Water Resources Modelling, Baseline Scenario, Yield Analysis, Stochastic Verification and Validation

Integrated Water Resources Management Plan for the Orange-Senqu River Basin

2014

Report No. ORASECOM 014/2014

The ***Support to Phase 3 of the ORASECOM Basin-wide Integrated Water Resources Management Plan*** Study was commissioned by the Secretariat of the Orange-Senqu River Basin Commission (ORASECOM) with technical and financial support from the German Federal Ministry for Economic Cooperation and Development (BMZ) in delegated cooperation with the UK Department for International Development (DFID) and the *Australian Department of Foreign Affairs and Trade (DFAT)* implemented through Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)°.

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Support to Phase 3 of the ORASECOM Basin-wide integrated Water Resources Management Plan

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Compiled by : Caryn Seago and Hermanus Maré

WATER RESOURCES MODELLING, BASELINE SCENARIO, YIELD ANAYSIS, STOCHASTIC VERIFICATION AND VALIDATION

Integrated Water Resources Management Plan for the Orange-Senqu River Basin – Phase 3

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ABBREVIATIONS AND ACRONYMS

DWA	Department of Water Affairs
EFR	Environmental flow requirements
EWR	Ecological water requirements
FSC	Full supply capacity
IMS	Information management system
IWRM	Integrated water resources management
LHWP	Lesotho Highlands Water Project
MAR	Mean annual runoff
ORP	Orange River Project
PES	Present ecological state
m.o.l	Minimum operating level
REC	Receommended environmental conditions
RI	Return interval
SAP	Strategic Action Programme
SD	Standard deviation
STOMSA	Stochastic Model of South Africa
TDA	Transbo
UNDP-GEF	United Nations Development Programme (Global Environmental Facility
VRESAP	Vaal Eastern sub-system Augmentation Project
WIS	Water information system
WRPM	Water resources yield model
WRYM	Water resources planning model

1. Introduction

1.1 CONTEXT AND OBJECTIVES OF THE STUDY

1.1.1 General Context

Southern Africa has fifteen (15) transboundary watercourse systems of which thirteen exclusively stretch over SADC Member States. The Orange–Senqu is one of these thirteen. The Southern African Development Community (SADC) embraces the ideals of utilising the water resources of these transboundary watercourses for the regional economic integration of SADC and for the mutual benefit of riparian states. The region has demonstrated a great deal of goodwill and commitment towards collaboration on water issues. Thus, SADC has adopted the principle of basin–wide management of the water resources for sustainable and integrated water resources development. The proposed ORASECOM basin-wide IWRM fits in to this background.

1.1.2 Water resources context

The Orange - Senqu River originates in the highlands of Lesotho on the slopes of its highest peak, Thabana Ntlenyana, at 3 482m, and it runs for over 2 300km to its mouth on the Atlantic Ocean.

The river system is one of the largest river basins in Southern Africa with a total catchment area of more than 850,000km^2 and includes the whole of Lesotho as well as portions of Botswana, Namibia and South Africa. The natural mean annual runoff at the mouth is estimated to be in the order of 11,500 million m^3/a, but this has been significantly reduced by extensive water utilisation for domestic, industrial and agricultural purposes to such an extent that the current flow reaching the river mouth is now in the order of half the natural flow. The basin is shown in **Figure 1-1**.

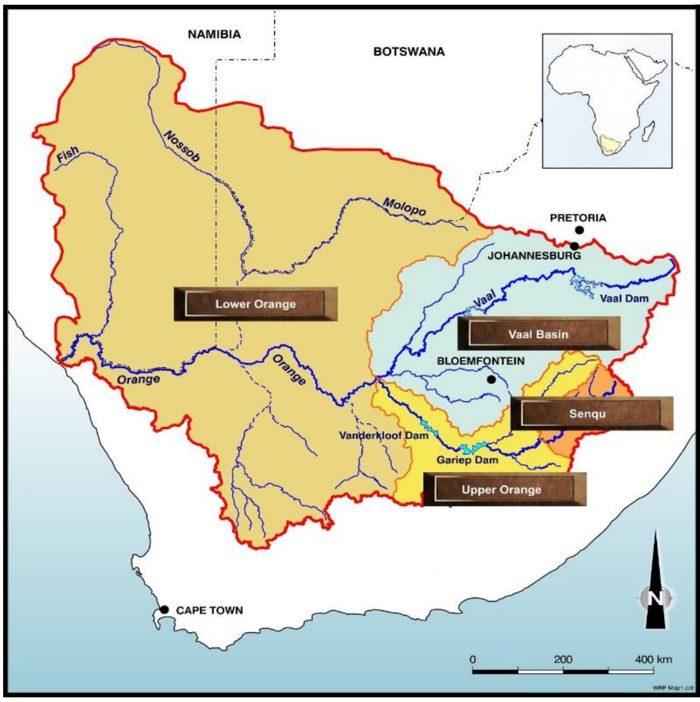

Figure 1-1: Orange – Senqu River Basin

REGULATION AND INTER-BASIN TRANSFERS

The Orange-Senqu system is regulated by more than thirty-one major dams. Two of these dams are situated in Lesotho, five in Namibia and 24 in South Africa. The largest five reservoirs are those formed by the Gariep, Vanderkloof, Sterkfontein, Vaal and Katse Dams with capacities ranging from 1 950 Mm^3 to 5 675 Mm^3. The Orange-Senqu river basin is a highly complex and integrated water resource system with numerous large inter-basin transfers which allow water to be moved from one part of the basin to another as well as into and out of neighbouring basins. For example, the Sterkfontein Dam (2 617Mm^3) is supplied from the adjacent Tugela basin and the Katse-Mohale dams system (2 910Mm^3) located in Lesotho augment the Vaal Dam (2 122Mm^3) which supplies water to the industrial heartland of South Africa. The Gariep Dam (5 675 Mm^3) and Vanderkloof Dam (3 237 Mm^3) on the Orange River downstream of Lesotho are the largest reservoirs in the Orange-Senqu river system respectively. Both dams are used to regulate the river flow for irrigation purposes as well as to generate hydro-electricity during the peak demand periods with a combined installed capacity of 600 MW. Releases from Vanderkloof Dam into the Orange River are dictated by the downstream flow requirements.

The tributaries downstream of the Vaal confluence are the Molopo-Nossob sub-basin system. Surface flow from this system has not reached the main stem of the Orange River in living memory. Further downstream, the Fish River sub-basin, entirely located within Namibia accounts for the two (Hardap, Naute Dams) of the five dams regulating the flows from Namibia into the Orange River.

The most important and highly utilised tributary of the Orange-Senqu system is the Vaal River which supplies water to the industrial heartland of Southern Africa, the Vaal Triangle including Pretoria. The Vaal River System also provides water to 12 large thermal power stations which produce more than 90% of South Africa's electricity, as well as water to some of the world's largest gold, platinum and coal mines.

The Orange-Senqu river basin is clearly one of the most developed and certainly most utilised river basins in the SADC region, with at least 9 major intra - and inter - basin water transfer schemes.

The complexity of this transboundary system and the resultant need for a sophisticated management system in the Orange-Senqu river basin, is one of the key drivers of the proposed project to develop an Integrated Water Resources Management Plan for the basin.

1.1.3 Phase 3 of the Basin-wide IWRM Plan

The basin-wide Integrated Water Resources Management (IWRM) Plan will provide a framework for management, development and conservation of water resources in the Orange-Senqu River Basin, serving to advise Parties on optimising overall water resource utilisation.

Since the establishment of ORASECOM in 2000, a significant number of studies have been completed or are in process and have provided the building blocks for the Basin-wide IWRM Plan. Phase I of the ORASECOM IWRM planning programme was implemented between 2004 and 2007 and focused on collating existing information that described the water resources of the Basin. Phase II of the IWRM Planning Programme (2009 to 2011) focused on bridging the planning gaps identified in Phase I. A Transboundary diagnostic analysis (TDA) has been carried out under the ongoing UNDP-GEF project and National and Strategic Action Plans are in the process of being finalised.

Strategically, ORASECOM has approached the point where, with some exceptions, sufficient preparatory work has been done to move towards drafting a Basin-Wide IWRM Plan. Representatives of the four member countries have tentatively defined an "overall objective" for preparing a Basin-wide IWRM Plan:

"To provide a framework for sustainable development and management of the water resources, taking into account the need for improved distribution and equitable allocation of benefits, in order to contribute towards socio-economic upliftment of communities within the basin, and ensure future water security for the basin States."

The plan will set out the actions necessary to achieve the strategic objectives of ORASECOM as well as those of the basin States. Some of these will be short term and others longer term. In the context of IWRM planning, once approved, "the Plan" will signify a transition from planning to implementation of the actions that are determined in the Plan. Moreover it will signify the transition of ORASECOM from a reactive to a pro-active mode, technically competent advisor to the Parties as envisaged in the ORASECOM Agreement.

The IWRM Plan will include an implementation plan that identifies activities that will be implemented collectively by all the Parties through ORASECOM and the existing bilateral institutions and those that will be implemented separately by the Parties. The IWRM Plan will be forward looking (10 years in scope) and provide a framework that enables the basin to realise economic and social benefits associated with better water resources management. In addition, the IWRM Plan should strive to link the water sector with national economic growth and poverty alleviation strategies based on the fact that IWRM is not an end in itself but rather a means to achieve economic and social development.

In summary, the objective of this consultancy is to develop a comprehensive 10 year IWRM Plan for the whole of the Orange-Senqu Vaal River Basin. The IWRM Plan will include an implementation plan that identifies activities that will be implemented collectively by all the Parties through ORASECOM and the existing bilateral institutions and those that will be implemented separately by the Parties.

1.2 This Report

1.2.1 Rationale

This study consists of five Work Packages to address all the requirements and actions for the preparation, tabling and approval of the IWRMP. This report focus on Work Package 4c-ii, which is one of the sub-work packages of Work Package 4. Work package 4 comprises the following sub-work packages, effectively the technical studies component of the Phase 3 work:

- **Work Package 4a: Conduct an economic analysis of water use based on water accounting.**
- **Work Package 4b: Consolidate water demands and infrastructure development plans.** The task comprises consolidation into a database, updating and filling of gaps for some parts of the basin.
- **Work Package 4c-i: Update the basin planning model and conduct a model based situation analysis**. 4c-Part i comprises the modelling work that has to be done before any new scenarios can be investigated
- **Work Package 4c-ii: Application of the basin planning model for testing and evaluation of scenarios**
- **Work Package 4d: Update ORASECOM Water Information System**: All information collected as well as results generated will be consolidated in the WIS.
- **Work Package 4e: Consolidate available knowledge on environmental flow requirements and water quality assessments**. The consolidation work will form part of the SAP work but the results will be required for consolidation in the water resources models.
- **Work Package 4f: Consolidate knowledge on economic approaches to water management**

These Sub-Work Packages are critical to finalising the inputs required for the drafting of the IWRM Plan.

The Senqu, Orange Vaal system is a highly complex and largely integrated system. It also includes several transfers into and out of the basin and therefore requires the inclusion of parts of other neighbouring river basins into the water resources modelling setup.

A proper detailed model representative of the water use and water resource activities within this integrated system is an absolute necessity as it is not possible to effectively and efficiently plan and operate this large and complicated system without the aid of such a tool. Two models are used to simulate the entire integrated system, the Water Resources Yield Model (WRYM) and the Water Resources Planning Model (WRPM). As the names indicate, the WRYM is used to determine the yield of the system and sub-systems within the entire system. The WRPM uses these yield results as input and are used for planning and operating purposes. Two separate reports will be produced from Work Package 4c, the "System Yield Analysis" Report that focus on the WRYM related work and the "System Planning Analyses and Evaluation of Scenarios" Report which summarises the work related to the WRPM analyses.

1. INTRODUCTION

Since the completion of Phase 2 of the ORASECOM IWRM Study the WRYM and WRPM models setups that were deliverables from the Phase 2 study, were already used as the basis for further studies in South Africa and Lesotho. Updated information and more detailed layouts were introduced which will form part of the final updated WRYM and WRPM to be used in this study. In a large and complex system such as this, there are always new developments and updates taking place. The scenarios that will be investigated in order that recommendations can be taken forward to the draft IWRM Plan will be evaluated, using the most up-to-date model configurations.

1.2.2 Tasks undertaken under Work Package 4c

The following main tasks were undertaken as part of **Work Package 4c**:

- Obtain the latest model versions and update the central models accordingly.
- Integrate the demand-side information as obtained from Work Package 4b and from Work package 3 where applicable
- Verify and validate the stochastic flow sequences before using the models in stochastic analysis mode.
- Carry out yield analysis with the WRYM using the base scenario for several of the sub-systems within the Orange Senqu Vaal basin and carry forward results to draft IWRM Plan.
- Carry out scenario analysis using the WRPM and carry forward results to draft IWRM Plan.
- Refine chosen scenario(s) depending on feedback received during discussion of the draft IWRM Plan with stakeholders
- Install the final updated and tested models on work stations in each Basin State and provide training.
- Reports to be compiled as a result of the work carried out as indicated in the above mentioned tasks.

Only the tasks shown in bold were completed thus far. The first four tasks were documented in the "Yield Analysis, Stochastic Verification and Validation" report and the fifth and sixth tasks (bold and underlined) are documented in this report.

1.2.3 Objective of this report

The objective of this report is therefore to:

- Include a summary of all the configurations that have been consolidated in order to create the latest version of the WRPM for this study.
- Describe the process followed in developing and defining different developments options or scenarios to be analysed in support of the IWRMP.
- The current situation simulation will be carried out to determine the current and immediate future water supply conditions in the study area. This system setup will form the baseline scenario which reflects the current system with only the existing water resource and water supply related infrastructure in place. Results from this scenario will be presented and used as the basis for comparing water supply impacts and improvements as captured in the selection of other possible scenarios.
- This report will present results on the various trail scenario options carried out in support of the development of the draft IWRM Plan.
- From the trail scenario results obtained, a Core Scenario will be defined and described in this report. The Core Scenario represents the most likely developments expected to occur in the basin over the next 10 to 15 years and results from the Core Scenario WRPM analyses will be summarised and discussed in this report.
- The Core Scenario WRPM setup will be the master tool to evaluate any future developments and possible deviations from the expected IWRMP developments, as well as the related impacts of these deviations on the Orange-Senqu Basin over the next 10 years.

1.2.4 Structure of the report

This report comprises of six sections with **Section 1** serving as the introduction, providing background on the study and more specifically on the system analysis related tasks.

Section 2 addresses the current development state and operating of the different systems to be able to understand the context in which the scenario selection will be taking place. This is followed in **Section 3** by the description of the process used to define and select scenarios that need to be analysed in support of the IWRMP as well as to document the definition of each of these scenarios.

Section 4 will capture the results from the scenario analyses as well as the evaluation of these results, based on the evaluation criteria given in **Section 5**. The Core Scenario will be developed based on results from the scenario analyses and inputs from related recent more detailed studies, to represent the most likely development scenario for the next 10 to 15 years. Results from the Core Scenario will be captured in Section 4 as well as the related evaluations and conclusions.

Section 6 presents a summary of the conclusions and recommendations drawn from the system analysis work carried out, which will form an essential input to the development of the IWRMP.

2. Resource modelling and scenario selection context

2.1 Current situation

The Orange-Senqu river basin is a highly complex and integrated water resource system characterised by a high degree of regulation and a large number of major inter-basin transfers which allow water to be moved from one part of the basin to another, as well as into and out of neighbouring basins. This, together with the highly variable nature of the rainfall and hence hydrology, makes management of the water resources very challenging.

Only in the source areas, mainly in Lesotho, are the flows not subject to regulation. The Orange-Senqu system is regulated by 62 significant dams, five situated in Lesotho, seven in Namibia and fifty in South Africa. The location and size of reservoir storage in the Orange-Senqu Basin is given **Figure 2.1**. The large Vanderkloof Dam is the most downstream storage on the Orange-Senqu mainstream, situated around 1 380 km upstream of the river mouth and since the contributions of tributaries downstream of this dam are either small or highly seasonal, the flow regime for much of the year is largely driven by releases from this dam.

The largest intra-basin transfer is the transfer of water from the Lesotho highlands to the Vaal sub-basin. The largest inter-basin transfers include the Tukela-Vaal, Orange-Fish, Usutu-Vaal, the Inkomati transfers as well as the Vaal Eastern sub-system augmentation project, assisting with transfers to the Upper Olifants from the Vaal (see **Figure 2.2**).

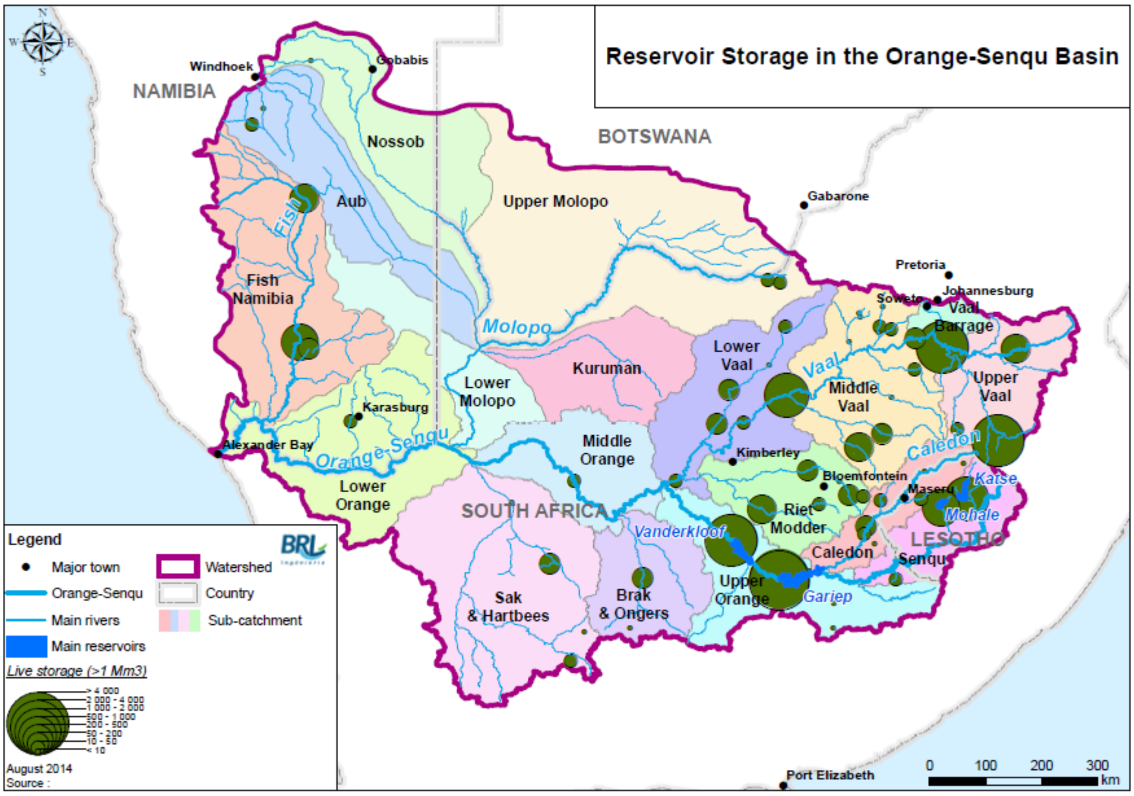

Figure 2-1: Location and size of reservoir storage in the Orange-Senqu Basin

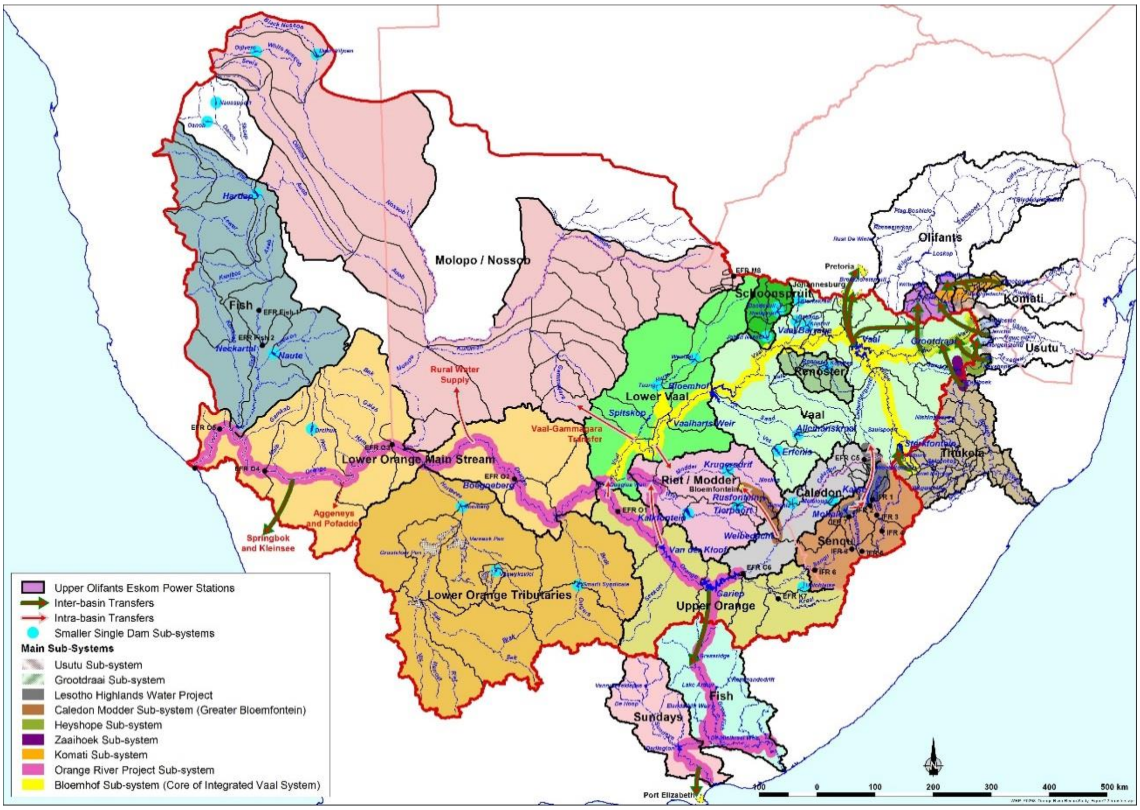

Figure 2-2: Location of transfers in the Orange-Senqu Basin

Storage and inter-basin transfers are necessary because of the mismatch between location of abundant water resources and the location of the largest demands centres. Assuring water to sustain agriculture and other economic activities and domestic needs, necessitates bulk storage and transmission of water to places and at times when it would otherwise not be available. Such development of the river system is also the underlying cause of many of the ensuing trans-boundary issues. This is in particular relevant to the Vaal River System that is the main water resource used to supply the Gauteng area, the economic hub of the RSA, as well as a large number of coal fired power stations in the Vaal and Upper Olifants catchment, used to supply the bulk of the energy requirements within the RSA. As result of all these transfer systems connected to the Vaal system, the Vaal System is referred to as the Integrated Vaal River System (IVRS), which then includes all the Vaal System related transfers.

Most of the large water supply schemes will soon be in deficit and several interventions options will be required to be able to maintain a positive water balance over time at the required assurance of supply to users within each of these schemes.

The Vaal River Reconciliation Strategy study completed in 2009 (DWA, 2009) showed the significant impact of the Acid Mine Drainage (AMD) on the water resources in the Vaal System. If this problem is not addressed, deficits in water supply can be expected in the IVRS as soon as 2015. Several intervention options were recommended from the Vaal River Reconciliation Strategy study to ensure that sufficient water will be available to supply the future water requirements within the IVRS. These intervention options include the desalination of the AMD drainage water, WC/WDM, re-use of return flows, removal of unlawful water use, as well as the development of major additional infrastructure which entails Phase II of the LHWP.

2. RESOURCE MODELLING AND SCENARIO SELECTION CONTEXT

The Greater Bloemfontein Water supply system is already moving into a deficit and some intervention options are currently in the process to be implemented. The Greater Bloemfontein Reconciliation Strategy Study was completed in 2012 and is currently in the implementation phase.

The Orange River Project is expected to start experiencing shortage by around 2017. This will increase significantly when Phase II of the LHWP is activated by 2022. Although the LHWP Phase II development will address the deficits in the IVRS, it will result in a decrease in the yield available from the ORP. The Reconciliation Strategy for Large Bulk Water Supply Systems: Orange River is almost completed. The draft final Reconciliation Strategy is already available and includes quite a number of recommended intervention options such as WC/WDM, real time monitoring and modelling, Vioolsdrift Dam, raising of Gariep Dam, Verbeeldingskraal Dam, utilise the lower level storage in Vanderkloof Dam, etc.

One of the most significant impacts of the highly altered hydrological regime has been on the environment. As reported in the TDA, these changes in the hydrological regime impacted on downstream ecosystems, including the estuary which is a declared Ramsar site. The final agreed EWR requirements to be supplied within the Vaal River System were established through the recently completed Classification Study carried out by the RSA DWA. These EWR requirements are referred to as the Reserve and need to be implemented in the Vaal System according to RSA law. Releases to meet the EWR at the Orange River mouth is currently released from Vanderkloof Dam. Due to the long distance of 1380km from Vanderkloof to the estuary, the correct timing and required flow rate at the river mouth is almost impossible to achieve by means of these releases. The current river mouth EWR releases were determined as part of the ORRS (Orange River Re-planning Study (DWAF, 1996)) completed in 1999, and are based on outdated methods.

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, 2011a). These EWRs were assessed at an Intermediate Level at selected key areas of the Orange River Basin. Further environmental flow investigations were recently completed through 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" (ORASECOM, 2012). The focus of this study was on the Orange River Mouth environmental requirement, the Fish River in Namibia as well as the Orange River downstream of the confluence of the Fish with the Orange River. The impact of these updated EWRs on the yield available from the ORP is quite significant and will result in deficits in the Orange System.

Operating rules can significantly impact on the system yield as well as the assurance of supply to different users. It is therefore important to provide a brief description of the operating rules as currently applied in the main sub-systems within the Orange Senqu basin.

Operating rules in general makes use of two types of trigger mechanisms. The first trigger mechanism used is specific i.e. fixed levels in the dams, which were selected and are used to control the event when supply to a specific user should cease or commence, and to be able to reserve water for users that can only be supplied from a specific resource. When there is a growing demand imposed on a dam, these fixed levels need to be adjusted often, as a different level will be required when the total demand imposed on the dam increased or decreased over time.

The second trigger mechanism is the use of the short-term yield capability of the sub-system, which is then compared against the demand imposed on the sub-system. When the balance is negative (demand is higher than the short-term yield), water from another possible resource need to be used to supply the difference or curtailments need to be imposed to reduce the demand load on the sub-system.

This option or trigger mechanism is used in most of the main sub-systems and are in most cases combined with trigger mechanism 1 (fixed dam levels). The benefit of the second trigger mechanism is that the short-term yield as well as the demand imposed on the system can be compared at the desired assurance level of supply, making it possible to supply the demands imposed on the sub-system at the required assurance.

2.1.1 Integrated Vaal System Operating rules

The following four important principles form part of the operating rules currently used for the IVRS:

- General operating principle – Operate the system as an integrated system in order to obtain the maximum yield benefit from the system.
- Maintain the assurance of supply to users – This is the primary objective of the operating rules used in the IVRS. The second trigger mechanism using the short-term yield characteristics is applied for this purpose.
- Cost saving operating rules – The secondary objective of the operating rules is to implement rules that will, where possible, reduce the cost of water supply.
- Restriction of demands – The operation of the system is based on the principle that demands are restricted during severe drought events. The short-term yield characteristics are used for this purpose.
- The objective of these restrictions is to reduce supply to less essential use to be able to protect the assurance of supply to more essential use.
- The basis on which restrictions are implemented is defined by means of the user priority classification definition as explained in **Section 4.1.1**.

The Bloemhof sub-system forms the core of the Integrated Vaal River System and includes Grootdraai Dam, Vaal Dam, Vaal Barrage, Bloemhof Dam and Sterkfontein Dam as the main storage dams. Woodstock Dam and Driel Barrage in the Upper Thukela River are the resources in the Thukela used to transfer water to the Vaal and forms part of the Bloemhof sub-system, although it is located outside the Vaal basin. The operating rules currently used to manage this sub-system were built into the WRPM data sets and entail the following:

- Grootdraai Dam does not support Vaal Dam. Only spills from Grootdraai Dam can therefore be utilised by Vaal Dam. Grootdraai Dam is used mainly to supply water to Sasol (Sasol Secunda Operations) and Eskom power stations of which most are located in the Upper Olifants.
- **Transfers from the Thukela to the Vaal** continue until Sterkfontein Dam is full (i.e. the short-term operating rule is applied whereby only evaporation losses from Sterkfontein Dam are replenished).

- The Thukela-Vaal Transfer scheme is currently constrained to 631 million m^3/a by the scheme capacity. Two alternative operating rules are applied for this transfer scheme depending on the state of the water resources. According to the long-term operating rule water is transferred at a rate of up to 20 m^3/s, as long as water is available from Kilburn Dam and Sterkfontein, Vaal and Bloemhof dams are not full. However, only 19 m^3/s can be delivered on a continuous basis due to limitations in the canal transferring water from Driel Barrage to Kilburn Dam. The short-term operating rule, which was adopted for the current system operation, states that transfers from the Thukela should only be made to replenish the evaporation losses from Sterkfontein Dam. The purpose of this alternative operating rule is to save on pumping costs and reduce the cost of water supply to the Vaal. The short-term operating rule is tested each year and is only applied when the major dams in the Vaal basin are at high storage levels and the long-term assurance of water supply to users is not jeopardized.
- Sterkfontein Dam starts to support Vaal Dam only when Vaal Dam is at a 18% or lower storage.
- The so-called dilution rule is applied at Vaal Dam. This rule implies that the Rand Water abstractions are made from Vaal Dam and water is released from Vaal Dam to maintain a Total Dissolved Solids (TDS) concentration of 600 mg/l downstream of Vaal Barrage.
- The Vaal River Eastern Sub-system Augmentation Project (VRESAP) pipeline transfers water from Vaal Dam to Knoppiesfontein and was constructed to augment the water supply to Sasol (Sasol Secunda Operations) and some of the Eskom Power Stations situated in the Upper Olifants catchment. The VRESAP pipeline has a maximum transfer capacity of 160 million m^3/a (5.07 m^3/s). The long-term VRESAP operating rule states that transfers should be made at maximum capacity when storage in Grootdraai Dam is below 90% (see additional comments on VRESAP below).
- Vaal Dam also releases water to support the abstractions at Sedibeng and Midvaal if local runoff, releases for dilution and spills are insufficient.
- Vaal Dam only starts to support Bloemhof Dam when Bloemhof reaches its minimum operation level of 6%

Several other smaller sub-systems located on the tributaries of the Vaal River are included in the data sets. These sub-systems do not support the Bloemhof sub-system and only spills from these sub-systems enter the Bloemhof sub-system and can contribute to the Bloemhof sub-system yield. These sub-systems include:

- Schoonspruit sub-system with Rietspruit, Elandskuil and Johan Neser dams.
- Renoster sub-system with Koppies Dam.
- Sand-Vet sub-system including Allemanskraal and Erfenis dams.
- Mooi River sub-system that includes the Mooi River Government Scheme comprising of Klerkskraal, Boskop and Lakeside dams as well as the Klipdrift Irrigation scheme using Klipdrift Dam in the Loopspruit River, a tributary of the Mooi River.

Operating rules and related penalties for these sub-systems are selected to allow them to be operated as individual systems without supporting the main Vaal system. In the WRPM setup these sub-systems will only supply the demand imposed on them. During dry periods with low system storage, curtailments are imposed on the related demands, based on the short-term yield characteristics of the particular sub-system, to protect the sub-system from total failure.

Other transfer schemes (Thukela-Vaal transfer already described above) used in support of the Vaal System are:

- **Phase 1 of the LHWP** (consisting of Katse and Mohale Dams as well as Matsoku Weir and associated conveyance tunnels) currently 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. This scheduled transfer volume is transferred on a continuous base, irrespective of the water levels in the Vaal System's major storage dams.
- **Zaaihoek Transfer Scheme** from Zaaihoek Dam in the Slang River (tributary of the Buffels River which eventually flows into the lower Thukela River). Zaaihoek Dam is Majuba Power Station's only water resource. The Zaaihoek transfer is in support of the water supply to Majuba Power Station in the Upper Vaal as well as in support of Grootdraai Dam and has a maximum transfer capacity of 63 million m^3/a. The maximum transfer volume to Grootdraai Dam is determined by the difference between the long-term yield of Zaaihoek Dam and the current in-basin water requirements, including the Majuba Power Station's requirements. Water is transferred to Grootdraai Dam only until Grootdraai Dam has reached 90% of its live storage.
- **Transfer from Heyshope** in the Upper Usutu catchment (Assegaai River) in support of Grootdraai Dam. Water is transferred up to a maximum of 4.28 m^3/s as long as Grootdraai Dam is below 90% of its live storage.
- **The Vaal – Olifants Transfer Scheme**: Transferring water from Upper Vaal WMA (Grootdraai Dam) to the Upper Olifants WMA at a maximum rate of 6.5 m^3/s. The transfers are required to supply water to the Sasol Secunda Operations as well as to Eskom's power stations located in the Upper Olifants. Komati, Arnot and Hendrina power stations can be supplied from the Komati and Usutu sub-systems. These power stations are first supplied from the Komati and then from the Usutu Sub-system. Camden can only be supplied from the Usutu Sub-system.
- **The Usutu-Olifants Transfer Scheme**: Although this scheme does not transfer water directly into or out of the Vaal Catchment, it augments a supply area of the Vaal Catchment in the Upper Olifants WMA for power generation purposes. Water can be transferred at a rate of up to 2.8 m^3/s. Part of the transfer can be used to support the Komati Sub-system, with the remainder to be used to directly supply the Usutu-Vaal Power Stations. Water is transferred from Jericho Dam which is supported from Morgenstond and Westoe dams. Inter-reservoir operating rules determine the support from these two dams to Jericho Dam. Morgenstond Dam can, when required, also be supported by transfers from Heyshope Dam, as soon as Morgenstond Dam is below 80 million m^3 storage.
- **The Komati-Olifants Transfer Scheme:** Although this scheme does not transfer water directly into or out of the Vaal Catchment, it augments a supply area of the Vaal Catchment in the Upper Olifants catchment for power generation purposes. Water can be transferred at a rate of up to 3.59 m^3/s. The maximum possible volume for the transfer is supplied from Vygeboom Dam with the remainder being supplied from Nooitgedacht Dam.

When required, Nooitgedacht Dam is also augmented by transfers from the Usutu Sub-system. Allowance for compensation releases from Vygeboom Dam (0.65 m^3/s) receive priority over any other requirements from the sub-system.

- **Vaal River Eastern Sub-system Augmentation Project (VRESAP)**: VRESAP is aimed at stabilising and extending industrial water supply to the Sasol Secunda Operation and the Eskom power stations on the Mpumalanga Highveld. The scheme is designed to be able to transfer water at a rate of up to 5.07 m^3/s, even when the water level of the Vaal Dam is at its minimum operating level. Priority in supply will be from the VRESAP pipeline when Grootdraai Dam is below 90% of its live storage, and the remainder will then be supplied from Grootdraai Dam. When Grootdraai is above the 90% storage level, the priority of supply will be from Grootdraai Dam and the remainder supplied via the VRESAP pipeline. The volumes to be transferred from each of the resources will be determined by the short-term stochastic yield characteristics.

The Integrated Vaal River System is not used to support the Orange River System, but is rather operated to minimise spills into the Orange River, as large volumes of water are transferred into the Vaal River System from neighbouring catchments at high cost, to augment the growing demand in the Vaal System. Consequently, water from Sterkfontein Dam will only be released to support the Vaal Dam when the Vaal Dam is at a fairly low level (18% of the full supply storage). Releases from the Vaal Dam, to support Bloemhof Dam, are only made when the Bloemhof Dam is at a low level (6% storage). This operating rule will therefore result in lower storage levels in the Bloemhof and Vaal dams, and will as a result, reduce evaporation and spillage from the two dams, as well as increase the possibility of the dams to capture local runoff.

A large portion of the runoff into the Vaal Barrage is due to effluent return flows, mine dewatering and urban storm-water runoff from the Southern Gauteng area. There are two possible options for the abstraction of water by Rand Water, from the Vaal System. The total Rand Water requirement can be supplied directly from Vaal Dam as the first option or secondly as a combination from the Vaal Barrage and Vaal Dam. For option one, where only Vaal Dam water is utilised by Rand Water, the dilution rule is applied. This means that water has to be released from Vaal Dam to maintain the TDS concentration downstream of Vaal Barrage at 600mg/l. This is currently the preferred option. For option two, Rand Water abstracts the maximum possible volume of water from the Vaal Barrage. This water needs to be blended with water directly from Vaal Dam to keep the TDS concentration at or below 300 mg/l. This is referred to as the blending option and no dilution downstream of Vaal Barrage is required for this option.

Currently short-term measures were already implemented to address the acid mine drainage AMD problem in the Upper Vaal, by first focussing on the neutralisation of mine water discharges. These short-term measures are thus already forming part of the set of operating rules for the IVRS. For the long-term the desalination of mine water discharges were recommended to enable the re-use of this water and to significantly reduce the releases from Vaal Dam for dilution purposes.

2.1.2 Orange Senqu system

There are three major water supply systems within the Orange Senqu:

- LHWP phase I (Phase II currently in planning phase).
- Orange River Project (Gariep and Vanderkloof dams and related supply area).
- Greater Bloemfontein water supply system.

Phase I of the LHWP (consisting of Katse, and Mohale Dams, Matsoku Weir and associated conveyance tunnels) is currently used only in support of the IVRS (See **Section 2.1.1** LHWP a transfer scheme in support of IVRS). Only releases for environmental purposes from Katse and Mohale dams will still flow to the Orange River. 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 approximately 2022. This will result in a reduction in the yield of the Orange River Project (Gariep and Vanderkloof dams) to such an extent that a negative water balance in the Orange River Project (ORP) is expected. This will require a yield replacement dam in the Orange River, to regain the positive water balance.

The ORP is used to supply all the water requirements along the Orange River from Gariep Dam to the Orange River Mouth. These demands include all the irrigation, urban, mining, environmental requirements, river requirements, etc. Except for the releases through the Orange-Fish tunnel and those into the Vanderkloof Canals, all the releases from Gariep and Vanderkloof dams, used to support downstream users, are made through the hydropower turbines directly into the Orange River. These river releases are therefore used to simultaneously generate hydropower.

Large volumes of water are also transferred from the ORP to other neighbouring catchments. These transfers include the following:

- The transfer from Gariep Dam to the Eastern Cape through the Orange-Fish tunnel to support large irrigation developments and some urban requirements in the Eastern Cape. An annual allocation of 648 million m^3/a (2014) is used for this purpose. This water can be transferred up to a maximum rate (tunnel capacity) of up to 54 m^3/s.
- The transfer through the Orange-Riet canal from Vanderkloof Dam to the Riet-Modder catchment is mainly for irrigation purposes. The maximum capacity of this transfer system is 15.6 m^3/s. The transfer is limited based on the total volume allocated to the users plus provision for canal losses and a maximum of 5 million m^3/a to improve the water quality on the lower Riet River.
- Orange-Vaal Transfer through the canal system from Marksdrift Weir in the Orange River to Douglas Weir in the Vaal River, with a maximum capacity of 6 m^3/s, and is mainly used for irrigation purposes. The total volume transferred is limited to the full allocation plus canal losses. The total transfer volume is very depended on the flows available from the Vaal system, as Douglas Weir is located at the downstream end of the Vaal River. The Douglas scheme is however not supported from storage dams in the Vaal River and only receives local incremental runoff and spills from the Vaal as well as return flows entering the lower Vaal.
- Transfer from the Lower Orange along the common border area to Springbok and Kleinzee for urban and mining use.

Any spills from the Vaal or Fish Rivers (Namibia) or any local runoff generated in the Lower Orange are not taken into account when releases are made from Vanderkloof Dam to supply the downstream users. This is due to the fact that it is extremely difficult to compensate for Vaal, Fish or any other inflows into the Lower Orange by means of reduced releases from Vanderkloof Dam, as releases take approximately one month to reach the river mouth located approximately 1380km downstream of Vanderkloof Dam.

The following four important principles form part of the operating rules currently used for the ORP:

- General operating principle – Operate the system as an integrated system in order to obtain the maximum yield benefit from the system.
- Maintain the assurance of supply to users – This is the primary objective of the operating rules used in the ORP. The second trigger mechanism using the short-term yield characteristics is utilised for this purpose.
- Reduce spills from Gariep and Vanderkloof dams by making use of storage control curves allowing water to be released in advance from the dams through the hydro-power turbines, to rather generate more hydro-power than allowing increased dam inflows to just spill over the crest of the dam wall.
- Utilise the short-term surplus yield available in Gariep and Vanderkloof dams to generate additional hydro-power over and above that generated by means of the normal downstream releases. This is possible at times when the dams are relatively full.
- Restriction of demands – The operation of the system is based on the principle that demands are restricted during severe drought events. The short-term yield characteristics are used for this purpose.
- The objective of these restrictions is to reduce supply to less essential use to be able to protect the assurance of supply to more essential use
- The basis on which restrictions are implemented is defined by means of the user priority classification definition as explained in **Section 4.1.1**.

The Greater Bloemfontein system is also located in the larger Orange Senqu system, and is using Welbedacht and Knellpoort Dams in the Caledon River as resources from where water is transferred to the Modder River catchment. This sub-system is used to supply part of the water requirements of Bloemfontein, Botshabelo, Thaba N'chu and other small users. Water treated at Welbedacht Dam is transferred directly to Bloemfontein and small users, while raw water from Knellpoort Dam is transferred via the Novo Transfer scheme to Rustfontein Dam in the upper reaches of the Modder River. Rustfontein Dam is then used to supply Botshabelo and Thaba Nchu via the water treatment works at Rustfontein Dam. Raw water is released from Rustfontein Dam to support Mockes Dam, from where water is again released to Maselspoort Weir, where it is abstracted and supplied to Bloemfontein via the water treatment works at Maselspoort.

The operating rule for this sub-system dictates that water is to be taken from Welbedacht Dam first, then from Knellpoort Dam, then from the upper 70% in Mockes Dam, then from Rustfontein Dam until Rustfontein Dam reaches 90% of its live storage. Transfers via the Novo Transfer Scheme from Knellpoort to Rustfontein Dam should then be activated, but with full abstractions from Rustfontein Dam still taking place. When Rustfontein is below 20% the Novo Transfer system should be running at maximum capacity all the time. When Knellpoort Dam is below the m.o.l. for Novo transfer pumps to abstract, the Novo transfer will stop and the water remaining in Knellpoort can then only be used in support of Welbedacht Dam by means of releases from Knellpoort Dam into the river. The remaining 5% in Rustfontein Dam will then be used only in support of Botshabelo and Thaba N'chu (Rustfontein m.o.l. is at 15%), followed by the remaining 25% in Mockes Dam to be used for Bloemfontein and as the last resort the remaining water in Knellpoort Dam in support of Welbedacht Dam and related transfer.

At all times pump water from Tienfontein pump station into Knellpoort Dam when there is sufficient water available in the Caledon, until Knellpoort dam reaches 90%.

The following four important principles form part of the operating rules currently used for the Greater Bloemfontein System.

- General operating principle – Operate the system as an integrated system in order to obtain the maximum yield benefit from the system.
- Maintain the assurance of supply to users – This is the primary objective of the operating rules used in the Greater Bloemfontein System. The second trigger mechanism using the short-term yield characteristics is used for this purpose.
- Determine the total annual target volume to be transferred from Knellpoort to Rustfontein Dam based on the short-term stochastic yield characteristics in combination with the trigger levels in Knellpoort and Rustfontein dams.
- Restriction of demands – The operation of the system is based on the principle that demands are restricted during severe drought events. The short-term yield characteristics are used for this purpose.
- The objective of these restrictions is to reduce supply to less essential use to be able to protect the assurance of supply to more essential use
- The basis on which restrictions are implemented is defined by means of the user priority classification definition as explained in **Section 4.1.1**.

Several other smaller sub-systems located on the tributaries of the Orange and Caledon rivers as well as in the Riet Modder catchment, are included in the WRPM data sets. These sub-systems do not support the ORP or Greater Bloemfontein sub-system and only spills from some of these sub-systems can contribute to the ORP yield. These sub-systems include:

- Krugersdrift Dam and related irrigation scheme in Modder River.
- Tierpoort Dam in and irrigation Scheme Upper Riet River.
- Kalkfontein Dam and related irrigation scheme in the Riet River.
- Smart Syndicate Dam and related irrigation scheme in the Ongers River
- Zastron Scheme Montagu and Kloof dam in a small tributary in the Upper Orange
- Sterkspruit Scheme Holohlatsi Dam (Jozanas Hoek Dam) in the Sterkspruit a small tributary in the Upper Orange
- Lady Brand scheme Cathcartdrift Dam in a tributary of the Caledon River.
- Rouxville scheme Kalkoenkrans Dam in a tributary of the Caledon River.
- Smithfield scheme Smithfield Dam in a tributary of the Caledon River.
- Ficksburg/Clocolan scheme Meulspruit Dam, Moperi Dam in tributaries of the Caledon River.
- Armenia scheme Armenia dam Hobhouse and Thaba Phatshwa in tributaries of the Caledon River.
- Rooiberg Dam in the Hartbees River a tributary of the Orange River in the Lower Orange.
- Van Wyksvlei Dam in the upper Hartbees River.
- Victoria West Dam in the Dorp River a tributary of the Ongers River
- Modderpoort Dam in Rietfontein River a tributary in the Upper Sak River catchment.
- Dreihuk in the Hom River in Namibia (Karasburg water supply) a small tributary of the Orange River in the Lower Orange.

Operating rules and related penalties for these sub-systems are selected to allow them to be operated as individual systems without supporting the ORP or Greater Bloemfontein system. In the WRPM setup these sub-systems will only supply the demand imposed on them. During dry periods with low system storage, curtailments are imposed on the related demands for the larger sub-systems, based on the short-term yield characteristics of the particular sub-system, to protect the sub-system from total failure.

Metolong Dam in Lesotho was recently completed. No specific operating rules were yet developed for this dam except for guidelines regarding the releases for environmental purposes. The EWR requirements were included in the WRPM data sets and a simple operating rule allowing abstractions to take place until the dam fails were used. As the demand and related growth imposed on this dam is still below the yield available from the dam, it should provide reasonable results for the meantime.

2.1.3 Fish River Namibia

Hardap and Naute dams are the only two existing large dams in the Fish River catchment an are mainly used to supply irrigation schemes with water. Both dams also include a small urban component, with Hardap supporting Mariental Town and Naute Dam used in support of Keetmanshoop.

Operating rules and related penalties for these sub-systems were selected to allow them to be operated as individual systems without supporting any of the other existing or future systems. Levels in these dams were used for the protection of the urban supply component and for flood controlling purposes at Hardap Dam.

Neckartal Dam currently under construction was included in the WRPM and activated in May 2016. No operating rules were yet developed for Neckartal Dam and the same approach as for Metolong Dam was followed.

2.1.4 Molopo River catchment

Several smaller sub-systems are located in the Molopo catchment within the RSA and Namibia. The water supply schemes in Namibia are mainly located in the Nossob River a tributary of the Molopo.

Namibia small sub-systems

- Otjivero main and silt trap dam supporting Gobabis and Omitara.
- Daan Viljoen and Tilda Viljoen dams supporting Gobabis
- Nauaspoort in Usib
- Oanob supplying Rehoboth

RSA small sub-systems

- Setumo Dam and Molopo Eye used to support Mafikeng

2.2 KEY WATER RESOURCE RELATED ISSUES

The large water supply systems such as the IVRS, the ORP and the Greater Bloemfontein will soon be in deficit and several interventions options are required to be able to maintain a positive water balance over the planning period. Maintaining the assurance of supply to users in these large systems is crucial to sustain the economy of the region and the well-being of its people. The development of the LHWP Phase II is one of the critical major infrastructure developments to ensure a sustainable water supply to the IVRS. The development of Phase II of the LHWP is expected to be in place by 2022. Although this development will address the deficits in the IVRS, it will result in a decrease in the yield available from the ORP. Several measures were already put in place in the IVRS to prevent deficits in the IVRS such as WC/WDM, re-use of return flows, neutralising of AMD water and the removal of unlawful water use.

Water quality related problems specifically in the Vaal system from Vaal Barrage and downstream is reaching the point where dilution by means of releases from Vaal Dam will not be sufficient to address the problem. The acid mine drainage (AMD) problem in this area is significantly impacting on the water resources in the Vaal System resulting also in related impacts on the Orange River from the Orange Vaal confluence downstream. Extraordinary measures are required to address this problem, of which the neutralisation of the AMD water has already been initiated and need to be followed by the desalination of the AMD water.

One of the most significant impacts as result of the highly developed basin and altered hydrological flow regime is the impact on the environment. The deterioration of ecosystem at the estuary (declared Ramsar Site) is of specific concern. Increased releases from the existing storage dams that will address part problem are expected to significantly impact on the system yield, resulting in deficits in the supply to current users. With the current infrastructure in place it is almost impossible to supply the correct water volumes at the estuary to adhere to the river mouth environmental requirements. A control structure closer to the river mouth is required to be able to achieve this in a satisfactory manner.

Botswana requires support through the Vaal Gamagara water supply scheme and is investigating the possibility of transferring water from Lesotho. These will increase the current demand load on the system and might impact on existing users.

Metolong Dam in Lesotho was recently completed, and already started to inundate water. This dam will now start to impact on downstream water resource systems such as the Greater Bloemfontein water supply system and ORP system.

Construction work on Neckartal Dam in the Fish River in Namibia already started. This dam will significantly impact on the flow regime in the Fish River downstream of the dam and to a lesser extent on the flows at the Orange River Mouth. Releases for environmental purposes from this dam will be essential to protect the ecology along the lower Fish to the Orange Fish confluence.

2.3 NATIONAL AND TRANSBOUNDARY PRIORITIES AND STRATEGIES

The Integrated Vaal River System (IVRS) provides water to one of the most populated and important areas in the RSA and most probably also in the entire Orange Senqu basin. This is clearly evident from magnitude of the developments located in the Upper and Middle Vaal, the Olifants and the upper portion of the Crocodile West catchments. Although some of these areas are located outside the Orange Senqu basin, they are interlinked with the Vaal system resources and receive support from the Vaal system. These developments include many of the RSA's power stations, gold mines, platinum mines, petro-chemical plants sprawling urban development as well as various other strategic industries. Numerous inter-basin transfers already link the Vaal System with other catchments such as the Komati, Usutu, Thukela and Senqu River to ensure a sustainable water supply to users within the IVRS. The water requirements in this area are therefore very important to sustain the economy of the RSA and the well-being of its people.

From a National perspective the IVRS is the most important water supply system in the RSA and it is of utmost importance for the RSA Government to maintain the assurance of water supply in this system, now and in the future. The Vaal River Reconciliation Strategy study by the DWA RSA identified several measures or intervention options to be able to supply in the growing demand imposed on the IVRS (see **Section 3.1**). Phase II of the Lesotho Highlands is the largest of these intervention options.

The Minister of the Department of Water Affairs RSA with agreement by the Cabinet in December 2008 decided to proceed with negotiations with the Government of Lesotho for the implementation of the Phase 2 Water Project of the Lesotho Highlands. These negotiations will take into consideration the RSA augmentation requirements and revised transfer schedule, the operating rules required to manage this system, the increased power generation to the benefit of Lesotho as well as the calculation of the payment tariffs including the Royalty payments of this scheme.

As mentioned in **Section 2.2**, the implementation of the LHWP Phase II will result in deficits in water supply from the ORP. These deficits will not only impact on users in the RSA, but also on the Namibian water users along the joint border area on the Lower Orange.

The Vioolsdrift possible future dam located in the Lower Orange on the Namibia RSA border, will benefit both Namibia and the RSA as it will increase the Orange system yield, reduce the current operational losses in the ORP system and will enable improved control of releases to adhere to the estuary environmental requirements. Negotiations between the Namibia and RSA Governments already started to take place regarding the development of this intervention option. A feasibility study is expected to be initiated as a combined Namibia RSA project. Findings from this study will provide further input and guidance towards the preparation of the agreement between the two Governments and the implementation of this scheme.

Botswana requires support from the RSA through the Vaal Gamagara water supply scheme and is also investigating the possibility of transferring water from Lesotho. The requested support through the Vaal Gamagara scheme is relative small (5 million m^3/a) and will result in a small impact on the IVRS. Negotiations between Botswana and the RSA are in initial stages and still need to be finalised. The transferring of water from Lesotho to Botswana is at this stage only a possibility and preliminary investigations still need to be carried out. Depending on the transfer volume and location of the point of abstraction, this proposed transfer can impact significantly on the water supply in all four basin states, thus requiring agreement amongst all.

The impact on the ecology as result of the highly developed basin is significant and need to be addressed. EWR releases are already imposed on the LHWP dams and the EWR releases to be released from Metolong Dam were determined. A classification study was completed for the Vaal River system to obtain agreement on the EWRs and related EWR classes to be implemented as the Reserve for the Vaal System. These final agreed EWR releases or Reserve are based on a balance between the environmental needs and the impact on the economy in the region.

The recommended EWRs to be implemented in the Orange System as determined from the ORASECOM studies will significantly impact on the ORP system yield, resulting in severe deficits in water supply to current users. It will therefore be important to obtain a balance between the ecological requirements and the economic sustainability in the system, similar to that done for the Vaal System. This process will require input from all the basin states and a high level involvement by ORASECOM.

3. Development and management Options

There is sometimes confusion around the use of the word "scenarios". In the remainder of this section this term is used to refer to different combinations of water resources development and management options that may be proposed to best cater for future needs. This is quite different from the concept introduced in the presentation on scenarios and uncertainty analysis. This concept is important and provides a context against which the development and management scenarios should be developed.

3.1 Process to define scenarios in support of the IWRMP

Several studies recently conducted by the DWAs of RSA, Namibia and Lesotho provided key information to be used as basis for the definition of the scenario analysis required in support of the IWRMP to be developed for the Orange-Senqu basin. These include the following studies:

- Vaal River System Large Bulk Water Supply Reconciliation Strategy Study (RSA).
- The implementation of the Reconciliation Strategy for the Vaal River System (RSA)
- Development of Reconciliation Strategies for Large Bulk Water Supply Systems: Orange River Study (RSA)
- Water Reconciliation Strategy Study for the large bulk water supply systems: Greater Bloemfontein Area (RSA)
- The implementation of the Reconciliation Strategy for the large bulk water supply systems: Greater Bloemfontein Area (RSA)
- Metolong Dam development related reports (Lesotho)
- Neckartal Dam development related reports (Namibia)

The aim of the Reconciliation Strategy studies commissioned by the RSA Department of Water Affairs is to develop water resource related strategies that will enable these three large water supply systems to maintain the assurance of supply to the users for the next 20 to 30 years. The Reconciliation Strategies for the Vaal River system and the Greater Bloemfontein system were already completed, and they are currently both in their second phase, which is the implementation of the strategies. The strategies were developed to be flexible so that future changes in the actual water requirements and transfers can be accommodated. This approach allows that the Strategies will evolve over time as part of an on-going planning process.

