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

PRELIMINARY RECONCILIATION STRATEGY

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List of Abbreviations & Acronyms

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<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tr>
<td>BHN</td>
<td>Basic Human Needs</td>
</tr>
<tr>
<td>CMA</td>
<td>Catchment Management Agency</td>
</tr>
<tr>
<td>CME</td>
<td>Compliance Monitoring and Enforcement</td>
</tr>
<tr>
<td>CMS</td>
<td>Catchment Management Strategy</td>
</tr>
<tr>
<td>CPA</td>
<td>Contract Price Adjustment</td>
</tr>
<tr>
<td>DWA</td>
<td>Department of Water Affairs</td>
</tr>
<tr>
<td>EWR</td>
<td>Ecological Water Requirements (Ecological Component of the Reserve)</td>
</tr>
<tr>
<td>FSL</td>
<td>Full Supply Level</td>
</tr>
<tr>
<td>IAP</td>
<td>Invasive Alien Plants</td>
</tr>
<tr>
<td>IBs</td>
<td>Irrigation Boards</td>
</tr>
<tr>
<td>ISP</td>
<td>Internal Strategic Perspective</td>
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<tr>
<td>IWA</td>
<td>International Water Association</td>
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<tr>
<td>IVRS</td>
<td>Integrated Vaal River System</td>
</tr>
<tr>
<td>IWQMP</td>
<td>Integrated Water Quality Management Plan</td>
</tr>
<tr>
<td>IWRM</td>
<td>Integrated Water Resource Management</td>
</tr>
<tr>
<td>JPTC</td>
<td>Joint Permanent Technical Commission</td>
</tr>
<tr>
<td>LHWP</td>
<td>Lesotho Highlands Water Project</td>
</tr>
<tr>
<td>LHWC</td>
<td>Lesotho Highlands Water Commission</td>
</tr>
<tr>
<td>LORMS</td>
<td>Lower Orange River Management Study</td>
</tr>
<tr>
<td>MAR</td>
<td>Mean Annual Runoff</td>
</tr>
<tr>
<td>MoU</td>
<td>Memorandum of Understanding</td>
</tr>
<tr>
<td>m³/a</td>
<td>Cubic metre per annum</td>
</tr>
<tr>
<td>NWRP</td>
<td>National Water Resource Planning</td>
</tr>
<tr>
<td>NWRS</td>
<td>National Water Resource Strategy</td>
</tr>
<tr>
<td>ORASECOM</td>
<td>Orange-Senqu River Commission</td>
</tr>
<tr>
<td>ORDP</td>
<td>Orange River Development Project</td>
</tr>
<tr>
<td>ORP</td>
<td>Orange River Project</td>
</tr>
<tr>
<td>PES</td>
<td>Present Ecological State</td>
</tr>
<tr>
<td>PSP</td>
<td>Professional Service Provider</td>
</tr>
<tr>
<td>RBL</td>
<td>Right bank level</td>
</tr>
<tr>
<td>RO</td>
<td>Regional Office</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
<td>-------------</td>
</tr>
<tr>
<td>RROs</td>
<td>Resource Quality Objectives</td>
</tr>
<tr>
<td>RQS</td>
<td>Resource Quality Services</td>
</tr>
<tr>
<td>RSA</td>
<td>Republic of South Africa</td>
</tr>
<tr>
<td>RWQOs</td>
<td>Resource Water Quality Objectives</td>
</tr>
<tr>
<td>SADC</td>
<td>Southern African Development Community</td>
</tr>
<tr>
<td>SANP</td>
<td>South African National Parks</td>
</tr>
<tr>
<td>SAWQG</td>
<td>South African Water Quality Guidelines</td>
</tr>
<tr>
<td>SMC</td>
<td>Study Management Committee</td>
</tr>
<tr>
<td>SSC</td>
<td>Study Steering Committee</td>
</tr>
<tr>
<td>TCTA</td>
<td>Trans Caledon Tunnel Authority</td>
</tr>
<tr>
<td>TWQR</td>
<td>Target Water Quality Range</td>
</tr>
<tr>
<td>URV</td>
<td>Unit Reference Value</td>
</tr>
<tr>
<td>WC/WDM</td>
<td>Water Conservation / Water Demand Management</td>
</tr>
<tr>
<td>WDM</td>
<td>Water Demand Management</td>
</tr>
<tr>
<td>WMA</td>
<td>Water Management Area</td>
</tr>
<tr>
<td>WMP</td>
<td>Water Management Plan</td>
</tr>
<tr>
<td>WQT</td>
<td>Water Quality Treatment</td>
</tr>
<tr>
<td>WRPM</td>
<td>Water Resource Planning Model</td>
</tr>
<tr>
<td>WRYM</td>
<td>Water Resource Yield Model</td>
</tr>
<tr>
<td>WTW</td>
<td>Water Treatment Works</td>
</tr>
<tr>
<td>WUAs</td>
<td>Water User Associations</td>
</tr>
<tr>
<td>WWTW</td>
<td>Waste Water Treatment Works</td>
</tr>
</tbody>
</table>
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 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, 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 1994, a significant driver of change in the water balance of the Orange River System was brought about by the storing of water in Katse Dam as the first component of the multi-phase Lesotho Highlands Water Project (LHWP). Currently Phase 1 of the LHWP (consisting of Katse, and Mohale Dams, Matsoku Weir and associated conveyance tunnels) transfers 780 million cubic metres per annum via the 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 2040. This Strategy must be flexible to accommodate future changes in the actual water requirements and transfers, with the result that the Strategy will evolve over time as part of an on-going planning process.

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

The purpose of this report

The purpose of this report is to present a first order reconciliation strategy which is based on the available information collected at the date of this document. The report contains a preliminary water balance with interventions scenarios that provides possible solutions to make sufficient water available for the planning period up to the year 2040.

As the study progresses and more information become available, the preliminary reconciliation strategy will be refined and a final reconciliation strategy will be produced as the final deliverable.
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 agency 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/a 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 Knelpoort 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.

