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DEVELOPMENT OF RECONCILIATION STRATEGIES FOR LARGE BULK WATER SUPPLY SYSTEMS: ORANGE RIVER

FINAL RECONCILIATION STRATEGY

JANUARY 2015

DEVELOPMENT OF RECONCILIATION STRATEGIES FOR BULK WATER SUPPLY SYSTEMS

ORANGE RIVER

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Prepared by:

WRP Consulting Engineers, Aurecon, Golder Associates Africa, and Zitholele Consulting.

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Approved for the Consultants by:

P G van Rooyen Study Leader

DEPARTMENT OF WATER AFFAIRS Directorate: National Water Resource Planning

Approved for DWA by:

T. Makembe Production Engineer: National Water Resource Planning (PE Study Management)

.....

JI Rademeyer Chief Engineer: National Water Resource Planning (Study Manager)

alleran

T Nditwani Acting Director: National Water Resource Planning

LIST OF REPORTS

The following reports form part of this study:

Report Title	Report number
Inception Report	P RSA D000/00/18312/1
Literature Review Report	P RSA D000/00/18312/2
International obligations	P RSA D000/00/18312/3
Current and future Water Requirements	P RSA D000/00/18312/4
Urban Water Conservation and Water Demand Management	P RSA D000/00/18312/5
Irrigation Demands and Water Conservation/Water Demand Management	P RSA D000/00/18312/6
Surface Water Hydrology and System Analysis	P RSA D000/00/18312/7
Water Quality	P RSA D000/00/18312/8
Review Schemes and Update Cost Estimates	P RSA D000/00/18312/9
Preliminary Reconciliation Strategy Report	P RSA D000/00/18312/10
Final Reconciliation Strategy Report	P RSA D000/00/18312/11
Executive Summary	P RSA D000/00/18312/12
Reserve Requirement Scenarios and Scheme Yield	P RSA D000/00/18312/13
Preliminary Screening Options Agreed: Workshop of February 2013	P RSA D000/00/18312/14

List of Abbreviations & Acronyms

BHN	Basic Human Needs
СМА	Catchment Management Agency
CME	Compliance Monitoring and Enforcement
CMS	Catchment Management Strategy
СРА	Contract Price Adjustment
DWA	Department of Water Affairs
EWR	Ecological Water Requirements (Ecological Component of the Reserve)
EPEWR	Ecological Preferred EWR
FSL	Full Supply Level
IAP	Invasive Alien Plants
IBs	Irrigation Boards
ISP	Internal Strategic Perspective
IWA	International Water Association
IVRS	Integrated Vaal River System
IWQMP	Integrated Water Quality Management Plan
IWRM	Integrated Water Resource Management
JPTC	Joint Permanent Technical Commission
LHWP	Lesotho Highlands Water Project
LHWC	Lesotho Highlands Water Commission
LORMS	Lower Orange River Management Study
MAR	Mean Annual Runoff
MoU	Memorandum of Understanding
m³/a	Cubic metre per annum
NWA	National Water Act (Act 36 of 1998)
NWRP	National Water Resource Planning
NWRS	National Water Resource Strategy
ORASECOM	Orange-Senqu River Commission
ORDP	Orange River Development Project
ORP	Orange River Project
PES	Present Ecological State
PSP	Professional Service Provider
RBL	Right bank level
RO	Regional Office

RQOs	Resource Quality Objectives
RQS	Resource Quality Services
RSA	Republic of South Africa
RWQOs	Resource Water Quality Objectives
SADC	Southern African Development Community
SANP	South African National Parks
SAWQG	South African Water Quality Guidelines
SMC	Study Management Committee
SSC	Study Steering Committee
ТСТА	Trans Caledon Tunnel Authority
TWQR	Target Water Quality Range
URV	Unit Reference Value
WC/WDM	Water Conservation /Water Demand Management
WDM	Water Demand Management
WMA	Water Management Area
WMP	Water Management Plan
WQT	Water Quality Treatment
WRPM	Water Resource Planning Model
WRYM	Water Resource Yield Model
WTW	Water Treatment Works
WUAs	Water User Associations
WWTW	Waste Water Treatment Works

DEVELOPMENT OF RECONCILIATION STRATEGIES FOR LARGE BULK WATER SUPPLY SYSTEMS: ORANGE RIVER

Final Reconciliation Strategy (July 2014)

EXECUTIVE SUMMARY

Introduction

The Department of Water Affairs (DWA) has identified the need for detail 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.

As part of this process the need for the Reconciliation Strategy for the Large Bulk Water Supply Systems of the Orange River was defined. Given the location of the Orange River System and its interdependencies with other WMAs as well as other countries, various water resource planning and management initiatives compiled during the past few years as well as those currently in progress have formed an integral part of the strategy development process.

Since 1996, 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 Ash 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 in its planning stages and is expected to be in place by 2022. This will reduce the yield of the Orange River System and result in a negative water balance in the Orange River, requiring a yield replacement option in the Orange River.

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 2050. 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 purpose of this report

A first order reconciliation strategy which is based on the available information collected at an early stage of the study was compiled which is referred to as the Preliminary Reconciliation Strategy. This next report, the Final Reconciliation Strategy, addresses the gaps in the Preliminary Reconciliation Strategy and is based on the latest information and assessments. It contains water balances for interventions scenarios that provide possible solutions to make sufficient water available for the planning period up to the year 2050.

Context of study

Water resources allocation must be based on the equitable and reasonable utilisation of the water sources in the shared watercourse by each watercourse state.

Specified factors/criteria including social, economic and environmental needs; the population dependent on the shared watercourse; the effects of the use or uses of a shared watercourse in one Watercourse State on other Watercourse States; as well as existing and potential uses must be taken into account when agreeing what is equitable and reasonable. All relevant factors are to be considered together and a conclusion reached on the basis of the whole.

This water reconciliation strategy by DWA will be an input to the future CMS once the CMA gets established. It is important that this reconciliation strategy is also in harmony with the to-be-established NWRS (2nd Edition).

System description

The Senqu River in Lesotho, with its tributaries, drains most of the Lesotho Highlands. After this river has crossed the Lesotho/South Africa border, it becomes the Orange River which then has its confluence with the Caledon River in the RSA in the upper reaches of the Gariep Dam.

Most of the tributaries within Lesotho will be controlled by the Lesotho Highlands Water Project (LHWP) once all the proposed phases have been developed. Phase I of LHWP, i.e. the Katse and Mohale Dams, Matsoku Weir and transfer tunnels is complete and 780 million m³/ water is transferred from these dams to the Vaal Dam in the Vaal River Catchment.

The two major dams within the Caledon catchment are the Welbedacht Dam and the Knellpoort Dam which are sources for the water supply to Bloemfontein.

The Kraai River drains from the North Eastern Cape into the Orange River, downstream of Lesotho and upstream of Gariep Dam.

The Gariep Dam, Vanderkloof Dam, Orange-Fish Tunnel, Orange Vaal transfer canal and Orange-Riet Canal system are all part of the Orange River Project (ORP).

Tributaries downstream of the Orange/Vaal confluence such as the Ongers, Sak and Fish (Namibia) Rivers are draining arid and semi-arid regions. The flows in these rivers are very infrequent and it is expected that their flows will only contribute to the Orange River's flow during periods of relative high flows in the Orange River. The individual yield contribution of these rivers to the Orange River is relatively small.

The Reserve

The Reserve is that portion of the natural flow that has to be available in a river or stream in order to sustain the aquatic ecology, and also to provide for basic human needs.

Currently a total of 288 million m^3/a is released to supply the river mouth EWR. Riverine EWRs were recently assessed at an Intermediate Level in a study by ORASECOM at selected key areas of the Orange River Basin. The implications of these EWRs on the yield of the system, including releases to the estuary will be a total reduction in the yield available for consumptive use of 722 million m^3/a . It is foreseen that the Ecological Preferred EWR can only be met once a new dam on the system comes into operation.

Current and projected water requirements

The projected total high and low growth water requirement figures for 2040 are shown in Table E1.

	Requirement in	Future requirement (2050)		
Sector	2012 (million m³/a)	High growth ⁽⁴⁾ (million m³/a)	Low growth (million m³/a)	
Irrigation	2 370	2 621	2 489	
Urban/Industrial	252	570	564	
Mining	16	34	34	
Riverine and Operational requirements	846	795	715	
Transfers not included in above given demands ⁽²⁾	780	1 217	1 105	
TOTAL ⁽³⁾	4 264	5 237	4 907	

Table E1: Total high and low growth water requirements

Notes ⁽¹⁾ The EWRs were excluded from the water users listed above and incorporated in the determination of the water availability (yield analysis) – see **Section 5.2**

⁽²⁾ Transfers from Phases 1 and 2 of Lesotho Highlands Water Project to the Vaal system. High growth assumes full Phase II transfer in place

⁽³⁾ The demands exclude non-consumptive power generation water use. Transfers to meet water requirements in the Eastern Cape (638 million m³/a in 2012) are included.

(4) WC/WDM for Bloemfontein already included in high demand projection

Water availability

Generally groundwater can be used for domestic and stock watering and supply for smaller towns supplied by well fields within the Orange River basin. The harvest potential estimates for the Upper and Lower Orange areas provide an estimate of the maximum volume of water available per surface area for sustained abstraction. It is assumed that there is adequate groundwater resources available in the basin to supply towns and communities not connected to the main surface water supply schemes. However, borehole siting should be based on scientific principles, and sound management practices need to be applied to ensure sustainability of the resource.

As far as surface water is concerned, the two large sub-systems within the study basin, the LHWP and the ORP (Gariep & Vanderkloof dams), are providing most of the available yield within the Orange/Senqu system. The historic firm yields which are available from the current systems at 2012 development level are summarised in **Table E2** below.

Sub-system	Dams	Live Storage (million m ³)	Yield (million m ³)	Remarks	
LHWP Phase I	Katse	1 517	780	Represents the system yield	
	Mohale	851			
Orango Pivor Project	Gariep	4 576	2 222	Represents the system yield	
Orange River Project	Vanderkloof	2 173	5 52 5		
	Knellpoort	131			
Caledon/Modder	Rustfontein	72		Represents the system yield	
sub-system	Welbedacht	6.6	84		
	Mockes	3.3			

Table E2: Historic Firm Yield from large dams in the system

Water Quality

The quality of surface water at any point in a catchment reflects the combined effect of many physical, chemical, and biological processes that affect water as it moves along hydrologic pathways over, under, and through the land. An assessment of the water quality of the Orange River was undertaken in order to identify water quality issues/aspects that may have an influence on the overarching planning and management of the system. The available water quality data in the study area was sourced from the Department of Water Affair's (DWA) Water Management System (WMS) database. The available Resource Water Quality Objectives (RWQOs) for the Upper and Lower Orange WMAs were collated and used to compare the instream water quality against. The results of the analysis were assessed and discussed and based on this, management actions for the water quality of the Orange River System are recommended. In addition based on an understanding of the water quality of the system, a high level qualitative assessment of the implications of the reconciliation options is presented

In terms of the water quality analysis and assessment of water quality issues undertaken, the following can be summarised in terms of the task conclusions and recommendations:

- The water quality present state analysis indicates increasing salinity (**Figure 6.4**) in the Orange River (temporal and spatial) and high nutrient concentrations that indicate the potential for eutrophic conditions throughout the catchment and a possibility of hypertrophic conditions. The evidence suggests that the high turbidity in the system is the limiting factor for algal growth.
- The high concentration of turbidity that is evident in the system specifically in the Upper Orange WMA does not appear to be a significant threat to the aquatic ecosystem based on ecological assessments that have been undertaken. However it is apparent that it must be taken into consideration in the design and management of water supply infrastructure.
- The development of an integrated water quality management strategy is required that addresses the nutrient and salinity management of the system, the refinement and adoption of the RWQOs,

the quantification of the extent of the actual and emerging problems of water pollution/water quality deterioration and the actions required for land use management.

- It is recommended that:
 - Nutrient modelling of the system be undertaken, and
 - Irrigation return flows be assessed.
- Improved and consolidated water quality monitoring of the Orange River System (surface and groundwater) is required to support effective water resource management.
- The qualitative high level assessment undertaken of the water quality implications of the reconciliation options indicates that there will be no significant impacts on the current water quality of the Orange River System. However the potential for Vioolsdrift Dam to act as a sink for nutrients and sediment and for Verbeeldingskraal Dam to capture sediments does exist. These impacts must be investigated further should these options be implemented.
- A desktop study was undertaken to identify the opportunities for re-use of treated sewage effluent from the urban areas. The current and future discharge volumes were obtained from the literature and from the municipalities. The water quality requirements for the re-use for irrigation, indirect re-use and direct re-use options are discussed. The water treatment requirements for the different re-use options are presented and the capital costs for the treatment determined. The assessment of the opportunities for re-use of treated effluent showed that currently the potential is limited. However effluent re-use could contribute to the suite reconciliation options in the future with the expected growth in the effluent volumes.

The current and future water balance

Currently there is a slight surplus in the system but the growth in water demand over the next 37 years up to 2050 will cause water shortages over time.

Polihali Dam will increase the yield of the Orange River System but the transfer to the Vaal River System will be greater than the increase in system yield, thus reducing the yield of the Orange River system. The yield created by Polihali Dam can be shared by the Orange and Vaal users for as long as the Vaal users do not need the full yield of the dam. The long term effect will be a growing water shortage as illustrated in **Figure E1**.



Figure E1: Future water balance of ORP – with LHWP Phase II and no further possible intervention scenarios

Intervention scenarios comprise the introductions over time of various combinations of reconciliation options, which can be divided into two main categories:

- Reconciliation Options that reduce the water requirements.
- Reconciliation Options that increase the water supply.

Reconciliation Options considered that reduce the water use or water requirements are:

- Water conservation and water demand management,
- Mechanism to re-allocate saved irrigation water,
- Reducing assurances of supply,
- Compulsory licensing.

Reconciliation Options considered that increase the water supply are:

- o Groundwater development,
- o Transfers in,
- o New dams,
- o Re-using sewage effluent,
- o System operating rules,
- o Rainfall enhancement,

- Removal of invasive alien plants,
- Desalination of sea water.

Options were screened at a Screening Workshop held in Kimberley on 7 February 2013 in accordance with agreed criteria.

Reconciling the water requirements with the water resource

A recommended reconciliation scenario, comprising a combination of options, has been selected in accordance with the selection criteria and a future water balance for this scenario was analysed. The scenario comprises:

• Groundwater Development

Groundwater is highly suited for small town domestic supply and in this basin should always be one of the first options to be considered before turning to a surface water option. No regional groundwater supply schemes are foreseen. It was therefore assumed that the future water deficits in the small towns will be satisfied with groundwater and therefore only surface water is shown on the water balance graphs.

• Real time monitoring at the Orange/Vaal confluence to optimise the releases from Vanderkloof Dam.

The estimated saving in operations losses is 80 million m^3/a . This intervention will be relatively inexpensive to implement and can be done quickly as it is not a labour intensive exercise. It was assumed that all telemetry will be installed and that the intervention will be operational by 2016.

• Water Conservation and Water Demand Management

The two water use sectors where WC/WDM can be successfully applied are the domestic water use sector and the irrigation sector. The contribution of water savings in the domestic water use sector will be very small relative to the total water use from the ORP, i.e. approximately 6 million m^3/a . The current irrigation water use is approximately 2 000 million m^3/a . A conservative 5% of the total irrigation water demand was taken as a possible water saving. It was assumed that the WC/WDM plan will be rolled out in 2015 and that it will take the irrigators 5 years to achieve the full water saving of 100 million m^3/a that can be made available.

• Minimum Operating Level – Vanderkloof Dam

The Vanderkloof Dam could be operated at a lowering Minimum Operating Level (MOL) and the yield of the system could increase by approximately 137 million m³/a. The current minimum operation level is 1 147.8 m amsl and it is proposed to lower it to 1 111.0 level. The new proposed minimum operating level is below the irrigation outlets and to continue to supply for irrigation, water would be abstracted from the right bank silt outlet. A pump station will be required to pump the water into the irrigation canal which supplies water to Ramah and Orange-Riet canals. Lowering the MOL would mean that ESKOM would not be able to generate hydropower for some limited periods.

The future water balance of the selected scenario is shown in Figure E2



Figure E2: Water balance with WC/WDM, real time monitoring and Vanderkloof Dam low level storage

This scenario assumed that the current EWR releases are maintained throughout the planning period. Initial preliminary results from EWR studies commissioned by ORASECOM indicated that the Ecological Preferred EWR requires additional releases from the ORP, reducing the available water by 434 million m^3/a , i.e. a total of 722 million m^3/a . A further reconciliation scenario was formulated where the Ecological Preferred EWR is implemented and it was shown the following two additional interventions are needed:

Vioolsdrift Dam

The dam at Vioolsdrift is needed for two purposes, i.e. to regulate the river flow and to increase the yield. The water loss that can be saved if Vioolsdrift is used as a regulating dam is 120 million m^3/a , and this is then available from Vanderkloof Dam. By utilising the remaining storage capacity in the dam, a further yield increase of 192 million m^3/a can be achieved. The additional total benefit of Vioolsdrift Dam will therefore be 312 million m^3/a . A dam with a full supply level of 210 mamsl and 510 million m^3 storage was found to be the optimum size. Any larger dam would not help meet the demand because the downstream demands would all have been met.

• Gariep Dam Raising

Among all the dam development options in the Upper Orange WMA, raising Gariep Dam by 10m and Verbeeldingskraal Dam was found to be economically the preferred two options. The URV for the combination of options that includes the raising of Gariep is of R0.31 m^3 , at 8% discount rate for a yield increase of 350 million m^3/a . The combination of options that includes

Verbeeldingskraal Dam as an alternative to the raising of Gariep produced a URV of R0.29 at 8% discount rate and relates to a yield increase of 230 million m^3/a in the context of the combined system.

The envisaged 10m raising of Gariep Dam would have social impacts since the town of Bethulie will have to be substantially rebuilt above the area that would be at risk of flooding. People in Bethulie will have to be relocated. Despite the associated mitigation costs, the raising of Gariep Dam was still one of the most economical options. The scenario where the Ecological Preferred EWR is implemented in 2025 is shown in **Figure E3**.



Figure E3: Vioolsdrift Dam and the raising of Gariep Dam are needed if the ecological preferred EWR needs to be operationalised

The water balance for the combination of options that includes Verbeeldingskraal Dam is given in **Figure E4**. Due to the lower yield produced by Verbeeldingskraal Dam, this option will not be able to maintain a positive water balance over the entire planning period, and deficits are expected to occur from 2037 onwards. The Verbeeldingskraal combination of options however significantly reduce the total evaporation losses from the Orange System in comparison with the raised Gariep combination of options, and resulted in significantly higher spills from Vanderkloof Dam, which will be to the advantage of the environment and the yield generated from Vioolsdrift Dam.



Figure E4: Vioolsdrift Dam and Verbeeldingskraal Dam are needed if the ecological preferred EWR needs to be operationalised

Actions required

A number of short term actions are required. They are:

- Complete the verification process in the Upper Orange and start the validation and verification process in the Lower Orange. Determine the increase in lawful and unlawful irrigation.
- Obtain confirmation that Polihali Dam will be utilised as a shared resource between the Vaal and Orange River systems.
- Conduct a study on the level of environmental protection weighed up against the socio-economic implications to establish whether a reduced EWR compared to the preferred ecological EWR, 2013 will suffice.
- Develop an Integrated Water Quality Management Strategy to ensure that available water resources remain fit for use.
- Interact with Water User Associations and Irrigation Boards, not yet transformed into WUA re lowering the assurances of supply.
- Develop a WC/WDM plan for each scheme under the ORP. These plans need to be ready for implementation by 2015.
- Determine the extent of water savings which can be made available through WC/WDM. Also develop a mechanism to re-allocate the saved water.

- Implement the real time monitoring of the Vaal River and Orange River flows downstream of Bloemhof and Vanderkloof dams as soon as possible, as this option is regarded as a quick win.
- Notify the co-basin states of the possible interventions.
- Initiate negotiations with Namibia on Vioolsdrift Dam.

The following medium to long-term actions is required:

- Commission a bridging study on the utilisation of the Vanderkloof Dam lower level storage. Negotiate with all affected stakeholders to define and agree on the appropriate institutional arrangement. Then proceed with the design and implementation of the pumping station and pipelines for pumping water from the reduced minimum operating level of Vanderkloof Dam into the existing Oranje Riet canal.
- Initiate a feasibility study for Vioolsdrift Dam.
- Commission a pre-feasibility study for choosing between the raising of Gariep Dam and the Verbeeldingskraal Dam
- The feasibility study for the raising of Gariep Dam or Verbeeldingskraal Dam should commence, after the completion of the pre-feasibility study mention above, assuming that the option is still needed when the final decision on the desirable EWR was taken.

Note:

Eskom prepared a brief report which was received almost at the study closure. This report provides details on hydro-power related impacts on two of the proposed intervention options.

- Vanderkloof Dam low level storage
 - Gariep Dam raising

It is recommended that the Eskom report be taken into consideration during the feasibility study for the Raising of Gariep Dam/Verbeeldingskraal Dam as well as when the Bridging Study is commissioned to proceed with the implementation of the option to utilise the Vanderkloof Lower Level Storage. The Eskom report is included in Appendix D of the Report "Review of Screened Options and Cost Estimates" Report no. P RSA D000/00/18312/9

The Orange Reconciliation Strategy in a Nutshell

The following measures are envisaged for the Orange River system (South African portion) to maintain a water balance between the water needs and availability up to the year 2050:

- (i) Water required to supply the current and future social and economic activities as well as supporting the transfer to the Vaal River system, will have to come from within the Orange/Senqu basin. It was found that transferring water from a neighbouring basin (e.g. Mzimvubu measures) will be too expensive.
- (ii) The existing EWR needs to be maintained and to avoid immediate large negative socioeconomic implications additional releases towards an alternative EWR can only be implemented as soon as a new dam is commissioned. Further optimisation of the EWR in combination with the proposed augmentation options is recommended. That is to achieve an acceptable balance between protection of the ecology and use of water for socio-economic purposes.
- (iii) Groundwater, if available, should be prioritised as the first choice to augment the water resources of towns and communities located far from the Orange River.
- (iv) All water requirements can be balanced by availability through the implementation of the following measures:
 - Shared utilisation of LHWP Phase II between the Vaal River and Orange River systems is an essential measure to postpone large capital expenditure that would otherwise be required at the same time Polihali Dam become operational;
 - Plan and implement WC/WDM in the domestic and irrigation water use sectors. Targeted savings of 6 million m³/a for the domestic/industrial water use sector (excluding Bloemfontein) and 5% of total water use in the irrigation water use sector need to be achieved not later than 2020;
 - The introduction of a mechanism whereby water, saved through water use efficiency, especially in agriculture, can be made available to other water users in the system;
 - Limit operational losses through real time monitoring of river flows in the Orange and Vaal rivers to maximise the beneficial use of the spillages from the Vaal River System target implementation date 2016, and
 - Utilising a greater portion of Vanderkloof Dam's storage capacity by lowering the minimum operating level in the dam. This measure will require pumping infrastructure which has to be in place by 2022.
- (v) If a decision is taken to implement the Ecological Preferred EWR during this planning horizon, the following actions are also required sooner:
 - Commission Vioolsdrift Dam at the decided date for alternative EWR implementation, and
 - Creating additional yield in the system by raising Gariep Dam by 10m or by building the Verbeeldingskraal Dam. The implementation date of either of these options will be dependent on the implementation date of the Ecological Preferred EWR, by approximately 2026.

- (vi) Investigating further management measures, such as lowering the assurances of supply, eliminating unlawful water use and eradicating invasive alien plants in the Kraai River catchment.
- (vii) Hold negotiations with WUA and Irrigation Boards to agree on appropriate assurances of supply for irrigated agriculture.
- (viii) Initiate a process to decide what the desirable EWR should be for the river system.

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

Final Reconciliation Strategy (July 2014)

1 INTRODUCTION

1.1 BACKGROUND

The Department of Water Affairs (DWA) has identified the need for detail 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 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). A Reconciliation Strategy has already been developed for this area – (DWA, 2012b). 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 I 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 II of the LWHP comprising of Polihali Dam and connecting tunnel to Katse Dam is in its planning stages and is expected to be in place by 2023. When a significant portion of the yield of the Polihali Dam is being transferred to the Vaal River System, it will reduce the yield of the Orange River System and result in a negative water balance in the Orange River, requiring a yield replacement option in the Orange River.

This description illustrates the complex assortment of interdependent water resources and water uses which spans across various international and institutional boundaries that were 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. Water balances and demand projections were however extended to 2050 to obtain some indication of what can be expected in the next 10 years, as this resource might by then be fully utilised. 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 A.1** of **Appendix A** (Map of study area), the study focused 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. The Senqu River originates in the highlands of Lesotho, with sub-catchments in Botswana in the northern 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 does not form part of the study area. However, strategies developed for the Vaal River System that impacts on the Orange River, were taken into account as well as the contribution of flows from the Vaal into the Orange for selected Integrated Vaal system scenarios.

As an international resource, shared by four countries any developments, strategies or decisions taken by any one of the countries that influences the water availability or quality in South Africa must be taken into account and forms part of this study. The opposite is also applicable. If this strategy leads to plans for 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 in South Africa. The Caledon and the Orange (called the Senqu River in Lesotho) rivers have their confluence upstream of the Gariep Dam.

Other prominent 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 which 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 carried out for the Greater Bloemfontein Area i.e. Water Reconciliation Strategy Study for Large Bulk Water Supply Systems: Greater Bloemfontein Area, (DWA, 2012). The recommendations of this strategy are also 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 directly influences the water availability in the study area and is therefore separately described in Sections 2.4.1, 4.1.1 and referred to in various sections where appropriate, despite the fact that it is situated in another country.

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 A.1 in Appendix A**). It should be noted that the DWA recently proposed that the two WMAs are managed as a single unit.

1.4 PURPOSE OF THE REPORT

This is the finalised reconciliation strategy after a first order reconciliation strategy which was prepared based on the available information collected at an early stage of the study. This report contains a water balance with interventions scenarios that provides possible solutions to make sufficient water available for the planning period up to the year 2050.

The report is structured as follows:

- **Chapter 1** (Introduction), describes the rationale for the study, gives general background information and an overview of the study procedure.
- **Chapter 2** (Context of the study and System Description), presents how the study relates to prevailing international, national as well as other parallel processes. This chapter also describes the system and its main components.

- **Chapters 3** and **4**, describes the water needs and respectively deals with the Reserve (Basic Human Needs and Ecological Water Requirements) as well as the current and projected future water requirements.
- In **Chapter 5**, the groundwater and surface water availability is presented, also providing a summary of the yield analysis assumption and results for the scenarios that were analysed.
- The water quality assessment is presented in **Chapter 6** as an overview of the water quality situation in the Orange River System.
- The current and future water balances for the situation where no interventions are implemented are discussed in **Chapter 7**. These serve as motivation why further interventions are required in the system.
- The possible intervention options and scenarios (both demand and supply side option) are described in **Chapter 8**. In this chapter information on the costs (economic comparison), environmental screening, international obligations and water availability are synthesised to formulate several motivated reconciliation scenarios consisting of different combinations of interventions.
- The outcome (reconciled water balances) of the scenarios are presented in **Chapter 9** with the focus on the future water balance graphs with relevant commentary on each scenario.
- All previous chapters are distilled into the reconciliation strategy, as reflected in **Chapter 10**, "Orange Reconciliation Strategy in a Nutshell".
- Relevant Risk and Uncertainties, Implementation Arrangement and Recommendation for Further Investigation are contained in **Chapters 11**, **12** and **13** respectively.
- Finally, the appropriate references are presented in **Chapter 14**.

1.5 STUDY PROCEDURE

The study is anchored by technical investigations and stakeholder engagement processes that are intertwined. **Figure 1-1** illustrates the flow of the processes.

The technical process started with a literature survey and review of current information with the Summary Report of previous and current studies as deliverable, DWA, 2013a.

The Preliminary Screening of Options was undertaken at a screening workshop which was held on 7 February 2013 where a list of possible reconciliation options were evaluated by the Study Steering Committee to define the shortlist of options that was investigated further.

The next three steps of the technical process, i.e. baseline evaluation, investigation of reconciliation options and assessment of environmental impacts all led to the development of the preliminary reconciliation strategy. The gaps in the preliminary reconciliation strategy were then investigated and the reconciliation options were refined.

Final Reconciliation Strategy Report



Figure 1-1: Technical Studies and Public Participation Process

The development of this Final Reconciliation Strategy is the last step in the technical process.

The reports which support the two main deliverables, i.e. the preliminary and final strategies, are the following:

- Inception Report;
- Literature review report (summary of current and previous studies|);
- Screening workshop proceedings report;
- Report on international obligations regarding water allocations;
- Current and future water requirements and return flows report;
- Report on urban water conservation and water demand management;
- Irrigation water requirements, value of irrigation water and the potential savings in water use through implementing water conservation and water demand management report;
- Surface water hydrology and system analysis report;
- Report on water quality and the potential for water re-use;
- Report on possible development interventions, their costs, Unit Reference Values (URVs) as well as social and environmental implications;
- Reserve requirement scenarios and scheme yields report;
- Preliminary reconciliation strategy report;
- Final reconciliation strategy report, and
- Executive summary report.

2 CONTEXT OF STUDY AND SYSTEM DESCRIPTION

2.1 INTERNATIONAL OBLIGATIONS

The Orange River is shared by four independent watercourse states.

Consequently, the reconciliation strategy must be implemented within a mutually acceptable framework of international law, comprising international agreements and Treaties that are recognised by each state.

Both multi-lateral and bi-lateral Treaties are important.

The aspects of the Treaties that have a bearing on the implementation of the reconciliation strategy are presented in the following sections. More information on international aspects is contained in the report on "International Obligations regarding Water Resources", DWA, 2013b.

2.1.1 Key Treaties, Agreements and Policies

Convention on the Law of the Non-navigational Uses of International Watercourses Adopted by the General Assembly of the United Nations on 21 May 1997 (UN, 1997)

This major international convention provides a comprehensive framework for international cooperation in the management of shared water courses. Its key provisions have all been taken up in the SADC Revised Protocol on Shared Water Courses.

The Law on Transboundary Aquifers (UN Resolution 11 December 2008) (UN, 2008)

The Law on Transboundary Aquifers reflects the Law on Non-navigational Uses of International Watercourses.

The Law of Transboundary Aquifers also provides for equitable and reasonable utilisation; for the obligation not to cause significant harm, for the obligation to cooperate; and for the protection, preservation and management of the ecosystem.

Convention on wetlands of international importance especially as waterfowl habitat (The Ramsar Convention on Wetlands), 1971 as amended 1982 and 1987 (RAMSAR, 1971)

Article 2 provides inter alia that each Contracting Party shall designate suitable wetlands within its territory for inclusion in a List of Wetlands of International Importance, hereinafter referred to as "the List"; and that Wetlands should be selected for the List on account of their international significance in terms of ecology, botany, zoology, limnology or hydrology. In the first instance wetlands of international importance to waterfowl at any season should be included.

The Orange River Mouth was placed on the list on 28 June 1991.

Article 5 provides that the Contracting Parties shall consult with each other about implementing obligations arising from the Convention especially in the case of a wetland extending over the territories of more than one Contracting Party or where a water system is shared by Contracting Parties. They shall at the same time endeavour to coordinate and

Final Reconciliation Strategy Report

support present and future policies and regulations concerning the conservation of wetlands and their flora and fauna.

SADC Revised Protocol on Shared Water Courses, 7 August 2000 (SADC, 2000)

The SADC Revised Protocol Article 1 defines "Significant Harm" as meaning non-trivial harm capable of being established by objective evidence without necessarily rising to the level of being substantial.

Article 3 sets out the general principles including:

Sub-article 3.2 which provide that the utilisation of shared watercourses within the SADC Region shall be open to each Watercourse State, in respect of the watercourses within its territory and without prejudice to its sovereign rights, in accordance with the principles contained in this Protocol. The utilisation of the resources of the watercourses shall include agricultural, domestic, industrial, navigational and environmental uses.

Sub-article 3.7(a) Watercourse States shall in their respective territories utilise a shared watercourse in an equitable and reasonable manner;

Sub-article 3.8 Utilisation of a shared watercourse in an equitable and reasonable manner requires taking into account all relevant factors and circumstances including:

- (i) geographical, hydrographical, hydrological, climatical, ecological and other factors of a natural character;
- (ii) the social, economic and environmental needs of the Watercourse States concerned;
- (iii) the population dependent on the shared watercourse in each Watercourse State;
- (iv) the effects of the use or uses of a shared watercourse in one Watercourse State on other Watercourse States;
- (v) existing and potential uses of the watercourse;
- (vi) conservation, protection, development and economy of use of the water resources of the shared watercourse and the costs of measures taken to that effect; and
- (vii) the availability of alternatives, of comparable value, to a particular planned or existing use.

The weight to be given to each factor is to be determined by its importance in comparison with that of other relevant factors. In determining what is an equitable and reasonable use, all relevant factors are to be considered together and a conclusion reached on the basis of the whole.

Article 3.10(a) provides that State Parties shall, in utilising a shared watercourse in their territories, take all appropriate measures to prevent the causing of significant harm to other Watercourse States.