All the above listed studies contain the development and management options to be implemented by the individual countries to ensure sustainable water supply to the users within the Orange-Senqu basin.

As a first step in the process to develop and define realistic scenarios for modelling purposes in support of the Orange-Senqu IWRMP, the above mentioned study reports were scrutinised and all the proposed development and management actions forming part of the reconciliation strategies, were obtained in listed. For each of these options a brief description were included in a summary table (**See Tables 3.1 to 3.4**), along with a description of the purpose of these options and the possible impacts a particular option will have one the system. These proposed development and management options are the most likely ones to be implemented in future, as they are driven by the respective departments of water affairs from the different basin states.

Table 3.1: Integrated Vaal River System possible future development and management options

Name	Description	Purpose	Possible impacts
WC/WDM	Vaal Recon Strategy: The potential savings that can be achieved through the reduction of water wastage. The focus of the WC/WDM is on the nine largest urban water users. Implement Water Conservation and Water Demand Management measures to reduce losses and reduce the urban demand by at least 15% by 2014. (might by later than 2014)	Essential to maintain a positive water balance in the Vaal River System over the next ten years. Currently various actions already implemented by City of Johannesburg, City of Tshwane, Ekurhuleni and Emfuleni.	Decrease Vaal Demand by approximately 180 million m^3/a, and reduce preliminary shortages in the Vaal before Phase2 of LHWP.
Unlawfull water use eradication	Vaal Recon Strategy: Apply all the necessary resources to eradicate the unlawful water use as a national priority by 2014.	This is an essential strategy that has to be implemented in order to rectify the current deficit (negative water balance) in the Vaal River System.	Increase water availability in Vaal and reduce the current system demand by ± 145 million m^3/a. Currently 65 million m^3/a already reduced. The expected. target is to reduce by it by another 80 million m^3/a in 2014.
Re-use of mine water effluent (Acid Mine Drainage) Some additional infrastructure will be required.	Vaal Recon Strategy: Treating of acid mine drainage before releasing into rivers and/or for re-use purposes. Currently only short-term measures are implemented focussing on the neutralisation of mine water discharges. In the Western basin all the AMD water flowing into Tweelopiespruit is neutralised. Central basin contract was already awarded for implementation of required works and for Eastern basin a bid was advertised which closed in Aug 2013. Still to be awarded. Pre-feasibility study addressing long-term measures was completed and Recommended the desalination of mine water discharges.	Re-use and treatment of mine water effluent to improve water quality in rivers, to maintain mine water at a level that will not create negative environmental impacts and to reduce the water shortage in the Vaal system between the year 2014 and 2019	Increase water availability by ± 58 million m^3/a from 2015 onwards in Vaal and improve water quality. Reduce releases from Vaal Dam for dilution purposes. Postponing the need for further augmentation after the implementation of Phase 2 LHWP

Name	Description	Purpose	Possible impacts
Phase II LHWP **Major additional infrastructure required** **(Also see notes for LHWP Phase II for Orange System)**	Vaal Recon Strategy: The Minister of the DWA RSA and Cabinet made the decision in December 2008 that the Department should proceed to negotiate with the Government of Lesotho for the implementation of Phase 2 (Polihali Dam) of the Lesotho Highlands Water Project. Plans are currently well underway and on target.	Augmenting the growing demand in the Vaal system with emphasis on the Gauteng demand centre until 2035. Polihali Dam makes 437 million m^3/a available for transfer to the Vaal River system	As soon as Polihali Dam starts to inundate water, it will impact on the yield available from the Orange River Project and yield replacement in the Orange will be required to be able to transfer the full 437 million m^3/a to the Vaal.
Vaal Reserve	Determine final agreed EWR requirements to be implemented in the Vaal River catchment at key points. This study was completed.	To maintain environmental status of the Vaal System at an agreed level. This level will differ depending on the location in the Vaal.	Changes to flow regimes in the Wilge River downstream of Sterkfontein Dam and downstream of Douglas Weir on the Lower Vaal were recommended. Implementing these flows will however result in an decrease in the Vaal system yield of approximately 100 million m^3/a.
Water Quality (Also see Re-use of urban return flows and AMD)	Short-term: Continue with dilution of the Vaal Barrage with releases from Vaal Dam. Medium-long term: Implement target saline effluent treatment schemes. Implement waste discharge charges. Implement WWTP retrofit and upgrading projects in the hot spot areas. Stricter discharge standards etc. according to the Integrated Water Quality Management Plan for the Vaal	Improve water quality in Vaal. Reduce releases from Vaal Dam for dilution purposes.	Prevent a significant decrease on Vaal System yield due to reduced releases for dilution purpose. Make water available for re-use purposes.
Re-use of urban return flows. Require some new infrastructure	A large portion of the Rand Water supply area is located in the Crocodile (west) River catchment. Urban/industrial return flows from this area are released into the Crocodile catchment. These return flows are used to support demands in the Crocodile River basin and will in future also be used to transfer water to Lephalale in support of Eskom Power Station developments.	Results presented at the Nov 2013 Strategy Steering Committee of the Crocodile West System showed that after all the water needs in the Crocodile West System as well as the required transfer to Lephalale are satisfied, excess return flows is still available in the Crocodile for further re-use purposes.	Can provide sufficient water for Crocodile (West) River System and transfers to Lephalale. Latest indications are that there is sufficient return flows to also offset some of the abstractions from the Vaal River system. This will reduce the RW abstraction and can postpone LHWP Phase II by ± 3 years.

Table 3.2: Orange River System possible future development and management options

Name	Description	Purpose	Possible impacts
WC/WDM	**Orange Recon Strategy**: Plan and implement WC/WDM in the domestic and irrigation water use sectors. In addition to WC/WDM 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.	Water use sector savings need to be achieved not later than 2020.	Targeted savings of 6 million m^3/a for the domestic/industrial water use sector (excluding Bloemfontein) and 5% (100 million m^3/a) of total water use in the irrigation.
Real Time Monitoring	**Orange Recon Strategy**: 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.	To reduce operating losses and increase utilisation of spills from the Vaal. Target implementation date 2016.	The estimated saving in operation losses is 80 million m^3/a
Phase II LHWP **Major additional infrastructure required** **(Also see LHWP Phase II description for Vaal system)**	**Orange & Vaal Recon Strategy**: Polihali Dam in Lesotho with interconnecting tunnels to Katse Dam to augment the Vaal System from approximately 2022 onwards.	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	Expected decrease in ORP yield is 284 million m^3/a when Polihali Dam is fully utilised by the Vaal. Can postpone the deficit in the Orange due to Phase II of the LHWP for several years. Detailed analyses are still required to determine the best operating rule for the shared use of Polihali Dam.
Low level storage in Vanderkloof Dam Require some new infrastructure	**Orange Recon Strategy**: 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 2021	Increase the ORP system yield.	This option will increase the system yield by 137 million m^3/a. Hydro-power can't be generated when dam is below current m.o.l.
Vioolsdrift Dam (Also indicated as a possible Namibia development) **Require significant additional infrastructure development**	**Orange Recon Strategy**: From Orange Recon Study a dam with a FSL of 210 mamsl and 510 million m^3 storage was found to be the optimum size. Any larger dam would not yield more for the system as the downstream water demand is limited.(The results from the reconciliation strategy study was obtained with preferred EWRs in place)	The dam at Vioolsdrift is needed for two purposes, i.e. to regulate the river flow and to increase the system yield. This dam can be utilised by both Namibia and the RSA and will most probably be a combined project by the two countries.	The saving in operating requirements was estimated as 120 million m^3/a. By utilising the remaining storage capacity of the dam, a further yield increase of 192 million m^3/a can be achieved. The total benefit of Vioolsdrift Dam will therefore be 312 million m^3/a.

Name	Description	Purpose	Possible impacts
Implementing the ecological preferred EWR Expected that infrastructure developments will be required to be able to supply the required EWRs	**Orange Recon Strategy**: The highest EWR is needed at Augrabies, upstream of Vioolsdrift Dam site. Releasing variable EWR flows from Vanderkloof Dam, is impractical, as it cannot be controlled accurately to obtain the correct flows at the estuary due to the long distance of 1380km and the time (one month) it takes for the water to reach the estuary. This normally results in too much water reaching the estuary which prohibits the estuary from closing and results in undesirable ecological conditions	To improve the current environmental status at key points to the preferred ecological class.	Commission Vioolsdrift Dam at the decided date for the preferred EWR implementation, as the river mouth environmental requirement can only be successfully supplied with a Vioolsdrif Dam in place. Current estuary requirements are 288 million m^3/a and implementation of the preferred EWR will result in an gross decrease in system yield of 722 million m^3/a.
Gariep Dam Raising Requires additional infrastructure development	**Orange Recon Strategy**: Raising the Gariep Dam by 10m. The raising date will be dependent on the implementation date of the Ecological Preferred EWR, approximately 2024	Creating additional yield in the ORP system. (Results in a significant increase in evaporation losses)	Increase the ORP yield by 350 million m^3/a. This option has low social and environmental impacts, compared to the other dams.
Bosberg/Boskraai Dam **Require significant additional infrastructure development**	**Orange Recon Strategy**: Bosberg located in Orange just upstream of confluence with Kraai River. For the Boskraai Dam a second wall is added on the Kraai, creating single basin covering both the Kraai & Orange rivers Dam on the Kraai side has potential fatal flaws as result of threats to the loss of important ecological drivers and the loss of threatened vegetation types. Bosberg Dam is very expensive due to a long saddle dam.	Creating additional yield in the ORP system.	Bosberg 2 970 million m^3/a storage 391 million m^3/a yield. Boskraai 8 530 million m^3/a storage 937 million m^3/a yield. Boskraai might result in unacceptable impacts on the environment downstream along Orange River.
Verbeeldingskraal Dam Requires significant additional infrastructure development	**Orange Recon Strategy**: Verbeeldingskraal Dam located upstream of the Bosberg site & do not require a saddle dam. Size is limited to prevent inundation of Lesotho.	Creating additional yield in the ORP system. As an alternative to Bosberg/ Boskraai and/or raising of Gariep Dam.	The yield of Verbeeldings- kraal Dam is 200 million m^3/a with active storage of 1 360 million m^3/a.
Management measures	**Orange Recon Strategy**: Lowering the assurances of supply, eliminating unlawful water use and eradicating invasive alien plants in the Kraai River catchment	Increase water availability in the system.	Improve system yield and or make more water available at lower assurances.

Name	Description	Purpose	Possible impacts
Eastern Cape transfer losses	**Orange Recon Strategy**: The irrigators also claim an additional requirement of 25% of the current irrigation transfer of 580 million m^3/a to compensate for water losses.	To cover transfer losses experienced in the Eastern Cape system. Applies to water transferred from Gariep through Orange/Fish tunnel to Eastern Cape.	This will have a significant impact on the ORP water balance. Further work as proposed in the Orange Recon Study is required to resolve this issue.

Table 3.3: Greater Bloemfontein water supply system possible future development and management options

Name	Description	Purpose	Possible impacts
WC/WDM	**Bloem Recon Strategy**: The implementation of WC/WDM in the urban sector. Two scenarios were considered: The "Best Case Scenario" and the "Most Probable Scenario"	Reduce water demand	"Best Case Scenario" has the potential to save approximately 25 million m^3/a. "Most Probable Scenario" the potential to save approximately 12 million m^3/a of water
Additional Yield in the Caledon River Requires additional infrastructure development	**Bloem Recon Strategy**: Increase the Capacity of Novo Pump Station to 2.4 m^3/s. Add two pumpsets at Tienfontein Pump Station Still to be implemented. The first pumpset to increase the design capacity of the pump station to 4 m^3/s, the second pumpset to provide standby capacity. This would provide an additional yield of approximately 4.4 million m^3/a. Further increase the capacity of Tienfontein Pump Station to 7 m^3/s. This will result in an expected increase in the system yield of 13.7 million m^3/a. To augment Knellpoort Dam from a pump station located at Welbedacht Dam, Using the same pipeline between Knellpoort Dam and Welbedacht WTP to address the turbidity at Welbedacht WTP, this pipeline could be used as a bi-directional pipeline to also augment Knellpoort Dam. Expected increase in yield 22.6 million m^3/a.	Increase the yield available for the Greater Bloemfontein Water Supply system.	The development of the additional yield (which could be as much as 60 million m^3/a) would depend on the capacity of the infrastructure that is constructed to abstract water from the Caledon River/Welbedacht Dam
Water Reuse for Bloemfontein Require some new infrastructure development	**Bloem Recon Strategy**: Treated waste water from the Bloemspruit WWTW would be purified and pumped over 3.8km into the Greater Bloemfontein supply area after blending	Increase Greater Bloemfontein Water Supply system yield.	The estimated yield is expected to be 10.8 million m^3/a (30Ml/d)
Augmentation from the Orange Require some new infrastructure development	**Bloem Recon Strategy**:To transfer water from Gariep Dam, either directly to Bloemfontein or to Knellpoort Dam.	Increase Greater Bloemfontein Water Supply system yield	An increase in yield of 20 million m^3/a is

Table 3.4: Other possible future development and management options

Name	Description	Purpose	Possible impacts
Lesotho Developments			
Metolong Dam Significant infrastructure development	Dam currently in construction. Will soon start to store water.	Supply water to Maseru and surrounding areas	Expected yield ± 30 million m^3/a. Decrease yield of Welbedacht and Gariep dams.
Namibia Developments			
Vioolsdrift Dam (also indicated as part of Orange system) Require significant additional infrastructure development	From Orange Recon Study a dam with a FSL of 210 mamsl 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 dam at Vioolsdrift is needed for two purposes, i.e. to regulate the river flow and to increase the system yield. This dam can be utilised by both Namibia and the RSA and will most probably be a combined project by the two countries.	This saving in operating requirements is estimated as 120 million m^3/a. By utilising the remaining storage capacity of the dam, a further yield increase of 192 million m^3/a can be achieved. The total benefit of Vioolsdrift Dam will therefore be 312 million m^3/a.
Neckartal Dam Significant infrastructure development	Dam on middle Fish River in Namibia near Seeheim	Supply of water to new irrigation scheme to be developed.	Expected yield ± 85 million m^3/a. Impact on Orange River mouth environmental requirements. Might require more support from Vanderkloof Dam
Naute Dam	Existing Dam in Namibia	Increase in irrigation area.	Utilise full yield available from Naute Dam
Botswana Developments			
Support to Botswana via the Vaal Gamagara water supply system.	Extend existing upgraded Vaal Gamagara transfer system to supply 5 million m^3/a water to Botswana	To support Botswana villages located close to the South African border from 2022/23 onwards.	Increased demand on the Vaal system.
Exports from Lesotho, to Botswana. Requires significant infrastructure development	No details yet. Study to commence.	Supply water to Botswana.	Decrease ORP system yield.
GENERAL			
Climate Change	Determine impact of climate change on water available in the system	Determine yield sensitivity in different climatic zones in the basin	Can result in decrease or increase in system yield depending on location.

The respective reconciliation strategies along with the information captured in **Tables 3.1** to **3.4** were presented at the ORASECOM Regional Working Group in Botswana on 5 and 6 March 2014. This information was then work shopped in group sessions to derive at realistic trail scenarios for modelling purposes in support of the IWRMP. These scenarios are described in **Section 3.2** and **Section 3.3**.

3.2 Baseline Scenario

The baseline scenario reflects the current system with only the existing water resource and water supply related infrastructure in place. Thus, no planned future dams or schemes were included in the baseline scenario. Although Metolong Dam is almost completed, this dam was still excluded from the baseline scenario, so that the impact on the system when Metolong Dam starts to deliver water can be determined.

Several actions within the Integrated Vaal and Integrated Orange-Senqu systems were already put in place to maintain an assured water supply to the users. These actions or intervention options all originated from the Reconciliation Strategy studies as mentioned in **Section 3.1** and represent the initial intervention options that were already activated or will very soon be activated. These actions or intervention options were considered to be part of the baseline scenario and include the following:

- Removal of unlawful irrigation in the Upper Vaal.
- The neutralising of mine water outflows relating to the acid mine drainage problem in the Vaal River.
- Water conservation and water demand management activities mainly focussed on the urban/industrial sector within the Integrated Vaal system.
- Water conservation and water demand management activities focussed on urban/industrial and irrigation sectors within the Integrated Orange Senqu system.
- Included the initial increase in the Tienfontein pumping capacity and the Novo Transfer scheme capacity as recommended in the Greater Bloemfontein Reconciliation Strategy study.

The remainder of the identified intervention options will be accommodated in the other scenarios to be defined for the purpose of the ORASECOM IWRMP study Phase III.

A detail description of the baseline scenario that covers all the main and important elements in the entire Orange-Senqu system is essential. The Orange-Senqu system is a highly developed and complex system, consisting of a number of large integrated systems and many small sub-systems. It is thus important to have a clear definition of the baseline scenario to enable sensible comparisons of WRPM analysis results between the different scenarios analysed.

3.2.1 Baseline Scenario Definition (Scenario 0)

Conditions applying to the Integrated Vaal River System

- All the urban/industrial demands imposed on the Integrated Vaal system will be at 2013 development level at the start of the analysis
- Use latest demand growth as used for the 2013/14 Vaal AOA and was also adopted in the updated demand data base for ORASECOM Phase III study. Assume WC/WDM is in place based on latest information from the "Maintenance of the Vaal River Reconciliation Strategy". (DWA, 2014) This reflects the current progress in WC/WDM as taking place in reality.

- Irrigation will be based on 2013 development level. Where irrigation allocations are applicable, the allocated volume will be used as the demand. This condition apply to the start year of the analyses where after the expected growth in irrigation will be included where applicable. In most areas however, irrigation will not be growing.
- In the Vaal Reconciliation Strategy study it was identified that there are a significant amount of unlawful irrigation in the Upper Vaal, partly utilizing the transferred water from Lesotho and the Tugela. The removal of the unlawful irrigation was one of the urgent matters included in the Final Strategy prepared for the Integrated Vaal System. The process has already been put into action and currently 66% of the unlawful irrigation has been removed. For the purpose of the base scenario it will therefore be accepted that these irrigation areas in the Vaal will be at lawful plus 34% at the start of the analyses. It is assumed that further eradication takes place according to the latest information from the "Maintenance of the Vaal River Reconciliation Strategy" (DWA, 2014) study, which is currently in process.
- Curtailments will be imposed on demands in the main systems when required, to meet the agreed levels of assurance and to protect the resources from total failure.
- Transfer from the LHWP to the Vaal is set equal to 780 million m^3/a according to the current agreement between RSA and Lesotho.
- Polihali Dam will not be included as part of this scenario.
- EWR releases from Katse and Mohale dams will be based on the latest implemented results as used in the Comparative Study.
- Operational losses from the Lower Vaal will be in line with the latest calibration done as part of the Vaal Reserve study.
- Include current and planned neutralising of mine water outflows. Although mine water desalination is also planned and need activated in future, it will be excluded from the base scenario. The timing of the planned neutralising will be according to latest information from the "Implementation of the Vaal River Reconciliation Strategy" (DWA, 2014) study.
- Mining demands are based on 2013 development level demand for the first year of the analyses with growth as included in the updated demand data base prepared as part of the ORASECOM Phase III study.
- Exclude recommendations from the Vaal Reserve study (DWA, 2010) regarding the required flows downstream of Sterkfontein Dam and Douglas Weir for the purpose of the base scenario. These recommendations are not implemented at this stage as it results in a decrease in the Vaal system yield.
- The Integrated Vaal System will be operated to minimise spills into the Orange River.

CONDITIONS APPLYING TO THE INTEGRATED ORANGE-SENQU RIVER SYSTEM

- All the urban/industrial and mining demands imposed on the Orange system will be at 2013 development level at the start of the analysis.
- Use latest urban/industrial mining demand growth as used for the Orange Reconciliation and ORASECOM studies.
- Irrigation will be based on 2013 development level allocations or requirements as applicable to the specific area under irrigation, at the start of the analysis.
- The 12 000 ha allocated for use by resource poor farmers. Only include those already developed at 2013 and allow for the expected further development as included in the ORASECOM Phase III data base.
- Transfer from the LHWP to Vaal equal to 780 million m^3/a according to the current RSA Lesotho agreement.
- EWR releases from Katse and Mohale based on the latest implemented results as used in the Comparative Study.
- EWR for Orange as currently released for the river mouth (287.5 million m^3/a) which was obtained from the Orange River Replanning Study (ORRS and is referenced as ORRS EWRs).
- Transfers to the Eastern Cape through the Orange/Fish tunnel based on the latest data from the Orange Annual Operating Analysis as captured in the ORASECOM Phase III data base. This demand is based on the allocation and scheduled irrigation area and supply to Port Elizabeth and several small towns in the Fish/Sundays sub-system. Allow urban and irrigation growth as referred to in items 2 and 4.
- Current transfer schemes and related operating rules from the Caledon to the Modder River catchment in place (Welbedacht to Bloemfontein and Novo Transfer). Only allow the initial proposed increase in Tienfontein Pumping capacity and Novo Transfer capacity according to latest information from Greater Bloemfontein Reconciliation Strategy implementation study (DWA, 2014b).
- Exclude the new Metolong Dam from the baseline scenario. The growing demands of Maseru and surrounding areas will be imposed on the existing supply systems used for that purpose and not from Metolong Dam.
- Orange/Riet transfer. The current demands with growth will be modelled in detail as part of the system.
- Orange/Vaal (Douglas) transfer. Current demands with growth will be modelled in detail as part of the system.
- Operational losses from the Lower Vaal will be in line with the latest calibration done for the Vaal Reserve study.
- Hydro-power at Gariep and Vanderkloof dams will be generated in accordance with downstream demands only.
- Hydro-power will be generated at Muela with the water transferred from Lesotho to the RSA.
- Minimum operating level for Gariep Dam will set to be equal to the minimum operating level for releases through the Orange Fish Tunnel.
- Minimum operating level for Vanderkloof Dam will be set equal to the minimum operating level for releases into the Vanderkloof main canal.

- Spills from Douglas Weir and contributions from the Lower Orange hydrology will not be used to supply Lower Orange demands, as there is no storage available in the lower Orange to be able to utilize these flows in practice. Currently the system is operated to release the total downstream requirement from Vanderkloof Dam, without taking into account any contributions from the Vaal, as the Vaal is operated to minimise spills into the Orange River.

Conditions applying to the Fish River in Namibia

- Neckartal Dam in Namibia will not be included.
- Projected demand growth imposed on both Hardap and Naute dams.
- Restriction not imposed on water supply to users from Hardap and Naute dams. Thus no curtailments imposed on these two sub-systems.

Remainder of the basin

- Urban industrial growth as updated for this study (ORASECOM Phase lll).
- Only current development infrastructure in place.
- Only current irrigation in place.

The baseline scenario will be used to compare against results other scenarios. This will enable one to evaluate and understand the impact of different development and management options or scenarios on the water supply and assurance of supply within the entire Orange-Senqu system.

3.3 Definition and selection of scenarios

An updated baseline scenario was defined which includes both Metolong and Neckartal dams. The updated baseline scenario will be the scenario mainly be used to compare with results from the other scenarios to follow. This is due to the fact that both Neckartal and Metolong dams are already under construction, with Metolong Dam basically completed. These two dams are thus already given infrastructure that needs to be part of all other scenarios. The reason why baseline scenario (0) was listed as one of the scenarios to include in the analysis, was to be able to determine the impact of the construction of these two most recent storage dams on the Orange-Senqu system.

A brief description of all the scenarios that were defined as part of the ORASECOM Regional Working Group in Botswana on 5 and 6 March 2014 and finally agreed on at the Regional Working Group meeting held in Pretoria on 21 and 22 June 2014 is given in **Table 3.5.**

Table 3.5: Summary of selected scenarios to be analysed in support of the IWRMP

Scenario ID	Option/ scenario title	Actions / interventions	Details of actions/interventions	Purpose of inclusion
0.0	Baseline	None		
0.1	Updated Baseline	Include Metolong and Neckartal dams	Impose growing demands on the two dams as indicated by Lesotho and Namibia	Construction on both dams already started with Metolong almost completed. What is the impact of these two new dams on the Orange-Senqu system.
1.1	Desalination (Based on Scenario 0.10)	Desalination of AMD water	Option 0.1 already includes the neutralising of AMD water. Add to this, the desalination of the mine water. The timing of the desalination of the different mine drainage point is according to the latest information from the Maintenance of the Vaal River reconciliation Strategy study.	To reduce dilution requirements from Vaal Dam and to make AMD water available for use in the Vaal system.
1.2	Utilise Crocodile return flows (Based on scenario 1.1)	Vaal demand centres located in Crocodile to be partly supplied by return flows	Large volumes of return flows are generated in the Crocodile catchment with water mainly supplied from the Vaal system. These return flows are currently partly utilised in the Crocodile catchment by existing users, but are also earmarked to be transferred to Lephalale to supply Eskom Power Stations and possible coal to liquid plants. After supplying these current and future demands in full, it was estimated that there is still unutilised return flows available in the catchment. Utilise 80% of this surplus to supply part of the user demands currently met by water from the Vaal system	To reduce the demand load on the Vaal system and to avoid additional flows into the Limpopo River as result of increasing return flows in the Crocodile catchment. By doing this the building of Polihali Dam can be postponed by 3 years, resulting in significant savings on capital expenditure for the next three years.
2.1	Polihali support to Vaal only (Based on scenario 1.2)	Polihali is built to specification Fixed transfer from outset	Polihali Dam start to deliver water in 2022 Transfer at full yield as soon as possible to Vaal	To determine the maximum impact on the Orange, to generate the maximum Hydro-power and to support the Vaal.
2.2	Polihali support to Vaal and Orange (Based on scenario 1.2)	Polihali is built to specification Transfer only on request from Vaal Allow to support Orange only when Gariep is almost at it's m.o.l.	Polihali Dam start to deliver water 2022 Transfer to Vaal has higher priority Support to Orange limited to yield available after transferring water to Vaal	To optimise the yield benefit from Polihali but without jeopardising the Vaal . Determine Impact on hydro-power at Muela
3.1	PEC EWR throughout (based on Scenario 2.2)	Maintain current environmental conditions	Inclusion of the latest consolidated PEC EWR information	Need to establish the impact of implementing what could be considered as the minimum acceptable set of EWRs
4.1	REC EWR throughout (based on Scenario 2.2)	Improve environmental conditions	Inclusion of the latest consolidated REC EWR information	Need to establish the impact of implementing what could be considered as the best "realistic" set of EWRs

Scenario ID	Option/ scenario title	Actions / interventions	Details of actions/interventions	Purpose of inclusion
4.2	Raised Gariep &	Raising of Gariep Dam and building of	Raising Gariep by 10m and building Vioolsdrift	Utilise raised Gariep to support new REC
	Vioolsdrift Dam	Vioolsdrift Dam to reduce operating	at same time when shortages start occurring	EWRs. Will raised Gariep in combination with
	(Based on Scenario 4.1)	losses	in ORP due to Polihali. Implement the REC EWRs	Vioolsdrift Dam be able to overcome the shortages in the ORP
4.21	Botswana-Vaal Gamagara (Based on Scenario 4.2)	Extend existing Vaal Gamagara transfer scheme to supply water to Botswana	Transfer 5 million m^3/a to Botswana. Expected date for transfers to start is between 2021 & 2023.	Increased demand on the Vaal system
4.22	Lesotho Botswana transfer (Based on Scenario 4.2)	Building of a transfer system taking water from Lesotho to Botswana	Details not yet available	
5	RECs EWR at key sites only	Refinement of EWRs on the Lower Orange to accommodate the required low flows at the estuary	Inclusion of the latest consolidated PES and REC EWR information	Need to establish the impact of implementing what could be considered as the pragmatic set of EWRs
6	Impact of sedimentation	Impact of expected future sedimentation on the yield available from some of the main storage dams	These analyses will be carried out using the WRYM. All other scenarios are analysed using the WRPM	To determine possible decrease in yield due to sedimentation.
7	Most probable future development scenario	This option includes the development options as proposed in the most recent updates of the different reconciliation strategy studies as well as expected planning by Namibia, Botswana and Lesotho.	WC/WDM actions, eradicate unlawful water use, AMD neutralisation followed by desalination and re-use, construction of Polihali Dam (Phase ll of LHWP), re-use of urban return flows, implementation of real time modelling in the Orange, utilise Lower Level storage in Vanderkloof Dam, construction of Vioolsdrift Dam on Lower Orange, Raising of Gariep dam or construction of Verbeeldingskraal Dam in Upper Orange, implement improved EWRs, increase pumping capacities at Tienfontein pumpstation and Novo transfer scheme, Complete water supply distribution system from Metolong Dam and support planned area of supply, complete construction of Neckartal Dam and support to irrigation, supply water to Botswana via the Vaal Gamagara transfer system.	Purpose of this scenario is to provide a most probable baseline scenario regarding the expected future developments within the Orange Senqu basin, to achieve a sustainable water supply to the users over the planning period.

Table 3.5 includes a reference or ID number and name for each of the defined scenarios. The main action or intervention option that is added to the previous scenario to form this scenario is listed in column 3 with details regarding those actions or intervention options summarised in column 4. These actions and interventions were regarded as important building blocks that will form part of future developments within the Orange-Senqu system and were obtained from **Tables 3.1** to **3.4** in **Section 3.1.** In column 5 of **Table 3.5** a brief explanation of the purpose of each of the actions or intervention option is given.

Scenarios 1.1 and 1.2 both still excludes the future Polihali Dam that will be part of Phase II of the LHWP used to increase the future augmentation to the Integrated Vaal system. Both the intervention options, desalination of acid mine drainage (AMD) and utilising of return flows in the upper Crocodile River basin as applicable to scenarios 1.1 and 1.2 respectively, is crucial intervention options with a significant impact on water availability in the Integrated Vaal system.

All the scenarios from scenario 2.1 onwards include Polihali Dam in Lesotho. Previous studies already indicated that once Polihali Dam is in place, the current yield available from Gariep and Vanderkloof dams (referred to as the Orange River Project or ORP) will significantly reduce to such an extent that the ORP will no longer be able to supply the existing demands at the required assurance. The Integrated Vaal system will not require the full yield from Polihali Dam at the time of its completion. As the Vaal system demands slowly increases over time, the demand load on Polihali Dam will increases and it is expected that the Vaal will utilise the full yield from Polihali only beyond 2040. Instead of building a yield replacement dam in the Orange at the same time Polihali Dam is constructed, the surplus yield available in Polihali Dam can be used to support the ORP, and thereby postponing very high capital expenditure for a yield replacement dam to a much later time. For this reason two scenarios were considered when Polihali Dam is activated, scenario one considering the option where Polihali Dam only supports the Vaal and the second scenario analyse Polihali Dam to initially support both systems, the Vaal and the Orange (See Scenarios 2.1 and 2.2 in **Table 3.5**).

The recently determine EWRs for the Orange and Namibia Fish rivers as part of an ORASECOM study, provided valuable information on the EWRs on the main Orange River, the Namibia Fish River and the Orange River mouth environmental needs. Currently environmental requirements for the estuary are released from Vanderkloof Dam in support of the estuary. These release volumes were determined during the middle 1990's and are based on outdated methods. The inclusion of the EWRs as recently determined through the ORASECOM study, however, significantly impact on the ORP system yield, as it requires more water than that currently being released from Vanderkloof Dam. Implementing these updated EWRs on the current ORP system will result in a significant deficit in supply to the existing users. Decisions need to be taken at some time, if and when these updated EWRs can be implemented, whether the recommended EWR classes (REC) should be adhered to, or will the EWR classes' representative of the present ecological state (PES) be sufficient etc. Scenarios 3.1 and 4.1 were thus considered as essential to include as part of the list of scenarios to be analysed in support of the ORASECOM study, where Scenario 3.1 represents the Present Ecological State (PES) EWRs and Scenario 4.1 the Recommended (REC) EWRs. All other scenario 4 related scenarios included the recommended EWRs as obtained from the ORASECOM (ORASECOM, 2011a)study.

3. DEVELOPMENT AND MANAGEMENT OPTIONS

Significant additional storage need to be created in the Orange system once a significant portion of the Polihali yield is transferred to the Vaal system and the updated EWRs in the Orange were phased in. The Raising of Gariep Dam by 10m was regarded as a viable option from the Orange Reconciliation Strategy study, as Gariep Dam was originally designed to be raised and was found to be one of the most economically viable options.

To be able to adhere to the updated environmental requirements along the Lower Orange and at the estuary in future, a control point will be required on the Lower Orange. To release the correct volumes from Vanderkloof Dam in practice is not be possible, as it takes these releases approximately one month to cover the distance of 1380km to the river mouth. Having a dam at Vioolsdrift will significantly improve the control of releases in particular to correctly address the EWR at the Orange River mouth. Vioolsdrift Dam can be used to increase the system yield and to significantly reduce the current operational losses which currently amounts to 180 million m^3/a. Vioolsdrift Dam was for this reason included as part of scenario 4.2.

The two Botswana related options that will impact on surface water availability are the additional transfer through the Vaal Gamagara pipeline to Botswana and the possible transfer from Lesotho to Botswana as accommodated in scenarios 4.21 and 4.22 respectively.

The new proposed EWRs from the ORASECOM (ORASECOM, 2011a) study significantly impact on the ORP yield as already mentioned earlier. In an attempt to reduce the impact of these EWRs on the ORP system yield and still be able to supply the EWRs at an acceptable level, some adjustments were made to the recommended EWRs. These adjusted or refined EWRs were included in scenario 5 to determine the reduced impact on the system.

The impact on the available system yield due to sediment captured in major storage dams was determined through scenario 6. For this analyses the wrym was used, which is the more appropriate tool if one is mainly interested in the change in the system yield.

Scenario 7 represents the **Core Scenario** that captures the most likely future developments that is expected to occur within the Orange Senqu system. This scenario includes a combination of most of the trail scenarios already evaluated. These trail scenarios and related results were discussed in follow up RWG and NWF workshops/meetings and finally resulted in the formulation of the Core Scenario.

The Baseline Scenario as defined in **Section 3.2.1**, was used as the point of departure for the development of the selected Core Scenario. The following intervention options were already captured in the Baseline Scenario:

- The removal of the unlawful irrigation was one of the urgent matters included in the Final Strategy prepared for the Integrated Vaal System. The process has already been put into action and currently (2013) 66% of the unlawful irrigation has been removed. For the purpose of the baseline scenario it was accepted that these irrigation areas in the Vaal will be at lawful plus 34% at the start of the analyses. It was assumed that further eradication takes place according to the latest information from the "Maintenance of the Vaal River Reconciliation Strategy" study, which is currently in process.
- Current and planned neutralising of mine water outflows was included. This is the first step in the intervention option to address the AMD problem. The timing of the planned neutralising is according to latest information from the "Implementation of the Vaal River Reconciliation Strategy" study.

- The initial increase in the Tienfontein pumping capacity to 3.87 m^3/s, and the Novo Transfer scheme capacity to 2.2 m^3/s as recommended from the Greater Bloemfontein Reconciliation Strategy study with refinements added as obtained from the Greater Bloemfontein Reconciliation Strategy Implementation study (DWA, 2012).
- Water conservation and water demand management activities mainly focussed on the urban/industrial sector in the Integrated Vaal and Greater Bloemfontein systems.

The selected Core Scenario includes all the components already defined for the baseline scenario plus the following:

- Metolong Dam starts to store water from May 2014 and deliver water to users in May 2015.
- Neckartal Dam starts impounding water in May 2016. The first water is delivered to irrigation in May 2017, with the full irrigation development in place and supplied from 2024 onwards. The EWR just downstream of Neckartal Dam is supplied by Neckartal from May 2016 onwards.
- Re-use and desalination of mine water effluent to address the AMD in the Upper/Middle Vaal area. This was modelled to start in July 2018 reaching its full capacity of 43.2 million m^3/a by May 2019.
- Real Time modelling and monitoring in the Lower Vaal downstream of Bloemhof Dam and in the Orange River downstream of Vanderkloof Dam to the Orange River mouth. In the Core Scenario this intervention option was activated from May 2016 and results in reducing the operating losses by 80 million m^3/a.
- Botswana water supply through Vaal Gamagara Scheme. Transfer 5 million m^3/a to Botswana villages located close to the South African border from 2022/23 onwards.
- Utilise the lower level storage in Vanderkloof Dam from May 2021 onwards. This will increase the yield available from Gariep and Vanderkloof dams by 137 million m^3/a.
- Polihali Dam (LHWP Phase II) and connecting tunnel to Katse Dam. Polihali Dam starts to store water from May 2022 and deliver the first water to the Vaal from May 2023. The increased volume transferred to the Vaal from Polihali is based on the expected deficit in the Vaal system at the time, and is initially only a small portion of the yield available from Polihali Dam.
- Polihali Dam is used to support Gariep Dam from May 2023 onwards. The operating rule used, gave priority to the transfers in support of the Vaal system and limit the volume used to support Gariep Dam to the Polihali Dam yield minus thebvolume transferred to the Vaal from Polihali Dam in the given year. The volume transferred from Polihali to the Vaal is calculated as the full volume transferred to the Vaal in a specific year, minus the LHWP Phase I transfer volume of 780 million m^3/a.
- Vioolsdrift Dam starts to store water in May 2025. Vioolsdrift Dam is used for reregulating purposes as well as to increase the Orange system yield. Using Vioolsdrift Dam for reregulation purposes will reduce the operating losses by approximately 120 million m^3/a. Vioolsdrift Dam has a gross storage of 510 million m^3 and produces a yield of 192 million m^3/a.

- The preferred EWRs as determined by the ORASECOM study "Orange-Senqu strategic Action Programme: Environmental flows Project" was included on the Lower Orange and Fish River in Namibia (ORASECOM, 2012). The EWR for site 5 just downstream of Orange Fish confluence was adjusted to produce acceptable flows at the river mouth and only the summer EWR flows at the Augrabies site were included in the Core Scenario to avoid too high flows at the river mouth during the winter months. The EWR releases in support of the estuary can only be accurately controlled by means of releases from Vioolsdrift Dam, as Vanderkloof Dam is located too far upstream. The adjusted preferred EWRs were only supplied from May 2026 onwards. The inclusion of the preferred EWRs is expected to result in a significant reduction in the system yield and related deficits in supply to the users.
- Yield increase intervention option: To overcome these deficits and to accommodate future demand growth in the system an increase in the Orange system yield is required. This can be obtained by the raising of Gariep Dam or the building of the Verbeeldingskraal Dam upstream of Gariep Dam. A feasibility study is recommended to be able to determine the most preferable option. Current information and results shows that it can be any of the two proposed options. The selected Core Scenario therefore considered both these options as briefly described below.
- Raising the existing Gariep Dam by 10m to increase the system yield by 350 million m^3/a. The raising of the dam needs to be completed by May 2026.
- Verbeeldingkraal Dam (alternative to the raising of Gariep Dam) starting to store water in May 2026 and was used to support the existing Gariep Dam. Water is however kept in Verbeeldingskraal Dam for as long as possible, and will only be released in support of Gariep Dam when Gariep is at low storage levels (below 1 232.78 m.a.s.l.). Using this operating rule results in a significant reduction in evaporation losses from Gariep Dam.
- A pumpstation at Welbedacht Dam to augment Knellpoort Dam. This includes a pipeline between Knellpoort Dam and Welbedacht WTP to deliver water into Knellpoort Dam, but also to address the turbidity at Welbedacht WTP by supplying clean water from Knellpoort Dam to Welbedacht WTP during periods of high turbidity in the Caledon. This pipeline would therefore be used as a bi-directional pipeline, with a maximum transfer capacity of 2 m^3/s.
- Tienfontein pumpstation capacity increase to $7m^3/s$.
- Planned direct reuse from the Bloem Spruit WWTW (± 11 million m^3/a)

4. Water resource modeling results

4.1 Water Resource Planning Model Analysis

The WRPM analyses for all the scenarios analysed used the start date for the analysis as 1 May 2014 calendar year. This represents month eight of hydrological year 2013 as the hydrological years start in October and end in September the following calendar year. For the purpose of the risk analyses a 1000 stochastic monthly flow sequences of 10 years each was analysed.

4.1.1 Baseline Scenario analyses and results

The baseline scenario represents the current 2013 system with its related infrastructure, demands and operating rules as used in reality. This scenario excludes future infrastructure developments or intervention options to reduce the demands or increase the system yield, except for those actions that were already implemented. The expected growth in water requirements are however included in all scenarios analysed. Current intervention options that were already implemented and are therefore included in the Baseline scenario are:

- The removal of the unlawful irrigation in the Upper Vaal. The process has already been put into action and currently 66% of the unlawful irrigation has been removed.
- WC/WDM in the Vaal System is in place and is based on latest information from the study "Maintenance of the Vaal River Reconciliation Strategy" (DWA, 2014). This reflects the current progress in WC/WDM as taking place in reality.
- Current and planned neutralising of mine water outflows in the Vaal System. Although mine water desalination is also planned, it will be excluded from the base scenario. The timing of the planned neutralising is according to latest information from the "Maintenance of the Vaal River Reconciliation Strategy" (DWA, 2014) study.
- The 12 000 ha allocated for use by resource poor farmers. Only include those already developed at 2013 and allow the expected growth as included in the ORASECOM Phase III data base.
- Only allow the initial proposed increase in Tienfontein Pumping capacity and Novo Transfer capacity according to latest information from Greater Bloemfontein Reconciliation Strategy implementation study (DWA, 2014b).
- Metolong Dam in Lesotho and Neckartal Dam in Namibia are both excluded from the baseline scenario.

In the definition of scenarios an updated baseline scenario was also formulated. The only difference between the baseline scenario and the Updated Baseline scenario is that the latter also includes Metolong Dam and Neckartal Dam, which is both currently under construction with Metolong Dam almost completed. The reason for the two baseline scenarios is to be able to determine the impact of these two new dams on the existing system.

The current operating rules used in the Orange-Senqu integrated system requires that the three large water supply systems use restrictions on water use during drought periods, to protect the resources from total failure in severe drought events. The three water supply systems using this type of operating rule are:

- The Integrated Vaal System
- The Orange River Project (Gariep and Vanderkloof dams)
- The Greater Bloemfontein water supply system.

Within each of these three water supply systems water is supplied at different assurances to the various water use sectors. The aim of the restriction operating rule is to restrict or curtail the water supply to the low assurance users first, to be able to protect the supply to the high assurance users and to over time be able to supply all the users at their required assurance levels. To be able model this rule the WRPM need to know at what assurance each user sector must be supplied. This is defined by means of a priority classification table as given in **Tables 4.1, 4.2** and **4.3** for the Integrated Vaal River System (IVRS), Orange River Project (ORP) and Greater Bloemfontein System, respectively.

Table 4-1: Priority Classification Integrated Vaal River System

User Category or Sector	Priority Classification and assurance of Supply (Portion of demand given as a percentage)		
	Low	Medium	High
	1 in 20 year (95%)	1 in 100 year (99%)	1 in 200 year (99.5%)
Irrigation	50	30	20
Domestic	30	20	50
Industrial	10	30	60
Strategic Industries	0	0	100
Losses	0	0	100

Users within the IVRS are supplied at three different assurance classes, low, medium and high as indicated in **Table 4.1**, representing a 95%, 99% and a 99.5% assurance respectively. From **Table 4.1** it is evident that 50% of the irrigation requirements are supplied at a low assurance of 95%, implying a 5% risk of not receiving its full requirement. This relates to a recurrence interval of 1 in 20 years for the occurrence of restrictions on average.

Table 4-2: Priority Classification Integrated Orange River Project

User Category or Sector	Priority Classification and assurance of Supply (Portion of demand given as a percentage)		
	Low	Medium	High
	1 in 20 year (95%)	1 in 100 year 99%)	1 in 200 year (99.5%)
Irrigation	50	40	10
Domestic/Industrial/Mining	20	30	50
Current River Mouth EWR	32	0	68
Losses	0	0	100

Similarly 30% of the irrigation demand requires a medium assurance of supply (99% assurance & 1 in 100 year recurrence interval) and 20% of the irrigation demand will be supplied at a high assurance of 99.5%, relating to a recurrence interval for the occurrence of restrictions of 1 in 200 years on average. The strategic industries typically includes water supply to users such as Eskom power stations and Sasol. It is not possible to restrict or curtail losses in a system, as losses will still occur during drought periods, and for this reason the losses were all allocated to the high assurance class.

The ORP uses the same water supply assurance classes as applicable to the IVRS, although the distribution between the different classes is slightly different. Some of the user categories in the ORP are different to those in the IVRS due to the composition of the different water user types. It is important to note that the priority classification given for the estuary EWR, is only relevant to the EWR currently imposed on the ORP system. This is an outdated method used to supply the EWR and will be changed when agreement on the implementation of the new updated EWRs is obtained between all the basin states.

Table 4-3: Priority Classification for Greater Bloemfontein System

User Category or Sector	Priority Classification and assurance of Supply (Portion of demand given as a percentage)		
	Low	Medium	High
	1 in 20 year (95%)	1 in 100 year (99%)	1 in 200 year(99.5%)
Domestic/industrial	20	30	50
Losses	0	0	100

The Greater Bloemfontein system only supply water to urban centres and required two user categories for the priority classification definition. The water supply assurance classes for the Greater Bloemfontein System are the same as used for the IVRS and the ORP.

The WRPM uses these priority classification definitions in combination with the short-term yield assurance characteristics (also referred to as short-term stochastic yield characteristics) to determine when restrictions need to be imposed on a system, as well as the severity of the restrictions that need to be imposed.

The short-term stochastic yield analyses were assessed for a five year record period. Starting storages of the resources are set at varying levels, and the short-term yields determined are thus applicable to a given starting storage. The results from the short-term stochastic analysis are used as a direct input into the WRPM. This provides the WRPM with the short-term yield characteristics of a particular system at different storage levels. When the total storage in a system is for example at 100%, the system will be able to over the short-term, deliver a significantly higher yield than when the storage is low, say at 20%. The results of the short-term stochastic yield analysis are given in the report "Water Resources Modelling; Base Scenario: Yield Analysis, Stochastic Verification and Validation", produced as part of this study. These short-term yield characteristics as determined for the related assurance levels for each priority classes are then compared with the system demands allocated to the specific priority or assurance class. Based on these comparisons, the WRPM are able to determine when curtailments need to be imposed within a specific priority class and how severe the curtailments need to be, not to exceed the short-term yield available at the related assurance and storage level in the resource, at the time.

To illustrate the results from the WRPM relating to the restrictions or curtailments that were imposed on a specific system over time, a curtailment plot is generated from the model output. The curtailment plot shows how frequent curtailments were imposed on the system within each of the priority classes. When for example, the low priority class users were curtailed on average more often than only once in 20 years, it means that the system was not able to supply these users at their required assurance of 95%. A 95% assurance implies that the risk of restrictions should not exceed 5% which also means that on average the restrictions should not occur more often than once in 20 years.

When the curtailment criteria is violated as describe above, it indicates that the current system is no longer able to support the growing demand of the users at the defined or required assurance. At such a time it will be necessary to activate an intervention option to either increase the system yield or to decrease the demands imposed on the system.

The curtailment plot for the IVRS as applicable for Baseline and Updated Baseline Scenario is given in **Figure 4.1**.

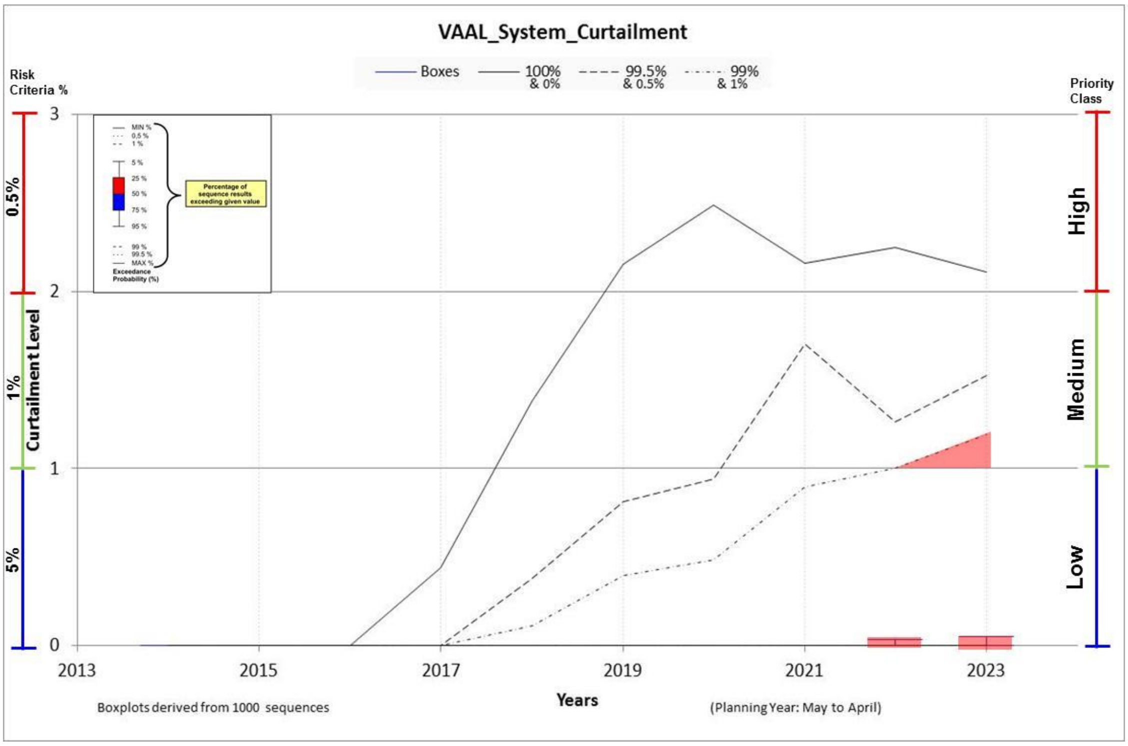

Figure 4-1: IVRS Curtailment Plot Baseline Scenario

From **Figure 4.1** it is evident that in 2022 and 2023 the 5% exceedance probability level (highlighted in red) is starting to show up in the Low assurance class or curtailment level 1. This means that the low assurance users were in 2022 and 2023 curtailed more often than only once in 20 years. For the medium assurance class the 1% exceedance probability level is starting to exceed curtailment level 1 (area shown in red) by 2023 This implies that from 2023 onwards the users in the medium priority class are being curtailed more often than once in 100 years. From the IVRS curtailment plot one can therefore conclude that the IVRS will require an intervention by 2022.

Phase II LHWP (Polihali Dam) was from previous studies already identified to be the next major additional infrastructure related intervention option to augment the IVRS. The inclusion of Polihali Dam and interconnecting tunnel is included in Scenario 2 and the related results will be presented in **Section 4.1.2.**

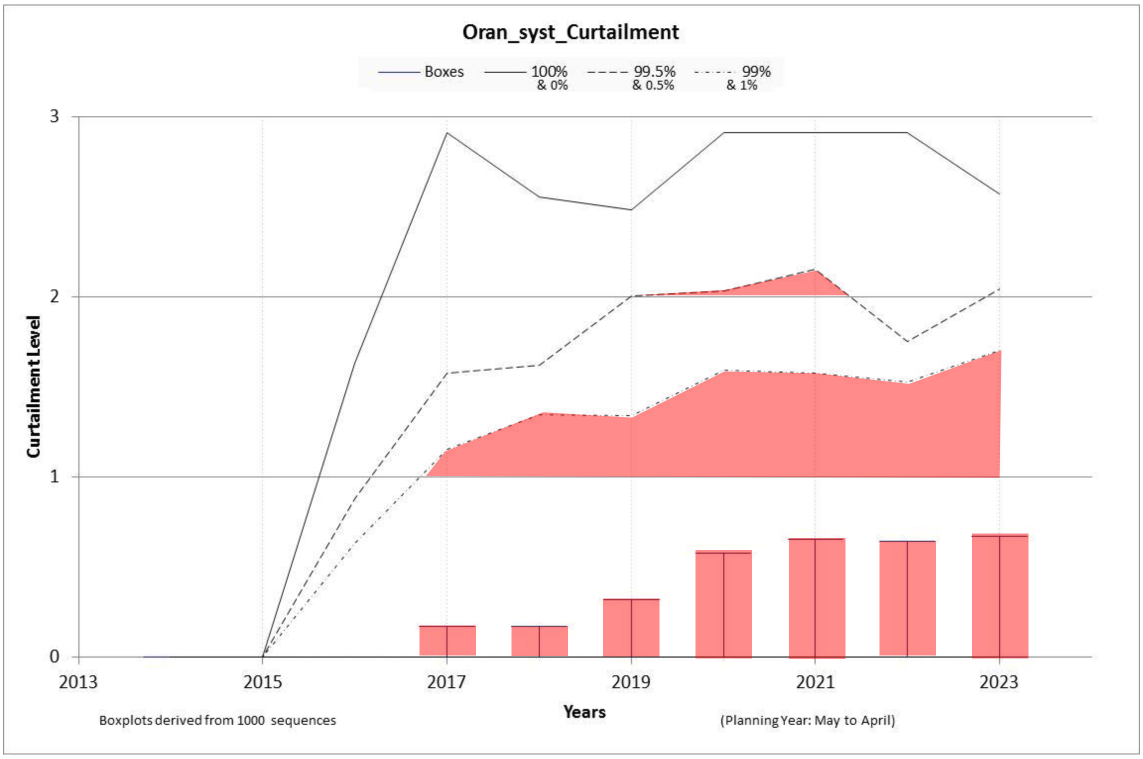

Figure 4-2: ORP Curtailment Plot Baseline Scenario

The curtailment plot for the ORP system representative of the Baseline scenarios is shown in **Figure 4.2**. From this figure it is evident that from 2017 onwards, the low assurance users are not receiving their required assurance (5% exceedance probability levels highlighted in red). This also applies to the medium assurance users see the red area below the 99% exceedance probability line within the curtailment level 1 zone. In 2020 and 2021 even the high assurance users received their water at a lower assurance than the required 99.5% as indicated by the red area below the 99.5% exceedance probability line in curtailment level 2 zone.

Several intervention options were identified from the Orange River Reconciliation Strategy Study (DWA, 2014c) to address the expected shortage in the ORP from 2017 onwards. These include WC/WDM, Real Time monitoring and modelling, utilising the lower level storage in Vanderkloof Dam, dual use of Polihali Dam and the raising of Gariep Dam (see details in **Table 3.2**).

