Institutional Aspects

The only direct international obligation affecting the water resources of the Vaal River System is in the Lower Vaal WMA, in particular the Molopo River catchment. Since these obligations have a minor impact on the water resources at an Overarching level, further reference to this aspect is given in the Lower Vaal WMA ISP. Institutional aspects on the sharing of the water resources among the Orange River Basin States (Lesotho, Namibia and Botswana) are addressed in the Orange Overarching ISP document.

A further important international institutional link to the Vaal River System is with Lesotho with regards to the transfer of water from the Lesotho Highlands Water Project. The communication of issues and any future planning will be done at the national level through existing institutional structures.

2.8.8 System Operation

Due to the inter dependencies of the Vaal WMAs, the operation of the infrastructure has to be undertaken in a coordinated way to achieve the best efficiencies and balance potential opposing objectives among stakeholders. The main activities for system management include the following:

- Operation planning should be undertaken on an annual basis. This includes both the water quantity blending and dilution options used to manage the TDS concentration in the Vaal Barrage.
- Management during drought periods in accordance with a drought management plan.

Due to the interlinked configuration of the water resource components in the Vaal River System the responsibility of the operation and management of the main elements will be a function of a dedicated DWAF operations division or a possible Utility. The operation and management of tributary catchments in each WMA will be the responsibility of the respective CMAs.

2.8.9 Monitoring and Information Management

The successful operation of the Vaal River catchment requires effective monitoring networks and information management systems. There is an extensive network of flow, rainfall and water quality monitoring stations in the catchment. However, studies have highlighted the need to expand the monitoring network to include more gauges to determine river losses, bulk distribution system losses, and to track water requirements. Bio-monitoring should be included to assist with the determination and implementation of the ecological Reserve. A consolidated assessment needs to be made of all the monitoring and data management requirements of the Vaal River System. This process should identify all the water resource management activities that require monitoring information, and should focus on the integration of monitoring systems that are directly under control of the Department, as well as from other institutions.
Co-ordination of all monitoring requirements is best undertaken by the WMA managers (currently the

regional offices and in future the CMAs). All monitoring requirements for water resource management should be defined by each of the relevant agencies and fed to the WMA managers for co-ordination. For example, monitoring needs that are required for the overarching management and operation of the Vaal River System should be communicated to the each WMA.

2.9 LESOTHO LOWLANDS WATER SUPPLY SCHEME FEASIBILITY STUDY (2004)

2.9.1 Water Resource Assessment of Final Development Options

2.9.1.1 Overview

Three schemes were selected for detailed analysis, these being:

- Hololo/Ngoajane System. A run-of-river abstraction directly from the Hololo River downstream of the confluence with the Ngoajane River, possibly supported with releases from a new Ngoajane Dam or from the existing Muela Dam;
- Hlotse System. A run-of-river abstraction directly from the Hlotse River downstream of the confluence with the Mamafubedu River possibly being supported with releases from the proposed Hlotse Dam; and
- Makhaleng System. A run-of-river abstraction directly from the Makhaleng River at the Mohales Hoek road bridge possibly being supported with releases from the Matsapong Dam.

The Water Resources Yield Model (WRYM) was used to determine the yield capabilities of the three proposed systems. The model is used to analyse systems at constant development levels i.e. the system and the system demands remain constant throughout the full simulation period. The hydrological database covered the period 1935 to 1999. This period of historical analysis therefore includes the droughts experienced in the early 1980's and 1990's.

2.9.1.2 Hololo/Ngoajane System

The development options that were considered in this case were:

1. A run-of-river abstraction directly from the Hololo River downstream of the confluence with the Ngoajane River;
2. Abstraction from the same position but being supported with releases from the Ngoajane Dam; and
3. Abstraction from the same position but being supported with releases from the Muela Dam.

Muela Dam, and the associated Lesotho Highlands Transfer Scheme, provides a complex dynamic in terms of simulating the water resources of this catchment. It is understood that the normal operating rule of Muela Dam is a present pattern of releases and that all surplus runoff from the upstream catchment is transferred along with the Highlands water. As a result it was practical to make a simplifying assumption that the influence of the Muela Dam could be simulated as a fixed transfer into the Ngoajane/Hololo catchment. This is a reasonable assumption since any change in the operating rule can be simulated as a different transfer pattern, whilst spills will only occur during extremely wet periods which are not likely to influence the system yield.

The WRYM was simulated based on the assumptions and system configurations listed in the report using 501 stochastically generated stream flow sequences. The first scenario considered no support from Muela Dam and the second scenario assumed a continuous release of 0.15 m^3/sec from Muela Dam. Various sizes of the proposed Ngoajane Dam were considered and the 1:50 year (98% reliability) firm system yields were determined. The resulting yields for the various dam sizes with no support from Muela Dam are listed in **Table 2-59** and the relationship is shown graphically in **Figure 2-9**. The corresponding results for the scenario with support from Muela Dam are shown in

Table 2-60 and **Figure 2-10** respectively.

Table 2-59: Ngoajane system yield (without support from Muela dam)

Full Supply Level (m.a.s.l.)	Capacity (million m^3)	98% Yield (mill m^3/a)
No dam	No dam	2.50
FSL = 1635	4.47	7.20
FSL = 1640	6.64	8.98
FSL = 1645	8.82	13.20
FSL = 1660	15.34	23.73
FSL = 1680	54.03	39.00

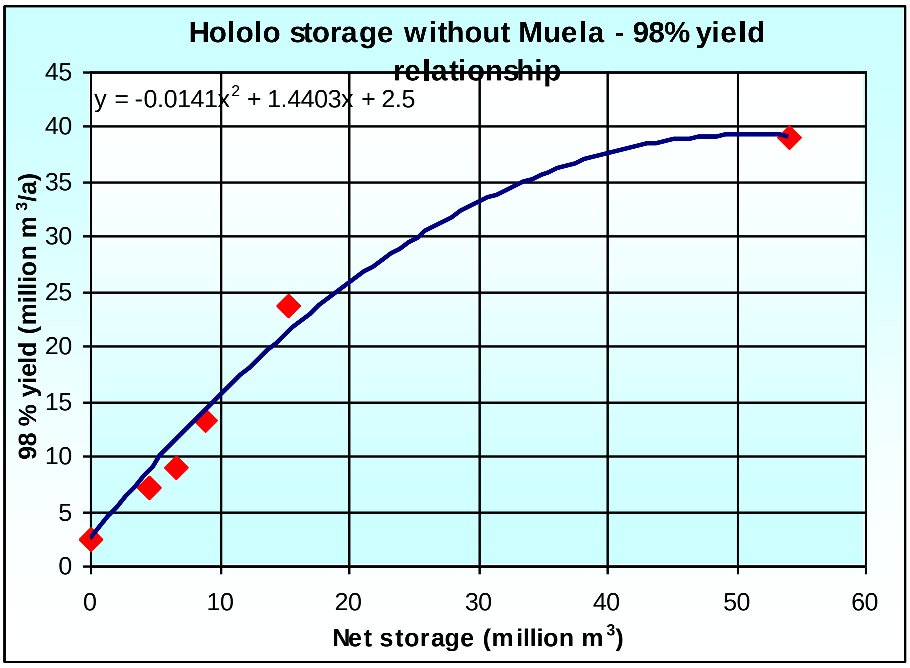


Figure 2-9: Yield-storage relationship for the Ngoajane system without support from Muela

Table 2-60: Ngoajane system yield (with support from Muela dam)

Full Supply Level (m.a.s.l.)	Capacity (million m^3)	98% Yield (million m^3/a)
No dam	No dam	7.28
1635	4.47	12.03
1640	6.64	14.03
1645	8.82	18.10
1660	15.34	28.47

1680	54.03	43.80

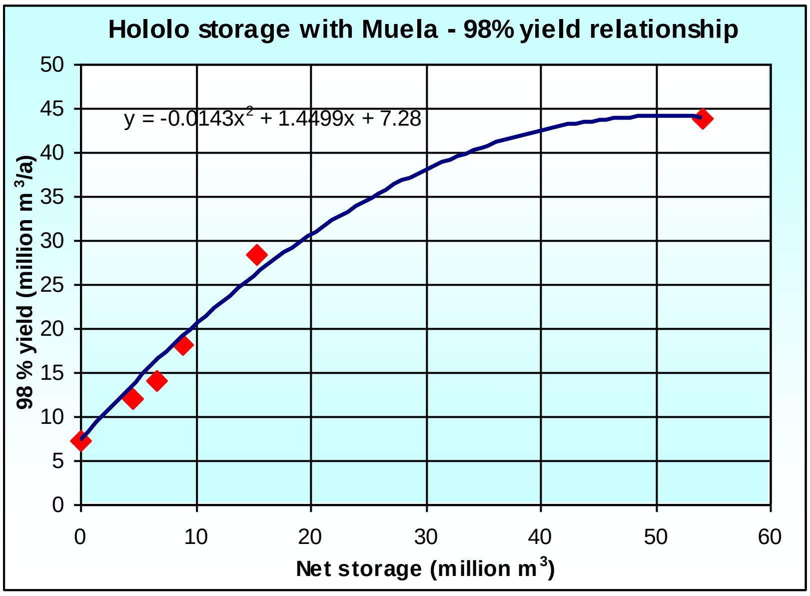


Figure 2-10: Yield-storage relationship for the Ngoajane system with support from Muela

2.9.1.3 Hlotse System

The development options that were considered in this case were:

1. A run-of-river abstraction directly from the Hlotse River downstream of the confluence with the Mamafubedu River; and
2. Abstraction from the same position but being supported with releases from the proposed Hlotse Dam.

The WRYM was simulated based on the assumptions and system configurations listed in the report using 501 stochastically generated stream flow sequences. Various sizes of the proposed Hlotse Dam were considered and the 1:50 year (98% reliability) firm system yields were determined. The resulting yields are listed in **Table 2-61** and the relationship is shown graphically in **Figure 2-11**.

Table 2-61: Hlotse system yield

Full Supply Level (m.a.s.l.)	Capacity (million m^3)	98% Yield (million m^3/a)
No dam	No dam	0.28
1600	9.28	10.75
1605	17.77	15.15
1610	26.26	18.35
1620	60.06	29.00

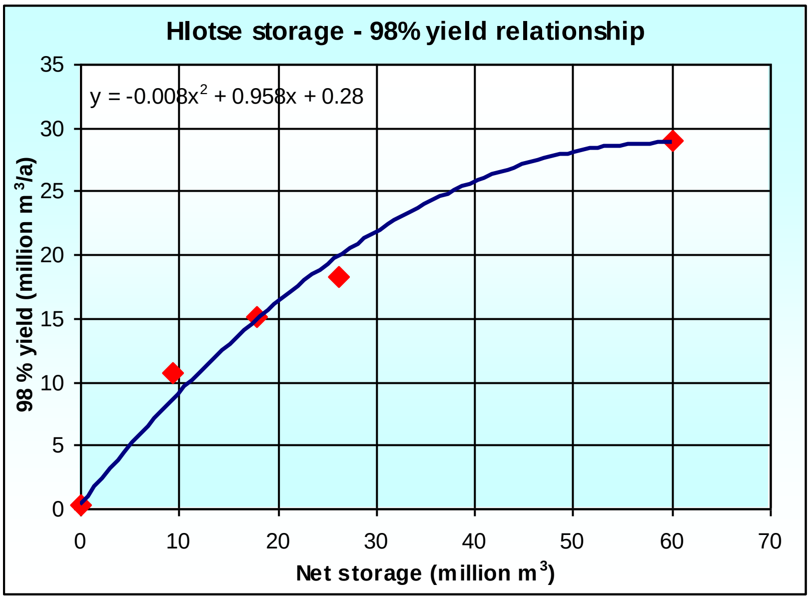


Figure 2-11: Yield-storage relationship for the Hlotse System

2.9.1.4 Makhaleng System

The development options that were considered in this case were:

1. A run-of-river abstraction directly from the Makhaleng River at the Mohale's Hoek road bridge; and
2. Abstraction from the same position but being supported with releases from the Matsapong Dam.

The WRYM was simulated based on the assumptions and system configurations listed in the report using 501 stochastically generated stream flow sequences. Various sizes of the proposed Matsapong Dam were considered and the 1:50 year (98% reliability) firm system yields were determined. The resulting yields are listed in **Table 2-62** and the relationship is shown graphically in **Figure 2-12**.

Table 2-62: Makhaleng system yield

Full Supply Level (m.a.s.l.)	Capacity (million m^3)	98% Yield (million m^3/a)
No dam	No dam	8.14
FSL = 1658	0.50	11.96
FSL = 1660	1.01	17.84
FSL = 1665	2.27	29.20
FSL = 1685	12.25	58.84
FSL = 1700	28.36	92.00

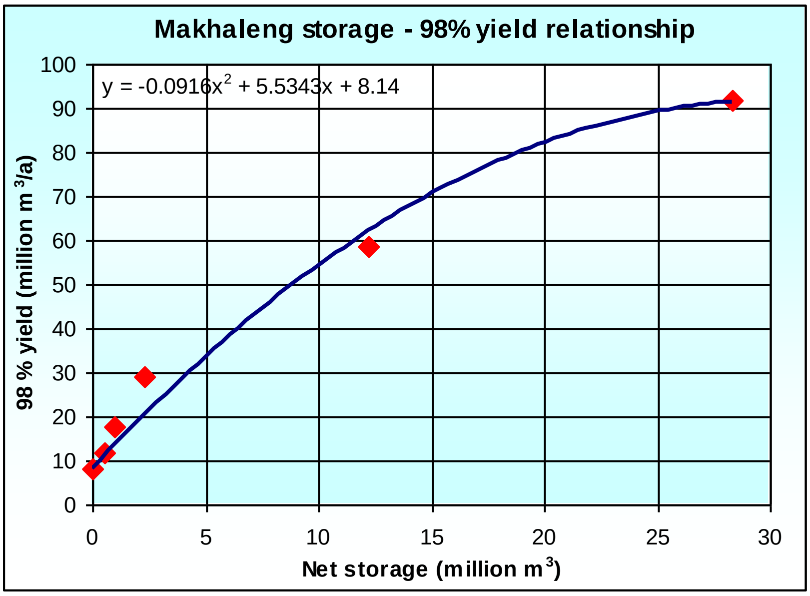


Figure 2-12: Yield-storage relationship for the Makhaleng system

2.10 PRE-FEASIBILITY STUDY INTO MEASURES TO IMPROVE THE MANAGEMENT OF THE LOWER ORANGE RIVER AND TO PROVIDE FOR FUTURE DEVELOPMENTS ALONG THE BORDER BETWEEN NAMIBIA AND SOUTH AFRICA (LORMS 2005)

2.10.1 Overview

The Orange River, with a catchment area of approximately 1 million km^2, originates in the highlands of Lesotho and flows west for approximately 2 200 km to the Atlantic Ocean. The last 600 km of the Orange River forms the border between South Africa and Namibia, and any measure to improve the management of the water resources available in the Lower Orange River, will benefit both countries. This Joint Study, under the control of the Permanent Water Commission between Namibia and South Africa, investigated and made recommendations on the more efficient management and use of water resources in the Lower Orange River.

The overall study objective was stated as “Investigate and report on the availability of water and options for improved management through the efficiency of water use and supply management measures to promote the strategic objectives of the countries involved”.

2.10.2 Legal, Institutional, Water Sharing, Management and Dam Operation

2.10.2.1 International Agreements

This preliminary report gives a detailed account of international law as it relates to the Orange River watercourse.

This preliminary report has formed the basis of, or been summarised in, a number of other reports and discusses the following documents.

2.10.2.1.1 Helsinki rules

The Helsinki Rules were found not to enjoy the status of treaty law.

2.10.2.1.2 The UN Convention of 1997

The UN Convention of 1997 is a framework convention.

It contains general principles that may be tailored for the purposes of an inter-state agreement on a specific watercourse or part of it (such as the Lower Orange.)

Article 3(3) allows specifically for subsequent watercourse agreements "which apply and adjust the provisions of the present Convention to the characteristics and uses of a particular international watercourse or part thereof".

When specific states conclude bilateral or regional agreements amongst themselves they enter into binding agreements for the parties involved. E.g. the SADC Revised Protocols, the Orange Senqu River Commission Agreement and the proposed bilateral agreement between Namibia and the RSA.

An "international watercourse" is a watercourse "parts of which are situated in different states." (Art 2(b), UN Convention.) Hydrologically a watercourse includes "the main surface water channel and the water contained therein, but also the other components of a watercourse system, in particular, tributaries and groundwater." (McCaffrey 34.)

Commentaries on the Convention divide its content into "substantive" and "procedural" obligations. (See McCaffrey 397.) Both categories are equally binding.

The substantive obligations are:

- To utilize an international watercourse in an equitable and reasonable manner.
- Not to cause significant harm to other states using the same watercourse.
- To protect international watercourses and their ecosystems.

The procedural obligations are:

- A General Duty to Co-operate.
- The Obligation to Exchange Data.
- Prior Notification. This is a specific manifestation of the duty to cooperate. Notification concerning "planned measures" triggers a whole process of consultation, reply, negotiation, information exchange and the manner of notification. A notified state has 6 months to study and evaluate the possible effects of any planned measure and to communicate its findings. This period may be extended for a further 6 months. In the case of disagreement, consultations, and if necessary, negotiations should follow.
- The Obligation to Consult.

2.10.2.1.3 Relationship between Equitable and Reasonable Use and the No Harm Obligation

In the absence of an agreement, a watercourse state must apply the relevant legal principles initially for itself to demonstrate to others that it has respected the law. It is now a norm of customary international law that other such states should not be deprived of their equitable share and benefits of an international watercourse.

- A watercourse state cannot simply increase its own utilization till others cry foul; it must exercise due diligence, prevent harm and act in good faith
- Article 5 of the 1997 UN Convention confirms the principle of equitable use as the cornerstone of the law on this point.
- Art. 6 provide factors for determining equitable use in a given situation. These factors should be considered together.
- In the event of a conflict between legitimate uses, special regard is to be given to vital human needs. Art. 10(2).)

- Otherwise and in the absence of custom to the contrary, “no use of an international watercourse enjoys inherent priority over other uses.” (Art. 10(1).)
- Prior or historical usage cannot provide a basis for preferential or absolute entitlement. (McCaffrey 337.)
- Preventive measures should be taken against serious or irreversible harm to watercourse ecosystems “even in the absence of clear scientific evidence”; it may often be too late by the time such evidence becomes available. McCaffrey 395 and the Danube judgment paragraph 140.)

2.10.2.1.4 The SADC Protocol

SADC is a regional organization (14 members) that aims at promoting regional integration and socio-economic development. It is based on a founding treaty and several subsequent protocols (including two on watercourses) have been adopted.

The first SADC Protocol on Shared Watercourse System entered into force on 29 September 1998. It has been ratified by Botswana, Lesotho, Malawi, Mauritius, Namibia, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe. This instrument has been based on the Helsinki Rules.

The Revised Protocol is based on the UN Convention and seeks to promote and facilitate the establishment of shared watercourse agreements and shared watercourse institutions for the management of shared watercourses.

The prospects for entry into force of the revised Protocol seem very good.

Compared to the UN Convention the Revised SADC Protocol emphasizes the unique features of the region and the needs regarding “regional integration and poverty relief.” (Art. 2.) One area where this will result in a different emphasis will become clear when “planned measures” involving specific regional watercourses are adopted or when regional “shared watercourse agreements” are concluded and “Shared Watercourse Institutions” are established. (Art. 2.)

2.10.2.2 **Orange-Senqu River Commission Agreement**

The Orange River is an international watercourse and some SADC countries are watercourse states to it. They are Namibia, the RSA, Lesotho and also Botswana. The Orange-Senqu River Agreement of November 2000 includes Botswana, Lesotho, Namibia and the RSA as parties.

Article 7.5 requires that the Council (the highest body) be informed about any project or activity “which may have a significant adverse effect” on other parties or the River System.

2.10.2.3 **Other agreements**

The Revised SADC Protocol foresees that watercourse states may enter into subsequent “watercourse agreements” which apply and adjust the Convention to that particular watercourse. (Art.3(3).)

Relevant Existing Agreements concerning the Orange River are:

- Agreement on the Establishment of the Permanent Water Commission, signed on 14 September 1992 between Namibia and South Africa;
- Agreement on the Vioolsdrift and Noordoewer Joint Irrigation Scheme, signed on 14 September 1992 between South Africa and Namibia; Article 11(1) (a) of the Vioolsdrift and Noordoewer Agreement of 1992 stipulates that nothing contained in that agreement shall be construed as precluding the abstraction of water from the Orange River or its tributaries and the utilisation of such water for any

purpose within the territories of the parties outside that irrigation district. Article 11(1)(b) furthermore stipulates that nothing contained in that agreement shall be construed as precluding the parties from entering into negotiations for the purpose of defining their respective entitlements to the use of water from the Orange River: provided that for the purpose of such negotiations and a resulting agreement, it shall be accepted by the parties that – (i) 9 million cubic metres of the entitlement of Namibia in terms of such an agreement have been committed by Namibia for use within the Vioolsdrift and Noordoewer Irrigation District; and (ii) 11 million cubic metres of the entitlement of South Africa in terms of such an agreement have similarly been committed by South Africa to the irrigation district.

- Treaty on the Lesotho Highlands Water Project (LHWP), signed on 24 October 1986 between South Africa and Lesotho;
- Agreement on the Establishment of the Orange-Senqu River Commission, signed on 3 November 2000 between South Africa, Namibia, Lesotho and Botswana.
- A draft agreement between Namibia and South Africa on the Utilisation of the Water Resources along the Lower Orange River (latest draft 12). Article 3.1 provides for a permanent Namibian entitlement of 50 millionm³ per annum from the Orange River System and in Article 4.1 for a temporary allocation of 60 million to be provided from the "Scheme", which is defined as the existing regulating dams of the Orange River Project in South Africa. In terms of Article 5.1 Namibia shall inform South Africa by 31 March of each year of the quantity of water required from the Scheme and the monthly distribution of that water. Namibia is to pay the operating costs of all water released from the Scheme plus a capital element of the temporary allocation.
- The Orange-Senqu River Commission Agreement of 2000. The parties are Botswana, Lesotho, Namibia and the RSA. The purpose of this agreement is to co-ordinate all uses and development of the Orange River and to ensure compliance with principles such as equitable and reasonable use and preventing significant harm to any party, pollution control and exchange of data.

2.10.2.4 **The Border Issue**

The Orange River west of 20° longitude forms the international border between Namibia and the RSA. For historical reasons and because of the membership of both states of SACU (the Southern African Customs Union) this is not an inter-state boundary associated with very tight control. There is, however, uncertainty as to the exact location of the borderline. That is apparently being attended to on inter-governmental level.

The sharing of water only from this international watercourse (as the Orange is) is not for the time being directly dependent on demarcation of the boundary.

2.10.2.5 **The Ramsar Convention on Wetlands**

This Convention was adopted in 1971. The original emphasis was on the conservation and use of wetlands to provide habitat for water birds. Over time it has broadened to cover all aspects of wetlands conservation. Wetlands are ecosystems of considerable importance for biodiversity conservation.

This Convention is in force. Namibia and South Africa are parties to it.

The Orange River mouth is a Ramsar trans-border site.

2.10.2.6 **Institutional**

The following Multi-national Commissions for the Orange River are in existence:

- Orange-Senqu River Basin Commission (ORASECOM) (Lesotho, South Africa, Botswana and Namibia);
- Permanent Water Commission (PWC) (South Africa and Namibia). This is a Commission that deals

with all matters related to common Watercourses and also supervises the Vioolsdrift/Noordoewer Joint Irrigation Authority (JIA).

- LHWC (Lesotho and South Africa). LHWC only has jurisdiction over the Lesotho Highlands Water for transfer to RSA. It is not a body like the JWC (RSA/Swaziland) or PWC (RSA/Namibia), which deal with all common watercourses between the countries. LHWC has no jurisdiction over Lesotho Lowlands.
- JPTC (South Africa and Botswana). Deals with all matters relating to common watercourses.

2.10.2.7 Legal, Institutional, Water Sharing, Cost Sharing, Management and Dam Operation Report

Yield analysis results from the Water Resources Planning Model (WRPM) analyses indicated that the Lower Orange River System is already being utilised close to its capacity and will only be sufficient to meet expected growth in demand until 2006.

If the LORMS environmental water requirements for Category D estuary are met, then the Orange River System is virtually in balance at 2005-development level.

2005 was thus used as the base year for allocating existing resources.

The report recommended the following water sharing arrangements:

- A total of 5 485 Million m³/a was estimated as the consumptive water requirements from the Orange River for 2005 and distributed in the ratio of 98,2% to 1,4% to 0,4% among South Africa, Namibia and Lesotho, respectively.
- Of this requirement, 176 Million m³/a was required from the Lower Orange (common border area) in a ratio of 56,6% to 43,4% between South Africa and Namibia, respectively.

Two systems, the Integrated Vaal River System (IVRS) and the Orange River System are important in the management of the Lower Orange River. Although the Integrated Vaal River System is not used to support the Orange River System, it is operated to minimize spills into the Orange River. This is important, as large volumes of water are transferred into the Vaal River from neighbouring catchments (e.g., from Lesotho Highlands Water Project) at high cost.

The Gariep and Vanderkloof Dams, which are part of the Orange River System, are the only resources currently used to supply the Lower Orange and stabilise water requirements along the Orange River from the Gariep Dam to the Orange River Mouth.

The Minimum operating levels (m.o.l) for hydropower are currently being used as minimum operating levels in both Gariep and Vanderkloof Dams

Principles for allocating water

In determining the practical sharing of allocable water, the following principles should be achieved:

- Water produced by an option should be able to be clearly defined with a known assurance and cost of supply, together with its point of delivery.
- Water provided should be available at the point of delivery as modelled in the analysis. Abstractions should be metered.
- The benefits of the development option should be achieved in practice, i.e., it should be ensured that water assessed to be available, should in practice, reach the consumers for whom it is meant.

Management issues that need to be considered include:

- Determining, managing and monitoring of Ecological Water Requirements and conservation responsibility.

- Management arrangements and operating rules of the current Orange River water resource that may need to be adjusted or expanded, to include new developments.
- Other developments in the Orange River System that may influence the Lower Orange River need to be agreed upon.

2.10.2.8 Options for sharing the cost of new developments

The sharing of the cost between the countries should be in accordance with an agreement reached between the two countries. Thereafter, each country would have to decide how it wishes to recover, or absorb the costs and the water tariffs to be charged to various users on the river system.

- Option 1: The cost is shared in relation to the benefit each country gains by developing a joint project compared with what each country would have paid, had each independently developed its own yield improvement measures.
- Option 2: The cost is shared in relation to the incremental water derived by each party from the improvement measures
- Option 3: The cost is shared in relation to water use from the entire Orange River System, by combining the cost of new developments into total system cost, including the cost of historic developments to get a total unit cost of water from the system. This is the approach commonly adopted by a country when developing the water resources of a basin within its borders.
- Option 4: The same as Option 3, but by limiting the system under consideration to the sub-system from Gariep Dam and downstream, excluding the Vaal System.

2.10.2.9 Responsibilities for Meeting Ecological Water Requirements

The sharing of this obligation should be in accordance with the utilization from the system. The sharing of this cost is based on the assumption that the upstream systems, such as the Upper Orange and Vaal both meet their obligations to the LOR System. That is a RSA responsibility and the sharing for the LORMS.

Ecological Water Requirements is thus independent of South Africa's arrangements with the upstream systems/countries.

2.10.2.10 New Infrastructure along Common Border Area (At Vioolsdrift)

The option of developing a dam along the common border area has proved to be beneficial, in particular the re-regulating dam, and is one of the selected options for further development.

The capital cost of the re-regulating dam, at April 2004 prices, amounts to R 56 million. This re-regulating dam can add 170 Million m³/a to the yield of the system after provision for losses and Ecological Water Requirements.

2.10.2.11 Institutional Arrangements

Proposed institutional options can be divided into:

- Multi-National basin wide management Orange-Senqu River Basin Commission (ORASECOM);
- Bi-National management of a specific portion of the Basin; The practical joint management of a dam at Vioolsdrift will require an institution (say, a Lower Orange River Authority –LORA) that will manage the releases from the dam, monitor the use of water by the Parties and ensure that the environmental protection goals and conservation obligations are met. The continued measurement and monitoring of the abstraction, flows, etc., will also be an important function.
- Water supply organisations (bi-national and national); and

- National institutions. The Catchment Management Agencies (in RSA) and proposed Basin Management Committees (in Namibia) will assist the bi-national and multi-national institutions with management, monitoring conservation and protection of water resources and implementation of catchment management strategies.

2.10.2.12 **Water Sharing Agreement**

The content of a typical water sharing agreement is provided. In determining the practical sharing of allocable water, the following principles should be achieved:

- Water produced by an option should be able to be clearly defined with a known assurance and cost of supply, together with its point of delivery.
- Water provided should be available at the point of delivery as modelled in the analysis. Abstractions should be metered.
- The benefits of the development option should be achieved in practice, i.e., it should be ensured, that water assessed to be available, should in practice, reach the consumers for whom it is meant.

The LORMS suggest that a project-driven approach to a water sharing agreement between South Africa and Namibia be followed whereby the two States agree on the project, environmental requirements, etc., and from that basis, expand the agreement towards systems management activities.

A summary of probable water demands and levels of assurance in the Orange System is provided in **Table 2-63**.

Table 2-63: Year 2025 Projected Demands (mill cu m per year)

	Irrigation	Urban, Industrial, Mining	Total
RSA	3381	2 487	5868
Namibia	227	48	274
Lesotho	9	17	26

An important finding of the LORMS is that it will not be possible to successfully manage the Orange River System as a stand-alone system with only the Gariep and Vanderkloof Dams included. The entire Watercourse should be modelled and analysed as an integrated system, which includes the Vaal River System for the purpose of the operating rules.

2.10.2.13 **Sharing Of New Hydro-Power Potential**

The results indicate that the economic viability of hydropower potential at Vioolsdrift Re-regulating Dam is marginal. The pre-conditions of generation according to required releases for other water demands may also require such generating capacity to be incorporated into a national / international grid, in order to be beneficial.

It may happen that one country may consider it worthwhile to proceed with such hydropower generation, whilst the other country does not support it. It may then be advantageous that the countries agree to allow such interested country to proceed.

The necessary provisions should be included in the agreement, to be able to allow such development and should cover:

- Access to the facilities;
- Operating rules of the dam; and
- Contribution towards the capital costs of the dam.

2.10.3 Specialist Report on the Environmental Flow Requirements – Riverine

Implementing the Ecological Flow Requirements (EFR) for the Orange River would be problematic if the EFR had to be supplied from Vanderkloof Dam (the last major structure on the Orange River main stem). Using the river as a conduit for irrigation water creates ecological problems related to unnaturally high and stable flows in the river. Using the environmental flow estimates of either the Orange River Replanning Study (ORRS) or the Desktop Model for planning purposes in LORMS may not be appropriate or feasible, and it was recommended that the relationship between the current flow regime in the river and the EFR recommended by the Desktop Model be examined, and that where appropriate, recommended flows be revised.

2.10.3.1 Study Area

The study focussed on the river reach of the Orange River between Augrabies and Onseepkans, however, where appropriate, specialists also contextualised their information within the wider LORMS study area (i.e., from the confluence of the Vaal to the mouth of the Orange River).

2.10.3.2 Assumptions and Results of Hydrological Modelling

The development scenarios shown in **Table 2-64** were provided for consideration.

Table 2-64: Development Scenarios Provided for Consideration

Scenario Description	Scenario No.*	Flow in Million m^3 at Given Site	
		Augrabies	River Mouth
Natural flow		10 587.30	10 833.01
Current system with 2005 demands	1-M	4 382.12	4 423.46
Vanderkloof lower level storage	1-P	4 254.89	4 296.43
Vioolsdrift reregulating dam	1-Q	4 268.94	4 082.10
Large Vioolsdrift	1-R	4 231.92	3 369.92

Note: All the development scenarios included the 2005 development level demands and the EFR from the ORRS.

The naturalised modelled data set was used as input to the Desktop Model, and EFR results were generated for Category C and D for the Lower Orange River.

A summary comparison of the various flow regimes is given in

Table 2-65. Key mismatches between Present Day flow patterns and Category C and D flow regimes recommended by the Desktop Model are:

- Volume of Desktop D EFR considerably less than present (2000) at Zeekoebaart-Upington;
- Lower winter flows recommended in Desktop D EFR;
- Seasonal distribution dampened relative to natural (i.e., less variation between the seasons), but retained in Desktop D EFR, has more variation than present day flow pattern.

Mismatches between predicted development flow patterns and Category C and D flow regimes recommended by the Desktop Model:

- Seasonal distribution maintained in 2005, Vanderkloof low-level storage (1-P) and Vioolsdrift re-regulating (1-R) dam scenarios.
- Low winter flows implemented in 2005, 1-P, 1-R and 1-Q Vioolsdrift storage dam.

Summer flows exceed Desktop – but well in line with naturalised and observed (1932- 1940) –delayed onset of high flows with 1-Q.

Table 2-65: Summary Comparison of flow Regimes

Scenario Description	Scenario No.*	Increased Dry Season Flows[2]	Stop-Flow Conditions	Intra-Annual Flood Events[2]		Variability	
				Normal/Wet Years	Draught Years	Year-on-Year	Short-term
Natural flow	Natural	No	Yes	Yes	Yes	Very high	Very high
1991-2000 Observed	Present Day	Yes, particular in Autumn	No	Reduced	No	Dampened	Much reduced
2005 (2005)	1-M	No	No	No	No	Very low	Cannot determine
Vanderkloof lower level storage	1-P	No	No	No	No	Very low	
Vioolsdrift reregulating dam	1-Q	No	No	No	No	Very low	
Large Vioolsdrift	1-R	No	No	No	No	Very low	
Hydropower release incl.	Hydro	Yes, particular in Autumn	No	No	No	Very low	
Category D Desktop	D-Desk	No	No	Reduced	Yes	Low-moderate	Reduced[3]
Category C Desktop	C-Desk	No	No	Reduced	Yes	Low-moderate	Reduced

Note: [2] Relative to the natural situation
[3] The Desktop Model only provides a flood volume and we have assumed that this related to a single flood. This could in effect be a volume that related to several smaller floods each with relatively short durations.

2.10.3.3 Present Ecological Status (PES) of the Orange River between Augrabies and Onseepkans, the trajectory of change in condition and flow-related reasons for river condition deviating from natural

Table 2-66 is a summary of the Present Ecological Status (PES) for each of the disciplines considered for the river in the environmental flow tasks. In general, the ecological condition of the river is deemed to be on a negative trajectory, with all disciplines expecting one-category deterioration in condition in the next twenty years. River systems function as an integrated whole, and changes made in one part of a system will inevitably lead to changes in another part, and so it is unsurprising that the disciplines predict similar trends.

Table 2-66: Summary of the Present Ecological Status (PES) for each of the disciplines considered, their predicted trajectory of change for 20 years and an indication of whether these changes documented/expected are related to changes in the flow regime of the Orange River

Discipline	PES	Trajectory	20-year prediction	Flow-related	Non flow-related

Water quality	B/C - Category	Negative	C/D - Category	No	Yes
Geomorphology	C - Category	Negative	D - Category	Largely	Channel manipulation - levees
Algae	D - Category	Negative	E/F - Category	Partly - not flushed	Partly - imported from u/s
Vegetation	D - Category	Negative	E - Category	Some	Predominately
Macro invertebrates	D - Category	Negative	D/E - Category	Some	Predominately
Fish	D - Category	Negative	D/E - Category	Partly	WQ also
Overall	D - Category	Negative	D/E - Category	ONLY PARTLY	Predominately

The most important aspects of the flow regime for maintaining or improving the current ecological condition are reinstating the winter low flows (i.e., reducing current flows) and the November freshet. The flow-related contribution factors identified were:

- unseasonal winter releases;
- lack of very low flow periods;
- lack of the November freshet;
- reduction in water volume;
- reduction in wet and dry season inter-annual floods; and
- Lack of flow variability.

2.10.3.4 Ecological Flow (EF) Regime Provided to LORMS Modellers for Use in Planning Models

The following process for providing an EF regime to LORMS modellers was agreed on and adopted:

1. The Desktop D Category EFR estimates were split into their low flow and high flow components.
2. The low flow requirements ONLY to be used as a demand file for the yield modelling from Vanderkloof Dam.
3. The monthly flow duration curves for the resultant flow regime (using the low flow ONLY demand file) at Augrabies were compared with the (total) Desktop D Category EFR estimations for Augrabies.
4. For months where the (total) Desktop D Category EFR estimates exceeded the actual flows at Augrabies obtained with the low flow ONLY demand file, the difference was considered to be a flood. The volume of water equating to the required flood was then added into the low flow ONLY demand file where required.
5. The resultant demand file comprised the low flows ONLY for the Desktop D, plus selected ‘top-up’ flood volumes.
6. This demand files is NOT the EFR, and the term “Top-up” D Demand File was coined to describe the resultant demand file.
7. Use of this file instead of the Desktop D demand file significantly improved system yield.
8. The EFR was considered to be the actual current day flows in the river at Augrabies, and the “Top-up” D Demand File merely part of the operating rules for achieving those flows.

2.10.3.5 Ecological Consequences of the Flow Regime Provided to LORMS Modellers for Use in Planning Models

Essentially the implementation of the “Top-up” D Demand File provides a slightly more varied flow regime than would be achieved with the low flows ONLY option, but has the advantage of not affecting the yield as negatively as the Desktop D reported in the LORMS January 2002 Progress Report.

The resultant flow regime at Augrabies, if the “Top-up” D Demand File is run in conjunction with other planning scenarios, should maintain the current gradual C to C/D Category trajectory. The extent to which the negative trajectory can be halted will depend on the degree of variability that can be managed in the system, as well as issues other than flow, and cannot be assessed in this task. This variability will include:

1. reinstatement of year-on-year variability;
2. provision of intra-annual floods; and
3. Capping of winter releases.

The recommended category for a Comprehensive Reserve Determination would most likely be a C-Category.

2.10.3.6 Limitations of the Study

Most of the data available for analysis in Task 8.3 were monthly data. Furthermore, no reliable gauge records were available with which monthly data could be disaggregated into daily flow sequences. This limited the analyses in the following ways:

1. Daily and monthly variability could not be adequately explored.
2. The number frequency and volumes of flood events within a month versus low flows cannot be determined.
3. Short-term distributional clashes between modelled scenarios and EFRs cannot be determined.
4. No hydraulic investigations were undertaken, and volumetric considerations could not be linked to velocity, wetted area or depth in the river channel itself.

2.10.3.7 Recommendations for Future Work to Determine the EFR for the LOR

A Comprehensive Reserve/EFR Determination on the lower Orange River should be undertaken as a matter of priority. It is of the utmost importance to control the mechanical manipulation of the river bed, banks and floodplain, as these factors are major contributors towards the decline in the condition of the riverine ecosystem and, together with the manipulation of the flow regime, will eventually lead to its complete collapse.

Particular attention should be given to maintaining the few remaining and relatively undisturbed anastomosed sections, such as upstream of Onseepkans. These areas are considered to be ecologically very important.

The periodic emptying of the existing Boegoeberg Dam for maintenance, which releases pulses of sediment-laden water, has detrimental downstream impacts, and should be managed to minimise the impact (i.e., sediments should be flushed more frequently during high-flow periods, and not during winter, when possible).

2.10.4 Specialist Report on the Determination of the Preliminary Ecological Reserve on a Rapid Level for Orange River Estuary

2.10.4.1 Importance of the Orange River Estuary

The Orange River Mouth Wetland was designated a Ramsar status, i.e. a wetland of international importance, in 1991. In September 1995 this Ramsar site was placed on the Montreux Record as a result of a belated recognition of the severely degraded state of the salt marsh on the south bank (the Montreux Record is a list of Ramsar sites around the world that are in a degraded state).

The Orange River Estuary is ranked as the 7th most important system in South African in terms of conservation importance. The prioritisation study calculated conservation importance on the basis of size, habitat, zonal type rarity and biodiversity) importance. The Estuarine Importance Score for the Orange River Estuary, based on its Present State, is 95, indicating that the estuary is considered as ‘Highly Important’. The estuary therefore qualifies as a Category A or Best Attainable State (BAS), however it is unlikely that the estuary could be returned to a Category A. The Best Attainable Status for the estuary is therefore considered to be an Ecological Category C, with a strong recommendation that mitigating actions to reverse modifications caused by the non-flow related activities and developments in the estuary be investigated by the responsible authorities.

2.10.4.2 Geographical Boundaries

For the purposes of the Rapid Ecological Reserve determination on the Orange River Estuary, the geographical boundaries are estimated as follows:

- Downstream boundary: The estuary mouth (28º38’30”S, 16º27’45”E)
- Upstream boundary: Head of tidal influence, approximately 9.5 km for mouth (28º33’45”S, 16º30’15”E)
- Lateral boundaries: 5 m contour above MSL along the banks.

2.10.4.3 Quantification of Ecological Water Requirement Scenarios

Ten simulated future runoff scenarios (in comparison to the Present State flows) was analysed in the study. For the purposes of this rapid assessment, a preliminary estimate of the recommended ‘Ecological Water Requirement Scenario’ for the Orange River Estuary (to meet the recommended Ecological Category of C) is estimated at a MAR of 4 758.93 x 106 m^3 (equivalent to Scenario 10: River Class D with floods).

Scenario 10 had the following distribution:

Month	Flow (m^3/s) – flow should > % in given month									
	90%ile	80%ile	70%ile	60%ile	50%ile	40%ile	30%ile	20%ile	10%ile	1%ile
OCT	54.95	53.72	50.64	46.25	39.4	32.11	25.65	20.05	18.1	5.93
NOV	178.06	82.19	76.11	67.59	55.37	43.18	34.06	28.53	26.19	14.73
DEC	228.73	120.75	96.31	78.53	59.44	43.42	35.94	31.54	29.99	27.44
JAN	545.82	147.26	82.87	70.39	54.06	47.74	41.1	37.92	36.72	27.64

FEB	1427.02	581.97	388.17	212.81	146.25	98.86	77.24	65.15	62.76	41.33
MAR	777.46	493.45	284.44	189.07	135.57	105.94	78.48	61.99	59.04	43.63
APR	736.15	218.39	145.73	103.03	96.22	74.42	64.29	58.27	54.21	43.9
MAY	223.13	81.83	47.96	44.89	41.77	38.29	35.68	33.51	32.5	26.28
JUN	61.89	30.69	29.17	28.44	27.31	25.17	23.3	21.9	21.17	19.77
JUL	24.81	24.56	23.85	22.82	21.96	20.57	19.18	18.08	17.46	17.24
AUG	23.14	22.85	22.36	21.59	20.12	18.75	17.45	16.31	15.73	13.53
SEP	21.03	20.51	19.88	19.17	17.99	17	15.62	14.03	8.96	6.11

White = State 1 (river dominated); Blue = State 2: Strong marine influence; Red = State 3: Mouth closure

Of particular significance is that the distribution of Abiotic States in this Scenario resembles that of the Reference Condition, namely a river dominated state (State 1) during the autumn/summer, with stronger marine influence (State 2) during late winter/spring and mouth closure (State 3) only occurring occasionally during spring. As a result the predicted biotic response is closer to that of the Reference Conditions (presently, State 2 (i.e. stronger marine influence) is dominant during the spring/summer, while the river dominated state (State 1) dominates during autumn/winter – almost a reversal of Reference Conditions).

The recommended Ecological Flow scenario for an Ecological Category C can still be refined. It is however important that the revised flow scenario maintains the distribution of Abiotic States presented in Scenario 10. It is estimated, that to maintain the estuary in its Present Ecological Status of a Category D+, a flow (and abiotic State) distribution represented by Scenario 7: Modified River Class D (MAR = 4 529.73 x 106 m^3) is required:

Month	Flow (m^3/s) – flow should > % in given month									
	90%ile	80%ile	70%ile	60%ile	50%ile	40%ile	30%ile	20%ile	10%ile	1%ile
OCT	54.95	53.72	50.64	46.25	39.4	32.11	25.65	20.05	18.1	5.93
NOV	178.06	82.19	76.11	67.59	55.37	43.18	34.06	28.53	26.19	14.73
DEC	228.73	120.75	96.31	78.53	59.44	43.42	35.94	31.54	29.99	27.44
JAN	545.82	147.26	82.87	70.39	54.06	47.74	41.1	37.92	36.72	27.64
FEB	1427.02	581.97	388.17	212.81	146.25	98.86	77.24	65.15	62.76	41.33
MAR	777.46	493.45	284.44	189.07	135.57	105.94	78.48	61.99	59.04	43.63
APR	736.15	218.39	145.73	103.03	96.22	74.42	64.29	58.27	54.21	43.9
MAY	223.13	81.83	47.96	44.89	41.77	38.29	35.68	33.51	32.5	26.28
JUN	61.89	30.69	29.17	28.44	27.31	25.17	23.3	21.9	21.17	19.77
JUL	24.81	24.56	23.85	22.82	21.96	20.57	19.18	18.08	17.46	17.24
AUG	23.14	22.85	22.36	21.59	20.12	18.75	17.45	16.31	15.73	13.53
SEP	21.03	20.51	19.88	19.17	17.99	17	15.62	14.03	8.96	6.11

White = State 1 (river dominated); Blue = State 2: Strong marine influence; Red = State 3: Mouth closure

2.10.4.4 Recommendations on Additional Data Requirements

It is strongly recommended that surveys to collect the additional data requirements on the different abiotic and biotic components in the Orange River Estuary be coordinated (i.e. undertaken simultaneously) to prevent duplication and to enable scientists to quantify linkage between different abiotic and biotic processes, a key requirements in predicting the effects of the modification in river inflow.

2.10.5 Water Requirements

2.10.5.1 Purpose of this report

The purpose of this report is to:

- Estimate the total water requirement of the Lower Orange River, including water demand projections to the year 2025.
- Provide an agreed basis for water allocations between South Africa and Namibia.
- Provide the basis for the Orange River systems analysis.
- Make recommendations for the development of a “curtailment model” for implementation during times of drought and water shortage.

2.10.5.2 Major Demand Centres of the Orange River

1. Vaal River System.
2. Upper Orange River (as far as the Vanderkloof Dam upstream of the Orange/Vaal confluence).
3. Eastern Cape (transfers through the Orange/Fish Tunnel).
4. Lower Orange River (Orange/Vaal confluence to the river mouth), which includes the Common Border Area – (Namibia/RSA border to the river mouth).

2.10.5.3 Water Demand on the Orange River System

2.10.5.3.1 Total Water Demand on the Orange River System

Table 2-67 below presents the current demand on the Orange River System.

Table 2-67: 2002 Consumer Demand on the Orange River System (Million m³/a)

Demand Area	Irrigation	Urban/Industrial/Mining	Total
Vaal River System	908	1 756	2 664
Eastern Cape	607	18	625
Upstream of Vanderkloof	111	82	193
Vanderkloof - 20° E Long.	1 273	20	1 293
Diffuse Irrigation	397		397
Common Border Area	102	24	126
Total	**3 398**	**1 900**	**5 298**

The largest consumers on the system are the Vaal urban demands and Irrigation. The urban, industrial and mining demand from the Orange River (excluding the Vaal) represents only 3% of the total demand. Irrigation demand is 64% of the total demand.

2.10.5.3.2 Return Flows

Substantial volumes of water from irrigation, urban and industrial developments are returned to streams and become available for re-use in the system. However, part of the return flow generated from the Rand Water (RW) supply area is returned to the Crocodile River Catchment and is lost to the Orange River System.

Transfers from Gariep Dam through the Orange/Fish tunnel are mainly used to support irrigation developments in the Eastern Cape. The Port Elizabeth supply area is the main urban supply area supported with water from the Orange River.

2.10.5.4 Riverine and Operational Demands

Losses from the Orange River System represent important "demands" that must be taken into account. The main losses are river requirements, operating losses and normal transmission or conveyance losses.

River requirements are a natural phenomenon to both regulated and unregulated rivers. As a result of the long conveyance distance and extreme dry and hot conditions, large river requirements are bound to occur. These requirements are mainly due to evaporation from the river surface area, but also include seepage and evapotranspiration from the riparian vegetation. The river requirement proposed for the Lower Orange River is estimated to be 615 Mm^3/a at a river flow of 70 m^3/s.

Gariep and Vanderkloof Dams are used to support the demands along the Lower Orange River from Vanderkloof Dam to the Orange River mouth. These demand centres are located along a river length of approximately 1 380 km which, together with river requirements and inflows from the Vaal and Fish (Namibia) Rivers, contribute to the complexity of operating the system and determining how much water to release from Vanderkloof Dam. The large controlling structures (sluice gates, hydropower turbines, etc.) at Vanderkloof Dam make it very difficult to release the required flow with accuracy. It is thus clear that some operating loss should be expected, which in this study, is currently estimated to be 270 Million m^3/a.

In the case of normal transmission or conveyance losses, the loss is expressed as a percentage of the up-stream inflow to a specific system node and is generally used for canal losses and transfer losses. The percentages used in this study vary from 4 to 12% depending on the conveyance systems used and the condition of canals.

2.10.5.5 Namibian Water Requirements

2.10.5.5.1 Orange River

The expansion of commercial irrigation land on the Namibian side of the river is currently progressing at a rate that results in substantial seasonal increases in the areas under irrigation. While commercial farms, and in particular table grape vineyards, are expanding, the planting of cash crops has decreased.

2 700 ha is currently under irrigation of which some 606 ha is under flood irrigation while the rest is irrigated by pressurized systems. The major urban consumers are the towns of Oranjemund, Rosh Pinah (including the Skorpion Mine) and Noordoewer.

The projections of future water demand in the Common Border Area depend to a large extent on the development of further irrigation projects. The forecast for the total Namibian demand from the Orange River is presented in **Table 2-68**.

Table 2-68: Total Water Demand Projections of the Lower Orange River Basin – Namibia (Most Probable) (Million m^3/a)

Consumer	2002	2005	2010	2015	2020	2025
Irrigation	40.55	59.70	102.75	150.00	196.50	226.73
Urban/Industrial	7.12	8.54	8.65	8.94	9.38	9.47
Mining	2.01	7.35	22.54	37.74	37.97	38.22
Total	**49.68**	**75.59**	**133.94**	**196.68**	**243.85**	**274.42**

2.10.5.5.2 Fish River (Namibia)

There are no mines that abstract water from the Fish River. Thus only the irrigation and domestic/industrial demands were considered. There are currently 2 490 ha under irrigation at the two main irrigation projects in the Fish River Basin – 2 200 ha at Hardap Dam and 290 ha at Naute Dam. The major towns on the Fish River are Keetmanshoop and Mariental.

Table 2-69: Water Demand Projections of Fish River (Most Probable) (Million m^3/a)

Consumer	2002	2005	2010	2015	2020	2025
Irrigation	46.4	48.0	48.0	48.0	48.0	48.0
Small scale abstraction	1.7	1.7	1.7	1.7	1.7	1.7
Urban/Industrial	2.7	2.9	3.0	3.1	3.2	3.3
Total	**50.8**	**52.6**	**52.7**	**52.8**	**52.9**	**53.0**

2.10.5.6 South African Water Requirements

There are currently 4 115 ha under irrigation along the common border on the South African side of the Orange River. This is expected to increase for two main reasons; the South African Government has allocated 4 000 ha of irrigable land for the establishment of small farmers from previously disadvantaged groups, and there is likely to be further demand from commercial farmers for irrigation of high value crops in the area.

Table 2-70: Total Water Demand Projections for South Africa in the CBA (Most Probable) (Million m^3/a)

Consumer	2002	2005	2010	2015	2020	2025
Irrigation	61.7	76.7	91.7	106.7	121.7	121.7
Urban/Mining	14.8	16.6	23.0	23.7	21.9	22.7
Total	**76.5**	**93.3**	**114.7**	**130.4**	**143.6**	**144.4**

2.10.5.7 Combined Water Requirements - Namibia and South Africa

The combined current demand and future demand projections within the Common Border Area are presented in **Table 2-71** and **Table 2-72**.

Table 2-71: 2002 Combined Demands in the CBA

User Category	Namibia		South Africa		Total	
	Mm^3/a	% Nam	Mm^3/a	% Nam	Mm^3/a	% Nam
Irrigation	40.55	79	61.72	78	102.27	15.4
Urban/Domestic	7.12	13	14.80	18	23.93	3.6
Mining/Industrial	2.01	4				
River Requirements					264.60	39.7
Operational losses					270.00	40.6
Conveyance losses	2.03	4	3.09	4	5.12	0.8

User Category	Namibia		South Africa		Total	
	Mm³/a	% Nam	Mm³/a	% Nam	Mm³/a	% Nam
Total	**51.71**		**79.61**		**665.92**	

Table 2-72: The Combined Water Demand Projection of Both Countries

Consumer Category	2002 Mm³/a		2005 Mm³/a		2010 Mm³/a		2015 Mm³/a		2020 Mm³/a		2025 Mm³/a	
	Nam	RSA	Nam	RSA	Nam	RSA	Nam	RSA	Nam	RSA	Nam	RSA
Irrigation	40.6	61.7	59.7	76.7	102.8	91.7	150.0	106.7	196.5	121.7	226.7	121.7
Urban/Domestic	7.1	14.8	8.5	16.6	8.7	23.0	9.0	23.7	9.4	21.9	9.5	22.7
Mining/Industrial	2.0		7.3		22.5		37.7		38.0		38.2	
Total	**49.7**	**76.5**	**75.5**	**93.3**	**134.0**	**114.7**	**196.7**	**130.4**	**243.9**	**143.6**	**274.4**	**144.4**

2.10.5.8 Assurance of Supply

2.10.5.8.1 Reliability Classifications

Table 2-73: User Category and Priority Classifications Used in the ORRS Study

System and User Category	Priority Classification (%)			
	Low (90% assurance) (1:10 year)	Medium (95% assurance) (1:20 year)	Intermediate (99% assurance) (1:100 year)	High (99.5% assurance) (1:200 year)
Irrigation	Percentage split varies from crop to crop (see **Table 2-74** below)			
Urban and mining	0	20	30	50
River Losses (Evaporation)	0	0	0	100
Environmental	0	36	66	0
Conveyance losses	0	0	0	100
Curtailment level	**0**	**1**	**2**	**3** **4**

Table 2-74: ORRS Priority Classifications for Different Crops

System and User Category	Priority Classification (%)			
	Low (90% assurance) (1:10 year)	Medium (95% assurance) (1:20 year)	Intermediate (99% assurance) (1:100 year)	High (99.5% assurance) (1:200 year)
Annual crops Maize	100	0	0	0

System and User Category	Priority Classification (%)			
	Low (90% assurance) (1:10 year)	**Medium (95% assurance) (1:20 year)**	**Intermediate (99% assurance) (1:100 year)**	**High (99.5% assurance) (1:200 year)**
Wheat	100	0	0	0
Cotton	100	0	0	0
Beans/Peas	100	0	0	0
Groundnuts	100	0	0	0
Fodder	100	0	0	0
Vegetables	50	50	0	0
Perennial fodder				
Lucerne	100	0	0	0
Perennial fruits/ nuts				
Dates	30	50	20	0
Citrus	30	30	40	0
Grapes	30	40	30	0
Curtailment level	**0**	**1**	**2**	**3** **4**

2.10.5.9 **Proposed Reliability Classification for This Study**

Questionnaires were sent to various users and their input and suggestions regarding the required reliability classifications were obtained. For this purpose four user categories were used, (Urban; Industrial; Mining and Irrigation) and three reliability classes (Low, Medium and High). The results obtained from this survey are summarised in **Table 2-75**.

Table 2-75: User Categories and Priority Classifications Obtained from Questionnaires

System and User Category	Priority Classification (%)		
	Low (95% assurance) (1:10 year)	**Medium (99% assurance) (1:20 year)**	**High (99.5% assurance) (1:100 year)**
Urban	19	31	50
Industrial	45	35	20
Mining	10	23	68
Irrigation	63	27	10

It is difficult, at this stage, to propose a final priority classification for this study. Two or three scenarios will be selected and the effect of these on the system yield will be analysed.

The priority classifications will be discussed in more detail in the Yield Analysis Report, which will contain the final recommended classifications for this study.

2.10.5.10 **Curtailment Model**

The Planning Model is used to analyse the system and allocate water in such a way as to maintain the assigned assurance of supply for all the users in the four proposed different user categories, subject to any physical constraints that may exist. Restrictions in water supply are applied first to the water use allocated to the low assurance level. The model will only start to impose curtailments on the water use allocated to the 95% assurance level, when 100% of the water use that is allocated to the low assurance level has been curtailed (curtailment level 1). In a similar way curtailments will each time only be imposed on the higher assurance level if all the water allocated to the lower assurance level has been curtailed in full.

2.10.5.11 **Conclusions**

Operational Losses downstream of Vanderkloof Dam are estimated at 270 Million m^3/a. This is a significant loss that can be substantially reduced by establishing further storage in the Lower Orange River.

Urban and industry consume 67% of the water consumption in the Vaal River System. Some of the return flows generated from the Rand Water supply area are returned to the Crocodile River Catchment and are lost to the Orange River System.

Along the Common Border irrigation constitutes 81% of total water consumption. This percentage will increase in the long-term.

Inefficient irrigation, high return flows and seepage contribute to the quality deterioration in the Vaal River. The water quality in the lower Vaal River is of concern because of the high total dissolved solids (TDS) values. This may in turn influence the water quality downstream of the confluence with the Orange River.
Most of the crops grown in the Upper Orange River are cash crops that are normally regarded as low value crops. A significant quantity of water is lost through inefficient irrigation and could contribute to significant savings, if reduced.

In the CBA the hot, dry climate contributes to the success of the high value grape growing industry that has established there. Irrigation along the Common Border generally uses high technology systems and the potential for improved water use efficiency is limited.

From available information, the gross margin of high value crops along the Lower Orange River is in excess of R 100 000/ha/annum. The direct job opportunities vary from 15 to 23 jobs per 1 000 m^3 of water consumed. This is much higher than for other crops grown in the Orange River System.

The long-term water quality in the Lower Orange River is a cause for concern. The selection of crops for the CBA west of Vioolsdrift/Noordoewer should be done in a way that water quality does not affect the long-term future production prospects.

The provision of bulk infrastructure in remote areas that have potential for irrigation development is a major task and very costly. The joint development of infrastructure such as roads, electricity and telephone services warrants further investigation to realise the benefit of scale.

Due to various problems that have been experienced over time with the development of small scale irrigation schemes, models should be investigated where commercial development is done in combination with the settlement of small farmers.

2.10.5.12 **Recommendations**

It is recommended that:

1. The water demand projections for the Lower Orange River as proposed in the report are accepted.
2. The proposed water demand projections are used as a basis for discussion in the allocation of the available water in the Lower Orange River between Namibia and South Africa.
3. The proposed curtailment model is accepted as the basis for modelling the operation of the system in times of water shortage.
4. Water allocations and the issuing of permits on both sides of border should follow the same principles and conditions.

5. Measurement of river flow is improved to facilitate a more accurate water balance.
6. Transfer of water rights is further investigated where feasible to get a higher return on water use.
7. The joint development of bulk infrastructure such as access roads, electricity and telephone services should be pursued to realise the benefits of scale.
8. Furthering of cross border co-operation takes place.
9. A proper data base is developed.

2.10.6 Hydrology, Water Quality and Systems Analysis (Volume A & B)

2.10.6.1 Scope of this Report

The purpose of Volume A and B of this report is to provide summarised details of the hydrological database, the land-use developments, the associated water requirements, as well as full details on the water supply systems, system yield and planning analyses. A detailed description of the updated hydrology of the Fish River (Namibia), as well as a review of the existing Republic of South Africa (RSA) hydrology is also provided.

2.10.6.2 Procedure Followed

The yield analyses and system modelling were undertaken in six phases:

- Phase 1: Model configuration for the Water Resources Yield Model (WRYM).
- Phase 2: Based on historic firm yield analyses determine the need and initial timing of proposed development measures.
- Phase 3: Determine the supply capability of the proposed development measures.
- Phase 4: Carry out selective long-term stochastic analyses and short-term stochastic yield analyses.
- Phase 5: Model configuration for the Water Resources Planning Model (WRPM).
- Phase 6: Carry out selective planning analyses using the Water Resources Planning Model, and obtain the refined and final results with regards to the need and timing of proposed developments.

The Water Resources Yield Model data sets, obtained from the Orange River Development Project Replanning Study (ORRS), were used as the base data sets and were updated with the latest hydrology, system demands and infrastructure changes. This system configuration excludes the detail of the Integrated Vaal River System upstream of the confluence of the Vaal and the Riet Rivers. At this point, the outflows for the Vaal were obtained from the detailed Vaal River Water Resources Planning Model system analysis, and used as the inflow to the Orange in the Water Resources Yield Model analysis. The most recent Water Resources Planning Model data sets for the Integrated Vaal River System were used as the basis for the planning analyses (Phase 6) and extended to include the whole Orange River System.

2.10.6.3 Scenario Descriptions and Historic Firm Yield Results

A specific reference scenario (Reference Scenario 1) was defined and used as the benchmark for the Water Resources Yield Model analysis. The results from other scenarios were compared with the reference scenario yield result, to determine their effect on the system yield. Due to a number of uncertainties with regards to the growth in the irrigation requirements, it was decided to use the existing irrigation demands (Year 2000) in all the analyses. A brief description of Reference Scenario 1 is given below.

2.10.6.3.1 Reference Scenario 1:

This scenario represents the current system with 2005 development level urban, industrial and mining demands imposed on the system. Current irrigation demands were included. It was assumed that the full phase 1 of the Lesotho Highlands Water Project is in place. The minimum operating levels in the Gariep and

Vanderkloof Dams were set equal to the Orange/Fish tunnel and canal outlets, respectively. These levels are slightly lower than the minimum operating levels applicable to hydropower generation in both dams. Hydropower is only generated with the water released into the river for downstream users below both dams, and no additional releases for hydropower generation were made. Spills from the Vaal, as well as any inflows from Lower Orange catchments, were not utilised by users along the Orange River. Environmental requirements as currently released from Vanderkloof Dam were included. These environmental requirements were obtained from the ORRS.

Several other scenarios or options were defined and analysed to determine the incremental yield benefit of possible developments, as well as sensitivity analyses to obtain an improved understanding of the system. These scenarios used Reference Scenario 1 as the basis and selected components were changed as described hereafter:

- Scenario 1a: As Reference Scenario 1, but with urban/industrial and mining developments at 2015-development level.
- Scenario 1b: As Reference Scenario 1, but with urban/industrial and mining developments at 2025-development level.
- Scenario 1c: The lower level storage in Vanderkloof Dam was used to supply downstream requirements and to pump water into the Vanderkloof canals.
- Scenario 1d: Used the minimum operating level (m.o.l.) related to hydropower generation for both dams.
- Scenario 1e: Spills from the Vaal were utilised. Water is released from Vaalharts Weir in the Lower Vaal to supply users along the Vaal River upstream of the confluence with the Riet River. More water than the actual downstream requirement is released to cover the operating losses. Some of these operating losses will, however, flow into the Orange. This scenario excludes the Vaal operating losses from the Vaal spills. For this scenario, it was assumed that these spills could be utilised from the Douglas Weir, as well as in the Orange River downstream of the Douglas Weir.
- Scenario 1f: Spills from the Vaal were utilised. For this scenario, the Vaal operating losses are included as part of the Vaal spills. It was assumed that these spills could be utilised from the Douglas Weir, as well as in the Orange River downstream of the Douglas Weir.
- Scenario 1g: The lower level storage in Vanderkloof Dam was used to supply downstream requirements, and to pump water into the Vanderkloof canals as for Scenario 1c, but also included the utilisation of the spills from the Vaal (operating losses included), as described for Scenario 1f.
- Scenario 1h: The ecological requirements, as obtained from the Orange River Replanning Study, were replaced with Desktop estimates for a Class C river. For this scenario, it was assumed that the spills from the Vaal, as well as the runoff generated from the Lower Orange River catchment can be utilised to supply the ecological requirements. The lower level storage in Vanderkloof Dam was also utilised for this scenario.
- Scenario 1i: The ecological requirements, as obtained from the Orange River Replanning Study, were replaced with Desktop estimates for a Class D river. For this scenario, it was assumed that the spills from the Vaal, as well as the runoff generated from the Lower Orange River catchment, can be utilised to supply the ecological requirements. The lower level storage in Vanderkloof Dam was also utilised for this scenario.