Article 4 provides for planned measures, information concerning planned measures and the notification concerning planned measures with possible adverse effects.

Article 5 provides institutional mechanisms for implementing this Protocol including Shared Watercourse Institutions.

Article 6 provides for shared water course agreements.

SADC Regional Water Policy 2005 (SADC, 2005)

While not a binding treaty, the SADC Regional Water Policy does provide a number of useful policy statements that have been agreed by the SADC members subsequently to the Revised Protocol which it reflects.

The policy statement for Water Resources Development and Management is particularly relevant to this Reconciliation Strategy and provide guidance on:

River Basin Approach:

- Member States will adopt a river basin or watercourse approach in the planning, development and management of water resources. This applies in particular to shared watercourses.
- (ii) Watercourse States will prepare and implement river basin development plans in a holistic and integrated manner, with the involvement of stakeholders to achieve equitable and efficient utilisation.
- (iii) The planning, development and management of watercourses, particularly in shared watercourses will consider the integrated use of surface and ground water resources, the re-use of water, proper pollution management and the provision of environmental requirements.
- (iv) Water resources allocation and utilisation will be based on equitable and reasonable mechanisms through negotiations between watercourse States.
- (v) Member States will ensure that major water uses in watercourses, particularly in shared watercourses will be regulated through authorisations such as a system of permits.

Integrated Planning:

- (i) Planning, development and management of water resources in the region should be based on the principles of IWRM and shall take full cognisance of the crosscutting nature of water.
- (ii) Watercourse States shall promote joint planning and implementation of water resources developments within their shared watercourse and transparently notify and/ or engage other Watercourse States in a dialogue, where such States are not proponents of the project.

Water Demand Management:

(i) When planning the development of water infrastructure and services, Member States or river basin organisations shall aim to utilise existing capacities more efficiently as part of the process of augmenting water supply. (ii) Water Demand Management (WDM) will be pursued by Member States as a fundamental requirement for integrated planning and management of water resources, particularly in shared watercourses.

Alternative Sources of Water

Member States will promote rainwater harvesting and alternative sources of water such as desalination, re-use of water, recycling and reclamation. Relevant research in this regard should be promoted as and where appropriate.

Dam Development and Management

- (i) Integrated planning, development and management of dams will be promoted so as to optimise the use of the water resources, maximise derived benefits (such as hydropower, tourism, flood control, irrigation, water supply) and take both positive and negative externalities into account.
- (ii) SADC shall encourage the participation of all stakeholders in decision-making processes for dam development and, where appropriate, with adequate facilitation and empowerment of vulnerable groups to ensure their effective involvement in decision-making.
- (iii) Watercourse States will negotiate on operating rules for dams on shared watercourses so as to optimise the socio-economic and environmental benefits in an equitable manner.

Affected Communities

- (i) Watercourse States shall promote the development and implementation of water infrastructure projects through a participatory process, especially of affected communities.
- (ii) Member States will put in place proper legislation to ensure/provide for compensation and resettlement of affected communities, so that they will not be worse off as a result of the project.

ORASECOM Agreement 3 November 2000 (ORASECOM, 2000)

In terms of this agreement, the Governments of the Republic of Botswana, the Kingdom of Lesotho, the Republic of Namibia and the Republic of South Africa established the Orange-Senqu River Commission as an international organisation with international legal personality and capacity to enter into international agreements.

Article 5 provides for the functions of the ORASECOM Council are to take all measures required to make recommendations, or to advise the Parties, on the following matters:

- Measures and arrangements to determine the long-term safe yield of the water sources in the River System;
- the equitable and reasonable utilisation of the water sources in the River System to support sustainable development in the territory of each Party;

- the investigations and studies conducted separately or jointly by the Parties, with regard to the development of the River System, including any project or the construction, operation and maintenance of any water works;
- the extent to which the inhabitants in the territory of each Party concerned shall participate in respect of the planning, development, utilisation, protection and conservation of the River System, as well as the harmonisation of policies in that regard and the possible impact on the social, cultural, economic and natural environment;
- the standardised form of collecting, processing and disseminating data or information with regard to all aspects of the River System;
- the prevention of the pollution of water resources and the control over aquatic weeds in the River System;
- contingency plans and measures for responding to emergency situations or harmful conditions resulting from natural causes such as droughts and floods, or from human conduct such as industrial accidents;
- the regular exchange of information and consultation on the possible effects of planned measures;
- measures with a view to arriving at a settlement of a dispute between two or more of the Parties; and
- such other matters as may be determined by the Parties.

Article 7 provides for the obligations of the parties which include:

- The Parties shall give their full co-operation and support to the implementation of this Agreement as well as the recommendations of the Council;
- The Parties shall, in their respective territories, utilise the resources of the River System in an equitable and reasonable manner with a view to attaining optimal and sustainable utilisation thereof, and benefits therefrom, consistent with adequate protection of the River System. The term "equitable and reasonable" shall be interpreted in line with the Revised Protocol on Shared Watercourses in the Southern African Development Community (SADC) Region;
- The Parties shall, in utilising the resources of the River System in their territories, take all appropriate measures to prevent the causing of significant harm to any other Party. The term "significant harm" shall be interpreted in line with the Revised Protocol on Shared Watercourses in the Southern African Development Community (SADC) Region;
- The Parties shall exchange available information and data regarding the hydrological, hydrogeological, water quality, meteorological and environmental condition of the River System; and
- A Party planning any project, programme or activity with regard to the River System which may have a significant adverse effect upon any one 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 with regard thereto. [Sub-articles 7.5 to 7.16 prescribe in detail the process of notifying and responding to a notification of a planned project, programme or activity.

Treaty on the Lesotho Highlands Water Project between the Government of the Republic of South Africa and the Government of the Kingdom of Lesotho, 24 October 1986 (Lesotho RSA, 1986)

The Treaty provides for the establishment, implementation, operation and maintenance of the Lesotho Highlands Water Project. The project stores water in the upper reaches of the Senqu River in Lesotho, generates electricity in Lesotho, and the Treaty provides for the eventual delivery of 70 m³/s (2 208 million m³/a in 2020) to a designated outlet point in the Vaal River basin.

The Treaty provides for Royalty payments from South Africa to Lesotho as well as for the establishment of the Trans Caledon Tunnel Authority (TCTA), the Lesotho Highlands Development Authority and a Joint Permanent Technical Commission (JPTC) which is now the Lesotho Highlands Water Commission (LHWC).

The Agreement on the Establishment of the Vioolsdrift and Noordoewer Joint Irrigation Scheme on the lower Orange River (RSA Nam, 1992)

This governs the management of this joint irrigation scheme which straddles the Orange River.

Memorandum of Understanding (MoU) for feasibility study to transfer water from Lesotho to Botswana (Lesotho Botswana MoU, 2012)

In terms of this MoU, the two countries have agreed to carry out a Feasibility Study into options for transfer of water from Lesotho to Botswana. It is not clear how South Africa has been involved in the discussions to date.

2.1.2 Conclusions

Water resources allocation must be based on the equitable and reasonable utilisation of the water sources in the shared watercourse by each watercourse state.

Specified factors/criteria including social, economic and environmental needs; the population dependent on the shared watercourse; the effects of the use or uses of a shared watercourse in one Watercourse State on other Watercourse States; as well as existing and potential uses must be taken into account when agreeing what is equitable and reasonable. All relevant factors are to be considered together and a conclusion reached on the basis of the whole.

ORASECOM Council is mandated to make recommendations, or to advise the Parties, on the safe yield of the river and on the equitable and reasonable utilisation of the water sources in the River System to support sustainable development in the territory of each Party.

States must adopt a river basin or watercourse approach in the planning, development and management of water resources and must follow IWRM principles.

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Water Demand Management (WDM) and co-use of ground and surface water are fundamental requirements for integrated planning and management of water resources.

Watercourse states should consult with a view to arriving at mutually agreeable measures and methods to prevent, reduce and control pollution.

The Orange River mouth is a listed Ramsar wetland site and the basin states should consult on how to protect this wetland.

All parties to the ORASECOM Agreement must be notified of any planned development that will adversely affect another watercourse state. The notification and response procedures are specified.

The planned development must not cause significant harm to another watercourse state.

2.1.3 Implications for the Strategy Development

Namibia could make the argument that if the dam was built partly on their territory then they could ensure their equitable and reasonable use. Namibia may for this reason favour a lower Orange River option.

Lesotho could make the argument that it has already concluded the LHWP Treaty with South Africa and that South Africa is thus morally obliged to develop the fully envisaged 70 m³/s delivery project before considering other options. The development of LHWP is a large economic contributor to Lesotho GDP as is the Royalty flow. However, there are two counter-arguments: a) the Treaty does make provision for the LHWP to only be partly developed and provides Royalty payment calculations that would be applicable in such a scenario, and b) Lesotho's interests cannot be served above the interests of optimally developing the watercourse as a whole in the interests of all watercourse states.

Botswana has a MoU with South Africa and Lesotho that envisages a supply out of the LHWP. Depending on the outcome of the feasibility study, Botswana might favour further LHWP developments. But other options considered in this reconciliation study may provide Botswana with a cheaper supply.

However, the most important international law principles are those of:

- Equitable and reasonable utilisation; and
- Not causing significant harm.

Given the circumstances of the Orange River, it could be argued that international law is unlikely to prevent any of the options under consideration from being developed, provided that:

- The watercourse states adopt a river basin or watercourse approach in the planning, development and management of the water resources of the Orange, and
- All parties are guaranteed their equitable and reasonable utilisation reflective of their population, their social needs, their environmental needs, and their existing entitlements, as agreed through negotiation under the umbrella of ORASECOM,

2.2 NATIONAL WATER RESOURCE STRATEGY

The National Water Act, 1998 (Act 36 of 1998) (National Water Act, 1998) places an obligation on the Minister of Water Affairs to establish a National Water Resource Strategy (NWRS), (Section 5 of the NWA). Section 9 of the same act requires that a Catchment Management Agency (CMA) must establish a Catchment Management Strategy (CMS). This CMS must be in harmony with the NWRS. In the absence of a CMA, the Department is responsible for managing a Water Management Area (WMA) and it was for this reason that the Department developed an Internal Strategic Perspective (ISP) for each WMA approximately a decade ago. The main purpose of the ISP was to establish synergy between DWA National Water Resource Planning in Head Office and the respective Regional Offices. The ISPs, similar to the CMSs, also had to be in line with the NWRS.

The first NWRS was established in 2004 and the second edition of the NWRS has recently been established.

An important aspect that has been written into the NWRS (2nd Edition) is the consolidation of certain WMAs to be managed by a single CMA. It will affect the two Orange River WMAs since WMA 13 (Upper Orange WMA) and WMA 14 (Lower Orange WMA) will in future be managed by one CMA.

This water reconciliation strategy by DWA will be an input to the future CMS once the agency gets established. It is important that this reconciliation strategy is also in harmony with the NWRS (2nd Edition).

2.3 PARALLEL INITIATIVES

Several studies on the Orange River basin or part thereof are currently, or will soon be running in parallel with the Orange Reconciliation Study and include the following:

- Upper Orange Validation/Verification Study (DWA);
- Orange-Senqu strategic Action Programme: Environmental flows Project (ORASECOM UNDP-GEF);
- Watern Quality Calibration study (DWA);
- Proposed study for the development of an integrated Water Quality Management Plan for the Orange River (DWA);
- Vaal River System Classification Study (DWA);
- Acid Mine Drainage Feasibility Study (Vaal) (DWA);
- Development of Water Conservation and water demand management strategy for the Fish to Tsitsikamma Water Management Area (Eastern Cape) (DWA);
- Orange River Integrated Water Resource Management Plan (Phase 3) by ORASECOM, and
- Maintenance of the Vaal River Reconciliation Study (DWA).

Most of the work on the validation component of the "Upper Orange Validation/Verification Study" was completed and provisional results are incorporated in this Reconciliation Strategy Report. This data focused on the qualifying period approximately 1998/1999 development level. In general the irrigation data representative of the qualifying period compared well with data from the recent annual operating analysis for the Orange River as well as with data from the ORASECOM IWRM Plan Study Phase II updated hydrology task.

Supplementary information provided by the validation study team estimated that the irrigation water use in the year 2012 could be as much as 145million m³/annum higher than what was validated for the 1998/1999 period. (It is important to note that no ground verifications was carried out on the 2012 water use estimates and still need to be undertaken as part of the verification of lawful water use that is underway). The potential implication of such an increase is considered as a risk and discussed further in **Section 9.2.7**.

The most recent environmental flow requirements were received from the Environmental flow Project by ORASECOM UNDP-GEF and incorporated as a scenario as discussed in **Section 9.2.3**.

The study to develop the Integrated Water Quality Management Plan for the Orange River was delayed and is only now in the process to be advertised for tendering purpose. The intention is that the calibrated WQT salinity model will be applied during the development of the water quality management plan while considering the recommendations from the Reconciliation Strategy.

The Vaal River System Classification Study was completed and the recommended EWRs were included for the purpose of this study.

The latest information on the proposed management of mine water decants/discharges were obtained from the Acid Mine Drainage Feasibility Study and incorporated in the scenarios analysed that are presented in subsequent sections in the report.

Water demands within the Eastern Cape system were aligned with those given in the Fish to Tsitsikamma Water Conservation and Water Demand Management Strategy study. Recommendations for a review of the transfer volumes and possible integration of the Orange and Eastern Cape system models are described in **Section 11**.

The study by ORASECOM to develop an Orange River IWRM Plan is still in its initial stages. Updated data on the Namibian demands along the Lower Orange could however be obtained and utilised in the Reconciliation study.

The latest expected growth in Vaal system water requirements and dates when transfers from Polihali Dam is required and commissioned, were obtained from the Maintenance of the Vaal River Reconciliation study.

All the above studies were used in the refinement of this Final Reconciliation Strategy.

2.4 SYSTEM DESCRIPTION

This section provides a general description of the water resource systems, commencing with the most upstream Senqu River Catchment, followed by the Upper and Lower Orange river catchment areas.

2.4.1 Current Status of the Senqu River Catchment

The Lesotho Highlands Water Project, Phase 1A (Katse Dam) and Phase 1B (Mohale Dam), were completed in 1998 and 2002 respectively and comprise the following:

Phase 1A: The 185 m high double curvature arch Katse Dam on the Malibamatso tributary from which a 45 km transfer tunnel runs to Muela Power Station from where a further 38 km delivery tunnel runs to the Ash River in the Vaal River catchment from where this transfer water is flowing to the Vaal Dam.

Phase 1B: The 145 m high Mohale Dam (a concrete faced rockfill dam) on the Senqunyane tributary from where the 32 km Mohale tunnel runs to Katse Dam and the Matsoku Diversion Weir from where additional water is diverted through the 6 km Matsoku tunnel into Katse Dam. The Katse and Mohale Dams are shown on **Figure 2-1**.



Figure 2-1: Katse and Mohale Dams on tributaries of the Senqu River

Currently 780 million m³/a water is transferred from the Mohale and Katse Dams to the Vaal Dam in the Vaal River Catchment.

2.4.2 Current Status of the Upper Orange River

The Senqu River in Lesotho with its tributaries drains most of the Lesotho Highlands. After this river has crossed the Lesotho/South Africa border, it becomes the Orange River which

then has its confluence with the Caledon River in the RSA in the upper reaches of the Gariep Dam.

Most of the tributaries within Lesotho will be controlled by the Lesotho Highlands Water Project (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 Gariep Dam.

The two major dams within the Caledon catchment are the Welbedacht Dam (see



Figure **2-2**) 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 (Vaal River tributary) to Bloemfontein. Water is also supplied from this system to Botshabelo, Thaba Nchu, as well as the smaller towns of Wepener, Dewetsdorp, Reddersburg, Edenburg and Excelsior, which are also dependent to varying degrees on local water resources.

The two largest dams in the RSA, i.e. the Gariep and Vanderkloof Dams are situated on the main stem of the Orange River, downstream of the confluence of the Caledon River with the Orange River (see



Figure 2-2). These two dams are utilised for river flow control, flood control, hydro power generation and storage of water for urban and irrigation use.

Water is transferred from the Gariep Dam via the Orange-Fish Tunnel to support the Eastern Cape Rivers. Water is also transferred from Vanderkloof Dam to supplement the irrigation demands along the Riet River, which is a tributary of the Vaal River. The third transfer scheme comprises the transfer of water from the Orange River at Marksdrift into the Douglas Weir which is located on the downstream end of the Vaal River.

The Gariep Dam, Vanderkloof Dam, Orange-Fish Tunnel, Orange Vaal transfer canal system and Orange-Riet Canal system are all part of the Orange River Project.



Figure 2-2: Gariep and Vanderkloof Dams in the Upper Orange WMA

2.4.3 Current Status of the Lower Orange River

The Lower Orange River 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 Vaal River;
- The Ongers and Sak Rivers from the northern Karoo;
- The Molopo and Nossob Rivers from Namibia, Botswana and the Northern Cape Province north of the Orange do not contribute to the Orange River as these river beds are impeded with sand dunes; and
- The Fish River from the southern part of Namibia.

Tributaries such as the Ongers, Sak and Fish (Namibia) Rivers are draining arid and semiarid regions. The flows in these rivers are very infrequent and will only contribute to the Orange River's flow during periods of relative high rainfall. The contribution from these rivers to the firm yield of the Orange River is small.

Water is abstracted for irrigation, urban and mining use along the main stem of the Orange River at various points, and for stock watering in the Kalahari. Water is also transferred via pipelines to the Aggenys mines and to the town of Springbok.



Figure 2-3: Lower Orange main developments

2.4.4 The Eastern Cape Rivers supported by the Orange

Water is transferred from Gariep Dam on the Orange River through the 83km long Orange/Fish tunnel to a tributary of the Great Brak River (tributary of the Great Fish River) in the Eastern Cape Province where it runs into the Grassridge Balancing Dam. Water is supplied along the Great Fish River for irrigation and urban use to towns such as Cradock and Cookhouse.

From the Elandsdrift weir on the Great Fish River, Orange River water is diverted through the 46km Cookhouse tunnel, a series of canals and diversion weirs and the Darlington Dam to the water users along the Little Fish River and Sundays River, mostly for irrigation purposes, but towns such as Somerset East, Kirkwood and the Nelson Mandela Metro also receives water for urban/industrial use.

From Elandsdrift weir on the Great Fish River, water is released to the Lower Fish Government Water Scheme from where the town of Grahamstown and further irrigation land are supplied with water.

3 THE RESERVE

The Reserve is that portion of the natural flow that has to be available in a river or stream in order to sustain the aquatic ecology, and also to provide for basic human needs (BHN), in order to comply with Sections 16, 17 and 18 of the National Water Act (NWA), Act 36 of 1998. The Reserve is not a steady flow, but is a variable flow that mimics natural variations in flows in the river. The quantity that is required takes into account "normal" conditions, as well as drought conditions.

3.1 BASIC HUMAN NEEDS COMPONENT

The intention of the BHN component is to ensure that enough water is left in the resources for those communities that rely on them. However, the basic human needs can be, and usually are, met from water supply systems. Most domestic water supply in the Orange River Basin is supplied via water supply infrastructure while the rural towns rely mostly on groundwater and hence the BHN are already catered for in the domestic water requirement estimates.

As part of the Phase II ORASECOM basin wide integrated resources management plan study (**ORASECOM**, **2010**), the environmental flow requirements were determined at different sites along the Orange and Caledon rivers. This was followed up by a second study (UNDP – GEF Orange-Senqu Strategic Action Programme: Research Project on Environmental Flow Requirements in the Namibian Fish River and the Orange-Senqu River Mouth) that focused on the environmental flow requirements in the Namibian Fish River as well as the Orange River mouth environmental requirement. The results of those Studies were used in developing this Preliminary Strategy.

3.2 ENVIRONMENTAL COMPONENT

The Environmental Water Requirements (EWR) in a river is the flow and capacity required to maintain the ecosystem in a negotiated ecological condition. This condition is normally a compromise between the social, economic and ecological demands on the resource.

3.2.1 Current Ecological Water Requirements (EWRs)

Releases are currently made from Vanderkloof Dam to supply the Environmental Water Requirements (EWRs) at the Orange River mouth. These EWRs were determined as part of the Orange River Re-planning Study (ORRS) that was completed in 1996 and formed the point of departure for the formulation of the scenarios that were considered in the study (see descriptions of Scenario 1 and 2 in Sections 9.2.1 and 9.2.2 respectively).

Currently a total of 288 million m /annum is released to supply the river mouth EWR and the system is operated to supply 195.8 million m /annum at a high assurance of 99.5% (1:200 year) and the remainder at a 95% (1:20 year) level of assurance.

3.2.2 Riverine

Updated riverine EWRs were determined for the Orange River as part of the ORASECOM study "Support to Phase II ORASECOM basin wide integrated water resources management plan", ORASECOM, 2010. These assessments were undertaken at an Intermediate Level of detail at selected key areas of the Orange River Basin and a summary of the Riverine EWRs at the different sites along the Orange River is given in **Table 3-1**.



Figure 3-1: Orange River EWR Sites

Table 3-1: Summary of ORASECOM EWR results as a percentage of the natural MAR

FWR site	EWR Class	Maintenance low flows		Drought low flows		High flows		Long term mean	
EWR Sile EWR Class		(%nMAR)	million m³/a	(%nMAR)	million m³/a	(%nMAR)	million m³/a	(%nMAR)	million m³/a
Virgin MARS	1				1				
EWR 01 Hopetown	PES/REC:C	Due to the u that results i	Due to the unlikely situation that the present operation of the dam will change and the strategic use (ESKON that results in this operation, the setting of flow requirements were not undertaken						use (ESKOM)
EW/P 02 Boegoeberg	PES/REC: C	11.6	1 226.5	4.4	465.24	5.4	570.98	15.2	1 607.20
LWIT OZ DOEGOEDEIG	AEC↓: D	5.8	613.27	3.1	327.78	5	528.69	11.3	1 194.83
	PES: C	8.4	883.10	2.6	73.34	4.7	494.12	11.9	1 251.06
EWR 03 Augrabies	REC: B	17.6	1 850.31	3.4	157.37	4.7	494.12	19.2	2 018.52
	AEC↓: D	4.1	431.04	2.2	231.29	4.4	462.58	9	946.18
	PES: C	6.3	651.11	0.9	35.16	4.2	434.07	8.9	919.82
EWR 04 Vioolsdrift	REC: B/C	10.1	1 043.85	1.3	134.36	4.2	434.07	12.2	1 260.88
	AEC↓: D	3.1	320.39	0.8	31.25	3.8	392.73	6.9	713.12
EWR C5 Upper Caledon	PES/REC: C/D	13.8	7.85	5.8	3.30	11.4	6.49	26	14.80
EWR C6 Lower Caledon	PES/REC: D	8.8	118.62	0.3	3.40	10.5	141.54	20.1	270.94
	AEC↑: C	15.5	208.93	2.2	29.66	13.1	176.58	26.1	351.82
	PES/REC: C	11.4	77.81	0	0.00	8.4	57.33	18.1	123.53
EWR K7 Lower Kraai	AEC↑: B	16.5	112.61	1.2	7.70	8.4	57.33	21.8	148.79
	AEC↓: D	5.1	34.81	0	0.00	7.1	48.46	12.9	88.04

Notes: The EWR site names presented in in column 1 (e.g. "EWR C5") were adopted from ORASECOM, 2010.

3.2.3 Alternative Estuarine, Fish River and Lower Orange EWR

Further environmental flow investigations were conducted at the same time the reconciliation strategy study was developed under the ORASECOM study with the title "UNDP-GEF Orange-Senqu Strategic Action Programme: Research Project on Environmental Flow Requirements of the Fish River and the Orange-Senqu River Mouth". The focus of this study was on the ecological water needs of Orange River Mouth, the Fish River in Namibia as well as the Orange River downstream of the confluence of the Fish with the Orange River.

Inspection of these result highlighted that a substantial reduction in the yield (usable water) of the ORP will occur should the ecologically preferred EWR scenario from the UNDP-GEF study be implemented. It was therefore decided to formulate and prepare water balances for the revised EWR as an alternative to the current EWR that is presented in **Section 3.2.1**. For discussion purposes this alternative EWR scenario is named "Ecological Preferred EWR 2013" in the remainder of this document.

This "Ecological Preferred EWR 2013" (EPEWR 2013) encompassed the following:

- Releases were made from Vanderkloof Dam during the summer months (November to April) to supply the minimum EWR requirements specified at EWR site 3 at Augrabies;
- The proposed Vioolsdrift Dam (See **Figure 3.1** located just upstream of EWR site 4) is in place to regulate the flow in the downstream river reach; and
- Releases were made from Vioolsdrift Dam according to a release rule that achieves the intended estuary conditions.

Note that both the release rules at Augrabies and downstream of the proposed Vioolsdrift Dam are variable requirements (not fixed monthly requirements) defined by flow distributions for the relevant months.

Yield analysis showed that making releases according to the Ecological Preferred EWR - 2013, resulted in a 722 million m^3/a reduction in yield. Representing an increase of 434 million m^3/a above the current EWR releases of 288 million m^3/a .

3.2.4 Whole Basin

Information on the ecological water requirements for the Integrated Vaal River System (IVRS) was obtained from the study, "Classification of Significant Water Resources in the Upper, Middle and Lower Vaal Water Management Areas", (DWA, 2012a). The purpose of the study was to set the Management Classes for the water resources by applying the seven step process as defined by the National Water Resource Classification System. The overarching aim of classification is to find the desired balance between the level of ecological protection and the utilisation of the resource for socio economic development.

Results from the study indicated that there are two river reaches, the Wilge River downstream Sterkfontein Dam and the Vaal River downstream of Douglas Weir, where the implementation of the flow regimes to achieve the Recommended Ecological Categories (REC) is estimated to reduce the Historical Firm Yield of the IVRS by 99 million m³/a. (Note that the river reach downstream of Douglas Weir is the portion of Vaal River immediately upstream of the confluence

with the Orange River). The operationalization of these EWRs will entail a phased implementation approach, where the first step is to optimise the release rules between Sterkfontein Dam and Vaal Dam, with the aim to further minimise the reduction in the system yield. Due to the prevailing pressure on the water resources of the Vaal River Systems the implementation of the EWR downstream of Douglas Weir will have to be phased and coincide with the implementation of future interventions.

The environmental flows to be released from the LHWP main structures are the product of negotiations between the Lesotho Highlands Development Authority (LHDA), the governments of Lesotho, South Africa, Namibia, the World Bank and various other interested and affected parties. The agreed environmental flows vary between 11.4% and 14.4% of the mean annual runoff at the specific site. These requirements were implemented and are currently released from Katse and Mohale dams.

As part of the Polihali Dam feasibility study an EWR was determined for planning purposes and is applied in all the scenarios where Polihali Dam was considered as an augmentation option.

3.2.5 Summary of EWR assumptions for scenario formulation

In summary the yield analysis results and water balance scenarios presented in subsequent section incorporate EWR releases as follow:

- All scenarios applied the specified releases from Katse, Mohale and Matsoku dams;
- Scenarios where Polihali Dam was implemented applied the feasibility study EWR;
- The current release for the estuary of 288 million m³/a during normal years and 195.8 million m³/a during drought years were implemented to determine the existing system yield;
- The alternative, Ecological Preferred EWR 2013, were implemented along with proposed developments at different future dates. This is defined in the reconciliation scenario described in **Chapter 9**), and
- EWR releases were implemented in the analysis of each of the proposed dam options. For Knoffelfontein the EWR from the Vaal Classification Study was used and for the analysis of the possible Lesotho dams and Boskraai dams EWRs were applied by scaling the Polihali EWR in proportion to the respective Mean Annual Runoff at each location – Section 5.2.1 presents the yield results of the dam options.

All scenarios incorporated inflows from the Fish River based on the simulation results of the UNDP-GEF study described in **Section 3.2.3**. (These analyses were carried out with revised hydrology developed for the Fish River catchment as part of the UNDP-GEF study.)

4 CURRENT WATER USE AND PROJECTED WATER REQUIREMENTS

4.1.1 Current Water Use

The current water use in the irrigation, domestic, industrial, mining and power generation water use sectors for the for the Orange Senqu basin excluding the Integrated Vaal River System is shown in **Figure 4.1**. Irrigation is the main water user within the study area. The transfer to the Eastern Cape through the Orange-Fish tunnel was included as part of the demands. The only transfer showed in **Figure 4.1** is the LHWP transfer to the Vaal System supporting urban/industrial requirements in the Vaal catchment.



Figure 4-1: Total Orange Senqu demand 2012 (Vaal system excluded)

The Orange River Project (Gariep and Vanderkloof Dams) is the largest system in the Orange and supplies more almost 70% of all the water requirements in the Orange Senqu (LHWP transfer included but Vaal demands excluded) basin (Integrated Vaal excluded).

A summary of the 2012 development level demands is given in **Table 4.1** comparing the Orange River Project (ORP) demand with the total Orange/Senqu (Integrated Vaal excluded) demand. **Figure 4.2** illustrates the different components of the total demand imposed on the ORP.

Total demand 2012	Orange River Project (million m ³ /a)	Orange/Senqu (million m³/a)
Irrigation	1 989	2 366
Urban/Mining	118	268
River Requirements	615	615
Operating Requirements	180	180
Consumptive Canal Losses	51	51
Transfer (LHWP)		780
Total	2 953	4 260
EWR	288	288
Total (EWR included)	3 241	4 548

 Table 4-1: Summary of current demands (2012)



Figure 4-2: Total Orange River Project demand 2012

Irrigation is by far the largest water user within the ORP system followed by the river requirements (consisting of evaporative losses along the 1 380 km long river between Vanderkloof Dam the Atlantic Ocean) and river mouth EWR which are both environmental related requirements.

4.1.2 Transfers Out

The transfers described in this section refer to the large transfer systems taking water out of the Orange Senqu River. The largest of these is the transfer from the LHWP to the Vaal River system, in support of Vaal Dam. This is followed by the Eastern Cape transfer system, taking water from Gariep Dam and supplying water through the Orange/Fish tunnel to the Fish and Sundays rivers. This transfer is mainly in support of irrigation, but also for urban/industrial requirements of which Port Elizabeth (Algoa Water Supply Area) is the largest of the urban/industrial demand centres and the furthermost point of transfer.

The LHWP started to operate in 1998, and Phase I comprises Katse and Mohale dams, the Matsoku Diversion Weir and a series of tunnels and a hydro-power station. Water is gravitated from Katse Dam through the tunnels to Ash River from where it flows into the Wilge River then into the Vaal River and finally into Vaal Dam.

The transfer volume of 780 million m³/a is according to the agreement between the RSA and Lesotho and is transferred to South Africa every year, independent of the water situation in Vaal or the water levels in the Vaal River System. Phase II of the LHWP has already been approved by RSA and Lesotho governments for implementation. This phase comprises the Polihali Dam and connecting tunnel to Katse Dam, and uses the existing tunnels to convey water into the Ash River (See **Figure 4.3**). With Phase II in place the maximum transfer volume will be increased by an additional 437 million m³/a.

The Eastern Cape transfer system obtains its water from Gariep Dam via the Orange/Fish tunnel from where the water is released into the Fish River tributaries in the Eastern Cape. Water is distributed through a combination of canals, tunnels, balancing dams and natural river courses to irrigators and small towns to eventually reach the Port Elizabeth (Nelson Mandela Bay Metro) abstraction point near the downstream end of the Sundays River.

The target transfer volume through the Orange/Fish tunnel is based on the total scheduled irrigated area in the Eastern Cape times the quota allocated to the different irrigation areas listed under the scheme, plus the urban industrial requirements applicable to the specific year under consideration. For the year 2012 this volume was determined as 620 million m³/a, of which 577.6 million m³/a, was for irrigation and 42.4 million m³/a for urban/industrial purposes.

The total demand imposed on Gariep Dam to be supplied via the Orange Fish tunnel vary around this target volume, depending on the rainfall as well as the water quality conditions and associated dilution requirements in the Eastern Cape sub-system. Historical flow data of the transfer volumes indicate the abstraction can be as much as 25% higher than the target volume. There remains a difference of opinion between DWA and the irrigation sector whether the target volume can be exceeded. Further investigations are however needed to review the water balance of the Eastern Cape System and clarify the reasons for the historical exceedance of the target volume. To this end the investigations described in **Section 13** is recommended. The transfer volume assumed for the water balances prepared for this study did not allow for the additional losses.



Figure 4-3 : Lesotho Highlands Phase I and Phase II

A total of 4 000 hectares of additional irrigation was allocated in the early 2000 for the development of resource poor farmers in the Eastern Cape, however, none of these developments have yet taken place. The development of this irrigation will in future result in an increase in the total irrigation demands by approximately 44 million m³/a and this will have to be supplied from the Orange River System mainly via the Orange-Fish Tunnel. (See **Section 4.2.1** for assumptions on how this additional use was incorporated into the water requirement scenarios).

The Caledon Modder transfer system convey water out of the Caledon River catchment to support the water supply of Bloemfontein, Mangaung, Botshabelo, Thaba Nchu and several small towns located in the Modder and Riet River catchment.