The curtailment plot (**Figure 4.3**) for the Larger Bloemfontein water supply system shows severe shortages already occurring in 2015. This is due to the low storage in the main storage dams on 1 May 2014, as well as the limited transfer capacity from Knellpoort to Rustfontein Dam. The Novo transfer capacity only increases in middle 2015 and the Tienfontein Pump capacity increases in middle 2016. The improvement in the water supply to users due to these intervention options is evident from the curtailment plot between 2016 to 2018. These two capacity increases is clearly not sufficient and the other intervention options as recommended from the Greater Bloemfontein Reconciliation Strategy Study (DWA, 2012) also need to be implemented (see details in **Table 3.3).**

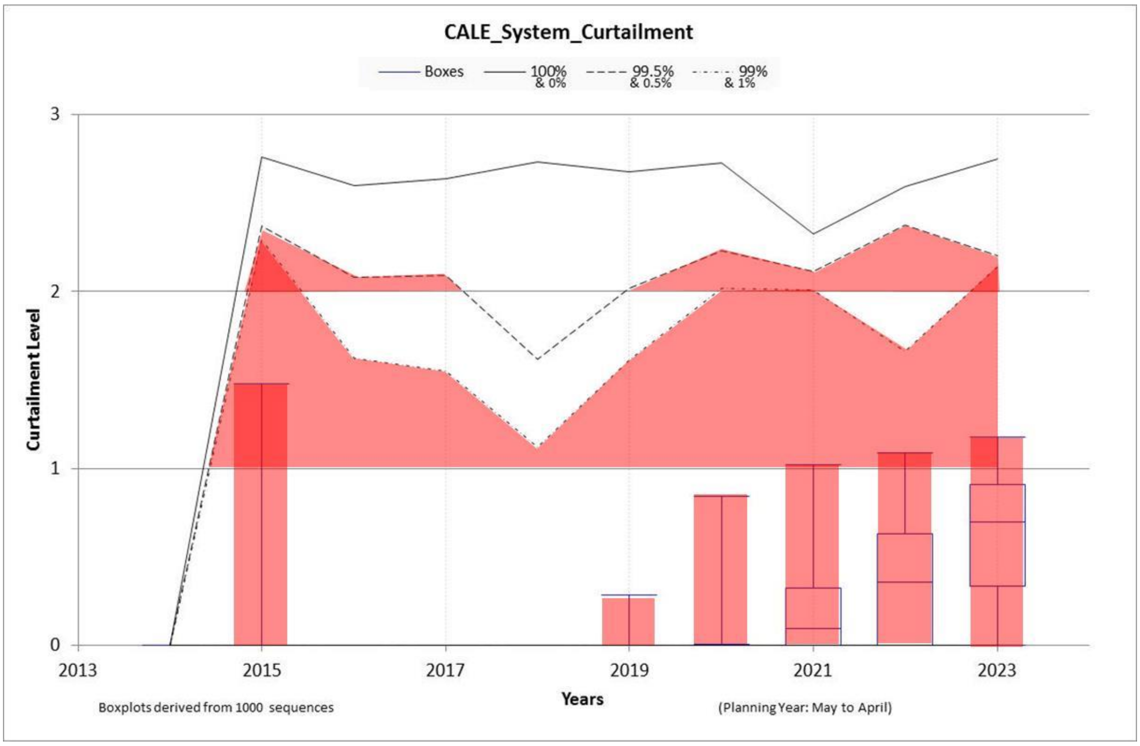

Figure 4-3: Greater Bloemfontein Curtailment Plot Baseline Scenario

By comparing results from the Baseline and Updated Baseline scenario the impacts on the existing water supply systems due to Metolong and Neckartal dams could be obtained. The results revealed the following impacts due to Metolong Dam.

- The BloemWater sub-system yield reduced by 1 million m³/a, which is only a 1.3% reduction in yield. Thus a fairly small impact.
- The average pumping from Tienfontein to Knellpoort Dam reduced over the 10 year period by 0.93 million m³/a. This is the component that contributed the most to the1 million m³/a reduction in yield referred to above.
- Almost no difference was evident in Gariep Dam. The average of the median storage in Gariep Dam dropped by approximately 4 million m³, which is less than 1 % of the average median storage.

The impacts on the existing water supply systems due to Neckartal as obtained from the WRPM scenario analysis are summarised in **Table 4.4**.

The impact of Neckartal Dam on the flows at the Orange River mouth is relatively small. These flows can however at times contribute to the EWRs at the estuary to reduce the load on the main Orange System. The impact on the flows in the lower Fish River just before its confluence with the Orange is quite severe, except for the high flows where it is only in the order of a 12% reduction. The Updated Baseline scenario did not include environmental releases from Neckartal Dam. The results therefore emphasises the importance of EWR releases from Neckartal Dam, mainly to support the flows along the lower Fish River.

Table 4-4: Neckartal Dam impact on flows in lower Fish and Orange River

Description	Flow (million m³/a)		
	Low flows (99.5%)	Median flow (50%)	High Flows (0.5%)
Fish River upstream of confluence with Orange	1.3	180	3300
Reduction (million m³/a)	1.1	116	390
% Reduction	81%	65%	12%
Orange River mouth	509	2 482	19 479
Reduction (million m³/a)	21.5	136.8	260.8
% Reduction at Orange River Mouth	4%	6%	1%

Both the baseline scenarios include the current and planned neutralising of mine water outflows. Although mine water desalination is also planned and will be done in future, it was excluded from the baseline scenario. To maintain the water quality in the Vaal Barrage as well as along the main Vaal River to Bloemhof Dam at acceptable levels, additional releases from Vaal Dam over and above the downstream requirements are made to dilute the polluted water. Due to this operating rule the storage levels in Bloemhof Dam at the lower end of the Vaal River tend to increase over time as can be seen in **Figure 4.4**.

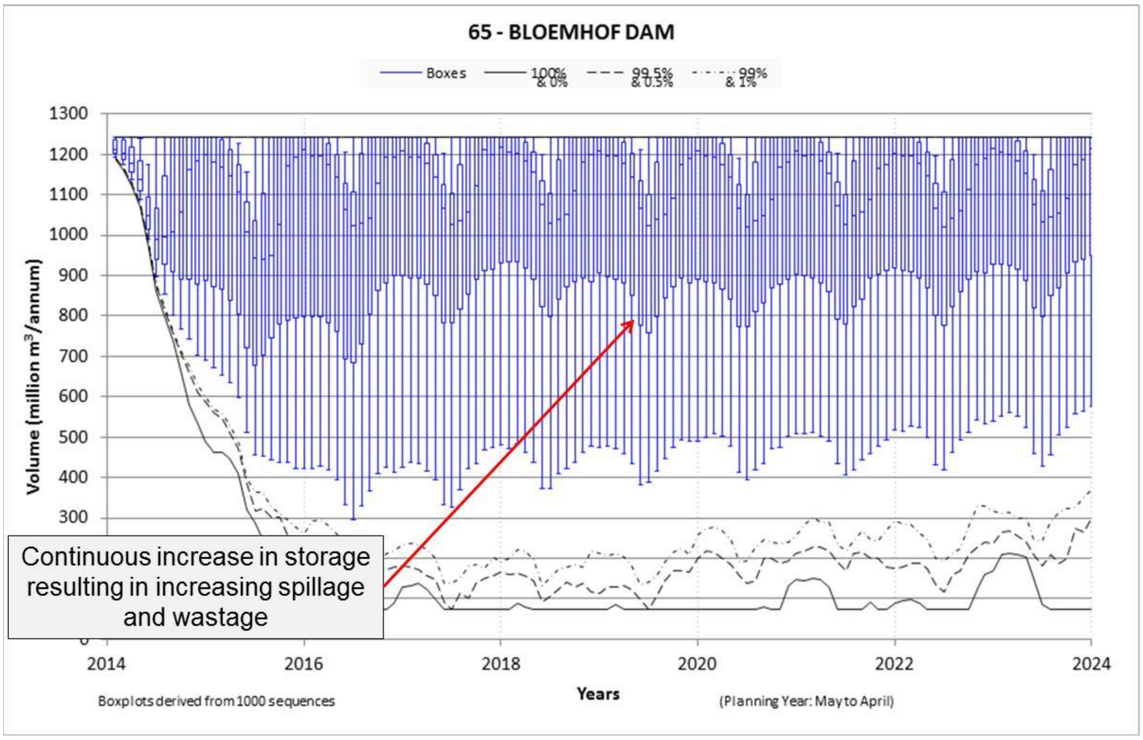

Figure 4-4: Bloemhof Dam storage projection for Baseline Scenario

This will result in increased spills from the Vaal System which is not acceptable, as large volumes of expensive water is transferred into the Vaal System from the several transfer systems used in support of the IVRS. This will also lead to a decrease in the yield available from the IVRS water will be lost to the Orange due to unnecessary spills at Bloemhof Dam. For this reason the desalination of mine water is of utmost importance and was strongly recommended as part of the Vaal Reconciliation Strategy.

The increase in the TDS concentrations over time just downstream of the Vaal Barrage can be seen in the boxplot of the simulated TDS values just downstream of Vaal Barrage as shown in **Figure 4.5**. The dilution operating rule currently used for Vaal Dam and Vaal barrage is to release water from Vaal Dam to keep the water in the Barrage at a TDS of 600 mg/l and lower. This is also evident in the TDS values just downstream of the Vaal Barrage which only for the most extreme flow sequences tend to slightly exceeds the 600 mg/l upper limit.

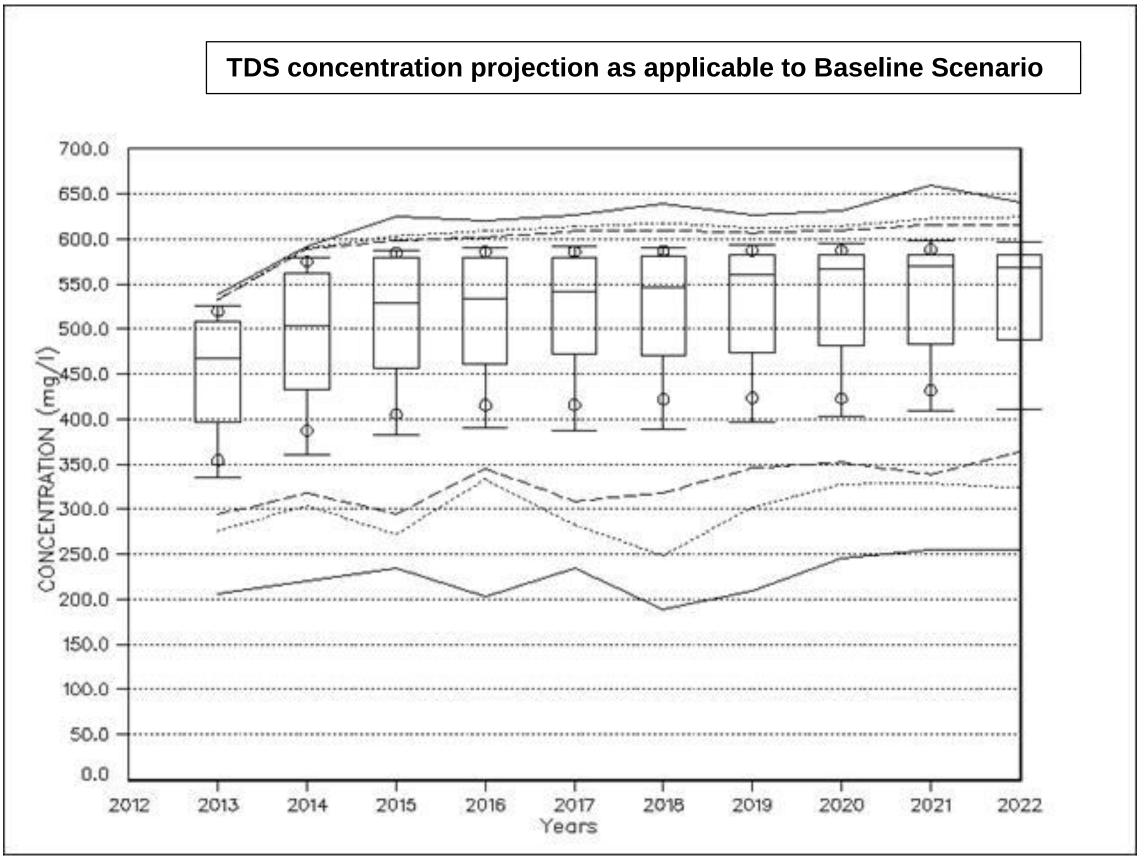

Figure 4-5: Water quality (TDS) in the Vaal River just downstream of Vaal Barrage

4.1.2 Results from Scenario 1.1 and 1.2

Scenario 1.1 used the Updated Baseline scenario as the basis and only added the desalination of Acid Maine Drainage (AMD) water. Desalination started in June 2018 and the impact of this can be seen on the TDS concentrations just downstream of Vaal Barrage (see **Figure 4.6**).

By comparing **Figures 4.5** and **4.6** the impact of desalination on the Vaal River TDS concentrations is clearly evident.

The impact of the desalination of the AMD is also evident as far downstream as Douglas Weir in the Lower Vaal and even at the Orange River Mouth, although too much lesser extent.

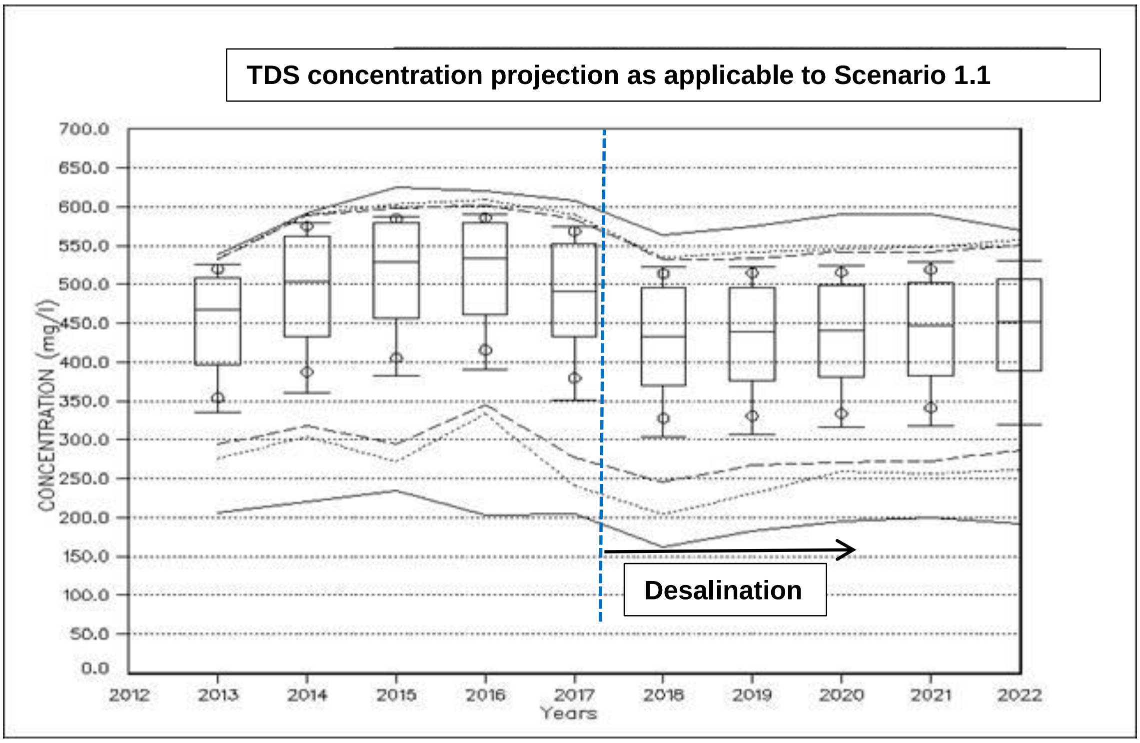

Figure 4-6: Water quality (TDS) in the Vaal River just downstream of Vaal Barrage

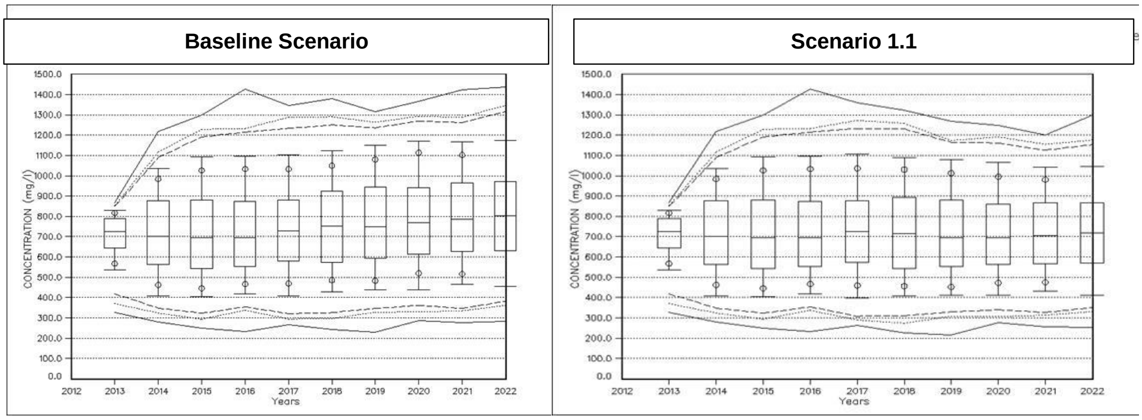

Figure 4-7: Water quality (TDS) in the Vaal River just upstream of Douglas Weir

At Douglas Weir the median Vaal TDS concentrations of the Vaal inflows reaches 800 mg/l by 2022, while the median TDS concentration decreases to 700 mg/l by 2022 for scenario 1.1 when desalination of AMD is activated in 2018.

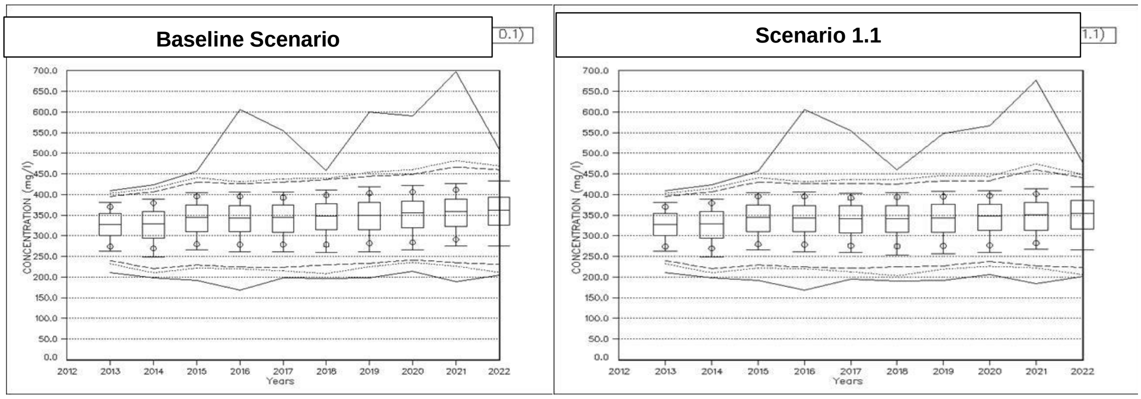

Figure 4-8: Water quality (TDS) in the Orange River at the River Mouth

The median TDS concentration for the Baseline Scenario at the Orange River mouth gradually increases to above 350 mg/l from 2020 onwards. When the AMD desalination is activated in 2018 the impact of this action is even evident at the Orange River mouth as the median TDS is prevented from increasing to above 350 mg/l. The impact of the desalination is not that significant in the Lower Orange due to the significantly higher flows from the Upper Orange, resulting in the dilution of the high TDS inflows from the Vaal River.

The storage projection plot for Bloemhof Dam as generated from the Baseline Scenario results (**Figure 4.4**) showed an increasing trend due to the increased releases from Vaal Dam for dilution purposes. When the desalination of the AMD is activated in 2018, the impact of reduced releases for dilution purposes is clearly evident in the related Bloemhof Dam storage projection (scenario 1.1) as given in **Figure 4.9**. A significant drop in the storage levels in Bloemhof Dam is evident at almost all the exceedance probability levels. This confirms the large reduction in additional releases from Vaal Dam to dilute the water in the Vaal Barrage to acceptable TDS concentrations.

Previous analyses carried out in support of the Vaal Reconciliation Strategy Study indicated that AMD desalination can postpone the next intervention option for the IVRS from 2015 to 2021. The increased releases from Vaal Dam for dilution purposes relating to the Baseline Scenario, reduces the yield available from the IVRS by as much as 500 million m^3/a over time.

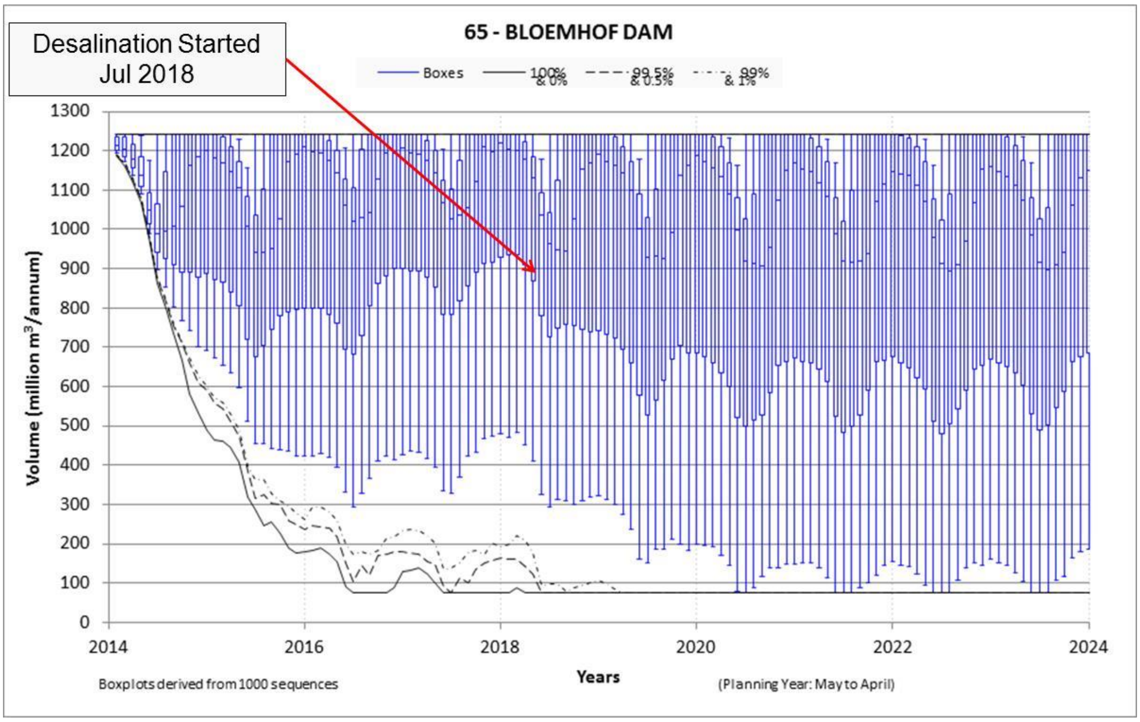

Figure 4-9: Bloemhof Dam storage projection for Scenario 1.1

By implementing the desalination of AMD the loss in yield in the IVRS can be regained fairly quickly as it will almost immediately reduce the releases from Vaal Dam for dilution purposes. The desalination of AMD water clearly impact significantly on the IVRS and the Lower Vaal and even on Orange but to a much lesser extent. It is therefore of utmost importance to implement this intervention option as recommended from the Vaal River Reconciliation Strategy study (DWA, 2009).

Scenario 1.2 used Scenario 1.1 as its basis and included the re-use of return flows in the Crocodile River catchment to reduce the demand load on the IVRS. This intervention option focus on demand centres in Crocodile River (see **Figure 4.10**) catchment which is supplied with water from IVRS.

A large component of the these return flows generated in the Crocodile Catchment was already earmarked for support to Lephalale due to the significant increase in water demand in that area as result of the proposed Eskom Power Station and Coal to Liquid Plant developments.

The transfer of water from the Crocodile to Lephalale is expected to start around 2015/17 and will reach a maximum of approximately 130 million m^3/a. Current estimates are that there is approximately 70 million m^3/a return flows available in the Crocodile Catchment, which is not yet used or earmarked for support to other users.

The Rand Water (Gauteng) supply area includes forty seven Sewage Drainage Areas (SDAs) as illustrated in **Figure 4.10**. The North / South catchment divide of supply area shows that there is a large number of drainage areas located within the Crocodile catchment. These areas are supplied with water from the IVRS, although the return flows will enter the Crocodile River catchment and will not return to the Vaal River, as for the drainage areas to the south of the catchment divide.

The Tshwane Water Resources Masterplan already included plans to implement the re-use of 11 million m^3/a by 2015, followed by another 9 million m^3/a by 2020. This intervention option will postpone the next Vaal intervention by almost 1 year but can be postponed by ±3 year when the full re-use potential is utilised.

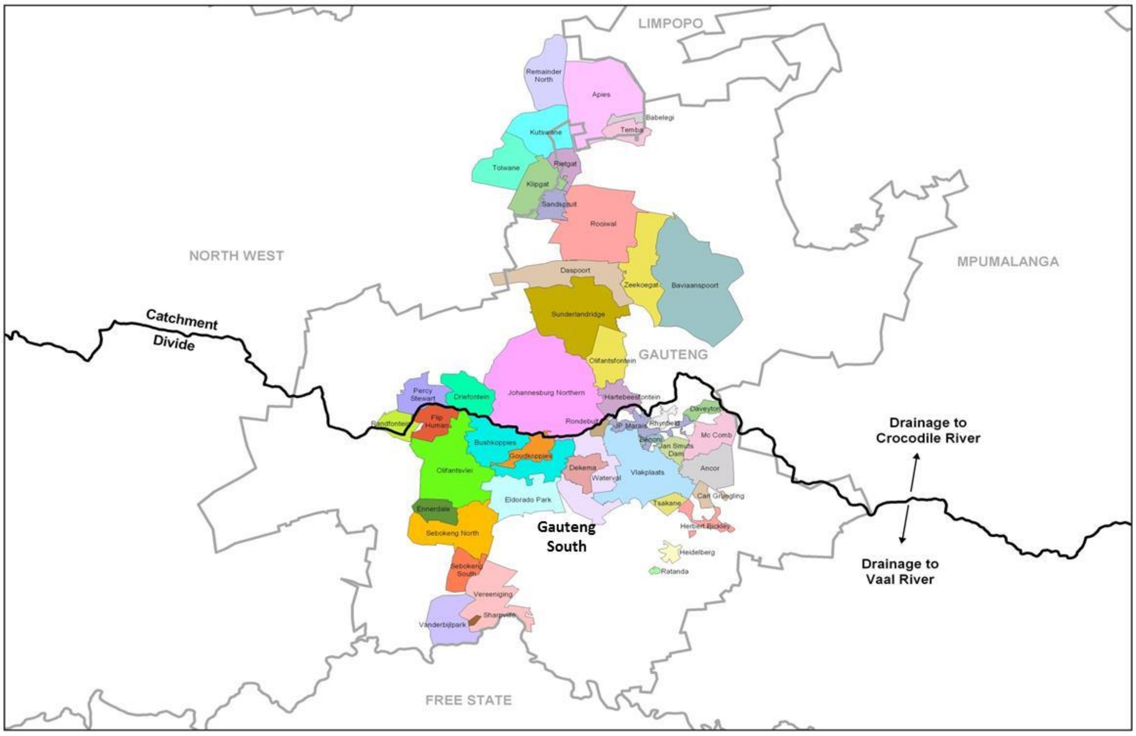

Figure 4-10: Gauteng water supply area North/South catchment divide and sewage drainage areas

4.1.3 Results from Scenario 2.1 and 2.2

Scenario 2.1 is as scenario 1.2 but includes the LHWP Phase II development. The LHWP Phase II development entails Polihali Dam and its interconnecting tunnel to Katse Dam. The purpose of the LHWP Phase II development is to support the IVRS. The RSA Cabinet made the decision in December 2008 that the RSA DWA should proceed to negotiate with the Government of Lesotho regarding the development of Phase II of the LHWP. Both governments agreed to go ahead with this project. Some details such as the operating rule that will be followed to manage the LHWP Phase II water supply system and the related transfers, still need to be agreed upon by both governments.

The operating rule to be followed is very critical and will impact significantly on the water supply within the IVRS, the amount of hydro power generated, as well the water supply situation in the Orange River downstream of the Lesotho border to the Orange River mouth. Due to the importance of this operating rule, two scenarios were considered when Phase II of the LHWP (Polihali Dam) is activated in the Orange Senqu Vaal system as a next IVRS intervention option.

The purpose of the Polihali intervention option is to deliver water to the IVRS only and was never intended to support the Orange River system. For this reason Scenario 2.1 was defined, that simulates the option where the full yield generated by Polihali Dam is transferred to the IVRS as soon as possible after the completion of the dam. This option will in particular benefit Lesotho as it will result in maximum hydro power generation.

The IVRS however do not require the full yield from Polihali Dam at its time of completion, as the expected growth in the IVRS demand will only reach that point by approximately 2040 to 2050. Once completed, Polihali Dam will severely impact on the yield available from the ORP (Gariep and Vanderkloof dams). This will require a yield replacement dam in the Orange at time when Polihali Dam starts to inundate water. It is possible that Polihali Dam can in fact be used to initially support both the IVRS as well as the ORP system, with priority to the IVRS transfers. This will postpone the necessity of a yield replacement dam in the Orange to a later date, which makes economic sense.

Scenario 2.2 was defined to represent this specific option, and therefore allowed duel support from Polihali Dam, but with priority to the IVRS transfers. Based on the most recent water balances prepared for the IVRS as part of the "Maintenance of the Vaal River Reconciliation Strategy" study, the expected average annual support required by the IVRS from the LHWP over time, was obtained. This transfer requirement (**Figure 4.11**) was adopted for Scenario 2.2 and the remaining Polihali Dam yield in each of the future years was then made available for support to the ORP.

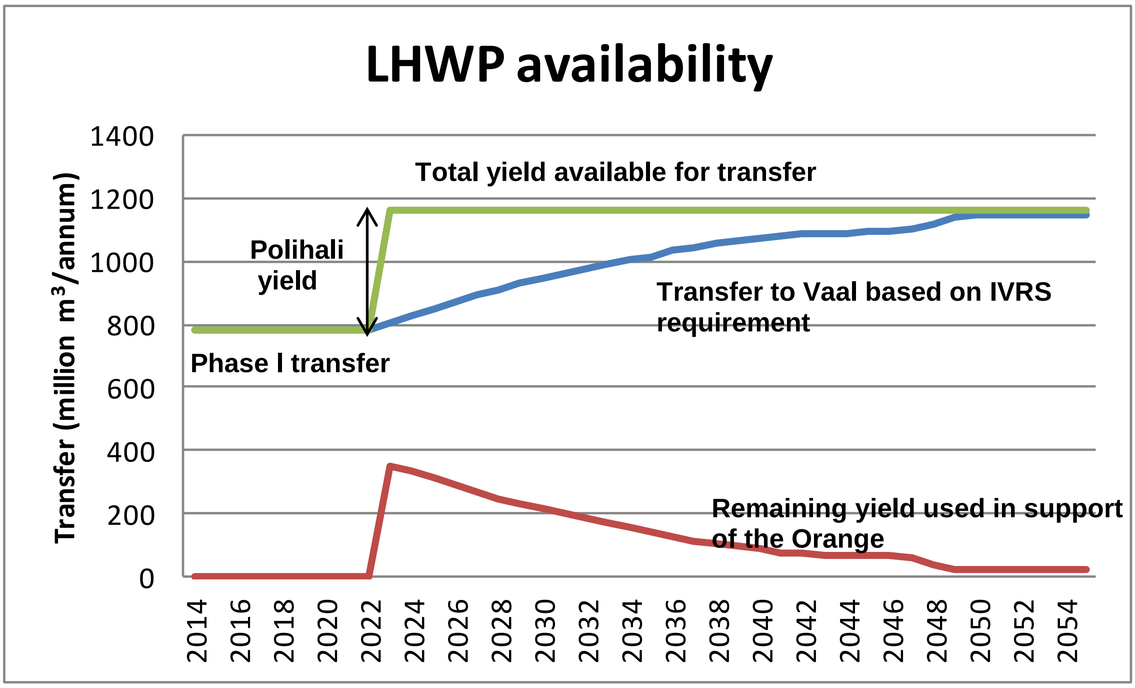

Figure 4-11: Duel support requirements from LHWP Polihali Dam

According to current planning Polihali Dam is expected to start inundating water by 2022. This occurs almost at the end of the 10 year basin-wide Integrated Water Resources Management (IWRM) Plan, covering the period 2015-2024. By using the WRPM to carry out analysis only to the end of 2024, will not provide a good indication of what can be expected after the introduction of Polihali Dam, which will result in significant impacts on both the IVRS and the ORP.

It was therefore decided to analyse all the scenarios that include Polihali Dam for at least a 20 year period.

The transfer requirements from Polihali to the IVRS and to the Orange as given in **Figure 4.11** were included in the WRPM as the desired transfer volumes. In **Figure 4.12** the actual transfers as simulated by means of the WRPM for both Scenario 2.1 and Scenario 2.2 are shown. Due to the priority given to the IVRS transfers, it is evident from **Figure 4.12** that the IVRS transfers were provided at higher assurances than the support to the ORP.

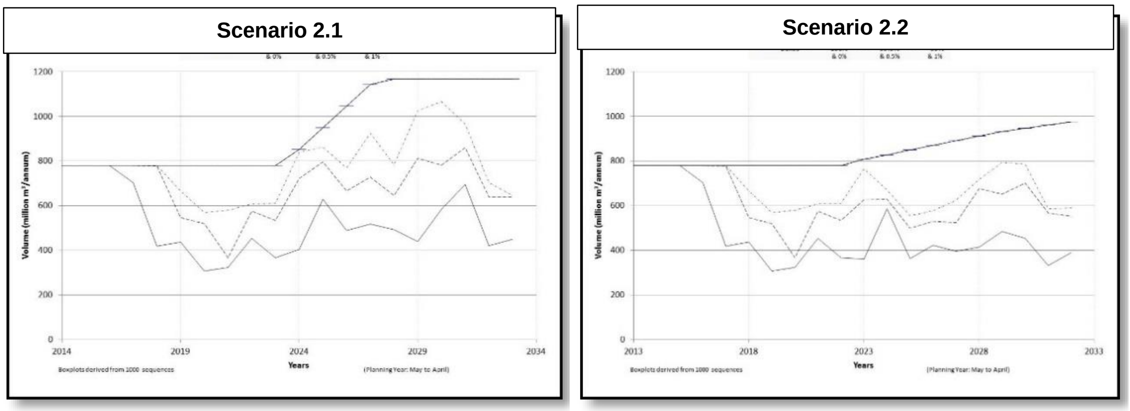

Figure 4-12: LHWP transfer to the Vaal Scenario 2.1 versus 2.2

In **Figure 4.13** the actual transfers as simulated by means of the WRPM as applicable to Scenario 2.2. Due to the priority given to the IVRS transfers it is evident from **Figures 4.13** that the IVRS transfers were provided at higher assurances than the support to the ORP.

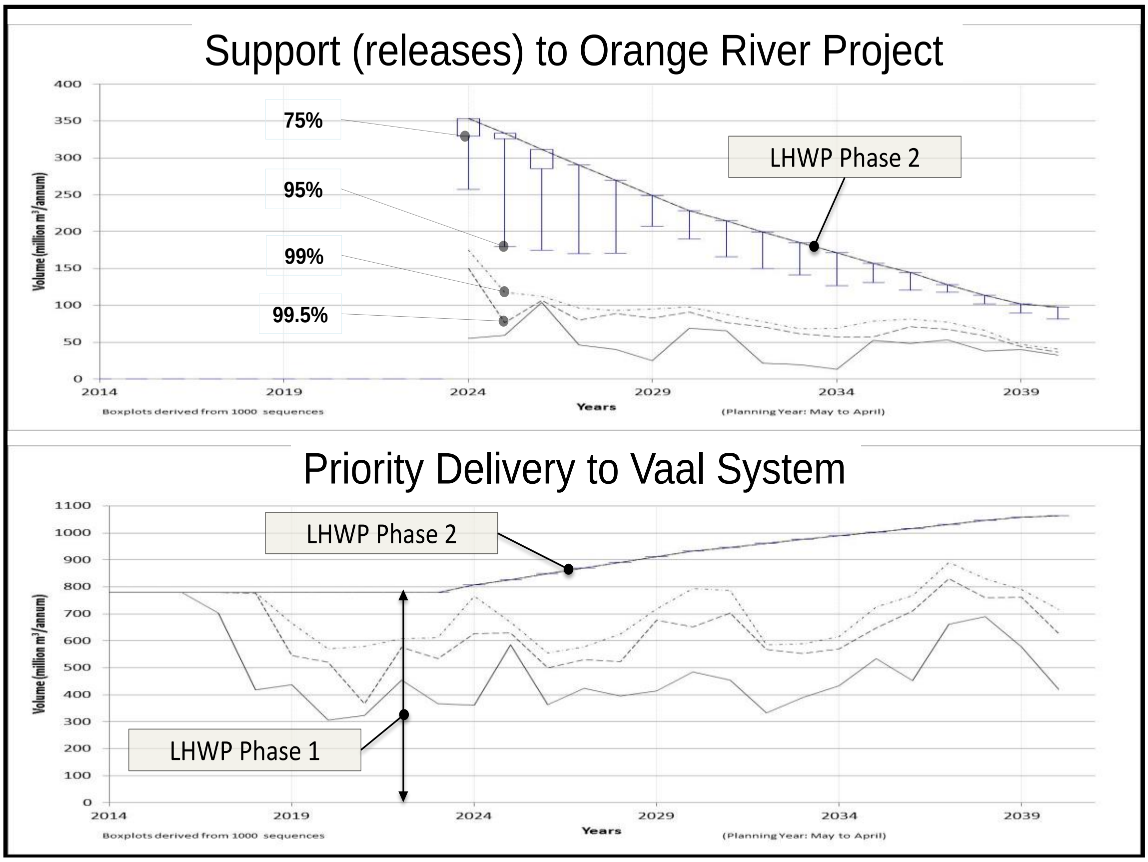

Figure 4-13: Simulated Polihali Dam support to the IVRS and to the ORP

The desired support to the ORP could only be fully met at the 50% assurance (median) level while the IVRS desired transfer was supplied at an assurance of between 95% and 99%. The assurance of the support to the ORP was particularly low during the first 5 years.

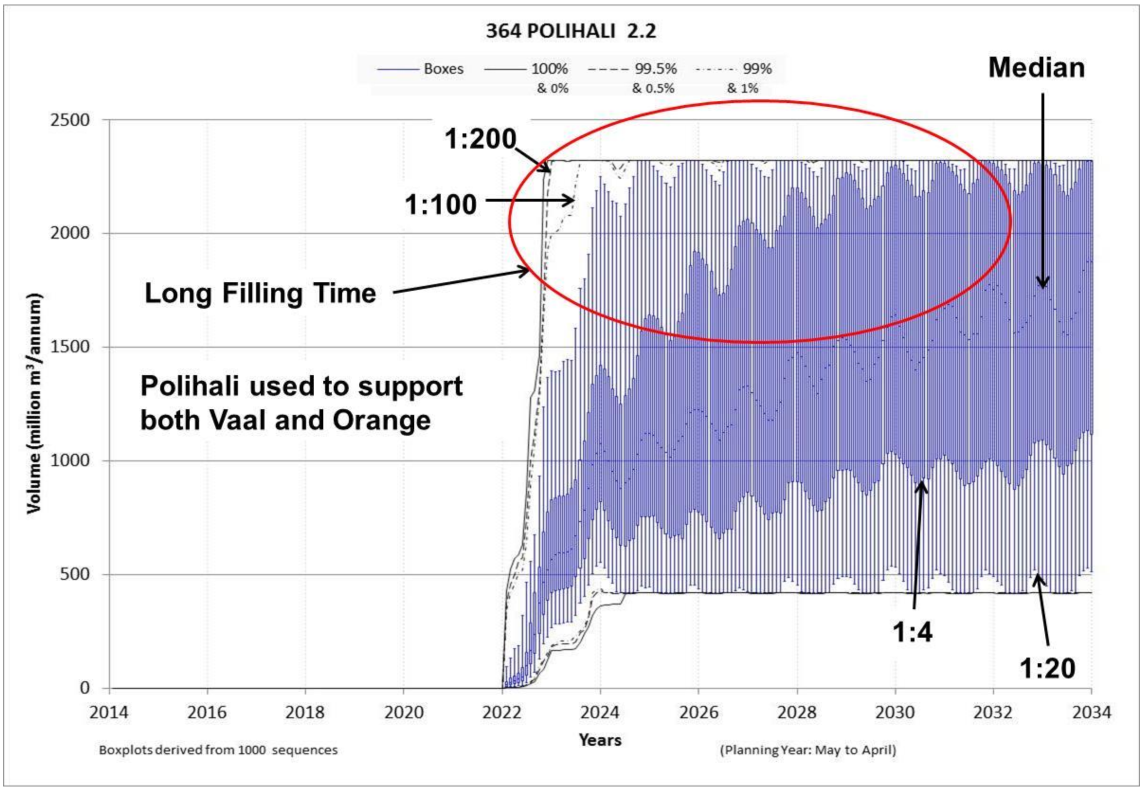

Figure 4-14: Polihali Dam Storage Projection Scenario 2.2

This is as result of the long filling time that is required for Polihali Dam as evident from **Figure 4.14**. For the purpose of this scenario the full transfer requirements were imposed on Polihali Dam from 2024 onwards. The results from this analysis showed that Polihali Dam requires a longer filling time before the full demand can be imposed on the dam.

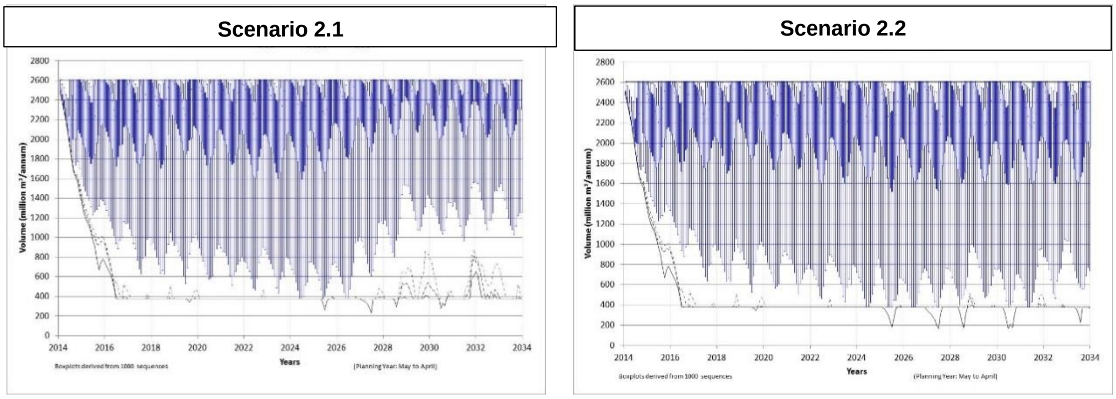

Figure 4-15: Vaal Dam storage Projection Scenario 2.1 versus 2.2

From **Figure 4.15** it is clear that for scenario 2.1 where the full yield from Polihali Dam is transferred to the IVRS two years after the completion of Polihali Dam, resulted in a significant increase in the Vaal Dam storage over time. This will lead to Vaal dam spilling more often and loosing water to Bloemhof Dam. Scenario 2.2 which only transfer the expected shortage in the IVRS over time, resulted in a much more stabilised storage volume over the analysis period, not really affecting the spills from Vaal Dam. The impact of these spills from Vaal Dam is clearly evident from the Bloemhof Dam storage projections for scenario 2.1 and 2.2, see **Figure 4.16**.

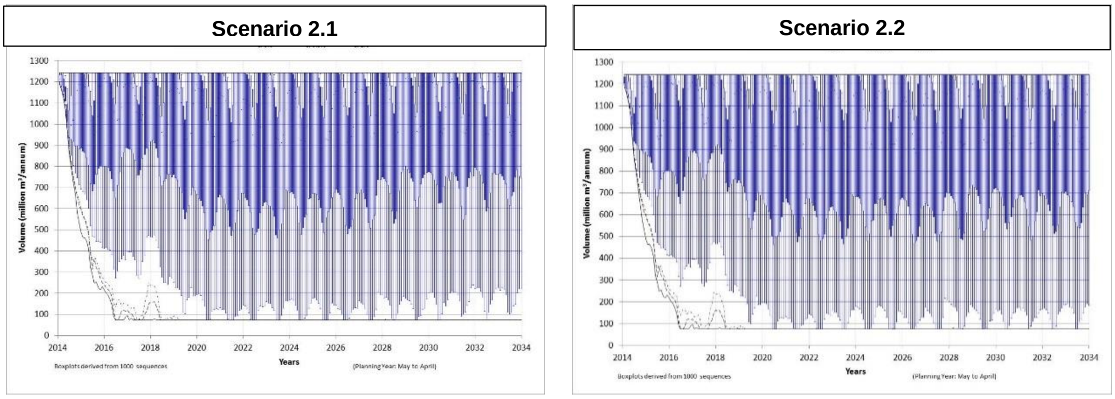

Figure 4-16: Bloemhof Dam Storage Projection Scenario 2.1 versus 2.2

Bloemhof Dam is the last storage dam on the Vaal River and spills from Bloemhof Dam will be lost to the IVRS and users. Similar to the Vaal Dam storage projections, scenario 2.1 also results in much higher storage levels in Bloemhof Dam, than those projected for Scenario 2.2. Due to the excessive spills from Bloemhof Dam the IVRS yield is reduced to such an extent that the IVRS requires the next intervention option after Polihali Dam approximately 14 years earlier than for Scenario 2.2. Utilising the correct operating rule for Polihali Dam is therefore essential. Scenario 2.2 does not represent the optimum operating rule and further refinements will be required.

The storage projection plots for Gariep Dam as given for scenarios 2.1 and 2.2 in **Figure 4.17** show a fairly steep reduction in the storage levels for both scenarios until 2024 and is result of the current above average high storage in the dam, followed by a fairly steep increase in demands until 2021 to accommodate the already allocated irrigation developments for the resource poor farmers. This is the followed by the implementation of Polihali Dam that starts to inundate water by 2022. From 2024 onwards the storage levels in Gariep Dam start to increase again for Scenario 2.2 due to the support from Polihali Dam. The storage levels in Gariep Dam for Scenario 2.1 remain very low from 2024 onwards, indicating that significant deficits will be experienced in the ORP system from 2024.

To provide an indication of the water supply and related assurance obtained from the ORP system for Scenarios 2.1 & 2.2, the supply to the Namakwa water supply system in the Lower Orange was selected and the results prepared for both scenarios. The water supply results applicable to the Namakwa water supply system as obtained from the WRPM analyses for the two scenarios are shown in **Figure 4.17**.

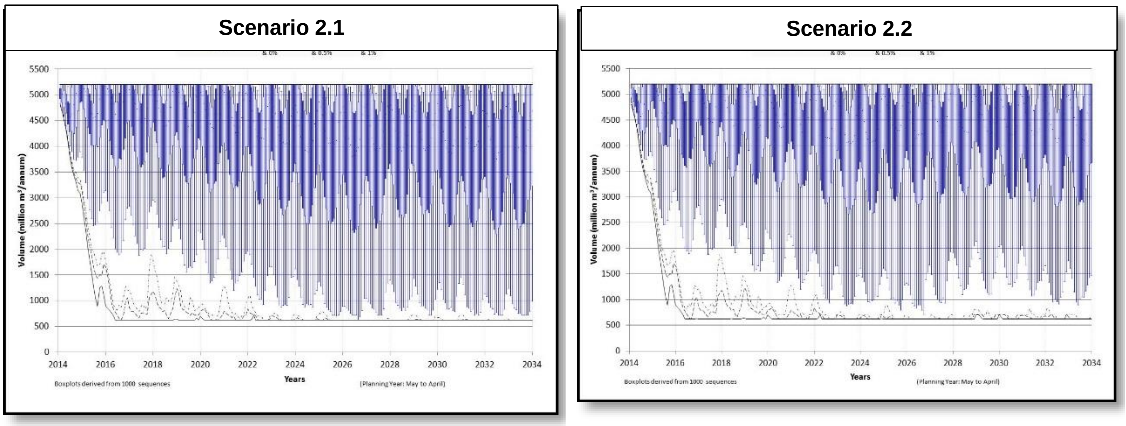

Figure 4-17: Gariep Dam Storage Projection Scenario 2.1 versus 2.2

As explained in Section 4.1.1 the urban/mining demand is subdivided into three priority classes, low, medium and high. The low priority class represent a 95% assurance (deficits 1 in 20 years on average) with 20% of the total urban demand allocated to this priority class. The medium class include 30% of the demand supplied at 99% assurance (1 in 100 year deficit recurrence interval) and the high class include the remaining 50% of the demand supplied at a 99.5% assurance (1 in 200 year deficit recurrence interval).

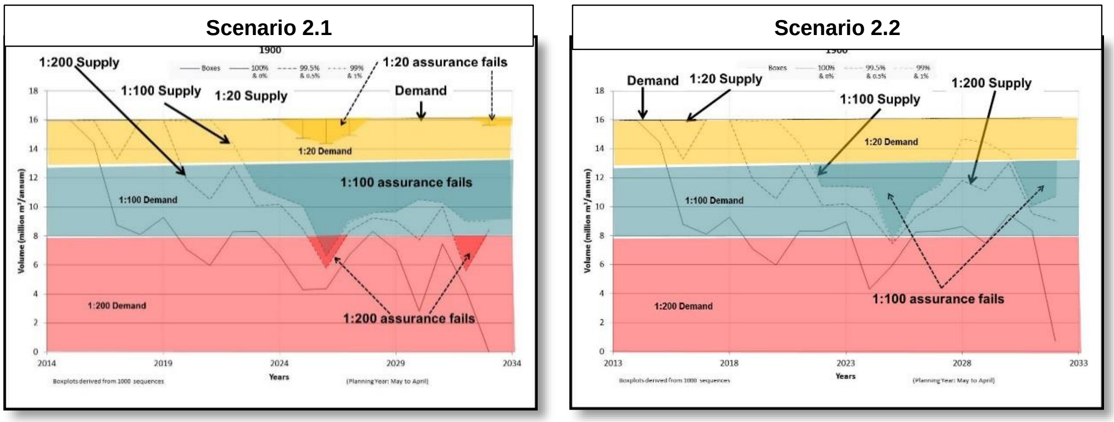

Figure 4-18: Namakwa urban and mining water supply Scenario 2.1 & 2.2

The total demand of 16 million m³/a showing almost no increase over time can be seen in **Figure 4.18** represented by the highest solid line over the analysis period. The area below the demand curve was sub-divided into the three priority classes, with the high priority class shown by the red zone, the medium priority class by the blue zone and low priority class by the light brown zone. The water supply at different assurance levels as obtained from the WRPM analysis is shown by the different lines as indicated on the graph.

The low assurance supply (95% or 1 in 20 year) for Scenario 2.1 was supplied most of the time at the required assurance. Only in 2025 to 2027 and again in 2033 the 95% exceedance probability indicator from the boxplot is visible below the demand line, indicating that during those years the ORP was not able to adhere to the required assurance of 95%. Quite a large portion of the medium (99% or 1 in 100 year) priority class was supplied at a lower assurance than 99% from 2023 onwards as presented by the dotted line. In 2026 and again in 2032 the high assurance requirements were also not fully met, as shown by the dashed line.

For Scenario 2.2 the 95% assurance (1 in 20 year) supply is always equal to the demand imposed on the system, indicating that the system was able to provide the low priority users at the required assurance over the entire simulation period. The maximum volume that could be supplied at a 99% assurance (medium class 1 in 100 year recurrence interval) is shown by the dotted line as indicated on the graph. Between the years 2022 to 2027, and again from 2030 to 2032, the ORP system was not able to supply the medium priority class users at the required 99% assurance (see the darker blue area indicating the failures). The high assurance (99.5%) supply is indicated by the dashed line. The lowest point of the 99.5% line just enters the high assurance component (red zone) of the demand in 2025, indicating a very small failure in the supply of the high assurance demand component, but no failures for the rest of the years. For practical purposes one can accept that the high assurance component of the demand was supplied at its required assurance (99.5%) over the entire simulation period for Scenario 2.2.

Conclusions and recommendations derived from the WRPM analysis results for scenarios 2.1 and 2.2 include the following:

- The operating rule used to govern the transfers from Polihali to the IVRS as well as the support to the ORP, significantly impacts on the water availability in both the IVRS and the ORP system.
- The operating rule as used in the scenario 2.2 analyses, do not present the optimum operating rule and further analysis are required to obtain the most viable rule to be used in future which need to be agreed upon by the RSA and Lesotho governments.
- Using Polihali Dam to initially support both the IVRS and the ORP system, significantly postpone the need of a yield replacement dam in the Orange. This will result in a significant economic advantage without negative impacts on the assurance of supply to the IVRS.
- Polihali Dam requires a longer filling time, combined with a more gradual increase in the demand imposed on the dam over the initial years. Further analyses are required to obtain the best solution in this regard. These analyses should form part of the refinement of the operating rule.
- Obtaining support from Polihali Dam will not fully cover the deficits experienced in the ORP and other interventions options such as real time monitoring, utilising the lower level storage in Vanderkloof Dam and WC/WDM also need to be implemented.

4.1.4 Analyse the impact of Updated EWRs (Scenario 3.1, 4.1 & 5.1)

Scenario 3 used the WRPM setup of Scenario 2.2 as the base data set. The current river mouth EWR of 288 million m³/a formed part of the Scenario 2.2 setup. In the ORASECOM Study "Support to Phase 2 of the ORASECOM Basin-wide Integrated Water Resources Management Plan" (ORASECOM, 2011a) the environmental flow requirements (EWR) was assessed at selected key areas of the Orange River Basin at an Intermediate Level. Previous WRYM analysis showed that the EWR at the Augrabies site was the main driver of the EWRs downstream of Vanderkloof Dam. These WRYM results showed a reduction in the ORP yield of 478 million m³/a when the PES (Present Ecological State) EWR from the ORSECOM study was imposed on the system.

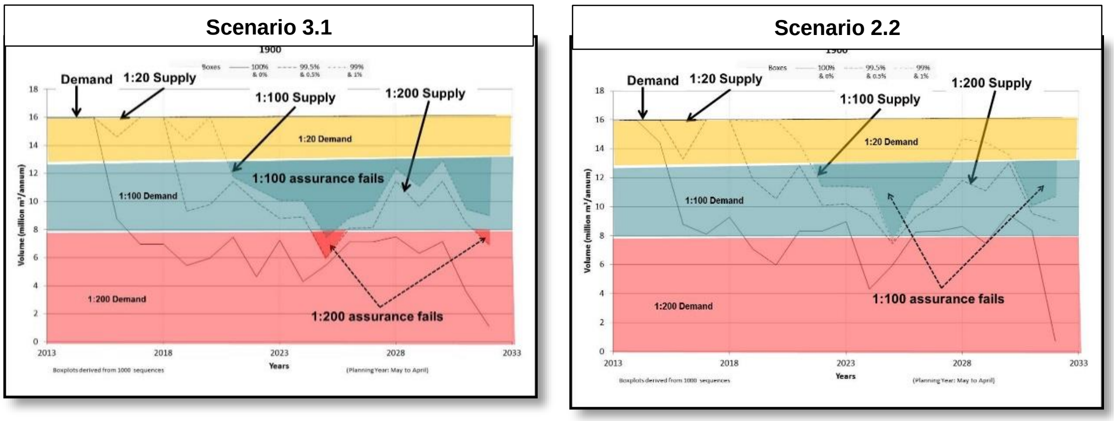

Figure 4-19: Namakwa urban and mining water supply Scenario 3.1 & 2.2

The yield impact due to the current implemented River Mouth EWR in comparison with the updated EWR from the ORASECOM study, showed an increased reduction of 478 – 288 = 190 million m³/a on the ORP system yield, which is not too severe when bearing in mind that the total ORP yield is 3 252 million m³/annum. This impact is also evident from the reduction in the assurance of supply when comparing the supply to the Namakwa Scheme for the two scenarios as illustrated in **Figure 4.19**. The impact on all demands supported from the ORP is very similar due to the operating rule currently used for this system designed to supply all the users at their required assurance.