Results from the historic firm yield analyses are summarised in **Table 2-76**. The surplus yield available in the system for Reference Scenario 1 is 120 million m³/a. This result shows that the system is almost in balance as the 120 million m³/a surplus represents less than 4% of the total system yield of 3 250 million m³/a.

The growth in urban/industrial and mining components have a relative small impact on the system yield as it reduces the system yield from 2005 to 2025 by only 86 million m³/a.

A similar reduction in yield (80 million m³/a) will occur when the current hydropower minimum operating level is used instead of the minimum operating level specified for Reference Scenario 1.

Table 2-76: Summary of Yield Results for Reference Scenario 1 and Related Scenarios

Scenario No.	Description	Units	Surplus/ Deficit Yield	Increase/ Decrease
1	Reference Scenario 1 (2005-development level	Million m^3/a m^3/s	120 3.8	0 0
1a	Reference Scenario 1 (2015-development level)	Million m^3/a m^3/s	67 2.1	-53 -1.7
1b	Reference Scenario 1 (2025-development level)	Million m^3/a m^3/s	34 1.1	-86 -2.7
1c	Vanderkloof lower level storage (2005-development level)	Million m^3/a m^3/s	271 8.6	151 4.8
1d	Hydro-power m.o.l. in both dams (2005-development level	Million m^3/a m^3/s	40 1.3	-80 -2.5
1e	Include Vaal spills operating losses excluded (2005 development level)	Million m^3/a m^3/s	172 5.5	52 1.6
1f	Include Vaal spills operating losses included (2005-development level)	Million m^3/a m^3/s	264 8.4	144 4.6
1g	Vanderkloof lower level storage plus Vaal spills operating losses included (2005-development level)	Million m^3/a m^3/s	483 15.3	363 11.5
1h	Desktop Class C EFR with Vanderkloof lower level storage plus Vaal soils operating losses included (2005-development level)	Million m^3/a m^3/s	-417 -13.2	-537 -17.0
1i	Desktop Class D EFR with Vanderkloof lower level storage plus Vaal spills operating losses included (2005-development level)	Million m^3/a m^3/s	-201 -6.4	-321 -10.2

The planning estimates for the environmental flow requirement (EFR), as obtained from the Desktop Model for the Orange River, are significantly different from that given in the Orange River Replanning Study. The environmental requirements from the Orange River Replanning Study are constant annual values with a specific monthly distribution, and are currently supplied by means of releases from the Vanderkloof Dam. The most recent methodology, as used for the LORMS environmental flow requirement planning estimates, links the environmental flow requirement for a specific month to the natural flow generated for that month. When the environmental flow, based on this methodology, is analysed in a system context, it requires that one utilise the spills available in the system, to partly supply the environmental requirement and only obtain the remaining deficit by means of releases from an upstream storage dam. The yield results indicated that deficits in excess of 400 million m^3/a, could be experienced in the system when the Desktop estimate of the environmental flow requirement for a Class C river has to be met.

Due to the significant reduction in yield, it was considered necessary to define a second reference scenario in which the environmental requirements obtained from the Desktop Model for a Class D river was included, instead of the Orange River Replanning Study environmental requirements.

At the time when Reference Scenario 2 was discussed, as part of the Lower Orange River Management Study (LORMS), updated environmental releases determined by Lesotho for the Lesotho Highlands Water Project, became available. These releases are higher than those specified in the Treaty between the Republic of South Africa and Lesotho. Lesotho was at that time already in the process of implementing the updated environmental releases and it was therefore decided to replace the Treaty environmental releases with the updated releases, as part of Reference Scenario 2. A brief description of Reference Scenario 2 is given below:

2.10.6.3.2 Reference Scenario 2:

This scenario is as Reference Scenario 1, with the following changes:

- Desktop environmental requirements for a Class D river were used instead of the Orange River Replanning Study environmental requirements.
- Spills from the Vaal were utilised to support the environmental requirements. The spill record used for the Vaal included the effect of the operating losses in the Vaal.
- The recently updated environmental requirements from the Lesotho Highlands Water Project were used.

Some sensitivity analyses were also carried out, relating to Reference Scenario 2, and include the following:

- Scenario 2a: As Reference Scenario 2, but included the Treaty environmental releases for the Lesotho Highlands Water Project, as used in Reference Scenario 1.
- Scenario 2b: As Reference Scenario 2, but allowed the Vaal River to contribute its part to the environmental requirement in the Lower Orange River. For this purpose, the Desktop Model was used to obtain an environmental requirement for a Class D river at the lower end of the Vaal River. Bloemhof Dam was used to support this environmental requirement.

Results from the historic firm yield analyses are summarised in

Table 2-77.

Reference Scenario 2 results in a deficit of almost 300 million m³/a in the system. This deficit will increase by 67 million m³/a when the Treaty environmental flow requirements are considered instead of the updated releases. This also means that the updated environmental flow requirement releases from the Lesotho Highlands Water Project will increase the Orange River System yield by approximately 70 million m³/a.

Table 2-77: Yield Results for Reference Scenario 2 and Related Scenarios

Scenario No.	Description	Units	Surplus/Deficit Yield	Increase/ Decrease
2	Reference Scenario 2 (2005-development level)	Million m³/a m³/s	-299 -9.5	0 0
2a	Reference Scenario 2 with treaty releases from LHWP (2005-development level)	Million m³/a m³/s	-366 -11.6	-67 -21
2b	Reference Scenario 2 with Vaal River EFR contribution (2025-development level)	Million m³/a m³/s	-104 -3.3	195 6.2

Results from Reference Scenarios 1 and 2, as well as the related scenarios, showed large differences in the yield available from the Orange River System, depending on the environmental requirement that is imposed on the system. From these results, it was clear that further work is required to determine the environmental flow requirement, which will be suitable for planning purposes as part of the Lower Orange River Management Study. An additional task was therefore approved to examine the relationship between the current flow regime in the river and the environmental flow requirement recommended by the Desktop Model. A more feasible environmental flow requirement was proposed from this task to be used for planning purposes in this Study. This environmental flow requirement is referred to as the Top-up environmental requirement. The Top-up environmental requirement was then used in the final set of scenarios to be analysed for this Study and Reference Scenario 3 was defined for this purpose. A brief description of Reference Scenario 3 is given below.

2.10.6.3.3 Reference Scenario 3:

This scenario is as Reference Scenario 1, with the following changes:

- The Top-up environmental requirements were included, as determined from the additional Lower Orange River Management Study environmental task, instead of the Orange River Replanning Study environmental requirements.
- Spills from the Vaal were utilised to support the environmental requirements. The spill record used for the Vaal included the effect of the operating losses in the Vaal.
- The recently updated environmental requirements from the Lesotho Highlands Water Project were used.
- The reduced Lesotho Highlands Water Project transfer, as result of the updated environmental releases, will be used. The reduced transfer rate from the Lesotho Highlands Water Project to the Vaal was determined as 780 million m³/a for the full Phase 1 of the Lesotho Highlands Water Project.

Several other scenarios or options were also defined and analysed to determine the incremental yield benefit of possible developments, as well as sensitivity analyses to obtain an improved understanding of the system. These scenarios used Reference Scenario 3 as the basis and some components were changed as described hereafter:

- <u>Scenario 3a:</u> As Reference Scenario 3, but with urban/industrial and mining developments at 2015-development level.
- <u>Scenario 3b:</u> As Reference Scenario 3, but with urban/industrial and mining developments at 2025 development level.
- <u>Scenario 3c:</u> The surplus from the Vaal was used to support the Orange River. This surplus is in excess of 100 million m³/a in 2005, but will reduce over time between (2015 & 2020) to zero.
- <u>Scenario 3d:</u> The spills from the Vaal were utilized by implementing real time modelling.
- <u>Scenario 3e:</u> The Lower Level storage in Vanderkloof Dam was utilized.
- <u>Scenario 3f:</u> The incremental yield benefit for a large Vioolsdrift Dam was determined (3 sizes were analysed). The live storage suggested for the 3 dam sizes are:
  - 500 million m³
  - 1 500 million m³
  - 2 400 million m³
- <u>Scenario 3g</u>: The incremental yield benefit for a large Boegoeberg Dam was determined (3 sizes were analysed). The live storage suggested for the 3 dam sizes are:
  - 500 million m³
  - 1 500 million m³
  - 2 400 million m³
- <u>Scenario 3h:</u> Re-regulating dams at either Vioolsdrift or Boegoeberg Dam sites were included to reduce operating losses.
- <u>Scenario 3i:</u> Water conservation and demand management (WC&DM) measures were included. Focus on the area between Gifkloof and the Namibian border, as this area is expected to provide the highest returns.
- <u>Scenario 3j:</u> A large Vioolsdrift Dam (3 sizes was included, as for Scenario 3f. For this scenario the yield gained from a large Vioolsdrift Dam will be used for additional development upstream of Vioolsdrift Dam and not downstream of the dam as for Scenario 3f. To accommodate this, the yield benefit was determined at Vanderkloof Dam and not at Vioolsdrift Dam. The live storage suggested for the three dam sizes are:
  - 500 million m³
  - 1 500 million m³
  - 2 400 million m³

Results from the historic firm yield analyses are summarised in **Table 2-78**. From **Table 2-78**, it can be seen that Reference Scenario 3 resulted in a surplus yield of 14 million m³/a at 2005-development level.

Table 2-78: Yield Results for Reference Scenario 3 and Related Scenarios

Scenario No.	Description	Units	Surplus/Deficit Yield	Increase/Decrease
3	Reference Scenario 3 (2005-development level)	Million m³/a m³/s	14 0.4	0 0
3a	Reference Scenario 3 (2015-development level)	Million m³/a m³/s	-42 -1.3	-56 -1.7
3b	Reference Scenario 3 (2025-development level)	Million m³/a m³/s	-75 -2.4	-89 -2.8
3c	Vaal surplus – 2005	Million m³/a m³/s	94 3.0	94 3.0
	Vaal surplus – 2010	Million m³/a m³/s	28 0.9	28 0.9
	Vaal surplus – 2015	Million m³/a m³/s	10 0.3	10 0.3
3d	Real time modelling	Million m³/a m³/s	80 2.5	0 0
3e	Vanderkloof Lower level storage utilisation	Million m³/a m³/s	157 5.0	143 4.5
3f	Large Vioolsdrift Dam - 44m spill height (500 million m³ live storage)	Million m³/a m³/s	*281-135 (197) *8.9-4.3 (6.2)	*267-121 (183) *8.5-3.8 (5.8)
	Large Vioolsdrift Dam - 54.6m spill height (1 500 million m³ live storage)	Million m³/a m³/s	*358-258 (311) *11.3-8.2 (9.9)	*344-244 (297) *10.9-7.7 (9.4)
	Large Vioolsdrift Dam - 54.6m spill height (2 400 million m³ live storage)	Million m³/a m³/s	*429-332 (379) *13.6-10.5 (12.0)	*415-318 (365) *13.2-10.1 (11.6)
3g	Large Boegoeberg Dam – 35.4m spill height (500 million m³ live storage)	Million m³/a m³/s	*203-0 *6.4-0	*189-(-14) *6.0-(-.4)
	Large Boegoeberg Dam – 35.4m spill height (500 million m³ live storage)	Million m³/a m³/s	*292-110 *9.3-3.5	*278-96 *8.8-3.0
	Large Boegoeberg Dam –44.6m spill height (2 400 million m³ live storage)	Million m³/a m³/s	*329-149 *10.4-4.7	*315-135 *10.0-4.3
3h	Re-regulation dam - Boegoeberg Dam (90 million m³ live storage)	Million m³/a m³/s	62 2.0	62 2.0
	Komsberg Dam (100 million m³ live storage)	Million m³/a m³/s	126 4.0	126 4.0
	Vioolsdrift Dam (110 million m³ live storage)	Million m³/a m³/s	170 5.4	170 5.4
3i	WCDM Gifkloof to Namibian border by 2010	Million m³/a m³/s	55 1.7	55 1.7
	WCDM Gifkloof to Namibian border by 2014	Million m³/a m³/s	118 3.7	118 3.7

Scenario No.	Description	Units	Surplus/Deficit Yield	Increase/Decrease
3j	Vioolsdrift Dam yield channel at Vanderkloof 44m spill height (500 million m^3 live storage)	Million m^3/a m^3/s	264 8.4	250 7.9
	Vioolsdrift Dam yield channel at Vanderkloof 54.6m spill height (1 500 million m^3 live storage)	Million m^3/a m^3/s	332 10.5	318 10.1
	Vioolsdrift Dam yield channel at Vanderkloof 54.6m spill height (2 400 million m^3 live storage)	Million m^3/a m^3/s	332 10.5	318 10.1

Note: *The first value represents the yield before the effect of sediment was taken into account and the second value after the effect of the estimated 50-year sediment volume was included. For the Vioolsdrift scenario, the yield value in brackets represents the yield where the evaporation area at the minimum operating level was adjusted to accommodate possible effects of the 50-year sediment.

2.10.6.4 Stochastic yield analyses

The stochastic analyses are used to determine the yield available at different levels of assurance. For the purpose of the long-term stochastic analysis, 501 stochastic sequences, with a record length of 68 years each, were analysed. Reference Scenario 3 was used for this analysis and results are summarised in **Table 2-79**. For the historic firm yield analyses, the surplus yield was always shown for each of the scenarios analysed. For the purpose of the stochastic yield analysis, it is, however, required to determine the total system yield so that the total system demand can be allocated to different assurance levels. The environmental requirement and river evaporation for this scenario were still imposed as demands on the system and therefore not included as part of the system yield. The main reason for this is that spills from the Vaal and Fish Rivers, as well as local runoff, were utilised to partly supply these requirements. To be able to compare the historic firm yield with the stochastic yield, the total system yield from a historic yield analysis was also determined for Reference Scenario 3 (see **Table 2-79**).

Results show that the historic firm yield has a recurrence interval of 1 in 100 years. The total demand imposed on the system is 2 162 million m^3/a at 2005-development level. When all the demands are supplied at a 1 in 100 year assurance (this means that there is a possibility of not supplying the demand in full only once in a 100 years), there will still be a small surplus of 56 million m^3/a available in the system. This surplus will increase to 288 million m^3/a if the demands are supplied at a 1 in 50 year assurance, which is significantly more than the 14 million m^3/a surplus from the historic firm yield analysis.

Table 2-79: Reference Scenario 3, Summary of Long-term Stochastic Yield Results

Scenario Description	Historic Firm Yield Recurrence Interval (Years)	Long-term Stochastic Firm Yield at indicated Recurrence intervals			
		1:20 year (million m^3/a)	1:50 year (million m^3/a)	1:100 year (million m^3/a)	1:200 year (million m^3/a)
Reference Scenario 3	100 (2 218)*	2 825	2 450	2 218	2 000

Note: *Value in brackets refers to the historic firm yield in million m^3/a.

In practise, however, all the demands are not supplied at the same assurance level and the assurance levels, as required for different categories of users in the Orange River System, is provided in **Table 2-80**. The results in this table show that almost 50% of the total demand needs to be supplied at a low assurance of 1 in 20 years, which is as result of the large irrigation component.

Table 2-80: User Categories and Priority Classifications used for the LORMS

User Category	Priority Classification & Assurance of Supply (million m^3/a)			Total (million m^3/a)
	Low 1 in 20 year	Medium 1 in 100 year	High 1 in 200 year	
Urban	12	18	30	60
Irrigation	1 062	531	177	1 770
Losses	0	0	332	332
Total	**1 074**	**549**	**539**	**2 162**

These demands, as allocated to the different assurance classes, were imposed on the long-term stochastic yield curve, which showed that there is still a surplus of 480 million m³/a available at a 1 in 20 year assurance level. Further sensitivity analyses indicated that the surplus can reduce to 338 million m³/a, if a different priority classification is used, such as that currently implemented for the Integrated Vaal River System.

According to the historic firm yield analysis and the stochastic analyses, the available surplus in the system differs significantly and so too does the resulting time when intervention is required, to ensure that the growing need of water users is met.

A different and more accurate approach is clearly required to obtain improved results with regards to the required timing of intervention measures and the available surplus. It was therefore decided to:

- Carry out some sensitivity analyses with regards to the long-term stochastic yield. This will also help to set the scene for the short-term stochastic analyses and related assumptions.
- Use the Water Resources Planning Model (WRPM) to obtain the required timing when intervention will be required.

The sensitivity analyses indicated that the stochastic yield results can be improved by means of the following:

- Analysing the inflow to the Orange from the Vaal stochastically and thereby producing inflow records consisting of 501 flow sequences of 68 years each, instead of a single sequence from a historic analysis.
- Setting the river evaporation losses to zero and considering them as part of the system yield.
- Excluding the Lower Vaal operational losses from the Vaal inflow record.

Results from the refined long-term stochastic analysis showed a surplus of 243 million m³/a at a 1 in 20 year assurance level. Based on the results of the sensitivity analyses and the fact that much more detailed stochastic analyses are involved in this refined long-term stochastic analysis result, the surplus of 243 million m³/a is regarded as the most accurate surplus indication from all the long term stochastic analyses performed.

2.10.6.5 WRPM Analyses

The WRPM is used to carry out planning or operating analyses using short-term stochastic yield characteristics, obtained from the WRYM as part of the operating rule. The growth projections of all the water requirements are also included in the WRPM, in order to determine when curtailments and, or, intervention measures will be required in future. Using the WRPM to determine the required intervention time will more than likely result in a more conservative and realistic result than that obtained by means of the long-term stochastic yield analysis, as well as a more optimistic result than that from the historic firm yield analyses.

Results from this analysis indicated that curtailment levels are clearly exceeded from 2006 onwards. This means that curtailments are being imposed on the system more often than the given risk criteria. From the results it is clear that actions need to be taken to improve the supply situation in the Orange River System from 2006 onwards, until a Vioolsdrift Reregulating Dam can be in place. In practise it will not be possible to have Vioolsdrift Dam in place before 2012.

As soon as the Vioolsdrift re-regulating dam is in place, one will require an additional development option such as Vanderkloof Lower Level Storage or a Large Vioolsdrift Dam. This is required to supply the higher environmental requirements in combination with the growth in demands up to that time (approximately 2015) and is clearly illustrated on **Figure 2-13**. It is also evident from **Figure 2-13** that a Vioolsdrift reregulating dam and Vanderkloof Lower level storage will not be sufficient to supply in the growing demand until 2025 and that additional live storage of approximately 280 million m³ is required for this purpose.

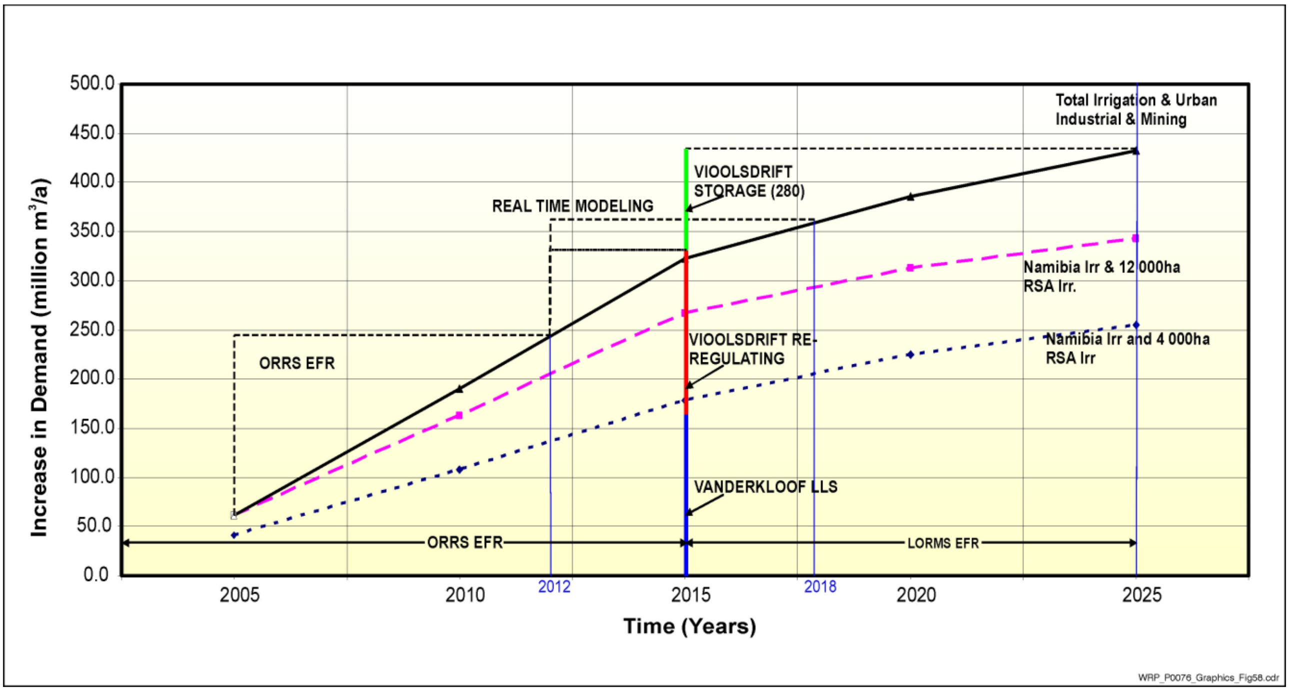


Figure 2-13: Required Intervention Time for Various Options versus the most probable Demand Growth

2.10.6.6 Recommendations

Based on the results from the analyses, the following recommendations are made:

- Economic and financial analyses must be carried out for the Vioolsdrift reregulating and large storage dams, the Vanderkloof Lower Level storage option, as well as for the possibility to utilize the current Vaal surplus. Results from the separate study on the impact of Vanderkloof Lower level storage utilisation on hydropower generation should be included in the economic and financial analyses.
- Detailed investigations and improved accuracy of low flow monitoring in the Lower Vaal are recommended to obtain improved information on the actual operating losses in the Lower Vaal, as well as for the portion of the losses that is in fact reaching the Orange River as yield results were sensitive to the spills assumed for the Vaal.

- Sedimentation has a major impact on the yield from dams in the Lower Orange and there is a lack of relevant data for this area. The processes should be put in place, to in time store and collect the necessary data.
- Water conservation and demand management should be strongly promoted in this area, as large volumes of water can be made available through the suggested actions. It is, however, foreseen that the additional water from water conservation and demand management will mainly be utilised by the irrigators themselves, to enable them to irrigate larger areas with the same volume of water, or to trade some of their allocation.
- To be able to manage the water supply to the Estuary to satisfy the environmental requirements according to the latest techniques developed and used in the Republic of South Africa, it will be necessary to significantly improve the operational management of the Orange River System. The upgrading of gauging stations and the implementation of real time modelling is therefore recommended as one of the first options to be implemented to improve the operational management of the system and to increase the water availability.
- Different environmental flow requirements resulted in significantly different impacts on the available surplus in the system. It is of utmost importance that processes should be put in place, to in time store and collect the necessary data required enabling specialists to make sound recommendations in future, with regards to the actual environmental flow requirement needed. This will also include the upgrading of current gauging structures to obtain accurate flow values at key points, specifically near the Estuary.
- It is recommended to include the Vaal and other major tributaries in future environmental flow requirement assessments for the Orange River, as sensitivity analyses showed that environmental flow requirement contributions from the Vaal alone could have a significant impact on the surplus available in the Orange River System.
- Findings from the water quality review indicated that the calibration of the WQT Model (total dissolved solids (TDS)) could possibly be postponed to a later date.
- It is strongly recommended that a separate study should be commenced to investigate the algae blooms/nutrients and other related water quality problems in the Lower Orange.
- A Vioolsdrift Re-regulating Dam needs to be constructed as soon as possible.
- Use ORRS EFRs and real time modelling in the period before the construction of Vioolsdrift Dam to be able to supply in the growing demand, and to improve the supply to the environment.
- Use the results from the Vanderkloof Lower Level Study and resulting URV to decide on the implementation of this option.
- By 2015 a combination of Vanderkloof Low Level Storage (LLS) and Vioolsdrift Re-regulating Dam is required to supply the needs of the growing demand and improved EFR (LORMS EFR). It is therefore recommended that a combined Vioolsdrift storage/re-regulating dam be constructed at that time or slightly earlier, as a raising of the dam will be required not later than 2016. An additional storage of 280 million m will be required at Vioolsdrift to be able to supply in the growing demand and EFR until 2025 in combination with Vanderkloof LLS.
- When Vanderkloof LLS is excluded as a possible future option, a storage dam of at least 830 million m^3 is required in combination with a re-regulation dam at Vioolsdrift.
- When a large storage dam is considered at Vioolsdrift, the possibility of a large dam such as Bosberg/Boskraai and Mashai should also be evaluated and compared with the large Vioolsdrift option.

2.10.6.7 **Hydrology of the Fish River (Namibia)**

2.10.6.7.1 Introduction

The hydrology in the Fish River was developed at a very cursory level of detail in the original South African studies and systems analyses. In view of the joint involvement of Namibia and South Africa on this project, it was thus envisaged that the Fish River hydrology would be reviewed and the current version in the Orange River data sets replaced with the updated information.

While a detailed rainfall/runoff assessment would be desirable, there is not sufficient time to carry out this work without causing major delays to the main study. Some review and limited modelling was therefore undertaken since the most recent major re-assessments were completed in 1987 and 1994 for the Naute and Hardap Dams respectively. A new study was initiated in 1995 by the Department of Water Affairs (DWA) (Namibia), but subsequently aborted due to the transfer of staff to the newly created Namibia Water Corporation Ltd (NamWater).

The work methodology was out in the following steps:

- Review of data (runoff at Seeheim and other key stations and rainfall data) and any preliminary findings from the incomplete 1995 study.
- Collection and analysis of rainfall data from selected key rainfall stations. Data were obtained from DWA (Namibia) and Namibia Meteorological Services (NMS)
- Simplified rainfall/runoff modelling to improve, patch and extend Fish River runoff records at the confluence with the Orange River, and at selected potential Lower Fish River dam sites.
- Analysis of lower Fish River runoff under different scenarios (present state and future/maximum dam and abstraction development)
- Short written report commenting on results and sensitivity analysis, as well as recommendations on further work.

The total water demand from the Fish River Basin was estimated at approximately 50million m³/a for 1999. This demand was supplied by a combination of ground and surface water and it is estimated that groundwater contributed 7.9 million m³/a to the total requirement. Urban and Industrial demands accounts for 3.5 million m³/a (7%), stock watering 4.5 million m³/a (9%) and the remaining 84% is mainly utilized for irrigation purposes.

Mean annual precipitation (MAP) within the Fish River catchment is low, ranging from as little as 50 mm at Ai Ais in the south to approximately 230 mm at Isabis in the north of the catchment. Rainfall occurs as convective showers and is confined mainly to a rainy season, which extends from October to April.

Potential evaporation rates are high due to low atmospheric humidity, high temperatures and long hours of sunshine. Annual potential evaporation (gross A-pan) in the catchment varies from 3 800 mm in the area to the east of Keetmanshoop to approximately 2 950 mm at the confluence with the Orange River.

2.10.6.7.2 Results

In order to provide appropriate inputs to the system analysis to be carried out as part of this study, the total Fish River Basin was sub-divided into five sub-catchments as listed in **Table 2-81**. Details of the sub-catchments areas, mean annual runoff, etc., are summarised in **Table 2-81**. Although a total runoff of 736 million m³/a is generated from the Fish River Basin, only 512 million m³/a reaches the Orange River under natural conditions, as 224 million m³/a is lost due to evaporation and riverbed losses. The bulk of the runoff is generated in the Hardap, Naute and Seeheim sub-catchments where the unit runoff varies between 7 mm/a to 14 mm/a in comparison with the 1 mm/a to 1.5 mm/a in the Lower Fish and Konkiep catchments.

Table 2-81: Fish River Basin Characteristics

Sub-catchment	Incremental catchment area (km^2)	Natural incremental runoff for period 1920-2000			
		MAR (million m^3/a)	Standard deviation (million m^3/a)	Coefficient of variation	Unit Runoff (mm/a)
Hardap Dam	13 600	193.63	305.32	1.58	14.24
Naute Dam	8 630	61.53	86.76	1.41	7.1
Seeheim	32 800	345.34	614.31	1.78	10.53
Konkiep	32 800	48.00	85.39	1.78	1.5
Lower Fish	8 650	87.72	156.03	1.78	1.0
Total Fish	**95 680**	**736.22**			
Minus river losses		224.02			
Total Fish	**95 680**	**512.20**	**842.54**	**1.64**	**5.3**

Due to the fact that a detailed rainfall/runoff assessment was not carried out for the Fish River, it was considered necessary to carry out some sensitivity analysis. The purpose of the sensitivity analysis was to determine the effect of changes in the hydrology as well as changes in development, on the system yield and on the spills from the Fish into the Orange River.

Results from the sensitivity analysis showed that the system yield and spills from the Fish River are not very sensitive to changes in the hydrology. Increasing the hydrology by 10% will typically result in an increase in yield of between 6% and 7,5%. The impact on the frequency of specific monthly flow events was also relatively small for changes in the hydrology. Typically, the occurrence of months with zero flow increased only with 0.1% from 74% of the time for the reference hydrology to 74.1% for the 15% reduced hydrology. High monthly flows (flows higher than 1000 million m^3) in return reduced from 0.4% of the time to 0.1% of the time as result of the reduced hydrology.

Development options resulted in an increase in the coefficient of variation and reduced the occurrence of low flows (less than 50 million m^3). For a 3 mean annual runoff (MAR) dam in the Lower Fish the number of zero spill months for example increased by 18 months over the simulation period 1920 to 1987.

The sensitivity analysis results therefore indicated that the system yield and Fish River spills were not affected significantly by the changed hydrology but rather by increased development options.

It can therefore be concluded that the simplified rainfall/runoff modelling as carried out for this study is sufficient for the purposes of this study and that a detailed rainfall/runoff assessment is not necessary.

2.10.6.7.3 Recommendations

It is recommended that the incremental MARs and associated monthly records be accepted for utilisation in subsequent work as part of the current Management Study of the Lower Orange River (LOR).

Despite the above recommendation, it is recognised that there is a need to carry out a detailed re-assessment of the hydrology of the Fish River, in particular the Fish River downstream of Hardap Dam and it is recommended that the Department of Water Affairs should program such a study. It is however not required for the purpose of the current Management Study where the focus is on the Lower Orange River and not on the Fish River.

It is recommended that a study into the technical feasibility of constructing a gauging station in the Lower

Konkiep, as close as possible to the confluence with the Fish River be considered.

2.10.6.8 Review of RSA Hydrology

The main aim of this review is to increase the transparency of South African studies for the benefit of the Namibian Team and at the same time to ensure that they are well acquainted with the hydrology of the river basin in South Africa and Lesotho.

This review is based on three key linked information sources:

- Hydrological reports as obtained from the "Vaal River System Analysis Update", "Orange River Development Project Replanning" (ORRS) and the "Orange River System Analysis" studies.
- The systems analysis set-ups, which facilitated understanding of priorities and transfers.
- The stream flow datasets for all of the sub-catchments as derived in the studies carried out to compile the systems analysis update.

The hydrological studies and systems analyses carried out in South Africa covering the entire Orange River Basin within South Africa and Lesotho have been reviewed. The general impression is that the work has been carried out thoroughly as far as the data will allow. There is no reason to disagree with the hydrological files being used as input for the systems analysis. However, as is generally the case with hydrological and associated data, given the human and financial resources, it would of course be possible and worthwhile to improve the accuracy of the data.

As stated on several occasions in the literature reviewed, the Vaal and Orange River Basins are the most important water resource systems in South Africa. They support more than 50% of the country's GDP. It is logical; therefore, that money spent on improving the accuracy of our knowledge of the system is well-spent and can be easily justified. Hence, the current study, and the major investments being made by the Governments of South Africa and Namibia. However, in view of the fact that some of the hydrological studies studied in this review are already more than a decade old, it would seem worthwhile to utilise any new data that have been collected since their completion and to update these studies. This includes the incremental catchment upstream of Vanderkloof Dam and downstream of the Lesotho Border, as well as the Lower Orange with the exception of the Fish River in Namibia.

The need to update hydrological data and the analysis thereof should not be limited to runoff data, but should also include improved collection of water demand data. The effort put over to analysis of water demand information in the studies reviewed reflects a strong awareness of the importance of water demand data. Any basin-wide efforts to update hydrology and water demand should not be undertaken lightly and will probably require a multi-disciplinary approach involving several Ministries. Consideration should be given to using a GIS-driven approach, which can be easily updated on a regular basis.
In the interest of transparency and common understanding at a technical level, it is recommended that key Orange River Basin river stations in South Africa (and Namibia) be identified for common monitoring. Joint monitoring would include water level monitoring (real-time telemetry), flow measurements for station calibration, and conversion of water levels into discharge. It would seem logical to extend this transparency to include all gauging stations and also to cover water demand data.

2.10.7 Water Conservation and Demand Management

2.10.7.1 Water Demand Management in the Irrigation Sector

The performance of the irrigation sector with respect to water management and conservation is not highly regarded in water management circles. Perceptions exist that:

- the majority of farmers do not "schedule" correctly to fulfil the needed crop water requirements;

- water supplies are not well managed;
- distribution losses are high;
- existing systems, both on scheme and on farm, are not well maintained;
- few farmers are concerned about actual crop irrigation requirements,
- water wastage is excessive;
- water management has a low priority; and
- Irrigation should be reserved for "high value" crops.

"These are universal perceptions that are not only confined to Southern Africa, and may or may not be justified. Most developed countries, our competitors in global markets, are taking active steps to improve irrigation farming effectiveness and water use efficiency. In most developing countries, including Southern Africa very little support is given by Central Governments to improve irrigation farming practices and water use efficiency. There are, of course, individual outstanding exceptions, but they remain exceptions", (Crosby, 2001).

2.10.7.2 Water Demand Management in the Vaal River System and Eastern Cape

A brief review was done of the Vaal River catchment and the Eastern Cape that receive water from the Orange River through the Lesotho Highlands Project and via the Orange - Fish transfer system respectively. Although the Vaal River System and the Eastern Cape abstract water upstream of the Common Border Area, they account for a significant portion of water use from the Orange River. In this study, it was assumed that any potential savings in the Vaal River System and the Eastern Cape would be used for expected future water requirements in those areas. The potential savings that can be realised in the irrigation sector in these areas, if it is assumed that the same conditions exist as in the LORMS area, are summarised in **Table 2-82.**

Table 2-82: Expected WDM Reductions in the Vaal River System and Eastern Cape

Demand Area	Irrigation Water use (Mm^3/a)	Management & Scheduling (% net savings)	Metering & Conservation tariffs (% net savings)	Improved Irrigation Systems (% savings)
Vaal River System	796	7%	7% on the reduced demand	10 to 15% the reduced demand
Eastern Cape	607	7%	7% on the reduced demand	10 to 15% on the reduced demand

Note: An allowance of 30% return flow was made to calculate net water savings

The following issues need to be taken into account regarding the efficient use of water in the Vaal River System:

1. Presently, the transfer volume for the implemented Lesotho Highlands Water Scheme is a fixed volume annually. Water use inefficiency in the Vaal catchment would impinge on the future availability of water in the Lower Orange River if further phases of the Lesotho Highlands Water Scheme need to be implemented as a result of higher water demand in the Vaal River System.
2. Deterioration of the water quality in the Vaal River and transfer of good quality water from the Senqu River may have a negative impact on the water quality below the Vaal/Orange confluence at Douglas. Although the operating rules on the Vaal River System strive to prevent spills from the Vaal River into the Orange River, the fixed transfer volumes in the upper catchments may create temporary spills.

2.10.7.3 Water Demand Management in LORMS

2.10.7.3.1 Reducing of Conveyance Losses in Canals

According to the estimated net losses of 21.54 Mm³/a (14.25%) the Orange/Riet Canal is a good candidate for a more detailed investigation by the Water User Association (WUA). It is not possible to quantify potential savings as part of this study due to a lack of more accurate information on the canal system.

2.10.7.3.2 Water Demand Management in Urban Areas

The biggest potential to improve water use efficiency is in Oranjemund, Rosh Pinah and Alexander Bay. Residents in the towns get unmetered water free of charge that leads to wastage. The per capita water consumption is summarised in **Table 2-83**. It is suggested that a value of 350 l/p/d be accepted as a norm.

Table 2-83: Urban Water Consumption of Mining Towns

Consumer	Consumption (Mm³/a)	Population	Consumption (l/p/d)
Oranjemund	6.45	5 451	3 239
Rosh Pinah Town	0.60	1 537	1 071
Alexander Bay Town	2.60	3 164	2 250

The following basic WDM instruments were identified as minimum requirements for implementation of WDM in Urban areas in the LORMS area:

- Appropriate tariffs that enhance water conservation;
- Metering of water to all end users;
- Information and education of the water users;
- Regular water balances to establish non-revenue water with benchmarking;
- Good maintenance of reticulation and plumbing systems;
- Monitoring of night-flow measurement; and
- Pressure management.

2.10.7.3.3 Water Demand Management in the Mining Sector

Most mines use water efficiently because they use high volumes of water and the total cost of water usage is relative high. Most mines in the Common Border Area (CBA) covered in the study have implemented various water saving measures.

2.10.7.3.4 Summary of Expected Savings

The figures in **Table 2-84** give a summary of what can be achieved through WDM initiatives, if implemented. The success of the measures will depend on:

- final conclusions after the yield modelling (reducing operation losses);
- clear policy guidelines pertaining to tariff policies and rebates;
- advice on scheduling; and
- Training of farmers.

Table 2-84: Summary of Expected Savings through WDM Initiatives

Activity and Location	Volume Mm³	Costs/m³ saved (cent)	Remarks
Water Efficiency Unit (Upington)	Unknown	Unknown	Improves water productivity
Scheduling* Upstream Vanderkloof	7.2	6.95	Improves water productivity. 7.0% net water saving

Downstream Vanderkloof Common border	63.9 3.6	3.20 10.24	5.0% net water saving 3.5% net water saving
Metering & Pricing* Upstream Vanderkloof Downstream Vanderkloof Common border	 6.7 84.3 6.9	 5.13 3.12 2.88	Improves water productivity. 7.0% net water saving on the reduced consumption after the implementation of scheduling
Irrigation Systems* Gifkloof/Neusberg	 53.4	 89.7	Improves water productivity by 24.1%
Conveyance losses Orange Riet Canal	 Unknown	 Unknown	 Requires a detailed investigation
Urban Oranjemund & Rosh Pinah Alexander Bay	 6.1 Unknown	 0.37 Unknown	 Lower water use. Water use to be verified
Mining	Unknown	Unknown	Reuse to be controlled with permit conditions

Note: *An allowance was made for 30% return flow in all the calculations to give net water savings

2.10.7.3.5 Recommendations

The following recommendations and time frames are proposed to improve Demand Management in the LORMS area:

It is recommended that:

1. That a Pilot Study be carried out (January 2005 to December 2009), covering approximately 20 farms in the Neusberg/Gifkloof area to verify expected water savings, cost of such savings and improved crop yields for farmers before any major WDM initiative are implemented in the two targeted areas identified in this study. The benefits and costs of specialised advice to farmers (Water Use Efficiency Group), scheduling, metering and tariffs (rebates) and improved irrigation systems needs to be established for the two farmer groups.
2. The proposed measures and time table to improve water use efficiency for the irrigation sector as summarised below be accepted:

Water Authority (Supplier)		
Timing	**WDM Measure**	**Expected results**
Short-term Immediate to five years	**Support structures** • Establish WUA's in the common border area • Establish water use efficiency advisory group • Foster private sector involvement • Train farmers **Policies and control** • Volumetric allocation of water • Control abstraction through the metering of irrigation water • Develop and implement conservation orientated tariffs/rebates etc.	Improved farm management and water productivity Estimated net water savings of 7%

Water Authority (Supplier)		
Timing	**WDM Measure**	**Expected results**
	Technical & Planning • Allocate quotas based on certified proper irrigation system planning on new schemes • Allocate quotas based on proper drainage systems on all schemes	Higher water use efficiency and higher yields through water application and proper drainage
Medium term Five to ten years	**Policies and Control** • Introduce water markets through legislative process • Introduce assurance-based supply mechanisms incorporated in the tariffs **Operational** • Lower conveyance losses	Higher crop yields
Management of Farms		
Timing	**WDM Measure**	**Expected results**
Short-term Immediate to five years	• Acquire scheduling system • Improve maintenance of application systems, canals and storage facilities • Initiate proper drainage	7% net water saving. Higher value crops and higher crop yields /m3 water used. Increasing financial returns/m³
Medium term Five to ten years	• Re-engineer existing irrigation systems • Install more efficient irrigation systems • Better matching of crops with climate, soil and water quality • Consider selling of water quotas	Net water savings up to 10.2% and increased crop yields. Uneconomic water uses would be lower.
Long term Ten to fifteen years	• Install more efficient irrigation systems • Cover soil to lower evaporation	Improve water use efficiency.

1. The principle that WDM options in a specific country can only be used to satisfy requirements (in-stream flow requirements, increased demand, etc.) for the whole river, and that allocation of an equitable share for Namibia cannot be linked to the successful implementation of WDM in South Africa be accepted.
2. The principle that both countries should strive for comparable levels of water use efficiency within the irrigation sector along the Common Border Area be accepted.
3. A Water Use Efficiency Group for the area downstream of Upington (similar crop types), including the Common Border Area, be established at an estimated initial cost of R 2.5 million (R 1.5 million recurrent costs) and that the cost be shared annually in accordance with the irrigation areas between the two countries.
4. The high estimated net losses of the Orange/Riet Canal are investigated in more detail during the full Feasibility Study in order to determine the viability of lowering conveyance losses.
5. A more detailed investigation is carried out for the Gifkloof/Neusberg area to determine the viability of improved irrigation systems as part of the main Feasibility Study.
6. The principles and guidelines as discussed in the report relating to metering and conservation tariffs are developed further for finalisation between the two countries.
7. Permit allocations for the mining towns of Oranjemund, Rosh Pinah and Alexander Bay (after verification) be reduced to lower the excessive water consumption to approximately 350 ℓ/p/d with the condition that end-consumers are metered, and that they pay for water consumed within the next three years.
8. The following basic WDM instruments be approved as minimum requirements for implementation of WDM in Urban areas in the LORMS area:

- Appropriate tariffs that enhance water conservation;
- Metering of water to all end users;
- Information and education of the water users;
- Regular water balances to establish non-revenue water with benchmarking;
- Good maintenance of reticulation and plumbing system;
- Monitoring of night-flow measurement; and
- Pressure management.

The following stipulations are added to permit applications and approvals pertaining to water use efficiency in the Mining Sector:

- Mandatory recycling of water from slimes dams, including the minimisation of evaporation (paddock system) within one year after starting with production.
- Metering and charging of water to households, no free water to residents in mining towns except for baseline water (6 kℓ/household/month).

2.10.8 Dam Development Options and Economic Analysis - Volume 1 & 2

This report includes:

- Revised and updated dam design component-sizing criteria, and dam costing criteria.
- Details of additional dam sites that were identified on the Orange River along the common border.
- Details of a dam site that was identified on the Fish River.
- Details of pre-screening factors that were applied in making an initial elimination of dam sites.
- Details of the various pre-screening processes in which dam development options were eliminated from further consideration.
- A list of more promising dam sites that were considered in more detail.
- Comparison of the best dam development option with the previously-identified Vioolsdrift and Boegoeberg Dam sites.

2.10.8.1 **Development of Design and Cost Criteria**

The study commenced with a review of the ‘Guidelines for the preliminary sizing, costing and engineering economic evaluation of planning options’ developed during the Vaal Augmentation Planning Study (VAPS) for the South African Department of Water Affairs and Forestry (DWAF).

The component sizing criteria were reviewed and modified where deemed necessary. In particular, the sections on flood determination for the various dam types were rewritten due to inconsistencies in the terminology and presentation in the VAPS guidelines. The sections on foundation grouting were rewritten to be consistent between the various dam types.
The cost models were updated by utilising contract prices, with appropriate escalation, for the recently constructed Maguga, Mohale, Inyaka and Bivane (Paris) Dams, as well as the Matsoku Weir.

2.10.8.2 **Identification of Dam Sites**

The purpose of this sub-task was to mark up all the relevant options identified in the Orange River Development Project Replanning Study (ORRS) on the 1:50 000 topographical maps, to identify any new options to the west of the 20° longitude along the common border between South Africa and Namibia and to identify a potential dam site on the Fish River.

2.10.8.2.1 Options Upstream of the Common Border

In the ORRS, eight possible development options upstream of the common border were identified and evaluated. No new sites were identified in this study. These development options are listed in the **Table 2-85**.

Table 2-85: Development Options Identified in the ORRS Upstream of the Common Border within the LORMS Study Area

Development Option	Location
New Boegoeberg Dam	~ 1 km downstream of existing Boegoeberg Dam
Lanyonvale Dam	~ 60 km downstream of Douglas
Torquay Dam	~ 47 km downstream of Hopetown and ~ 35 km upstream of Vaal/Orange Confluence
Hospital Dam	~ 20 km upstream of Prieska
Hereford Weir	~ 35 km downstream of Hopetown
Eskdale Weir	~ 15 km downstream of Hopetown
Elandsdraai Dam	~ 15 km upstream of Hopetown

2.10.8.2.2 Options along the Common Border

All the potential dam sites along the common border that were identified in this study, as well as those identified in the ORRS, are listed in the **Table 2-86**.

Table 2-86: Development Options Identified along the Common Border

Name of Dam Site	Approximate Chainage [(1)] (km)	Comment
Kabies	148	Identified in ORRS
Grootpens A	173	
Grootpens B	177	
Aussenkehr	223	Identified in ORRS
Vioolsdrift A	303	Identified in ORRS
Vioolsdrift B	318	Identified in ORRS
Vioolsdrift C	322	Identified in ORRS
Vioolsdrift D	327	
Kambreek	433	Identified in ORRS
Coboop A	465	
Coboop B	475	
Coboop C	479	
Beenbreek	512	
Yas	542	
Komsberg	580	

Note: 1) The chainage is the approximate distance measured along the Orange River, starting at the mouth of the river.

2.10.8.2.3 Options on the Fish River

A site was selected at Koubis, immediately upstream of the Ai-Ais Nature Reserve, as being representative of typical sites in the area to provide reservoir characteristics for input into the hydrological model of the Lower Orange River (LOR). Initial runs of the hydrological model indicated that a dam on the Fish River would not be attractive in the regional context and no further investigation was carried out.

2.10.8.3 Pre-Screening of Development Options

2.10.8.3.1 Options Upstream of the Common Border

The ORRS concluded that most of the initial development options considered in the Orange River Basin could be eliminated from further consideration on financial, social, engineering or environmental grounds. Only a small number of options remained as possible future developments, however, it was not possible to make firm recommendations at that stage.

In all of the remaining options, it was considered necessary to create some form of operational storage along the Orange River at either Vioolsdrift or Boegoeberg. Both options had similar Unit Reference Values (URVs) and it was not possible to eliminate either of them during the Pre-feasibility Phase of the ORRS.

In the LORMS, no reason could be found to differ from the conclusion of the ORRS that the most feasible option for the construction of a new dam upstream of the common border is the New Boegoeberg Dam.

2.10.8.3.2 Options along the Common Border:

A preliminary pre-screening was done on the dam sites that were identified earlier, with a view of eliminating those options that were clearly flawed from engineering, social or environmental considerations. The remaining options, namely Vioolsdrift A (as representative of the four sites), Yas and Komsberg were subjected to a cost analysis and evaluation against the pre-screening criteria. The comparison between the pre-screening cost and the reservoir capacities showered that Komsberg had the lowest cost, and the costs of other two were similar but about 20% higher

The evaluation against the pre-screening criteria is shown in the **Table 2-87**.

Table 2-87: The Evaluation against the Pre-screening Criteria

Pre-screening Factor	Dam Site		
	Vioolsdrift A	Yas	Komsberg
Site Considerations			
Topography of site and basin	Moderately good dam site	Good dam site	Very good dam site - narrow valley
Geological conditions	Only the Vioolsdrift Dam site was investigated (in the ORRS study) and this pre-screening factor can therefore not be used as a factor for pre-screening purposes.		
Construction Materials & borrow areas	Only the Vioolsdrift Dam site was investigated (in the ORRS study) and geological conditions can therefore not be used as a factor for pre-screening purposes.		
Storage capacity potential	Potential storage capacities all exceed the maximum volume that can be utilized effectively		
Small re-regulating dam or large storage dam	All sites are suitable for either a small re-regulating dam, or a larger storage dam.		
Design floods & spillway arrangements	Design floods similar due to relatively great distance to main catchment areas		
	Mass concrete overflow	Mass concrete overflow plus possible by-wash	Mass concrete overflow
Seismic characteristics	All of the sites are situated in a low seismic risk area.		
River diversion during construction	For pre-screening purposes only mass concrete gravity dams were considered, and river diversion considerations are therefore identical.		
Considerations to site establishment	Not considered during pre-screening.		
Access roads	Access is difficult due to steep valley sides	1:50 000 maps do not indicate roads in the immediate vicinity of the dam sites	
Contribution to the system yield	Considered to be similar for all sites due to negligible additional inflow from catchment areas in the vicinity of these dam sites.		

Pre-screening Factor	Dam Site

	Vioolsdrift A	Yas	Komsberg
Social and environmental impacts			
Potential social impacts	Social impacts of the individual sites were not investigated, but the social impacts of the sites should not differ from one another significantly.		
Potential environmental impacts	Considered relatively low	Inundation of parts of the Augrabies Falls National	
Proximity / location to major centres	~ 20 km from Vioolsdrift /Noordoewer	~ 60 km from Onseepkans	~ 90 km from Onseepkans
International borders	Situated on the border between Namibia and South Africa.	The above dams and other dams constructed in the vicinity will have a lesser effect on international borders as water pushes up past 20^{o} longitude.	
Possibility of hydro-power generation	There is the possibility of hydro-power generation at all sites investigated.		
Proximity to power lines	20 km (line at Vioolsdrift /Noordoewer)	200 km (line on farm Kabis)	240 km (line on farm Kabis)
Flooding of existing infrastructure	No flooding of major infrastructure		
Flooding of irrigation areas: existing and potential	Potential flooding of irrigation areas in the vicinity of the river.		Smaller irrigation areas flooded
Flooding of mining and prospecting license areas	On Namibian side of border, all dams flood areas over which mining and prospecting licenses have been issued. Not much difference between one dam and the other.		Smaller areas flooded
Flooding of areas of archaeological importance	The conclusions of the desk study are that not many detailed investigations had been carried out to date and further investigations would have to be carried out for particular sites in the case of dam construction.		
Sedimentation rate	The difference is sedimentation rates between the different sites was not investigated but is not considered to be significant enough to influence a choice between the sites.		
Potential effects on water quality	The difference on the effects on the water quality between the different sites was not investigated, but is not considered to be significant enough to influence a choice between the sites.		
Cost	Moderate cost	Similar to Vioolsdrift	Lowest cost of all sites

2.10.8.4 Discussion of Pre-screening Analysis

2.10.8.4.1 Vioolsdrift A

The dam site is situated close to existing infrastructure, but access to the site will be difficult due to the steep valley sides. The dam will inundate areas over which mining and prospecting licenses have been issued, over most of the distance that the impounded water pushes up the river.

2.10.8.4.2 Yas

This dam site is situated approximately 54 km downstream of the border at 20^{o} longitude. As in the case of the Komsberg site, much of the water stored by the dam will be on the South African side of the border and the dam will inundate parts of the Augrabies Falls National Park. The dam would not inundate much irrigable land, areas of mining and prospecting licenses, towns or villages, road infrastructure, or power lines. A dam at this site would have a similar cost to dams at the Vioolsdrift sites.

2.10.8.4.3 Komsberg

This dam site is situated approximately 7 km downstream of the border at 20^{o} longitude. Most of the water stored by the dam will therefore be on the South African side of the border and the dam will inundate parts of the Augrabies Falls National Park, which is situated along the northern side of the river. The dam would not inundate much irrigable land, areas of mining and prospecting licenses, towns or villages, road infrastructure, or power lines.

Based on the 1:50 000 mapping, this site was found to be the most economical site along the common border for the construction of a dam for the range of reservoir capacities under consideration. However, the extent of the inundation of the Augrabies Falls National Park remained of concern.

2.10.8.4.4 Conclusions

Based on the pre-screening the following conclusions were made:

- The Yas Dam site does not offer any significant cost benefits over the Vioolsdrift site and will inundate parts of the Augrabies Falls National Park. It was therefore excluded from further analysis.
- From a capital cost point of view (as defined in this report), the Komsberg site is more cost-effective than the Vioolsdrift site for the construction of either a smaller re-regulating dam or a larger dam to improve the yield of the system. The allowable inundation of the Augrabies Falls National Park, however, still had to be determined.

The net result of the pre-screening was that both the Vioolsdrift A and the Komsberg Dam sites were taken to a Decision-making Workshop.

2.10.8.5 **Assessment of Pre-Screened Development Options**

In the pre-screening process the number of dam sites that could possibly be carried forward to the preliminary design stage was reduced to the following sites:

Upstream of 20^{o} longitude (i.e. upstream of the common border):

- New Boegoeberg Dam

Downstream of 20^{o} longitude (i.e. along the common border):

- Vioolsdrift Dam
- Komsberg Dam

These three possible options were investigated in order to make more accurate cost estimates, determine yields and assess benefits and impacts. The options were then evaluated at a Decision-making Workshop by a team consisting of the Client, selected stakeholders and the Consultant.

Prior to the workshop, the following activities were carried out on the three dams:

- A yield analysis was carried out in order to determine the required storage capacities for specified yields.
- A sedimentation analysis was carried out on the New Boegoeberg and Vioolsdrift sites in order to estimate the sedimentation volumes.
- A financial analysis was carried out in order to determine the unit reference values of dams of various

storage capacities.

The pertinent data for the New Boegoeberg, Vioolsdrift and Komsberg Dam sites is summarised in **Table 2-88**.

Table 2-88: Pertinent Values for the Preferred Sites for Re-regulating Dams

	New Boegoeberg	Vioolsdrift	Komsberg
Proposed dam size (million m³)	163	260	260
Unit reference value (@ 8%) (R/m³)	0.35	0.26	0.24
Saving in operational losses (million m³/a)	62	170	126

At the workshop, it was decided that the Vioolsdrift and Komsberg Dam sites were preferred to the New Boegoeberg Dam site for the following reasons:

- Significantly lower unit reference values; and
- Significantly larger saving in operational losses.

Due to the fact that dams for all heights under consideration at the Komsberg site would inundate parts of the Augrabies Falls National Park, it was decided that the Komsberg site should not be considered unless there were significant cost advantages. The cost estimates of the Vioolsdrift and New Boegoeberg Dam sites had been done on 1:10 000 mapping with 5 m contours, whilst that of the Komsberg Dam site was done on 1:50 000 mapping with 20 m contours. It was therefore decided that 1:10 000 mapping should also be prepared for the Komsberg site.

Based on this mapping, the quantities for the Komsberg Dam site were re-calculated. The URV for a dam with a capacity of 260 million m³ increased to R0.28/m³. The river bed levels downstream of the Augrabies Falls were also checked by using the Digital Elevation Models (DEMs) of the area.

The river bed level at the Komsberg Dam site is at approximately RL 430.8 m. Above a full supply level (FSL) of approximately RL 432 m water will start pushing up into the Augrabies Falls National

Park, and the rapids downstream of the Falls will start to be inundated at levels above RL 450 m. The FSL for the proposed re-regulating dam will be at approximately RL 446m.

After the workshop, field visits were made to the Vioolsdrift and Komsberg areas in order to carry out a vegetation study and ecological and archaeological assessments. The improved costs, the results of the vegetation and archaeological studies, the ecological assessment, as well as other factors that needed to be considered in assessing the options were presented to the Client.

A summary of the above assessments is presented in **Table 2-89**.

Table 2-89: Summary of Assessment of Vioolsdrift and Komsberg Options

Dam Sites	Vioolsdrift	Komsberg
Issues		
Potentially serious implications of any raising of the dam in future	None	Inundation of the rapids downstream of the Augrabies Falls.
Impact on Augrabies Falls and National Park	None	Dam basin inside the Park and potential sediment and back water affects in rapids
Saving in operational losses	170	126

Dam Sites	Vioolsdrift	Komsberg
Issues		
(million m³/a)		
Ecological	Would have the most impact relative to the other options.	Would have a lower impact than the Vioolsdrift Dam option
Archaeological	Would have the greater impact on archaeological remains.	Would have a lesser impact on Archaeological remains than Vioolsdrift.
Vegetation	Would overall affect a less developed stretch of riparian landscapes and habitats.	Would affect large stretches of relatively pristine riparian woodlands, though interrupted by agricultural developments.
Unit reference values (R/m³)	0.26	0.28

On the basis of these factors, it was decided that the development of a re-regulating dam at the Vioolsdrift Dam site was preferred to the Komsberg Dam site.

2.10.8.6 Preliminary Design

2.10.8.6.1 Dam Site

The preliminary design was based on the Vioolsdrift A Dam site due to the smaller cross-sectional area than the other three sites and to facilitate comparison with the ORRS work.

2.10.8.6.2 Available Mapping

All the work in the ORRS at the Vioolsdrift Dam sites was based on the 1:50 000 topocadastral maps of the area. The 1:50 000 mapping was retained to compile the storage capacity curve for the site, but survey plans at a scale of 1:10 000 with 5 m contours were prepared from aerial photography for the dam site.

2.10.8.6.3 Flood Determination

In terms of the Guidelines for Sizing of Mass Concrete Dams, the flood magnitudes were based on the Regional Maximum Flood (RMF) concept. The Safety Evaluation Discharge (SED) was calculated to be 26 300 m³/s and the Recommended Design Discharge (RDD) 14 250 m³/s. The diversion flood for a concrete dam is based on the 1:10 year recurrence interval (RI) flood, which was estimated to be 3 000 m³/s.

For the preliminary design a total freeboard of 10 m was used.

2.10.8.6.4 Spillway Design

Due to the high flood magnitudes that need to be passed over the dam, the complete base width of the valley of 375 m will be used as spillway.

2.10.8.6.5 Dam Size

The preliminary design was done for a dam with the following parameters:

- Total storage capacity 260 million m³
- Allowance for sedimentation 150 million m³ (from ORRS)
- Live storage capacity 110 million m³
- Wall height to (NOC) 35.1 m

- Wall height to FSL 25.1 m
- River bed level RL 176.4 m (approximately)
- FSL RL 201.5 m
- NOC RL 211.5 m
- Total crest length 485 m

2.10.8.6.6 Dam Type Selection

Due to the large design floods the complete river section must be utilised as a spillway. A concrete gravity dam was therefore considered to be the only type of dam suitable for the site. Due to its inherent lower costs a Roller Compacted Concrete (RCC) dam was chosen for the preliminary design.

2.10.8.6.7 Outlet Works

The estimated monthly demand figures for a re-regulating dam vary from a minimum of 2.3 m^3/s in June to 11.8 m^3/s in January. Two 2 m diameter pipe stacks are allowed for with 1.8 m diameter inlets at 7 m centres. With a normal operating flow velocity of 4 m/s each pipe stack can discharge 12.6 m^3/s. The water will be discharged through 1.2 m diameter sleeve valves. The estimated maximum environmental flow requirement is 400 m^3/s in February.

Whilst it can be expected that the dam would normally overflow during this time, allowance has been made for the installation of two 3.0 m wide by 3.5 m high radial gates to act as bottom outlets.

2.10.8.6.8 Flood Diversion Works

The first stage of the river diversion will consist of an approximately semi-circular 8 m high Roller Compacted Concrete (RCC) cofferdam that will be built on the left hand side of the river valley to close off 250 m of the river channel. Culverts will be installed in the Roller Compacted Concrete (RCC) for diversion purposes during the second stage.

The second stage will require 15 m high Roller Compacted Concrete (RCC) upstream and downstream cofferdams to link the right flank with the already completed dam.

2.10.8.6.9 Access Roads and Site Establishment

Access to the site is difficult due to the steep valley sides. There is also no space available at the dam site for site establishment. For the purposes of the preliminary design a gravel access road on the left bank was cost. The access road will be prone to frequent flooding unless it can be located above approximately 10 m above the river bed level.

2.10.8.6.10 Dam Raising

According to the systems analysis, the projected future downstream demands would require a live storage volume of 1 500 million m^3. The 50-year sediment volume was estimated at approximately 600 million m^3. The total storage volume would be 2 100 million m^3 at a spillway height of 54.6 m. This would require a 29.5 raising of the re-regulating dam.

The re-regulating dam can be raised by adding Roller Compacted Concrete (RCC) on the downstream side. In order to allow for such an eventuality the Outlet Works were moved 24 m downstream in the preliminary design. The Intake Tower will be extended vertically whilst adding further intakes to the pipe stacks.

2.10.8.6.11 Hydropower Potential

The available flow rate for hydropower generation was taken as the monthly demand figures plus the minimum environmental flow requirement (EFR). The average flow rate over a full year was estimated at 15.4 m^3/s. The minimum available head is 20.3 m.

The maximum generating capacity is 4.2 MW. The total annual power generation was estimated at 21.3 GWh.

The estimated capital cost of the power station is R30 million, which allows for all civil and mechanical/electrical works up to and including the switchgear at the dam site. No allowance was made for the cost of any distribution lines. The estimated potential income is R3.4 million per annum, based on a selling rate of R0.12 per kWh and a carbon emission reduction subsidy of R0.04 per kWh.

2.10.8.7 Cost Estimate

The total project cost for a Roller Compacted Concrete (RCC) re-regulating dam at the Vioolsdrift A site at April 2004 rates is estimated to be R 561 million.

2.10.8.8 Economic Analysis

The Boegoeberg, Vioolsdrift and Komsberg sites were compared on an engineering economic basis. It firstly proved that the Vioolsdrift site is more beneficial than the Boegoeberg site for the full spectrum of capacities investigated. Initially, a reregulating dam at Komsberg seemed more beneficial than at Vioolsdrift, but after more detailed mapping was obtained, Vioolsdrift proved to be the more economic site for the re-regulating dam.

The analysis proved that the re-regulating dam only will not make adequate additional yield available to serve the full demand until 2025. Additional storage on the system is required.

Analysis of the Vioolsdrift Dam options proved that a phased development, i.e., the future raising of the re-regulating dam, is economically more beneficial than construction to full capacity at once for the larger capacity dam. The outcome of other studies will also influence the decision if the re-regulating dam is to be raised or additional storage is to be created elsewhere in the system. It is recommended that this aspect be investigated further in the Feasibility Study.

2.10.9 Environmental Assessment of the Proposed Dam Sites on the Orange River

The LORMS included an initial comparative environmental assessment (Environmental Assessment of the Proposed Dam Sites - DWAF Report No PB D000/00/4503) on the Orange River that aims to compare the potential environmental implications of preferred dam sites.