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 contribute to the Orange River’s flow only 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 m³/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 722 million m³/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.
Table E1: Total high and low growth water requirements (all values are given in million m$^3$/a)

<table>
<thead>
<tr>
<th>Sector</th>
<th>Requirement in 2012 (million m$^3$/a)</th>
<th>Future requirement (2040)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>High growth (million m$^3$/a)</td>
</tr>
<tr>
<td>Irrigation</td>
<td>2 366</td>
<td>2 614</td>
</tr>
<tr>
<td>Urban/Industrial</td>
<td>252</td>
<td>540</td>
</tr>
<tr>
<td>Mining</td>
<td>16</td>
<td>33</td>
</tr>
<tr>
<td>Riverine and Operational</td>
<td>846</td>
<td>726</td>
</tr>
<tr>
<td>requirements</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transfers not included in</td>
<td>780</td>
<td>1 217</td>
</tr>
<tr>
<td>above given demands(2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL (3)</td>
<td>4 260</td>
<td>5 130</td>
</tr>
</tbody>
</table>

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.
3. The demands exclude none-consumptive power generation water use.
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 the by far 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.
Table E2: Historic Firm Yield from large dams in the system

<table>
<thead>
<tr>
<th>Sub-system</th>
<th>Dams</th>
<th>Live Storage (million m³)</th>
<th>Yield (million m³)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>LHWP Phase I</td>
<td>Katse</td>
<td>1 517</td>
<td>780</td>
<td>Represents the system yield</td>
</tr>
<tr>
<td></td>
<td>Mohale</td>
<td>851</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orange River Project</td>
<td>Gariep</td>
<td>4 576</td>
<td>3 323</td>
<td>Represents the system yield</td>
</tr>
<tr>
<td></td>
<td>Vanderkloof</td>
<td>2 173</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caledon/Modder sub-system</td>
<td>Knellpoort</td>
<td>131</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rustfontein</td>
<td>72</td>
<td>84</td>
<td>Represents the system yield</td>
</tr>
<tr>
<td></td>
<td>Welbedacht</td>
<td>6.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mockes</td>
<td>3.3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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. Water quality is neither a static condition of a system, nor can it be defined by the measurement of only one parameter. Rather, it is variable in both time and space and requires routine monitoring to detect spatial patterns and changes over time.

The following is a summary description of the water quality status in the Orange River Basin:

- The water in the uppermost reach is moderately soft, relatively low in salt concentrations, but generally high in suspended solids and turbidity.
- The water quality in the upper Orange River was suitable for domestic use, recreational use and irrigation with low TDS and low SAR (sodium adsorption ratio).
- The concentration of turbidity in the upper Orange River is high because of soil erosion.
- The TDS concentrations in the upper section of the Orange River (i.e. from Oranjedraai to Dooren Kuilen, just downstream of Vanderkloof Dam), were relatively low (mean 147 mg/ℓ). From Marksdrift and downstream the dissolved salts increases continuously and reached occasionally concentrations >500 mg/ℓ from Vioolsdrift to Alexander Bay.
- The pH values in the whole Orange River were high (median, 8.1); generally increase downstream and occasionally exceeds the upper limit for irrigation of 8.4.
- The overall dissolved salt concentrations in the Orange River are increasing significantly (in space and time), especially in the Lower Orange (below Marksdrift), that occasionally exceeds 500 mg/ℓ, with negative consequences for the river’s ecosystem as well as for crop production further downstream.
• The phosphate concentrations in the Orange River show the largest non-compliance in terms of the water quality variables assessed. All sites on the Orange River were moderately and more or less the same (50 ± 10 µg/ℓ).

• The high turbidity in the Orange River catchment will limit algal growth for most of the year.

• The mean chlorophyll-a concentrations (algae biomass) in the Gariep and Vanderkloof Dams were low (<5 µg/l) and fall in the range of oligotrophic systems, but the Chl-a concentrations, were much higher at Upington and Pella (mean 15 µg/l) corresponding to mesotrophic water bodies.

• The water quality in the Lower Orange River was occasionally above the target water quality range (ideal) for irrigation especially because of high salts and high pH values.

• Some of the water withdrawn for irrigation is returned to the river environment for reuse, but its quality is seriously degraded with considerably higher salts and nutrient concentrations and evidently contributes significantly to the salts load in the Orange River.

• The general water quality in Kornetspruit and Kraai River was good.

• The Seekoei River’s salt and nutrient concentrations are high but are considered to represent natural conditions.

• The water quality in the Caledon River is highly variable but in general is in a fair condition however, nutrient levels were elevated.

• 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.

The current and future water balance

Currently there is a slight surplus in the system but the growth in water demand over the next 27 years up to 2040 will cause water shortages over time.

Polihali Dam which forms part of LHWP Phase II, will reduce 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.
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:

- Groundwater development
- Transfers in
- New dams
- Reusing sewage effluent
- System operating rules
- 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 m³/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 m³/a. The current irrigation water use is approximately 2 000 million m³/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 m³/a that can be made available.

- **Minimum Operating Level – Vanderkloof Dam**

The Vanderkloof Dam can be operated by lowering its operating level and the yield of the system could increase approximately by 137 million m³/a. The current minimum operation level is 1 147.8 mamsl and it is proposed to be lowered to 1 111.0 mamsl 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 pump the water into the irrigation canal which supplies water to Ramah and Orange-Riet canals.

The future water balance of the selected scenario is shown in **Figure E2**
The above scenario assumed the current EWR is implemented throughout the planning period. Initial preliminary results from EWR studies commissioned by ORASECON indicated that the Ecological Preferred EWR requires additional releases from the ORP, reducing the available water by 434 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. A dam with a full supply level of 210 m amsl and of 510 million m\(^3\) storage was found to be the optimum size. Any larger dam would not yield more as the downstream water demand is limited.

  The water loss that can be saved if Vioolsdrift is used as a regulating dam is 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.

- **Gariep Dam Raising**
Among all the dam development options in the Upper Orange WMA, Gariep Dam raising was found to be economically the preferred option. It had a URV of 0.37 at 8% discount rate for a yield increase of 350 million m$^3$/a and the least social and environmental impacts, compared to the other dams.

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 Bethulie will have to be relocated. Despite the associated mitigation costs, the raising of Gariep Dam was still the most economical option.

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

**Actions required**

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

- Complete validation and verification process in the upper Orange and start the 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.
Interactions with Water User Associations and Irrigation Boards, not yet transformed into WUA re lowering the assurances of supply

Development of 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.

The real time monitoring of the Vaal River and Orange River flows downstream of Vanderkloof Dam needs to be implemented as soon as possible as this option is regarded as a quick win.

Negotiations with Namibia on Vioolsdrift Dam need to be initiated.