Scenario 4.1 is as Scenario 3.1 with only difference being that Recommended (REC) EWRs were imposed on the ORP instead of the PEC EWRs. Analysis using the WRYM to determine the impact of the REC EWRs on the ORP system yield showed a significant reduction in the ORP Yield of 1 060 million m³/a. This means an increased reduction in yield of 1060 – 288 = 772 million m³/a, which is quite excessive.

By comparing the storage projections of Gariep Dam (**Figure 4.20**) for Scenario 2.2 (the current EWRs in place) with that from Scenario 4.1 with the updated REC EWRs in place, it is clear that Gariep Dam is overloaded and is frequently dropping to its minimum operating level. This is also evident from the supply assurance to the users supported from the ORP as shown in **Figure 4.21** where the water supply to the Namakawa scheme is given as a typical example. The impact on water availability in the ORP is very severe when the updated REC EWRs are imposed on the system as evident from **Figure 4.21**. Deficits are already experienced from 2017 onwards.

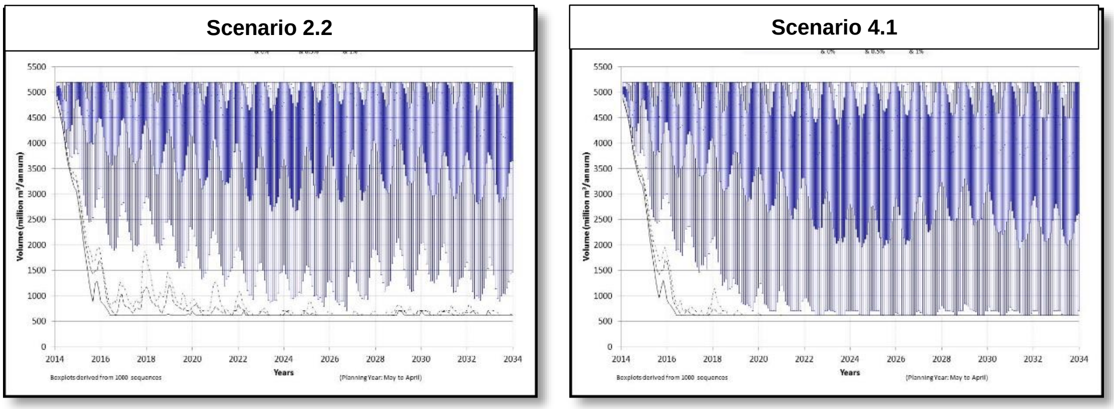

Figure 4-20: Gariep Dam storage projections for Scenario 4.1 & 2.2

For scenario 4.1 the ORP is unable to meet the supply assurances in all three the priority classes for most of the analysis period. At the time when Polihali Dam is implemented (2022) the deficits significantly increase even with Polihali Dam being used in this scenario to support both the IVRS and the ORP.

When comparing Scenario 4.1 supply result (**Figure 4.21**) with that from Scenario 2.1 (**Figure 4.18** it is clear that the inclusion of the updated REC EWRs, impacts more severely on the water availability in the ORP system, than when Polihali Dam is not used support the ORP.

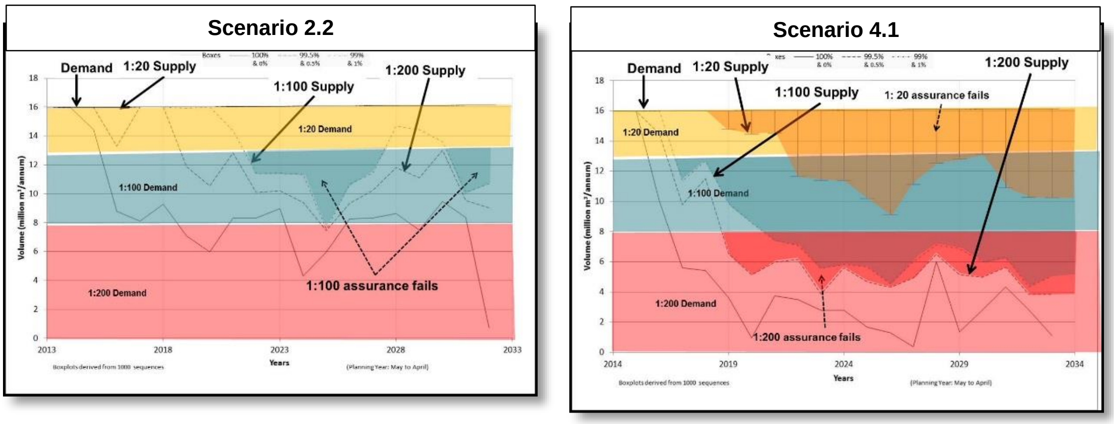

Figure 4-21: Namakwa urban and mining water supply Scenario 4.1 & 2.2

Scenario 5.1 is as Scenario 4.1 but included refinements on the REC EWRs at Augrabies and downstream. The ORASECOM Phase 2 EWR related work did not provide information on the river mouth environmental requirements or the EWRs applicable to the Fish River in Namibia. ORASECOM therefore introduced a follow up study (ORASECOM, 2012) focusing on these specific requirements. This follow up study provided valuable information on the EWRs on the main Lower Orange River, the Namibia Fish River and the Orange River mouth environmental requirements. Scenario analyses carried out as part of the follow up ORASECOM study showed that too much flows during the dry seasons were reaching the Orange River estuary, preventing the river mouth to close during the winter. To be able to provide the estuary team with a flow scenario which met their estuary criteria, the EWR at site 5 on the Lower Orange was manipulated in order to provide the required low flows. This manipulation entailed shifting excess low flow into a period of floods until the desired duration curves were achieved. To avoid too much low flows from the Augrabies site reaching EWR 5, the Augrabies winter flow EWRs were set to zero, thus only requesting flows during the summer months. It seemed that the winter month releases from Vanderkloof Dam to supply irrigation and river losses along the lower Orange was sufficient for the dry seasons EWRs.

For the purpose of Scenario 5.1 the updated and refined REC EWRs where included so that the EWR requirements at the Orange River estuary are addressed in the correct manner.

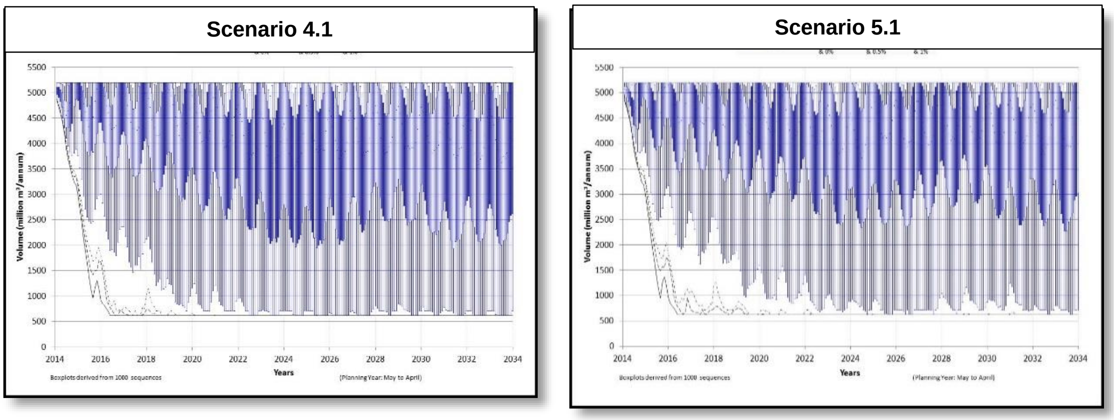

Figure 4-22: Gariep Dam Storage projection for Scenario 4.1 & 5.1

From **Figure 4.22** and **4.23** it is evident that the updated EWR refinements not only improved the supply to the estuary EWR requirements, but also resulted in an improved performance of Gariep Dam as well as a significant improvement in the assurance of supply to the users downstream of Gariep and Vanderkloof dams.

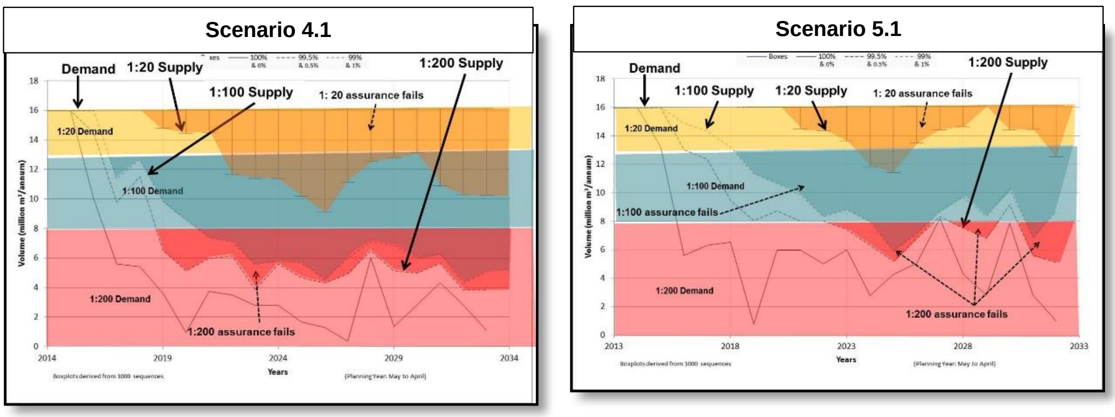

Figure 4-23: Namakwa urban and mining water supply Scenario 4.1 & 5.1

The improved water supply and related Gariep Dam storage improvement were confirmed by the yield analysis carried out where only summer EWR flows were requested at the Augrabies site. This reduced the impact of the EWR on the system yield to 722 million m³/a (net reduction 722 – 288 = 434 million m³/a) which is significantly lower than the initial net reduction of 772 million m³/a. The above mentioned refinements were only done for the option with the updated REC EWRs in place.

Conclusions and recommendations derived from the WRPM analysis results of scenarios 3.1, 4.1 and 5.1 include the following:

- The impact of the PES EWRs on the ORP is not too severe and can be reduced further when it's refined in a similar manner as the refinement already done for the REC EWRs in combination with the river mouth EWR.
- The impact of the REC EWRs are very severe but could be reduced considerably as result of the refinements done as part of the follow up ORASECOM EWR study, which included the estuary and Namibia Fish River EWRs.
- The impact on the water supply assurance from the ORP with the refined REC EWRs in place is still severe and will lead to significant economic implications on the entire ORP supply area.
- It is recommended that a study be initiated to find a balance between the EWR and socio economic impacts. In the RSA these types of studies is referred to as a Classification Study with the aim to obtain agreement on the EWR classes that should be implemented in different areas of the basin, and to derive the final refined and agreed EWRs. These agreed EWRs are referred to as the Reserve, which will finally be implemented and need to be adhered to according to law. The flows in the Orange River do not only effect the users in the RSA, and it will therefore be important to include all four the basin states in the process to derive at the final agreed EWRs as well as to decide on the implementation time frame.
- From the analyses results it is clear that additional intervention options will be required to maintain a positive water balance within the ORP system when the updated EWRs from the ORASECOM study are phased in. The intervention options already mentioned in **Section 4.1.3** might not be sufficient and high yielding intervention options such as the raising of Gariep Dam or the construction of another dam in the Orange upstream of Gariep Dam will most probably be required to provide sufficient yield for the increased demand load on the ORP system.
- It is currently very difficult to control the flow at the estuary by means of releases from Vanderkloof Dam over the distance of 1380 km, in combination with large abstraction along the entire river and with significant variations in the climatic conditions from time to time. To achieve the required EWR flow rates at the estuary to an acceptable level of accuracy for environmental purposes will be impossible to achieve by releases from Vanderkloof Dam. Several previous studies recommended a storage and re-reregulation dam at Vioolsdrift on the Lower Orange. The main purpose of this dam was considered to be the reduction of the operating losses in the ORP system due to the long distance of control as well as to increase the system yield for future irrigation developments along the Lower Orange, specifically for Namibia. The location of the Vioolsdrift Dam is however ideal for the proper control of releases for the purpose of supplying the river mouth EWR, as it is located fairly close to the river mouth. With a dam at Vioolsdrift it will also be possible to utilise flows from the Namibia Fish River from time to time when sporadic flows from the Fish River do enter the Orange downstream of Vioolsdrift Dam.

4.1.5 Intervention options to increase the ORP system Yield - Scenario 4.2 & 4.3

The WRPM results from scenarios 2.2, 3.1 and 4.1 all showed that additional interventions are required in future to be able to maintain positive water balance, specifically within the ORP. The interventions already included for the IVRS with the last intervention being LHWP Phase II will be able to maintain a positive water balance in the IVRS to beyond 2040.

The preliminary strategy derived from the study "Water of Reconciliation Strategies for Large Bulk Water Supply Systems: Orange River" (DWA, 2013), recommended the raising of Gariep dam by 10m as one of the most viable options to increase the ORP system yield in future. Gariep Dam was originally designed to be raised at a later time. For the purposes of Scenario 4.2 the Raised Gariep option as well as Vioolsdrif storage/reregulating dam was included as additional intervention options over and above those already included in Scenario 4.1.

Raising Gariep Dam by 10m significantly increases the storage in Gariep by 4 700 million m^3, to almost double the current gross storage 5 198 million m^3 (net 4 575 million m^3). WRYM yield analyses gave an expected increase in the ORP yield of 350 million m^3/a when Gariep is raised by 10m. The 10m raising of Gariep Dam significantly increases the surface area at full supply capacity from the existing 344.4 km^2 to 552.8 km^2 which resulted in an increase in the average evaporation losses from Gariep Dam of 280 million m^3/a. This will result in reduced spills from Gariep and Vanderkloof dams, followed by reduced water availability for environmental purposes and a possible reduction in the yield generated from Vioolsdrift Dam.

It is estimated that Vioolsdrift Dam will be able to reduce the operating losses by approximately 120 million m^3/a, and also increases the system yield by another 190 million m^3/a. The total benefit from Vioolsdrift Dam is thus 190 + 120 = 310 million m^3/a.

The significant increase in storage due to the 10m raising of Gariep Dam is clearly illustrated in **Figure 4.24**. Although to a lesser extent than for Scenario 4.1, the combined storage projection (raised Gariep + Vanderkloof) levels for the high exceedance probabilities, still drop to the m.o.l. on a frequent basis, showing that even with the raising of Gariep Dam and the inclusion of Vioolsdrift dam, shortages in supply will still be experienced in the ORP system. This is confirmed when evaluating the assurance of supply to one of the users from the ORP (Namakwa urban supply sub-system) as shown in **Figure 4.25**. Although the raising of Gariep in combination with Vioolsdrift Dam did improve the assurance of supply as evident when comparing the results from Scenario 4.1 with those from Scenario 4.2 in **Figure 4.25**, the assurance of supply is still violated within all three the different assurance classes, low, medium and high.

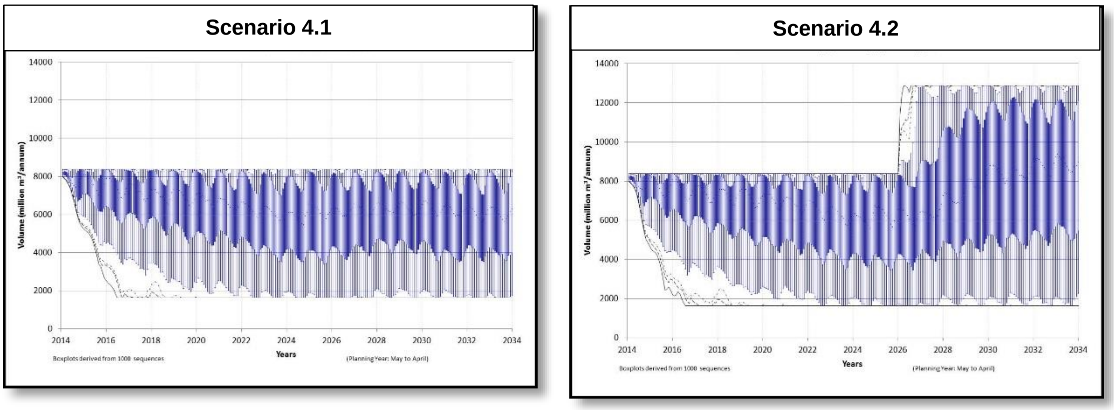

Figure 4-24: Combined Gariep and Vanderkloof Storage projection for Scenario 4.1 & 4.2

In **Section 4.1.4** it was shown that the refined updated REC EWRs had a significantly lesser impact on the ORP system than the updated REC EWR before the refinements were introduced (See **Figure 4.23**).

Scenario 4.3 was then defined in addition to Scenario 4.2 and included the refined REC EWRs instead of the original updated EWRs developed in Phase 2 of the ORASECOM Basin-wide Integrated Water Resources Management Plan study (ORASECOM, 2011a).

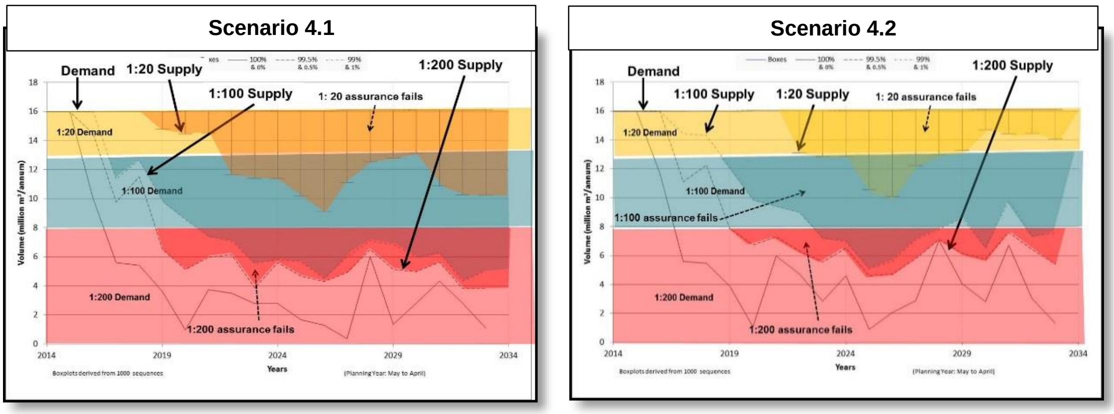

Figure 4-25: Namakwa urban and mining water supply Scenario 4.1 & 4.2

The significant improvement in the storage levels is clearly evident when comparing the storage projection of the combined Gariep and Vanderkloof storage given in **Figure 4.26.** This in turn resulted in the highly improved assurance of supply to the users within the ORP systems shown in **Figure 4.27**.

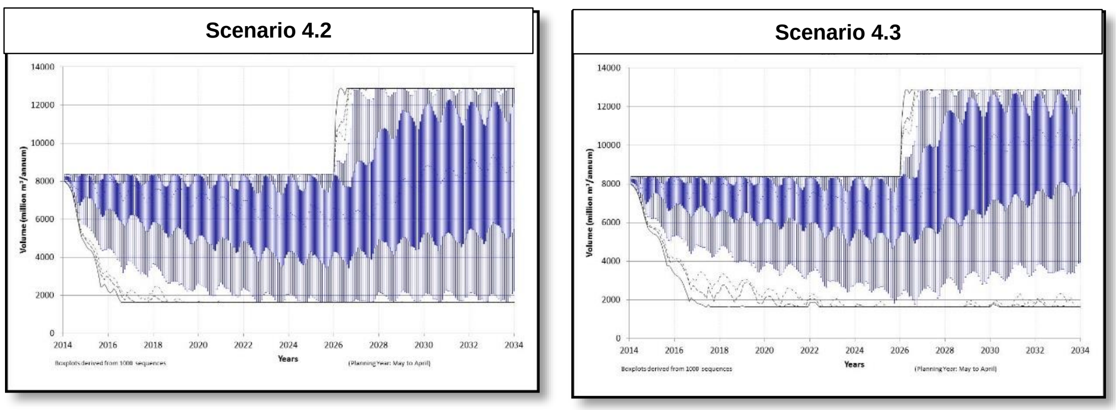

Figure 4-26: Combined Gariep and Vanderkloof Storage projection for Scenario 4.2 & 4.3

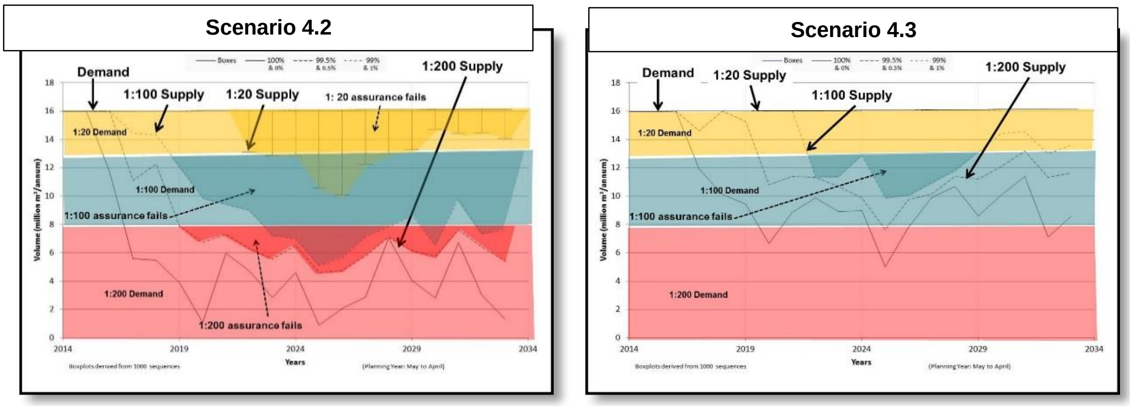

Figure 4-27: Namakwa urban and mining water supply Scenario 4.2 & 4.3

These results illustrate the benefits that can be achieved by applying some changes or refinements to the REC EWRs, which were in this case mainly aimed at improving the EWR supply to the estuary.

Scenarios 4.1, 4.2 and 4.3 addresses impacts on the Orange River as results of different Orange River related intervention options. These changes will not impact on the IVRS as evident from the Vaal Dam storage projections plots for scenarios 2.2 and 4.3 given in **Figure 4.28**.

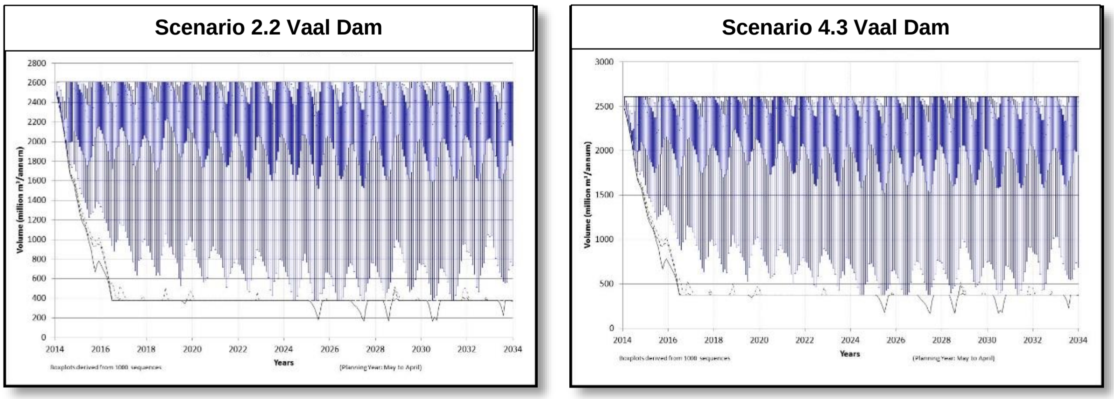

Figure 4-28: Vaal Dam Storage projection for Scenario 2.2 & 4.3

The storage projection plots for the Vaal Dam and Vaal system as obtained from Scenario 4.3 is shown in Figure 4.29. It is important to note that the Vaal system storage follow a much higher storage projection than that evident from Vaal Dam alone. This is due to the operating rule that keep the water in Sterkfontein Dam for as long as possible, resulting in low storage levels in Vaal Dam and corresponding lower evaporation losses from Vaal Dam and the Vaal system as a whole.

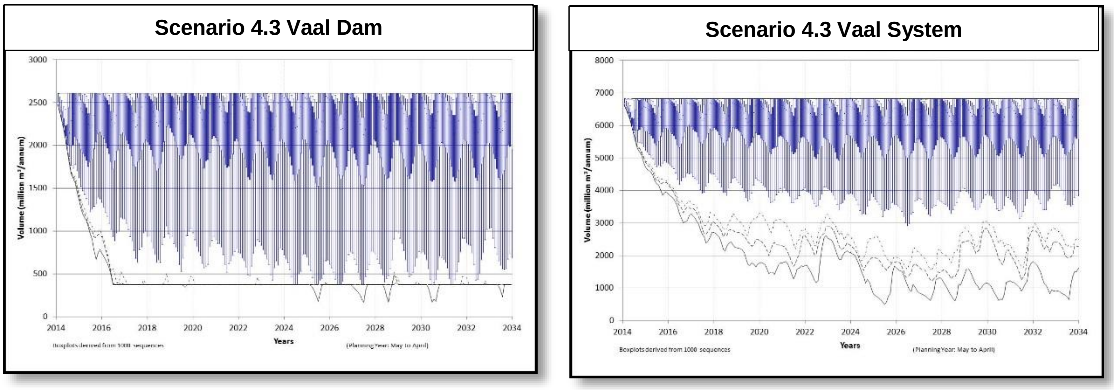

Figure 4-29: Vaal Dam and Vaal System Storage projection for Scenario 4.3

4.2 Water Resource Yield Model Analysis

4.2.1 Orange River Project – Yield Impact due to Sedimentation

A detail description of the yield analyses carried out for the Orange River project (ORP) is given in the Yield Report "Water Resources Modelling; Base Scenario, Yield Analysis, Stochastic Verification and Validation" produced as part of this study.

The water resources of the Orange River project (ORP) are Gariep and Vanderkloof dams. The yield analysis carried out for the ORP base scenario represented the current conditions and related developments as briefly described below:

- The full transfer to the Vaal is imposed on Katse and Mohale dams, and these dams are not used to support the Orange River Project. Only the agreed environmental requirements are released from these two dams.
- All upstream demands were set at 2013 development level, except for the Bloemfontein urban area, which was set at a 2023 development level and the infrastructure capacity constraints were removed from the Caledon/Modder transfers. This was so that the Bloemfontein demand could be fully supplied before the outflows from the Caledon system enters Gariep Dam, which will result in a more conservative yield for ORP.
- An additional future demand was placed on the Metolong Dam, and the dam was switched on in the analysis.

Results from the ORP Base Scenario are given in the ORASECOM Phase lll Yield Report and reported the Historic Firm Yield of the ORP as 3 252 million m^3/annum.

Extensive work on sedimentation was previously carried out as part of the Orange River Development Project Replanning Study and documented in the report "Sedimentation of the reservoirs in the Orange River Basin". Recorded catchment sediment yields were obtained for Gariep and Vanderkloof dams and were 367,9 t/km^2/a, 128 t/km^2/a respectively. The trap efficiencies for both the Gariep and Vanderkloof dams are, due to their capacities and MAR's assumed to be 98 %.

Based on the information given in the Orange Replanning Study report (DWAF, 1996), it was estimated that the storage in Gariep Dam will reduce with 220 million m^3/a by 2040 and that for Vanderkloof Dam by 40 million m^3. The impact of sedimentation on Vanderkloof Dam is much less as most of the sediment is trapped in Gariep Dam, with a relative small incremental catchment between the two dams that will contribute very little to sedimentation in Vabderkloof Dam. The reduction in storage capacity at both dams resulted in a reduction in yield of only 22 million m^3/a. The impact on the yield is thus very small and is less than 0.7% of the current yield from the system.

4.2.2 Caledon River – Impact due to Sedimentation

The Caledon River is well known for its high sediment loads and related impacts. Welbedacht Dam is the only major dam located on the mainstream with its current storage of approximately 6 million m^3/a in comparison with its original capacity of 115 million m^3. The silt build up in the dam is near equilibrium and measures are currently being put in place to slightly increase the storage capacity. The Welbedacht sub-system yield is for many years already based on the reduced system yield using the current storage capacity. Although sedimentation in his river is a major concern, further reduction in the Welbedacht sub-system yield is not expected due to siltation. The sediment from the Caledon is now mainly impacting on Gariep Dam as described in **Section 4.2.1.**

4.2.3 LHWP Storage and sedimentation

The dead storage in the Katse and Mohali dams is 430 million m^3 and 90 million m^3 respectively. Sedimentation rates in these catchments is much lower than that experienced in the Caledon and no significant impact on the LHWP system yield is expected as result of sedimentation.

4.2.4 Vaal River System – Sedimentation Impacts

Reduction in the IVRS yield due to sedimentation is not regarded as a problem in the Vaal system and was not addressed in any of the recent studies, including the recently completed IVRS reconciliation Strategy study.

4.2.5 Neckartal Dam - Impact of sedimentation

Yield results for Neckartal Dam were for the first time determined with the updated hydrology as part of this study. The historic firm yield with the recommended EWR from the ORASECOM study imposed on the dam, was estimated as 97.5 million m^3/a for Neckartal Dam with a full supply level of 787.5 m.a.s.l. and gross storage of 857 million m^3.

The Neckartal Dam design reports stated an expected reduction in storage due to sedimentation over 50 years of 117 million m^3. This relates to a sedimentation rate of 100t/km^2/a and a 100% trap efficiency due to the size of Neckartal Dam (2.5 MAR dam). For the purpose of the yield analysis the dead storage of 16.2 million m^3 in Neckartal was increased to 130 million m^3 to accommodate the sediment volume after 50 years.

The historic firm yield reduced from the 97.5 million m^3/a to 77.5 million m^3/a, representing an almost 21% reduction in yield, which is quite significant.

4.3 Selected Core Scenario

The Core Scenario as described in **Section 3.3** represents the most likely developments expected to occur in the basin over the next 10 to 15 years. The trail scenarios and related results as discussed in **Sections 4.1** and **4.2** in combination with the information from the recently completed reconciliation strategy studies were all used to provide inputs to the final definition of the core Scenario.

The Core Scenario will form the basis for WRPM setup that will be the master tool to evaluate the future developments and possible deviations from the expected IWRMP developments, as well as the related impacts of these deviations the Orange-Senqu Basin over the next 10 years.

The description of the Core Scenario states that the raising of Gariep Dam and the construction of Verbeeldingskraal Dam is mutually exclusive intervention options. More detailed work will be required before a final recommendation can be made towards the more viable of the two options. The selected Core Scenario (Scenario 7) therefore addresses both these possible alternatives. Scenario 7.1 considers the Raised Gariep Dam and Scenario 7.2 the possible Verbeeldingskraal Dam.

Scenario 4.2 clearly showed that Vioolsdrift Dam and the raising of Gariep Dam was not sufficient to address the shortages within the ORP system and several other intervention options were added to obtain an acceptable water balance as reflected by Core Scenario 7a. Scenario 4.3 results revealed a significant improvement in the water supply to the ORP users when the refined updated REC EWR is used in the Lower Orange. The intervention options and changes made to Scenario 4.2 to obtain the Core Scenario included the following:

- Real Time modelling and monitoring in the Lower Vaal downstream of Bloemhof Dam and in the Orange River downstream of Vanderkloof Dam to the Orange River mouth.
- Utilise the lower level storage in Vanderkloof Dam from May 2021 onwards.
- WC/WDM.
- Updated and refined Lower Orange EWRs.

4.3.1 Core Scenario Results - IVRS

This section will focus on results from the Core Scenario with the emphasis on the IVRS. All the expected future intervention options related to the IVRS were included from Scenario 2.1 onwards. The water supply and related water balances for the IVRS for all the scenarios analysed from Scenario 2.1 onwards will be fairly similar, showing a positive water balance for the IVRS as indicated in **Figures 4.15, 4.28** & **4.29**.

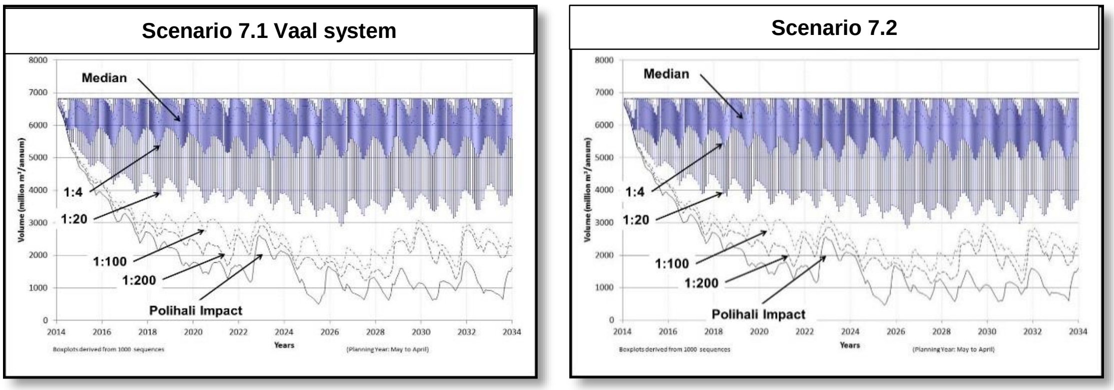

Figure 4-30: Vaal System Storage projection for Scenario 7.1 & 7.2

The Vaal System storage projections for both scenarios 7.1 and 7.2 are the same, as the changes in the Upper Orange are not impacting on the IVRS. This is further confirmed when comparing the Vaal system storage projection as given in **Figure 4.30** with that from **Figure 4.29** for Scenario 4.3 which is almost identical.

A simplified water balance for the IVRS as achieved by both Core Scenarios 7.1 and 7.2 is given in **Figure 4.31**. The importance of desalination of the AMD water was already indicated by the results from Scenario 1.1 in **Section 4.1.2**. In **Figure 4.31** it is clear that the desalination in fact restores the Vaal System yield back to the approximately 3 000 million m^3/a as before 2014.

When the eradication of unlawful use as well as the implementation of WC/WDM were both successfully introduced and managed according the given Vaal System reconciliation strategy, the demand projection is expected to follow the green line as indicated in **Figure 4.31**. Under these conditions and in combination with the desalination of the AMD water, the first transfers from Polihali Dam (LHWP Phase II) will only be required from 2022 onwards.

With all these intervention options in place it is expected that the IVRS will be in balance until approximately 2050. The IVRS curtailment plot as given in **Figure 4.32** does indicate some small deficits that can be expected at the 99.5% assurance (1 in 100 year). This is as result of Polihali dam being used to support both the Orange and the Vaal. The operating rule used to govern the dual support is not the optimum rule and requires more detailed analyses to develop and refine the Polihali operating rule so that the IVRS will not experience any deficits.

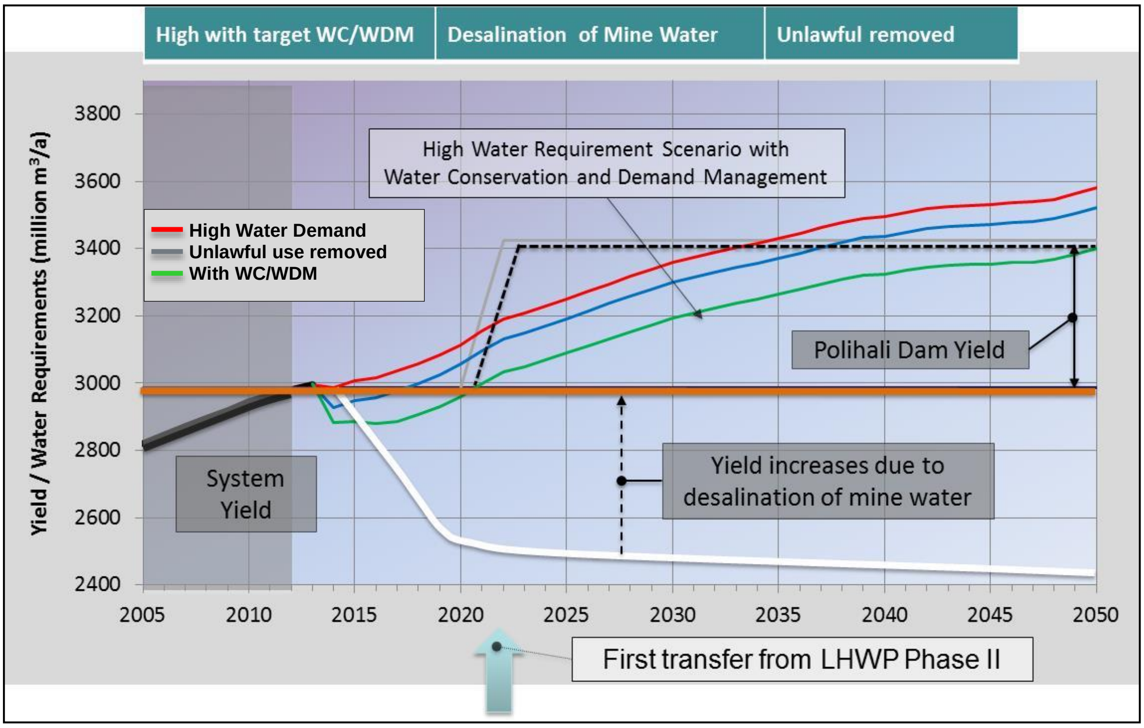

Figure 4-31: The Integrated Vaal system Water balance using high demand projection with WC/WDM, the removal of unlawful irrigation and desalination of the AMD water.

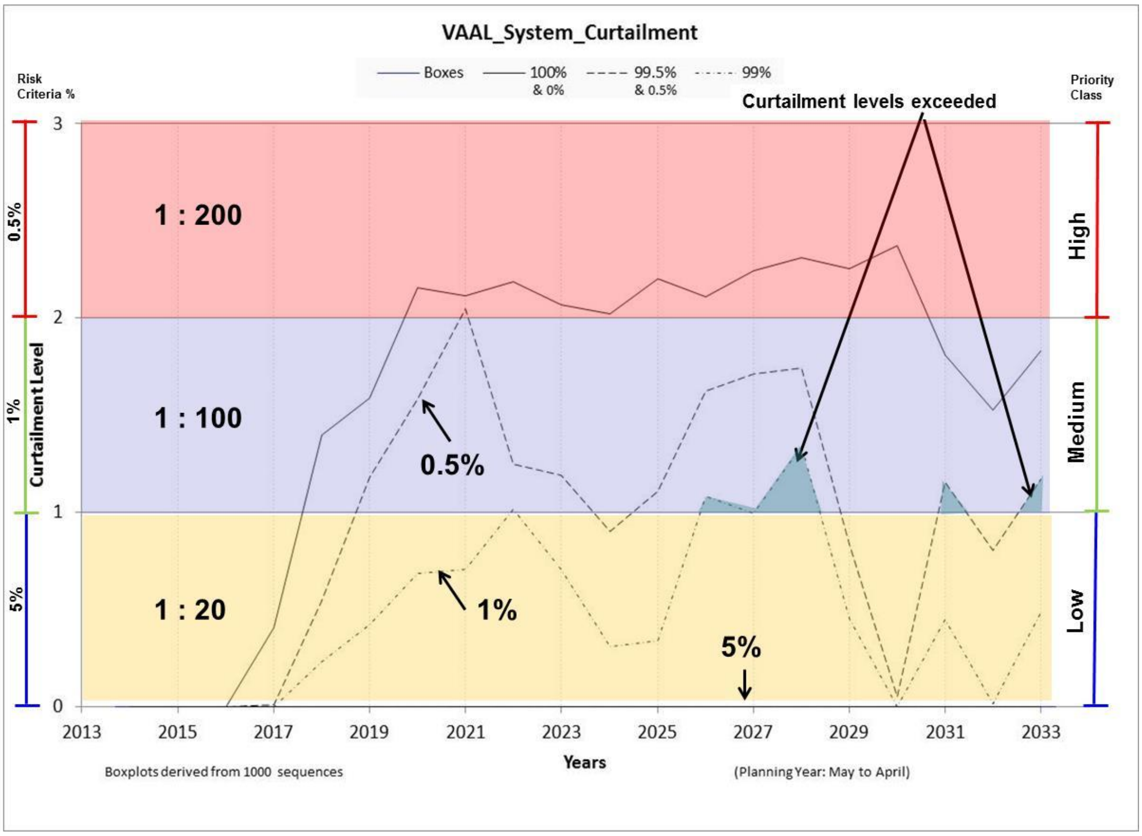

Figure 4-32: Vaal System Curtailment Plot for Scenario 7.1 & 7.2

For the purpose of both Core Scenarios a first order average operating rule was used to control the transfers in support of the IVRS and the support to the Orange River. Significantly more work need to be carried out to obtain the desired operating rule, which also need to be agreed upon by both Lesotho and the RSA.

From the Polihali Storage projection plot it is clear that Polihali Dam requires a long filling time, which need to be taken into account when the final operating rule is developed. This is clearly one of the reasons why the IVRS curtailment plot is showing some violations regarding the assurance of supply to the IVRS users. The LHWP storage increase significantly when Polihali Dam is activated as it reaches a gross storage of over 5 000 million m³ total storage.

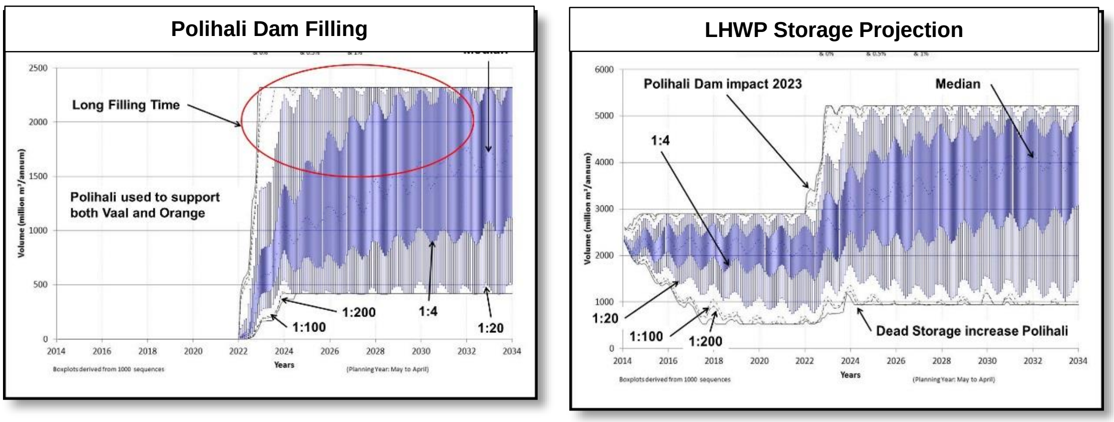

Figure 4-33: Polihali Dam and LHWP Storage projections for Scenarios 7.1 & 7.2

4.3.2 Core Scenario Results – Greater Bloemfontein System

The Greater Bloemfontein system is used to support the Bloemfontein and Botshabelo urban demand centres as well as several other towns such as Thaba N'chu, Wepener, Dewetsdorp, Reddersburg, Edenburg, and Excelsior (See **Figure 4.34**). This water supply system utilise water from two sub-systems, the Modder River sub-system and the Caledon River sub-system. The water resources of the Caledon sub-system are a combination of Knellpoort and Welbedacht Dams. Knellpoort Dam is an off channel storage and is supplied with water from the Caledon River through the Tienfontein Pump Station. Water is transferred from Knellpoort Dam through the Novo transfer scheme to Rustfontein Dam in the Modder catchment. Water from Welbedacht Dam is transfered directly to Bloemfontein and small towns via a pipeline. Mockes Dam is located on the Modder River and supplies water to Bloemfontein via the Maselspoort WTW and is supported by releases from Rustfontein Dam when required. Knellpoort and Rustfontein dams are the two largest storage dams representing almost 92% of the system storage, with storage capacities of 136 million m³ and 71 million m³ respectively. Welbedacht Dam is almost silted up and is currently more a diversion weir than a storage dam.

The Baseline scenarios showed that severe shortages (**Figure 4.3 Section 4.1.1**) were already experienced in 2015 and then started to reduce until 2018 where after the deficits started to increase again. The initial severe deficits are due to the low storage in the main storage dams at the start of the analysis. The baseline scenario included only two of the intervention options that were identified from the Greater Bloemfontein Reconciliation Strategy Study (DWA, 2012) and is the reason why the baseline scenario again showed increasing deficits from 2018 onwards. The Greater Bloemfontein System water balance as prepared from the Reconciliation Strategy Study is shown in **Figure 4.35** below.

The Core Scenarios both included all the above intervention options except the re-use of return flows and the support from Gariep which is a very expensive option.

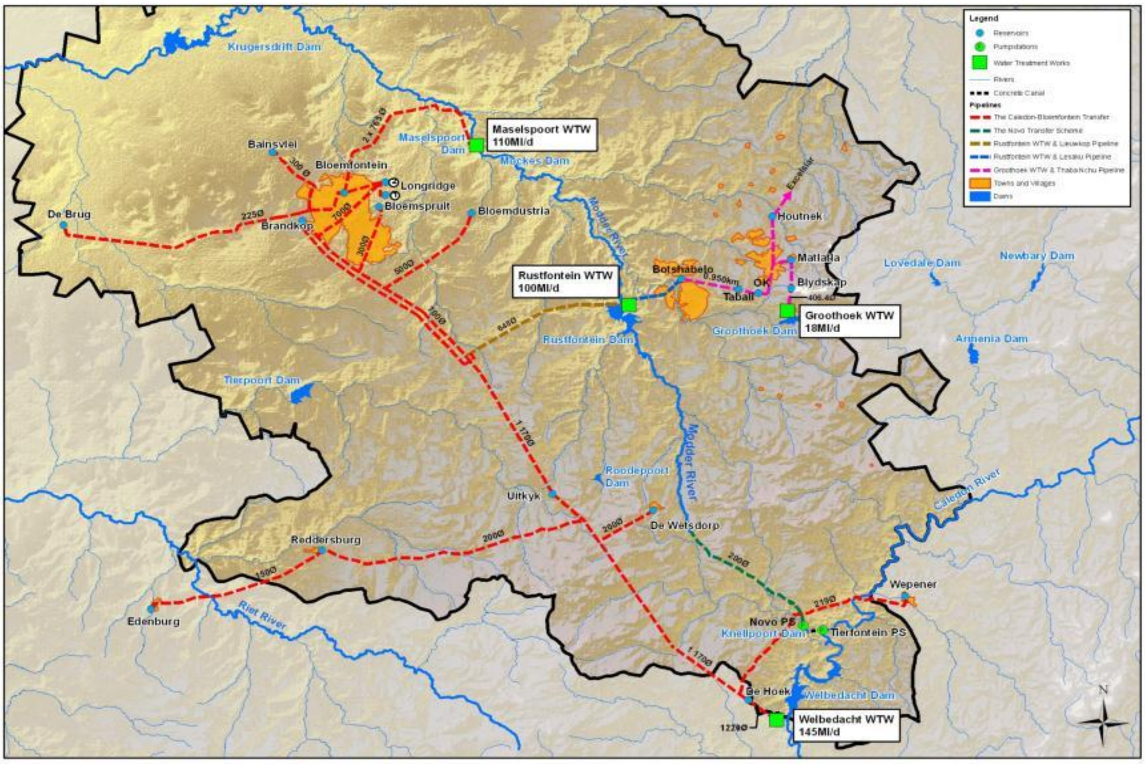

Figure 4-34: Greater Bloemfontein Water Supply System

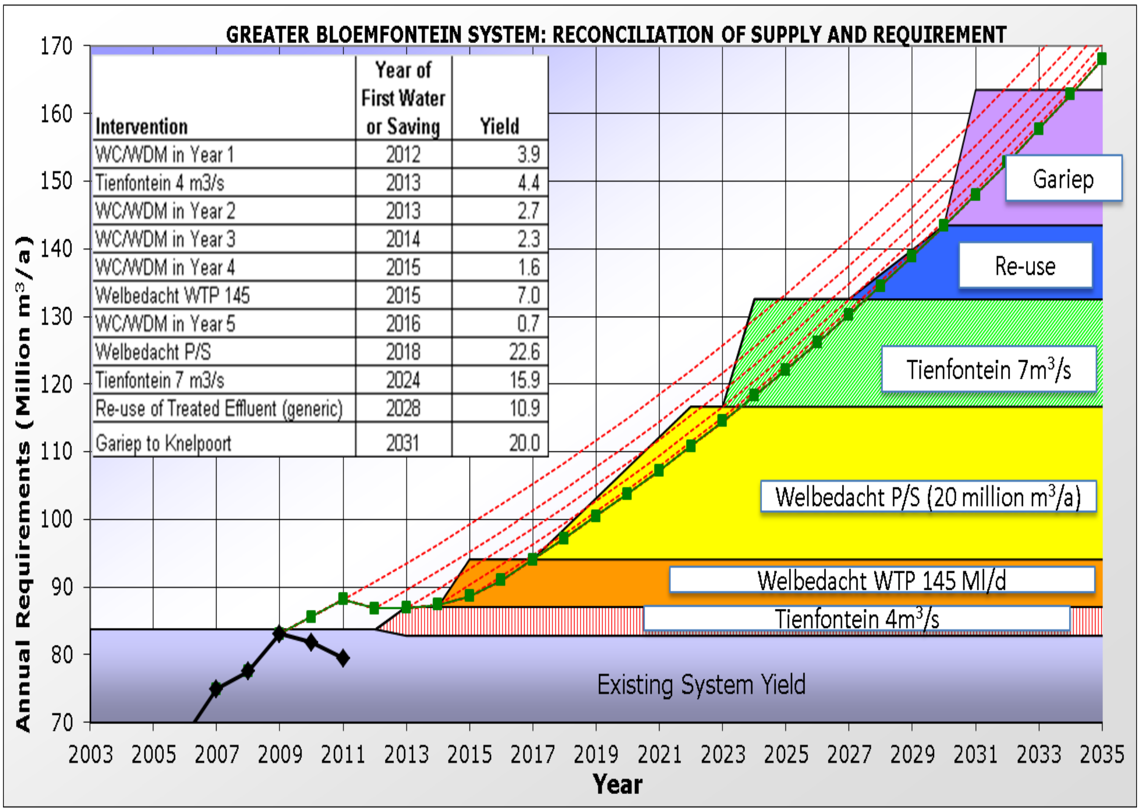

Figure 4-35: Greater Bloemfontein System Water balance

When evaluating the storage projection plot (**Figure 4.36**) produced from the Core Scenario analysis for the combined Rustfontein and Knellpoort dams, the following can be seen:

- The selected interventions options made it possible for the system to recover from its low starting storage levels fairly quickly.
- By 2027 the 99.5% and 99% exceedance probability storage levels dropped to the m.o.l. indicating that the system will start to experience deficits. This is in line with the Water balance from the reconciliation strategy, showing that re-use should be implemented by 2027 followed by support from Gariep Dam shortly thereafter.
- The water supply from the Greater Bloemfontein sub-system is very sensitive to the operating rule imposed on the system as well as the capacity of the Novo transfer link. This operating rule was not optimised as part of this study and need to be done every time when infrastructure changes are made as well as when the Novo Transfer capacity becomes a limitation due to increased system demands.

The water supply to the Greater Bloemfontein system users as simulated for scenarios 7.1 & 7.2 is given in **Figure 4.37** for the entire 20 year simulation period.

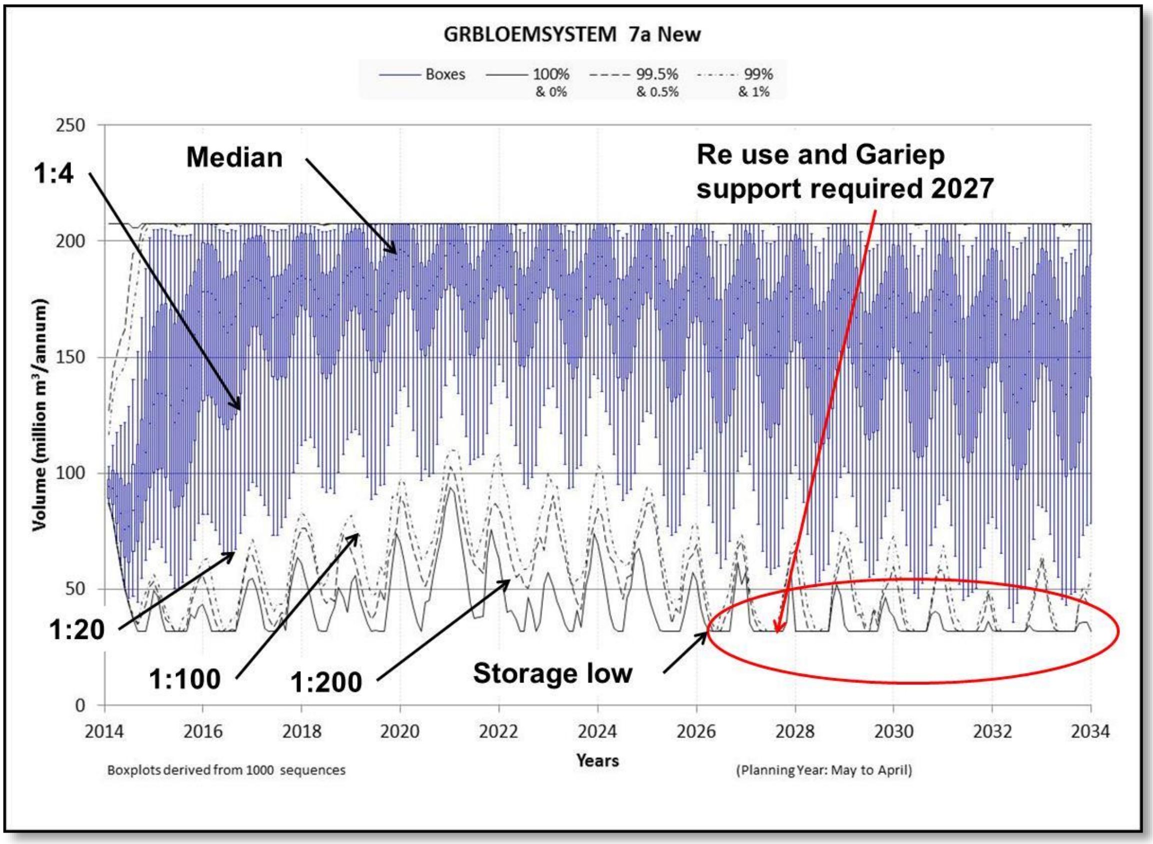

Figure 4-36: Greater Bloemfontein System Storage projection for Scenario 7.1 & 7.2

From **Figure 4.37** it is evident that with the given intervention options in place the following apply:

- The Greater Bloemfontein system was able to supply the growing demands at the required assurances in all the priority classes' low (95%), medium (99%) and high (99.5%) until 2027.
- The yellow triangle shows that from 2028 onwards an increasing portion of the low assurance class will not receive any water and the remainder of the low class will be supplied at a lower assurance than the required 95%.
- From 2030 onwards the supply to the medium priority class will not be able to adhere to the required assurance of 99% and will experience increasing deficits over time.
- The high assurance priority class however received its total allocated demand at the required assurance over the entire analysis period.