It was initially envisaged that this assessment would be based on the Boegoeberg and Vioolsdrift Dam sites. However, the Boegoeberg site was rejected during the initial screening exercise and the Komsberg site was added as a potential option for further review. The assessment compares the merits of three alternative dam sizes at Vioolsdrift and, one at Komsberg as follows:

- Vioolsdrift: Dam wall heights of 25 m; 44 m and 55 m;
- Komsberg: Dam wall height of 23 m.

The Vioolsdrift Dam site is located some 9 to 10 km upstream of the existing Vioolsdrift Weir, while the Komsberg site is situated approximately 7 km downstream of the border at 20 degree longitude. Most of the area inundated by the Komsberg reservoir will be in South Africa and the reservoir will inundate parts of the Augrabies Falls National Park, but not the canyon area. The dam would not inundate much irrigable land, areas of mining and prospecting licenses, towns or villages, road infrastructure, or power lines.

The purpose of this comparative environmental assessment was to:

- document the key environmental issues, at a pre-feasibility level;
- gather focussed information on the most relevant environmental parameters at the Komsberg and Vioolsdrift sites;
- provide a comparative assessment of the two dam sites in order to compare the potential impacts and to ascertain whether either should be rejected on environmental grounds; and
- Identify areas of uncertainty that need further investigation.

The studies were restricted to the ecological, social and heritage issues. In addition it should be noted that the effect of downstream flows and downstream impacts on the river and estuary are not covered in this document as these aspects were covered in the Specialist Report on the Environmental Flow Requirements – Riverine and the Specialist Report on the Determination of the Preliminary Ecological Reserve on a Rapid Level for the Orange River Estuary. Also, being an initial comparative environmental assessment, the report was based primarily on a desktop study with limited site visits. This report did not aim to meet the requirements of any specific environmental legislation.

The report provides a brief description of the existing biophysical and socioeconomic environment for the Lower Orange River, with a focus on the area below the Augrabies Falls and the inundation area of the proposed Komsberg and Vioolsdrift Dams.

The report concluded that any of the proposed dam sites will have significant negative environmental impacts on the biophysical, as well as the socio-economic environment in the vicinity of the dam site, as well as upstream and downstream. These impacts and the opportunities for mitigation need to be carefully weighed up against the advantages resulting from the dam.

With regard to biophysical impacts it is noted that rivers are interconnected wholes. Impacts that affect one component of the ecosystem do so through their effect on other components of the riverine ecosystem. For instance, reduced habitat availability or quality, fragmentation of the river system or loss of invertebrates will affect fish populations. Changes in the abundance or species composition of fish communities will, in turn, affect the abundance and distribution of other animals and plants, both riverine and terrestrial, as food supplies or preferences change and competition for food and space changes. Some of the potential biophysical impacts of the proposed dams can be ameliorated, through for instance, provision of environmental flows, fish ladders and careful positioning of outlet structures, but others cannot. The LOR has increasingly had the natural checks and balances, that controlled (and promoted) the distribution of species, removed. In their place, a more stable, more predictable flow regime has paved the way for the proliferation of those species best able to adapt to it, at the expense of other, more sensitive or specialised, species. More abstraction, impounding and artificial management of the system is likely to exacerbate these trends, bringing along with it the threats of species extinction and the costs of coping with the resultant problems, such as the proliferation of pest species of both fauna and flora; a deterioration in water quality; and the development of algal blooms.

With regard to social issues, the major areas of concern relate to the displacement of communities and changes brought about directly and indirectly as a result of a dam, as well as heritage impacts.

From the above table the following can be concluded that:

- All of the proposed options are likely to have a significant detrimental impact on the riverine and terrestrial ecosystems.
- There will be clear social and economic benefits associated with the provision of further water, but there will be impacts on the local communities.
- The dam at Vioolsdrift with the highest wall (55 m) has the most negative environmental impact and dams with lower dam walls would have relatively less impact.

- The inundation of a portion of the Augrabies Falls National Park by the proposed Komsberg Dam is perceived to be a potential fatal flaw.
- Vioolsdrift site has a number of significant impacts, but does not appear to have a fatal flaw from a biophysical and socio-economic perspective, especially at the lower two full supply levels.
- Although the opportunities for and likely success of mitigation measures have not been considered, some general comments have been made on those impacts which rated differently for Vioolsdrift (25 m) and Komsberg, as follows:
  - Some of the impacts of the barrier effects may be able to be mitigated;
  - The inundation of riparian and terrestrial ecologies cannot be mitigated; and
  - Impact on the “sense of place”.

The report concludes that from an environmental perspective, the Komsberg site is not preferred due to the impact on the Augrabies National Park. As no fatal flaws have become apparent with the two smaller Vioolsdrift Dam options, this site could be considered further from an environmental perspective.

A detailed Environmental Impact Assessment (EIA) will have to be undertaken to improve the confidence in the assessment and guide the formulation of mitigation measures. This Environmental Impact Assessment should be undertaken as part of the Feasibility Study and should meet the legal requirements of both Namibia and South Africa and comply with international best practice.

2.10.10 Vioolsdrift/Noordoewer Joint Irrigation Scheme: Assessment of Viability

2.10.10.1 Background

This report was submitted in October 2004 to the DWA Namibia by the Lower Orange River Consultants.

Vioolsdrift and Noordoewer are small towns on opposite banks of the Lower Orange River (LOR), some 350 km from the river mouth. Vioolsdrift is in South Africa and Noordoewer is in Namibia. The South African Government constructed a canal system serving the two settlements in 1933. The canal is fed from a weir upstream of the river crossing. The canal infrastructure has supported agriculture on the southern and northern banks of the LOR for some 70 years.

At Namibian independence, an international boundary was established along the LOR. This development required new management arrangements for the irrigation scheme. A Joint Irrigation Authority (JIA) was established at the end of 1993, based on an agreement between the Governments of Namibia and South Africa.

The South African Department of Water Affairs and Forestry (DWAF) had embarked on a renovation and upgrading programme just prior to the establishment of the JIA, but this work was stopped when the JIA was formed. In the view of the farmers, the support formerly provided by DWAF, has not been adequately replaced since the establishment of the JIA. In the previous decade, the JIA and the farming community experienced financial difficulties, and the JIA requested financial assistance from the Namibia / South Africa Permanent Water Commission (PWC), mainly to repair and upgrade the deteriorating canals. This study is a strategic assessment of the JIA, the farmers and their role in the communities to assist PWC decision-making on whether or not to support the JIA and under what conditions.

2.10.10.2 The study

The objectives of this study were:

- To determine (at a strategic level) the financial viability of the Vioolsdrift and Noordoewer Irrigation Scheme, including possible further investment, and the socio-economic benefits that the scheme holds for the area.
- To achieve the above through a strategic investigation and assessment of the irrigation development and the farming community.
- To make recommendations, including the institutional, managerial and agricultural changes that may be necessary to improve the financial and socio-economic situation of the scheme and the agricultural community.

These recommendations will inform decisions by the PWC regarding the role of the JIA and in particular its request for financial assistance.

2.10.10.3 **Situation assessment**

An assessment was undertaken of the following key factors:

- Scheme Infrastructure and Irrigation Development at Noordoewer/Vioolsdrift
- Future Irrigation Development at Noordoewer/Vioolsdrift
- Project Team's Findings and Cost Estimate for Rehabilitation of the Scheme

(Engineering)

- Irrigation Requirement
- Conveyance System Capacity
- Rehabilitation of the Scheme
- Water Demand Management
- Agriculture
- Economics of Agriculture Activities and Tendencies in the Area
- Barriers/Incentives to Change
- Financial Situation of JIA
- Financial Situation of the Farmers
- Institutional
- Regional Economics and Planning
- Social
- Support Infrastructure

2.10.10.4 **Conclusions**

2.10.10.4.1 Institutional Framework

The Vioolsdrift and Noordoewer JIA are too narrowly constituted to deal with the management challenges that confront the irrigation scheme and the communities that depend on it for their livelihoods.

Local Government is relatively pro-active and supportive on the Namibian side of the river, and less so on the South African side.

National and Regional Government in Namibia appear to have provided a strategic and operational framework for the economic development of the LOR, including Noordoewer. A similar framework is not evident in South Africa.

2.10.10.4.2 Agricultural Economics

The importance of Noordoewer/Vioolsdrift must not be underestimated as it is a growth point with considerable expansion possibilities that will improve the viability of the irrigation scheme.

2.10.10.4.3 Social Fabric

The local economies and the associated social fabrics of the communities are very fragile. In deciding whether to invest in the irrigation scheme or not, the two Governments need to weigh the investment and its potential returns against the cost of providing welfare support to growing numbers of poor and unemployed people.

2.10.10.4.4 Impact of Scheme Failure

The failure or serious financial deterioration of agricultural enterprises in Vioolsdrift and Noordoewer will have a number of local impacts. These are outlined under headings of severe, serious and moderate. Severe impacts relate to substantial primary loss of employment and livelihoods, serious impacts relate mostly to secondary job loss and the deterioration of physical and social infrastructure, and moderate impacts refer to a scaling down of public service activities.

2.10.10.4.5 Potential Viability of the Scheme

Evidence suggests that the Vioolsdrift and Noordoewer Joint Irrigation Scheme are currently marginal. The outlook is that the scheme will remain marginal unless support matches funding with the facilitation of business and organizational reforms.

Obstacles to the viability of the Vioolsdrift and Noordoewer Joint Irrigation Scheme have been identified. Most of the obstacles are critical, but it is encouraging that many can be addressed locally. The obstacles are:

Institutional arrangements for managing the water resource and the integrated development of agribusiness are weak.

- Small economic units and conservative farming and marketing practices.
- The lack of a cohesive and strategic approach to the development of agribusiness.
- Competition in the chosen markets and poor market selection.
- A lack of attractiveness to investors.
- The peripheral status of the joint irrigation scheme in National and Regional development planning, particularly in South Africa.

2.10.10.4.6 Intervention options

Identification and Definition of Options.

The identified different options are:

- No direct Financial Support by Governments;
- Unqualified Government Financial Support; and
- Conditional Direct Financial Support.

2.10.10.4.7 Recommendations

Short Term Actions and Responsibilities

It is recommended that for the immediate and short-term, the PWC makes sufficient funds available to repair those sections of the canal where the need is the most urgent. This would, however, be conditional on the JIA embarking on a programme to evaluate its own options and also that a long-term management plan be drafted and implemented.

Medium- and Long-Term Interventions

For the medium and longer term it is recommended that the PWC makes available funding to:

- Appoint professional facilitators to assist the JIA and its members to draft a long-term management plan for the entire scheme, including the larger Noordoewer/Vioolsdrift community.
- Evaluate the role that the scheme could play in broader Regional and National development programmes and initiatives.
- Identify other funding partners who might provide grants or soft loans, which could be applied to the rehabilitation of the scheme, as well as launching additional capacity building programmes in the communities.

2.10.11 Main Report & Synopsis

This Joint Study took place under the control of the Permanent Water Commission between Namibia and South Africa, investigated and made recommendations on the more efficient management and use of water resources in the Lower Orange River.

The overall study objective was stated as "Investigate and report on the availability of water and options for improved management through the efficiency of water use and supply management measures to promote the strategic objectives of the countries involved". The countries' Strategic Objectives for the joint management of the Lower Orange River were agreed by the countries to be:

- Regional Economic Development;
- Poverty Alleviation;
- Job Creation;
- Food Security;
- Protection of the Environment;
- Ensuring Water Supply to Downstream Users; and
- Water Resources Management aligned with National Policies, Objectives and
- Strategies for Water Resources.

The river reach west of the 20° longitude, where the river forms the border between Namibia and South Africa, was subject to the most detailed study. The Vaal River System was not studied in any detail since the results of recent studies by South Africa were suitable for use in this study.

It has been estimated that the natural runoff of the Orange River Basin is in the order of 11 300 Million m3/a. Much of the runoff originating from the Orange River downstream of the Orange/Vaal confluence is highly erratic and cannot be relied upon to support the downstream water requirements unless regulation is provided. The portion of runoff originating from the Fish River in Namibia can support some of the downstream demands, particularly the environmental demands at the river mouth.

Updated preliminary assessments were made of the ecological water requirements for the Orange River, downstream of Augrabies, and the River Estuary, as the releases currently being made from Vanderkloof Dam for ecological water requirements, were determined before current methodologies were available.

The recommended category for the river from a comprehensive study of Ecological Water Requirements would most likely be a C-Category. The Orange River Estuary is considered to be an estuary of 'high importance'. The Orange River Mouth Wetland is a RAMSAR site and is on the Montreaux Record.

If the estimated volumes of water are released to maintain the estuary, either category D or C, the necessary variability in flow should be re-introduced to stop the negative trajectory of the river and the non-flow related issues must be addressed. In terms of water resource planning and yield analysis, it is the estuarine flow requirements which control the allocatable yield.

The current and estimated future water requirements of the whole Orange River Basin up to 2025 and a proposed curtailment model for implementation during times of drought, assigning different assurances of supply to different sections, were developed. The potential future agricultural water demand along the cross border area, in both Namibia and South Africa, was assessed on the basis of potentially irrigable land, a percentage that might reasonably be developed and an annual application of water.

South African Government Policy only allocates water from the Orange River to resource poor farmers for the following areas of irrigation:

4 000 ha in Lower Orange at 15 000 m^3/ha;
4 000 ha in Eastern Cape at 11 000 m^3/ha; and
4 000 ha in Upper and Middle Orange at 11 000 m^3/ha.

A total irrigation development for Namibia of 15115 ha, is projected for 2025.

While the main focus was on the Middle and Lower Orange, downstream of Gariep Dam and excluding the Vaal System, developments in the Vaal System and upstream of Gariep Dam, such as the Lesotho Highlands Water Project and various other dams and users, affect the yield available from Gariep and Vanderkloof Dams and were considered in the yield analysis of the Gariep and Vanderkloof Dams.

Results showed that with the 2002 irrigation water requirements in place, there is an estimated surplus of only 14 Million m^3/a at 2005-development level a deficit of 47 million m^3/a. The historic firm yield of the system, which is available for consumptive use, is dependent on the agreed ecological category for the estuary. At 2005-development levels and 2002 irrigation water use, it has been calculated that:

- To maintain the Estuary at a Category D: Surplus yield = 14 Million m^3/a.
- To improve the Estuary to a Category C: Deficit of 500 Million m^3/a will be experienced.

2.11 DEVELOPMENT OF A CATCHMENT MANAGEMENT STRATEGY FOR THE MODDER AND RIET RIVERS IN THE UPPER ORANGE WMA (2006)

2.11.1 Background

The Modder and Riet Rivers are situated in the Orange Free State and Northern Cape provinces in South Africa. They form part of the drainage into the Vaal River, which subsequently flows into the Orange River. The Modder and Riet Rivers catchment covers an area of almost 35 000 km^2.

2.11.2 Water Use

Agriculture is one of the most important land uses of the area under consideration. Many of the farmers are groundwater users and several abstract high volumes of water to irrigate their crops. There are a total of 925 groundwater and 354 surface water registered users in the catchment area. It has been estimated that approximately 400 million m^3/year of water is used for agricultural purposes in the study area. This is not expected to increase significantly, if at all.

Urban areas cover a small portion of this catchment area, with the most prominent ones being Thaba'Nchu, Mangaung and Sol Plaatje. Less significant urban areas are Brandfort, Koffiefontein, Edenburg, Petrusburg, Dewetsdorp, Fauresmith, Jagersfontein, Reddersburg, Jacobsdal and Trompsburg.

The current urban water requirements in the catchment can be summarized as shown in the table below:

Table 2-90: Urban Requirements

Sub-Catchment	Description	Annual Requirement (Million m^3/a)
Upper Modder	Botshabelo Thaba'Nchu	10.5 3.00
Middle Modder	Bloemfontein	75.5
Lower Modder		0
Upper Riet		0
Middle Riet	Jacobsdal, Koffiefontein, Koffiefontein Mine	3.19
Lower Riet	Ritchie	0.36
Total		**92.59**

Urban use in the catchment is expected to increase to 146 million m^3/a in the year 2025.

2.11.3 Water Quality

The water quality in the Modder and Riet River Catchment is generally acceptable, with a few exceptions:

2.11.3.1 Domestic use

The only variable of concern is chloride in the Lower Riet River. However the value is still below where it will have an effect on human health, and at present the only concern would be its corrosive properties with respect to the distribution system and household appliances that are made of metal. At the same time the water is fairly hard which will result in a protective coating of pipes and appliances. The elevated chloride concentration in the Lower Riet River is therefore not seen as significant.

2.11.3.2 Agricultural use

Both the Lower Modder and Lower Riet Rivers are affected by high salinity. In the case of the Lower Modder River, the exceedance is slight and will occur predominantly during the winter low flow season, i.e. outside the growing season. Although not ideal, the situation is not seen as serious. In the Lower Riet River the salinity significantly exceeds the upper limit for good (acceptable) water quality, but is still far below the upper limit of marginal (200 mS/m). As it stands, the water quality will allow the irrigation of salt-tolerant crops on well-drained soils only.

2.11.3.3 Aquatic Ecology

The aquatic ecology is mainly affected by the elevated levels in nutrients, specifically phosphorous. This can lead to eutrophic conditions in standing water, although in clear, shallow, moving water it can lead to excessive growth of rooted water plants and/or anchored algae that can choke waterways. The situation is seen as serious. The Middle Modder River is also subject to elevated ammonia levels that are cause for concern.

2.11.3.4 Industrial use

Industrial use will only be affected in the Lower Riet River, but as there are no industries in that part of the catchment, this is not significant.

2.11.3.5 Recreational use

Recreational use is not affected by water quality in the catchment.

2.11.4 Reserve

Although an intermediate level Reserve determination was initially planned, lack of high flows prevented this, and a rapid 3 medium-high confidence Reserve assessment was undertaken as input to this strategy. The results of the study are that all the sites have a Present Ecological State of D and the recommended Ecological Category for all the EWR sites is a Category D, with an alternative Category of C.

2.11.5 Availability of Water

There is not enough water for the current demand for diffuse irrigation. The Water Resources Yield Model (WRYM) was used to analyse the water supply to irrigation users in the Modder-Riet system. Through iterative analyses the maximum irrigation requirements at each one of the irrigation abstraction points upstream of the confluence of the Modder and Riet Rivers were determined. This is the abstraction that is in competition with the EWR, and it was found that very little of this can be supplied if the requirements for the Reserve are to be met.

2.11.6 Ground Water

The average ground water recharge is about 3% of the mean annual precipitation (MAP). This represents a volume of about 500 million m^3/a, which is more than the natural mean annual runoff (MAR) from the catchment. However, only a fraction of this water can be economically abstracted. At an average of 1ℓ/s it would require about 16 000 boreholes to abstract the water. Nonetheless, groundwater forms an important source of water in the area, and there are a number of towns and communities that are totally dependent on ground water:

Masilonyana Municipal Area (Soutpan); Tokologo Municipal Area (Dealesville); Letseneng Municipal Area (Petrusburg); Kopanong Municipal Area (Fauresmith); Naledi Municipal Area (Dewetsdorp); and Kopanong Municipal Area (Edenburg).

Most of the other towns in the catchment are at least partially dependent on groundwater. Groundwater is also used extensively for irrigation purposes. **Table 2-91** summarises the use of ground water for irrigation.

Table 2-91: Groundwater use for irrigation

Sub-Catchment	Area (ha)	Abstraction (Million m^3/a)	Irrigation (mm/ha/a)
Lower Riet River	638.1	3.58	524
Middle Riet River	1 077.2	3.56	330
Upper Riet River	535.25	2.47	462
Lower Modder River	9 635	46.92	487
Middle Modder River	1 835	8.66	472
Upper Modder River	19.5	0.08	430

Total	**1 3 785**	**65.28**	**474**

The Management Unit in the study area which rely the most on groundwater abstraction is the Lower Modder. Within this unit two areas of high volume abstraction were identified, namely the Petrusburg area and the Bainsvlei area. The sub-unit is largely dependent on agriculture for economical subsistence. These areas of high abstraction must be managed separately on local scale and together on regional scale to protect the groundwater resources. Special attention should also be given to communities in the WMA that are totally depended on groundwater as a source of potable water. These critical areas should receive priority.

2.11.7 Conclusion

Catchment management problems in the Modder-Riet River Catchment centre on the following issues:

- The present ecological state (category D) indicates that the resource is in a precarious condition;
- Irrigation abstraction from run-of-river is at a very low assurance of supply and in direct competition with the Reserve;
- There is over-exploitation of ground water in the Kalkveld (Bainsvlei and Petrusburg) area, and
- There is a significant difference in the registered water use and what was assumed before.

In order to address these issues, the following high priority actions have been identified:

MR2.1 Verification and validation of surface water use.
Responsibility = DWAF Region
Priority = High

MR4.1 Initiate the verification and validation of existing lawful use (surface water and ground water in the Kalkveld area).
Responsibility = DWAF Region
Priority = High

MR5.1 Implement WC & DM first to reduce current water usage, before developing alternative water resources.
Responsibility = DWAF and Water Services Authorities
Priority 1 = High

MR5.3 Assess local groundwater yield capabilities in support of the local authorities that require additional water resources.
Priority = High
Responsibility = Water Services Authority

MR6.1 Determine the Reserve at the Comprehensive level.
Priority = High
Responsibility = DWAF RDM office

MR7.1 Declare the Modder Riet catchment an area where the Special Standard for Phosphate is applicable.

Priority = High
Responsibility = DWAF

MR8.4 Determine the ground water reserve as part of the Comprehensive Reserve Determination (see MR6.1).
Priority = High
Responsibility = DWAF RDM Office

MR8.6 Design and implement ground water monitoring programmes, focusing on the priority areas first.
Priority = High
Responsibility = DWAF Region

MR11.1 Prepare Water Conservation and Demand Management Plans
Priority = High
Responsibility = Water Services Authorities, Water Services providers

MR11.2 Prepare Water Management Plans for irrigation areas
Priority = High
Responsibility = Water User Associations

MR12.1 There is a need to co-ordinate and encourages communications between the various government and regional and local authorities. A communication strategy and innovative means of communicating current and planned activities should be developed and implemented.
Priority = High
Responsibility = DWAF Region
MR13.1 The Regional Office should arrange the first meeting of the Modder and Riet Rivers Forum, and ensure that the forum starts to meet and operate.
Priority = High
Responsibility = DWAF Region

M15.1 Develop a river protection plan
Priority = High
Responsibility = DWAF Region

2.12 ORANGE RIVER INTEGRATED WATER RESOURCE MANAGEMENT PLAN (ORASECOM) 2007

2.12.1 Overview

2.12.1.1 Objective of the study

In view of the existing and possible future developments which will influence the availability of water in the Orange River, a project has been initiated by ORASECOM and commissioned and funded by GTZ involving all four basin states (Botswana, Lesotho, Namibia and South Africa. The main objective of the project is to facilitate the development of an Integrated Water Resources Management Plan for the Orange River Basin.

The plan will in turn facilitate the following specific objectives:
- Maximise benefits to be gained from Orange River water;
- Harmonise developments and operating rules;
- Foster peace in the region and prevention of conflict;
- Encourage proper and effective disaster management;
- Ensure that developments are sustainable and encourage the maintenance of bio-diversity in the

basin, and

- Management of potential negative impacts of current and possible future developments.

In order to achieve the above objective it is envisaged that the resulting Water Resources Development Plan will be founded on the following four basic principles:

- Reasonable utilisation of available water resources;
- Equitable accrual of benefits to basin states;
- Sustainable utilisation of water resources, and
- Minimisation of harm to the environment.

The strategy to be adopted by the project team to meet the objectives should involve the following:

- Sharing of information on existing and proposed future developments;
- Facilitation of a common understanding of key issues based on comparable technical and institutional capacity;
- Development of comparable legislation and institutional structures;
- Adoption of comparable standards and management approaches;
- The development of a Water Resource Management Plan for the future development and management of the water resources of the Orange River.

It is anticipated that the development of the Water Resource Management Plan will be undertaken in phases and the remainder of this document refers to the work involved with Phase 1 of the project. Phase 1 will involve the following:

- A desktop study to establish the status quo within the basin and to create an agreed base from which the subsequent phases of the project can be developed;
- To facilitate capacity building where possible in order to strengthen expertise throughout the four basin states;
- To identify and highlight deficiencies in the knowledge base which must be addressed before the Water Resource Management Plan can be finalised. Some fieldwork may be required in subsequent phases of the project;
- To develop a preliminary Water Resource Management Plan which can be used as the basis from which the final plan can ultimately be developed;
- To develop a draft scope of work for subsequent phases of the project from which a Terms of Reference can be developed by the Client.
- An inaugural meeting to discuss the project and in particular the expected content for the Inception Report was held in Botswana on 8 February 2004.

2.12.2 Review of Existing Infrastructure in the Orange River catchment

2.12.2.1 Infrastructure

Infrastructure related data obtained from the then existing reports already included a vast amount of data. This data was more than sufficient to provide a clear overall picture of the current infrastructure development in the Orange-Senqu Basin for phase 1 of the study.

As only available information from existing reports was captured, the level of detail of the available information differs from area to area and also between the four basin states.

Comprehensive infrastructure related data with regards to the main Vaal System, the Orange River Project, the Caledon Modder Transfer Scheme and the Lesotho Highlands Water Project are available although updates on the capacities of the older infrastructure might be required. Less information is in general available for the smaller sub-systems which are operated as stand-alone schemes and are not supporting the major schemes mentioned above, and in particular for the drier areas such as the Lower Orange which is currently not modelled to the same level of detail. This also applies to a most of the smaller towns which is in most cases are supplied from groundwater resources.

Information on groundwater related infrastructure is in general limited and is most probably due to the relative small scale of the most of the groundwater supply schemes.

2.12.2.2 Operation of the current System

The operation of the main water supply schemes such as the Integrated Vaal River System, the Orange River Project, the Lesotho Highland Water Project and the Hardap Water Supply Scheme is well defined and is based on well-founded scientifically and proven techniques. Long-term and short-term stochastic yield characteristics are used together with the Water Resources Planning (WRPM) and operational model to be able to impose restriction on the water use when required to protect the resources and still supply the different users at their required assurance of supply. Dilution and blending operating rules are also in place in the Integrated Vaal River System to keep the TDS concentrations downstream of Vaal Dam at acceptable levels.

The smaller sub-systems are operated individually using fairly simple operating rules based on specific levels in the storage dam. Most of the operating rules are however not documented clearly in the existing reports and it seems if water are abstracted to supply the full demand until a specific level in the storage dam is reached, where after curtailments are imposed. Details of how this level is determined and how severe curtailments should be were not given in the existing reports. The assurance of supply from the smaller sub-systems is in most cases not well defined and if it does exist, it is based only on the historic sequence which can be misleading, and is often too short to be able to determine volumes available at high assurances. Different methodologies are followed by the four basin states to determine the assurance of the yield from a resource as well as the assurance of supply to the users.

The DWAF in the RSA is currently in the process to develop operating rules for the smaller sub-systems within the Vaal System. These new operating rules are based on the long-term and short-term stochastic yield characteristics of the sub-system and are developed with the aid of the WRPM.

2.12.2.3 Dams

While the report also provides information on canals, water transfer schemes, irrigation schemes and water treatment works, only the dams are listed below.

Table 2-92: Main Dams in the Upper Vaal System

Name	Gross Storage (mcm)	Live Storage (mcm)
Saulspoort	16.9	16.9
Driekloof		32.2
Sterkfontein	2 617.0	2 482.3
Grootdraai	356.0	318.0
Vaal Dam	2 609.8	2 442.5

Table 2-93: Main Dams in the Upper Vaal System

Name	Gross Storage (mcm)	Live Storage (mcm)

Name	Gross Storage (mcm)	Live Storage (mcm)
Erfenis	212.2	207.5
Allemanskraal	179.3	174.2
Koppies	42.3	41.8
Klipdrift	13.6	13.6
Boskop	21.3	21.0
Klerkskraal	8.0	7.9
Lakeside	2.0	2.0
Rietspruit	7.3	7.3
Johan Neser	5.7	5.7
Bloemhof	1 241.3	1 239

Table 2-94: Main Dams in the Lower Vaal System

Name	Gross Storage (mcm)	Live Storage (mcm)
Douglas	17.7	16.1
Vaalharts	48.7	48.7
Spitskop	57.9	57.8
Taung	66.0	66.0
Wentzel	6.6	6.6

Table 2-95: Main Dams in the Lesotho Highlands Water Project

Name	Gross Storage (mcm)	Live Storage (mcm)
Katse	1950.0	1518.6
Mohale	946.9	857.1

Table 2-96: Main Dams in the Lower Orange System

Name	Gross Storage (mcm)	Live Storage (mcm)
Upper Orange sub-catchment		
Gariep	5348.1	4710.0
Vanderkloof	3188.6	2173.2
Bethulie		4.6
Caledon sub-catchment		
Welbedacht	15.5	15.5
Knellpoort	137.0	130.3
Armenia		13.2
Egmont		9.3
Modder/Riet sub-catchment		
Kalkfontein	318.9	318.9
Tierpoort	34.0	34.0
Krugersdrift	73.2	73.2
Rustfontein	71.2	71.2

Groothoek		11 906.0
Mockes		3.3

Table 2-97: Main Dams in the Lower Orange System

Name	Gross Storage (mcm)	Live Storage (mcm)
Boegoeberg	20.7	20.7
Modderpoort		10.0
Ratelfontein		6.9
Rooiberg		3.7
Smart Syndicate		101.1
Van Wyksvlei		143.1
Victoria West		3.7

Table 2-98: Main Dams in the Orange River Basin in Namibia

River	Dam Name	Storage (mcm)
Oanab	Oanob	35
White Nossob	Otjivero Main	9.8
White Nossob	Otjivero Silt Trap	7.8
Black Nossob	Daan Viljoen	0.3
Black Nossob	Tilda Viljoen	0.5
Fish	Hardap	294
Loewen	Naute	84

2.12.3 Review of Surface Hydrology in the Orange River Catchment

2.12.3.1 Purpose of this Report

This report will be used to summarise the findings from the two main components of the hydrology review task. The first component is the data base inventory. A description of the data base inventory along with summaries on pertinent data and data gaps are given in the report. The second component includes a description of the situation assessment of the prevailing hydro-meteorological conditions, in the Orange River Basin.

2.12.3.2 Conclusions

For system analysis purposes one would in general require natural flow sequences with a relative high confidence rating of an A or at least and B. Confidence ratings of C and lower should preferably not be used. The natural flow data for the total Vaal River catchment as well as the Orange River catchment from Vanderkloof Dam and upstream falls in the A and B confidence rating with the exception of two small areas which will have a negligible effect on results. In the remainder of the Orange River catchment only two sub-catchments (Hardap and Naute) within the Fish River sub catchment has a B rating which is also regarded as a low B rating. All the rest of the sub-catchment has ratings of a C and less.

This means that on a catchment area basis approximately 32 percent of the area has natural flow records with a confidence rating that is high enough to be used in system analysis. From this 32 percent of the catchment area, approximately 94 percent of the natural flow reaching the Orange River is however generated. This brings along a total different perspective, showing that on a volume basis only 6% of the natural flow records for the Orange River are not at an acceptable confidence level. This 6% represents the runoff volume that is expected to reach the Orange River main stream and expressed as a volume it would be in the order of 680 million m³/a. This volume was not neglected in previous analyses, but is just not at the desired confidence level. This means that the margin of error is most probably higher than the 10% to 15% generally accepted for hydrology and might be in the range of 25% to 30% (170 to 200 million m³/a error) for 68% of the catchment. Improving these flow records will contribute to an overall improvement in accuracy of approximately 1% which is not much. Considering only the Lower Orange and Fish River inflows the improvement might be in the order of 12%, which need to be taken into account when the focus is on developments in the Lower Orange and Fish River sub-catchment.

Areas where no natural flow records are currently available amount to a total of 220 500 km². Although this area is significant in size, it includes mainly arid and semi-arid areas. If the unit runoff for this area is between half to equal that of the Lower Orange RSA, which is also an arid to semi-arid area, it means that the runoff generated from the 220 500 km² can be in the order of 110 to 220 million m³/a, of which only approximately 16% (17 to 35 million m³/a) is expected to reach the Orange River. The remainder will only be useful for local use close to the area where it was generated. Most of this runoff currently evaporates and/or is contributing to the recharging of groundwater resources.

No data was available on small dams in the Senqu and Lower Orange Sub catchments. It is however expected that small dams in the Senqu sub-catchment will be negligible. In the Lower Orange River catchments the effect of the smaller dams will quite possibly be significant and should be taken into account.

2.12.3.3 Recommendations

From the findings and conclusions given in this report the following recommendations are made.

- Upgrade the hydrology for the areas contributing to flow in the main Orange River to at least a B rating. Effect of small dams need to be included.
- Develop and upgrade hydrology for the areas (Lower Orange Namibia and Botswana) that is not contributing to flow in the Orange River main stem, to a confidence level representing at least a C rating. Effect of small dams and endoreic areas need to be included.
- Discrepancies in the rainfall isoline between the different counties need to be resolved (mainly RSA & Botswana).
- Discrepancies in evaporation isoline between the different counties need to be resolved and which evaporation data should be used A-pan or S-pan or both.
- Agreement on the Orange River Basin boundary specifically between Namibia and Botswana need to be reached.
- Standardise the approach that need to be followed to develop hydrology of an acceptable confidence level between the four countries.

2.12.4 Review of Groundwater Resources in the Orange River catchment

Report Title: Orange River Integrated Water Resources Management Plan. Review of Groundwater Resources in the Orange River Catchment. ORASECOM. Report No. 004/2007.

November 2007. Prepared by WRP Consulting Engineers, Jeffares and Green, Sechaba Consulting, WCE Pty Ltd, Water Surveys Botswana (Pty) Ltd.

To facilitate the integrated development and management of the resources of the Orange River jointly by the four basin member countries, it is essential that common ground exist among the basin countries with respect to the principles and objectives salient to the joint management and that appropriate strategies and plans be developed to achieve this. A key component and common reference base was the development in 2007 of an Integrated Water Resources Management Plan (IWRMP) for the Orange River Basin. This report formed part of that plan and deals with the review of the groundwater resources and relevant groundwater issues as they relate to the Orange River Basin.

The report describes and provides information on the following within South Africa, Botswana, Namibia and Lesotho:

- An overview of the available data on groundwater
- An overview of the state of groundwater
- Assessment of the level of groundwater development
- Assessment of the level of stress on the groundwater development
- Assessment of the capacity for further groundwater development.

The study identified that if groundwater was to be included in the ORASECOM IWRMP or any other Integrated Water Resource Management Plan, management of groundwater had to comply with the policy, strategy and practice of common standardised water resource management within the Orange River Basin and all of its member states. Clear explanation from Geohydrological Department of the relevant ORASECOM basin member is required if deviation from policy or strategy applied in the IWRMP is to occur.

The report lists a number of recommendations for addressing practical problems which is aimed at setting up mechanisms to fill the data gaps and identify additional systems and structures needed for standardised groundwater management. Five generic strategies are proposed to change the traditional approach and ensure successful implementation:

- Integrate groundwater into the management of water resources for the benefit of all;
- Actively promote groundwater and the conjunctive use of groundwater so that water resource managers, water-users and the general public are more aware of the role, occurrence and value of groundwater;
- Encourage and enable geohydrologists to work outside their line function, and be integrated into the broader water resource planning and management functions;
- Develop a larger, skilled and experienced specialist geohydrological workforce, and
- Develop a common groundwater monitoring network and a common geohydrological information system to assist in the provision of data to those who need it.

The study concluded that no one full and detailed regional groundwater overview of the complete basin area has been completed to date and it was therefore recommended that a full and detailed regional study encompassing the co-basin member states be conducted. A strategy to accomplish this, needed to be developed. On international and national level, co-operative governance needs to be factored into the overall integrated water resources management undertakings, to ensure a benefit to all users. Initiatives are required to ensure the ORASECOM Integrated Water Resources Management Plan can be implemented at an international, national, catchment and local level.

2.12.5 Environmental Considerations Pertaining to the Orange River

Each country within the Orange River Basin has its own water management legislation as well as their own water demands or stressors. It is therefore pressures or drivers that contribute to the environmental issues within the Orange River.

The environmental issues associated with the Orange River are directly related to the anthropogenic use of the water. The major impact is due to the altered flows of the Orange River due to man reallocating this water for uses outside the catchment, for hydro-power, agricultural and mining use. As a result the river's ecological integrity has been compromised to such an extent that the current flow regime has resulted in the loss of biodiversity, nutrient enrichment, increasing salt loads and nuisance plants and animals.

In order to manage the Orange River basin's environmental aspects in a holistic manner the ORASECOM initiative must continue to promote the use of environmental flow requirements. A comprehensive environmental flow study should be undertaken for the Orange River. This will include the existing study that has been undertaken in Lesotho for Phase 1 as well as the comprehensive study to be undertaken for the Vaal River system (2006 to 2008). It is important that all the countries within the Orange River basin are part of this study and that the appropriate socio-economic assessments and public participation takes place concurrently with the environmental flows study.

The following recommendations are suggested:

- The holistic management of the Orange River Basin (source to sea) should be promoted through ORASECOM;
- The data collected in each country (water quality, flow, GIS etc.) should be collated and stored in a standardized format that will allow way easy exchange between countries;
- ORASECOM initiative must continue to promote the use of environmental flow
- requirements (and appropriate methods for all countries and rivers);
- Environmental water flow requirements of the Fish and other ephemeral rivers should be determined;
- Appropriate socio-economic assessments and public participation takes place concurrently with the environmental flows study;
- The flow monitoring in the lower Orange River is inadequate and should be addressed; and
- Agricultural return flows, and more efficient irrigation should be studied as results to date have shown that the degraded condition of the Lower Orange River is only partially as a result of the severely altered hydrology of the system.

2.12.6 Summary of Water Requirements from the Orange River

2.12.6.1 Purpose of this Report

This report is used to summarise the findings from the Water Requirements Task. A description of the data base inventory and a summary of the demands and return flows for the current and future demands are given in the report.

2.12.6.2 Conclusions

2.12.6.2.1 Vaal River Systems

The water resources of the Vaal River system are an important asset to the RSA and its people supporting major economic activities and a population of almost 12 million people. Demands imposed on the main Vaal System are in general well defined and updated on a regular basis, as part of the annual operating analysis carried out for the integrated Vaal River System. This system is largely utilised to supply water to urban/industrial/mining and power stations (65%), with irrigation (19%) being a much smaller component. Only surface water resources are used to supply these demands.

The resources within the Vaal Basin itself is not sufficient to supply in the large demand of almost

2 800 million m^3/a currently imposed on the system. Several major transfer schemes were therefore introduced to augment the ever increasing demand in the basin. Indications are that intervention will again be required by approximately 2013. The intervention will most probably include a combination of water conservation and demand management actions, together with a transfer scheme.

The ecological requirements for both the main Vaal System as well as for the smaller systems are based on desktop estimates recently determined by the RSA DWAF. These environmental requirements are only first order indications of what the ecological reserve will be, and are thus currently not supplied by means of any releases from the reservoirs.

The demands imposed on the smaller systems within the Vaal River Basin is not supplied or supported from the main Vaal system. It however impacts significantly on the main Vaal System, as large volumes of water is utilised in these smaller systems, which reduces the total volume of water reaching the main system. The total water use from the smaller systems accumulates to 1 055 million m^3/a at 2005 development level. The bulk of the water use in the smaller systems is for irrigation purposes, representing 64% of the total demand. Most of the demands are supplied from surface water resources with the exception of the rural domestic and livestock requirements, which are mainly met from groundwater resources.

Data for demands imposed on the smaller systems and in particular for the diffuse irrigation demands are at a lower confidence level than those available for the main Vaal System. Indications from the verification and validation of registered water use in the Vaal Basin showed that the diffuse irrigation is significantly more than previously estimated. A large amount of the irrigation use (241 million m^3/a) is expected to be unlawful and need to be eradicated.

The confidence level on groundwater use related data is in general much lower than that from surface water. There is not always a clear cut sub-division between whether surface or groundwater resources are used to supply the certain demands, in particular with regards to diffuse irrigation requirements. Reliable data in this regard should become available at the completion of the validation and verification of the registered water use in the RSA.

The bulk of the return flows in the Vaal River basin are generated from the urban/industrial sector in the Gauteng area. Approximately 50% of the total demand is received as return flows from this area, producing in excess of 600 million m^3/a, of which 335 million m^3/a returns to the Vaal River while the remainder (270 million m^3/a) end up in the Crocodile West River catchment. Increased urban runoff due to paved areas and mine dewatering each add another 114 million m^3/a, and 101 million m^3/a respectively. Return flows from the main irrigation schemes accumulates to almost 70 million m3/a, or approximately 12% of the gross irrigation demand. Although the large volumes of return flows from the Vaal catchment improves the water availability in the catchment, it has a negative effect on the quality of the water, to such an extent that operational measures had to be introduced to improve the quality in certain river reaches.

2.12.6.2.2 Orange River Systems

In contradiction to the main Vaal System, the main Orange System or ORP is used to mainly supply water for irrigation purposes (approximately 60% of demand), with a small portion (only 2.5%) of the demand comprising of urban/industrial & mining requirements. Irrigation demands are in general obtained by the quota for the given area times the allocated irrigation area. There is very little observed measured irrigation abstraction data available and the actual true irrigation use will differ from that obtained from the allocated area and quota. Although this data is, as in the case for the Vaal System, also updated on an annual basis as part of the operational analysis, it is not to the same confidence level as that of the Vaal, due to the large irrigation component. Return flows from urban/industrial requirements is almost negligible and those from irrigation amounts to 207 million m^3/a, or 13% of the gross irrigation requirement.

The main Orange River System in not supported or augmented by any other sub-system. Water is in fact transferred from the Orange River Main System to support other subsystems such as the Eastern Cape, the Riet/Modder, Douglas in the Lower Vaal etc. With the current expected growth in demand, the main Orange River System will require intervention by 2012. This is expected to be accomplished by increased system efficiency in combination with utilising Vanderkloof Dam lower level storage and or a dam at Vioolsdrift.

The river mouth ecological requirement currently released from Vanderkloof Dam amounts to 289 million m^3/a, and is based on fairly old methodology. Recent estimation of the ecological requirement indicated an average requirement of in the order of 1 062 million m^3/a. This ecological requirement has not been implemented as it was not determined at a detailed level and only provided and better indication of what the reserve could be. Ecological requirements as determined and implemented for the LHWP were recently updated and can be used with confidence.

The total demand, transfers included from the other systems in the Orange Basin is in excess of 1 400 million m^3/a, which will have a significant impact on the water availability in the main Orange System. Most of the demands are supplied from surface water resources with the exception of the rural domestic and livestock requirements which are mainly supplied from groundwater. The demands and transfer data with regards to the LHWP and the Caledon/Modder transfer are at a fairly high confidence level. The confidence level with regards to groundwater use is in general much lower than those from surface water resources. The smaller towns as well as diffuse irrigation are in many cases supplied by both surface and groundwater resources, making it difficult to allocate the demand to the correct resource.

2.12.6.3 **Recommendations**

- The confidence in groundwater related data need to be improved in both the Orange and Vaal River Systems. This must include the distinction between groundwater and surface water use in particular when both the resources are used to supply a specific demand centre.
- Ecological requirements given for the Vaal Systems and the Main Orange System should be treated with caution as they are only preliminary values, used to provide an indication of what the reserve could be. These values should be replaced when more recent and up to date estimations are available.
- Unlawful irrigation need to be eradicated and controlled as it has a significant effect on the total water demand imposed on the systems.
- High return flow volumes are available from both the Vaal and Orange River systems. One should be very careful in allocating those return flows for other uses as more efficient use in the systems can lead to significant reductions in return flows.
- Results from Verification / Validation studies should be used to improve the confidence level of data currently used in models, as soon as it becomes available.
- The irrigation demand is in the Orange systems the largest and in the Vaal systems the second largest water consumer. Very little of the irrigation use is however metered. It is recommended that measures should be put in place to encourage the proper metering and recording of irrigation abstractions.
- There is a need to do a proper survey within the Orange River basin in Botswana to determine the location of new settlements, villages and towns, the number of people, the number of livestock the different water uses and the quantity of water used in order to make present and future water demand assessments based on more accurate information.
- There is a need to update the 2000 assessment of the present and future water demand in Namibia with specific reference to the Orange River Basin.

2.12.7 Water Quality in the Orange River

2.12.7.1 Introduction

A desktop assessment of the surface water quality status of the Orange River catchment was required as input into the development of the Integrated Water Resource Management Plan (IWRMP) for the Orange River. The objectives of the study were:

- Collection and assessment of information in reports dealing with water quality
- Collection and assessment of water quality data on the Vaal and Orange Rivers
- Approach to water quality management
- Overview of water quality status
- Identification of issues and gaps.

2.12.7.2 Conclusions and Recommendations

The following conclusions and recommendations can be made as a result of this desktop study:

- The water quality has to be managed in conjunction with the development of the water resource for supply. The reduction in flow from Lesotho due to transfers to Vaal Dam could affect the water quality in the lower Orange. Similarly the management of the system to meet water requirements and generate hydropower should be coupled to the management of water quality;
- The salinity is currently being managed with releases of water for dilution from Vaal Dam. The modelling tools have been set up to manager the salinity aspects of the water quality of the Orange River Basin. The consensus is that the salinity aspects of the water quality meet user requirements. However the water quality must not be allowed to deteriorate further.
- Many of the coal and gold mines are closing down and the workings are starting to fill and will decant sometime in the future. Management strategies have to be developed to manage the filling process and the decants.
- Nutrients and the resulting algal growth are an issue. The modelling of nutrients has not reached the same level as salinity and the nutrient pathways are not well understood. Attention will have to be given to the development of modelling tools; management of point sources such as sewage works as well as diffuse sources associated with runoff from urban areas and agriculture. A nutrient management strategy needs to be developed.
- Currently very little information is available on pesticides and herbicides in the river systems. There is extensive agriculture on the banks of the Vaal and Orange Rivers. The presence of these pollutant types should be determined by designing and carrying out a round of monitoring.
- An integrated water quality monitoring programme and data management systems need to be developed for the Orange River Basin. The monitoring programme should include discharge information.

2.12.8 Demographic and Economic Activity in the four Orange basin States

Key activities undertaken to meet the demographic objectives of the study included:

- A review of Census data in all countries
- A review of post-census reports, particularly those dealing with the impact of HIV/AIDS
- The creation of a basic demographic map showing variations in population density and growth
- A review of reports dealing with key areas of economic activity, particularly of water-dependent sectors
- A review of websites with electronic data and / or reports

The demographic component was not intended to generate a definite report on the demographics of the Basin but rather to review existing data and reports whilst commenting on issues pertaining to data quality, accessibility and gaps. The report begins with an overview of broad demographic trends and then provides detailed information on Botswana, followed by Lesotho, Namibia and then South Africa.

In 2001, the Basin as a whole was home to some 15.7 million people, the vast majority of whom (85%) live in South Africa. Botswana and Namibia have relatively few people living in the Basin (0.3 and 1.1 respectively), while Lesotho's entire population is in the Basin, making up just over 13% of the total number in the Basin. The report also provides an overview of Major Economic Activities and corresponding water use. Economic activity in the Orange-Vaal river system is dominated by the urban-industrial centre in Gauteng, the economic hub of Southern Africa, which accounts for 38% of South Africa's GDP, and nearly 9 million people, or 20% of South Africa's population. Other major water-dependent economic activities in the basin include mining, the energy sector, and irrigated agriculture.

The sections dealing with economic activities and the value of water are presented in a way that is intended to highlight key issues and stimulate debate regarding the future management of the Basin's water resources. It is not a comprehensive listing of all economic activities, but rather an introduction to major themes.

The demographic data is mostly based on outdated 2001 data from the census bureaus of each country.

2.12.9 Institutional Structures in the four Orange Basin States

2.12.9.1 Institutional history

The Permanent Water Commission (PWC):

The PWC evolved from the Joint Technical Committee formed between Namibia and South Africa in 1987. The commission advises the governments of the two basin states on the use and development of the lower Orange River. The commission focuses on the Vioolsdrift and Noordoewer Irrigation Schemes (the PWC evolved from the Vioolsdrift / Noordoewer Joint Irrigation Scheme).

2.12.9.2 The Lesotho Highlands Water Commission (LHWC)

The Lesotho Highlands Water Commission is a bi-national body that evolved from the Joint Permanent Technical Commission established under the terms of the Lesotho Highlands Water Treaty. This organisation is responsible for matters of joint concern to Lesotho and South Africa with regard to the implementation of the Lesotho Highlands Water Project (LHWP). Activities include the appointment of auditors and consultants, operating and maintenance plans, tendering procedures, the allocation of costs between the parties and the quantities of water to be delivered.

There are two national institutions linked with the LHWC. The Trans-Caledon Tunnel Authority (TCTA) manages and maintains the delivery tunnel which transfers water across the border (i.e. under the Caledon River) to the Ash River in the Vaal catchment as well as all other aspects of the infrastructure in South Africa.

The Lesotho Highlands Development Authority (LHDA) is responsible for the management of all aspects of the project that fall within Lesotho, including infrastructure and social aspects, such as the resettlement and compensation of displaced communities, water supply to resettled communities, irrigation and tourism.

It is important to note that there are comprehensive and specific management provisions for the LHDA in the Treaty, while the functions of the TCTA, which are similar to those of the LHDA, "are provided for in considerably less detail and no attention is given to downstream responsibilities". This is an indication of the significant power inequalities between the two states, and also raises the issue of the exclusion of Namibia and Botswana from the Treaty despite the fact that the LHWP has a very significant impact on the waters of the Orange-Senqu Basin.

2.12.9.3 The Orange-Senqu River Commission (ORASECOM)

The Orange-Senqu River Commission (ORASECOM) was established in November 2000 as a result of the evolution of this policy context. ORASECOM includes representation from all four basin states under the terms of the ORASECOM Agreement (2000).

ORASECOM is considered an international organisation with an international and national legal personality. It encourages communication on basin issues between the member states through the mechanism of an annual meeting of the representatives of the states, and provides that the basin states must utilise the resource within their respective states equitably and reasonably (according to the SADC Protocol). It also operates as a funding coordinator for joint basin projects. ORASECOM serves as a technical advisor to the member states and can execute the necessary feasibility studies to support decision-making.

It does not, however, have any direct links (through formal mechanisms) with the bilateral organisations (the LHWC or the PWC), although the basin states are required to inform ORASECOM of any issues pertaining to the basin, changes to agreements or impacts on the waters of the basin. Furthermore, the Commission does not set out criteria for equitable allocation, which is subject to negotiation at political level, and if there is no agreement within the Commission about a proposed project, it is also subject to negotiation at political level.

2.12.9.4 Criteria for Institutional Arrangements

Some key lessons are made in relation to an institution for the Orange-Senqu Basin (ORASECOM):

- Provision of a common forum for meeting.
- Promotion of information sharing among the relevant states and organisations.
- An adaptable management structure incorporating participation at deeper than state level.
- The existence of a coordinated water resource management plan – to ensure that realistic management objectives are met in a basin-wide context.
- Adequate financing and the ability to secure funding from donor agencies.
- Clear and flexible water allocation criteria – clear allocation schedules and quality standards that incorporate the changing conditions of the basins, as well as providing for extreme events.
- Equitable distribution benefits (and the costs) of water use throughout the basin – distributing the benefits of water use rather than dividing the water itself lends flexibility to allocations and the ability to manage changing basin dynamics, as well as facilitating management of the system as a whole.
- Clear and effective conflict resolution mechanisms – in order that, when disputes arise, the management objectives of the basin are not compromised.

2.12.10 Legislation and Legal Issues Surrounding the Orange River Catchment

The report comments on the national legislation of South Africa, Botswana, Lesotho and Namibia.
This literature review only summarises the LHWP Treaty as that is of common interest to the water course states.

2.12.10.1 The Treaty on the Lesotho Highlands Water Project:

The Treaty on the Lesotho Highlands Water Project between South Africa and Lesotho dates from 1986 and has had the greatest impact on the water usage of the Orange River.

The purpose of the Treaty is to eventually deliver up to 70 cubic metres of water from the headwaters of the Orange/Senqu in Lesotho to the Vaal River System in South Africa via dams and tunnels. At the same time the delivery system is utilised to generate hydroelectric power in Lesotho.

The water transferred to South Africa is water that South Africa is entitled to abstract from the Orange River in any case, but which is taken out at a more convenient point.

South Africa carried the total cost of the water delivery system and pays Lesotho royalties based on a percentage of the benefit, calculated to reflect the saving to South Africa expected to be achieved by the Project in comparison to a similar scheme built entirely within South Africa.

The Treaty provides for the Project to be built in 5 or more phases.
The parties have recently commissioned a feasibility study for a possible Phase II (agreed on by the parties subsequently to the report).

The Treaty has few provisions dealing with water resource management:

Article 6(15) - measures to prevent or abate water pollution.

Article 7(9) - minimum rates of flow to be maintained in the river beds below Katse and Mohale Dam. The Treaty only requires releases of 500 litres/second (Katse) and 300 litres/second (Mohale) but provides for subsequent adjustments. These have now been upgraded in line with more recent IFR requirements.

Article 7(11) - minimum flow rates for further phases to be agreed before such phase is implemented.

Article 7(12) - the parties must agree from time to time on the minimum rate of flow in the Orange/Senqu on the border between the countries.

Article 7(13) and 7(14) - although the water stored in the reservoirs built for the Project is intended for delivery to South Africa, the parties may agree to release water either downstream of a reservoir or at abstraction points for use in Lesotho.

The two parties did not really involve the other watercourse states in the establishment of the Treaty although they did obtain a no objection from Namibia to Phase I.

Article 8 of the Revised Protocol and Article 7 of the ORASECOM Treaty require that Lesotho and the RSA involve ORASECOM and the other watercourse states in any decision on the construction of a further phase.

2.12.10.2 **In-stream Flow Requirements**

The question of In-stream Flow Requirements (IFR's) requires further legal investigation because different countries have different requirements in their legislation. In addition, the LHWP Treaty has its own requirements. This could be a major stumbling block since the requirements of upstream and downstream countries are not identical.

2.13 PRELIMINARY TRANSBOUNDARY DIAGNOSTIC ANALYSIS (ORASECOM) (2008)

2.13.1 Purpose of the Report

Awareness of the need for integrated water resource planning at the basin level has promoted the development of a UNDP-GEF sponsored "Transboundary Diagnostic Analysis (TDA) of the Orange-Senqu River Basin" and Strategic Action Programme development project among four of the riparian nations. This project aims to ensure that the quality and quantity of the water throughout the Orange-Senqu river system meets the short and long-term needs of the ecosystem, the communities and economies relying upon the river and its associated resources. The project is expected to achieve its objectives by: encouraging regional cooperation; increasing capacity to address water quality and quantity problems; demonstrating water quality/quantity improvements; initiating required policy and legal reforms; identifying and preparing priority investments; and developing sustainable management and financial arrangements.

2.13.2 Key findings and recommendations

The key findings of the **water resource and hydrological regime** studies are:

- Surface water resources of the Orange-Senqu Basin are highly utilized to the extent that the residual flows to the mouth represent only 25% of the natural MAR at the mouth;
- The DWAF/Namibian Water Resource Planning Model developed under the LORMS study and which models the whole basin, indicates that there is already under a significant deficit in the Lower Orange which may grow to over 400Mm^3/a by 2025. This calculation excludes demand from Botswana and assumes that the current Ecological Water Requirement (EWR) of 1,000 Mm^3/a remains;
- The strategy for new infrastructure development is not yet defined with options including LHWP phase 2, expansion of Thukela- Vaal transfer scheme, a re-regulating dam at Vioolsdrift, and an upper Orange dam, and therefore the yield cannot be defined with any certainty. The earliest implementation date for LHWP is 2018 at which time the deficit in the Lower Orange is forecast to be 374 Mm^3/a;
- Improved resource management in the Vaal and Orange systems could yield up to 223 Mm^3/a and maintain a surplus in the Vaal system until 2015, however, this includes utilisation of spillages from the Vaal system and there may be double counting;
- Water demand management in the irrigation sector has a forecast potential saving of 226 Mm^3/a deliverable in 5-10 years. There are limited available figures for demand management savings in the domestic, industrial and mining sectors or estimate of potential transfer and distribution savings. A detail demand management strategy needs to be established;
- Significant improvements are required in the hydrological flow monitoring network, particularly the low flows;
- The Lower Orange and the mouth currently has a category D ecological status and the provisional EWR is estimated to be 1 000 Mm^3/a. From existing data and information it is difficult to establish whether this requirement is being met. It has been estimated that raising the ecological status of the mouth to category C will require a further 500 Mm^3/a, which will increase the deficits in the lower Orange accordingly;
- The potential impact of climate change on the supply and demand side of the water balance is not taken into account in the calculation of the water resource balance;
- Groundwater resources are limited and it has yet to be established what contribution, if any, they could make to the water balance.

The key recommendations and conclusions of the **water resource and hydrological regime** studies are:

- To enable the decision makers to clearly understand the issue, a detailed water resource balance for the whole basin needs to be prepared, based upon agreed planning criteria (assurances, EWRs etc.), consistent component demand forecasts and climate change scenarios, against which potential water resource development options and demand management targets can be superimposed to determine the geographical planning surplus and deficits over a twenty year planning period.
- To undertake an assessment of Ecological Water Requirements in the Lower Orange and mouth and establish an agreed methodology which can be applied in other key points of the Basin.
- Establish a 'vision' for the Orange-Senqu River Basin water resources in the national larger economic planning frameworks of the four countries. The vision should indicate the level of environmental protection the river should be afforded. Can protection be increased from category D to category C.
- Develop and agree criteria for establishing equitable sharing of water resources between the four countries in order to set bounds on development demand.
- Establish a decision framework for future water allocation based on economic water evaluation criteria.

- Improve implementation of regulatory functions and responsibilities in all four countries and strengthen regional coordination through ORASECOM.
- Agreed climate change scenarios need to be incorporated into the water balance calculations - perhaps with different scenarios for different sub-basins - and develop adaptation strategies.

The key findings of the **water quality** studies are:

- The Vaal catchment is highly polluted which has implications for water resource availability and transboundary impacts. The water quality of the Upper and Lower Orange is said to be good; however there are insufficient data for certain categories of contaminants to make any conclusive statements.
- There are concerns along all the rivers which flow through towns and villages throughout the catchment regarding localized micro-biological pollution from untreated and partially treated sewage entering the rivers;
- The increase in Total Dissolved Solids (TDS) in the Vaal and Lower Orange catchments and the concomitant increase in constituents such as chloride and sulphate, has had major implications for domestic, industrial and agricultural water use;
- The transboundary impacts of POPs, heavy metals and radio-nuclides are unknown due to a lack of monitoring data and detailed studies, but some level of transboundary transfer of these pollutants is suspected;
- Eutrophication is a severe problem in the Vaal catchment and in isolated pockets in other parts of the Basin.

The key recommendations and conclusions of the **water quality** studies are:

- Establish basin-wide Receiving Water Quality Objectives (RWQOs) and agree and develop sectoral short- and medium-term targets to meet the objectives. RWQOs are being set in isolation in priority catchments; whilst integration of the RWQOs for the Vaal River is being addressed in the Integrated Water Quality Management Plan (IWQMP) that is being developed by the South African DWAF, there are no objectives agreed for the whole of the Orange-Senqu basin.
- Undertake a water quality assessment of the major aquifers in the basin. There are concerns regarding the quality of groundwater resources and their protection, however there is insufficient data to make any conclusive statements in this regard;
- Improve compliance monitoring and enforcement in all four countries. Lack of institutional capacity to effectively manage water quality in their respective countries is a major constraint;
- Improve the water quality monitoring network throughout the region. In Lesotho and Namibia, the water quality monitoring networks are poorly developed and there are no formal sampling networks or water quality databases. South Africa has a more sophisticated and extensive monitoring system, but there are still a number of deficiencies in the data sets, the extent of the network – especially along the Lower Orange and in some of the more polluted sub-catchments of the Vaal River.
- Undertake an assessment of Persistent Organic Pollutants, heavy metals and radio-nuclides in the Vaal and Lower Orange catchments for which there is a general lack of information in the catchment.

The key findings of the **land degradation** studies are:

- Land degradation poses a risk to ecosystem integrity in fragile highland and dry land environments, defined in terms of the health, connectivity and stability of both the biotic and abiotic components of ecosystems and the interconnectedness between them. Overstocking, caused by communal land tenure systems and the uneven distribution of water, is a major factor in rangeland degradation throughout the basin;
- The Lesotho highlands are particularly sensitive to land degradation which causes critical impacts to run-off (e.g. damage of the water sponges) and sediment loadings;
- In the Lower Orange, land degradation due to overgrazing and overstocking is widespread but its economic impact on water resources has not been determined;
- Deforestation in the riparian belt and/or invasion by alien species can cause disruption to the

hydrological cycle, but it is unclear to what degree this is prevalent in the Orange-Senqu River Basin due to a lack of any basin-wide studies in this regard;

- Lack of alternative livelihoods and access to market and financial facilities lock the rural populations into unsustainable range management practices;
- Poor land-use policies and historical tenure systems have exacerbated the land degradation problem;
- There is an urgent need for community-based natural resource management initiatives across the basin, particularly for rangeland managed areas (under livestock, wildlife or both), involving integrated approaches in communal and freehold areas.

The key recommendations from the **land degradation** studies are:

- Undertake an assessment of the scale and scope of land degradation in the Orange-Senqu Basin particularly in the Upper and Lower Orange.
- Undertake a more detailed assessment of the water resource implications of existing and potential future land degradation; the linkage between land-use and water resource management is fragmentary which makes the development of a strategy to address the problem difficult; there is a tendency for generic solutions.
- Strengthen monitoring and evaluation systems need and the dissemination of information and knowledge to the local level to help develop adaptive management strategies.
- Demonstrate various governance models at the community level which will deliver best practice integrated rangeland and water resource management in various biomes.

The key findings of the **invasive species** study are:

- Increases in the distribution and occurrence of alien invasive species across the basin are contributing to the environmental degradation of riparian and aquatic ecosystems in the Orange-Senqu Basin.
- The upper catchments of the Basin within Lesotho, and the Eastern Free State and Gauteng provinces of South Africa show significant riparian infestations of alien species, such as Silver wattle, Black wattle, Grey poplar, Blue gum, Syringa and Jacaranda. These species are significant water users, and compound degradation of riparian ecosystems.
- The Vaal River contains sections of dense infestations of aquatic plant species, especially Water hyacinth. This species disturbs aquatic habitats, alters the flow of the river and blocks water abstraction, conveyance and irrigation equipment.
- The drier middle to lower sections of the Orange River Basin is impacted mostly by growing infestations of Mesquite. This woody shrub species is commonly encountered in riparian areas, and is responsible for significant river yield losses, as well as land degradation.
- The eradication programmes are fragmented in approach and, with the exception of South Africa, donor driven.

Key recommendations of the invasive species studies are:

- Integrate eradication efforts should across the basin to control common invasive species and where applicable incorporated them into the national and regional IWRMs.
- Strengthen monitoring of alien invasive species throughout the basin and establish a database.
- Undertake an assessment of the water resource losses due to invasive species in the Orange-Senqu and evaluate the economic cost.