Water is transferred from Welbedacht Dam in the Caledon River via a pipeline to Bloemfontein and to several of the smaller towns. Welbedacht Dam's original storage capacity has diminished substantially due to siltation over the years and a second water supply scheme was implemented. This scheme comprises of the Tienfontein pump station, diverting water from the Caledon River (located upstream of Welbedacht Dam), a rising main to convey the water to the off channel Knellpoort Dam located on a tributary of the Caledon River. From Knellpoort Dam water is abstracted at the Novo Pump station and transferred via a pipeline over the catchment divide to the Modder River Catchment and into Rustfontein Dam, which is located in the upper Modder River.



Figure 4-4: Caledon Modder Scheme and transfers

The total volume transferred depends on the combination of the water requirements and the water levels of Rustfontein, Mockes and Groothoek dams within the Modder River basin. The transfer volume is further limited by the infrastructure to the maximum transfer capacity of 47 million m^3/a (1.49 m^3/s) from Welbedacht and 52.7 million m^3/a (1.67 m^3/s) via the Novo transfer system. Latest indications are that the Novo transfer is being operated at approximately 1.3 m^3/s (41 million m^3/a). The maximum volume that can currently be transferred is therefore 88 million m^3/a (2.79 m^3/s). The current planning is to increase the Novo transfer capacity to 2.2 m^3/s by the middle 2015.

The Orange Riet Transfer scheme abstracts water from Vanderkloof Dam and conveyed via canals to the Riet River catchment. The water is primarily used for irrigation with relative small quantities supplying the urban requirements of Koffiefontein, Richie and Jacobsdal.

The total volume transferred is in the order of 260 million m³/a, and depends on the scheduled irrigation area and urban demands. From time to time an additional 5 million m³/a is released through the canal, to improve the water quality situation in the Lower Riet River. It is expected that the irrigation in this area will increase over time supporting the development of resource poor farmers with allocations from Vanderkloof Dam. Canal improvements and increase in capacity

will however be required before this can take place. (See **Section 4.2.1** for assumptions on how this additional use was incorporated into the water requirement scenarios).

The Orange Vaal Transfer Scheme supplies water for irrigation and the town of Douglas. This scheme consists of a pumping station at Marksdrift in the Orange River, a rising main and a 22 km 6 m³/s capacity canal, terminating at the Douglas Weir, the most downstream storage structure on the Vaal River. The volume transferred depends on the water available from the Vaal River and the water level in the Douglas Weir. The volume transferred can therefore vary considerably from year to year, but is in the order of 120 million m³/a, with a maximum of 142 million m³/a observed historically.

4.1.3 Irrigation Sector

Irrigation is by far the largest water use sector in the Upper and Lower Orange WMA. Both surface and ground water resources are used to supply the irrigation water requirements, with the bulk of the demands being supplied from surface water. There are many well-structured irrigation schemes located within the study area which in most cases use storage dams in the main rivers as the source of water supply. There is however also a large component of individual irrigators abstracting water directly from the river, from farm dams and from boreholes to supply irrigation developments. These are normally referred to as diffuse irrigation and are generally supplied at a lower assurance of supply than the irrigation forming part of the schemes.

A summary of all the irrigation schemes is given in **Table 4-2.** The Orange River Project is the largest water supply scheme and comprises of a large number of sub-schemes that are all supplied from the same resource, Gariep and Vanderkloof dams. The irrigation demand imposed on this system totals to almost 2 000 million m³/a, supplying approximately 165 900 ha of irrigation. Almost 580 million m³/a are transferred via the Orange Fish tunnel from Gariep Dam to supply about 50 000 ha of irrigation in the Eastern Cape within the Fish and Sunday river basins. Approximately 44 million m³/a is also supplied to irrigators located in Namibia along the Lower Orange River.

The other small irrigation schemes in the study area cover a further 13 163 ha with a total demand of 142 million m^3/a . The Hardap and Naute irrigation schemes are both located in the Fish River basin in Namibia with a total demand of 48.8 million m^3/a .

The bulk of the diffuse irrigation (opportunistic irrigation supplied from tributary rivers) is located in the Caledon River catchment. There are some uncertainties about the irrigation use within the Lesotho portion of the Caledon River basin as it is expected that not all of that irrigation is currently in use. Information of irrigation in Lesotho was obtained from the report "First Annual State of Water Resources" prepared under the Lesotho Water Sector Improvement Project completed in June 2010 (**Lesotho, 2012**).

Significant volumes of diffuse irrigation are also found in the Upper Orange upstream of Gariep Dam as well in the Riet & Modder catchment. All the irrigation included in **Table 4-1 and Table 4-2** is supplied with surface water resources. There is quite a substantial amount of irrigation supplied from groundwater which is mainly located in the Riet & Modder River basin.

Table 4-2: Summar	y of irrigation schemes
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Irrigation Schemes	Area (ha)	Demand (million m³/a)
Orange River Project (Gariep and Vanderkloof dams)		
Eastern Cape (Fish and Sundays)	49 624	577.17
Gariep to Vanderkloof scheme	2 025	22.27
Ramah+Vanderkloof main canal	5 271	57.98
Orange Riet Canal	12 406	137.07
Scholtzburg	691	7.60
Lower Riet	3 873	42.60
Vanderkloof to Marksdrift	17 455	187.38
Douglas	11 410	104.29
Marksdrift to Boegoeberg	17 236	173.95
Boegoeberg canal	7 679	115.19
Upington canal	7 896	118.45
Keimoes canal	4 010	60.15
Kakamas N&S & Rhenosterkop, Augrabies & Noudonzies		
canal	8 735	131.03
River abstractions Boegoeberg to Namibia border	9 295	139.42
River abstractions	4 143	62 15
Vioolsdrift South Canals	600	9.00
Alexander Bay	553	8 29
Namihia (main Orange)	2 961	35 19
Sub-Total	165 864	1 989.18
Other Irrigation Schemes		
Hardap (Namibia)	2200	44.00
Naute (Namibia)	320	4.80
Modder GWS	3 568	29.95
Tierpoort	707	6.36
Kalkfontein Scheme	3 510	38.62
Egmont	857	5.23
Ongers (Smartt Syndicate)	2 000	13.20
Sub-Total	13 163	142.16
Total for all schemes	179 027	2 131

The irrigation areas and related demands for the Upper Orange WMA were obtained from the current Validation/Verification study initiated by DWA. The purpose of the validation is to confirm that the registered irrigation development do exist on the ground. The Verification of lawful water use still needs to be carried out and will be incorporated in the subsequent continuation and maintenance phase of the Reconciliation Strategy.

Diffuse Irrigation	Area	Demand
	(ha)	(million m³/a)
Caledon RSA	14 907	71.64
Caledon Lesotho	4 882	20.63
Main Orange upstream of Gariep	2 220	16.75
Kraai River	6 341	27.95
Stormberg and minor tributaries in Gariep		
incremental	6 886	42.38
Seekoei and minor tributaries in Vanderkloof		
incremental	1 096	5.46
Riet River	2 987	19.86
Modder River	3 436	22.56
Molopo River		1.85
Sak/Hartbeest	3 680	6.59
Total	46 434	235.67

Table 4-3: Summary of diffuse irrigation developments supplied from Surface Water

The information from the validation work represents the irrigation development during the registration period, also referred to as the qualifying period and represents water use at 1998/99 development level. This water use data in general compared well with existing information captured in the Water Resource Planning Model (WRPM) and related hydrology studies that were carried out in the past.

Supplementary information provided by the validation study team estimated that the irrigation water use in the year 2012 could be as much as 145 million m³/a higher than what is validated for the 1998/1999 period. (It is important to note that no ground verifications was carried out on the 2012 water use estimates and still need to be undertaken as part of the verification of lawful water use that is underway). The potential implication of such an increase is considered as a risk and discussed further in **Section 11**.

4.1.4 Urban and Rural Water Requirements

The study focuses on the Upper and Lower Orange WMA and therefore includes the subsystems of the Caledon, Upper Orange, Riet/Modder, Lower Orange Main stem and part of the Lower Vaal. There are no major abstractions for individual industrial users, and all industrial users are supplied from the urban water supply systems and are therefore not described separately.

The 2012 urban/industrial demand within the study area, including the Eastern Cape portion supplied with water from the Orange, totals 198.7 million m³/a.

The historic and current urban industrial RSA water requirements are provided in Table 4-4.

SUB-SYSTEM / DESCRIPTION	2009	2010	2011	2012
Caledon	9.06	9.65	10.09	10.53
Upper Orange (Eastern Cape included)	51.09	55.3	59.48	60.50
Lower Vaal	1.83	1.92	2.02	2.12
Riet/Modder	88.62	87.44	85.20	92.63
Lower Orange Main Stem	31.02	31.65	32.29	32.92
Total Urban Industrial RSA	181. 61	185.99	189.43	198.70

Table 4-4: Urban Industrial RSA Historic and 2012 Water requirements (million m³/a)

Although Lesotho is not the focus area of the study it is important to take into account the urban industrial demands within Lesotho as they will impact on the available flows in the Caledon and Senqu rivers both feeding into the Orange River. A summary of the Lesotho urban/industrial demand is given in **Table 4-5** showing a total urban/industrial demand for Lesotho of almost 19 million m³/a at 2012 development level (**Lesotho, 2012**).

Table 4-5: Urban Industrial Lesotho Historic and 2012 Water requirements (million m³/a)

SUB-SYSTEM / DESCRIPTION	2009	2010	2011	2012
Senqu/Makaleng	0.89	0.93	0.98	1.03
Caledon	16.09	15.30	16.54	17.77
Total Urban & Industrial Lesotho	16.98	16.23	17.52	18.80

Part of the Namibian urban demand is located along the Lower Orange main river and is supported by releases from Vanderkloof Dam. Water for urban use is also supplied from the Fish River in Namibia although the influence thereof on the water balance of the Orange River is negligible. This is due to the erratic flow contribution of the Fish River as well as the location of the tributary, as it cannot be utilised to support demands in the Lower Orange River. A summary of the urban demands in Namibia forming part of the Orange River basin is given in **Table 4-6**.

Table 4-6: Urban Industrial Namibia Current Water Allocations and Abstractions (million m³/a)

SUB-SYSTEM / DESCRIPTION	2009	2010	2011	2012
Lower Orange Main Stem	8.60	8.65	8.71	8.77
Sub-Total Fish River System	2.90	2.90	2.90	2.90
Total Urban Industrial Namibia	11.50	11.56	11.61	11.67

4.1.5 Mining Sector

Mining activities are mainly located along the Lower Orange both within the RSA and Namibia. The 2012 mining water requirement within the RSA is 8.5 million m³/a and in Namibia 7.6

million m³/a. Details of the RSA and Namibian mining demands are given in **Table 4-7** and **Table 4-8** respectively.

SUB-SYSTEM / DESCRIPTION	2009	2010	2011	2						

Table 4-7: Mining RSA Current Water A	Allocations and Abstractions (million m³/a)
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SUB-SYSTEM / DESCRIPTION	2009	2010	2011	2012
Riet/Modder	1.50	1.50	1.50	1.50
Lower Orange Main Stem	6.82	6.85	6.91	6.96
Total Mines RSA	8.32	8.35	8.41	8.46

Table 4-8: Mining Namibia Current Water Allocations and Abstractions (million m³/a)

SUB-SYSTEM / DESCRIPTION	2009	2010	2011	2012
Lower Orange Main Stem	7.53	7.53	7.61	7.64
Total Mines RSA	7.53	7.53	7.61	7.64

4.1.6 Unlawful Water Use

Reliable estimates of unlawful water use were not available to consider in the development of the Reconciliation Strategy. DWA is in the process of undertaking Verification of lawful water use and once information become available from this process, the water balances will be reassessed to determine if there are implications for the Reconciliation Strategy.

4.1.7 Power Generation

Hydro-power is generated at both Gariep and Vanderkloof Dams with four 90MW generation sets are installed at Gariep Dam and two 120 MW sets at Vanderkloof Dam. These stations are mainly used for the generation of peaking power with a load factor of approximately 10%. This means that the hydro-power plants will be operated at the equivalent of their full potential for 10% of the time.

The agreement between Eskom and DWA establishes the principle that water use for irrigation, urban-industrial, mining and environmental purposes has priority with the allowance to generate hydro-power with the water released for such purposes. Hydro-power generated with these releases is therefore defined and limited by the flow volumes and monthly distribution pattern required by the downstream users. The releases used to generate hydro-power therefore represent a non-consumptive demand.

When the dams are relatively full and there is a short-term surplus available in the system, Eskom is allowed to generate additional hydro-power at a time that suits them best. This hydro-power generation is over and above what is generated by means of the normal releases for downstream users and will thus represent a consumptive demand. Risk analyses are carried out in May and November each year to determine the short-term surplus available in the ORP system for allocation to Eskom to use at their discretion.

4.1.8 Streamflow Reduction

There is very limited stream flow reduction due to afforestation and invasive alien plants in the Upper Orange WMA with none in the Lower Orange WMA. At the Screening Workshop on 7 February 2013, it was pointed out by a stakeholder that there is infestation of willow trees on the banks of the Kraai River. The extent of this infestation has however not been verified. The impact on the runoff due to the stream flow reduction activities has, for the purpose of this preliminary reconciliation strategy, not been taken into account.

4.2 PROJECTED FUTURE WATER REQUIREMENTS

For the purpose of this study a high growth scenario was produced to be used in the water balances. This projection is shown in **Figure 4-5** and included **Table 4-9**. A second projection that includes the benefits of WC/WDM has also been prepared.



Figure 4-5: Orange Senqu high demand projection (Vaal system excluded)

The increase in water requirements within the Orange Senqu (Vaal excluded) is estimated to be 913 million m^3/a between 2012 to 2050. The main increases are as result of:

- The increased transfer of 437 million m³/a from the LHWP to the Vaal;
- Increase in irrigation outside ORP of 103 million m³/a mainly in Namibia (Neckartal Dam)
- The 120 million m³/a allocated to resource poor farmers (RSA), and
- BloemWater sub-system increase of 105 million m³/a.



Figure 4-6 : Orange River Project demand projection

Description	Demand growth in million m ³ /annum							
Description	2012	2015	2020	2025	2030	2040	2050	
Net demand	2 889	2 976	3 067	3 099	3 124	3 135	3 147	
Total gross demand	2 954	3 039	3 134	3 168	3 194	3 205	3 217	
Irrigation	1 989	2 026	2 113	2 137	2 137	2 137	2 137	
Transfer to Bloemfontein (Greater Bloemfontein Reconciliation Study)	0	0	0	0	20	20	20	
Urban	118	167	175	185	191	203	214	
River requirements	615	615	615	615	615	615	615	
Operating Requirements	180	180	180	180	180	180	180	
Canal losses	51	51	51	51	51	51	51	
Return flows	128	128	132	134	135	135	135	

 Table 4-9: Orange River Project high demand projection

The expected growth in water requirements on the Orange River Project is shown in **Figure 4-6**. The overall expected increase in the water requirements for this system from 2012 to 2050 is 263 million m^3/a . The implementation of river releases in accordance with the alternative Ecological Preferred EWR 2013, would add an additional 434 million m^3/a abstraction in the system.

4.2.1 Irrigation Sector

Future growth in irrigation within the RSA from the Orange River Project is limited to 12 000ha for the development of resource poor farmers. By 2012, 815ha of the 12 000 ha were already developed. Current estimates indicate that the 12 000 ha should be fully developed by 2025. This is however only a first order indication as no detailed planning is yet in place for the

remaining portion. For the purpose of this study it was assumed the remaining portion with water use of 130 million m^3/a will be developed by 2025, applying the growth estimations as obtained from the DWA regional offices as part of the Annual Operating Analysis (2012) carried out for the ORP.

Namibia indicated (ORASECOM, 2013) that the irrigation along the Lower Orange on the Namibian side might expand by another 1 500 ha with a related demand of 22.5 million m³/a. Namibia is also planning the Neckartal Dam on the lower Fish River which is expected to support between 3 000 ha to 5 000 ha of irrigation. This development will not directly impact on the Orange River, but will reduce the spills from the Fish into the lower Orange, and as result reduce the Fish river contribution to the Orange River mouth environmental requirement. Details of the Namibia Fish River system were included in the WRPM analysis as updated hydrology become available during the second phase of the Orange Reconciliation Strategy study. This however had almost no impact on the water balances prepared for the Orange System.

4.2.2 Urban and Rural Water Use

Water requirement projections for the Bloemfontein, Thaba Nchu and Botshabelo, as well as the small towns of Wepener, Dewetsdorp, Reddersburg, Edenburg, and Excelsior were obtained from the Reconciliation Strategy Report for the Large Bulk Water Supply Systems of the Greater Bloemfontein area (**DWA**, **2012b**).

SUB-SYSTEM / DESCRIPTION	2012	2015	2020	2025	2030	2040	2050
Caledon	10.53	11.83	13.26	14.68	16.12	19.04	22.17
Upper Orange (Eastern Cape included)	60.50	91.38	93.53	95.66	98.09	102.90	107.05
Lower Vaal	2.12	2.42	2.73	3.00	3.26	3.77	4.31
Riet Modder	92.63	95.18	111.10	130.19	152.19	204.00	260.49
Lower Orange	32.92	34.82	36.37	37.96	39.60	42.87	45.48
Total Urban Industrial RSA	198.70	235.64	256.99	281.49	309.26	372.54	439.51

Table 4-10: Urban Industrial RSA Estimated Future Water Requirements (million m³/a)

The high growth (about 3% per annum) with the most probable water conservation and water demand management scenario was used for the purposes of this assessment. The projections for all other towns were obtained from the All Town Reconciliation Strategies (**DWA**, 2011b).

The expected high growth scenario for South Africa, Lesotho and Namibia urban/industrial demands, are summarised in **Tables 4.10**, **4.11** and **4.12** respectively.

SUB-SYSTEM / DESCRIPTION	2012	2015	2020	2025	2030	2040	2050
Senqu/Makaleng	1.03	1.21	1.56	2.03	2.65	4.29	6.17
Caledon	17.77	21.48	27.70	34.98	42.32	57.11	74.22
Total Urban & Industrial Lesotho	18.80	22.69	29.27	37.01	44.97	61.40	80.39

Table 4-11: Urban Industrial Lesotho Estimated Future Water Requirements (million m³/a)

Table 4-12: Urban Industrial Namibia Estimated Future Water Requirements (million m³/a)

SUB-SYSTEM / DESCRIPTION	2012	2015	2020	2025	2030	2040	2050
Lower Orange	8.77	8.94	9.38	9.47	9.57	9.76	9.94
Fish River	2.90	2.90	2.90	2.90	2.90	2.90	2.90
Total Urban Industrial Namibia	11.67	11.84	12.28	12.38	12.47	12.66	12.838

4.2.3 Mining Sector

The estimated future mining requirements for the RSA is given in **Table 4-13** showing a significant increase from 2012 to 2015. This is a result of the Gamsberg project that will be online by 2014, requiring an increase of 12 million m /a. to be supplied through the current Pella Water Board System.

Table 4-13: Estimated Future Mining Water Requirements RSA (million m³/a)

SUB-SYSTEM / DESCRIPTION	2012	2015	2020	2025	2030	2040	2050
Riet Modder Sub-system	1.50	1.69	2.01	2.32	2.64	3.27	3.96
Lower Orange Main Stem	6.96	19.13	16.79	16.94	17.10	17.42	17.73
Total Mines in RSA	8.46	20.82	18.79	19.26	19.74	20.69	21.69

The Namibian mining requirements, **Table 4-14**, also show an increase between 2012 and 2015 due to the inclusion of Haib Mine. The exact time when the Haib Mine will become active is however still uncertain.

Table 4-14: Estimated Future Mining Water Requirements Namibia (million m³/a)

SUB-SYSTEM / DESCRIPTION	2012	2015	2020	2025	2030	2040	2050
Lower Orange Main Stem	7.64	10.75	10.97	11.22	11.47	11.98	12.46
Total Mines Namibia	7.64	10.75	10.97	11.22	11.47	11.98	12.46

4.2.4 Power Generation

Power generation will continue to take place at Gariep and Vanderkloof dams. As the demand imposed on Gariep and Vanderkloof dam's increases over time the short term surplus available from these two dams will decrease. This will result in a decrease in the discretional allocation given to Eskom on an annual basis to generate hydro-power over and above that generated from the river releases to supply the downstream water requirements.

Three companies, RVM 1 Hydro Electric Power (Pty) Ltd, RVM 2 Hydro Electric Power (Pty) Ltd & RVM 3 Hydro Electric Power (Pty) Ltd are investigating the possible construction of one 10 Megawatt (MW) and one 9.9MW hydro-power station on the Orange River, on the farm Riemvasmaak1, north of the Augrabies Falls, approximately 40 km North West of Kakamas in the Northern Cape Province of South Africa. The proposed projects would entail the abstraction of water upstream of Augrabies at a combined maximum rate of some 35m³/s. this will however be a non-consumptive use.

4.3 TOTAL HIGH AND LOW SCENARIO WATER REQUIREMENT PROJECTIONS

The projected total high and low growth water requirement figures for 2040 are shown in **Table 4-15.** These high and low growth water requirement figures have been used for the reconciliation scenarios that will be described in **Section 9**. It should be noted that the water requirement projections presented in this section exclude the potential savings that can be achieved through the implementation of Water Conservation and Water Demand Management (WC/WDM) interventions.

Detail information of the potential for WC/WDM in the urban sector are given in **Section 8.2.1**, indicating a reduction of 6.4 million m^3/a in the urban/industrial demand is possible. For the purpose of the water balances the savings were phased in over a period of 5 years. This saving estimate excludes the savings potential in the Greater Bloemfontein supply area, as those was already captured in the demand projection presented in this section.

The potential for saving water through WC/WDM interventions in the irrigation sector is described in **Section 8.2.2**, indicating that an average net saving of about 5% (phased in over a period of 5 -10 years) can be adopted as a conservative but realistic estimate for the sector.

	Requirement in	Future requirement (2050)			
Sector	2012 (million m³/a)	High growth (million m³/a)	Low growth (million m³/a)		
Irrigation	2 370	2 621	2 489		
Urban/Industrial	252	570	564		
Mining	16	34	34		
Riverine and Operational requirements	846	795	715		
Transfers not included in above given demands ⁽²⁾	780	1 217	1 105		
TOTAL ⁽³⁾	4 264	5 237	4 907		

Table 4-15:	Total high	and low	growth water	requirements
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Notes ⁽¹⁾ The EWRs were excluded from the water users listed above and incorporated in the determination of the water availability (yield analysis) – see Section 5.2

(2) Transfers from Phases 1 and 2 of Lesotho Highlands Water Project to the Vaal system. High growth assumes full Phase II transfer in place

⁽³⁾ The demands exclude none-consumptive power generation water use.

5 WATER RESOURCE AVAILABILITY

5.1 METHODOLOGY

The starting point for the development of the strategy was to determine the surface water resource availability based on the historical hydrological data through simulation analysis (modelling) of the Orange River System as configured in the Water Resource Yield Model (WRYM). This was followed by undertaking risk analysis to determine the assurance of supply through the application of stochastic flow modelling.

Section 5.2.1 presents the yield results of the historical analysis while **Section 5.2.2** describes the risk analysis.

The groundwater assessment was carried out using information from literature covering the Upper and Lower Orange WMAs. The available and utilisable groundwater varies widely across the study area depending on the geology, recharge for aquifers and water abstraction methods. **Section 5.3** and **Section 5.4** provide an overview description of the groundwater resources and utilisation in the two WMAs respectively.

5.2 SURFACE WATER AVAILABILITY

5.2.1 Yield of Large Dams (historical analysis)

The two large sub-systems within the study area, the Lesotho Highlands Water Project (LHWP) and the Orange River Project (ORP) (main water source Gariep & Vanderkloof dams), are providing by far the largest portion of the available yield within the Orange/Senqu system. The ORP supplies the bulk of its water to users within the Orange basin except for the transfer (620 million m³/a) to the Eastern Cape, mainly for irrigation but also to urban/industrial users including Port Elizabeth.

Phase 1 of the LHWP transfers most of the available water to the Vaal River system except for the releases in the rivers downstream of Katse, Mohale and Matsoku dams - to comply with environmental requirements. The LHWP therefore reduces the available water in the ORP by holding water in storage as well as diverting water to the Vaal River System.

The Caledon/Modder sub-system consisting of four storage dams, two in the Caledon and two in the Modder River catchment is the third largest sub-system. This sub-system supplies Bloemfontein, Mangaung, Botshabelo and several smaller towns with water. A separate reconciliation strategy (Greater Bloemfontein Reconciliation Strategy) was developed for this sub-system and the recommendations of the utilisation of the Caledon to transfer water to the Modder River basin were included in the yield assessment of the ORP.

The historic firm yields that are available from the respective sub-systems at 2012 development level are summarised in **Table 5-1** below.

Sub-system	Dams	Live Storage (million m ³)	System Yield (million m³/a)
LHWP Phase I	Katse	1 517	
	Mohale	851	780
	Matsoku	-	
Orango Biver Broject	Gariep	4 576	2 0 2 0
	Vanderkloof	2 173	3 030
	Knellpoort	131	
Caledon/Modder sub-system	Rustfontein	72	0.4
	Welbedacht	6.6	04
	Mockes	3.3	

Table 5-1: Historic Firm Yield from large dams in the system

5.2.2 Risk analysis

Projection simulation analyses were carried out with the Water Resource Planning Model (WRPM) to determine the risk of supply shortages over the planning period for selected scenarios. The model configuration, assumptions and results are presented in the task report with the title, 'Reserve requirement scenarios and scheme yields report'.

The purpose of projection risk analyses was to assess the following:

- Confirm the date when the first intervention is required given the projected growth in water requirements. The analysis determine the risk of drought restrictions in each year in the planning period, which is compared against risk criteria made up of the different water use sectors. The year the criteria is violated indicate the date when intervention measures should be operational.
- Evaluate the implications alternative risk criteria (assurance of supply) have on the supply profile to users, as well as the need and timing for intervention measures.
- Evaluate the filling requirements (time since commissioning of the dam to reach sufficient storage levels to provide the required assurance of supply) of large dams. The analysis method determines the risk of failure (depleted storage) by simulating the changes such as the growth in water usage, increasing water transfer schedules and the date when impoundment of the new dam(s) commence. This is particularly important in the Orange River where there are existing large dams of which the operation influences the inflow to proposed downstream dams.
- Undertake the simulation risk analysis of the scenarios by accounting for the complex interdependencies of all significant activities (storage, abstraction, transfers) as well as the spatial varying climate (rainfall, runoff and evaporation) across the Orange River system.

5.2.3 Diffuse Water Resources

Several small dams including farm dams are used to supply irrigation and small towns within the study area. Runoff river abstractions are also very common in most of the higher rainfall areas and along perennial rivers for towns as well as for irrigation purposes. These diffuse water resources are all accounted for in the WRYM and WRPM data sets and the impacts of these developments are therefore reflected in the water balances. A separate study that was completed for the Upper and Lower Orange WMA referred to as the "All Towns Reconciliation Study" addressed the water supply to all the towns in the study area.

5.2.4 Transfers in

There are currently no transfers bringing water into the Orange as all the transfers are using the Orange/Senqu as source to transfer water in support of other neighbouring catchments.

5.3 GROUNDWATER IN THE UPPER ORANGE RIVER CATCHMENT

5.3.1 Geology and Geohydrology

Sedimentary rocks of the Karoo Supergroup underlie the main area and have been intruded by dolerite dykes and sills, with the maximum occurrence in the Beaufort Group (

Figure 5-1). The Supergroup can be described lithologically as follows (Meyer, 2003):

- The Dwyka Group comprises bluish-grey, unbedded, unsorted tillite with a thickness that varies from a few meters up to 120m;
- The Ecca Group comprises carbonaceous shale, dark bluish-green to grey massive shale, olive-green micaceous shale/mudstone, light green to greenish-grey shale, mudstone, siltstone and fine-grained sandstone, with a thickness that varies between 340–360m;
- The Beaufort Group comprises the Adelaide Subgroup (sandstone, siltstone, grey to reddish mudstone, blue-green-grey shales and red to purple mudstone) and the Tarkastad Subgroup (light coloured, feldspathic sandstone, red, purple and green mudstone). The Adelaide Subgroup can be up to 400m in thickness while the Tarkastad Sub-group has been reported as up to 900m thick;
- The Molteno formation comprises grey-green and red-purple mudstone with bands of fine to coarse-grained sandstone. A maximum thickness of 250m has been recorded;
- The Elliot Formation comprises maroon or green mudstone and medium grained feldspathic sandstone;
- The Clarens Formation comprises cream-coloured, fine-grained, massive Aeolian sandstone with a maximum thickness of 200m, and
- The Drakensberg Group overlies the Clarens Formation with sharp contacts and comprises of basaltic lava with a maximum thickness of 900m.

In the north-western part of the area patchy occurrences of the Ventersdorp Supergroup are observed. The Supergroup is characterised as porphyritic lava, quartzite, tuff and volcanic breccia, (Meyer, 2003).



Figure 5-1: Geology of the Upper Orange WMA

Alluvium occurs in broad valleys along streams and rivers. It is made up of various materials typically including clayey sand, sandy silt, limestone, sand pebbles and small boulders. Thicknesses can vary from 1- 15m, (Meyer, 2003).

The Upper Orange WMA lies mainly on the Bloemfontein 2924 1:500 000 hydrogeological map with small portions of the area on the Kimberley 2722, Kroonstad 2726, Prieska 2920, Beaufort West 3122 and Queenstown 3126 hydrogeological maps.

Two aquifer types occur in the area namely fractured (Dwyka, Ecca Group and portions of the Tarkastad Subgroup) and fractured and intergranular (Ventersdorp Supergroup, Beaufort Group, Molteno, Elliot and Clarens Formations) aquifers. The geohydrology of the Karoo Supergroup is briefly described as the following (Meyer, 2003 and WRP, 2007):

- The Dwyka Group rocks offer poor groundwater potential (0.1 0.5 l/s). Yields are associated with jointing, fracturing and weathering of the rocks;
- Groundwater occurrence in the Ecca Group is mainly associated with dolerite contact zones, joints and bedding planes. Thick calcrete layers with a high porosity can enhance recharge to the aquifer, but these are not present as a blanket covering the Group. Borehole yields average between 0.5-2.0 l/s but more than 10% of recorded boreholes yield more than 5 l/s;
- The Adelaide Subgroup of the Beaufort Group has been extensively intruded by dolerite sills and to a lesser extent by dolerite dykes. Groundwater occurs in joints and fractures on the contact zones, in weathered dolerite zones, weathered and jointed sedimentary rocks and on bedding planes. Borehole yields vary from 0.5-2.0 l/s;
- Groundwater occurs in dolerite contact zones, joints and fractures and on bedding planes in the Tarkastad Subgroup of the Beaufort Group. Weathering promotes the groundwater potential although this unit is less prone to weathering. Borehole yields vary from 0.5-2.0 l/s but 17% of the recorded borehole yields are more than 5 l/s;
- The Molteno, Elliot and Clarens Formations cover the eastern portion of the area along the Lesotho border and have been intruded by a variety of dolerite dykes and sills. Groundwater can be developed on contact zones, joints and fractures in the sedimentary rocks and in weathered zones, but occurrence is restricted because of high runoff causing little infiltration and relative scarcity of dolerite intrusions which limit possible borehole sites. Groundwater does however occur in dolerite dykes and sills, especially where these have been weathered, jointed, and/or fractured;
- Groundwater in the Drakensberg Group is associated with weathered lava and contact zones between lava and dolerite intrusions. Numerous low-yielding springs emerge on contacts between weathered and solid rocks. Borehole yields are known to be very low, with ranges between 0.1-0.5 *ll*/s but these are a large proportion of boreholes with less than 0.1 *l*/s, and
- Groundwater occurrence in the Allanridge Formation of the Ventersdorp Supergroup is associated with jointed diabase dykes and their contact zones, fractures in the occasional fault zones and weathered basins with associated joints. Borehole yields vary from 0.5-2.0 l/s. (Meyer, 2003).

No meaningful inter-granular (alluvial) aquifers have been reported, although alluvium along rivers and streams can act as a groundwater recharge mechanism.

Site-specific case studies give an indication of the general aquifer characteristics typical of the Upper Orange WMA. The Kalkveld Groundwater management area (see

Figure 5-1), which include the Bainsvlei and Petrusburg agricultural areas is one of the most utilised groundwater abstraction areas in the WMA. The area is specifically characterized by a high density of irrigation from groundwater sources. Borehole yields in the Bainsvlei area vary between 0.2-20 ℓ s with an average of about 1 ℓ l/s. This area has been studied in detail and is also the only aquifer for which a Reserve determination has been completed (quaternary catchments C52G, C52H and C52J) (Van Tonder & Rudolph, 2003).

The Reserve determination of the area concluded the following:

"It was estimated in 2003 that about 7 000 Ha is irrigated in the area (total area = 6080 km^2), i.e. 1.2% of the total area, and that the annual total abstraction from boreholes was in the order of 33 million m³. Recharge amounts to 57 million m³/a (using 2% of the average annual rainfall of 500 mm, as estimated with the CI-method). Human dependency on groundwater amounts to about 1 million m³/a. The annual groundwater flux of groundwater to the Modder River was estimated as 0.26 million m³Ia, and it was noted that in about 50% of all months the flow in the Modder River is zero (naturalised conditions). It was concluded that the Aquatic Reserve is very small compared to the annual recharge, and that in the Bainsvlei agricultural holdings area the abstraction is higher than the annual recharge."