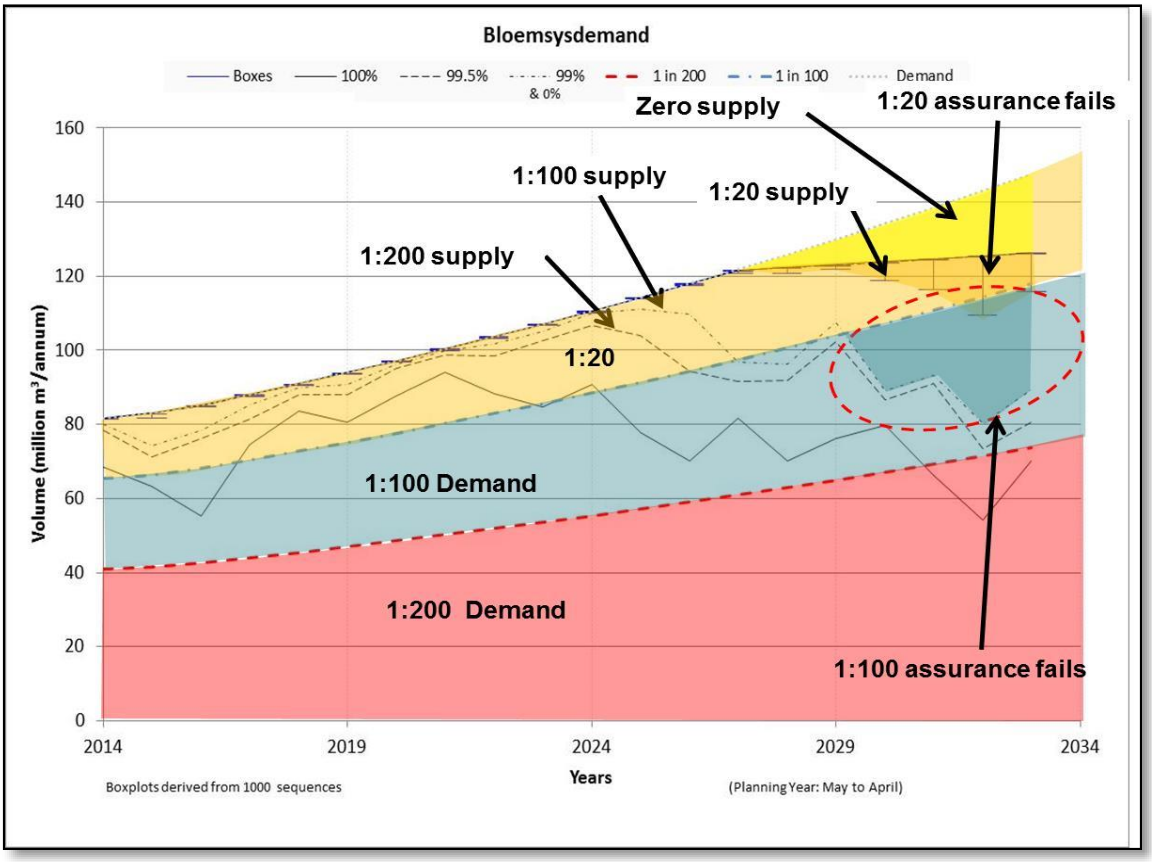

Figure 4-37: Greater Bloemfontein System supply for Scenario 7.1 & 7.2

4.3.3 Core Scenario Results – Orange River Project (ORP)

The Orange River Project (ORP) is the largest water supply system in the Orange Senqu basin and comprises Gariep and Vanderkloof dams and the supply area as highlighted by the magenta strip along the main Orange River, including several transfers as shown in **Figure 4.38** below.

Gariep and Vanderkloof dams are the two largest storage dams in the basin with gross storage capacities of 5 198 million m^3 and 3 188 million m^3 respectively. There are several transfers from the ORP to support users in other sub-catchments of which some are located outside the Orange Senqu Basin. There are no transfers in support of the ORP. Upstream of the ORP there are two transfers that directly impacts on the ORP yield, the LHWP transfer to the IVRS and the transfers from the Caledon to the Modder River catchment in support of the Greater Bloemfontein Water Supply system. Details of the main transfers from the Senqu and Orange are summarised in **Table 4.5**.

The Water Balance for the ORP over time is given in **Figure 4.39**, showing the impact of Polihali Dam (LHWP Phase ll) on the water availability from the ORP. No intervention options were included in this balance to restore the expected future shortage in the ORP. Deficits in the ORP system is expected to occur already from 2017 onwards (see baseline scenario results **Figure 4.2**). Due to the implementation of Polihali Dam around 2022 these deficits increase significantly.

In this water balance it is assumed that Polihali Dam will be used to support both the IVRS and the ORP. The purple triangle in **Figure 4.39** represents the portion of the Polihali yield that is available to support the ORP after the IVRS requirements were met. The support available from Polihali significantly reduces the ORP deficits initially, but as the IVRS requires more support from Polihali Dam, this advantage reduces over time. Several interventions options are therefore required to be able to maintain a positive water balance in the ORP in future. These intervention options were selected and evaluated in detail as part of the Orange River Reconciliation Strategy Study (DWA, 2013) and are all included in the Core Scenario.

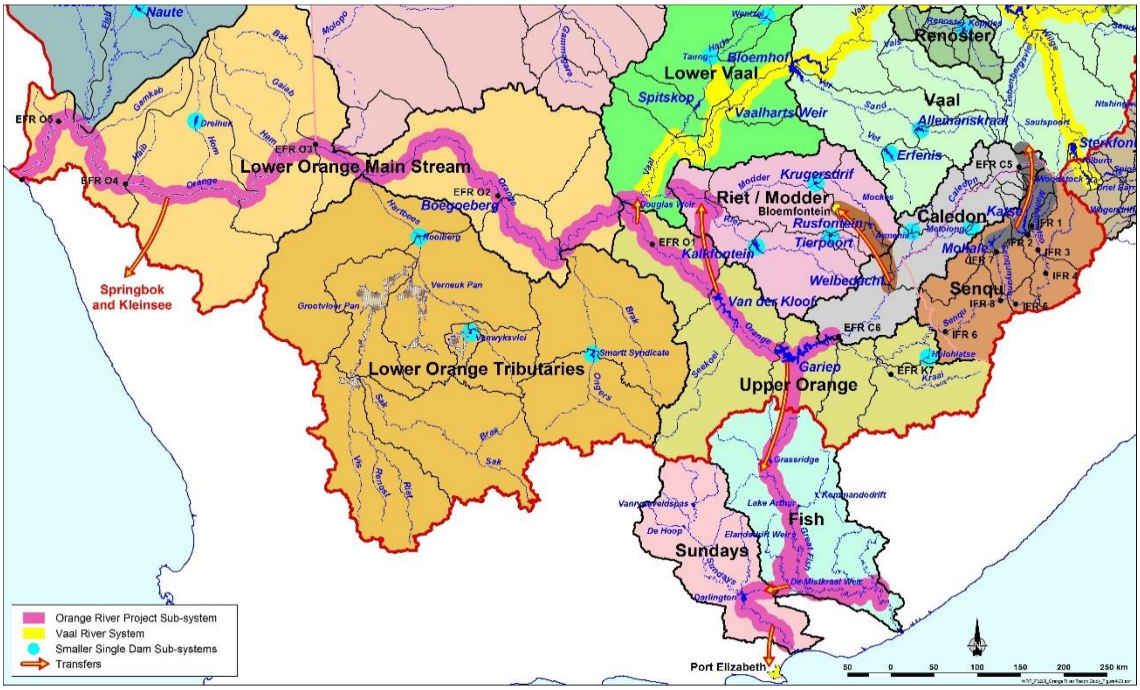

Figure 4-38: Orange River project water supply system

Table 4-5: Summary of Transfers from the Senqu & Orange

Transfer scheme	From and To	Purpose & Details	Tranfer & Componet	Capacity (m^3/s)	Mean transfer (10 years)	
					(m^3/s)	**(million m^3/a)**
Lesotho Highlands Transfer System	Senqu to Vaal	Urban/industrial water supply in Gauteng; Water is transferred from Katse and Mohale dams in Lesotho Highlands in support of Vaal Dam.	Tunnel Katse to Vaal Gravity flow	35.7	24.7	780 (1)
Caledon-Modder Transfer	Caledon to Modder	Greater Bloemfontein supply system imports water from the Caledon system (Welbedacht and Knellpoort dams) to supply the bulk of their requirement as there is insufficient water in the Modder system	Novo Transfer	1.5	1.5	47.3
			Welbedacht Transfer	1.68	1.64	51.9
Orange-Riet Transfer	Orange to Riet	Primarily used for irrigation purposes, but also supplies urban requirements of Koffiefontein, Ritchie and Jacobsdal; Transfer from Vanderkloof Dam main canal over the water shed to the Orange Riet canal in the Riet River catchment	Pump pipeline but mainly canal	15.6	6.83	215.6
Orange-Vaal Transfer	Orange to Vaal	The bulk of the transfers are used for irrigation purposes, with a small portion also supplied to but the town of Douglas; Transfer from Marksdrift Weir in the Orange River to Douglas Weir at the downstream end of the Vaal River.	Pump pipeline but mainly canal	6	3.6	113.5
Springbok Kleinsee	Orange to Buffels (West Coast)	Raw water is abstracted from the Orange River and pumped to the Henkries WTW. Purified water is then pumped in bulk pipelines to a number of towns and village settlements, including the Concordia-Springbok Cluster, all located outside the Orange River Basin	Pump & pipeline	0.21	0.38	11.9

Note: (1) – This transfer volume will increase significantly once Polihali Dam is in place and is expected to reach approximately 1100 million m^3/a by 2050

Results from Scenario 4.1 and 4.2 confirm these deficits and showed that even with the support from Polihali Dam in combination with a Vioolsdrift Dam as well as with the raising of Gariep Dam, the ORP was not able to supply the users at their required assurances. Additional Orange River related intervention options were thus added to Scenario 4.2 for the purpose of the Core Scenario. These included the real time modelling and monitoring option, utilising of the lower level storage in Vanderkloof Dam, WC/WDM as well as the updated and refined Lower Orange EWRs.

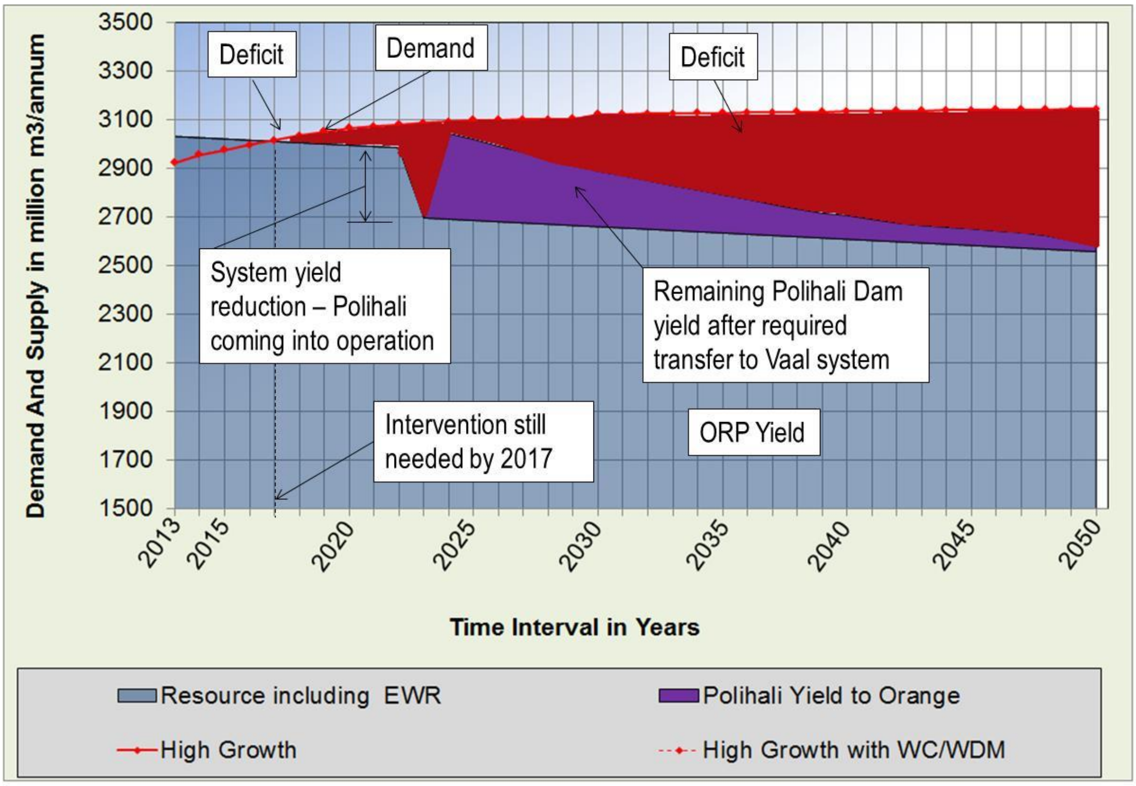

Figure 4-39: Orange River Project Water balance projection with Polihali Dam and no intervention options included

These intervention options resulted in a significant improvement in the performance of the major dams in the ORP and the related assurance of supply to the users within this system (See **Figures 4.40 & 4.41**)

Figure 4.40 shows the significant improvement in the projected storage levels for Scenario 7.1 versus scenario 4.2 with the 99.5% (1 in 200 year) and 99% (1 in 100 year) projected levels only start touching the m.o.l. between 2026 and 2029, where after the ORP system started to recover. Both storage projections indicate that the raising of Gariep Dam requires quite a long warming up period, before the Raised Gariep Dam will be able to supply its full additional yield. This is evident from the long time required to reach the new full supply level. One should therefore investigate the option to raise the dam earlier, to allow sufficient warming up time for the ORP system.

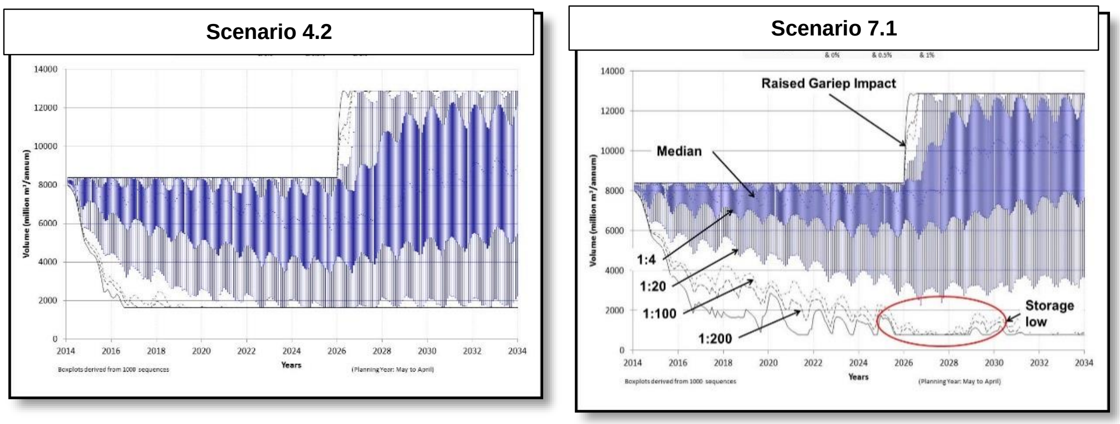

Figure 4-40: Combined Gariep and Vanderkloof Storage projection for Scenario 4.2 & 7.1

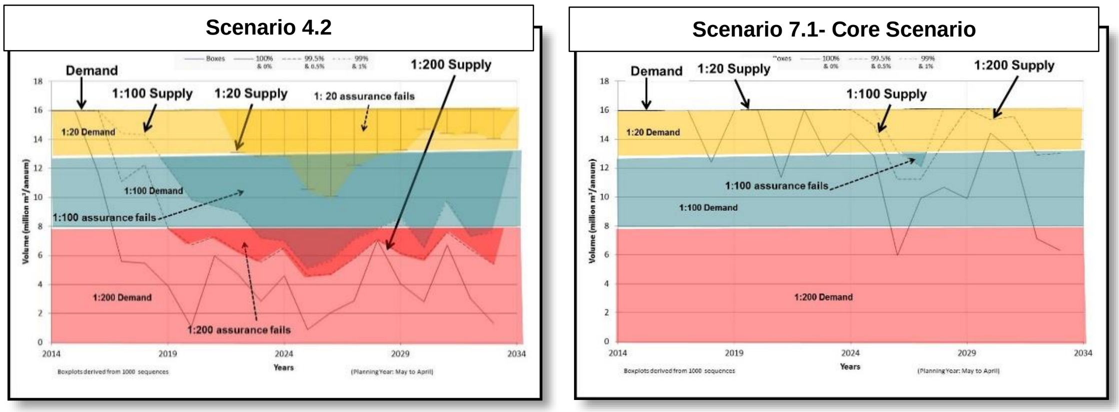

Figure 4-41: Namakwa urban and mining water supply Scenario 4.2 & 7.1

From **Figure 4.41** the significant improvement in supply to the Namakwa water supply system in the Lower Orange as achieved with Core Scenario (7.1), is clearly evident. Deficits are only occurring around 2028 and 2029 due to the low storage in the dams around that time. Similar demand supply graphs are shown in **Figure 4.42** indicating that the support to the Eastern Cape through the Orange Fish tunnel was well supplied and at the required assurances with some small deficits experienced in the Springbok Kleinsee transfer around the 2026 to 2029 problem period.

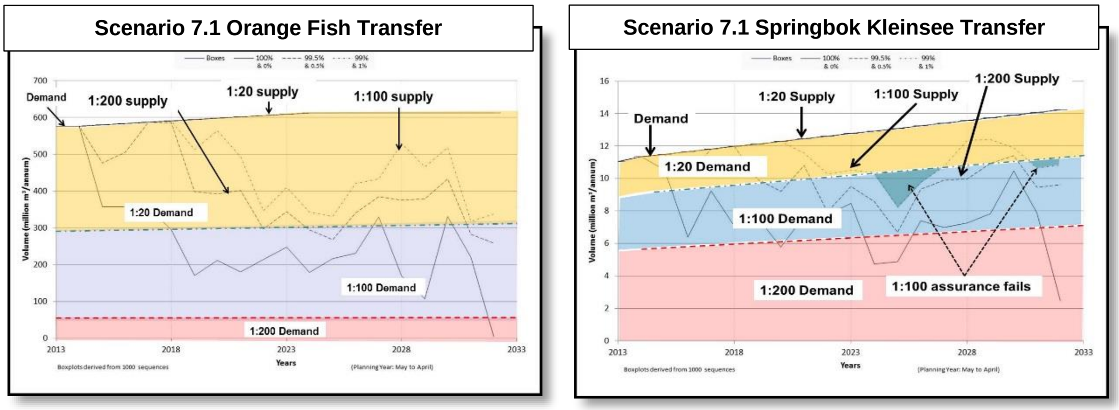

Figure 4-42: Scenario 7.1water supply to the Eastern Cape and Springbok Kleinsee system

The ORP water balance representing Core Scenario 7.1 is given in **Figure 4.43** and indicates all the intervention options included as well as their related impact on the ORP system. The real time modelling and monitoring option as well as WC/WDM need to be phased in from 2016 onwards to overcome the first deficits that started to occur by 2017. This is followed by utilising the Vanderkloof lower level storage and the dual support from Polihali Dam to overcome the significant increase in deficits when LHWP Phase II is activated. Vioolsdrift Dam is activated in 2024 followed by the implementation of the refined updated Orange EWRs. It will only be possible to supply the Orange River mouth EWR successfully by means of a proper control structure in the Lower Orange, such as Vioolsdrift Dam. For this reason the implementation of the refined updated Orange EWRs only took place in 2025. Note the significant reduction in the ORP yield when the new EWRs are imposed on the system. The 10m raising of Gariep Dam is the last intervention option and is activated in 2026. From this water balance it follows that with all these intervention options included, deficits are expected to occur again by 2046.

Core Scenario 7.2 considers the Verbeeldingskraal option in place of the raising of Gariep Dam and has the advantage of significantly reducing evaporation losses from the ORP system. The disadvantage of the Verbeeldingskraal option is that the size of the dam is limited as it will start to inundate parts of Lesotho when the 1 385 masl full supply level is exceeded. The storage projections for the two Core Scenario options are for comparison purposes included in **Figure 4.44**.

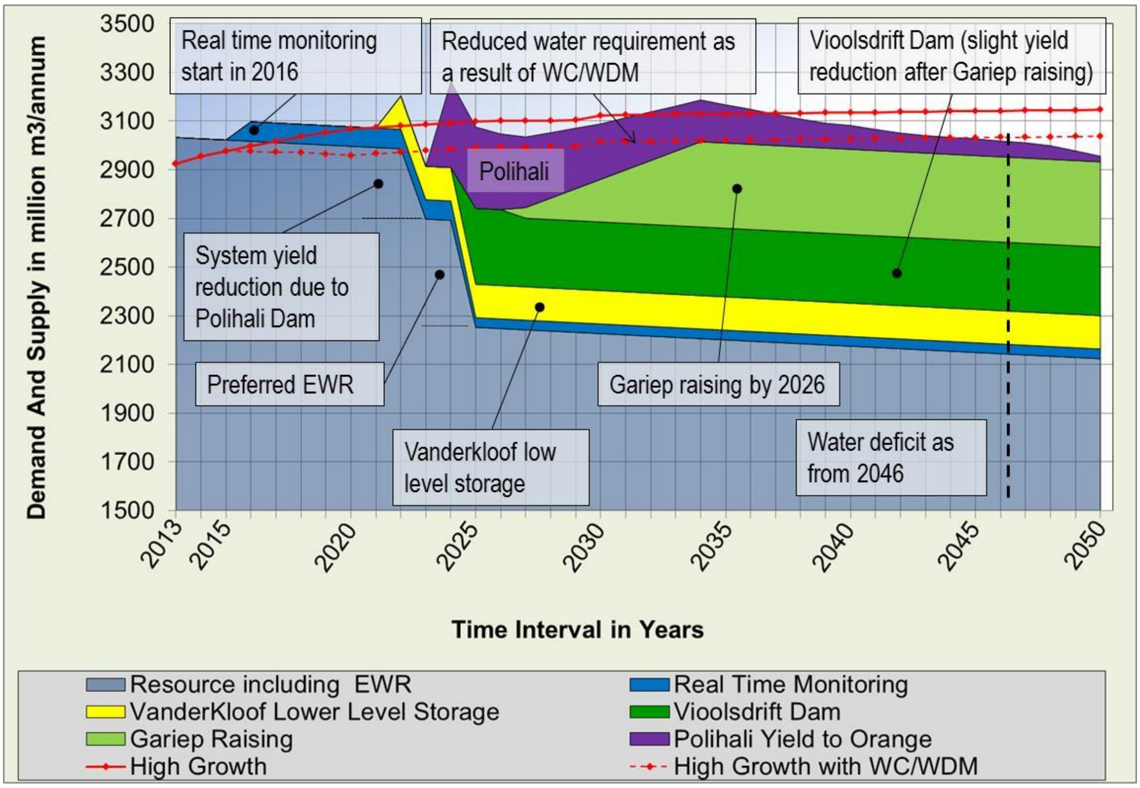

Figure 4-43: Orange River Project Water balance projection for Core Scenario 7.1

The increase in the overall system storage for Scenario 7.2 is considerably less than that for Scenario 7.1 (see **Figure 4.44**). It is interesting to note that the very low 99.5% and 99% storage projections levels over the period 2026 to 2029 are for both scenarios very similar, although the storage added to the system by Verbeelingskraal Dam is much less.

The Verbeelingskraal Dam option do not require a long warming up period as in the case of the Raised Gariep Dam option, an a quicker response in the storage recovering is evident, specifically from the 95% exceedance probability level for Scenario 7.2. When comparing the water supply to users within the ORP, the two Core Scenario options provided very similar results (**Figure 4.45**), although the supply based on Scenario 7.2 seems slightly better over the low storage period of 2026 to 2029, which is due to the quicker reaction time of the smaller Verbeeldingskraal storage dam, as well as the much lower evaporation losses from the ORP system when Verbeeldingskraal Dam is used.

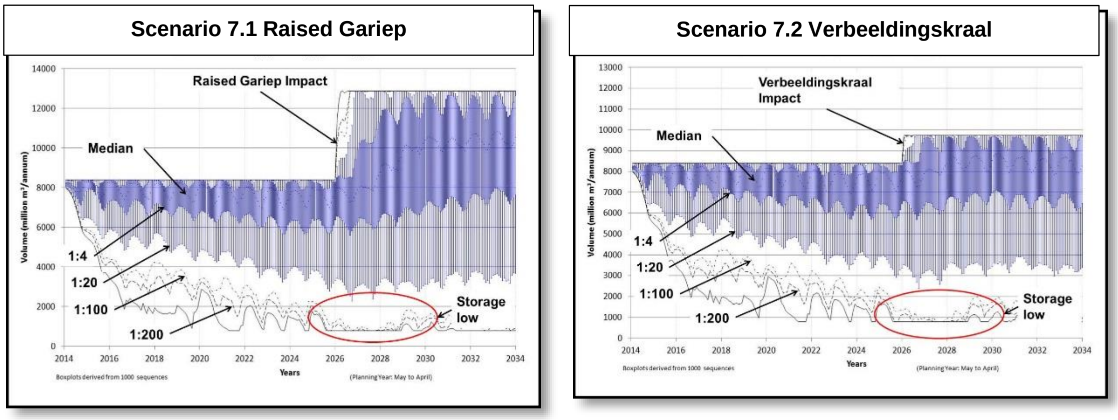

Figure 4-44: ORP Storage projection for Core Scenario 7.1 & 7.2

The additional yield generated by Verbeeldingskraal Dam (230 million m³/a) is however less than the 350 million m³/a generated by the raised Gariep Dam option. Due to the lower additional yield added to the ORP system by Verbeeldingskraal Dam, deficits within the ORP will start sooner, and is expected to occur from approximately 2036 onwards (see **Figure 4.46**).

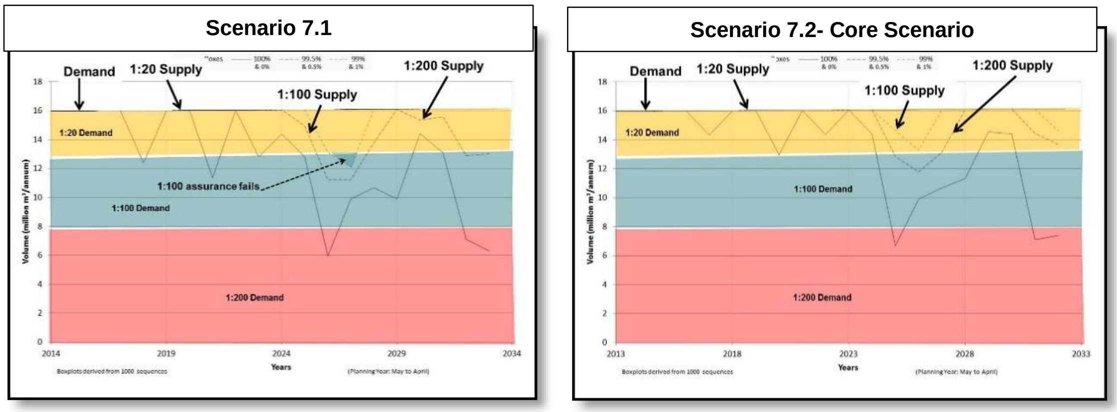

Figure 4-45: Namakwa urban and mining water supply Core Scenario 7.1 & 7.2

The intervention options and related implementation dates as shown in **Figure 4.46** are exactly the same as those for Core Scenario 7.1 given in **Figure 4.43,** with the only difference the inclusion of the Verbeeldingskraal Dam option in place of the raised Gariep Dam option.

To be able to obtain the significant reduction in evaporation losses from the ORP system of approximately 200 million m³/a, it is important that the correct operating rule be used to control the support from Verbeeldingskraal Dam to Gariep Dam. Water should be kept for as long as possible in Verbeeldingskraal Dam, where the evaporation is much less and releases in support of Gariep Dam must only take place when the storage level in Gariep Dam is close to its m.o.l. The fact that evaporation losses as well as the incremental storage increase for the Verbeeldingskraal option are much less than for the raised Gariep option, will contribute to higher and more frequent spills from Vanderkloof Dam. This will be to the benefit of a dam at Vioolsdrift as well as for the environmental requirements along the Orange River and at the Orange River mouth.

To be able to illustrate these differences between the two Core Scenarios, the spills at the Orange River estuary were compared graphically for the two scenarios as shown in **Figure 4.47**.

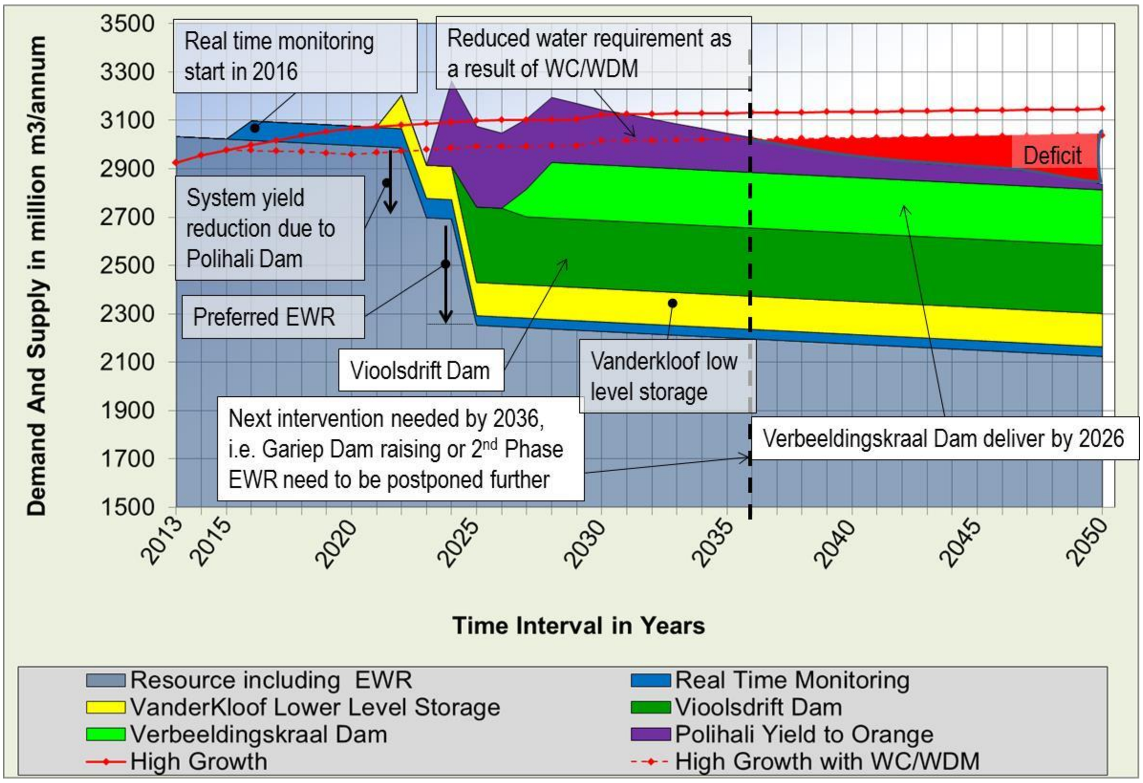

Figure 4-46: Orange River Project Water balance projection for Core Scenario 7.2

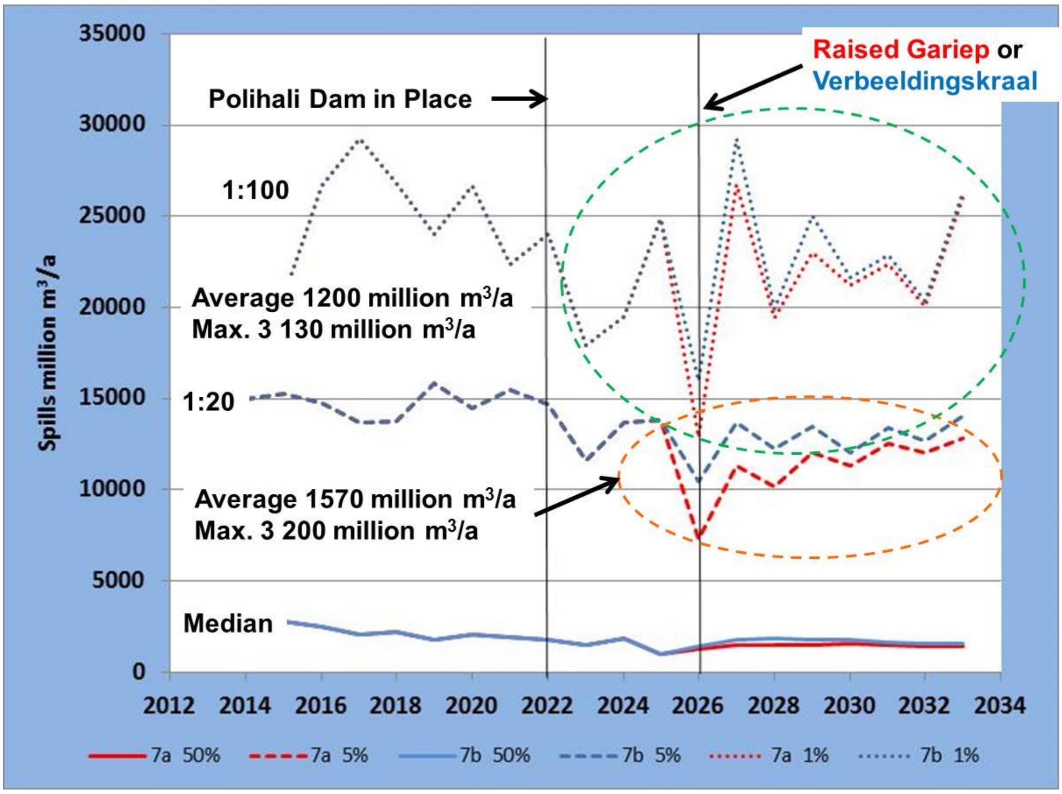

Figure 4-47: Comparative flows at the Orange River mouth Core Scenario 7.1 & 7.2

The annual median simulated flows at the estuary are in the order of 1800 million m^3/a for both Core Scenarios and on average about 200 million m^3/a higher for the Verbeeldingskraal option from 2026 onwards, when the Raised Gariep and Verbeeldingskraal options were activated.

At the 5% exceedance probability level (typical 1 in 20 year floods) the Verbeeldingskraal option resulted in significantly higher flows from 2026 onwards. These flows were on average 1 570 million m^3/a higher than the average annual 5% exceedance probability flows from the Raised Gariep option, with a highest difference of 3 200 million m^3/a evident over this period (2026 to 2033).

Similar increases in the Orange River flows at the estuary are evident when the Verbeeldinskraal option is used and the 1% exceedance probability flows are compared. An average increase of 1 200 million m^3/a was found with the maximum increase within a single year of 3 130 million m^3/a.

The Orange River Reconciliation Strategy as prepared by the RSA DWS recommended that a Pre-feasibility study be carried out before a final decision is made on which of the two intervention options to implement (Gariep Dam Raising or Verbeeldingskraal Dam) in future. From the results obtained from Core Scenarios 7.1 and 7.2 it is clear that the impact on the environment will be an important component to take into account in the final evaluation of these two intervention options.

4.3.4 Core Scenario Results – Other Important Water Supply Systems

The main water resource related developments in Lesotho that will significantly impact on the Orange Senqu system are Phase II of the LHWP and the recently completed Metolong Dam. The impacts on the system and more specifically the ORP due to LHWP Phase II developments are quite severe, and were already addressed in **Section 4.3.3.**

Metolong Dam was recently completed and already started to store water. The water distribution systems are not yet in place and the dam will therefore only start to deliver water to the users over the next year or two. The existing Maseru river abstraction from the Mohokare (Caledon) River to the Maqalika balancing dam is insufficient to support the growing water needs of Maseru and surrounding areas. Metolong Dam and related distribution system will in the near future provide support to these and other areas within Lesotho, bringing relief to the currently water stressed Maseru water supply system.

The impacts of Metolong Dam on the water supply from the Caledon (Mohokare) River located downstream of Metolong Dam, are given in **Section 4.1.1** and are in general very small. This entails a 1 million m^3/a or 1% reduction in the BloemWater supply system, with a reduction of less than 1 % in the average projected median storage level in Gariep Dam over the next 10 years. The yield reduction at Gariep Dam is for practical purposes negligible.

The WRPM analysis results show that Metolong Dam will fill up fairly quickly, which is quite different from the long filling time expected for Polihali Dam as shown in the LHWP storage projection plot.

In the Core Scenario it was accepted that Metolong Dam will start to support the total Maseru demand from May 2015 onwards, to allow for the maintenance and upgrading of the existing old Maseru Water Supply System. From 2025 onwards the old Maseru water system was re-activated again and only the growth portion of the system demand was then supported from Metolong Dam (See **Figure 4.50**).

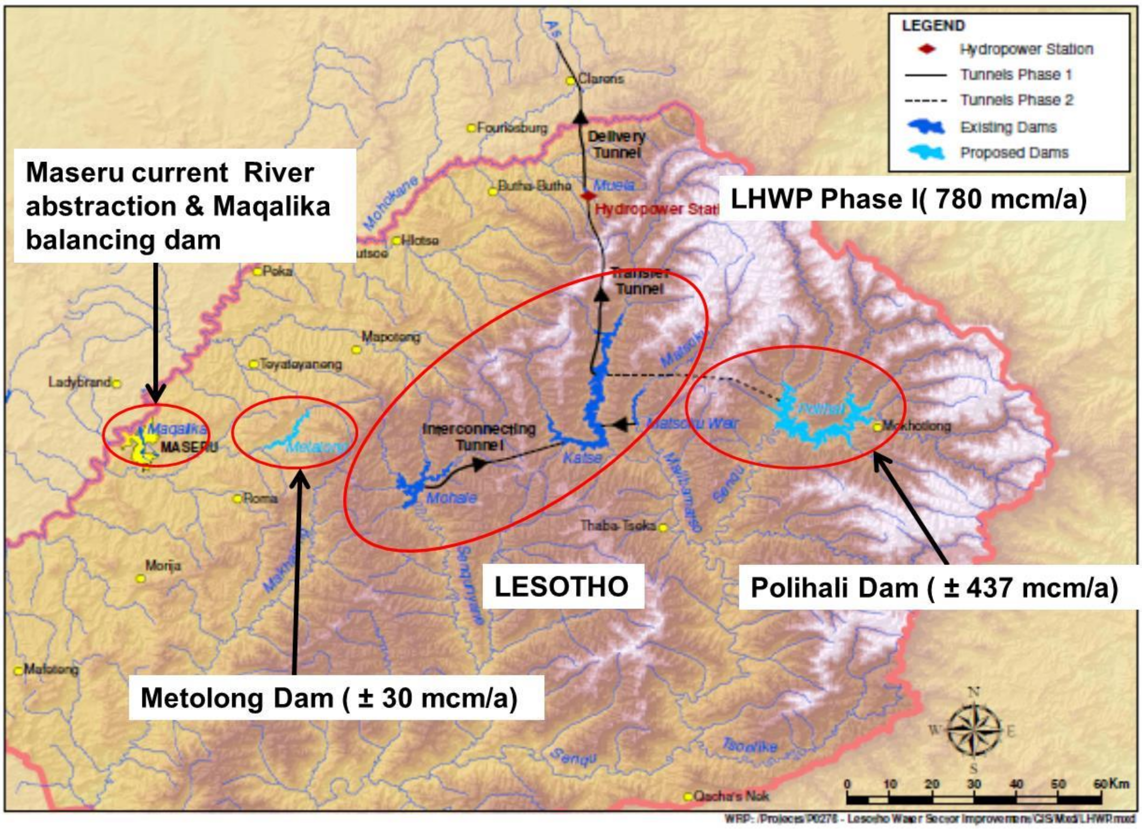

Figure 4-48: Major Water Supply Systems in Lesotho

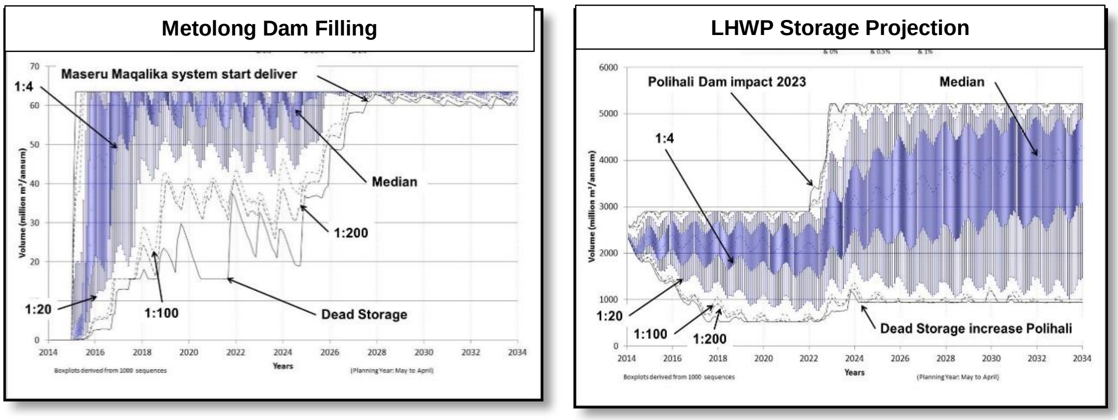

Figure 4-49: Metolong Dam & LHWP Storage projections for Scenario 7.1 & 7.2

Deficits in the Maseru System supply are expected in 2015 and 2016 if the full demand load is imposed on Metolong Dam from 2015 onwards, as the dam requires at least a 1 year period for filling. For the remainder of the analysis period Metolong Dam is able to support the projected demands at a very high assurance without any failures. When the old Maseru System start supporting the system again in2025, it is clear the combination of the two systems will be totally underutilised. One should rather consider supplying a larger part of the demand from Metolong Dam, as less pumping and related cost implications will be required. The phasing in of the demands to be supplied from Metolong Dam was based on preliminary estimates by Lesotho and will most probably be adjusted depending on the progress made with the construction of the distribution system and water treatment plants.

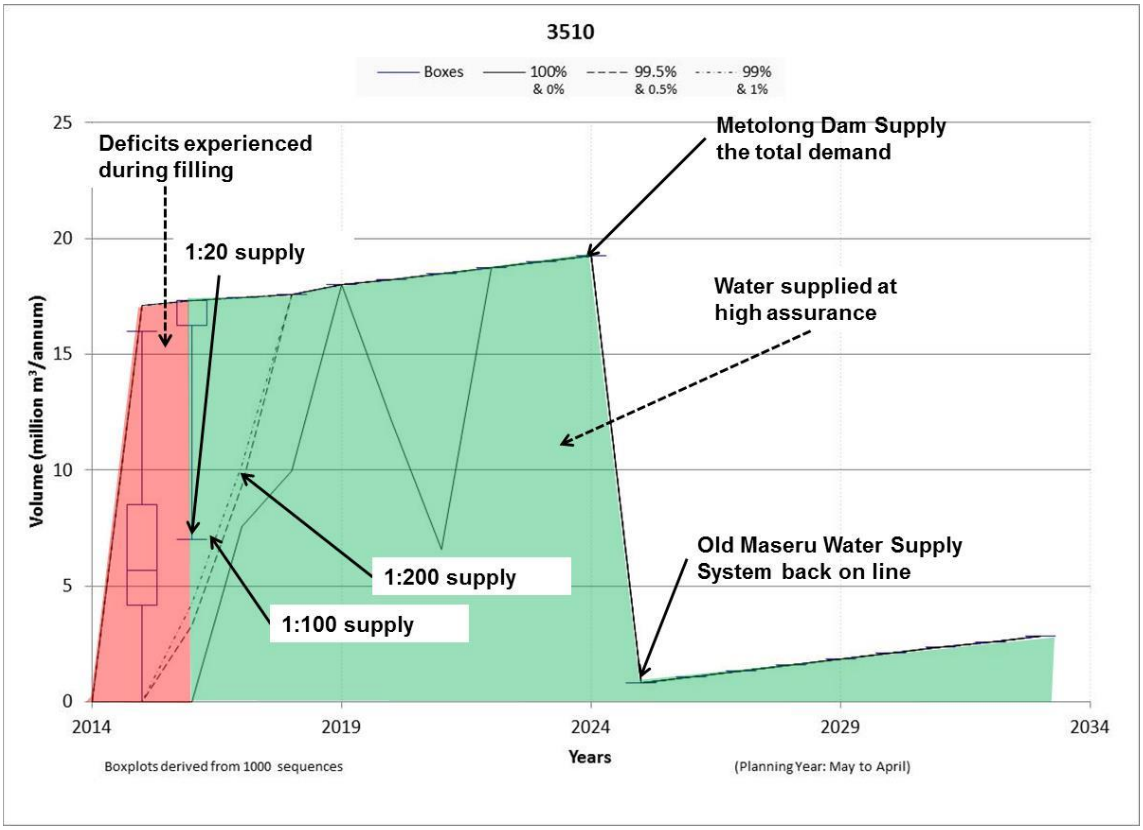

Figure 4-50: Water supply from Metolong Dam Scenario 7.1 & 7.2

<u>Neckartal Dam in Namibia</u> is currently under construction and will be the largest storage dam in Namibia within the Orange Senqu basin, once completed. There is no other storage dam located downstream of Neckartal Dam and this dam will thus not impact on the yield of any existing storage dam.

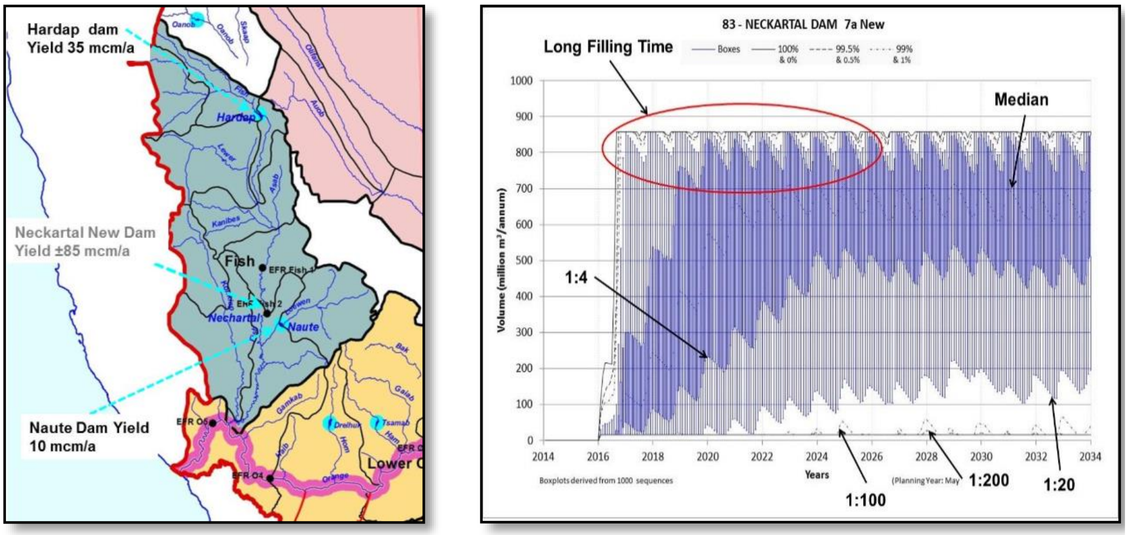

Figure 4-51: Neckartal Dam location and Storage projection Scenario 7.1 & 7.2

In **Section 4.1.1** the impacts of Neckartal Dam on flows just before the Orange Fish confluence and at the Orange River mouth was already given and discussed. Significant reduction in flows of between 60 t0 80% is evident in the lower Fish River when no releases are made from Neckartal Dam in support of the environment. This emphasise the importance of environmental releases from Neckartal Dam in future.

The impacts of Neckartal Dam on flows at the estuary are in general small.

Due to the size of Neckartal Dam and the relative arid catchment, the filling time of this dam will be quite long, as can be seen from the storage projection plot in **Figure 4.51**. This needs to be taken into account when planning the development of the irrigation scheme as well as the phasing in of the related demand load on Neckartal Dam. It was assumed that Neckartal Dam will start inundating water by May 2016.

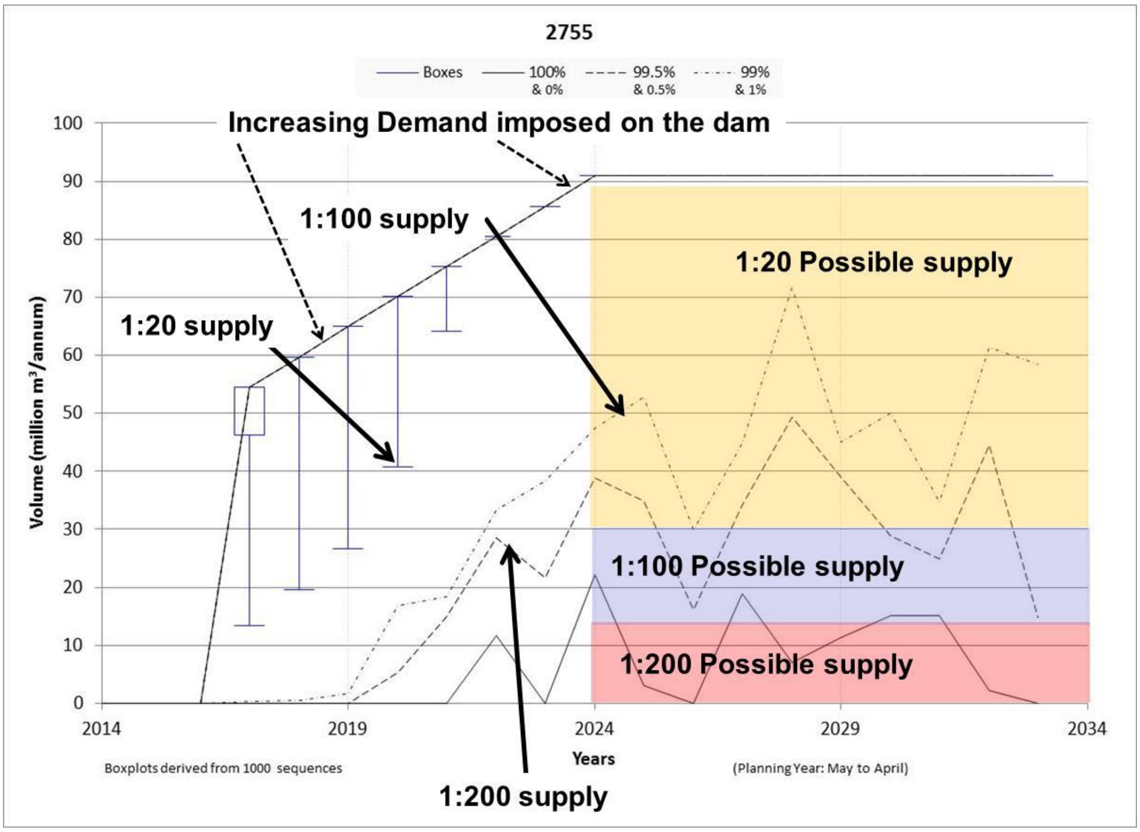

Figure 4-52: Expected supply from Neckartal Dam as simulated for Scenario 7.1 & 7.2

For the purpose of the Core Scenario the demand imposed on Neckartal Dam was phased in over a period of 8 years, starting in 2017 as indicated by the demand line shown on **Figure 4.52**. In the first two to three years the assurance of supply might be too low, requiring a lower initial demand or waiting another year before starting to deliver water to the users. Once the storage levels in Neckartal Dam stabilised, it seems as if the dam will be able to supply approximately 13 million m^3/a of the 90 million m^3/a total demand, at a high assurance of 99.5% (1 in 200year) with another 17 million m^3/a at a 99% assurance (1 in 100 year) and the remainder at a 95% (1 in 20 year) assurance.

The two Botswana related options impacting on surface water availability, are the additional transfer through the Vaal Gamagara pipeline to Botswana and the possible transfer from Lesotho to Botswana. Until now no details were available on the possible transfer of water from Lesotho to Botswana and this option could therefore not be analysed.

The upgrading of the Vaal Gamagara pipeline is currently in its design phase. This includes a possible transfer 5 million m^3/a to Botswana villages located close to the South African border from 2022/23 onwards. The Vaal Gamagara scheme forms part of the greater IVRS and the demand increase due to this support to Botswana was included in the demand growth imposed on the IVRS. The IVRS water balance and related results from the Core Scenario analysis was already covered in **Section 4.3.1**. This additional demand of 5 million for the support to Botswana represents less than 0.2% of the net demand imposed on the IVRS and will have almost no impact on the IVRS.