2.14 LESOTHO HIGHLANDS WATER PROJECT PHASE II FEASIBILITY STUDY (2009)

2.14.1 Overview

The development of the Lesotho Highlands Water Project was agreed between South Africa and Lesotho in the Lesotho Highlands Water Project Treaty signed in October 1986. The project was envisaged in a number of Phases and the Treaty committed both parties to implement Phase I. The Treaty provided for further Phases to be developed to transfer up to a maximum of 70 cubic metres per second (m3/s) of water from the Highlands of Lesotho to the Vaal River system in South Africa.

Before agreement could be reached on the development of further phases of the Lesotho Highlands Water Project (LHWP), certain key issues needed to be resolved between the Parties and the main features of the further phases had to be defined. The Parties agreed to jointly undertake a two stage Feasibility Study in order to acquire and collate the information necessary for decision making.

An assessment of the floods which could be anticipated at all the potential dam sites was undertaken as part of the study.

The Stage 1 Study culminated in a multi criterion; technical, environmental, social, cost and economic, assessment of layouts. This resulted in a recommendation of the layout for all future phases of the project, to meet the Delivery Schedule, and in particular, the configuration of Phase II of the recommended layout, the subject of the Stage 2 Feasibility Study.

The recommended and subsequently accepted Phase II option to be studied in Stage 2 comprised, the Polihali Concrete Faced Rock fill Dam, on the Senqu River, at a Full Supply level (FSL) of about 2065 metres above sea level (m.a.s.l), transferring water through a gravity tunnel to Katse Dam. The Phase II layout is shown on Error! Reference source not found.**Figure 1.2.**

At the beginning of the Stage 2 Study, the cost / yield and environmental implications of alternative FSL's for Polihali were reassessed. A higher FSL of 2075 m.a.s.l, with a wall height of 163.5 m, was then agreed for this Feasibility Study, since it was expected to give an economically attractive increase in yield, with a manageable increase in environmental implications.

The Stage 2, Feasibility level Study comprised dam and tunnel design, assessment of hydropower generation potential, as well as feasibility level designs and costing for access roads, power supply, telecommunications, and construction camp facilities. These were supported by surveys and mapping, geotechnical investigations, reservoir simulation modelling, water quality, public participation, social and environmental studies. Legal, institutional, procurement and financing together with implementation studies completed the Stage 2 Study.

Figure 2-14: Phase I Layout and Proposed Phase II

2.14.2 Hydrology Supporting (WRP - Outstanding)

2.14.2.1 Background

During Stage 1 of the Feasibility Study, the monthly inflow sequence that was used in the yield analysis for Polihali Dam was prescribed by LHWC to be derived by applying a scaling factor to the "Agreed Hydrology +1%" cumulative natural stream flow sequence at the Mashai Dam site for the period October 1926 to September 1996. The scaling factor for the Polihali Dam site had been derived through an empirical assessment of the general relationship of unit MAR versus MAP for the Lesotho Highlands region, as reflected by the "Agreed Hydrology" stream flow sequences at the nine previously determined dam and diversion sites of interest to the overall LHWP. This approach led to the derivation of a unit MAR of 220 mm/a for the Polihali Dam site which was used for the purposes of Stage 1 of this Feasibility Study.

At the conclusion of Stage 1 the need for rainfall-runoff catchment modelling specific to the Polihali Dam site was motivated on the grounds that the unit MAR of 220mm/a for the Polihali Dam Site needed to be verified by catchment-specific hydrological analysis. It was thought that the availability of stream flow records at two gauging stations inside the Polihali Dam catchment, gauge G06 on the Senqu and gauge G36 on the Khubelu, together with the spread of rainfall gauges in the area, would make such a catchment-specific analysis highly feasible.

2.14.2.2 **Methodology**

The monthly rainfall-runoff catchment model, WRSM2000, was used for this simulation of the long-term natural stream flow hydrology of the Polihali Dam catchment. The simulation was based on a calibration of this model's functional parameters against the aforementioned two observed stream flow records. Unfortunately, the quality of the records at these two flow gauges proved to be questionable, given that gauge G06 had missing/incomplete values for 35% of the months on record, while the equivalent proportion for G36 was 31%. Prior to the calibration of the parameters of WRSM2000, the missing values in the monthly flow records at G06 and G36 were "patched" (filled in) by means of well-established methodologies.

2.14.2.3 **Conclusions**

- The long-term unit MAR/MAP values for Polihali Dam sub-catchments produced by the modelling exercise described above are consistently and markedly lower than what might be expected from the "Agreed Hydrology" regional trend.
- The quality and reliability of the flow records at gauges G06 and G36 are open to serious question. Future studies regarding Polihali Dam should be preceded by attempts to improve these flow records by improving the gauged sections reprocessing of historical ratings and of primary break-point stage recordings. A new gauge downstream of the proposed Polihali dam should also be established.
- Despite careful infilling of missing values in both flow records and rainfall records the outcome of this extensive modelling exercise was disappointing in that it could not yield increased confidence in the Stage 1 inflow sequence to Polihali Dam and its unit MAR.
- Given the topography and its enhancing influences on water yield, a catchment MAP of 885 mm/a and the regional trends imbedded in the "Agreed Hydrology +1%", an unit MAR at the Polihali Dam site of at least 220 mm/a is still considered to be the most appropriate.

2.14.3 In-stream Flow Requirements

2.14.3.1 **Introduction**

The results presented in this report build on work that was undertaken in various projects and activities, which form part of on-going IFR-related activities for the Lesotho Highlands Water Project.

2.14.3.2 **Study Area**

The IFA study area comprises the Senqu River downstream of the wall of the proposed Polihali Dam, to the Lesotho - South Africa border, with particular reference to the section of the river between the proposed Polihali Dam wall and the confluence with the Malibamatso River.

2.14.3.3 **Present Ecological Condition**

The Present Ecological Condition for the Senqu River between Polihali and confluence with the Malibamatso River is a State 3. The main impact on the riverine ecosystem is an over-supply of sediments from a heavily-grazed and eroding catchment.

2.14.3.4 In-stream Flow Assessment Method

The DRIFT methodology was used to provide flow scenarios and descriptive summaries of their consequences in terms of the condition of the river ecosystem, for examination and comparison by decision makers. In this study, only Module 1 of DRIFT was used, i.e., the biophysical module, in which the river ecosystem is described and predictive capacity developed on how it would change with flow changes.

2.14.3.5 In-stream Flow Assessment Results

Results are presented for two situations:

1. REDUCED SEDIMENT SUPPLY: For a situation where the proposed dam would trap EXCESS sediment supply to the reach. This would reduce sediment supply to the river for approximately c. 30 km downstream of the dam.
2. PRESENT DAY SEDIMENT SUPPLY: For a hypothetical situation where the sediment supplies to the reach remains at present-day levels. If the assumption that the dam will trap sediment is correct, this would only apply to sections of the river > c. 30 km downstream of the dam. (Additional sediment supplied by the incremental catchment is, of course, accompanied by additional flow from the incremental catchment. Thus the implications for the river should take into account the sediment supply and the volume, timing and variability of flows generated downstream of the dam.)

Three scenarios were provided for consideration, namely:

- Scenario 1: A possible point of departure – only 1-in-2 year floods captured.
- Scenario 2: Scenario 1 but with 1-in-2 and 1-in-5 year floods captured.
- Scenario 3: Scenario 2 but with an additional Class 4 flood.

Their summary details are given in **Table 2-99.**

Table 2-99: Scenario Summary

Scenario	Condition with present-day sediments	Condition with reduced sediments	Volumes in the river				Inter-annual floods
			Total - including inter-annual floods	% MAR including inter-annual floods	Release as IFR from Polihali, i.e., excl. inter-annual floods	% MAR of releases	
Scenario 1	State III	State III	190	26%	136	18.6%	>/= 1:5
Scenario 2	State IV	State III	165	22.5%	136	18.6%	>/= 1:10
Scenario 3	State IV	State III	244	33%	215	29.4%	>/= 1:10

Scenario 2 was selected for further analysis. The IFR volumes provided here are guides; the actual releases will be made in conjunction with rainfall events, i.e., no rain – no flood, and will differ from the annual volumes given. As a general rule, the volumes given by DRIFT Category are higher than the long-term average volumes that would be arrived at through detailed calculations for a particular release from a dam, when floods are capped and/or are not cued by climatic events. Furthermore, flows in the river will be augmented by contributions from the incremental catchment as distance downstream increases.

2.14.3.6 In-stream Flow-Related Studies for the Planning and Implementation Stages of LHWP Phase II

The following additional studies are required:

- Generation of additional scenarios, and more detailed hydrological analysis.
- Monitoring, in particular the establishment of a baseline IFR data set.
- Design of IFR-operating rules.

2.14.4 Legal Studies

The report undertakes a detailed study of certain issues relating to the 1986 Treaty on The Lesotho Highlands Water Project, including the Treaty review, SACU Rebate factor, taxes, and in-stream flow requirements.

This literature survey mainly deals with those aspects that affect the water course states, i.e. notification of other water course states and with the in-stream flow requirements.
This Treaty is a bilateral international agreement between the two states concerned and is still in force.

In the definitional clause in Article 1 the continuous nature of the agreement and the projects included thereunder is confirmed. “Project” for example means a “water delivery project ultimately delivering 70 cubic metres of water per second consequent on the implementation of phases providing for in paragraph 1 of Article 5 as well as the concomitant hydro-electric power project.

The question now arises whether, under the new conditions and legal principles now prevailing, the development of a new phase more than 20 years after the conclusion of the original agreement requires a refinement of this legal basis.

The answer to this question should be in the affirmative insofar as there is a need to respect the subsequent legal obligations now binding upon Lesotho and South Africa.

Namibia (which was not an independent state in 1986) and Botswana are entitled to invoke the Revised SADC Protocol, ORASECOM agreement and contemporary principles of customary international law. They are not party to the 1986 Treaty and South Africa and Lesotho cannot invoke their bilateral agreement vis-à-vis these other two states or the other parties to the Revised SADC Protocol.

A new phase in the development of the Project will take place within the context of new legal arrangements and there are new obligations which bind the two Parties and which they will have to honour. The Revised SADC Protocol contains indications on how to deal with these prior agreements

Article 7.5 of the ORASECOM Agreement is directly applicable. “A Party planning any project, programme or activity with regard to the River System which may have a significant adverse effect upon any or more of the other Parties, or which may adversely affect such River System, shall forthwith notify the Council and provide all available data and information thereto.”

2.14.4.1 In-stream Flow Requirements

The Treaty has a general provision regarding both environmental and social considerations in Article 15 which reads as follows:

“The Parties agree to take all reasonable measures to ensure that the implementation, operation and maintenance of the Project are compatible with the protection of the existing quality of the environment and, in particular, shall pay due regard to the maintenance of the welfare of persons and communities immediately affected by the Project."

The protection of the environment and maintenance of the welfare of the local communities are intimately linked in this Article.

The Treaty prescribes minimum releases from Katse and Mohale dams only. Article 7(9) obliges the LHDA to ".at all times maintain rates of flow in the natural river channels immediately downstream of Katse and Mohale dams of not less than 500 and 300 litres per second respectively and shall, if so required, release the quantities of water, from either Katse or Mohale reservoirs as the case may be, to maintain such rates of flow: Provided that subsequent to the implementation of Phase II of the Project, such rates of flow may be adjusted by agreement between the Parties and provided further that in the event of either reservoir being at its minimum operating level, the quantities of water released shall be equal to the flow rate into such reservoir not in excess of the specified rate of release. "

The Treaty does not prescribe environmental releases for the Matsoku Weir. Similarly, no environmental releases are prescribed for Muela dam as the Treaty stipulates in Article 7(10) that all the water originating in the catchment areas of the head pond and the tail pond dam are to be released downstream.
With regard to releases from dams to be constructed in later phases, Article 7(11) stipulates that prior to the implementation of any phase subsequent to Phase I, the minimum rate of flow to be maintained downstream of dams forming part of such phase, shall be established by agreement between the Parties.

2.14.4.2 Lesotho Highlands Water Project Phase I - Policy for In-stream Flow Requirements

For various reasons the Parties decided in the mid-1990's that the environmental releases prescribed by the Treaty were insufficient and commissioned an IFR study for Phase I which was completed in 2002. The LHDA adopted a document titled "Lesotho Highlands Water Project Phase I - Policy for In-stream Flow Requirements".

This Policy was approved by the Commission in July 2003 and the approval and implementation instructions were conveyed by the Commission to the LHDA by letter dated 30 July 2003.

The prescribed dam releases are considerably higher than the minimum releases prescribed by the Treaty. For Katse the bulk releases amount to 12,1% of the MAR, compared to 2,8% for the Treaty releases. For Mohale the figures are 10,3% compared to 3,1% in the Treaty. Since the figures in the Treaty are minimum figures, these increases are not strictly speaking in conflict with the Treaty.

The above releases are the long term average flows. However, the water will not be released as permanent steady flows, as envisaged in the Treaty, but the releases will be distributed in the optimal distribution of base flows and floods as determined by the DRIFT (Downstream Response to Imposed Flow Transformation) methodology, using the present flow regime of the rivers as a starting point.

2.14.5 System Analysis Supporting Report

2.14.5.1 Hydrology

A review / revision of the flood hydrology for all dam sites in the Lesotho Highlands was prudent to ensure that over estimations of the flood hydrology do not adversely impact on some of the scenarios to be assessed. The review was motivated due to the suggested over estimation of the design input peaks and the limited number of methods used in the flood peak estimation in previous studies. A reasonable amount of flow data is also available for the region to include regional statistical analysis to the flood peak estimation methods used.

The following flood peak estimation methods were used:

- Regional Statistical Analyses using the Log Pearson 3, Log Normal and the General Extreme Value distributions;
- The MIPI empirical method (Midgley & Pitman 1974)
- The Regional Maximum Flood (RMF) empirical method (Kovacs 1988) and
- The Safety Design Flood (SDF) empirical method (Alexander 2000)
- The Rational deterministic method as applied by DWAF and described by Kovacs (1987)
- The Synthetic Unit Hydrograph (SUH) (HRU 1/72) deterministic method.

A weighted average of the results of the various methods were calculated, and adopted for use in this study. The results are presented in **Table 2-100** below:

Table 2-100: Flood peaks for each dam site for various record periods

Site	Catch-ment Area (km^2)	Flood Discharge Q_t (m^3/s) for various Return Periods T (Year)									Extreme Flood		
		2	5	10	20	50	100	200	1000	10000	RMF	RMF+	PMF/ Ext. Event
Oxbow	288	140	240	330	440	600	740	930	1280	1990	1690	2200	3200
Katse	1867	360	640	900	1190	1660	2060	2510	3310	5170	4320	5390	6010
Polihali	3290	480	870	1200	1580	2210	2740	3470	4320	6660	5700	7100	7200
Taung/ Mashai	7900	780	1430	1970	2580	3610	4460	5440	6850	10600	8900	10800	9600
Tsoelike	10375	850	1590	2220	2930	4180	5200	6350	7800	12200	10200	12300	10850
Ntoahae	11500	900	1680	2370	3110	4400	5473	6700	8200	12800	10700	13000	11100
Mohale	938	250	450	620	820	1140	1400	1750	2320	3600	3050	3900	4750
Lebelo	3078	460	840	1170	1550	2160	2680	3300	4230	6570	5540	6900	7100
Malatsi	3566	500	900	1270	1670	2340	2900	3600	4560	7100	6000	7400	7500

This study further concluded that:

- The original VAPS study only used one method to estimate the required flood peaks.
- Based on an assessment using the Francou-Rodier "K" value the original VAPS study flood peaks overestimated the more extreme events.
- Although the RMF methodology was used the results were never included in the final flood estimation.
- The only real site specific data used in the VAPS study were the estimates of the MAP. The other rainfall inputs into the SUH method were based on generalisation from other areas and regions deemed to have similar characteristics.

The present study used statistical, empirical and deterministic methods to estimate the peaks and the variations between the results were acceptable. The methods also show a reasonable agreement with the observed data. The SUH results from this study were adjusted to match the observed or statistical results and the adjusted PMF estimate showed a reasonable agreement with the RMF estimate for a "K"=5.2 region which is also used as the SEF.

2.14.5.2 Hydrology and Yield Analysis

This study required a revision of previous dam and system yield analyses that use the agreed hydrological records supplied by the Client as well as implementing the environmental releases as specified in the inception report.

Previous dam and system layouts investigated in previous studies like the VAPS study were revisited and modified (if required) and new dam and transfer options were also investigated.

The latest agreed cumulative monthly flow records for the record period October 1926 to September 1996 were supplied by the client for the Katse, Mashai, Tsoelike, Ntoahae, Mohale and Malatsi catchments. The incremental inflow into the Polihali dam site was revised and the procedure followed was described. Details of the hydrological input used in the yield analyses are presented in **Table 2-101** below for each dam site:

Table 2-101: Catchment areas and runoff information used in the study

Catchment Name	Incremental Catchment Area (km^2)	MAP (mm)	Unit Runoff (mm)	% Runoff	Incremental MAR (million m^3)
Polihali	3170	900	220.0	24.4	697.4
Matsoku	650	730	147.8	20.3	96.1
Taung	2213	650	44.0	6.8	97.4
Mashai	77	600	40.0	6.7	3.1
Katse	1867	950	296.9	31.3	554.3
Tsoelike	2400	720	150.8	20.9	361.9
Ntoahae	1123	720	137.8	19.1	154.7
Mohale	938	1040	329.2	31.7	308.8
Malatsi	2628	750	112.3	15.0	295.0

2.14.5.3 Yield Analysis

The Water Resources Yield Model (WRYM) setup used to determine the Nominal annual yield of the Lesotho Highlands Phase 1 system was provided by the Client. The hydrological information used in the model was based on the agreed hydrological records, with a record period of October 1920 to September 1996. This study requires that the agreed hydrological information + 1% of the MAR to be used for dam and system yield purposes, with a record period of October 1926 to September 1996. The WRYM Model setup was thus modified to include the runoff records supplied by the Client.

Potential new dam sites at Oxbow (on the Malibamatso River upstream of Katse Dam) and Lebelo (on the Senqunyane River downstream of Mohale Dam, but upstream of the Malatsi dam site) were also added to the WRYM Model setup. The Terms of reference prescribed that an environmental release of 15% of the cumulative MAR need to be included in all dam yield analyses. Time series records for all dam sites were determined using the cumulative flow records (as received from Client) and calculating new monthly values using the 15% rule. The environmental releases were simulated in the WRYM model using an additional release channel from the dam. The total flow modelled that were simulated downstream of a dam thus includes the environmental release as well as any uncontrolled spills that might occur.

2.14.5.4 Results of Yield Analyses:

Table 2-102 below contains summarised results of the yield analyses per layout and development phase.

Table 2-102: Yield results summary per layout and development phase

Layout Number	Phase II New Tunnel	Phase II New Dam	Phase II Incremental Yield (m^3/s)	Phase III New Tunnel	Phase III New Dam	Phase III Incremental Yield (m^3/a)	Phase IV New Tunnel	Phase IV New Dam	Phase IV Incremental Yield (m^3/a)	Total Incremental Yield (m^3/s)
1 POL-MUE	Polihali - Muela	Polihali	17.30	Tsoelike - Taung - Polihali	Tsoelike & Taung	13.00	Malatsi - Ntoahae - Tsoelike	Malatsi & Ntoahae	12.10	42.40
2 POL-MUE			17.30	Lebelo - Mohale	Lebelo	6.75	Tsoelike - Taung - Polihali	Tsoelike & Taung	13.00	37.05
3 POL-MUE			17.30	Tsoelike - Taung - Polihali	Tsoelike & Taung	13.00	Lebelo - Mohale	Lebelo	6.75	37.05
4 POL-KAT	Polihali - Katse	Polihali	17.30	Tsoelike - Taung - Polihali	Tsoelike & Taung	13.00	Malatsi - Ntoahae - Tsoelike	Malatsi - Ntoahae	12.10	42.40
5 POL-KAT			17.30		Tsoelike & Taung	13.00	Lebelo - Mohale	Lebelo	6.75	37.05
6 POL-KAT			17.30	Lebelo - Mohale	Lebelo	6.75	Tsoelike - Taung - Polihali	Tsoelike & Taung	13.00	37.05
7 POL-ELA	Polihali - Elands	Polihali	17.30	Tsoelike - Taung - Polihali	Tsoelike & Taung	13.00	Malatsi - Ntoahae - Tsoelike	Malatsi - Ntoahae	12.10	42.40
8 POL-ELA			17.30		Tsoelike & Taung	13.00	Lebelo - Mohale	Lebelo	6.75	37.05
9 POL-ELA			17.30	Lebelo - Mohale	Lebelo	6.75	Tsoelike - Taung - Polihali	Tsoelike & Taung	13.00	37.05
11 TAU-MUE	Taung - Muela	Taung	20.00	Tsoelike - Taung	Tsoelike	10.40	Malatsi - Ntoahae - Tsoelike	Malatsi - Ntoahae	10.70	41.10
12 TAU-MUE			20.00		Tsoelike	10.40	Lebelo - Mohale	Lebelo	6.75	37.15
13 TAU-MUE			20.00	Lebelo - Mohale	Lebelo	6.75	Tsoelike - Taung	Tsoelike	10.40	37.15
14 TAU-KAT	Taung - Katse	Taung	20.00	Tsoelike - Taung	Tsoelike	10.40	Malatsi - Ntoahae - Tsoelike	Malatsi - Ntoahae	10.70	41.10
15 TAU-KAT			20.00		Tsoelike	10.40	Lebelo - Mohale	Lebelo	6.75	37.15
16 TAU-KAT			20.00	Lebelo - Mohale	Lebelo	6.75	Tsoelike - Taung	Tsoelike	10.40	37.15
21 LEB-MOH	Lebelo - Mohale	Lebelo	6.75	Polihali - Katse	Polihali	17.30	Tsoelike - Taung - Polihali	Tsoelike - Taung	13.00	37.05
22 LEB-MOH			6.75	Polihali - Elands	Polihali	17.30		Tsoelike - Taung	13.00	37.05
23 LEB-MOH			6.75	Polihali - Muela	Polihali	17.30		Tsoelike - Taung	13.00	37.05
24 LEB-MOH			6.75	Taung - Muela	Taung	20.00	Tsoelike - Taung	Tsoelike	10.40	37.15
25 LEB-MOH			6.75	Taung - Katse	Taung	20.00		Tsoelike	10.40	37.15

2.14.5.5 Conclusion of Yield Analyses

The following can be concluded from the Stage 1 historical Yield analyses:

An incremental yield (excluding the yield from the existing Phase 1 development) of between 17.3 m^3/s

(Polihali) and 20.1 m^3/s (Taung) can be expected from a Phase 2 development.

The incremental yield will increase to 31.1 m^3/s if the envisaged Phases 2 and 3 are developed.

If all four envisaged phases are developed, one can expect a Phase 2 – 4 yield of 42.4 m^3/s, which equate to a total Lesotho Highlands yield of 67.1 m^3/s.

2.14.5.6 Investigation of Further Phase Development on the Yield of the Orange River System

The benefit of a possible Phase II development of dams and transfer infrastructure in the Lesotho Highlands for the incremental system yield of the whole Senqu / Orange River system was also investigated.

The LORMS WRYM setup (obtained from the Client) was used for this study, as it include all current water use in the Orange River System including irrigation, potable water use, environmental requirements and water losses from the river. The details of the various water uses are documented in Report PB D000/00/4303.

Two methods were used to assess the reduction in system yield at Van Der Kloof Dam:

1. The river losses downstream of Van Der Kloof Dam was set to zero, and
2. No demands downstream of Van Der Kloof Dam were allowed to be supplied from storage, i.e. Van Der Kloof Dam only supplied water to a yield channel, and spills from Van Der Kloof Dam were allowed to exit the system.

The available system yield at Van Der Kloof Dam (excluding downstream water losses) was determined for four scenarios for each potential Phase II dam. The scenarios investigated are:

2.14.5.6.1 Taung Dam Option:

Scenario 1 : Present Day scenario with Phase 1 of Lesotho Highlands developed (Katse, Mohale and Matsoku)

Scenario 2 : Taung Dam at max FSL (1 885 m.a.s.l) transferring 17.9 m^3/s into Katse, for a total transfer to the Vaal of 44.8 m^3/s.

Scenario 3 : Taung Dam at FSL of 1 845 m.a.s.l transferring 11.5 m^3/s into Katse, for a total transfer to the Vaal of 38.4 m^3/s.

Scenario 4 : Taung Dam at FSL of 1 847 m.a.s.l transferring 12.5 m^3/s into Katse, for a total transfer to the Vaal of 39.4 m^3/s.

2.14.5.6.2 Polihali Dam Option:

Scenario 1 : Present Day scenario with Phase 1 of Lesotho Highlands developed (Katse, Mohale and Matsoku)

Scenario 2 : Polihali Dam at FSL of 2 065 m.a.s.l transferring 17.1 m^3/s into Katse, for a total transfer to the Vaal of 41.9 m^3/s.

Scenario 3 : Polihali Dam at FSL of 2 039 m.a.s.l transferring 13.5 m^3/s into Katse, for a total transfer to the Vaal of 38.2 m^3/s.

Scenario 4 : Polihali Dam at FSL of 2 045 m.a.s.l transferring 14.5 m^3/s into Katse, for a total transfer to the Vaal of 39.2 m^3/s.

2.14.5.7 Results

The results from this section of the study are presented in **Table** 2-103 (Method 1) and **Table 2-104** (Method

2) below:

Table 2-103: Reduction in System Yield at Van Der Kloof Dam - Method 1

	System Yield from Van Der Kloof Dam:		Reduction in System Yield @ Van Der Kloof Dam		Lesotho Highlands Transfer to Vaal River		LHFP - Phase II Dam Gross Yield[1]		Increase in Orange River system yield[2]	
	10^6 m^3/a	m^3/s	10^6 m^3/a	m^3/s	10^6 m^3/a	m^3/s	10^6 m^3/a	m^3/s	10^6 m^3/a	m^3/s
Scenario 1	841	26.7			780	24.7				
Polihali Option										
Scenario 2	578	18.3	263	8.3	1321	41.9	541	17.2	278	8.8
Scenario 3	586	18.6	255	8.1	1206	38.2	426	13.5	171	5.4
Scenario 4	578	18.3	263	8.3	1237	39.2	457	14.5	194	6.1
Taung Option										
Scenario 2	573	18.2	268	8.5	1413	44.8	633	20.1	365	11.6
Scenario 3	573	18.2	268	8.5	1209	38.4	429	13.7	161	5.2
Scenario 4	537	18.2	268	8.5	1241	39.4	461	14.7	193	6.2

Table 2-104: Reduction in System Yield at Van Der Kloof Dam - Method 2

	System Yield from Van Der Kloof Dam:		Reduction in System Yield @ Van Der Kloof Dam		Lesotho Highlands Transfer to Vaal River		LHFP - Phase II Dam Gross Yield[1]		Increase in Orange River system yield[2]	
	10^6 m^3/a	m^3/s	10^6 m^3/a	m^3/s	10^6 m^3/a	m^3/s	10^6 m^3/a	m^3/s	10^6 m^3/a	m^3/s
Scenario 1	2656	84.2			780	24.7				
Polihali Option										
Scenario 2	2404	76.2	252	8.0	1321	41.9	541	17.2	289	9.2
Scenario 3	2410	76.4	246	7.8	1206	38.2	426	13.5	180	5.7
Scenario 4	2404	76.2	252	8.0	1237	39.2	457	14.5	205	6.5
Taung Option										
Scenario 2	2386	75.6	270	8.6	1413	44.8	633	20.1	363	11.5
Scenario 3	2386	75.6	270	8.6	1209	38.4	429	13.7	159	5.1
Scenario 4	2386	75.6	270	8.6	1241	39.4	461	14.7	191	6.1

Note: [1] Taung Dam Option: Includes increase in Phase I yield of 2.1 m^3/s due to non-release of IFR from Katse dam following construction of Taung dam

[2] Provided no diversion to the Vaal River is made

2.14.5.8 **Conclusion:**

The increases in the Orange River system yield are similar between the two methods described above, but not identical. The reason for this marginal difference is that with Method 1, the downstream irrigation demands are still being supplied, and these demands differ from month to month, i.e. the monthly yield distribution is not equal.

The second method uses an equal monthly yield distribution of the system yield.

2.14.6 The Stage 2 Feasibility Study

The Stage 2 study included an extensive catchment-specific hydrological modelling exercise for the catchment of the proposed Polihali Dam in order to improve the confidence in the Stage I inflow sequence to the Dam. The results reinforced the agreed Stage 1 unit Mean Annual Runoff figure of 220 mm/a, giving a natural mean annual inflow of 697 million m^3/a. However, it is strongly recommended that stream flow gauging in the vicinity of the Polihali dam site be improved as a matter of urgency.

Flood hydrographs for the 1:10, 1:20, 1:50, 1:100, 1:200, year as well as the Regional and Probable Maximum Flood events were routed through the proposed Polihali reservoir to optimise the spillway dimensions against dam freeboard, resulting in a spillway with a 100 m width and an anticipated maximum overflow depth of 7.2 m for a Probable Maximum Flood. The size of the river diversion works was also optimised.

In the yield determination the long term average Instream Flow Requirement was modelled at 130 million m^3/a, about 18.7% of the long term average natural mean annual inflow of 697 million m^3/a.

In the yield analysis a number of scenarios were modelled to test the sensitivity of yield to a number of parameters.

From the Stochastic Yield Analysis at 98% Assurance of Supply, the Base Case results are:

- The incremental yield of Phase II will be 465 million m^3/a or 14.75 m^3/s.
- The total System yield will then be 1271 million m^3/a or 40.30 m^3/s.
- The overall increase in yield of the Orange River System will be 182 million m^3/a.

The proposed Dam is a 163.5m high dam with a concrete lined side channel spillway as well as a 49.5 m high concrete faced rock fill saddle dam.

The proposed tunnel to transfer water, under gravity, from Polihali Dam to Katse Dam is a 38.2 km long 5.2 m diameter tunnel sized to convey a maximum flow of about 35m^3/s. The intake is located approximately 5 km upstream of the Polihali Dam wall.

Water from Phase II will flow under gravity into the Katse reservoir, from where it will flow through the existing Transfer Tunnel, to the Muela Power Station, into the Muela reservoir and through the Delivery Tunnel to the Ash River outfall. The Ash River already has extensive energy dissipation and erosion control measures and it is not anticipated that significant further work, other than some limited additional protection, will be required.

The existing delivery tunnel has sufficient capacity to transfer the water required, until at least 2048. The Muela Dam, will not require any modification, but raising the dam and upgrading the delivery tunnel are future options, which will increase the hydraulic capacity of the Delivery Tunnel if required.

As part of the Feasibility Study, an EIA was compiled, in terms of the statutory requirements of Lesotho. The Assessment Report, which used the results of the Biophysical, Social and Public Consultation components of this study, was submitted to, and accepted by, the National Environmental Secretariat of Lesotho.

As this EIA was carried out during the Feasibility Stage of the project, the project makeup could change during subsequent design phases. This EIA therefore sought to obtain overall project approval, subject to further approvals for the various project components, once their detailed design has been completed.

The proposed Phase II Resettlement and Compensation Policy seek to integrate the activities of resettlement, compensation, development, monitoring and evaluation. It calls for a single implementing unit to ensure synchronisation of compensation and resettlement with that of major engineering works, whilst providing for a framework for effectively addressing project challenges and community concerns.

The policy covers the economic and social impacts caused by the Project, including:

- Relocation or loss of shelter;
- Loss of assets or access to assets;
- Loss of income sources and/or means of livelihood, whether or not the affected are required to move.

The programme showed the MOU being concluded in early 2010, the commencement of project implementation as March 2009, which will allow for the studies to be reviewed and approved as well as for the parties to agree the principals for implementation.

The programme indicates that it will take about 10 years from when the Parties sign a Memorandum of Understanding, allowing project implementation to commence, until the first delivery of water from Polihali Dam can only be expected in 2019 or 2020.

The Feasibility Study defined the main features of Phase II and further phases, thus providing the information required to enable the Lesotho and South African governments to resolve key issues, and to decide whether or not to proceed with Phase II of the project.

2.15 TAUNG DAM UTILISATION FEASIBILITY STUDY (2008)

2.15.1 Main Report

2.15.1.1 Background and purpose of the study

The Taung Dam is a Roller Compacted Concrete (RCC) dam located on the Harts River upstream of the Vaalharts Irrigation Scheme in the Lower Vaal System. A recent survey indicated that the capacity of the dam at full supply level is 62.97 million m^3. The Taung Dam was constructed to augment supply to the Taung

Irrigation Scheme, but there is currently no infrastructure to convey water from the Taung Dam to potential beneficiaries. As a result water from the Taung Dam is at present not utilised. Local expectation was created that the Taung Dam could resolve all the potable and irrigation water supply issues. The purpose of the feasibility study was therefore to establish if the resource could be economically used for primary water supply, irrigation or other purposes within the project area.

The project area extends over the whole of the Taung Dam catchment area and the Vaal-Harts River system and includes Phokwane Local Municipality (PLM), Naledi Local Municipality (NLM) and the Greater Taung Local Municipality (GTLM).

2.15.1.2 **Key Findings**

The key findings made through this study are summarised below.

- Local expectation was created that the Taung Dam could resolve all the potable and irrigation water supply issues in the Taung area. This is however not true. The dam has a limited yield of approximately 7 Million m^3/annum which is recommended to be utilised for potable supply only.
- Undeveloped areas with agricultural potential were identified. These areas are however larger than what can be irrigated with water from the Taung Dam.
- An unutilised allocation of 22.51 Million m^3/annum of water from the Vaal River System exists for irrigation development, but infrastructure improvements will be required to deliver it to the areas identified.
- Preliminary groundwater investigations indicated that sufficient good quality groundwater is available at some areas of the study area. The groundwater potential investigations should therefore be refined and the installation of new borehole schemes as well as the upgrading of the existing schemes should be investigated as an alternative to supplying these areas with surface water from the Taung Dam.
- The quality of the groundwater at some villages is not acceptable due to high concentrations of nitrates in the water.
- A bulk potable water supply layout has been proposed, but needs demographic information confirmed before being implemented.

2.15.1.3 **Demographics (Kyamandi Done)**

The demographic component of this study, undertaken by Kyamandi Development Services (Pty) Ltd, entailed the compilation of an updated demographic status quo and the development of a demographic model that provides demographic projections at 5-year intervals up until 2030 for Greater Taung, Naledi, and Phokwane Local Municipalities.

The methodology followed in the undertaking of the study entailed consulting the latest revised development plans and secondary existing data sources to determine current priorities of the municipalities with regard to developmental issues and to obtain updated information and projections with regards to demographics of the study area. All demographic base data was obtained to compile up-to-date quantitative demographic profile of the study area in terms of population size and age, household size and composition, income and expenditure, education, employment, urbanisation trends, etc. Key incumbents from various public service organisations were also consulted to augment information on current social trends relevant to the study from their respective professional perspectives. The development of a demographic model followed the updated demographic profile.

As initial input into the model, DWA 2006 base population data was utilised. The base data utilised is more than 6 years old and the study also noted that should the project be implemented more time should be spent to confirm accurate population figures of individual villages.

2.16 METOLONG DAM ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT (2008)

2.16.1 In-stream Flow Assessment

2.16.1.1 Study Area

The Phuthiatsana River is situated in western Lesotho near Thaba Bosiu. It is also known as the Little Caledon River, and is a tributary of the Caledon River. It rises in the highlands of Lesotho, but the bulk of its length flows through the lowlands.

The site of the proposed Metolong Dam is situated in a gorge immediately upstream of the location at which the Phuthiatsana River flattens out considerably, and an IFR site was selected just downstream of the gorge.

2.16.1.2 Major assumptions

The following important major assumptions apply:

- The hydrological record supplied for the IFR study represents the true hydrological status of the river.
- Predictions are based on a c. 30-year horizon.
- Climatic conditions in the next 30 years would mirror those of the past 30 years.
- There will be no major changes in land use in the catchment.
- Trout are present in the system.
- Water quality (apart from sediments) was not considered, and it is assumed that it will not constitute a significant contributor to reduced ecological condition with a reduction in flows.

2.16.1.3 Results

Results are presented for two situations:

1. For a situation where the sediment supplies to the site remained at present-day levels. If the assumption that the dam will trap sediment is correct, this second situation would apply to sections of the river > 30 km downstream of the dam.
2. For a situation where the proposed dam would trap the majority of the sediment supply to the IFR site depending on the contribution from Liphiring River. This would effectively reduce sediment supply to the river for approximately 30 km downstream of the dam.

2.16.1.4 Feasibility study allocations to IFR

The Feasibility study allocations to IFR are summarised in **Table 2-105**.

Table 2-105: Feasibility study allocations to IFR

Feasibility allocations to IFR	
Wet season	100 ℓ/s
Dry season	200 ℓ /s
Class 2 flood	4
Class 4 flood	1
Total	**11% MAR**

2.16.1.5 Expected outcome at the IFR site of feasibility allocations to IFR

The data indicate the following:

The site is currently between a C and D category.

- The site is expected to be relatively insensitive to flow changes, i.e., a reduction from 100% present day MAR to 16% present day MAR is not expected to result in a change from a D-category.
- The Feasibility Allocation IFR releases may run the risk of a drop from one category to another (D-E) in condition at the site. It is however expected that the effects of the flow changes will be mitigated to some extent by the proximity of the proposed dam wall, and a reduction in sediment supply to the site (shaded red area).
  - Consequently, the predicted future condition for the IFR site, and the river reach it represents, is expected to remain somewhere between a C and a D condition if 11% of the MAR at the dam site is released from the dam provided that the releases adhere to the distribution of flows recommended in **Table 2.106**

Note: This presupposes no additional developments on the tributaries in the incremental catchment between the dam site and the IFR site.

2.16.1.6 Required flow distributions and volumes at the IFR site

The following is a brief summary of the flow distribution and volumes at the IFR site for the IFR recommended in the Feasibility study.

2.16.1.6.1 Expected Ecological Category

Expected Ecological Category = D, assuming that the proposed Metolong Dam will result in a slight decrease in sediments at the IFR site.

2.16.1.6.2 In-stream flow requirements

The volumes reported in the Feasibility study excluded the volumes of the ≥ 1:2 year return period flood: Mean annual volume required for the river at IFR Site: c. 11.18 MCM a^{-1} (c. 21% nMAR).

Note: This is the maximum annual volume linked to the IFR (excl. 1:5 year return period flood). As a general rule, the volumes given in DRIFT Category are higher than the long-term average volumes that would be arrived at through detailed calculations for a particular release from a dam, when floods are capped and/or are not cued by climatic events.

2.16.1.6.3 Flow reduction levels used

The following mix of change levels for the 10 components is required:

1)	Wet season low flows	Level 4, i.e., Capped at the 60% percentile of the PD low flow duration curve.
2)	Dry season low flows:	Level 3, i.e., Capped at the 60% percentile of the PD low flow duration curve.
3)	Class 1 Intra-annual floods:	Two Class 1 floods.
4)	Class 2 Intra-annual floods:	Two Class 2 floods.
5)	Class 3 Intra-annual floods:	One Class 3 floods.
6)	Class 4 Intra-annual floods:	No Class 4 floods.
7)	Inter-annual floods (1:2 year):	Not present.
8)	Inter-annual floods (1:5 year):	Present Day.
9)	Inter-annual floods (1:10 year):	Present Day.
10)	Inter-annual floods (1:20 year):	Present Day.

2.16.1.7 Modified flow regime expected at the IFR site

The modified flow regime expected at the IFR site under the Feasibility Allocation IFR is shown in **Table 2.106** and more details about the flood requirements are provided in **Table 2.107**.

The depicted regime does not assign ≥ 1:5 year floods to the IFR, but these are vital for achieving the expected condition.

Table 2-106: Water quantity for Phuthiatsana River (Feasibility Allocation IFR). To be met at IFR Site. MCM = million cubic metres

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL (MCM)	nMAR %
N MAR = 53.67 MCM (estimated).														
IFR Ecostatus Category = D.														
MAINTENANCE														
LOW FLOWS Q m^3s^{-1}	0.28	0.30	0.60	0.37	0.45	0.40	0.40	0.40	0.20	0.11	0.10	0.07	7.72	14%
FLOOD Class 1: 1.6 m^3s^{-1}	1							1					0.31x2	0.62
FLOOD Class 2: 3.73: m^3s^{-1}			1		1								0.76x2	1.52
FLOOD Class 3: 7.12: m^3s^{-1}	1			1									1.32x1	1.32
FLOOD Class 4: 13.82: m^3s^{-1}	-												-	-
Inter-annual floods	Not included in IFR volume													
MAINTENANCE TOTAL (Volume)	**Annual**												**11.18**	**21**
	Long-term average												**9.79**	**18**

Table 2-107: Summary of the flood requirements

Flood type	Daily average peak (m^3s^{-1})	Duration (days)	Volume (MCM)	Number requested	Months
Intra-annual Class (i.e., each flood has a return period of 1:1)					
Class 1	1.6	3	0.31	2	Oct-Nov and Apr-May-June
Class 2	3.7	3	0.76	2	
Class 3	7.1	3	1.32	1	
Class 4	13.8	5	3.23	0	Not applicable
Inter-annual Class (return period given below)					
1:2	50	8	10.9	0	Not stipulated
1:5	80	10	19.1	Present	Not stipulated
1:10	Not available			Present	Not stipulated
1:20	Not available			Present	Not stipulated

2.16.1.8 Conclusions

The current ecological condition of the Phuthiatsana River is considerably removed from what it would have been under pre-development conditions. Two major impacts on the river include:

- accelerated supply of sediments to the site, which appear to have resulted in a reduction in the depth of the pools and infilling of several key habitats;
- human use of the system, such as removal of riparian vegetation and cultivation, which have impinged on the riparian buffer zone, and appear to have resulted in a considerable reduction in the integrity of the zone.

The flow regime in the river is also likely to have been affected by land use in the surrounding catchment.
If Metolong Dam is constructed, the sections of the Phuthiatsana River closest to the dam are likely to be most affected by alterations to the flow regime. However, it is the opinion of the specialists on this study that such flow impacts may be partially off-set by an amelioration of the accelerated supply of sediments to the site.

The predicted future condition for the IFR site, and the river reach it represents, is expected to remain somewhere between a C and a D condition if the Feasibility Allocation of 11% of the MAR at the dam site is released from the dam.

Increased IFR allocations are expected to achieve a slightly better condition in the downstream river, but not necessarily considerably better.

With distance downstream from the site, both the sediment supply and the flow regime will gradually move towards an approximation of present day conditions.

Such conclusions are however dependent on adherence to the recommended distribution of flows.

Finally, moving forward from the determination of the IFR, experience in other parts of the world has shown that the creation of a decision support system for implementation and operation of an IFR, e.g., formulation of operating rules for the dam, is an important contributor to the success of these endeavours. Such a system should include multi-disciplinary input from the outset, including representation of an IFR specialist.

In order to achieve the estimated schedule of IFR releases, operating rules and a decision support system will be needed to guide operation of the off-take from the reservoir. The development of such operating rules and decision support system should be undertaken during detailed design of the dam with input from an IFR specialist as mentioned above. To further reinforce this requirement, it is also recommended that the Environmental and Social Management Program for the Project include IFR baseline and implementation monitoring.

2.17 VAAL RIVER RECONCILIATION STRATEGY STUDY (2009)

2.17.1 Overview

Over decades the water resources of the Vaal River System were augmented to match the growing water requirements and major inter-basin transfer schemes were developed to convey water into the system from the high rainfall regions of the upper Thukela and Usutu rivers as well as from the headwaters of the Orange River in the highlands of the Kingdom of Lesotho. The water resource components of the Integrated Vaal River System are highly inter-dependant due to the cascading orientation of the three Vaal River Water Management Areas as well as the links that exist as a result of the transfer schemes.

The Department of Water Affairs and Forestry is conducting a number of studies of the large metropolitan areas of which the Large Bulk Water Supply Reconciliation Strategy for the Vaal River System and the Crocodile (West) River Reconciliation Strategy studies serve to inform this document. These are comprehensive planning studies with the objective to determine a strategy that will ensure that enough water will be available when it is required in future. Scenarios of future demands are developed and the measures that would have to be implemented to meet those future needs are identified and investigated. Climate change and its possible impacts on water resource availability were also considered. From the limited information available with the associated low level of confidence, it was decided that the impact of climate change on the overall Vaal River System is not substantial enough for it to be incorporated into the strategy.

2.17.2 Second Stage Reconciliation Strategy

2.17.2.1 Water requirement scenarios

Table 2-108, **Table 2-109** and **Table 2-110** summarises the water requirements for the High, Base and Low Population scenarios, presenting the overall system gross and net water requirements for the planning years 2007 to 2030.

Table 2-108: Summary of water requirements and return flows (High Population Scenario)

Water users	Planning years					
	2007	2010	2015	2020	2025	2030
Water requirements						
Rand Water (South)	787	814	888	983	1 050	1 107
Rand Water (North)	566	632	704	763	805	872
Mittal Steel	17	17	17	17	17	17
ESKOM[2]	349	402	418	413	398	381
SASOL (Sasolburg)	25	27	30	33	37	41
SASOL (Secunda)	91	95	107	115	123	130
Midvaal Water Company	37	37	37	37	37	37
Sedibeng Water (Balkfontein only)	59	45	46	47	48	49
Other towns and industries	168	185	188	189	189	190
Vaalharts/Lower Vaal irrigation	542	542	542	542	542	542
Other irrigation (adjusted for updated lawful irrigation)	668	550	471	471	471	471
Wetland / River Losses	325	326	327	329	330	331
Return Flows						
Southern Gauteng (Rand Water)	331	315	317	337	351	366

Water users	Planning years					
	2007	2010	2015	2020	2025	2030
Midvaal Water Company	1	1	1	1	1	1
Sedibeng Water	2	2	2	2	2	2
Other towns and industries	63	65	69	73	76	81
Irrigation	68	52	43	43	43	43
Mine dewatering	116	109	126	128	126	126
Increased urban runoff	101	103	107	113	121	129
OVERALL GROSS SYSTEM DEMAND:	**3 634**	**3 671**	**3 775**	**3 938**	**4 046**	**4 168**
OVERALL NET SYSTEM DEMAND:	**2 952**	**3 024**	**3 111**	**3 241**	**3 326**	**3 420**
Portion of Southern Gauteng Return Flow excluded from net demand calculation. (Contribution to lower Vaal excess)	23	63	102	118	130	143

Notes: (1) All volumetric values are given in million m³/annum.
(2) Includes 3rd party users.

Table 2-109: Summary of water requirements and return flows (Base Population Scenario)

Water users	Planning years					
	2007	2010	2015	2020	2025	2030
Water requirements						
Rand Water (South)	738	799	857	916	961	1 007
Rand Water (North)	537	600	664	718	761	821
Mittal Steel	17	17	17	17	17	17
ESKOM[2]	349	402	418	413	398	381
SASOL (Sasolburg)	25	27	30	33	37	41
SASOL (Secunda)	91	95	107	115	123	130
Midvaal Water Company	37	37	37	37	37	37
Sedibeng Water (Balkfontein only)	59	45	46	47	48	49
Other towns and industries	168	185	188	189	189	190
Vaalharts/Lower Vaal irrigation	542	542	542	542	542	542
Other irrigation (adjusted for updated lawful irrigation)	668	550	471	471	471	471
Wetland / River Losses	325	326	327	329	330	331
Return Flows						
Southern Gauteng (Rand Water)	331	315	317	337	351	366
Midvaal Water Company	1	1	1	1	1	1
Sedibeng Water	2	2	2	2	2	2
Other towns and industries	63	65	69	73	76	81
Irrigation	68	52	43	43	43	43
Mine dewatering	116	109	126	128	126	126
Increased urban runoff	101	103	107	113	121	129
OVERALL GROSS SYSTEM DEMAND:	**3 557**	**3 624**	**3 704**	**3 827**	**3 914**	**4 016**
OVERALL NET SYSTEM DEMAND:	**2 874**	**2 977**	**3 040**	**3 129**	**3 194**	**3 268**
Portion of Southern Gauteng Return Flow excluded from net demand calculation. (Contribution to lower Vaal excess)	16	52	82	89	95	102

Notes: (1) All volumetric values are given in million m³/annum. (2) Includes 3rd party users.

Table 2-110: Summary of water requirements and return flows (Low Population Scenario)

Water users	Planning years					
	2007	2010	2015	2020	2025	2030
Water requirements						
Rand Water (South)	725	767	806	825	828	828
Rand Water (North)	529	584	614	639	650	672
Mittal Steel	17	17	17	17	17	17
ESKOM[2]	349	402	418	413	398	381
SASOL (Sasolburg)	25	27	30	33	37	41
SASOL (Secunda)	91	95	107	115	123	130
Midvaal Water Company	37	37	37	37	37	37
Sedibeng Water (Balkfontein only)	59	45	46	47	48	49
Other towns and industries	168	185	188	189	189	190
Vaalharts/Lower Vaal irrigation	542	542	542	542	542	542
Other irrigation (adjusted for updated lawful irrigation)	668	550	471	471	471	471
Wetland / River Losses	325	326	327	329	330	331
Return Flows						
Southern Gauteng (Rand Water)	331	315	317	337	351	366
Midvaal Water Company	1	1	1	1	1	1
Sedibeng Water	2	2	2	2	2	2
Other towns and industries	63	65	69	73	76	81
Irrigation	68	52	43	43	43	43
Mine dewatering	116	109	126	128	126	126
Increased urban runoff	101	103	107	113	121	129
OVERALL GROSS SYSTEM DEMAND:	**3 535**	**3 577**	**3 603**	**3 657**	**3 668**	**3 688**
OVERALL NET SYSTEM DEMAND:	**2 853**	**2 930**	**2 939**	**2 960**	**2 948**	**2 941**
Portion of Southern Gauteng Return Flow excluded from net demand calculation. (Contribution to lower Vaal excess)	10	39	54	43	30	16

Notes: (1) All volumetric values are given in million m^3/annum.
(2) Includes 3rd party users.

2.17.2.2 Potential savings through water conservation and water demand management measures

The focus of the WC/WDM assessment was on the nine largest urban water users, which in total used 1 186 million m^3/annum of water in the year 2004. Three saving scenarios were compiled from the assessment of the potential for water conservation and water demand managements (WC/WDM) in the urban sector. The savings were applied to come of the water requirement scenarios and were labelled Scenarios C, D and E respectively. The description and saving results from the scenarios are as following:

- Scenario C: 5 Year water loss programme where water wastages are reduced through measures such as leak detection and repair. The loss management measures are maintained after the five year period. This scenario also include measures to improve the efficiency of water use and the assumption was made that a 1% saving can be gained per annum from the year 2015 onwards for the entire planning period (1% of selected large urban users that were assessed in detail).
- Scenario D: Reduction in wastage over 5 years. No efficiency improvement measures were included in this scenario.
- Scenario E: Reduction in wastage over 10 years, allowing for a slower implementation period of the proposed measures.

A summary of the estimated savings in the water requirements for the pertinent scenarios are presented in **Table 2-111**.

Table 2-111: Savings for the indicated scenarios and planning years

Scenarios	Planning Years				
	2010	2015	2020	2025	2030
C3, L8, High	185 (11%)	282 (15%)	315 (17%)	402 (19%)	402 (18%)
D3, L8, High	180 (11%)	191 (10%)	204 (10%)	217 (10%)	217 (10%)
D3, L8, Base	185 (11%)	191 (11%)	204 (11%)	217 (11%)	217 (10%)
D3, L8, Low	185 (11%)	191 (11%)	204 (12%)	217 (13%)	217 (12%)

Notes: (1) All volumetric values are given in million m^3/annum.
(2) Values in brackets give the percentage reduction in the total system urban demand for the different scenarios. The urban demand includes the following components; Rand Water, Midvaal Water Company, Sedibeng Water and "Other towns and industries" as listed in Table 2-108, Table 2-109 and Table 2-110.

2.17.2.3 Future intervention requirements and augmentation schemes

2.17.2.3.1 Planning scenarios and reconciliation options

Given the water requirement and return flow scenarios as well as the WC/WDM saving options, the following planning scenarios were compiled for analysis of the water balance:

- Scenario I: High population scenario for the urban water requirements including the eradication of unlawful irrigation and the implementation of loss reduction measures over the next 5 years i.e. 15% WC/WDM.
- Scenario II: High population scenario for the urban water requirements including the eradication of unlawful irrigation.
- Scenario III: High population scenario for the urban water requirements and unlawful irrigation not removed.
- Scenario IV: Low population scenario for the urban water requirements including the eradication of unlawful irrigation and the implementation of loss management measures over the next 5 years i.e. 15% WC/WDM Scenario.
- Scenario V: Rand Water high water requirement projection including the eradication of unlawful irrigation and the implementation of loss management measures and water use efficiency over the next 5 years i.e. 30% WC/WDM Scenario.

Comparing the net system demand to the supply capability of the system shows:

- The unlawful water use in the irrigation sector results in the system being in a deficit situation from 2007 to 2009.
- Based on the projected balance situation for Scenario I, it is shown that the system will require intervention by the year 2014.
- If the potential savings through WC/WDM are not achieved as in Scenario II, and the unlawful irrigation is also not reduced (Scenario III) the system is in deficit throughout the projection period and a severe risk of water shortages exists. This is an extreme scenario and was only configured to motivate why the eradication of the unlawful water use and loss management measures are essential to ensure a sustainable water supply is available for the users receiving water from the Vaal River System.
- The balance situation for Scenarios IV shows that if the low population projection realises and the unlawful irrigation is reduced and waste management initiatives are implemented, the system surplus water is available throughout the projection period.
- The balance situation for Scenario V shows that if Rand Water's high water requirement projection

realises and both the unlawful irrigation is reduced and both waste management and water use efficiency initiatives are implemented the system will require an intervention by 2018.

The following perspective on the augmentation requirements for the Vaal River System can be formulated:

- Eradication of the unlawful water use in the irrigation sector is essential to obtain a positive water balance in Vaal River System.
- Water Conservation and Water Demand Management initiatives to reduce the losses in the system are necessary to reduce the risk of drought curtailments until the next large augmentation scheme can be implemented by the year 2019.
- Planning activities required to implement the next bulk augmentation scheme should continue to ensure delivery is possible by 2019.

The results of the simulation analysis showed that excess water that is effectively a loss to the Vaal River System water users will occur in Bloemhof Dam should the 600ml/g water quality management blending rule in the Vaal Barrage be implemented without considering re-use.

It was found that the combined effect of implementing Phase II of the LHWP and re-using mine water effluent (desalinate to potable quality) has the benefit that the subsequent (follow-on) augmentation scheme is postponed until 2038. This is a significant benefit in that the capital expenditure of the subsequent follow-on scheme can be postponed for many years and that the quality of the water in the Middle and Lower Vaal Water Management Areas will be improved due to the removal of salts from the mine water effluent.

It can therefore be concluded that re-use of effluent improves the water balance and contributes to reduce the risk of drought curtailments until the next bulk augmentation scheme can deliver water.

2.17.2.4 Perspective on water quality management

The findings from the Integrated Water Quality Management Plan were used to formulate the following management measures to improve the water quality in the system.
The proposed immediate to short term management strategy is as follows:

- Continue with dilution of the Vaal Barrage water with releases from Vaal Dam. This approach does not result in the RWQOs set for the Vaal main stem being met. A waste discharge charge will be levied on discharges to offset the economic dis-benefit of the downstream users.
- Implement an upgraded monitoring programme.
- Selection of target saline effluent treatment schemes.
- Incorporated into the dilution releases will be the flow manipulation required to manage the algal blooms in the middle reaches of the Vaal River.
- Audit WWTWs and develop perspectives on hotspots requiring urgent action.
- Document and pilot protocols for flow manipulation releases as a strategy in Middle Vaal from Vaal Barrage to Bloemhof Dam.
- Source control, through Water Use Licence Application and Integrated Water and Waste Management Plans.
- Implement monitoring plan of nutrient sources.
- Implement upgraded monitoring and reporting plan.

The medium to long term management strategy is:-

- Implement target saline effluent treatment schemes.
- Implement waste discharge charges.
- Continue monitoring/assessment.
- Implement WWTW retrofit and upgrading projects in the hot spot areas.
- Nutrient Balance Study.

2.17.2.5 Strategic perspective on water resource management

Ensuring that sufficient water is available to supply the future water requirements in the supply area of the Vaal River System requires a five pillar strategy consisting of the following main components:

- Water use compliance enforcement to eradicate unlawful water use.
- Water Conservation and Water Demand Management measures to reduce losses and improve efficiency.
- Utilisation of treated effluent and other discharges, especially those from the mines.
- Implementation of infrastructure augmentation option.
- Management of the water quality in the system.

2.17.3 Groundwater assessment: Dolomite aquifers

The groundwater assessment of the Vaal Water Management Area (WMA) has been limited to the dolomitic aquifers which are divided into three main regional and morphological groups, namely:

- Far East to Far West Rand
- North-West
- Ghaap Plateau

2.17.3.1 Far East to Far West Rand

The chert-rich dolomite has the best groundwater potential, i.e. the Monte Christo and Eccles Formations. There are 11 main compartments in the area of which 5 have been severely impacted by mining and other activities. The general recharge estimates is between 10 and 15% but higher recharge occurs in areas where sinkholes, subsidence, lowering of water levels and widening of conduits can enhance recharge potential. The water quality is typically $Ca/Mg(HCO_3)_2$ type but is impacted in the mining areas by sulphate, nitrate and dissolved radionuclides in the Bank and Oberholzer Compartments. Total groundwater abstraction and spring flow is estimated at 292 million m^3/a. Assuming an allowable 5 m drawdown in the compartments unaffected by mining and present users then an estimated 150 m^3/a may be available. To develop this will require an estimated 190 boreholes yielding 25 ℓ/s. In the affected by mining area possible scenarios are considered such as to allow spring outflow after rewatering or treatment of mining water.

2.17.3.2 North West Dolomites

There are six large compartments with sub-compartments in the area. The best occurrence for development also appears in the Monte Christo Formation. Groundwater quality is good with only nitrate impact by livestock and irrigation in some areas. Based on an estimated 10% recharge the total recharge is estimated to be in the order of 245 million m^3/a. Groundwater use is estimated at 117 million m^3/a while spring flow is estimated at about 96 million m^3/a. Available volume estimated on water balance calculations might be in the order of 75 million m^3/a. To develop this may require in the order of 94 boreholes if it is assumed that the yield per borehole at 25 ℓ/s. These boreholes must be selected in the Monte Christo and Eccles Formations away from the spring locations.

2.17.3.3 Ghaap Plateau Dolomites

Sinkholes and subsidence is not common in the Ghaap Dolomites and in the Kathu area the dolomites are overlain by Banded Ironstone Formation (BIF) and Kalahari Formation. Groundwater levels vary considerably from 0 (artesian) to 150 meters below ground level. These deep levels occur upstream from the Kuruman eye. Groundwater users are mainly towns, mines and selected areas of irrigation. The groundwater quality is generally good except in polluted areas and two localities where Dwyka Tillite rocks are present in sinkholes. Recharge varies over the area due to the variation in annual rainfall decreasing from east to west. The average recharge is 6% which provide an estimated 495 million m^3/a. The current groundwater abstraction amounts to about 68 million m^3/a. The surplus allowing for droughts is estimated at 131 million m^3/a. This can be developed by 271 boreholes yielding between 10 and 40 ℓ/s. A groundwater deficit occurs in the Postmasburg/Kathu area.

2.17.3.4 **Future development recommendations**

Both SANS and DWA have published documents that need to be considered when developing dolomitic land. SANS 1936-1:2012 Edition 1 consists of 4 parts under the general title *Development of dolomite land*. The DWA documents consist of 3 volumes titled: *Guideline for the Assessment, Planning and Management of Groundwater Resources within Dolomitic Areas in South Africa*. These documents have two main objectives namely:

- The SANS document set requirements for the development of dolomite land to avoid any hazards associated with dolomite land.
- The DWA Dolomite Guideline’s objective is to assist in the sustainable development, protection and management of groundwater resources and will assist in achieving the overall goal of integrated water resource management.

The following recommendations are made:

- Any development must consider the SANS and DWA guidelines.
- Available groundwater resources have been identified in all three dolomite areas and future developments of these resources need to be planned.
- Areas for future development need to be selected and zones of high transitivity away from the main springs must be identified.
- Groundwater Reserve Determination studies must be done in areas considered for development.
- Modelling such as done for the Zeerust area should be applied to other dolomite areas considered for future development.

2.17.4 Demographics

The starting point of compiling water requirement scenarios (for the water uses depending on the Vaal River System) was the development of alternative (high, base and low) scenarios of possible future population. These were in turn applied as the main driver for the water requirement and return flow scenarios of the urban centres. The High population scenario represents the situation where in-migration to Gauteng occurs at a steady rate due to strong economy growth, effective service delivery and successful interventions for HIV/AIDS are implemented. For the Base Scenario it was assumed that recent and current trends are extended into the future, where the Low Scenario assumes sluggish economic growth, experiencing constraints in service delivery and lower population growth due to the effect of HIV/AIDS.

The scope of the Urban Water Requirements and Return Flows Report was to provide an update of the current and projected urban demands and return flows in the Vaal River System/ Study Area up to year 2030. The Urban Return Flow Model was used to derive five possible future water demands and return flow scenarios. The scenarios were defined in terms of the source of population data used and the three detailed WCDM scenarios that had been developed for Ekurhuleni, Johannesburg, Emfuleni , Randfontein, Tshwane, Mogale, Govan Mbeki, Rusternburg and Matjhabeng municipality areas in another parallel Water Conservation and Demand Management Study (DWAF, 2006).

The current and projected water demands and return flows are presented at a municipality level in the report. Results of future urban water requirements and return flows at a municipality and Sewage Drainage levels were produced for five scenarios for the Study Area.

The methodology followed entailed that all urban water users in the study area were split into the following four groups:

- Large metropolitan metros supplied by Rand Water, where each municipality was analysed separately;
- Other water users supplied by Rand Water. This group included small municipalities, individual users and mines, all of them receiving water from the Rand Water system;
- Water users supplied by Sedibeng Water or Midvaal Water Company; and
- Other smaller urban water users, not covered by the above three groups.

The methodology to derive the current and future urban water requirements and return flow scenarios in this study was based on procedures applied in the Crocodile (West) River Return Flow Analysis Study (CRFAS) (DWAF, 2004a). In total, three different population scenarios were analysed. These were:

- January 2006 population scenario;
- National Water Resource Strategy population scenario; and
- August 2006 population scenario.

It is noted from the reports that a substantial effort went into defining the population numbers for each SDA, as well as to determine the portion of the population for each of the housing categories.

Water requirement scenarios for Sedibeng Water and MidVaal Water Company were obtained from the respective organisations and for all the other urban areas the water requirement projections were determined using the growth rates from the National Water Resource Strategy (NWRS). Where actual water use data was available, the starting point (volume for the first year in the projection) was adjusted to match the actual value on which the future growths were applied.

With regards to the Irrigation Sector developments, economic importance and related demands and return flows, three separate Water Authorisation Registration Management System (WARMS) databases were received from the Department of Water Affairs, one from Gauteng one from the Free State and one from the Northern Cape. The data was up to November 2005.

The validation of irrigation development in the Upper Vaal WMA showed that the registered data provided in most cases a total over estimation of the actual water use, and could therefore not be relied upon. It is noted that it was therefore necessary to improve the irrigation data for the Middle and Lower Vaal WMAs as no validated data was available for these two WMAs. The data from the Validation Verification study provided the best data currently available for the Upper Vaal WMA. Meetings were held with the DWAF Regional offices in Bloemfontein and Kimberley as well as with the Irrigation Scheme manager at the Vaalharts Irrigation Scheme, to discuss the data from the different data sources. Based on their experience and knowledge of the irrigation schemes and catchments, the most appropriate irrigation volume was selected for use in this study and in some cases more accurate and recent data was provided by the Regional Offices.