The following medium to long term actions are required:

- 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.
- Initiate a feasibility study for Vioolsdrift Dam.
- The feasibility study for the raising of Gariep Dam should commence given that the option is still needed when the final decision on the desirable EWR is taken.
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 2040:

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 socio-economic 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 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.

- 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.
- Creating additional yield in the system by raising the Gariep Dam by 10m. The raising date will be dependent on the implementation date of the Ecological Preferred EWR, approximately 2032.

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 appropriate assurances of supply for irrigated agriculture.

viii. Initiate a process to decide what the desirable EWR should be for the river downstream of the ORP.
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Development of a Reconciliation Strategies for Large Bulk Water Supply Systems: Orange River

Preliminary Reconciliation Strategy (October 2013)

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, 2012). 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 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.

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. 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 will focus on the water resources of the Upper and Lower Orange River Water Management Areas (WMAs), while also considering all the tributary rivers and transfers affecting the water balance of the system. This core area forms part of the Orange-Senqu River Basin, which straddles four International Basin States. 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 will have an impact on the Orange River, will be taken into account as well as the impacts of flows from the Vaal into the Orange for selected Integrated Vaal system scenarios.

As an international resource, shared by four countries any developments, strategies or decisions taken by any one of the countries that will impact on the water availability or quality in South Africa must be taken into account and 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 done 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 will also be taken into account in this study.

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

1.4 PURPOSE OF THE REPORT

The purpose of this report is to present a first order reconciliation strategy which is based on the available information collected at the date of this document. The report contains a preliminary water balance with interventions scenarios that provides possible solutions to make sufficient water available for the planning period up to the year 2040.

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

• **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 situations where no interventions are implemented is discussed in **Chapter 7**. This 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 is distilled into the preliminary reconciliation strategy, as reflected in **Chapter 10**, “Orange Reconciliation Strategy in a Nutshell”.

• Relevant Risk and Uncertainties, strategy 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**.

The study procedure has been designed such that as the study progresses and more information become available, the preliminary reconciliation strategy will be refined and a final reconciliation strategy will be produced as the final deliverable

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.
Preliminary Reconciliation Strategy

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 performed at a preliminary screening workshop which was held on 7 February 2013 where a list of possible reconciliation options were evaluated by a group of key stakeholders who had to decide which options should be 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 this preliminary reconciliation strategy. The gaps in the preliminary reconciliation strategy will then be investigated and the reconciliation options will be refined. The development of the Final Reconciliation Strategy will be the last step in the technical process. The reports which will support the two main deliverables, i.e. the preliminary and final strategies, are the following:

- Summary report of current and previous studies;
- Screening workshop proceedings report for the Preliminary Screening Workshop;
- Report on international obligations regarding water allocations;
- Water requirements and return flows report;
- Report on potential savings in terms of water demand reduction;
- Report on the possibilities of reusing water;
- Report on irrigation water requirements and the potential water savings through water conservation and water demand management;
- Report on the value of water;
- Report on yield analyses;
- Report on water quality;
- Report on groundwater;
- Report on possible development interventions, their costs and URVs, and
- Report on social land environmental impacts.

Figure 1.1: Technical Studies and Public Participation Process
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 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

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


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:**

(i) 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 reuse 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 cross-cutting 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, reuse 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.

• 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.]


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 m$^3$/s (2,208 million m$^3$/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.

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 m^3/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 whole 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 NWRS is at the point of being established. Notice of the NWRS (2nd edition) has already been given in the Government Gazette and the 90 days period for comments has already elapsed.

An important aspect that has been written into the draft 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 to-be-established 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);
• WQ 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 Preliminary 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 ORSECOM IWRM Plan Study Phase II updated hydrology task.

The validated data on irrigation at 2012 development level was not completed at the time the system analysis in support of this preliminary reconciliation strategy were carried out. Indications are however that irrigation development increased significantly in some areas and there is the possibility that some of the irrigation may be unlawful. It is expected that the validation study data will be finalised by July 2013 and appropriate scenarios will therefore be formulated and incorporated in the final reconciliation strategy to be delivered in April 2014.

The most recent environmental flow requirements were received from the Environmental flow Project by ORASECOM UNDP-GEF, in time for inclusion in the system analysis. The impact of these requirements on the system yield were determined and included in the appropriate scenarios.

The calibrated WQT salinity model and WRPM configuration will be available by September 2013 and will be used for system simulation risk analysis in preparation for the final reconciliation strategy.

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. No inputs could therefore be obtained for this Preliminary Strategy.

The Vaal River System Classification Study was completed and the recommended EWR’s 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 2040 development scenarios analysed as part of the system analysis task for this preliminary strategy.

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. Results regarding the possible savings were not yet available and will be included in the second phase of the Orange Reconciliation Study to prepare the final Reconciliation Strategy.
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 Preliminary Reconciliation study.

The latest expected growth in Vaal system demands 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 will continue to play a role in the further execution of the Orange Reconciliation study and will be used in the refinement of the Final Reconciliation Strategy to be developed for the Orange River

2.4 SYSTEM DESCRIPTION

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.
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 supplement to irrigation and urban water demands along the Great Fish and Sundays Rivers, as well as in Port Elizabeth. 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 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.
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 semi-arid regions. The flows in these rivers are very infrequent and it is expected that their flows will contribute to the Orange River’s flow only during periods of relative high flows in the Orange River. The individual yield contribution from these rivers to the Orange River is regarded as relatively 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.

2.4.4 The Eastern Cape Rivers supported by the Orange

Water is transferred from Gariep Dam on the Orange River through the 83 km 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 46 km 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 receive 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 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 are 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 Previous Ecological Water Requirements (EWRs) Study

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 ORRS (Orange River Re-planning Study), but are based on outdated methods. For the purpose of the Orange Reconciliation Study, these outdated EWRs are only used for the base or current day scenario, as they represent the current EWR releases released from Vanderkloof Dam.