A typical rock transmissivity for the Bainsvlei area is between 5-10 m^2/d with a storativity of 0.005. Porosity values vary between 1 and 7% (Van Tonder & Rudolph, 2003). From the 72 hour pump test analysis done for 5 boreholes in the Petrusburg area, the following conclusions were made (Veltman, 2003):

- The aquifer is defined as a double porosity fractured hard-rock system (Implying that there is storage in both the matrix and the fractures of the rock formations);
- Radial flow in this system cannot be attributed to flow from the porous matrix, but rather a network of fractures that function as a matrix;
- Depths of the fractures are also site specific, but most fractures observed appear in the range of 20-30 m below ground level, and
- Distribution of fractures horizontally and vertically controls the borehole yield.

Water Quality

Precipitation is usually the most important source of recharge, but due to the nature of the rocks and topography, recharge generally increases from east to west in contrast with precipitation that reduces from east to west (Meyer, 2003). This trend in recharge is also reflected in the water quality of the WMA.

The National Groundwater Monitoring Programme's database as well as other DWA databases was accessed to obtain information regarding the groundwater quality of the WMA. The majority of the monitoring points were established in the mid 1990's and samples are taken for inorganic water quality on a quarterly basis. The location of the monitoring points was selected to provide a representative cover of water quality points, and many of the points are located in towns where groundwater is utilised as the main supply (see **Figure 5-2**).
A summary of the water quality trends on a catchment scale is provided below.

All of the sampling points (with exceptions at Soutpan area, EC >400 m^S/m)) fall within acceptable water quality guidelines for Electrical Conductivity (EC) of less than 170 m/Sm, as provided by SANS241:2011. The water character across the WMA can be described as neutral pH and of CaNaMg – bicarbonate type. The eastern sub-catchments (D21, D22, D23, and D24) tend to be more Na-bicarbonate dominant indicative of higher and more rapid groundwater recharge. Cation exchange occurs at some sites, and the extent of the ion exchange is likely linked to residence time in the aquifer and depth to water table. Where water quality deterioration is observed over the monitoring period increased salinity is linked to an increase in NaCl content.



Figure 5-2: Distribution of groundwater monitoring points in the Upper Orange WMA (From Veltman, 2005)

Generally the water quality has remained stable over the 18 years of monitoring with exceptions in catchment C52. Here the deterioration of water quality from 30 to 130 m^S/m is likely caused by higher density of population and over exploitation of the aquifer. This is the catchment in which Greater Mangaung is located and the Kalkveld agricultural area.

The catchments located on higher grounds towards the east of the WMA (D12, D13) are characterised by excellent water quality (EC of less than 35 m^{S}/m) indicative of rapid groundwater recharge mechanisms in these areas. Contrary to this, the catchments towards the

west of the WMA (C51M) are characterised by salinity increases in excess of 300mS/m, which may be indicative of a decrease of recharge due to lower rainfall in recent years.

Constituents of concern in the groundwater are limited to F, Mn, Fe an Al in isolated areas. These constituents are often elevated where dolerite or diabase intrusions are in close proximity of the boreholes. However, the levels of these constituents are not elevated to such an extent that this will be limiting factor on groundwater use for the WMA.

5.3.2 Potential Groundwater Use and Potential

From the work done by several researchers (i.e. Chevalier, Woodford, Van Tonder, Bredenkamp, Botha, and Veltman) on the Karoo formations it is concluded that recharge estimates are site-specific and a single recharge value cannot be assigned to the whole area. However, as a rule of thumb, recharge of between 2-5% is used for determining volumes of water available in Karoo aquifers. The variance of this value will depend on different (local) factors influencing recharge to the aquifer.

The Harvest Potential Map (Seymour & Seward, 1995) can be used to determine the maximum volume of water available per surface area for sustained abstraction from groundwater and is estimated for the WMA as 10 000 m³/km²/a. The total catchment area for the Upper Orange WMA (Lesotho excluded) amounts to 101 977 km². The harvest potential for the WMA as a whole is thus estimated at 1 020 million m³/a.

Irrigation:

The main agricultural activity in the WMA is mixed dry land farming, although various crops are irrigated with the use of groundwater. Small scale irrigation is typical in most of the WMA, with exception of the Kalkveld area (Bainsvlei and Petrusburg -Catchment C52) where abstraction of groundwater for irrigation is done on large scale.

The following is a summary of groundwater abstraction for irrigation within the WMA:

Catchment area C52 is where most irrigation from groundwater occurs, at 13 000ha. An estimated 76 million m³/a of groundwater is utilised for irrigation of mainly maize, wheat, lucerne, and/or animal feeds. The catchment is characterised by the use of optimal irrigation methods (i.e., sprinkler, centre pivot and drip methods) at 94% of the farms. Approximately 50% of the irrigation areas are less than 8ha in size, with maximum areas up to 40ha per farm. It should be noted that the number of hectares and volume calculated by this 2012 reconciliation is almost double that of the first estimates made by Van Tonder and Rudolph in 2003.

Catchment C51 is ranked second for irrigation using groundwater at 2 600ha with abstraction of approximately 14 million m³/a. Irrigation methods are less efficient than in C52, with 40% of the farms being under flood irrigation. The majority of farms have irrigation areas of less than 10ha.

2 460ha of the catchments D31 to D35 are irrigated with a total groundwater abstraction of 5.4 million m³/a. These catchments have the highest rate of inefficient irrigation (56% under flood irrigation) and 18% of irrigation is sourced from free flowing from springs (eyes).

Catchment D21 to D24 have an area of 840 ha under irrigation, for which 3.8 million m^3/a is abstracted. 41% of the abstraction is from free flowing from springs (highest percentage for the

WMA), and 45% of the farms are under flood irrigation. The crop profile is similar to other catchments, with 1% of the irrigation utilised for fruit trees.

Catchments D12 to D14 have a combined abstraction of 2.9 million m³/a of groundwater covering an area of approximately 570ha. 30% of the farms utilise flood irrigation methods and approximately 2% of the sources of groundwater are from free flowing springs.

It can therefore be concluded that a total of 180 million m³/a is abstracted from groundwater for irrigation, which amounts to 17% of the harvest potential of the WMA. The majority (7.5%) of this is from catchment C52. It should however be noted that this area is also the one area where efficient irrigation methods are favoured above the inefficient flood type irrigation common in other areas.

Mining:

Mining is limited to historical diamond mining at Koffiefontein and Jagersfontein and salt mining at Herbert, Fauresmith, Jacobsdal and Hopetown. Therefore mining has limited impact on groundwater resources in the WMA.

Water Supply:

The De Beers mining company supplies the settlement of Jagersfontein and water is pumped from the adjacent closed mine a depth of 220m below surface (Meyer, 2003).

In the past various boreholes (60-70) have been drilled in the Thaba Nchu rural area, at the time being its only supply of fresh water. At present Bloemwater is supplying the area through a pipe system (Meyer, 2003).

Groundwater is widely used in the WMA to supply small towns (approximately 35 towns) either as the sole source of supply or in combination with surface water resources. Often the utilisation of groundwater in these towns is based on the distance from other surface water supply schemes, or to supplement sources during periods of drought.

5.3.3 Further Groundwater Development Options

Generally the exploitable Karoo aquifers are limited to depths less than 120m below ground level. The Council for Geoscience investigated the potential of deeper occurrence of groundwater for the Kalkveld area in 2005. It was found that the total depths reached by the existing boreholes in the area ranged from 5m to 252m, with the majority between 20m and 90m. It was concluded that: "*The Kalkveld area is characterized by several aquifers at various depths: a top aquifer in the fractured weathered zone (first 30 m) recharged effectively via surficial deposits and various deeper fractured aquifers controlled by dolerite intrusions and possibly the basement. Deeper aquifers form an important part of the abstractable water reserves.*

Other drilling programmes that were focused on town supply also investigated deeper seated groundwater sources. However, in the majority of the cases water quality (high salinity) was found to be the limiting factor where high yielding deeper boreholes were drilled.

Unfortunately the development of groundwater is seldom done correctly on a local municipal scale. Municipalities tend to restrict their search for water to municipal boundaries and

properties. The municipalities could also investigate groundwater potential beyond town boundaries for possible water sources.

Non-scientific borehole siting often results in dry holes being drilled. Borehole siting needs to be based on proper geotechnical work to limit the drilling of unsuccessful boreholes and to improve the yield from the boreholes. High resolution airborne geophysics, combined with ground geophysical siting, is an option to be considered to increase the success rate of higher yielding boreholes.

Where water quality is a limiting factor to groundwater use, on site treatment should be considered. Water treatment technologies are developing at a rapid rate and are likely to be most promising technology in ensuring sustainable water supply from higher yielding aquifers characterised by poorer water quality.

5.4 GROUNDWATER IN THE LOWER ORANGE RIVER CATCHMENT

5.4.1 Geology and Geohydrology

The Lower Orange River WMA is mainly underlain by granites and gneisses and sedimentary rocks of the Karoo Supergroup while Quaternary and Tertiary dune deposits are present in the northern part of the Catchment. The aquifers present in the Catchment are mainly fractured in some formations, fractured and intergranular in other formations and intergranular in the primary aquifers. Fractured aquifers are present in the Karoo formations along dolerite dike contact zones. In the far eastern portion of the Lower Orange the Malmani Dolomite Formation is present with Griquatown the only town in the catchment area. The Groundwater Resources of the Republic of South Africa by Vegter (1995) showed that the probability to drill a successful borehole (>0.1 I/s) in the area is lower than 40% in the Karoo, granite and gneiss formations, while the probability in the Kalahari dune area it is 40 - 60%. The probability to drill a borehole yielding more than 2 I/s is below 30% in the whole WMA. In the Askham area between the Kuruman and Malopo rivers where the probability is higher than 60% and the probability to drill a borehole higher than 2 I/s is greater than 50%, the general borehole yield in the granites and gneisses vary between 0.1 and 2.0 I/s while yields between 0.1 and 0.5 I/s can be expected in the other formations.

5.4.2 Groundwater Use and Potential

Groundwater is the most important source for bulk water supply to local towns and rural settlements in the Lower Orange as these towns and settlements are located far from the surface water bulk supply network. The potential for sustainable groundwater supply is dependent on recharge from rainfall. Rainfall varies from around 300 mm in the eastern part of the Lower Orange to as low as 50 mm on the west coast. According to Vegter (1995) the mean annual recharge vary from 10 mm in the east to less than 1 mm in the west and north of the area. The Annual Potential Recharge based on the GRA II Quaternary Catchment data from DWA is shown in **Table 5-2.** This added to the available volume in the aquifers as shown as AGRP and is double the recharge.

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. In the Kalahari area only small towns in the northern catchment area are Van Zylsrus, Askham and Rietfontein that rely on groundwater and their abstraction is just lower than the potential potable volume calculated for the dry season.

In the D6 secondary catchment the towns of De Aar, Britstown, Victoria West, Richmond, Carnavon and Loxton all depend on groundwater. The reported annual abstraction in **Table 5-2** show only 3 435 822 m³/a, which is low compared to the 64 million cubic metres potable groundwater available in the dry season. In the D5 secondary catchment Fraserburg, Sutherland and Williston are towns dependent on groundwater. They only abstract 4 301 655 m³/a of the potable volume of 23 million available. The areas along the Orange River in Catchment D7 seems to abstract the most groundwater in the WMA. It is assumed that it is not only groundwater use but that the groundwater is used for irrigation in conjunction with surface water. Pofadder and Aggeneys in the west are linked to the Orange River by pipeline for bulk water supply. Abstraction in this D8 secondary catchment is more than the potable portion due to quality in this arid area.

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 for the Upper Orange WMA. Based on the GRAII Quaternary Catchment data from DWA (**Table 5-2** the Annual Abstraction is only a fraction of the Annual Potential Recharge which is less than half of the calculated Groundwater Resource Potential. The reason for these discrepancies in the use, recharge and resources is the large surface area and low population and poor groundwater quality.

The groundwater quality is one of the main factors affecting the development of groundwater resources. The groundwater quality in the Lower Orange River Catchment varies from good to unacceptable in terms of potable standards. Potable quality in the east presents about 75% of the samples tested while in the west only 13% of samples qualified. In the northern part only 17% of samples are potable. The rest of samples tested fell into Class 2 or above, which is only for short term use and not even unusable for stock drinking. One of the reasons for poor quality is groundwater flow dynamics resulting in almost stagnant resources as shown in the Kalahari dunes area where water quality comes close to sea water quality (Levin, 1980) and piped bulk water supply was introduced. Rietfontein supply is also poor quality and wells and boreholes are further impacted by pit latrines and animals. Apart from high salinity the groundwater of low salinity can be of unacceptable quality as result of high Fluoride (Moola, 2008) and Uranium (Toens et al, 1998) which is from natural sources. High nitrate is also noted in boreholes close to villages or feedlots. The impact of quality on the health needs to receive more attention.

	Annual Abstraction	Annual Poten	tial Recharge	Groundwater Poten	^r Resource tial	Utilisable G Exploitatio	roundwater n Potential	Utilisable Potable Groundwater Exploitation Potential		
Quaternary	m ³ /a/	m³/a/cat	chment	m³/a/cato	hment	m³/a/cat	tchment	m³/a/catchment		
Catchment	catchment	Normal (Mean)	Dry	Normal	Dry	Normal	Dry	Normal	Dry	
	At	Re	Re (dry)	AGRP	AGRP (Dry)	UGEP	UGEP (dry)	UPGEP	UPGEP (dry)	
D4	2 509 804	60 214 308	37 118 832	72 704 455	49 837 120	16 407 809	10 349 786	4 787 209	3 009 020	
D5	4 301 655	55 346 628	34 632 735	202 137 858	181 284 402	46 664 958	36 512 367	29 739 317	23 069 522	
D6	3 435 822	207 610 650	132 868 190	471 133 410	396 268 350	122 030 840	90 269 270	87 818 442	64 866 843	
D7	7 030 435	135 394 637	86 966 090	337 881 090	289 339 450	95 941 375	77 652 077	69 386 886	55 962 614	
D8	1 443 263	3 414 371	2 08 938	26 491 210	24 786 196	2 422 245	2 031 078	427 639	356 528	
TOTALS	18 720 979	461 980 594	293 634 785	1 110 348 023	941 515 518	283 467 227	216 814 578	192 159 493	147 264 527	

Table 5-2: Groundwater availability in the quaternary catchments of the Lower Orange WMA

5.4.3 Further Groundwater Development Options

Studies indicate that the groundwater resources are limited in some areas due to low rainfall and poor quality. The following recommendations for further development are made:

- The WARMS data base must be updated for Groundwater Reserve and Usage studies done for all sub-catchments to provide reliable estimates of the unused groundwater resources;
- These studies must also indicate the distribution and estimate the poor quality resources that cannot be included in the available unused resources;
- Apart from high salinity, the groundwater of low salinity can be of unacceptable quality as result of high Fluoride and Uranium (WRC, 1998), which is from natural sources. High nitrate is also noted in boreholes close to villages or feedlots. The impact of quality on health needs to receive more attention;
- 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, and
- 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. Such studies to identify the most optimum drilling sites were done in the Britstown Municipal area.
- Feasibility studies need to assess the implication groundwater abstraction option could have on the base flow to rivers and the implications on the ecology.

5.5 MANAGEMENT OF GROUNDWATER

Boreholes and abstraction from boreholes are seldom managed properly and therefore failure of boreholes in the WMA is a common experience. Proper management and monitoring of groundwater sources by municipalities and other users are of vital importance.

The Department of Water Affairs developed a strategy for the management of groundwater quality and it is crucial that this document be distributed to all Municipalities and the necessary training of stakeholders' takes place. The document states that it is common for groundwater to be poorly managed. It takes a long time to detect that groundwater has become polluted and groundwater has only a limited ability to purify itself. It is difficult, often impossible, and also very expensive to restore polluted groundwater. The major reason for poor management of groundwater resources, however, has been a lack of structured approach to management and a lack of knowledge and information about groundwater.

The following general recommendations for management of groundwater are made:

- Awareness of the DWA document Policy and Strategy for Groundwater Quality Management in South Africa, First Edition 2000;
- Protection zones around groundwater resources are vital and no pollution sources must be allowed close to supply boreholes, as per DWA, 2000 strategy;
- Water quality must be monitored regularly and the sustainability must be monitored by regular water level measurements during operation;

- Sustainable groundwater use benefits from having a large number of boreholes available for supply and circulating production between the boreholes, and
- In areas where aquifers are under stress from over abstraction (i.e. Petrusburg, Bainsvlei), further development needs to be restricted and controlled.

6 WATER QUALITY

This section provides a summary of the Water Quality assessment carried out for the study and the reader is referred to the separate report with the title "Development of Reconciliation Strategies for Large Bulk Water Supply Systems: Orange River. Water Quality", for further detail information.

6.1 BACKGROUND

Quantity and quality water requirements of different users will not always be compatible, and the activities of one user may restrict the activities of another, either by requiring water of a quality outside the range required by the other user or by lowering quality during use of the water (e.g. discharges). Efforts to improve or maintain a certain water quality often require a compromise between the quality and quantity requirements of different users and management measures. The DWA recognises that, just as a quantity of water can be "used", so can water quality. For water to be regarded as "fit for use" for a number of different users in the same catchment, the water quality needs to satisfy the most beneficial of those users. The achievement of this desired resource water quality requires a combination of planning guidance and management actions that is integrated with the quantity aspect.

Thus in the development of the Reconciliation Strategy for Large Bulk Water Supply Systems in the Orange River an understanding of the water quality is required to determine the possible implications of the proposed options identified to balance the supply with the demand. A perspective of where the Orange River System is now and what interventions are required in terms of water quality management (issues and concerns) is necessary to determine how water quality will be changed or water use impacted upon by implementation of each of the identified intervention options. This will ensure that in planning for the bulk water supply reconciliation, the water quality requirements and implications are addressed through an integrated approach that will ensure long term sustainability of the Orange River.

In order to determine the water quality impacts and pollution sources that would feed into reconciliation option development, it was considered necessary to undertake an assessment of water quality of the Orange River and identify water quality "hot spots" and issues/aspects that may have an influence on the overarching planning and management of the system.

6.2 STATE OF WATER QUALITY IN THE ORANGE RIVER

The water quality in the Orange River catchment is highly variable due to a combination of natural factors such as rainfall, evaporation, geology and soils, and anthropogenic factors which cause man-made changes to the chemistry of the rivers in the basin. In the case of the Orange River, natural factors play a major role in determining water quality due to the size and extent of the catchment, stretching across several topographical, geological and climatic zones.

Against this natural variability in water chemistry, there are significant anthropogenic sources of pollution in the basin, particularly in the Vaal catchment. This catchment includes the main urban and industrial conurbations of South Africa, the main gold mining areas of the country, parts of the Highveld coal fields, some of the country's power stations and significant areas of dry land and irrigation agriculture. The Orange River catchment as a whole is less developed, although

irrigation agriculture occurs extensively along the river downstream of Vanderkloof Dam (UNDP/GEF, 2008).

Based on previous assessments undertaken and current understanding of the system the main threats to water quality in the Orange River have been identified as altered flow regime, nutrient enrichment; increased salinity from acid mine drainage and irrigation return flows; microbial contamination from urban settlements and poorly operated wastewater treatment works and elevated sediment concentrations. In addition trace metals and persistent organic pollutants, while they do not pose catchment-wide risk currently, do show high concentrations in certain localised areas. Other concerns include lack of adequate, co-ordinated and appropriate water quality monitoring and the implementation of resource water quality objectives to sustainably manage water quality in the catchment.

The key issues that have been identified as potential threats are briefly discussed below:

 Altered flow regime: In the Orange River system, the controlled releases of water from the major storage reservoirs have improved the reliability of supply to water users along the lower reaches of the Orange-Senqu River in South Africa and Namibia, with the result that the river no longer experiences periods of low flow. However, the construction of dams has also homogenized the flow regimes, chiefly through modification of the magnitude and timing of ecologically critical high and low flows. It also has greatly dampened the seasonal and inter-annual stream flow variability of the Orange River, thereby altering natural dynamics in ecologically important flows.

Large volumes of water are diverted from the Orange River. The Lesotho Highlands Water Project has resulted in large volumes of low salinity water being diverted from the Senqu River into the Vaal River catchment. This has led to an increase in salt levels in the Gariep and Vanderkloof dams.

Regulated releases from the dams also resulted in a constant blackfly problem in the lower Orange. Blackflies breed in rivers in a constant flow of fast-moving water where they attached to rocks and plants and filter out suspended particles.

The total mean annual runoff as measured in the lower Orange River has decreased significantly during the past 45 years. The recent flow volumes are about 46 % lower at Upington, about 68 % lower at Pella, and 60 % lower at Vioolsdrift compared to the natural flow. Therefore, the significant water abstractions from the lower Orange River (primarily for irrigation) are drastic having severe impacts on the aquatic environment (DWA, 2009).

Eutrophication: Eutrophication is a severe problem in the Vaal catchment and in isolated pockets of the Orange River catchment. Localised eutrophication and microbial pollution is known along the Caledon River, along the Orange River downstream of Lesotho and downstream of the Upington irrigation area. However, there is insufficient information to determine the extent of this pollution. Gariep and Vanderkloof Dams are relatively low (<5 µg/ℓ) and fall in the range of oligotrophic systems. Algal blooms, including cyanobacteria, were recorded at Upington and Pella. Serious cyanobacterial blooms, aesthetic problems and toxic algal species in central and lower Orange have been recorded since 2000 and more recently in the Upper Orange.

A Joint Basin Survey-1 undertaken by ORASECOM to provide a snapshot of the quality of the water resources of the Orange-Senqu Basin in 2010, indicates that nutrient concentrations throughout most of the Basin are sufficiently high to cause algal blooms (ORASECOM, 2011).

Salinisation: 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 have had major implications for domestic, industrial and agricultural water use. The increase in salinity has been ascribed to irrigation return flow and reduced flows. Of special concern, is the river reach between Boegoeberg Dam and Kakamas where TDS regularly exceeds 500 mg/L. Salinity problems in the Lower Riet River have also been observed. Impact on sustainability of agriculture is a concern. The salt load from the Vaal River needs to be taken into account in the siting of future dams.

Salinity modelling was undertaken on the Orange River as part of a recent DWA study (DWA, 2013) on the calibration of the WQT TDS Model. The annual average volumes and loads were calculated for the WQT model calibration period from 1970 to 2004.

• The acid mine drainage originating from the Vaal catchment has been identified as a potential threat. Critical problems are known to exist in the Eastern and Central Basins where, respectively, limited and no pumping is taking place. Decant has occurred in the Eastern Basin, while the Central Basin is currently flooding and will decant within two to three years. The Eastern Basin is also considered an AMD priority area, due to the lack of adequate measures to manage and control the problems related to AMD. The critical urgency in this basin is to implement intervention measures before the problems become more serious.

In April 2011, the Minister of Water Affairs in South Africa directed the Trans Caledon Tunnel Authority to undertake emergency works as part of short term interventions to deal with the problem of Acid Mine Drainage on the Witwatersrand. The short term management measures include the installation of pumping systems in the basins to manage the water level below the environmental critical level and to neutralise the mine water before discharge. The South African Department of Water Affairs is in the process of investigating and recommending a feasible long-term solution to the AMD problem, in order to ensure long term water supply security and continuous fitness for use of Vaal River water.

Downstream of the Vaal Dam, the discharge of AMD has contributed to increased sulphate levels in the Vaal River – primarily through the Klip and Suikerbosrand rivers. The salinity of these rivers is frequently in the 'unacceptable' range. However, salinity in the Klip River has gradually improved since 1986 (largely because of the higher volumes of effluent from the wastewater treatment works and the reduction in the mine water discharge volumes over time) and now falls mainly in the 'tolerable' range. Historically, the Klip River contributed most of the salt load (about 80%) to the Vaal Barrage. The TDS concentration in the Vaal Barrage is managed through dilution releases from Vaal Dam to a concentration of 600 mg/L.

 Suspended Solids and Turbidity: The suspended solid loads in the lower Orange River have changed dramatically and reduced by up to 97 % from the 'natural' levels. The total suspended solids in the Orange River from the Gariep Dam and downstream have however decreased drastically after the construction of the dams, particularly during the last 10 – 20 years (DWA, 2009). The growth of benthic algae and phytoplankton, which include important nuisance organisms, is limited by light availability, which is restricted by the turbidity. New dams, or an increase in the salinity of the water (with which flocculation and sedimentation of suspended solids is associated), or both factors acting together, could reduce the turbidity thus increasing the risk of blooms of algae and phytoplankton.

- *Microbiological Pollution:* There are concerns along all the rivers which flow through towns and villages throughout the catchment regarding localized microbiological pollution from untreated and partially treated sewage entering the rivers. Microbiological quality risks are also associated with the large urban areas but the available data shows that the risks are localised.
- Heavy metals: The impacts of heavy metals are unknown due to a lack of monitoring data and detailed studies, but some level of prevalence of these pollutants is suspected. The available data highlighted that the concentrations of Aluminium, Cadmium, Copper and Lead were occasionally unacceptably high and could potentially be harmful to human health and the aquatic environment – the reason for the high metal concentrations measured at Upington, Neusberg, Pella, and Vioolsdrift are unknown and are a matter of concern, especially in the Lower Orange River. The role of the numerous mineral mines along the river should be particularly investigated as possible sources of metals. High uranium concentrations have been recorded on the Vaal River at Schmidtsdrift. In addition higher than average levels of several elements have been recorded on the Caledon and Malibamatso rivers draining into the Orange River (ORASECOM, 2011).
- Water Quality Monitoring: An extensive monitoring system does exist for the Orange River as
 part of the DWA's monitoring programme, although there are a number of deficiencies in the
 data sets available, particularly along the Lower Orange River. The historical chemical data
 sets of DWA are good at several monitoring sites on the Orange River and tributaries,
 however, serious gaps and low frequency occurred and some critical parameters, like TSS
 and turbidity are not measured at most of the sites. Upgrading and expansion of the
 monitoring programme is required. Trace metals and microbiological pollutants need to be
 monitored. Lack of co-ordinated sampling and inconsistent sampling as well as the selection
 of the most appropriate sites for water quality monitoring has presented problems.
- *Resource Water Quality Objectives:* The Orange River is currently managed without Resource Water Quality Objectives being formerly adopted or uniformly applied throughout the system. RWQOs provide the numeric or descriptive goals, within which the water quality component of the water resource must be managed. Preliminary RWQOs have been developed for the Orange River as part of a DWA study undertaken in 2009. These RWQOs need to be refined and implemented as part of a water quality management strategy for the Orange River.

6.3 RESOURCE WATER QUALITY OBJECTIVES FOR THE ORANGE RIVER CATCHMENT

Resource directed management of water quality includes the development and implementation of Resource Water Quality Objectives (RWQOs). RWQOs are a mechanism through which the balance between sustainable and optimal water use and protection of the water resource can be achieved. RWQOs are the water quality components of the Resource Quality Objectives (RQOs)

which are defined by the National Water Act as "clear goals relating to the quality of the relevant water resources" (DWAF, 2006). RWQOs are typically set at a finer resolution than RQOs to provide greater detail upon which to base the management of water quality. RWQOs provide the basis for determining the allocatable water quality and water quality stress.

Preliminary RWQOs are currently available for the Orange River (Upper and Lower WMAs) (DWA, 2009). These recommended preliminary RWQOs were set through the DWA (2009) study ("Orange River: Assessment of Water Quality data requirements for WQP Purposes"). The needs of the water users and other stakeholders with respect to the in-stream water quality of the water resources in their catchments, and their needs with respect to the disposal of water that contains waste to the resource were formulated into objectives.

Major water user requirements include irrigation (mainly maize, wheat and Lucerne in upper Orange and mainly grapes in lower Orange), stock farming (mainly cattle sheep and goat farming) and supplying domestic water to towns and rural communities. In the Lower Orange area, producers of table grapes, dried fruit and wine grapes need to give proof of compliance with the SANS:241 requirements to the Perishable Products Export Control Board (PPECB).

In the Orange River, the major consumptive water user is agriculture (principally irrigation) with on average about 89.8 %, followed by domestic use and industrial use - 9.6 %, while mining uses the remainder 0.6 %. Afforestation is negligible in the Orange River WMAs. The pressure on the water supply from dry-land crop production, as well as stock and game farming, is insignificant compared with the demand for irrigation water. The irrigation industry is the biggest single water user in the Orange River catchment.

The RWQOs for the Upper and Lower Orange River WMAs are shown in **Table 6-1; Table 6-2** and **Table 6-3** per monitoring station (river reach). The RWQOs for the Orange comprise Level 1 and that for the tributaries comprise Level 2. The RWQOs determined are primarily based on the DWA South African Water Quality Guidelines (DWAF, 1996) through application of the RWQOs Model 4.1 of DWAF (DWAF, 2006), and were guided by the catchment visions of the WMAs that describe the level of protection required by the water users and stakeholders in the area. The output RWQOs by the Model were adjusted based on the need for more stringent water quality requirements and expert knowledge to recommend the final RWQOs (DWA, 2009).

Variable	Units	Bound	ASH RIVER TUNNEL	ORANJE DRAAI	ALIWAL NORTH	GARIEP DAM	ROODE- POORT	VANDERKL OOF DAM	DOORIEN KUILEN	MARKSDRIFT
Algae (ChI- <i>a</i>)	ug/l	Upper	5	5	10	10	10	5	10	10
Alkalinity (CaCO ₃)	mg/l	Upper	175	175	175	175	175	175	175	175
Ammonia (NH ₃ -N)	mg/l	Upper	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
Calcium (Ca)	mg/l	Upper	60	60	80	60	60	60	60	80
Chloride (Cl)	mg/l	Upper	40	40	40	40	40	40	40	50
Fluoride (F)	mg/l	Upper	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.75
Magnesium (Mg)	mg/l	Upper	30	30	30	30	30	40	40	30
NO ₃ (NO ₃ -N)	mg/l	Upper	0.4	0.4	0.3	0.4	0.4	0.4	0.4	0.5
n H	unite	Upper	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4
рп	units	Lower	6.9	6.9	6.9	6.9	7.3	7.1	7.1	7.1
Potassium (K)	mg/l	Upper	10	10	25	25	10	10	10	25
Ortho-phosphate (PO ₄ -P)	mg/l	Upper	0.045	0.045	0.045	0.040	0.04	0.043	0.040	0.030
SAR	mmol/l	Upper	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Sodium (Na)	mg/l	Upper	30	30	40	40	40	40	40	70
Sulphate (SO ₄₎	mg/l	Upper	60	60	80	60	80	80	65	60
TDS	mg/l	Upper	260	260	260	260	260	260	260	360
Total Hardness	mg/l	Upper	175	175	175	175	175	175	175	175
Si	mg/l	Upper	20	20	20	20	20	20	20	20

Table 6-1: Resource Water Quality Objectives (Level 1): Upper Orange River

Table 6-2: Resource Water Quality Objectives (Level 1): Lower Orange River

Variable	Units	Bound	BOEGE- BERG	NEUSBERG	UPINGTON	PELLA MISSION	VIOOLS- DRIFT	ALEXANDER BAY
Algae (Chl- <i>a</i>)	ug/l	Upper	10	10	15	15	15	30
Alkalinity (CaCO ₃)	mg/l	Upper	300	300	300	300	300	300
Ammonia (NH ₃ -N)	mg/l	Upper	0.015	0.03	0.058	0.03	0.03	0.015
Calcium (Ca)	mg/l	Upper	80	80	80	80	80	80
Chloride (Cl)	mg/l	Upper	100	100	100	100	100	100
Fluoride (F)	mg/l	Upper	0.7	0.7	0.7	1	1	0.7
Magnesium (Mg)	mg/l	Upper	30	50	70	70	70	70
NO ₃ (NO ₃ -N)	mg/l	Upper	0.4	0.2	0.2	0.15	0.15	0.25
5 4	unite	Upper	8.4	8.4	8.4	8.4	8.4	8.5
рп	units	Lower	7.1	7.6	7.2	7.4	7.0	7.5
Potassium (K)	mg/l	Upper	15	25	25	25	25	25
Ortho-phosphate (PO ₄ -P)	mg/l	Upper	0.03	0.025	0.025	0.03	0.03	0.03

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Variable	Units	Bound	BOEGE- BERG	NEUSBERG	UPINGTON	PELLA MISSION	VIOOLS- DRIFT	ALEXANDER BAY
SAR	mmol/l	Upper	1.5	2	3	3	3	3
Sodium (Na)	mg/l	Upper	70	70	92.5	92.5	92.5	92.5

CALEDON KORNET-STORMBERG TIENFONTEIN Variable Units Bound KRAAI SEEKOEI KOMMISSIE-SPRUIT FICKSBURG (WELBEDACHT -SPRUIT POPLARS DRIFT DAM) Algae (Chl-a) 10 20 10 15 15 15 10 10 ug/l Upper Alkalinity (CaCO₃) Upper 175 175 450 450 300 300 300 300 mg/l Ammonia (NH₃-N) 0.015 0.015 0.058 0.015 0.015 0.015 0.015 0.058 mg/l Upper Calcium (Ca) 80 60 150 80 80 80 80 80 Upper mg/l Chloride (CI) Upper 40 20 138 138 50 40 40 100 mg/l Fluoride (F) Upper 0.7 0.4 1.0 1 0.7 0.7 0.7 0.7 mg/l 30 100 70 30 70 70 30 Magnesium (Mg) mg/l Upper 70 NO₃ (NO₃-N) 0.2 0.15 0.75 0.2 0.4 0.2 0.25 0.8 mg/l Upper 8.4 8.4 8.4 8.5 8.5 8.4 8.4 8.4 Upper pН units 7.4 7.1 7.1 7.1 7.0 7.1 7.6 7.1 Lower Potassium (K) 5 25 50 50 25 10 25 25 mg/l Upper Ortho-phosphate (PO₄-P) Upper 0.04 0.03 0.13 0.05 0.05 0.04 0.05 0.1 ma/l SAR 1.5 1.0 3 6.0 1.5 1.5 1.5 1.5 mmol/l Upper Sodium (Na) Upper 45 20 92.5 115 70 50 70 70 mg/l 80 25 80 80 100 Sulphate (SO₄₎ Upper 100 150 80 mg/l TDS mg/l Upper 260 260 550 1000 400 360 450 195

300

20

Table 6-3: Resource Water Quality Objectives (Level 2): Orange River Tributaries

Total Hardness

Si

50

20

Upper

Upper

mg/l

mg/l

175

20

200

20

200

20

200

20

200

20

300

20

6.4 WATER QUALITY COMPLIANCE TO RESOURCE QUALITY OBJECTIVES

Analysis of the available water quality data and comparison to RWQOs listed above was undertaken as part of this task in order to identify water quality variables of concern and possible water quality issues in the Orange River catchment, as well as assess how the results compare to the state of water quality in the catchment.