An economic model was used with the objective to estimate the economic value of agricultural production in the Vaal catchment area at 2006 base data. In order to do this, a mathematical programming model was compiled in order to simulate current agricultural production in financial terms in the project area. The model was run to estimate the net present value (NPV) of the different enterprise areas. A number of economic scenarios were undertaken, namely:

- A scenario was undertaken assuming that the current enterprise mix would change over time. It was assumed that the area under citrus and table grape would increase to 10% of the total cropped area.
- A scenario was undertaken only on estimated lawful use of water. From the study results it was estimated that only 40% of irrigation is lawful in the Upper Vaal region. At the time of the study no information was available on the other regions and it was therefore assumed that 80% of current irrigation was lawful in the Middle Vaal region and 90% in the lower Vaal region.
- It was assumed that there will be a 10% decrease in water allocation for irrigation purposes
- It was assumed that there will be a 10% increase in the water cost for irrigation water.

The assessment of the irrigation water requirements revealed that the estimated water use in the year 2005 for this sector was 1060 million m3/annum, which is 294 million m3/annum higher than what was applied in previous investigations. Preliminary results from the Upper Vaal Water Management Area Validation Study indicated that as much as 241 million m3/annum of the year 2005 irrigation water use could be unlawful. The total registered water use for irrigation in the Vaal River System was estimated to be 1 375 million m3/annum and was described as an indication that the increasing trend experienced since 1998 could continue further if interventions to curb unlawful water use are not successful.

Information contained in the Irrigation Water Use and Return Flows are based on 2006 data and represents the best available data for the study area. However, the demographic data utilised is based on Census 2001 with projections up to the year 2025 in five-year intervals and thus outdated. Population numbers were a mixture of sub-place, main place and municipal level with a split into rural and urban components. Sub-places were grouped/split according to SDA (sub-place population was multiplied by portion factors indicating what area of a sub-place falls within a specific SDA).

In addition to the direct water needs of increased urbanisation in the Gauteng Province, water is also required for the provision of energy to feed the expanding economy, not just of Gauteng but also of the Southern African region. Plans to provide in the medium to long term energy needs of the region are by means of large scale developments by Eskom, Sasol and related mining in the Lephalale area located in the Mokolo River catchment. As such, water requirement scenarios for the three large industries Eskom, Sasol and Mittal Steel were also provided.

2.18 FEASIBILITY STUDY OF THE POTENTIAL FOR SUSTAINABLE WATER RESOURCES DEVELOPMENT IN THE MOLOPO-NOSSOB WATERCOURCE (2009)

The Molopo River receives most of its flow from tributaries in the Republic of South Africa, most of which have now been dammed for irrigation in agriculture. As a result, inflow from these sources to the Molopo River, which forms the boundary between Botswana and South Africa, has become reduced and even non-existent in some years. The Nossob River originates in Namibia and some dams have been constructed in the upper reaches. It later forms the south-western boundary between Botswana and South Africa down to its confluence with the Molopo River. There is no record of the Molopo River surface flows ever reaching the main stem of the Orange River. The reduction of flows in these sub-basins has placed a strain on the sustainability of rural activities in the south-western corner of Botswana and some parts of South Africa along the Molopo and Nossob Rivers.

As an attempt to remedy the situation, the ORASECOM countries has appointed ILISO Consulting, in association with Ninham Shand Incorporated, Schoeman and Partners and Conningarth Economists to study the feasibility of the potential for the sustainable water resources development in the Molopo Nossob Sub River Basin.

The objective of the project was to assess and evaluate the water resources of the Molopo-Nossob catchment to formulate a method to improve the management of the area that will be environmentally sound, economically viable and financially achievable. The possibility of restoring flows to the river system was also investigated, as well as the identification and assessment of sustainable surface water development options. In doing so the catchment was studied as an interrelated system, even though it falls within the political area of three different countries (Namibia, Botswana and South Africa).

Hydrological modelling has been undertaken to provide first order estimates of typical surface water runoff volumes in the main rivers in the Molopo-Nossob catchment. The modelling was done by means of the Pitman rainfall-runoff model, local observed rainfall records and current land use information. Estimates of natural and present day surface water runoff have been calibrated based on observed flow records where available as well as on historical records of floods in the Molopo-Nossob catchment.

The modelling results have shown that the total natural runoff from the Molopo-Nossob catchment, without any channel losses, equals 164 Mm^3/a. However, once losses are taken into account, the total cumulative runoff for each of the main sub catchments reduces to zero, except in the case of the Kuruman catchment where the average net outflow equals 4.1 Mm^3/a under natural conditions and 4.0 Mm^3/a under present day conditions

First order estimates of typical gross storage-yield characteristics for the upper parts of the Molopo, Kuruman and Nossob catchments have shown that significant storage is required to provide yield at an acceptable level of assurance. An assessment of the central parts of the Molopo-Nossob catchment, situated within the drier, central Kalahari Desert, has indicated that it is not feasible for dams to be constructed in this area due to the lack of reliable runoff.

The Molopo-Nossob system does not function in the same way as more conventional rivers, where groundwater discharge provides a base flow during dry conditions. In the case of the Molopo-Nossob system, the occasional floods are totally absorbed along the river bed and recharge the ground water aquifers along the course of the river. From the investigation it is clear that surplus water is only generated at a recurrence interval of less than 20 years. For the rest of the time, floods are entirely absorbed as ground water recharge along the course of the river.

As the water along the course of the river is needed for small communities and stock watering, there is little sense in building storage dams. It is far more financially and economically viable to abstract the water from boreholes and wells at the point of use, as this will not only cut out the evaporation losses from the surface of a reservoir, but also the necessity of an expensive distribution network.

The study has conclusively shown that there is no surplus water in the Molopo-Nossob catchment that can be economically exploited. It was also shown that the occasional floods serve to recharge the ground water aquifers along the river course, and that any storage that is created will therefore reduce the availability of ground water along the course of the river.

It is therefore recommended that no further surface water development in the form of dams is considered in the study area, and that the development of ground water sources is investigated in more detail.

However, the development of ground water should be undertaken with some caution, as making more water available may lead to overgrazing and the destruction of the natural vegetation, especially where subsistence farming is practised.

2.19 GROUNDWATER REVIEW OF THE MOLOPO-NOSSOB BASIN FOR RURAL COMMUNITIES INCLUDING ASSESSMENT OF NATIONAL DATABASES AT THE SUB-BASIN LEVEL FOR POSSIBLE FUTURE INTEGRATION (2009)

Report Title: Groundwater Review of the Molopo-Nossob Basin for Rural Communities including Assessment of National Databases at the sub-basin level for Possible Future Integration. ORASECOM. Final. Report No. 005/2009. July 2009. Prepared by Geotechnical Consulting Services (Pty) Ltd in association with Continental Consultants (Pty) Ltd.

The Molopo River is an ephemeral tributary of the Orange – Senqu River system, an international river basin shared by Lesotho, Namibia, Botswana and South Africa. The main objective of the project was to evaluate the groundwater resources of the Molopo-Nossob Basin based on an analysis of the available data and information. This included a thorough analysis of the data/databases in each of the basin states in order to make recommendations on how data can best be shared between the basin states and integrated in a common database.

The report provides a detailed description of the Molopo Nossob Basin, its water requirements, development activities, geohydrology and hydrology and groundwater resources. The study reported that the development on information and the amount of information differed between the basin countries.

It was recommended that for the understanding of the groundwater situation and for planning and implementation of future water and environment related activities, there was a need to share the data between the three countries. The integration of both databases and the exchange facilities requires that information systems within the countries are compatible. It was therefore proposed that in order to facilitate the exchange of data as well as possible integration a GIS data storage and management system was needed. The system should have capabilities to be used as an information centre for the basin in order to provide rapid responses to groundwater evaluation and modelling of the sub-basin and facility for dissemination and exchange of data within the states.

The following recommendations were made:

- That the database be developed in Microsoft SQL Server technology.
- That monitoring of groundwater; both quality and level should be continued and extended to include areas which are remote and not affected by human development.
- That more than the currently used chloride mass method for recharges assessment should be applied in the basin. The current assessment of recharge should also be assessed in comparison with the general flow of groundwater in the basin through mathematical modelling.
- The use of the concept of Groundwater Harvest Potential introduced in South Africa should be extended and map produced also for Namibia and Botswana, especially for areas of low groundwater recharge.
- Large parts of the basin has water unfit for human consumption and for livestock watering. Water treatment options exist and could be applied for private and communal use. The current and future use of such treatment option should be addressed.

2.20 ASSESSMENT OF POTENSIAL FOR DEVELOPMENT AND USE OF MARGINAL WATERS (ORASECOM) (2009)

Scarcity of water in semi-arid regions of the world, similar to the Orange-Senqu River Basin, has necessitated the development of strategies to optimise the use of available water resources. One of the most widely adopted measures is the augmentation of the water supply through the use of unconventional or “marginal” water sources. Marginal water can be used to supplement intensively exploited conventional sources.

Scarcity of water in semi-arid regions of the world, similar to the Orange-Senqu River Basin, has necessitated the development of strategies to optimise the use of available water resources. One of the most widely adopted measures is the augmentation of the water supply through the use of unconventional or "marginal" water sources. Marginal water can be used to supplement intensively exploited conventional sources.

- **Re-cycle** – When water is used in a process and then reused in the same process with or without any purification / treatment or improvement of the water quality.
- **Reuse** – When water is used and is then used again for another purpose with or without purification to some acceptable level (not yet potable).
- **Reclaim** – Water that was previously used for potable or any other purposes is treated up to potable quality standards so that it can again be used for potable purposes.

2.20.1 SUMMARY OF THE STATUS QUO

Examples of the different types of marginal water have been obtained from within the Orange-Senqu River Basin. An indication of the different types of marginal water is shown in Table E1.

Table 2-112: Different Types of marginal waters within the Orange-Senqu basin

Table E1: Different types of marginal waters within the Orange-Senqu Basin

	Namibia	*Botswana*	*Lesotho*	*South Africa*
1. Reclamation of waste water for potable use	•			
2. Reuse for irrigation after treatment	•			•
3. Reuse and recycling of industrial water	•	•	•	•
4. Reuse of water in mining sector	•	•	•	•
5. Rainwater & fog harvesting	•	•	•	•
6. Fog harvesting	•			•
6. Rainfall Enhancement	•			•
7. Use of brackish groundwater	•	•	•	•
8. Sea water and desalinisation	•			•
9. Use of dual systems	•	•		

Examples from within the basin countries that are worth mentioning are:

- Botswana: Debswana mine. This mine is a good example in the sense that four types of marginal water are being exploited, i.e.:
  - Rainwater harvesting
  - Irrigation with treated effluent
  - Recycling of process water
  - Use of brackish water

- Namibia: Windhoek reclaiming water from sewage water to potable standards.
- Lesotho: Rainwater harvesting
- South Africa: Emalahleni plant in Witbank, where heavy metals are removed from acid mine water and where the water is treated to potable standards.

Two distinct examples in other countries of the world are:

- Australia: Irrigation of open spaces with water from package treatment plants plugged into sewers.

- Japan: Best example of dual systems for large scale buildings.

2.20.2 IMPORTANT ISSUES RELATING TO MARGINAL WATER USE

The following implications have been identified for marginal water use:

- Institutional: Different tiers of institutional structures do not cooperate to promote marginal water Use to its optimum.
- Legislation: Regulation needed on water quality standards.
- Environment: Marginal water use can have both positive and negative impacts on the environment e.g. positive when water is released into the environment with improved water quality and negative when e.g. lime precipitates and blocks boreholes in limestone areas.
- Health: Faecal coliform guidelines must be met when irrigating with treated waste water in order to avoid helminth and bacterial infections.
- Cost trends of marginal water use are shown.

2.20.3 TRENDS AND FUTURE POTENTIAL OF MARGINAL WATER

Trends in marginal water use and future potential are shown in in a detailed spread sheet which shows current and future potential for the nine defined types of marginal water use in each of the four basin countries.

2.20.4 ASSESSMENT OF KEY PROJECTS

The following key projects have been identified in the four basin countries.

Lesotho

- Irrigation of sport fields, the golf courses and suitable food crops in Maseru with treated sewage effluent.
- Reclamation of Maseru's sewage water for potable use.
- Rainwater harvesting from rooftops of large buildings in Maseru.

Botswana

- Irrigation of food crops with treated sewage effluent.
- Reclaiming Botswana's treated sewage effluent to potable standards.
- Recharge aquifers with treated sewage effluent.
- ·Better utilization of Botswana's saline groundwater.
- Public awareness strategy for reclaiming sewage water to potable standards (directly or by means of aquifer recharge) and irrigating food crops with treated waste water.

Namibia

- Irrigation of sport fields and suitable food crops with treated sewage effluent.

South Africa

- Installation of dual systems for new developments in Gauteng
- Rainwater harvesting for food security.
- Reclaiming mine water to potable e standards in Gauteng.
- Developing guidelines for the installation of dual reticulation systems in Gauteng.

Transboundary

- Review of institution, policy, legislation, and guidelines in the four countries.
- Development of guidelines for marginal water use by the industry sector.

2.20.5 SELECTION CRITERIA

Eleven criteria were identified for the selection of priority projects for implementation. A further recommended condition was that all projects should be in place where all possible water conservation and water demand management (WC/WDM) measures should already be being implemented. Normally WC/WDM is the cheapest and most efficient way of making the most use of the available water. However in cases where the usage of any marginal water option would be cheaper, the latter could be pursued as long as the WC/WDM had been considered.

Apart from the above 11 criteria, a separate objective was set, namely to get an even spread of projects in the four basin countries.

2.20.6 SELECTED PROJECTS

Six projects were selected for further study, i.e.:

i. **Botswana:** Awareness campaign to promote indirect potable water reuse and irrigation of food crops with treated sewage effluent.

ii. **South Africa:** Dual reticulation system guidelines for Gauteng

iii. **Lesotho:** Irrigation of sport fields, the golf course and suitable food crops in Maseru with treated wastewater

iv. **Namibia:** Irrigation of sport fields and suitable food crops in larger Namibian towns

v. **Transboundary:** Institutional, Policy, Legislative and Guidelines Review

vi.**Transboundary:** Guidelines for marginal water use for the industrial sector

Scopes of Works have been drafted for each of the above six projects and are bound in the ORASECOM report as Appendix C.

2.21 ORANGE RIVER REALTIME MODELING (2010)

2.21.1 Introduction

Significant contributions from tributaries of the Lower Orange River are limited to sporadic high flows from the Vaal and Fish Rivers. The flow in the Lower Orange River is therefore controlled by the water released from Vanderkloof Dam during the majority of the year. Up to date the additional inflows from the Vaal and Fish Rivers were not considered during the operation of the Lower Orange River System (LORS). However, although the Lower Vaal River System (LVRS) is operated to minimise outflows, a substantial volume of water still enters the Orange River from the Vaal River catchment.

The Department of Water Affairs and Forestry (DWAF) Directorate: Water Resource Planning Systems (D:WRPS) identified the need to develop a Decision Support System (DSS) that would support the DWAF in establishing the optimal releases from the Vanderkloof Dam on a day-to-day basis. It was anticipated that the DSS would minimise losses from the system by providing information on an optimised release from Vanderkloof Dam to meet downstream users' demands and the environmental requirements, making use of inflows from the Vaal River. The release would be optimised within the context of the overall medium term water resource strategy and defined policies between the DWAF, ESKOM and other stakeholders in the LOR catchment.

2.21.2 Current operational practices

Current operational practices on the LORS and LVRS (at the time of the LOROS Situation Assessment Phase) were investigated as part of the LOROS and are described below to gain a better understanding of the challenges and opportunities for improvement that exist in the management of these systems:

- **Current operational practises on the Lower Orange River System**
  The LORS is currently operated in accordance with the Orange River System (ORS) Annual Operating Analysis (AOA) which is used to determine the required releases and the Storage Control Curves (SCCs) for the Vanderkloof and Gariep Dams, using the Water Resources Planning Model (WRPM), on a biannual basis. The primary update of the AOA is done during May of each year and a second update is done during November. The November update's purpose is to re-assess the curtailments imposed on downstream water users based on the water levels experienced in the Gariep and Vanderkloof Dams at that time. Curtailments may be implemented during times of low runoff and resulting low water levels in the Vanderkloof and Gariep Dams.

  The results from the AOA have a direct impact on ESKOM's generation of hydropower at the Gariep and Vanderkloof Dams. ESKOM is obligated to release the minimum monthly volume as specified by the AOA. ESKOM can, however, release additional water if the water levels in the Gariep and Vanderkloof Dams are above their respective SCCs. In addition to the above allocations to ESKOM, an additional volume of water may also be allocated to ESKOM annually for use at their discretion.

- **Current operational practices on the Lower Vaal River System**
  The LVRS is currently operated in isolation from the LORS. Inflows from the LVRS are currently not taken into account by the AOA when determining releases from the Vanderkloof Dam. The operation of the LVRS is done by Vaalharts Water User Association (WUA) (trading as Vaalharts Water) on a day-to-day basis.

- **Stakeholder consultation**
  Stakeholder consultation was undertaken to inform stakeholders about the LOROS study, to gain knowledge on operational issues and constraints relating to the management of the LOR and to establish channels of communication. Stakeholders were provided with the opportunity to give input on the deliverables of the LOROS and what they foresee to be implications and opportunities that would present them as a result of the study.

2.21.3 Design of Decision Support System

The LOROS DSS is designed to specifically provide decision support for the short-term day-to-day management of the LOR during periods of low and normal flow in the LOR (not flood flows). It takes into account the evapotranspiration losses along the LOR based on the actual weather experienced and the future expected weather along the LOR. Rainfall runoff would not be modelled as the catchment downstream of the Vanderkloof Dam is dry for most of the year.

Currently, the medium term water resources outlook is provided by the AOA study with the help of the WRPM modelling framework. Although the AOA study is conducted bi-annually, it does not take into account the flows accrued from the LVRS even though the Vaal River does contribute to flow at certain times of the year. These inflows tend to be sporadic and cannot be planned for in the medium term. Also, the AOA does not take into account the actual weather experienced or expected future weather along the LOR. Weather forecasting for the purpose of medium term planning, up to six months in advance, is not accurate.

For this reason it is anticipated that the LOROS DSS would provide better day-to-day decision support on the releases from the Vanderkloof Dam and the management of the LOR catchment than the AOA. The medium term planning of the AOA, however, remains an important task for establishing the required curtailments on downstream water users and SCCs of the Gariep and Vanderkloof Dams. It also supplies the LOROS with the curtailed water demands of water users along the LOR bi-annually.

Decision support would be provided with the help of the Mike Flood Watch software. This software provides a framework that manages the collection of real-time data, the interaction with the AOA, the Mike 11 hydrodynamic model runs and the dissemination of results to the DWAF and other stakeholders.

The DSS collects data from the AOA and different real-time telemetry systems and then either published the data immediately or uses it as input for the LORS and LVRS Mike 11 hydrodynamic models. The Mike 11 models are run and the results are transferred back to the DSS. Once the DSS receives the updated result information, the information can be published and viewed by DWAF and other stakeholders.

2.21.4 Implication of implementation of DSS on ESKOM

The implementation of the LOROS would have an influence on ESKOM's hydropower generation at the Vanderkloof Dam. Currently, ESKOM is obligated to release the minimum monthly volume as specified by the ORS AOA. In future the DSS would replace the AOA's function of specifying the required releases from Vanderkloof Dam on a day-to-day basis. Once the DSS has been implemented, the DWAF would, with the help of the DSS, provide an optimised volume of water to be released by ESKOM the following day. In return, ESKOM would provide the DWAF with the planned release schedule once it has been finalised. It is recommended that an agreement between DWAF and ESKOM be put in place to formalise this interaction.

2.21.5 Operation of Decision Support System

The DSS has been configured and set up at the DWAF D: WRPS Sub-Directorate: Systems Operations. The DSS is, through the use of several different editor options of the Mike Flood Watch software package, able to:

- Collect information from various sources and construct time-series files required for input for the LORS and LVRS model runs.
- Initiate the LORS and LVRS Mike 11 hydrodynamic models which will generate information used in the optimisation of releases from Vanderkloof Dam.
- Publish information to the LOROS website and/or produce e-mail reports containing results produced by the DSS.

2.21.6 Conclusions

The most important conclusions from the LOROS are:

- The LOROS DSS is successfully configured and running at the DWAF D: WRPS Sub-Directorate: Systems Operations. The DSS was designed specifically for the management of the LOR catchment and the optimisation of releases from the Vanderkloof Dam during low flow conditions in the Orange River.
- In the long run, the implementation of the DSS should reduce the low-flow releases from Vanderkloof Dam by optimising releases from the dam, taking inflows from the LVRS into account and helping to identify unauthorised water use.
- The successful implementation of the DSS will depend on the continuous engagement of the relevant DWAF personnel.
- In order to realise the aims of the LOROS, the hydrodynamic models relating to the LORS and LVRS required accurately calibration. It is believed that an accurate calibration of the LORS and LVRS hydrodynamic models were achieved when measured against the recorded flow data available to the PSP at the time calibration was completed.
- Provision was made in the DSS for real-time hydrodynamic modelling of the LVRS to allow the estimation of inflows from the LVRS into the LORS. The original study requirements did not include the setup of comprehensive real-time model of the LVRS and therefore the LVRS was included

simplistically.

- Further refinements, outside the scope of this study, could be made to the DSS to improve its results and extend its purposes.

2.21.7 Recommendations

The following recommendations are made:

- Improvement of flow gauging
  Inaccuracies of gauged data at a number of flow gauging stations were observed. Reassessment of the stage-discharge relationships and/or recalibration of the Dooren Kuilen (D3H012), Marksdrift Weir (D3H008), Neusberg Weir (D7H014), Vioolsdrift Weir (D8H003), Bloemhof Dam outflow (C9H021), Schmidtsdrift Weir (C9H024), Klipdrift Weir (C5H014) and Zoutpansdrift Weir (C5H048) flow gauging stations are to be considered. Also, Zeekoebaart Weir gauging station (D7H008) would require calibration once its upgrading has been completed.

- Refinement of water demands, losses and environmental requirements
  - The monthly distribution of irrigation water requirements along the LOR were estimated using the SAPWAT software (as part of the LORMS study) and based on a survey of only part of the irrigated area. These monthly distributions may have changed since the LORMS and therefore it is recommended that :
  - A study re-assessing of the monthly distribution be done using gauged flow data on major canal systems (Boegoeberg, Upington and Kakamas WUAs); or
  - All irrigation abstractions should be metered; or
  - A comprehensive water ordering and billing system be put in place along the LOR.

- The volume and distribution pattern of operational losses from the ORS (sourced from the AOA) were based on experience of the operation and management of the LOR and when problems were experienced with water supply. During the months of March, April and May the operational losses are significantly higher. It is recommended that the reasons for these higher losses are investigated.

- The EWR for the LOR is sourced from the AOA which uses data from the ORRS. This data is only used as an interim measure and environmental requirements should be re-assessed as part of the planned Orange River Reserve determination study and replace those used by the AOA.

- Return flows from irrigation along the river are uncertain. There are uncertainties with regard to both the quantity and timing of these flows. It is particularly difficult to model the return flows accurately when the amount of water being used for irrigation, from which the return flows are generated, is also not certain. A pilot study done as part of the WRC study “Evaporation Losses from South African River” investigated return flows from irrigation practices along the LOR. The results from this study are, however, not considered to be accurate or comprehensive enough. It is therefore recommended that a study that assesses the amount of water and lag times associated with return flows from irrigation practices along the LOR should be done.
- Weather data from the SAWS’s real-time weather station telemetry system is currently not incorporated into the DSS. It is recommended that a real-time station from this network is used, in future, to estimate the evapotranspiration losses that occurred along the LOR in the area of Alexander Bay.

- Improvements of data sourcing
  - The exchange of data between the ARC, DWAF and SAWS should be improved. This would ensure that there are no interruptions in the provision of critical data from the ARC and SAWS to the DSS.

- Thefts of solar panels that provide power to the real-time gauging stations occur regularly. Installing a Tracker device or a similar movement activated alarm system on solar panels or motion activated video recording may deter theft of solar panels.
- Currently there is no real-time flow gauging taking place of the outflow from the Vaalharts Weir on the Vaal River. It is recommended that the DWAF set up a real-time flow gauging station at Schoonplaats Weir just downstream of the Vaalharts Weir.
- Currently data for inflows at the Spitskop Dam are sourced from Vaalharts Water e-mail. It is recommended that real-time gauging of flow data be implemented at the Spitskop Dam and that the recorded flow data be placed on the DWAF Directorate: Hydrology's website. This real-time data could then be used instead of the data sourced from the Vaalharts Water e-mail.
- Two additional weirs specifically constructed for the purpose of flow gauging are being planned. The first would be located at Blouputs, just upstream of the 20° East latitude which forms the border between South Africa and Namibia. The second weir would be located at Sendelingsdrift, downstream of the Orange-Fish confluence. Both these weirs would be strategically placed to collect key flow data on the LOR. Provision was made in the DSS for data assimilation at the Blouputs and Sendelingsdrift Weirs once they are constructed and provide real-time data. It is recommended that the data assimilation routine be set up for these two flow gauging station once they become operational.
- Provision was also made for data assimilation at the Zeekoebaart Weir (D7H008), which was in the process of being upgraded at the time that this report was compiled. It is recommended that the required changes to the DSS configuration be made once this gauging station starts to provide reliable real-time flow data.
- At the time of the study completion, the Ai-Ais real-time gauging station was not operational and did not provide data to the DSS due to vandalism and theft at its telemetry station. It is recommended that this station be repaired once construction activities in the area, suspected to be the cause of the vandalism, are finished. The installation of a South African-type telemetry station in addition to the Namibian station should be considered. It is recommended that once the station is repaired that its data be posted on the DWAF Directorate: Hydrology's website along with the DWAF's real-time data. This would allow the DSS to automatically collect real-time Ai-Ais Weir flow data in future. Also note that the DSS would require minor configuration for this data to be included at that time.

- DWAF-ESKOM agreement and interaction

  A formal agreement between DWAF and ESKOM needs to be put in place whereby:
  - DWAF specifies the average release required from Vanderkloof Dam for the following day in order to satisfy downstream demands according to the DSS results. This average release needs to be communicated to ESKOM before 10h00 on a specific day.
  - ESKOM provides the DWAF with the release schedule from the Vanderkloof Dam for the following day once it has been finalised.
  - Communication channels between DWAF and ESKOM relating to the above points are formalised.

  Opportunities exist to allow more flexibility in the way ESKOM makes releases, allowing them to generate electricity with more freedom. It is recommended that these opportunities be investigated fully in collaboration with ESKOM.

- Future recalibration of LORS model

  Discrepancies were observed in the calibration of the LOR reach between Neusberg Weir and Vioolsdrift Weir. It is recommended that the reach between Neusberg Weir and Vioolsdrift Weir is recalibrated at a time when:
  - Neusberg and Vioolsdrift Weirs' stage-discharge tables are verified and possibly recalibrated;

and/or
- Blouputs Weir is constructed.

Also, the LOR reach downstream of Vioolsdrift Weir could not be calibrated due to the lack of reliable flow gauging data. It is recommended that this river reach is recalibrated once sufficient gauged flow data becomes available from the future Sendelingsdrift Weir located downstream of the Orange-Fish confluence.

- Future improvement of LVRS model
  - The purpose of the current LVRS model is to estimate inflow from the LVRS into the LOR during times of high flow or flood events in the LVR. If the LVRS operational practices change in future and water is provided to the LOR, the LVRS model would need to be reassessed. If forecasted inflows lower than 40 m³/s are required, it is recommended the LVRS model be adapted in the following way:
    - Include surveyed cross-sections in the LVRS model (a cross-section every 20 km).
    - Define water demands and losses more accurately, possibly linked to the water ordering system which is already in place.
    - Conduct a topographical survey of the Vaalharts Weir to ascertain the overflow level of this weir (linked to the national grid) to a greater degree of accuracy.
    - Assess the need for recalibration of the Bloemhof Dam outflow, Schmidtsdrift Weir, Klipdrift Weir and Zoutpansdrift Weir gauging stations.
    - Include real-time flow gauging at the Spitskop Dam outflow.
    - Recalibrate the LVRS Mike 11 hydrodynamic model once the abovementioned tasks have been carried out.
  - It is recommended that the possibility of extending the LVRS model further upstream to provide a forecast of inflows into the LORS longer in advance be considered.
  - The DSS does not make provision for the automatic updating of the irrigation, urban and industrial demands for the LVRS. It is recommended that, if significant new irrigation developments take place along LVR, the forecasted irrigation demands should be reassessed and manually updated in the DSS.

- Inclusion of the Orange River reach between Gariep and Vanderkloof Dams and the optimisation of hydropower releases from these dams
  - The DSS currently only extends up to Vanderkloof Dam. The Gariep and Vanderkloof Dams are operated in unison during normal and flood flow conditions. The DSS, however, only focussed on the operation of Vanderkloof Dam during normal flow conditions. It is recommended that the DSS be extended upstream to include the forecasting of flood events and the operation of Gariep Dam.
  - As part of the abovementioned extension the optimisation of structure (turbine) operation at the Gariep and Vanderkloof Dams can also be done. This extension to the DSS would unify the optimisation of releases during normal and high (flood) flow conditions and the optimisation of ESKOM's release schedule from the Gariep and Vanderkloof Dams. It is envisaged that this extension would lead to significant water savings and increased hydropower generation. This would be to the advantage of both the DWAF and ESKOM.

- Service Maintenance Agreement
  In order to ensure continued support from the developers of the Mike Flood Watch software who are experts in DSS setup, a Service Maintenance Agreement (SMA) needs to be kept in place. The newest version of the Mike Flood Watch software would annually be provided to the DWAF as part of this agreement.

- Dedicated computing centre
  The routine which is used to optimise the releases from Vanderkloof Dam supports the use of distributed computing solutions such as office grid technology whereby the computational burden is distributed to multiple processors (multiple processor computers and/or a network of computers). In effect, this makes it feasible to carry out optimisation for large river systems in real-time. It is recommended that the need for a dedicated computing centre, utilising a number of computers to speed up the optimisation routine, be considered.

- Distribution of Main Study Report to other stakeholders
  The ARC and Vaalharts Water both expressed interest in the LOROS and how the data that they provide to the DSS are utilised. It is recommended that the LOROS Main Study Report be distributed to these stakeholders once it has been finalised.

2.22 VAAL RIVER WRDP: COMPARITIVE STUDY BETWEEN LHWP PHASE 2 AND TUKELA WATER PROJECT (2010)

2.22.1 Overview

The purpose of this study was to carry out a comparison of two water resource schemes, the proposed Phase 2 of the Lesotho Highlands Water Project and the proposed Thukela Water Project, which are alternative Water Resource Development Projects (WRDP) to augment the water resources of the Vaal River System.

Feasibility studies of these schemes concluded that both are viable options to supplement the Vaal River System and in 2007 the interim findings of the Vaal River Reconciliation Strategy Study identified that further augmentation is required and this study was commissioned by the Directorate: Options Analysis.

The objective of the study was to evaluate and compare the schemes on technical grounds and to recommend which is the preferred solution as the next scheme to supply additional water to the Vaal River System.

The methodology applied for the assessment was to review the feasibility studies and other reports and to undertake the following:

- Evaluate the relevant water resource availability information to define the yield of the existing Integrated Vaal River System and the transferable yield of the two proposed options.
- Obtain projections of water requirements for the Vaal River System from the Vaal River System Reconciliation Study and compile yield vs. demand balance projections for the planning period until the year 2040.
- Evaluate the descriptions of all the engineering aspects, social and environmental assessments, costing analysis as well as the institutional and funding arrangements to formulate an opinion on the confidence and comparability of the definitions of both the schemes.
- Derive common base date costs (October 2007 was selected as the base date) for all the components of both options. Particular attention was given to the assumptions with respect to the energy costs and implications of the Royalty calculations.
- Derive the Royalty payments associated with the LHWP considering the appropriate conditions with respect to each of the options.
- Undertake economic analysis of the two options for different scenarios to assess the sensitivity of selected variables. Determine the Unit Reference Values of each scenario which is to be used as the economic index or parameter for comparing the economic efficiency of the options.
- Identify advantages and disadvantages of both schemes and present conclusions of the results from the above described evaluations. A qualitative identification of risks that could influence the results

was provided.

- Provide recommendations based on the results and conclusions.

2.22.2 Main Report

2.22.2.1 Comparison of options

Based on the findings from all the aspects of the comparison, **Table 2-113** below provides a concise summary of the advantages and disadvantages of the two development options.

Table 2-113: Qualification of Advantages and Disadvantages of the two Development Options

Phase II of the Lesotho Highlands Water Project	Thukela Water Project
Advantages	
1. Water can be transferred without pumping (low energy requirement).	1. Yield available for transfer has no adverse effect on yield of Orange River.
2. Possibility of hydro power generation (income stream to offset future costs).	2. Development takes place within RSA – construction costs can be better controlled.
3. Improved living standards for project affected people in Lesotho.	3. Benefits of project implementation accrue in RSA to our citizens in an area in need of growth stimulation.
4. Job creation in Lesotho.	4. Improved living standards for project affected people in RSA.
5. Increased Royalty revenue stream for Lesotho.	5. Job creation in RSA.
6. Leaves TWP option for later implementation (flexibility).	6. No complex international negotiations.
7. Avoids complication of getting out of perceived commitment to further development of LHWP.	
Disadvantages	
1. Complex international negotiations required. (RSA/Lesotho, RSA/Nambia and ORASECOM).	1. Water from project must be pumped at additional cost (energy requirement and cost).
2. Project implementation not under direct RSA control (risk of cost increases).	2. Pumping impacts on scarce energy resources.
3. Yield replacement required to mitigate for reduced yield available for existing Orange River users.	3. May require unilateral cancellation of existing LHWP Treaty increasing costs of water from LHWP.
4. Higher royalty payments than if LHWP cancelled after Phase I.	4. Potential delays due to the process that will be necessary to comply with new environmental legislation promulgated after the Feasibility Study.

2.22.2.2 Recommendations

No clear preferred option emerges from the results of the comparative evaluation of the two options.

South Africa has taken the decision to proceed with LHWP Phase II on condition that the negotiations with Lesotho results in a satisfactory agreement. Based on these findings SA could at any point decide to implement the TWP should the negotiations prove to be highly unfavourable for South Africa.

It is important to note that even though the conditional decision has been taken to proceed with Phase II of the LHWP, the final date to implement should remain flexible and will be dependent on the success of other interventions in the Vaal River System such as Water Conservation and Water Demand Measures as well as reuse of treated effluent.

Given these findings, it is recommended that the following aspects need further investigative work and clarification:

- Detail review of the parameters assumed in the Royalty calculations in close cooperation with Lesotho.
- Further and more detailed geotechnical work of the LHWP Phase II and an associated update of the engineering and cost estimates.
- Further analysis of the option to re-use mine water that is currently being discharged into the Vaal River.

2.23 COMPREHENSIVE RESERVE DETERMINATION STUDY OF THE INTEGRATED VAAL RIVER SYSTEM (2010)

2.23.1 Background

The Chief Directorate Resource Directed Measures (RDM) of the Department of Water Affairs (DWA) identified the need to undertake detail Reserve determination studies for the various components in the Integrated Vaal River System (IVRS). This study consists of the yield modelling component and the main objective of this study is to ensure that the actual integration of the Ecological Water Requirement (EWR) results obtained from the parallel technical Reserve determination studies takes place.

2.23.2 Description of WRPM scenarios

The eight scenarios selected for analysis with the WRPM are summarised in **Table 2-114**. It is important to note that the basic assumptions described in the report were adopted for all the scenarios and only additional assumptions relevant to a specific scenario are highlighted in **Table 2-114**.

Scenario 1 represents the current (2008) situation and was used as a benchmark for assessing the impact of implementing the EWRs. The impact of implementing alternative combinations of EWRs was evaluated as part of the analyses of Scenarios 2, 3 and 4. Scenario 4 was based on the selected EWR scenario. Scenario 5 represents the baseline for the 2020 development conditions and Scenario 6 evaluates the impact of implementing the selected EWRs on the future development conditions. Scenarios 7 and 8 were evaluated as part of the socio-economic assessment and are not representative of a specific development level. These two scenarios are defined as future scenarios with full utilization of the existing water resources which means that for sub systems not in deficit, the highest possible demand which could be supplied at a 100% assurance was imposed on the relevant water resource.

Table 2-114: Description of WRPM Scenarios

Scenario No.	WRPM Reference	Development Level	EWR Status	Comments
1	V8RES05	2008	Excluded	Base scenario representing the status quo.
2	V8RES06	2008	Included	Based on Scenario 1.

Scenario No.	WRPM Reference	Development Level	EWR Status	Comments
				Alternative EWR Scenario: All EWRs included with JMRBS EWRs adopted for Usutu.
3	V8RES07	2008	Included	Based on Scenario 1. Alternative EWR Scenario: Including all EWRs in Vaal and Senqu but with all other sub-system EWRs excluded.
4	V8RES08	2008	Included	Based on Scenario 1. Selected EWR Scenario: With exception of EWR4, EWR5 and EWR7, all EWRs in Vaal, one EWR in Thukela downstream of Driel Barrage and all Senqu EWRs were included.
5	V8RES09	2020	Excluded	Base scenario representing the future 2020 development conditions excluding the EWRs. Includes VRESAP pipeline from Vaal Dam to Eastern Sub-system. Includes proposed Polihali Dam and conveyance infrastructure. Includes proposed re-use of mine water. Includes projected possible transfer to the Crocodile catchment.
6	V8RES10	2020	Included	Based on Scenario 5. Selected EWR Scenario: With exception of EWR4, EWR5 and EWR7, all EWRs in Vaal, one EWR in Thukela downstream of Driel Barrage and all Senqu EWRs were included.
7	V8RES13	Full utilization (Future development scenario)	Excluded	Scenario representing the full utilization of available water. Based on current infrastructure. Includes VRESAP pipeline from Vaal Dam to Eastern Sub-system.
8	V8RES14	Full utilization (Future development scenario)	Included	Based on Scenario 7. Selected EWR Scenario: With exception of EWR4, EWR5 and EWR7, all EWRs in Vaal, one EWR in Thukela downstream of Driel Barrage and all Senqu EWRs were included.

2.23.3 WRPM scenario results

Based on the scenario results, the following conclusions were made:

- The implementation of the EWRs had a negative impact on the assurance of supply to water users situated in the tributaries of the Vaal River;
- The Vaal River main stem benefitted from the EWR contributions of the tributaries;
- The assurance of supply of water users receiving water from the main stem water resources was, therefore, not jeopardized by the implementation of the EWRS.

2.23.3.1 Tributaries of the Vaal River

The impact of implementing the EWRs in the tributary catchments of the Vaal River System is discussed in the Report. The results of Scenarios 7 and 8 were used for the socio-economic assessments. Information in terms of the assurance of supply (or risk of failure) is presented in terms of the % of months with failures (all analyses were based on a record period of 900 months). A failure month is defined as a month during which no or only part of the irrigation/urban water requirements could be met.

The water requirement and supply results of the analyses are summarized in **Table 2-115**. It is important to note that **Table 2-115** only contains information on tributary catchments where the implementation of the EWRs had a negative impact.

Table 2-115: Summary of results for tributary catchments

EWR Site No. (Name)	Demand (million m^3/a)	Scenario 7 Supply (million m^3/a)	Scenario 8 Supply (million m^3/a)	Difference: Scen 7 - Scen 8 (million m^3/a)
RE-EWR1 (Klein Vaal)	3.028	2.697	2.447	0.250
EWR1 (Vaal -Uitkoms)	36.25	31.48	31.35	0.130
EWR6 (Klip)	11.514	11.260	11.188	0.072
EWR8 (Wlige - Bavaria)	52.51	45.34	45.34	0.000
EWR WA1 &WA2 (Waterval)	14.56	14.37	14.34	0.030
EWR M2 (Klipdrift)	6.42	6.42	4.51	1.91
EWR R1 (Renoster - Koppies Dam)	10.05	10.00	3.93	6.07
EWR R2 (Renoster - C70H)	-	2.139	1.915	0.224
EWR14 (Vals - Proklameerdrift)	23.50	14.79	13.60	1.19
EWR V1 (Sand - Allemanskraal)	51.92	48.93	31.15	17.78
EWR V2 (Vet - Erfenis)	50.82	50.20	35.52	14.68
EWR15 (Vet - Fisantkraal)	11.75	11.32	9.82	1.50
Total	**-**	**248.946**	**205.110**	**43.836**

From **Table 2-115** it can be seen that the biggest impact of implementing the EWRs was experienced in the Sand and Vet River catchments. This was expected as the Allemanskraal Dam Sub-system is currently over-allocated and the Erfenis Dam Subsystem is just in balance. The impact on irrigation water users supplied from Koppies Dam was also found to be significant.

2.23.3.2 Main stem of the Vaal River

The methodology adopted for the assessment of the impact of the EWR on the main-stream of the Vaal River has been changed since the presentation of the initial results. The alternative approach adopted for the EWR impact assessment was to establish a firm yield situation by ensuring full utilization of all available water within the Vaal River System (WRPM Scenario 7). To this end, it was assumed that the VRESAP pipeline transferring water from Vaal Dam to users situated in the Vaal River Eastern Subsystem (VRESS) is fully operational. The addition “firm” supply (above the 2008 water use) which could be supplied 100% of the time was then determined by means of an iterative process. The EWRs were subsequently included in the analysis (WRPM Scenario 8) and it was envisaged that adjustments might be required in terms of the VRESAP pipeline capacity and/or the additional “firm” supply. The required changes (differences between Scenario 7 and 8 results) would then reflect the impact of implementing the EWR.

The following results were obtained:

- It was not necessary to increase the transfer capacity of the VRESAP pipeline as the assurance of supply criteria adopted for all users could be maintained by adjusting the VRESS operating rules;
- It was not necessary to adjust the additional “firm” supply as all water requirements, including the EWR, could be supplied without failure.

In summary, it can be concluded that:

- Implementation of the EWR resulted in more water to be transferred via the VRESAP pipeline (an additional amount of 55.6 million m^3/a was transferred for Scenario 8);
- Implementation of the EWR did not impact on the date at which the next augmentation scheme would be required; and
- Implementation of the EWR resulted in Sterkfontein Dam to be operated at lower storage levels (average storage for Scenario 7 was 2 367 million m^3 compared to the average storage of 2 294 million m^3 for Scenario 8).

2.23.4 Conclusions and recommendations

Based on the results of the WRPM scenario analyses the following conclusions are made:

- The available water to supply users situated in the tributary catchments of the Vaal River is reduced due to the implementation of the EWRs.
- The failures in supply to the irrigation and the EWR at EWR17 that occurred downstream of Spitskop Dam were not water resource related but due to the dam outlet capacity constraints.
- The comprehensive EWR of EWR site 19 at Lilydale Lodge on the Riet River is not in agreement with the Rapid EWRs derived as part of the BKS study (BKS, 2006).
- The main stream of the Vaal River benefit from the EWR contributions of the tributary catchments;
- Implementation of the EWR resulted in more water needed to be transferred via the VRESAP pipeline (an additional of 55.6 million m^3/annum was transferred);
- Implementation of the EWR did not reduce the available water to users receiving water from water resources located on the main stem of the Vaal River;
- Implementation of the EWR did not impact on the date at which the next augmentation scheme is required.

Based on the findings of this study the following recommendations are made:

- The hydrology and WRPM system configuration of the Usutu Sub-system (which includes Heyshope Dam) should be updated based on the information compiled as part of the JMRBS.
- The hydrology and WRPM configuration of the Komati Sub-system should be updated based on the information resulting from the Inkomati WAAS.
- The EWR as determined for EWR19 at Lilydale Lodge on the Riet River should be re-evaluated before implementation.
- Alternative management scenarios, particularly relating to the treatment and use of mine water discharges in combination with the main stem EWRs should be assessed.

2.24 DEVELOPMENT OF RECONCILIATION STRATEGIES FOR ALL TOWNS IN THE CENTRAL REGION (2011)

The water supply reconciliation strategy was compiled for the Directorate: National Water Resource Planning (D:NWRP) of the Department of Water Affairs (DWA) to identify measures that are necessary to ensure the current and future water requirements of all the towns in the Central Area (Vaal and Orange river basin) can be supplied from the available water resources. The total number of towns located in the Orange and Riet/Modder catchments are in the order of 180 towns. Strategies were prepared for each of the towns. The document describing each town's strategy includes the following:

- An introduction describing the study area, and providing background on the National Spatial Development Perspective as well as on the the Provincial Spatial Development Framework. It was also important to ensure that the results of the nodal economic profiling project are considered in the development of the water reconciliation strategies for the towns, to ensure that water does not hamper the envisaged economic development of the country as planned by the government.
- A section on the demographics of the specific towns in order to determine the most accurate base population figures.
- Water requirements section: The water requirements calculation was based on the water use categories as developed by DWA: Water Resource Planning Systems. The categories were updated using the 2001 Census, 2007 Community Survey and the Water Services National Information System (WSNIS) databases to make them more relevant for the current study.
- Water infrastructure section: Describing the bulk supply infrastructure, the water treatment works and related capacity as well as the service storage.
- Water conservation and water demand management possibilities were investigated to obtain a first order indication of possible savings.
- Sanitation levels were reported on as well as details of the waste water treatment works and point of discharge back into streams where applicable.
- Information on surface and groundwater resources is given, providing an indication of the available yield and water quality.
- Water balance was provided for current and future conditions covering the period 2008 to 2030.
- Possible reconciliation options were briefly discussed for each town.
- A section on institutional issues
- A last section on conclusions and strategy recommendations

Towns covered in the Orange Reconciliation Study area are listed in **Table 2.116**.

Table 2-116: Towns included in the study area

Town name	Town name	Town name	Town name
Koffiefontein Urban	Qwaqwa Urban	Ward 1	Britstown
Petrusburg Urban	Kestell Urban	Ward 5	Hanover
Jacobsdal Urban	Memel Urban	Ward 6	Carnarvon
Luckhoff Urban	Vrede Urban	Ward 10	Vanwyksvlei
Oppermans Urban	Warden Urban	Ward 4	Vosburg
Bethulie Urban	Kroonstad Urban	Ward 3	Phillipstown Urban
Jagersfontein Urban	Steynsrus Urban	Ward 2	Petrusville Urban
Edenburg Urban	Viljoenskroon Urban	Ward 7	Vanderkloof Urban
Fauresmith Urban	Vierfontein Urban	Ward 8	Hopetown
Gariep Urban	Edenville Urban	Ward 9	Orania
Trompsburg Urban	Heilbron Urban	Ward 11	Strydenburg
Springfontein Urban	Koppies Urban	Kuruman	Prieska
Phillipolis Urban	Vredefort Urban	Batlharos	Marydale
Reddersburg Urban	Parys Urban	Sedibeng	Niekerkshoop
Zastron Urban	Viljoensdrift Urban	Mothibistad	Douglas
Smithfield Urban	Coalbrook Urban	Kagung	Campbell
Rouxville Urban	Deneysville Urban	Olifantshoek	Griekwastad
Dewetersdorp Urban	Skurweberg Urban	Dibeng	Askham
Wepener Urban	Oranjeville Urban	Sishen/Dingleton	Klein Mier
Van Stadensrus Urban	Sasolburg Urban	Kathu	Welkom
Baralong Boo Moroka South	Cornelia Urban	Hotazel	Rietfontein
Baralong Boo Moroka North	Frankfort Urban	Van Zylsrust	Kakamas
Bloemfontein Urban	Tweeling Urban	Alexander Bay	Augrabies
Botshabelo Urban	Villiers Urban	Eksteenfontein	Keimoes
Morago Urban	Wesselsbron Urban	Port Nolloth	Kenhardt
Thaba Nchu Urban	Clocolan Urban	Sanddrift	Riemvasmaak
Tweespruit Urban	Ficksburg Urban	Concordia	Upington
Hobhouse Urban	Marquard Urban	Kleinsee	Grootdrink
Excelsior Urban	Senekal Urban	Komaggas	Groblershoop
Ladybrand Urban	Bethlehem Urban	Steinkopf	Postmasburg
Thaba Phatchoa Urban	Clarens Urban	Brandvlei	Danielskuil
Winburg Urban	Paul Roux Urban	Calvinia	Lime Acres
Brandfort Urban	Fouriesburg Urban	Loeriesfontein	Kimberley
Ikgomotseng Urban	Rosendale Urban	Nieuwoudtville	Ritchie
Theunissen Urban	Vaalbank Urban	Fraserburg	Barkly West
Verkeerdevlei Urban	Arlington Urban	Sutherland	Windsorton
Boshof	Reitz Urban	Williston	Delportshoop
Dealesville	Lindley Urban	Aggeneys	Warrenton
Hertzogville	Petrus Steyn Urban	Onseepkans	Jan Kempdorp
Bultfontein Urban	Harrismith Urban	Pella	Hartswater
Hoopstad Urban	Bothaville Urban	Pofadder	Pampierstad
Allanridge Urban	Sterkspruit Urban	Loxton	Norvalspont Urban
Hennenman Urban	Barkly East Urban	Victoria West	De Aar
Odendaalsrus Urban	Lady Grey Urban	Richmond	Jamestown Urban
Virginia Urban	Rhodes Urban	Colesberg Urban	Burgersdorp Urban
Ventersburg Urban	Rossouw Urban	Noupoort Urban	Steynsburg Urban
Welkom Urban	Aliwal North Urban		Venterstad Urban

2.24.1 Demographics

Kayamandi undertook the demographic and economic component of this study. The study Area/Central Region is comprised of a relatively large land base and is made up of the Free State, the greater part of the Northern Cape Province and the western part of the North West Province and a small northern part of the Eastern Cape Province.

It is relevant to note upfront that the demographics of areas covered in the Vaal Reconciliation strategy, were not redone, and were thus based on the demographics as reported on in the Vaal Reconciliation strategy.

Population size is one of the main drivers of water demands, and Kayamandi undertook a detailed analysis of population size. Existing data and sourcing and reviewing additional historic and base demographic data was also undertaken to compile a practical and up-to-date quantitative demographic model of the study area in terms of population size. Each of the municipalities was contacted to obtain latest population figures, inputs and first-hand knowledge of the size of the towns. Detailed demographic modelling and projections were undertaken. These were augmented and verified with up-to-date growth expectations and took cognisance of significant influencing factors on population growth such as the impact of HIV/Aids, income groups, proposed housing developments, urbanisation and migration trends, etc.

The base population data comprised the use of Eskom Spot Building Count (SBC) database (Eskom, SBC database, 2006) utilising the sub-places as a basis. The point information of the individual households in the Eskom Spot Building Count (SBC) data (one of the datasets analysed) was counted. Other datasets that were used included Census 1996 and 2001, Community Survey 2007 and the National Settlement database as supplied by DWA. The Eskom SBC database has been captured from SPOT 5 satellite photos and mapping was done per dwelling unit.

In terms of future population estimates, two scenarios were derived based on a high and a low population growth. The low population estimate was based on the future scenario compiled by Stats SA for DWA: C Dir-IWRP at a District Municipality level. The local municipality level figures were firstly derived from the district municipality figures and then to a sub-place level based on the historical trends between the 1996 and 2001 Census data.

The outcome of the analysis was two projection scenarios, i.e. high and low and a database of towns/grouped settlements with a base 2008 population split by water use categories and a high and low population projection for 2010, 2015, 2020, 2025 and 2030.

The demographics contained in this report is based on data which is more than 6 years old (2006 Eskom Spot building counts) and needs to be updated for the purpose of this study.

2.25 DEVELOPMENT OF RECONCILIATION STRATEGIES FOR THE AREA SERVED/INTERACTING BY/WITH SEDIBENGS WATER'S VAAL GAMAGARA SCHEME AS WELL AS A WATER MASTER PLAN (2011)

2.25.1 Feasibility Study Main Report

2.25.1.1 Background and purpose of the study

During the first phase of the All Town Reconciliation strategies study, it became evident that in the Central planning region, that the towns that are being supplied from the Vaal Gamagara Scheme required the development of a more detailed reconciliation strategy.

The objectives of the study can be summarised as follows:

- Establish water demand and use.
- Investigate the quality and quantity of the two available water sources namely groundwater and the Vaal Gamagara scheme.
- Investigate the capacity of existing infrastructure and the need for upgrading, as well as the economic viability thereof. The calibration of the existing hydraulic model form part of this objective.
- Investigate possible augmentation options.
- Determine the economic viability of possible conveyance options.
- Develop reconciliation strategies for all municipalities and the bulk water users.
- Develop a Master Plan for the Vaal Gamagara water supply scheme.

2.25.1.2 Water Requirements

The total water currently used from the Vaal Gamagara Scheme is 13.7 million m³/a, which is projected to increase substantially to 40.1 million m³/a by 2030. The water use currently supplied from ground water is 36.7 million m³/a and is currently projected to increase to 46.0 million m³/a by 2030.

The total current and projected water use from the Vaal Gamagara Scheme, according to the different water use sectors, is presented in **Table 2-117**. From the table it can be deduced that the mining sector currently utilises the most water (63.5%) of the Vaal Gamagara Scheme, whereas the local authorities and other water users currently utilise 14.7% and 21.8% of the total scheme's water use respectively.

Table 2-117: Vaal Gamagara Scheme water use summary according to users

Water Use Sectors	Surface Water (Vaal Gamagara Scheme)		
	2010	2015	2030
Local Authority	2 707 319	3 229 380	9 812 200
Governmental	786 569	2 300 617	8 817 875
Agricultural Other	87 812	92 167	97 036
Agricultural Kalahari East	2 140 015	3 250 433	3 250 433
Industry	52 641	55 273	63 923
Mining	7 931 300	17 036 010	18 021 225
Total	**13 705 665**	**25 963 890**	**40 062 703**

2.25.1.3 Water Sources - Groundwater

It was found that the local groundwater source of the towns of; Schmidtsdrift, Campbell, Griekwastad, Danielskuil, Lime Acres, Papkuil, Jenhaven, Skeyfontein, Dibeng, Kuruman Cluster and Heuningvlei Cluster will be sufficient and sustainable for the planning horizon of 20 years and do not require additional water from the VGG scheme.

It is however recommended that the community of Metsimatale (Groenwater) receive VGG water due to poor groundwater quality. The VGG water should be used to blend water with existing boreholes to meet the required quality and future demands.

Based on the resource potential of resource groupings and shortfalls identified in the short to medium term capacity of the VGG pipeline scheme, four large scale source development target areas were identified.

2.25.1.4 Water Source – Vaal Gamagara Scheme

2.25.1.4.1 Existing Infrastructure Condition Analysis

From the external integrity surveys and investigations it is recommended that the Cathodic Protection system be redesigned from first principles to meet the current demand to adequately protect the pipeline(s) regardless of which refurbishment/upgrading scenario are to be implemented. It is envisage that this will result in an increased number of locations for CP stations using traditional ICCP rectifiers and associated ground beds. Regular maintenance and repairs to the CP System are essential to maintain the integrity of the existing and future pipelines.

The drained and live CCTV inspections on selected sections of the Vaal-Gamagara scheme yielded very meaningful results. The overall result is that the internal lining is in an advanced state of degradation. Although the degree and type of failure vary from section to section, the entire pipeline will require re-lining. Further investigation as outlined below may be justified if prioritisation of the re-ling operation is required.
The re-ling process will be significantly more cost effective if it is undertaken once a new line is operational, as no temporary bypasses will be required and the lining contract can proceed un-interrupted.

2.25.1.4.2 Existing System Capacity and Comparison with the Current Demand

The existing system capacity and comparison with current water demand projections was done as the second step to determine the feasibility of the current scheme. For the purposes of evaluating the sufficiency of the existing Vaal Gamagara scheme the current capacity is compared with the current (so-called 2010) demand and done per pipe segments as indicated.

It is likely that the scheme would be able to supply the anticipated current demand (2010) between the abstraction works to Clifton reservoir. This after the refurbishment of the pump sets and if the pumps run 24 hours per day.

For the supply to Gloucester the optimal utilization of the existing system capacity and sources requires from Beeshoek under peak demand periods will results in an available net supply to Gloucester, for which the hydraulic capacity of the existing system is sufficient.

The required supply downstream of Gloucester under anticipated peak demand conditions should be sufficient since the deficit can be made up by the supply from Sishen.

The section of the scheme between Gloucester and Kathu pump station can supply more than the required demand. The deficit currently anticipated North of Kathu can be made up if the Kathu pump station is in operation with the pumps having similar characteristics than before with at least one pump operating 18 hours per day during peak day. The flow velocity in the feeder pipe northwards, however, reaches values up to 1.9 m/s.

2.25.1.5 Effect of the short term (2011 to 2015) demand scenario and potential measures

Four large scale source development target areas were identified initially to augment the water demand in the short to medium term. The four sources are located in the Danielskuil area (SD 1), Postmasburg area (SD 2), Kathu area (SD 3) and Hotazel area (SD 4).

To utilize these groundwater resources to augment the current VGG scheme, detail investigations and surveys are required. It is anticipated that the total yield of the four proposed groundwater sources could be 20.3 million m³/a consisting out of 66 production boreholes. The cost to develop these sources as well as the EIA and licence application processes is estimated at R 34.4 million and could be completed within 12 to 18 months. The study team did not investigated the long terms benefit or the reduction in size of the proposed new scheme by developing these groundwater sources and recommend that this is investigated.

Since the development of these groundwater sources will probably not be achieved in time to alleviate the situation the short term as well as updated information received from the second workshop held with the water users, solution will depend on the potential to utilize and accommodate the water produce by mines in their dewatering programmes.

In order to utilize the water provided by the mines as effectively as possible the following modifications are required:

- The Beeshoek Phase 1 pumps must be upgraded by installing the original designed for additional stages to allow pumping from Beeshoek pump station to Clifton reservoir. According to the pump curves this should result in a pump rate of 700 kℓ/h or 16.8 Mℓ/d;
- The Kathu pump station must be re-commissioned to boost the supply northwards;
- Additional pumps must be installed at Kathu pump station to allow pumping southwards up to the Khumani off-take. The detail of this installation needs to be investigated, but an initial evaluation indicates that a pump rate of 1 900 kℓ/h (45.6 Mℓ/d) at a head of 140 m can be achieved;
- The detail arrangement and controls to be able to accommodate operating of the system with the above modifications need to be established;
- In order to provide a backup for the mine water source the potential for the development of the identified ground water sources should be considered.

Given that the above mentioned mortifications are provided the results can be summarized as follows:

- The hydraulic capacity of the section of the VGG scheme north of the Kathu booster pump station is insufficient to convey the 2015 demand and would require up grading over its full length if the full demand is to be delivered from a southern source. If, however, the groundwater source identified in the Hotazel area (SD4 with reference to Annexure D, Map 7) could be developed to supply close to its indicated potential of 15.6 Mℓ/d under peak demand conditions, no upgrading of the northern sector is required before 2015. In this case the supply from SD4 should be directly into the scheme's pipe system in the vicinity of the Hotazel off-take. To reduce the head at which the supply must occur the supply point can be downstream of the PRV to the north of the Hotazel off-take but with a by-pass and check valve on the PRV to allow supply southwards during peak demand conditions.

2.25.1.6 Planning for Future (2030) Demand

Since the demand of the VGG scheme is projected to increase substantially from 13.7 million m³/a to 40.1 million m³/a, the condition assessment confirmed the urgent need for refurbishment and the results of the hydraulic analyses indicated that the existing infrastructure has insufficient capacity to accommodate the anticipated 2030 demand, upgrading options were investigated for proposed 20 year design horizon.

The planning that was performed for three options were:

- Option 1: Replace the existing scheme with a single pipeline with sufficient capacity to supply the anticipated 2030 demand.
- Option 2: Add capacity to the existing scheme to supply the anticipated 2030 demand by an additional pipeline.
- Option 3: Replace the existing scheme with a double pipeline with sufficient capacity to supply the anticipated 2030 demand.

From the calculations it was evident that Option 1 has the lowest URV and thus from an engineering economic point of view, Option 1 - Replace the existing scheme with a single pipeline with sufficient capacity to supply the anticipated 2030 demand, is the recommended way forward.

The estimated cost to implement Option 1 for the 2030 water demand projections are estimated at R 7 165 223 602.90 (VAT excluded).

Should Option 1 be taken to replace the existing pipeline with a single larger diameter pipeline and abandon the existing pipeline, the new pipeline must be designed so as to be CP compatible. In addition, the existing pipeline should not be abandoned in the ground but removed completely or form part of the CP design, as it may compromise the integrity of the replacement pipeline by acting as a parallel conductor and aggravating stray current interference effects.

Due to the anticipated rapid growth of the demand over the entire length of the VGG scheme and current lack of spare capacity in large sections it is evident that the proposed upgrading of all components should proceed as soon as possible. However the development of groundwater sources or the utilization of water produced by mines in their dewatering programmes could drastically influence the urgency of upgrading of certain sections.

It is however recommended that a forth option is investigating determining the effect, cost as well as operational, to have the additional groundwater sources be developed and operated by Sedibeng Water.

2.25.2 Demographics

The demographic and economic activity component of this study, undertaken by Kayamandi, entailed the following users groups: households, mining, agricultural and government development initiatives.

The study entailed refining, updating and extending information relating to the economic growth and population size of towns. These figures played an integral role in determining the water demand of the area and eventually the scheme’s required capacity for a 20 year planning horizon (2010 to 2030).

The data utilised by the All Towns Study was ground-trothed (tested on the ground for reliability and accuracy), refined, confirmed and updated. This was done by reviewing the latest municipal documents (IDPs, SDFs, LEDs, Housing Sector plans, etc.), undertaking personal interviews with the LMs to obtain latest development plans and subsidy housing plans, identifying the housing plans of strategic water users, and undertaking limited on the ground settlement surveys. The limited settlement surveys were undertaken to refine, verify and confirm information and to augment the existing database through obtaining updated data on household size per homogenous areas, growth prospects, migratory patterns, estimated size of settlements, degree of second dwelling rentals, etc. Interviews were also conducted with local informants in the field as part of the primary information gathering process. Key informants were asked a series of questions pertaining to the population dynamics, housing typologies and other relevant issues.

With the exception of some towns/settlements where adjustments to the base were made, similar to that noted in the All Towns Study, many settlement informants revealed that the estimated size of settlements is either unknown or based on Stats SA and in most cases do not have any future growth scenarios. Were relevant adjustments to the All Towns Study were made based on ground-trothed information relating to latest housing developments, for example adjustments to household size, etc.

The outcome of this step entailed identification of additional settlements on the ground, updated number of households, refined average household size, and refined base population.

Once the base population was refined, confirmed and updated, scenario assumptions were tested based on up-to-date mining related population growth/decline expectations and associated population migration (in and out) in search of employment opportunities.

In addition to the natural growth, existing and future strategic water users were consulted for their future plans with the aim of identifying the resultant impact on the demographics of the study area. Development scenarios were also applied to prospecting mines in order to anticipate growth of potential future mines. All future growth and expansion plans of existing and future mines were identified to take place prior to 2015.
Spin-off developments from growth in economic activity were also factored into the towns/settlements impacted by existing and known future mining developments.

The outcome of the demographic and economic growth analysis was refinement of growth scenarios, attainment of housing plans of existing and known future mines, and attainment of population growth prospects/expectations and related migratory patterns. Two projection scenarios, namely a low and a high growth scenario based on demographic and economic growth was applied to the refined base demographics.