Currently a total of 288 million m³/a is released to supply the river mouth EWR of which at least 195.8 million m³/a need to be supplied during drought periods. In the current WRPM setup, the drought EWR is supplied at a high assurance of 99.5% (1:200 year) and the normal EWR at a 95% (1:20 year) 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. EWRs were assessed at an Intermediate Level at selected key areas of the Orange River Basin. A summary of the Riverine EWRs at the different sites along the Orange River is given in Table 3.1.
Table 3.1: Summary of ORASECOM EWR results as a percentage of the natural MAR

<table>
<thead>
<tr>
<th>EWR site</th>
<th>EWR Class</th>
<th>Maintenance low flows</th>
<th>Drought low flows</th>
<th>High flows</th>
<th>Long term mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(%nMAR)</td>
<td>MCM/a</td>
<td>(%nMAR)</td>
<td>MCM/a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(%)nMAR)</td>
<td>MCM/a</td>
<td>(%)nMAR)</td>
<td>MCM/a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(%)nMAR)</td>
<td>MCM/a</td>
<td>(%)nMAR)</td>
<td>MCM/a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(%)nMAR)</td>
<td>MCM/a</td>
<td>(%)nMAR)</td>
<td>MCM/a</td>
</tr>
<tr>
<td>Virgin MARs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EWR O1 Hopetown</td>
<td>PES/REC: C</td>
<td>Due to the unlikely situation that the present operation of the dam will change and the strategic use (ESKOM) that results in this operation, the setting of flow requirements were not undertaken</td>
<td>11.6</td>
<td>1226.5</td>
<td>4.4</td>
</tr>
<tr>
<td>EWR O2 Boegoeberg</td>
<td>AEC↓: D</td>
<td>5.8</td>
<td>613.27</td>
<td>3.1</td>
<td>327.78</td>
</tr>
<tr>
<td>EWR O3 Augrabies</td>
<td>PES: C</td>
<td>8.4</td>
<td>883.10</td>
<td>2.6</td>
<td>273.34</td>
</tr>
<tr>
<td></td>
<td>REC: B</td>
<td>17.6</td>
<td>1850.31</td>
<td>3.4</td>
<td>157.37</td>
</tr>
<tr>
<td></td>
<td>AEC↓: D</td>
<td>4.1</td>
<td>431.04</td>
<td>2.2</td>
<td>231.29</td>
</tr>
<tr>
<td>EWR O4 Vioolsdrift</td>
<td>PES: C</td>
<td>6.3</td>
<td>651.11</td>
<td>0.9</td>
<td>35.16</td>
</tr>
<tr>
<td></td>
<td>REC: B/C</td>
<td>10.1</td>
<td>1043.85</td>
<td>1.3</td>
<td>134.36</td>
</tr>
<tr>
<td></td>
<td>AEC↓: D</td>
<td>3.1</td>
<td>320.39</td>
<td>0.8</td>
<td>31.25</td>
</tr>
<tr>
<td>EWR C5 Upper Caledon</td>
<td>PES/REC: C/D</td>
<td>13.8</td>
<td>7.85</td>
<td>5.8</td>
<td>3.30</td>
</tr>
<tr>
<td>EWR C6 Lower Caledon</td>
<td>PES/REC: D</td>
<td>8.8</td>
<td>118.62</td>
<td>0.3</td>
<td>3.40</td>
</tr>
<tr>
<td></td>
<td>AEC↓: C</td>
<td>15.5</td>
<td>208.93</td>
<td>2.2</td>
<td>29.66</td>
</tr>
<tr>
<td>EWR K7 Lower Kraai</td>
<td>PES/REC: C</td>
<td>11.4</td>
<td>77.81</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>AEC↓: B</td>
<td>16.5</td>
<td>112.61</td>
<td>1.2</td>
<td>7.70</td>
</tr>
<tr>
<td></td>
<td>AEC↓: D</td>
<td>5.1</td>
<td>34.81</td>
<td>0</td>
<td>0.00</td>
</tr>
</tbody>
</table>
3.2.3 Alternative Estuarine, Fish River and Lower Orange EWR

Further environmental flow investigations are currently being done 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 is on the Orange River Mouth requirement and the Fish River in Namibia as well as the Orange River downstream of the confluence of the Fish with the Orange River.

Reports from the abovementioned study were not available at the time when these analyses were carried out. However, communication with the team responsible for the execution of this study revealed that initial results are available for consideration in the Preliminary Strategy.

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 apply this EWR as an alternative to the current EWR presented in Section 3.2.1). 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 is in place to regulate the flow in the downstream river reach.
- Releases were made from Vioolsdrif 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 Vioolsdrif 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 EPS - 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

The most recent environmental requirements available for the Integrated Vaal River System (IVRS) was determined in the study “Classification of Significant Water Resources in the Upper, Middle and Lower Vaal Water Management Areas”, (ORASECOM, 2012). The purpose of the study was to determine the Reserve that needs to be implemented in the IVRS.

Results from the study indicated that EWR sites with a High Environmental Importance were all located in the Upper Vaal WMA with almost none in the Middle and Lower Vaal WMAs except for the Douglas EWR site, in the Lower Vaal. All the sites in the Middle and Lower Vaal WMAs are in a reasonable to good PES (Present Ecological State) with the majority in a B/C environmental class and require non-flow related interventions to achieve the required improvements. For the Middle and Lower Vaal EWR sites, it was therefore concluded that the present flow regime and operation of the system should be signed off as the Reserve.
The implementation of the Douglas EWR will however affect the available yield in the Vaal River System. Results from the Classification study indicated a decrease of approximately 70 million m³/a for development conditions in the Vaal between 2011 and 2020. For the 2020 development level with Polihali Dam in place the reduction in the Vaal system yield due to the implementation of the Douglas EWR, is expected to be 99 million m³/a.

It therefore seems that the proposed EWRs in the Vaal System will in general have almost no effect on the flows from the Vaal into the Orange, except for the Douglas EWR.

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 to be supplied from Polihali Dam. This EWR was applied in scenarios analysed in this study, in cases where Polihali Dam was included as part of the option.

3.2.5 EWR assumptions for scenario formulation (summary)

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).
- EWR releases were implemented in the analysis of each of the proposed dam options. For Knoffelfontein the EWR from the Vaal Classification was used and for the possible Lesotho dams and Boskraai dams EWRs scaled from the Polihali EWR were used – Section 1.1.1 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 that should be incorporated in the modelling system of the Orange River for future analysis.)
4 CURRENT WATER USE AND PROJECTED WATER REQUIREMENTS

4.1 CURRENT WATER USE

The current water use in the irrigation, domestic, industrial, mining and power generation water use sectors for the Upper and Lower Orange as well as for the Eastern Cape are shown in Table 4.2, illustrated in Figure 4.1 and described below.