6.4.1 Water Quality Data and Analysis

The historical data on physico-chemical parameters were obtained from the DWA Resource Quality Services (RQS) for the monitoring sites on the Orange and Caledon Rivers and some major tributaries. The DWA has a comprehensive monitoring system of water quality sites throughout the country as part of the National Chemical Monitoring Programme (NCMP). Monitoring data collected is stored on the Department's Water Management System (WMS). The current water quality status (2000 - 2013) was determined using the long-term chemical data collected at relevant water quality monitoring sites. The changes in the water quality over time (temporal) and the spatial (downstream) variability of salinity in the Orange River were also assessed.

The analysis included 22 water quality monitoring sites in the Upper and Lower Orange WMAs. See **Table 6-4** for a description of the sites on the Orange River, Caledon River and major tributaries. Thirteen of the sites are on the Orange River main stem, including the two major dams, 4 on major tributaries of the Orange and 4 on the Caledon River. The additional site is at the Ash River Tunnel outfall from Katse Dam. This was included to obtain an indication of the water quality of the Senqu River.

The monitoring sites on the Upper Orange River main stem are at Oranjedraai, Aliwal North, Roodepoort, Dooren Kuilen and Marksdrift. The main tributaries are Kornetspruit, Kraai River, Stormbergspruit and Seekoei River. Sites on the Caledon River main stem are at confluence with the Little Caledon River, at Ficksburg, Kommissiedrift and the tributary Little Caledon River. There are 11 monitoring sites on the lower Orange River, from Zeekoeibaard to Alexander Bay.

WQ STATION	MONITORING SITE – DESCRIPTION	LOCATION: GPS CO- ORDINATES	ELEVATION/CATCHMENT
C8H036	Ash River Tunnel Outlet from Katse Dam (at Butterworth)	S28.43778; E 28.39806	Elevation: 1742 m; D83A
D1H001	Stormbergspruit at Burgersdorp (Wonderboomspruit at Diepkloof)	S31.00109; E26.35314	Elevation, 1 379 m; below weir; D14E
D1H003	Orange River at Aliwal North (Road bridge)	S30.68612; E26.70600	Elevation: 1 310 m; D14A
D1H006	Kornetspruit at Maghaleen	S30.16003; E27.40145	Elevation, 1 428 m; D15G
D1H009	Orange River at Oranjedraai; at Lesotho border	S30.33772; E27.36277	Elevation, 1 392 m; D12A

 Table 6-4: Water Quality Monitoring sites on the Orange River

WO STATION	MONITORING SITE -	LOCATION: GPS CO-	ELEVATION/CATCHMENT
WQ STATION	DESCRIPTION	ORDINATES	
D1H011	Kraai River at Roodewal	S30.73707; E26.78440	Elevation, 1 299 m; D13L
D2H012	Little Caledon River at The Poplars; confluence with Caledon River	S28.69477; E28.23486	Elevation: 1 603m; D21C At border (Caledon poort bridge)
D2H035	Caledon River d/s from Ficksburg	S28.90409; E27.83084	Elevation, 1 536m; D22C
D2H036	Caledon River at Kommissiedrift at N6 crossing	S30.27994; E26.65427	Elevation: 1 323 m; D24G
D2R004	Welbedacht Dam	S29.90889; E26.86056	Elevation:1 388m; D24C
D3R002	Gariep Dam on Orange River: near dam wall	S30.60794; E25.50465	Elevation: 1 273 m, D34A
D3H013	Orange River at Roodepoort; ds of Gariep Dam	S30.58487; E25.42084 (S30.62062; E25.46511)	Elevation: 1 195 m D34A, 1976 – 2013 (1548)
D3H015	Seekoei River at De Eerste Poort	S30.53480; E24.96250	Elevation: 1 214 m, D32J
D3R003	Vanderkloof Dam, near dam wall	S29.99447; E24.73524	Elevation: 1 169 m, D31E
D3H012	Orange River at Dooren Kuilen; below Vanderkloof Dam	S29.99141; E24.72414	Elevation: 1 083 m, D31E
D3H008	Orange River at Marksdrift	S29.16201; E23.69447	Elevation: 980 m, D33K
D7H008	Orange River at Boegeberg Reserve/Zeekoebaard	S29.02625; E22.18608	Elevation: 973 m, D73BC
D7H016	Orange River at Neusberg weir (North canal)	S28.77481; E20.74558	Elevation: 678 m, D73F
D7H005	Orange River at Upington Water Works	S28.45259; E21.25994	Elevation: 791 m D73F
D8H008	Orange River at Pella Mission	S28.96443; E19.15276	Elevation: 301 m, D81G
D8H003	Orange River at Vioolsdrift	S28.76208; E17.72631	Elevation: 167 m; D82E
D8H012	Orange River at Alexander Bay/ Ernest Oppenheimer Bridge	S28.56689; E16.50728	Elevation: 9 m; D82L

The key water quality variables for the assessment were based on the associated activities and impacts in the catchment and the typical water quality variables that are assessed in characterising the natural background state. Major sources of impact in the Orange River catchment area include irrigation return flows, intensive fertilizer use, discharges from wastewater treatment works, un-serviced dense settlements (sewage pollution), and erosion. The water quality variables analysed at the sites included:

- Chemical water quality parameters, including total dissolved salts, alkalinity, mineral ions (Ca²⁺, Mg²⁺, Na⁺, K⁺, Cl⁻, F⁻, Si & SO₄²⁻), nutrients [nitrogen (NO₃²⁻ & NH₃) and phosphorus (PO₄³⁻)
- Physical parameters: Turbidity and total suspended solids (TSS) (where available).
- Biological parameters: Algal biomass (*Chl-a*), at selected sites.

Microsoft Office Excel software was used for data manipulation and for the statistical analyses. The water quality analysis was undertaken within the constraints of the available data on the WMS of the DWA.

6.4.2 Water Quality Analysis: Results

The results of the water quality analysis are presented in Error! Reference source not found. below which indicate compliance in terms of the RWQOs as listed in **Section 6.3**. Turbidity data was only available for 16 of the 22 monitoring stations. The turbidity readings are shown in Error! Reference source not found. for information purposes. Compliance assessment of turbidity was not undertaken due to the fact that turbidity RWQOs are yet to be established. It is not possible to apply a generic RWQO for the entire system. A RWQO for turbidity is highly site specific, dependent on reference conditions and the species of aquatic biota present.

Error! Reference source not found. represents the water quality of selected variables at the water quality monitoring sites.

In summary the water quality assessment highlighted the following:

- The water quality and quantity in the uppermost reaches of the Orange River, above Gariep Dam, is still in a largely un-impacted state and show minor changes over the past 13 years.
- The water in these uppermost reaches is moderately soft, relatively low in salt concentrations, but generally high in suspended solids and turbidity.
- The water quality in the Lower Orange River occasionally exceeded the RWQO for irrigation especially the salt concentrations and high pH values.
- The nutrient (nitrate and orthophosphate) concentrations in the Orange River are in general non-compliant to the RWQOs.
- Some of the water withdrawn for irrigation is returned to the river environment for re-use, but its quality is degraded with considerably higher salt and nutrient concentrations which contributes significantly to the salt load in the Orange River.

The mean chlorophyll-*a* concentrations (algal biomass) in the Gariep and Vanderkloof Dams were low (<12 μ g/ ℓ) and fall in the range of oligotrophic systems, but the Chl-*a* concentrations, were much higher at Upington and Pella (mean 30 μ g/ ℓ) corresponding to mesotrophic water bodies. More monitoring data is required to obtain a better understanding of the trophic status of these sites.

• Chl-a data is limited and more data is required to provide a conclusive understanding.

- The general water quality in Kornetspruit and Kraai River was good. Orthophosphate levels are high which indicates contributions from urban areas such as wastewater discharges and urban runoff.
- The Seekoei River's salt and nutrient concentrations are high but are possibly considered to represent natural conditions.
- The analysis of the available Stormbergspruit water quality data indicates high salts and nutrient levels.
- The water quality in the Caledon River is highly variable but in general is in a fair condition when compared to the RWQO, however, nutrient levels were elevated and turbidity levels are high, indicating high sediment concentrations.
- Water quality at the Ash River tunnel outlet is very good (natural state) indicating the water quality at the headwaters of the Senqu River is ideal.

6.4.3 Key water quality variables of concerns and related issues

6.4.3.1 Turbidity

The concentration of turbidity in the upper Orange River is high and is primarily attributed to soil erosion. Turbidity refers to water clarity. The Orange River is known as a very turbid river. Most Orange River suspended sediment is produced upstream of the Caledon-Orange confluence. The majority of the Orange River suspended load is derived from erosion of Karoo sedimentary bedrock and soils (DWA, 2009). The high turbidity in the Upper Orange River and specifically in the Caledon will limit algal growth. Assessment of the temporal variation of turbidity between 1992 and 2007 at Oranjedraai, Dooren Kuilen and Boegeberg Dam in the Orange and at Kommissiedrift on the Caledon Rivers does not indicate any increasing trend in concentration (DWA, 2009). The high concentration of turbidity that is evident in the system specifically in the Upper Orange WMA does not appear to be a significant threat to the aquatic ecosystem based on ecological assessments that have been undertaken. However it is apparent that it must be taken into consideration in the design and management of water supply infrastructure.

6.4.3.2 pH

The pH values in the whole Orange River were high (alkaline, median, 8.3); generally increase downstream and occasionally exceeds the upper limit for irrigation of 8.4.

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Table 6-5: Summary of water quality compliance to RWQOs at the identified monitoring sites on the Orange River

Monitoring Site	Chl-a	Calcium	Chloride	TDS	Flouride	Hardness	к	Mg	NH ₃	Nitrate	Na	PO₄ ⁻	SAR	SO₄	Si	Alkalinity	рН
C8H036Q01 AS RIVER TUNNEL OUTLET FROM KATSE AT BOTTERKLOOF		Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non- compliant (95th%tile)	Compliant	Compliant	Compliant	Compliant	Compliant
D1H001Q01 WONDERBOOM/STORMBERG SPRUIT AT DIEPKLOOF/BURGERSDORP		Compliant	Compliant	Non- compliant	Compliant	Non- compliant (95th%tile)	Compliant	Compliant	Non- compliant (95th%tile)	Non- compliant	Compliant	Non- compliant	Compliant	Compliant	Compliant	Compliant	Non- compliant (95th%tile)
D1H003Q01 ORANGE RIVER AT ALIWAL NORTH		Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non- compliant (95th%tile)	Compliant	Non- compliant (95th%tile)	Compliant	Compliant	Compliant	Compliant	Compliant
D1H006Q01 KORNET SPRUIT AT MAGHALEEN		Compliant	Compliant	Compliant	Compliant	Non- compliant (95th%tile)	Compliant	Compliant	Compliant	Non- compliant	Compliant	Non- compliant	Compliant	Compliant	Compliant	Compliant	Compliant
D1H009Q01 ORANGE RIVER AT ORANJEDRAAI		Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non- compliant (95th%tile)	Compliant	Non- compliant (95th%tile)	Compliant	Compliant	Compliant	Compliant	Compliant
D1H011Q01 KRAAI RIVER AT ROODEWAL		Compliant	Compliant	Non- compliant (95th%tile)	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non- compliant	Compliant	Compliant	Compliant	Compliant	Non- compliant (95th%tile)
D2H012 CALEDONSPOORT 190 THE POPLARS 199 AT THE POPLARS ON LITTLE CALEDON RIVER		Compliant	Compliant	Compliant	Compliant	Non- compliant (95th%tile)	Compliant	Compliant	Compliant	Compliant	Compliant	Non- compliant (95th%tile)	Compliant	Compliant	Compliant	Compliant	Non- compliant (95th%tile)
D2H035Q01 CALEDON RIVER AT FICKSBURG/ FICKSBURG BRIDG		Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non- compliant	Compliant	Non- compliant (95th%tile)	Compliant	Compliant	Compliant	Compliant	Non- compliant (95th%tile)
D2H036Q01 CALEDON RIVER AT KOMMISSIEDRIFT		Compliant	Compliant	Compliant	Compliant	Non- compliant (95th%tile)	Compliant	Compliant	Compliant	Non- compliant	Compliant	Non- compliant (95th%tile)	Compliant	Compliant	Compliant	Compliant	Non- compliant
D2R004Q01 WELBEDACHT 285 - WELBEDACHT DAM ON CALEDON RIVER: NEAR DAM WALL		Compliant	Compliant	Non- compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non- compliant (95th%tile)	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non- compliant
D3R002Q01 OVISTON NATURE RESERVE - GARIEP DAM ON ORANGERIVIER: NEAR DAM WALL	Non- compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non- compliant	Compliant	Non- compliant (95th%tile)	Compliant	Compliant	Compliant	Compliant	Compliant
D3H013Q01 ROODEPOORT ON ORANGE RIVER		Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non- compliant	Compliant	Non- compliant	Compliant	Compliant	Compliant	Compliant	Compliant
D3H015Q01 SEEKOEI RIVER AT DE EERSTE POORT		Compliant	Compliant	Compliant	Compliant	Non- compliant	Compliant	Compliant	Non- compliant (95th%tile)	Non- compliant (95th%tile)	Non- compliant (95th%tile)	Non- compliant (95th%tile)	Compliant	Compliant	Compliant	Non- compliant (95th%tile)	Non- compliant
D3R003Q01 VANDERKLOOF DAM ON ORANJERIVIER: NEAR DAM WALL	Non- compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non- compliant (95th%tile)	Compliant	Non- compliant (95th%tile)	Compliant	Compliant	Compliant	Compliant	Compliant
D3H012Q01 ORANGE RIVER AT DOOREN KUILEN (DOWNSTREAM OF D3R003)		Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non- compliant (95th%tile)	Compliant	Non- compliant (95th%tile)	Compliant	Compliant	Compliant	Compliant	Compliant
D3H008Q01 AT MARKSDRIFT ON ORANGE RIVER		Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non- compliant (95th%tile)	Compliant	Non- compliant (95th%tile)	Compliant	Compliant	Compliant	Compliant	Compliant
D7H008Q01 ORANGE RIVER AT BOEGOEBERG RESERVE/ZEEKOEBAART		Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non- compliant (95th%tile)	Compliant	Non- compliant	Compliant	Compliant	Compliant	Compliant	Non- compliant (95th%tile)
D7H016Q01 NORTH CANAL FROM ORANGE RIVER AT KAKAMAS/NEUSBERG	Non- compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non- compliant (95th%tile)	Compliant	Non- compliant	Compliant	Compliant	Compliant	Compliant	Non- compliant (95th%tile)
D7H005Q01 ORANGE RIVER AT UPINGTON	Non- compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non- compliant	Compliant	Non- compliant	Compliant	Compliant	Compliant	Compliant	Non- compliant (95th%tile)
D8H008Q01 ORANGE RIVER AT PELLA MISSION	Non- compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non- compliant (95th%tile)	Compliant	Non- compliant	Compliant	Compliant	Compliant	Compliant	Non- compliant (95th%tile)
D8H003Q01 AT VIOOLSDRIFT ON ORANGE RIVER		Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non- compliant (95th%tile)	Compliant	Non- compliant	Compliant	Compliant	Compliant	Compliant	Non- compliant (95th%tile)
D8H012Q01 ORANGE RIVER AT ALEXANDER BAY		Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non- compliant (95th%tile)	Compliant	Non- compliant	Compliant	Compliant	Compliant	Compliant	Non- compliant (95th%tile)

Table 6-6: Turbidity data for some water quality sites on the Orange River and tributaries (mg/l)

	D1H003Q01 ORANGE RIVER AT ALIWAL NORTH (D14E)	D1H006Q01 KORNET SPRUIT AT MAGHALEEN (D15G)	D1H009Q01 ORANGE RIVER AT ORANJEDRAAI (D12A)	D1H011Q01 KRAAI RIVER AT ROODEWAL (D13L)	D2H012 CALEDONSPOO RT AT THE POPLARS ON LITTLE CALEDON RIVER (D21C)	D2H035Q01 CALEDON RIVER FICKSBURG BRIDGE (D22C)	D2H036Q01 CALEDON RIVER AT KOMMISSIE- DRIFT (D24G)	D2R004Q01 WELBEDACHT DAM ON CALEDON RIVER: NEAR DAM WALL (D24C)	D3R002Q01 OVISTON NATURE RESERVE - GARIEP DAM ON ORANGERIVIER (D34A)	D3H013Q01 ROODEPOORT ON ORANGE RIVER (D34A)	D3H015Q01 SEEKOEI RIVER AT DE EERSTE POORT (D32J)	D3R003Q01 VANDERKLOOF DAM ON ORANJERIVIER: NEAR DAM WALL (D31E)	D3H012Q01 ORANGE RIVER AT DOOREN KUILEN (DOWNSTREAM OF D3R003) (D33A)	D3H008Q01 AT MARKSDRIFT ON ORANGE RIVER (D33K)	D7H008Q01 ORANGE RIVER AT BOEGOEBERG RESERVE / ZEEKOEBAART (D73B)	D8H003Q01 AT VIOOLSDRIFT ON ORANGE RIVER (D82E)
Median	37.1	15.4	19.3	4.3	2.8	13.3	38.8	26.6	6.3	12.0	1.8	2.2	3.2	5.5	3.2	4.0
75%tile	138.5	78.9	146.0	18.3	7.1	39.3	201.5	95.0	19.8	28.0	4.6	6.1	6.8	13.8	10.1	17.4
95%tile	553.0	525.8	623.8	145.1	28.3	266.1	960.5	547.2	53.4	86.6	53.7	31.6	32.3	48.4	30.5	90.8





Figure 6-1: Water quality compliance to RWQOs for selected variables along the length of the Orange River

The pH is an important variable in water quality assessment, as it influences many biological and chemical processes within a water body and all processes associated with water supply and treatment. The pH values were relatively low in the upper part of the river (mean of 8.1). The higher pH values in the middle and lower part of the Orange River are primarily ascribed to higher algal concentrations.

Water having a pH in excess of 8.4 may cause foliar damage, decrease the visual quality of marketable products (if they are wetted during irrigation), affect the availability of several micro and macro-nutrients, and also increase problems with encrustation of irrigation pipes and clogging of drip irrigation systems (DWAF, 1996).

6.4.3.3 Nitrate and Orthophosphate (PO4⁻)

The nitrate and orthophosphate concentrations in the Orange River show the largest noncompliance in terms of the water quality variables assessed. The analysis of the available data showed that the orthophosphate concentrations at the sites on the Orange River, except at Oranjedraai, similar (50 ± 30 μ g/ℓ). However the tributaries of the Orange River, *viz.* Stormbergspruit, Kornetspruit, and Seekoei River indicate much higher levels of orthophosphate (> 100 μ g/ℓ).

The present state nitrate concentrations are at an average concentration of 0.82mg/l in the Orange River and its tributaries. The concentrations are approximately 3 times higher than the RWQOs in the Lower Orange from Neusberg to Alexander Bay. The tributaries with the exception of the Kraai River also show non-compliance to the RWQOs.

The nutrient concentrations are indicating the potential for eutrophic conditions throughout the catchment and a possibility of hypertrophic conditions. There are a number of factors however that determines the extent of algal growth. These include the availability of adequate sunlight and suitable temperatures. The turbid waters experienced in the catchment is limiting sunlight penetration and limiting algal growth. The assessment results shown can only be considered indicative. However the indications are supported by observations of algal blooms in the lower reaches of the Orange River downstream of the confluence of the Orange and Vaal River. The eutrophication effects in the Orange River need to be investigated further.

6.4.3.4 Salinity

Salinity is an indication of the concentration of dissolved salts in a body of water. The level of salinity in aquatic systems is important to aquatic plants and animals as species can survive only within certain salinity ranges. Salinisation is the process by which the concentration of total dissolved solids in inland waters is increased.

The total dissolved salt (TDS) concentrations in the Orange River show a clear downstream increase (Error! Reference source not found.). The TDS concentrations in the upper section of the Orange River (*i.e.* from Oranjedraai to Dooren Kuilen, just downstream of Vanderkloof Dam), are relatively low (mean 182 mg/ ℓ).

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Figure 6-2: Spatial variation of Total dissolved salts (mg/l) in the Orange River during 2000 - 2013

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From Marksdrift and downstream the dissolved salts increases continuously and reached concentrations (95th percentile) of approximately 500 mg/*l* from Vioolsdrift to Alexander Bay. These increasing concentrations of salinity may have negative consequences for the river's ecosystem as well as for crop production further downstream. Some of the water withdrawn for irrigation is returned to the river environment for re-use, but its quality is degraded with considerably higher salts and nutrient concentrations. The increased TDS concentration of the return flow contributes significantly to the salt load in the Orange River. There are also significant water losses in the lower reaches of the Orange River due to evaporation. The evaporation of water from the water body results in the increase in the downstream TDS concentrations.

The ionic composition in the Orange River changes downstream, with proportionally higher sulphate (SO₄), sodium (Na) and chloride (Cl) concentrations probably originating from the irrigation return flows. In the Orange River, the sulphate concentration has increased from 12.9 mg/ ℓ at Oranjedraai (upper reaches) to 85.5 mg/ ℓ at Alexander Bay (lower end), while sodium and chloride increase from approximately 7 mg/l to 64 mg/l. The increase in sulphate concentration is likely to be attributed to the impact of the Vaal River.

6.5 CONCLUSIONS AND RECOMMENDATIONS

In terms of the water quality analysis and assessment of water quality issues undertaken the following can be summarised in terms of the task conclusions and recommendations:

- The water quality present state analysis indicates increasing salinity in the Orange River (temporal and spatial) and high nutrient concentrations that indicate the potential for eutrophic conditions throughout the catchment and a possibility of hypertrophic conditions. The evidence suggests that the high turbidity in the system is the limiting factor for algal growth.
- The high concentration of turbidity that is evident in the system specifically in the Upper Orange WMA does not appear to be a significant threat to the aquatic ecosystem based on ecological assessments that have been undertaken. However it is apparent that it must be taken into consideration in the design and management of water supply infrastructure.
- The development of an integrated water quality management strategy is required that addresses the nutrient and salinity management of the system, the refinement and adoption of the RWQOs, the quantification of the extent of the actual and emerging problems of water pollution/water quality deterioration and the actions required for land use management.
- It is recommended that:
 - Nutrient modelling of the system be undertaken, and
 - Irrigation return flows be assessed.
- Improved and consolidated water quality monitoring of the Orange River System (surface and groundwater) is required to support effective water resource management.
- The qualitative high level assessment undertaken of the water quality implications of the reconciliation options indicates that there will be no significant impacts on the current water

quality of the Orange River System. However the potential for Vioolsdrift Dam to act as a sink for nutrients and sediment and for Verbeeldingskraal Dam to capture sediments does exist. These impacts must be investigated further should these options be implemented.

• A desktop study was undertaken to identify the opportunities for re-use of treated sewage effluent from the urban areas. The current and future discharge volumes were obtained from the literature and from the municipalities. The water quality requirements for the re-use for irrigation, indirect re-use and direct re-use options are discussed. The water treatment requirements for the different re-use options are presented and the capital costs for the treatment determined. The assessment of the opportunities for re-use of treated effluent showed that currently the potential is limited. However effluent re-use could contribute to the suite reconciliation options in the future with the expected growth in the effluent volumes.

7 THE WATER BALANCE

7.1 CURRENT WATER BALANCE WITHOUT INTERVENTIONS

The water balances presented in this and subsequent sections reflect the current and future situation in the Orange River Project (ORP).

All components of the upstream sub-systems (Caledon Modder, the Senqu River system in Lesotho – including the Lesotho Highlands Water Project) as well as the other tributaries in RSA and Namibia have been accounted for in the system analysis when the available yields presented in **Table 7-1** were determined for the year 2012 development conditions.

Any changes in these sub-systems over the planning horizon (subsequent to the year 2012), which have an effect on the ORP were reflected in changes to the ORP yield or indicated as contributions such as in the case of operations releases from Polihali Dam (LHWP Phase 2) – see **Chapter 9** for further discussions in this regard.

Sub-system	Dams	Yield (million m ³)	2012 Demand/Transfer (million m ³ /a)		
LHWP phase 1	Katse	780	780		
	Mohale				
	Knellpoort				
Caledon/Modder	Rustfontein	04	04		
sub-system	Welbedacht	04	94		
	Mockes				
Orange River	Gariep	3 038*	2 801#		
Project	Vanderkloof	5 030	2 091#		

 Table 7-1: Sub-system yield and current demands

Notes: * This refers to the yield after the current EWR was supplied. # The total net yield of the system excluding the (EWR)

The LHWP Phase I sub-system is currently in balance as the agreed transfer between Lesotho and the RSA is in line with the yield available from the sub-system. The implementation of Phase II of the LHWP will reduce the available water in the Orange River Project – see **Section 7.2** for further details.

The Caledon/Modder sub-system supply water to Bloemfontein/Mangaung, Botshabelo, Thaba Nchu and several small towns has already exceeded its yield. The Greater Bloemfontein Area Reconciliation Strategy recommends several interventions to achieve a water balance including additional transfers from the Caledon River and 20 million m³/a support from Gariep Dam from 2030 onwards.

The water balance for the Orange River Project in the year 2012 shows there is a surplus of 147 million m^3 , 5% of the system yield.

There are several smaller sub-systems in the study area for which water balances have been compiled as part of the All Town Reconciliations strategies or the recently completed study, 'Establish Water Supply and Drought Operating Rules for Stand Alone Dams and Schemes Typical of Rural/Small Municipal Water Supply Schemes' (DWA, 2013).

A summary of the yield and water use information obtained from these studies is given in **Table 7-2.**

The assurance of supply from the tributary river systems in the Lower Orange are low due to the highly variable runoff, however, the water use practices have adapted to the variability and demand is therefore considered to be in balance with the available water.

Sub system/dam	2012 demand	Historic	Stochastic Yield (million m³/a)					
Sub-system/dam	(million m ³ /a)	firm yield	1 in 20 year ⁽¹⁾	1 in 50 year	1 in 100 year			
Kalkfontein	42.3	39.0	55.0	44	36.0			
Krugersdrift	38.4	23.9	37.0	33.5	30.5			
Burgersfort Scheme	0.82	1.09	1.65	1.35	1.20			
Sterkspruit Scheme	5.09	6.7	8.9	7.7	7.1			
Lady Brand Scheme	2.7	6.5	7.3	7.2	7.0			
Zastron Scheme	1.7	1.57	2.1	1.8	1.6			
Smithfield Scheme	0.62	0.57	0.84	0.72	0.63			
Ficksburg/ Clocolan Scheme	4.0	4.3						
Armenia Scheme	6.85	4.0	5.1	4.4	4.0			
Molteno Scheme	0.42	0.73	0.97	0.82	0.73			

 Table 7-2: Summary of 2012 demands and yields for smaller schemes

Note: (1) – Recurrence Interval of a supply failure (once in 20 years).

7.2 FUTURE WATER BALANCE WITH NO INTERVENTIONS

The water requirement projection scenario described in **Section 4.2** and the system yield (water availability) presented in **Section 5** are combined to produce the water balance for the planning horizon 2013 to 2050 as presented in **Figure 7-1** and shows the following:

• No interventions are implemented;

- The decrease in the system yield from 3 038 million m³/a in 2012 to 2 842 million m³/a in 2050 is as a result of growing water use from the Caledon for abstraction to the Greater Bloemfontein area, abstraction for Maseru and several small towns in the Caledon and Upper Orange upstream of Vanderkloof Dam;
- There is currently (2012) a surplus of 147 million m³/a;
- This surplus is fully utilised in the year 2017 by the increasing water use, largely as a result of the scheduled uptake of unused allocations for irrigation to resource poor farmers and growth in the urban/industrial and mining water requirements, and
- The total shortfall in the year 2050 is 304 million m³/a. Note that this balance excludes the effect of the proposed Phase 2 of the LHWP.



Figure 7-1: Future water balance of ORP, no interventions

Given that the decision to proceed with the implementation of LHWP Phase II (comprising of Polihali Dam and transfer tunnel) is confirmed by South Africa and Lesotho governments, a second water balance is provided to illustrate the implications on the ORP – see **Figure 7-2**. The storage and delivery for water from LWHP Phase II is expected to be in place around 2022, reducing the ORP yield by 284 million m³/a while making an additional volume of 437 million m³/a available for transfer to the Vaal River system.

According to the Vaal River Reconciliation Scenario the full transfer volume is not required by 2022 and if water is delivered in accordance with the growing water needs in the Vaal River

System (to maintain a positive water balance in the Vaal River system), the remaining yield from Polihali Dam can be made available to support the deficit in the ORP as indicated by the purple area shown on **Figure 7-2**.

The remaining yield from Polihali Dam to temporarily support the Orange will relieve the projected deficit in the ORP, but **Figure 7-2** shows that the ORP will still continuously be in deficit from 2017 onwards, which indicates that an intervention is already needed within the next few years. With no intervention other than Polihali Dam, the deficit will grow as more of the available yield from Polihali Dam is transferred to the Vaal System over time.



Figure 7-2: Future water balance of ORP – with LHWP Phase II and no further interventions

Based on the water balances presented above, the conclusion can be made that a "do-nothing" scenario will not be acceptable and that interventions are required.

It should further be noted that the introduction of the Ecological Preferred EWR 2013 (alternative EWR requirements described in **Section3.2.3**) will reduce the indicated system yield by 434 million m³/a and will only be feasible to implement along with a future augmentation option. This was considered in the formulation of the scenarios described in the subsequent sections of the report.

Chapter 8 therefore describes possible water reconciliation interventions and how the preferred intervention scenario was selected.

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8 POSSIBLE OPTIONS FOR RECONCILIATION

8.1 INTRODUCTION

Intervention scenarios comprise the implementation over time of various combinations of reconciliation options, which can be divided into two main categories:

- Reconciliation Options that reduce the water requirements.
- Reconciliation Options that increase the water supply.

The above mentioned two categories of reconciliation options focusses on the volume of water use and water supply assuming that the water available is fit for use. Water quality related issues can however result in a reduced volume available for use as some of the water might not be fit for use. A water quality assessment was carried out as part of this study, which indicated an increasing salinity in the Orange River and high nutrient concentrations that indicate the potential for eutrophic conditions. It is thus strongly recommended that the development of an integrated water quality management strategy should start a soon as possible and that nutrient modelling of the system be undertaken and irrigation return flows be assessed.

8.2 OPTIONS THAT WILL REDUCE WATER USE OR WATER REQUIREMENTS

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

Water conservation and water demand management (WC/WDM) has been identified as a strategic intervention which could have an impact on the future demand projections of the Orange River Supply System. More details are provided in the separate report on WC/WDM in the Urban Sector. The focus of this component of the study is to develop a high level WC/WDM strategy and business plan for the supply system which will form part of the reconciliation strategy, with specific focus on the Water Services Authorities which fall within this supply system as shown in **Table 8-1**. The objective of this task was to review the status quo and progress made with WC/WDM in the study area and focusses on the following key aspects which are described in the stand alone report.

i. Status Quo Assessment

Municipal code	Municipality	Water Service Authority
DC08	Siyanda DM	Yes
NC083	//Khara Hais	Yes
NC082	!Kai! Garib	Yes
DC06	Namakwa DM	Yes
NC067	Khâi-Ma	Yes
NC062	Nama Khoi	Yes
NC061	Richtersveld	Yes

Table 8-1: Summary of Water Service Authorities (WSA) (Municipalities) Investigated

ii. Water Requirements

The current water requirements for the municipalities in the Orange Water Supply System are summarised in **Table 8-2**.