It was anticipated that the total population of the towns served by the VGG scheme would increase with 67% (high scenario) over the 20 year planning period. Kathu/Dingleton and Hotazel indicated the highest average growth rate of around 4.5% and 8% respectively. This could mainly be attributed to development and expansion in the mining sector.

2.26 ORANGE RIVER SYSTEM ANNUAL OPERATING ANALYSIS (2011)

2.26.1 Introduction

The study is a follow on from the study that took place over a period of three years and included three annual operating analyses, 2008/2009, 2009/2010, 2010/2011. This report describes the analyses that took place for the 2011/2012 calendar year based on a main decision date of 1 May 2011 and a relaxation decision date 1 November 2011.

In order to optimise the generation of hydro-power from Gariep and Vanderkloof dams, and to supply the other water users at the required risk levels, a system utilisation agreement was formed between Eskom and DWA. As part of this agreement, system specific data files together with the Water Resources Planning Model (WRPM) are used to determine the volume of water available for the generation of hydro power.

The main tasks carried out for the 2011/2012 systems analyses were as follows:

- the updating of the water demands and water demand projections imposed on the system;
- the inclusion of an updated operating rule for the Caledon-Modder sub-system used to supply Bloemfontein, Mangaung, Botshabelo, Thaba ‘Nchu and several other small towns with water.

2.26.2 Water Availability

Historic yield analyses for a 68 year period starting in 1920 carried out previously for the Gariep-Vanderkloof sub-system indicated that the historic firm yield for the Gariep-Vanderkloof subsystem is 3 349 million m^3/a.

The historic yield analyses for a 68 year period starting in 1920 previously performed for the Caledon subsystem indicated that the historic firm yield is 87.67 million m^3/a.

2.26.3 Conclusions and Recommendations

- The SCC could be utilized again for the 2011/12 planning year, enabling Eskom to utilise otherwise lost spills for hydro-power generation purposes.
- Releases from Gariep Dam during periods when Gariep is below its SCC must not allow Vanderkloof Dam to raise above its SCC. This will be critical particularly during the first 5 months of the operating year.

- A discretional allocation of 112 million m^3 was given to Eskom to use in the first 6 months of the year.
- Discretional allocation of a 100 million m^3 was given to DWA Northern Cape region to be used during emergencies as well as for normal operational requirements.
- The water use allocation and water to improve water quality in the Eastern Cape need to be clarified and agreed upon. The operating rule with regards to the water supply and support to the Eastern Cape needs to be investigated and formalized. Results from the current Real-time model need to be obtained, assessed and considered when making this decision.
- Real-time modelling of the Orange River downstream of Vanderkloof and Bloemhof dams needs to be implemented to reduce the current operating requirements of approximately 180 million m^3/a and to utilise spills from the Vaal.
- Further actions need to be undertaken to enhance the connection and alignment between the real-time model and the annual operating analysis by means of the WRPM.
- The updated operating rule for the Caledon-Modder subsystem improved the situation from previous analyses and should be implemented in practise.
- No curtailments are required for the 2011/2012 year for the Orange River Project or for the Caledon-Modder subsystem.
- The curtailment levels of the Orange River project is exceeded from 2016 onwards. This is a year later than indicated by the 2010/2011 analysis and is mainly as result of the higher start storage for the 2011/2012 analysis.
- The curtailment levels for the Caledon-Modder sub-system is now exceeded in 2015 which is a significant improvement on the 2011 date from the 2010/2011 operating analysis. The reasons for this improvement are the significantly higher starting storage and improved operating rule used for the current analysis.
- The target volume to be transferred from Knellpoort to Rustfontein Dam is 29 million m^3 over the entire year. Due to the current wet conditions it is expected that less would be required. This will be dictated by the levels in the dams and according to the updated operating rule.

2.27 SUPPORT TO PHASE 2 OF THE ORASECOM BASIN-WIDE INTEGRATED WATER RESOURCES MANAGEMENT PLAN (ORASECOM) (2011)

2.27.1 Overview

The main objectives of this consultancy were to enlarge and improve the existing models for the Orange-Senqu Basin, so that they incorporated all of the essential components in the four Basin States and are accepted by each Basin State. These models must be capable of providing the current and likely future information needs of ORASECOM. This will involve being able to assess the implications of additional water resource development options to achieve water security in each Basin State – including possible changes to operating rules for water supply and storage infrastructure. This will ensure that ORASECOM is able to demonstrate that its operations are aligned with the principles embodied in the SADC Water Protocol.

In order to contribute to the realisation of the above-mentioned objectives, the project included six work packages as outlined in **Table 2-118**. The first of these work packages is central to Phase 2 of the IWRM Plan and will also be at the core of the final plan to be developed in Phase 3.

Table 2-118: Summary of Work Package Objectives and Main Activities

Work Package	Main Objectives	Main Activities
WP 1: Development of Integrated Orange-Senqu River Basin Model	To enlarge and improve existing models so that they incorporate all essential components in all four States and are accepted by each	• Extension and expansion of existing models • Capacity building for experts and decision makers • Review of water balance and yields • Design/initiation of continuous review process

Work Package	Main Objectives	Main Activities
	State	
WP 2: Updating and Extension of Orange-Senqu Hydrology	Updating of hydrological data, hands-on capacity building in each basin state for generation of reliable hydrological data including the evaluation of national databases	• Assessment of Required Improvements to the Existing Gauging Networks. • Capacity Development • Extension of Naturalized Flow Data • Review of Existing Data Acquisition Systems, proposals on basin-wide data acquisition and display system.
WP 3: Preparation and development of integrated water resources quality management plan	Build on Phase 1 initial assessment to propose water quality management plan, based on monitoring of agreed water quality variables at selected key points	• Establishment of protocols, institutional requirements for a water quality monitoring programme, data management and reporting. • Development of specifications for a water quality model that interfaces with the systems models. • Capacity building to operate the water quality monitoring system and implement the water quality management plan.
WP 4: Assessment of global climate change	Several objectives leading to assessment of adaptation needs	• Identification of all possible sources of reliable climate data and Global Climate Model downscaling for the Orange-Senqu Basin • Scenario assessment of impacts on soil erosion, evapotranspiration, soil erosion, and livelihoods • Identification of water management adaptation requirements with respect to observed/expected impacts on water resources • Assessment of major vulnerabilities and identification of measures for enhancing adaptive capacities
WP 5: Assessment of Environmental Requirements	Several objectives leading to management and monitoring system responsive to environmental flow allocations	• A scoping level assessment of ecological and socio-cultural condition and importance • Delineation into Management Resource Units and selection of EFR sites. • One biophysical survey to collate the relevant data at each EFR site and two measurements at low and high flows for calibration. • Assessment of the Present Ecological State and other scenarios • Assessment of flow requirements, Goods and Services, and monitoring aspects.
WP 6: Water Demand management in irrigation sector	To arrive at recommendations on best management practices in irrigation sector and enhanced productive use of water	• Establish a standard methodology for collecting data on irrigation water applied to crops, water use by crops and crop yields; • Document best management practices for irrigation in the basin and finalise representative, best-practice demonstration sites through stakeholder consultation • Consider and assess various instruments that support water conservation/water demand management.

2.27.2 Water Resource Modelling of the Orange Senqu basin

2.27.2.1 Work Package Objectives

The main objectives for this Work Package are to enlarge and improve the existing models to cover the total Orange River Basin and to capacitate representatives of each of the basin states to set up and use the models effectively. The improvement of the existing models included a number of aspects, namely:

- Updated demands and return flows: All demands and return flows were updated to 2010 development level using latest available information: Vaal & Orange River Annual Operating Analyses, Small Towns Studies;
- Extended hydrology included: All hydrology extended till 2004-05 (carried out in WP2);
- New catchments configured into the model including the Molopo River and the Lower Orange tributaries; and
- Finer level of details included on existing catchments including selected Vaal sub-catchments and the Lesotho Lowlands area.

2.27.2.2 Conclusions and Recommendations

To be completed after WRPM analysis was carried out.

- The system data sets for the first time now cover the entire Orange Senqu River Basin. This enables basin states to also carry out simulations and determine water balances on the smaller sub-systems that are not used to support the main Orange and Vaal systems.
- Flows from the Lower Orange tributaries is for the first time modelled in detail which will improve the accuracy of incremental yield calculations on dams in the Lower Orange such as Vioolsdrift Dam as well as for dams on these tributaries.
- Details on possible future dams in the Lesotho Lowlands are included for the first time. It is now relative easy to carry out analysis to improve operating rules on these dams, to determine short and long-term stochastic yield results, and to determine the effect of these dams on downstream users.
- Improved hydrology for the Caledon and Upper Orange will result in improved yield and operating analysis of the Orange and Caledon sub-systems.
- The in general improved and extended hydrology (between 10 to 17 years extension) covering the same record period (1920 to 2004) hydrological years of the entire basin will result in improved yield analysis and improved stochastic flow generation.
- The extended record period did not include a more severe drought and a decrease in sub-systems yields are in general not expected. Results from yield analysis carried out for some of the main sub-systems also confirmed this.
- Verification and Validation of Stochastic flow sequences need to be carried out before any stochastic yield analysis can be carried out.
- Results from the analysis showed that almost no flow from the Molopo downstream of the confluence of the Molopo and Nossob is experienced. Due to the lack of observed flow information in this area it is not possible to confirm the accuracy of this. It is however expected that these flows will not reach the Orange River as it disappears into the Kalahari sand dunes.
- Results from the yield analysis showed a slight increase in historic firm yield of about 2.1% for the Orange River Project (Gariep and Vanderkloof dams). This is as result of improved hydrology upstream of Gariep Dam and higher environmental flow releases from Katse and Mohale dams.
- The historic firm yield for the Bloemhof sub-system increased by almost 13% as result of return flows that was not included in the previous yield estimation.
- The historic firm yield for Grootdraai Dam decreased significantly as result of compensation releases that were supplied first in the recent estimation, before the available yield was determined.
- Historic firm yield for Koppies and Taung dams remained unchanged.

2.27.3 Extension and Expansion of the Hydrology of the Orange Senqu Basin

2.27.3.1 Work Package Objectives

The central objective of this Work Package is to produce updated and extended hydrological sequences for the basin as a whole. This will help to address certain deficiencies with the existing hydrological data sets which are not consistent throughout the Orange-Senqu river basin. To ensure that the hydrological data sets are easily accessible for any future work, they will be incorporated into an appropriate database system with proper referencing. In addition to the main objectives mentioned above, the hydrological data sets for the river basin should ultimately be improved through the following:

- Recommendations on the upgrading of gauging stations and associated systems and processes;
- Provision of appropriate Capacity Building in a number of key areas to be agreed with each basin state;
- Recommendations on appropriate protocols and procedures for data collection and data sharing throughout the whole basin; and,
- Agreement on a proposed data acquisition and display system to be available to and adopted by, all four basin states and covering key stations basin-wide.

The main tasks of work package 2 are as follows:

- Assessment of Required Improvements to the Existing Gauging Networks;
- Capacity Development;
- Extension of Naturalized Flow Data; and
- Review of Existing Data Acquisition Systems.

2.27.3.2 Recommendations

2.27.3.2.1 Rainfall

Although certain areas of the Senqu-Orange Basin still have adequate coverage of rainfall gauges, there has been a significant reduction in open rainfall stations in most of the sub catchments of the basin. Today, the density of rainfall stations that are still open, and used in the analysis, ranges between 0.3 and 2.3 gauges per 2500 km2.

When analysing the runoff generating capabilities of the highest runoff generating catchments (SE and CA), the average rainfall gauge density was approximately 1 gauge per 2500 km2. This may be due to the lack of reliable data or due to the fact that in previous analyses these were the only gauges that were found suitable for rainfall-runoff modelling. For example, there is currently only one station remaining that drives the runoff generation for the upstream catchments of Katse and Mohale Dams. It is recommended that the rainfall data (historic and present day) for the higher runoff yielding catchments (CA,SE, VU and OU) be re-evaluated to ensure that the best available point sources are identified. These stations should remain open to ensure that future analyses are still representative.

With the projected effects of climate change, it is very important to safeguard and even expand the rainfall monitoring network to assess if the projected effects are actually occurring. It is also important to assess the possible effects on the meteorological conditions and therefore the projected water resource capabilities.

2.27.3.2.2 Stream flow gauges

Although there seem to be an adequate coverage of the flow gauging stations within the Senqu-Orange

Basin, it is of the utmost importance that at least the stations used for this analysis be maintained to ensure on-going monitoring. This will ensure that the effects of the ever-increasing water and land-use impacts can be assessed and that the impact of projected trends in the climate can be monitored. Water resources models can only provide adequate spatial and temporal disaggregation of information if proper stream flow monitoring takes place. Once again, the high runoff areas (such as the SE, CA, VU and the OU) should receive adequate attention when it comes to monitoring, especially when large infrastructure is implemented, such as the Katse and Mohale Dams. It is essential that all components necessary for a detailed dam balance of the Katse and Mohale dams are monitored and that an on-going calculated inflow record is generated. The same applies for all the other large dams in the Senqu-Orange River Basin.

2.27.3.2.3 Modelling

A relatively fine spatial resolutions hydrological model has been developed and it is essential to keep the model updated with land-use as it occurs, to ensure that the hydrological database stays representative. In particular, the Senqu River Basin might be required to revaluate the simulated part of the original “agreed” hydrology

2.27.4 Development of a Water Quality Monitoring Programme and data Management Framework

Report Title: Support to Phase 2 of The ORASECOM Basin-Wide Integrated Water Resources Management Plan. Work Package 3: Integrated Water Resources Quality Management Plan. Development of a Water Quality Monitoring Programme and data Management Framework. ORASECOM. Report No. 007/2011. December 2010. Prepared by WRP Consulting Engineers in association with DMM Consulting; Golder Associates, PIK; Ramboll and WCE.

The purpose of this task was to establish the protocols, institutional requirements for a water quality monitoring programme, data management and a reporting system to provide water quality management information to the water resource managers of the basin states. This report presents the trans-boundary water quality monitoring program developed for the Orange Basin as part of the water quality work package number 3. This was based on the need for the development of a collaborative monitoring program and reporting system as expressed by the member states so that trust can be developed in the data and the perceived water quality issues can be clarified.

The objectives of the monitoring program were:

- To identify monitoring point locations in consultation with the Basin States;
- Select the water quality variables to monitor and the sampling frequency;
- Propose a structure to manage the water quality data; and
- Develop quality assurance and quality control procedures for inter-laboratory comparisons of results.

The report presents:

- A Monitoring Programme;
- A sampling protocol
- A structure for data management,
- Trigger values, and
- Results of an Inter-laboratory benching exercise.

The following conclusions and recommendations were made as a result of this study:

- The success of the monitoring program in future will depend on the support of the basin states and the capacity of ORASECOM. ORASECOM must continue to actively support the initiatives and progress developed during this project and the JBS. If ORASECOM does not drive the process going forward, the trans-boundary monitoring program will not be a success.

- The trigger values, sampling point locations, sampling frequency and the water quality variables to be tested for can be changes as the trans-boundary monitoring programme evolves going forward.
- The linking of the sampling points to the hydrology network and the installation of continuous monitoring equipment should be considered going forward.
- The establishment of a central database and management system at ORASECOM to handle the data must be developed in the future. The system should be web enabled which allows the input and access to the data by the Basin States.
- Key groundwater trans-boundary sampling points of the major aquifers should be added to the reporting system in future.
- The initial inter-laboratory bench marking indicated that a number of the laboratories, including the independent laboratory used in the Joint Basin Study did not compare well with the spiked sample concentrations. In the future, training and continued use of samples must be carried out during the trans-boundary sampling programme, to bring all the laboratories to the same level.

2.27.5 Development of Specifications for the Water Quality Model

Report Title: Support to Phase 2 of The ORASECOM Basin-Wide Integrated Water Resources Management Plan. Work Package 3: Integrated Water Resources Quality Management Plan. Development of Specifications for the Water Quality Model. ORASECOM. Report No. 006/2010. December 2010. Prepared by WRP Consulting Engineers in association with DMM Consulting; Golder Associates, PIK; Ramboll and WCE.

The salinity models have been successfully applied in managing the salinity related aspects of water quality in the Vaal River System. The management of nutrients is the next modelling challenge facing the Orange River Basin. Although nutrient models have been applied to sectors of the Vaal River, there is a need for a planning level nutrient model which can be applied to develop nutrient management strategies for the basin.

This report concentrates on the water quality modelling needs for larger scale water resource planning and operation. In this context, the two primary types of water variables were identified viz. salinity and eutrophication. Models addressing these two water quality problems are needed for planning and river system operation.

The purpose of this work package was to develop algorithms for the inclusion of river and reservoir phosphate and chlorophyll-a in the WQT and WRPM planning models. Specifications for salinity modelling for planning and eutrophication modelling for planning were defined. The high level requirements for water quality operating models and possible development routes were also considered.

The results of the undertaking showed that satisfactory salinity modelling functions are already integrated into the WRPM and WQT models and improvements are being incorporated as required. Algorithms for a river and reservoir phosphate and chlorophyll-a model that is suitable for inclusion in the WQT and WRPM models were developed.

The following recommendations were made:

- That the phosphate and chlorophyll-a modelling algorithms developed in this report be incorporated in the WQT and WRPM models
- Water quality operating model requirements should be examined in detail and tested on key system

elements.

- On-going improvements to the WQT and WRPM salinity modelling routines should proceed.

2.27.6 Climate Change in the Orange-Senqu Basin

2.27.6.1 Work Package Objectives

The Overall objective of Work package 4 is to carry out a detailed assessment of the occurrence, extent and possible effects of climate change in the Orange-Senqu River basin.
Sub-objectives include:

- detection of statistically significant change in the climate;
- assessment of to which extent the detected climate change is consistent with the predicted climate change;
- if there is an inconsistency, identification of physically plausible explanations of the detected climate change; and
- Assessment of major adaptation needs in terms of water resource management, communities and economic activities, with a view to countering observed and/or expected impacts of climate variability and change on the hydro-climatology and water resources.

2.27.6.2 Conclusions and outlook

The regional climate models CCLM and STAR were used in order to determine characteristics of the future climate in the Orange River basin, up to the year 2060. Both represent complementary approaches to regional climate modelling, STAR being a statistical model, and CCLM being a dynamical model. For the validation period, STAR produced excellent results, both for the 2 m temperature and the precipitation. On the other hand, CCLM produced acceptable results for most of the basin in case of the 2 m temperature. However, on the coastal zones of Namibia it failed to yield realistic results or to reproduce realistic precipitation patterns. In particular for the crucial area of Lesotho, the precipitation was strongly underestimated.

For the period up to 2060, CCLM predicts a temperature increase for the whole basin. For parts of the basin, the temperature increase is projected to be larger than 2°C. The strongest increase is predicted to occur in summer and autumn. For the precipitation, CCLM predicts a decrease throughout the river basin, but due to the validation results, this prediction is not considered to be reliable.

STAR was used to generate future projections of temperature and precipitation for the Orange River basin based on the mean temperature trend for the time period from 2011 to 2060. This was extracted from several GCMs (based on the SRES A1B scenario). An ensemble of future climate projections was computed yielding the following results:

According to the median realisation the 2 m temperature in the Orange River basin will increase by over 2°C, with the strongest increase in the centre of the basin (especially in the southern Kalahari) and the weakest at the mouth of the Orange River. The same realisation results in a weak decrease of annual precipitation (down to -80 mm per annum) for most of the Orange/Senqu river basin. The precipitation decrease is evenly spread across the basin. Regarding the dry realisation, there is a decrease of precipitation for the largest part of the river basin, especially in the area of the Vaal River, with values decreasing down to -140 mm per annum. To the contrary, the wet realisation results in a decrease of precipitation for the largest part of the river basin, with its maximum around the Gariep Dam (down to -100 mm per annum). Note that all three realisations agree in an increase of precipitation in eastern Lesotho and in the east of South Africa, reaching values of up to 80 mm per annum.

Both 2 m temperature projections from STAR and CCLM are consistent. They largely concur in magnitude and spatial distribution.

Several improvements over the obtained results are conceivable. CCLM could be fine-tuned for the region. Technical improvement to CCLM could also be carried out, such as improved convection schemes etc. An improved CCLM could be used for focusing on particular areas of interest as well, which could then be simulated with a higher resolution than 0.44° × 0.44°. Another possible approach to the simulation of the climate in the Orange River basin would be to carry out long term simulations by STAR. These could be complemented by short term CCLM runs, in order to produce extreme event ensembles. New and improved SRES emission scenarios, as well as new GCM runs for the IPCC AR5 are also due this year (2011), providing the basis for better regional climate projections.

2.27.7 Irrigation GIS Database Interactive Database and irrigation Scenario Tools

2.27.7.1 **Background**

This report (working paper) forms part of Work Package 6 of the ORASECOM study involving Water Demand Management in the Irrigation Sector. For derails of this Work Package and its objectives and main activities, please see chapters 2.28.1 and 2.28.8 above.

This working paper reports on:

- Establishing a standard methodology for collecting data on irrigation water applied to crops, water use by crops and crop yields;
- Building up of a GIS Database irrigation inventory through the collection and collation of reliable and detailed information about the use of irrigation water by crops and crop yields and provides findings, conclusions and recommendations.

Obtaining a clear picture of the irrigation sector is fundamental to optimising the management of the sector. The irrigation sector is, by far, the largest user of water in the basin with current use estimated to be 3,624 Mm3/annum. Return flows are not accurately known for all schemes but are estimated at 13% on average for the main irrigation areas.

It is anticipated that areas under irrigation will continue to increase in some areas of the basin, most notably in the Lower Orange where the Namibian demand, mainly for high value export crops, may quadruple by 2025 to more than 300Mm3. South African demand from the lower Orange is also predicted to increase albeit more slowly, but could rise from the current 1891 Mm3 to more than 2,000 Mm3 by 2025. In South Africa, between 2006-2008 the South African Department of Agriculture, Forestry and Fisheries (DAFF)-field crop boundary survey and the project 2009-2010 survey some 22,000 Ha of additional and/or “change of use to Centre Pivot” irrigation has been recorded.

This report describes the work undertaken on mapping the extent of land probably irrigated, or equipped for irrigation. The words “probably irrigated” or “equipped for irrigation” are used because it was apparent that some centre pivots showed up as fallow at all times, but nevertheless had the potential for use.

It is to be noted that one of the fundamental aims of this survey of crop water demands was to update the baseline (2009) crop water demands for the Water Resources System Simulation model. The most recent studies, using the Water Resources System Model, were apparently based on data provided in approximately 2001 and this data has been reviewed as part of the study.

The study provides a tool to assist with predicting demands in future scenarios. The information available to generate scenarios includes:

- South African Department of Agriculture, Forestry and Fisheries (DAFF) field crop boundaries for 2006-2008;

- DAFF field crop boundaries updated by the project for 2009-10; and
- WARMS water use registration database for January 2010.

The DAFF 2006-08 study mainly identified irrigation as only “centre pivots”. The updating undertaken by this study attempts to identify: new centre pivots, new field crop boundaries and existing field crop boundaries under irrigation during 2009-10. The study also includes Botswana, Namibia and Lesotho. A coarse qualitative inventory was prepared for Lesotho but the areas involved tend to be relatively small and, for the purposes of use in future scenarios, it is considered more appropriate to use the official plans and proposals for irrigation in Lesotho.

The authors are of the opinion that the cost effective approach used to update the DAFF field crop boundaries, and to map irrigated areas, has produced results of sufficient reliability to use in developing scenarios for irrigation planning.

2.27.7.2 **Approach adopted**

The approach adopted was first to establish the extent of irrigated areas and then to aggregate these areas, according to the water demand units used in the Water Yield and Allocation Model (WYAM). Once the aggregated irrigated area was established to each WYAM the current WARMS database was used to determine the proportions of irrigated land, for each aggregate unit licensed, for each crop.

The consultants proposed to use remotely sensed satellite imagery to map the extent of irrigation. This was supplemented by access to the DAFF Field Crop Boundaries (FCB) for South Africa GIS coverage for 2006 to 20081. It was also proposed to consider the potential for extracting more than the official extent of irrigation, as a precursor for a follow-up study mapping crop extents using remote sensing. A proposal for such an activity has been prepared. The presentation of the results of the current mapping has been presented in such a way as to facilitate comprehensive crop mapping in the future. A key element of this would be the regular acquisition of ‘ground truth’2 for each satellite ‘Tile’ acquired (and to be acquired in the future).

The mapping of irrigated areas using remote sensing was accomplished using automatic (hard) classification procedures within the IDRISI image processing software. This was supplemented by visual examination of the Standard False Colour Composite images3 for each scene. Before deciding on the best approach to classification, a number of different classifiers were evaluated.

This report only deals with the estimation of areas believed to be irrigated or equipped for irrigation. The words ‘believed to be irrigated’ and ‘equipped for irrigation’ are used because, when using remote sensing methods, it is not all that easy to be absolutely sure that an area is being irrigated, and/or it is ‘equipped for irrigation’, and, as set out in the consultants’ proposal, an evidence based approach was considered; with the possibility of combining the evidence from the multi-temporal imagery with other evidence, such as: the shape of the field crop boundary; proximity to water sources (farm dams, rivers); issuance of WARMS registrations (these have a point location); land slope; mean annual rainfall; and expert knowledge of the irrigated agriculture by team members. The automatic classification of the satellite imagery was only the first step in the process because, without extensive ground truth, it is difficult to distinguish always between irrigated, partially irrigated and non-irrigated land parcels, despite having multi-temporal imagery. To assist with separating out confusing classifications additional evidence was considered.

2.27.7.3 **Satellite imagery used and acquired**

Since the main objective was to update the DAFF field crop boundary mapping with respect to irrigated areas, the main source of imagery used was the Landsat 7 – ETM+ for 2009 up to 2011. As far as possible, the whole USGS archive for this dataset was downloaded and is provided as an output to the project. It was, however, impracticable with the resources available for processing, to process every scene downloaded.

A figure indicates the irrigated areas differentiating between centre pivot and other irrigated areas, overlain on the irrigation and agro-economic zones. The dry-land agriculture is also shown in a different colour. **Table 2-119** lists the final areas of irrigation for all the irrigation zones as derived from the remote sensing process. This includes only the areas falling within the field boundaries as defined by DAFF in South Africa plus all the areas manually identified in the other three basin states. Once the additional areas as discussed are taken into account the figures increase slightly.

Table 2-119: Summary of Irrigation Area (ha) per Irrigation Zone

COUNTRY	ZONE	Description	Irrigated Area (ha)
RSA	BO	Ongers	1 456
Namibia	FI	Fish River	2 580
RSA	KU	Kuruman	3 635
RSA	SER	Senqu (RSA)	51
RSA	ML	Lower Molopo Nossob	7
Namibia	AU	Auob	582
Lesotho	O1	Caledon U/S Welbedacht Dam	174
RSA	O15	Orange-Vaal confluence to Boegoeberg Dam	15 576
RSA	O16	Boegoeberg Dam to Upington	9 806.
RSA	O17	Upington to Neusberg	11 535
RSA	O18	Neusberg to Namibia border	9 216
RSA	O19	Namibia border to Onseepkans	912
RSA	O4	U/S Gariep, D/S Aliwal North	1 465
RSA	O20	Onseepkans to Vioolsdrift	1 887
RSA	O22	Orange-Fish confluence to river mouth	198
RSA	O3	U/S Aliwal North, D/S Oranjedraai	262
RSA	O5	Kraai U/S Aliwal North	699
RSA	O6	U/S Van der Kloof, D/S Gariep	2 345
RSA	O7	Canals ex Van der Kloof Dam	4 474
RSA	O9	Van der Kloof Dam to Douglas	23 011
RSA	SH	Sak River	11 758
RSA	V1	U/S Grootdraai Dam to Vaal Dam	15 202
RSA	V10	Vaal and Riet U/S of confluence with Orange	29 594
RSA	V2	Wilge, Liebenbergsvlei Rivers	15 591
RSA	V3	Vaal Dam to Barrage	15 670
RSA	V4	Barrage to Bloemhof Dam	33 981
RSA	V5	Sand and Vet Rivers	23 198
RSA	V6	Bloemhof Dam to Schmidtsdrift	69 523
RSA	V7	Harts River	20 405
RSA	V8	Riet River	5 303
RSA	V9	Modder River	27 470
RSA	O2	U/s Gariep, D/S Welbedacht Dam	2 978
Botswana	MU	Molopo	92
RSA	MU	Molopo	11 508
Namibia	O19	Namibia border to Onseepkans	273
Namibia	O22	Orange-Fish confluence to river mouth	181
Namibia	O21	Vioolsdrift to Orange-Fish confluence	2 239
RSA	O21	Vioolsdrift to Orange-Fish confluence	324
Namibia	OLU	Lower Orange D/S Onseepkans	6
Namibia	O20	Onseepkans to Vioolsdrift	316
RSA	OML	Middle Orange - D/S Boegoeberg	217
RSA	O1	Caledon U/S Welbedacht Dam	1 064

RSA	CAU	Upper Caledon tributaries	2 293
RSA	CALR	Lower Caledon tributaries (RSA)	220
RSA	OUL	Orange tributaries - Van der Kloof to Douglas	888
RSA	OUU	Orange tributaries U/S Van der Kloof	3 965
RSA	OMU	Middle Orange - U/S Boegoeberg	239
RSA	OLU	Lower Orange D/S Onseepkans	293
TOTAL			**385 321**

It is important to note that the irrigated areas in the zones that fall entirely within South Africa is about 75 000 ha or 29% more than the registered areas in the WARMS database for the comparable zones. The differences are particularly evident in the G5 (Lower Vaal) and G7 (Modder-Riet) agro-economic zones. Areas under centre pivot irrigation (which were identified with high confidence) in zone G5 amount to about 107 600 ha, which by itself is about 60% more than the WARMS registered area for this zone. The total area, and the area under centre pivot irrigation in zone G7, both exceed the WARMS area by a large margin.

2.27.7.4 **Conclusions and recommendations**

2.27.7.4.1 General

The study has shown at the country level significant changes in irrigation practice are taking place, and that additional areas are being put under irrigation. Of particular interest is the apparently large under-registration of irrigated areas in the Lower Vaal (G5) and Modder-Riet (G7) areas. It was also found that not all areas apparently equipped for irrigation (centre pivots) were being irrigated. This could be due to allowance for fallow periods, abandonment, and other reasons. One small study of the C83 quaternary catchment shows large increases in centre pivot irrigation over the period from approximately 1988 to the present.

2.27.7.4.2 Ground Truthing

While the use of remote sensing has allowed the estimation of irrigation areas in the basin to be improved, the importance of ground truthing should not be underestimated. Ground truth information permits a more accurate estimate of irrigated areas, particularly in areas where rainfed agriculture is taking place. For crop classification, ground truthing is even more critical.

2.27.8 The Promotion of Water Conservation and Water Demand Management in the Irrigation Sector

2.27.8.1 Introduction

The overall objective of this work package is to attain an overall understanding of how better management practices could reduce water demand in the irrigation sector in the Orange-Senqu River Basin, and to make recommendations on improved water demand management in this sector in the future. In order to reach this goal a number of sub-objectives were identified in the terms of reference:

- Building up of a GIS Database irrigation inventory through the collection and collation of reliable and detailed information about the use of irrigation water by crops and crop yields
- Assessment of various instruments for enhancing productive use of water, e.g. water markets and their operation in a local as well as trans-boundary context
- Detailing the best management practices for irrigation in the basin;
- Selection and evaluation of demonstration projects of best practices at suitable sites;

The first item is covered in a separate report (see 2.27.8.2 below)

2.27.8.2 **Approach and methodology**

The methodology utilized to identify implementable Water Conservation and Water Demand Management (WC/ WDM) approaches comprised:

- a desk study to review water conservation and water demand management in the irrigation sector followed by,
- The analysis and evaluation of best management practices currently in operation. The distribution of water to irrigators and the use of the water require very different management practices. It was therefore decided to evaluate BMPs at two levels;
- Distributor level i.e. Water User Associations (*water user association*s), Irrigation Boards (IBs), Departments of Water Affairs; and
- Irrigator level**.**

Table 2-120: Gross Margin analysis of the main crops grown

Crop	Yield (t/ha)	Price (R/t)	Revenue (R/ha)	Total variable costs (R/ha)	Gross margin (R/ha)	Establish-ment costs (R/ha)	Crop life cycle (yrs)	Amortization of establishment costs over crop cycle (R/yr)	Gross margin including amortized establish-ment costs (R/ha)
Eastern Zone									
Lucerne	19.0	917	17,426	10,524	6,902	13,933	7	2,787	4,115
Maize	14.0	1,300	18,200	14,608	3,592	-	1	-	3,592
Wheat	6.0	2,280	13,680	11,329	2,351	-	1	-	2,351
Dry beans	2.5	5,000	12,500	10,389	2,111	-	1	-	2,111
Cherries	3.0	50,000	150,000	70,000	80,000	240,000	20	12,000	68,000
Central Zone									
Lucerne	20.0	917	18,343	10,884	7,459	13,933	7	1,990	5,469
Early Maize	16.0	1,300	20,800	14,608	6,192	-	1	-	6,192
Late Maize	14.0	1,300	18,200	14,403	3,797	-	-	-	3,797
Wheat	7.0	2,280	14,820	11,447	3,373	-	1	-	3,373
Potatoes	40.0	3,250	130,000	83,831	46,169	-	1	-	46,169
Dry beans	2.5	5,000	12,500	10,389	2,111	-	1	-	2,111
Table grapes	18.0	16,667	300,000	168,186	131,814	321,812	20	16,091	115,723
Western Zone									
Lucerne	21.0	917	19,260	11,243	8,017	13,933	7	1,990	6,026
Melons	12.0	16,250	195 000	98,969	128,531	-	1	-	96 031
Table grapes	18.0	16,667	300,000	168,186	131,814	321,812	20	16,091	115,723
Dates	5.0	20,000	100,000	34,743	65,257	-	50	-	65,257
Raisins	10.0	8,675	85,883	56,889	34,754	36,059	20	1,803	32,951

The analysis of best management practices was carried out through a combination of site visits and stakeholder workshops. During this process a great deal was learnt about the caveats and realities of many theoretical best practices when tested on the ground. During the stakeholder workshops, a number of best management practice sites were identified and then visited and evaluated.

This approach applied to all South Africa and Namibia.

The report provides a review of the irrigation sector in each of the countries with respect to regulatory and Institutional aspects, technological aspects, agronomic aspects and agro-economic aspects. A Gross margin analysis of the main crops grown in three broad agro-economic regions of the Orange River catchment in South Africa are summarized in the **Table2-120**.

2.27.8.3 Conclusions

2.27.8.3.1 Global Trends in Water Resources Management

Water conservation and water demand management (WC/WDM) initiatives in the Orange River Basin should be aligned to three important global trends in water resource management, namely:

- integrated water resource management within catchment boundaries;
- decentralised management, operation and maintenance of water delivery; and
- Improved management of existing water resources to promote water use efficiency and water conservation.

All of these trends are evident, to a greater or lesser extent, in member-state legislation and/or policy on water management which provides a sound foundation for their implementation over time.

2.27.8.3.2 The Role of Water Management Institutions in Water Conservation and Water Demand Management

With respect to the need for decentralized management, operation and maintenance of water delivery, effective improvements in water conservation and water demand management in the basin will primarily depend on strong and active water management institutions at the water-user level. The Water User Associations (water user association), which are currently being established in South Africa, in terms of the Water Act, are a good example of the effective devolution of water management responsibility. The water user associations should not have to operate in isolation and require mentorship and monitoring from a catchment management agency (catchment management agency) which initially will be country–based. Catchment management agencies for the South African portion of the Orange River Basin (one for the Vaal River catchment and one for the remainder of the Orange River basin) have not yet been established. In the interim the Department of Water Affairs (DWA) fulfils the responsibilities of a catchment management agency.

In South Africa, water user associations are required, in terms of the Water Act, to submit water management plans to their catchment management agencies or Department of Water Affairs, in the absence of a catchment management agency. However there is evidence in the Orange River Basin that the Department of Water Affairs is not yet enforcing this legislation or as yet encouraging water user associations to prepare water management plans. However, plans are afoot within DWA to use consulting services to assist water user associations in preparing water management plans. The development of a Water Management Plan (WMP) by a water user association is central to implementing WC/WDM in the agricultural sector.

A water management plan is not an end in itself but is a process with an annual cycle, which can assist water user associations and their irrigators in realising the economic and social benefits of improved water use efficiency.
The water management plans may be rudimentary to start with and may be lacking in certain data, but it can be improved annually during the review process In addition, the development of the plans provides an opportunity to improve agricultural water management by stimulating self-analysis and forward thinking on the part of farmers, their water suppliers, catchment management agencies, officials, consultants and advisors. The plans can be used as a management tool for water user associations, Department of Water Affairs and the catchment management agencies to compile catchment databases and determine national

water balances. Developing a water management plan and reviewing it annually is a major stimulus to efficiency, provides input to the business planning process, promotes coordinated action and facilitates negotiations with the catchment management agencies and other stakeholders. The process involves analysing current water use, setting targets for improved efficiency and planning a realistic means of reaching these targets.

A set of implementation guidelines for water management have been prepared for the irrigation industry in South Africa by the Department of Water Affairs and provide a valuable framework for the preparation of water management plans and the establishment of best practice in the sector. These guidelines have relevance to all member states. The water management plans must identify appropriate best practice for a specific water supplier and its irrigators.

2.27.8.3.3 Best practice for irrigation water suppliers and irrigators

Irrigation water suppliers

In the case of irrigation water suppliers, best practice can be divided into primary and secondary elements. Examples of primary best practice include:

- Appointing a person with responsibility for Water Conservation Coordination (apart from normal *water user association* management roles).
- Ensuring that available information for improved on-farm water management is distributed to farmers.
- Making progress towards the use of acceptable measuring devices or techniques *(You can't manage what you can't measure).*
- Making progress towards measuring the quality and quantity of inflows and outflows, and measuring losses and water supplied to customers,
- Making progress towards establishing GIS type data bases on irrigated lands, crop types and areas, irrigation requirements and actual applications, etc.
- Making progress towards implementing a water pricing structure to facilitate water conservation.
- Maintaining and improving infrastructure, according to a long-term maintenance plan, supported by a financial plan.
- Positively promoting good communication between all concerned in water management
- Preventing unlawful withdrawals of surface and groundwater.

Examples of secondary best practice for irrigation water suppliers include:

- Facilitating support services to enable farmers to use water more efficiently on-farm.
- Coordinating the evaluation of energy and water efficiency of pumps, distribution and irrigation systems belonging to *water user associations* or private irrigators.
- Considering the suitability of irrigation methods and crops to an area.
- Reducing losses by lining canals, balancing dams, etc.
- Promoting better management procedures for water bailiffs and other management staff.
- Training *water user association* personnel.
- Facilitating the financing of capital improvements for on-farm irrigation systems.
- Facilitating voluntary water transfers.
- Eradicating invasive alien plants.
- Practicing adequate soil conservation and drainage measures.

Irrigators

While the role of a water management authority is critical for the sustainable improvement in water use efficiency and water demand management, the role of individual irrigators in this initiative is equally important. Examples of best practice for irrigators include:

- Establishing benchmark irrigation water requirements of their selected crops in their climatic zone
- Practicing irrigation scheduling to meet irrigation requirements
- Installing flow meters or other appropriate measuring devices for accurate measurement of irrigation water. Without the ability to measure application rates it is not possible to manage irrigation efficiently.

The lack of good water measurement impacts directly on the ability to:

- transfer water from one irrigator to another within a WUA (water trading),
- effectively schedule irrigation,
- monitor abuse of water allocations to farmers, and
- Apply almost any aspect of water management best practice.

The following are all aspects which can encourage farmers to use water efficiently:

- Maintaining on-farm canals, pipelines and dams to minimize wastage
- Maintaining irrigation equipment to ensure efficient application of the correct amount of water
- Installing (where necessary) and maintain irrigation drainage facilities.
- Improving production practices to optimize net returns from crops per unit volume of irrigation water used.

These initiatives are unlikely to be effective unless there is a tangible benefit to the supplier and/or the irrigator. Examples of tangible incentives include:

- Cost savings (e.g. pumping costs and user charges)
- Improved yield and quality of crop (improved income)
- Easier management, especially with automated systems
- Income from sale of saved water (water market)
- Irrigate larger area with same water allocation
- Long-term assuredness of supply of adequate water.

Without the ability to measure water flow, all incentives for improved water use efficiency are undermined.

Water Markets

Water markets are very much in their infancy in South Africa. However this is considered an important mechanism for improving water use efficiency. Examples of successful irrigation water marketing include the Sand Vet water user association and Orange Riet water user association which both operate a water bank. Unused water allocations can be surrendered to the water user association who on-sells at a premium to a willing buyer, typically 30% above the normal tariff. This additional income makes a contribution to the costs of managing the water user association and improving overall water use efficiency.

Water markets on schemes fed by canals are constrained by system capacity in that they can only transfer water from the lower end of the canal to the upper end. Water markets can only function in a system where water can be measured accurately as applies in the Orange Riet water user association for example.

Measuring and Monitoring of Diffuse Irrigation

A key finding during the study is that diffuse irrigation (not part of a formal scheme) in the easterly region of the Basin, above Gariep Dam, is not measured or adequately monitored by the DWA which appears not to have the means or personnel to do so. Better control of irrigation in this area would result in significant water savings. The DWA is aware of the problem and is taking certain steps to address it. However it would be far more effective when this responsibility falls on water user associations (when they are formed to cover the whole of the Basin) as they will see illegal water use in their area as “stealing their own water”.

Improved Crop Net Income per Unit Volume of Irrigation Water Used

It was observed at a number of the irrigator demonstration sites that maximising net financial returns per unit of irrigation water used was not only a water-use–efficiency objective but was fundamental to the viability and sustainability of their agribusiness based on irrigation. With the inevitable increase in irrigation water costs over time the “improved crop per drop” concept must become increasingly important. This can be achieved through one or more of the following factors:

- Increased yields and crop quality through improved agronomic practices,
- Selection of higher value orchard and vineyard crops such as grapes and citrus and high annual fruit and vegetable crops such as melons and potato,
- Improved irrigation efficiency through appropriate system selection and irrigation
- Scheduling.

2.27.8.3.4 Recommendations

Legislative and institutional issues

ORASECOM should interact with South Africa’s Department of Water Affairs to encourage them to implement their legislation with respect to (a) the formation of a catchment management agency for the Vaal River Basin and the remainder of the Orange River Basin and (b) the formation of Water User Associations and, in turn, to encourage, support and monitor the implementation of annual Water Management Plans by water user associations as a primary tool for improving water conservation and water demand management. ORASECOM should also encourage other member states to accommodate the above approach to water conservation and water demand management in their legislation which is presently being formulated. The use of the Noordoewer/ Vioolsdrift Joint Irrigation Authority provides the ideal venue for such an initiative on a trial/demonstration basis.

Technical issues

The need for improved irrigation water measurement at both the distributor and irrigator level has emerged as an important factor limiting effective water management and the improvement in irrigation water use efficiency. It is recommended that an investigation into the extent and cost of this need should be facilitated by ORASECOM and funding opportunities identified. ORASECOM should investigate the possibility of assisting WUA in the establishing of an appropriate GIS-type data base of irrigation lands, cropping patterns, irrigation, requirements etc. (including the training of personnel) to improve water management and water use efficiency. The value of modern, commercial irrigation scheduling systems and the professional back-up that comes with them is well illustrated on two of the irrigator demonstration sites. It is recommended that opportunities for the expansion of these systems to a far higher proportion of irrigators should be investigated and promoted.

Water markets

Water markets should be encouraged, particularly within water user associations, but also between water user associations provided the integrity and viability of the source water user association is not violated. This can be prevented by the intervention and monitoring of a catchment management agency.

Illegal water use

The issue of illegal water use requires urgent attention in South Africa. Although there are initiatives in place to try and deal with this pervasive problem it is most likely to be controlled in a sustainable way when the responsibility is passed to the water users through their water user associations.

Smallholder irrigation viability
The viability of smallholder irrigation schemes for resource poor farmers should be investigated with the view to finding more sustainable and viable models for this important initiative. The need for on-site training in various spheres, including water user association management and irrigation management training for farm labourers, is clearly evident and might be an intervention that ORASECOM could facilitate.

2.27.9 Project Executive Summary

2.27.9.1 Introduction

This report provides an overview of the work carried out under Phase 2 of GIZ Support to the ORASECOM Basin-wide IWRM Plan and summarises the outputs produced under each of the six work packages.

A number of overall conclusions and recommendations are presented and are essentially of a strategic nature aimed at defining some of the key issues to be included in the Basin-wide IWRM Plan to be developed in Phase 3.

2.27.9.2 Conclusions and Recommendations

There are a number of broad conclusions and strategic recommendations that come out of the study as a whole and which could be considered as providing some key elements of a strategic framework for Phase 3, the design and implementation of the Basin-wide IWRM Plan.

2.27.9.2.1 Improved knowledge of the resource base

A main input for the yield and planning models is hydrological data.

- Long historic records are important in establishing reliable estimates of yields. Reliable real-time data are required for operational planning. A major drive at improving the quality of data from key river gauging stations is required
- Hydrological modelling (rainfall-runoff modelling) requires historic and real-time rainfall data from an adequate number of rain gauges with good areal coverage. Efforts to improve the rain gauge network should be pursued and the current trend of closing rainfall stations should be reversed.

2.27.9.2.2 Improved Water Resource Modelling and increased Basin-wide Transparency

- Efforts have been made to expand and enhance the existing water resources models and to capacitate decision-makers and experts in all basin states. Continuous upgrading of the models as well as regular capacity building should be an essential part of the IWRM plan.

2.27.9.2.3 Reduced Water Demand

Overall water demand should be reduced, or at least growth rates must be kept to very low levels.

- The irrigation sector has to be made more efficient. Examination of best management practices has shown that this is possible. Priorities include accelerating the creation of water user associations and empowering them. Measurement and billing volumetrically is essential for other Water demand management measures to follow. Potential savings in water demand use are highest in this sector and are achievable.
- Water demand management in the urban environment already receives attention but more effort is required. Leakage management and other water demand management interventions should be pursued vigorously throughout the basin.

2.27.9.2.4 Environmental Flows

- Now that environmental flow requirements for different ecological states have been established, there is a need for the basin states to agree on what ecological states should be maintained in the future and the means to monitor this.
  - Testing of various operational scenarios that could include new developments or changes in the existing operation of the system. Testing of these scenarios must be undertaken in terms of changes in ecological state and Goods and Services.
  - These results should then be presented to the stakeholders so that agreement can be reached on the future ecological state of the river.
- An extensive and joint monitoring system should then be implemented. It is strongly recommended that an Ecological Water Resources Monitoring (EWRM) programme is initiated as soon as possible. The information gathered during this study is suitable for the baseline, but if too much time relapses between the baseline and monitoring, new surveys and Eco-Classification process will have to be undertaken. It must be noted that monitoring of essential Goods and Services should be included as part of the EWRM.

2.27.9.2.5 Climate Change

There is a need to prepare for the impacts of climate change and also to continually improve estimates of the anticipated climate change:

- Fine-tuning of the CCLM for the region and incorporation of further technical improvements such as improved convection scheme
- An improved CCLM could be used to focus on particular areas by undertaking high resolution runs. Clearly the source areas such as the Lesotho Highlands would be obvious targets.
- This year's (2011) new IPCC emission scenarios and GCM results should be used to yield improved downscaling results
- Improved accuracy of GCC downscaling will depend not only on advances in the modelling process but relies on large and good quality climate observation datasets. In view of the importance of having accurate predictions of climate change in the source areas, there is a need to improve the meteorological network in these areas.
- Design of a flexible adaptation strategy for the different parts and livelihoods around the basin.

2.27.9.2.6 Water Quality

There is a need to formalise the joint basin-wide initiative of water quality monitoring at critical points and to make this part of the overall resource modelling process throughout the basin. Phase 3 should see implementation of the water quality monitoring programme. During this process capacity-building should continue.

2.28 LESOTHO WATER SECTOR IMPROVEMENT PROJECT SECOND PHASE (2012)

2.28.1 Introduction

The objective of the annual State of the Water Resources Report is to position the importance of water in the national development context, to inform policy development and directions, articulate work plans to integrate activities across the sector and to reflect progress relating to the strategies put in place in pursuit of the national development goals.

2.28.2 Water Transfers

Lesotho transfers water to South Africa in terms of "the Treaty on The Lesotho Highlands Water Project between The Government of the Republic of South Africa and The Government of the Kingdom of Lesotho". The Treaty provides for the sharing of the benefit (or savings) of constructing and operating the Lesotho Highlands Water Project in Lesotho over the best alternative scheme in South Africa (the Least Cost Orange Vaal Transfer Scheme). In return for these water transfers South Africa pays Lesotho a Royalty equal to 56% of that benefit or savings and enjoys a Southern African Customs Union rebate.

The Royalty comprises three components, a fixed cost component, a variable cost component relating to the benefit due to the electricity costs; and a variable component relating to the remaining operations and maintenance costs.

The electricity royalty reflects the savings in pumping costs that South Africa enjoys by receiving water gravity fed by tunnel from the LHWP as opposed to the pumping costs that South Africa would have incurred had it built an alternative scheme in South Africa. The electricity royalty should not be confused with electricity sales from the Muela Power Station due to hydro-electric energy production.

The royalty payments received by Lesotho are included as contributions towards the GDP of Lesotho as exports.

Additions made to LHDA assets are included as contributions towards the GDP of Lesotho as capital formation and investment spending.

Table 2-121 summarises data on LHDA's assets and recurrent expenditures and the royalty payments received over the reporting period.

Table 2-121: LHDA assets, recurrent expenditure and royalty payments

	2011 M'000	2012 M'000	Notes
Carrying Value of Lesotho Highlands Water Projects			Lower 2011 values are mainly due to accumulated depreciation
Hydropower Civil Works	682 375	700 224	
Hydropower Plant	228 435	246 149	
Water Transfer Civil Works	9 971 096	10 239 807	
Vehicles and Equipment	33 143	27 049	
Total	**10 915 049**	**11 213 229**	
Additions made to assets			Phase 2 procurement (Polihali Dam & associated works) has just commenced and will be reported on in next year's SoWR.
Additions to new capital works	8 056	10 498	
Recurrent expenditure incurred			
Operating costs excluding depreciation	141 676	84 898	
Depreciation	306 983	307 718	
Total	**447 659**	**392 616**	
Royalty payments and sales revenue are received by the Government of Lesotho			Royalty payments are received by Government of Lesotho not LHDA. During 2011 730.303 Mm^3 were transferred. During 2010 783.637 Mm^3 were transferred
Fixed royalty	166 803	155 522	
O&M royalty	15 463	15 859	
Electricity sales	254 924	170 227	
Total	**437 191**	**341 610**	

The water transfer from the Lesotho Highlands scheme to South Africa is currently the largest demand imposed on the entire Lesotho system. The transfer volume currently amounts to 780 million m^3/a and is expected to remain at that rate until the completion of Phase 2 of this project. Phase 2 of the Project consists of Polihali Dam and transfer tunnel to Katse Dam. Polihali Dam will increase the yield of the system by another 437 million m^3/a (the net yield is 151 million m^3/a when the yield reduction of 286 million m^3/a in the Orange River is accounted for). Transfers from Polihali Dam are expected to start in May 2019 and the related operating rule and transfer pattern for this additional transfer volume still needs to be agreed.

2.28.3 WRPM setup and improvements

Two existing and fairly recent WRPM setups were available for the Senqu-Orange-Vaal integrated system at the start of this study. Both these systems include the entire Lesotho as well as large parts of South Africa. The one WRPM setup is currently used to carry out the annual operating analysis for the Orange (South Africa) and Vaal systems. This system setup is updated on an annual basis and therefore reflects the most recent developments. The other WRPM setup is a product of the ORASECOM Study entitled "Support to Phase 2 of the ORASECOM basin-wide Integrated Water Resources Management Plan" and was completed in April 2011. The main difference between the two WRPM system setups is that the hydrology used for the ORASECOM study was extended to the 2004/5 year and for the Caledon/Mohokare catchment an entire update for the hydrology was carried out, covering the hydrological years 1920 to 2004. The new Caledon/Mohokare hydrology was done on a far more detailed level than the previous hydrology that is used for purpose of the Orange RSA and Vaal annual operating analysis. The only reason why the ORASECOM WRPM setup is not yet used by South Africa for the annual operating analysis, is that the additional task on the ORASECOM study to do the validation and verification tests for the stochastic flow sequences, was not yet carried out.

For the purpose of this study a significant amount of detail was added on the Lesotho part of the WRPM system setup. In the previous two system setups the only Lesotho demands included in the Lesotho System was that of Maseru, a small amount of irrigation in the Mohokare catchment and the transfer from the Lesotho Highlands to South Africa.

For the current Lesotho system in excess of 40 additional demand centres were added and approximately 13 additional key monitoring points. Detail on the Makhaleng River system and the Maqalika off-channel storage dam at Maseru was for the first time included, as well as the support from 'Muela to Maseru that takes place on an ad hoc basis.

The improved hydrology from the ORASECOM study and the more detailed Caledon/Mohokare system layout was included in the Lesotho WRPM system setup. Validation and verification test were carried out on the stochastic flows relevant to the Lesotho system. Some problems were encountered with flows in the Senqu sub-catchments. These were overcome by using the same stochastic distributions as used for the previous hydrology system setup, as currently used for the Orange and Vaal annual operating analysis. Further detail work in this regard will be done as part of the current South African study entitled " The Development of Reconciliation Strategies for large bulk water supply systems: Orange River" Any improvements to the generation of the stochastic flow sequences from South African study will be provided to Lesotho for future use. It is important that Lesotho and South Africa use the same basis for the generation of the stochastic flow sequences.

Possible future improvements to be considered include the following:

- The latest area capacity characteristics for Maqalika Dam need to be included. No data could be obtained and assumptions were made.
- Details of the pump capacities and pipeline capacity limitations for abstractions from the Mohokare/Caledon River in support of the Maseru water supply system need to be built into the WRPM setup. Daily observed data at, or close to these abstraction points will be valuable in order to

determine the diversion characteristics at the site. This information will contribute to a more accurate simulation of the water abstractions for the Maseru water supply system.

- When sufficient detail of the current Maseru water supply system is available as described in the two bullets above, the generation of short-term stochastic yield reliability curves for the Maqalika system should be considered which could then be used in conjunction with the Metolong sub-system.
- Short-term stochastic yield characteristics need to be determined for Metolong Dam. These yield curves are necessary for establishing the operating rules of the dam and will enable the water supply authority to supply the users at the required assurances and also to protect the dam during drought periods against total failure. This should ideally be in place by the time Metolong Dam starts to supply water to the identified users.
- Lesotho needs to decide on an appropriate priority classification to be used for the Lesotho system. This is of particular importance at the time when Metolong Dam starts to deliver water to the users.
- The operating rule applicable to the combined Metolong and existing Maseru water supply system has not yet been determined. Analyses need to be carried out to determine the most beneficial operating rule.
- Water demand projections need to be refined. Several anomalies were found when comparing demand projections from different sources. These differences need to be clarified and projections improved.
- Very little data on irrigation developments and related water use could be obtained. This information needs to be improved and extended.

2.28.4 Operating Rules

The only well-defined operating rules currently used in the Lesotho system are those applicable to the Lesotho Highlands System. These rules are aligned with the Lesotho RSA treaty as applicable to Phase 1 of the Lesotho Highlands project and entail the following:

- A fixed transfer rate of 780 million m^3/a regardless of the storage levels in the Vaal River System.
- When in any given 12 month period there is not sufficient water available in Katse & Mohale Dams, the first six months following the 12 month period can be used to make up shortages experienced during the 12 month period, if sufficient water is available.
- Flow between Katse and Mohale dams through the transfer tunnel will take place as soon as the difference in the water level between the two dams exceeds 12 m.
- The agreed environmental requirements need to be released from Katse and Mohale dams.
- Matsoku Weir must allow 0.65 m^3/s minimum flow to bypass the weir for environmental purposes when available. This amounts to 20.51 million m^3/a.
- The remainder of the available flow up to the capacity limitation of the Matsoku Katse tunnel will be diverted into Katse Dam.
- Lesotho is entitled to 1.5 million m^3/a to be released from Muela Dam to support Maseru when required. If not used or fully used, this volume can be banked in Katse Dam for a maximum of two years not exceeding 3 million m^3 in total. This is to compensate for the runoff generated upstream of ‘Muela Dam, which is currently captured in Muela Dam.
- The water transferred to South Africa is used to generate hydropower for Lesotho.

2.29 WATER RECONCILIATION STRATEGY STUDY FOR THE LARGE BULK WATER SUPPLY SYSTEMS: GREATER BLOEMFONTEIN AREA

2.29.1 Final Interventions Report

The “Interventions Report” developed as part of the Water Reconciliation Strategy Study for the Greater Bloemfontein Area, was prepared to identify and document potential interventions which could be utilised to reconcile supply and requirement for the area. A Preliminary Options Workshop with Stakeholders was held in November 2009 to specifically address the potential interventions and obtain stakeholder input. Thirty-four potential interventions which could contribute to meeting the future water requirements were identified. The following categories of interventions were identified:

- Urban and agricultural Water Conservation and Water Demand Management (WC/WDM);
- Groundwater interventions;
- Re-use of treated effluent;
- Optimising the efficiency of surface water transfer schemes;
- Surface water interventions;
- Trading of water use authorisations; and
- Other options, such as re-use of mine water and alternate storage in the Caledon River.

A brief summary of the key interventions is given below.

It is believed that Agricultural Water Conservation and Demand Management will not make more water available for urban consumption as should farmers use existing water more efficiently they would most likely expand the irrigated area.

The intervention which was prioritised as part of the Reconciliation Strategy Study was the implementation of Urban Water Conservation and Demand Management. This implementation of this intervention under the “Best Case Scenario” has the potential to save approximately 25 million m^3 of water per annum and under the “Most Probable Scenario” the potential to save approximately 12 million m^3 of water per annum.

The development of large scale groundwater abstraction schemes to supply the future water requirements of the Greater Bloemfontein Area is not deemed feasible due to the low yielding boreholes, current over utilisation of groundwater and the potential socio economic impact should vast areas of agricultural land be expropriated. The development of boreholes to supply the smaller towns of Reddersberg, Edenberg, Dewetsdorp and Wepener are viable options which should be further considered.

A yield analysis of the Caledon system has shown that there is still significant water available in the Caledon River to reconcile water supply and requirement for the Greater Bloemfontein area. The development of the additional yield (which could be as much as 60 million m^3/a) would depend on the capacity of the infrastructure that is constructed to abstract water (and the feasibility thereof given the sediment related problems being experienced) from the Caledon River/Welbedacht Dam. The yield of the existing system is currently being negatively impacted by the problems associated with the on-going high siltation experienced at Welbedacht Dam, Welbedacht WTP and Tienfontein Pump Station. It is important to address the scouring of Welbedacht Dam and the associated sediment related issues prior to the development of additional water resource capacity/infrastructure (especially increasing the capacity of Tienfontein Pump Station).

Given the close proximity of the Caledon River to Bloemfontein and the existing infrastructure, it would be considerably less costly to further develop this source than to obtain additional water from the Gariep Dam or from the Van der Kloof Dam (the current cost estimates indicate that it would be in excess of 3 times more expensive to obtain water from the Gariep Dam than from the Caledon River).

It must be noted however that in the longer term obtaining additional water from the Gariep Dam (or alternatively the Vander Kloof Dam or the proposed Bosberg/Boskraai Dam) should be weighed up against other potential supply schemes such as water reuse. Water re-use could be a more cost effective supply side intervention than utilising sources such as Gariep Dam. Public resistance to this intervention may be encountered, possibly stemming from concerns of poor design or control of processes which may allow sub-standard water to be introduced into the potable water supply system, or for religious reasons. The water to be re-used would only be from that associated with growth after 2009, from the WWTW’s in the catchment area.

The future Polihali Dam site is situated on the Senqu River approximately 1.5 km downstream of the confluence of the Senqu and Khubelu Rivers. Polihali Dam would increase the water delivered from Lesotho Highlands Water Project (LHWP) to the high value industries in the Vaal catchment, but would, in the long term, result in a reduction in the water available at downstream Gariep and Vanderkloof dams. It is envisaged that the Polihali Dam would reduce the yield of the Orange River downstream by approximately 283 million m^3/a. For the intervention identified as part of the Greater Bloemfontein Reconciliation Strategy Study, it is proposed that water from the LHWP would be released into one of the tributaries of the Caledon River, probably at the existing release structure on the Little Caledon River. Water released into the Caledon River would be abstracted at Tienfontein Pump Station and delivered to Knellpoort Dam, from where it would be transferred via the Novo Transfer Scheme and Modder River to the Rustfontein Dam to augment the supply to Bloemfontein and the surrounding towns.

2.29.2 Water Quality Assessment Report

Report Title: Water Reconciliation Strategy Study for the Large Bulk Water Supply Systems: Greater Bloemfontein Area: Water Quality Assessment Report. Final. 2012. Report No. P WMA 14/C520/00/0910/04. Department of Water Affairs. Prepared by Aurecon in association with GHT Consulting Scientists and ILISO Consulting.

The assessment of the water quality situation, focusing mainly on river salinity in the Greater Bloemfontein Area was undertaken as part of Task 8 of the Water Reconciliation Strategy Study for the Large Bulk Water Supply Systems: Greater Bloemfontein Area. In addition to salinity, nitrate/nitrite, phosphates, ammonium, and pH, sulphates, and chlorides were also assessed.

The focus of the water quality assessment task included:

- Conducting a water quality assessment of the surface and groundwater resources in the study area;
- Conducting a qualitative investigation of the impacts of future potential schemes on river salinity; and the effects of wastewater effluent return flows and urban pollution on potential schemes.

The water quality data used for the evaluation of water quality was obtained from the monitoring stations managed by the DWA. Water quality was assessed on ‘Fitness for Use’ which was based on the South Africa Water Quality Guidelines of the Department of Water Affairs.

The findings of the assessment were as follows:

- The surface water quality in the study area is of good quality. The electrical conductivity (EC) is within the ideal to acceptable ranges. The assessment shows that the EC for the Caledon River (Welbedacht Dam), the Orange River (Gariep Dam) and the Modder River (Upper, Middle and Lower) are within the ideal and acceptable ranges. The Lower Riet River has higher EC which is in the tolerable range, which may be attributable to irrigation return flows which have a major impact on salinity in the lower Riet River.
- An assessment of the nutrients showed that the water quality in the study area is of good quality. The levels of nitrite/nitrates in the study area are within ideal ranges. Ammonium and phosphate levels in the four rivers are mostly within tolerable ranges. The only cause for concern is the high levels of phosphates in the Upper Riet River as high nutrient levels lead to eutrophication. Drainage from agricultural land on which fertilizers have been applied is believed to represent the biggest contributor of phosphorous loading in this catchment.
- An assessment of groundwater EC levels was also conducted for some of the towns in the study area (Bloemfontein, Thaba Nchu, Dewetsdorp, Edenburg, Ikgomotseng and Reddersburg). The results

show that the EC in all the towns are within acceptable ranges except for Ikgomotseng where the EC is within unacceptable ranges. Industrial, chemical and mining activities as well as irrigation are often the factors responsible for elevated salts. Furthermore, various sub-factors, such as geology, soil, land use and flow of water (*i.e*. conductivity increases as water flow decreases) also affect the salinity of water, thus influencing electrical conductivity. The high levels of EC in groundwater at Ikgomotseng, which is also known as Soutpan may be due to high levels of Na+ and Cl- ions from salts from Salt Mining which may be leaching into the groundwater. There are a number of salt lakes that are found in and around Ikgomotseng.