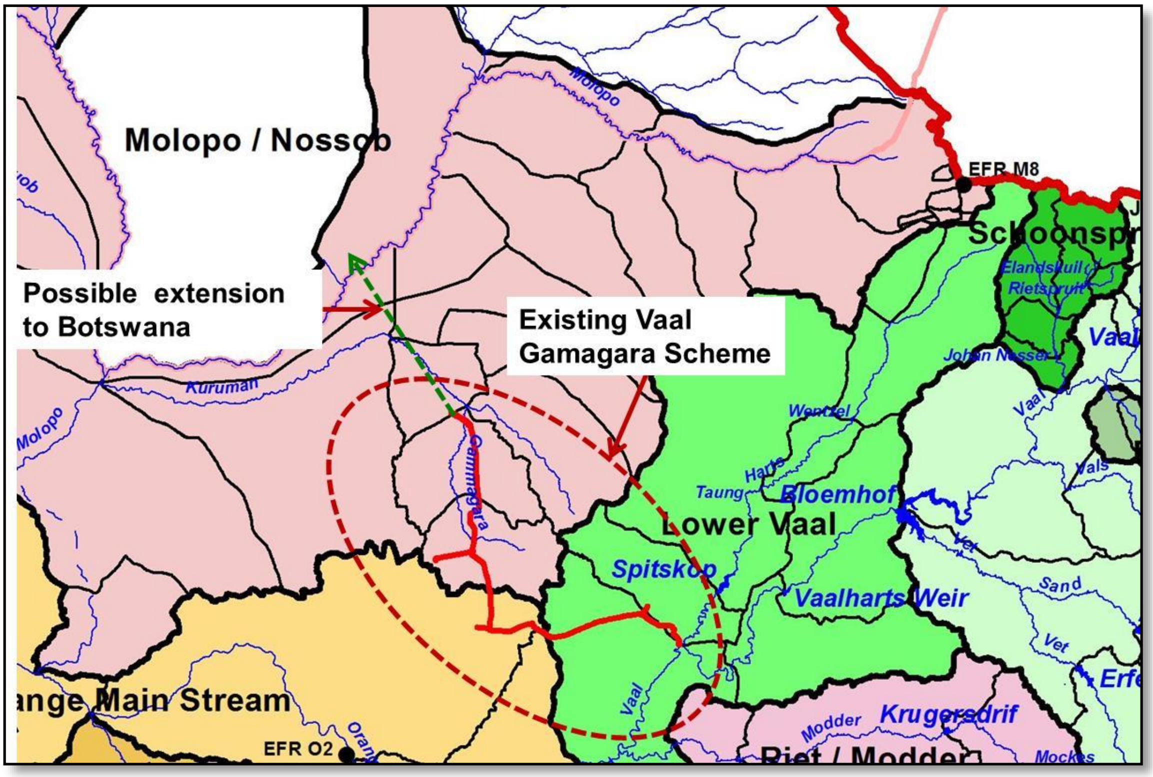

Figure 4-53: Extended Vaal Gamagara pipeline in support of Botswana

5. Evaluation criteria

The criteria used in the evaluation of results from different scenarios depend on the specific goal or goals that need be achieved and will differ from one scenario to another. In some cases a specific criteria might be totally irrelevant to the specific case and therefore not used in the evaluation process.

The following evaluation criteria were developed during the April 2014 RWG and can be applied where applicable:

General comparison and evaluation

- Assurance of supply to key users
  - From when is the assurance of supply to users violated
  - The total period of violation
- Deficits in water supply
  - When did deficits start to occur
  - The total period in which deficits occurred
- The performance of key storage dams (Storage projection plots)
- Sub-system losses (disaggregate)
- Supply of EWRs at key sites
- Spills and or flows at key points in the system
- Hydro-power generated (GWH)
  - Consumptive water use for hydro-power generation purposes
  - Non consumptive use for hydro-power generation purposes
  - Periods of no hydro-power generation
- Total volume of water that need to be pumped
- Water quality (TDS) at key sites
- Volume required for dilution purposes

Long term planning overall system

- Total volume of water used by coal fired Power Stations
- Water supplied for renewable energy generation
  - Solar power plants
  - Hydro-power
- Total system losses (disaggregate)
- Total volume of return flows re-used
- Total volume of water supplied to irrigation

Water supply systems within the Orange Senqu basin are operated and managed in different ways. This is in most cases depended on the responsible person, entity and country that owns or manage the specific water supply system. The large water supply systems within the RSA in general include risk management as part of the operating rule. Within these systems water is supplied to users at a specified and agreed assurance. This rule accepts that the water supply to users can be restricted or curtailed during droughts. Risk based short-term yield characteristics are developed for this purpose and included in the WRPM. These yield characteristics are used by the WRPM to decide when curtailments need to be imposed on the specific system, and how severe these curtailments or restrictions must be. The users requiring a low assurance of supply will be restricted first, followed by the medium assurance users and finally by the high assurance users. In this manner the supply to the high assurance users will be protected. For water supply systems where this type of rule is used, one needs to evaluate the assurance of supply to the different users to be able to determine when the curtailment criteria were violated, which mean that the users did not receive their water at the agreed assurance.

Many other sub-systems supply water to users until a failure occurs and only a part of or none of the demand can be supplied. If some sort of higher assurance of supply is required for a certain group of users within this sub-system, the supply from such a resource is in general controlled by means of levels in a dam. When the storage in the dam drops below this level, water supply to low assurance users will be ceased, and only the users requiring a higher assurance then still receive water. In sub-systems such as these, the water supply assurance levels are not well defined and results from the WRPM will then be evaluated mainly on the basis of failures or deficits that occurred in the sub-system.

The type of operating rule used will thus dictate whether the violation of the assurance of supply to users is used as the criteria or simply the deficits in supply.

Evaluation of results from the different scenarios analysed was done as part of the discussion of results in **Section 4,** by using the above mentioned criteria as applicable.

6. Preliminary Conclusions and recommendations

From the scenario analyses carried out using the WRPM and related input data sets as prepared for the ORASECOM Phase III Integrated Water Resources Management Plan study, the following conclusions were drawn and related recommendations were made. Valuable work done as part of several Reconciliation Strategy Studies, was also taken into account in this process. The following reconciliation strategy studies were of high importance in this respect:

- The Orange Reconciliation Strategy Study "Development of Reconciliation Strategies for Large Bulk Water Supply Systems: Orange River" (DWA, 2013),
- The IVRS Reconciliation Strategy "Vaal River System: large Bulk Water Supply Reconciliation Strategy" study supported by feedback from the current implementation of the Reconciliation Strategy for the Vaal River (Maintenance Phase) (DWA, 2014) as well as,
- The "Reconciliation Strategy Report for the Large Bulk Water Supply Systems of the Greater Bloemfontein Area" and its current Maintenance Phase (DWA, 2014b).

6.1 Baseline and updated baseline Scenarios

- IVRS need intervention by 2022
- ORP require intervention by 2017
- Greater Bloemfontein system is violating curtailment criteria from 2015 onwards
- Impact of Metolong Dam on water supply schemes downstream is relatively small will not result in water supply difficulties or non-supply events.
- Impact of Neckartal Dam on flows in the Lower Fish is quite severe – very important to release flows from Neckartal in support of the environment.
- Neutralising of mine water outflows in Upper and Middel Vaal is not sufficient and the desalination of the AMD is essential and must happen. If desalination is not implemented it will severely impact on the IVRS yield and WQ (The Core Scenario modelled desalination to start in June 2018, this should rather be earlier than later)
- The positive impact of desalination is quite significant on entire Vaal River main stem from Vaal Barrage to Douglas Weir at the downstream end of the Vaal River just before its confluence with the Orange. Orange River flows provide a significant dilution effect on the inflows from the Vaal and masks the WQ improvement due to desalination in the Upper Vaal. Even with the Orange River flows masking the WQ improvements in the Vaal, the WQ related improvement is still evident at the Orange River estuary, although very small.

6.2 Scenario 2 – LHWP Phase II impacts

- Using the future Polihali Dam to initially support both the IVRS and the Orange system is one of the best options to postpone the construction of expensive yield replacement options in the Orange at the time when Polihali Dam (LHWP Phase II) is implemented. Significant economic advantage without negative impacts on the assurance of supply in the IVRS will be obtained by using this option.
  - The operating rule to be implemented when Polihali is used to support both the Vaal and the Orange is crucial. Further extensive work will be required for the development of this rule which need to be agreed on by both Lesotho and the RSA.
  - Polihali Dam requires a long warming up period before it can deliver its full yield. This is in particular the case when Polihali is used to support both the IVRS and the Orange System, as a large demand is then imposed on the dam, fairly early after its completion. This need to be taken into account when the operating rule is developed.
  - Obtaining support from Polihali Dam will not fully cover the deficits experienced in the ORP, and other interventions options such as real time monitoring, utilising the lower level storage in Vanderkloof Dam and WC/WDM also need to be implemented.
- Using the future Polihali Dam only in support of the IVRS and transferring as much as possible to the IVRS with the aim of generating more hydro-power, will result in increasing spills from Vaal Dam and Bloemhof Dam, as well as high evaporation losses from the IVRS. This results in a significant loss in yield from the Vaal in comparison with the option where the transfer to the IVRS is based on the support required in the IVRS as determined on an annual basis.

6.3 Scenario 3 & 4 – EWR impacts

Currently environmental requirements for the estuary are released from Vanderkloof Dam in support of the river mouth. These release volumes were determined during the middle 1990's and are based on outdated methods. The environmental conditions in particular at the estuary are as a result of this deteriorating. EWRs were recently determined through two ORASECOM studies and showed that more water than that currently being released from Vanderkloof Dam is required and that the timing of specifically low flows that allows mouth closure is essential and are not achieved by the current releases. The current river mouth EWR as released from Vanderkloof Dam amounts to a total of 288 million m^3/a.

The ORASECOM Phase 2 EWR (ORASECOM, 2011a) related work did not provide information on the river mouth environmental requirements or the EWRs applicable to the Fish River in Namibia. ORASECOM therefore introduced a follow up study (ORASECOM, 2012) focusing on these specific requirements. To be able to provide the estuary with a flow that meets the estuary criteria, the EWR at site 5 on the Lower Orange was manipulated in order to provide these required low flows. This manipulation entailed shifting excess low flow into a period of floods, until the desired duration curves were achieved. As part of this process the refined updated EWRs were developed for the Lower Orange, Augrabies and downstream.

6. PRELIMINARY CONCLUSIONS AND RECOMMENDATIONS

- WRYM analysis showed that the EWR at the Augrabies site is the main driver and resulted in a reduction in the ORP yield of 478 million m^3/a when the PES (Present Ecological State) EWR from the Phase 2 ORASECOM Basin-wide Integrated Water Resources Management Plan study, was imposed on the system. This is an increased reduction of 478 – 288 = 190 million m^3/a on the ORP system yield in comparison with the current EWR releases.
- Analysis using the WRYM to determine the impact of the REC (Required Ecological Class) EWRs on the ORP system yield showed a significant reduction in the ORP yield of 1 060 million m^3/a. This means an increased reduction in yield of 1060 – 288 = 772 million m^3/a, which is quite excessive.
- The impact of the REC (Required Ecological Class) EWRs on the ORP system yield was reduced considerably as result of the refinements done as part of the follow up ORASECOM EWR (ORASECOM, 2012) study. The impact of the refined updated EWR on the system yield reduced to 722 million m^3/a (net reduction 722 – 288 = 434 million m^3/a) which is significantly lower than the initial net reduction of 772 million m^3/a.
  - The impact on the water supply assurance from the ORP, even with the refined REC EWRs in place, is still severe and will lead to significant economic implications on the entire area supplied from the ORP.
  - It is recommended that a study be initiated to find a balance between the EWR and related socio economic impacts. In the RSA these types of studies is referred to as a Classification Study, with the aim to find agreement on the EWR classes to be implemented in different areas of the basin, and to derive the final refined and agreed EWRs. These agreed EWRs are referred to as the Reserve, which will finally be implemented and need to be adhered to, according law. The flows in the Orange River not only impacts on the users in the RSA, and it will therefore be important to include all four the basin states in the process to derive at the final agreed EWRs, as well as the time when it should be implemented.
- From the analyses results it is clear that additional intervention options will be required to maintain a positive water balance within the ORP system, when the updated EWRs are phased in. High yielding intervention options such as the raising of Gariep Dam or the construction of another dam in the Orange upstream of Gariep Dam will most probably be required to provide sufficient yield for the increased demand load on the ORP system.
- It is currently very difficult to accurately control the flow at the estuary by means of releases from Vanderkloof Dam over the long distance of 1380 km, with large abstractions along the entire river combined with significant variations in the climatic conditions from time to time. To achieve the required EWR flow rates at the estuary to an acceptable accuracy for environmental purposes, will for practical purposes be impossible to achieve by means of releases from Vanderkloof Dam. Several previous studies recommended a storage and re-reregulation dam at Vioolsdrift on the Lower Orange. The main purpose of this dam was to reduce the operating losses in the ORP system, due to the long distance of control as well as to increase the system yield for future irrigation developments along the Lower Orange, specifically for Namibia. The location of the Vioolsdrift Dam is ideal for the proper control of releases to meet the river mouth EWR, as it is located fairly close to the estuary. With a dam at Vioolsdrift it will also be possible to utilise flows from the Namibia Fish River from time to time when sporadic flows from the Fish River do enter the Orange downstream of Vioolsdrift Dam. This will however require real time monitoring along the Lower Fish River.

- It is estimated that Vioolsdrift Dam will be able to reduce the operating losses by approximately 120 million m^3/a, and also increases the system yield by another 190 million m^3/a. The total benefit from Vioolsdrift Dam is thus 190 + 120 = 310 million m^3/a.
- Raising Gariep Dam by 10m, increases the ORP yield by 350 million m^3/a. The 10m raising of Gariep Dam unfortunately also significantly increases the full supply surface area from the existing 344.4 km^2 to 552.8 km^2, which in turn resulted in an increase in the average evaporation losses from Gariep Dam of 280 million m^3/a. This lead to reduced spills from Gariep and Vanderkloof dams, followed by reduced water availability for environmental purposes and a reduction in the yield generated from Vioolsdrift Dam.
- The raised Gariep Dam in combination with Vioolsdrift Dam and using the refined REC EWRs significantly improved the assurance of supply to the ORP users. The improvement was however not sufficient to adhere to the required assurance of supply in all the priority classes, as violations still occurred within the medium assurance class.
- The refined REC EWRs significantly reduced the yield impact on the ORP system. This illustrated the benefits that can be achieved by applying some changes or refinements to the REC EWRs, which were in this case mainly aimed at improving the EWR supply to the estuary.

6.4 Core Scenario Results

6.4.1 Integrated Vaal River System

The intervention options included in the Core Scenario relating to the IVRS were aligned with those proposed in the Vaal River System Reconciliation Strategy as prepared by DWA RSA.

- With all these intervention options in place it is expected that the IVRS will be in balance until approximately 2050.
- For the purpose of the Core Scenario, Polihali Dam (LHWP Phase II) was used to support both the IVRS and the Orange, with priority given to the IVRS. The support to the Orange will decrease over time as the demand in the IVRS increases. In order to control this duel support requirement, a first order operating rule based on the average expected IVRS demand growth, was used. Significantly more work need to be carried out to obtain the desired operating rule, as the performance of both the IVRS and the Orange is very sensitive to the operating rule applied. It is important that both Lesotho and the RSA take part in the development of this operating rule, which finally need to be agreed upon between these two parties.
- The Polihali Storage projection plot revealed that Polihali Dam requires a long filling time. This is in particular important when Polihali Dam is used to support the IVRS and the Orange System or when the maximum possible volume is transferred to the IVRS from the start. It is very important to take this behaviour of Polihali Dam into account when the final operating rule is developed.
- Transferring the maximum possible to the IVRS from Polihali Dam will be very ineffective, and will results in high losses in the IVRS due to significant increases in evaporation and spills.

- Successful implementation of WC/WDM, eradication of unlawful water in the Vaal system as well as the desalination of AMD, is of utmost importance to obtain a positive water balance in the IVRS over time, as well as to allow sufficient time for the implementation of the LHWP Phase II.

6.4.2 Orange River Project System (Gariep and Vanderkloof dams)

The intervention options applicable to the ORP as included in the Core Scenario were obtained from the recently completed strategy "Development of Reconciliation Strategies for Large Bulk Water Supply Systems: Orange River" (DWA, 2013) and are therefore in line with the DWA RSA planning in this regard. The Orange Reconciliation Strategy included several intervention options of which Verbeeldingskraal Dam and the raising of Gariep is mutually exclusive. All the other options to be used in combination with these two large infrastructure related options remain the same. For the purpose of the ORP component in the Core Scenario, both these possible options were considered and are referred to as Core Scenario 7.1 (Gariep Raising) and Core Scenario 7.2 (Verbeeldingskraal Dam).

- With all these intervention options in place in combination with the raised Gariep Dam option, the ORP is expected to maintain a positive balance until approximately 2046.
- With all these intervention options in place in combination with the Verbeeldingskraal Dam option, the ORP is expected to maintain a positive balance until approximately 2036. This is due to the lower additional yield of 230 million m^3/a generated by Verbeeldingskraal in comparison with the 350 million m^3/a from the raised Gariep option.
- The operating rule used to govern the transfers from Polihali to the IVRS, as well as the support to the ORP significantly impacts on the water availability in both the IVRS and the ORP system.
- Using Polihali Dam to initially support both the IVRS and the ORP system, significantly postpone the need of a yield replacement dam in the Orange. This will result in a significant economic advantage, without negative impacts on the assurance of supply in the IVRS.
- Polihali Dam requires a longer filling time combined with a more gradual increase in the demand imposed on the dam, over the initial years. Further analyses are required to obtain the best solution in this regard. These analyses should form part of the refinement of the LHWP Phase II operating rule.
- Obtaining support from Polihali Dam will not fully cover the deficits experienced in the ORP and other interventions options such as real time monitoring, utilising the lower level storage in Vanderkloof Dam and WC/WDM, also need to be implemented.
- Storage projections indicated that the raising of Gariep Dam requires quite a long warming up period, before it will be able to supply its full additional yield. One should therefore investigate the option to raise the dam earlier, to avoid failures in the assurance of supply during this critical warming up period.
- The real time modelling and monitoring option as well as WC/WDM need to be phased in from 2016 onwards, to overcome the first deficits that are expected to occur from 2017 onwards.

- This is followed by utilising the Vanderkloof lower level storage and the dual support from Polihali Dam, to overcome the significant increase in deficits when LHWP Phase II is activated.
- Vioolsdrift Dam is activated in 2024, followed by the implementation of the refined updated Orange EWRs. It will only be possible to supply the Orange River mouth EWR successfully by means of a proper control structure in the Lower Orange, such as Vioolsdrift Dam. For this reason the implementation of the refined updated Orange EWRs was scheduled for 2025 in the Core Scenario.
- The 10m raising of Gariep Dam or Verbeeldingskraal Dam is the last intervention option and need to be activated by 2026.
- Verbeeldingskraal Dam option has the advantage of significantly reducing the evaporation losses from the ORP system by approximately 200 million m^3/a, as well as the fact that it requires a very short warming up period.
  - To obtain this significant reduction in losses, it is important that the correct operating rule be used to control the support from Verbeeldingskraal Dam to Gariep Dam. Water should be kept for as long as possible in Verbeeldingskraal Dam, where the evaporation losses are much less and only be released in support of Gariep Dam when the storage level in Gariep is close to its m.o.l.
  - Verbeeldingskraal Dam option with much lower evaporation losses and significantly smaller incremental storage than for the raised Gariep Dam option will result in higher and more frequent spills from Vanderkloof Dam. This will be to the benefit of a dam at Vioolsdrift, as well as for the environmental requirements along the Orange River and at the Orange River mouth. This is evident from the following analysis results.
- The annual median simulated flows at the estuary are in the order of 1800 million m^3/a for both Core Scenarios and on average about 200 million m^3/a higher for the Verbeeldingskraal option from 2026 onwards, when the Raised Gariep and Verbeeldingskraal options were activated.

- At the 5% exceedance probability level (typical 1 in 20 year floods) the Verbeeldingskraal Dam option resulted in significantly higher flows from 2026 onwards. These flows were on average 1 570 million m^3/a higher than the average annual 5% exceedance probability flows from the Raised Gariep Dam option, with a highest difference of 3 200 million m^3/a evident over this analysis period (2026 to 2033).
- Similar increases in the Orange River flows at the estuary are evident when the Verbeeldinskraal Dam option is used and the 1% exceedance probability flows are compared. An average increase of 1 200 million m^3/a was found with the maximum increase within a single year of 3 130 million m^3/a for the Verbeeldingskraal Dam option..
- The Orange River Reconciliation Strategy as prepared by the RSA DWS recommended that a Pre-feasibility study be carried out before a final decision can be made on which of the two intervention options to implement (Gariep Dam Raising or Verbeeldingskraal Dam) in future. From the results obtained from Core Scenarios 7.1 and 7.2 it is clear that the impact on the environment will be an important component to take into account in the final evaluation of these two options.

6.4.3 Greater Bloemfontein system

The Greater Bloemfontein System water balance as prepared from the Reconciliation Strategy Study (DWA, 2012) included several intervention options and was also adopted for both of the Core Scenarios.

- Although the actual storage in this system was low at the start of the analysis, the selected interventions options made it possible for the system to recover from its low starting storage levels fairly quickly.
- By 2027 the 99.5% and 99% exceedance probability storage levels again dropped to the m.o.l. of the system, indicating that the system will start to experience deficits at that time if the re-use and support from Gariep Dam is not implemented.
- With all interventions successfully implemented, the system should be able to maintain a positive balance until 2035.
- The water supply from the Greater Bloemfontein sub-system is very sensitive to the operating rule imposed on the system, as well as the capacity of the Novo transfer link. The operating rule used in the Core Scenario was not optimised as part of this study. This operating rule urgently needs to be refined and require updates every time when infrastructure changes take place and or when the Novo Transfer capacity becomes a limitation due to increased system demands.

6.4.4 Recently completed Metolong Dam

- The impacts of Metolong Dam on the water supply from resources located downstream of Metolong Dam, are in general very small. This entails a 1 million m^3/a or 1% reduction in the yield from the BloemWater supply system with a reduction of less than 1 % in the average projected median storage level in Gariep Dam over the next 10 years. The yield reduction at Gariep Dam is for practical purposes negligible.
- WRPM analysis results showed that Metolong Dam will fill up fairly quickly and do not require a long warming up period.
- Metolong Dam is able to support the projected demands at a very high assurance, without any failures.
- When the revitalising of the old Maseru System was completed and started supporting the system again in combination with Metolong Dam, it was clear that the yield available from the two combined resources, was more than sufficient and the system was in fact underutilised.
- One should rather consider to always supplying a larger part of the system demand from Metolong Dam, as less pumping will be required with related savings in operating costs.
- The phasing in of the demands to be supplied from Metolong Dam was based on preliminary estimates by Lesotho and will most probably be adjusted depending on the progress made with the construction of the distribution system and water treatment plants.

6.4.5 Neckartal Dam currently under construction in Namibia

- Significant reduction in flows of between 60% to 80% is evident in the lower Fish River when no releases from Neckartal Dam are made in support of the environment. This emphasise the importance of environmental releases from Neckartal Dam in future.
- The impacts of Neckartal Dam on flows at the Orange River estuary are in general small.
- Due to the size of Neckartal Dam and the relative arid upstream catchment, the filling time of this dam is quite long, as obtained from the WRPM analyses results. It will be important to take this into account when planning the phasing in of the irrigation demands from the scheme over time.
- Once the storage levels stabilised after the phasing in of the scheme demands over time, it seems as if the dam will be able to supply approximately 13 million m^3/a of the 90 million m^3/a total demand, at a high assurance of 99.5% (1 in 200 year) another 17 million m^3/a at a 99% assurance (1 in 100 year) and the remainder at a 95% (1 in 20 year) assurance.

6.4.6 Botswana transfers

- The additional transfer through the Vaal Gamagara pipeline of 5 million m^3/a to Botswana villages located close to the South African border, is expected to start by approximately 2022/23. Almost no impact on the IVRS supply was evident from the WRPM results, as this additional demand represents less than 0.2% of the net demand imposed on the IVRS.
- The possible transfer from Lesotho to Botswana can have a significant impact on the existing users downstream of the point of abstraction. Until now no details were available on this possible transfer scheme and it could therefore not be analysed. It is however important to determine the related impacts of such a scheme on the bigger system, once information becomes available.

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ANNEXES

Annex 1. WRPM Schematic Diagrams

Annex 2. Demand Projections

Table 1: Demands modelled by means of min-max channels in the WRPM

SUB-SYSTEM	Resource	WRPM CHANNEL NO.	DESCRIPTION	RECIPIENT COUNTRY	DEMAND TYPE	WRPM TYPE	FIGURE NO.	2014	2015	2020	2025	2030	2035	2040
Caledon	Mohokare Tributary	3492	Butha-Buthe	Lesotho	Urban Demand	Min-Max	A-9	1.46	1.53	1.91	2.31	2.74	3.21	3.68
Caledon	Caledon Tributary	4316	Fouriesburg & Clarens	RSA	Urban Demand	Min-Max	A-9	1.69	1.77	1.91	2.06	2.21	2.35	2.50
Caledon	Armenia Dam Tributary	4314	Tweespruit	RSA	Urban Demand	Min-Max	A-9	0.66	0.67	0.68	0.68	0.69	0.70	0.70
Caledon	Armenia Dam	4307	Thaba Patchoa & Hobhouse	RSA	Urban Demand	Min-Max	A-9	0.26	0.27	0.29	0.31	0.34	0.36	0.38
Caledon	Mohokare Tributary	3483	Leribe (Hlotse)	Lesotho	Urban Demand	Min-Max	A-9	2.85	2.94	3.32	3.76	4.23	4.75	5.27
Caledon	Main Mohokare	4329	Maseru	Lesotho	Urban Demand	Min-Max	A-9	16.94	0.00	0.00	18.71	18.71	18.71	18.71
Caledon	Main Caledon & Meulspruit Dam	4310	Net effect: Ladybrand, Ficksburg, Clocolan	RSA	Urban Demand	Min-Max	A-9	13.10	13.61	15.59	17.58	19.58	21.58	23.58
Caledon	Metolong Dam	3510	Metolong	Lesotho	Urban Demand	Min-Max	A-9	0.00	17.13	18.21	0.81	2.09	3.36	4.53
Caledon	Lower Caledon Tributary	4313	Van Stadensrus	RSA	Urban Demand	Min-Max	A-9	0.08	0.08	0.09	0.09	0.10	0.11	0.11
Caledon	Lower Caledon Tributary	4315	Rouxville	RSA	Urban Demand	Min-Max	A-9	0.59	0.61	0.67	0.72	0.78	0.83	0.89
Caledon	Lower Caledon Tributary	4312	Smithfield	RSA	Urban Demand	Min-Max	A-9	0.50	0.52	0.56	0.60	0.65	0.69	0.74
Upper Orange	Kraai River	4322	Dordrecht	RSA	Urban Demand	Min-Max	A-10	0.36	0.39	0.55	0.60	0.64	0.69	0.74
Upper Orange	Kraai River	4328	Jamestown	RSA	Urban Demand	Min-Max	A-10	0.14	0.15	0.16	0.18	0.20	0.23	0.25
Upper Orange	Kraai River	4323	Net effect: Rhodes & Barkley East	RSA	Urban Demand	Min-Max	A-10	0.32	0.33	0.34	0.35	0.36	0.38	0.40
Upper Orange	Orange Tributary	4317	Sterkspruit	RSA	Urban Demand	Min-Max	A-10	5.79	6.15	6.30	6.45	6.76	7.08	7.39
Upper Orange	Orange Tributary	4327	Net effect: Zastron & Lady Grey	RSA	Urban Demand	Min-Max	A-10	1.65	1.70	1.70	1.70	1.71	1.71	1.71
Upper Orange	Orange River	4325	Net effect: Aliwal North	RSA	Urban Demand	Min-Max	A-10	1.00	1.05	1.11	1.17	1.25	1.34	1.43
Upper Orange	Molteno dam	4321	Molteno	RSA	Urban Demand	Min-Max	A-10	0.43	0.43	0.46	0.48	0.50	0.51	0.52
Upper Orange	JL de Bruin & Chiappinis Klip dam	4320	Net effect: Burgersdorp	RSA	Urban Demand	Min-Max	A-10	0.30	0.31	0.34	0.36	0.40	0.43	0.47
Fish	Hardap Dam	1799	Hardap Irrigation REMOVED 3 CHANNELS FROM NAMIBIA	Namibia	Irrigation Demand	Min-Max	A-11	44.00	44.00	44.00	44.00	44.00	44.00	44.00
Fish	Hardap Dam	1813	Hardap Urban	Namibia	Urban Demand	Min-Max	A-11	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Fish	Naute Dam	1806	Naute Irrigation	Namibia	Irrigation Demand	Min-Max	A-11	6.75	7.25	9.75	9.75	9.75	9.75	9.75
Fish	Naute Dam	1814	Naute Urban	Namibia	Urban Demand	Min-Max	A-11	1.95	1.95	1.95	1.95	1.95	1.95	1.95
Lower Orange Main Stem	ORP	1895	Upington Return Flow (35.7%)	RSA	Urban Return Flow	Min-Max	A-13	6.61	7.11	9.11	11.07	11.57	12.07	12.57
Eastern Cape Great Fish		5162	CRADOCK DOMESTIC	RSA	Urban Demand	Min-Max	A-14	1.93	1.97	2.20	2.38	2.59	2.63	2.67
Eastern Cape Great Fish		5228	COOKHOUSE DMD & Somerset East & Bedford	RSA	Urban Demand	Min-Max	A-14	2.16	2.20	2.39	2.61	2.84	3.09	3.36
Eastern Cape Great Fish		5258	GRAAF-REINET DOM DMD	RSA	Urban Demand	Min-Max	A-14	2.66	2.70	2.89	3.18	3.49	3.78	4.09
Eastern Cape Great Fish		5166	PORT ELIZABETH DMD	RSA	Urban Demand	Min-Max	A-14	31.05	31.05	31.05	31.05	31.05	31.05	31.05
Eastern Cape Great Fish		5241	ADDO KIRKWOOD ENON	RSA	Urban Demand	Min-Max	A-14	3.84	3.90	4.23	4.58	4.95	5.36	5.81
Eastern Cape Great Fish		5299	Grahamstown demand (Originally modelled as spec dem gran	RSA	Urban Demand	Min-Max	A-14	1.01	1.02	1.11	1.20	1.30	1.40	1.52
Zaaihoek Sub-system	Zaaihoek Tributaries	402	DEM 19: Wakkerstroom, Esizamelani	RSA	Urban Demand	Min-max	A-2	0.50	0.51	0.61	0.72	0.83	0.95	1.09
Upper Vaal: Vaal Barrage	Vaal Dam	76	SASOL: Sasolburg Complex abstraction from Vaal Dam	RSA	Strategic Demand	Min-max	A-4	21.18	21.18	21.18	21.18	21.18	21.18	21.18
Upper Vaal: Vaal Barrage	Vaal Dam	158	SASOL: Sasolburg Complex abstraction from Barrage	RSA	Strategic Demand	Min-max	A-4	1.09	1.56	3.96	6.58	9.47	12.66	16.18
Upper Vaal: Vaal Barrage	Suikerbosrand Dummy Dam (Vaal barra	833	Balfour abstractions (Suikerbosrand_Haarhof Dam))	RSA	Urban Demand	Min-max	A-4	1.78	1.90	2.01	2.12	2.24	2.37	2.50
Middle Vaal: Schoonspruit	Schoonspruit Eye	1674	Ventersdorp - (Supplied from Schoonspruit Spring)	RSA	Urban Demand	Min-max	A-5	2.25	2.31	2.46	2.61	2.77	2.91	3.06
Middle Vaal: Schoonspruit	Schoonspruit Mainstream	1682	Venterdorp - Ret Flow (45.4%) on growth in demand	RSA	Urban Return Flow	Min-max	A-5	-1.02	-1.05	-1.12	-1.19	-1.26	-1.32	-1.39
Lower Vaal: Harts River	Spitskop Dam Main stream	657	Kgomotso Cluster (Harts River us of Spitskop Dam)	RSA	Urban Demand	Min-max	A-6	0.25	0.25	0.25	0.25	0.26	0.26	0.26
Thukela Catchment	Spioenkop Dam mainstream	316	DEM 1: Bergville, Emmaus	RSA	Urban Demand	Min-max	A-2	3.00	3.19	4.29	4.34	4.39	4.43	4.48
Thukela Catchment	Woodstock Dam	307	DEM 2: Rural	RSA	Urban Demand	Min-max	A-2	10.02	10.33	12.02	12.13	12.24	12.36	12.49

Table 2-a: Demands modelled by means of Master Control channels in the WRPM

SUB-SYSTEM	Resource	WRPM CHANNEL NO.	DESCRIPTION	RECIPIENT COUNTRY	DEMAND TYPE	WRPM TYPE	FIGURE NO.	2014	2015	2020	2025	2030	2035	2040
Senqu	LHWP	582	LHWP losses	Lesotho	Loss	Master Control	A-9	0	0	0.000	0.000	0.000	0.000	0.000
Senqu	Polohali Dam tributaries	4782	Mokhotlong	Lesotho	Urban Demand	Master Control	A-9	1.04709	1.07461	1.223	1.393	1.587	1.808	2.029
Senqu	Mashai Dam tributaries	4778	Thaba-Tseka	Lesotho	Urban Demand	Master Control	A-9	1.08483	1.11763	1.297	1.505	1.745	2.024	2.303
Senqu	Oranjedraai catchment tributaries	4790	Qachas Nek	Lesotho	Urban Demand	Master Control	A-9	1.12662	1.15742	1.324	1.518	1.736	1.984	2.231
Senqu	Oranjedraai catchment tributaries	4780	Quithing	Lesotho	Urban Demand	Master Control	A-9	0.15132	0.15393	0.168	0.183	0.199	0.217	0.234
Makaleng	Oranjedraai catchment tributaries	4791	Mohales Hoek	Lesotho	Urban Demand	Master Control	A-9	1.3864	1.42994	1.661	1.918	2.206	2.529	2.853
Caledon	Caledon Tributary	4715	RR 1369: Irr demand	RSA	Irrigation Demand	Master Control	A-9	0.58003	0.58003	0.580	0.580	0.580	0.580	0.580
Caledon	Caledon Tributary	4716	RR 1369: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-9	0.27834	0.27834	0.278	0.278	0.278	0.278	0.278
Caledon	Caledon Tributary	4713	RR 968: Irr demand	RSA	Irrigation Demand	Master Control	A-9	6.07989	6.07989	6.080	6.080	6.080	6.080	6.080
Caledon	Caledon Tributary	4714	RR 968: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-9	2.83766	2.83766	2.838	2.838	2.838	2.838	2.838
Caledon	Caledon Tributary	4733	RR 804: Irr demand	RSA	Irrigation Demand	Master Control	A-9	2.0301	2.0301	2.030	2.030	2.030	2.030	2.030
Caledon	Caledon Tributary	4732	RR 804: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-9	0.84133	0.84133	0.841	0.841	0.841	0.841	0.841
Caledon	Caledon Tributary	4730	RR 1301: Irr demand	RSA	Irrigation Demand	Master Control	A-9	2.51987	2.51987	2.520	2.520	2.520	2.520	2.520
Caledon	Caledon Tributary	4731	RR 1301: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-9	0.85016	0.85016	0.850	0.850	0.850	0.850	0.850
Caledon	Armenia Dam	4739	RR 1316: Irr demand	RSA	Irrigation Demand	Master Control	A-9	0.23005	0.23005	0.230	0.230	0.230	0.230	0.230
Caledon	Armenia Dam	4740	RR 1316: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-9	0.0325	0.0325	0.033	0.033	0.033	0.033	0.033
Caledon	Armenia Dam Tributary	4734	RR 1312: Irr demand	RSA	Irrigation Demand	Master Control	A-9	2.34	2.34	2.340	2.340	2.340	2.340	2.340
Caledon	Armenia Dam Tributary	4735	RR 1312: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-9	0.62831	0.62831	0.628	0.628	0.628	0.628	0.628
Caledon	Caledon Tributary	4720	RR 975: Irr demand	RSA	Irrigation Demand	Master Control	A-9	5.34996	5.34996	5.350	5.350	5.350	5.350	5.350
Caledon	Caledon Tributary	4721	RR 975: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-9	2.01906	2.01906	2.019	2.019	2.019	2.019	2.019
Caledon	Main Caledon	4718	RR 974: Irr demand	RSA	Irrigation Demand	Master Control	A-9	6.94993	6.94993	6.950	6.950	6.950	6.950	6.950
Caledon	Main Caledon	4719	RR 974: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-9	1.43903	1.43903	1.439	1.439	1.439	1.439	1.439
Caledon	Caledon Tributary	4724	RR 1387: Irr demand	Lesotho	Irrigation Demand	Master Control	A-9	0.31212	0.31212	0.312	0.312	0.312	0.312	0.312
Caledon	Caledon Tributary	4725	RR 1387: Irr return flow	Lesotho	Irrigation Return Flow	Master Control	A-9	0	0	0.000	0.000	0.000	0.000	0.000
Caledon	Caledon Tributary	4728	RR 1399: Irr demand	Lesotho	Irrigation Demand	Master Control	A-9	4.10661	4.10661	4.107	4.107	4.107	4.107	4.107
Caledon	Caledon Tributary	4729	RR 1399: Irr return flow	Lesotho	Irrigation Return Flow	Master Control	A-9	0.12118	0.12118	0.121	0.121	0.121	0.121	0.121
Caledon	Caledon Tributary	4742	RR 1239: Irr demand	Lesotho	Irrigation Demand	Master Control	A-9	4.43333	4.43333	4.433	4.433	4.433	4.433	4.433
Caledon	Caledon Tributary	4743	RR 1239: Irr return flow	Lesotho	Irrigation Return Flow	Master Control	A-9	1.08495	1.08495	1.085	1.085	1.085	1.085	1.085
Caledon	Caledon Tributary	4745	RR 836: Irr demand	Lesotho	Irrigation Demand	Master Control	A-9	8.34794	8.34794	8.348	8.348	8.348	8.348	8.348
Caledon	Caledon Tributary	4746	RR 836: Irr return flow	Lesotho	Irrigation Return Flow	Master Control	A-9	0.96314	0.96314	0.963	0.963	0.963	0.963	0.963
Caledon	Main Caledon	4749	RR 1234: Irr demand	RSA	Irrigation Demand	Master Control	A-9	0.97008	0.97008	0.970	0.970	0.970	0.970	0.970
Caledon	Main Caledon	4751	RR 1234: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-9	0.22974	0.22974	0.230	0.230	0.230	0.230	0.230
Caledon	Mohokare Mainstream	4804	Maseru Return Flow (12.8	Lesotho	Urban Return Flow	Master Control	A-9	2.06397	2.18597	2.796	3.636	4.477	5.317	6.158
Caledon	Mohokare Tributary	4767	total Mapoteng	Lesotho	Urban Demand	Master Control	A-9	1.58507	1.5892	1.612	1.638	1.668	1.703	1.844
Caledon	Mohokare Tributary	4772	Mafeteng	Lesotho	Urban Demand	Master Control	A-9	0.81673	0.8344	0.932	1.042	1.149	1.255	1.362
Caledon	Mohokare Tributary	4774	Morija	Lesotho	Urban Demand	Master Control	A-9	0.10399	0.10399	0.104	0.104	0.104	0.104	0.104
Caledon	Mohokare Tributary	4784	Berea District Rural	Lesotho	Urban Demand	Master Control	A-9	1.1902	1.22591	1.421	1.648	1.910	2.214	2.518
Caledon	Mohokare Tributary	4786	Mafeteng District Rural	Lesotho	Urban Demand	Master Control	A-9	1.30639	1.34558	1.560	1.808	2.096	2.430	2.764
Caledon	Mohokare Tributary	4789	Maseru District Rural	Lesotho	Urban Demand	Master Control	A-9	1.65236	1.70193	1.973	2.287	2.652	3.074	3.496
Caledon	Knellpoort Dam tributary	4753	RR 1323: Irr demand	RSA	Irrigation Demand	Master Control	A-9	1.62995	1.62995	1.630	1.630	1.630	1.630	1.630
Caledon	Knellpoort Dam tributary	4754	RR 1323: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-9	0.29001	0.29001	0.290	0.290	0.290	0.290	0.290
Caledon	Lower Caledon Tributary	4758	RR 1251: Irr demand	RSA	Irrigation Demand	Master Control	A-9	1.33867	1.33867	1.339	1.339	1.339	1.339	1.339

Table 2-b: Demands modelled by means of Master Control channels in the WRPM

SUB-SYSTEM	Resource	WRPM CHANNEL NO.	DESCRIPTION	RECIPIENT COUNTRY	DEMAND TYPE	WRPM TYPE	FIGURE NO.	2014	2015	2020	2025	2030	2035	2040
Caledon	Lower Caledon Tributary	4759	RR 1251: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-9	0.37585	0.37585	0.376	0.376	0.376	0.376	0.376
Caledon	Egmond Dam	4764	RR 957: Irr demand	RSA	Irrigation Demand	Master Control	A-9	0.30926	0.30926	0.309	0.309	0.309	0.309	0.309
Caledon	Egmond Dam	4763	RR 957: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-9	0.10035	0.10035	0.100	0.100	0.100	0.100	0.100
Caledon	Lower Caledon Tributary	4769	RR 964: Irr demand	*RSA*	Irrigation Demand	Master Control	A-9	1.20392	1.20392	1.204	1.204	1.204	1.204	1.204
Caledon	Lower Caledon Tributary	4770	RR 964: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-9	0.19503	0.19503	0.195	0.195	0.195	0.195	0.195
Caledon	Main Lower Caledon	4771	RR 1352: Irr demand	RSA	Irrigation Demand	Master Control	A-9	9.02958	9.02958	9.030	9.030	9.030	9.030	9.030
Caledon	Main Lower Caledon	4773	RR 1352: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-9	1.56747	1.56747	1.567	1.567	1.567	1.567	1.567
Caledon	Main Lower Caledon	4775	RR 1467: Irr demand	RSA	Irrigation Demand	Master Control	A-9	14.5525	14.5525	14.552	14.552	14.552	14.552	14.552
Caledon	Main Lower Caledon	4776	RR 1467: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-9	2.47412	2.47412	2.474	2.474	2.474	2.474	2.474
Caledon	Main Lower Caledon	4777	RR 873: Irr demand	RSA	Irrigation Demand	Master Control	A-9	6.18403	6.18403	6.184	6.184	6.184	6.184	6.184
Caledon	Main Lower Caledon	4779	RR 873: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-9	1.01268	1.01268	1.013	1.013	1.013	1.013	1.013
Caledon	Lower Caledon Tributary	4783	RR 875: Irr demand	RSA	Irrigation Demand	Master Control	A-9	2.99608	2.99608	2.996	2.996	2.996	2.996	2.996
Caledon	Lower Caledon Tributary	4781	RR 875: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-9	0.48409	0.48409	0.484	0.484	0.484	0.484	0.484
Upper Orange	Kraai River	4797	RR 1498: Irr demand	RSA	Irrigation Demand	Master Control	A-10	6.31688	6.31688	6.317	6.317	6.317	6.317	6.317
Upper Orange	Kraai River	4792	RR 1498: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-10	1.74577	1.74577	1.746	1.746	1.746	1.746	1.746
Upper Orange	Kraai River	4858	RR 1412: Irr demand	RSA	Irrigation Demand	Master Control	A-10	18.6559	18.6559	18.656	18.656	18.656	18.656	18.656
Upper Orange	Kraai River	4860	RR 1412: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-10	4.78035	4.78035	4.780	4.780	4.780	4.780	4.780
Upper Orange	Kraai River	3132	Kraai resource poor	RSA	Irrigation Demand	Master Control	A-10	1.37778	1.91667	4.611	7.306	10.000	10.000	10.000
Upper Orange	Kraai River	4865	RR 1433: Irr demand	RSA	Irrigation Demand	Master Control	A-10	3.05004	3.05004	3.050	3.050	3.050	3.050	3.050
Upper Orange	Kraai River	4864	RR 1433: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-10	1.15343	1.15343	1.153	1.153	1.153	1.153	1.153
Upper Orange	Kraai River	4866	RR 1427: Irr demand	RSA	Irrigation Demand	Master Control	A-10	6.13006	6.13006	6.130	6.130	6.130	6.130	6.130
Upper Orange	Kraai River	4867	RR 1427: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-10	1.90923	1.90923	1.909	1.909	1.909	1.909	1.909
Upper Orange	Orange Tributary	4787	RR 1489: Irr demand	RSA	Irrigation Demand	Master Control	A-10	1.93858	1.93858	1.939	1.939	1.939	1.939	1.939
Upper Orange	Orange Tributary	4788	RR 1489: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-10	0.44275	0.44275	0.443	0.443	0.443	0.443	0.443
Upper Orange	Orange River	3133	RR 3133: Irr demand	RSA	Irrigation Demand	Master Control	A-10	1.22	1.22	1.220	1.220	1.220	1.220	1.220
Upper Orange	Orange River	3140	RR 3133: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-10	0.122	0.122	0.122	0.122	0.122	0.122	0.122
Upper Orange	Orange River	3134	RR 3135: Irr demand	RSA	Irrigation Demand	Master Control	A-10	5.42	5.42	5.420	5.420	5.420	5.420	5.420
Upper Orange	Orange River	3136	RR 3135: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-10	0.542	0.542	0.542	0.542	0.542	0.542	0.542
Upper Orange	Orange Tributary	4884	RR 1466: Irr demand	RSA	Irrigation Demand	Master Control	A-10	5.80975	5.80975	5.810	5.810	5.810	5.810	5.810
Upper Orange	Orange Tributary	4885	RR 1466: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-10	0.9442	0.9442	0.944	0.944	0.944	0.944	0.944
Upper Orange	Orange Tributary	4893	RR 1327: Irr demand	RSA	Irrigation Demand	Master Control	A-10	5.5251	5.5251	5.525	5.525	5.525	5.525	5.525
Upper Orange	Orange Tributary	4892	RR 1327: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-10	0.91265	0.91265	0.913	0.913	0.913	0.913	0.913
Upper Orange	Orange Tributary	4900	RR 1284: Irr demand	RSA	Irrigation Demand	Master Control	A-10	7.25762	7.25762	7.258	7.258	7.258	7.258	7.258
Upper Orange	Orange Tributary	4006	RR 1284: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-10	1.05529	1.05529	1.055	1.055	1.055	1.055	1.055
Upper Orange	Orange Tributary	4897	RR 1321: Irr demand	RSA	Irrigation Demand	Master Control	A-10	3.7361	3.7361	3.736	3.736	3.736	3.736	3.736
Upper Orange	Orange Tributary	4898	RR 1321: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-10	0.5633	0.5633	0.563	0.563	0.563	0.563	0.563
Upper Orange	Orange River	4877	RR 1326: Irr demand	RSA	Irrigation Demand	Master Control	A-10	14.7074	14.7074	14.707	14.707	14.707	14.707	14.707
Upper Orange	Orange River	4878	RR 1326: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-10	1.46017	1.46017	1.460	1.460	1.460	1.460	1.460
Upper Orange	Orange Tributary	4907	RR 854: Irr demand	RSA	Irrigation Demand	Master Control	A-10	6.89092	6.89092	6.891	6.891	6.891	6.891	6.891
Upper Orange	Orange Tributary	4919	RR 854: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-10	0.85805	0.85805	0.858	0.858	0.858	0.858	0.858

Table 2-c: Demands modelled by means of Master Control channels in the WRPM

SUB-SYSTEM	Resource	WRPM CHANNEL NO.	DESCRIPTION	RECIPIENT COUNTRY	DEMAND TYPE	WRPM TYPE	FIGURE NO.	2014	2015	2020	2025	2030	2035	2040
Upper Orange	ORP	530	Eastern Cape Irrigation	RSA	Irrigation Demand	Master Control	A-10	577.168	577.168	595.168	613.168	613.168	613.168	621.168
Upper Orange	ORP	529	Eastern Cape Urban	RSA	Urban Demand	Master Control	A-10	70.7668	70.9845	72.073	73.300	74.527	75.727	76.927
Upper Orange	ORP	1951	Operational Losses	RSA/Namibia	Loss	Master Control	A-10	180	180	180.000	180.000	180.000	180.000	60.000
Upper Orange	ORP	1767	Losses Reach 1A	RSA	Loss	Master Control	A-10	44.3	44.3	44.300	44.300	44.300	44.300	44.300
Upper Orange	Orange Tributary	4967	RR 1329: Irr demand	RSA	Irrigation Demand	Master Control	A-10	0.46011	0.46011	0.460	0.460	0.460	0.460	0.460
Upper Orange	Orange Tributary	4970	RR 1329: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-10	0.04544	0.04544	0.045	0.045	0.045	0.045	0.045
Upper Orange	Orange Tributary	4000	RR 950: Irr demand	RSA	Irrigation Demand	Master Control	A-10	0.40015	0.40015	0.400	0.400	0.400	0.400	0.400
Upper Orange	Orange Tributary	4004	RR 950: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-10	0.05396	0.05396	0.054	0.054	0.054	0.054	0.054
Upper Orange	Orange Tributary	4976	RR 1336: Irr demand	RSA	Irrigation Demand	Master Control	A-10	2.29992	2.29992	2.300	2.300	2.300	2.300	2.300
Upper Orange	Orange Tributary	4978	RR 1336: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-10	0.22122	0.22122	0.221	0.221	0.221	0.221	0.221
Upper Orange	Orange Tributary	4993	RR 1343: Irr demand	RSA	Irrigation Demand	Master Control	A-10	0.27992	0.27992	0.280	0.280	0.280	0.280	0.280
Upper Orange	Orange Tributary	4994	RR 1343: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-10	0.02966	0.02966	0.030	0.030	0.030	0.030	0.030
Upper Orange	Orange Tributary	4995	RR 941: Irr demand	RSA	Irrigation Demand	Master Control	A-10	0.65009	0.65009	0.650	0.650	0.650	0.650	0.650
Upper Orange	Orange Tributary	4997	RR 941: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-10	0.07321	0.07321	0.073	0.073	0.073	0.073	0.073
Upper Orange	Orange Tributary	4987	RR 944: Irr demand	RSA	Irrigation Demand	Master Control	A-10	0.36007	0.36007	0.360	0.360	0.360	0.360	0.360
Upper Orange	Orange Tributary	4986	RR 944: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-10	0.04134	0.04134	0.041	0.041	0.041	0.041	0.041
Upper Orange	Orange Tributary	4983	RR 938: Irr demand	RSA	Irrigation Demand	Master Control	A-10	0.24994	0.24994	0.250	0.250	0.250	0.250	0.250
Upper Orange	Orange Tributary	4982	RR 938: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-10	0.03124	0.03124	0.031	0.031	0.031	0.031	0.031
Upper Orange	Orange Tributary	4989	RR 349: Irr demand	RSA	Irrigation Demand	Master Control	A-10	0.75991	0.75991	0.760	0.760	0.760	0.760	0.760
Upper Orange	Orange Tributary	4990	RR 349: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-10	0.06469	0.06469	0.065	0.065	0.065	0.065	0.065
Upper Orange	ORP	484	Irr from Gariep compensa	RSA	Irrigation Demand	Master Control	A-10	21.948	21.948	21.948	21.948	21.948	21.948	21.948
Upper Orange	ORP	1743	Irr VDK to Torquay	RSA	Irrigation Demand	Master Control	A-10	141.14	141.14	141.140	141.140	141.140	141.140	141.140
Upper Orange	ORP	1853	Ramah Canal Irrigation	RSA	Irrigation Demand	Master Control	A-10	53.34	53.34	53.340	53.340	53.340	53.340	53.340
Upper Orange	ORP	2155	Ramah Canal Return Flo	RSA	Irrigation Return Flow	Master Control	A-10	11.5	11.5	11.500	11.500	11.500	11.500	11.500
Upper Orange	ORP	1878	RR239: Orange Riet Can	RSA	Irrigation Demand	Master Control	A-10	171.339	171.339	171.339	171.339	171.339	171.339	171.339
Upper Orange	ORP	2171	Resource poor upper ora	RSA	Irrigation Demand	Master Control	A-10	19.11	24.7325	30.845	31.825	31.825	31.825	31.825
Upper Orange	ORP	1929	RR239: Orange Riet Can	RSA	Irrigation Return Flow	Master Control	A-10	5.2212	5.2212	5.221	5.221	5.221	5.221	5.221
Upper Orange	ORP	4324	Venterstad	RSA	Urban Demand	Master Control	A-10	0.42424	0.43908	0.470	0.496	0.537	0.577	0.617
Upper Orange	ORP & Bethuli Dam	4326	Bethulie	RSA	Urban Demand	Master Control	A-10	1.77087	1.79027	1.858	1.923	1.984	2.046	2.107
Upper Orange	ORP	1883	Urban between Gariep ar	RSA	Urban Demand	Master Control	A-10	3.38841	3.4665	3.669	3.877	4.090	4.302	4.515
Upper Orange	ORP	2161	Bloemfontein on curve	RSA	Urban Demand	Master Control	A-10	21.54	21.54	21.540	21.540	21.540	21.540	21.540
Upper Orange	ORP	1745	Hopetown, Vanderkloof &	RSA	Urban Demand	Master Control	A-10	2.2255	2.29797	2.496	2.698	2.903	3.108	3.313
Riet/Modder	Modder Tributary	967	RR 435: Irr demand	RSA	Irrigation Demand	Master Control	A-8	1.03288	1.03288	1.033	1.033	1.033	1.033	1.033
Riet/Modder	Modder Tributary	969	RR 435: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-8	0.35345	0.35345	0.353	0.353	0.353	0.353	0.353
Riet/Modder	Modder Tributary	971	RR 438: Irr demand	RSA	Irrigation Demand	Master Control	A-8	0.21996	0.21996	0.220	0.220	0.220	0.220	0.220
Riet/Modder	Modder Tributary	972	RR 438: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-8	0.14706	0.14706	0.147	0.147	0.147	0.147	0.147
Riet/Modder	Caledon/Modder	943	Botshabelo Abstractions	RSA	Urban Demand	Master Control	A-8	9.68319	9.82725	11.505	13.535	15.889	18.617	21.461
Riet/Modder	Caledon/Modder	1700	Manguang LM Demand s	RSA	Urban Demand	Master Control	A-8	0	0	0.000	0.000	0.000	0.000	0.000
Riet/Modder	Caledon/Modder	748	ThabaN'Chu dem	RSA	Urban Demand	Master Control	A-8	4.87541	4.94794	5.793	6.815	8.000	9.374	10.806
Riet/Modder	Modder Tributary	935	RR 416: Irr demand	RSA	Irrigation Demand	Master Control	A-8	0.13002	0.13002	0.130	0.130	0.130	0.130	0.130