**Figure 4.1:** Total Orange Senqu demand 2012 (Vaal system excluded)

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 4.2 is the LHWP transfer to the Vaal System supporting urban/industrial requirements.
### Table 4.1: Summary of current demands (2012)

<table>
<thead>
<tr>
<th>Total demand 2012</th>
<th>Orange River Project (million m³/a)</th>
<th>Orange/Senqu (million m³/a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigation</td>
<td>1 989</td>
<td>2 366</td>
</tr>
<tr>
<td>Urban/Mining</td>
<td>118</td>
<td>268</td>
</tr>
<tr>
<td>River Requirements</td>
<td>615</td>
<td>615</td>
</tr>
<tr>
<td>Operating Requirements</td>
<td>180</td>
<td>180</td>
</tr>
<tr>
<td>Consumptive Canal Losses</td>
<td>51</td>
<td>51</td>
</tr>
<tr>
<td>Transfer (LHWP)</td>
<td></td>
<td>780</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2 953</strong></td>
<td><strong>4 260</strong></td>
</tr>
</tbody>
</table>

*Note: The Ecological Water Requirements are excluded from the table and are accounted in the system yields – See Chapter 5*

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

![Orange River Project Demand](image)

**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 and river mouth EWR which are both environmental related requirements.
4.1.1 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 and most downstream of the urban/industrial demand centres.

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. Implementation of Phase II of the LHWP has already been announced. This phase comprises the Polihali Dam and connecting tunnel to Katse Dam, and uses the existing tunnels to the Ash River. 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 will however vary around this target volume, depending on the rainfall as well as the water quality conditions in the Eastern Cape sub-system. Indications are that this can be as much as 25% higher than the target volume. Whether this additional volume will or need to be supplied from Gariep Dam, has not yet been agreed on. Discussions in this regard are still taking place between the irrigators and the DWA. For modelling purposes the 25% losses was not included as a demand on the system.

A total of 4 000 hectares of irrigation in the Eastern Cape was allocated in the early 2000 for the development of resource poor farmers, 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. (See Section 4.2.1 for assumptions on how this additional use was incorporated into the water requirement scenarios).

The Caledon Modder transfer system is used to support the water supply to Bloemfontein, Mangaung, Botshabelo, Thaba N’chu and several small towns located in the Modder Riet River catchment. Water resources of the Modder Riet River catchment are insufficient to supply in the water requirements of these demand centres and water therefore need to be transferred from the neighbouring Caledon River catchment, which has a much higher available annual runoff.

Water is transferred from Welbedacht Dam in the Caledon River to Bloemfontein and several of the smaller towns. Welbedacht Dam has almost fully silted up over the years and Knellpoort Dam, an off channel dam was built. To avoid Knellpoort Dam from silting up, water is being pumped from the Tienfontein pump station located along the Caledon River. The Caledon Modder transfer scheme was then extended by adding the so called Novo Transfer scheme, comprising of the Novo pump station, pumping water from Knellpoort Dam over the water shed to Rustfontein Dam located in the upper Modder River.

The total volume transferred depends on the combination of the water requirements and the water levels the dams within the Modder River basin. These dams are Rustfontein, Mockes and Groothoek dams. The transfer volume is further limited by the infrastructure to the maximum transfer capacity of 47 million m³/a (1.49 m³/s) from Welbedacht and 52.7 million m³/a (1.67 m³/s) via the Novo transfer system. Latest indications are that the Novo transfer capacity has reduced to approximately 1.3 m³/s (41 million m³/a). The maximum volume that can currently be transferred is therefore 88 million m³/a (2.79 m³/s). The current planning is to increase the Novo transfer capacity to 2.4 m³/s by end of 2013.

The Orange Riet Transfer scheme abstracts water from Vanderkloof Dam, and is transferred via canals to the Riet River catchment. The water is primarily used for irrigation but is also used to supply 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. It is expected that the irrigation in this area will significantly increase over time due to 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 on the Vaal River. The volume transferred depends on the water available in 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, to a maximum of 142 million m³/a.
4.1.2 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 quite 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 total irrigation demand imposed on this system totals to almost 2 000 million m³/a, to supply 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 m³/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 m³/a.

Table 4.2: Summary of irrigation schemes

<table>
<thead>
<tr>
<th>Irrigation Schemes</th>
<th>Area (ha)</th>
<th>Demand (million m³/a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orange River Project (Gariep and Vanderkloof dams)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eastern Cape (Fish and Sundays)</td>
<td>49 624</td>
<td>577.17</td>
</tr>
<tr>
<td>Gariep to Vanderkloof scheme</td>
<td>2 025</td>
<td>22.27</td>
</tr>
<tr>
<td>Ramah+Vanderkloof main canal</td>
<td>5 271</td>
<td>57.98</td>
</tr>
<tr>
<td>Orange Riet Canal</td>
<td>12 406</td>
<td>137.07</td>
</tr>
<tr>
<td>Scholtzburg</td>
<td>691</td>
<td>7.60</td>
</tr>
<tr>
<td>Lower Riet</td>
<td>3 873</td>
<td>42.60</td>
</tr>
<tr>
<td>Vanderkloof to Marksdrift</td>
<td>17 455</td>
<td>187.38</td>
</tr>
<tr>
<td>Douglas</td>
<td>11 410</td>
<td>104.29</td>
</tr>
<tr>
<td>Marksdrift to Boegoeberg</td>
<td>17 236</td>
<td>173.95</td>
</tr>
</tbody>
</table>
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.

The irrigation areas and related demands for the Upper Orange WMA were obtained from the current Validation/Verification study initiated by DWA. Most of the Validation work on this study is completed. The purpose of the validation is to ensure 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.

**Table 4.3:** Summary of diffuse irrigation developments supplied from Surface Water

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

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.

The Validation study also evaluated the current irrigation development (2012 year), although not to the same level of detail as for the qualifying period. Preliminary water use data for the 2012 development level (only approximately 60% of the Upper Orange WMA area were completed) was compared to the 1998/1999 data for the same area. The comparison showed the increase in the irrigation requirement from 1998 to 2013 can be as much as 300 million m³/a with approximately 85 million m³/a in the Caledon, 77 million m³/a in the Orange and Kraai catchments upstream of Gariep Dam and 110 million m³/a in the Riet/Modder basin with the balance of about 30 million m³/a in the remainder of the WMA. The completed results from the 2012 development level will be obtained from the Validation study and applied in the development of the Final Reconciliation Strategy.