In terms of the qualitative assessments undertaken with regard to the impacts of future potential schemes and the effects of wastewater effluent return flows and urban pollution it was found that although the nutrient levels for the WWTWs are below the standard, loads from treated wastewater in the catchment will in future have a negative impact on the Krugersdrift Dam, unless the discharge standard for orthophosphate is changed from the current 10mg/ℓ (general standard) to 1mg/ℓ (special standard). Nutrients and urban pollution are not expected to have an impact on water quality, but the disposal of the reject from reverse osmosis may present a problem.

2.29.3 Reconciliation Strategy Report

2.29.3.1 **Purpose of the Strategy**

The purpose of the Reconciliation Strategy is to determine the current water balance situation and to develop various possible future water balance scenarios up to 2035 and beyond. It aims to describe the proposed strategy, and the associated actions, responsibilities and timing of such actions that are urgently needed to reconcile the supplies and requirements, to enable additional interventions to be timeously implemented.

2.29.3.2 **The Greater Bloem Water Supply System**

The Greater Bloemfontein supply system provides the majority of potable water requirements to the larger centres of Bloemfontein, Thaba Nchu and Botshabelo, as well as the smaller towns of Wepener, Dewetsdorp, Reddersburg, Edenburg, and Excelsior, which are also dependent to varying degrees on local water sources. Bloemfontein has been the focus of development in recent years resulting in a decline in many of the small rural towns. Migration from farms to towns by farm workers in search of employment opportunity has further placed increased burden on the water supply to the towns. Currently approximately 66% of the treated water is supplied by Bloem Water, primarily through Welbedacht and Rustfontein Water Treatment Plant (WTP) and the balance via Mangaung Metropolitan Municipality's (MMM) Maselspoort WTP.

2.29.3.3 **Water Availability**

The latest water balance from the Orange River System indicated a surplus of 274 million m^3/a for the year 2008. Subsequent planning to supply water to emerging farmers and for the growth in water requirements in the Upper Orange, Lower Orange and the Fish to Tsitsikamma WMAs would reduce this surplus to only 40 million m^3 by 2025. Furthermore the proposed developments under Phase 2 of the Lesotho Highlands Water Project would reduce the yield of the Orange River downstream by approximately 283 million m^3/a (proposed Polihali Dam and transfer). Based on a conceptual estimate of the mass balance across the Orange River system, it can be inferred that a system deficit of about 243 million m^3/a could be expected by 2037. It can be concluded that there is currently surplus water available in the Orange River system (including the Caledon River) which can be allocated to the Greater Bloemfontein Area. Other water resource development options on the Orange River will only become feasible after the water requirements from the Vaal WMA have increased to such an extent that they reduce the availability of water in the Orange River, and a new supply intervention is implemented to augment the loss in yield. Such interventions include the utilisation of the lower level storage in Vanderkloof Dam, the construction of Bosberg/Boskraai Dams, and the raising of Gariep Dam.

2.29.3.4 Current Water Requirements

MMM purchases approximately two thirds of its potable water from Bloem Water. In 2011 the amount of bulk water (excluding groundwater) supplied from the Bloem Water System was 56.8 million m^3, and that supplied from MMM's own sources, 22,7 million m^3. The smaller towns of Excelsior, Wepener, Dewetsdorp, Reddersburg and Edenburg supplement their water supply from local groundwater sources which in 2011 totalled approximately 2.9 million m^3/a. Authorised water consumption has been growing at an average rate of 3% per annum over the period 2007 through to 2010 and on average by 1.7 % over the period 2005 through to 2010. The 2010 population in the Bloemfontein, Botshabelo and Thaba Nchu area of supply is estimated to be 630 000 people. The population for the full supply area including the smaller towns is estimated to be 720 000 people.

It is apparent that there is also an increase in unaccounted water which in the Bloemfontein area alone has reached more than 39% of the total annual consumption (Ref: 2006/7 WSDP). Similar levels of unaccounted water are occurring in Botshabelo, and in Thaba Nchu, the unaccounted for water is 94% of the total water use.

Cognisance has also been taken of the agricultural water requirements in those catchments which also supply water to Bloem Water and MMM for potable use. In terms of the yield modelling of the Welbedacht/Knellpoort System, the existing agricultural water requirements along the Caledon River, both upstream and downstream of Welbedacht Dam, and the proposed water requirements of the resource poor farmers, were taken into account.

2.29.3.5 Future Water Requirement Projections

The following assumptions were made for the development of the future water requirement scenarios from the Greater Bloemfontein Water Supply System:

- A High Growth Water Requirement Scenario based on the authorised billed and unbilled water consumption figures for the last 3 years and a growth rate of 3% per annum.
- Low Growth Water Requirement Scenario based on a low population growth and low economic growth, with an effective growth in water requirements of 1% per annum.

2.29.3.6 Comparison of requirement and Availability

It appears that the 2009 water requirement was in balance with available supply (historical firm yield) and any increase in use (as predicted by the high and low water requirement scenarios) would put the system at risk. The higher the growth in water requirements, the higher the risk would be. It is clear that measures to increase the surety of supply need to be implemented as soon as possible. This includes measures to increase the supply of water as well as WC/WDM measures to reduce the demand.

2.29.3.7 Interventions

Thirty-four potential interventions which could contribute to meeting the future water requirements have been identified. **Table 2-122** provides a summary of some of the interventions considered for the reconciliation of supply and requirement for the Greater Bloemfontein system.

Table 2-122: Detailed Information on Selected Surface Water Interventions

Intervention	Yield (Million m^3/a)	Capital Cost (R million)	Operating Cost	URV (R/m^3)

			(R million/a)	
Novo Transfer Scheme and obtaining additional water from Welbedacht Dam. Intervention shown based on 2 m^3/s P/S at Welbedacht Dam pumping to Knellpoort Dam.	22.6	374	7.9	1.51
	Yield and Cost dependent of capacity of infrastructure proposed.			
WC/WDM (Most Likely Scenario)	11.5	240		Approx 1.5
Utilising surplus capacity in Orange River by pumping to Knellpoort Dam from Gariep Dam	20	825	33	6.1
Utilise surplus capacity in Orange River system by pumping to Knellpoort Dam from Van der Kloof Dam	20	1 700	40	10
Planned direct reuse – Bloem Spruit[1]	10.8	179	4.9	1.56
Treated indirect reuse - Krugersdrift Dam[1]	10.8	306	9.5	2.83
Bloemfontein aquifer (Bainsvlei aquifer)	28	4 743	39	15.58
Thaba Nchu aquifer	0.89	32.7	2.1	5.35

Note 1: Significant uncertainty surrounds the CAPEX and OPEX costs, as costing was undertaken at a very high level.

2.29.3.8 Recommended Interventions

The following recommendations are made with regard to the implementation of interventions

- The MMM should implement their WC/WDM strategy which was developed in 2011.
- The MMM should strive to achieve the maximum possible water savings through the implementation of their WC/WDM Strategy, namely "the best case savings scenario".
- Install two additional (1 m^3/s) Pump Sets at Tienfontein Pump Station. The first pump set should be utilised to increase the design capacity of the pump station to 4 m^3/s and the second pump set to provide additional standby capacity. With the implementation of the two additional pump sets the total standby capacity of the pump station would be increased to 50% (based on the proposed new design capacity). The implementation of this solution would reduce the risk of restrictions and would be a cost effective interim solution to implement at Tienfontein Pump Station
- The Welbedacht Dam should be scoured to increase the capacity of the dam and to ensure that the siltation at Tienfontein Pump Station does not further hamper operations and maintenance.
- Bloem Water should further investigate the inability of the water treatment plant to deal with high turbidity levels which currently limit the production capacity of the water treatment plant.
- Urgently initiate a feasibility Study to consider the most appropriate means to scour Welbedacht Dam and to augment Knellpoort Dam. The outcome of the feasibility study will guide the selection of future water resource development interventions. The feasibility study should inter alia address the following:
  - incremental yield generated and total yield available;
  - synergies with potential supply schemes' e.g. bi-directional pipeline between Knellpoort and Welbedacht;
  - the most appropriate intervention to augment Knellpoort Dam (e.g. implement a pump station at Welbedacht Dam and use the bi-directional scour pipeline to pump water into Knellpoort Dam, or further increase the capacity of Tienfontein Pump Station);
  - cost estimates; and
  - implementation programme.
- Bloem Water should take steps to ensure the integrity of the Welbedacht Pipeline. Bloem Water has proposed to relay sections of the Welbedacht pipeline which are considered as high risk.
- Mangaung Metropolitan Municipality should construct additional storage reservoir capacity in order to ensure that the network peaks are not transmitted through to the bulk supply infrastructure.
- It is expected that maintenance problems and associated expenditure will continue to persist into the

future, unless Tienfontein pump station is modified/redesigned to cope with the sedimentation problems. With the near equilibrium sediment regime in the Caledon River now being reached, the redesign of Tienfontein pump station should be considered.

- A Feasibility Study on Water Re-use should be undertaken. The timing of the feasibility study should be recommended by the Strategy Steering Committee.

2.29.3.9 **Small Town Specific Recommendations**

2.29.3.9.1 Wepener

- It is imperative that the Naledi Municipality develop a business plan for the implementation of WC/WDM.
- Based on the URVs, the booster pump station is the preferred option for implementation at Wepener. However incremental development of the groundwater resource also appears favourable and could be considered as an alternative, introducing some independence of the town on the Bloemfontein system as well as conjunctive use of a local water source.

2.29.3.9.2 Reddersburg and Edenburg

- It is imperative that Kopanong Municipality develops a business plan for the implementation of WC/WDM.
- Develop groundwater interventions to augment the supply to Reddersburg and Edenburg.

2.29.3.9.3 Dewetsdorp

- It is imperative that Naledi Municipality develops a business plan for the implementation of WC/WDM.
- The provision of a new pipeline and pump station from the existing Bloem Water scheme is the most favourable option when comparing the URVs for Dewetsdorp. However if the desire for these smaller towns is that they become less dependent on the Bloem Water System, and more dependent on their own local sources, then groundwater does offer this opportunity, but at a higher financial cost than the potential surface water augmentation.

2.29.3.9.4 Excelsior

- It is imperative that the municipality develops a business plan for the implementation of WC/WDM.
- Undertake a study to investigate the following aspects: (1) the actual extent of water use in Excelsior and (2) the apparent limitations in supply of water during peak periods, and 3) the actual operation of the sources that supply water to the town.

2.29.4 Demographics

The Greater Bloemfontein supply system provides the majority of potable water requirements to the larger centres of Bloemfontein, Thaba Nchu and Botshabelo, as well as the smaller towns of Wepener, Dewetsdorp, Reddersburg, Edenburg, and Excelsior, which are also dependent to varying degrees on local water sources.

No detail is provided in the report on the method for determining the baseline population. It is noted from the studies that water use, when expressed on a per capita basis, is in the region of 200 litres per person per day. The report reveals that there are uncertainties with determining future population growth rate figures which include:

- Population growth rates vary between various sources of information, ranging from 3.1% per annum down to 1% per annum, and a flat rate of zero % per annum in certain low growth scenarios such as those developed in the All Towns study for Central Region
- The effect of migration from the rural into the urban areas is linked to economic growth and the search for improved employment opportunities in the urban centres.
- The mortality rates as a result of HIV/Aids have been assumed to be as high as 0.4% for the urban towns, and as high as 0.75% for the rural towns and villages.

The following assumptions were made for the development of the future water requirement scenarios from the Greater Bloemfontein Water Supply System:

- A High Growth Water Requirement Scenario based on the authorised billed and unbilled water consumption figures for the last 3 years and a growth rate of 3% per annum.
- Low Growth Water Requirement Scenario based on a low population growth and low economic growth, with an effective growth in water requirements of 1% per annum.

The study also reveals that current water requirement (based on 2009 data) is approximately 83 million m^3/a, which is in balance with the available supply of 84 million m^3/a (Historical Firm Yield).

The study also revealed a breakdown of potable water use as derived from the 2006/07 Water Service Development Plan for Bloemfontein, Botshabelo, and Thaba Nchu. More recent figures were not available. Agricultural water requirements were also considered. For the purposes of this study, agricultural water requirements were considered in two areas, namely: The Modder-Riet Catchment upstream of Krugersdrift Dam; and along the Caledon River. With regards to agricultural growth, the only expected growth in irrigation requirements was the allocation of 12 000 ha to resource poor farmers. The effect of the 12 000 ha (4 000 ha for the Upper Orange WMA, 4 000 ha for the Lower Orange WMA, and 4 000 ha for the Fish-Tsitsikamma WMA) was estimated to be in the region of 114 m^3/a. The Implementation Strategy for the development of 3 000 ha irrigation in the Free State Province indicates that there is ± 200 ha available near Ficksburg (Caledon River) and ± 2 000 ha available next to the Orange- Riet Canal, which starts at the Vanderkloof Dam. The agricultural water requirement for the 200 ha near Ficksburg was taken into account in the determination of the available yield.

Detailed scenario planning for the small towns including provision of a 2009 base population was undertaken for: Wepener, Reddersburg and Edenburg, Dewetsdorp, and Excelsior.

The water requirement scenarios were developed during the global economic crisis which is likely to have implications for water requirement growth projections for the Greater Bloemfontein Water Supply System.

2.30 MZIMVUBU RIVER BASIN: WATER TRANSFER TO FISH RIVER

REPORT: MZIMVUBU RIVER BASIN: WATER UTILIZATION OPPORTUNITIES (DWAF 2005)

This report was prepared in order to inform the Eastern Cape Province of the development opportunities that exist within the Mzimvubu River Basin and possibly also in other parts of the province to utilize the water resources of the basin.

The report addresses the availability of water in the Eastern Cape in general, and then in particular, the natural and physical environment of the Mzimvubu River Basin, the overall availability of water in the basin, the development potential and the water required for this. This is followed by an analysis of the costs of securing water supplies in the basin and the incremental costs of transferring the potential surplus water to areas where it can be beneficially used, such as the Orange River Basin and the Fish and Lower Sundays

River catchments in the Eastern Cape. The report also examines the factors that could limit their sustainable utilization of the water resources of the Mzimvubu River Basin summarises the findings and conclusions and makes recommendations for further actions.

It is estimated that the so-called reference development scenario in the Mzimvubu valley (which includes existing development) could use the following quantities of water at an equivalent assurance of 98%.

• Forestry	140 million m^3/a
• Irrigation cultivation	450 million m^3/a
• Domestic, industrial and livestock watering	50 million m^3/a
	640 million m^3/a

After full development of the water resources, the total utilizable water in the basin would amount to about 1 300 million m^3/a. This will therefore result in a surplus of at least 660 million m^3/a that would be available for use in other areas if the cost of securing and transferring the water is affordable.

Three alternative options to transfer surplus water from the Mzimvubu River Basin to as far as the Fish and Sundays River catchments in the Eastern Cape have been assessed. These are the following:

- The Northern transfer option. This consists of a number of additional dams in the Mzimvubu River Basin together with a system of canals, pump stations, pipelines and tunnels that transfer the water into a small tributary of the Orange River near Rhodes. From here the water flows to the Orange Ricer from where it can be released through the Orange Fish Tunnel into the headwaters of the Fish River at Teebus, for further distribution.
- The Southern Piped transfer option. This consists of a large dam in the lower reaches of the Mzimvubu River and pump stations and pipelines that transfer the water into another small tributary of the Orange River near Dordrecht. From here the water can flow to the headwaters of the Fish River as in the case of the Northern transfer option.
- The Southern Canal transfer option. This consists of a large dam in the lower reaches of the Mzimvubu River and pump stations, pipelines and canals that transfer the water as far as the Little Fish River at the outlet of the Cookhouse Tunnel near Somerset East. Through an exchange of water with that which is being supplied by the Orange River Project at present, it would also be possible to abstract water further upstream in the Fish River.

Of these three options only the Southern Canal transfer option would transfer water directly to the Fish Tsitsikamma WMA, the first two via the Upper Orange WMA and existing Orange Fish Tunnel.

URVs have been calculated for a transfer quantities of 600 million m^3/a and 100 million m^3/a respectively.

2.31 DEPENDENCY OF THE EASTERN CAPE ON THE ORANGE RIVER

2.31.1 ISP FOR FISH TO TSITSIKAMA WMA

2.31.1.1 Introduction

The Fish to Sundays ISP area forms the eastern part of the Fish to Tsitsikamma Water Management Area (WMA 15), and falls almost totally within the Eastern Cape Province. It derives its name from its two largest rivers, the Great fish and the Sundays Rivers. The remainder of the WMA was separately addressed in the Tsitsikamma to Coega ISP Report.

This document presents the Department of Water Affairs and Forestry's (DWAF's) internal strategic perspective (ISP) or view on how it currently manages and intends managing the water resources within the ISP area, during the period leading up to the establishment of a fully operational Fish to Tsitsikamma Catchment Management Agency, and the development of a catchment management strategy. One of the major goals of the ISP is to obtain a common understanding within DWAF about management objectives and strategies.

2.31.1.2 Description of the Water Resource and Supply Situation

2.31.1.2.1 Water Resource Availability

The total available yield of the ISP area is estimated to be 757 million m³/a.

2.31.1.2.2 Surface Water Availability

The water resources are not evenly distributed across the catchment. The natural mean annual runoff of 972 million m³/a has been reduced by abstractions and other consumptive usages, but has been substantially augmented through transfers from the Orange River for irrigation, urban use and freshening releases. The available yield of local surface water resources is estimated to be 160 million m³/a. The impact of water transferred into the ISP area from the Upper Orange WMA is 160 million m³/a. The impact of water transferred into the ISP area from the Upper Orange WMA is 575 million m³/a. There are no natural lakes or large wetlands in the ISP area, although there are many small wetlands. There is uncertainty about the estimates of the Reserve and how these may change in future. The available yield in the ISP area is a combination of surface water, groundwater usable return flows and transfers into the ISP area. Very limited potential for development of new dams and other water resources remain.

2.31.1.2.3 Surface Water Quality

The relatively flat topography, low mean annual runoff, high evaporation and underlying mudstones generally give rise to saline groundwater and resulting saline base flows in the Fish and Sundays Rivers, irrespective of water transferred in from the Orange or irrigation return flows. Water quality in the Fish River deteriorates significantly in a downstream direction from good to very poor and from poor to very poor in the Sundays River. These rivers are significantly impacted on by saline irrigation return flows. High salinity is also the main concern in the Bushmans, Kariega and Kowie River catchments. The Bushmans River water quality is mostly unacceptable. Water quality in the Kowie River is poor and in the Kariega River the water quality is completely unacceptable.

2.31.1.2.4 Groundwater availability

Groundwater is often the only source of water for rural domestic use and stock watering, whilst several towns also obtain a large proportion or all of their water from underground sources. Groundwater is also used for urban supply by coastal towns, but cannot always support growing demands and peak seasonal uses. Exploited aquifers are not necessarily well managed. Actual groundwater use, especially for irrigation, is likely to be significantly higher than has been reflected in the National Water Resource Strategy and these numbers requiring verification. The potential for groundwater use is under-developed. It is suggested that improved borehole siting and well field management would significantly increase both the yield and the reliability of the groundwater resource.

2.31.1.2.5 Groundwater quality

In the Albany Coastal Range groundwater of poor quality is associated with outcrops of the Bokkeveld Group and the Dwyka-basal Ecca formations. Areas of low slope in the Ecca Group and lower Beaufort Group (Adelaide Sub-group) between the coastal ranges and the Middle Veld escarpment also have a higher salinity. In the south, the best quality groundwater is associated with the limited areas of the Witpoort aquifer in the Albany Coastal range. In the north, good quality groundwater is generally associated with the Katberg sandstone aquifer in the Winterberg Range between Seymour and Cradock, and along the Great fish and

Sundays headwater divides near Nieu Bethesda, Middelburg and Steynsburg.

2.31.1.2.6 Available yield

Calculations of the available water per river sections, rivers and the ISP area were carefully studied, revisited and, where necessary, refined for this ISP, following the publication of the NWRS. This required limited changes to the NWRS yields. The major difference is in the presentation of results and in the way river losses have been included. Significant river losses due to the large volumes of transferred water have been taken into account in the calculations of total available yields. These river loss have not been included as part of the surface water resource as in the NWRS, because it can almost entirely be ascribed to losses from transferred Orange River water. This change however has no impact on the final calculated values of available yield in the ISP area. The following tables shows the yields per ISP sub-area as revisited during the ISP process.

Table 2-123: Available yield in the year 2000 (million m³/a) at 1:50 year assurance

ISP Sub-area	Natural Resources		Usable return flows			Total Yield (1)	Transfers in (2)	River losses (3)	Grand-total (1)+(2)+(3)
	Surface Water	Ground-water	Irrigation	Urban	Mining and bulk				
Fish	91	6	77	5	0	179	575	-94	660
Albany Coast	15	2	0	4	0	21	1	0	22
Sundays	54	16	22	2	0	94	123	-18	199
Total for ISP area	**160**	**24**	**99**	**11**		**294**	**575**	**-112**	**757**

1) After allowance for the impacts on the yield of the ecological component of the Reserve, river losses, invasive alien plants, dry land agriculture and urban runoff.
2) Transfers into and out of hydrological sub-divisions or sub-areas may include transfers between sub-areas as well as transfers between WMAs. Addition to the transfers therefore does not necessarily correspond to the total transfers into and out of the WMA.
3) River losses as calculated for the Orange River Replanning Study (ORRS) and used in the NWRS.

The *major* difference between the available yields as determined in the ISP and the NWRS yields are the following:

- Available yield in the ISP area was determined as 757 million m³/a compared to 786 million m³/a in the NWRS;
- Sub-area available yields (according to the NWRS sub-areas) were determined as:
  - 660 million m³/a in the Fish sub-area which is virtually the same as the 659 million m³/a in the NWRS;
  - 22 million m³/a in the Albany Coast sub-area which is the same as the 22 million m³/a of the NWRS;
  - 199 million m³/a in the Sundays sub-area compared to the 217 million m³/a of the NWRS;
- The yields of Grassridge and Darlington dams, which are reflected in the surface water yields, have been adjusted, because under 1:50 year drought conditions, these dams operate purely as balancing dams for transferred water, and their yields become negligible. The reduction in yield due to the Reserve, for the hydrological sub-divisions in which these dams fall, were consequently also adjusted;
- The impact on yield of the transfer from the Fish to the Sundays sub-area was increased from the 116 million m³/a in the NWRS to 123 million m³/a, to reflect a situation where just enough water is transferred to ensure a balanced situation.

2.31.1.2.7 Water use

Total water use of the ISP area is estimated at 759 million m³/a. At 94%, irrigation currently constitutes by far the largest user of water in the ISP area. The water is mainly used to grow vegetables, deciduous fruit, citrus, Lucerne and maize, and for the irrigation of pasture. There is believed to be significant scope for more efficient use. Other uses are small in comparison.

Calculations of the water requirements of the ISP area were refined for this ISP, following the publication of the NWRS. The later calculations and updates of requirements show that there is significant uncertainty associated with irrigation water use. There is enough confidence in these revisited values that they have been shown in tables in this report. It is, however, essential that the apparent discrepancies be addressed as a matter of priority. The following table shows the water requirements per ISP sub-area as revisited during the ISP process.

Table 2-124: Water requirements for the year 2000 (million m³/a)

ISP Sub-area	Average	1:50 year assurance								
	Average irrigation use (1)	Irrigation (2)	Urban (3)	Rural (3)	Mining and bulk industrial (4)	Power generation (5)	Afforestation (5)	Total local require-ments	Transfers out	Grand Total
Fish	513	447	12	6	0	0	2	467	193 (6)	660
Albany Coast	13	11	9	2	0	0	0	22	0	22
Sundays	217	174	5	3	0	0	0	182	18 (6)	200
Total for ISP area	**743**	**632**	**26**	**11**	**0**	**0**	**2**	**671**	**88 (6)**	**759**

1) Actual average irrigation use has only been included here to show the comparison with the 1:50 year requirement, and has not been included in the total requirement.
2) Irrigation requirements allows for canal losses.
3) Includes component of Reserve for basic human needs at 25 ℓ/c/d.
4) Mining and bulk industrial water uses, which are not part of urban systems.
5) Quantities given refer to impact on yield only.
6) 70 million m³/a water flows to sea from the Fish River and 7 million m³/a from the Sundays River, while 11 million m³/a is transferred on to NMMM from the Sundays Sub-area.

The *major* differences between the water requirements as determined in the ISP from the NWRS water requirements are the following:

- The irrigation requirement in the Fish sub-are was corrected to 447 million m³/a, compared to 453 million m³/a for the NWRS. This as a result of:
  - the Kat River use that was changed to 17 million m³/a, in line with allocations, compared to 14 million m³/a shown in the NWRS;
  - a reduction in the irrigation water requirements from the Commando Drift Dam, which should not include the irrigation below Lake Arthur in the Tarka River catchment (as it does in the NWRS), as this (except for 180 ha) receives transferred Orange River water via the Fish River.
- The transfer into the Tsitsikamma to Coega ISP area from this ISP area, for use by the NMMM, was

corrected to 11 million m³/a, compared to the 31 million m³/a of the NWRS.

- A major difference between the ISP and NWRS is the presentation of flows to sea, which have been included in the ISP as downstream transfers out of the lowest sub-divisions, sub-areas and the ISP area. This was done to be able to show more realistic water balances, as this water is not used because of its very poor water quality. These changes then lead to the following differences:
  - Total requirements in the Fish sub-area is 660 million m³/a, compared to 599 million m³/a of the NWRS;
  - Water requirements in the Sundays sub-area is 200 million m³/a, compared to 213 million m³/a of the NWRS;
  - Local requirements of the ISP area, is 759 million m³/a, which includes transfers out of the area of 88 million m³/a (most of which is due to freshening releases that flows to the sea), compared to 825 million m³/a of the NWRS.

2.31.1.2.8 Potential maximum water use

A calculation of the potential maximum use of Orange River water requirements of the ISP area, according to current water allocations, indicates a maximum allocated quantity of 658 million m³/a, compared to the annual 1:50 year transfer of 575 million m³/a. The implications of this difference of 83 million m³/a at 1:50 year assurance of supply, is that farmers could potentially use more water than have been allocated for transfer from the Upper Orange WMA. It is necessary to urgently address this difference.

2.31.1.2.9 Current yield balance

The following table shows the yield balance per ISP sub-area as revisited during the ISP process. The *yield balance* is: the *total available water* (the sum of the available local resources and the transfers into the area) compared or reconciled with *the total requirements* (the sum of the various water requirements and losses and the transfers out of the area).

Table 2-125: ISP reconciliation of water requirements and availability for the year 2000 at 1:50 year assurance (million m³/a)

ISP sub-area	Available yield				Water requirements			Balance
	Local yield	Transfers in (1)	River Losses (2)	Total	Local require-ments	Transfers out (1)	Total	
Fish	179	575	-94	660	467	193 (3)	660	0
Albany Coast	21	1	0	22	22	0	22	0
Sundays	94	123	-18	199	182	18 (3)	200	-1
Total for ISP area	**294**	**575**	**-112**	**757**	**671**	**88 (3)**	**759**	**-2**

1) Transfers into and out of sub-areas may include transfers between sub-areas as well as transfers between WMAs. Addition of the transfers per sub-area therefore does not necessarily correspond to the total transfers into and out of the WMA.

2) The river losses resulting from evaporation and seepage for the transferred volumes have been included here. This was a best estimate from the ORRS modelling.

3) 70 million m³/a flows to sea from the Fish River and 7 million m³/a from the Sundays River and 11 million m³/a is transferred on from the Sundays sub-area to NMMM.

The reconciliation of available water and requirements for the year 2000, including transfers of Orange River water, indicates that the ISP area is approximately in balance, mainly because transfers are sufficient to satisfy the demand. The Tarka River catchment (Great Fish River tributary) is stressed. There are unused and under-utilised water allocations in the Kat River catchment (Great Fish River tributary). These unused allocations must be addressed, as well as the unlawful use of these current unused allocations.

The NWRS shows a balance of 38 million m³/a, which is substantially more than the balance determined in the ISP. The major difference is in the NWRS Fish sub-area, where the NWRS shows a balance of 37 million m³/a, compared to the ISP balance of zero million m³/a.

The surplus flow at the bottom end of the Fish and Sundays rivers include freshening releases made, unused irrigation releases, and return flows downstream of the last point of abstraction. The salinity of such flows may be too high for direct beneficial use without blending or treatment. This water is therefore generally not available for use.

2.31.1.2.10 Meeting future water requirements

Water for significant new envisaged resource-poor farmer developments (4 000 ha), involving a total estimated water requirement of about 38 million m³/a of Orange River water to alleviate property, have been reserved for future transfers to this ISP area from the Upper Orange WMA. About two-thirds is expected to be used in the lower Sundays River catchment. Significant growth in urban water use is expected in the Albany Coast sub-area, due to the large projected growth of especially coastal towns. Some growth is also expected in urban use of towns in the Fish and Sundays rivers catchment.

In addition to the 38 million m³/a reserved for future use by resource-poor farmers, 2 million m³/a could be transferred to meet urban growth in small towns using Orange River water, totalling 40 million m³/a that has been reserved for future transfer of Orange River water to this ISP area. Provision has also been made for a limited additional transfer of 10 million m³/a to NMMM to meet the growth in urban demand. Local resources, mostly through an increase in the use of groundwater, will need to be developed to meet the urban water needs of growing towns. In a 1:50 year drought situation in the ISP area, additional transfers for freshening of the Orange-Fish-Sundays Water Supply System will depend on the availability of “surplus” water in the Upper Orange WMA, which is only available when Gariep and Van der Kloof dams are spilling.

3 SYNTHESIS OF AVAILABLE INFORMATION

3.1 APPROACH

Chapter 2 of the report summarises a wealth of information relating to the water resource and supply systems of the Upper and Lower Orange WMAs. The documentation reviewed covers a wide range of topics that are required for integrated water resource management and form a solid knowledge base for the development of the water supply reconciliation strategy.

The summaries given in **Chapter 2** were given by study and for individual reports and have to be interpreted and assessed to form a synthesised view of the current status of integrated water resource management and identify the themes or topics that need to be covered in the reconciliation strategy.

This chapter provides the synthesis of the information reviewed as well as the knowledge obtained from numerous discussions and interactions with the stakeholders in the study area.

The chapter is structured according to sub-areas, i.e. Senqu catchment, Upper Orange catchment area, Lower Orange catchment area and the Eastern Cape area.

For each of the four sub-areas a Synthesis is provided for each of the following topics:

- Brief description of the water resource and supply situation.
- Pertinent water resource management issues.
- Identified intervention measures.
- Perspective on water resource management of the sub-area.

It should be noted that the water resource management synthesis given in this chapter is based on the information at hand and aims to guide the formulation of the strategy and the associated technical tasks. The perspective indicated here will be scrutinised during the course of the study and will be amended, changed or may even be discarded in the final strategy documentation.

3.2 FUTURE AND NEW DEVELOPMENTS IN THE VAAL AND THOSE OUTSIDE RSA EFFECTING WATER AVAILABILITY IN THE ORANGE

The Orange River is shared by four basin states, i.e. Lesotho, Botswana, Namibia and the RSA. Developments in these basin states can also impact on the available flow in the basin, and need to be taken into account where applicable. The focus of this study is on the Orange River WMAs and therefore excludes most of the Vaal catchment except the Riet/Modder tributaries. Developments in the Vaal basin affecting flow in the Orange also need to be included in the different options to be considered.

Developments or possible developments in neighbouring states include the following:

- Metolong Dam currently under construction in Lesotho in a tributary of the Caledon River. This dam will supply in the growing demands of Maseru and surrounding villages.
- Polihali Dam already approved as the next phase of the LHWP.
- Possible further phases of the LHWP to be developed in future.
- Several other possible dams were identified as part of the Lesotho Lowlands study of which Metolong is the first dam to be constructed. It is not clear when and if any of the other identified will be built in future.
- Investigations by Botswana to obtain water from Lesotho.
- Necketral Dam in Namibia that will only affect flows in the lower Orange downstream of the Orange Fish confluence.

Developments in the Vaal system that will impact on the Orange:

- Eradication of unlawful irrigation in the Vaal system.
- Treatment of mine water and mine dewatering for usage purposes in the Vaal.
- Transfers from the LHWP to the Vaal system and the related operating rule used for these transfers.
- Water quality related operating rules in the Vaal System.
- WC/WDM initiation.

3.3 DEMOGRAPHICS (GENERAL)

It is noted from the literature reviewed that demographic and economic activities were mostly based on 2006 or older data which was then projected into the future. Since population size and economic activity is one of the main drivers of water demands it is deemed essential that demographic and economic base data be updated. In this regard it is relevant to note that there has been no new StatsSA releases as of yet, and even though the latest Census by StatsSA was undertaken in 2011, the figures are not expected to be released at municipal or lower levels until 2013/14. Fortunately though 2010 Eskom Spot Building Count (SBC) data exists and it is was utilised in the DWA study “Development of Reconciliation Strategies for All Towns in the Central Region”. The All town stategy study utilised a number of data sets that were analysed and compared at a Town Area/grouped settlement level. Each of the municipalities in the study area was contacted for base population information and economic and demographic growth scenarios relating to their respective areas. Population data used for the All town stategy study included StatsSA 1996, StatsSA 2001, The point information of the individual households in the Eskom SBC data was counted utilising the subplaces as a basis. In the majority of cases the Eskom data was utilised as the base data, as it provided an up to date and verifiable dataset. The Eskom data has been updated using 2007 satellite photos. The Eskom data has been checked and analysed by a third party in a number of sample areas utilising various techniques and has been found to be accurate with a maximum discrepancy of 10% in the number of households. As the urban/industrial demands is a very small portion of the total water demand within the Orange, the demographic data from the All town stategy study was regarded as sufficient for the purpose of the Orange Reconciliation Strategy Study.

3.4 SENQU CATCHMENT AREA

3.4.1 Description of the water resource and supply situation

This sub-region falls entirely within Lesotho and includes the upper reaches of the Orange River, referred to as the Senqu River in Lesotho. The Senqu River drains two thirds of Lesotho and originates in the extreme north east of the country and leaves Lesotho near Quthing and enters the RSA at Oranjedraai. Rainfall in this area varies between 600 to 1 500 mm/a resulting in approximately 35% of the entire runoff from the Orange/ Senqu (Vaal included) to be generated in this catchment. Major dams have been constructed in Lesotho as part of Phase I of the LHWP. These include:

- Katse Dam in the Central Maluti Mountains that was completed in May 1997. It is a concrete arch dam, 185 m high, with 710 m crest length and a storage capacity of 1 950 million m^3. It impounds the Malibamatso River catchment.
- Mohale Dam is a concrete faced rock fill dam, 145 m high, with 540 m crest length. It impounds the Senqunyane River catchment (938 km^2) and has a storage capacity of 860 million m^3.
- Muela Dam, a 55 m high, 6 million m^3 capacity dam acts as the tail pond of the Muela hydropower station.
- Matsoku Diversion weir and tunnel, diverting water through a 3.5 m diameter tunnel into Katse Dam.

- Mohale Dam is linked to Katse Dam by means of a 31.5 km 4.6 m diameter tunnel.
- Katse Dam with support from Mohale Dam transfer water to the Vaal System through a 35 km long tunnel to Muela Dam where hydro-power is generated. From Muela Dam a second tunnel transfer the water over a distance of 37km into the upper reaches of the Ash River, a tributary of the Vaal River.

The purpose of the scheme is to support the Vaal System in the RSA, by transferring a fixed volume of 780 million m^3/a to the Vaal as agreed between Lesotho and the RSA and at the same time the transfer volume is used generating hydro-power to be utilised by Lesotho.

The LHWP transfer volume for Phase 1 is fixed and is in line with the available yield from the system. The second phase of the LHWP is currently in planning and will result an in increased transfer volume to the Vaal System. The second phase will include a third storage dam, Polihali Dam with a tunnel linking Polihali with Katse Dam. The second phase is in principle already agreed on between Lesotho and the RSA. Details such as transfer volume and related operating rules still need to be confirmed.

3.4.2 Pertinent water resource management issues

The focus of this study is on the water supply to and within the RSA. Therefore only management issues relating the supply of water to the RSA will be addressed in this section.

Management issues regarding the phase 1 supply to the RSA are in general limited to infrastructure related maintenance problems and are in general in control. Due to droughts experienced in the Caledon River catchments requests are from time to time made to release water from Muela Dam in support of Maseru. In this year a similar request was also made in support of Ficksburg and RSA town located close to the Caledon River and utilising flow from the river to supply in their water requirements.

The operating rule for the LHWP Phase 1 dictates that the agreed 780 million m^3/a transfer volume be released to the Vaal System on a continues basis, irrespective of the storage levels in the Vaal System. Thus even with the Vaal System spilling, the full volume needs to be transferred. This results in wastage in the Vaal System, but allows for continues hydro-power generation for Lesotho.

The operating rule for Phase 2 of the LHWP still needs to be developed and agreed on. Initial analysis in this regard was already carried out by the RSA. These results indicated that a fixed release volume is not the optimal solution, and a rule that will keep the water in Polihali Dam to only be transferred to the Vaal when required is by far the better option.

When Polihali Dam is in place it will result in a shortage in the Orange System as the yield from Gariep and Vanderkloof dams will reduce to below the current demand imposed on the Orange River Project. Some intervention option will therefore be required to correct the water balance once Polihali Dam is in place.

Detailed analyses are required to determine the most suitable operating rule for phase 2 of the LHWP. These analyses are also required to support both Lesotho and the RSA in their decision making process to agree on the most suitable operating rule.

Although the operating rule for phase 1 as captured in the Treaty between the RSA and Lesotho is fixed and cannot be changed easily, some evaluation of this rule versus other possible options is recommended. This might result in a new agreed operating rule also for phase 1, that benefits the efficient use of the resource.

The possibility of utilising the storage in Polihali Dam to also support the Orange River until the full yield from Polihali Dam is required for the Vaal System, will results in the postponement of costly intervention options in the Orange to replace the yield taken out by Polihali Dam. It is important that this option be evaluated in combination with the development of the operating rule for Phase 2 of the LHWP.

3.4.3 Identified intervention measures

i) The Lesotho Highlands Further Phases (LHFP), those phases which will follow the completed Phase I of the Lesotho Highlands Water Project (LHWP), have been studied at Pre-Feasibility Level (LHWC 2008 – Stage 1 Study) and layouts for possible future Phases II, III and IV were identified and ranked. The recommended layout for further phases comprised:

Phase II The new Polihali Dam transferring water to Katse Dam with water transfers through the existing Transfer and Delivery Tunnels.

Phase III The new Tsoelike Dam pumping to the new Taung Dam pumping to Katse Dam with a new Transfer Tunnel to Muela HP plant and a new Delivery Tunnel from Muela to the Ash River.

Phase IV New dams at Malatsi and Ntohae Dam with pumped transfer from Ntoahae Tsoelike and then, via the Phase III infrastructure to Taung, Katse, Muela and the Ash River.

An alternative layout with the same Phases II and III but an alternative layout for Phase IV, with a dam at Lebelo was also considered. That layout, or possibly others, could be recommended in further studies which will be required prior to any decision to proceed with Phase III or IV of the LHWP.

The Phase II layout was studied at Feasibility Level and although this was the recommended layout for three further phases, only Phase II was studied further, accepted for implementation by South African and Lesotho. In the Feasibility Study it was estimated that it will increase the Orange River System yield by an estimated 182 million m³/annum (LHWC 2009) and have a transferable yield of 460 million m³/annum.

Although each new phase will initially be able to support the Orange, until transfers from that phase to the Vaal exceed the incremental Orange River System yield, they will ultimately reduce the Orange System Yield.

The principle characteristics of the dams in each further Phase of the LHWP as reported in the Feasibility Study are summarised below.

Stage 2 – Feasibility Study Results (LHWC 2009)

- LHWP Phase II: Polihali Dam:

	With IFR Releases (m^3/s)+
Full Supply Level	2065
Yield* million m^3/a / (m^3/s)	465 (14.75)
Active Storage (million m^3)	2 322
Dam Height (m)	163.5
Dam Type	CFRD
Spillway Type	RC Side Channel
PMF outflow m^3/s	4024

* Stochastic Analyses at 98% Assurance of Supply
+ IFR releases are always required.

Stage 1 - Pre-Feasibility Study Results

The net historic firm yields of the dams in Phases III and IV were determined after making an allowance of 15% of monthly cumulative MAR, plus spills, for the IFRs and assuming upstream dams are in place. The yields shown below are the incremental system yields which can be attributed to each dam assuming that IFR releases are only made from the most downstream dam on each river and that all dams are in place or that the dam is the last one in the system. Concrete Faced Rock fill Dams (CFRD) were adopted as the standard dam type for costing on the Pre-Feasibility Study but other dam types including clay core embankment dams could be possible.

- LHWP Phase IIIa: Taung Dam

	With IFR Releases (m^3/s)	Without IFR Releases (million m^3/a)
Full Supply Level	1885	1885
Yield million m^3/a / (m^3/s)	63 (2)	202 (6.4)
Active Storage (million m^3)	1739	1739
Dam Height (m)	125	
Dam Type	Clay Core Embankment	
Spillway Type	Concrete Lined Chute	
PMR Outflow m^3/s	7870	

- LHWP Phase IIIb: Tsoelike Dam

	With IFR Releases (m^3/s)	Without IFR Releases (million m^3/a)
Full Supply Level	1740	1740
Yield million m^3/a / (m^3/s)	142 (4.5)	265 (8.5)
Active Storage (million m^3)	1739	1739
Dam Height (m)	140	
Dam Type	CFRD	
Spillway Type	Concrete Lined Chute	
PMR Outflow m^3/s	10360	

- LHWP Phase IVa: Malatsi Dam

	With IFR Releases (m^3/s)
Full Supply Level	1660
Yield million m^3/a / (m^3/s)	254 (8.0)
Active Storage (million m^3)	743
Dam Height (m)	150
Dam Type	CFRD
Spillway Type	Concrete Lined Chute
PMR Outflow m^3/s	5884

- LHWP Phase IVb: Ntohae Dam

	With IFR Releases (m^3/s)
Full Supply Level	1638
Yield million m^3/a / (m^3/s)	0 (0.0)
Active Storage (million m^3)	771
Dam Height (m)	133
Dam Type	RCC
Spillway Type	RCC Central Overflow
PMR Outflow m^3/s	11752

Note: The LHWP feasibility study stage 1, main report (Table 5.2) states that there is “no incremental yield” for Ntoahae. The system yield reports to some conclusion, however by examination of the tables of the results estimates that the yield may be in the order of 100 million m^3/annum.

- LHWP Alternative Phase IV: Lebalelo Dam

	With IFR Releases (m^3/s)
Full Supply Level	1705
Yield million m^3/a / (m^3/s	213 (6.75)
Active Storage (million m^3)	790
Dam Height (m)	114
Dam Type	CFRD
Spillway Type	100 m crest Concrete Lined Chute
PMR Outflow m^3/s	6240

ii) Lesotho has undertaken a feasibility study for a dam at Metolong to supply Maseru and surrounding towns, and considered two dam sizes.

Metolong Dam	**Size 1**	**Size 2**
Yield (Mℓ/d)	70	80
Active Storage (million m^3)	31	52
Dam Height (m)	60	68
Dam Type	RCC Gravity	
Spillway Type	Gated Central	

3.4.4 Perspective on water resource management

Detailed analyses are required to determine the most suitable operating rule for phase 2 of the LHWP. These analyses are also required to support both Lesotho and the RSA in their decision making process to agree on the most suitable operating rule.

Although the operating rule for phase 1 as captured in the treaty between the RSA and Lesotho is fixed and cannot be changed easily, some evaluation of this rule versus other possible options is recommended. This might result in a new agreed operating rule also for phase 1, that benefits the efficient use of the resource.

The possibility of utilising the storage in Polihali Dam to also support the Orange River until the full yield from Polihali Dam is required for the Vaal System, will results in the postponement of costly intervention options in the Orange to replace the yield taken out by Polihali Dam. It is important that this option be evaluated in combination with the development of the operating rule for Phase 2 of the LHWP.

3.5 UPPER ORANGE RIVER CATCHMENT AREA

3.5.1 Description of the water resource and supply situation

The Upper Orange WMA lies predominately in the Free State. Rainfall mainly occurs in the summer and ranges from as high as 1000 mm/a to the East of the catchment to as low as 200 mm/a to the West of the catchment.

Bloemfontein/Mangaung, Botshabelo and Thaba ‘Nchu represent the main urban/industrial developments in the WMA. The two largest reservoirs in the RSA, Gariep and Vanderkloof, are located in this WMA and is the main resources for the Orange River Project (ORP) supplying vast areas under irrigation in the Upper Orange WMA, in the Lower Orange WMA as well as in the Eastern Cape via transfers through the Orange Fish tunnel. Several towns and mines along the Orange River are also supplied from the ORP as well as towns in the Eastern Cape including part of the requirements of Port Elizabeth. Hydro-power is generated mainly for peaking purposes at both Gariep and Vanderkloof dams by utilising releases for the downstream users. When there is a short-term surplus available in the system, it is given to Eskom as a discretional allocation, which can be used for hydro-power generation at times as required by Eskom, and is therefore not depended on the required releases to supply downstream users. Namibian requirements along the Lower Orange are also supplied from the ORP. The ORP yield is almost in balance with the current system demand, and only allows for the development of irrigation areas allocated for the development of resource poor farmers as well as for some of the growth in the Bloemfontein and Port Elisabeth areas.

Several smaller dams located on the tributaries of the Caledon are used to supply towns with water as well as some irrigation. These include dams such as Armenia, Egmont, Meulspruit, etc. Lesotho is currently constructing the Metolong Dam on one of the tributaries of the Caledon. The purpose of this dam is to supply water to Maseru and surrounding areas. The dam is expected to be completed by middle 1013, and will have an effect on the water available in the Caledon and Upper Orange. Welbedacht Dam is located on the main stem of the Caledon River and is used to supply Bloemfontein and several small towns with water. The dam is however severely silted up. Knellpoort Dam a large off-channel storage dam receives the bulk of its water from Tienfontein pump station located on the main stem of the Caledon River. This dam together with Welbedacht Dam forms part the BloemWater System, used to supply Bloemfontein/Mangaung, Botshabelo and Thaba ‘Nchu with water. Rustfontein and Mockes dams located on the Modder River also form part of the BloemWater System with water transferred from Knellpoort Dam into Rustfontein Dam.

The Bloemwater System, also referred to as the Caledon Modder System, is currently in balance with the demand imposed on the system and will require intervention measures to be able to cope with the increasing demand.

Other large dams in this area include Krugersdrift Dam on the Modder River downstream of Mockes Dam and Kalkfontein and Tierpoort dams on the Riet River. These dams are mainly used for irrigation purposes and are all fully utilised and in some cases even over utilised.

Groundwater is widely used in this area for domestic and agricultural purposes. The Petrusburg region abstracts approximately 14 million m^3/a and the Bainsvlei region in the order of 33 million m^3/a for irrigation purposes. Groundwater plays a major role in the sustainability and economy of the Modder Riet catchment.

3.5.2 Pertinent water resource management issues

The current surface water resources in the Upper Orange WMA is in most cases fully utilised and in some cases already over utilised. The ORP system still has a small surplus available, but that is already allocated to the development of irrigation for resource poor farmers. The ORP system will be in a deficit when the second Phase of the LHWP is in place, as the yield of the ORP system will reduce as result of the significant additional volume transferred to the Vaal system. Some intervention option or options will be required to rectify the water balance in the ORP system, once Polihali Dam is in place.

As the demand on the ORP system increases, less and less water is available for hydro-power generation purposes and it is expected to reduce to a level where only the releases to supply downstream users, will be available for power generation purposes.

Operational requirements along the main Orange River downstream of the ORP, has reduced over the last couple of years from 270 million m^3/a to 180 million m^3/a. It is however still a substantial volume and further improvement in the operating of the system can save even more. The Eastern Cape system has however indicated that an additional requirement of approximately 25% on top of their allocation is required to cover losses in the Eastern Cape part of the system. If this volume is added to the total demand imposed on the ORP, the system will be in deficit.

Releases for hydro-power purposes from Vanderkloof Dam, in particular during winter, are resulting in environmental problems at the Orange River Mouth. It is further more very difficult to control the releases from Vanderkloof Dam to be able to supply all the users along the main Orange River over the long distance of approximately 1 300 km from Vanderkloof Dam to the estuary.

Indications are that the current volume released to satisfy the river mouth environmental requirement is insufficient and that a more up to date estimation will result in significantly higher requirements. This will reduce the yield available from the system and needs to be taken into account in any future analyses.

Limited measured water abstraction data is available regarding water use on the ORP system. Observed data is mainly available for releases from the two major dams, directly into the river, canals and tunnels directly linked to the dams and for the larger canal abstraction systems along the Orange River main stem.

Releases to cover operational requirements and losses downstream of Bloemhof Dam and Vaalharts Weir seems to be lost from the system as it is not entering Douglas Weir. These results in the largest portion of the water supplied to the Douglas Irrigation Scheme, to be pumped from the Orange at Marksdrift. Due to the lack of reliable observed data at Douglas weir, it is difficult to determine where the water is lost from the system and how one should model this system to accurately represent what is happening in practise at the scheme.

Strategies were recently compiled for the Bloemwater or Caledon Modder sub-system from the “Water Reconciliation Strategy Study for the Large Bulk Water Supply Systems: Greater Bloemfontein Area”. Several intervention options were recommended from this study, some which due to the urgent nature of the shortages, were already implemented, and some that are in the process of implementation. The high silt load in the Caledon is one of the difficult problems that are experienced in this sub-system.

Additional releases through the Orange Riet canal are already taking place to improve the water quality along the Lower Riet River. Water that is pumped from the Orange at Marksdift to the Douglas Weir in the Lower Vaal is not only to supply adequate water to the scheme, but also to improve the water quality. Large volumes of return flows from irrigation is generated along the Lower Vaal and this in combination with the pollution from mines and urban centres in the Middle and Upper Vaal contributes to a poor water quality along the Lower Vaal. This water enters the Orange River downstream of Douglas Weir and is slowly starting to impact on the Orange River. With the development of Phase 2 of the LHWP, more good quality water will be taken out of the Orange System resulting in an increase water quality problem due to less dilution that will be taking place.

Most of the sewage works in the WMA are also in a poor state and are inadequate and therefore contributing to poor water quality at some points in the river systems. The groundwater in the Riet/Modder catchment is polluted at specific sites, elsewhere the water quality is good. This is partly due to the use of pit latrines.

3.5.3 Identified intervention measures

i) Bosberg

Yield (million m^3/a)	691
Active Storage (million m^3)	5768

Dam Height (m)	Upto 57
Dam Type	RCC
Spillway Type	Central Overflow

ii) Boskraai:

Yield (million m^3/a)	1104
Active Storage (million m^3)	10605
Dam Height (m)	75
Dam Type	RCC
Spillway Type	Central Overflow

iii) Gariep dam raising:

Increased Yield (million m^3)	316	635
Increased Active Storage (million m^3)	2000	5575
Dam Raising (m)	+5m	+10m
Dam Type	Double Curvature Arch	
Spillway Type	Gated	

iv) Van der Kloof reduced Minimum Operating Level:

Yield (million m^3)	143
Increase in Active Storage (million m^3)	+765
Change in MOL (m)	-20
Dam Type	Existing
Spillway Type	Existing

Groundwater Future development recommendations

Studies indicate that the groundwater resources are underutilised in some areas. The following recommendations are made:

- The highest usage according to Upper Orange WMA ISP is in the Lower Modder River catchment which necessitates special management and protection of the groundwater resources in this unit.
- It is stated that there is a need for more groundwater supply to local municipalities.
- Exploration and development of groundwater resources must be done utilising the modern available techniques such as high resolution airborne surveying to identify the most optimum drilling sites.
- Deeper boreholes must be drilled to better utilise the resources.
- Groundwater Reserve and Usage studies must be done for all sub-catchments to improve the confidence in the estimates of the unused groundwater resources.

3.5.4 Perspective on water resource management

The strategies already compiled from the “Water Reconciliation Strategy Study for the Large Bulk Water Supply Systems: Greater Bloemfontein Area” study will be adopted for this particular sub-system an evaluated in terms of the broader study area and related water supply systems.

The operating rules to be followed for the Polihali Dam (LHWP Phase 2) can have a significant effect on the Orange River and the ORP over the short to medium term. By implementing this in the correct manner can help to postpone other costly intervention options in the Orange for quite a number of years. Options such as real time modelling on the Main Orange downstream of Vanderkloof Dam and the Lower Vaal downstream of

Bloemhof Dam can assist to significantly reduce operational losses, and improve the utilisation of water available in the Vaal from time to time.

The total yield from the Orange River is not yet fully harnessed, and significant yield can be added by another dam upstream of Gariep, where evaporation is considerably lower. Such a dam can be used to support the Orange as well as to transfer more water to the Vaal system.

The additional releases through the Orange/Fish tunnel to cover the 25% losses in the Eastern Cape need to be evaluated and investigated in detail to provide proper guidelines for the management of the Eastern Cape system and the related transfers through the Orange /Fish tunnel. The impact of local runoff in the Eastern Cape, irrigation return flows and water quality aspects will be important to take into account in this evaluation.

The impacts of the latest EWR and water quality objectives need to be taken into account when evaluation and simulating different possible intervention options.

Future groundwater development recommendations

Studies indicate that the groundwater resources are underutilised in some areas. The following recommendations are made:

- The highest usage according to Upper Orange WMA ISP is in the Lower Modder River catchment which necessitates special management and protection of the groundwater resources in this unit.
- It is stated that there is a need for more groundwater supply to local municipalities.
- Exploration and development of groundwater resources must be done utilising the modern available techniques such as high resolution airborne surveying to identify the most optimum drilling sites.
- Deeper boreholes must be drilled to better utilise the resources.
- Groundwater Reserve and Usage studies must be done for all sub-catchments to improve the confidence in the estimates of the unused groundwater resources.

3.6 LOWER ORANGE RIVER CATCHMENT AREA

3.6.1 Description of the water resource and supply situation

The Lower Orange WMA is the most downstream WMA in the Orange basin and as such is affected by all the upstream developments. This is mostly an arid area and the rainfall varies from 400mm/a in the east to as low as 50mm/a on the west coast. The Lower Orange River forms the border between Namibia and the RSA over about 550 km to the west of the 20^0Longitude. The confluence of the Vaal and the Orange River is located at almost the most upstream part of the WMA on its eastern side. Other tributaries are the Ongers and Hartbeest Rivers from the south and the Molopo and Fish (Namibia) rivers from the north.

Ninety percent of the runoff generated in the two WMAs is generated in the Upper Orange. The bulk of the runoff generated in the Lower Orange comes from the Fish River in Namibia entering the main Orange close to the river mouth.

Gariep and Vanderkloof dams located in the Upper Orange WMA are both used to supply all the irrigation, urban, mining and environmental requirements along the main Orange River in the Lower Orange WMA. There is no large storage dams located in the Lower Orange WMA, with only a few smaller storage dams on some of the tributaries. These include dams such as the Smart Syndicate on the Ongers River, and the Vanwyksvlei Dam on the Carnarvonleegte.

The possible future Vioolsdrift Dam was identified by previous studies as the best option for re-regulation purposes on the Lower Orange as well as to supply some additional yield by using a larger dam at the same site.

Ground water utilisation is of major importance across wide areas of the Lower Orange WMA. In the Lower Orange tributary catchment areas about 60% to 70% of the available water is supplied from groundwater resources.

Irrigation is by far the dominant water user in the Lower Orange using approximately 94% of the total water requirement. Virtually all the irrigation is allocated along the Orange River main stem and abstracts water from the river. Most of the urban and mining developments and related water requirements are located along the Orange River main stem. In addition to these users water is transferred to towns such as Springbok, Steinkopf and Port Nolloth and some mines located in the coastal sub-area.

The temporary short term surplus in the Orange is utilised to maximise hydro-power generation. This surplus will be taken up once the 12000 ha allocated to resource poor farmers have been taken up, of which 4000ha is located in the Lower Orange. Shortages in the Upper Orange WMA will directly impact on the Lower Orange WMA as well.

3.6.2 Pertinent water resource management issues

All the water resource management issues applicable to the Upper Orange WMA in relation to the ORP system, also applies to the Lower Orange WMA.

As it is difficult to control the river flow by releases from Vanderkloof Dam to supply all the users along the 1 300km long river reach, it do sometimes happen that users experiences shortages for limited periods and sometimes too much water, specifically in the winter time at the river mouth. This is as result of heat waves that are experienced from time to time but possibly also as result of unlawful abstractions. The accuracy of most of the gauging weirs is not very good for low flows, as the weir are in general very long and slight increases in the flow depth over the weir result in significant volumes flowing over the weir. This further complicates the operating of the river, specifically to know whether the correct volume has reached the river mouth.

Salinity has increased in the Orange River due to the transfer of high quality water out of the Lesotho Highlands to the Vaal system and as result of high salinity irrigation return flows along the Orange River main stem. Poor quality water from the Vaal that contains a high proportion of irrigation return flows as well as treated urban effluent and mine water enters the Orange just downstream of Douglas Weir.

Algal blooms were experienced in the Lower Orange River due to a combination of irrigation return flows, diffuse sources and poor quality water from the upstream Vaal WMAs.

Groundwater quality in this area varies from good to unacceptable in terms of potable standards. The water quality is one of the main factors affecting the development of ground water resources.

3.6.3 Identified intervention

Although a number of dam sites have been identified on the Lower Orange River the Lower Orange River Management Study concluded that the only appropriate site for further consideration was at Vioolsdrift. Two possible dams were considered. A re-regulating dam and a yield dam.

i) Vioolsdrift re-regulating dam:

Full Supply Level	201.5 m.a.s.l
Yield (million m^3/a)	170
Active Storage (million m^3)	260-150 =110
Dam Height to NOC	25
Dam Type	Concrete gravity
Spillway	Central

ii) Vioolsdrift yield dam:

Full Supply Level	220.5
Yield (million m^3/a)	183, 297, 365
Active Storage (million m^3)	500, 1500, 2400
Dam Height to FSL	44, 54.6, 62.6
Dam Type	Concrete Gravity
Spillway	Central

Groundwater Future development recommendations

Studies indicate that the groundwater resources are limited in some areas due to low rainfall and poor quality. The following recommendations are made:

- Groundwater Reserve and Usage studies must be done for all sub-catchments to provide estimates of the unused groundwater resources.
- These studies must also estimate poor quality resources that cannot be included in the available unused resources.
- The impact of quality on the health needs to receive more attention.
- Exploration and development of groundwater resources for bulk supply to villages and towns must utilise the modern available techniques such as high resolution airborne surveying to identify the most optimum drilling sites.

3.6.4 Perspective on water resource management

Water requirements along the Orange River main stem is totally depended on the water supplied from Gariep and Vanderkloof dams in the Upper Orange WMA. Any changes in the Upper Orange therefore directly impact on the water availability in the Lower Orange. Perspectives on water resource management as given for the Upper Orange WMA as applicable to the ORP system will therefore also be applicable to the Lower Orange WMA.

A dam on the Lower Orange at or close to Vioolsdrift can assist to reduce operating losses significantly and to enable far more accurate releases to satisfy the river mouth environmental releases. A larger Vioolsdrift yield dam can capture local runoff and spills from the Vaal to increase the system yield. With Namibia also wanting to expand irrigation development along the Lower Orange River border, this will be a useful intervention to consider.

Options such as real time modelling on the Main Orange downstream of Vanderkloof Dam and the Lower Vaal downstream of Bloemhof Dam can assist to significantly reduce operational losses, and to supply the correct volume at the correct time along the Lower Orange River main stem.

Future groundwater development recommendations

Studies indicate that the groundwater resources are limited in some areas due to low rainfall and poor quality. The following recommendations are made:

- Groundwater Reserve and Usage studies must be done for all sub-catchments to provide estimates of the unused groundwater resources.
- These studies must also estimate poor quality resources that cannot be included in the available unused resources.
- The impact of quality on the health needs to receive more attention.
- Exploration and development of groundwater resources for bulk supply to villages and towns must utilise the modern available techniques such as high resolution airborne surveying to identify the most optimum drilling sites.

3.7 EASTERN CAPE AREA SUPPORTED FROM THE ORANGE

3.7.1 Description of the water resource and supply situation

The Orange-Fish-Sundays Water Supply System (OFSWSS) primarily supports irrigation in the Fish and Sundays river catchments as well some towns in the area and Port Elizabeth taking water from the downstream end of the Sundays River. The rest of the area has very little water of its own and the underlying geology also results in local water of a poor quality.

Most of the inland has a typical dry Karoo climate. Rainfall vary from 300 mm/a to as high as 900 mm/a in small localised areas. Significant areas under irrigation (in excess of 50 000ha) takes place in the Fish and Sunday river catchments with water transferred from Gariep Dam in the Orange River via the Orange-Fish tunnel. Irrigation from local sources takes place along the Kat and Tarka rivers. A total of 4 000ha is allocated for the development of resource poor farmers with water supplied from the Orange System. None of the 4000ha has to date been developed.

The Orange-Fish-Sundays transfer scheme consists of the Grassridge and Darlington dams and various balancing dams, weirs, canals and tunnels. (See **Figure 3.1** below).

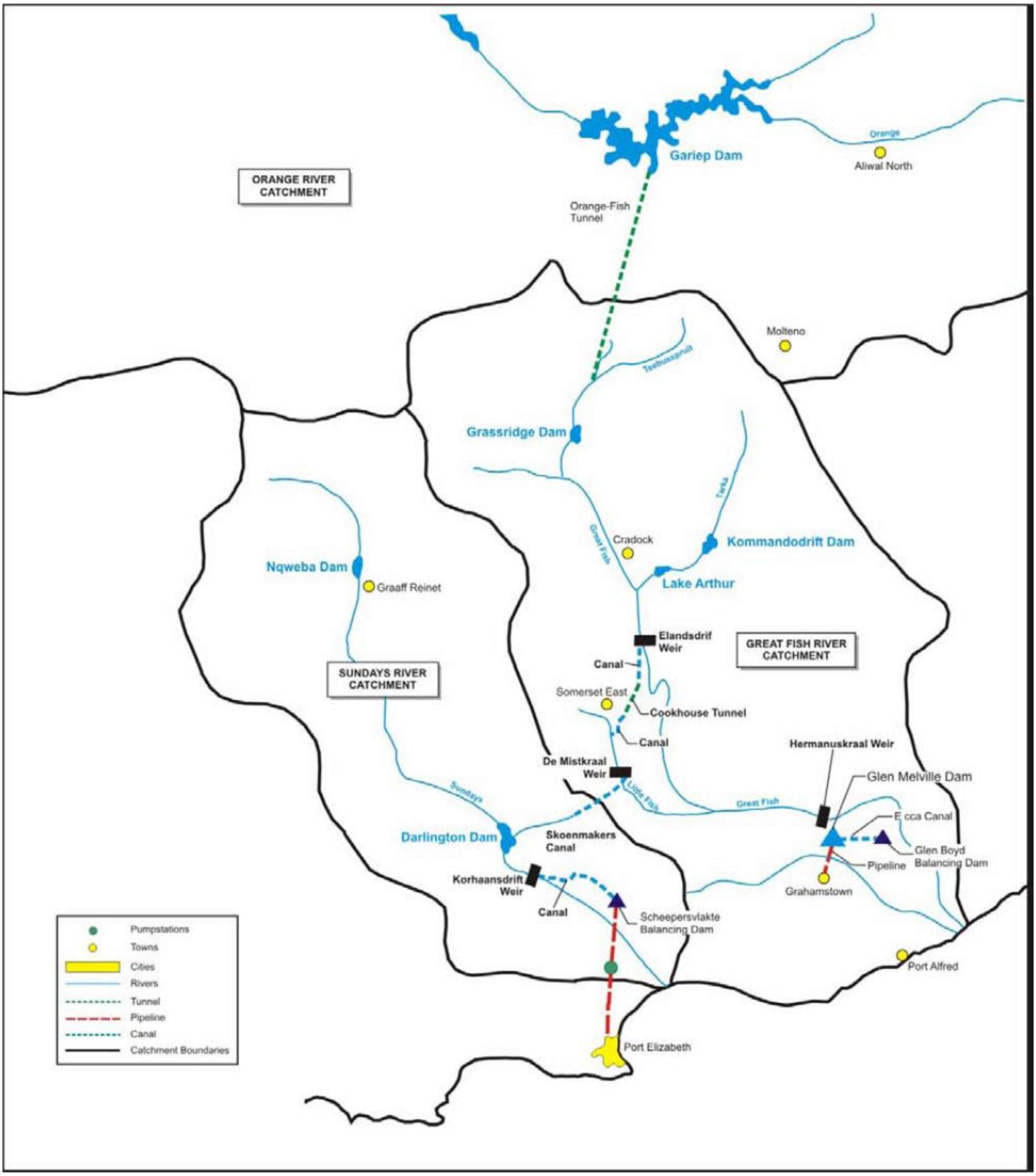


Figure 3-1: Schematic diagram of the Orange-Fish-Sundays Transfer Scheme

Due to the large volume of water imported into this system from the Orange, the total demand imposed on the system and the available yield is in balance. The requirement of the future 4 000 ha development for resource poor farmers will require a further about 38 million m^3 to be imported from the Orange. The allocation from the Orange System to Port Elizabeth has recently been increased to 59 million m^3/a. Due to infrastructure limitations this is not yet fully utilised. The upgraded infrastructure should be completed by the end of 2014.