Table 2-d: Demands modelled by means of Master Control channels in the WRPM

SUB-SYSTEM	Resource	WRPM CHANNEL NO.	DESCRIPTION	RECIPIENT COUNTRY	DEMAND TYPE	WRPM TYPE	FIGURE NO.	2014	2015	2020	2025	2030	2035	2040
Riet/Modder	Modder Tributary	937	RR 416: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-8	0.06028	0.06028	0.060	0.060	0.060	0.060	0.060
Riet/Modder	Modder Tributary	944	RR 420: Irr demand	RSA	Irrigation Demand	Master Control	A-8	1.77007	1.77007	1.770	1.770	1.770	1.770	1.770
Riet/Modder	Modder Tributary	945	RR 420: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-8	0.42161	0.42161	0.422	0.422	0.422	0.422	0.422
Riet/Modder	Modder Tributary & Bloemfontein Retur	955	RR 430: Irr demand	RSA	Irrigation Demand	Master Control	A-8	3.96995	3.96995	3.970	3.970	3.970	3.970	3.970
Riet/Modder	Modder Tributary & Bloemfontein Retur	956	RR 430: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-8	0.91265	0.91265	0.913	0.913	0.913	0.913	0.913
Riet/Modder	Main Modder River	962	RR 424: Irr demand	RSA	Irrigation Demand	Master Control	A-8	13.1501	13.1501	13.150	13.150	13.150	13.150	13.150
Riet/Modder	Main Modder River	963	RR 424: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-8	3.29304	3.29304	3.293	3.293	3.293	3.293	3.293
Riet/Modder	Caledon/Modder	951	Bloemfontein Return Flov	RSA	Urban Return Flow	Master Control	A-8	35.5351	36.0638	42.220	49.670	58.307	68.320	78.758
Riet/Modder	Caledon/Modder	941	Botshabelo Return Flows	RSA	Urban Return Flow	Master Control	A-8	4.16377	4.22572	4.947	5.820	6.832	8.005	9.228
Riet/Modder	Caledon/Modder	749	ThabaN'Chu Return Flow	RSA	Urban Return Flow	Master Control	A-8	2.4377	2.47397	2.896	3.407	4.000	4.687	5.403
Riet/Modder	Caledon/Modder	948	Bloemfontein return flows	RSA	Urban Return Flow	Master Control	A-8	2.65684	2.65684	2.657	2.657	2.657	2.657	2.657
Riet/Modder	Caledon/Modder	950	Bloemfontein total	RSA	Urban Demand	Master Control	A-8	69.3639	70.3958	82.412	96.955	113.815	133.360	153.733
Riet/Modder	Caledon/Modder	101	Small Users and Towns a	RSA	Urban Demand	Master Control	A-8	3.46364	3.51518	4.115	4.841	5.683	6.659	7.677
Riet/Modder	Krugersdrift Dam	3127	Krugersdrift Urban	RSA	Urban Demand	Master Control	A-8	0.27013	0.27833	0.313	0.338	0.363	0.389	0.414
Riet/Modder	Modder Tributary	981	RR 445: Irr demand	RSA	Irrigation Demand	Master Control	A-8	1.04014	1.04014	1.040	1.040	1.040	1.040	1.040
Riet/Modder	Modder Tributary	983	RR 445: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-8	0.09341	0.09341	0.093	0.093	0.093	0.093	0.093
Riet/Modder	Krugersdrift Dam	986	RR 453: Irr demand	RSA	Irrigation Demand	Master Control	A-8	14.2633	14.2633	14.263	14.263	14.263	14.263	14.263
Riet/Modder	Krugersdrift Dam	987	RR 453: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-8	2.15665	2.15665	2.157	2.157	2.157	2.157	2.157
Riet/Modder	Krugersdrift Dam	989	RR 454: Irr demand	RSA	Irrigation Demand	Master Control	A-8	14.2633	14.2633	14.263	14.263	14.263	14.263	14.263
Riet/Modder	Krugersdrift Dam	990	RR 454: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-8	2.15665	2.15665	2.157	2.157	2.157	2.157	2.157
Riet/Modder	Krugersdrift Dam	992	RR 455: Irr demand	RSA	Irrigation Demand	Master Control	A-8	14.2633	14.2633	14.263	14.263	14.263	14.263	14.263
Riet/Modder	Krugersdrift Dam	993	RR 455: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-8	2.15665	2.15665	2.157	2.157	2.157	2.157	2.157
Riet/Modder	Tierpoort Tributary	144	RR 458: Irr demand	RSA	Irrigation Demand	Master Control	A-8	0.56015	0.56015	0.560	0.560	0.560	0.560	0.560
Riet/Modder	Tierpoort Tributary	145	RR 458: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-8	0.21649	0.21649	0.216	0.216	0.216	0.216	0.216
Riet/Modder	Tierpoort Tributary	147	RR 461: Irr demand	RSA	Irrigation Demand	Master Control	A-8	1.17016	1.17016	1.170	1.170	1.170	1.170	1.170
Riet/Modder	Tierpoort Tributary	148	RR 461: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-8	0.41151	0.41151	0.412	0.412	0.412	0.412	0.412
Riet/Modder	Tierpoort Dam	152	RR 469: Irr demand	RSA	Irrigation Demand	Master Control	A-8	7.76128	7.76128	7.761	7.761	7.761	7.761	7.761
Riet/Modder	Tierpoort Dam	198	RR 469: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-8	1.66435	1.66435	1.664	1.664	1.664	1.664	1.664
Riet/Modder	Riet River Tributary	195	RR 468: Irr demand	RSA	Irrigation Demand	Master Control	A-8	3.96995	3.96995	3.970	3.970	3.970	3.970	3.970
Riet/Modder	Riet River Tributary	197	RR 468: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-8	0.45538	0.45538	0.455	0.455	0.455	0.455	0.455
Riet/Modder	Riet River Tributary	473	RR 472: Irr demand	RSA	Irrigation Demand	Master Control	A-8	14.1599	14.1599	14.160	14.160	14.160	14.160	14.160
Riet/Modder	Riet River Tributary	474	RR 472: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-8	1.63437	1.63437	1.634	1.634	1.634	1.634	1.634
Riet/Modder	Kalkfontein Dam	996	RR 342: Irr demand	RSA	Irrigation Demand	Master Control	A-8	45.4401	45.4401	45.440	45.440	45.440	45.440	45.440
Riet/Modder	Kalkfontein Dam	997	RR 342: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-8	7.26014	7.26014	7.260	7.260	7.260	7.260	7.260
Riet/Modder	Kalkfontein Dam	3128	Kalkfontein Urban	RSA	Urban and Mining Dema	Master Control	A-8	4.84018	5.00427	5.825	6.645	7.466	8.286	9.107
Riet/Modder	ORP	483	RR 479: Irr demand	RSA	Irrigation Demand	Master Control	A-8	2.661	2.661	2.661	2.661	2.661	2.661	2.661
Riet/Modder	ORP	486	RR 479: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-8	0.168	0.168	0.168	0.168	0.168	0.168	0.168
Riet/Modder	ORP	490	RR 482: Irr demand	RSA	Irrigation Demand	Master Control	A-8	65.5401	65.5401	65.540	65.540	65.540	65.540	65.540
Riet/Modder	ORP	493	RR 482: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-8	4.401	4.401	4.401	4.401	4.401	4.401	4.401
Riet/Modder	ORP	1973	RR 594: Irr demand	RSA	Irrigation Demand	Master Control	A-8	9.02888	9.02888	9.029	9.029	9.029	9.029	9.029

Table 2-e: Demands modelled by means of Master Control channels in the WRPM

SUB-SYSTEM	Resource	WRPM CHANNEL NO.	DESCRIPTION	RECIPIENT COUNTRY	DEMAND TYPE	WRPM TYPE	FIGURE NO.	2014	2015	2020	2025	2030	2035	2040
Riet/Modder	ORP	1995	RR 594: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-8	0.57108	0.57108	0.571	0.571	0.571	0.571	0.571
Riet/Modder	ORP	1843	Richie, Luckhoff, and Opp	RSA	Urban Demand	Master Control	A-8	2.39369	2.51132	2.706	2.898	3.094	3.289	3.484
Lower Vaal	ORP	467	Losses Reach 1B	RSA	Loss	Master Control	A-8	11.72	11.72	11.720	11.720	11.720	11.720	11.720
Lower Vaal	ORP	525	RR 5: Irr demand	RSA	Irrigation Demand	Master Control	A-8	94.18	94.18	94.180	94.180	94.180	94.180	94.180
Lower Vaal	ORP	526	RR 5: Irr return flow	RSA	Irrigation Return Flow	Master Control	A-8	10.1244	10.1244	10.124	10.124	10.124	10.124	10.124
Lower Vaal	ORP	450	Irr from Orange Vaal Tran	RSA	Irrigation Demand	Master Control	A-8	26.35	26.35	26.350	26.350	26.350	26.350	26.350
Lower Vaal	ORP	543	Irr Torquay to Vaal	RSA	Irrigation Demand	Master Control	A-8	46.24	46.24	46.240	46.240	46.240	46.240	46.240
Lower Vaal	ORP	655	Upper Orange Irr Growth	RSA	Irrigation Demand	Master Control	A-8	0	0	0.000	0.000	0.000	0.000	0.000
Lower Vaal	ORP	497	Douglas Urban	RSA	Urban Demand	Master Control	A-8	2.32111	2.42157	2.729	3.004	3.258	3.512	3.766
Molopo	Molopo Eye & Setumo Dam	3131	Mafikeng from Setumo Da	RSA	Urban Demand	Master Control	A-12	10.664	10.838	12.980	14.085	14.461	14.837	15.213
Lower Orange Main	ORP	1844	Losses Reach 2	Namibia	Loss	Master Control	A-12	105.96	105.96	105.960	105.960	105.960	105.960	105.960
Lower Orange Main	ORP	8001	Losses Reach 2	Namibia	Loss	Master Control	A-12	20.59	20.59	20.590	20.590	20.590	20.590	20.590
Lower Orange Main	ORP	1842	Prieska Urban Demand	RSA	Urban Demand	Master Control	A-12	1.72106	1.75325	1.875	2.002	2.131	2.260	2.389
Lower Orange Main	ORP	1846	Middel Orange Irrigation	RSA	Irrigation Demand	Master Control	A-12	152.21	152.21	152.210	152.210	152.210	152.210	152.210
Lower Orange Main	ORP	1850	Return Flow Mid. Orange	RSA	Irrigation Return Flow	Master Control	A-12	18.2379	18.2379	18.238	18.238	18.238	18.238	18.238
Lower Orange Main	ORP	1854	Boegoeberg Canal Irr	RSA	Irrigation Demand	Master Control	A-12	101.37	101.37	101.370	101.370	101.370	101.370	101.370
Lower Orange Main	ORP	1864	Boegoeberg Irr Return Flo	RSA	Irrigation Return Flow	Master Control	A-12	26.0201	26.0201	26.020	26.020	26.020	26.020	26.020
Lower Orange Main	ORP	1880	Losses Reach 3	Namibia	Loss	Master Control	A-12	101.25	101.25	101.250	101.250	101.250	101.250	101.250
Lower Orange Main	ORP	8002	Losses Reach 3	Namibia	Loss	Master Control	A-12	29.65	29.65	29.650	29.650	29.650	29.650	29.650
Lower Orange Main	ORP	1855	Upington River Irrigation	RSA	Irrigation Demand	Master Control	A-12	76.67	76.67	76.670	76.670	76.670	76.670	76.670
Lower Orange Main	ORP	4796	Upington River Irrigation r	RSA	Irrigation Return Flow	Master Control	A-12	8.222	8.222	8.222	8.222	8.222	8.222	8.222
Lower Orange Main	ORP	1893	Upington and Others Urba	RSA	Urban Demand	Master Control	A-12	18.5263	19.9223	25.508	31.015	32.414	33.813	35.211
Lower Orange Main	ORP	1866	Upington Canals Irrigation	RSA	Irrigation Demand	Master Control	A-12	104.24	104.24	104.240	104.240	104.240	104.240	104.240
Lower Orange Main	ORP	1872	Upington Irr Return Flows	RSA	Irrigation Return Flow	Master Control	A-12	26.7568	26.7568	26.757	26.757	26.757	26.757	26.757
Lower Orange Main	ORP	1897	Keimoes Irrigation	RSA	Irrigation Demand	Master Control	A-12	51.13	51.13	51.130	51.130	51.130	51.130	51.130
Lower Orange Main	ORP	1874	Keimoes Irr Return Flows	RSA	Irrigation Return Flow	Master Control	A-12	14.8332	14.8332	14.833	14.833	14.833	14.833	14.833
Lower Orange Main	ORP	1884	Kakamas Urban Demand	RSA	Urban Demand	Master Control	A-12	2.46681	2.53648	2.758	2.974	3.199	3.424	3.649
Lower Orange Main	ORP	1857	Kakamas River Irrigation	RSA	Irrigation Demand	Master Control	A-12	31.39	31.39	31.390	31.390	31.390	31.390	31.390
Lower Orange Main	ORP	4795	Kakamas River Irrigation	RSA	Irrigation Return Flow	Master Control	A-12	2.939	2.939	2.939	2.939	2.939	2.939	2.939
Lower Orange Main	ORP	1927	Kakamas Canals Irrigatio	RSA	Irrigation Demand	Master Control	A-12	111.38	111.38	111.380	111.380	111.380	111.380	111.380
Lower Orange Main	ORP	1889	Kakamas Irr Return Flows	RSA	Irrigation Return Flow	Master Control	A-12	28.2801	28.2801	28.280	28.280	28.280	28.280	28.280
Lower Orange Main	ORP	1894	Namakwa Irrigation	RSA	Irrigation Demand	Master Control	A-12	10.44	10.44	10.440	10.440	10.440	10.440	10.440
Lower Orange Main	ORP	4800	Namakwa Irrigation return	RSA	Irrigation Return Flow	Master Control	A-12	0.978	0.978	0.978	0.978	0.978	0.978	0.978
Lower Orange Main	ORP	1892	Losses Reach 4	Namibia	Loss	Master Control	A-12	25.72	25.72	25.720	25.720	25.720	25.720	25.720
Lower Orange Main	ORP	8003	Losses Reach 4	Namibia	Loss	Master Control	A-12	11.39	11.39	11.390	11.390	11.390	11.390	11.390
Lower Orange Main	ORP	1902	Losses Reach 5	Namibia	Loss	Master Control	A-12	113.76	113.76	113.760	113.760	113.760	113.760	113.760
Lower Orange Main	ORP	8004	Losses Reach 5	Namibia	Loss	Master Control	A-12	30.16	30.16	30.160	30.160	30.160	30.160	30.160
Lower Orange Main	ORP	1900	Pelladrift Water Board	RSA	Urban Demand	Master Control	A-12	15.9802	15.9948	16.035	16.079	16.126	16.172	16.230
Lower Orange Main	ORP	1898	Namakwa Irrigation	RSA	Irrigation Demand	Master Control	A-12	52.83	52.83	52.83	52.83	52.83	52.83	52.83

Table 2-f: Demands modelled by means of Master Control channels in the WRPM

SUB-SYSTEM	Resource	WRPM CHANNEL NO.	DESCRIPTION	RECIPIENT COUNTRY	DEMAND TYPE	WRPM TYPE	FIGURE NO.	2014	2015	2020	2025	2030	2035	2040
Lower Orange Main	ORP	4801	Namakwa Irrigation returr	RSA	Irrigation Return Flow	Master Control	A-12	3.51	3.51	3.51	3.51	3.51	3.51	3.51
Lower Orange Main	ORP	1818	Namakwa Water Board	RSA	Urban Demand	Master Control	A-12	11.05	11.3496	12.1448	12.9408	13.756	14.5713	15.3865
Lower Orange Main	ORP	1859	Namibia Irrigation (Namal	Namibia	Irrigation Demand	Master Control	A-12	10.15	11.15	15.15	15.15	15.15	15.15	15.15
Lower Orange Main	ORP	4802	Namibia Irrigation (Namal	Namibia	Irrigation Return Flow	Master Control	A-12	0.84	0.84	0.84	0.84	0.84	0.84	0.84
Lower Orange Main	Lower Orange Tributaries	3129	Ariamsvlei, Grunau, Kara	Namibia	Urban Demand	Master Control	A-11	0.12901	0.1909	0.4022	0.4221	0.442	0.4619	0.4818
Lower Orange Main	ORP	2147	Vioolsdrift and others Irrig	RSA	Irrigation Demand	Master Control	A-12	7.52	7.52	7.52	7.52	7.52	7.52	7.52
Lower Orange Main	ORP	3138	Vioolsdrift and others Irrig	RSA	Irrigation Return Flow	Master Control	A-12	0.752	0.752	0.752	0.752	0.752	0.752	0.752
Lower Orange Main	ORP	1861	Namibia Irrigation (Vioolsd	Namibia	Irrigation Demand	Master Control	A-12	0	0	0	0	0	0	0
Lower Orange Main	ORP	1906	Haib Mine	Namibia	Mining Demand	Master Control	A-12	0	6	6	6	6	6	6
Lower Orange Main	ORP	3130	Aussenkehr Noordoewer	Namibia	Urban Demand	Master Control	A-12	0.31031	0.35915	0.57661	0.64466	0.71271	0.78076	0.84881
Lower Orange Main	ORP	2146	Aussenkehr Noordoewer	Namibia	Irrigation Demand	Master Control	A-12	35.8	38.8	41.8	41.8	41.8	41.8	41.8
Lower Orange Main	ORP	3137	Aussenkehr Noordoewer	Namibia	Irrigation Return Flow	Master Control	A-12	2.68	2.68	2.68	2.68	2.68	2.68	2.68
Lower Orange Main	ORP	1912	Losses Reach 6	Namibia	Loss	Master Control	A-12	38.33	38.33	38.33	38.33	38.33	38.33	38.33
Lower Orange Main	ORP	8005	Losses Reach 6	Namibia	Loss	Master Control	A-12	15.87	15.87	15.87	15.87	15.87	15.87	15.87
Lower Orange Main	ORP	659	Lower Orange Irr Growth	RSA	Irrigation Demand	Master Control	A-12	35.6981	33.6335	42.8884	42.5522	37.4539	37.4539	37.4539
Lower Orange Main	ORP	1918	Alexander Bay Irrigation	RSA	Irrigation Demand	Master Control	A-12	7.3	7.3	7.3	7.3	7.3	7.3	7.3
Lower Orange Main	ORP	4803	Alexander Bay Irrigation r	RSA	Irrigation Return Flow	Master Control	A-12	1.005	1.005	1.005	1.005	1.005	1.005	1.005
Lower Orange Main	ORP	1924	Alexander Bay Transhex	RSA	Urban and Mining Dema	Master Control	A-12	7.10263	7.2141	4.86939	5.02608	5.18396	5.34184	5.49972
Lower Orange Main	ORP	1817	Mines Rosh Pinah, Aucha	Namibia	Mining Demand	Master Control	A-12	7.67608	8.74488	4.27756	3.19755	2.07802	1.14784	1.21767
Lower Orange Main	ORP	1863	Namibia Irrigation	Namibia	Irrigation Demand	Master Control	A-12	0	0	0	0	0	0	0
Lower Orange Main	ORP	1865	Urban Rosh Pinah, Skorp	Namibia	Urban Demand	Master Control	A-12	8.38806	8.39006	8.39956	8.40706	8.41456	8.42206	8.42956
Lower Orange Main	ORP	1916	Losses Reach 7	Namibia	Loss	Master Control	A-12	42.86	42.86	42.86	42.86	42.86	42.86	42.86
Lower Orange Main	ORP	8006	Losses Reach 7	Namibia	Loss	Master Control	A-12	23.64	23.64	23.64	23.64	23.64	23.64	23.64
Lower Orange Main	ORP	1920	IFR CS Moved from Min M	RSA	EFR	Master Control	A-12	91.7	91.7	91.7	91.7	91.7	91.7	91.7
Lower Orange Main	nosch	2156	Loss demand on curve	RSA	Loss	Master Control	A-12	53.34	53.34	53.34	53.34	53.34	53.34	53.34
Lower Orange Main	ORP	3139	resource poor lower oran	RSA	Irrigation Demand	Master Control	A-12	6	12	42	42	42	42	42
Lower Orange Main	ORP	1961	Lower orange return flows	RSA	Irrigation Return Flow	Master Control	A-12	0	0	0	0	0	0	0
Lower Orange Main	ORP	2142	Orange IFR CS Added	RSA	EFR	Master Control	A-12	195.8	195.8	195.8	195.8	195.8	195.8	195.8
Lower Orange Tribut	Farm dam	2600	Irrigation demand Upper (	RSA	Irrigation Demand	Master Control	A-11	17.83	17.83	17.83	17.83	17.83	17.83	17.83
Lower Orange Tribut	Farm dam	2634	Irrigation return flow Uppe	RSA	Irrigation Return flow	Master Control	A-11	1.783	1.783	1.783	1.783	1.783	1.783	1.783
Lower Orange Tribut	Farm dam	2596	Irrigation demand Riet Riv	RSA	Irrigation Demand	Master Control	A-11	0.726	0.726	0.726	0.726	0.726	0.726	0.726
Lower Orange Tribut	Farm dam	2630	Irrigation return flow Riet I	RSA	Irrigation Return flow	Master Control	A-11	0.0726	0.0726	0.0726	0.0726	0.0726	0.0726	0.0726
Lower Orange Tribut	Riet River	2592	Irrigation demand Riet Riv	RSA	Irrigation Demand	Master Control	A-11	8.71	8.71	8.71	8.71	8.71	8.71	8.71
Lower Orange Tribut	Riet River	2631	Irrigation return flow Riet I	RSA	Irrigation Return flow	Master Control	A-11	0.871	0.871	0.871	0.871	0.871	0.871	0.871
Lower Orange Tribut	Farm dam	2587	Irrigation demand Riet Riv	RSA	Irrigation Demand	Master Control	A-11	1.262	1.262	1.262	1.262	1.262	1.262	1.262
Lower Orange Tribut	Farm dam	2632	Irrigation return flow Riet I	RSA	Irrigation Return flow	Master Control	A-11	0.1262	0.1262	0.1262	0.1262	0.1262	0.1262	0.1262
Lower Orange Tribut	Van Wyksvlei Dam	2577	Irrigation demand Vanwyk	RSA	Irrigation Demand	Master Control	A-11	6.848	6.848	6.848	6.848	6.848	6.848	6.848
Lower Orange Tribut	Van Wyksvlei Dam	2633	Irrigation return flow Vanw	RSA	Irrigation Return flow	Master Control	A-11	0.6848	0.6848	0.6848	0.6848	0.6848	0.6848	0.6848
Eastern Cape Sundays		5293	PE DEMAND ABSTRAC	RSA		Master Control	A-14	31.05	31.05	31.05	31.05	31.05	31.05	31.05
Eastern Cape Sundays		5141	WATER YIELD	RSA		Master Control	A-14	0	0	0	0	0	0	0
Eastern Cape Great Brak		5022	ALL IRRIG BETWEEN T	RSA		Master Control	A-14	57.96	57.96	57.96	57.96	57.96	57.96	57.96

Table 2-g: Demands modelled by means of Master Control channels in the WRPM

SUB-SYSTEM	Resource	WRPM CHANNEL NO.	DESCRIPTION	RECIPIENT COUNTRY	DEMAND TYPE	WRPM TYPE	FIGURE NO.	2014	2015	2020	2025	2030	2035	2040
Eastern Cape Great Brak		5023	IRRIG RETURN FLOW	RSA		Master Control	A-14	20.286	20.286	20.286	20.286	20.286	20.286	20.286
Eastern Cape Great Fish		5129	ALL IRRIG FROM GREA	RSA		Master Control	A-14	0	0	0	0	0	0	0
Eastern Cape Great Fish		5002	IRRIG RETURN FLOW	RSA		Master Control	A-14	0	0	0	0	0	0	0
Eastern Cape Great Fish		5153	ALL IRRIG FROM GREA	RSA		Master Control	A-14	91.23	91.23	91.23	91.23	91.23	91.23	91.23
Eastern Cape Great Fish		5004	IRRIG RETURN FLOW	RSA		Master Control	A-14	31.9305	31.9305	31.9305	31.9305	31.9305	31.9305	31.9305
Eastern Cape Great Fish		5157	ALL IRRIG FROM GREA	RSA		Master Control	A-14	76.47	76.47	76.47	76.47	76.47	76.47	76.47
Eastern Cape Great Fish		5025	IRRIG RETURN FLOW	RSA		Master Control	A-14	26.7645	26.7645	26.7645	26.7645	26.7645	26.7645	26.7645
Eastern Cape Tarka		5081	ALL IRRIG ABSTRACTI	RSA		Master Control	A-14	12.43	12.43	12.43	12.43	12.43	12.43	12.43
Eastern Cape Tarka		5008	IRRIG RETURN FLOW	RSA		Master Control	A-14	4.3505	4.3505	4.3505	4.3505	4.3505	4.3505	4.3505
Eastern Cape Great Fish		5160	ALL IRRIG ABSTR FRO	RSA		Master Control	A-14	19.35	19.35	19.35	19.35	19.35	19.35	19.35
Eastern Cape Great Fish		5006	IRRIG RETURN FLOW	RSA		Master Control	A-14	6.7725	6.7725	6.7725	6.7725	6.7725	6.7725	6.7725
Eastern Cape Great Fish		5069	ALL IRRIG ABSTR FRO	RSA		Master Control	A-14	49.03	49.03	49.03	49.03	49.03	49.03	49.03
Eastern Cape Great Fish		5011	IRRIG RETURN FLOW	RSA		Master Control	A-14	17.1605	17.1605	17.1605	17.1605	17.1605	17.1605	17.1605
Eastern Cape Great Fish		5175	ALL IRRIG ABSTR FRO	RSA		Master Control	A-14	67.37	67.37	67.37	67.37	67.37	67.37	67.37
Eastern Cape Great Fish		5044	IRRIG RETURN FLOW	RSA		Master Control	A-14	23.5795	23.5795	23.5795	23.5795	23.5795	23.5795	23.5795
Eastern Cape Great Fish		5216	ALL IRRIG ABSTR FROM	RSA		Master Control	A-14	23.61	23.61	23.61	23.61	23.61	23.61	23.61
Eastern Cape Great Fish		5042	IRRIG RETURN FLOW	RSA		Master Control	A-14	8.2635	8.2635	8.2635	8.2635	8.2635	8.2635	8.2635
Eastern Cape Little Fish		5021	ALL IRRIG ABSTR ABO	RSA		Master Control	A-14	0.88	0.88	0.88	0.88	0.88	0.88	0.88
Eastern Cape Little Fish		5029	IRRIG RETURN FLOW	RSA		Master Control	A-14	0.308	0.308	0.308	0.308	0.308	0.308	0.308
Eastern Cape Great Fish		5095	ALL IRRIG ABSTR FRO	RSA		Master Control	A-14	7.49	7.49	7.49	7.49	7.49	7.49	7.49
Eastern Cape Great Fish		5094	IRRIG RETURN FLOW	RSA		Master Control	A-14	2.6215	2.6215	2.6215	2.6215	2.6215	2.6215	2.6215
Eastern Cape Little Fish		5220	ALL IRRIG ABSTR FRO	RSA		Master Control	A-14	25.04	25.04	25.04	25.04	25.04	25.04	25.04
Eastern Cape Little Fish		5013	IRRIG RETURN FLOW	RSA		Master Control	A-14	8.764	8.764	8.764	8.764	8.764	8.764	8.764
Eastern Cape Sundays		5223	ALL IRRIG ABSTR FRO	RSA		Master Control	A-13	0	0	0	0	0	0	0
Eastern Cape Sundays		5031	IRRIG RETURN FLOW	RSA		Master Control	A-13	0	0	0	0	0	0	0
Eastern Cape Sundays		5063	ALL IRRIG ABSTR FRO	RSA		Master Control	A-13	0	0	0	0	0	0	0
Eastern Cape Sundays		5033	IRRIG RETURN FLOW	RSA		Master Control	A-13	0	0	0	0	0	0	0

Table 2-h: Demands modelled by means of Master Control channels in the WRPM

SUB-SYSTEM	Resource	WRPM CHANNEL NO.	DESCRIPTION	RECIPIENT COUNTRY	DEMAND TYPE	WRPM TYPE	FIGURE NO.	2014	2015	2020	2025	2030	2035	2040
Komati Sub-system	Komati System & (Usutu & Heyshope)	22	Arnot:exceeding 70 million m3/a lin	RSA	Strategic Demand	Master Contr	A-12	18.7855	17.201	9.523	0.000	0.000	0.000	0.000
Komati Sub-system	Komati System & (Usutu & Heyshope)	966	Arnot within 70 million m3/a limit	RSA	Strategic Demand	Master Contr	A-12	11.1955	11.7544	15.822	22.936	3.883	1.542	1.542
Komati Sub-system	Komati System & (Usutu & Heyshope)	960	Hendrina :Portion exceeding 70 Mn	RSA	Strategic Demand	Master Contr	A-12	0	0	0.000	0.000	0.000	0.000	0.000
Komati Sub-system	Komati System & (Usutu & Heyshope)	929	Hendrina (Within 70 million m3/a lir	RSA	Strategic Demand	Master Contr	A-12	31.0491	30.9713	34.345	20.504	6.478	6.478	6.478
Komati Sub-system	Komati System & (Usutu & Heyshope)	11	Duvha2 (Komati with Usutu sub-sy	RSA	Strategic Demand	Master Contr	A-12	0	0	0.000	0.000	0.000	0.000	0.000
Komati Sub-system	Grootdraai Dam & Vaal Dam (VRESAP)	177	Duvha1 (Naauwpoort-supply from	RSA	Strategic Demand	Master Contr	A-12	42.2568	42.1974	41.919	48.552	43.549	43.454	43.454
Komati Sub-system	Komati System & (Usutu & Heyshope)	957	Komati Power Station & DWA 3rd	RSA	Strategic Demand	Master Contr	A-12	27.7553	27.2744	19.834	14.311	9.756	9.756	9.756
Komati Sub-system	Komati tributaries	711	Dummy Demand on Vygeboom fo	RSA	Dummy Demand	Master Contr	A-12	8.37	8.37	8.370	8.370	8.370	8.370	8.370
Komati Sub-system	Komati tributaries	1196	Dummy Demand for CH25 for Kon	RSA	Dummy Demand	Master Contr	A-1	26.6	26.6	26.600	26.600	26.600	26.600	26.600
Komati Sub-system	Komati tributaries	1194	Dummy Demand for CH25 for Kon	RSA	Dummy Return Flov	Master Contr	A-1	-26.6	-26.6	-26.600	-26.600	-26.600	-26.600	-26.600
Usutu Sub-system	Usutu system & (Heyshope dam)	27	Camden & DWA 3rd Party Users	RSA	Strategic Demand	Master Contr	A-1	27.9135	28.3677	22.717	11.685	8.403	8.403	8.403
Usutu Sub-system	Usutu system & Heyshope & Grootdraai	80	Kriel_1 (Usutu-with support from (	RSA	Strategic Demand	Master Contr	A-1	38.5703	37.7756	44.229	39.173	37.732	37.732	37.732
Usutu Sub-system	Grootdraai Dam & Vaal Dam (VRESAP)	476	Kriel_2 (Supply from Grootdraai ar	RSA	Strategic Demand	Master Contr	A-1	0	0	0.000	0.000	0.000	0.000	0.000
Usutu Sub-system	Usutu system & Heyshope & Grootdraai	171	Matla 1 (Within Usutu supply capac	RSA	Strategic Demand	Master Contr	A-1	19.5997	20.4271	9.108	12.213	13.805	14.105	14.105
Usutu Sub-system	Grootdraai Dam & Vaal Dam (VRESAP)	10	Matla 2 (Supply from Grootdraai ar	RSA	Strategic Demand	Master Contr	A-1	31.8538	31.6774	50.664	57.981	50.301	49.818	49.818
Usutu Sub-system	Usutu system & Heyshope & Grootdraai	28	Kendal_1 (Usutu- with support fro	RSA	Strategic Demand	Master Contr	A-1	3.64065	3.60788	8.474	10.424	10.274	9.974	9.974
Usutu Sub-system	Grootdraai Dam & Vaal Dam (VRESAP)	477	Kendal_2 (Supply from Grootdraai	RSA	Strategic Demand	Master Contr	A-1	0	0	0.000	0.000	0.000	0.000	0.000
Usutu Sub-system	Heyshope Dam	1304	Driefontein	RSA	Urban Demand	Master Contr	A-1	0.94952	0.99556	1.052	1.247	1.457	1.689	1.957
Zaaihoek Sub-system	Zaaihoek Sub-system	56	Majuba	RSA	Strategic Demand	Master Contr	A-2	27.6647	26.3488	23.312	37.656	39.830	39.830	39.830
Zaaihoek Sub-system	Zaaihoek Sub-system	55	Grootdraai support from Zaaihoek	RSA	Transfer	Master Contr	A-2	-20.035	-21.351	-24.388	-10.044	-7.870	-3.332	0.000
Zaaihoek Sub-system	Zaaihoek Sub-system	60	Zaaihoek support to Chelmsford D	RSA	Urban Demand	Master Contr	A-2	0	0	0.000	0.000	0.000	4.538	12.175
Zaaihoek Sub-system	nosch	138	Dummy Demand on Zaaihoek Dan	RSA	Dummy Demand	Master Contr	A-2	5.11	5.11	5.110	5.110	5.110	5.110	5.110
Upper Vaal : Grootdraai	Grootdraai Dam	48	Tutuka & DWA 3rd Party Users	RSA	Strategic Demand	Master Contr	A-1	36.4974	35.6291	34.972	39.374	40.236	40.236	40.236
Upper Vaal : Grootdraai	Grootdraai Dam & Vaal Dam (VRESAP)	43	SASOL Secunda:	RSA	Strategic Demand	Master Contr	A-1	82.3359	82.582	85.153	95.199	98.383	99.818	99.818
Upper Vaal : Grootdraai	Vaal Dam	2252	VRESAP 3rd Party Users: Greyling	RSA	Urban Demand	Master Contr	A-1	9	9	9.000	9.000	9.000	9.000	9.000
Upper Vaal : Grootdraai	Grootdraai Dam	881	Lekwa LM (Former Standerton TL(	RSA	Urban Demand	Master Contr	A-1	10.9736	11.1125	11.347	11.694	11.822	11.941	12.061
Upper Vaal : Grootdraai	Returnflow to Grootdraai Dam tributaries	47	Amersfoort, Msukaligwa,Morgenzo	RSA	Urban Demand	Master Contr	A-1	-6.6361	-6.6654	-7.222	-8.118	-9.061	-9.007	-8.950
Upper Vaal : Grootdraai	Grootdraai Dam & Vaal Dam (VRESAP)	687	Region B (Olifants support from Gı	RSA	Urban Demand	Master Contr	A-1	0	0	0.000	0.000	0.000	0.000	0.000
Upper Vaal : Grootdraai	Grootdraai Dam tributaries	1409	Grootdraai RE-EWR1 Mstr Irrig (R	RSA	Irrigation Demand	Master Contr	A-1	0.252	0.252	0.252	0.252	0.252	0.252	0.252
Upper Vaal : Grootdraai	Grootdraai Dam tributaries	1410	Grootdraai RE-EWR1 Mstr Irrig (R	RSA	Irrigation Return Flo	Master Contr	A-1	-0.0317	-0.0317	-0.032	-0.032	-0.032	-0.032	-0.032
Upper Vaal : Grootdraai	Grootdraai Dam tributaries	1417	Grootdraai RE-EWR1 Mstr Irrig (R	RSA	Irrigation Demand	Master Contr	A-1	0.43	0.43	0.430	0.430	0.430	0.430	0.430
Upper Vaal : Grootdraai	Grootdraai Dam tributaries	1426	Grootdraai RE-EWR1 Mstr Irrig (R	RSA	Irrigation Return Flo	Master Contr	A-1	-0.0511	-0.0511	-0.051	-0.051	-0.051	-0.051	-0.051
Upper Vaal : Grootdraai	Grootdraai Dam tributaries	1000	Grootdraai EWR1 Mstr Irrig (RR17	RSA	Irrigation Demand	Master Contr	A-1	1.796	1.796	1.796	1.796	1.796	1.796	1.796
Upper Vaal : Grootdraai	Grootdraai Dam tributaries	1821	Grootdraai EWR1 Mstr Irrig (RR17	RSA	Irrigation Return Flo	Master Contr	A-1	-0.2257	-0.2257	-0.226	-0.226	-0.226	-0.226	-0.226
Upper Vaal : Grootdraai	Grootdraai Dam tributaries	765	Grootdraai EWR1 Mstr Irrig (RR18	RSA	Irrigation Demand	Master Contr	A-1	8.95	8.95	8.950	8.950	8.950	8.950	8.950
Upper Vaal : Grootdraai	Grootdraai Dam tributaries	766	Grootdraai EWR1 Mstr Irrig (RR18	RSA	Irrigation Return Flo	Master Contr	A-1	-1.069	-1.069	-1.069	-1.069	-1.069	-1.069	-1.069
Upper Vaal : Grootdraai	Grootdraai Dam tributaries	1439	Grootdraai EWR2 Mstr Irrig (RR39	RSA	Irrigation Demand	Master Contr	A-1	0.7245	0.7245	0.725	0.725	0.725	0.725	0.725
Upper Vaal : Grootdraai	Grootdraai Dam tributaries	1442	Grootdraai EWR2 Mstr Irrig (RR39	RSA	Irrigation Return Flo	Master Contr	A-1	-0.091	-0.091	-0.091	-0.091	-0.091	-0.091	-0.091
Upper Vaal : Grootdraai	Grootdraai Dam tributaries	1449	Grootdraai EWR2 Mstr Irrig (RR41	RSA	Irrigation Demand	Master Contr	A-1	4.41	4.41	4.410	4.410	4.410	4.410	4.410
Upper Vaal : Grootdraai	Grootdraai Dam tributaries	1450	Grootdraai EWR2 Mstr Irrig (RR41	RSA	Irrigation Return Flo	Master Contr	A-1	-0.5244	-0.5244	-0.524	-0.524	-0.524	-0.524	-0.524
Upper Vaal : Grootdraai	Returnflow to Grootdraai Dam	878	Msukaligwa LM (Ermelo):Return flo	RSA	Urban Return Flow	Master Contr	A-1	-0.75	-0.75	-0.750	-0.750	-0.750	-0.750	-0.750
Upper Vaal : Grootdraai	nosch	3	Dummy Demand on Grootdraai Da	RSA	Dummy Demand	Master Contr	A-1	22.1	22.1	22.100	22.100	22.100	22.100	22.100

Table 2-i: Demands modelled by means of Master Control channels in the WRPM

SUB-SYSTEM	Resource	WRPM CHANNEL NO.	DESCRIPTION	RECIPIENT COUNTRY	DEMAND TYPE	WRPM TYPE	FIGURE NO.	2014	2015	2020	2025	2030	2035	2040
Upper Vaal: Vaal Incrementa	Vaal Dam tributaries	68	Bethlehem, Deneysville,Villiers & C	RSA	Urban Demand	Master Contr	A-1	26.4221	27.6905	30.900	33.868	37.202	39.410	41.890
Upper Vaal: Vaal Incrementa	Returnflow to Vaal Dam tributaries	879	Bethlem,Harrismith & Qwa Qwa (1	RSA	Urban Return Flow	Master Contr	A-1	-9.3658	-9.4614	-9.930	-10.398	-10.867	-10.867	-10.867
Upper Vaal: Vaal Incrementa	Wilge River Dummy Dam	705	Wilge Dummy Dam1 (RR9) Lawfu	RSA	Irrigation Demand	Master Contr	A-1	13.61	13.61	13.610	13.610	13.610	13.610	13.610
Upper Vaal: Vaal Incrementa	Wilge River Dummy Dam	760	Wilge Dummy Dam1 (RR9) Lawfu	RSA	Irrigation Return Flo	Master Contr	A-1	-1.55	-1.55	-1.550	-1.550	-1.550	-1.550	-1.550
Upper Vaal: Vaal Incrementa	Wilge River Dummy Dam	1004	Wilge Dummy Dam1 (RR1783) Ur	RSA	Irrigation Demand	Master Contr	A-1	2.511	2.511	2.511	2.511	2.511	2.511	2.511
Upper Vaal: Vaal Incrementa	Wilge River Dummy Dam	1822	Wilge Dummy Dam1 (RR1783) Ur	RSA	Irrigation Return Flo	Master Contr	A-1	-0.282	-0.282	-0.282	-0.282	-0.282	-0.282	-0.282
Upper Vaal: Vaal Incrementa	Wilge River mainstream	763	Wilge EWR8 mainstream (RR11)	RSA	Irrigation Demand	Master Contr	A-1	6.22	6.22	6.220	6.220	6.220	6.220	6.220
Upper Vaal: Vaal Incrementa	Wilge River mainstream	764	Wilge EWR8 mainstream (RR11)	RSA	Irrigation Return Flo	Master Contr	A-1	-0.71	-0.71	-0.710	-0.710	-0.710	-0.710	-0.710
Upper Vaal: Vaal Incrementa	Wilge River mainstream	1006	Wilge EWR8 mainstream (RR549	RSA	Irrigation Demand	Master Contr	A-1	1.872	1.872	1.872	1.872	1.872	1.872	1.872
Upper Vaal: Vaal Incrementa	Wilge River mainstream	1824	Wilge EWR8 mainstream (RR549	RSA	Irrigation Return Flo	Master Contr	A-1	-0.213	-0.213	-0.213	-0.213	-0.213	-0.213	-0.213
Upper Vaal: Vaal Incrementa	Wilge River Dummy Dam 2	1646	Wilge Dummy Dam2 (RR571) Lav	RSA	Irrigation Demand	Master Contr	A-1	4.17	4.17	4.170	4.170	4.170	4.170	4.170
Upper Vaal: Vaal Incrementa	Wilge River Dummy Dam 2	1660	Wilge Dummy Dam2 (RR571) Lav	RSA	Irrigation Return Flo	Master Contr	A-1	-0.48	-0.48	-0.480	-0.480	-0.480	-0.480	-0.480
Upper Vaal: Vaal Incrementa	Wilge River Dummy Dam 2	1645	Wilge Dummy Dam2 (RR572) Un	RSA	Irrigation Demand	Master Contr	A-1	1.5705	1.5705	1.571	1.571	1.571	1.571	1.571
Upper Vaal: Vaal Incrementa	Wilge River Dummy Dam 2	1648	Wilge Dummy Dam2 (RR572) Un	RSA	Irrigation Return Flo	Master Contr	A-1	-0.177	-0.177	-0.177	-0.177	-0.177	-0.177	-0.177
Upper Vaal: Vaal Incrementa	Wilge River mainstream	1642	Wilge mainstream (RR575) Lawfu	RSA	Irrigation Demand	Master Contr	A-1	4.01	4.01	4.010	4.010	4.010	4.010	4.010
Upper Vaal: Vaal Incrementa	Wilge River mainstream	1643	Wilge mainstream (RR575) Lawfu	RSA	Irrigation Return Flo	Master Contr	A-1	-0.46	-0.46	-0.460	-0.460	-0.460	-0.460	-0.460
Upper Vaal: Vaal Incrementa	Wilge River mainstream	1661	Wilge mainstream (RR576) Unlaw	RSA	Irrigation Demand	Master Contr	A-1	0.53	0.53	0.530	0.530	0.530	0.530	0.530
Upper Vaal: Vaal Incrementa	Wilge River mainstream	1662	Wilge mainstream (RR576) Unlaw	RSA	Irrigation Return Flo	Master Contr	A-1	-0.06	-0.06	-0.060	-0.060	-0.060	-0.060	-0.060
Upper Vaal: Vaal Incrementa	Saulspoort Dam	761	Saulspoort Dummy Dam (RR10) L	RSA	Irrigation Demand	Master Contr	A-1	0.99	0.99	0.990	0.990	0.990	0.990	0.990
Upper Vaal: Vaal Incrementa	Saulspoort Dam	762	Saulspoort Dummy Dam (RR10) L	RSA	Irrigation Return Flo	Master Contr	A-1	-0.11	-0.11	-0.110	-0.110	-0.110	-0.110	-0.110
Upper Vaal: Vaal Incrementa	Saulspoort Dam	1005	Saulspoort Dummy Dam (RR1784	RSA	Irrigation Demand	Master Contr	A-1	0.102	0.102	0.102	0.102	0.102	0.102	0.102
Upper Vaal: Vaal Incrementa	Saulspoort Dam	1823	Saulspoort Dummy Dam (RR1784	RSA	Irrigation Return Flo	Master Contr	A-1	-0.0135	-0.0135	-0.014	-0.014	-0.014	-0.014	-0.014
Upper Vaal: Vaal Incrementa	Liebenbergsvlei Mainstream	1795	Liebenbergsvlei mainstream (RR4	RSA	Irrigation Demand	Master Contr	A-1	39.76	39.76	39.760	39.760	39.760	39.760	39.760
Upper Vaal: Vaal Incrementa	Liebenbergsvlei Mainstream	1796	Liebenbergsvlei mainstream (RR4	RSA	Irrigation Return Flo	Master Contr	A-1	-4.54	-4.54	-4.540	-4.540	-4.540	-4.540	-4.540
Upper Vaal: Vaal Incrementa	Liebenbergsvlei Mainstream	1664	Liebenbergsvlei mainstream (RR4	RSA	Irrigation Demand	Master Contr	A-1	0	0	0.000	0.000	0.000	0.000	0.000
Upper Vaal: Vaal Incrementa	Liebenbergsvlei Mainstream	1788	Liebenbergsvlei mainstream (RR4	RSA	Irrigation Return Flo	Master Contr	A-1	0	0	0.000	0.000	0.000	0.000	0.000
Upper Vaal: Vaal Incrementa	Vaal Dam Tributary	1455	Delangesdrift Incr (RR465) Unlawf	RSA	Irrigation Demand	Master Contr	A-1	0.83	0.83	0.830	0.830	0.830	0.830	0.830
Upper Vaal: Vaal Incrementa	Vaal Dam Tributary	1456	Delangesdrift Incr (RR465) Unlawf	RSA	Irrigation Return Flo	Master Contr	A-1	-0.3137	-0.3137	-0.314	-0.314	-0.314	-0.314	-0.314
Upper Vaal: Vaal Incrementa	Vaal Dam Tributary	581	Delangesdrift Incr (RR1781) Unlaw	RSA	Irrigation Demand	Master Contr	A-1	0.339	0.339	0.339	0.339	0.339	0.339	0.339
Upper Vaal: Vaal Incrementa	Vaal Dam Tributary	1820	Delangesdrift Incr (RR1781) Unlaw	RSA	Irrigation Return Flo	Master Contr	A-1	-0.1275	-0.1275	-0.128	-0.128	-0.128	-0.128	-0.128
Upper Vaal: Vaal Incrementa	Vaal Dam Tributary	1637	Upper Waterval Dummy dam(RR6	RSA	Irrigation Demand	Master Contr	A-1	1.11	1.11	1.110	1.110	1.110	1.110	1.110
Upper Vaal: Vaal Incrementa	Vaal Dam Tributary	1667	Upper Waterval Dummy dam(RR6	RSA	Irrigation Return Flo	Master Contr	A-1	-0.43	-0.43	-0.430	-0.430	-0.430	-0.430	-0.430
Upper Vaal: Vaal Incrementa	Vaal Dam Tributary	2028	Upper Waterval Dummy dam(RR6	RSA	Irrigation Demand	Master Contr	A-1	0.2715	0.2715	0.272	0.272	0.272	0.272	0.272
Upper Vaal: Vaal Incrementa	Vaal Dam Tributary	2029	Upper Waterval Dummy dam(RR6	RSA	Irrigation Return Flo	Master Contr	A-1	-0.105	-0.105	-0.105	-0.105	-0.105	-0.105	-0.105
Upper Vaal: Vaal Incrementa	Vaal Dam Tributary	1684	Upper Waterval Mainstream (RR63	RSA	Irrigation Demand	Master Contr	A-1	0.3	0.3	0.300	0.300	0.300	0.300	0.300
Upper Vaal: Vaal Incrementa	Vaal Dam Tributary	1698	Upper Waterval Mainstream (RR63	RSA	Irrigation Return Flo	Master Contr	A-1	-0.12	-0.12	-0.120	-0.120	-0.120	-0.120	-0.120
Upper Vaal: Vaal Incrementa	Vaal Dam Tributary	1318	Lower Waterval Dummy Dam1 (R	RSA	Irrigation Demand	Master Contr	A-1	1.2	1.2	1.200	1.200	1.200	1.200	1.200
Upper Vaal: Vaal Incrementa	Vaal Dam Tributary	1319	Lower Waterval Dummy Dam1 (R	RSA	Irrigation Return Flo	Master Contr	A-1	-0.47	-0.47	-0.470	-0.470	-0.470	-0.470	-0.470
Upper Vaal: Vaal Incrementa	Vaal Dam Tributary	1468	Lower Waterval Dummy Dam1 (R	RSA	Irrigation Demand	Master Contr	A-1	0.294	0.294	0.294	0.294	0.294	0.294	0.294
Upper Vaal: Vaal Incrementa	Vaal Dam Tributary	1469	Lower Waterval Dummy Dam1 (R	RSA	Irrigation Return Flo	Master Contr	A-1	-0.114	-0.114	-0.114	-0.114	-0.114	-0.114	-0.114

Table 2-j: Demands modelled by means of Master Control channels in the WRPM

SUB-SYSTEM	Resource	WRPM CHANNEL NO.	DESCRIPTION	RECIPIENT COUNTRY	DEMAND TYPE	WRPM TYPE	FIGURE NO.	2014	2015	2020	2025	2030	2035	2040
Upper Vaal: Vaal Incrementa	Vaal Dam Tributary	1323	Lower Waterval Mainstream (RR5	RSA	Irrigation Demand	Master Contr	A-1	1.95	1.95	1.950	1.950	1.950	1.950	1.950
Upper Vaal: Vaal Incrementa	Vaal Dam Tributary	1325	Lower Waterval Mainstream (RR5	RSA	Irrigation Return Flo	Master Contr	A-1	-0.76	-0.76	-0.760	-0.760	-0.760	-0.760	-0.760
Upper Vaal: Vaal Incrementa	Vaal Dam Tributary	1470	Lower Waterval Mainstream (RR6	RSA	Irrigation Demand	Master Contr	A-1	0.477	0.477	0.477	0.477	0.477	0.477	0.477
Upper Vaal: Vaal Incrementa	Vaal Dam Tributary	1471	Lower Waterval Mainstream (RR6	RSA	Irrigation Return Flo	Master Contr	A-1	-0.186	-0.186	-0.186	-0.186	-0.186	-0.186	-0.186
Upper Vaal: Vaal Incrementa	Vaal Dam Tributary	1747	Lower Waterval Dummy Dam2 (R	RSA	Irrigation Demand	Master Contr	A-1	1.14	1.14	1.140	1.140	1.140	1.140	1.140
Upper Vaal: Vaal Incrementa	Vaal Dam Tributary	1749	Lower Waterval Dummy Dam2 (R	RSA	Irrigation Return Flo	Master Contr	A-1	-0.44	-0.44	-0.440	-0.440	-0.440	-0.440	-0.440
Upper Vaal: Vaal Incrementa	Vaal Dam Tributary	2030	Lower Waterval Dummy Dam2 (R	RSA	Irrigation Demand	Master Contr	A-1	0.279	0.279	0.279	0.279	0.279	0.279	0.279
Upper Vaal: Vaal Incrementa	Vaal Dam Tributary	2031	Lower Waterval Dummy Dam2 (R	RSA	Irrigation Return Flo	Master Contr	A-1	-0.1095	-0.1095	-0.110	-0.110	-0.110	-0.110	-0.110
Upper Vaal: Vaal Incrementa	Vaal Dam Tributary	1750	Lower Waterval Mainstream (RR6	RSA	Irrigation Demand	Master Contr	A-1	2.79	2.79	2.790	2.790	2.790	2.790	2.790
Upper Vaal: Vaal Incrementa	Vaal Dam Tributary	1751	Lower Waterval Mainstream (RR6	RSA	Irrigation Return Flo	Master Contr	A-1	-1.09	-1.09	-1.090	-1.090	-1.090	-1.090	-1.090
Upper Vaal: Vaal Incrementa	Vaal Dam Tributary	2032	Lower Waterval Mainstream (RR6	RSA	Irrigation Demand	Master Contr	A-1	0.6825	0.6825	0.683	0.683	0.683	0.683	0.683
Upper Vaal: Vaal Incrementa	Vaal Dam Tributary	2033	Lower Waterval Mainstream (RR6	RSA	Irrigation Return Flo	Master Contr	A-1	-0.2655	-0.2655	-0.266	-0.266	-0.266	-0.266	-0.266
Upper Vaal: Vaal Incrementa	Vaal River Main stream	1461	Vaal Incr EWR3 Mainstream (RR4	RSA	Irrigation Demand	Master Contr	A-1	0.88	0.88	0.880	0.880	0.880	0.880	0.880
Upper Vaal: Vaal Incrementa	Vaal River Main stream	1462	Vaal Incr EWR3 Mainstream (RR4	RSA	Irrigation Return Flo	Master Contr	A-1	-0.3421	-0.3421	-0.342	-0.342	-0.342	-0.342	-0.342
Upper Vaal: Vaal Incrementa	Vaal River Main stream	1463	Vaal Incr EWR3 Mainstream (RR5	RSA	Irrigation Demand	Master Contr	A-1	0.96	0.96	0.960	0.960	0.960	0.960	0.960
Upper Vaal: Vaal Incrementa	Vaal River Main stream	1464	Vaal Incr EWR3 Mainstream (RR5	RSA	Irrigation Return Flo	Master Contr	A-1	-0.3719	-0.3719	-0.372	-0.372	-0.372	-0.372	-0.372
Upper Vaal: Vaal Incrementa	Vaal Dam Tributary	770	Vaal EWR3 Dummy Dam1 (RR13	RSA	Irrigation Demand	Master Contr	A-1	4.57	4.57	4.570	4.570	4.570	4.570	4.570
Upper Vaal: Vaal Incrementa	Vaal Dam Tributary	771	Vaal EWR3 Dummy Dam1 (RR13	RSA	Irrigation Return Flo	Master Contr	A-1	-1.79	-1.79	-1.790	-1.790	-1.790	-1.790	-1.790
Upper Vaal: Vaal Incrementa	Vaal Dam Tributary	1007	Vaal EWR3 Dummy Dam1 (RR17	RSA	Irrigation Demand	Master Contr	A-1	0.9795	0.9795	0.980	0.980	0.980	0.980	0.980
Upper Vaal: Vaal Incrementa	Vaal Dam Tributary	1825	Vaal EWR3 Dummy Dam1 (RR17	RSA	Irrigation Return Flo	Master Contr	A-1	-0.3795	-0.3795	-0.380	-0.380	-0.380	-0.380	-0.380
Upper Vaal: Vaal Incrementa	Vaal River Main stream	772	Vaal mainstream (RR14) Lawful U	RSA	Irrigation Demand	Master Contr	A-1	7.61	7.61	7.610	7.610	7.610	7.610	7.610
Upper Vaal: Vaal Incrementa	Vaal River Main stream	773	Vaal mainstream (RR14) Lawful R	RSA	Irrigation Return Flo	Master Contr	A-1	-2.97	-2.97	-2.970	-2.970	-2.970	-2.970	-2.970
Upper Vaal: Vaal Incrementa	Vaal River Main stream	1008	Vaal mainstream (RR1787) Unlaw	RSA	Irrigation Demand	Master Contr	A-1	0	0	0.000	0.000	0.000	0.000	0.000
Upper Vaal: Vaal Incrementa	Vaal River Main stream	1826	Vaal mainstream (RR1787) Unlaw	RSA	Irrigation Return Flo	Master Contr	A-1	0	0	0.000	0.000	0.000	0.000	0.000
Upper Vaal: Vaal Incrementa	Vaal Dam Tributary	1473	Vaal Dummy Dam2 (RR545) Law	RSA	Irrigation Demand	Master Contr	A-1	2.54	2.54	2.540	2.540	2.540	2.540	2.540
Upper Vaal: Vaal Incrementa	Vaal Dam Tributary	1465	Vaal Dummy Dam2 (RR545) Law	RSA	Irrigation Return Flo	Master Contr	A-1	-0.99	-0.99	-0.990	-0.990	-0.990	-0.990	-0.990
Upper Vaal: Vaal Incrementa	Vaal Dam Tributary	1466	Vaal Dummy Dam2 (RR546) Unla	RSA	Irrigation Demand	Master Contr	A-1	1.902	1.902	1.902	1.902	1.902	1.902	1.902
Upper Vaal: Vaal Incrementa	Vaal Dam Tributary	1467	Vaal Dummy Dam2 (RR546) Unla	RSA	Irrigation Return Flo	Master Contr	A-1	-0.738	-0.738	-0.738	-0.738	-0.738	-0.738	-0.738
Upper Vaal: Vaal Incrementa	nosch	750	Dummy Inflow	RSA	Dummy Inflow	Master Control Chanr		-600	-600	-600.000	-600.000	-600.000	-600.000	-600.000
Upper Vaal: Vaal Barrage	Vaal Dam	66	Eskom PSs (Grootvlei, Lethabo, K	RSA	Strategic Demand	Master Contr	A-4	57.7572	58.3462	55.191	57.368	47.468	47.468	47.468
Upper Vaal: Vaal Barrage	Vaal Dam	67	SASOL: Sasolburg Complex (Raw	RSA	Strategic Demand	Master Contr	A-4	22.2721	22.7406	25.141	27.757	30.646	33.836	37.358
Upper Vaal: Vaal Barrage	Vaal Dam	70	Rand Water (Northern Gauteng) &	RSA	Urban Demand	Master Contr	A-4	898.228	909.835	987.524	1047.789	1135.589	1192.657	1252.636
Upper Vaal: Vaal Barrage	Vaal Dam	69	Rand Water: Southern Gauteng U	RSA	Urban Demand	Master Contr	A-4	455.11	461.873	502.569	533.498	566.763	595.673	626.059
Upper Vaal: Vaal Barrage	Return flow to Vaal Barrage tributaries	864	Rand Water (DC40): Return Flow	RSA	Urban Return Flow	Master Contr	A-4	-288.27	-292.56	-318.367	-337.972	-359.056	-377.372	-396.621
Upper Vaal: Vaal Barrage	Vaal Dam	1017	Rand Water: Southern Gauteng U	RSA	Urban Demand	Master Contr	A-4	105.436	107.152	117.293	125.008	133.301	140.101	147.247
Upper Vaal: Vaal Barrage	Return flow to Vaal Barrage tributaries	865	Rand Water (DC293): Return Flow	RSA	Urban Return Flow	Master Contr	A-4	-66.695	-67.782	-74.205	-79.089	-84.338	-88.640	-93.162
Upper Vaal: Vaal Barrage	Vaal Dam	1029	Rand Water: Southern Gauteng U	RSA	Urban Demand	Master Contr	A-4	53.0201	53.7974	58.504	62.089	65.927	69.290	72.824
Upper Vaal: Vaal Barrage	Return flow to Vaal Barrage tributaries	866	Rand Water (DC294): Return Flow	RSA	Urban Return Flow	Master Contr	A-4	-31.744	-32.21	-35.031	-37.179	-39.479	-41.492	-43.609
Upper Vaal: Vaal Barrage	Vaal Dam	1047	Rand Water: Southern Gauteng U	RSA	Urban Demand	Master Contr	A-4	61.4359	62.3858	68.097	72.463	77.109	81.042	85.176
Upper Vaal: Vaal Barrage	Return flow to Vaal Barrage tributaries	867	Rand Water (DC294): Return Flow	RSA	Urban Return Flow	Master Contr	A-4	-22.696	-23.048	-25.160	-26.775	-28.492	-29.946	-31.473