Municipality	Blue Drop million m ³	WISIP 2012 million m ³	All Town 2011 million m ³	WSDP/IDP million m ³	Municipality million m ³	Adopted Value million m ³
Khara Hais	31.5	16.1	12.8	15.9	13.06	13.06
Kai Garib	7.5	1.4	2.2		4.49	4.49
Nama Khoi	1.7	0.01	11.6		2.09	2.09
Khâi-Ma	9.6		4.2	0.6	0.8	0.8
Richtersveld			0.7		0.59	0.59
Total						21.03

Table 8-2: Summary of Municipal Water Requirements

There are significant discrepancies between the various information sources as depicted in **Table 8.2** which required engineering judgement combined with knowledge of the areas to assess the current water demands in the Orange River Supply System. The study team adopted and utilised one value from the available sources which appeared most credible in order to assess the current consumption for individual municipalities. What became clear from the status quo assessments is that most of the municipalities are not in a position to provide definitive water balance calculations. A few of the municipalities provided estimated values which are not yet fully based on actual bulk meter readings.

	Current IWA Water Balance Diagram (millionm³/annum)								
	System Input Volume = 21.026	Authorised consumption = 14.468	Billed authorised = 14.413	Billed metered = 13.608	Revenue water = 14.413				
		Water losses = 6.559	Apparent losses = 1.115 Real Losses = 5.444	Apparent losses = 1.115 Real Losses = 5.444	Non-revenue water = 6.614				

Figure 8-1: Consolidated IWA Water Balance for the Orange River Supply System

The water loss / Non Revenue Water (NRW) situation for the complete study area is shown in **Figure 8-1.** (method as recommended by the International Water Association - IWA)

Based on the water balance depicted in **Figure 8-1**, the estimated Non-Revenue Water for the Orange River Supply System is 31.5% which is below the national average of 36.8%.

Based on the municipal status quo assessments and the issues noted above potential savings through the implementation of WC/WDM were determined and applied in the water balances of the relevant scenarios.

Target water Balance

Annual projected water balances were compiled for all the participating municipalities utilising the International Water Association (IWA) standard water balance model. The consolidated results are presented in the target water balance for the Orange River Supply System shown in **Figure 8-2** below.



Figure 8-2: Target Water Balance for Orange River Supply System

Based on the calculations, the targeted water balance illustrates a system input volume reduction of 30.6% and Non-Revenue Water reduction of 11.7% from 31.5% to 19.7% giving a total saving of 6.4 million m³/a.

It was assumed that municipalities can start applying WC/WDM measures immediately and that it will take approximately 5 years to phase in the full benefits of the water saving for the domestic water use sector.

8.2.2 WC/WDM in the Irrigation Sector

The irrigation sector is by far the largest water user in the Orange River catchment, with an estimated requirement of 2 370 million m³/a, comprising 52% of the water requirements within the study area and 61% of the total demand imposed on the Orange River Project. Any percentage reduction in water use in this sector will therefore have a substantial effect on the total water requirements within the catchment.

A more detailed description of the potential benefits of WC/WDM in the irrigation sector is given in the separate report on irrigation water use and possible savings which will form part of this study.

i. Constraints to increased water savings in the irrigation sector

The following main constraints to increased water use efficiency and WC/WDM in general need to be addressed by DWA, Water User Associations (WUAs) / Irrigation Boards and irrigators as appropriate:

- The practice of allocating water on an irrigation area basis and a standard volume (quota) per unit area (m³/ha/a), rather than on a volumetric basis;
- The different statutory requirements of Irrigation Boards (in terms of old legislation) and Water User Associations (in terms of new legislation);
- The lack of accurate water measurement on many schemes;
- There are inadequate incentives for farmers to save water. There is a perception amongst certain farmers that if they use less water than their allocation, then in terms of the new Water Act, which no longer recognises a "right" to water, he runs the risk of losing a portion of his allocation. The water allocation is attached to the property and determines the value of the property. Any reduction in allocation would devalue the property. On flood irrigation schemes, most plots of land are bordered by other plots and the farmer has no access to more land which he could irrigate should he save on his allocation, and
- There are inadequate incentives for WUAs to save water. Their operational budgets are based on selling a certain volume of water. If water is saved, the *WUA* will have less revenue and may not be able to meet its obligations to member irrigators.

ii. The role of Institutional structures in WC/WDM

The Water Act provides guidelines for the implementation of water conservation and water demand management in the irrigation sector and the Department of Water Affairs (DWA) has developed (WC/WDM) strategies and guideline documents for agriculture. (DWA, 2006)

The Act requires that WC/WDM be driven primarily by WUAs.

WUAs are, in turn, required to submit annual business plans, to a CMA, or the DWA in the absence of a CMA.

The development of a Water Management Plan (WMP) by a WUA is central to implementing water conservation and water demand management in the irrigation sector. The WMP sets out benchmarks and best management practices for WC/WDM and a manageable and affordable programme for their implementation by both the water supplier (in the case of controlled irrigation schemes) and their irrigators over time. The water management plan is therefore the primary

tool with which the irrigation sector can implement WC/WDM initiatives in controlled irrigation areas.

This approach is strongly supported by all the main WUAs and Irrigation Boards in the Orange River Catchment. There is an appeal by these institutions that DWA should drive the establishment of WUAs to provide the vehicle for improved WC/WDM and the related water savings that will result.

The "best practice" initiatives that have the greatest impact on improved water use efficiency on these Schemes are:

- Effective measurement of irrigation water through sluices and water meters and the use of computerised telemetry systems. You can't manage what you can't measure;
- Creating a sense of awareness amongst staff and irrigators about irrigation efficiency and it benefits, and
- Preparation of an annual Water Management Plan which allows for a systematic and practically achievable improvement in water management and water-use efficiency.

If other WUAs and Irrigation Boards in the catchment were to improve their WC/WDM practices in line with the above examples, significant improvements in water use efficiency are possible. Support from DWA is required for this to happen in the foreseeable future.

Expansion of diffuse irrigation away the main stream of the Orange River and controlled irrigation areas:

• An important finding during the study is that diffuse irrigation, particularly in the Upper Orange, is inadequately measured and monitored. Better control of irrigation in this area would result in significant water savings.

Unregistered (unlawful) water use:

 Unregistered water use in the catchment has also been identified by most of the existing WUAs and Irrigation Boards as a significant cause of water "loss". 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 WUAs (when they are formed to cover the whole of the Basin) as they will see illegal water use in their area as "unlawfully using their own water".

iii. Incentives to improve irrigation water use efficiency

Water saving by irrigators is more likely to be made if it makes business sense to do so. To illustrate this aspect the following examples are provided:

- A leading table grape farming company in the Upington area practices high-tech irrigation scheduling and achieves up to 20% savings in irrigation water (12 000 m³/ha/a) compared to standard allocations in the area of 15 000m³/ha/a. This was achieved not to save water primarily but:
 - to satisfy the buyer of his export table grapes who requires documented proof that the minimum amount of water is used in the production of the product ,and

- to minimise electricity costs which have become a major production cost in areas where pumping of irrigation water is required.
- The allocation of irrigation water to irrigators on an accurately measured volumetric basis, for which a unit charge applies as is being applied on the Orange, Riet WUA. However, at present, many Irrigation Boards have inadequate water measuring infrastructure and systems in place to implement this approach.

iv. Recommendations

- Where bulk water reticulation infrastructure on regulated schemes is the responsibility of the DWA, repair and maintenance programmes should be established and funding sought for this purpose. Most irrigation scheme infrastructure is owned by DWA but is not always being maintained by them. This makes the management of scheme irrigation infrastructure by the WUA difficult. Where infrastructure is owned by IBs or WUAs they should be encouraged to repair and maintain their bulk infrastructure;
- Incentive systems should wherever possible be considered for WUAs as well as individual farmers to encourage water saving. In the case of irrigators, the introduction of allocation by volume, where water measuring devices are available would be an effective incentive to improve efficiency, and
- The installation of efficient measuring devices on all regulated irrigation schemes should become a high priority for DWA and WUA/Irrigation Boards and where possible incentives for farmers to purchase such devices should be sought.

v. Quantifying water savings

Estimation of achievable savings in irrigation water through improved best practice at both distributor level and irrigator level and the period over which the savings can be achieved can only be approximate.

Based on interaction and discussion with WUAs and Irrigation Boards and taking account of the WUAs where water use efficiencies are already in place throughout the catchment there is an opportunity for savings of between 5% and 10%.

The total irrigation water demand is 1 990 million m^3/a and the saving could be between 99 million m^3/a and 200 million m^3/a in the ORP

However these estimates must be viewed with caution because of two essential realities.

- Firstly, present irrigation in the catchment results in significant return flows as a result of irrigation exceeding crop water use. If efficiency of irrigation is improved, there will be direct impact (reduction) on the return flows and the net savings estimated above will be significantly reduced. The estimated savings could consequently be reduced by as much as 60 -70%, and
- Secondly, the present basis of irrigation water allocation provides the incentive for irrigators to apply water saving to an extended irrigation area, where additional irrigable land is available rather than making a real water saving for the system as a whole.
It is therefore recommended that an average net saving of about 5% over a period of 5 -10 years be adopted as a conservative but realistic estimate of what could be achieved.

8.2.3 Developing a mechanism to reallocate saved irrigation water

An incentive for the irrigation farmer to implement WC/WDM measures is to expand his/her irrigation land with the saved water. This needs to be encouraged as it leads to more efficient use of water, higher income for that farmer and, on a national level, improved food production for the country.

The irrigation farmer with limited land for horizontal expansion does not have the same incentive. A reduction in water tariff for a reduced water use will not be a good motivation as the water tariffs for irrigation are already very low compared to the tariff of other water use sectors. A better incentive must therefore be established which will make it more attractive for the irrigation farmer to implement WC/WDM and relinquish his/her saved water. In principle the farmer should not be worse off. He/she must be able to harvest the same volumes, to maintain his/her income levels and to retain all his/her staff.

If these conditions are met, one such a mechanism could be to remunerate the irrigation farmer for the saved water. Such remuneration for relinquishing a partial water entitlement could either be done from the fiscus or a levy could be introduced for all water users which can then finance such an incentive. A sound policy prescribing the rules, need to be developed before this option can be implemented. The policy need to address issues such the checks and balances that will protect the irrigation farmer and the water use authority, documentation required to define the amended water allocation/entitlement, conditions of relinquishing, type of incentive, etc.

The linking of WC/WDM savings to such an opportunity is a possible measure that will not necessarily cause economic prejudice and social hardships. This option is attractive in the sense that it can be implemented almost immediately and is not dependent on completion of the entire validation and verification processes. It is only those water users who offer a portion of their water use entitlements for whatever incentive whose entitlements must be validated and verified and this can be done on an ad hoc basis.

The process is relatively inexpensive, either funding mechanism can be used, and it is easy to implement. However the appropriate policy within the Department of Water Affairs needs to be developed and user guidelines need to be prepared.

8.2.4 Reducing the impact of EWR on system yield

The recent EWRs as obtained from the ORASECOM study "Orange-Senqu strategic Action Programme: Environmental flows Project" (Ecological Preferred EWR 2013) was analysed and the implications on the system yield was determined. The results showed a significant reduction in the system yield of 722 million m³/a, in total, which will substantially decrease the availability of water to the current and possible future water users in the system.

It is therefore suggested that the Ecologically Preferred - 2013 EWR be refined to further optimise the level of protections and water use in the ORP. This will typically involve further

EWR scenario evaluation, for both the river and estuary, in combination with the interventions proposed in the strategy.

8.2.5 Reducing Assurances of Supply

The volume of water available from the system could be increased if the water users agree to accept lower assurances of supply. The current user priority definition (criteria defining the maximum allowed risk of restrictions during drought periods) for the Orange River Project is presented in **Table 8-3** below.

User Group	% of the water demand to be supplied at the indicated Priority Category							
	⁽¹⁾ 1:20 year (95%)	1: 100 year (99%)	1:200 year (99.5%)					
Irrigation	50	40	10					
Urban/Industrial	20	30	50					
Losses/River	0	0	100					
requirements								
Environmental	32	0	68					

Table 8-3: Priority classification for different user groups and priority categories

Note: (1) Recurrence interval of a supply failure to occur only once in twenty years (1:20) or assurance of supply of 95% (implying an annual risk of restriction of not more than 5%)

Losses and river requirements are not something that can be restricted as it will always occur even under extreme drought conditions. These requirements cannot be restricted and is therefore allocated to the high assurance class.

The assurance classes for the environmental requirement are only applicable for the current EWR releases which are based on a total different methodology than the recently determined EWRs. The latest EWRs follow the same pattern as the natural flows generated in the basin and do not require a specified assurance.

To give an indication of the available yield at different assurance levels, the long term stochastic yield results for the ORP (Gariep and Vanderkloof dams) are provided in **Table 8-4**.

Table 8-4: Orang	e River Project	t Long-term	stochastic yield
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Yield at the given Assurance level (million m ³ /a)									
1 in 20 year1 in 50 year1 in 100 year1 in 200 year95%98%99%99.5%									
3 900	3 500	3 200	3 000						

From **Table 8-4** it is evident that 900 million m^3/a more water could be supplied at the low assurance of 95% versus the high assurance of 99.5%. A fist order calculations showed that by

assuming that the irrigators in the ORP lower their assurance to be in line with that used in the Algoa system (see **Table 8-5**) for irrigation of areas, approximately 200 million m³/a will become available for other use at 1 in 50 year assurance.

The supply assurances currently applied for irrigation water in the ORP is fairly high compared to other systems in the country. For example the supply assurances used for the Algoa System is given below, showing significant lower assurances are applied specifically for irrigation user groups.

	% of the water demand to be supplied in the indicated Priority Category									
User Group	1 in 5 year 80%	1 in 10 year 90%	1 in 50 year 98%	1 in 100 year 99%						
Irrigation Orchards	30	20	20	30						
Irrigation Other	40	20	20	20						
Urban	10	20	20	50						

Table 8-5: Priority classes for different category water users in the Algoa system

Projection simulation risk analysis were carried out with the WRPM for two alternative risk criteria profiles for irrigation and the results showed the date when intervention is needed could be postponed by two years. This benefit therefore warrants further consideration and it is recommended that stakeholders in the irrigation sector be engaged, during the implementation phase of the strategy, to agree on the appropriate assurance criteria to be applied in future.

8.2.6 Compulsory Licensing

The NWA allows the Minister to require the licensing of all water use. The procedure means that nearly all existing users would have to apply for a licence. The Minister considers all the licence applications, taking cognisance of the water availability, and may licence or where required reduce the existing uses to ensure that International Obligations and the Reserve (BHN and EWR) are met within the water balance. The Minister may also reallocate the available water in fair and equitable manner.

The procedure for compulsory licensing is described in Sections 43 to 48 of the National Water Act (Act 36 of 1998). The process is started when the responsible authority (in this case the Minister in view of the fact that a CMA has not yet been established), issues a notice in the Government Gazette that water users must apply for licences within a certain period of time.

The procedure makes provision for the compilation of a proposed allocation schedule and any water user will have the opportunity to object to his/her new water allocation within 60 days after the proposed allocation schedule has been published in the Government Gazette. After considering all objections, the Preliminary Allocation Schedule must be published and after a prescribed appeal period the Preliminary Schedule becomes the Final Allocation Schedule.

It was decided by the SSC that compulsory licensing is not the appropriate vehicle to use in this Reconciliation Strategy. The implementation of WC/WDM and the development of additional

infrastructure are put forward as the preferred solutions to maintain a positive water balance and provide water to supply the Ecological Water Requirements.

8.3 OPTIONS THAT WILL INCREASE WATER SUPPLY

8.3.1 Groundwater Development

Generally groundwater can be used for domestic and stock watering and supply for smaller towns supplied by well fields within the Upper Orange River WMA.

The Kalkveld Groundwater management area is the only area where large scale development of groundwater takes place for utilisation of commercial irrigation. However, based on Reserve calculations (for a portion of the area) and the irrigation verification figures, the area is under stress and no further development of the groundwater resource will be advised for additional water supply of towns. Before any further development of the resource can take place it is recommended that a comprehensive reserve determination be done for the area and the verification process be completed. The Harvest Potential Map (Seymour & Seward, 1995) can be used to determine the maximum volume of water available per surface area for sustained abstraction from groundwater, which amounts an estimated at 1 020 million m³/a. Therefore it is assumed that there is adequate groundwater resources available in the remainder of the WMA to supply towns and communities not connected to the main surface water supply schemes. However, borehole siting should be based on scientific principles, and sound management practices need to be applied to ensure sustainability of the resource.

8.3.2 Transfers In

Transfers from the Mzimvubu River basin were listed as one of the possible intervention options and was discussed at the first screening workshop. Of all the options listed, the Mzimvubu-Kraai Transfer option was rewarded the lowest score of 17. It was felt that this possible scheme should be marked as a fatal flaw because of the high capital and operational costs which are prohibitive. No other possible future transfer option in support of the Orange River system was considered.

8.3.3 New Dams

Introduction:

The existing ratio of storage to MAR in the Upper Orange/Senqu (ORP and LHWP combined) of 1.37, compared with a ratio of 2 or more for many more developed catchments, indicates that additional water can be made available by providing additional storage.

A number of options have been investigated for creating additional storage and these are discussed below. The yield of any dam is dependent on any new developments upstream, so this chapter evaluates possible new dams independently. The yields quoted in this chapter for different dams can therefore not be simply added together, but are used to select the most favourable options after which they are combined in various scenarios to identify the most favourable system yield.

Designs and cost estimates from previous studies were reviewed, adjusted where appropriate, and the costs escalated using the Contract Price Adjustment (CPA) formula or current costs for

construction. Annual operating and maintenance costs were based on standard DWA percentages of capital costs.

Unit Reference Values (URVs) were calculated by dividing the discounted 45 year lifetime costs by the discounted volume of water supplied, using discount rates of 6%, 8% and 10%.

Ntoahae Dam - Lesotho:

Initially two potential dams, Tsoelike and Ntoahae were identified as options on the Senqu River in Lesotho. They are mutually exclusive and after considering the URV, social and environmental assessment, Ntoahae was selected.

The proposed dam site was identified in the Feasibility Study for Phase II of the LHWP (LHWC, 2007), and is situated on the Senqu River. The site is approximately 62 km downstream of the confluence with the Tsoelike River and 15.5 km upstream of the confluence with the Senqunyane River. The site is located in a sheer-sided gorge cut into sandstones (with minor siltstones and thinner bedded sandstones) of the Clarens Formation and a River Bed level of 1 506 mamsl.

A roller compacted concrete gravity dam with a height of 139 m, a full supply level (FSL) of 1 645 mamsl and active storage of 1 700 million m³ was selected for this site due to the steep abutments which preclude a chute type spillway associated with a concrete faced rockfill dam. The spillway crest length was selected at 90 m to fit the valley topography. The routed probable maximum flood peak of 11 750m³/s will require a freeboard of 15.3 m. Energy dissipation will be by means of a deflector bucket and tailpond arrangement. River diversion will be achieved by means of a cofferdam.

Cost models that were prepared for the LHWP Feasibility Study for Phase II: Dam Design, were evaluated. The rate applied in the cost estimate, base date 2006 was escalated with a factor of 1.29 to obtain 2012 rates. The total capital cost estimate for Ntoahae dam at full supply level 1645 masl is R1 371 million. The historic firm yield is 232 million m³/a giving a URV of R0.57/m³ at 8% discount rate.

Malatsi Dam:

Initially two potential dams, Lebelo and Malatsi were identified as options on the Senqunyane River in Lesotho. They are mutually exclusive and after considering the URV, social and environmental assessment, Malatsi was selected as the preferred option.

The proposed dam site is situated on the Senqunyane River approximately 80 km downstream of Mohale Dam and 10 km upstream of the confluence with the Senqu River. The Relatively steep-sided narrow gorge, in which the proposed dam site is situated, is cut into gently dipping massive sandstones inter-bedded with siltstones of the Clarens Formation.

A concrete faced rockfill dam with a height of 145 m, a FLS of 1 652 mamsl, an active storage of 870 million m³ and a chute spillway of 100 m crest length and a freebord of 9 m is proposed.

Cost models that were prepared for the LHWP Feasibility Study for Phase II: Dam Design, (LHWC 2007), was escalated with a factor of 1.29 to obtain 2012 rates. The total capital cost estimate for Malatsi dam at full supply level of 1652 masl is R1 373 million. This historic firm yields is 119 million m³a, giving a URV of R 1.11 /m³ at 8%.

Bosberg Dam:

The dam site is situated on the Orange River about 13 km east of Aliwal North on the border between the Orange Free State and the Eastern Cape and about 110 km upstream of the confluence of the Caledon River with the Orange River. The site is in a narrow gorge formed by a prominent ridge crossing the river at that point, with the top of the ridge formed by a dolerite cill, and with a RBL of 1 304 mamsl.

This dam site was previously analysed for FSLs ranging between 1 352 and 1 400 masl. A rollcrete gravity dam with a 200 m central overflow spilling and a total freeboard to NOC of 12 m, and FSL of 1 385 masl and active storage of 3 065 million m^3 giving a yield of 377 million m^3/a was selected for this Preliminary Strategy

For the larger dams considered, a low point or saddle on the left (south) flank will require a saddle dam with a minimum ground level of about 1 357 masl. This saddle has been designated as the Partition Saddle.

The outlet works will be incorporated on the right hand side of the spillway section. River diversion will be achieved by means of an earthfill cofferdam

The cost model prepared for the ORRS Potential Dam Development and Hydro Power Options in 1994, for a concrete mass dam at full supply level of 1 385 masl was reviewed. The rates used in April 1994 were escalated by a factor of 3.55 to determine 2012 rates. The total capital cost estimate for the Bosberg Dam, including the saddle dam, is R4 133 million, giving a URV of R1.11/m³.

Consideration was briefly given to a dam with FSL 1 352 masl, requiring a minimal saddle embankment, but remained uneconomic, and with a yield of only 100 million m^3/a , was not considered further.

Verbeeldingskraal Dam:

As a result of the high cost of the alternative Bosberg Dam, consideration was given to possible sites further upstream on the Orange River where the narrow gorge provides numerous topographically favourable dam sites albeit with less attractive storage characteristics than Bosberg. A site was selected on the farm Verbeeldingskraal where the river bed level is 1 318 masl. Costs were estimated for a rollcrete gravity dam with a FSL of 1 385 masl, as for Bosberg, and has a HFY of 200 million m³/a. The capital cost was estimated at R1 048 million. With a yield of 200 million m³/a, this gave a URV of R0.51/m³ at a discount rate of 8%. This makes it a favourable site, being the most economical of the new dam options.

Kraai Dam:

The same ridge crossing the Orange River also crosses the Kraai River about 11 km upstream the river from the Orange River confluence. The RBL at this site is at 1314 masl, and the site is

affected by the Partition Saddle at 1365 masl, now being on the right (north) flank of the Kraai river.

The ORRS considered dams with FSLs ranging from 1372 masl to 1400 masl. For the purposes of this study, a mass gravity rollcrete dam with a height of 58 m with a FSL of 1372 masl, an active storage of 2 989 million m³ and a NOC of 1384 masl and a 135 m central spillway has been adopted.

The Kraai Reservoir basin has a much larger surface area than the Bosberg Reservoir which will result in higher evaporation for the same volume than Bosberg Dam.

The cost model that was prepared for the ORRS in 1994, for a mass concrete dam at full supply level of 1372 masl was reviewed. The rates used in April 1994 were escalated by a factor of 3.55 to determine 2012 rates. It was established that the previous study failed to identify significant lengths of major road which would have to be relocated, and appropriate costs were added to the estimate. The total capital cost estimates for the Kraai Dam, including the saddle dam, is R1999 million. The historic firm yield is 330 million m³/a, giving a URV of R 0.58 / m³ at 8% discount rate.

Boskraai Dam:

This option comprises a combination of the Bosberg and Kraai river dams, with the two dams being at the same FSL, which is above the height of the Partition saddle. This option has the advantage that the large flows in the Orange River can be stored in the large storage capacity in the Kraai river portion of the basin, providing a larger yield that can be provided by the two dams separately. The two dams will act as a single reservoir as water from one basin will spill over to the other at 1 365 masl and higher.

For the purpose of this study, a FSL of 1 385 masl giving an active storage of 10 700 million m³ and an HFY of 937 million m³/a, has been adopted. A saddle is required left of the Kraai Dam at a FSL of 1 385 to prevent spilling. A cost model that was previously prepared for the ORRS in 1994, for a rollcrete dam at full supply level of 1 385 masl was reviewed. The rates used in April 1994, were escalated by a factor of 3.55 to determine 2012 rates. It was established that the previous study failed to identify significant lengths of major road which would have to be relocated, and appropriate costs were added to the estimate.

The total capital cost estimate for the Boskraai Dam with FSL 1385 is R4 962 million. The historic firm yield is 937 million m³/a, giving a URV of R 0.56/m³ at 8% discount rate.

Raising of Gariep Dam

The Gariep Dam is located on the Orange River between the Eastern Cape and Free State and about 30 km north east of Colesberg. It is situated in a gorge at the entrance to the Ruigte Valley some 5 km east of Norvalspont.

ORRS indicates that the Gariep Dam was designed for a possible raising, and considered raising of 5 m or 10 m by means of two possible methods: either radial gates or by adding a solid concrete section. A solid raising of 15 m was also considered. DWA dam Safety Office has advised that they do not favour gates on large dams.

For the purpose of this study a 10 m solid concrete raising up to a new FSL of 1268.98 masl has been adopted giving an increase in storage of 4 485 million m³. Capital costs are based on quantities taken from the ORRS and have been escalated from 1994 to 2012 by a factor of 3.55.

A significant impact of this raising, inadequately considered in the previous study, is the flooding of the town of Bethulie. The town is located near the upstream end of the reservoir where flood levels will be impacted by tail-water effects. In addition, the town is located just downstream of the confluence of the silt-laden Caledon River. Large silt volumes are expected to be deposited in the vicinity of the town, significantly raising the tail-water. A detailed sediment deposition study is required to establish the long term flood levels, but for the purpose of this study it has been assumed that the 100 year tail-water levels will be raised by a nominal 4 m above the maximum flood level. This will require the relocation of about half the town and an appropriate allowance has been included in the cost estimate. It should be noted that Gariep Dam raising increases the maximum surface area by 208.4 km² from 344.4 km² to 552.8 km² (Verbeeldingskraal Dam full supply surface area only 65.4 km²) and will result in substantial increases in evaporation losses.

The total capital cost estimate for the 10 m raising of Gariep dam is R 1 368 million. The historic firm yield is 350 million m^3/a giving a URV of R 0.40/ m^3 at 8% discount rate.

Knoffelfontein Dam

The proposed Knoffelfontein Dam is situated on the Riet River about 11 km downstream of the Modder river confluence and of the small Northern Cape town of Ritchie. The proposed dam site is situated in a relatively steep-sided narrow valley with rock outcrop in the river and up much of the flanks.

The dam's catchment area is very small, making it insignificant in terms of the water resources of the Orange river, but has been included in the study as it has been proposed as a local supply for a possible small scale irrigation scheme for emerging farmers.

A rollcrete gravity dam is proposed with a downstream slope of 1V:075H, and a stepped spillway having a length of 100 m The Regional Maximum Flood was calculated to be 2 330 m³/s and used to determine the freeboard of 5 m.

A cost model was prepared for a rollcrete dam at full supply level of 1090 masl. The rates used in April 1994 in ORRS report were escalated by a factor of 3.55 to determine 2012 rates. The total capital cost estimate for the Knoffelfontein Dam is R240 million. The historic firm yield is 3.2 million m³ /a, giving a URV of R 6.89 / m³ at 8% discount rate.

New Boegoeberg Dam

A dam downstream of the existing Boegoeberg dam was considered in the LORMS study (March 2005) but was eliminated because it was considerably more expensive than the alternative Vioolsdrift option and had higher environmental and social risks. However, in this study's screening process, it was reported that the existing Boegoeberg dam was in a poor condition and would need to be replaced, and that the replacement cost should be taken into account when comparing Vioolsdrift and new Boegoeberg.

This study therefore reviewed reports prepared by the DWA Dam Safety Office in 1993, 2002 and 2009. These reports all concluded that the main structure was in good condition and

shortcomings with the mechanical equipment, identified in the first study, were described as rectified in the subsequent studies, with detailed programmes for on-going maintenance put in place.

It is therefore concluded that the existing dam will not in fact, need to be replaced, and will therefore not impact on the comparison of Vioolsdrift and a New Boegoeberg.

The New Boegoeberg dam has therefore not been considered further in this study.

Vioolsdrift Dam

Previous studies already showed that a re-regulation dam at Vioolsdrift will provide the most savings in the operational requirements. Operational requirements is currently estimated to be in the order of 180 million m³/a, and a reduction of approximately 120 million m³/a is expected when a Vioolsdrift reregulation dam is in place. This dam is also essential if the correct river mouth environmental requirements need to be released as it is not possible to release it with the required accuracy from Vanderkloof Dam located 1300km upstream. For reregulation purposes a live storage of 110 million m³ is required.

The Vioolsdrift combined re-regulating and yield dam was from previous studies already indicated as one of the schemes with the lowest URV. For this reasons the combined Vioolsdrift yield and re-regulation dam is seen as an obvious choice and this option was included in all future intervention scenarios.

Various sites for dam walls were identified just upstream of the existing weir, where the river valley is at its narrowest in the area. A range of dam heights have been considered in previous studies, but it has been determined that the demands which could be supplied from this dam do not warrant the larger options

For this study a dam wall was chosen some 8.5 km upstream of the existing weir. A straight rollcrete gravity dam was considered at a FSL of 210m with a dam height to non-overflow crest of 44 m and an active storage of 510 million m^3 .

The total capital cost estimate for this dam is R 986 million. The historic firm yield is 312 million m^3/a , giving a URV of R0.29 m^3 at 8%

Combination of Options

The yield and related URV for the individual options discussed in **Section 8.3.3** thus far were based on the historic firm yield results obtained with the WRYM. These results were used to select the most appropriate options or combination of options to ensure a positive water balance over the entire planning period. The risk of supply shortages over the planning period for the selected combination of options was however not evaluated for the purpose of the Preliminary Strategy. Projection simulation analyses as discussed in **Section 5.2.2** were carried out in support of the final strategy for the two recommended scenarios of combined options. The risk analysis results provided more accurate dates for when the first intervention is required as well as for the interventions to follow.

These analyses include changes such as the growth in water usage, increasing water transfer schedules and the date when new interventions are phased in and account for the complex interdependencies of all significant activities (storage, abstraction, transfers) and the spatial varying climate across the system.

The components included in the two combinations of option scenarios are summarised in **Table 8.6** as well as the URV related to the specific combination of intervention options.

No	Scenario A Combination	Scenario B Combination				
	Intervention option	Date	Intervention option	Date		
1	WC/WDM	2015	WC/WDM	2015		
2	Real Time monitoring	2016	Real Time monitoring	2016		
3	Vanderkloof LLS	2021	Vanderkloof LLS	2021		
4	Shared utilisation of Polihali Dam	2023	Shared utilisation of Polihali Dam	2023		
5	Vioolsdrift Dam	2024	Vioolsdrift Dam	2024		
6	Raised Gariep (10m)	2026	Verbeeldingskraal Dam	2026		
Rate	URV at g	iven disc	count Rate R/m ³			
6%	0.25		0.23			
8%	0.31		0.29			
10%	0.37		0.34			

Table 8-6: Summary of combination of option scenarios and URV

The selection of the combination of options was based on the yield and URV results from the individual options and selection criteria as given in **Section 8.4.5** and the recommendations from the preliminary strategy. This involved an iterative process as some of the work described in **Section 8.4** and **Section 9** need to be done first to be able to obtain the proposed combination of options given in **Table 8.6**.

Results from the risk analyses showed that the Scenario B combination which include Verbeeldingskraal Dam option, performed much better as a combination in comparison with that obtained when the yield and URVs were determined on an individual basis using the historic firm yield. This is most probably due to the significant savings in evaporation losses as well as

increased spills from Vanderkloof when the Verbeeldingskraal option is used instead of the raising of Gariep. This resulted in a lower URV for the Scenario B combination, while when considered individually the Verbeeldingskraal Dam option had a higher URV than the Raised Gariep Dam option. The risk analysis further showed that the Raised Gariep option requires a very long filling period of 8 years which was not taken into account in the URV calculations when considering the options on an individual basis.

Summary of Live Storage and Dam Yields

The live storage and yield of the dams on the Orange River system are summarised in **Table 8-7** below.