### 4.1.3 Urban and Rural Water Requirements

The study focuses on the Upper and Lower Orange WMA and therefore includes the sub-systems of the Caledon, Upper Orange, Riet/Modder, Lower Orange Main stem and part of the Lower Vaal. There are no major industrial areas, 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**.

**Table 4.4:** Urban Industrial RSA Historic and 2012 Water requirements (million m³/a )

<table>
<thead>
<tr>
<th>SUB-SYSTEM / DESCRIPTION</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caledon</td>
<td>9.06</td>
<td>9.65</td>
<td>10.09</td>
<td>10.53</td>
</tr>
<tr>
<td>Upper Orange (Eastern Cape included)</td>
<td>51.09</td>
<td>55.3</td>
<td>59.48</td>
<td>60.50</td>
</tr>
<tr>
<td>Lower Vaal</td>
<td>1.83</td>
<td>1.92</td>
<td>2.02</td>
<td>2.12</td>
</tr>
<tr>
<td>Riet/Modder</td>
<td>88.62</td>
<td>87.44</td>
<td>85.20</td>
<td>92.63</td>
</tr>
<tr>
<td>Lower Orange Main Stem</td>
<td>31.02</td>
<td>31.65</td>
<td>32.29</td>
<td>32.92</td>
</tr>
<tr>
<td><strong>Total Urban Industrial RSA</strong></td>
<td><strong>181.61</strong></td>
<td><strong>185.99</strong></td>
<td><strong>189.43</strong></td>
<td><strong>198.70</strong></td>
</tr>
</tbody>
</table>

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)

<table>
<thead>
<tr>
<th>SUB-SYSTEM / DESCRIPTION</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Senqu/Makaleng</td>
<td>0.89</td>
<td>0.93</td>
<td>0.98</td>
<td>1.03</td>
</tr>
<tr>
<td>Caledon</td>
<td>16.09</td>
<td>15.30</td>
<td>16.54</td>
<td>17.77</td>
</tr>
<tr>
<td>Total Urban &amp; Industrial Lesotho</td>
<td>16.98</td>
<td>16.23</td>
<td>17.52</td>
<td>18.80</td>
</tr>
</tbody>
</table>

Part of the Namibian urban demand is located along the Lower Orange main river and is supported by releases from Vanderkloof. The other Namibian urban demands impacting on flows in the Orange River but to a much lesser extent are those supplied from the Fish River in Namibia. The Fish River only enters the Orange River close to the River mouth. Due to this and the erratic flow nature of the Fish River, 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)

<table>
<thead>
<tr>
<th>SUB-SYSTEM / DESCRIPTION</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Orange Main Stem</td>
<td>8.60</td>
<td>8.65</td>
<td>8.71</td>
<td>8.77</td>
</tr>
<tr>
<td>Sub-Total Fish</td>
<td>2.90</td>
<td>2.90</td>
<td>2.90</td>
<td>2.90</td>
</tr>
<tr>
<td>Total Urban Industrial Namibia</td>
<td>11.50</td>
<td>11.56</td>
<td>11.61</td>
<td>11.67</td>
</tr>
</tbody>
</table>

4.1.4 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.

Table 4.7: Mining RSA Current Water Allocations and Abstractions (million m³/a)

<table>
<thead>
<tr>
<th>SUB-SYSTEM / DESCRIPTION</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riet/Modder</td>
<td>1.50</td>
<td>1.50</td>
<td>1.50</td>
<td>1.50</td>
</tr>
<tr>
<td>Lower Orange Main Stem</td>
<td>6.82</td>
<td>6.85</td>
<td>6.91</td>
<td>6.96</td>
</tr>
<tr>
<td>Total Mines RSA</td>
<td>8.32</td>
<td>8.35</td>
<td>8.41</td>
<td>8.46</td>
</tr>
</tbody>
</table>
### Table 4.8: Mining Namibia Current Water Allocations and Abstractions (million m³/a)

<table>
<thead>
<tr>
<th>SUB-SYSTEM / DESCRIPTION</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Orange Main Stem</td>
<td>7.53</td>
<td>7.53</td>
<td>7.61</td>
<td>7.64</td>
</tr>
<tr>
<td>Total Mines RSA</td>
<td>7.53</td>
<td>7.53</td>
<td>7.61</td>
<td>7.64</td>
</tr>
</tbody>
</table>

#### 4.1.5 Power Generation

Hydro-power is generated at both Gariep and Vanderkloof Dams. 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 of priority of water use for irrigation, urban-industrial, mining and environmental purposes with the allowance to generate hydro-power with the water released for such purposes. Hydro-power generated with these releases is therefore 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 that generated by means of the normal releases for downstream users and will thus represent a consumptive demand. Analyses are carried out in May and November each year to determine the short-term surplus available in the ORP system that can be used by Eskom for this purpose.

#### 4.1.6 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 4.3 and included Table 4.9. A second projection that includes the benefits of WC/WDM has also been prepared.
The increase in water requirements within the Orange Senqu (Vaal excluded) is estimated to be 888 million m³/a between 2012 to 2040. The main increases are as result of:

- The increased transfer of 437 million m³/a from the LHWP to the Vaal
- The 120 million m³/a allocated to resource poor farmers.
- BloemWater sub-system increase of 105 million m³/a.

The expected growth in water requirements on the Orange River Project is shown in Figure 4.4. The overall expected increase in the water requirements for this system from 2012 to 2040 is 131 million m³/a.

The implementation of river releases in accordance with the alternative Ecological Preferred EWR 2013, would add an additional 434 million m³/a abstraction in the system.
Figure 4.4: Orange River Project demand projection

Table 4.9: Orange River Project high demand projection

<table>
<thead>
<tr>
<th>Description</th>
<th>Demand growth in million m³/annum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2012</td>
</tr>
<tr>
<td>Net Demand</td>
<td>2 826</td>
</tr>
<tr>
<td>Total gross demand</td>
<td>2 954</td>
</tr>
<tr>
<td>Irrigation</td>
<td>1 989</td>
</tr>
<tr>
<td>Transfer to Bloemfontein (Greater Bloemfontein Reconciliation Study)</td>
<td>0</td>
</tr>
<tr>
<td>Urban</td>
<td>118</td>
</tr>
<tr>
<td>River requirements</td>
<td>615</td>
</tr>
<tr>
<td>Operating Requirements</td>
<td>180</td>
</tr>
<tr>
<td>Canal losses</td>
<td>51</td>
</tr>
<tr>
<td>Return flows</td>
<td>128</td>
</tr>
</tbody>
</table>

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 130 million m3/a will be developed by 2025, applying the growth estimations as obtained from the DWA regional offices as part of the Annual Operating Analysis 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 on 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. (Detail modelling of scenarios in the Fish River was not carried out for these balances due to the unavailability of revised hydrological data. Further analysis work will be carried out in preparation of the Final Strategy. It is however expected that changes in the modelling (water balance) of the Fish River will not significantly change the results presented in this document.)