3.7.2 Pertinent water resource management issues

The support through the Orange Fish tunnel to the Eastern Cape is currently based on the total irrigated area times the applicable quota plus the urban requirements. The Eastern Cape also requested that an additional 25% be added on top of the irrigation volume as determined above to cover losses in the system. This is considered as the maximum allowed transfer and depends on the availability of water in the ORP system and the situation in the Eastern Cape.

A real time model was recently implemented to monitor and control the water flow in the Orange-Fish-Sundays transfer scheme. This model takes into account flow generated in the Fish-Sundays catchment as well as the water quality at various places in the system. During the last 2 to 3 years that were fairly wet years in the Eastern Cape, the real time model requested in general less water than the area times quota calculated volume. Therefore none of the 25% losses was added to the transfer volumes. Adding the 25% losses onto the Eastern Cape demand will result in an over allocation of the ORP, and shortages will be experienced on a regular basis.

It is however at this stage not clear if the additional transfer volume to cover the 25% losses is really required or not over the long term. Detailed analysis including water quality and water quantity will be required to evaluate and determine the actual requirement.

During periods when both Gariep and Vanderkloof dams are spilling, maximum flow are allowed through the Orange-Fish tunnel to improve the water quality in the Fish-Sundays transfer scheme.

3.7.3 Identified intervention measures

Opportunities for new surface water developments are extremely limited and will generally be very costly (DWA 2005). New irrigation development would be too expensive in most cases. Water for expansion of irrigation, where land is still available, should preferably be acquired through increased water use efficiency and water trading (DWA, 2005).

If it is therefore assumed that the promised 38 million m³/a for resource poor irrigation farming will be supplied from the Orange via the Orange Fish tunnel. The additional water transfer demand for urban water use from the Orange-Fish Tunnel will be 12 million m³/a.

Whilst the water resource development opportunities for water demands in the Eastern Cape itself are limited, there is however the opportunity to transfer water from the neighbouring WMA, i.e. the Mzimvubu to Keiskama WMA in order to reduce the water demands from the Orange River through the Orange-Fish tunnel. Three transfer options for transferring Mzimvubu water to the Eastern Cape were investigated (DWAF 2005). Two of these options entailed the transfer of Mzimvubu water into the headwaters of the Orange River and taking it back to the Eastern Cape through the Orange Fish Tunnel. The third option was the Southern Canal Transfer Option which would take the Mzimvubu water directly to the Fish to Tsitsikamma WMA. Whilst the first two options would not benefit the Orange River basin more than merely transferring the Mzimvubu water to the Orang and using it in the Orange, the third option could possibly reduce the water transfer demand through the Orange-Fish Tunnel. However in view of the fact that this third option resulted in the highest URV, it would be better to opt for one of the first two transfer options into the Orange River basin while maintain (instead of increasing as in the Southern Canal Transfer proposal) the water transfer volume through the tunnel.
WC/WDM is one of the intervention options that need to be applied, as significant savings can be obtained in both the urban/industrial and irrigation sectors.

3.7.4 Perspective on water resource management

Significant saving can be obtained from some of the irrigations schemes with excessive losses. A current study “The Development of Comprehensive Water Conservation and Water Demand Management Strategy and Business Plan for the Fish to Tsitsikamma Water Management Area” is currently looking at some of the irrigation schemes in this area. Results from this study should be utilised in further detailed analysis of the Fish-Sundays transfer scheme. Clarity is required on the 25% loss component and the operating rule to be imposed on the systems (Orange Fish transfer system including the complete ORP system). This might also entail to impose separate restrictions on the water users of the Orange Fish transfer system.

3.8 IDENTIFIED INTERVENTION OPTIONS

The augmentation options that were identified from the literature to be considered in the reconciliation study are presented in **Appendix A** and shown on **Figures A-1** to **A-4** of **Appendix A**. The tables include a basic description of the scheme, the proposed assessments that is envisaged as part of the study and give relevant comments on the strategic advantages or disadvantages that can be deduced from existing information.

Appendix A is similar to **Section 3**, structured according to sub-areas, Senqu catchment, Upper Orange catchment and the Lower Orange catchment area.

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LHWC 2008 – Stage 1 Study

Appendix A
LIST OF AUGMENTATION OPTIONS

1. General

Appendix A is structured according to the following sub-areas, the Senqu catchment, the Upper Orange catchment and the Lower Orange catchment area. Possible intervention options applicable to each of the sub-areas will be discussed and presented individually in the tables included for each sub-area in **Appendix A**. A map showing the location of the possible intervention options is included at the beginning of each sub-area.

Water conservation and water demand management options in both the urban/industrial and irrigation sectors will be investigated as an intervention option considering the entire study area.

Trading or descheduling of irrigation. Trading of irrigation water savings as result of WC/WDM is also an option to consider. (Descheduling was given as an option in the ORRS)

Combination of options: In the ORRS quite a number of possible combinations of options were considered. These typically included combinations of

- Gariep lower level storage
- Raised Gariep max 10m
- Vanderkloof lower level storage
- Large Bosberg Dam
- Boskraai Dam
- Dam in Lesotho such as Mashai Dam

These combined options were considered in the ORRS to be able to harness the full yield from the Orange. For the purpose of this study a different combination of options will most likely be used depending on that what need to be achieved.

Real Time Modelling: A real time model is already developed and in use for the Eastern Cape sub-system and is resulting in substantial savings. A real time model was already set up and calibrated for the Orange and Vaal downstream of Vanderkloof and Bloemhof Dams, but is not utilised yet. This option should be considered, as it can assist to utilise spills from the Vaal as well as to reduce the operating requirements in the Orange.

Groundwater Options:

Studies indicate that the groundwater resources are underutilised in some areas of the Upper Orange WMA. It is stated in these studies that there is a need for more groundwater supply to local municipalities. Borehole sites should be carefully selected using modern technology. Deeper boreholes will enable better utilisation of the resource.

Groundwater harvesting potential in the Lower Orange WMA is lower than in the Upper Orange WMA. The groundwater quality also varies from good in the dolomites and Beaufort Formation of the Karoo Supergroup to poor in the granites, despite, some small towns can still fruitfully utilise groundwater in this area but borehole sites must be carefully selected with modern technology.

2. Future and new developments in the Vaal and those outside RSA effecting water availability in the Orange

The Orange River is shared by four basin states, i.e. Lesotho, Bostwana, Namibia and the RSA. Developments in these basin states can also impact on the available flow in the basin, and need to be taken into account where applicable. The focus of this study is on the Orange River WMAs and therefore excludes most of the Vaal catchment except the Riet Modder tributaries. Developments in the Vaal basin affecting flow in the Orange also need to be included in the different options to be considered.

<u>Developments or possible developments in neighbouring states include the following</u>:

- Metolong Dam currently under construction in Lesotho in a tributary of the Caledon River. This dam will supply in the growing demands of Maseru and surrounding villages.
- Polihali Dam already approved as the next phase of the LHWP.
- Possible further phases of the LHWP to be developed in future.
- Several other possible dams were identified as part of the Lesotho Lowlands study of which Metolong is the first dam to be constructed. It is not clear when and if any of the other identified will be built in future.
- Investigations by Botswana to obtain water from Lesotho.
- Necketral Dam in Namibia that will only affect flows in the lower Orange downstream of the Orange Fish confluence.

<u>Developments in the Vaal system that will impact on the Orange</u>:

- Eradication of unlawful irrigation in the Vaal system.
- Treatment of mine water and mine dewatering for usage in the Vaal.
- Transfers from the LHWP to the Vaal system and the related operating rule used for these transfers.
- Water quality related operating rules in the Vaal System.
- Possible transfer of treated waste water to the Crocodile West System.
- Implementation of WC/WDM

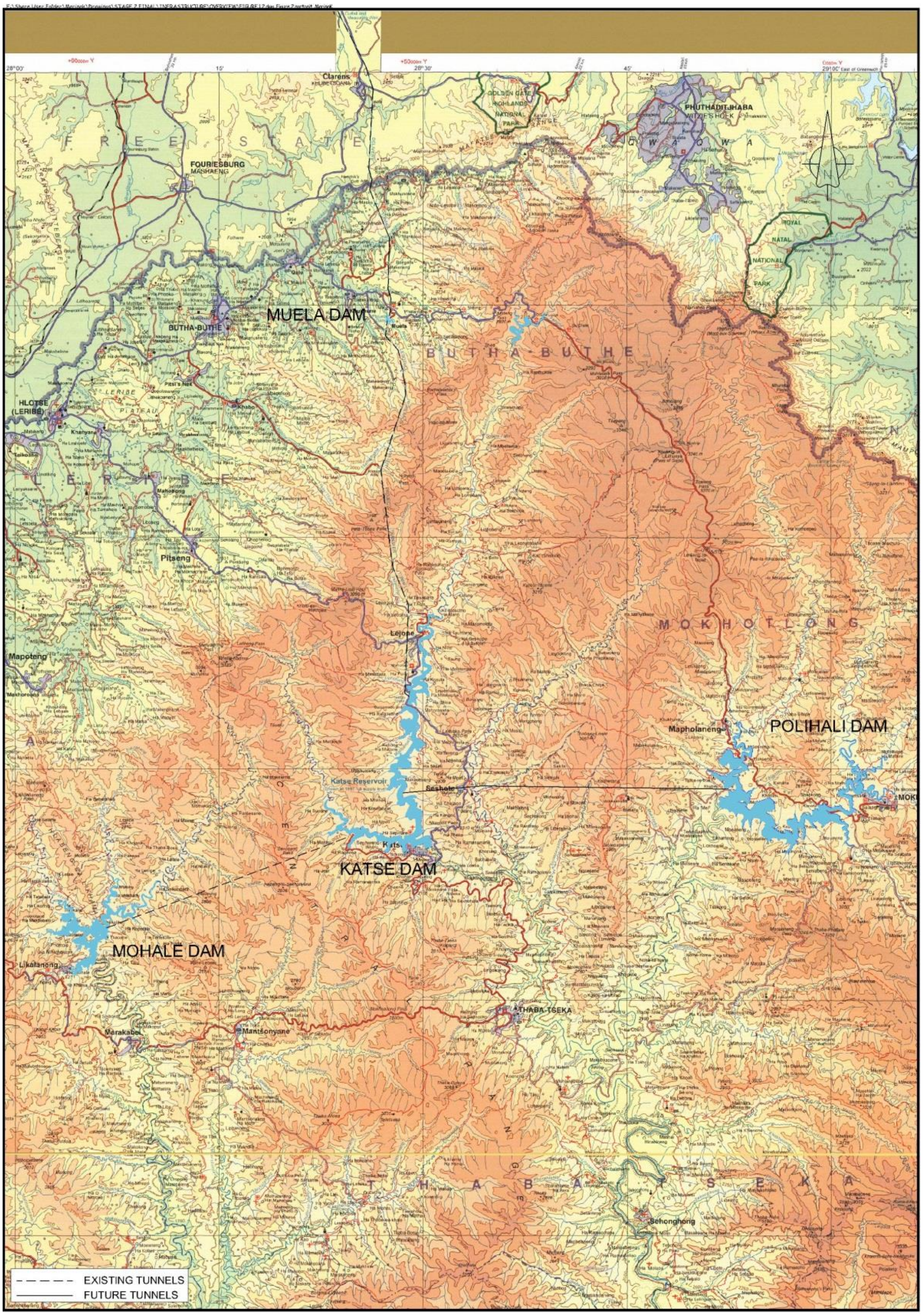
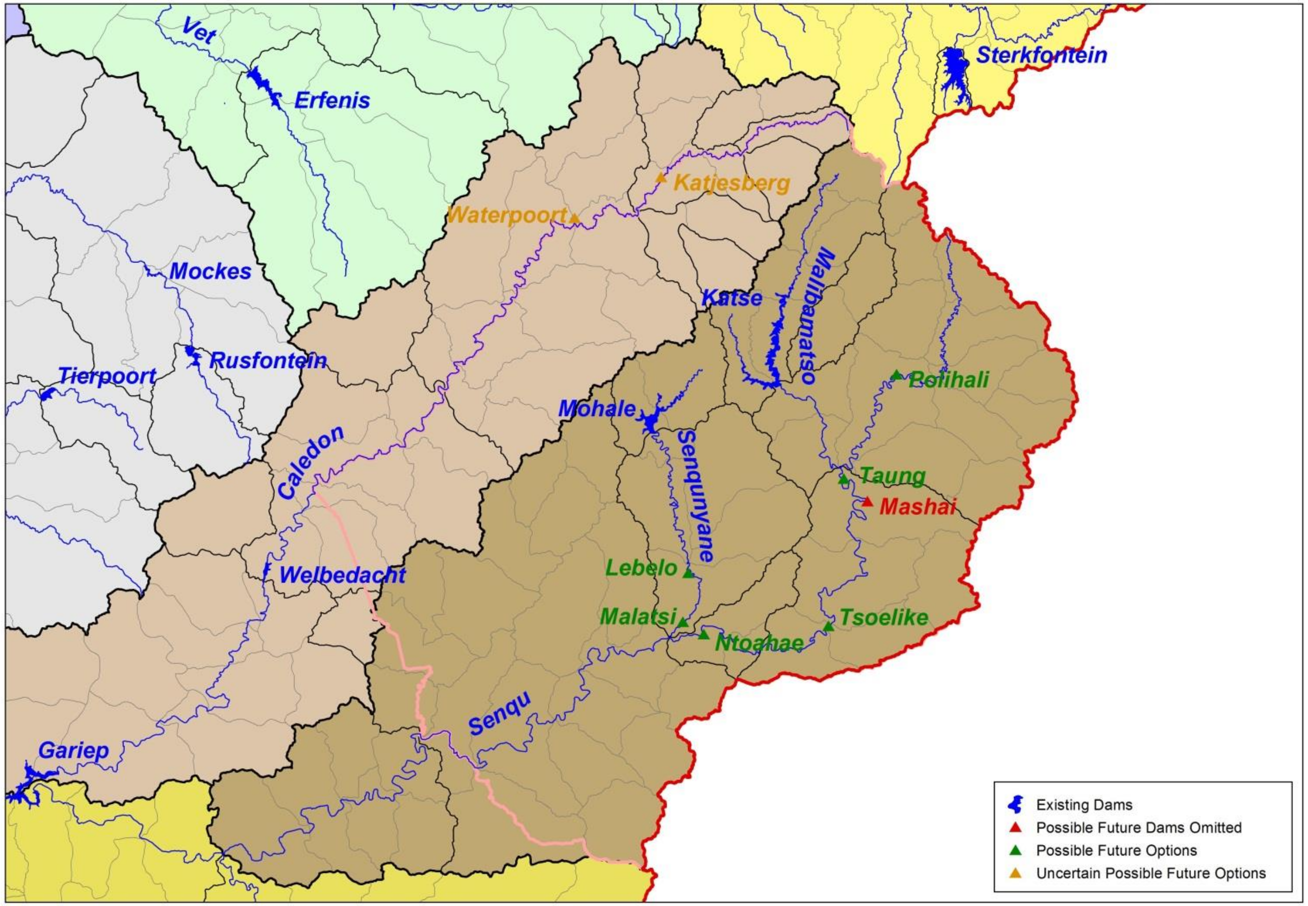


Figure A-1: Location of existing LHWP Phase I and future Phase II (Polihali Dam)



SUB-AREA 1: SENQU CATCHMENT

Figure A-2: Location of Possible Future Intervention Options in the Senqu catchments

Table A-1: Augmentation options identified from the literature – Senqu catchment Area

Table A-1: Augmentation options identified from the literature – Senqu catchment Area

No:	Name of option	Level of Assessment	Date of Assessment	Key Features
1	Polihali Dam	Feasibility Study (LHWP Phase II Stage 2)	2008/09	• Polihali Dam (2 322 million m^3 storage) and tunnel (max capacity 35 m^3/s) to transfer water to Katse Dam from where water is transferred to Vaal Dam. • Increase transfer volume to Vaal by 479 million m^3/a (15.2 m^3/s) • Purpose is to primarily support the Vaal System. • Can initially be used to support both the Vaal and the Orange until the Vaal demand increased to a point that no support can be given to the Orange system. • The increase in the overall system yield with Gariep & Vanderkloof included is only 191 million m^3/a • When the total yield from Polihali dam is utilized by the Vaal System it is expected that the yield of Gariep and Vanderkloof dams will reduce by almost 290 million m^3/a.
	Proposed assessments in the Reconciliation Study			**Comments:**
	• Need to determine the effect on the Orange with Polihali Dam fully utilised by the Vaal System. • Determine when the Orange will require an intervention option to cancel the effect of Polihali Dam. • Identify possible intervention options to be used for this purpose.			• The operating rule used for Polihali Dam will have a significant effect on its impact on the Orange, in particular until the time when the dam is fully utilised. • There is a possibility of a separate operating rule study to address this issue. Results from this study should be used if available in time.
No:	**Name of option**	**Level of Assessment**	**Date of Assessment**	**Key Features**
2	Mashai Dam	Planning ORRS and Vaal Augmentation Planning (VAPS)	1998 & 1994	• This dam would constitute Phase III of LHWP conveying water North wards to the Vaal system. • Two optional sizes were considered. A 107 m high dam transferring 10 m^3/s to the Vaal and a 150 m high dam delivering 20 m^3/s to the Vaal. The high transfer volume can

No:	Name of option	Level of Assessment	Date of Assessment	Key Features of the Option
				however only be achieved should a low IFR be decided on. • In the Phase 1 of the Feasibility Study, Taung dam was the preferred alternative and Mashai was not considered further.
	Proposed assessments in the Reconciliation Study			**Comments:**
	• None, as it is no longer an option for augmenting the Orange, after Polihali Dam			• Polihali was proposed and has been agreed as Phase II of the LHWP and Taung in combination with Tsoelike as the best option for LHWP Phase III. • With Polihali Dam in place the yield from Mashai Dam will be reduced to almost zero and it is therefore no longer regarded as an option for augmenting the Orange.
No:	**Name of option**	**Level of Assessment**	**Date of Assessment**	**Key Features of the Option**
3	Taung Dam	Feasibility Study (LHWP Phase II Stage 1)	2008	• This dam would constitute Phase IIIa of LHWP, acting as a conveyance to transfer water almost to Katse and then through new conveyances northwards to the Vaal system. • Three optional sizes were considered. 117m high delivering 16.64 m^3/s, 122m high delivering 17.38 m^3/s and 127 m high delivering 17.94 m^3/s.
	Proposed assessments in the Reconciliation Study			**Comments:**
	None, as it is no longer an option for augmenting the Orange, after Polihali Dam			• With Polihali Dam in place the yield from Taung Dam will be reduced to less than 70 million m^3 / annum and it is therefore no longer regarded as an option for augmenting the Orange.
No:	**Name of option**	**Level of Assessment**	**Date of Assessment**	**Key Features of the Option**
4	Tsoelike Dam	Feasibility Study (LHWP Phase II Stage 1)	2007	• This dam would constitute Phase IIIb of LHWP with its yield being transferred to Taung dam and then Katse dam with conveyances northwards to the Vaal system. • Tsoelike Dam can be used to support the Orange or partly support the Orange, even if Phase III of LHWP does not proceed • Dam sizes between 135m and 165m and storages respectively of 1 400 & 2 942 million m^3, were evaluated. • The yield with Taung and Polihali dams in place was estimated at 28.93 m^3/s
	Proposed assessments in the Reconciliation Study			**Comments:**

	• Determine if Tsoelike dam as part of Phase III of LHWP could be used to replace the yield in the Orange. • Determine if Tsoelike dam could be used to replace the yield in the Orange, if Phase III does not proceed, or if it was constructed ahead of Phase III and used fir augmenting the Orange in the interim.			• This can be used as an intervention option for the Orange to replace the yield taken out by Polihali Dam. • This dam could be used as part of phase lll of the LHWP
No:	**Name of option**	**Level of Assessment**	**Date of Assessment**	**Key Features of the Option**
5	Ntoahae Dam	Feasibility Study (LHWP Phase ll (Stage 1) and Planning (VAPS)	2007	• This dam would constitute Phase IVa of LHWP, acting as a conveyance to transfer the yield of Malatsi almost to Tsoelike and then to Taung and Katse dames and then through conveyances northwards to the Vaal system.
	Proposed assessments in the Reconciliation Study			**Comments:**
	None, as it is no longer an option for augmenting the Orange, after Tsoelike Dam			• Was identified in the VAPS to form part of phase IV of the LHWP • As part of the Feasibility Study (LHWP Phase ll Stage 2) this dam was again recommended to form Phase IVa of LHWP • With Tsoelike Dam in place the yield from Ntoahae Dam will be virtually zero and it is therefore no longer regarded as an option for augmenting the Orange.
No:	**Name of option**	**Level of Assessment**	**Date of Assessment**	**Key Features of the Option**
6	Malatsi Dam	Feasibility Study (LHWP Phase ll Stage 1) and Planning (VAPS)	2007 &1994	• Was identified in the VAPS to form part of phase IV of the LHWP • As part of the Feasibility Study (LHWP Phase ll Stage 1) this dam was again recommended to form phase IVb of LHWP • It has a yield of 254 million m^3/annum
	Proposed assessments in the Reconciliation Study			**Comments:**
	Determine if Malatsi dam could be used to replace the yield in the Orange, if Phase IV of LHWP does not proceed, or if it was constructed ahead of Phase IV and used fir augmenting the Orange in the interim.			• This can be used as an intervention option for the Orange to replace the yield taken out by Polihali, Taung, & Tsoelike Dams
No:	**Name of option**	**Level of Assessment**	**Date of Assessment**	**Key Features of the Option**
7	Lebelo Dam	Feasibility Study (LHWP	2007	• This was a new dam site identified as part of the Feasibility

		Phase ll Stage 1)		Study (LHWP Phase ll Stage 1). It was considered as an alternative Phase IV to Malatsi and Ntoahae. It would have transferred water to Mohale dam, but it was not the preferred phase IV of LHWP at that time. • Lebelo and Malatsi are mutually exclusive • The yield was estimated at 213 million m^3 /annum
	Proposed assessments in the Reconciliation Study			**Comments:**
	Determine if Lebelo dam could be used to replace the yield in the Orange, if Phase IV does not proceed, or if it was constructed ahead of Phase III and used fir augmenting the Orange in the interim.			• To replace yield in the Main Orange due to upstream developments

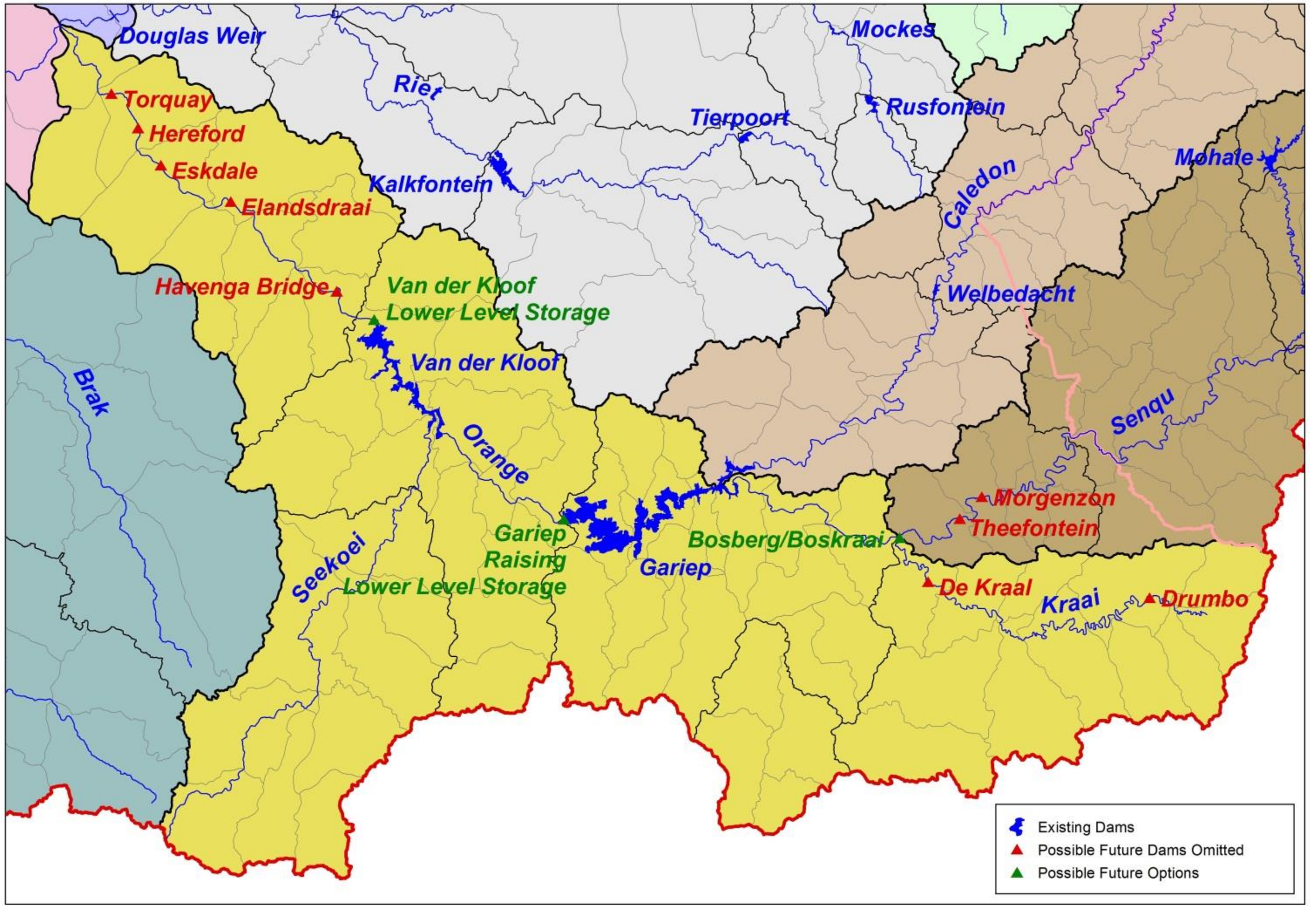


Figure A-3: Location of Possible Future Intervention Options in the Upper Orange

SUB-AREA 2: UPPER ORANGE WMA

Table A-2: Augmentation options identified from the literature – Upper Orange River Catchment Area

No:	Name of option	Level of Assessment	Date of Assessment	Key Features of the Option
1	Bosberg Dam	Planning (ORRS)	1998	• Dams up to 57m high were considered feasible at this site. • Higher dams would start to spill through a saddle to the Kraai River, requiring an expensive saddle dam. • Large Bosberg 5768 million m^3 storage plus 1500 storage Vioolsdrift provide yield of 979 million m^3/a. Vioolsdrift contribution approximately 288 million m^3/a
	Proposed assessments in the Reconciliation Study			**Comments:**
	• Determine if Bosberg Dam can be used to replace the yield in the Orange as result of Polihali Dam • Which is the best option to use? Bosberg or Taung/Tsoelike (or another dam in Lesotho)			• This can be used as an intervention option for the Orange to replace the yield taken out by Polihali Dam. • The operating rule for this dam is important as it keeps the water in Bosberg until Gariep reaches its m.o.l. and therefore significantly reduces evaporation losses from Gariep. • Reduced hydro-power at Gariep and Vanderkloof, but additional hydro-power from Bosberg
No:	**Name of option**	**Level of Assessment**	**Date of Assessment**	**Key Features of the Option**
2	Boskraai Dam	Planning (ORRS)	1998	• The Boskraai Dam actually consists of a Bosberg Dam of higher than 57m together with a dam of similar height on the Kraai River. • Although the dam site allows for higher dams to be built a maximum water depth of 75m was assumed to prevent backwater to extend into Lesotho. • Large Boskraai Dam of 10 605 million m^3 in combination with a 1500 storage Vioolsdrift provide yield of 1 392 million m^3/a. Vioolsdrift contribution approximately 288 million m^3/a
	Proposed assessments in the Reconciliation Study			**Comments:**
	• Determine if Boskraai Dam can be used to replace the yield in the Orange as result of Polihali Dam • Determine if and how much additional water can be made available for transfers to the Vaal after balance in the Orange was achieved.			• This can be used as an intervention option for the Orange to replace the yield taken out by Polihali Dam as well as to transfer water to the Vaal System. • The operating rule for this dam is important as it keeps the water in Boskraai until Gariep reaches its m.o.l. and therefore significantly reduces evaporation losses from Gariep. • Reduced hydro-power at Gariep and Vanderkloof, but

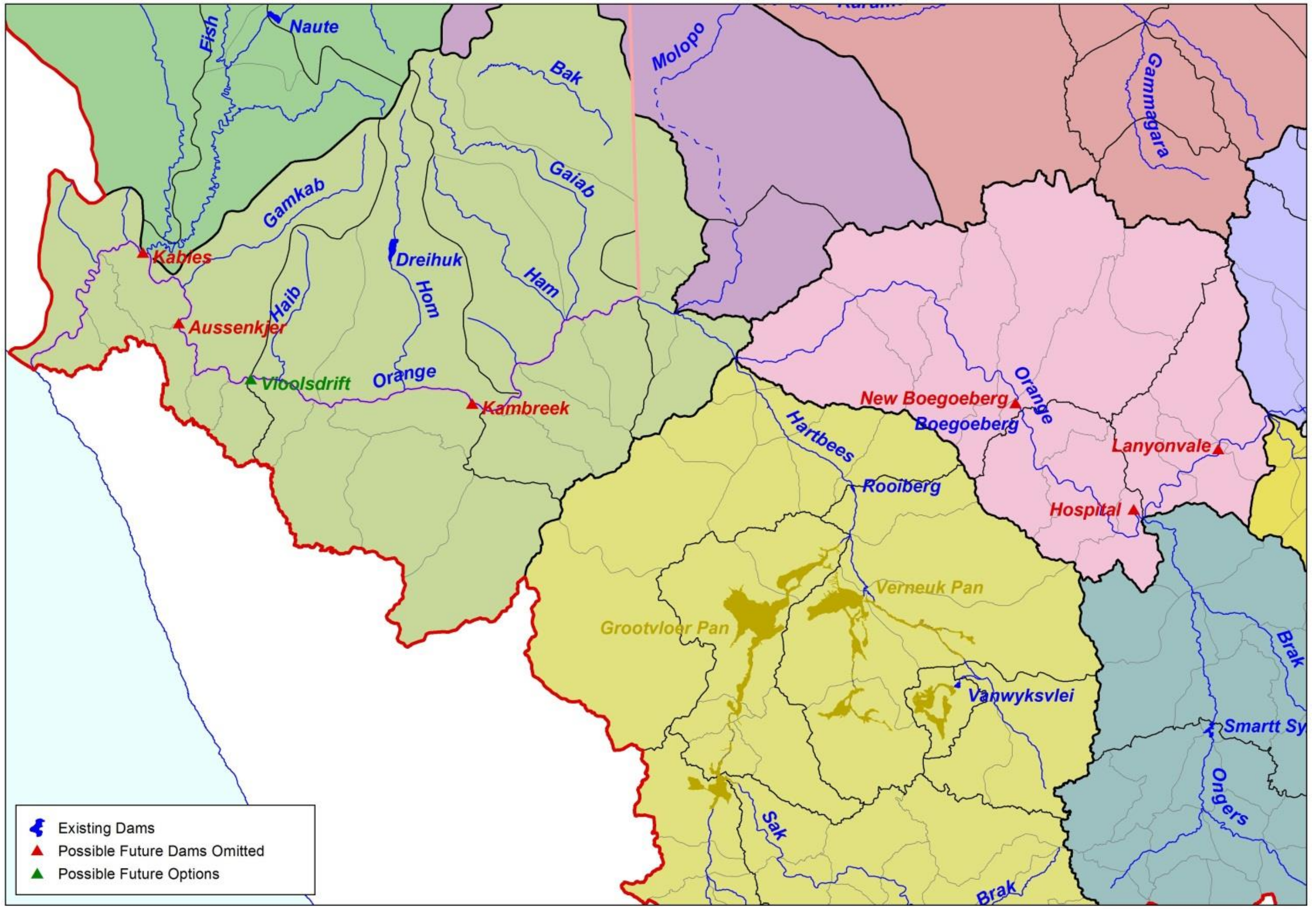
No:	Name of option	Level of Assessment	Date of Assessment	Key Features of the Option
				additional hydro-power from Boskraai Dam
3	Mzimvubu Transfer Options	Pre 1990 Studies (e.g. Hydro Electric Power Potential Study – Henry Olivier Consortium	1986	• Studied possible transfer routes from Mbokazi Dam to Eastern Cape • Rejected as a result of too high cost
		Orange River System Analysis Phase 2	1993	• Assessed 3 options, i.e. Mzimvubu/Kraai, Mzimvubu/Tugela and Mzimvubu/LHWP transfers • Mzimvubu/Kraai came out as the option with lowers URV • Recommended further in detail investigations
		Mzimvubu River Basin: Water Utilization Opportunities	2005	• Report prepared for the Eastern Cape Province: Focus was on the Eastern Cape • Assessed 3 Options: Northern Transfer, Southern Transfer and Southern Canal Transfer options
	Proposed assessments in the Reconciliation Study			**Comments:**
				• Mzimvubu/Kraai of ORSA Ph2 could be a possible option to augment the Orange River • Southern Canal Transfer Option could reduce the dependency of the Eastern Cape on the Orange River
No:	**Name of option**	**Level of Assessment**	**Date of Assessment**	**Key Features of the Option**
4	Raised Gariep Dam	Planning (ORRS) Pre-feasibility	1998	• Increase in yield for a 5m raising is 316 million m^3/a • Increase in yield for a 10 m raising 635 million m^3/a
	Proposed assessments in the Reconciliation Study			**Comments:**
				• This can be used as an intervention option for the Orange to replace the yield taken out by Polihali Dam. • When raising Gariep higher than 10m a significant decrease in the rate of yield increase are experienced • Results in very high evaporation losses
No:	**Name of option**	**Level of Assessment**	**Date of Assessment**	**Key Features of the Option**

5	Vanderkloof Dam reduced m.o.l.	Pre-feasibility (LORMS)	2005	• 143 million m^3/a yield increase for storage between canal outlets and existing bottom outlets at Vanderkloof Dam
	Proposed assessments in the Reconciliation Study			**Comments:**
				• This can be used as an intervention option for the Orange to replace the yield taken out by Polihali Dam. • Disbenefit: Due to periods when no hydro-power can be generated
No:	**Name of option**	**Level of Assessment**	**Date of Assessment**	**Key Features of the Option**
6	Torquay Dam	Planning (ORRS) Pre-feasibility	1998	• The main purpose of Torquay Dam is to re-regulate the water released through the hydro-power turbines for later release to the irrigation farmers downstream. • This will enable the generation of more hydro-power during the winter periods. • Depending on the size of Torquay dam an additional yield of 253 million m^3/a for a 1500 million m^3 storage dam.
	Proposed assessments in the Reconciliation Study			**Comments:**
	• Check if the yield benefit is worth considering this option at all.			• This can be used as an intervention option for the Orange to replace the yield taken out by Polihali Dam. • The Valley at the dam site is 60m high. Higher dams will require extensive walls on the left flank • Omitted by Pre-feasibility study as Boegoeberg and Vioolsdrift dams provided more cost effective and practical options • Benefit of hydro-power generation was however not included
No:	**Name of option**	**Level of Assessment**	**Date of Assessment**	**Key Features of the Option**
7	Drumbo dam	Reconnaissance Phase (ORRS)	**1998**	• Located in the Kraai River ± 25 km north east of Barkley East • To provide storage for the proposed interbasin transfer from the Mzimvubu River. • Increase the Orange River's yield
	Proposed assessments in the Reconciliation Study			**Comments:**

				• Was omitted since it is part of the Mzimvubu transfer scheme which was not included as part of the ORRS
No:	**Name of option**	**Level of Assessment**	**Date of Assessment**	**Key Features of the Option**
8	De Kraal / Upper Kraai Dam	Reconnaissance Phase (ORRS)	**1998**	• Located in the Kraai River ± 10 km south east of Aliwal North • Storage of water for hydro-power generation
	Proposed assessments in the Reconciliation Study			**Comments:**
				• Was omitted since irrigation areas will be inundated. • People in the dam basin will have to be relocated
No:	**Name of option**	**Level of Assessment**	**Date of Assessment**	**Key Features of the Option**
9	Theefontein / Oranjedraai dam	Reconnaissance Phase (ORRS)	**1998**	• Located in the Orange River ± 25 km upstream of Aliwal North • Storage of water for Hydro-power generation
	Proposed assessments in the Reconciliation Study			**Comments:**
				• Was omitted since it is part of the Mzimvubu transfer scheme
No:	**Name of option**	**Level of Assessment**	**Date of Assessment**	**Key Features of the Option**
10	Morgenson Dam	Reconnaissance Phase (ORRS)	**1998**	• Located in the Orange River ±35 km upstream of Aliwal North • Storage of water for Hydro-power generation
	Proposed assessments in the Reconciliation Study			**Comments:**
				• Was omitted since it will inundate land in Lesotho • And it is less attractive than the Bosberg Dam option. •
No:	**Name of option**	**Level of Assessment**	**Date of Assessment**	**Key Features of the Option**
11	Raising of Vanderkloof Dam	Reconnaissance Phase (ORRS)	**1998**	• Located in the Orange River ±8 km North of Petrusville • Increase water yield • Increase hydro-power generation
	Proposed assessments in the Reconciliation Study			**Comments:**
				• Was omitted since the dam was not designed to be raised • And consequently any raising will be prohibitively expensive

No:	Name of option	Level of Assessment	Date of Assessment	Key Features of the Option
12	Utilize dead storage in Gariep Dam	Planning (ORRS) Pre-feasibility	1998	• Increase water yield
	Proposed assessments in the Reconciliation Study			**Comments:**
				• Might be a good option in combination with a upstream dam such as Bosberg that can make up for hydropower losses at Gariep Dam
No:	**Name of option**	**Level of Assessment**	**Date of Assessment**	**Key Features of the Option**
13	Havenga Bridge Dam	Planning (ORRS)	1998	• Alleviation of abstraction problems experienced by irrigators between Vanderkloof Dam and Prieska
	Proposed assessments in the Reconciliation Study			**Comments:**
				• Was omitted in Pre-feasibility phase as it was only for hydro-power purposes and not for yield increase
No:	**Name of option**	**Level of Assessment**	**Date of Assessment**	**Key Features of the Option**
14	Eskdale Weir	Reconnaissance Phase (ORRS)	**1998**	• 15km downstream of Hopetown • Increase hydro-power • Increase irrigation development in the Plooysburg area
	Proposed assessments in the Reconciliation Study			**Comments:**
				• Omitted since Torquay Dam provides similar benefits and was found to be a more cost effective and practical option
No:	**Name of option**	**Level of Assessment**	**Date of Assessment**	**Key Features of the Option**
15	Hereford Weir	Reconnaissance Phase (ORRS)	1998	• 35km downstream of Hopetown • Increase hydro-power • Increase irrigation development in the Douglas area
	Proposed assessments in the Reconciliation Study			**Comments:**

				• Omitted since Torquay Dam provides similar benefits and was found to be a more cost effective and practical option
No:	**Name of option**	**Level of Assessment**	**Date of Assessment**	**Key Features of the Option**
16	De Khans Dam	Reconnaissance Phase (ORRS)	1998	• Located ±15km downstream of Ritchie • Regulation and balancing of water supply from the Orange-Riet canal and Riet River flow. • Storage capacity for irrigation supply
	Proposed assessments in the Reconciliation Study			**Comments:**
				• Omitted since the sedimentation forecast for this dam is very high • Demands below the dam are relatively low.
No:	**Name of option**	**Level of Assessment**	**Date of Assessment**	**Key Features of the Option**
17	Kloksfonten Dam	Reconnaissance Phase (ORRS)	1998	• Off-channel Storage located ±12km south of Ritchie • Off channel storage for balancing of water from Orange Riet canal. • Storage capacity for irrigation supply
	Proposed assessments in the Reconciliation Study			**Comments:**
	Reconsider when supply to Douglas and irrigation for resource poor farmers are included.			• Omitted from ORRS since the demands downstream of the dam are too small to justify such a development.
No:	**Name of option**	**Level of Assessment**	**Date of Assessment**	**Key Features of the Option**
18	Elandsdraai Dam	Reconnaissance Phase (ORRS)	1998	• Minimization of abstraction problems by providing more constant base flow • Increase in Hydro-power
	Proposed assessments in the Reconciliation Study			**Comments:**
				• Was omitted in Pre-feasibility phase as it was only for hydro-power purposes and not for yield increase •



SUB-AREA 3: LOWER ORANGE WMA

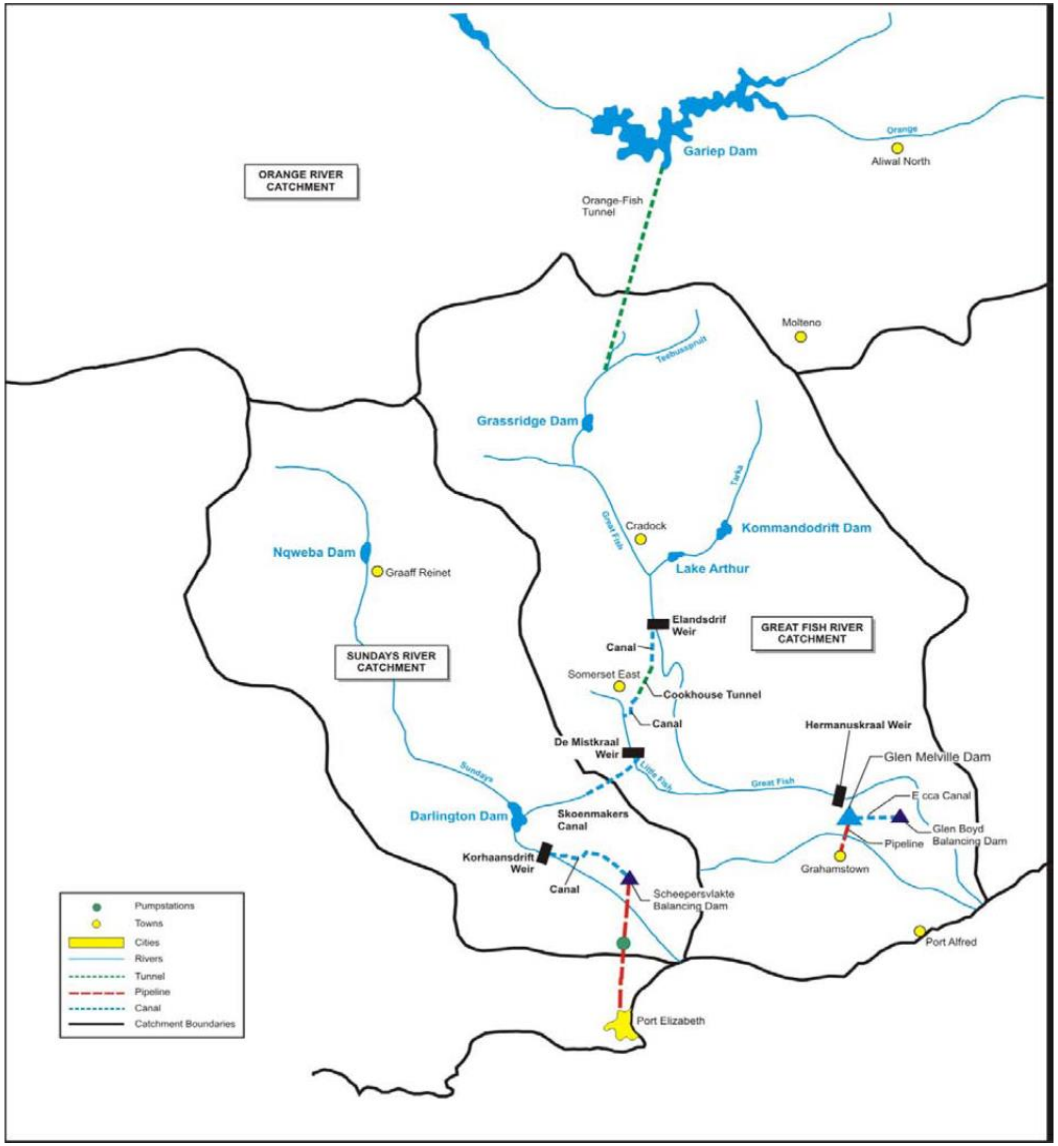
Figure A-4: Location of Possible Future Intervention Options in the Lower Orange

Table A-3: Augmentation options identified from the literature – Lower Orange Catchment Area

No:	Name of option	Level of Assessment	Date of Assessment	Key Features of the Option
1	Vioolsdrift Yield Dam	Pre-feasibility (LORMS)	2005	• Three different Vioolsdrift Dam options are considered: ○ Yield dam ○ Re-regulating dam ○ Yield in combination with re-regulation • These can be used as intervention options for the Orange to replace the yield taken out by Polihali Dam.
	Proposed assessments in the Reconciliation Study:			**Comments:**
No:	**Name of option**	**Level of Assessment**	**Date of Assessment**	**Key Features of the Option**
2	Lanyonvale Dam	Reconnaissance Phase (ORRS)	1998	• Orange river ± 60km downstream of Douglas • Flood absorption and attenuation • Regulation of seasonal irrigation supply from Vanderkloof Dam to increase hydro-power generation
	Proposed assessments in the Reconciliation Study:			**Comments:**
				• Omitted since a new Bosberg Dam is considered to be a more cost effective and practical dam
No:	**Name of option**	**Level of Assessment**	**Date of Assessment**	**Key Features of the Option**
3	New Boegoeberg Dam	Reconnaissance Phase (ORRS)	1998	• Orange river ± 1km downstream of existing Boegoeberg • Regulation of river flow to improve supply of lower Orange River water. • Reduction in water losses due to excessive releases at Vanderkloof • Increase in Water Yield • Increase in hydro-power

No:	Name of option	Level of Assessment	Date of Assessment	Key Features of the Option
				• Better utilization of spills from the Vaal River System
	Proposed assessments in the Reconciliation Study:			**Comments:**
				• Parts of Prieska will be inundated for a dam with a capacity in excess of 2000 million m^3 • Omitted in LORMS since Vioolsdrift Dam offers a more cost effective and practical solution
No:	**Name of option**	**Level of Assessment**	**Date of Assessment**	**Key Features of the Option**
4	Kambreek Dam	Reconnaissance Phase (ORRS)	1998	• Orange river ± 15km downstream of Pelladrift • Regulation of river flow to improve supply of far lower Orange River. • Reduction in water losses due to excessive releases at Vanderkloof • Increase in Water Yield • Better utilization of spills from the Vaal River System
	Proposed assessments in the Reconciliation Study:			**Comments:**
				• Omitted since Vioolsdrift Dam offers a more cost effective and practical solution
No:	**Name of option**	**Level of Assessment**	**Date of Assessment**	**Key Features of the Option**
5	Aussenkjer Dam	Reconnaissance Phase (ORRS)	1998	• Orange river ± 65km downstream of Vioolsdrift • Regulation of river flow to the Orange River mouth. • Increase in Water Yield • Better utilization of spills from the Vaal River System
	Proposed assessments in the Reconciliation Study:			**Comments:**
				• Omitted since the dam is located too far downstream to accommodate certain water demands and too far upstream to capture the Fish River water.
No:	**Name of option**	**Level of Assessment**	**Date of Assessment**	**Key Features of the Option**

6	Kabies Dam	Reconnaissance Phase (ORRS)	1998	• Orange river ± 2km downstream of Orange/Fish confluence • Regulation of river flow to the Orange River mouth. • Increase in Water Yield
	Proposed assessments in the Reconciliation Study:			**Comments:**
				• Omitted since the cost/yield ratio is very high and downstream demands are low.
No:	**Name of option**	**Level of Assessment**	**Date of Assessment**	**Key Features of the Option**
7	Hospital Dam	Reconnaissance Phase (ORRS)	1998	• Flood absorption and attenuation • Regulation of seasonal irrigation supply from Vanderkloof Dam to increase hydro-power generation
	Proposed assessments in the Reconciliation Study:			**Comments:**
				• Omitted since Boegoeberg Dam is considered to be a more cost effective and practical option



SUB-AREA 4 EASTERN CAPE

Figure A-5: Location of existing infrastructure in the Eastern Cape System

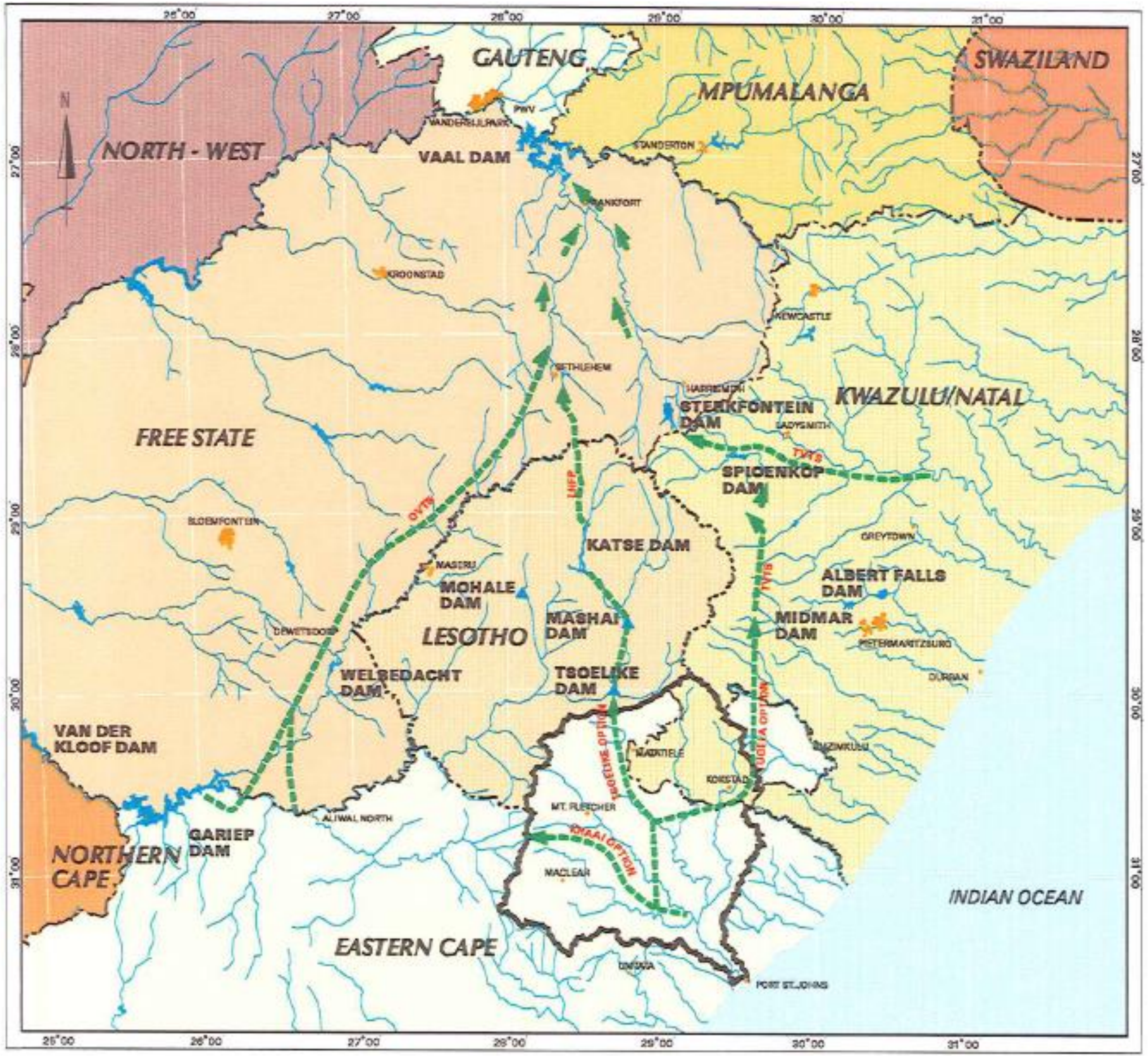


Figure A-5: Possible Mzimvubu transfer option used in the VAPS

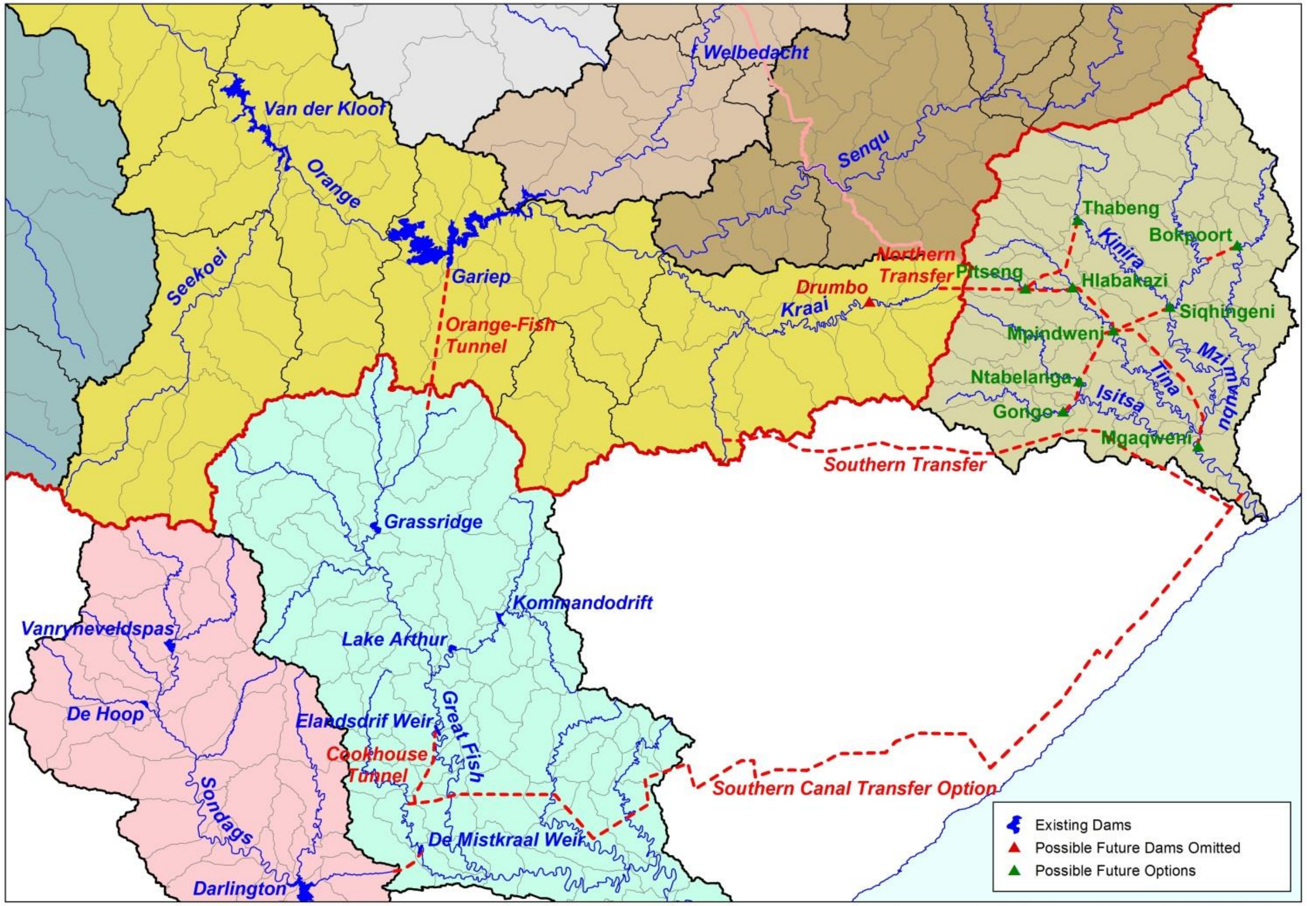
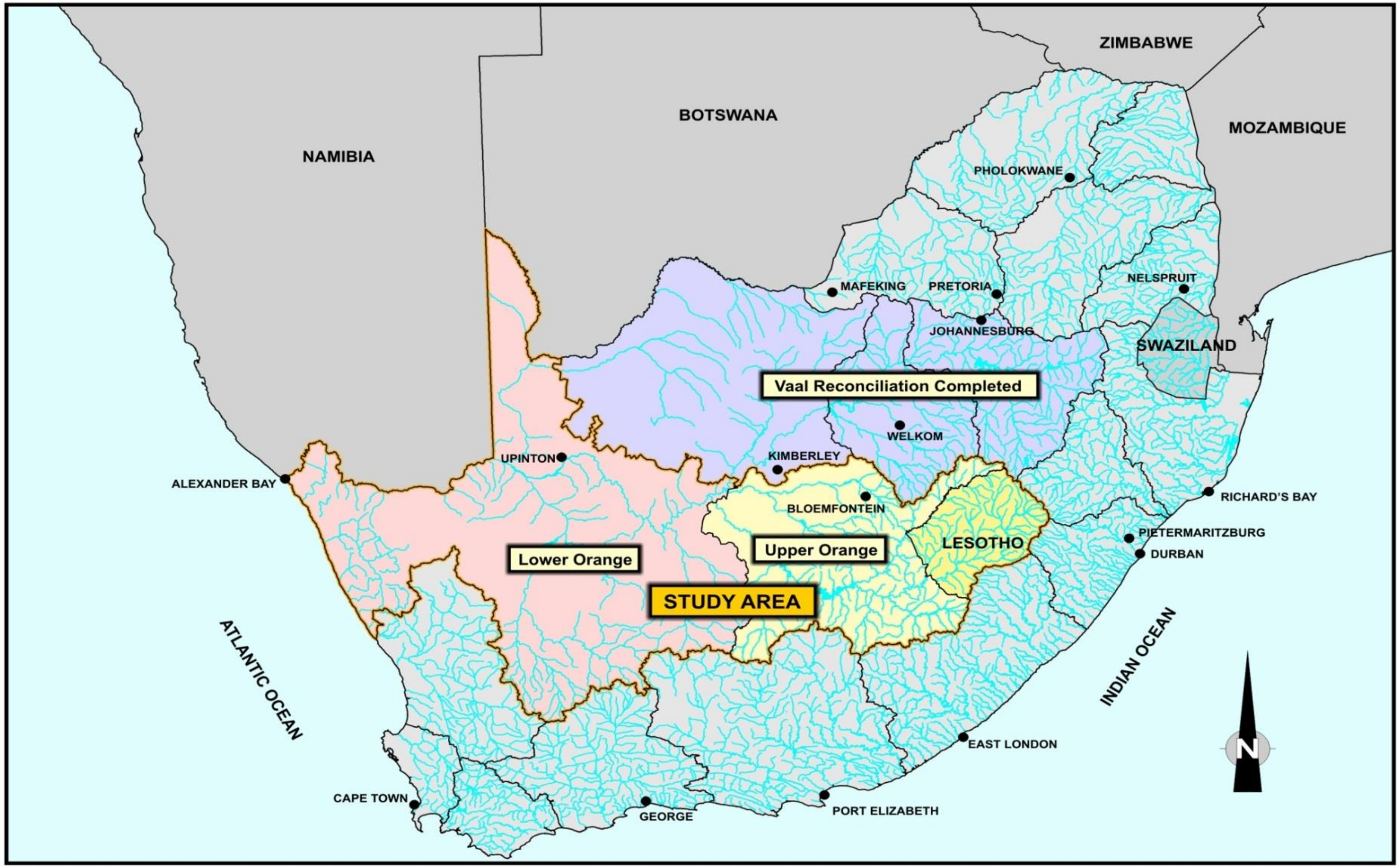


Figure A-6: Possible Mzimvubu transfer options considered

Table A-4: Augmentation options identified from the literature – Eastern Cape Area supplied from the Orange

<table>
<tr><th>No:</th><th>Name of option</th><th>Level of Assessment</th><th>Date of Assessment</th><th>Key Features of the Option</th></tr>
<tr><td rowspan="3">1</td><td>Transfer from Mzimvubu</td><td>Mzimvubu River basin: Water utilisation opportunities</td><td>2005</td><td>• Three options were considered
○ The Northern transfer option. Number of additional dams in the Mzimvubu River Basin together with a system of canals, pump stations, pipelines and tunnels that transfer the water into a small tributary of the Orange River near Rhodes. From here the water flows to the Orange Ricer from where it can be released through the Orange Fish Tunnel into the headwaters of the Fish River at Teebus, for further distribution
○ The Southern Piped transfer option. This consists of a large dam in the lower reaches of the Mzimvubu River and pump stations and pipelines that transfer the water into another small tributary of the Orange River near Dordrecht. From here the water can flow to the headwaters of the Fish River.
○ The Southern Canal transfer option. This consists of a large dam in the lower reaches of the Mzimvubu River and pump stations, pipelines and canals that transfer the water as far as the Little Fish River at the outlet of the Cookhouse Tunnel near Somerset East.</td></tr>
<tr><td colspan="3">Proposed assessments in the Reconciliation Study</td><td>Comments:</td></tr>
<tr><td colspan="3"></td><td>• These options were considered to support the Eastern Cape with water from the Mzimvubu</td></tr>
</table>

Appendix B
STUDY AREA



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

Study area locality map

Title:	***Literature Review Report***
Authors:	*Study Team*
Project Name:	***Development of Reconciliation Strategies for Large Bulk Water Supply Systems: Orange River***
DWA Report No:	*P RSA D000/00/18312/2*
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Consultants: WRP Consulting Engineers (Pty) Ltd in association with Aurecon, Golder Associates Africa and Zitholele Consulting

Approved for the Consultants by:

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