Sub-system	Dams	Active Storage (million m ³)	Yield (million m ³)	Remarks	
LHWP phase 1&2	Katse	1 517		Depresents the	
2040 development	Polihali Dam	1 904	1 217	system yield	
	Mohale	850			
Orange River Project	Gariep	4 567		Represents the	
2040 development level	Vanderkloof	2 174	2 202	system yield	
	Vioolsdrif re- regulating Dam	110	120	Vioolsdrift yield only	
	Vioolsdrift Yield Dam	250	312	Vioolsdrift yield including savings	
	Raised Gariep 5m	1 986 (increase)	181	Incremental yield	
Extended Orange	Raised Gariep 10m	4 485 (increase)	350	Incremental yield	
River Project at 2040 development level	Bosberg	3 065	377	Bosberg incremental yield only	
	Boskraai	8 288	937	Boskraai	
	Verbeeldingskraal	1 360	200	incremental yield only	
	Malatsi	870	119	Malatsi yield only	
	Ntoahae	1 700	232	Ntoahae yield only	
Lower Riet 2012	Knoffelfontein	11	8.2	No EWR	
development level			3.2	EWR included	

Table 8-7: Historic firm yield from indicated dams at 2040 development levels

8.3.4 Re-using Sewage Effluent

The only urban area which is currently large enough to generate sufficient quantities of treated sewage effluent and where there is a need for augmentation is Bloemfontein and environs. Currently the treated wastewater from this area is discharged into the Modder River which is an additional resource that was not present or was at reduced volumes (relative to current return flow levels) at the time the downstream irrigation allocations were determined and promulgated. The wastewater can therefore be re-used as long as the assurance of supply to the downstream users are maintained to what is defined in a White Paper, official operational documentation, court orders or the prevailing conditions when the proclamation for the scheme with related abstraction were made. The downstream water users thereof do not have a default entitlement to the discharged treated wastewater.

It is proposed that a process be commissioned to establish (or determine) the appropriate assurance level the downstream users should be supplied with. This need to be carried out in consultation with the water users and will be the first step to enable re-use in future.

Based on the information obtained from the Green Drop reports, the Mangaung Municipality, which covers the greater Bloemfontein area, is well suited for investigating re-use options. The Bloemspruit Works, Sterkwater North East and North West Works were considered for possible future advanced treatment and re-use. The Sterkwater North West works is a new WWTW and the North East works is being upgraded. There are plans to upgrade the Bloemspruit works once the North West Works is commissioned. These treatment plants receive relatively high flows in the catchment and the treated water from these WWTWs is currently being discharged downstream of the water collection dams in the area. These plants currently discharges approximately 30 million m³/a. Re-use options considered included re-use for irrigation, indirect re-use for potable use and direct re-use for potable use.

Five different options were investigated as part of the Water Reconciliation Strategy Study for the Large Bulk Water Supply Systems; Greater Bloemfontein Area. The five options were:

Planned direct re-use – new North Eastern WWTW

A new WTW at the new North Eastern WWTW, from where the treated water could be pumped to the existing reservoir at Maselspoort. Estimated yield of 10.8 million m³/a (30MI/d).

Planned indirect re-use – Transfer to upstream of Mockes Dam

Abstraction at the new North Eastern WWTW and pumping to a stream feeding the existing Mockes Dam. The WTW at the Maselspoort Weir would be extended. Yield is as above.

Treated indirect re-use – Krugersdrift Dam

Treating surplus surface runoff which accumulates in the dam and pumping the treated water back to the main Bloem Water reservoirs at Brandkop. A booster pump station 35km rising main to Bloemfontein is also required. The yield would be about million 10.8 m³/a (30Ml/d).

Planned direct re-use – Bloemspruit

Treated waste water from the Bloemspruit WWTW would be purified and pumped over 3.8km into the Greater Bloemfontein supply area after blending. The estimated yield would also be 10.8 million m³/a (30Ml/d).

Re-use of treated effluent – Direct use: Irrigation

The direct use of treated waste water from any WWTW via a dedicated additional distribution system in the city for "in-city" irrigation purpose or extended to agricultural and industrial uses. A re-use volume of about 2.3 million m^3/a (6.3 Ml/day) is possible.

Public resistance to the water re-use intervention may be encountered, possibly stemming from concerns of poor design or control process which may allow sub-standard water to be introduced into the potable water supply system or for religious reasons.

The priority interventions defined in the Greater Bloemfontein Reconciliation Strategy were urban WC/WDM, groundwater interventions for towns in the supply area, solving siltation problems at Welbedacht Dam and developing additional yield in the Caledon River catchment. Re-use remain an option for the long term to be considered after the measures listed above were implemented.

Re-use of treated effluent will have the benefit of reducing pollution load into the streams and could supply the growth in water use of the Bloemfontein area for a number of years.

The yield of this option, for the purposes of the scenario planning, has been assumed to be 10.8 million m³/a, but may ultimately be significantly more, dependent on the growth in waste water to be treated.

The earliest date/year in which re-use of water was considered in the Greater Bloemfontein Reconciliation Strategy was in 2027.

8.3.5 System Operating Rules

Three different operating measures in the Orange system were evaluated for potential yield increases. These are:

- The Utilisation of water below the current minimum operating levels at the Gariep Dam;
- The Utilisation of water below the current minimum operating levels at the Vanderkloof Dam, and
- Real time monitoring of flows in the Vaal and the Orange system to allow improved operation.

Gariep Dam

The option was investigated to utilise water below the current minimum operating level of the dam which is set up to make provision for ESKOM power generation. The challenge is that the current operating level is also defined by the intake level at Oviston to the Orange Fish Tunnel. The Orange-fish Tunnel supplies water to the Eastern Cape through a 80km tunnel from Gariep Dam to provide water for irrigation and domestic use. With a lower minimum operating level, water will have to be pumped from a downstream point in the dam to the intake tower to ensure a

continuity of water supply to the Eastern Cape. A more feasible abstraction point downstream of the dam would be at Goodlands.

Infrastructure will be required to pump water from the Goodlands abstraction point, a bridge structure 400m into the basin with pumps attached to the 22km long pipeline. It was established that the cost of pumping and infrastructure development will be too expensive compared to the yield gain. The URV calculation for this option was R54.42 $/m^3$, which has shown to be in comparison with alternative excessively expensive and therefore this option was discarded for further investigation.

Vanderkloof Dam

The Vanderkloof Dam can be operated by lowering its minimum operating level with the benefit of increasing the yield of the system by approximately 137 million m³/a. The option entail lowering the current minimum operation level is 1 147.8 mamsl to the proposed level of 1 111.0 mamsl. The new proposed minimum operating level is below the irrigation outlets and to continue to supply for irrigation; water would be abstracted from the right bank silt outlet and a pump station will pump the water into the irrigation canal which supplies water to Ramah and Orange-Riet canals.

From the silt outlets, a 2m diameter pipe will be provided at the southern side of the access road and connected to a new pump station at level 1 100m situated near the existing river outlet. A 50 metre delivery line of 2m diameter will be connected to the number 4 river outlet. Water can then be supplied into the right bank canal through one of the river outlet pipelines operating in the reverse direction. During the pumping operations, the associated gate at the right bank canal intake of the dam must remain closed to prevent the pumped water from returning into the dam. The three river outlets unaffected by the scheme are adequate for normal river flow releases from the dam. The existing silt outlet valve house will be extended to accommodate the new off-take for the pipeline, as well as a large hydraulically operated valve.

The costs is estimated at R150 million and the yield 137 million m³/a. The URV is R0.20m³.

Real time Monitoring

This option consists of implementing a real time motoring system consisting of telemetry to be installed downstream of Bloemhof Dam in the Vaal and downstream of Vanderkloof Dam in Orange River at strategic points along the rivers. It will be used to monitor flows from the Vaal River system as well as the releases from Vanderkloof Dam. The real time information will then be used to control the releases from Vanderkloof Dam which will be reduced when excess flows are observed from the Vaal River. Estimations that were determined by the use of a hydraulic river model as part of the ORASECOM IWMP Phase 2 study showed a potential increase in the available water within the ORP of 80 million m³/a when real time modelling is implemented.

DWA has developed and calibrated a river model to be used for this purpose. The implementation of the model in practice in combination with real time monitoring has however not yet been implemented. A decision support system will need to be developed to synchronise the Orange and the Vaal system operation. Appropriate data on river discharges, dam levels and releases, restrictions/curtailments, weather and dam storage projections will be used to set up

the system for both catchments. Proper institutional arrangements also need to be put in place involving relevant stakeholders to successfully operating the proposed operating system.

8.3.6 Rainfall Enhancement

Experiments on rainfall enhancement through cloud seeding were previously done in the Bethlehem area of the southern Free State to enhance the runoff in the Vaal catchment but this yielded limited success.

For the purpose of this strategy this option was not further explored or considered.

8.3.7 Removal of Invasive Alien Plants

Invasive Alien Plants (IAPs) use more water than indigenous plants, especially in the riparian zones. By removing these plants and restoring indigenous vegetation, water losses are prevented.

Infestations along the Orange River and its tributaries, with exception of the Kraai River, do not appear to be high as can be seen on **Figure 8-3**.



Figure 8-3: Invasive alien plant cover in South Africa

High willow tree infestations have been reported along the Kraai River. The extent of the infestation, the cost of removal and estimated reduction in losses will be investigated further as part of the Working for Water programme of the Department of Environmental Affairs. It was assumed the increases in the sustainable yield of the ORP will be minimal.

8.3.8 Desalination of Sea Water

With South Africa bordered by ocean to the east, south and west, it cannot be said that the country will ever be short of water per se. Rather, the problem is the quality of that water and the location.

The option of desalination of sea water and pumping it to water demand centres within the Orange River is a definite possibility for the future but the main demands, apart from those on the Lower Orange, are quite far from the sea and desalination is an expensive option which is unlikely to be economical for supplying irrigation. For the purpose of this strategy desalination of sea water has not been considered as an option as there are more economically attractive options.

Sea water desalination for various catchments, including the Orange River was investigated in another DWA planning study, i.e. "Assessment of the Ultimate Potential and Future Marginal Cost of Water Resources in South Africa" (DWA. 2010). In this study the desalination of sea water option was only assessed as a reference benchmark, as it would not be logical to pump desalinated seawater to the Orange River, whilst water is being supplied from the Orange River to Port Elizabeth, via the Orange-Fish transfer. The benchmark URV for a system yield increase of approximately 200 million m³/a was in the order of R25/m³.

8.3.9 Summary of the Yield and Cost Information of the Reconciliation Options

The costs and yields for the individual options to be considered further and described in the previous sections are summarised in **Table 8-8** and **Figure 8-4** below.

Option	FSL	Active Storage	Cost	Yield ²		URV	
			(R	(mil			
Real Time Monitoring & Modelling			million)	m³/a)	6%	8%	10%
Vanderkloof Lower Minimum Operating	LLS	1 015 ⁽¹⁾					
Levels			150	137	R 0.17	R 0.20	R 0.23
Vioolsdrift	210	510	986	312	R 0.23	R 0.29	R 0.36
Gariep Dam raised 10m	1 269	4 050 ⁽¹⁾	1 368	350	R 0.31	R 0.40	R 0.50
Verbeeldingskraal	1 385	1 363	1 048	200	R0.39	R0.51	R0.63
Ntoahae Dam	1 545	1 700	1 371	232	R 0.44	R 0.57	R 0.71
Boskraai Dam	1 385	10 700	4 962	937	R 0.43	R 0.56	R 0.72
Kraai Dam	1 372	1 576	1 999	330	R 0.46	R 0.58	R 0.73
Bosberg Dam	1 385	3 050	4 133	337	R 0.86	R 1.11	R 1.40
Malatsi Dam	1 652	743	1 373	119	R 0.87	R 1.11	R 1.39
Knoffelfontein Dam	1 090	11	240	3.2	R 5.42	R 6.89	R 8.49

Table 8-8: Summary of Yield and Cost Information

Notes: 1. Increase in Storage

2. After EWR releases

It is however important to note that although Verbeedlingskraal Dam as an individual option resulted in a higher URV than the Raised Gariep option, the risk analysis highlighted the importance of taking into account the complex interdependencies of all significant activities between the various intervention options and existing infrastructure within the system. The risk analysis results clearly showed that the Verbeeldingskraal option evaluated as part of the combined set of intervention options produced a lower URV of R0.29/m³ than the combined set of options with Raised Gariep included, giving an URV of R0.31/m³. (See section 8.3.3 Combination of Options for detail)



Note: The values next to the names refer to the dam full supply level (masl)

Figure 8-4: Yields and URV of Individual Development Options

8.4 CONSIDERATIONS FOR SELECTING THE MOST APPROPRIATE RECONCILIATION OPTIONS

8.4.1 Basis for Water Reconciliation

Reflecting on the status of the water resources of the basin, described above, it is necessary to agree on specific principal management objectives for the future use of the resource. These objectives are associated with a number of assumptions that had to be made for the catchment.

The principal water reconciliation objectives are to:

- Recognise South Africa's International Obligations in terms of existing Treaties and Agreements and the Southern African Development Community (SADC) Revised Protocol on Shared Water Courses in terms of which there should be fair and equitable sharing of the water resource between South Africa and the Shared Basin States;
- Balance the social and economic water requirements and the protection of the environment to achieve sustainable development, and
- Ensure that water is used efficiently.

The initial assumptions on future water use are:

Assumption 1: All unlawful water use will be eliminated.

Assumption 2: Water for basic human needs in the study area will be made available. Together with this, appropriate sanitation must be provided.

Assumption 3: Additional releases for the EWR, to improve the ecological state by supplying the Ecological Preferred EWR 2013 or an alternative without incurring adverse socio-economic disruption. The water required to maintain, and where agreed, improve the environmental status of the Orange River Catchment, should be supplied.

Assumption 4: Water for strategic use for the benefit of the country will receive priority above any other economic development.

Assumption 5: Water for economic growth in the study area, within the policy parameters of the government, will be provided.

Assumption 6: Limited irrigation expansion will be allowed and a special effort will be made to promote irrigation for emerging farmers with water that was previously allocated for this purpose but which allocations have not as yet been taken up.

8.4.2 International Obligations

There are no international obligations that limit any of the possible options, but the following factors need to be considered:

- The LHWP Treaty with Lesotho and possible further phases;
- The MoU between Lesotho, South Africa and Botswana to study the options for transferring water from Lesotho to Botswana, and
- The current and future agreements on the volume of water to be allocated to Namibia from the Orange River.

The implications of these factors have been considered in the reconciliation scenarios that have been developed and which are presented in Chapter 9.

8.4.3 Yield and Cost Information of the Reconciliation Options

The costs, yields and URVs described in the previous chapters were taken into consideration.

8.4.4 Environmental Screening of Options

The environmental and social screening focused on the possible schemes identified as options for consideration and aimed to:

- Determine the key social impacts of identified schemes;
- Determine key environmental impacts of identified schemes;
- Aid in optimising preliminary site selection with regards to environmental and social suitability, and
- Summarise the findings on social and environmental impacts.

The assessment was based on documents and policies coupled with the latest GIS datasets currently available. No site visits, field work or additional primary data collection were undertaken to verify or update the available information. Documents and policies on which the screening is based are the Lesotho Highlands Phase 2 Feasibility Study (1998), Lower Orange River Management Study (2005), National Freshwater Ecosystem Priority Atlas (2011), National Biodiversity Assessment (2012) and the Vegetation of South Africa, Lesotho and Swaziland (2006).

In order to determine potential fatal flaws with regards to <u>environmental</u> receptors that can be related across the entire study area, a consistent and representative dataset was necessary. As a result the latest national datasets available for biodiversity importance were used in the environmental screening process. These datasets included the National Freshwater Ecosystem Priority Atlas (NFEPA) and the National Biodiversity Assessment (NBA) datasets released in 2011/2012 and was considered as the only consistent datasets that could be applied at a sub-quaternary catchment level for aquatic ecosystems and vegetation type level for terrestrial ecosystems from Lesotho to the Namibian border. Although Critical Biodiversity plans (CBA) at provincial level for terrestrial and aquatic ecosystems are available, they do not cover the entire study area as some provinces are still in the process of setting up CBA plans.

In order to determine potential fatal flaws with regards to <u>social</u> aspects that can be related across the entire study area, a consistent and representative dataset was necessary. As a result the latest national datasets available for social information were used in the social screening process.

Implementation of the Reserve (surface water, groundwater and water quality aspects) during construction and operational phases is assumed to be a condition of any proposed scheme. It is assumed that this will ensure that the aquatic ecology and requirements for basic human needs are adequately provided for and protected.

Due to the desktop nature and limited timeframe of the work, the assessment is qualitative, in that actual costs of replacing infrastructure or urban settlements were not considered, and the combination of aspects were considered in order to derive a rating. The level of confidence for the social data is low as very little information was available with regards to the number of people or households per settlement. A settlement as indicated on the national database could range from a small farm community to large settlements containing thousands of residents.

The assessment results are summarised in Table 8-9.

The raising of the Gariep Dam or construction of any of the possible new large dams identified will have potentially significant social and ecological impacts which will require a full environmental and social impact assessment and to which the hierarchy of mitigation measures (enhance, avoid, reduce, restore, compensate, offset) will have to be applied.

Based on previous experience, each of the proposed dams has been assigned a qualitative risk rating.

Table 8-9 : Environmental and Social Ratings

Receptor	Dam	Terrestrial Biodiversity	Aquatic Biodiversity	Protected Areas	Resettlement impact	Construction Social impacts	Access impacts	Overall Score	Risk Scale	Comment	Heading
	Malatsi	4	5	5	-	-	-	4.7	Low	No major environi biodiversity impac	mental and cts expected.
	Ntoahae	4	5	5	-	-	-	4.7	Low	No major environi biodiversity impac	mental and ts expected.
	Bosberg	4	2	5	-	-	-	3.7	Mod	Freshwater Ecosy (PES = A/B). Impacts considered	vstem Priority River ed manageable.
	Kraai	2	1	5	-	-	-	2.7	High	Free-flowing river and endangered e Potential fatal flav	status for Kraai ecosystem type. v.
	Boskraai	2	1	5	2.7 High Free-flowing ri and endanger		Free-flowing river and endangered e	status for Kraai ecosystem type.			
	Gariep	4	5	3	-	-	-	4.0	Mod Formally Protected Oviston and Hendrik Verwoerd Provincial Reserves.		
	Vioolsdrift	1	2	5	-	-	-	2.7	Mod	Endangered ecos Impacts considered dependent on sca	ed manageable. system type. ed manageable ale.
ıental	New- Boegoeberg	goeberg 1 2 5 ⁻ ⁻ 2.7 Mo	Mod	National Critical E and an endangere Impacts considere dependant on sca	Biodiversity Area ed ecosystem type. ed manageable ale.						
Environn	Knoffelfontein	2	5	2	-	-	-	4.0	Mod	Mokala National F and endangered e Impacts considered	Park downstream ecosystem type. ed manageable.
	Malatsi	-	-	-	4	4	5	4.3	Low	No major social in	npacts expected.
	Ntoahae	-	-	-	3	3	4	3.3	Low	Few settlements, impacts expected	but no major social
	Bosberg	-	-	-	2	3	4	3.0	Mod	Some settlements impacts, Impacts, manageable.	s and access considered
	Kraai	-	-	-	1	2	2	1.7 High		Extensive resettle needed.	ement action
Social	Boskraai	-	-	-	1	2	2	1.7	High	Extensive resettle needed. Potential fatal flav	ement action

Receptor	Dam	Terrestrial Biodiversity	Aquatic Biodiversity	Protected Areas	Resettlement impact	Construction Social impacts	Access impacts	Overall Score	Risk Scale	Comment	Heading	
	Gariep	-	-	-	2	3	4	3.0	Mod	Predominantly urban resettlement which may carry significant cost. Impacts considered manageable.		
	Vioolsdrift	-	-	-	4	4	5	4.3	Mod	No major social impacts expected.		
	New- Boegoeberg	-	-	-	4	4	5	4.3	Mod	No major social impacts expected.		
	Knoffelfontein	-	-	-	5	4	5	4.7	Mod	No major social impacts expected.		

Potential Fatal Flaws were identified for Boskraai Dam and Kraai Dam as a result of threats to the loss of important ecological drivers and/ or related to the loss of threatened vegetation types, which the dam will inundate. The main concerns for the Boskraai and Kraai dams are:

- The Kraai River is one of the few remaining free-flowing rivers of South Africa and is considered as one of the Flagship Free Flowing Rivers of South Africa. According to the 2011 NFEPA Atlas, Flagship Rivers obtain top priority in order to retain their free-flowing character;
- The Upper Gariep Alluvial Vegetation Type within the study area is classified as a vulnerable vegetation type and exacerbates the environmental and biodiversity threats associated with the Boskraai Dam, and
- Approximately 30 settlements will be affected which is currently below the proposed flood line. Actual population data is not available, although it can be estimated that more than 1000 people may have to be resettled.

A red flag was raised for Vioolsdrift Dam and New-Boegoeberg Dam based on their locations, which are situated in National Critical Biodiversity Areas.

- Both areas are classified as a terrestrial critical biodiversity area according to the 2011 NBA, and
- Both areas contain the Endangered Lower Gariep Alluvial Vegetation Type.

As part of the overall conclusion for assessing potential risks associated with the proposed and existing dam locations, the scale of each project was assessed. As Vioolsdrift Dam will mainly serve as a regulating dam, the quantity and timing of water supply for upstream and downstream water users (e.g. estuaries) will be better regulated. When scale is taken into account for Vioolsdrift and New Boegoeberg, the environmental and social risks for both dams are decreased from being potential fatal flaws to being manageable, but high risk options.

A more comprehensive impact assessment will have to be done as part of future feasibility studies.

8.4.5 Selection of Reconciliation Scenarios

A reconciliation scenario comprises a combination of reconciliation options which will render a resultant water balance. The list of possible reconciliation options were first screened at the screening workshop held in Kimberley on 7 February 2013. At that meeting an agreement was reached on which options warranted further investigation. Thereafter a further process of screening followed through discussions at the Study Management Committee. The criteria used to decide on the reconciliation options for consideration were:

Primary Criteria

- Fatal flaw;
- International Obligations (Impact on neighbouring country);
- Political acceptability and alignment with National Strategies;
- URV:
 - o Yield contribution / water requirement reduction
 - Capital cost of option.
 - Operational cost of option.
- Biophysical impacts, and
- Social impacts.

Secondary Criteria

- Ease of implementation;
- Capacity of implementing institution;
- Time required to implement;
- Risks in key parameters (costs, yield, etc.), and
- Eventual happiness among water user sectors.

The overarching criterion was the requirement to achieve a water balance in the area of the ORP.

9 POSSIBLE SCENARIOS FOR RECONCILING THE WATER REQUIREMENTS WITH THE WATER RESOURCE

9.1 INTRODUCTION

From **Chapter 7** it is evident that the Orange River System is currently in balance but water deficits will develop in the near future as a result of growing water demands and the reduction in system yield owing to the growing water requirements upstream of the ORP. The Polihali Dam will, after its commissioning, reduce the deficit as the full allocation to the Vaal System will initially not needed to be transferred and the remaining yield can be utilised to the advantage of the Orange River Project. However, this benefit will eventually be phased out as the water transfers to the Vaal River System increases, up to the maximum yield of Polihali Dam.

Various options to reconcile water demand and water availability have been considered and a recommended reconciliation scenario, comprising a combination of options, has been selected in accordance with the selection criteria described in **Section 8.4**. Some variants to the recommended scenario and scenario to mitigate possible risks have been identified.

This chapter describes how a water balance can be achieved for the selected development scenario. The water balance will be considered for the ORP while taking the upstream development into consideration. A separate water balance for the Eastern Cape has not been done. The water transfer to the Eastern Cape plus the future water demands for inter alia the Nelson Mandela Metro has been taken as a water demand on the ORP system. This is in line with the ORP annual operating analysis and the Algoa Reconciliation study recommendations.

The high growth scenario which has been used as the base comprises:

- Irrigation demands at 1998/99 levels plus qualifying irrigation;
- Urban demands at 2012 with associated growth;
- An additional transfer of 49 million m³/a through the Orange Fish Tunnel for Nelson Mandela Metropolitan Municipality;
- An additional 20 million m³/a supplied to Bloemfontein from Gariep Dam over the long term;
- System requirement of 120 million m³/a at Vioolsdrift, and
- Current riverine requirements of 288 million m³/a and updated future riverine EWR with a reduction on yield of 722 million m³/a as soon as a new dam comes into operation.

Groundwater is highly suited for small town domestic supply and in this basin should always be one of the first options to be considered before turning to a surface water option. No regional groundwater supply schemes are foreseen. It was therefore assumed that the future water deficits in the small towns will be satisfied with groundwater and therefore only surface water is shown on the water balance graphs.

9.2 FUTURE BALANCE ORP

The future water requirement and availability projections as displayed in **Figure 7.1 of Chapter 7** were used and the six preferred interventions were introduced in order of priority to see the effect on the water balance. The interventions in the order of priority are:

- (i) Water Conservation and Water Demand Management in the domestic/industrial and irrigation water use sectors.
- (ii) Real Time Monitoring of the river flows to the Vaal/Orange River confluence to enable adjustments of water releases at Vanderkloof Dam which will lead to a reduction in water losses.
- (iii) Vanderkloof low level storage conveyance infrastructure required to pump water from a lower dam level into the Orange-Riet canal.
- (iv) Shared utilisation of Polihali Dam to supply water to the Vaal and Orange systems.
- (v) Implementation of the ecological preferred EWR 2013 (note that the eventual EWR to be selected for implementation is dependent on a decision as to what is the desirable balance between ecological protection and socio-economic implications).
- (vi) Vioolsdrift Dam only required if releases for the EWR are higher than the current scenario or the dam need to provide flow regulation to achieve estuary mouth closer requirements.
- (vii) Raising of Gariep Dam or the construction of Verbeeldingskraal Dam only required if (v), or alternative EWR is implemented.

9.2.1 Scenario 1: Postponing capital expenditure and implementing WC/WDM and Real Time Monitoring

WC/WDM is a measure which is regarded as best practice and with water use efficiency benefits attainable with moderate capital expenditure.

The two water use sectors where WC/WDM can be successfully applied are the domestic water use sector and the irrigation sector. The contribution of water savings in the domestic water use sector will be very small relative to the total water use from the ORP, i.e. approximately 6 million m³/a. This water saving does not include the WC/WDM water saving which can be expected from Bloemfontein as the Bloemfontein water saving had already been subtracted when Bloemfontein's water requirement was determined. The current irrigation water use is approximately 2 200 million m³/a. Some irrigation is very efficiently managed, e.g. where vineyards or other permanent crops are irrigated with drip irrigation. Crops such as cash crops, lucerne and cotton which are irrigated with flood irrigation are not irrigated with the same efficiency and measures can be taken to improve the efficiency of such irrigation practices.

Not all water savings in the irrigation sector will reduce the water demand as some irrigation farmers will prefer to expand their irrigation areas with the saved water. There will however be those that cannot expand horizontally (e.g. due to limited land), and they might prefer to sell their saved water by relinquishing a portion of their quota. A conservative 5% of the total irrigation water demand was taken as a possible water saving. It was assumed that the WC/WDM plan

will be rolled out in 2015 and that it will take the irrigators 5 years to achieve the full water saving of 109 million m^3/a , that can be made available.

The real time monitoring as described in **Section 8.3.5** is an activity that is relatively inexpensive and can be implemented quickly as it is not a labour intensive exercise. It was assumed that all telemetry will be installed and that the intervention will be operational by 2016.

The estimated saving in operation losses is 80 million m^3/a .

Figure 9-1 shows the water balance if the WC/WDM option and the real time monitoring options are implemented. It was assumed that the WC/WDM will start in 2015 and that it will take 5 years to achieve the full saving. It was also assumed that the real time monitoring telemetry system will be in place by 2016 and that the full 80 million m³/a benefit will be attained within one year after implementation.



Figure 9-1: Water balance with only WC/WDM and real time monitoring reconciliation interventions

A comparison between **Figures 7.2** and **9.1** shows that a water balance can be achieved up to the year 2029 with WC/WDM and Real Time Monitoring as interventions. The temporally deficit in the year 2024 is a result of Polihali Dam filling up for the first time. This can be overcome by operating the system with care and, if that fails, by applying short term restrictions.

9.2.2 Scenario 2: Low level storage in Vanderkloof Dam added to Scenario 1

The option to lower the minimum operating level of Vanderkloof Dam is described in **Section 8.3.5**. This option will increase the system yield by 137 million m^3/a . By completing the pumping station at the Vanderkloof Dam which will enable the lowering of the minimum operating level in 2021 a water balance without any water deficits up to the year 2035 can be achieved as shown in **Figure 9-2**.



Figure 9-2: Scenario 2 with WC/WDM, real time monitoring and Vanderkloof Dam low level storage

The low level storage in Vanderkloof Dam is the least cost option of the capital intensive options and has the lowest URV as shown in **Table 8.7**. It is therefore desirable to postpone the Vioolsdrift Dam and Gariep Dam raising options by first implementing this option.

This reconciliation scenario indicates that the water requirements to sustain the socio-economic activities until the year 2035 in the Orange River as well as transferring water to the Vaal through Phase II of the LHWP can be achieved by implementing the following:

- Continue to supply the current EWR releases;
- Water Conservations and Water Demand Management savings of 109 million m^3/a ;
- Real time monitoring saving operating losses of 80 million m³/a;

- Shared operation of Polihali Dam (see purple area indicated on Figure 9.2), and
- Infrastructure to operate Vanderkloof Dam at a lower minimum operating level increase in yield of 137 million m³/a.

Note that the Ecological Preferred EWR 2013 is not implemented in Scenario 2 and the implications thereof are demonstrated in Scenario 3, described in the following section.

9.2.3 Scenario 3: Implementing ecological preferred EWR and Vioolsdrift Dam

Different sizes for a new dam at Vioolsdrift were investigated. Eventually a dam with a FSL of 210 mamsl and of 510 million m³ storage was found to be the optimum size. Any larger dam would not yield more as the downstream water demand is limited.

The dam at Vioolsdrift is needed for two purposes, i.e. to regulate the river flow and to increase the yield.

As shown in **Table 3-1** in **Section 3** the highest EWR is needed at Augrabies, upstream of Vioolsdrift. Releasing variable EWR flows from Vanderkloof Dam is impractical, as it cannot be controlled accurately to obtain the correct flows at the estuary due to the long distance of 1 300km and the time (one month) it takes for the water to reach the estuary. This normally results in too much water reaching the estuary which prohibits the estuary from closing resulting in undesirable ecological conditions.

Due to the difficulties with operating the releases from Vanderkloof Dam, additional water referred to as operating requirements is released from Vanderkloof for unforeseen events such as heat waves, unpredictable abstractions by farmers etc. These operating requirements can be reduced if Vioolsdrift Dam is used as a regulating dam. This saving in operating requirements is estimated as 120 million m^3/a . By utilising the remaining storage capacity of the dam, a further yield increase of 192 million m^3/a can be achieved. The total benefit of Vioolsdrift Dam will therefore be 312 million m^3/a .

The lead time for commissioning Vioolsdrift Dam is approximately 10 to 12 years taking into account the international negotiations which are required with Namibia, a feasibility study, design, tender procedure, construction and filling time. If it is therefore assumed that Vioolsdrift Dam will be operational in 2025, this is then also the year when the ecological preferred EWR can be implemented. The commissioning date for the low level storage in Vanderkloof Dam was retained as 2021. The water balance of this scenario is shown graphically in **Figure 9-3**.

It should be noted that the full benefit of the real time monitoring (estimated 80 million m³/a reduction in losses) will no longer be attained when Vioolsdrift Dam comes into operation as the operational losses can then be stored in Vioolsdrift Dam. The real time monitoring will however still provide benefits and it was assumed that the benefits of this option will be halved once Vioolsdrift Dam comes into operation.



Figure 9-3: Ecological Preferred EWR 2013 and Vioolsdrift Dam operational from 2025 plus interventions of Scenario 2

Figure 9-3 illustrates that bringing in Vioolsdrif Dam will not improve the water balance situation, but rather bring the date from which the deficit will occur earlier by one year. The reason for this is the implementation of the Ecological Preferred EWR which needs to be operationalised together with Vioolsdrift Dam. A further intervention is therefore necessary to overcome the water deficit which starts occurring from 2028. The next best intervention in terms of URV is Gariep Dam raising. The addition of Gariep Dam raising is described in **Section 9.2.4** as Scenario 4.

9.2.4 Scenario 4: Addition of Gariep Dam raising to Scenario 3

Among all the dam development options in the Upper Orange WMA, Gariep Dam raising was found to be the preferred option based on economic criteria as determined for individual options. It had the lowest URV of R0.40/m³ at 8% discount rate for a yield increase of 350 million m³/a and low social and environmental impacts, compared to the other dams, Verbeeldingskraal Dam excluded.

A 10m raising is envisaged which would have social impacts since the town of Bethulie will have to be expanded significantly to compensate for the area that would be at risk of flooding. People in Bethuli will have to be relocated. Despite the associated mitigation costs, the raising of Gariep Dam was still the most economical option when evaluated as an individual option.

Figure 9-4 illustrates the scenario were Vioolsdrift Dam comes into operation in 2025 and Gariep Dam raising in 2026. Based on the risk analysis it was evident that it would take eight years for the Raised Gariep Dam to attain its full yield. Results from the risk analysis were used to determine the URV for the combination of intervention options as captured in **Figure 9.4**, and resulted in an URV of R0.31/m³. This is less than the URV for the Raised Gariep option on it's own, as the other options included in this combination produced URV as low as R0.2 m³.



Figure 9-4: Scenario 4 with both Vioolsdrift Dam (from 2025) and Gariep Dam raising (from 2026)

Whilst Gariep Dam raising will contribute 350 million m³/a to the system yield, the contribution of yield by Vioolsdrift Dam will be reduced from 192 million m³/a to 162 million m³/a, thus by 30 million m³/a. The regulation benefit of Vioolsdrift Dam will remain on 120 million m³/a savings in water losses. However, by operating the Vanderkloof Dam low level storage, Gariep Dam raising and Vioolsdrift Dam together as a system will effectively save evaporation water losses compared to operating Gariep Dam Raising and Vioolsdrift Dam on their own, without the Vanderkloof Dam low level storage benefit. This saving in water losses resulted in a yield increase of 32 million m³/a, and was taken as equal yield increases of 16 million m³/a for both Gariep Dam and Vanderkloof Dam for the purpose of the water balance given in **Figure 9-4.** A water balance up to 2046 can be easily sustained with this scenario.