4.2.2 Urban and Rural Water Use

Water requirement projections for the Bloemfontein, Thaba N’chu 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, 2012). 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 Strategy (DWA, 2011).

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

Table 4.10: Urban Industrial RSA Estimated Future Water Requirements (million m³/a)

<table>
<thead>
<tr>
<th>SUB-SYSTEM / DESCRIPTION</th>
<th>2012</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
<th>2035</th>
<th>2040</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Orange (Eastern Cape included)</td>
<td>60.50</td>
<td>91.38</td>
<td>93.53</td>
<td>95.66</td>
<td>98.09</td>
<td>100.49</td>
<td>102.90</td>
</tr>
<tr>
<td>Lower Vaal</td>
<td>2.12</td>
<td>2.42</td>
<td>2.73</td>
<td>3.00</td>
<td>3.26</td>
<td>3.51</td>
<td>3.77</td>
</tr>
<tr>
<td>Riet Modder</td>
<td>92.63</td>
<td>95.18</td>
<td>111.10</td>
<td>130.19</td>
<td>152.19</td>
<td>177.58</td>
<td>204.00</td>
</tr>
<tr>
<td>Lower Orange</td>
<td>32.92</td>
<td>34.82</td>
<td>36.37</td>
<td>37.96</td>
<td>39.60</td>
<td>41.27</td>
<td>42.87</td>
</tr>
<tr>
<td>Total Urban Industrial RSA</td>
<td>198.70</td>
<td>235.64</td>
<td>256.99</td>
<td>281.49</td>
<td>309.26</td>
<td>340.38</td>
<td>372.54</td>
</tr>
</tbody>
</table>

Table 4.11: Urban Industrial Lesotho Estimated Future Water Requirements (million m³/a)

<table>
<thead>
<tr>
<th>SUB-SYSTEM / DESCRIPTION</th>
<th>2012</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
<th>2035</th>
<th>2040</th>
</tr>
</thead>
<tbody>
<tr>
<td>Senqu/Makaleng</td>
<td>1.03</td>
<td>1.21</td>
<td>1.56</td>
<td>2.03</td>
<td>2.65</td>
<td>3.47</td>
<td>4.29</td>
</tr>
<tr>
<td>Caledon</td>
<td>17.77</td>
<td>21.48</td>
<td>27.70</td>
<td>34.98</td>
<td>42.32</td>
<td>49.71</td>
<td>57.11</td>
</tr>
<tr>
<td>Total Urban &amp; Industrial Lesotho</td>
<td>18.80</td>
<td>22.69</td>
<td>29.27</td>
<td>37.01</td>
<td>44.97</td>
<td>53.18</td>
<td>61.40</td>
</tr>
</tbody>
</table>
Table 4.12: Urban Industrial Namibia Estimated Future Water Requirements (million m³/a)

<table>
<thead>
<tr>
<th>SUB-SYSTEM / DESCRIPTION</th>
<th>2012</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
<th>2035</th>
<th>2040</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish River</td>
<td>2.90</td>
<td>2.90</td>
<td>2.90</td>
<td>2.90</td>
<td>2.90</td>
<td>2.90</td>
<td>2.90</td>
</tr>
<tr>
<td>Total Urban Industrial Namibia</td>
<td>11.67</td>
<td>11.84</td>
<td>12.28</td>
<td>12.38</td>
<td>12.47</td>
<td>12.57</td>
<td>12.66</td>
</tr>
</tbody>
</table>

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 m³/a. to be supplied through the current Pella Water Board System.

Table 4.13: Estimated Future Mining Water Requirements RSA (million m³/a)

<table>
<thead>
<tr>
<th>SUB-SYSTEM / DESCRIPTION</th>
<th>2012</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
<th>2035</th>
<th>2040</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riet Modder Sub-system</td>
<td>1.50</td>
<td>1.69</td>
<td>2.01</td>
<td>2.32</td>
<td>2.64</td>
<td>2.95</td>
<td>3.27</td>
</tr>
<tr>
<td>Lower Orange Main Stem</td>
<td>6.96</td>
<td>19.13</td>
<td>16.79</td>
<td>16.94</td>
<td>17.10</td>
<td>17.26</td>
<td>17.42</td>
</tr>
<tr>
<td>Total Mines in RSA</td>
<td>8.46</td>
<td>20.82</td>
<td>18.79</td>
<td>19.26</td>
<td>19.74</td>
<td>20.21</td>
<td>20.69</td>
</tr>
</tbody>
</table>

The Namibian mining requirements, Table 4.14, also show a 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)

<table>
<thead>
<tr>
<th>SUB-SYSTEM / DESCRIPTION</th>
<th>2012</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
<th>2035</th>
<th>2040</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Orange Main Stem</td>
<td>7.64</td>
<td>10.75</td>
<td>10.97</td>
<td>11.22</td>
<td>11.47</td>
<td>11.73</td>
<td>11.98</td>
</tr>
<tr>
<td>Total Mines Namibia</td>
<td>7.64</td>
<td>10.75</td>
<td>10.97</td>
<td>11.22</td>
<td>11.47</td>
<td>11.73</td>
<td>11.98</td>
</tr>
</tbody>
</table>

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 dams increases over time the short term surplus available from these two dams will decrease. This will result in a decrease in the discreitional 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 Agraubies at a combined maximum rate of some 35m³/s. this will however be a non-consumptive use.

4.2.5 Unlawful Water Use

Reliable estimates of unlawful water use were not available to consider in the Preliminary Reconciliation Strategy. Estimated water use for the year 2012 is currently being prepared by the Validation Study team and will provide an indication of what water use is possible unlawful. Once the 2012 data is made available, estimates of unlawful water use will be prepared in consultation with the Validation Study Team for consideration in the Final Reconciliation Strategy.

Note that the definitive quantification of unlawful water use will only be possible after conclusion of the Verification process, which could take up to five years to complete.