Table 2-k: Demands modelled by means of Master Control channels in the WRPM

SUB-SYSTEM	Resource	WRPM CHANNEL NO.	DESCRIPTION	RECIPIENT COUNTRY	DEMAND TYPE	WRPM TYPE	FIGURE NO.	2014	2015	2020	2025	2030	2035	2040
Upper Vaal: Vaal Barrage	Vaal Dam	1048	Rand Water: Southern Gauteng Us	RSA	Urban Demand	Master Contr	A-4	13.4087	13.6599	15.187	16.471	17.882	18.794	19.753
Upper Vaal: Vaal Barrage	Vaal Dam	1798	Re-use Option: Mine water treated	RSA	Inflow	Master Contr	A-4	0	0	-42.300	-42.300	-42.300	-42.300	-42.300
Upper Vaal: Vaal Barrage	Vaal Dam	1993	Transfer of raw water from Vaal to	RSA	Transfer	Master Contr	A-4	0	0	0.000	0.000	0.000	0.000	0.000
Upper Vaal: Vaal Barrage	Blesbokspruit Dummy Dam (Vaal Barrag	58	Blesbokspruit Dummy Dam (RR1)	RSA	Irrigation Demand	Master Contr	A-4	1.29	1.29	1.290	1.290	1.290	1.290	1.290
Upper Vaal: Vaal Barrage	Blesbokspruit Dummy Dam (Vaal Barrag	59	Blesbokspruit Dummy Dam (RR1)	RSA	Irrigation Return Flo	Master Contr	A-4	-0.27	-0.27	-0.270	-0.270	-0.270	-0.270	-0.270
Upper Vaal: Vaal Barrage	Blesbokspruit main stream (Vaal Barrage	1009	Blesbokspruit Mainstream (RR178	RSA	Irrigation Demand	Master Contr	A-4	0.435	0.435	0.435	0.435	0.435	0.435	0.435
Upper Vaal: Vaal Barrage	Blesbokspruit main stream (Vaal Barrage	1827	Blesbokspruit Mainstream (RR178	RSA	Irrigation Return Flo	Master Contr	A-4	-0.0915	-0.0915	-0.092	-0.092	-0.092	-0.092	-0.092
Upper Vaal: Vaal Barrage	Suikerbosrand main stream (Vaal Barrag	2041	Upper Suikerbos Mainstream (RR4	RSA	Irrigation Demand	Master Contr	A-4	0.1515	0.1515	0.152	0.152	0.152	0.152	0.152
Upper Vaal: Vaal Barrage	Suikerbosrand main stream (Vaal Barrag	2042	Upper Suikerbos Mainstream (RR4	RSA	Irrigation Return Flo	Master Contr	A-4	-0.0345	-0.0345	-0.035	-0.035	-0.035	-0.035	-0.035
Upper Vaal: Vaal Barrage	Suikerbosrand Dummy Dam (Vaal Barra	2037	Upper Suikerbos Dummy Dam (R	RSA	Irrigation Demand	Master Contr	A-4	2.36	2.36	2.360	2.360	2.360	2.360	2.360
Upper Vaal: Vaal Barrage	Suikerbosrand Dummy Dam (Vaal Barra	2038	Upper Suikerbos Dummy Dam (R	RSA	Irrigation Return Flo	Master Contr	A-4	-0.5174	-0.5174	-0.517	-0.517	-0.517	-0.517	-0.517
Upper Vaal: Vaal Barrage	Suikerbosrand Dummy Dam (Vaal Barra	838	Lower Suikerbos Dummy Dam1 (	RSA	Irrigation Demand	Master Contr	A-4	3.38	3.38	3.380	3.380	3.380	3.380	3.380
Upper Vaal: Vaal Barrage	Suikerbosrand Dummy Dam (Vaal Barra	839	Lower Suikerbos Dummy Dam1 (	RSA	Irrigation Return Flo	Master Contr	A-4	-0.7557	-0.7557	-0.756	-0.756	-0.756	-0.756	-0.756
Upper Vaal: Vaal Barrage	Suikerbosrand main stream (Vaal Barrag	1011	Lower Suikerbos Mainstream (RR	RSA	Irrigation Demand	Master Contr	A-4	0.17	0.17	0.170	0.170	0.170	0.170	0.170
Upper Vaal: Vaal Barrage	Suikerbosrand main stream (Vaal Barrag	1828	Lower Suikerbos Mainstream (RR	RSA	Irrigation Return Flo	Master Contr	A-4	-0.0375	-0.0375	-0.037	-0.037	-0.037	-0.037	-0.037
Upper Vaal: Vaal Barrage	Suikerbosrand Dummy Dam (Vaal Barra	2052	Lower Suikerbos Dummy Dam2 (	RSA	Irrigation Demand	Master Contr	A-4	2.57	2.57	2.570	2.570	2.570	2.570	2.570
Upper Vaal: Vaal Barrage	Suikerbosrand Dummy Dam (Vaal Barra	2053	Lower Suikerbos Dummy Dam2 (	RSA	Irrigation Return Flo	Master Contr	A-4	-0.5797	-0.5797	-0.580	-0.580	-0.580	-0.580	-0.580
Upper Vaal: Vaal Barrage	Suikerbosrand main stream (Vaal Barrag	2057	Lower Suikerbos Mainstream (RR	RSA	Irrigation Demand	Master Contr	A-4	0.2625	0.2625	0.263	0.263	0.263	0.263	0.263
Upper Vaal: Vaal Barrage	Suikerbosrand main stream (Vaal Barrag	2058	Lower Suikerbos Mainstream (RR	RSA	Irrigation Return Flo	Master Contr	A-4	-0.06	-0.06	-0.060	-0.060	-0.060	-0.060	-0.060
Upper Vaal: Vaal Barrage	Klipriver mainstream (Vaal Barrage Tribu	842	Klip River Mainstream (RR336) La	RSA	Irrigation Demand	Master Contr	A-4	10.92	10.92	10.920	10.920	10.920	10.920	10.920
Upper Vaal: Vaal Barrage	Klipriver mainstream (Vaal Barrage Tribu	843	Klip River Mainstream (RR336) La	RSA	Irrigation Return Flo	Master Contr	A-4	-1.9103	-1.9103	-1.910	-1.910	-1.910	-1.910	-1.910
Upper Vaal: Vaal Barrage	Klipriver mainstream (Vaal Barrage Tribu	1012	Klip River Mainstream (RR1790) U	RSA	Irrigation Demand	Master Contr	A-4	2.8	2.8	2.800	2.800	2.800	2.800	2.800
Upper Vaal: Vaal Barrage	Klipriver mainstream (Vaal Barrage Tribu	1829	Klip River Mainstream (RR1790) U	RSA	Irrigation Return Flo	Master Contr	A-4	-0.4701	-0.4701	-0.470	-0.470	-0.470	-0.470	-0.470
Upper Vaal: Vaal Barrage	Vaal Barrage Tributary	852	Barrage Mainstream (RR337) Law	RSA	Irrigation Demand	Master Contr	A-4	13.68	13.68	13.680	13.680	13.680	13.680	13.680
Upper Vaal: Vaal Barrage	Vaal Barrage Tributary	853	Barrage Mainstream (RR337) Law	RSA	Irrigation Return Flo	Master Contr	A-4	-1.7915	-1.7915	-1.791	-1.791	-1.791	-1.791	-1.791
Upper Vaal: Vaal Barrage	Vaal Barrage Tributary	1013	Barrage Mainstream (RR1791) Un	RSA	Irrigation Demand	Master Contr	A-4	1.48	1.48	1.480	1.480	1.480	1.480	1.480
Upper Vaal: Vaal Barrage	Vaal Barrage Tributary	1830	Barrage Mainstream (RR1791) Un	RSA	Irrigation Return Flo	Master Contr	A-4	-0.2373	-0.2373	-0.237	-0.237	-0.237	-0.237	-0.237
Middle Vaal: Kromdraai Catc	Middle Vaal Tributaries (Kromdraai Dumr	160	Kromdraai dummy (RR338) Lawfu	RSA	Irrigation Demand	Master Contr	A-5	5.69	5.69	5.690	5.690	5.690	5.690	5.690
Middle Vaal: Kromdraai Catc	Middle Vaal Tributaries (Kromdraai Dumr	868	Kromdraai dummy (RR338) Lawfu	RSA	Irrigation Return Flo	Master Contr	A-5	-0.5063	-0.5063	-0.506	-0.506	-0.506	-0.506	-0.506
Middle Vaal: Kromdraai Catc	Middle Vaal Tributaries (Kromdraai Dumr	1016	Kromdraai dummy (RR1792) Unla	RSA	Irrigation Demand	Master Contr	A-5	0.9	0.9	0.900	0.900	0.900	0.900	0.900
Middle Vaal: Kromdraai Catc	Middle Vaal Tributaries (Kromdraai Dumr	1831	Kromdraai dummy (RR1792) Unla	RSA	Irrigation Return Flo	Master Contr	A-5	-0.0901	-0.0901	-0.090	-0.090	-0.090	-0.090	-0.090
Middle Vaal: Kromdraai Catc	Middle Vaal mainstream	77	SASOL: Sasolburg Return Flow (	RSA	Industry Return Flow	Master Contr	A-5	-15.479	-15.805	-17.473	-19.291	-21.299	-23.516	-25.964
Middle Vaal: Mooi River Catc	Boskop & Lakeside dams	104	Potchefstroom Demand (1994 dev	RSA	Urban Demand	Master Contr	A-5	12.55	12.55	12.550	12.550	12.550	12.550	12.550
Middle Vaal: Mooi River Catc	Boskop & Lakeside dams	921	Potchefstroom Demand Increase (	RSA	Urban Demand	Master Contr	A-5	4.24275	4.42872	5.278	6.108	6.450	6.450	6.450
Middle Vaal: Mooi River Catc	Klipdrift Dam tributary	797	Mine Dewatering: Mines in Loopsp	RSA	Industry Discharge	Master Contr	A-5	-4.56	-4.56	-4.560	-4.560	-4.560	-4.560	-4.560
Middle Vaal: Mooi River Catc	Boskop Dam tributary Return flow	75	Rand Water: Flip Human Return F	RSA	Urban Return Flow	Master Contr	A-5	-8.5178	-8.6773	-9.648	-10.463	-11.359	-11.939	-12.548
Middle Vaal: Mooi River Catc	Klerkskraal Dam	102	Klerkskraal Dam (RR550) Lawful	RSA	Irrigation Demand	Master Contr	A-5	6.36	6.36	6.360	6.360	6.360	6.360	6.360
Middle Vaal: Mooi River Catc	Boskop Dam	1790	Klerkskraal Dam (RR550) Lawful	RSA	Irrigation Return Flo	Master Contr	A-5	-0.28	-0.28	-0.280	-0.280	-0.280	-0.280	-0.280
Middle Vaal: Mooi River Catc	Boskop Dam tributary	1018	Boskop irrigation (Diffuse) Node 25	RSA	Irrigation Demand	Master Contr	A-5	0	0	0.000	0.000	0.000	0.000	0.000
Middle Vaal: Mooi River Catc	Boskop Dam tributary	1015	Boskop dummy dam (RR551) Law	RSA	Irrigation Demand	Master Contr	A-5	3.68	3.68	3.680	3.680	3.680	3.680	3.680

Table 2-l: Demands modelled by means of Master Control channels in the WRPM

SUB-SYSTEM	Resource	WRPM CHANNEL NO.	DESCRIPTION	RECIPIENT COUNTRY	DEMAND TYPE	WRPM TYPE	FIGURE NO.	2014	2015	2020	2025	2030	2035	2040
Middle Vaal: Mooi River Catc	Boskop Dam tributary	1791	Boskop dummy dam (RR551) Law	RSA	Irrigation Return Flo	Master Contr	A-5	-0.11	-0.11	-0.110	-0.110	-0.110	-0.110	-0.110
Middle Vaal: Mooi River Catc	Boskop Dam tributary	1116	Gerhard Minnebron irrigation (RR5	RSA	Irrigation Demand	Master Contr	A-5	2.22	2.22	2.220	2.220	2.220	2.220	2.220
Middle Vaal: Mooi River Catc	Boskop Dam tributary	1793	Gerhard Minnebron irrigation (RR5	RSA	Irrigation Return Flo	Master Contr	A-5	-0.06	-0.06	-0.060	-0.060	-0.060	-0.060	-0.060
Middle Vaal: Mooi River Catc	Boskop Dam	105	Boskop Dam (RR552) Lawful	RSA	Irrigation Demand	Master Contr	A-5	20.8	20.8	20.800	20.800	20.800	20.800	20.800
Middle Vaal: Mooi River Catc	Lakeside Dam	1755	Boskop Dam (RR552) Lawful	RSA	Irrigation Return Flo	Master Contr	A-5	-0.7	-0.7	-0.700	-0.700	-0.700	-0.700	-0.700
Middle Vaal: Mooi River Catc	Lakeside Dam	1119	Lakeside Dam (RR553) Lawful	RSA	Irrigation Demand	Master Contr	A-5	8.59	8.59	8.590	8.590	8.590	8.590	8.590
Middle Vaal: Mooi River Catc	Middle Vaal Tributaries (Mooi River)	1792	Lakeside Dam (RR553) Lawful	RSA	Irrigation Return Flo	Master Contr	A-5	-0.31	-0.31	-0.310	-0.310	-0.310	-0.310	-0.310
Middle Vaal: Mooi River Catc	Klipdrift Dam tributary	1019	Klipdrift (Diffuse from Node 231) R	RSA	Irrigation Demand	Master Contr	A-5	0.0525	0.0525	0.053	0.053	0.053	0.053	0.053
Middle Vaal: Mooi River Catc	Klipdrift Dam tributary	1833	Klipdrift (Diffuse from Node 231) R	RSA	Irrigation Return Flo	Master Contr	A-5	-0.0045	-0.0045	-0.005	-0.005	-0.005	-0.005	-0.005
Middle Vaal: Mooi River Catc	Klipdrift Dam tributary	577	Klipdrift Dummy Dam (RR20) Law	RSA	Irrigation Demand	Master Contr	A-5	0	0	0.000	0.000	0.000	0.000	0.000
Middle Vaal: Mooi River Catc	Klipdrift Dam tributary	793	Klipdrift dummy dam (RR20) Lawfu	RSA	Irrigation Return Flo	Master Contr	A-5	0	0	0.000	0.000	0.000	0.000	0.000
Middle Vaal: Mooi River Catc	Klipdrift Dam tributary	1022	Klipdrift (Diffuse from Node 253) R	RSA	Irrigation Demand	Master Contr	A-5	0.063	0.063	0.063	0.063	0.063	0.063	0.063
Middle Vaal: Mooi River Catc	Klipdrift Dam tributary	1819	Klipdrift (Diffuse from Node 253) R	RSA	Irrigation Return Flo	Master Contr	A-5	-0.006	-0.006	-0.006	-0.006	-0.006	-0.006	-0.006
Middle Vaal: Mooi River Catc	Klipdrift Dam tributary	794	Klipdrift Mainstream (RR21) Lawfu	RSA	Irrigation Demand	Master Contr	A-5	0	0	0.000	0.000	0.000	0.000	0.000
Middle Vaal: Mooi River Catc	Klipdrift Dam tributary	795	Klipdrift Mainstream (RR21)	RSA	Irrigation Return Flo	Master Contr	A-5	0	0	0.000	0.000	0.000	0.000	0.000
Middle Vaal: Mooi River Catc	Klipdrift Dam	107	Klipdrift Dam metered	RSA	Irrigation Demand	Master Contr	A-5	6.41	6.41	6.410	6.410	6.410	6.410	6.410
Middle Vaal: Renoster River	Koppies Dam	110	Koppies (incl. Nat Cons)	RSA	Urban Demand	Master Contr	A-5	1.10702	1.13771	1.144	1.148	1.150	1.111	1.072
Middle Vaal: Renoster River	Koppies Dam	1272	Voorspoed Mine (Koppies Dam)	RSA	Industry Demand	Master Contr	A-5	2.64	2.64	2.640	2.640	2.640	2.640	2.640
Middle Vaal: Renoster River	Koppies Dam return flow	1097	Heilbron Return Flows : 50% to Ko	RSA	Urban Return Flow	Master Contr	A-5	-0.6939	-0.7242	-0.773	-0.824	-0.876	-0.876	-0.876
Middle Vaal: Renoster River	Renoster main stream (Middle Vaal Tribu	1276	Viljoenskroon	RSA	Urban Demand	Master Contr	A-5	2.23108	2.28321	2.431	2.580	2.733	2.599	2.472
Middle Vaal: Renoster River	Koppies Dam Tributaries	173	Koppies dummy dam (RR15)	RSA	Irrigation Demand	Master Contr	A-5	2.39	2.39	2.390	2.390	2.390	2.390	2.390
Middle Vaal: Renoster River	Koppies Dam Tributaries	775	Koppies dummy dam (RR15)	RSA	Irrigation Return Flo	Master Contr	A-5	-0.31	-0.31	-0.310	-0.310	-0.310	-0.310	-0.310
Middle Vaal: Renoster River	Koppies Dam Tributaries	776	Koppies riparian (RR16)	RSA	Irrigation Demand	Master Contr	A-5	0.66	0.66	0.660	0.660	0.660	0.660	0.660
Middle Vaal: Renoster River	Koppies Dam Tributaries	777	Koppies riparian (RR16)	RSA	Irrigation Return Flo	Master Contr	A-5	-0.09	-0.09	-0.090	-0.090	-0.090	-0.090	-0.090
Middle Vaal: Renoster River	Koppies Dam	1275	Koppies Dam GWS Canal Irrigatio	RSA	Irrigation Demand	Master Contr	A-5	3.03	3.03	3.030	3.030	3.030	3.030	3.030
Middle Vaal: Renoster River	Renoster main stream (Middle Vaal Tribu	1288	Koppies Dam GWS Canal Irrigatio	RSA	Irrigation Return Flo	Master Contr	A-5	-0.36	-0.36	-0.360	-0.360	-0.360	-0.360	-0.360
Middle Vaal: Renoster River	Koppies Dam	1274	Koppies Dam GWS River Irrigation	RSA	Irrigation Demand	Master Contr	A-5	3.41	3.41	3.410	3.410	3.410	3.410	3.410
Middle Vaal: Renoster River	Renoster main stream (Middle Vaal Tribu	1287	Koppies Dam GWS River Irrigation	RSA	Irrigation Return Flo	Master Contr	A-5	-0.42	-0.42	-0.420	-0.420	-0.420	-0.420	-0.420
Middle Vaal: Renoster River	Renoster Tributary (Middle Vaal Tributary	1254	Renoster C70D Dummy Dam (RR	RSA	Irrigation Demand	Master Contr	A-5	0.91	0.91	0.910	0.910	0.910	0.910	0.910
Middle Vaal: Renoster River	Renoster Tributary (Middle Vaal Tributary	1283	Renoster C70D Dummy Dam (RR	RSA	Irrigation Return Flo	Master Contr	A-5	-0.02	-0.02	-0.020	-0.020	-0.020	-0.020	-0.020
Middle Vaal: Renoster River	Renoster Tributary (Middle Vaal Tributary	1257	Renoster C70D Mainstream (RR3	RSA	Irrigation Demand	Master Contr	A-5	0.35	0.35	0.350	0.350	0.350	0.350	0.350
Middle Vaal: Renoster River	Renoster Tributary (Middle Vaal Tributary	1284	Renoster C70D Mainstream (RR3	RSA	Irrigation Return Flo	Master Contr	A-5	0	0	0.000	0.000	0.000	0.000	0.000
Middle Vaal: Renoster River	Renoster Tributary (Middle Vaal Tributary	1260	Renoster C70E Dummy Dam (RR	RSA	Irrigation Demand	Master Contr	A-5	0.57	0.57	0.570	0.570	0.570	0.570	0.570
Middle Vaal: Renoster River	Renoster Tributary (Middle Vaal Tributary	1286	Renoster C70E Dummy Dam (RR	RSA	Irrigation Return Flo	Master Contr	A-5	-0.02	-0.02	-0.020	-0.020	-0.020	-0.020	-0.020
Middle Vaal: Renoster River	Renoster Tributary (Middle Vaal Tributary	1259	Renoster C70F Dummy Dam (RR	RSA	Irrigation Demand	Master Contr	A-5	0.37	0.37	0.370	0.370	0.370	0.370	0.370
Middle Vaal: Renoster River	Renoster Tributary (Middle Vaal Tributary	1285	Renoster C70F Dummy Dam (RR	RSA	Irrigation Return Flo	Master Contr	A-5	0	0	0.000	0.000	0.000	0.000	0.000
Middle Vaal: Renoster River	Renoster Tributary (Middle Vaal Tributary	781	Renoster C70F Mainstream (RR1	RSA	Irrigation Demand	Master Contr	A-5	2.73	2.73	2.730	2.730	2.730	2.730	2.730
Middle Vaal: Renoster River	Renoster Tributary (Middle Vaal Tributary	782	Renoster C70F Mainstream (RR1	RSA	Irrigation Return Flo	Master Contr	A-5	-0.28	-0.28	-0.280	-0.280	-0.280	-0.280	-0.280
Middle Vaal: Renoster River	Renoster Tributary (Middle Vaal Tributary	1264	Renoster C70H Dummy Dam (RR	RSA	Irrigation Demand	Master Contr	A-5	0.22	0.22	0.22	0.22	0.22	0.22	0.22
Middle Vaal: Renoster River	Renoster Tributary (Middle Vaal Tributary	1305	Renoster C70H Dummy Dam (RR	RSA	Irrigation Return Flo	Master Contr	A-5	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04

Table 2-m: Demands modelled by means of Master Control channels in the WRPM

SUB-SYSTEM	Resource	WRPM CHANNEL NO.	DESCRIPTION	RECIPIENT COUNTRY	DEMAND TYPE	WRPM TYPE	FIGURE NO.	2014	2015	2020	2025	2030	2035	2040
Middle Vaal: Renoster River	Renoster Tributary (Middle Vaal Tributary	184	Rietfontein dummy dam (RR17)	RSA	Irrigation Demand	Master Contr	A-5	1.47	1.47	1.47	1.47	1.47	1.47	1.47
Middle Vaal: Renoster River	Renoster Tributary (Middle Vaal Tributary	780	Rietfontein dummy dam (RR17)	RSA	Irrigation Return Flo	Master Contr	A-5	-0.095	-0.095	-0.095	-0.095	-0.095	-0.095	-0.095
Middle Vaal: Renoster River	Renoster Tributary (Middle Vaal Tributary	1266	Renoster C70K Dummy Dam (RR	RSA	Irrigation Demand	Master Contr	A-5	0.43	0.43	0.43	0.43	0.43	0.43	0.43
Middle Vaal: Renoster River	Renoster Tributary (Middle Vaal Tributary	1307	Renoster C70K Dummy Dam (RR	RSA	Irrigation Return Flo	Master Contr	A-5	-0.063	-0.063	-0.063	-0.063	-0.063	-0.063	-0.063
Middle Vaal: Vals River Catc	Serfontein Dam	822	Serfontein Dam (RR333) Irrigation	RSA	Irrigation Demand	Master Contr	A-5	0	0	0	0	0	0	0
Middle Vaal: Vals River Catc	Middle Vaal Tributaries (Vals River)	823	Serfontein Dam (RR333) Irrigation	RSA	Irrigation Return Flo	Master Contr	A-5	0	0	0	0	0	0	0
Middle Vaal: Vals River Catc	Middle Vaal Tributaries (Vals River)	123	Klipbank dummy dam (RR332) Irri	RSA	Irrigation Demand	Master Contr	A-5	6.51	6.51	6.51	6.51	6.51	6.51	6.51
Middle Vaal: Vals River Catc	Middle Vaal Tributaries (Vals River)	825	Klipbank dummy dam (RR332) Irri	RSA	Irrigation Return Flo	Master Contr	A-5	-0.65	-0.65	-0.65	-0.65	-0.65	-0.65	-0.65
Middle Vaal: Vals River Catc	Middle Vaal Tributaries (Vals River)	1879	Klipbank riparian U/S EWR14 (RR	RSA	Irrigation Demand	Master Contr	A-5	13.04	13.04	13.04	13.04	13.04	13.04	13.04
Middle Vaal: Vals River Catc	Middle Vaal Tributaries (Vals River)	1885	Klipbank riparian U/S EWR14 (RR	RSA	Irrigation Return Flo	Master Contr	A-5	-1.45	-1.45	-1.45	-1.45	-1.45	-1.45	-1.45
Middle Vaal: Vals River Catc	Middle Vaal Tributaries (Vals River)	826	Klipbank riparian (RR334) Irrigatio	RSA	Irrigation Demand	Master Contr	A-5	10.55	10.55	10.55	10.55	10.55	10.55	10.55
Middle Vaal: Vals River Catc	Middle Vaal Tributaries (Vals River)	827	Klipbank riparian (RR334) Irrigatio	RSA	Irrigation Return Flo	Master Contr	A-5	-1.18	-1.18	-1.18	-1.18	-1.18	-1.18	-1.18
Middle Vaal: Schoonspruit C	Middle Vaal Tributaries (Schoonspruit)	1724	Midvaal WC: Klerksdorp Return Fl	RSA	Urban Return Flow	Master Contr	A-5	-6.72	-6.72	-6.72	-6.72	-6.72	-6.72	-6.72
Middle Vaal: Schoonspruit C	Schoonspruit Eye	1776	Schoonspruit C24E Mainstream (R	RSA	Irrigation Demand	Master Contr	A-5	4.59	4.59	4.59	4.59	4.59	4.59	4.59
Middle Vaal: Schoonspruit C	Schoonspruit Mainstream	1775	Schoonspruit C24E Mainstream (R	RSA	Irrigation Return Flo	Master Contr	A-5	-1.14	-1.14	-1.14	-1.14	-1.14	-1.14	-1.14
Middle Vaal: Schoonspruit C	Schoonspruit Eye	1679	Schoonspruit C24E Mainstream (R	RSA	Irrigation Demand	Master Contr	A-5	3.76	3.76	3.76	3.76	3.76	3.76	3.76
Middle Vaal: Schoonspruit C	Rietspruit Dam return flow	1692	Schoonspruit C24E Mainstream (R	RSA	Irrigation Return Flo	Master Contr	A-5	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8
Middle Vaal: Schoonspruit C	Rietspruit Dam	119	Rietspruit Dam (RR529) Irrigation	RSA	Irrigation Demand	Master Contr	A-5	9.92	9.92	9.92	9.92	9.92	9.92	9.92
Middle Vaal: Schoonspruit C	Schoonspruit Mainstream	800	Rietspruit Dam (RR529) Irrigation	RSA	Irrigation Return Flo	Master Contr	A-5	-2.16	-2.16	-2.16	-2.16	-2.16	-2.16	-2.16
Middle Vaal: Schoonspruit C	Johan Neser dam Tributaries	188	Schoonspruit C24F Dummy Dam	RSA	Irrigation Demand	Master Contr	A-5	0.53	0.53	0.53	0.53	0.53	0.53	0.53
Middle Vaal: Schoonspruit C	Johan Neser dam Tributaries	801	Schoonspruit C24F Dummy Dam	RSA	Irrigation Return Flo	Master Contr	A-5	-0.07	-0.07	-0.07	-0.07	-0.07	-0.07	-0.07
Middle Vaal: Schoonspruit C	Johan Neser dam Tributaries	189	Schoonspruit C24F Mainstream (R	RSA	Irrigation Demand	Master Contr	A-5	0.53	0.53	0.53	0.53	0.53	0.53	0.53
Middle Vaal: Schoonspruit C	Johan Neser dam Tributaries	802	Schoonspruit C24F Mainstream (R	RSA	Irrigation Return Flo	Master Contr	A-5	-0.08	-0.08	-0.08	-0.08	-0.08	-0.08	-0.08
Middle Vaal: Schoonspruit C	Johan Neser dam Tributaries	1777	Schoonspruit C24G Dummy Dam	RSA	Irrigation Demand	Master Contr	A-5	0.53	0.53	0.53	0.53	0.53	0.53	0.53
Middle Vaal: Schoonspruit C	Johan Neser dam Tributaries	1787	Schoonspruit C24G Dummy Dam	RSA	Irrigation Return Flo	Master Contr	A-5	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09
Middle Vaal: Schoonspruit C	Johan Neser dam Tributaries	1778	Schoonspruit C24G Mainstream (R	RSA	Irrigation Demand	Master Contr	A-5	0.55	0.55	0.55	0.55	0.55	0.55	0.55
Middle Vaal: Schoonspruit C	Johan Neser dam Tributaries	1781	Schoonspruit C24G Mainstream (R	RSA	Irrigation Return Flo	Master Contr	A-5	-0.08	-0.08	-0.08	-0.08	-0.08	-0.08	-0.08
Middle Vaal: Schoonspruit C	Schoonspruit Mainstream	1713	Schoonspruit C24G Minstream (R	RSA	Irrigation Demand	Master Contr	A-5	7.13	7.13	7.13	7.13	7.13	7.13	7.13
Middle Vaal: Schoonspruit C	Schoonspruit Mainstream	1709	Schoonspruit C24G Minstream (R	RSA	Irrigation Return Flo	Master Contr	A-5	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3
Middle Vaal: Schoonspruit C	Johan Neser Dam	1716	Johan Neser Dam 1 (RR452) Irriga	RSA	Irrigation Demand	Master Contr	A-5	0.54	0.54	0.54	0.54	0.54	0.54	0.54
Middle Vaal: Schoonspruit C	Middle Vaal Tributaries (Schoonspruit)	1715	Johan Neser Dam 1 (RR452) Irrig	RSA	Irrigation Return Flo	Master Contr	A-5	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05
Middle Vaal: Schoonspruit C	Johan Neser Dam	121	Johan Neser Dam 2 (RR542) Irriga	RSA	Irrigation Demand	Master Contr	A-5	0.82	0.82	0.82	0.82	0.82	0.82	0.82
Middle Vaal: Schoonspruit C	Middle Vaal Tributaries (Schoonspruit)	803	Johan Neser Dam 2 (RR542) Irrig	RSA	Irrigation Return Flo	Master Contr	A-5	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05
Middle Vaal: Schoonspruit C	Middle Vaal Tributaries (Schoonspruit)	1719	Johan Neser Mainstream 1 (RR54	RSA	Irrigation Demand	Master Contr	A-5	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Middle Vaal: Schoonspruit C	Middle Vaal Tributaries (Schoonspruit)	1708	Johan Neser Mainstream 1 (RR54	RSA	Irrigation Return Flo	Master Contr	A-5	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04
Middle Vaal: Schoonspruit C	Middle Vaal Tributaries (Schoonspruit)	1725	Johan Neser Mainstream 2 (RR45	RSA	Irrigation Demand	Master Contr	A-5	1.11	1.11	1.11	1.11	1.11	1.11	1.11
Middle Vaal: Schoonspruit C	Middle Vaal Tributaries (Schoonspruit)	1726	Johan Neser Mainstream 2 (RR45	RSA	Irrigation Return Flo	Master Contr	A-5	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16
Middle Vaal: Sand-Vet Catch	Allemanskraal Dam	829	Virginia: Urban Demand from Sand	RSA	Urban Demand	Master Contr	A-5	15.2	15.2	15.2	15.2	15.2	15.2	15.2
Middle Vaal: Sand-Vet Catch	Erfenis Dam	691	Urban from Erfenis (Theunissen,B	RSA	Urban Demand	Master Contr	A-5	10.9558	11.4764	12.2496	12.94698	13.65072	13.68991	13.7293
Middle Vaal: Sand-Vet Catch	Allemanskraal Dam Tributaries	746	Allem dummy dam (RR30) Irrigatic	RSA	Irrigation Demand	Master Contr	A-5	6.34	6.34	6.34	6.34	6.34	6.34	6.34

Table 2-n: Demands modelled by means of Master Control channels in the WRPM

SUB-SYSTEM	Resource	WRPM CHANNEL NO.	DESCRIPTION	RECIPIENT COUNTRY	DEMAND TYPE	WRPM TYPE	FIGURE NO.	2014	2015	2020	2025	2030	2035	2040
Middle Vaal: Sand-Vet Catch	Allemanskraal Dam Tributaries	811	Allem dummy dam (RR30) Irrigati	RSA	Irrigation Return Flo	Master Contr	A-5	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6
Middle Vaal: Sand-Vet Catch	Allemanskraal Dam	131	Allemanskraal Dam (RR26) Irrigati	RSA	Irrigation Demand	Master Contr	A-5	36.76	36.76	36.76	36.76	36.76	36.76	36.76
Middle Vaal: Sand-Vet Catch	Middle Vaal Tributaries (Sand River)	804	Allemanskraal Dam (RR26) Irrigat	RSA	Irrigation Return Flo	Master Contr	A-5	-7.02	-7.02	-7.02	-7.02	-7.02	-7.02	-7.02
Middle Vaal: Sand-Vet Catch	Erfenis Dam Tributaries	585	Erfenis dummy dam (RR331) Irriga	RSA	Irrigation Demand	Master Contr	A-5	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Middle Vaal: Sand-Vet Catch	Erfenis Dam Tributaries	812	Erfenis dummy dam (RR331) Irrig	RSA	Irrigation Return Flo	Master Contr	A-5	-0.36	-0.36	-0.36	-0.36	-0.36	-0.36	-0.36
Middle Vaal: Sand-Vet Catch	Erfenis Dam	133	Erfenis Dam (RR27) Irrigation Den	RSA	Irrigation Demand	Master Contr	A-5	43.6	43.6	43.6	43.6	43.6	43.6	43.6
Middle Vaal: Sand-Vet Catch	Middle Vaal Tributaries (Vet River)	805	Erfenis Dam (RR27) Irrigation Ret	RSA	Irrigation Return Flo	Master Contr	A-5	-4.77	-4.77	-4.77	-4.77	-4.77	-4.77	-4.77
Middle Vaal: Sand-Vet Catch	Middle Vaal Tributaries (Sand River)	743	Sand dummy dam (RR28) Irrigatio	RSA	Irrigation Demand	Master Contr	A-5	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Middle Vaal: Sand-Vet Catch	Middle Vaal Tributaries (Sand River)	806	Sand dummy dam (RR28) Irrigatio	RSA	Irrigation Return Flo	Master Contr	A-5	-0.14	-0.14	-0.14	-0.14	-0.14	-0.14	-0.14
Middle Vaal: Sand-Vet Catch	Middle Vaal Tributaries (Sand River)	807	Sand River riparian U/S EWR15 (F	RSA	Irrigation Demand	Master Contr	A-5	3.03	3.03	3.03	3.03	3.03	3.03	3.03
Middle Vaal: Sand-Vet Catch	Middle Vaal Tributaries (Sand River)	809	Sand River riparian U/S EWR15 (F	RSA	Irrigation Return Flo	Master Contr	A-5	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13
Middle Vaal: Sand-Vet Catch	Middle Vaal Tributaries (Sand River)	1913	Sand River riparian D/S EWR15 (F	RSA	Irrigation Demand	Master Contr	A-5	8.78	8.78	8.78	8.78	8.78	8.78	8.78
Middle Vaal: Sand-Vet Catch	Middle Vaal Tributaries (Sand River)	1915	Sand River riparian D/S EWR15 (F	RSA	Irrigation Return Flo	Master Contr	A-5	-0.36	-0.36	-0.36	-0.36	-0.36	-0.36	-0.36
Middle Vaal: Vaal River Main	Vaal Dam	166	MIDVAAL WC & Vaalreefs Mine: Al	RSA	Urban Demand	Master Contr	A-5	46.7906	46.8219	46.9849	47.14791	47.31092	47.4288	47.55269
Middle Vaal: Vaal River Main	Bloemhof Dam Return flow	128	MIDVAAL WC and Vaalreefs (2.3	RSA	Urban Return Flow	Master Contr	A-5	-1.0865	-1.0872	-1.091	-1.094774	-1.09856	-1.1013	-1.10417
Middle Vaal: Vaal River Main	Vaal Dam	127	SEDIBENG WATER (Net Dem): A	RSA	Urban Demand	Master Contr	A-5	45.7991	46.2822	48.7564	51.33125	54.01071	56.20598	58.49048
Middle Vaal: Vaal River Main	Middle Vaal Tributaries	117	Net Urban Demand in Middle Vaal	RSA	Urban Demand	Master Contr	A-5	10.9742	11.3209	11.9822	12.61597	13.76108	12.44059	13.30291
Middle Vaal: Vaal River Main	Middle Vaal Tributaries	876	Bloem upper dum dam (RR340) Ir	RSA	Irrigation Demand	Master Contr	A-5	4.46	4.46	4.46	4.46	4.46	4.46	4.46
Middle Vaal: Vaal River Main	Bloemhof Dam Return flow	877	Bloem upper dum dam (RR340) Ir	RSA	Irrigation Return Flo	Master Contr	A-5	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7
Middle Vaal: Vaal River Main	Vaal Dam	872	Bloem upper riparian (RR339) Irrig	RSA	Irrigation Demand	Master Contr	A-5	14.93	14.93	14.93	14.93	14.93	14.93	14.93
Middle Vaal: Vaal River Main	Bloemhof Dam Return flow	873	Bloem upper riparian (RR339) Irrig	RSA	Irrigation Return Flo	Master Contr	A-5	-2.36	-2.36	-2.36	-2.36	-2.36	-2.36	-2.36
Middle Vaal: Vaal River Main	Middle Vaal Tributaries	741	Bloem lower dum dam (RR341) Irr	RSA	Irrigation Demand	Master Contr	A-5	3.76	3.76	3.76	3.76	3.76	3.76	3.76
Middle Vaal: Vaal River Main	Bloemhof Dam Return flow	875	Bloem lower dum dam (RR341) Irr	RSA	Irrigation Return Flo	Master Contr	A-5	-0.29	-0.29	-0.29	-0.29	-0.29	-0.29	-0.29
Middle Vaal: Vaal River Main	Vaal Dam	129	Bloem lower riparian (RR2) Irrigati	RSA	Irrigation Demand	Master Contr	A-5	31.83	31.83	31.83	31.83	31.83	31.83	31.83
Middle Vaal: Vaal River Main	Bloemhof Dam Return flow	130	Bloem lower riparian (RR2) Irrigati	RSA	Irrigation Return Flo	Master Contr	A-5	-4.8	-4.8	-4.8	-4.8	-4.8	-4.8	-4.8
Lower Vaal: Vaal River Main	Bloemhof Dam	729	Kimberley (Registered Volume: 28	RSA	Urban Demand	Master Contr	A-6	22.1329	22.7576	24.9973	27.22007	29.5477	32.14611	34.97303
Lower Vaal: Vaal River Main	Bloemhof Dam	730	Other Urban Users: Region G (Lo	RSA	Urban Demand	Master Contr	A-6	17.6376	18.3534	19.9211	21.5368	23.28155	25.20463	27.28657
Lower Vaal: Vaal River Main	Bloemhof Dam	673	Vaal-Gamagara (Scen 4 proj from	RSA	Urban Demand	Master Contr	A-6	22.8493	25.964	30.0028	34.66992	40.063	46.21898	53.32087
Lower Vaal: Vaal River Main	Bloemhof Dam	298	River Evaporation d/s Bloemhof Da	RSA	Loss	Master Contr	A-6	78.1	78.1	78.1	78.1	78.1	78.1	78.1
Lower Vaal: Vaal River Main	Bloemhof Dam	651	Vaalharts Irrigation Distribution Los	RSA	Loss	Master Contr	A-6	127.02	127.02	127.02	127.02	127.02	127.02	127.02
Lower Vaal: Vaal River Main	Bloemhof Dam	1919	RR598 Lower Vaal Irrig (U/S of EW	RSA	Irrigation Demand	Master Contr	A-6	2.77	2.77	2.77	2.77	2.77	2.77	2.77
Lower Vaal: Vaal River Main	Bloemhof Dam	1923	RR598 Lower Vaal Irrig (U/S of EW	RSA	Irrigation Return Flo	Master Contr	A-6	-0.23	-0.23	-0.23	-0.23	-0.23	-0.23	-0.23
Lower Vaal: Vaal River Main	Bloemhof Dam	682	RR397 Lower Vaal Irrig (U/S of VH	RSA	Irrigation Demand	Master Contr	A-6	24.65	24.65	24.65	24.65	24.65	24.65	24.65
Lower Vaal: Vaal River Main	Bloemhof Dam	684	RR397 Lower Vaal Irrig (U/S of VH	RSA	Irrigation Return Flo	Master Contr	A-6	-2.07	-2.07	-2.07	-2.07	-2.07	-2.07	-2.07
Lower Vaal: Vaal River Main	Bloemhof Dam	731	RR405 Lower Vaal Irrig (U/S of De	RSA	Irrigation Demand	Master Contr	A-6	25.06	25.06	25.06	25.06	25.06	25.06	25.06
Lower Vaal: Vaal River Main	Bloemhof Dam	733	RR405 Lower Vaal Irrig (U/S of De	RSA	Irrigation Return Flo	Master Contr	A-6	-2.34	-2.34	-2.34	-2.34	-2.34	-2.34	-2.34
Lower Vaal: Vaal River Main	Bloemhof Dam	984	RR289 Lower Vaal Irrig (D/s of De	RSA	Irrigation Demand	Master Contr	A-6	24.2	24.2	24.2	24.2	24.2	24.2	24.2
Lower Vaal: Vaal River Main	Bloemhof Dam	985	RR289 Lower Vaal Irrig (D/s of De	RSA	Irrigation Return Flo	Master Contr	A-6	-2.27	-2.27	-2.27	-2.27	-2.27	-2.27	-2.27
Lower Vaal: Vaal River Main	Bloemhof Dam	998	RR290 Lower Vaal Irrig (D/s of Ha	RSA	Irrigation Demand	Master Contr	A-6	7.67	7.67	7.67	7.67	7.67	7.67	7.67
Lower Vaal: Vaal River Main	Bloemhof Dam	999	RR290 Lower Vaal Irrig (D/s of Ha	RSA	Irrigation Return Flo	Master Contr	A-6	-0.72	-0.72	-0.72	-0.72	-0.72	-0.72	-0.72

Table 2-o: Demands modelled by means of Master Control channels in the WRPM

SUB-SYSTEM	Resource	WRPM CHANNEL NO.	DESCRIPTION	RECIPIENT COUNTRY	DEMAND TYPE	WRPM TYPE	FIGURE NO.	2014	2015	2020	2025	2030	2035	2040
Lower Vaal: Vaal River Main	Bloemhof Dam	1001	RR291 Lower Vaal Irrig (D/s of Sc	RSA	Irrigation Demand	Master Contr	A-6	2.4	2.4	2.4	2.4	2.4	2.4	2.4
Lower Vaal: Vaal River Main	Bloemhof Dam	1002	RR291 Lower Vaal Irrig (D/s of Sc	RSA	Irrigation Return Flo	Master Contr	A-6	-0.22	-0.22	-0.22	-0.22	-0.22	-0.22	-0.22
Lower Vaal: Vaal River Main	Bloemhof Dam	1376	Bloemfof Dam Excess Water supp	RSA	Transfer	Master Contr	A-6	0	0	0	0	0	0	0
Lower Vaal: Vaal River Main	nosch	1364	Dummy Bloemfof Dam Excess W	RSA		Master Contr	A-6	0	0	0	0	0	0	0
Lower Vaal: Vaal River Main	nosch	1365	Dummy Bloemfof Dam Excess W	RSA		Master Contr	A-6	0	0	0	0	0	0	0
Lower Vaal: Harts River	Wentzel Dam	620	Schweizer Reneke (Registered: 1.	RSA	Urban Demand	Master Contr	A-6	1.89598	2.078	2.43647	2.7763	3.125757	3.519289	3.962367
Lower Vaal: Harts River	Wentzel Dam Tributaries	612	RR357 (Wentzel Dummy Dam) Irr	RSA	Irrigation Demand	Master Contr	A-6	1.21	1.21	1.21	1.21	1.21	1.21	1.21
Lower Vaal: Harts River	Wentzel Dam Tributaries	614	RR357 (Wentzel Dummy Dam) Irr	RSA	Irrigation Return Flo	Master Contr	A-6	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15
Lower Vaal: Harts River	Wentzel Dam Tributaries	617	RR360 (Mainstream Wentzel Dam	RSA	Irrigation Demand	Master Contr	A-6	3.62	3.62	3.62	3.62	3.62	3.62	3.62
Lower Vaal: Harts River	Wentzel Dam Tributaries	618	RR360 (Mainstream Wentzel Dam	RSA	Irrigation Return Flo	Master Contr	A-6	-0.46	-0.46	-0.46	-0.46	-0.46	-0.46	-0.46
Lower Vaal: Harts River	Wentzel Dam	621	RR362 (Wentzel Dam Irrigation) Ir	RSA	Irrigation Demand	Master Contr	A-6	0	0	0	0	0	0	0
Lower Vaal: Harts River	Taung Dam Tributaries	625	RR362 (Wentzel Dam Irrigation) Ir	RSA	Irrigation Return Flo	Master Contr	A-6	0	0	0	0	0	0	0
Lower Vaal: Harts River	Bloemhof Dam	629	RR370 Vaalharts GWS Part Taung	RSA	Irrigation Demand	Master Contr	A-6	6.32	6.32	6.32	6.32	6.32	6.32	6.32
Lower Vaal: Harts River	Spitskop Dam return flow	632	RR370 Vaalharts GWS Part Taung	RSA	Irrigation Return Flo	Master Contr	A-6	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8
Lower Vaal: Harts River	Bloemhof Dam	646	RR379 Vaalharts GWS North Cana	RSA	Irrigation Demand	Master Contr	A-6	270.04	270.04	270.04	270.04	270.04	270.04	270.04
Lower Vaal: Harts River	Spitskop Dam return flow	644	RR379 Vaalharts GWS North Cana	RSA	Irrigation Return Flo	Master Contr	A-6	-49.77	-49.77	-49.77	-49.77	-49.77	-49.77	-49.77
Lower Vaal: Harts River	Bloemhof Dam	654	RR383 Vaalharts GWS West Cana	RSA	Irrigation Demand	Master Contr	A-6	51.44	51.44	51.44	51.44	51.44	51.44	51.44
Lower Vaal: Harts River	Spitskop Dam return flow	652	RR383 Vaalharts GWS West Cana	RSA	Irrigation Return Flo	Master Contr	A-6	-6.2	-6.2	-6.2	-6.2	-6.2	-6.2	-6.2
Lower Vaal: Harts River	Spitskop Dam Tributaries	640	RR376 (Spitskop Dummy Dam) Ir	RSA	Irrigation Demand	Master Contr	A-6	0.49	0.49	0.49	0.49	0.49	0.49	0.49
Lower Vaal: Harts River	Spitskop Dam Tributaries	642	RR376 (Spitskop Dummy Dam) Ir	RSA	Irrigation Return Flo	Master Contr	A-6	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05
Lower Vaal: Harts River	Spitskop Dam	728	RR407 (Spitskop Dam Irrigation) D	RSA	Irrigation Demand	Master Contr	A-6	12.81	12.81	12.81	12.81	12.81	12.81	12.81
Lower Vaal: Harts River	Lower Vaal Tributaries (Harts River)	734	RR407 (Spitskop Dam Irrigation) R	RSA	Irrigation Return Flo	Master Contr	A-6	-1.55	-1.55	-1.55	-1.55	-1.55	-1.55	-1.55
Olifants		1110				Master Control Chann		8.97	8.97	8.97	8.97	8.97	8.97	8.97
Olifants		1303				Master Control Chann		0	0	0	0	0	0	0
Olifants		1302				Master Control Chann		0	0	0	0	0	0	0
Olifants		1207				Master Control Chann		29	29	29	29	29	29	29
Olifants		1195				Master Control Chann		0.01	0.01	0.01	0.01	0.01	0.01	0.01
								2202.06	2221.46	2296	2418.32	2489.31	2586.736	2695.415

Annex 3. Figures

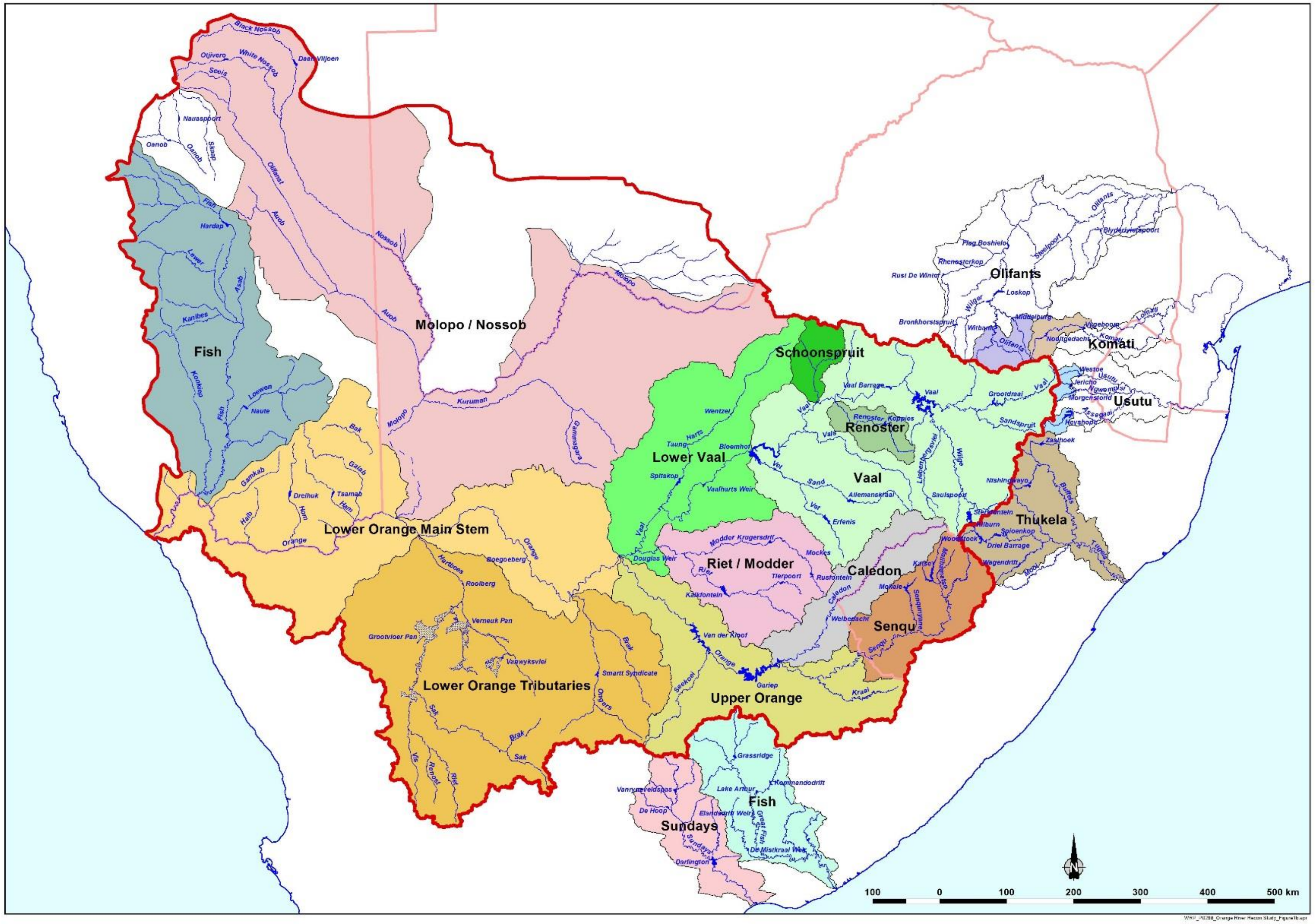

Figure 1: Sub-catchments applicable to the WRPM configuration