9.2.5 Scenario 5: Addition of Verbeeldingskraal Dam to Scenario 3

The Verbeeldingskraal Dam site (See par. 8.3.3) has slightly lower capital costs compared to the raising of Gariep Dam, but the option is less economic in terms of URV. When considering the options on an individual basis, the URV of Verbeeldingskraal Dam is R0.51/m³ compared to a URV of R0.40/m³ for Gariep Dam Raising, both at 8% discount rate.



Figure 9-5: Scenario 5 Verbeeldingskraal Dam instead of Gariep Dam raising

The yield of Verbeeldingskraal Dam within the combined system context is 230 million m³/a compared to the 350 million m³/a, which the Gariep Dam raising offers. The Verbeeldingskraal Dam will achieve a water balance up to the year 2037 as shown in **Figure 9.5**. The risk analyses showed that Verbeeldingskraal Dam requires a very short filling time before it can start to deliver its yield. Consequently a period of 2 years after the commissioning of Verbeeldingskraal Dam will have the advantage of less system losses as a result of reduced evaporation since the surface area of a full Verbeeldingskraal Dam will be much smaller than that for the raised Gariep Dam. Spills from Vanderkloof Dam are for this combination significantly more than that from the Riased Gariep combination, which is to the advantage of the environment along the lower Orange and the yield generated at Vioolsdrift Dam. The Verbeeldingskraal combination of options therefore resulted in a URV of only R0.29 which is slightly less than the URV for the Raised Gariep combination of options.

9.2.6 Selected intervention scenario

Scenario 1 illustrated that large capital expenditure can be postponed only for a relative short period by implementing WC/WDM and real time monitoring downstream of Vanderkloof Dam in combination with operating Polihali Dam as a shared resource between the Vaal and the Orange system. For this scenario water shortages will still occur from 2029 onwards. The Vanderkloof Dam Low Level Storage option in combination with WC/WDM and real time monitoring, i.e. Scenario 2, can postpone the point in time where water shortages will occur by six years up to 2035. The Ecological Preferred EWR 2013 cannot be realised with Scenarios 1 and 2. If the Ecological Preferred EWR 2013 needs to be operationalised, the Vioolsdrift Dam is needed to regulate the flow to the estuary. In view of South Africa's desire to maintain good international relations and in view of the need expressed by Namibia for a dam at Vioolsdrift, it was assumed that Vioolsdrift Dam would be the next option and would have to be built within a reasonable time. The lead time for the construction of this international project was assumed to be 10 - 12 The operationalising of Ecological Preferred EWR 2013 however will impact on the vears. system yield and the Vioolsdrift Dam will not contribute towards postponing the date from which water deficits will occur. Either the raising of Gariep Dam or the construction of Verbeeldingskraal Dam is needed to achieve this. (Scenario 4 or 5).

These results indicate that a decision should be made regarding the desirable balance between the level of ecological protection and the socio-economic implications. Both Vioolsdrift Dam and either Gariep Dam raising or Verbeeldingskraal Dam is required, each with their particular environmental implications.

The decision making process will most likely involve all the Basin States and will be facilitated through the ORASECOM structures.

Alternative protection scenarios (alternative EWR configurations) should also be evaluated during the decision making process, and presented to the decision makers for consideration and to agree on the final selection of the desired level of ecological protection.

9.2.7 Impact of the Validation results

Supplementary information provided by the validation study team indicated that the irrigation water use estimated for the year 2012 could be as much as 145 million m³/annum higher than what was validated for the 1998/1999 period. It is important to note that no ground verifications was carried out on the 2012 water use estimates and still need to be undertaken as part of the verification of lawful water use that is underway.

If provision has to be made for the full increase in upstream development, the water deficits will occur much sooner for Scenario 4 or Scenario 5. It will then not be desirable to operationalise the Ecological Preferred EWR 2013 within one year but it would be better to phase in this requirement in two steps. The two scenarios involving the raising of Gariep Dam and the construction of Verbeeldingskraal Dam with the lower system yield as a result of the increased upstream demands are shown in **Figure 9.6** and **Figure 9.7** respectively.



Figure 9.6: Scenario 4 with the reduced system yield as a result of increase water use since 1998 upstream of the ORP

The date on which water deficits will occur is brought forward from 2046 to 2037 in the case of Scenario 4 if the full increase in upstream water use were to be acknowledged as lawful developments. In the case of Scenario 5 the date moves forward from 2037 to 2031.

The 2nd phase of the ecological preferred EWR, 2013 has been assumed to be implemented 6 years after the 1st phase. By postponing the 2nd phase even further, the dates on which deficits occur, will move on further into the future. It is however uncertain from an environmental perspective how acceptable it will be to implement the 2nd phase so long after the first phase.

Should the upstream irrigation developments and water use therefore be fully acknowledged, both the Gariep raising and Verbeeldingskraal Dam will be needed to achieve a water balance over the planning horizon of this study.

With both these options being implemented the Orange River should be viewed as developed to its full potential. Any further developments may have severe impacts on the environment.



Figure 9.7: Scenario 5 with the reduced system yield as a result of increase water use since 1998 upstream of the ORP

9.3 RISKS THAT MAY INFLUENCE THE RECONCILIATION SCENARIOS

9.3.1 Risks relating to system yield

A risk that needs to be considered is how the water balance will be affected if the Lesotho and South African Governments do not agree on the use of Polihali Dam to support the Orange or the transfer needs to the Vaal River system are higher than assumed in Scenario 1 to 5.

A sixth scenario was therefore developed where it is assumed Polihali Dam will not contribute to the Orange River system as shown in **Figure 9.8**.

For Scenario 6 it was assumed the Ecological Preferred EWR is implemented in two steps, the first, i.e. 77% of the Ecological Preferred EWR, is when Vioolsdrift Dam is commissioned in 2024 (earliest date) and involves releases and regulation of flow downstream of the dam. The second step, i.e. the remaining 23%, commences from 2030. In order to achieve a water balance, the Gariep Dam raising need to be implemented earlier and need to be commissioned by 2022.

It is evident that the water balance can only be maintained until 2036 after which the water deficit will steadily grow. Verbeeldingskraal Dam will have to be ready by then.



Figure 9.8: Scenario in which Polihali Dam is not operated as a shared resource between the Vaal and Orange

As explained in **paragraph 9.2.4** the reduction in yield contribution of Vioolsdrift Dam as a result of Gariep Dam raising has been taken into account.

There is a possibility that, at some time the possible future Tsoelike Dam in Lesotho could be used to transfer water to Botswana. This would have a similar effect to not using Polihali to support the Orange. However, since the Feasibility Study for the possible transfer to Botswana has still to be started and there is no certainty or timing regarding this development, the possible option has not been considered further.

9.3.2 Risks related to water requirements

• Eastern Cape transfers.

Provision has been made for the full additional water allocation for Nelson Mandela Metropolitan area of 47 million m³/a. The irrigators also claim an additional requirement of 25% of the current irrigation transfer water use of 580 million m³/a, to compensate for water losses. This would have a significant impact on the water balance and since the request has so far been rejected, the additional water requirement has not been factored into the water balance scenarios presented in this document.

9.4 WATER RECONCILIATION GREATER BLOEMFONTEIN SUPPLY AREA

A water reconciliation strategy study for large bulk water supply systems for the Greater Bloemfontein Area was recently completed. The interventions for this area were identified as the following in order of priority:

- (i) Urban WC/WDM;
- (ii) Groundwater Interventions;
- (iii) Solving siltation problems at Welbedacht Dam;
- (iv) Developing additional yield in the Caledon River;
- (v) Water re-use, and
- (vi) Augmentation from the Orange

(i) Urban WC/WDM for Bloemfontein

The implementation of this intervention under the "Best Case Scenario" has the potential to save approximately 25 million m^3/a of water and the "Most Probable Scenario" the potential to save approximately 12 million m^3/a of water.

(ii) Groundwater Interventions

The development of boreholes to supply the smaller towns of Reddersburg, Edenburg, De Wetsdorp and Wepener are viable options which should be further considered.

(iii) Developing Additional Yield in the Caledon River

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 requirements for the Greater Bloemfontein area. The development of the additional yield (which could be as much as 60 million m³/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 before increasing the capacity of Tienfontein Pump Station).

(iv) Water Re-use for Bloemfontein

Water re-use could be a next intervention for Bloemfontein. This has already been described under **Section 8.3.4**.

(v) Augmentation from the Orange

This option has been provided for in the water balance of the ORP and it was accepted that 20 million m^3/a would be needed in 2032 and it was assumed that this would be pumped from Gariep Dam. Alternatively the water for transfer could be abstracted from the proposed Verbeeldingskraal Dam.

9.5 PRIORITY ACTIONS THAT NEED TO BE STARTED AS SOON AS POSSIBLE

For the purpose of confirming and implementing the preferred intervention scenario, a number of associated actions will be required soon. These actions are the following:

(i) Verification of water entitlements – Upper Orange

The Validation exercise for the Upper Orange is almost complete, but verification (determining lawfulness) is still outstanding. Due to the apparent increase in water use for irrigations since the 1998/1999 qualifying period (estimated to be 145 million m³/annum higher in the year 2012) it is considered possible that there could be a significant amount of unlawful irrigation in the Upper Orange. This needs to be confirmed with the verification programme. Once the extent of unlawful irrigation water use has been determined, the Department of Water Affairs need to prepare a compliance monitoring and enforcement plan. This plan must clearly determine whether unlawful water use should be eliminated through prosecution or whether licences for the unlawful water users will be considered. If the latter is going to become the policy of the Department, an amended high water demand curve will need to be considered for the water balance.

It is possible that this exercise may also show that the lawful irrigation is more than that used in the recommended scenario. The option for addressing this is discussed in (iv) below.

(ii) Validation and Verification for the Lower Orange

A similar validation and verification programme as for The Upper Orange needs to be initiated for the Lower Orange and the extent of unlawful water use needs to be determined.

It is possible that this exercise may also show that the lawful irrigation is more than that used in the recommended scenario. The option for addressing this is discussed in (iv) below.

(iii) Utilise Polihali Dam as a shared resource

In view of the risk described in **Section 9.3**, confirmation needs to be obtained and operating rules should be developed to utilise Polihali Dam as a shared resource between the Vaal River and Orange River systems. This should entail determining the most optimal allocation and transfer methods through simulation analysis of alternative rule scenarios with the aim to balance the risk of drought restrictions over the planning horizon in both systems.

(iv) Study on the level of environmental protection.

A study on the level of environmental protection weighed up against the socio-economic implications must be done, as the ecological preferred EWR, 2013 has a major impact on the water balances. Alternative scenarios of EWR releases need to be assessed to find the preferred balance between ecological protection and water use for socio-economic development.
(v) Interactions – Assurance of supply

Engagement with Water User Associations and Irrigation Boards, not yet transformed into WUA are required to find out what lower assurance of supply will be acceptable to them. It is perceived that the irrigators currently enjoy an assurance which is unnecessary high. Permanent crops (e.g. vineyards) should be able to tolerate a 95% assurance of supply while non-permanent crops can do with much lower assurances of supply.

(vi) Interactions on WC/WDM

Interactions with the same organisations as described in (iv) are necessary on WC/WDM. A WC/WDM plan needs to be developed for each scheme under the ORP and be ready for implementation by 2015.

(vii) Mechanism to reallocated saved irrigation water

The extent of water savings which can be made available must be determined. See **Section 8.2.3**.

(viii)Real time monitoring

The real time monitoring of the Vaal River and Orange River flows need to be implemented as soon as possible as this option is regarded as a quick win. The telemetry system therefore needs to be designed and a tender invitation document needs to be prepared for the delivery and instalment of such a system.

(ix) Negotiations with Namibia on Vioolsdrift Dam

Negotiations with Namibia (LORMS Prefeasibility 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, Main Report, September 2005) (LORMS, 2005) on Vioolsdrift Dam need to be initiated. Aspects that need to be negotiated are:

- Acceptability of the Vioolsdrift Dam to Namibia;
- Possible sharing in the dam;
- Namibia's water demand, and
- Namibia's contribution to the cost of the project.

The normal lead time for a dam of this size (i.e. for a feasibility study, tendering processes, design, construction, commissioning) is approximately 10 years. The process can, however, not be started without an Agreement or a Treaty in place between Namibia and South Africa.

- (x) Develop an Integrated Water Quality Management Strategy to ensure that available water resources remain fit for use.
 - Undertake nutrient modelling of the system
 - Assess irrigation return flows

• Improve and consolidate water quality monitoring of the Orange River System

9.6 MEDIUM AND LONG TERM ACTIONS REQUIRED

A number of actions are required over time. They are:

(i) Low level minimum operating level, Vanderkloof Dam

Initiate the design of the pumping station and pipelines for pumping water from the reduced minimum operating level of Vanderkloof Dam into the existing Oranje Riet canal. Negotiations with all affected stakeholders also need to the undertaken to define and agree on the appropriate institutional arrangement. The preparation of tenders, tender procedure, construction and commissioning, need to follow this action. It is proposed that a bridging study be commissioned to proceed with the implementation of the option.

(ii) Feasibility study for the Vioolsdrift Dam

A feasibility study for Vioolsdrift Dam must be initiated on time for a possible commissioning of Vioolsdrift Dam in 2025 if Scenario 4 or Scenario 5 is adopted. Other processes such as design, Environmental Impact Assessment, preparing of tender documents, tender process, construction and commissioning will follow if Scenarios 4 or 5 are to go ahead.

(iii) Pre-Feasibility study for choosing between the raising of Gariep Dam and the Verbeeldingskraal Dam.

A choice between these options need to be made taking into account the risk of the backwater curve of Verbeeldingskraal Dam pushing up in Lesotho, the relocation of Bethulie residents, the evaporation advantages, impacts on the environment, etc..

(iv) Feasibility study for the raising of Gariep Dam or Verbeeldingskraal Dam.

A feasibility study for the raising of Gariep Dam or Verbeeldingskraal Dam can be delayed until after the decision to select the desirable EWR was taken.

A summary of all the short term and medium to long term actions are provided in Table 9-1.

Table 9-1: Summary of short term and medium to long term actions

Action	Responsibility	Timeline
Verification of Water Entitlements – Upper Orange	DWA Regional Office, Bloemfontein	Process started already. Complete within 3 years, i.e. 2016.
Validation & Verification – Lower Orange	DWA Regional Office, Kimberley	Complete Validation by 2015 and Verification by 2019.

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Action	Responsibility	Timeline
Confirm Polihali Dam to be operated as a shared resource and develop optimal operating rules.	DWA Head Office, International relations. Through ORASECOM & DWA National Water Resource Planning	Immediately.
Do a study on the impacts if the ecological preferred EWRs, 2013 are reduced	DWA Head Office, RDM	Start Immediately
Develop an Integrated Water Quality Management Strategy	DWA Head Office Water Quality Planning	Start immediately.
Negotiate reduced assurances of supply with water users.	DWA Regional Offices, Bloemfontein & Kimberley.	Start immediately. To be concluded in 2015.
Develop WC/WDM plans for municipalities, WUAs and IBs not yet transformed into WUAs.	Municipalities and WUAs, with support from Directorate Water Use Efficiency in DWA Head Office.	Start immediately. Plans must be in place and ready for implementation in 2015.
Install telemetry for real time monitoring – Design of system.	DWA Head Office Mechanical and Electrical	Start immediately. System must be installed by 2015.
Negotiate with Namibia about Vioolsdrift Dam.	DWA Head Office, International Relations through ORASECOM	As soon as possible. Try to reach agreement before 2015
Commission a bridging study to proceed with the implementation of the option to utilise the Vanderkloof LLS. To be followed by design of pumping station and piping for pumping from reduced m.o.l in Vanderkloof Dam into the Oranje Riet Canal	DWA; Options Analyses in Head office (Bridging Study) & DWA Mechanical & Electrical to prepare tender documents.	2017.
Feasibility Study for the Vioolsdrift Dam. Other dam building processes to follow.	DWA; Options Analyses in Head Office.	Start at the latest in 2016.
Pre-feasibility study for choosing between Gariep Dam Raising and Verbeeldingskraal Dam.	DWA Options Analyses in Head Office.	After Vioolsdrift Feasibility Study.

Action	Responsibility	Timeline
Delay feasibility Study for the raising of Gariep Dam or Verbeeldingskraal Dam until EWR is selected. Other dam building processes to follow.	DWA: Options Analyses in Head Office.	Pending decision on EWR.

10 THE ORANGE RECONCILIATION STRATEGY IN A NUTSHELL

The following measures are envisaged for the Orange River system (South African portion) to maintain a water balance between the water needs and availability up to the year 2050:

- (i) Water required to supply the current and future social and economic activities as well as supporting the transfer to the Vaal River system, will have to come from within the Orange/Senqu basin. It was found that transferring water from a neighbouring basin (e.g. Mzimvubu measures) will be too expensive.
- (ii) The existing EWR needs to be maintained and to avoid immediate large negative socioeconomic implications additional releases towards an alternative EWR can only be implemented as soon as a new dam is commissioned. Further optimisation of the EWR in combination with the proposed augmentation options is recommended. That is to achieve an acceptable balance between protection of the ecology and use of water for socioeconomic purposes.
- (iii) Groundwater, if available, should be prioritised as the first choice to augment the water resources of towns and communities located far from the Orange River.
- (iv) All water requirements can be balanced by availability through the implementation of the following measures:
 - Shared utilisation of LHWP Phase II between the Vaal River and Orange River systems is an essential measure to postpone large capital expenditure that would otherwise be required at the same time Polihali Dam become operational;
 - Plan and implement WC/WDM in the domestic and irrigation water use sectors. Targeted savings of 6 million m³/a for the domestic/industrial water use sector (excluding Bloemfontein) and 5% of total water use in the irrigation water use sector need to be achieved not later than 2020;
 - The introduction of a mechanism whereby water, saved through water use efficiency, especially in agriculture, can be made available to other water users in the system;
 - Limit operational losses through real time monitoring of river flows in the Orange and Vaal rivers, to maximise the beneficial use of the spillages from the Vaal River System – target implementation date 2016, and
 - Utilising a greater portion of Vanderkloof Dam's storage capacity by lowering the minimum operating level in the dam. This measure will require pumping infrastructure which has to be in place by 2022.
- (v) If a decision is taken to implement the Ecological Preferred EWR during this planning horizon, the following actions are also required sooner:
 - Commission Vioolsdrift Dam at the decided date for alternative EWR implementation, and
 - Create additional yield in the system by raising the Gariep Dam by 10m or by building the Verbeeldingskraal Dam. The implementation date of either of these options will be

dependent on the implementation date of the Ecological Preferred EWR, approximately 2026.

- (vi) Investigating further management measures, such as lowering the assurances of supply, eliminating unlawful water use and eradicating of invasive alien plants in the Kraai River catchment.
- (vii) Hold negotiations with WUA and Irrigation Boards to agree on appropriate assurances of supply for irrigated agriculture.
- (viii) Initiate a process to decide what the desirable EWR should be for the river system.

11 RISKS AND UNCERTAINTIES

The following risks and uncertainties have been identified in accordance with the NWA:

- The extent of unlawful water use and lawful growth in water use is unknown. Until the V&V processes are complete, the water reconciliation strategy will be based on water use as in 1998 (qualifying period);
- The success of the purchasing of water entitlements (WC/WDM savings) as an option is difficult to predict. It is not clear how many water users would, in the longer term, offer water entitlements or parts thereof for sale and how much water will be made available for other users through this measure. The socio-economic implication of exchanging water use entitlements between users and sectors need to be understood and regulated to avoid negative consequences. There must therefore be a well-structured policy in place that will maintain socio-economic development imperatives, while allowing the improvement of the production efficiency of the water used;
- The cooperation of District and Local Municipalities is of utmost importance for achieving the WC/WDM targets in the urban water use sector;
- The water reconciliation strategy is based on the assumption that water from Polihali Dam will be transferred to the Vaal System in accordance with the growing water demand in the Vaal, and that the unused portion of the yield will temporarily be made available to the Orange River. Should this not be the case, both Vioolsdrift Dam and Gariep Dam raising will have to be constructed earlier;
- The possible future exports from Lesotho, potentially from Tsoelike Dam, to Botswana have not been incorporated in the water balance scenarios and the recommended strategy. The studies and related results into this option should be monitored;
- The Vaal Gammagara Scheme as well as Kimberly might require support from the Orange River in future. This and the associated volumes required is still uncertain. The possibility to combine the possible transfers to Botswana with the support to Vaal Gammagara and Kimberley should be investigated.
- The transfer volume through the Orange-Fish tunnel to the Eastern Cape needs to be confirmed through detail analysis of the Fish and Sunday systems. The proposed work should entail the following components:
 - Validation of water use followed by the Verification of lawful water use;
 - Recalibrate and extend the hydrological data and revise the system models accordingly;
 - Undertake simulation risk analysis to determine the required transfers needed from the Orange River. (Requires integrated stochastic simulation of the Orange and Fish Sundays systems.), and
 - Consider combining the Eastern Cape and Orange network models into an integrated modelling system.
- A red flag was raised for the construction of Vioolsdrift Dam, as the dam will possibly impact on the bio-diversity of the area. It was however not a fatal flaw. At feasibility stage the red flag might turn into a fatal flaw after a comprehensive impact assessment;

 The acceptability of linking the pumping station for the Vanderkloof minimum operating level option to the scour outlet of Vanderkloof Dam is uncertain. If unacceptable, the option will be more expensive;

• Due to the gradual increasing slope of the water requirement projection, small deviations in the growth of the water use will result in substantial changes to the dates interventions are needed. Coupled to this, the prevailing storage in the dams at the time when future implementation decisions are taken will influence the short term risk of supply and the degree of urgency to implement interventions. Drought restriction operational decisions are therefore a key management mechanism where-by the acceptance of short duration restrictions could postpone eminent capital expenditure by several years. Given this characteristic, operational and intervention planning must be closely integrated to ensure prudent decisions are taken at any point in time. These decisions should be supported by risk assessments that are based on system analysis (simulations) with the Water Resources Planning Model.

12 IMPLEMENTATION ARRANGEMENTS

It is DWA's intention to form a Strategy Steering Committee that will oversee the implementation of the strategy as well as recommend adaptive measures to accommodate any changes that may affect the reconciliation scenarios.

The strategy actions will be the responsibility of the respective institutions listed in **Table 9.1**. Detail project plans need to be compiled in which the actions will have to be broken down further with time lines and budgetary requirements for each organisation.

The SSC members will convene twice a year where each organisation will be requested to present progress on implementation of their respective activities.

Particular attention needs to be given to strategy recommendations requiring negotiations with the Shared Basin States. DWA International Liaisons will have to take the lead, most likely through the structures provided by ORACECOM. Integration of the Reconciliation Strategy with the Integrated Water Resource Management Plan currently been developed by ORACECOM need to be coordinated.

13 RECOMMENDATIONS FOR FURTHER WORK

A number of issues go beyond the scope of this study and separate studies are recommended for such issues.

- The high growth water demand curve is based on the 1998 level of irrigation as the National Water Act (Act 36 of 1998) specified existing lawful water use as all water use exercised two years prior to 1998. The verification process will determine which portion of the irrigation expansion since 1998 is lawful and which is not. However, the verification process can still take a long time and for the Lower Orange WMA it hasn't even started yet. The water balances should be reviewed as part of the continuation study once the validated water uses have been verified.
- Northern Cape Department of Agriculture, Conservation and Rural Development indicated at the final public meeting that additional irrigation development is planned to take place along the Orange over and above the 12 000 ha allocated to resource poor farmers. These planned developments are understood to be areas that received allocations in the past, but were not taken up until now. These possible developments need to be confirmed to determine whether they were captured in the total irrigation allocation as used in the Orange Reconciliation Strategy water balances.
- The environmental impact of a Vioolsdrift Dam was investigated for a dam with a large storage capacity and subsequently a large inundated area. A red flag was raised by the screening exercise. In view of the fact that the smaller 510 million m³ storage dam was chosen, the exercise needs to be redone for a dam with a much smaller inundation area. It must be confirmed whether the red flag is going to be maintained.
- Engage with the process undertaken by ORACESOM, in particular the development of an Integrated Water Resource Management Plan (IWRMP) for the Orange Senqu Basin. The sharing of information and findings will be of mutual benefit to the continuation study.
- A policy on unlawful water use in the Orange System needs to be developed by DWA. The policy must spell out what to do with unlawful water users, e.g. should the NWA be applied and all unlawful water users be prosecuted and directed to stop using water or, in the light of the National Planning Commission's vision to increase irrigation in the country, should the DWA issue licences to unlawful irrigators and improve the control over unlawful practices?
- The outcome of such a policy direction will have a direct impact on the water requirement projections which was used for developing this strategy. Principals of fairness need to be considered where any user is allowed to partake (compete) for additional water use entitlements, not only the irrigators that were using water unlawfully. The implication of increases in irrigation on the water balance will be that interventions and large capital expenditure will be required earlier, than what is presented in the strategy.
- The transfer volume through the Orange-Fish tunnel to the Eastern Cape needs to be confirmed through detail analysis of the Fish and Sunday systems. The proposed work should entail the following components:
 - Validation of water use followed by the Verification of lawful water use;

- Recalibrate and extend the hydrological time series data and revise the system models accordingly;
- Undertake simulation risk analysis to determine the required transfers needed from the Orange River. (Requires an integrated stochastic simulation model of the Orange and Fish Sundays systems.), and
- Consider combining the Eastern Cape and Orange network models into an integrated modelling system.

Note:

Eskom prepared a brief report which was received almost at the study closure. This report provides details on hydropower related impacts on two of the proposed intervention options.

- Vanderkloof Dam low level storage
- Gariep Dam raising

It is recommended that the Eskom report be taken into consideration during the feasibility study for the Raising of Gariep Dam/Verbeeldingskraal Dam as well as when the Bridging Study is commissioned to proceed with the implementation of the option to utilise the Vanderkloof Lower Level Storage. The Eskom report is included in Appendix D of the Report "Review of Screened Options and Cost Estimates" Report no. P RSA D000/00/18312/9.

14 REFERENCES

- UN (1997) Convention on the Law of the Non-navigational Uses of International Watercourses Adopted by the General Assembly of the United Nations on 21 May 1997
- RAMSAR (1971) Convention on Wetlands of international importance especially as waterfowl habitat (The Ramsar Convention on Wetlands), 1971 as amended 1982 and 1987
- Darcy Groundwater Consultants. (2004). Ongoing project: Establishment of a Groundwater Management Plan for the Kalkveld WUA, Progress Report 1, Project completion due in June 2004. Geohydrology, Free State Regional Office, The Department of Water Affairs & Forestry, Bloemfontein.
- DWAF (1996) South African Water Quality Guidelines
- DWAF (2009). Directorate Water Resource Planning Systems: Water Quality Planning. Orange River: Assessment of water quality data requirements for planning purposes. Water Quality Monitoring and Status Quo Assessment. Report No. 3 (P RSA D000/00/8009/1). ISBN No. 978-0-621-38690-5, Pretoria, South Africa.
- DWA (2010). Directorate National Water Resource Planning: Assessment of the Ultimate Potential and Future Marginal Cost of Water Resources in South Africa.
- DWA (2011). Directorate Water Resource Planning Systems: Water Quality Planning. Resource Directed Management of Water Quality. Planning Level Review of Water Quality in South Africa. Sub-series No. WQP 2.0. Pretoria, South Africa.
- DWA (2011b). All Town Reconciliation Strategy Reports are available on the DWA website and is assessable with the following link: http://www6.dwa.gov.za/iwrp/dss/DashboardEngine.aspx?DashboardID=IWRP\Map_Search
- DWA (2012) Department of Water Affairs, South Africa, June 2012. Classification of Significant Water Resources (River, Wetlands, Groundwater and Lakes) in the Upper, Middle and Lower Vaal Water Management Areas (WMA) 8, 9, 10: Management Classes of the Vaal River Catchment Report.
- DWA (2012b) Department of Water Affairs, South Africa, June 2012. Reconciliation Strategy Report for the Large Bulk Water Supply Systems of the Greater Bloemfontein Area. DWA Report No. P WMA 14/C520/00/0910/05.
- DWA (2013). Establish Water Supply and Drought Operating Rules for Stand Alone Dams and Schemes Typical of Rural/Small Municipal Water Supply Schemes: Mafikeng Scheme. Reports prepared by WRP Consulting Engineers and associates for the Directorate Water Resource Planning Systems: Department of Water Affairs, 2013.
- DWA (2013a) Development of Water of Reconciliation Strategies for Large Bulk Water Supply Systems: Orange River: Literature Review Report report number P RSA D000/00/18312/2 dated March 2013. (Part of the list of reports prepared for this study)
- DWA (2013b) Development of Water of Reconciliation Strategies for Large Bulk Water Supply Systems: International Obligations, report number P RSA D000/00/18312/3 dated July 2013 (first issue). (Part of the list of reports prepared for this study)

GRAII Data received personally from Rainier Dennis North West University.

- Levin M (1980) A Geological and Hydrogeochemical Investigation of the Uranium Potential of an area between the Orange and Kuruman Rivers, Northwestern Cape Province. Atomic Energy Board Report PEL 272, Dated April 1980.
- Lesotho (2012) Lesotho Water Sector Improvement Project: First Annual State of Water Resources Report (1 April 2010 to 31 March 2011) Dated June 2010, By the Government of the Kingdom of Lesotho, The Ministry of Natural Resources. Report no.LWSIP II/06/02/2011
- Lesotho Botswana MoU (2012) Memorandum of Understanding (MoU) for feasibility study to transfer water from Lesotho to Botswana
- Lesotho RSA (1986) Treaty on the Lesotho Highlands Water Project between the Government of the Republic of South Africa and the Government of the Kingdom of Lesotho, 24 October 1986
- LHWC (2007) LHWP Feasibility Study for Phase II: Dam Design, (LHWC 2007)
- LORMS, (2005) LORMS Prefeasibility 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, Main Report, September 2005
- Meyer, P.S. (2003). An explanation of the 1:500 000 General Hydrogeological Map, Bloemfontein 2924. Directorate: Geohydrology, Department of Water Affairs & Forestry, Pretoria.
- Moola M (2008) Fluoride in drinking water and its effects on human health and nutrition in selected towns of the Northern Cape Province, South Africa. WRC Report No 1094/1/08.

National Water Act (1998) The National Water Act, 1998 (Act 36 of 1998)

- ORASECOM (2000) ORASECOM Agreement 3 November 2000
- ORASECOM (2010) Phase II ORASECOM basin wide integrated resources management plan study (2010)
- ORASECOM (2012) EWR requirements received from D Louw for Namibia Fish River and Lower Orange downstream of Vioolsdrift. Final reports were not available at the time.
- ORASECOM (2013) Information gathered as part of ORASECOM Phase III study. Data received from Dr. G Petersen as obtained from his visit to Namibia and discussions for P Liebenberg (Namibia Agriculture) Reports from this study are not available yet.
- RSA Nam (1992) The Agreement on the Establishment of the Vioolsdrift and Noordoewer Joint Irrigation Scheme on the lower Orange River (1992)
- SADC (2000) SADC Revised Protocol on Shared Water Courses, 7 August 2000
- SADC (2005) SADC Regional Water Policy 2005
- Seymour, A. & Seward, P. (1995) Groundwater Harvest Potential Map of the Republic of South Africa. Department of Water Affairs & Forestry, Pretoria.

- Toens PD, Stadler W and Wullschlege NJ (1998) The association of groundwater chemistry and geology with atypical lymphocytes (as Biological Indicator) in the Pofadder area, North Western Cape, South Africa, WRC Report No 839/1/98.
- UN (2008) The Law on Transboundary Aquifers (UN Resolution 11 December 2008)
- UNEP/WHO (1996). Water Quality Monitoring A Practical Guide to the Design and Implementation of Freshwater Quality Studies and Monitoring Programmes. Published on behalf of United Nations Environment Programme and the World Health Organization. Edited by Jamie Bartram and Richard Balance. ISBN 0 419 22320 7 (Hbk) 0 419 21730 4 (Pbk).
- Van Tonder, G. & Rudolph, D. (2003). Rapid Determination of the Groundwater Component of the Reserve for Bainsvlei, Quaternary Catchments (C52G, C52H and C52J). The Department of Water Affairs & Forestry, Pretoria.
- Vegter J R (1995) Groundwater Resources of the Republic of South Africa. Department of Water Affairs & Forestry, Pretoria
- Woodford, AC and Chevalier L, (2002). Hydrogeology of the Main Ka0ro Basin: Current Knowledge and Future Research Needs. WRC Report No. TT179/02

Appendix A

MAPS

Final Reconciliation Strategy Report



DEVELOPMENT OF RECONCILIATION STRATEGIES FOR LARGE BULK WATER SUPPLY SYSTEMS: ORANGE RIVER: PROPOSAL

Study area locality map