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.

<table>
<thead>
<tr>
<th>Sector</th>
<th>Requirement in 2012 (million m³/a)</th>
<th>Future requirement (2040)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>High growth (million m³/a)</td>
<td>Low growth (million m³/a)</td>
</tr>
<tr>
<td>Irrigation</td>
<td>2 366</td>
<td>2 614</td>
<td>2 482</td>
</tr>
<tr>
<td>Urban/Industrial</td>
<td>252</td>
<td>540</td>
<td>534</td>
</tr>
<tr>
<td>Mining</td>
<td>16</td>
<td>33</td>
<td>33</td>
</tr>
<tr>
<td>Riverine and Operational</td>
<td>846</td>
<td>726</td>
<td>726</td>
</tr>
<tr>
<td>requirements</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transfers not included in</td>
<td>780</td>
<td>1 217</td>
<td>1 217</td>
</tr>
<tr>
<td>above given demands(2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL (3)</td>
<td>4 260</td>
<td>5 130</td>
<td>4 992</td>
</tr>
</tbody>
</table>

Table 4.15: Total high and low growth water requirements (all values are given in million m³/a)
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.
(3) The demands exclude none-consumptive power generation water use.

Details on the WC/WDM for the urban sector are given in Section 8.2.1. From this section a possible reduction in the urban/industrial demand of 6.4 million m³/a, was given. This can be phased in over a period of 5 years. This excludes the savings due to WC/WDM in the Greater Bloemfontein supply area, as that was already captured in the demand projection used for the Greater Bloemfontein area.

Section 8.2.2 provides detail on the possible WC/WDM saving in the irrigation sector. From this section it was recommended that an average net saving of about 5% over a period of 5-10 years can be adopted as a conservative but realistic estimate for this sector.
5 WATER RESOURCE AVAILABILITY

5.1 METHODOLOGY

Surface water resource availability was determined through simulation analysis (modelling) of the Orange River System as configured in the Water Resource Yield Model (WRYM). The yield results presented in the following section represent the Historical Firm Yield of the indicated system or option.

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

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 m$^3$/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.
Table 5.1: Historic Firm Yield from large dams in the system

<table>
<thead>
<tr>
<th>Sub-system</th>
<th>Dams</th>
<th>Live Storage (million m³)</th>
<th>System Yield (million m³/a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LHWP Phase I</td>
<td>Katse</td>
<td>1 517</td>
<td>780</td>
</tr>
<tr>
<td></td>
<td>Mohale</td>
<td>851</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Matsoku</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Orange River</td>
<td>Gariep</td>
<td>4 576</td>
<td>3 038</td>
</tr>
<tr>
<td></td>
<td>Vanderkloof</td>
<td>2 173</td>
<td></td>
</tr>
<tr>
<td>Caledon/Modder</td>
<td>Knellpoort</td>
<td>131</td>
<td>84</td>
</tr>
<tr>
<td>sub-system</td>
<td>Rustfontein</td>
<td>72</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Welbedacht</td>
<td>6.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mockes</td>
<td>3.3</td>
<td></td>
</tr>
</tbody>
</table>

5.2.2 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 included 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.

5.2.3 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

General:
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.
- 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 Venterdorp Supergroup are observed. The Supergroup is characterised as porphyritic lava, quartzite, tuff and volcanic breccia, (Meyer, 2003).
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 (Venterdorp 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 ℓ/l/s but these is a large proportion of boreholes with less than 0.1 ℓ/s.

- 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/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 km²), 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 Cl-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 m³/a, 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 m²/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.
- 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 were 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 mS/m) fall within acceptable water quality guidelines for Electrical Conductivity (EC) of less than 170 mS/m, 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.
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 mS/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 mS/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 m$^3$/km$^2$/a. The total catchment area for the Upper Orange WMA (Lesotho excluded) amounts to 101 977 km$^2$. The harvest potential for the WMA as a whole is thus estimated at 1 020 million m$^3$/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 m$^3$/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 2600ha with abstraction of approximately 14 million m$^3$/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.

2460ha of the catchments D31 to D35 are irrigated with a total groundwater abstraction of 5.4 million m$^3$/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 m$^3$/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 m$^3$/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 no 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 l/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 l/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 l/s is greater than 50%, the general borehole yield in the granites and gneisses vary between 0.1 and 2.0 l/s while yields between 0.1 and 0.5 l/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, Askhamp 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 m\(^3\)/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 m\(^3\)/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 usable 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.
Table 5.2: Groundwater availability in the quaternary catchments of the Lower Orange WMA

<table>
<thead>
<tr>
<th>Quaternary Catchment</th>
<th>Annual Abstraction m²/a/catchment</th>
<th>Annual Potential Recharge m³/a/catchment</th>
<th>Groundwater Resource Potential m³/a/catchment</th>
<th>Utilisable Groundwater Exploitation Potential m³/a/catchment</th>
<th>Utilisable Potable Groundwater Exploitation Potential m³/a/catchment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal (Mean)</td>
<td>Dry</td>
<td>Normal</td>
<td>Dry</td>
<td>Normal</td>
</tr>
<tr>
<td>D4</td>
<td>2 509 804</td>
<td>60 214 308</td>
<td>37 118 832</td>
<td>72 704 456</td>
<td>49 837 120</td>
</tr>
<tr>
<td>D5</td>
<td>4 301 655</td>
<td>55 346 628</td>
<td>34 632 735</td>
<td>202 137 858</td>
<td>181 284 402</td>
</tr>
<tr>
<td>D6</td>
<td>3 435 822</td>
<td>207 610 650</td>
<td>132 858 190</td>
<td>471 133 410</td>
<td>396 263 350</td>
</tr>
<tr>
<td>D7</td>
<td>7 030 435</td>
<td>135 394 637</td>
<td>85 966 090</td>
<td>337 881 090</td>
<td>289 339 450</td>
</tr>
<tr>
<td>D8</td>
<td>1 443 253</td>
<td>3 414 371</td>
<td>2 048 938</td>
<td>26 491 210</td>
<td>24 786 195</td>
</tr>
<tr>
<td>TOTALS</td>
<td>18 720 979</td>
<td>461 980 594</td>
<td>293 634 785</td>
<td>1 110 348 023</td>
<td>941 515 518</td>
</tr>
</tbody>
</table>
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.
- 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.

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:

- 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.